1-11-94

TIME	EXP	photo #
~~0950~~ 2130	80	5
~~0953~~ 2133	150	6
~~0959~~ 2139	300	7

NIGHT SKY BRIGHTNESS photographic Monitoring

1/11/94

Subject: α Tauri (Aldebaran) at near the zenith

Camera: 35 mm SLR
Pentax MX

LENS: 1:2 50 mm
SMC PENTAX-M
5052655 Asahi opt. co.

Film: Kodak Ektachrome
400 HC
Slide film

f/ = 4.0

Exposures = 80, 150, 300 seconds

This is a roll of night-time time exposures taken to assess light pollution around Ajo.

Since finding the right spots to cut can be difficult to find when mounting this kind of photography here is a rough guide to what is on the roll.

From the beginning
Two frames exposed
a few blank shots (2013)
A series of 4 tests,
each consisting of 4 shots.
The 3rd series may have a repeated shot, for a total of 5.
The last few frames are unexposed.
I hope this helps.

Submitted by Jerry Van Wyngarden
Ajo, AZ Spring 1993

METHOD

~~ATM CONDITIONS~~

All scenes shot with 50 mm lens set at f/4.
All scenes exposed for 60, 150, and 300 sec.

SOYNOTA

- Aim first scene at 532E
- pan next scene to R, include some of 1st scene for Linhoge
- Aim at R side of Soynota with ORPI campground in bottom of frame.

SKY

Aim at area of sky with star Aldebaran in center of frame.

— — — —

While Tucson and Phoenix sky glow are visible to dark adapted eye they are not strong enough to record on ASA 400 film at these exposure ranges. 15 min, 30 min, and 1 hour exposures should be tried.

EQUIPMENT LIST

1 35 mm camera - one with mechanical non electric shutter capable of being locked open on "B" or "T" settings

1 locking cable release

1 50 mm lens capable of being set on f/4

1 tripod

SEVERAL flashlights

1 notebook and pens or pencils

1 compass

1 stop watch

1 400 ASA color slide film

While the strong headlights of south bound cars on Hwy 86 were very visible visually they did not seem to record excessively on film. Visual inspection of film does not show fogging from headlights. Densiometer inspection may show otherwise.

SUNRIVER NATURE CENTER

January 13, 1995

Dennis Casper
Organ Pipe Cactus National Monument
Route 1 Box 100
Ajo AZ 85231

Dear Dennis:

Please accept my apology for taking so long to send the report on using CCDs for baseline sky brightness studies. The enclosed report gives a good description of the protocol we developed. The important factor in the procedure is that we did not manipulate the images in the "standard" way, that is, to stretch all we could from the data. Instead we tried to obtain minimum resolution from the images. If you read the report I think you'll find all you need for now.

I have not specifically included any materials from our library on lights, applications and lighting ordinances that our study produced. If, however, you deem you need such material I can send that information along later.

Finally, I would reiterate that I am available as a consultant if your office needs help with your baseline study. I will gladly send you information on any fees that such services would entail if you deem that my experience would be helpful.

Good luck and clear skies!

Best Regards,

Larry

Larry Pratt
Observatory Director

P.O. BOX 3533 SUNRIVER, OREGON 97707-2709 (503) 593-4394
A Non-Profit Corporation
E. I. #93-0817907

Central Oregon Lighting Study

Background Sky Transparency Measurement



17 April 1993

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Background

This brief presents the results of measurements of sky brightness in selected parts of Deschutes County, Oregon. The overall project is a joint effort of the Sunriver Nature Center, the Bonneville Power Administration, Mid-State Electric, Pacific Power, Central Electric Co-op, and other interested industries and municipalities. The overall purpose is to examine the effects and efficiency of current lighting standards and fixtures.

This section of the lighting study attempted to detect variations in the background sky transparency from various urban and suburban locations. Using teams of high school students, concrete data was collected to determine what effects, if any, population density, lighting ordinances, and light pollution might have on the night sky. Project coordinator for this study was Ray Spreier.

This phase of the study was intended to compare the background sky transparency at various urban and rural locations. The overall methodology was fairly straightforward. A CCD camera attached to a portable telescope was used to photograph the same areas of the sky from different locations. These locations were affected by varying degrees of illumination and "washout" from artificial lighting. The exposure information was then analyzed and the frames compared using a computer.

Apparatus

Exposures were taken using a charge-coupled device (CCD) camera loaned to the project by the Santa Barbara Instrument Group. This model ST-6 camera features an array of light sensitive pixels 375x242 in size, with each pixel being 23x25 microns in size (0.001 inches). It's 16 bit resolution allowed for exposures that could classify the relative brightness of objects to about one part in 65,000. This camera was connected at the prime focus of a Meade 8" Schmidt-Cassegrain telescope equipped with a clock drive and dual axis correction. The camera itself was connected to a control unit, which was in turn connected to a Compaq Contura portble computer (see diagram). The software in the computer allowed the user to control the setup, calibration, focus, and exposure parameters. Each exposure was sent by the camera to the control unit, and then on to the computer, where it was stored for later iewing and software analysis using the ST OPS program.

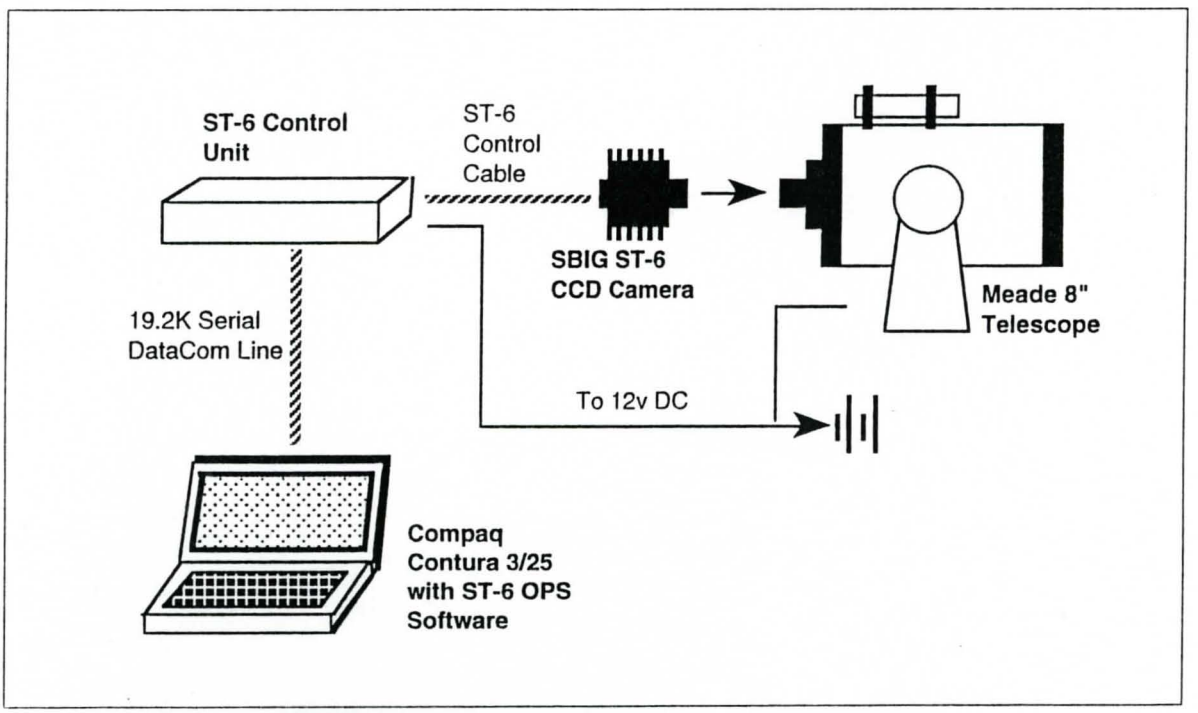


Fig 1. Schematic Layout of Test Equipment

Target Field Selection

Four target fields were selected, representing areas of the sky that, at the time of the study, were located at key altitudes relative to the horizon - at or near zenith, about 45°, about 30°, and about 15°. These fields were all centered about stars of known magnitude:

	Field 1	Field 2	Field 3	Field 4
Centered On :	θ1 Orionis	ρ Geminorum	16 Auriga	η Cassiopeia
Description :	Primary star in Trapezium cluster in the Orion Nebula.	Star just WNW of Castor.	Yale 1726. Star at the tip of the 'leaping' minnow asterism.	Yale 219. Easily resolved double star.
Location :	05h 35.3m RA -05° 23' DEC	07h 29.1 RA 31° 47' DEC	05h 18.2 RA 33° 22' DEC	00h 49.1m RA 57° 49' DEC
Known Magnitude:	5.13	4.17	4.54	3.44

The target stars were selected in 4th-5th magnitude range in order to allow exposures to capture faint background stars without overexposing, or "blooming" the frame.

Location Selection

Originally, the intention was to take exposures from urban and rural locations for all of the main Central Oregon communities. However, due to time limitations and poor weather conditions, it was decided to select three sites:

	Site 1	Site 2	Site 3
Location :	Sunriver Nature Center Parking lot	20634 Colt Lane Front driveway	Vince Genna Stadium Parking lot
Reason :	Representative of rural location.	Representative of suburban residential location.	Representative of urban business location.
Lighting situation :	Strict lighting ordinances. Any lighting is in cutoff fixtures. Little to no light pollution.	No street lighting. Unshielded house and porch lights. Little to moderate light pollution.	Severely light polluted sky. One block from major arterial route and shopping center.

Setup and Exposure Sequence

At each location, the following procedure was used to collect the exposures:

[1] Setup physical apparatus without attaching CCD to telescope.
[2] Polar align telescope and verify tracking by measuring the apparent drift of a target star at high magnification.
[3] Attach camera to telescope.
[4] Bring up software and verify communications with CCD camera.
[5] Prepare CCD camera for use:
  (a) Set operating temperature for -20° C (reduces inherent thermal noise).
  (b) Allow camera to reach operating temperature.
  (c) Set video offset to between 5000$ and 10000$
  (d) Set anti-blooming gate to ON.
[6] Focus CCD camera on test object.
[7] For each target field:
  (a) Visually center telescope on target using finder scope.
  (b) Verify target star in exposure field by taking quick exposure. Make any necessary alignment corrections.
  (c) Take a 60 second exposure of the test field, including a dark frame exposure to compensate for inherent noise in the CCD chip.
  (d) Verify the acquisition and quality of the image on the computer. If necessary, repeat the exposure.
  (e) Store the image using the following filename convention: *ConExp.ST6*
    Where *Con* is the constellation of the target field, and *Exp* is the duration of the exposure in seconds. Example: a 60 second exposure of field 1 would be stored as ORI60.ST6
  (f) Move on to the next target field and repeat sequence.
[8] Shut down and disassemble apparatus.

The raw data is attached, as is a demonstration version of the ST-6 Ops program. Due to poor weather conditions, exposures of all target fields were not obtainable from all sites during the period in which the CCD camera had been made available. Images diskette were recorded in three directories on a diskette, each corresponding to a test site, and each containing the image files.

SRNC ..... Sunriver Nature Center, 25 February 1993
  ORI60.ST6 ..... 60 sec exposure centered on θ1 Orionis
  AUR300.ST6 ..... 300 sec. exposure centered on 16 Aurigae
  GEM300.ST6 ..... 300 sec. exposure centered on ρ Geminorum
COLT ..... Colt Lane, 26 February 1993
  ORI60.ST6 ..... 60 sec exposure centered on θ1 Orionis
VG ..... Vince Genna Stadium, 27 February 1993
  ORI60.ST6 ..... 60 sec exposure centered on θ1 Orionis
  AUR300.ST6 ..... 300 sec. exposure centered on 16 Aurigae
  GEM300.ST6 ..... 300 sec. exposure centered on ρ Geminorum
  CAS300.ST6 ..... 300 sec exposure centered on η Cassiopeiae

To analyze the data, the ST-6 OPS software was used on a machine with a video resolution of VGA grade or bette (256 colors/greys). Each frame was brought up on the screen, and the software used to remove the hot pixels (pixels with abnormal charge response) and the cool pixels (pixels with dead response). Other image manipulation functions, such as smoothing and contrast enhancement, were deliberately avoided.

The second step involved setting the software into the analysis mode and calibrating the gray scale to the known magnitudes involved. This was done for each frame by first placing the crosshair cursor directly on the object of known magnitude and adjusting the display to register as close to the catalog magnitude as possible. Next, the cursor was moved onto the darkest area visible within the exposure, and the software set to register these pixel values as 'absolute' black.

Finally, the image was scanned for the faintest object visible in the frame. This was often easier to accomplish after inverting the image (white to black, black to white), as faint objects then appeared as small black pixels. Once the object judged to be the "faintest" was found, the crosshair cursor would again be used to measure the software-calculated magnitude of the faint object. This magnitude then becomes the apparent limiting magnitude for that location. This data was then recorded for future comparison to other frames and locations.

The following pages contain the logs and printouts for each exposure.

Data Sheet

General Information

Date : 25 February 1993

Time : 21:31:27 PST

Location : Sunriver Nature Center Pkg Lot

Conditions

Weather: Clear, Cold ~5°F, Ground Fog Rising Toward Meadow

Surroundings: Distant light visible from stables and from Great Hall

Exposure Information

Altitude : ☐ Zenith ☒ 45° from Horizon ☐ 15° from Horizon ☐ 05h 35.3m, -05°23'

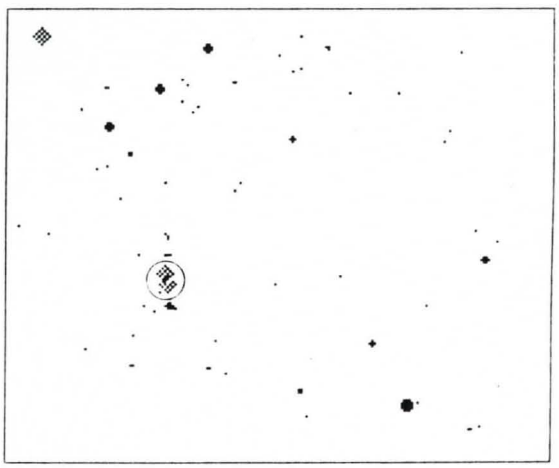
Duration (sec): 60.0 sec

Centered On : M42 θ1 ORI Catalog Magnitude: 5.13 CCD Magnitude: 5.13

Faintest Obj : 13.13

CCD Image (Sample)





Other Notes

f/1 1000mm, Meade 8", 375x242 pixel image, camera temp -31.16°C, Offset 8500.

Data Sheet

General Information

Date : 25 February 1993

Time : 21:45:25 PST

Location : Sunriver Nature Center Pkg Lot

Conditions

Weather: Clear, Cold ~5°F, Ground Fog Rising Toward Meadow

Surroundings: Distant light visible from stables and from Great Hall

Exposure Information

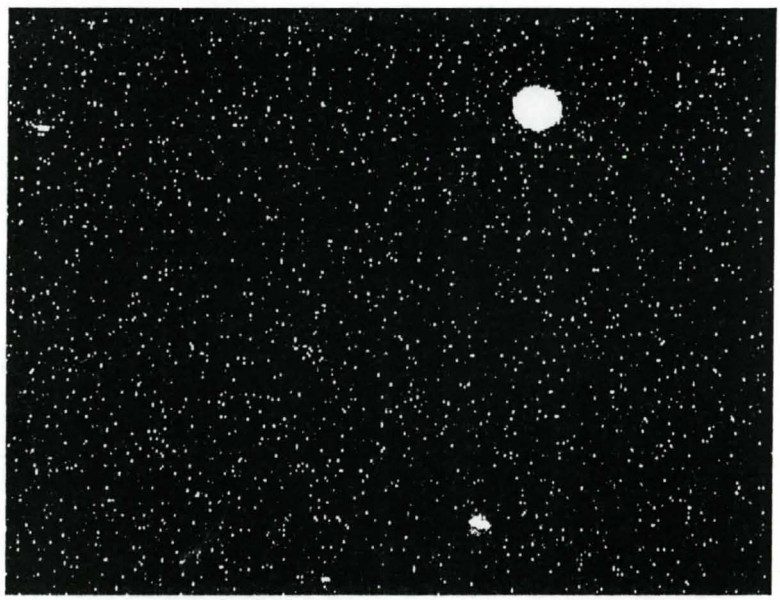
Altitude : ☒ Zenith ☐ 45° from Horizon ☐ 15° from Horizon ☐ 07h29.1m, 31°47'

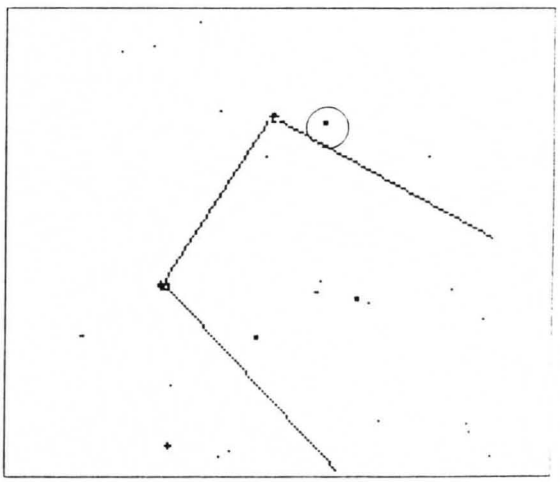
Duration (sec): 300.0 sec

Centered On : ρ Geminorum Catalog Magnitude: 4.17 CCD Magnitude: 4.21

Faintest Obj : 10.73

CCD Image (Sample)





Other Notes

f/l 1000mm, Meade 8", 375x242 pixel image, camera temp -31.25°C, Offset 8500.

Data Sheet

General Information

Date : 25 February 1993

Time : 22:05:27 PST

Location : Sunriver Nature Center Pkg Lot

Conditions

Weather: Clear, Cold ~5°F, Ground Fog Rising Toward Meadow

Surroundings: Distant light visible from stables and from Great Hall

Exposure Information

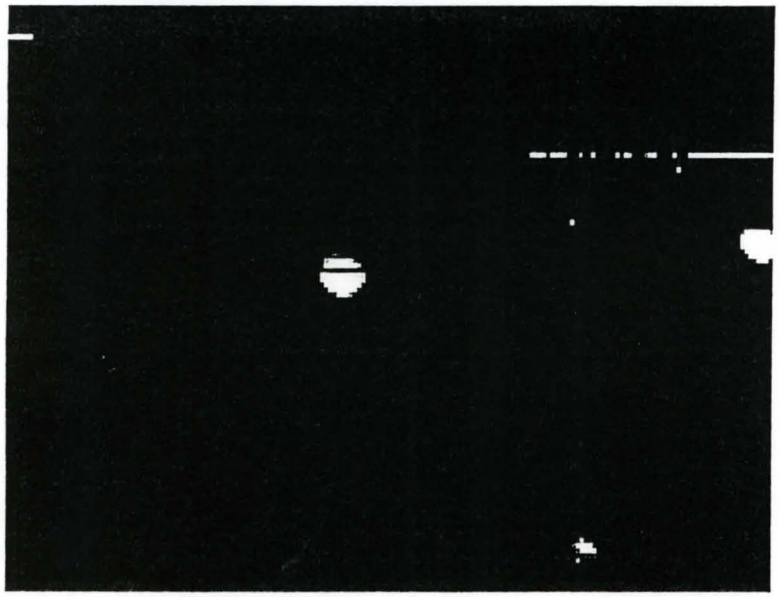
Altitude : ☐ Zenith ☐ 45° from Horizon ☒ 30° from Horizon ☐ 05h18.2m, 33°22'

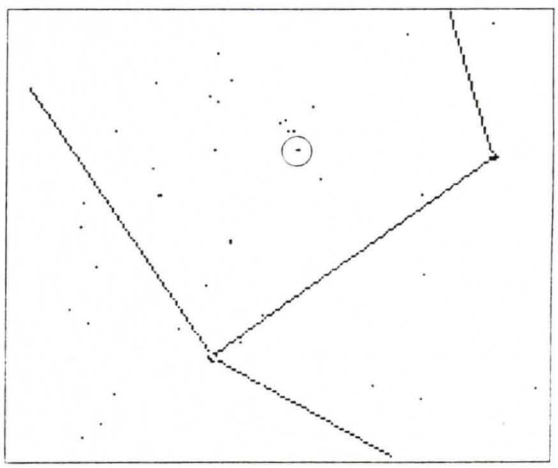
Duration (sec): 300.0 sec

Centered On : 16 Auriage Catalog Magnitude: 4.54 CCD Magnitude: 4.54

Faintest Obj : 8.29

CCD Image (Sample)





Other Notes

f/l 1000mm, Meade 8", 375x242 pixel image, camera temp -30.65°C, Offset 8500.

Data Sheet

General Information

Date : 26 February 1993

Time : 21:02:10 PST

Location : 20634 Colt, Bend, OR

Conditions

Weather: Clear, Cold 8°F, Slight Haze Rising

Surroundings: Obnoxious security light on neighbor garage, 75 ft distant.

Exposure Information

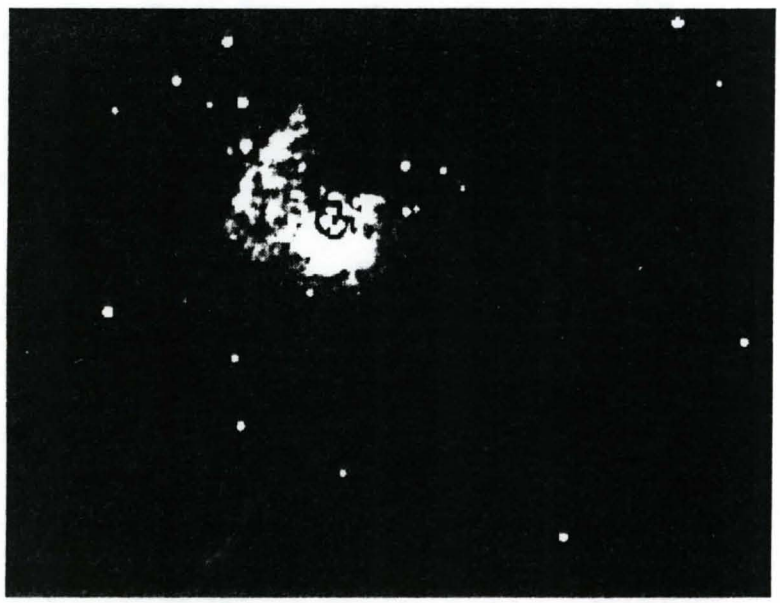
Altitude : ☐ Zenith ☒ 45° from Horizon ☐ 15° from Horizon ☐ 05h 35.3m, -05°23'

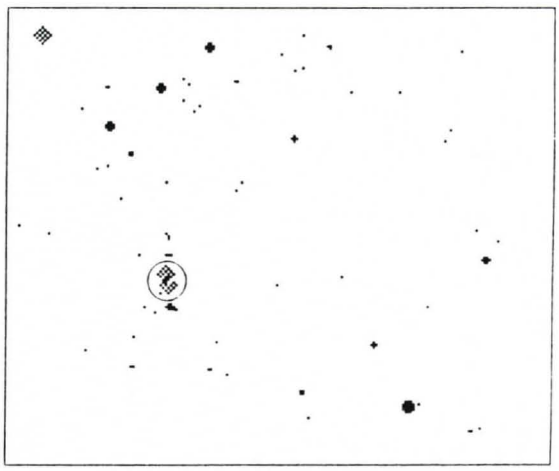
Duration (sec): 60.0 sec

Centered On : M42 θ1 ORI Catalog Magnitude: 5.13 CCD Magnitude: 5.13

Faintest Obj : 10.85

CCD Image (Sample)





Other Notes

f/l 1000mm, C-8 Celestron, 375x242 pixel image, camera temp -20.88°C, Offset 8500.

Data Sheet

General Information

Date : 27 February 1993

Time : 20:57:11 PST

Location : Vince Genna Stadium Pkg Lot

Conditions

Weather: Clear, Very Cold about -5°F, hazy toward horizon

Surroundings: Residential area 1 block from shopping center and major highway.
Extreme light pollution evident with sky 'washout' toward downtown.

Exposure Information

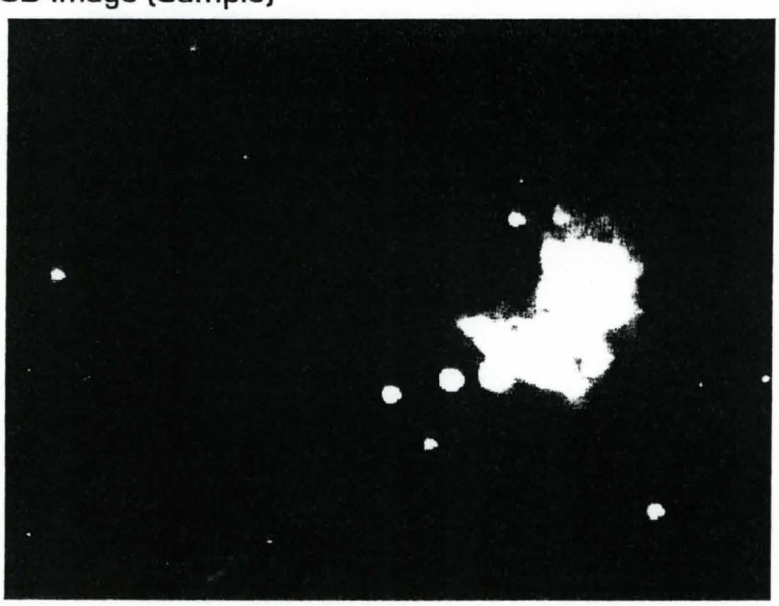
Altitude : ☐ Zenith ☒ 45° from Horizon ☐ 10° from Horizon ☐ 05h 35.3m, -05°23'

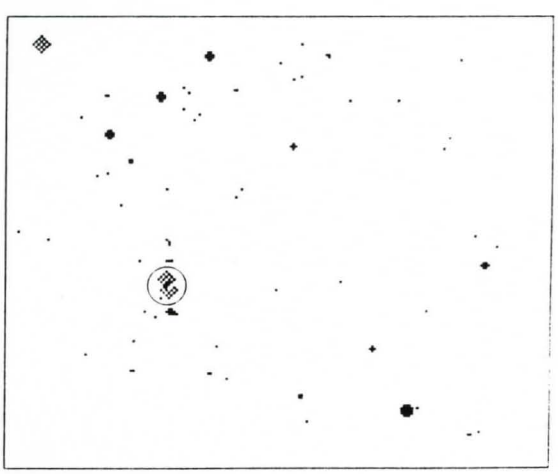
Duration (sec): 60.0 sec

Centered On : Theta 1 ORI Catalog Magnitude: 5.13 CCD Magnitude: 5.13

Faintest Obj : 7.42

CCD Image (Sample)





Other Notes

f/1 1000mm, Meade 8", 375x242 pixel image, camera temp -21.4°C, Offset 8500.

Image shows contouring not apparent in other images.

Data Sheet

General Information

Date : 27 February 1993

Time : 22:32:58 PST

Location : Vince Genna Stadium Pkg Lot

Conditions

Weather: Clear, Very Cold about -5°F, hazy toward horizon

Surroundings: Residential area 1 block from shopping center and major highway.
Extreme light pollution evident with sky 'washout' toward downtown.

Exposure Information

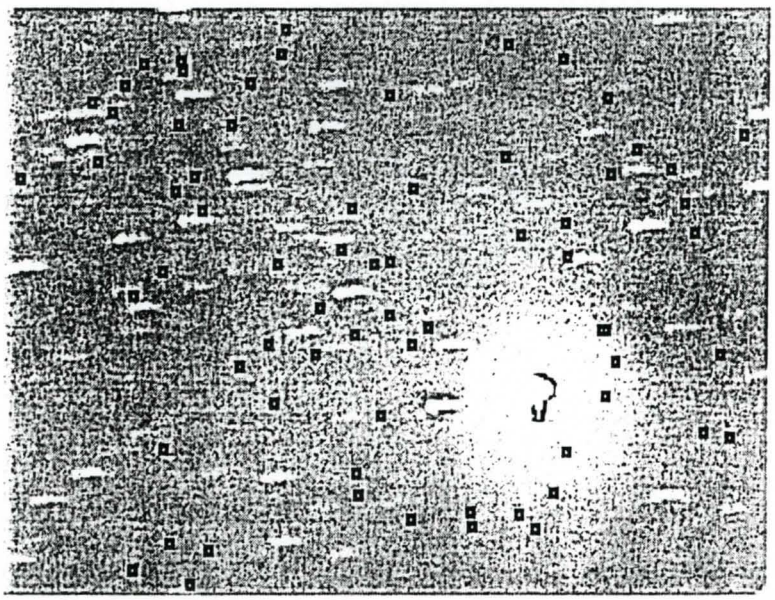
Altitude : ☐ Zenith ☐ 45° from Horizon ☒ 10° from Horizon ☐ 00h 49.1m, 57°49'

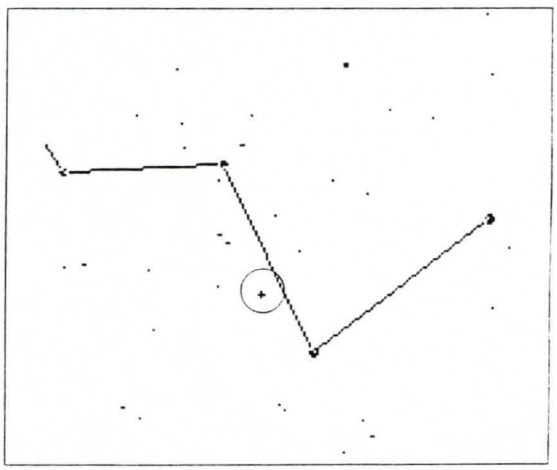
Duration (sec): 300.0 sec

Centered On : Eta Cas Catalog Magnitude: 3.44 CCD Magnitude: 3.49

Faintest Obj : N/A (Bad Frame)

CCD Image (Sample)





Other Notes

f/l 1000mm, Meade 8", 375x242 pixel image, camera temp -24.08°C, Offset 8500.

Image shows washout from streelights close to field of view.

Data Sheet

General Information

Date : 27 February 1993

Time : 21:11:45 PST

Location : Vince Genna Stadium Pkg Lot

Conditions

Weather: Clear, Very Cold about -5°F, hazy toward horizon

Surroundings: Residential area 1 block from shopping center and major highway.
Extreme light pollution evident with sky 'washout' toward downtown.

Exposure Information

Altitude : ☒ Zenith ☐ 45° from Horizon ☐ 10° from Horizon ☐ 07h 29.1m, 31° 47'

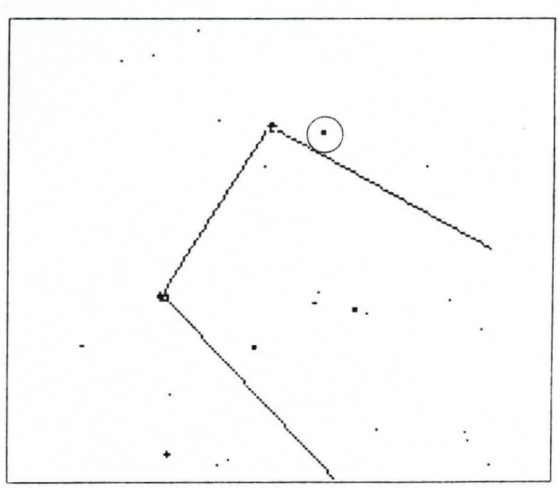
Duration (sec): 300.0 sec

Centered On : Rho Gem Catalog Magnitude: 4.17 CCD Magnitude: 4.19

Faintest Obj : 7.72

CCD Image (Sample)





Other Notes

f/1 1000mm, Meade 8", 375x242 pixel image, camera temp -22.58°C, Offset 8500.

Image shows slight washout from nearby lights.

Data Sheet

General Information

Date : 27 February 1993

Time : 21:28:19 PST

Location : Vince Genna Stadium Pkg Lot

Conditions

Weather: Clear, Very Cold about -5°F, hazy toward horizon

Surroundings: Residential area 1 block from shopping center and major highway.
Extreme light pollution evident with sky 'washout' toward downtown.

Exposure Information

Altitude : ☐ Zenith ☐ 45° from Horizon ☒ 20° from Horizon ☐ 05h18.2m, 33°22'

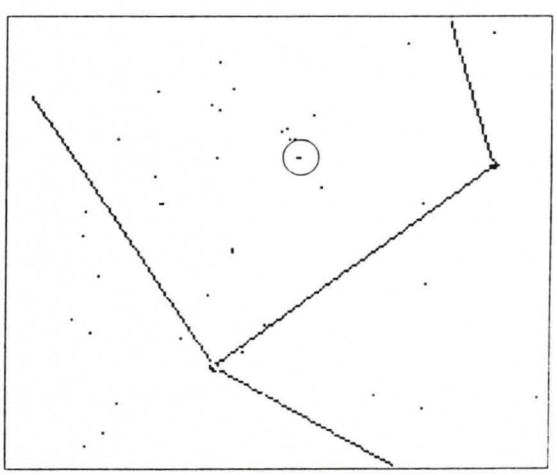
Duration (sec): 300.0 sec

Centered On : 16 Auriage Catalog Magnitude: 4.54 CCD Magnitude: 4.59

Faintest Obj : 7.99

CCD Image (Sample)





Other Notes

f/1 1000mm, Meade 8", 375x242 pixel image, camera temp -22.65°C, Offset 8500.

Image shows beginning of washout.

The quality of the data obtained appeared to affected by two primary factors - (1) Weather - which limited the number of viewing opportunities available, and (2) Tracking Errors - apparently due to binding of gear faces due to the extreme cold. Some frames were also severely affected by nearby lighting, causing washout and automatic operation of the anti-blooming gate in the CCD camera. One fortunate and notable exception was the series of frames centered on θ1 Orionis, all of which are quite acceptable. With the resulting "average" quality of the raw data, it was possible to see some relationships emerge:

Target Object	Date	Time	Exposure Duration	Camera Temp	Catalog Mag	CCD Mag	Faintest Magnitude
Sunriver Nature Center							
Theta 1 ORI	25 Feb 1993	21:37:27	0:00:60	-31.16° C	5.13	5.15	13.13
Rho GEM	25 Feb 1993	21:45:15	0:05:00	-31.25° C	4.17	4.21	10.73
16 AUR	25 Feb 1993	22:05:44	0:05:00	-30.65° C	4.54	4.56	8.29
Colt Lane							
Theta 1 ORI	26 Feb 1993	21:02:10	0:00:60	-20.88° C	5.13	5.13	10.85
Vince Genna Stadium							
Theta 1 ORI	27 Feb 1993	20:57:11	0:00:60	-21.40° C	5.13	5.13	7.42
Rho GEM	27 Feb 1993	21:11:45	0:05:00	-22.58° C	4.14	4.18	7.72
16 AUR	27 Feb 1993	21:28:19	0:05:00	-22.65° C	4.54	4.55	7.99
Eta Cas	27 Feb 1993	22:32:58	0:05:00	-24.08°C	3.44	Unusable	Unusable

In the above data, it is apparent that there is a significant difference in the average background sky transparency between the three locations:

Target Location	Faintest Object From All Frames	Δ Mag. of Abs. All Frames	Avg. Faintest Mag. Of All Frames	Δ Mag. of Avg. All Frames
Sunriver Nature Center *Strict lighting ordinances. Heavy foliage blocking ambient commercial and residential light. Example of rural / residential interface.*	13.13	0 (baseline)	10.71	0 (baseline)
20634 Colt, Bend *Suburban residential area. Ambient lighting from porch and security lights. No street lighting.*	10.85	2.28	10.85	- 0.14
Vince Genna Stadium *Urban residential area adjacent to major shopping center and highway. Extreme ambient light from residential and commecial sources.*	7.99	5.14	7.71	3.0

Examination of the "horizon to horizon" data from all frames appears to indicate a loss of about 3 magnitudes in average sky transparency between rural Sunriver and downtown Bend, although there appears to be no significant difference between Sunriver and the outer, suburban areas of Bend. However, if one examines the overall faintest object found from each site, the difference is significant. A loss of about 2 magnitudes occurs between rural and suburban areas, and the loss jumps to six magnitudes when moving into an urban site. In more realistic terms, an average loss of three magnitudes (Sunriver to Bend) means that a naked-eye observer may lose the ability to see up to 80% of the total number of stars in the sky.

Contributing Factors

In looking for factors that affect the data, population density stands out. The lighting ordinances in effect in the Sunriver area would also seem to play a significant role, as would perhaps the amout of shielding foliage in the area compared to the more developed urban areas. Even if one compares suburban and urban Bend, the difference would seem to be attributed primarily to the much greater concentration of unshielded commercial and municipal lighting fixtures in the urban areas.

Conclusion

Admittedly, this preliminary study is far from comprehensive, and is, for all practical purposes, less than adequate for developing any formal strategy for the future. What is apparent is that there is, indeed, a significant and measurable loss in sky transparency in the Bend metro area in comparison to its surrounding environs. As Deschutes County moves into the next century, where commercial development and population densities are expected to climb at exponential rates, this condition can be expected to worsen.

Acknowlegdements

The contributions of the following people enabled this preliminary study to take place:

Santa Barbara Instruments Group, Richard Schwartz - for the generous use of the ST-6 CCD camera and his patience in bearing with the vagaries of the Central Oregon winter.

The participants from Mountain View, Bend, and La Pine High Schools, for their willingness to be on a standby mode, and for their eagerness to explore:

Orion Richardson
Eric Wing
Jason DeSinso
Justin Chase
Olivia Zirker

Sunriver Nature Center - for the use of equipment and facilities.

Nancy Spreier and Kathy Pratt - for putting up with their husbands' galavanting about the frozen countryside in the middle of the night.

United States Department of the Interior

NATIONAL PARK SERVICE
Kings Canyon National Park
Sequoia National Park
Three Rivers, California 93271-9700

IN REPLY REFER TO:
N1623

April 17, 1993

Dear Colleague,

Enclosed is a document proposing a method for monitoring "night sky visibility" in wilderness areas. This issue has been particularly important to me as an amatuer astronomer living in an area of the west that used to enjoy rather dark nighttime skies. I circulate it to Air Quality and Wilderness Specialists at the regional level to the National Park Service and Forest Service regions administering large wilderness areas to promote discussion and interest in this issue. I submit this document to express my concern over a valuable natural resource whose protection has been neglected. My interest is as a concerned citizen as well as a public employee who possesses some expertise in this field.

Please direct any questions or comments you may have to me at the above address or phone 209-565-3722. I hope this document serves as a reminder of our responsibilities to preserve this valuable natural resource and inform you as to monitoring methods currently in use in Japan. I believe an active interest in this issue by our respective agencies would help mobilize public support and result in the collection of valuable baseline data. Please give it careful consideration.

Sincerely,

Dan

Dan Durisoce
Biological Technician
Resources Management

Jim -

from DAN DURISCOE

HERE'S SOME BLURBS, ON THE USE OF CCD CAMERAS FOR NIGHT SKY BRIGHTNESS MONITORING.

IF WE GET EQUIPMENT DAN DURISCOE WILL HELP ME SET UP THE SAMPLING PROGRAM (3-5 DAYS OF HIS TIME) IF YOU'LL LET ME GO TO SEKI TO HELP HIM RESAMPLE AN AIR QUALITY PLOT WE SAMPLED IN 1989.

I'D LIKE TO TALK MORE ABOUT THIS WITH YOU WHEN I RETURN.

HASTA LA VISTA!

DD

ORGAN PIPE CACTUS NATIONAL MONUMENT:
DESERT TORTOISE PROJECT BUDGET - Alternative 1

	Year 1	Year 2	Year 3
Habitat Identification Survey [1]	$12,000.00	----------	---------
Establish Monitoring Plots [2]	---------	$12,000.00	$6,000.00
Travel [3]	$1,600.00	$1,400.00	$700.00
Misc. Expenses [4]	$7,800.00	$500.00	$500.00
University Graduate Student [5]	$3,494.00	$3,494.00	$3,494.00
University Overhead @20% [6]	$4,979.00	$3,479.00	$2,139.00
GIS/GPS Equipment [7]	$25,421.00	----------	---------
FY TOTAL	$55,294.00	$20,873.00	$12,833.00
TOTAL			$89,000.00

[1] 60 field days @ $200.00/day.
[2] 30 day kilometer square census plots @ $200.00/day.
[3] Travel @ $0.29/mile; includes travel to and from survey sites/census plots and weekly travel between ORPI and Tucson, AZ (300 miles).
[4] Includes a variety of field and office equipment including weather sensing equipment, radio tracking equipment and photographic film and film processing.
[5] Graduate student @ 8.50/hr, 20 weeks/yr, 3 years.
[6] University of Arizona overhead costs for work done through existing cooperative agreements.
[7] GPS/GIS equipment includes 2 Trimble Geoexplorer field units @$3,500.00/unit, SUN Sparc 10 GIS workstation @$15,000.00, ARC/INFO software @$2,500.00, Misc. Supplies (plotter paper etc..) @$941.00.

IDA

USE OF CCD CAMERA FOR NIGHT SKY BRIGHTNESS MONITORING

--CONCEPT: CCD cameras are fast, efficient, and accurate means of collecting photometric data. Small variations in light intensity can be detected with very short exposure times. Therefore, they may be the ideal tool for use in a program of monitoring night sky brightness over time.

--ISSUES:

COST: Initial investment for a camera can be high ($1,000 to $3,000). Also, a computer and lens or telescope are required to use the instrument. However, data can be obtained at virtually no cost after the initial investment since no film or film processing is required.

TECHNICAL KNOW-HOW: CCD cameras have been known to require tremendous technical skill and patience to make them work. However recent advances in hardware and software have alleviated some of this monkey business. Still, the use of computer software and hardware is required to operate the camera, in addition to setting up the camera itself (focusing, cooling, maintaining the temperature constant, taking calibration exposures, etc.). So it is still not a "point and shoot" operation by any means. For truly research-grade photometery, rigorous quality assurance and calibration procedures must be followed. Experiments may show that the required precision for this project can be obtained with much less trouble, however.

SOFTWARE DEVELOPMENT: Software for image processing is available at low cost, but some custom programming with probably have to be done to summarize the data from images into a form that will tell us what we want to know. That is, what is the overall background sky brightness over the frame. Bright star images will have to be filtered out, and thermal and electronic noise accounted for through comparison with calibration images. Not exactly rocket science, but....

PRACTICALITY FOR FIELD USE: The need for a computer and power supply for the thermoelectric cooler severely limit the CCD cameras applicability to remote sites. It can be done (use a laptop and a battery pack), but obviously the most convenient use of this device would be at a "base station" where continuous monitoring can occur over time. Whether a telescope or standard camera lens are used will determine the size of camera set-up. For our purposes, it seems like a relatively cheap 135 mm f/2.8 lens could be coupled to the detector, put on a tripod, pointed at the sky, hooked up via cable to a computer (which could be inside a building or office) and power supply, and start shooting. The SBIG ST-6 is fair big and heavy (6" diameter & 2.5 lbs.), but not unreasonbly so for remote use. The main bulk would be in the computer and power supply.

United States Department of the Interior

NATIONAL PARK SERVICE
ORGAN PIPE CACTUS NATIONAL MONUMENT
ROUTE 1, BOX 100
AJO, ARIZONA 85321

IN REPLY REFER TO:

N22

February 16, 1993

Memorandum

To: Mark Skruggs, Air Quality Division

From: Superintendent, Organ Pipe Cactus National Monument

Subject: Night-sky Monitoring

My Division of Resources Management and Research is currently developing a protocol to monitor night-sky brightness in Organ Pipe Cactus National Monument (ORPI). Photography using 35 millimeter cameras fitted with 50 millimeter lenses and shooting ISO 400 slide film will be used to estimate the night-sky's surface brightness.

We would like to be able to read these slides with a densitometer to assure our compatibility with other organizations monitoring night-sky brightness such as the National Astronomical Observatory in Tokyo, Japan, and the International Dark-Sky Association in Tucson, Arizona.

My estimate is that we would be shooting around 80 - 100 slides per year. Would it be possible to have the Air Quality Division read these slides with your densitometer?

If you have any questions about this request you may contact Jonathan F. Arnold, Resources Management Specialist, ORPI, at (602) 387-7661, extension 7112. Thank you most kindly for considering this request.

Harold J. Smith

cc: Unit Leader, CPSU/UA

30 MARCH 93

N,

I talked with Bill Malone & he seemed skeptical about the Japanese program - he said film development would have the greatest influence on quality of data and would have to be carefully controlled with gray scale exposed on the film end to calibrate each roll of film. So the info you got from Scruggs was not entirely correct. I get the impression that they feel the park-level staff would not be technically skilled enough to carry out an actual program. He mellowed out quite a bit after I explained the method better but still was skeptical - he said try it & see. I'll send him the document anyway & see what happens. If we can get him on our side I think he would be a powerful ally.

Politics, politics. Let's just go do it!

Dan

United States Department of the Interior

NATIONAL PARK SERVICE
AIR QUALITY DIVISION
P.O. BOX 25287
DENVER, CO 80225

IN REPLY REFER TO:

February 26, 1993

N3615 (475)

Memorandum

To: Jonathan Arnold, Resources Management Specialist, Organ Pipe Cactus National Monument

From: Chief, Research Branch, Air Quality Division

Subject: Night Sky Monitoring

I passed your Superintendent's February 16 request for assistance for slide densitometer measurements on to Dr. William Malm of my staff. Dr. Malm manages the National Park Service visibility research and monitoring program and has access to a densitometer. Unfortunately, the instrument that is available to him is simply too inaccurate to be used for absolute readings. It was designed to make relative contrast readings and would not work for your application.

I know that you have already arranged for astronomical and photographic expertise for this program, but if Dr. Malm can be of any assistance with his knowledge of film calibration techniques and slide densitometry please contact him at (303) 491-8292.

On a related matter, the Air Quality Division has sponsored night sky model development and application studies for Canyonlands and Bryce Canyon National Parks to estimate the effect of lighting on the night sky. I have attached copies of these studies for your information. If I can provide any additional information please contact me at (303) 969-2077.

for

Mark A. Scruggs

Attachments

(303) 969-2070
AIR QUALITY DIV.
MARK SKRUGGS

RECEIVED
Organ Pipe Cactus N. M.
DEC 15 '92

International Dark-Sky Association
3545 N. Stewart, Tucson AZ 85716 U.S.A.

CTION/INFO
SUPERINTENDENT
ADMIN TECHN
CH RANGER
CH RES MGMT
CH MAINT
INTERP SPEC
FILE

10 December 1992

Harold J. Smith
Organ Pipe Cactus Nat. Monument
Route 1, Box 100
Ajo AZ 85321

Dear Mr. Smith,

Thanks for your letter. It is great to hear from people who have an active interest in controlling light pollution. IDA and the Park Service are great potential allies in these efforts, as we are both most interested in preserving the best of nature. Dark skies are certainly part of that resource. Many involved in environmental protection efforts forget that the night is part of the environment too.

I enclose a number of the IDA Information Sheets for your information and files. Any feedback would be most welcome.

As to measuring the slides: We have not planned to do that, at this time anyway, due to lack of resources and time. However, it may very well be that the group in Japan would volunteer to do it. They are all set up for it and they do many. I think that they are interested in showing an international flavor to their efforts, and as such may well volunteer to measure some or all of yours (and others perhaps). They are active in IDA and their program has been well received in Japan, with quite a bit of good publicity. We hope that the one here will grow, and that many more will participate as time goes on. It is a natural for schools, for amateur astronomy groups, for planetaria, and even for national parks (we can easily develop a summer time program, as they have in Japan).

I will phone Jonathan Arnold, as you suggest, to discuss some of this with him. I will also send the IDA sheets to him as well.

Call In MORNING

My phone at Kitt Peak Nat Obs (where I am employed full time, as a senior tenured astronomer is 602-325-9346 (fax 325-9360). Either the IDA or the KPNO address is OK, IDA being a bit better.

Can we use Organ Pipe as a originator and pilot program for many other parks as well?

Sincerely yours,

Dave Crawford

Dr. David L. Crawford

United States Department of the Interior

NATIONAL PARK SERVICE
ORGAN PIPE CACTUS NATIONAL MONUMENT
ROUTE 1, BOX 100
AJO, ARIZONA 85321

IN REPLY REFER TO:

N22

December 3, 1992

Dr. David Crawford
International Dark Sky Association
3545 North Stewart Avenue
Tucson, Arizona 85716

Dear Dr. Crawford:

Organ Pipe Cactus National Monument is in the process of establishing a light pollution monitoring program.

As part of our program we plan to use the photographic method developed in Japan and adopted by the International Dark Sky Association as mentioned in the November, 1991 and November, 1992 Sky and Telescope articles.

The November, 1992 article mentions reading the slides with a densiometer. Could you please send us information on the equipment needed and methods used. Do you know of any organizations or individuals who can be hired to read the slides we take?

Any suggestions you have about establishing our light pollution monitoring program will be greatly appreciated and may be directed to Jonathan F. Arnold, Resources Management Specialist. His telephone number is (602) 387-7661, ext. 7112. Thank you.

Sincerely,

Harold J. Smith
Superintendent

10/21/92

Hello Diane:

I just received your cc_mail message asking about night sky monitoring. Hope all is going well for you. Days only recently have started cooling off here in the Sonoran Desert, with temps still reaching 90 degrees. Summer field work was extremely busy, as always, and winter office work beckons. I did manage to take a few weeks off this summer with Kathy to make a wonderful hike in SEKI. We hiked with Dan to Simpson Meadow for a part of that outing.

I enclose a few articles Dan sent me on light pollution, etc. that are good. David Crawford of I.D.A. would be a good contact for you to make. As far as the monitoring program at ORPI, I am redesigning the monitoring protocols this fall. The P.I. who designed our light pollution monitoring protocols (as part of his larger study entitled Land Use Trends Surrounding Organ Pipe Cactus National Monument) did an inadequate job, I think, with particular aspects of this protocol. I also enclose sections of this final report and monitoring protocols. As I progress with my work, I will keep you informed.

Give my regards to all at Ash Mountain.

Jon

[11] From: Diane M. Ewell at NP_SEKI 10/15/92 12:09PM (589 bytes: 7 ln)
To: ORPI Administration (ORPI Resource Management) at NP_SOAR
Subject: TO JOHN ARNOLD
---------- Message Contents ----------

DARK SKY MONITORING
Have you developed a monitoring program yet? Dan said he gave you a number of contacts for this and I was wondering how far along you were in your efforts. We are thinking of doing this as an interagency effort in the Sierra. I would appreciate any help you can give me. By the way, how are you doing?

28''

Tucson Meeting w/ D. Crumbo & D. Davis 11/9/94

National Weather Service
1-800-582-7929

-Dan Duriscoe

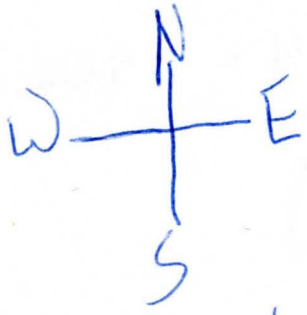
Notes from Tucson Meting

Kodak
ST-6 → Adapter
100mm Main Lens F/2

- Meade Pictor 416
F/4
~100mm FL

- Tripod
- Laptop (docking station)
-- Software
- V Filter
- Filter adapter

Mounting Block



Z
~ 15° steps
10°-15°

Sample thruout Night

*Seasonal

Z 45 15

3min exp
4 directions

Optec Inc Filter

Filter holder over the Front.

AVADS
LOADAVAD

Jan 4, 1995

14:40
7
21:40 UT

2415020 + 365(95) + 4 + 23 - .5

2449721.5

18 21 45 UT = 21.75 / 24 = .90625

2449722.40625

From bessell@merlin.anu.edu.au Tue Nov 1 15:42:39 1994
From: bessell@merlin.anu.edu.au (Mike Bessell)
To: Steve Howell <howell@PSI.EDU>
Subject: Re: CCD FILTERS
Date: Wed, 2 Nov 1994 09:41:19 +1000

Steve
Got some more results last night and have looked theoretically at a bluer B filter combination suggested by Alistair Walker.

I now think that the best filters for the ST6 will be
B: 1mm GG385 + 2mm BG1 + 2mm BG39
V: 2mm GG495 + 3mm BG40
R: 3mm OG570 + 2mm KG3
I: 2mm RG9 + 3mm GG385(fill)

Mike

==========
Mike Bessell	Telephone Nos: Work: 61 6 249 0268
Mount Stromlo &	Home: 61 6 288 1097
Siding Spring Observatories	Fax: 61 6 249 0233
Private Bag	
Weston P.O., ACT 2611	Internet Email: bessell@mso.anu.edu.au
Australia	
==========
==*

From bessell@merlin.anu.edu.au Tue Nov 1 15:42:39 1994
From: bessell@merlin.anu.edu.au (Mike Bessell)
To: Steve Howell <howell@PSI.EDU>
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Mike

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Mike Bessell	Telephone Nos: Work: 61 6 249 0268
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Australia	
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==*

Computer Model CCD iterations
Prepared by Bill Marlin

desig		gain	pixsiz	qe(v)	rn	dark	fullwell	T
Pic 201	TC-255	273.4	10	.4	20	17.4	70000	20
Pic 208	TC-255	273.4	10	.4	20	1.6	70000	-5
Pic 216	TC-255	1.07	10	.4	20	1.6	70000	-5
Pic 416	KAF-0400	1.30	9	.36	13	0.2	85000	-20
Pic 1616	KAF-1600	1.30	9	.39	13	0.2	85000	-20
ST 4X	TC-211	6	15	.4	20	5	95000	-5
ST 5	TC-255	3.05	10	.4	22	0.5	50000	-15
ST 6		6.10	24.9	.4	30	30	400000	-20
ST 6I-1	TC-241	6.10	24.9	.6	25	13	400000	-20
ST 6I-2	TC-241	6.10	30.9	.6	25	20	400000	-20
ST 6I-3	TC-241	6.10	43.1	.6	25	40	400000	-20
ST 6I-4	TC-241	6.10	24.9	.6	25	13	400000	-20
ST 6I-5	TC-241	6.10	49.8	.6	25	50	400000	-20
ST 6I-6	TC-241	6.10	70.5	.6	25	100	400000	-20
ST 6I-7	TC-241	6.10	86.3	.6	25	150	400000	-20
ST 6I-8	TC-241	6.10	387.7	.6	110	3200	400000	-20
	KAF-1000	3.05	24	.36	13	0.63	200000	-30
	KAF-1300	2.29	16	.44	13	0.28	150000	-30
	KAF-1400	1.	6.8	.42	13	0.05	45000	-30
	KAF-4200	1.30	9	.37	13	0.08	85000	-30
	KAF-6300	1.30	9	.36	13	0.08	85000	-30

telescope diameter (mm) = 200.00
f/# = 2.00
exposure time (s) = 30.00

desig		arcsec/pix	npix	tmax	e/s/pix	tot DN	sigsky	sigbkgd	sigdig	SIGMA(e)	S/N
Pic 201	TC-255	5.16	135.	3521.6	2.477	36.796	253.3896	295.8976	979.5313	1054.1553	9.5432
Pic 208	TC-255	5.16	135.	17168.4	2.477	36.796	253.3896	121.2709	979.5313	1019.0165	9.8723
Pic 216	TC-255	5.16	135.	17168.4	2.477	9401.919	253.3896	121.2709	3.8336	280.9406	35.8085
Pic 416	KAF-0400	4.64	167.	42374.6	1.806	6964.654	193.1243	76.7475	5.2470	207.8814	43.5539
Pic 1616	KAF-1600	4.64	167.	39417.3	1.956	7545.041	195.0679	76.7475	5.2470	209.6884	46.7768
ST 4X	TC-211	7.74	60.	8984.4	5.574	1676.676	184.7296	104.9529	13.8484	212.9129	47.2496
ST 5	TC-255	5.16	135.	16794.0	2.477	3298.379	274.9127	105.7075	10.9275	294.7380	34.1322
ST 6		12.84	22.	8818.5	15.359	1649.190	172.3647	143.2045	8.3267	224.2464	44.8616
ST 6I-1	TC-241	12.84	22.	11099.1	23.039	2473.784	169.5157	94.8610	8.3267	194.4313	77.6114
ST 6I-2	TC-241	15.94	14.	7209.9	35.480	2473.784	154.7606	93.5551	6.6847	180.9643	83.3871
ST 6I-3	TC-241	22.23	7.	3668.8	69.027	2473.784	140.1589	94.0288	4.7762	168.8453	89.3722
ST 6I-4	TC-241	12.84	22.	11099.1	23.039	2473.784	169.5157	94.8610	8.3267	194.4313	77.6114
ST 6I-5	TC-241	25.68	5.	2813.8	92.155	2473.784	136.0201	90.8329	4.1299	163.6127	92.2305
ST 6I-6	TC-241	36.36	3.	1405.0	184.689	2473.784	129.5850	90.5397	2.9133	158.1082	95.4415
ST 6I-7	TC-241	44.50	2.	937.3	276.748	2473.784	127.3815	90.5313	2.3788	156.2934	96.5497
ST 6I-8	TC-241	199.94	0.	45.5	5585.395	2473.784	127.1997	92.9856	0.5291	157.5639	95.7712
x	KAF-1000	12.38	24.	14845.5	12.842	2968.541	114.1302	23.4082	4.3230	116.5862	77.6597
x	KAF-1300	8.25	53.	20672.7	6.976	4832.341	141.4295	30.6623	4.9381	144.7994	76.4234
x	KAF-1400	3.51	293.	35920.8	1.203	10563.059	245.0246	122.6824	5.6221	274.0796	38.5401
x	KAF-4200	4.64	167.	43903.1	1.856	7158.116	193.7743	72.0279	5.2470	206.7947	44.9990
x	KAF-6300	4.64	167.	45070.9	1.806	6964.654	193.1243	72.0279	5.2470	206.1857	43.9121

telescope diameter (mm) = 50.00
f/# = 4.00
exposure time (s) = 60.00

desig		arcsec/pix	npix	tmax	e/s/pix	tot DN	sigsky	sigbkgd	sigdig	SIGMA(e)	S/N
Pic 201	TC-255	10.31	34.	3884.7	0.619	4.600	121.6309	192.3126	467.3556	519.8071	2.4192
Pic 208	TC-255	10.31	34.	31541.3	0.619	4.600	121.6309	61.7804	467.3556	486.8594	2.5829
Pic 216	TC-255	10.31	34.	31541.3	0.619	1175.240	121.6309	61.7804	1.8291	136.4339	9.2170
Pic 416	KAF-0400	9.28	42.	130472.2	0.451	870.582	90.5124	28.5884	2.4786	94.9522	11.9192
Pic 1616	KAF-1600	9.28	42.	123348.7	0.489	943.130	91.0319	28.5884	2.4786	95.4476	12.8455
ST 4X	TC-211	15.47	15.	14858.9	1.393	209.584	85.2863	68.3413	6.7752	109.4998	11.4841
ST 5	TC-255	10.31	34.	44670.2	0.619	412.297	132.8034	40.0487	5.2137	138.8086	9.0593
ST 6		25.68	5.	11820.4	3.840	206.149	78.5486	99.5249	4.1299	126.8548	9.9130
ST 6I-1	TC-241	25.68	5.	21322.3	5.760	309.223	72.7849	65.5687	4.1299	98.0507	19.2376
ST 6I-2	TC-241	31.87	4.	13855.3	8.870	309.223	64.0426	65.3918	3.3248	91.5893	20.5948
ST 6I-3	TC-241	44.45	2.	6986.1	17.257	309.223	54.9988	66.1989	2.3816	86.0978	21.9083
ST 6I-4	TC-241	25.68	5.	21322.3	5.760	309.223	72.7849	65.5687	4.1299	98.0507	19.2376
ST 6I-5	TC-241	51.36	1.	5476.5	23.039	309.223	52.3365	64.0344	2.0607	82.7270	22.8010
ST 6I-6	TC-241	72.71	1.	2736.5	46.172	309.223	48.0813	63.9402	1.4552	80.0142	23.5741
ST 6I-7	TC-241	89.01	0.	1824.9	69.187	309.223	46.5860	63.9647	1.1886	79.1400	23.8345
ST 6I-8	TC-241	399.87	0.	87.0	1396.349	309.223	46.4616	65.7482	0.2645	80.5083	23.4294
x	KAF-1000	24.75	6.	52076.2	3.211	371.068	46.0942	15.1401	2.1428	48.5642	23.3043
x	KAF-1300	16.50	13.	74111.1	1.744	604.043	60.1441	15.9547	2.4221	62.2715	22.2133
x	KAF-1400	7.01	73.	128318.7	0.301	1320.382	116.9995	33.7762	2.5612	121.8043	10.8402
x	KAF-4200	9.28	42.	156244.0	0.464	894.765	90.6859	22.4480	2.4786	93.4558	12.4465
x	KAF-6300	9.28	42.	159930.8	0.451	870.582	90.5124	22.4480	2.4786	93.2874	12.1319

telescope diameter (mm) = 400.00
f/# = 2.00
exposure time (s) = 30.00

desig		arcsec/pix	npix	tmax	e/s/pix	tot DN	sigsky	sigbkgd	sigdig	SIGMA(e)	S/N
Pic 201	TC-255	2.58	541.	3521.6	2.477	147.184	506.7792	743.6105	2282.6899	2453.6614	16.4001
Pic 208	TC-255	2.58	541.	17168.4	2.477	147.184	506.7792	396.6554	2282.6899	2371.6731	16.9670
Pic 216	TC-255	2.58	541.	17168.4	2.477	37607.676	506.7792	396.6554	8.9337	643.6151	62.5222
Pic 416	KAF-0400	2.32	668.	42374.6	1.806	27858.615	386.2485	286.7236	12.5471	481.2024	75.2619
Pic 1616	KAF-1600	2.32	668.	39417.3	1.956	30180.162	390.1358	286.7236	12.5471	484.3282	81.0075
ST 4X	TC-211	3.87	241.	8984.4	5.574	6706.703	369.4593	260.6708	29.9617	453.1525	88.8006
ST 5	TC-255	2.58	541.	16794.0	2.477	13193.515	549.8254	392.9624	25.4653	676.2957	59.5009
ST 6		6.42	87.	8818.5	15.359	6596.758	344.7294	303.8523	17.1788	459.8474	87.5078
ST 6I-1	TC-241	6.42	87.	11099.1	23.039	9895.137	339.0315	204.4513	17.1788	396.2799	152.3174
ST 6I-2	TC-241	7.97	57.	7209.9	35.480	9895.135	309.5212	194.8456	13.6468	365.9979	164.9199
ST 6I-3	TC-241	11.11	29.	3668.8	69.027	9895.137	280.3177	191.1245	9.6555	339.4110	177.8385
ST 6I-4	TC-241	6.42	87.	11099.1	23.039	9895.137	339.0315	204.4513	17.1788	396.2799	152.3174
ST 6I-5	TC-241	12.84	22.	2813.8	92.155	9895.137	272.0401	183.7448	8.3267	328.3859	183.8092
ST 6I-6	TC-241	18.18	11.	1405.0	184.689	9895.136	259.1700	181.9682	5.8503	316.7266	190.5755
ST 6I-7	TC-241	22.25	7.	937.3	276.748	9895.135	254.7630	181.6227	4.7706	312.9117	192.8989
ST 6I-8	TC-241	99.97	0.	45.5	5585.395	9895.136	254.3994	185.9996	1.0583	315.1444	191.5323
x	KAF-1000	6.19	94.	14845.5	12.842	11874.164	228.2605	58.6267	8.9388	235.8386	153.5635
x	KAF-1300	4.13	212.	20672.7	6.976	19329.363	282.8590	98.5537	10.5940	299.7237	147.6835
x	KAF-1400	1.75	1171.	35920.8	1.203	42252.234	490.0492	485.3308	14.5714	689.8598	61.2476
x	KAF-4200	2.32	668.	43903.1	1.856	28632.465	387.5486	279.6341	12.5471	478.0655	77.8600
x	KAF-6300	2.32	668.	45070.9	1.806	27858.615	386.2485	279.6341	12.5471	477.0121	75.9230

t4.out Wed Nov 9 07:50:44 1994 1

25mm 25mm f/ 25mm f/4 2rm~ t/0

telescope diameter (mm) = 50.00
f/# = 2.00
exposure time (s) = 60.00

desig		arcsec/pix	npix	tmax	e/s/pix	tot DN	sigsky	sigbkgd	sigdig	SIGMA(e)	S/N
Pic 201	TC-255	20.63	8.	3521.6	2.477	4.600	68.1296	94.5302	230.7915	258.5389	4.8639
Pic 208	TC-255	20.63	8.	17168.4	2.477	4.600	68.1296	29.1152	230.7915	242.3924	5.1879
Pic 216	TC-255	20.63	8.	17168.4	2.477	1175.240	68.1296	29.1152	0.9032	74.0956	16.9714
Pic 416	KAF-0400	18.57	10.	42374.6	1.806	870.582	53.8232	12.0451	1.2205	55.1681	20.5147
Pic 1616	KAF-1600	18.57	10.	39417.3	1.956	943.130	54.6923	12.0451	1.2205	56.0163	21.8877
ST 4X	TC-211	30.94	4.	8984.4	5.574	209.584	52.5506	33.7334	3.3687	62.5369	20.1082
ST 5	TC-255	20.63	8.	16794.0	2.477	412.297	73.1595	17.0470	2.5747	75.1635	16.7303
ST 6		51.36	1.	8818.5	15.359	206.149	49.8558	49.6107	2.0607	70.3638	17.8715
ST 6I-1	TC-241	51.36	1.	11099.1	23.039	309.223	52.3365	32.6644	2.0607	61.7278	30.5577
ST 6I-2	TC-241	63.74	1.	7209.9	35.480	309.223	49.3969	32.6301	1.6602	59.2245	31.8493
ST 6I-3	TC-241	88.91	0.	3668.8	69.027	309.223	46.5930	33.0710	1.1900	57.1491	33.0060
ST 6I-4	TC-241	51.36	1.	11099.1	23.039	309.223	52.3365	32.6644	2.0607	61.7278	30.5577
ST 6I-5	TC-241	102.73	0.	2813.8	92.155	309.223	45.8200	31.9974	1.0298	55.8960	33.7459
ST 6I-6	TC-241	145.43	0.	1405.0	184.689	309.223	44.6391	31.9611	0.7274	54.9062	34.3542
ST 6I-7	TC-241	178.02	0.	937.3	276.748	309.223	44.2409	31.9765	0.5942	54.5904	34.5530
ST 6I-8	TC-241	799.75	0.	45.5	5585.395	309.223	44.2082	32.8738	0.1323	55.0915	34.2387
x	KAF-1000	49.51	1.	14845.5	12.842	371.068	37.1482	7.4811	1.0691	37.9090	29.8545
x	KAF-1300	33.00	3.	20672.7	6.976	604.043	44.0656	7.5862	1.2051	44.7300	30.9246
x	KAF-1400	14.03	18.	35920.8	1.203	1320.382	66.4267	10.6052	1.2474	67.2795	19.6253
x	KAF-4200	18.57	10.	43903.1	1.856	894.765	54.1145	8.3124	1.2205	54.7628	21.2406
x	KAF-6300	18.57	10.	45070.9	1.806	870.582	53.8232	8.3124	1.2205	54.4750	20.7757

ST 7

Kodak - KAF 0400
ST 6 -
TI dip

40 e⁻/pix

S/N = 10

0.1 mag →

0.1 = e.rg

1.1 10%

telescope diameter (mm) = 200.00
f/# = 10.00
exposure time (s) = 60.00

desig		arcsec/pix	npix	tmax	e/s/pix	tot DN	sigsky	sigbkgd	sigdig	SIGMA(e)	S/N
Pic 201	TC-255	1.03	3384.	4000.2	0.099	73.592	1172.0819	4479.9897	9624.1562	*********	1.8839
Pic 208	TC-255	1.03	3384.	41198.5	0.099	73.592	1172.0819	2450.5649	9624.1562	*********	2.0120
Pic 216	TC-255	1.03	3384.	41198.5	0.099	18803.840	1172.0819	2450.5649	37.6659	2716.7007	7.4061
Pic 416	KAF-0400	0.93	4178.	312228.2	0.072	13929.308	850.9886	1791.5183	55.2588	1984.1302	9.1265
Pic 1616	KAF-1600	0.93	4178.	305473.5	0.078	15090.081	851.8748	1791.5183	55.2588	1984.5105	9.8851
ST 4X	TC-211	1.55	1504.	18188.9	0.223	3353.352	788.5080	1426.4500	106.4154	1633.3489	12.3183
ST 5	TC-255	1.03	3384.	83459.9	0.099	6596.758	1287.6504	2447.0508	107.3653	2767.2422	7.2708
ST 6		2.57	546.	13065.8	0.614	3298.379	715.0931	1336.7345	51.2073	1516.8518	13.2644
ST 6I-1	TC-241	2.57	546.	28732.4	0.922	4947.568	609.3585	918.8671	51.2073	1103.7467	27.3434
ST 6I-2	TC-241	3.19	354.	18674.8	1.419	4947.568	501.6964	809.0582	38.6253	952.7678	31.6763
ST 6I-3	TC-241	4.45	182.	9354.3	2.761	4947.568	379.5271	733.2259	25.8712	826.0329	36.5363
ST 6I-4	TC-241	2.57	546.	28732.4	0.922	4947.568	609.3585	918.8671	51.2073	1103.7467	27.3434
ST 6I-5	TC-241	5.14	136.	7450.7	3.686	4947.568	339.8008	690.5523	21.9532	769.9409	39.1980
ST 6I-6	TC-241	7.27	68.	3724.8	7.388	4947.569	269.6945	662.7524	15.0337	715.6828	42.1698
ST 6I-7	TC-241	8.90	45.	2483.4	11.070	4947.567	242.0318	654.8447	12.1504	698.2468	43.2228
ST 6I-8	TC-241	39.99	2.	116.8	223.416	4947.567	239.6296	658.2607	2.6482	700.5259	43.0821
x	KAF-1000	2.48	588.	174873.5	0.514	5937.082	342.6364	305.9291	26.9197	460.1271	39.3546
x	KAF-1300	1.65	1322.	268318.1	0.279	9664.681	495.5181	588.9767	36.6659	770.5687	28.7218
x	KAF-1400	0.70	7319.	458667.4	0.048	21126.115	1121.5953	3038.8652	71.3082	3240.0251	6.5204
x	KAF-4200	0.93	4178.	551077.2	0.074	14316.232	851.2841	1747.5065	55.2588	1944.6123	9.5706
x	KAF-6300	0.93	4178.	558340.8	0.072	13929.308	850.9886	1747.5065	55.2588	1944.4829	9.3126

telescope diameter (mm) = 25.00
f/# = 2.00
exposure time (s) = 180.00

desig		arcsec/pix	npix	tmax	e/s/pix	tot DN	sigsky	sigbkgd	sigdig	SIGMA(e)	S/N
Pic 201	TC-255	41.26	2.	3521.6	2.477	3.450	42.2985	81.4877	115.0322	147.1795	6.4080
Pic 208	TC-255	41.26	2.	17168.4	2.477	3.450	42.2985	24.7431	115.0322	125.0351	7.5429
Pic 216	TC-255	41.26	2.	17168.4	2.477	881.430	42.2985	24.7431	0.4502	49.0060	19.2452
Pic 416	KAF-0400	37.13	3.	42374.6	1.806	652.936	35.9181	9.7674	0.6079	37.2275	22.8008
Pic 1616	KAF-1600	37.13	3.	39417.3	1.956	707.348	36.8897	9.7674	0.6079	38.1657	24.0937
ST 4X	TC-211	61.88	1.	8984.4	5.574	157.188	36.3200	29.1064	1.6820	46.5742	20.2500
ST 5	TC-255	41.26	2.	16794.0	2.477	309.223	44.3490	13.8898	1.2833	46.4909	20.2863
ST 6		102.73	0.	8818.5	15.359	154.612	35.3575	42.9287	1.0298	55.6246	16.9553
ST 6I-1	TC-241	102.73	0.	11099.1	23.039	231.917	40.3473	28.2596	1.0298	49.2704	28.7129
ST 6I-2	TC-241	127.48	0.	7209.9	35.480	231.917	39.4100	28.2432	0.8298	48.4924	29.1736
ST 6I-3	TC-241	177.81	0.	3668.8	69.027	231.917	38.5468	28.6339	0.5949	48.0220	29.4593
ST 6I-4	TC-241	102.73	0.	11099.1	23.039	231.917	40.3473	28.2596	1.0298	49.2704	28.7129
ST 6I-5	TC-241	205.45	0.	2813.8	92.155	231.917	38.3145	27.7061	0.5149	47.2852	29.9183
ST 6I-6	TC-241	290.85	0.	1405.0	184.689	231.917	37.9644	27.6771	0.3637	46.9835	30.1105
ST 6I-7	TC-241	356.04	0.	937.3	276.748	231.917	37.8477	27.6912	0.2971	46.8971	30.1660
ST 6I-8	TC-241	******	0.	45.5	5585.395	231.917	37.8381	28.4695	0.0661	47.3523	29.8760
x	KAF-1000	99.01	0.	14845.5	12.842	278.301	30.1807	6.4559	0.5342	30.8681	27.4982
x	KAF-1300	66.01	1.	20672.7	6.976	453.032	34.3085	6.4646	0.6018	34.9174	29.7114
x	KAF-1400	28.05	5.	35920.8	1.203	990.287	41.9919	6.7001	0.6195	42.5276	23.2858
x	KAF-4200	37.13	3.	43903.1	1.856	671.073	36.2449	6.2331	0.6079	36.7820	23.7180
x	KAF-6300	37.13	3.	45070.9	1.806	652.936	35.9181	6.2331	0.6079	36.4600	23.2808

telescope diameter (mm) = 25.00
f/# = 4.00
exposure time (s) = 180.00

desig		arcsec/pix	npix	tmax	e/s/pix	tot DN	sigsky	sigbkgd	sigdig	SIGMA(e)	S/N
Pic 201	TC-255	20.63	8.	3884.7	0.619	3.450	65.7820	163.5562	230.7915	290.4180	3.2475
Pic 208	TC-255	20.63	8.	31541.3	0.619	3.450	65.7820	49.8581	230.7915	245.1078	3.8478
Pic 216	TC-255	20.63	8.	31541.3	0.619	881.430	65.7820	49.8581	0.9032	82.5464	11.4255
Pic 416	KAF-0400	18.57	10.	130472.2	0.451	652.936	51.1273	19.9595	1.2205	54.8987	15.4615
Pic 1616	KAF-1600	18.57	10.	123348.7	0.489	707.348	51.8144	19.9595	1.2205	55.5392	16.5568
ST 4X	TC-211	30.94	4.	14858.9	1.393	157.188	49.4691	58.3311	3.3687	76.5576	12.3192
ST 5	TC-255	20.63	8.	44670.2	0.619	309.223	70.9784	28.3287	2.5747	76.4662	12.3339
ST 6		51.36	1.	11820.4	3.840	154.612	46.5964	85.9087	2.0607	97.7536	9.6480
ST 6I-1	TC-241	51.36	1.	21322.3	5.760	231.917	47.6187	56.5559	2.0607	73.9618	19.1274
ST 6I-2	TC-241	63.74	1.	13855.3	8.870	231.917	44.3677	56.5083	1.6602	71.8641	19.6857
ST 6I-3	TC-241	88.91	0.	6986.1	17.257	231.917	41.2231	57.2784	1.1900	70.5803	20.0438
ST 6I-4	TC-241	51.36	1.	21322.3	5.760	231.917	47.6187	56.5559	2.0607	73.9618	19.1274
ST 6I-5	TC-241	102.73	0.	5476.5	23.039	231.917	40.3473	55.4198	1.0298	68.5589	20.6347
ST 6I-6	TC-241	145.43	0.	2736.5	46.172	231.917	39.0011	55.3579	0.7274	67.7208	20.8901
ST 6I-7	TC-241	178.02	0.	1824.9	69.187	231.917	38.5447	55.3848	0.5942	67.4798	20.9647
ST 6I-8	TC-241	799.75	0.	87.0	1396.349	231.917	38.5072	56.9391	0.1323	68.7378	20.5810
x	KAF-1000	49.51	1.	52076.2	3.211	278.301	33.1217	12.9295	1.0691	35.5719	23.8620
x	KAF-1300	33.00	3.	74111.1	1.744	453.032	39.9494	12.9984	1.2051	42.0282	24.6845
x	KAF-1400	14.03	18.	128318.7	0.301	990.287	63.8938	14.9752	1.2474	65.6371	15.0873
x	KAF-4200	18.57	10.	156244.0	0.464	671.073	51.3574	13.0543	1.2205	53.0046	16.4589
x	KAF-6300	18.57	10.	159930.8	0.451	652.936	51.1273	13.0543	1.2205	52.7817	16.0817

telescope diameter (mm) = 25.00
f/# = 2.00
exposure time (s) = 300.00

desig		arcsec/pix	npix	tmax	e/s/pix	tot DN	sigsky	sigbkgd	sigdig	SIGMA(e)	S/N
Pic 201	TC-255	41.26	2.	3521.6	2.477	5.749	49.1723	105.1946	115.0322	163.4510	9.6169
Pic 208	TC-255	41.26	2.	17168.4	2.477	5.749	49.1723	31.9246	115.0322	129.1104	12.1747
Pic 216	TC-255	41.26	2.	17168.4	2.477	1469.050	49.1723	31.9246	0.4502	58.6285	26.8109
Pic 416	KAF-0400	37.13	3.	42374.6	1.806	1088.227	43.0812	12.5791	0.6079	44.8842	31.5188
Pic 1616	KAF-1600	37.13	3.	39417.3	1.956	1178.913	44.4284	12.5791	0.6079	46.1789	33.1881
ST 4X	TC-211	61.88	1.	8984.4	5.574	261.981	44.1350	37.5731	1.6820	57.9868	27.1076
ST 5	TC-255	41.26	2.	16794.0	2.477	515.372	50.9469	17.8913	1.2833	54.0123	29.1023
ST 6		102.73	0.	8818.5	15.359	257.686	43.3464	55.4201	1.0298	70.3659	22.3387
ST 6I-1	TC-241	102.73	0.	11099.1	23.039	386.529	50.7054	36.4824	1.0298	62.4745	37.7406
ST 6I-2	TC-241	127.48	0.	7209.9	35.480	386.529	49.9627	36.4615	0.8298	61.8579	38.1168
ST 6I-3	TC-241	177.81	0.	3668.8	69.027	386.529	49.2848	36.9661	0.5949	61.6103	38.2700
ST 6I-4	TC-241	102.73	0.	11099.1	23.039	386.529	50.7054	36.4824	1.0298	62.4745	37.7406
ST 6I-5	TC-241	205.45	0.	2813.8	92.155	386.529	49.1032	35.7684	0.5149	60.7517	38.8108
ST 6I-6	TC-241	290.85	0.	1405.0	184.689	386.529	48.8305	35.7310	0.3637	60.5083	38.9669
ST 6I-7	TC-241	356.04	0.	937.3	276.748	386.529	48.7399	35.7492	0.2971	60.4456	39.0074
ST 6I-8	TC-241	******	0.	45.5	5585.395	386.529	48.7324	36.7540	0.0661	61.0386	38.6284
x	KAF-1000	99.01	0.	14845.5	12.842	463.835	38.4285	8.3336	0.5342	39.3254	35.9741
x	KAF-1300	66.01	1.	20672.7	6.976	755.053	43.2285	8.3411	0.6018	44.0300	39.2704
x	KAF-1400	28.05	5.	35920.8	1.203	1650.478	49.2291	8.5125	0.6195	49.9635	33.0336
x	KAF-4200	37.13	3.	43903.1	1.856	1118.456	43.5349	7.9991	0.6079	44.2679	32.8453
x	KAF-6300	37.13	3.	45070.9	1.806	1088.227	43.0812	7.9991	0.6079	43.8218	32.2829

telescope diameter (mm) = 25.00
f/# = 6.00
exposure time (s) = 300.00

desig		arcsec/pix	npix	tmax	e/s/pix	tot DN	sigsky	sigbkgd	sigdig	SIGMA(e)	S/N
Pic 201	TC-255	13.75	19.	3960.3	0.275	5.749	95.8447	318.4388	347.9978	481.3439	3.2656
Pic 208	TC-255	13.75	19.	37328.3	0.275	5.749	95.8447	97.2423	347.9978	373.8244	4.2049
Pic 216	TC-255	13.75	19.	37328.3	0.275	1469.050	95.8447	97.2423	1.3620	136.5434	11.5120
Pic 416	KAF-0400	12.38	24.	212151.1	0.201	1088.227	73.3918	39.1986	1.8426	83.2243	16.9986
Pic 1616	KAF-1600	12.38	24.	203651.7	0.217	1178.913	74.1906	39.1986	1.8426	83.9296	18.2604
ST 4X	TC-211	20.63	8.	16906.0	0.619	261.981	70.3990	113.2542	5.0649	133.4474	11.7791
ST 5	TC-255	13.75	19.	64495.3	0.275	515.372	103.8518	55.5437	3.8822	117.8362	13.3396
ST 6		34.24	3.	12615.7	1.707	257.686	65.8415	166.5096	3.0937	179.0814	8.7775
ST 6I-1	TC-241	34.24	3.	25707.2	2.560	386.529	65.3967	109.6202	3.0937	127.6827	18.4663
ST 6I-2	TC-241	42.49	2.	16706.9	3.942	386.529	60.0322	109.4914	2.4917	124.8937	18.8787
ST 6I-3	TC-241	59.27	1.	8391.1	7.670	386.529	54.7567	110.9514	1.7855	123.7404	19.0546
ST 6I-4	TC-241	34.24	3.	25707.2	2.560	386.529	65.3967	109.6202	3.0937	127.6827	18.4663
ST 6I-5	TC-241	68.48	1.	6640.2	10.239	386.529	53.2687	107.3434	1.5451	119.8438	19.6742
ST 6I-6	TC-241	96.95	0.	3318.9	20.521	386.529	50.9627	107.2116	1.0912	118.7127	19.8616
ST 6I-7	TC-241	118.68	0.	2213.0	30.750	386.529	50.1754	107.2598	0.8914	118.4189	19.9109
ST 6I-8	TC-241	533.17	0.	104.7	620.599	386.529	50.1105	110.2625	0.1984	121.1153	19.4676
x	KAF-1000	33.00	3.	97233.7	1.427	463.835	44.4208	25.0703	1.6050	51.0324	27.7215
x	KAF-1300	22.00	7.	142165.8	0.775	755.053	54.6418	25.2705	1.8114	60.2297	28.7080
x	KAF-1400	9.35	41.	245045.0	0.134	1650.478	92.7780	30.4851	1.8921	97.6764	16.8974
x	KAF-4200	12.38	24.	296962.3	0.206	1118.456	73.6590	25.8963	1.8426	78.1004	18.6170
x	KAF-6300	12.38	24.	302860.0	0.201	1088.227	73.3918	25.8963	1.8426	77.8484	18.1724

PCOLC meeting
11/9/94

OUTDOOR LIGHTING CODE



1993

TUCSON/PIMA COUNTY OUTDOOR LIGHTING CODE
1993 EDITION

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1 TUCSON/PIMA COUNTY OUTDOOR LIGHTING CODE
1993 EDITION

Sec. 1. Purpose and Intent.

The purpose of this Code is to provide standards for outdoor lighting so that its use does not unreasonably interfere with astronomical observations. It is the intent of this Code to encourage, through the regulation of the types, kinds, construction, installation and uses of outdoor electrically powered illuminating devices, lighting practices and systems to conserve energy without decreasing safety, utility, security and productivity while enhancing nighttime enjoyment of property within the jurisdiction.

Sec. 2. Conformance with Applicable Codes.

All outdoor electrically powered illuminating devices shall be installed in conformance with the provisions of this Code, the Building Code, the Electrical Code and the Sign Code of the jurisdiction as applicable and under appropriate permit and inspection.

Sec. 3. Approved Materials and Methods of Construction or Installation/Operation.

The provisions of this Code are not intended to prevent the use of any design, material or method of installation or operation not specifically prescribed by this Code, provided any such alternate has been approved. The building official may approve any such proposed alternate provided he finds that it:

(a) provides at least approximate equivalence to the applicable specific requirements of this Code; and

(b) is otherwise satisfactory and complies with the intent of this Code; or

(c) has been designed or approved by a registered professional engineer and content and function promotes the intent of this Code.

Sec. 4. Definitions.

As used in this Code, unless the context clearly indicates otherwise, certain words and phrases shall mean the following:

Sec. 4.1. **Person** means any individual, tenant, lessee, owner, or any commercial entity including but not limited to firm, business, partnership, joint venture, or corporation.

Sec. 4.2. **Installed** means the attachment, or assembly fixed in place, whether or not connected to a power source, of any outdoor light fixture.

Sec. 4.3. **Outdoor light fixtures** means outdoor electrically powered illuminating devices, outdoor lighting or reflective surfaces, lamps and similar devices, permanently installed or portable, used for illumination or advertisement. Such devices shall include, but are not limited to, search, spot and flood lights for:

(a) buildings and structures

(b) recreational areas

(c) parking lot lighting

(d) landscape lighting

(e) billboards and other signs (advertising or other)

(f) street lighting

(g) product display area lighting

(h) building overhangs and open canopies

Sec. 4.4. **Area A** means the circular area, 35 miles in radius, the center of which is the center of the Kitt Peak Observatory and the circular area, 25 miles in radius, the center of which is the center of Mount Hopkins Observatory.

The boundary lines for Area A around Mt. Lemmon is defined as: The Pinal County line on the north, along the center line of the Santa Cruz River, to the center line of Rillito Creek, to the center line of Tanque Verde Creek with the junction to the northern border of the Saguaro National Monument, then along that border until it ends on the east side and bends east to the County line.

Sec. 4.5. Area B means all areas outside Area A and outside the territorial limits of every Indian Reservation lying wholly or partly within Pima County.

Sec. 5. Shielding.

All non-exempt outdoor lighting fixtures shall have shielding as required by Table 5 of this Code.

Sec. 5.1 **Fully shielded** shall mean outdoor light fixtures shielded or constructed so that no light rays are emitted by the installed fixture

at angles above the horizontal plane, as certified by photometric test report.

Sec. 5.2 **Partially shielded** shall mean outdoor light fixtures shielded or constructed so that no more than ten percent (10%) of the light rays are emitted by the installed fixture at angles above the horizontal plane as certified by photometric test report.

Sec. 5.2 **Poles and Standards.** All poles or standards used to support outdoor lighting fixtures shall be anodized or otherwise coated to minimize glare from the light source.

Sec. 6. Filtration.

Metal halide fixture lamp types shall be filtered. "Filtered" means any outdoor light fixture which has a glass, acrylic or translucent enclosure of the light source. Quartz glass does not meet this requirement.

Sec. 7. Outdoor Advertising Signs.

Sec. 7.1. **Top Mounted Fixtures Required.** Lighting fixtures used to illuminate an outdoor advertising sign shall be mounted on the top of the sign structure. All such fixtures shall comply with the shielding requirements of Section 5 .

Exception: Lighting for existing and new outdoor advertising structures need not be shielded in accordance with Section 5 of this Code if the following conditions apply:

(a) The structure exceeds 301 square feet per sign face; and

(b) The structure consists of panels which are designed to be removed from the top of the sign board; and

(c) The outdoor advertising structure is equipped with an automatic device which shuts off the fixtures between 11:00 p.m. and sunrise.

For such signs, the lighting may consist of no more than four (4) bottom mounted individual fixtures (or lamps) which produce a maximum of forty thousand (40,000) lumens per fixture; and where no more than one thousand seventeen (1,017) lumens per fixture spills or is cast beyond the sign face.

Sec. 7.2. **Compliance Limit.** Existing outdoor advertising structures shall be brought into conformance with this Code within three (3) years from the date of adoption of this provision.

Sec. 7.3. **Prohibitions.** Electrical illumination of outdoor advertising off-site signs is prohibited in Area A. Electrical illumination of outdoor advertising off-site signs between the hours of 11:00 p.m. and sunrise is prohibited in Area B.

Sec. 8. **Submission of Plans and Evidence of Compliance with Code; Subdivision Plats.**

Sec. 8.1. **Submission Contents.** The applicant for any permit required by any provision of the laws of this jurisdiction in connection with proposed work involving outdoor light fixtures shall submit (as part of the application for permit) evidence that the proposed work will comply with this Code. The submission shall contain but shall not necessarily be limited to the following, all or part of which may be part of or in addition to the information required elsewhere in the laws of this jurisdiction upon application for the required permit:

(a) plans indicating the location on the premises, and the type, of illuminating devices, fixtures, lamps, supports, reflectors and other devices;

(b) description of the illuminating devices, fixtures, lamps, supports, reflectors and other devices and the description may include, but is not limited to, catalog cuts by manufacturers and drawings (including sections where required);

(c) photometric data, such as that furnished by manufacturers, or similar, showing the angle of cut off of light emissions.

Sec. 8.2. **Additional Submission.** The above-required plans, descriptions and data shall be sufficiently complete to enable the plans examiner to readily determine whether compliance with the requirements of this Code will be secured. If such plans, descriptions and data cannot enable this ready determination, by reason of the nature or configuration of the devices, fixtures or lamps proposed, the applicant shall additionally submit as evidence of compliance to enable such determination such certified reports of tests as will do so provided that these tests shall have been performed and certified by a recognized testing laboratory.

Sec. 8.3. **Subdivision Plat Certification.** If any subdivision proposes to have installed street or other common or public area outdoor lighting, the final plat shall contain a statement certifying that the applicable provisions of the Tucson/Pima County Outdoor Lighting Code will be adhered to.

Sec. 8.4. **Lamp or Fixture Substitution.** Should any outdoor light fixture or the type of light source therein be changed after the permit has been issued, a change request must be submitted to the building official for his approval, together with adequate information to assure compliance with this Code, which must be received prior to substitution.

Sec. 9. Prohibitions.

Sec. 9.1. **Mercury Vapor Fixtures and Lamps.** The installation, sale, offering for sale, lease or purchase of any mercury vapor fixture or lamp for use as outdoor lighting is prohibited.

Sec. 9.2. **Certain other Fixtures and Lamps.** The installation, sale, offering for sale, lease or purchase of any low pressure sodium, high pressure sodium, metal halide, fluorescent, quartz or incandescent outdoor lighting fixture or lamp, the use of which is not allowed by Table 5 is prohibited.

Sec. 9.3. **Laser Source Light.** Except as provided in minor Section 9.4, the use of laser source light or any similar high-intensity light for outdoor advertising or entertainment, when projected above the horizontal, is prohibited.

Sec. 9.4. **Searchlights.** The operation of searchlights for advertising purposes is prohibited in unincorporated Pima County. In the territorial limits of the City of Tucson, the operation of

searchlights for advertising purposes is prohibited in Area A and is prohibited in Area B between 10:00 p.m. and sunrise the following morning.

Sec. 10. Special Uses.

Sec. 10.1. **Recreational Facilities.** Any light source permitted by this Code may be used for lighting of public or private outdoor recreational facilities such as, but not limited to football fields, soccer fields, baseball fields, softball fields, tennis courts, auto race-tracks, horse race-tracks or show arenas, provided all of the following conditions are met:

(a) Lighting for parking lots and other areas surrounding the playing field, court or track shall comply with this Code for lighting in the specific area as defined in Section 4.4 and 4.5 of this Code.

(b) All fixtures used for event lighting shall be fully shielded as defined in Section 5 of this Code, or be designed or provided with sharp cut-off capability, so as to minimize up-light, spill-light and glare.

(c) All events shall be scheduled so as to complete all activity before or as near to 10:30 p.m. as practical, but under no circumstances shall any illumination of the playing field, court or track be permitted after 11:00 p.m.; Except to conclude a scheduled event that was in progress before 11:00 p.m. and circumstances prevented concluding before 11:00 p.m.

Exception: Recreational facilities located along roads and streets designated as scenic routes shall be lighted using only fixtures approved for the area in which they are located.

Sec. 10.2. **Outdoor Display Lots.** Any light source permitted by this Code may be used for lighting of outdoor display lots such as, but not limited to automobile sales or rental, recreational vehicle sales or building material sales, provided all of the following conditions are met:

(a) Lighting for parking lots and other areas surrounding the display lot shall comply with this Code for lighting in the specific area as defined in Section 4.4 and 4.5 of this Code.

(b) All fixtures used for display lighting shall be fully shielded as defined in Section 5 of this Code, or be designed or provided with sharp cut-off capability, so as to minimize up-light, spill-light and glare.

(c) Display lot lighting shall be turned off within thirty (30) minutes after the closing of the business. Under no circumstances shall the full illumination of the lot be permitted after 11:00 p.m. Any lighting used after 11:00 p.m. shall be used as security lighting.

Exception: Display lots located along roads and streets designated as scenic routes shall be lighted using only fixtures approved for the area in which they are located.

Sec. 11. Temporary Exemption.

Sec. 11.1. **Request or Renewal; Information Required.** Any person may submit a written request, on a form prepared by the jurisdiction, to the building official for a temporary exemption from the requirements of this Code. The Request for Temporary Exemption shall contain the following information:

(a) specific exemption or exemptions requested

(b) type and use of outdoor light fixture involved

(c) duration of time for requested exemption

(d) type of lamp and calculated lumens

(e) total wattage of lamp or lamps

(f) proposed location on premises of the outdoor light fixture(s)

(g) previous temporary exemptions if any and addresses of premises thereunder

(h) physical size of outdoor light fixture(s) and type of shielding provided

(i) such other data and information as may be required by the building official

Sec. 11.2. **Approval; Duration.** The building official shall have five (5) business days from the date of submission of the Request for Temporary Exemption to act in writing on the request. If approved, the exemption shall be valid for not more than thirty (30) days from the date of issuance of the approval. The approval shall be renewable at the discretion of the building official upon a consideration of all the circumstances. Each such renewed exemption shall be valid for not more than thirty (30) days.

Sec. 11.3. **Disapproval; Appeal.** If the Request for Temporary Exemption is disapproved, the person making the request will have the appeal rights provided in Section 13.

Sec. 12. Other Exemptions.

Sec. 12.1. **Non-Conformance.**

(a) Merury vapor lamps in use for outdoor lighting on the effective date of this Code shall not be so used.

(b) Bottom-mounted outdoor advertising sign lighting shall not be used, except as provided in Secton 7.

(c) All other outdoor light fixtures lawfully installed prior to and operable on the effective date of this Code are exempt from all requirements of this Code except those regulated in Section 7 and in minor Sections 9.3 and 9.4 and Section 10. There shall be no change in use or lamp type, or any replacement or structural alteration made, without conforming to all applicable requirements of this Code.

Sec. 12.2. **Fossil Fuel Light.** All outdoor light fixtures producing light directly by the combustion of natural gas or other fossil fuels are exempt from all requirements of this Code.

Sec. 12.3. **State and Federal Facilities.** Outdoor light fixtures installed on, in and in connection with those facilities and land owned or operated by the Federal Government or the State of Arizona, or

any department, division, agency or instrumentality thereof, are exempt from all requirements of this Code. Voluntary compliance with the intent of this Code at those facilities is encouraged.

Sec. 13. Appeals.

Any person aggrieved by any decision of the building official made in administration of this Code has the rights and responsibilities of appeal to the Advisory/Appeals Board of this jurisdiction.

Sec. 14. Law Governing Conflicts.

Where any provision of federal, state or city statutes, codes or laws conflicts with any provision of this Code, the most restrictive shall govern unless otherwise required by law.

Sec. 15. Violation.

It shall be a civil infraction for any person to violate any of the provisions of this Code. Each and every day during which the violation continues shall constitute a separate offense.

Sec. 16. Enforcement and Penalty.

Sec. 16.1. (CITY ONLY) Pursuant to Sec. 28-12 of the Tucson Code, a violation of this Code is considered a civil infraction.

(a) When a violation of this Code is determined, the following penalty shall be imposed:

(1) A fine of not less than Fifty Dollars ($50.00) nor more than One Thousand Dollars ($1,000.00) per violation. The imposition of a fine under this Code shall not be suspended.

(2) Any other order deemed necessary in the discretion of the hearing officer, including correction or abatement of the violation.

(b) Failure of a defendant to comply with any order contained in a judgment under this Code shall result in an additional fine of not less than Fifty Dollars ($50.00) nor more than One Thousand Dollars ($1,000.00) for each day the defendant fails to comply.

Sec. 16.2. (COUNTY ONLY) A violation of this Code is considered a civil infraction. Civil infractions shall be enforced through the hearing officer procedure provided by A.R.S. Sec.11-808 and Sections 18.95.030, 18.95.040 and 18.101.60 of the Pima County Code. A fine shall be imposed of not less than Fifty Dollars ($50.00) nor more than Seven Hundred Fifty Dollars ($750.00) for any individual or Ten Thousand Dollars ($10,000.00) for any corporation, association or other legal entity for each offense. The imposition of a fine under this Code shall not be suspended.

TABLE 5
SHIELDING REQUIREMENTS

	AREA A	AREA B
FIXTURE LAMP TYPE	SHIELDED	SHIELDED
Low Pressure Sodium[1]	Partially	Partially
High Pressure Sodium	Prohibited except fully shielded on arterial streets and collector streets of 100' or more in right-of-way width	Fully
Metal Halide	Prohibited[7]	Fully[2,6]
Fluorescent	Fully[3,5]	Fully[3,5]
Quartz[4]	Prohibited	Fully
Incandescent		
Greater than 160W	Fully	Fully
160W or Less	None	None
Any light source of 50W or Less	None	None
Glass Tubes filled with Neon, Argon, Krypton	None	None
Other Sources	AS APPROVED BY BUILDING OFFICIAL	

[1]This is the preferred light source to minimize undesirable light emission into the night sky affecting astronomical observations.

[2]Metal halide lighting used primarily for display purposes shall not be used for security lighting after 11:00 p.m. Metal halide lamps shall be installed only in enclosed luminaires.

[3]Outdoor advertising signs of the type constructed of translucent materials and wholly illuminated from within do not require shielding. Dark backgrounds with light lettering or symbols are preferred, to minimize detrimental effects. Unless conforming to the above dark background preference, total lamp wattage per property shall be less than 41 Watts in Area A.

[4]For the purposes of this Code, quartz lamps shall not be considered an incandescent light source.

[5]Warm white and natural lamps are preferred to minimize detrimental effects.

[6]For filtering requirements for metal halide fixture lamp types, see Section 6.

[7]Fully shielded metal halide fixtures shall be allowed for applications where the designing engineer deems that color rendering is critical.

OPTION A

ADOPTED BY THE
MAYOR AND COUNCIL
MAR 21 1994

ORDINANCE NO. 8210

* RELATING TO OUTDOOR LIGHTING; PROHIBITING THE SALE, OFFERING FOR SALE, LEASE OR PURCHASE OF CERTAIN LIGHTING FIXTURES AND LAMPS; RESTRICTING THE USE OF CERTAIN HIGH-INTENSITY LIGHT FOR OUTDOOR ADVERTISING OR ENTERTAINMENT; ESTABLISHING TIME OF DAY USE RESTRICTIONS AND PROHIBITIONS FOR CERTAIN TYPES OF LIGHTING; CONTINUING THE PROHIBITION AGAINST BOTTOM-MOUNTED OUTDOOR ADVERTISING SIGN LIGHTING; MAKING CERTAIN CONFORMING AND CORRECTIVE CHANGES; AMENDING SECTIONS 1, 4, 5, 7, AND 9 THROUGH 16, OF THE TUCSON/PIMA COUNTY OUTDOOR LIGHTING CODE; ADOPTING PORTIONS OF SAID CODE AS AMENDED AS THE OUTDOOR LIGHTING CODE OF THE CITY OF TUCSON, 1993 EDITION; AND PROVIDING FOR A PENALTY.

BE IT ORDAINED BY THE MAYOR AND COUNCIL OF THE CITY OF TUCSON, ARIZONA, AS FOLLOWS:

SECTION 1. The Tucson Code is amended by amending Section 6-101 thereof to read:

Sec. 6-101. Outdoor lighting code adopted.

The document entitled "Tucson/Pima County Outdoor Lighting Code, 1993 Edition," a copy of which is attached to Ordinance No. 8210 as Exhibit A, is adopted, except for those provisions which are designated for use by Pima County, by reference as the Outdoor Lighting Code of the City of Tucson.

SECTION 2. The Tucson/Pima County Outdoor Lighting Code, 1993 Edition, is set forth in Exhibit A to this ordinance and said exhibit is incorporated herein by this reference as though fully set forth herein.

SECTION 3. It shall be a civil infraction for any person, firm or corporation to violate any of the provisions of the Outdoor Lighting Code adopted by this ordinance. Each and every day during

*Ordinance heading amended at the Mayor and Council Meeting of 3/21/94. KSD:oa

which any violation continues shall constitute a separate offense.

SECTION 4. If any provision of this ordinance, or the application thereof to any person or circumstance is invalid, the invalidity shall not affect other provisions or applications of this ordinance which can be given effect without the invalid provision or application, and to this end the provisions of this ordinance are severable.

SECTION 5. WHEREAS, it is necessary for the preservation of the peace, health and safety of the City of Tucson that this ordinance become immediately effective, an emergency is hereby declared to exist and this ordinance shall be effective immediately upon its passage and adoption.

PASSED, ADOPTED AND APPROVED by the Mayor and Council of the City of Tucson, Arizona, MAR 21 1994.

Gladys Miller
MAYOR

ATTEST:

Kathleen S. Detrich
CITY CLERK

APPROVED AS TO FORM:

CITY ATTORNEY

3-22-94

REVIEWED BY:

CITY MANAGER

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3/22/94
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EXHIBIT A TO ORDINANCE NO. 8210

TUCSON/PIMA COUNTY OUTDOOR LIGHTING CODE, 1993 EDITION

Sec. 1. Purpose and Intent.

The purpose of this Code is to provide standards for outdoor lighting so that its use does not unreasonably interfere with astronomical observations. It is the intent of this Code to encourage, through the regulation of the types, kinds, construction, installation and uses of outdoor electrically powered illuminating devices, lighting practices and systems to conserve energy without decreasing safety, utility, security and productivity while enhancing nighttime enjoyment of property within the jurisdiction.

Sec. 2. Conformance with Applicable Codes.

All outdoor electrically powered illuminating devices shall be installed in conformance with the provisions of this Code, the Building Code, the Electrical Code and the Sign Code of the jurisdiction as applicable and under appropriate permit and inspection.

Sec. 3. Approved Materials and Methods of Construction or Installation/Operation.

The provisions of this Code are not intended to prevent the use of any design, material or method of installation or operation not specifically prescribed by this Code, provided any such alternate has been approved. The building official may approve any such proposed alternate provided he finds that it:

(a) provides at least approximate equivalence to the applicable specific requirements of this Code; and

(b) is otherwise satisfactory and complies with the intent of this Code; or

(c) has been designed or approved by a registered professional engineer and content and function promotes the intent of this Code.

Sec. 4. Definitions.

As used in this Code, unless the context clearly indicates otherwise, certain words and phrases shall mean the following:

Sec. 4.1. Person means any individual, tenant, lessee, owner, or any commercial entity including but not limited to firm, business, partnership, joint venture, or corporation.

Sec. 4.2. Installed means the attachment, or assembly fixed in place, whether or not connected to a power source, of any outdoor light fixture.

Sec. 4.3. Outdoor light fixtures means outdoor electrically powered illuminating devices, outdoor lighting or reflective surfaces, lamps and similar devices, permanently installed or portable, used for illumination or advertisement. Such devices shall include, but are not limited to, search, spot and flood lights for:

(a) buildings and structures

(b) recreational areas

(c) parking lot lighting

(d) landscape lighting

(e) billboards and other signs (advertising or other)

(f) street lighting

(g) product display area lighting

(h) building overhangs and open canopies

Sec. 4.4. Area A means the circular area, 35 miles in radius, the center of which is the center of the Kitt Peak Observatory and the circular area, 25 miles in radius, the center of which is the center of Mount Hopkins Observatory.

The boundary lines for Area A around Mt. Lemmon is defined as: The Pinal County line on the north, along the center line of the Santa Cruz River, to the center line of Rillito Creek, to the center line of Tanque Verde Creek with the junction to the northern border of the Saguaro National Monument, then along that border until it ends on the east side and bends east to the County line.

Sec. 4.5. Area B means all areas outside Area A and outside the territorial limits of every Indian Reservation lying wholly or partly within Pima County.

Sec. 5. Shielding.

All non-exempt outdoor lighting fixtures shall have shielding as required by Table 5 of this Code.

Sec. 5.1. Fully shielded shall mean outdoor light fixtures shielded or constructed so that no light rays are emitted by the installed fixture at angles above the horizontal plane, as certified by photometric test report.

Sec. 5.2. Partially shielded shall mean outdoor light fixtures shielded or constructed so that no more than ten percent (10%) of the light rays are emitted by the installed fixture at angles above the horizontal plane as certified by photometric test report.

Sec. 5.3. (COUNTY ONLY) Poles and standards. All poles or standards used to support outdoor lighting fixtures shall be anodized or otherwise coated to minimize glare from the light source.

TABLE 5
SHIELDING REQUIREMENTS

FIXTURE LAMP TYPE	AREA A SHIELDED	AREA B SHIELDED
Low Pressure Sodium[1]	Partially	Partially
High Pressure Sodium	Prohibited except fully shielded on arterial streets and collector streets of 100' or more in right-of-way width	Fully
Metal Halide	Prohibited[7]	Fully[2,6]
Fluorescent	Fully[3,5]	Fully[3,5]
Quartz[4]	Prohibited	Fully
Incandescent Greater than 160W	Fully	Fully
160W or Less	None	None
Any light source of 50W or Less	None	None
Glass Tubes filled with Neon, Argon, Krypton	None	None
Other Sources	AS APPROVED BY BUILDING OFFICIAL	

[1]This is the preferred light source to minimize undesirable light emission into the night sky affecting astronomical observations.

[2]Metal halide lighting used primarily for display purposes shall not be used for security lighting after 11:00 p.m. Metal halide lamps shall be installed only in enclosed luminaires.

[3]Outdoor advertising signs of the type constructed of translucent materials and wholly illuminated from within do not require shielding. Dark backgrounds with light lettering or symbols are preferred, to minimize detrimental effects. Unless conforming to the above dark background preference, total lamp wattage per property shall be less than 41 Watts in Area A.

[4]For the purposes of this Code, quartz lamps shall not be considered an incandescent light source.

[5]Warm white and natural lamps are preferred to minimize detrimental effects.

[6]For filtering requirements for metal halide fixture lamp types, see Section 6.

[7](CITY ONLY) Fully shielded and installed metal halide fixtures shall be allowed for applications where the designing engineer deems that color rendering is critical.

[7](COUNTY ONLY) Fully shielded metal halide fixtures shall be allowed for applications where the designing engineer deems that color rendering is critical.

Sec. 6. Filtration.

Metal halide fixture lamp types shall be filtered. "Filtered" means any outdoor light fixture which has a glass, acrylic or translucent enclosure of the light source (quartz glass does not meet this requirement).

Sec. 7. Outdoor Advertising Signs.

Sec. 7.1. Top Mounted Fixtures Required. Lighting fixtures used to illuminate an outdoor advertising sign shall be mounted on the top of the sign structure. All such fixtures shall comply with the shielding requirements of Section 5 and the time controls of minor Section 9.5.

Exception: (COUNTY ONLY) Lighting for existing and new outdoor advertising structures need not be shielded in accordance with Section 5 of this Code if the following conditions apply:

(a) The structure exceeds 301 square feet per sign face; and

(b) The structure consists of panels which are designed to be removed from the top of the sign board; and

(c) The outdoor advertising structure is equipped with an automatic device which shuts off the fixtures between 11:00 p.m. and sunrise.

(COUNTY ONLY) For such signs, the lighting may consist of no more than four (4) bottom mounted individual fixtures (or lamps) which produce a maximum of forty thousand (40,000) lumens per fixture; and where no more than one thousand seventeen (1,017) lumens per fixture spills or is cast beyond the sign face.

Sec. 7.2. (CITY ONLY) Prohibitions. See minor Section 9.5 for prohibitions.

Sec. 7.2. (COUNTY ONLY) Compliance Limit. Existing outdoor advertising structures shall be brought into conformance with this Code within three (3) years from the date of adoption of this provision.

Sec. 7.3. (COUNTY ONLY) Prohibitions. Electrical illumination of outdoor advertising off-site signs is prohibited in Area A. Electrical illumination of outdoor advertising off-site signs between the hours of 11:00 p.m. and sunrise is prohibited in Area B.

Sec. 8. Submission of Plans and Evidence of Compliance with Code; Subdivision Plats.

Sec. 8.1. Submission Contents. The applicant for any permit required by any provision of the laws of this jurisdiction in connection with proposed work involving outdoor light fixtures shall submit (as part of the application for permit) evidence that the proposed work will comply with this Code. The submission shall contain but shall not necessarily be limited to the following, all

or part of which may be part of or in addition to the information required elsewhere in the laws of this jurisdiction upon application for the required permit:

(a) plans indicating the location on the premises, and the type, of illuminating devices, fixtures, lamps, supports, reflectors and other devices;

(b) description of the illuminating devices, fixtures, lamps, supports, reflectors and other devices and the description may include, but is not limited to, catalog cuts by manufacturers and drawings (including sections where required);

(c) photometric data, such as that furnished by manufacturers, or similar, showing the angle of cut off of light emissions.

Sec. 8.2. Additional Submission. The above-required plans, descriptions and data shall be sufficiently complete to enable the plans examiner to readily determine whether compliance with the requirements of this Code will be secured. If such plans, descriptions and data cannot enable this ready determination, by reason of the nature or configuration of the devices, fixtures or lamps proposed, the applicant shall additionally submit as evidence of compliance to enable such determination such certified reports of tests as will do so provided that these tests shall have been performed and certified by a recognized testing laboratory.

Sec. 8.3. Subdivision Plat Certification. If any subdivision proposes to have installed street or other common or public area outdoor lighting, the final plat shall contain a statement certifying that the applicable provisions of the Tucson/Pima County Outdoor Lighting Code will be adhered to.

Sec. 8.4. Lamp or Fixture Substitution. Should any outdoor light fixture or the type of light source therein be changed after the permit has been issued, a change request must be submitted to the building official for his approval, together with adequate information to assure compliance with this Code, which must be received prior to substitution.

Sec. 9. Prohibitions.

Sec. 9.1. Mercury Vapor Fixtures and Lamps. The installation, sale, offering for sale, lease or purchase of any mercury vapor fixture or lamp for use as outdoor lighting is prohibited.

Sec. 9.2. Certain other Fixtures and Lamps. The installation, sale, offering for sale, lease or purchase of any low pressure sodium, high pressure sodium, metal halide, fluorescent, quartz or incandescent outdoor lighting fixture or lamp, the use of which is not allowed by Table 5 is prohibited.

Sec. 9.3. Laser Source Light. Except as provided in minor Section 9.4, the use of laser source light or any similar high-intensity light for outdoor advertising or entertainment, when projected above the horizontal, is prohibited.

Sec. 9.4. Searchlights. The operation of searchlights for advertising purposes is prohibited in unincorporated Pima County. In the territorial limits of the City of Tucson, the operation of searchlights for advertising purposes is prohibited in Area A and is prohibited in Area B between 10:00 p.m. and sunrise the following morning.

Sec. 9.5. (CITY ONLY) Outdoor Advertising Off-Site Signs. Electrical illumination of outdoor advertising off-site signs is prohibited in Area A. Electrical illumination of outdoor advertising off-site signs between the hours of 11:00 p.m. and sunrise is prohibited in Area B.

Sec. 10. Special Uses.

Sec. 10.1. Recreational Facilities. Any light source permitted by this Code may be used for lighting of outdoor recreational facilities (public or private), such as, but not limited to football fields, soccer fields, baseball fields, softball fields, tennis courts, auto race-tracks, horse race-tracks or show arenas, provided all of the following conditions are met:

(a) Lighting for parking lots and other areas surrounding the playing field, court or track shall comply with this Code for lighting in the specific area as defined in Section 4.4 and 4.5 of this Code.

(b) All fixtures used for event lighting shall be fully shielded as defined in Section 5 of this Code, or be designed or provided with sharp cut-off capability, so as to minimize up-light, spill-light and glare.

(c) All events shall be scheduled so as to complete all activity before or as near to 10:30 p.m. as practical, but under no circumstances shall any illumination of the playing field, court or track be permitted after 11:00 p.m.; Except to conclude a scheduled event that was in progress before 11:00 p.m. and circumstances prevented concluding before 11:00 p.m.

Exception: (CITY ONLY) Any portion of a recreational facility located within 300 feet of a road or street designated as a scenic route shall be lighted using only fixtures approved for use under this Code for the Area, as defined in Section 4.4 and 4.5 of this Code, in which said recreational facility is located.

Exception: (COUNTY ONLY) Recreational facilities located along roads and streets designated as scenic routes shall be lighted using only fixtures approved for the area in which they are located.

Sec. 10.2. Outdoor Display Lots. Any light source permitted by this Code may be used for lighting of outdoor display lots such as, but not limited to automobile sales or rental, recreational vehicle sales or building material sales, provided all of the following conditions are met:

(a) Lighting for parking lots and other areas surrounding the display lot shall

comply with this Code for lighting in the specific area as defined in Section 4.4 and 4.5 of this Code.

(b) All fixtures used for display lighting shall be fully shielded as defined in Section 5 of this Code, or be designed or provided with sharp cut-off capability, so as to minimize up-light, spill-light and glare.

(c) Display lot lighting shall be turned off within thirty (30) minutes after the closing of the business. Under no circumstances shall the full illumination of the lot be permitted after 11:00 p.m. Any lighting used after 11:00 p.m. shall be used as security lighting.

Exception: (CITY ONLY) Any portion of a display lot located within 300 feet of a road or street designated as a scenic route shall be lighted using only fixtures approved for use under this Code for the Area, as defined in Section 4.4 and 4.5 of this Code, in which said display lot is located.

Exception: (COUNTY ONLY) Display lots located along roads and streets designated as scenic routes shall be lighted using only fixtures approved for the area in which they are located.

Sec. 11. Temporary Exemption.

Sec. 11.1. Request; Renewal; Information Required. Any person may submit a written request, on a form prepared by the jurisdiction, to the building official for a temporary exemption from the requirements of this Code. The Request for Temporary Exemption shall contain the following information:

(a) specific exemption or exemptions requested

(b) type and use of outdoor light fixture involved

(c) duration of time for requested exemption

(d) type of lamp and calculated lumens

(e) total wattage of lamp or lamps

(f) proposed location on premises of the outdoor light fixture(s)

(g) previous temporary exemptions if any and addresses of premises thereunder

(h) physical size of outdoor light fixture(s) and type of shielding provided

(i) such other data and information as may be required by the building official

Sec. 11.2. Approval; Duration. The building official shall have five (5) business days from the date of submission of the Request for Temporary Exemption to act in writing on the request. If approved, the exemption shall be valid for not more than thirty (30) days from the date of issuance of the approval. The approval shall be renewable at the discretion of the building official upon a consideration of all the circumstances. Each such renewed exemption shall be valid for not more than thirty (30) days.

Sec. 11.3. Disapproval; Appeal. If the Request for Temporary Exemption is disapproved, the person making the request will have the appeal rights provided in Section 13.

Sec. 12. Other Exemptions.

Sec. 12.1. Non-Conformance.

(a) Mercury vapor lamps in use for outdoor lighting on the effective date of this Code shall not be so used.

(b) (CITY ONLY) Bottom-mounted outdoor advertising sign lighting shall not be used after December 31, 1987.

(b) (COUNTY ONLY) Bottom-mounted outdoor advertising sign lighting shall not be used, except as provided in Section 7.

(c) All other outdoor light fixtures lawfully installed prior to and operable on the effective date of this Code are exempt from all requirements of this Code except those regulated in Section 7 and in minor Sections 9.3 and 9.4 and Section 10. There shall be no change in use or lamp type, or any replacement or structural alteration made, without conforming to all applicable requirements of this Code.

Sec. 12.2. Fossil Fuel Light. All outdoor light fixtures producing light directly by the combustion of natural gas or other fossil fuels are exempt from all requirements of this Code.

Sec. 12.3. State and Federal Facilities. Outdoor light fixtures installed on, in and in connection with those facilities and land owned or operated by the Federal Government or the State of Arizona, or any department, division, agency or instrumentality thereof, are exempt from all requirements of this Code. Voluntary compliance with the intent of this Code at those facilities is encouraged.

Sec. 13. Appeals.

Any person substantially aggrieved by any decision of the building official made in administration of this Code has the rights and responsibilities of appeal to the Advisory/Appeals Board of this jurisdiction.

Sec. 14. Law Governing Conflicts.

Where any provision of federal, state or city statutes, codes or laws conflicts with any provision of this Code, the most restrictive shall govern unless otherwise required by law.

Sec. 15. Violation.

It shall be a civil infraction for any person to violate any of the provisions of this Code. Each and every day during which the violation continues shall constitute a separate offense.

Sec. 16. Enforcement and Penalty.

Sec. 16.1. (CITY ONLY) Pursuant to Sec. 28-12 of the Tucson Code, a violation of this Code is considered a civil infraction.

(a) When a violation of this Code is determined, the following penalty shall be imposed:

(1) A fine of not less than Fifty Dollars ($50.00) nor more than One Thousand Dollars ($1,000.00) per violation. The imposition of a fine under this Code shall not be suspended.

(2) Any other order deemed necessary in the discretion of the hearing officer, including correction or abatement of the violation.

(b) Failure of a defendant to comply with any order contained in a judgment under this Code shall result in an additional fine of not less than Fifty Dollars ($50.00) nor more than One Thousand Dollars ($1,000.00) for each day the defendant fails to comply.

Sec. 16.2. (COUNTY ONLY) A violation of this Code is considered a civil infraction. Civil infractions shall be enforced through the hearing officer procedure provided by A.R.S. Section 11-808 and Sections 18.95.030, 18.95.040 and 18.101.60 of the Pima County Code. A fine shall be imposed of not less than Fifty Dollars ($50.00) nor more than Seven Hundred Fifty Dollars ($750.00) for any individual or Ten Thousand Dollars ($10,000.00) for any corporation, association or other legal entity for each offense. The imposition of a fine under this Code shall not be suspended.

1994

TUCSON/PIMA COUNTY
OUTDOOR LIGHTING CODE COMMITTEE

SUMMARY MINUTES--FOR INFORMATIONAL PURPOSES ONLY

September 7, 1994

A meeting of the Tucson/Pima County Outdoor Lighting Code Committee was held this date at the Tucson Metropolitan Chamber of Commerce, 465 West Mary's Road, Tucson, Arizona, beginning at approximately 9:00 a.m.

MEMBERS PRESENT	MEMBERS ABSENT
Don Davis	Lee J. Beaudry
Darel Magee	Dave Crawford
John B. Samuelson	Howard Birch
James R. Singleton	John R. Lane
Earl Zoeller	Ed Schultz
	Robert Walters

STAFF
Ruben N. Montano, Development Services Center
Thelma M. Gallardo, Development Services Center

GUESTS
Mark Mayer, Neighborhood Coalition of Greater Tucson, 7072 E. 22nd, #144 (11)
Ed Colapret, Tucson Electric Power Company

CALL TO ORDER AND ROLL CALL
The Chair introduced Mr. Ed Colapret representing the Tucson Electric Power Company. Due to organizational changes within Tucson Electric Power Company, Mr. Colapret will replace Mr. Ed Schultz. Mr. Colapret's attendance is being recorded as a guest until official action has been taken to appoint him to the Committee. Staff contacted the City Clerk's Office and it was determined that a quorum was not established at the meeting. The following summary minutes are for informational purposes only.

REVIEW OF THE OUTDOOR LIGHTING CODE SECTIONS 1-16
Considerable discussion was taken on Sections 7.2 and 12.1 of the Outdoor Lighting Code Ordinance, 1993 Editions, as adopted by both jurisdictions (City of Tucson and Pima County). The Committee expressed concern with the wording of both sections and pointed out some discrepancies as adopted by both jurisdictions. Mr. James R. Singleton volunteered to draft revised wording regarding the sections in question of the Outdoor Lighting Code Ordinance, 1993 Edition, and present them to the Committee at the next scheduled meeting.

The Committee directed the Chair to submit a letter to Mr. Leroy A. Sayre requesting him to respond to requested information as stated in the minutes.

REVIEW AND DISCUSSION OF SECTION 7, OUTDOOR ADVERTISING SIGNS
This agenda item will be addressed at the next scheduled meeting as requested by Mr. James R. Singleton.

DISCUSSION OF POTENTIAL WORKSHOP
Mr. Davis informed the Committee that Dr. Dave Crawford is pending a request by the City and County to formulate an educational workshop for inspectors and interested parties.

REPORT ON STREET LIGHTING FROM EARL ZOELLER
This subject is recommended to be deleted from the agenda until further data is gathered from the City by Mr. Earl Zoeller.

DISCUSSION OF NON-CONFORMING LIGHT SOURCES
This item will be addressed at the next scheduled meeting.

DISCUSSION OF THE EATON TOWN, NEW JERSEY ORDINANCE
Mr. Don Davis distributed a newsletter and several sheets of information from the International Dark-Sky Association for the Committee member's review.

NEWS NOTES
Mr. Don Davis announced that Dr. Dave Crawford attended the I.A.U. meeting. It was noted that Dr. Crawford wrote a glossary of terms used by the Illumination Industry.

A meeting of The American Astronomical Society is to be held in Tucson in January 1995.

The International Dark-Sky Association's annual meeting is scheduled to be held on April 29, 1995 in Tucson.

Photographs were viewed by the Committee members that were taken by Mr. Darel Magee's father illustrating proper lighting techniques.

The Committee requested a presentation of the Model Energy Code by Mr. Leroy A. Sayre or Mr. Logan T. White. Concern was expressed by some Committee members regarding the Model Energy Code's limitation on the amount of energy/light that can be installed in a parking lot.

ESTABLISH AGENDA ITEMS FOR NEXT MEETING
1. Call to Order and Roll Call
2. Introduction of Guests in Attendance
3. Pledge of Allegiance
4. Review and Approval of Minutes of April 27, 1994
5. Presentation of the Model Energy Code
6. Review of the Outdoor Lighting Code Sections 1-16
7. Review and Discussion of Section 7, Outdoor Advertising Signs
8. Discussion on Potential Workshop
9. Report on Street Lighting from Earl Zoeller

10. Non-Conforming Light Sources
11. Discussion of the Eaton Town, New Jersey Ordinance
12. Discussion of the Committee Member's Expiration Terms
13. Schedule Meeting Dates for 1995
14. News Notes
15. Establish Agenda Items for Next Meeting
16. Adjournment

ADJOURNMENT
The discussion of the Outdoor Lighting Code Committee adjourned at approximately 10:30 a.m.

NEXT MEETING
The next meeting is scheduled for **Wednesday, November 9, 1994** at 9:00 a.m. at the Tucson Metropolitan Chamber of Commerce, 465 West St. Mary's Road.

A COPY OF THE CASSETTE TAPE RECORDING OF THIS DISCUSSION IS AVAILABLE AT THE CITY CLERK'S OFFICE.

OUTDOOR LIGHTING CODE COMMITTEE
Thelma M. Gallardo, Secretary I
201 N. Stone Avenue (01)
791-5550

1994

TUCSON/PIMA COUNTY
OUTDOOR LIGHTING CODE COMMITTEE

MINUTES

April 27, 1994

A meeting of the Tucson/Pima County Outdoor Lighting Code Committee was held this date at the Tucson Metropolitan Chamber of Commerce, 465 West St. Mary's Road, Tucson, Arizona, beginning at approximately 9:00 AM.

MEMBERS PRESENT	MEMBERS ABSENT
Lee J. Beaudry	Don Davis
Howard Birch	Ed Schultz
Dave Crawford	Robert Walters
John R. Lane	
Darel Magee	
John B. Samuelson (Arr'd @ 9:05 AM)	
James R. Singleton	
Earl Zoeller	

STAFF

Dick Guthrie, City Engineering (Arr'd @ 9:15 AM)
Thelma M. Gallardo, City Development Services Center

CALL TO ORDER AND ROLL CALL

Mr. Lee J. Beaudry, Vice Chairman, presided over this meeting as the Chair was unable to attend. Roll call was taken and a quorum was established at 9:00 AM.

INTRODUCTION OF ANY GUESTS IN ATTENDANCE

There being no guests, the Committee proceeded to the next item.

PLEDGE OF ALLEGIANCE

The Pledge of Allegiance was recited by all in attendance.

REVIEW AND APPROVAL OF MINUTES OF APRIL 27, 1994

A motion was made for approval of the minutes of February 2, 1994.

MOTION: by Mr. James R. Singleton, seconded by Mr. Earl Zoeller, to approve the minutes as mailed and distributed.

A vote was called and the motion passed.

REVIEW OF THE OUTDOOR LIGHTING CODE SECTIONS 1-16

The Committee has expressed concern with Mr. Leroy A. Sayre's interpretation of Footnote 7 (the County version only) on page 5 of the Outdoor Lighting Code Ordinance adopted by the City on March 21, 1994. There is concern that the County is not enforcing the Light Pollution Ordinance, therefore, clarification on this item is requested from Mr. Leroy A. Sayre.

MOTION: by Mr. Darel Magee, seconded by Mr. Howard Birch, to have Mr. Leroy A. Sayre interpret Footnote 7 (the County version) of Table 5.

The motion carried.

It was the consensus of the Committee to review and discuss Section 7, Outdoor Advertising Signs, at the next scheduled meeting as requested by Mr. Earl Zoeller.

DISCUSSION OF POTENTIAL WORKSHOP

Dr. Crawford requested to table this agenda item to the next scheduled meeting until a workshop is requested by the City/County.

DISCUSSION ON IES SPORTS LIGHTING AND SHARP CUT-OFF FIXTURES

Dr. Crawford reported that the IES Sports Lighting Committee held a meeting in Phoenix, Arizona, however, he indicated that he was unable to attend due to other business which was held out-of-town. Citing that the IES Sports Lighting Committee is continuing to address the issue of sharp cut-off fixtures, Dr. Crawford requested to remove this item from the agenda until more information is acquired on this subject.

MOTION: by Dr. Dave Crawford, seconded by Mr. Howard Birch, to remove this item from the agenda.

Moved, seconded and carried.

Discussion ensued on the issue of uncontrolled field lighting (during daylight hours) in sport parks. The Committee suggested that Parks and Recreation Department be notified when unnecessary usage of field lighting was noted at various sport parks.

REPORT ON STREET LIGHTING FROM EARL ZOELLER

This topic is continued as requested by Mr. Earl Zoeller until a report is obtained from Mr. Dick Guthrie.

MOTION: by Mr. James R. Singleton, seconded by Mr. John Lane, to table this agenda item until a report is presented by Mr. Earl Zoeller.

The motion was moved, seconded and carried.

NON-CONFORMING LIGHT SOURCES

It was the consensus of the Committee to continue this subject to the next scheduled meeting. Dr. Crawford announced that he will address wall packs at the annual meeting of the International Dark Sky Association, and he volunteered to present slides to the Committee in a future meeting.

PIMA COUNTY RESIDENTIAL LIGHTING DISTRICTS

Mr. Dick Guthrie informed the Committee of a request from Pima County made to the City for assistance in designing residential street lighting districts as required by the existing Tucson/Pima County Outdoor Lighting Code, 1993 edition. The City of Tucson is in the process of assisting Pima County in achieving their request.

A current light ordinance map specifying Area A and Area B will be distributed to all committee members.

NEWS NOTES

Dr. Crawford announced the annual meeting of the International Dark Sky Association (IDA), and he stated that the Illuminating Engineering Society's monthly meeting will be forthcoming and will include a tour of the field lighting at the Catalina Foothills High School.

An IDA informational sheet specifying both minimum and maximum lighting levels will be distributed to the Committee for discussion at the next scheduled meeting by Dr. Crawford.

Mr. Dick Guthrie presented information on collector street lighting and the problems he encountered regarding the selected type of light source.

ESTABLISH AGENDA ITEMS FOR NEXT MEETING

1. Call to Order and Roll Call
2. Introduction of Guests in Attendance
3. Pledge of Allegiance
4. Review and Approval of Minutes of April 27, 1994
5. Review of the Outdoor Lighting Code Sections 1-16
6. Discussion of Section 7, Outdoor Advertising Signs
7. Discussion of Potential Workshop
8. Report on Street Lighting from Earl Zoeller
9. Non-Conforming Light Sources
10. Discussion of the Eaton Town, New Jersey Ordinance
11. News Notes
12. Establish Agenda Items for Next Meeting
13. Adjournment

ADJOURNMENT

This meeting held April 27, 1994 was adjourned at 10:00 AM.

NEXT MEETING

The next meeting is scheduled for September 7, 1994 at 9:00 AM., at the Tucson Metropolitan Chamber of Commerce, 465 W. St. Mary's Rd.

COPIES OF CASSETTE TAPE(S) ARE AVAILABLE AT THE CITY CLERK'S OFFICE.

Thelma M. Gallardo, Secretary
Development Services Center
201 N. Stone Avenue (01)
791-5550 ext. 141

OUTDOOR LIGHTING CODE COMMITTEE

A*G*E*N*D*A

NOVEMBER 9, 1994

TUCSON METROPOLITAN CHAMBER OF COMMERCE
465 W. ST. MARY'S ROAD
TUCSON, ARIZONA

1. CALL TO ORDER AND ROLL CALL: 9:00 A.M.
2. INTRODUCTION OF GUESTS IN ATTENDANCE
3. PLEDGE OF ALLEGIANCE
4. REVIEW AND APPROVAL OF MINUTES OF APRIL 27, 1994
5. PRESENTATION OF THE MODEL ENERGY CODE
6. REVIEW OF OUTDOOR LIGHTING CODE SECTIONS 1-16
7. REVIEW AND DISCUSSION OF SECTION 7, OUTDOOR ADVERTISING SIGNS
8. DISCUSSION OF POTENTIAL WORKSHOP
9. REPORT ON STREET LIGHTING FROM EARL ZOELLER
10. NON-CONFORMING LIGHT SOURCES
11. DISCUSSION OF THE EATON TOWN, NEW JERSEY ORDINANCE
12. DISCUSSION OF THE COMMITTEE MEMBER'S EXPIRATION TERMS
13. SCHEDULE MEETING DATES FOR 1995
14. NEWS NOTES
15. ESTABLISH AGENDA ITEMS FOR NEXT MEETING
16. ADJOURNMENT

NOTE: UNDER STATE OPEN MEETINGS ACT RULES, NO TOPICS OTHER THAN THOSE LISTED ABOVE MAY BE ADDRESSED OR ACTED ON AT THIS MEETING.

OUTDOOR LIGHTING CODE COMMITTEE
THELMA M. GALLARDO, SECRETARY
DEVELOPMENT SERVICES CENTRE
201 N. STONE AVENUE
TUCSON, AZ 85701
791-5550

Skillman | SkiFF | *Lugenbuhl

*Cold
Winter time
Standardized Low Temp
~ -30°C or Lower
*Noise would be a major Factor

Fisheyelens
- gives wide Field
- more light per pixel
- Gives a picture (For demonstration)
- Standard stars For calibration would already be in the Field of view

Larger Chip the better
ST-6 → 16 bit data is also better
+ This camera cools more

measure dark current

Flat Fields
Bias Fields

Calibration is crucial For getting meaningful data.
Both agree it will not be easy.

Amateur CCD Photometry expert.

Astronomer at Lowell Obs. Does Stellar photometry

Astronomer at U.S. Naval Obs. Does Sky S.B. measurements

Site tester at [illegible] (mostly w/ atmospheric cond.)

Camera

* Crucial to have Cold camera
- Not sure whether Inexpensive camera can cool enough to get a reliable Absoulte measure

*Calibration
- Measure how much light is getting thru the system (measure standard stars)
- Long exposure w/ shutter closed to measure dark current. (Noise)

- Doesn't think ST-6 will be cool enough. Have to do protocol in cool time of year.
* Calibrate on
  - Standard Stars
  - use Flat Fields & Bias Fields
* Important to have larger detector.

Does not think inexp. camera will be good enough All the light From a Star may be in one Pixel - date structure of the CCD Array may interfere

After some thought he thinks the ST-6 will work.

Suggests using Film w/ SLR & Fixed piers.
*CCD camera may work. (He will think about it & get back to us)

Blue & Visual Filters are necessary to det mag. of Calibration stars ON Lens → Need to know Signal-Noise ratio to det. the optimum system

24-28mm Lens w/ SLR & Color Film on Fixed piers pointing at source of C.P. + Photos toward a dark horizon

* Need a equatorial mt & clock drive to get calibratable Star images

STILL Believes that wide field photography of sonoyta is the most important thing

* Low noise is crucial
- IR Filter - gets CCD Camera to respond more like human eye (CCD's are Red sensitive)

Lens

Fish eye lens
- gives all sky coverage (Probably not easily compatible w/ CCD Camera) Have to build a Fish eye camera

Fist suggested 2000mm F/10 I told him about Fish-eye lens & he agreed it would be good to have a wide Field.
* Standard stars would already be in the field

Short F.L. - large area shows how sky brightness varies. Also gives a brighter image w/ a Fast Lens, shorter exp. time & less noise build up.

Protocol

Difficult to pull off. Calibration is crucial as well as repeatability.

Difficult

Misc.

Adv of Fish-eye lens
- gives wide Field
- more light per pixel
- Gives a picture For demonstration [illegible] ndard stars calibration would be in the Field

Image scale
$206265 / FL_{mm} = \frac{\text{arc sec}}{\text{mm}}$

He uses 800x800 TI chip & 1M Reflector to det sky brightness
In mag/square arc sec →
* Politically a pretty Photo will mean more to people than numerical data.

disadvantages of Fisheye Lens
Hard to couple w/ CCD
Hard to mount
Light is [illegible] centrated in Pixels [illegible] estruct. of CCD arr[illegible] ay interfere

	Skillman	Skiff	Luginbuhl	
	Amateur CCD Photometry expert.	Astronomer at Lowell Obs. Does stellar photometry	Astronomer at US Naval Obs. Does Sky S.B. measurements	Site tester at Mt Graham Obs. (mostly w/ atmospheric cond.)
Camera	* Crucial to have Cold camera - Not sure whether Inexpensive camera can cool enough to get a reliable Absolute measure * Calibration - Measure how much light is getting thru the system (measure standard stars) - Long exposure w/ shutter Closed to measure dark current. (Noise)	- Doesn't think ST-6 will be cool enough. Have to do protocol in cool time of year. * Calibrate on - Standard Stars - use Flat Fields & Bias Fields * Important to have larger detector.	Does not think inexp. camera will be good enough All the light From a Star may be in one Pixel - date structure of the CCD Array may interfere After some thought he thinks the ST-6 will work. Suggests using Film w/ SLR & Fixed piers. * CCD Camera may work. (He will think about it & get back to us)	* Low noise is Crucial - IR Filter - gets CCD Camera to respond more like human eye (CCD's are Red sensitive)
Lens	Fish eye lens - gives all sky Coverage (Probably not easily compatible w/ CCD Camera) Have to build a Fish eye camera	First suggested 2000mm F/10 I told him about Fish-eye lens & he agreed it would be good to have a wide Field. * Standard stars would already be in the field	Blue & Visual Filters are necessary to det mag. of Calibration stars ON Lens → Need to know Signal-Noise ratio to det. the optimum system 24-28mm Lens w/ SLR & Color Film on Fixed piers pointing at source of C.P. + Photos toward a dark horizon	Short F.L. - large area shows how sky brightness varies. Also gives a brighter image w/ a Fast Lens, shorter exp. time & less noise build up.
Protocol	Difficult to pull off. Calibration is crucial as well as repeatability.	Difficult	* Need a equatorial mt & clock drive to get calibratable Star images STILL Believes that wide field photography of Sonoyta is the most important thing	
Misc.	Adv of Fish-eye lens - gives wide field - more light per pixel - Gives a picture For demonstration ndard stars calibration would e in the field	Image Scale $206265 / FL_{mm} = \frac{\text{arc sec}}{mm}$	He uses 800x800 TI chip & 1M Reflector to det sky brightness In mag / square arc sec → * Politically a pretty Photo will mean more to people than Numerical data.	disadvantages of Fisheye Lens Hard to couple w/ CCD Hard to Mount Light is centrated in Pixels estruct. of CCD ar ay interfere

Eric Craine
Astronomer / owns a company that uses CCD technology

- No doubts the ST-6 would be a good detector
- IF Dark Frames are done properly calibration From one time of year to another is easy.
- Set camera as cold as possible whenever you take a measurement
- He agrees that 100 mm Lens would be a good choice.
- He thinks that clock drive would be necessary
- Re aquiring same Field not necessary

STEVE HOWELL - He will use a program to det. the sensitivity of cameras
Sent him data on ST-4, 5, & 6 and Kodak 0400 based cameras by Meades Spectra source

Don Dairs.

- Suggested using the Following stuff:
  - Richard Berry's - Cookbook CCD Camera book
  - NIH Image (Public domain image processing software) For Macintosh
  - IAPPP (Photometry journal) - He believes he has read and article on using ST-6 to due photometry on the night-sky.

* Zenith magnitude measure is critical For Comparison.
He so likes the transect idea.

PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC
102: 1046–1051, September 1990

THE SPECTRUM OF THE KITT PEAK NIGHT SKY

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Received 1990 April 23, revised 1990 May 29

ABSTRACT

We have obtained absolute spectrophotometry of the Kitt Peak night sky at a variety of azimuths and zenith angles. Our zenith measurements confirm the finding of Pilachowski *et al.* that Kitt Peak is still a dark site, as we find $\langle B \rangle = 22.8$ mag/arc sec^2 and $\langle V \rangle = 21.9$ mag/arc sec^2 on 1988 February 18, a night of fairly low solar activity. (A year later the sky was appreciably brighter; this increase correlates well with solar activity as measured from the 10-cm flux.) The "pseudocontinuum" encountered by spectroscopists is about 0.02–0.05 mag/arc sec^2 darker in B and 0.2–0.3 mag/arc sec^2 darker in V than the broad-band measures. The major line contributor to the B band is Hg, while the dominant source of contamination to the V-band measures are atmospheric lines, most notably O I λ5577. Using fluxed observations of street lamps we find that the relative contribution to light pollution in the yellow-red (5000 Å–6500 Å) is 10% Hg, 30% LPS, and 60% HPS. The sky brightness increases a few tenths going from the zenith to a zenith distance of 60°, but the contribution of light pollution remains small. No significant azimuthal effects are seen: The sky is as dark toward Phoenix or Tucson as toward anywhere else, at least for zenith distances of 60° or less. Comparison with earlier measurements of the Kitt Peak sky brightness suggests that there has been no significant increase in light pollution at Kitt Peak from the mid-1960s to the late 1980s, a fact which we attribute to the stringent lighting ordinances adopted by the state.

Key words: observatory sites–light pollution

1. Introduction

Astronomical observations have been made from Kitt Peak National Observatory for over 30 years. In that time the population of nearby Pima County (which contains Tucson) has nearly tripled (De Gennaro 1989). To what extent have the dark-sky properties been compromised? This question is of timely importance given the plans for construction of new 4-m class telescopes on the mountain.

Pilachowski *et al.* (1989) have recently published the results of photoelectric photometry of the KPNO night sky. These observations were made near solar minimum (which occurred in 1986) and should therefore reflect the best the site can currently offer. Pilachowski *et al.* find sky-brightness values at the zenith of $\langle B \rangle = 22.9$ mag/arc sec^2 and $\langle V \rangle = 21.9$ mag/arc sec^2 during late 1986 and early 1987; a year later the mean values were $\langle B \rangle = 22.7$ and $\langle V \rangle = 21.6$. These numbers agree very well with those predicted by Garstang's (1986, 1989) night-sky brightness models. However, since the models indicate at best a very modest effect (<0.1 mag/arc sec^2) at the Kitt Peak zenith due to light pollution, the agreement is essentially due to Garstang's choice for the natural night-sky background brightness. The change in sky brightn from late 1986/early 1987 to late 1987/early 1988 is accord with Walker's (1988) estimate of change in zen sky brightness of San Benito Mountain with solar activ and shows a similar correlation with the solar 10-cm fl By solar maximum, the zenith sky brightnesses may b magnitude brighter than at solar minimum according Walker. The Pilachowski *et al.* study indicates that Peak is still an exceptionally good site; the solar minim zenith values are within 1/10 of a mag of those predic by Garstang for Mauna Kea and Cerro Tololo.

While these numbers are of interest to those do broad-band observations, they tell only a partial story spectroscopists. Accordingly, we have undertaken a co plementary program of spectrophotometry of the Peak night sky. These data can be used to assess contribution of artificial lighting and atmospheric em sion lines to broad-band measures and serve as a use check on the previously reported broad-band photom try. Finally, this spectrophotometry allows us to meas the azimuthal dependence of artificial lighting: Is the significantly brighter toward Tucson and Phoenix?

2. Observations and Reductions

The observations were made with the Intensified R

*Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

con Scanner (IRS) on the No. 2 0.9-m telescope. The IRS dual-beam analog detector on the White spectrograph. Grating 26 was used in first order to provide wavelength coverage from λλ3800–6500. The spectral resolution (3.0 pixels) was ≈ 10 Å. The two entrance apertures were 22.6 arc sec in diameter (as discussed further below) and were separated by 1.0 arc min. The integration times were typically 20 minutes.

The observations reported here were primarily made on the moonless night 1988 February 18 (UT) at a variety of zenith distances and azimuthal angles throughout the night. One additional observation was made at the zenith roughly a year later (1989 March 29) at the beginning of the night while the Moon was well below the horizon. In the following we will refer to the azimuthal directions by the cities they are toward: Tucson has an azimuth of 64° and Phoenix has an azimuth of 346°. Observations were also made toward the mythical town of "Nowhere" (azimuth 205°), chosen to be away from the two large cities as well as Casa Grande (350°), Sells (265°), and Nogales (142°).

In making the observations, care was taken to make all observations at least 15° from the ecliptic or Galactic planes; the exception is the zenith measurement 1988 February 18.2, which was only 5° from the Galactic plane. Although the acquisition TV was used to ascertain that no stars brighter than 15th mag were being placed in either ure, stars of even 18th mag would raise the counts in an aperture by 10%. Thus, the most useful check of whether the sky measurement was contaminated by an unfortunately placed star or not was the agreement between the two apertures. In a few cases the counts in one aperture would appear to be significantly higher than in the other, and the telescope would be moved slightly and the integration redone. Flux calibration was provided by observing spectrophotometric standard stars (Massey *et al.* 1988).

The data were reduced using the "onedspec" package in IRAF[1]. Exposures of a quartz lamp were divided into each observation. Exposures of a HeNeAr lamp were used to provide wavelength calibration. The observations were then flux calibrated (no atmospheric extinction correction was made on the sky data) and the flux-calibrated sky spectra of the two apertures were averaged.

Pilachowski *et al.* (1989) have emphasized that the greatest source of systematic error in such measurements is in the determination of the size of the entrance aperture(s) of the photometer, which requires an accurate knowledge of the plate scale as well as the physical size of the holes. In the course of this study we made an independent measurement of the plate scale of the No. 2 0.9-m telescope and found for one test a scale of 28.7 ± 0.2 arc sec/mm and for another 28.6 ± 0.1 arc sec/mm. These numbers differ somewhat from the value of 29.5 ± 0.5 arc sec/mm found by Pilachowski *et al.* who also used this telescope for their work. We adopt a value of 28.6 arc sec/mm for the present study in the spirit of keeping the current measurements independent of the Pilachowski *et al.* data; the resulting systematic difference of 0.07 mag/arc sec^2 will prove insignificant given the typical scatter within a night. Representative spectra are shown in Figure 1a and 1b.

In addition to the sky measurements, observations were made of some typical artificial lighting sources: a low-pressure sodium (LPS) lamp, a high-pressure sodium (HPS) lamp, and a mercury streetlamp. These spectra are shown in Figure 1c.

3. Analysis

We give in Table 1 the resolvable emission lines found in our sky data, along with their origin. These lines are also identified in Figure 1a–c where visible.

In order to produce synthetic broad-band photometry from our spectra we convolved each spectrum with the sensitivity functions of the *B* and *V* bandpasses as tabulated by Allen (1973). The contributions of the various night-sky emission lines were evaluated by constructing spectra free of the various contributions listed in Table 1 by linearly interpolating across the lines and then convolving these spectra with the sensitivity functions. (We assign all of the Na D emission to HPS+LPS in this exercise, although we expect that a small atmospheric contribution is also present.) The sky brightness determined from our spectra and the contributions made by the various sources are given in Table 2.

On 1988 February 18 the zenith sky varied by a few

TABLE 1

Line ID's

Line	Sources
HgI λ4047	Hg lighting
HgI λ4358	Hg lighting
NaI λ4669	HPS lighting
NaI λ4983	HPS lighting
NaI λ5149	HPS lighting
N I λ5199	Atmospheric
HgI λ5461	Hg lighting
OI λ5577	Atmospheric
NaI λ5688	HPS lighting
HgI λ5770	Hg lighting
HgI λ5791	Hg lighting
NaI λ5890(blend)	HPS,LPS,Atmospheric
NaI λ6161	HPS lighting
OI λ6300 – 64	Atmospheric

[1] IRAF is distributed by National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc., under contract to the National Science Foundation.

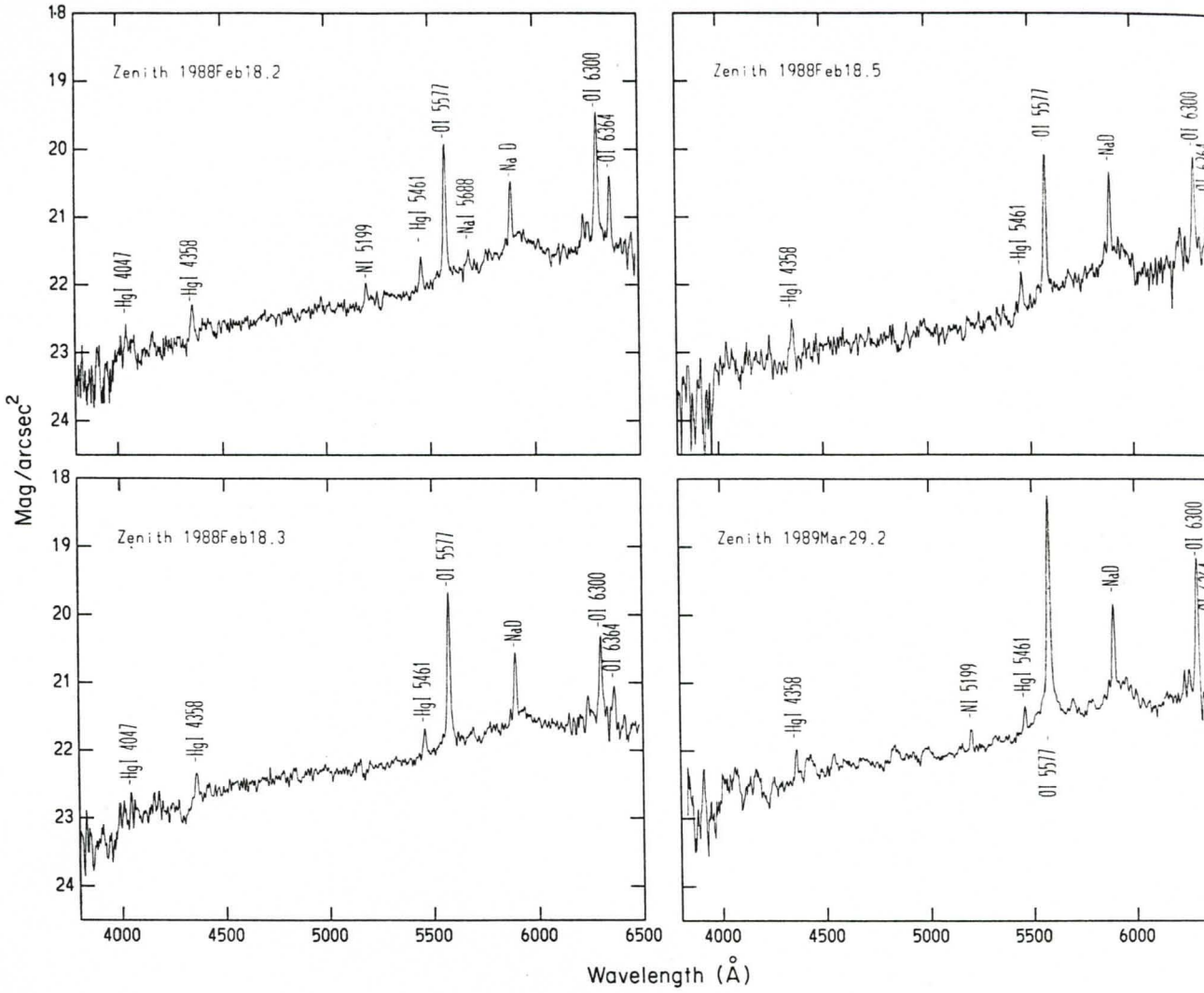


FIG. 1a–Representative spectra of the zenith sky.

tenths of a magnitude/arc sec^2; such fluctuations are also found in the data of Pilachowski *et al.* (1989) and Walker (1988). On this night it was indeed "darkest before the dawn", at least at the zenith. Walker's data show a systematic decrease in sky brightness throughout most nights, while the data of Pilachowski *et al.* are more random. Our measurements are too scant to discuss a trend throughout the night, but the data do show that the sky-brightness fluctuations are not due to the O I λ5577 line varying in intensity during the night—the contribution made by this atmospheric line has little effect given its dilution throughout the *V* bandpass. (The actual flux in O I λ5577 varied by a factor of two as is apparent from Fig. 1a, but this variation had little effect on the broad-band measures.) The average zenith values for this night are $\langle B \rangle$ = 22.79 mag arc sec^2 ± 0.15 (s.d.) and $\langle V \rangle$ = 21.87 mag arc sec^2 ± 0.13(s.d.); these are in excellent agreement with those found by Pilachowski *et al.* (1989) and serve as an independent confirmation that the zenith sky is still quite dark at Kitt Peak.

The zenith values on 1989 March 29 show a si
cantly brighter value. While some of the increased b
ness at *V* is indeed due to the increased flux in th
λ5577 line (see Fig. 1a in addition to Table 2), this
the only source of the increase—the "pseudocontin
itself is considerably brighter. This is well reflect
increased sky brightness in the *B* bandpass, which is
affected by atmospheric lines as can be seen from Ta

Is this increase in sky brightness due to increased
activity? Walker (1988) found a good correlation of z
sky brightness with solar activity where the latte
measured by the "decorrected" Ottawa 10-cm flux
not referred to 1 AU but to the Earth's actual dis
from the Sun) as determined on the *previous* UT
Pilachowski *et al.* (1989) found a similarly excellent
lation for their measurements. We show in Figure
data from Figure 1 of Pilachowski *et al.* where we
added our new measurements. The 10-cm values

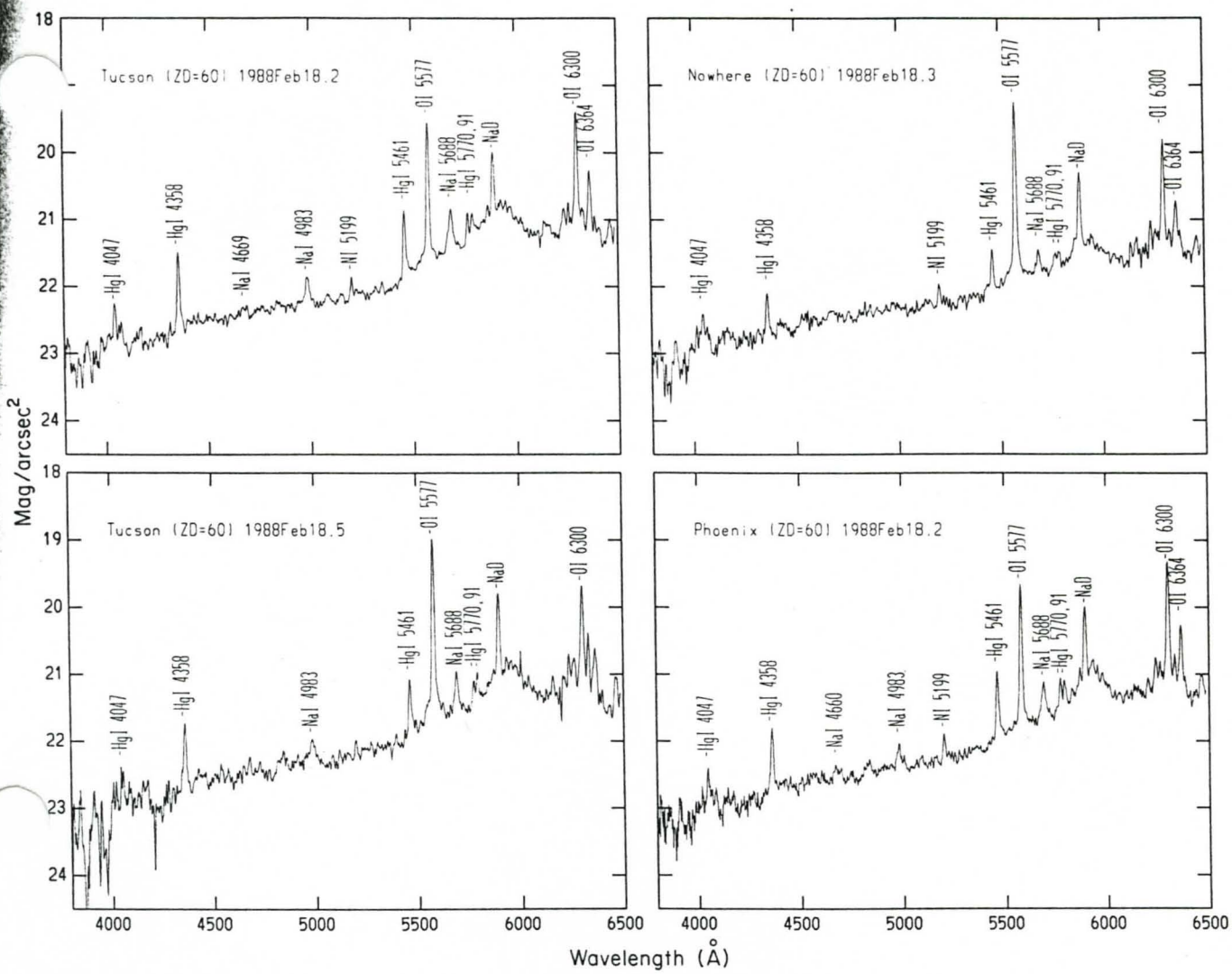


FIG. 1b—Representative spectra of the sky at a zenith distance of 60°.

from the Solar-Geophysical Data prompt reports (1988). We can see that the March 1989 data fit in well with that expected from the increased solar activity.

We see in Table 2 that the "spectroscopist's sky brightness" is about 0.02 to 0.05 mag/arc sec^2 fainter in B and 0.2 to 0.3 mag/arc sec^2 fainter in V than the broad-band measures. The dominant sources of line emission to the broad-band V values are atmospheric, with HPS+LPS making a contribution of less than 0.1 mag/arc sec^2 to the V measures. Hg is the dominant line contributor to the B measure, but even so it is fairly insignificant, amounting to less than 0.5 mag/arc sec^2.

The relative contributions of HPS, LPS, and Hg lamps to light pollution at Kitt Peak can be assessed from these observations as well. Although the lamp spectra had been fluxed in the sense that the relative line intensities for a given lamp are free of instrumental effects, these were by no means on any kind of absolute scale and so we needed to normalize these lamps relative to each other. For each of the sky spectra we subtracted a smooth continuum (in units of flux F_ν), leaving only the line emission from the airglow and artificial light. The lamp spectra were then each normalized to the continuum-subtracted sky spectrum by finding the multiplicative factor that resulted in the best match between the lamp spectrum and the strength of the emission lines attributed to each lamp in the night sky. The integral of each normalized lamp spectrum then represents the approximate relative contribution from that source. As discussed above, Hg lamps dominate the light pollution seen in the blue spectral region. In the red (from 5000 Å to 6500 Å) Hg lamps contribute only about 10% of the pollution, while LPS lamps contribute about 30% and HPS lamps about 60%. During the next decade the distribution of light among these three sources may well change as Tucson and Pima County convert to LPS lighting and

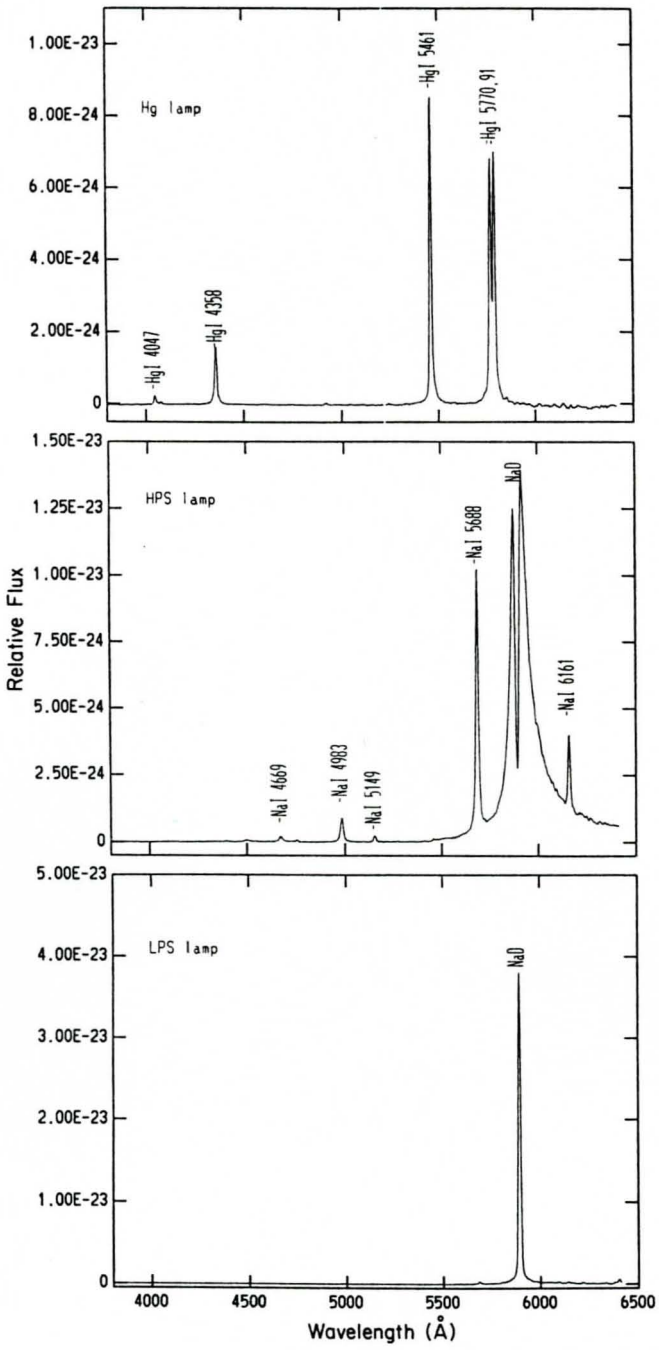


FIG. 1c–Representative spectra of three different types of street lights.

Hg lamps are phased out.

The sky brightness increases by a few tenths going from the zenith to a zenith distance of 60°. On some of the 12 nights of data used by Pilachowski *et al.* (1989) the change in sky brightness with respect to zenith distance was steeper than that; on other nights it was flatter. It is interesting to note from our data in Table 2 that the flux in each set of emission lines tracks well with the increase in continuum level (e.g., the relative contribution to the sky brightness remains nearly constant with respect to zenith

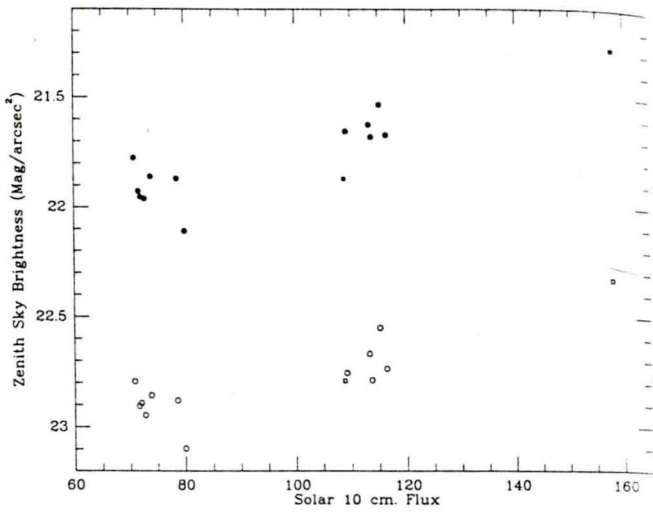


FIG. 2–Correlation of the zenith sky brightness with "decorrected" Ottawa 10-cm flux from the previous UT day. The filled symbols are *V*-band measurements, and the open symbols are *B*-band measurements. The circles are the Pilachowski *et al.* (1989) photoelectric values, and the squares are the average zenith values measured here. This figure is adapted from Figure 1 of Pilachowski *et al.*

distance). By comparing Figure 1b to Figure 1a we can see that the Hg lines *are* somewhat stronger relative to the continuum at a zenith distance of 60° than at the zenith, but the effect is quite small. We believe that this finding can be credited to the community support for astronomy exhibited in Arizona by the adoption of strict lighting ordinances that have forbidden the installation of new mercury streetlights and which encourage the use of LPS and, in limited cases, HPS. Although the sodium lamps make spectroscopic observations at the sodium lines more difficult, the contamination to the *V* band is still quite modest and is, in fact, significantly less than that contributed by atmospheric night-sky lines.

A curious and unexpected finding in Table 2 is that the contribution of artificial lighting to the spectrum of the night sky does *not* show an obvious azimuthal effect: At a zenith distance of 60° the sky is not appreciably worse toward Tucson or Phoenix than it is in any other direction. This can be seen by intercomparing the spectra shown in Fig. 1b: The Hg and Na lines are only slightly weaker toward "Nowhere" than they are toward Tucson or Phoenix. Pilachowski *et al.* (1989) did not study their data as a function of azimuth, only of zenith distance, but the small scatter in their elevation plots within a single night suggests that any azimuthal variations were not large. At greater zenith distances some azimuthal effects *must* be present, given that one can readily distinguish Tucson and Phoenix by eye at night near the horizon, but at least within "sensible" observing limits such efforts are so far small.

There has been one previously published study of absolute spectrophotometry of the Kitt Peak night sky

TABLE 2

Sky Brightness Contributions (mag/arcsec^2)

ZD	Azimuth	UT	Sky Bright.		HPS+LPS		Hg		Atmosph.		Everything	
			B	*V*	*B*	*V*	*B*	*V*	*B*	*V*	*B*	*V*
0°	Zenith	1988Feb18.2	22.71	21.78	0.00	0.05	0.02	0.01	0.00	0.10	0.02	0.17
		1988Feb18.3	22.68	21.83	0.00	0.04	0.02	0.01	0.00	0.11	0.02	0.17
		1988Feb18.4	22.76	21.81	0.00	0.05	0.01	0.01	0.00	0.15	0.02	0.21
		1988Feb18.5	23.01	22.06	0.00	0.07	0.02	0.02	0.00	0.12	0.03	0.21
		Average:	22.79	21.87	0.00	0.05	0.02	0.01	0.00	0.12	0.02	0.19
0°	Zenith	1989Mar29.2	22.33	21.28	0.01	0.05	0.02	0.01	0.01	0.29	0.03	0.39
45°	Tucson	1988Feb18.4	22.79	21.76	0.01	0.05	0.02	0.02	0.00	0.21	0.04	0.33
	Nowhere	1988Feb18.4	22.59	21.55	0.01	0.06	0.02	0.01	0.01	0.26	0.04	0.33
		Average:	22.69	21.66	0.01	0.05	0.02	0.02	0.00	0.24	0.04	0.33
60°	Tucson	1988Feb18.2	22.54	21.48	0.01	0.08	0.04	0.03	0.00	0.11	0.05	0.23
	Tucson	1988Feb18.5	22.63	21.48	0.01	0.09	0.03	0.02	0.00	0.18	0.05	0.32
	Phoenix	1988Feb18.2	22.67	21.61	0.01	0.08	0.03	0.03	0.01	0.11	0.05	0.24
	Nowhere	1988Feb18.3	22.61	21.73	0.01	0.06	0.03	0.02	0.00	0.15	0.04	0.24
	Nowhere	1988Feb18.5	22.34	21.44	0.01	0.07	0.01	0.02	0.00	0.15	0.02	0.28
		Average:	22.56	21.55	0.01	0.08	0.03	0.02	0.00	0.14	0.04	0.26

that of Broadfoot and Kendall (1968). Their observations ·e obtained over several years prior to 1968 (Broadfoot, ·ate communication). The study extends from 3100 Å–10000 Å at comparable resolution to ours. Their data show a surface brightness of ≈0.5 Rayleigh/Å near the *B* band and ≈1.0 Rayleigh/Å near the *V* band; these translate[2] to 22.9 mag/arc sec^2 and 21.9 mag/arc sec^2 which, coincidentally, are identical with the most recent solar minimum values. These data confirm that light pollution at Kitt Peak did not increase significantly from the mid-1960s to the late 1980s.

We are indebted to Mike Belton for pointing out the Broadfoot and Kendall reference and to Lloyd Wallace for comments on the manuscript. We are grateful to W. Robinson, Sr., C. Danielson, and the City of Tucson for their assistance in obtaining the necessary lamps for this experiment. C.G. was supported by the NSF Research Experiences for Undergraduates program in the summer of 1989.

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Pilachowski, C. A., Africano, J. L., Goodrich, B. D., and Binkert, W. S. 1989, *Pub. A.S.P.*, **101**, 707.
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[2]A perusal of Allen (1973) leads to the conversion (mag/arc sec^2) = 1.18 − 2.5 log(Å) − 2.5 log(*R*/Å).

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SKY BRIGHTNESS AT THE KITT PEAK NATIONAL OBSERVATORY

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ABSTRACT

We report results of a program to determine the brightness of the night sky at Kitt Peak during the recent solar minimum. Well-calibrated photometry in B and V suggests that the average brightness of the night sky during this period was approximately $V = 21.9$, $B = 23.0$ in magnitudes per square arc second but that variations of a few tenths of a magnitude can occur from night to night, or even during a single night. Since 1987 the sky has already brightened considerably, probably due to the increase in solar activity as the Sun moves toward sunspot maximum in 1991.

Key words: sky brightness–observatory sites

1. Introduction

Kitt Peak was selected in 1958 as the site for a new national observatory based in part on the expectation that population growth in southern Arizona would be limited and that nighttime skies would remain dark. Since 1958 the population of Tucson has increased substantially, with an accompanying growth in lighting and light pollution. The potential effects of light pollution on observations made from Kitt Peak and from other observatories in southern Arizona caused astronomers to campaign locally for ordinances to limit the effect of increased lighting on sky brightness by eliminating mercury vapor lights and shielding new lighting wherever possible. The first ordinance in Tucson was adopted in 1972. Since then, most of the towns and counties in Arizona have passed similar ordinances. A quantitative evaluation of the effectiveness of these ordinances has, however, not been available.

Recently, Garstang (1989*a*) has provided new calculations of the expected increase in B and V sky brightness at Kitt Peak due to the presence of cities and towns near the observatory and predictions of the expected growth of light pollution through the year 2035. Garstang's calculations suggest that by 1980 the zenith sky brightness had increased by 0.057 magnitude in B and 0.085 magnitude in V above the natural background and by 0.114 magnitude in V in 1990. These calculations do not include the anticipated positive effects of light-pollution-control ordinances. The phase of sunspot minimum in 1986 seemed a good time to begin a program to monitor the sky brightness from Kitt Peak, both in order to determine the current estimate of the sky brightness and to provide a baseline against which we can measure the growth of light pollution at the time of the next sunspot minimum in 1997. The increase in natural sky brightness due to increased solar activity in the next eight or nine years will make it hard to detect light pollution from Tucson.

2. Observations and Reductions

Photometry has been obtained during 12 photometric nights near new moon in 1986–88 using the No. 2-0.9-m telescope of the Kitt Peak National Observatory. Observations in B and V (Johnson 1952) were obtained with a 1P21 photomultiplier, except for data on 1987 January 27 (UT) which were taken with a GaAs phototube. The photometry is summarized in Table 1, which includes the date of observations, the lunar phase, the nightly V-band extinction coefficient, the average zenith B and V magnitudes, and the average B and V magnitudes at a zenith distance of 45°.

A grid of standard stars was selected at a uniform spacing in declination and right ascension (a pair of stars at every hour of right ascension, at declinations 90°, 70°, 50°, 30°, 10°, −10°, and −30°, eliminating those grid positions that fall within 25° of the Galactic plane). One of the pair of stars was observed in B and V, and then the telescope was offset to a nearby sky patch, usually 2 arc minutes west and north, unless another star was visible in the aperture in that patch of the sky. Since the sky was measured near a relatively bright star, the telescope was offset in a direction between the diffraction spikes of the secondary mirror support. The signal from the sky was integrated for at least 30 seconds to obtain sufficient counts for 1% photometry. The other star and sky of the pair were observed in the same way. Observations of the grid standard stars were also used to monitor the photometric condition of

*Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

TABLE 1

Sky Brightness Observations (Magnitudes Arc-Second^{-2})

U.T. Date	Lunar Phase	V Extinction Mag. Airmass^{-1}	V Zenith	B Zenith	n	V 45°	B 45°	n
Observations at Sunspot Minimum:								
02 Dec. 1986	0.01	0.150	21.961	22.946	10	21.788	22.841	4
30 Dec. 1986	0.97	0.128	21.926	22.905	20	21.638	22.754	16
31 Dec. 1986	0.00	0.131	21.952	22.891	8	21.697	22.785	24
27 Jan. 1987	0.12	0.103	21.860	22.856	10	21.719	22.726	6
23 Feb. 1987	0.36	0.173	21.775	22.794	9	21.608	22.692	16
21 Jun. 1987	0.28	0.169	21.869	22.871	4	...	...	...
22 Jun. 1987	0.19	0.161	22.108	23.097	22	21.663	22.698	8
Mean Brightness			21.922	22.909	...	21.686	22.749	...
Observations after Sunspot Minimum:								
20 Nov. 1987	0.00	0.115	21.654	22.755	5	21.426	22.543	4
21 Jan. 1988	0.11	0.128	21.671	22.735	37	21.600	22.632	9
16 Mar. 1988	0.03	0.131	21.679	22.787	97	...	...	...
17 Mar. 1988	0.00	0.180	21.534	22.550	152	...	...	...
14 Jun. 1988	0.00	0.167	21.624	22.668	45	...	...	...
Mean Brightness			21.632	22.699	...	...	...	...

Image Scale 29.5"/mm

the sky throughout the night. Alternate observations of the two stars of the pair nearest the zenith were used to monitor the zenith sky brightness. Approximately 20 Landolt (1983) standards were observed every night over a range of air mass to allow a good photometric calibration and a measurement of the extinction.

Data reductions for the stellar observations followed the standard procedures of Harris, FitzGerald, and Reed (1981). For reductions of the sky magnitudes, the air mass was arbitrarily set to zero in the transformation equations, in order that no extinction corrections be applied. Note that values reported earlier by Pilachowski *et al.* (1987) and Massey and Pilachowski (1987) are revised due to a better measurement of the plate scale.

Accurate calibration of the sky-brightness data also requires measurement of the aperture diameter and the plate scale of the telescope. The aperture diameter was measured to be 2.002 ± 0.009 mm or 59 arc seconds. The plate scale of the telescope is 29.5 arc seconds per millimeter, with an uncertainty of approximately 0.″5 mm^{-1}. These uncertainties affect our absolute calibration of the sky brightness at the level of 0.010 magnitude for the aperture and 0.037 magnitude for the plate scale. The combined systematic error in our sky-brightness measurements could be as large as 0.05 magnitude.

3. Sky-Brightness Measurements

The nightly mean sky brightness in *B* and *V* at the zenith and at 45° are included in Table 1. The zenith valu is computed by simply averaging all measuremen within 20° of the zenith, and the 45° values by averagin measurements between 40° and 50° zenith distance at a azimuths. The limit of 20° is derived both from the ob served lack of dependence on elevation for points with this angular distance of the zenith and from the mathe matical dependence of sky brightness on the secant of th zenith distance, which suggests that sky brightness de pends only slightly on zenith distance within 20° of th zenith.

The zenith sky brightness seems to have increased b approximately 0.29 magnitude in *V* between June an November 1987. The observations are plotted in Figure against the solar 10.7-cm flux, an index known itself correlate with intensity of the solar EUV flux. Walk (1988) has suggested that sky brightness correlates bett with the actual solar 10-cm flux, rather than the publishe value which is corrected to a distance of 1 AU, and that th best correlation occurs for the solar flux measured durin the day before the nighttime observations. The 10-cm flu values plotted in Figure 1 are the uncorrected Ottaw solar radio flux on the day before the observations.

Figure 1 suggests that the observed recent increase sky brightness does, in fact, correlate with the solar 10-c flux and the general increase in solar activity sin sunspot minimum in 1986. As found by Walker (1988 the correlation of sky brightness with solar 10-cm flu

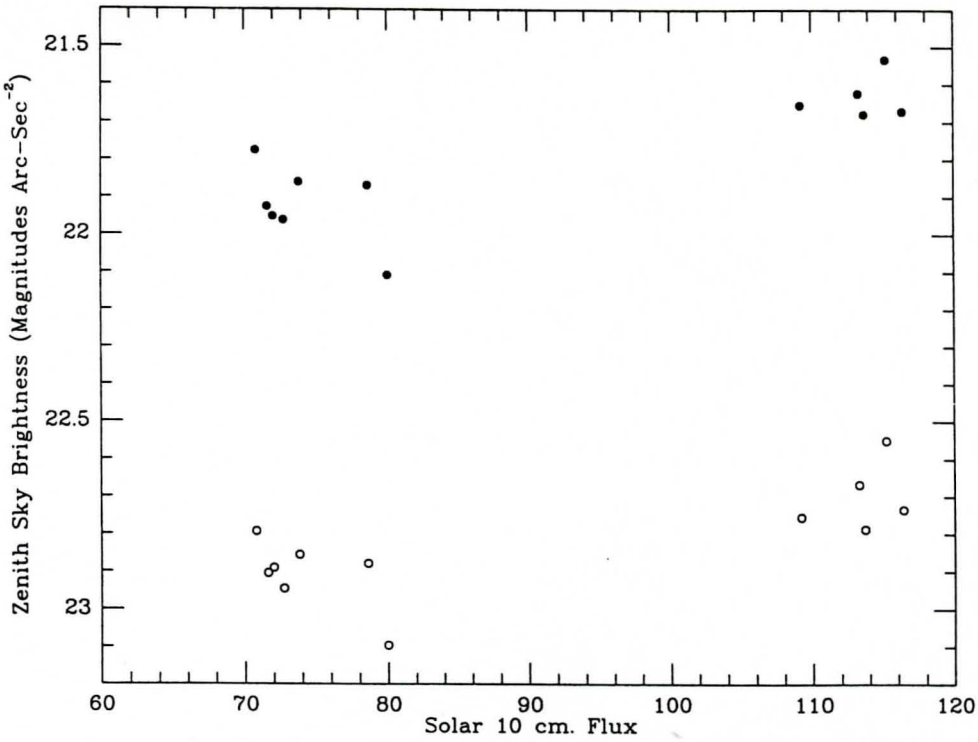


FIG. 1–Zenith sky brightness for B and V as a function of the "uncorrected" solar 10-cm flux. V measurements are plotted as filled circles and B measurements are plotted as open circles.

appears to hold for both V and B, although the color of the sky changed from $(B-V) = 0.99$ in 1987 to $(B-V) = 1.07$ in 1988. Typical values of the solar 10-cm flux at solar maximum and minimum are near 200×10^{-22} and 70×10^{-22} Watts m^{-2} Hz^{-1}, respectively. We may expect the night sky to continue to be brighter for the next several years as the Sun passes through maximum in the current sunspot cycle.

In Figures 2 and 3 are plotted the individual sky-brightness measurements in V and $(B-V)$ as a function of elevation above the horizon for each of the nights observations were obtained. Measurements at all azimuths are included; an increase in sky brightness in the direction of Tucson at a zenith distance of 60° could not be discerned in our data. Measurements of two nearby sky patches generally agree closely. The average difference between nearby sky patches is 0.029 magnitude, probably due to variations in the number or brightness of faint stars contaminating the aperture. The typical standard deviation of zenith measurements on a single night is slightly larger, typically 0.052 magnitude. This increase can most probably be attributed to temporal variation through the night. Color data are shown in Figure 3 in plots of $(B-V)$ vs. elevation for all the nights observations were obtained. N[illegible]at the sky becomes increasingly red for zenith [illegible]es greater than 45°, consistent with the model predictions of Garstang (1989*b*).

In Figure 4 are plotted the zenith sky brightnesses for four nights during which the zenith was monitored for an extended period. On some nights, the zenith sky brightness varies over 0.1 magnitude within an hour for the same patch of sky. The four nights plotted in Figure 4 are all in 1988, after the sky had brightened due to increased solar activity. These data suggest that the sky brightness can vary dramatically over relatively short intervals of time compared to many astronomical observations.

4. Comparison to Model Predictions and other Astronomical Sites

Garstang (1989*a*) has recently provided calculations of the expected artificial brightening of the night sky due to light pollution at several astronomical sites. His estimates for Kitt Peak are relative to an expected zenith sky brightness of 22.99 magnitudes in B and 21.99 magnitudes in V at sunspot minimum. The estimates for Kitt Peak are given in Table 2, along with our measured values at the zenith and at a zenith distance of 45°. Predicted values for 1987 have been interpolated from Garstang's computed values for 1980 and 1990 to compare directly to the observed sky brightness. While the B measurements agree with the predictions to 0.01 magnitude at the zenith, and to 0.02 magnitude at 45°, the V measurements suggest that the sky at sunspot minimum was darker by 0.04 magnitude than predicted by the model. The possible

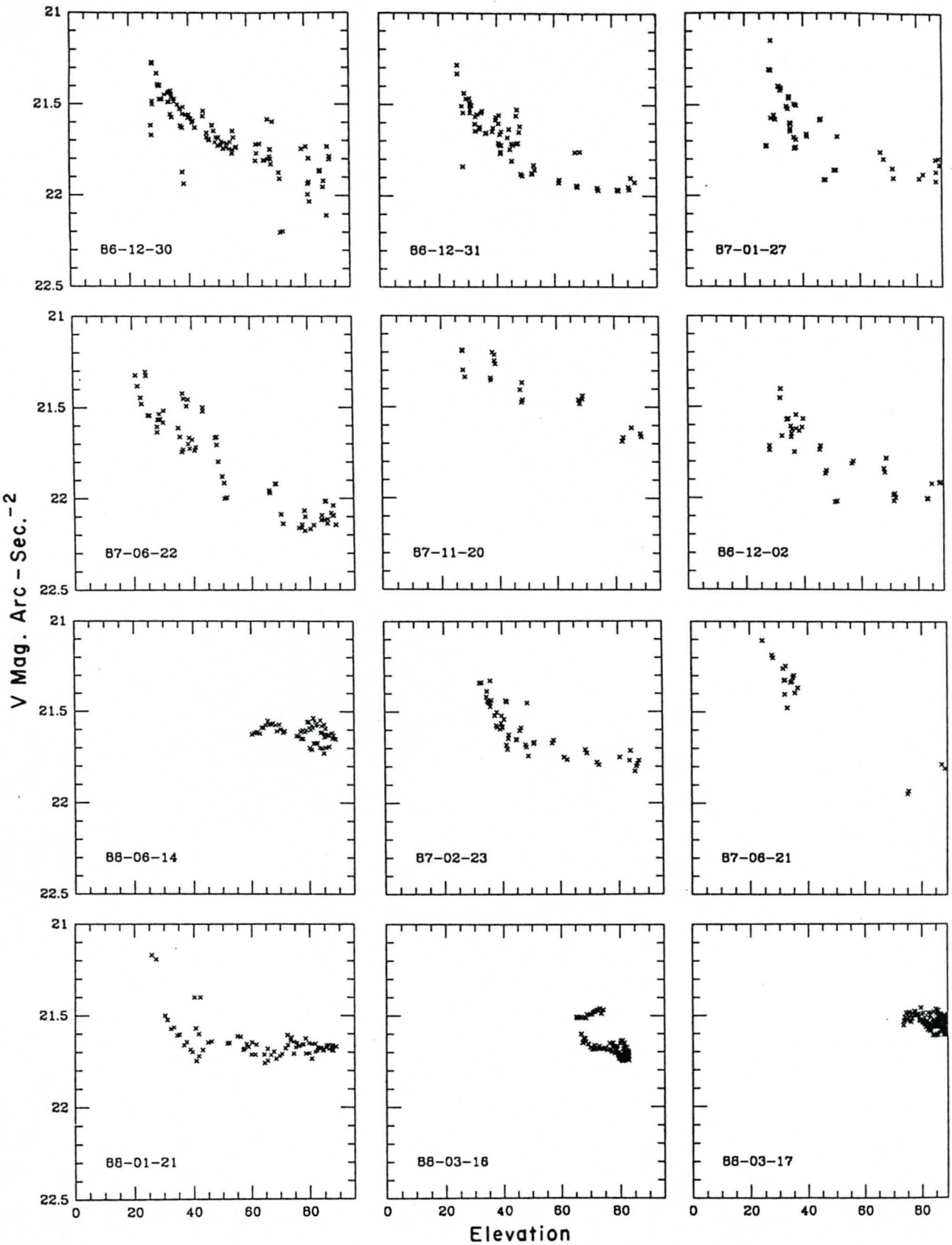


FIG. 2–Sky brightness in V vs. elevation for the 12 nights that observations were obtained.

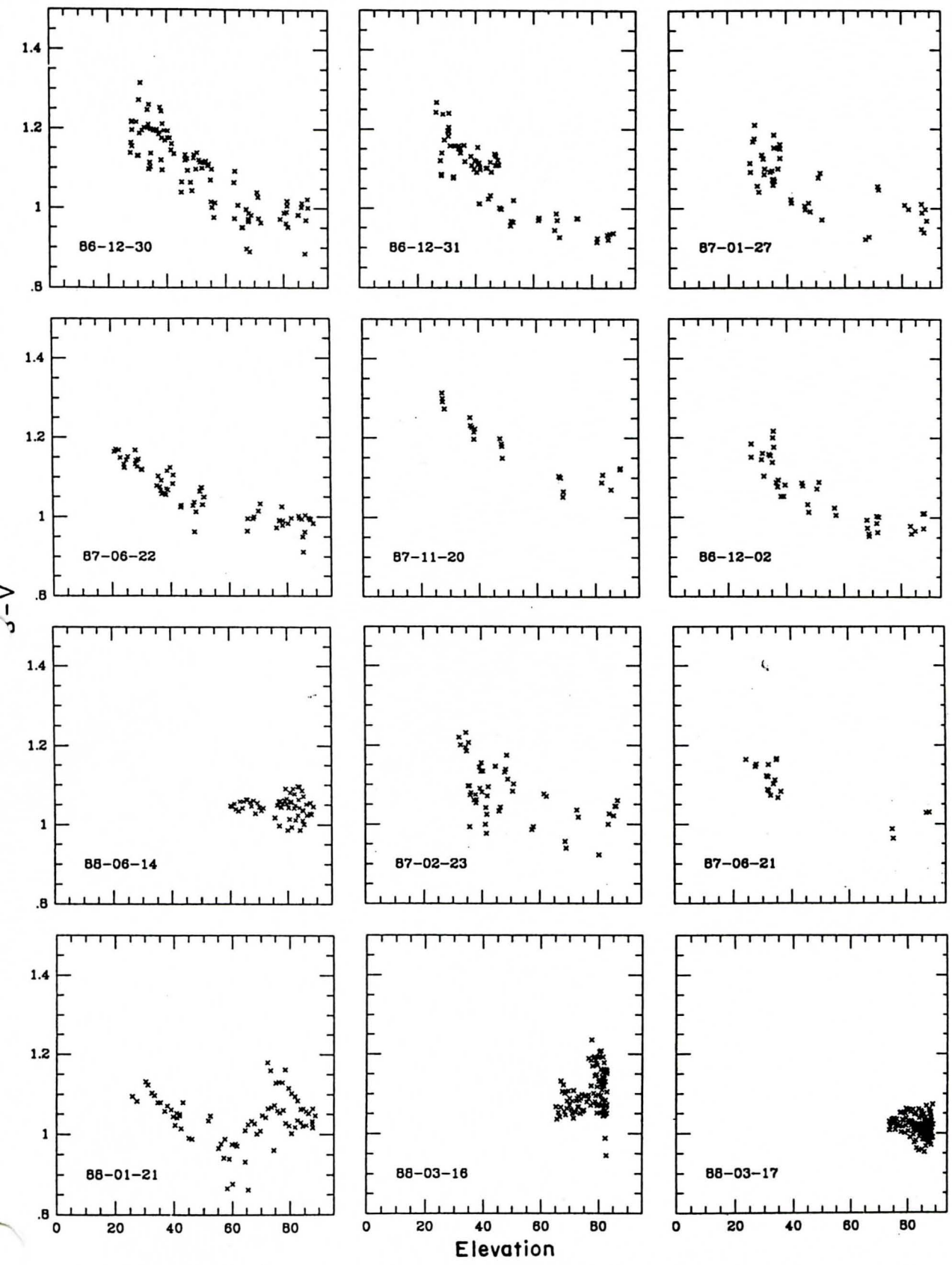


FIG. 3–$(B-V)$ color of the night sky vs. elevation for the 12 nights that observations were obtained.

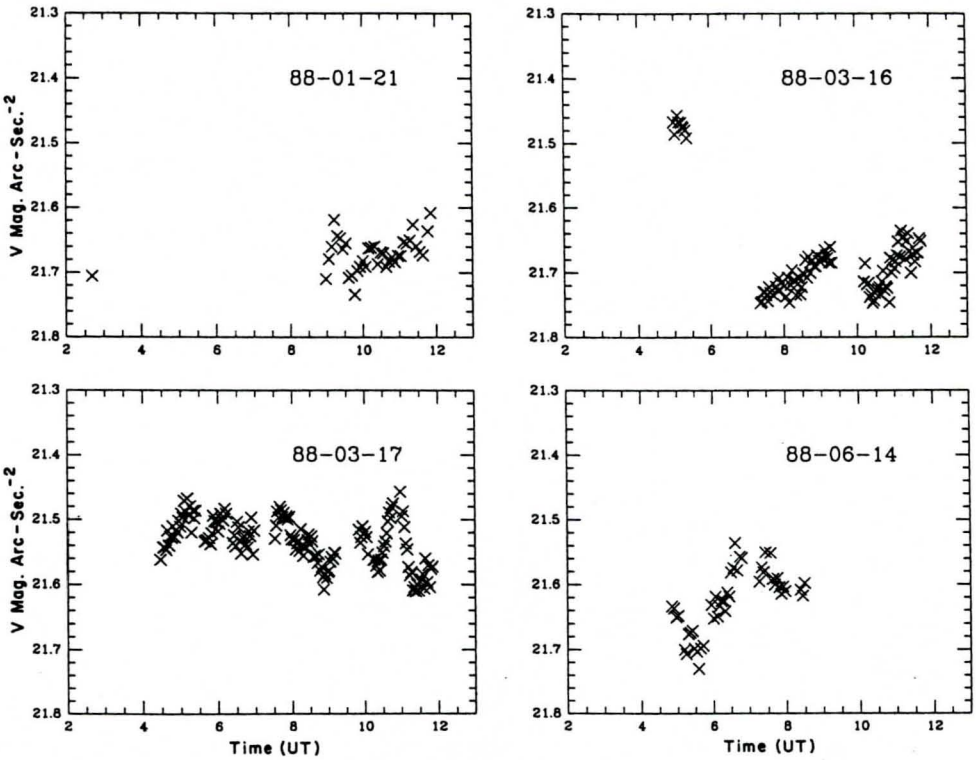


FIG. 4–Variations in the zenith sky brightness vs. time for four nights in 1988.

TABLE 2

Comparison with Model Predictions

Direction	Observed Magnitude	Predicted Magnitude 1980	1990	1987
V (zenith)	21.922	21.905	21.876	21.885
B (zenith)	22.909	22.931	22.914	22.919
V (45°)	21.686	21.672	21.632	21.644
B (45°)	22.749	22.755	22.723	22.728

systematic error in our measurements or an error in the assumption of $V = 21.99$ for the natural sky background could account for the discrepancy, but the good agreement with the B-band predictions suggests that the sky at Kitt Peak is 0.04 magnitude darker in V than the models suggest, perhaps due to the success of the light-pollution-control efforts of Tucson.

In comparison to observations at other astronomical sites summarized by Garstang (1989*b*) Kitt Peak remains a competitively dark site for astronomy. Such comparisons should be made carefully, however, to insure that measurements were obtained at similar solar phases, and preferably at solar minimum. A value of $V = 21.99$ is reported for Cerro Tololo for 1987 (Geisler 1988). Few additional measurements are yet available in the literature from the period of the recent solar minimum, but with an increase of only 0.07 magnitude in V above the natural sky background, Kitt Peak remains one of the darkest sites now in use with large telescope facilities.

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CITY LIGHT POLLUTION: ITS EFFECT ON ASTRONOMY
A Two-Year Investigation Utilizing a CCD Detector

Third Annual IAPPP Special Award in Astronomy
International Science and Engineering Fair
9-15 May 1993, Gulfport, Mississippi USA

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1. INTRODUCTION

Because of my love for astronomy and concern over its uncertain future, I have decided to investigate the problem of light pollution in astronomy. I assume it is the responsibility for a concerned amateur astronomer to enlighten the general public about this topic (pun intended). In my opinion the majority of the public does not even recognize the basic constellations in the night sky. Probably the cause of this deficiency is that people usually live in a city where excess light is cast upward and thus interferes with the dark sky background. In other words, light pollution could be a main cause of public disinterest and ignorance in astronomy.

My science project last year helped portray the light pollution problem with the use of astrophotographs. I determined that the visibility of the Orion Nebula (M-42) was seriously affected by the city sky brightness by comparing pictures taken in the country. I also determined that special filters can block out certain wavelengths of mercury and sodium vapor lamp emissions. However, these filters are very expensive and most people cannot obtain them. Furthermore, these filters still block out some of the light transmission; the amount of light entering the eyepiece is important in distinguishing details in, say, a nebulous object like the Orion Nebula. Therefore, the best way to deal with the problem is to use better shields on lights and to install low pressure sodium lamps near observatories. In any case, an observa-



FIGURE 1. (Left) The author, with Celestron-8 and SBIG CCD camera, preparing for a night of observing.

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tional astronomer is always going to have a problem inside any city, and this led me to my investigation of light pollution.

This year I investigated three hypotheses with the aid of a Charge-Coupled Device (CCD). The three questions which I posed were: (1) Is there a sky brightness increase in images made in the city versus those made in the country; (2) Does humidity play a role in the effects of city light pollution on sky brightness; and (3) How much does city light pollution cost?

With the CCD camera I had hoped to obtain data which would support my first hypothesis. I assumed that there would be an apparent increase in the brightness of the Orion Nebula and area surrounding it. To test this I made various images of M-42 in the city to get a basis for comparison to the country images. Once I obtained the perfect image (in the city) of M-42, I traveled to a country site 40 miles north of Woolmarket and took images of M-42 at the exact time of night that I had made the city image. However, I reasoned that if several days elapsed between the city and country images then I should take the country images a few minutes early to compensate for the earth's revolution around the sun.

To test my second hypothesis I had to take various images of M-42 on days where the humidity was different, with either high or low humidity. I could then look for a brightness increase in the nebula as the humidity content increased (if the hypothesis is correct).

My last hypothesis involved the calculation of the economic cost of city light pollution in Gulfport, Mississippi. I obtained various lamp data from the Mississippi Power Company and from Cooper Lighting in Vicksburg. Basically, I had to figure out the cost of wasted light for each different luminaire, taking into account the wattage of each and whether it was mercury or sodium.

As the last step in my investigation of city light pollution I compared the percentage of brightness increase (city vs. country) with the percentage of wasted light escaping above the horizontal plane of the luminaire and light indirectly reflected upward from the ground. In theory the brightness increase of city images and the amount of light going upward into the atmosphere should be directly correlated.

II. EXPERIMENTS

My main purpose this year was to calculate the magnitude increase of the sky (or star) in the city verses the country. I used a Charge-Coupled Device (CCD), made by Santa Barbara Instruments, rather than astrophotographs to calculate magnitudes. I decided to use a CCD camera because I could actually get raw numbers back from an analog to digital converter, and therefore a digital image could be put on a computer for analysis. Also, a CCD is more linear than the chemical process used in photography. The CCD is also many times more sensitive to light than regular photographic film (ASA). I only had to expose the CCD chip for a few seconds, whereas the photographic film had to be exposed for about twenty minutes. However, the downside in using CCD's (at least the less expensive kinds) are that they have a very small field size, and the image has less resolution compared to a photograph.

Besides the CCD camera, I used my 8" Schmidt-Cassegrain Telescope, which has a 2000 mm focal length, and *f*/10 focal ratio. The software for the CCD control programs required that the telescope dimensions be expressed in inches. In my case the effective aperture was 45.36 square inches (with the area of the secondary mirror subtracted out) and the focal length was about 201 inches.

Because my object of study last year was the Ori
object again this year. To those which might try to perf
must note that M-42 is not the best candidate for a light
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of stars near the bright core of M-42.

All of the images collected in the city were taken i
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However, for some calculations I utilized Richard Berry's
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to the left of the comparison star. Then I made an imag
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number. It was necessary to record every pixel value in
about 100 different values. This process was repeated for t
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calculated. However, for the experiment involving the humi
magnitude readings determined by the program that came w

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different mercury and sodium vapor lights had to be broke
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expressed every luminaire by its lumens per watt (lm/w) ra
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radiated above the horizontal.

Besides light going directly up, there is also light b
Therefore, I requested a footcandle meter from the Missi
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wattage. Finally, by collecting all necessary data on eac
determine the amount of money wasted in lighting the night
knew the percentage of wasted light going up, I then mul
initial lumens of a luminaire (including ballast). The result
wasted for upward lighting. Then I divided the wasted lum
data to get the number of watts wasted. I then applied these f

Because my object of study last year was the Orion Nebula (M-42) I used this object again this year. To those which might try to perform this type of experiment, I must note that M-42 is not the best candidate for a light pollution study— this will be explained below. Because of the CCD's small field of view I concentrated my study inside the nebula, near the Trapezium. I used a comparison star located east of a triangle of stars near the bright core of M-42.

All of the images collected in the city were taken in Gulfport. The other images were taken out in the country, about 40 miles north of Woolmarket. While in the city, I used a 486 DX2 50MHZ Zeos computer. However, out in the country I borrowed someone else's laptop with similar performance characteristics.

In the process of taking pictures, I also had to keep in mind some of the factors which might have contributed to a decrease or increase in magnitude. I took both city and country images under similar humidity, sky conditions, moon phase and airmass. Airmass is the term for describing how much atmosphere the light of the object of interest has to pass through. In other words, both city and country pictures had to be taken so that they were both located in the same part of the sky or atmosphere. Therefore, every time I captured an image of M-42 I recorded the exact time I took it. Hence, as the days progressed I had to take into account the effect of the earth's revolution around the sun in determining the best time of exposure.

In comparing my images I used the magnitudes calculated by the CCD software. However, for some calculations I utilized Richard Berry's ImagPro imaging software to get a more accurate reading of the star and nebula's count numbers. In this program I maneuvered the dot (or pixel indicator), while in "Examine" mode, about 40 key presses to the left of the comparison star. Then I made an imaginary 10x10 box around the desired background (near the trapezium in M-42) and recorded the average count number. It was necessary to record every pixel value in that box, which contained about 100 different values. This process was repeated for the country images, that way the percentage of brightness increase (caused by city light pollution) could be calculated. However, for the experiment involving the humidity relationship, I chose the magnitude readings determined by the program that came with the CCD.

The last experiment involved calculating (directly and indirectly) the cost of lighting the night sky, i.e. city light pollution. First of all I had to know the amount of street lights (mostly the barreled type) that were in Gulfport. Also, the number of different mercury and sodium vapor lights had to be broken down into wattages (e.g. there are 624 100w high pressure sodium luminaires). Then I obtained lamp data which expressed every luminaire by its lumens per watt (lm/w) rating. Also my experiment required that I search for some specific data which would tell me the percentage of light radiated above the horizontal.

Besides light going directly up, there is also light being reflected off the road. Therefore, I requested a footcandle meter from the Mississippi Power Company to determine the percentage of reflectance off the road. In addition to the foot-candle meter, I obtained the monthly rating (cost in Kwh) for each luminaire with a different wattage. Finally, by collecting all necessary data on each luminaire, I was able to determine the amount of money wasted in lighting the night sky. For example, once I knew the percentage of wasted light going up, I then multiplied this value with the initial lumens of a luminaire (including ballast). The result was the amount of lumens wasted for upward lighting. Then I divided the wasted lumens by the lumens per watt data to get the number of watts wasted. I then applied these figures to the formula:

$$\frac{\text{total wattage of luminaire (with ballast) x 4043 hours/year}}{\text{1000 x 12 months/year}} \quad (1)$$

to determine the monthly Kwh for the wasted light. Furthermore, when I multiplied the monthly Kwh rating with the energy charge per Kwh, the cost of wasted light going upward per month was found for one light. Finally, by multiplying the monthly cost of wasted light for one luminaire with the total number of luminaires of that wattage in the city, I was able to determine the total cost of wasted light per month for the particular luminaires of one wattage type. This computation was repeated for all of the luminaires (including the mercury and sodium vapor lights).

III. OBSERVATIONS

I began observing in December 1992 and continued through February 1993. While analyzing the data I discovered that the December and January data were useless because of calibration problems. However, I observed several times in February and most of this was useful. I chose a 12.3 magnitude star and part of the nebula itself as calibration points for each image. Let me note here that I did not get good flat fields on certain nights because I was just learning how to use the camera. However this paper is intended to be a "proof of concept" for the basic techniques anyone can use to the study of light pollution rather than a report of definitive results. Anyway, it was not until February 12, 1993, that I obtained satisfactory images. Table 1 gives a log of the observations I made.

TABLE 1.
Log of Observations

1993 Date	Local Time p.m.	Temp. °F	Humidity %	Dewpt. °F	Wind mph	Pressure in., Hg	Star Mag.	Nebula Mag.
12 Feb.	8:50	47	83	42	NNW7	30.03	12.10	17.03
13 Feb.*	9:50	50	89	47	calm	30.08	12.30	17.25
18 Feb.	9:15	39	60	25	SW5	30.36	12.31	17.27
22 Feb.	8:40	54	40	30	N6	30.06	12.12	16.89
26 Feb.	8:34	48	68	38	N12	30.24	11.77	16.46

* Country measurement; all others in city

The image that I obtained on 12 February 1993 was used as a comparison image for all others obtained (see Figure 2). It was taken shortly after obtaining the weather data from the local TV station. This image was scrutinized carefully for a suitable comparison star; I decided to use a known 12.3 magnitude star located near the Trapezium. However, in this image I measured the magnitude of this star at 12.1, which suggested it had risen in brightness— or that my measurements were subject to some unknown calibration uncertainty. In determining the magnitude of a diffuse portion of M-42, I moved 40 pixels to the left of this star and then opened the box to 11 x 11 pixels instead of the 5 x 5 pixel box used for stars. In this image I measured a magnitude of 17.03 for this portion of M42.

On 13 February 1993 I went out into the country and obtained another CCD image of M42. Comparing the two images, I computed the brightness increase using Richard Berry's astronomical imaging program. Using a 10 x 10 pixel box, I calculated

the average counts for the nebula and the 12.3 magnitu
percentage of brightness increase caused by the light poll
formula: % increase = 100 x {1 - (country counts / city cou
apparent brightness of the nebula had increased by 25.2% (
section for my light pollution study) and that the star had
17.8%. Both effects were presumably due to light pollution i

I also investigated the effects of relative humidity b
M-42 on four different nights (including 2/12/93) under con
humidity. These observations are also listed in Table 1.
February and 18 February images suggested that as the hun
brightness of the star and nebula. It also suggested tha
increases so do the effects of city light pollution on my m
obtained additional images to test this hypothesis, which are a

I videotaped the computer monitor when each image
the tape in a back and forth motion to see if there was any
image with the highest humidity content. Changes in the im
limited data that I have collected so far does not show any cl
A more complete study will require many carefully flat-fielde

III. ECONOMIC IMPACT OF LIGHT PO

Before trying to estimate the economic impact of ligh
on the lamps most commonly in use in Gulfport, Mississipp
Table 2. I also calculated the amount of money wasted by
and determined the annual cost of wasted light for each type
equation:

$$T = \frac{N * L_o * W * H * R}{1000 * LPW}$$

where N is the total number of lights of a particular type, L
particular lamp type; W = 7.3% is the percentage of waste
horizontal; H = 4043 hours is the average time a light stays



the approximate
kilowatt hour i
number of watts
lumens-per-watt
lamp; and T is
wasted light emi
light.

FIGURE 2. (Le
the Orion Nebu
February 1993,
for sky backgro

the average counts for the nebula and the 12.3 magnitude star and computed the percentage of brightness increase caused by the light pollution in the city from the formula: % increase = 100 x {1 - (country counts / city counts)}. I computed that the apparent brightness of the nebula had increased by 25.2% (the figure used in the next section for my light pollution study) and that the star had apparently brightened by 17.8%. Both effects were presumably due to light pollution in the city measurements.

I also investigated the effects of relative humidity by taking several images of M-42 on four different nights (including 2/12/93) under conditions of different relative humidity. These observations are also listed in Table 1. A comparison of the 12 February and 18 February images suggested that as the humidity decreased so did the brightness of the star and nebula. It also suggested that as the humidity content increases so do the effects of city light pollution on my measurements. Therefore, I obtained additional images to test this hypothesis, which are also logged in Table 1.

I videotaped the computer monitor when each image was loaded up, and played the tape in a back and forth motion to see if there was any brightness increase in the image with the highest humidity content. Changes in the images were obvious, but the limited data that I have collected so far does not show any clear correlation to humidity. A more complete study will require many carefully flat-fielded and calibrated images.

III. ECONOMIC IMPACT OF LIGHT POLLUTION

Before trying to estimate the economic impact of light pollution, I collected data on the lamps most commonly in use in Gulfport, Mississippi. These data are listed in Table 2. I also calculated the amount of money wasted by each street light separately and determined the annual cost of wasted light for each type of street light by using the equation:

$$T = \frac{N * L_o * W * H * R}{1000 * LPW} \qquad (2)$$

where N is the total number of lights of a particular type, L_O is the initial wattage of a particular lamp type; W = 7.3% is the percentage of wasted light radiated above the horizontal; H = 4043 hours is the average time a light stays on in a year; R = $0.0482 is the approximate hourly charge rate for one kilowatt hour in my region; 1000 is the number of watts in a kilowatt; LPW is the lumens-per-watt rating for a particular lamp; and T is the total annual cost of wasted light emitted by one particular street light.

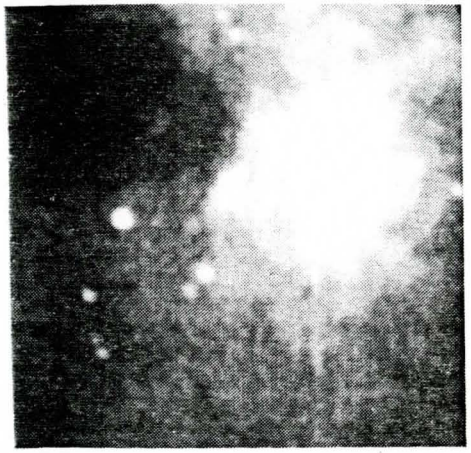


FIGURE 2. (Left) CCD image of a field in the Orion Nebula (M-42) obtained on 12 February 1993, used as a comparison image for sky background measurements.

TABLE 2.
Street Lights Used in Gulfport, MS

Percent of light output = 72.5%
Percent of light consumed by ballast = 27.5%
Percent of downward light (< 90°) = 65.2%
Percent of upward light (> 90°) = 7.3%

Type	Quantity	Wattage	Initial Lumens	Lumens per Watt (including ballast)	Waste (per year)
Mercury	2529	175	8,600	40	$7735.80
Mercury	115	400	21,500	47	744.48
Sodium	624	100	9,500	90	937.08
Sodium	438	150	16,000	85	1173.00
Sodium	54	250	27,500	91.7	230.40
Sodium	257	400	50,000	107.5	1700.64
Sodium	34	1000	140,000	127.3	531.96
					Annual Total: $13,053.36

The annual cost of wasted light that I calculated for each type of lamp is given in the last column of Table 2. I was surprised to learn that the total cost of my own city's street light pollution is about $13,053.36. One must understand that this figure includes only the streetlights; it does not include the cost of security lighting or other types of lighting in Gulfport, therefore the cost of Gulfport's light pollution is well over $13,000.

In order to take into account the fact that some of the light pollution comes from light that is reflected from the ground I measured the reflectance of the road surfaces under typical streetlights. I used a foot-candle meter supplied by the Mississippi Power Company to record light readings at fifteen sites on the road and fifteen sites off the road and determined that the average reflectance of the road was about 15.0%. Using this value I then was able to improve my previous estimate of the total percentage of wasted light traversing upward. I recalled that the percentage of light directly radiated above the horizontal plane was 7.3%. I added this percentage to the road reflectance and obtained a sum of 22.3% of wasted light going up into the night sky.

I then remembered that from my previous observations the percentage brightness increase (city vs. country images) was 25.2%. This was quite interesting because the percentage of brightness increase (25.2%) was very close to what I computed to be the percentage of wasted light (22.3%) going upward. It could be that the discrepancy of 2.9% between these two figures could have been caused by security lighting or other personal lighting systems which were not taken into account.

IV. CONCLUSIONS

I have come to several conclusions during the course of my project. When I observed the effects of light pollution in city and country images of the nebula, I determined that the sky in my city was about 25.2% brighter than in the country. Since

measurements of the star's apparent brightness increas
that light pollution affects observations of diffuse exten
stellar objects. This would explain why objects like the
Nebula, and the Horse head Nebula are nearly, if not to
noticed this effect over the years when I tried to searc
For instance, the Owl Nebula is about 12th magnitude a
clear nights when the humidity is below 30%..

I also noticed that the amount of humidity i
brightness. Generally (though my limited data do not
humidity increases so do the effects of light pollution.
02/22/93 and 02/26/93 suggest that as more water vapor
reflects more artificial light. When the humidity content
was at 12.12 magnitude. However, when I took the sam
mass) on 02/26/93 with humidity at 68%, the comparison
must note here that I do not yet have enough data to con
To do this I would have to continue my observations o
several months, but time ran out because of the close-appr

In my study of the actual cost of light pollution,
pays at least $13,000.00 a year to uselessly illuminate the
the total lighting cost a year for street lighting in Gulfpor
of light pollution into the various types of lamps, proba
Gulfport is the 175w mercury vapor street light. These
about $645.00 a month in wasted energy. To make ma
only provide 8500 initial lumens, compared to the 100
provide 9500 initial lumens. This is why Gulfport, like oth
the 100w sodium vapor lamps.

Because there are mostly mercury vapor street
pollution has many emission lines near the blue end of
found that the light pollution in the Gulfport sky has a blu
vapor street lights). A filter that can block out some of th
be used in the city to cut down the effects of light pollutio
my project last year and concluded that the skyglow filte
the effects of light pollution on my observing. In my proje
the light pollution in the sky has emission lines typical of t

In the course of my project I discovered that
contribute to about a 0.2 magnitude increase in sky brigh
very small to some— Gulfport is not like New York Ci
third magnitude stars are visible. These results imply that
a year to illuminate the night sky. This cost varies beca
growing and the price of electricity changes from time
investigation, if conducted in other cities, will help to ale
light pollution.

The last part of my project involved trying to link
to the percentage of brightness increase in the city image
the percentage of reflectance off the road and the perc
degree plane, I obtained a total of 22.3%. This value rep

measurements of the star's apparent brightness increased only about 17.8%, I suspect that light pollution affects observations of diffuse extended objects more than point-like stellar objects. This would explain why objects like the Owl Nebula, Crab Nebula, Veil Nebula, and the Horse head Nebula are nearly, if not totally, invisible in a city. I have noticed this effect over the years when I tried to search for these objects in Gulfport. For instance, the Owl Nebula is about 12th magnitude and is only visible on extremely clear nights when the humidity is below 30%..

I also noticed that the amount of humidity in the atmosphere affects sky brightness. Generally (though my limited data do not prove this conclusively), as the humidity increases so do the effects of light pollution. The images that were taken on 02/22/93 and 02/26/93 suggest that as more water vapor is present in the atmosphere it reflects more artificial light. When the humidity content was at 40%, the comparison star was at 12.12 magnitude. However, when I took the same image (compensating for air mass) on 02/26/93 with humidity at 68%, the comparison star was at 11.77 magnitude. I must note here that I do not yet have enough data to conclude that my theory is correct. To do this I would have to continue my observations over a much longer period, like several months, but time ran out because of the close-approaching science fairs.

In my study of the actual cost of light pollution, I have estimated that the city pays at least $13,000.00 a year to uselessly illuminate the night sky. This is about 7% of the total lighting cost a year for street lighting in Gulfport. When I broke down the cost of light pollution into the various types of lamps, probably the worst light polluter in Gulfport is the 175w mercury vapor street light. These lights cost Gulfport a total of about $645.00 a month in wasted energy. To make matters worse, these 175w lamps only provide 8500 initial lumens, compared to the 100w sodium vapor lamps which provide 9500 initial lumens. This is why Gulfport, like other cities, is trying to convert to the 100w sodium vapor lamps.

Because there are mostly mercury vapor street lights in Gulfport, the light pollution has many emission lines near the blue end of the spectrum (coincidentally I found that the light pollution in the Gulfport sky has a blush hue to it, typical of mercury vapor street lights). A filter that can block out some of these mercury vapor lines could be used in the city to cut down the effects of light pollution. I used this kind of filter in my project last year and concluded that the skyglow filter did in fact help to decrease the effects of light pollution on my observing. In my project this year, I reconfirmed that the light pollution in the sky has emission lines typical of the mercury vapor street lights.

In the course of my project I discovered that city street lights in Gulfport contribute to about a 0.2 magnitude increase in sky brightness. This value might seem very small to some— Gulfport is not like New York City where only the second and third magnitude stars are visible. These results imply that Gulfport pays at least $13,000 a year to illuminate the night sky. This cost varies because, for example, Gulfport is growing and the price of electricity changes from time to time. I hope this type of investigation, if conducted in other cities, will help to alert the public to the problem of light pollution.

The last part of my project involved trying to link the percentage of wasted light to the percentage of brightness increase in the city images of M-42. When I added up the percentage of reflectance off the road and the percent of light escaping the 90 degree plane, I obtained a total of 22.3%. This value represents the amount of wasted

light going up into the sky. Then after getting this value, I calculated the percentage of brightness increase in the city images with my CCD camera. My images showed about a 25.2% increase in the city sky brightness compared to the country. Finally, I noticed that the percentage of wasted light nearly equaled that of the percentage of brightness increase in the city images. The 2.9% discrepancy might be the wasted light caused by security, advertising and other lighting which I did not include in my study.

In this project I learned a lot more than the effects light pollution. Probably the most important thing I learned was that to be a good research scientist one must learn from one's mistakes. Indeed, I encountered many problems during my investigation, from not combining flat fields to not getting a good night's sleep before a major test on that same day! I would like to say thank you to all at I.A.P.P.P for selecting me as a special award winner at the International Science and Engineering Fair.

I would be pleased to hear from anyone who despises that awful thing called light pollution and who might be interested in conducting studies like this.

V. REFERENCES

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AN INTRODUCTION T
THE NASA ASTROPHYSICS DATA S

ADS User Support Group
Center for Astrophysics and Space A
Campus Box 389
University of Colorado
Boulder, Colorado 80309 US
Phone: (303) 492-0466; Internet: ads@cua

Received: 7 June 1993; Revised: 25 Septemb

I. BACKGROUND

The Astrophysics Data System is a research tool th to data and information convenient and easy for the science level of computer comfort. ADS allows users to make qu interesting catalogs located in various places in this countr These queries are made in a uniform way regardless of organized and independent of where they are actually loc only one method for accessing the information— the ADS t soon extend the ADS connections to data archives where to mission data files ranging from raw edited data stream products to final data sets. Astronomical images, spectra, the data files that are maintained in various mission archives

The ADS includes tools (functions) that allow users have been retrieved. In the case of information taken fr tabular format in which each row of data is a separate entry the columns contain the different bits of information (e.g. R A full set of database management functions is available within the ADS software environment.

These data are displayed in tabular form. They can formats including ASCII and FITS ASCII. These formats al be imported into astronomical data analysis systems such ADS also includes visualization tools that allow users to column versus another. The current release includes a serv a database of astronomy and astrophysics abstracts comp service. About 125,000 abstracts are available via this ser Additional graphical and image display functions are under in future ADS updates and releases.

II. GRAPHICAL USER INTERF

The Astrophysics Data System recently met a major Version 3.2. The Graphical User Interface (GUI) version run the ADS with just a few mouse clicks and requires virtu We have concentrated on providing a consistent and intuiti

[1] Adapted with permission from *NASA ADS Newsletter*, vol.1 no.1. The Harvard Smithsonian Astrophysical Observatory (SAO), the University of Space Astronomy (CASA) and the JPL Infrared Processing and Analysis Cer

ST-6

8.6mm X 6.5mm detector dimensions

15mm Fish-eye: $\frac{206265}{15} = 13751 \frac{arcsec}{mm}$

$8.6mm \times 13751 \frac{arcsec}{mm} = 118258.6 arcsec$

$6.5mm \times 13751 \frac{arcsec}{mm} = 89381.5 arcsec$

$118258.6 arcsec \times \frac{1 minutes}{60 sec} \times \frac{1^\circ}{60 min} = 32.8^\circ$

$89381.5 arcsec \times \frac{1'}{60 sec} \times \frac{1^\circ}{60'} = 24.8^\circ$

Field on chip: $32.8^\circ \times 24.8^\circ$

28mm wide angle: $\frac{206265}{28} = 7367 \frac{arcsec}{mm}$

$63356.2 arcsec \times \frac{1^\circ}{3600''} = 17.6^\circ$

$47885.5 arcsec \times \frac{1^\circ}{3600''} = 13.3^\circ$

Field on chip: $17.6^\circ \times 13.3^\circ$

500mm Maksutov: $\frac{206265}{500} = 412.53 \frac{''}{mm}$

$3547.5'' \times \frac{1^\circ}{3600''} = .99^\circ$

$2681.25'' \times \frac{1^\circ}{3600''} = .74^\circ$

Field on chip $.99^\circ \times .74^\circ$ or $59.4' \times 44.4'$

2000mm CAT: $\frac{206265}{2000} = 103.1 \frac{''}{mm}$

$886.7'' \times \frac{1'}{60''} = 14.8'$

$670.2'' \times \frac{1'}{60''} = 11.2'$

Field on chip: $14.8' \times 11.2'$

ST-6 w/100mm Lens

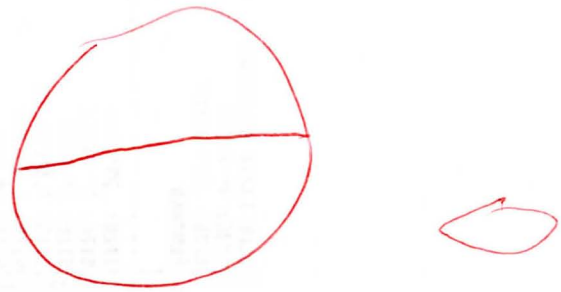
$$\frac{206265}{100} = 2062.65''/mm$$

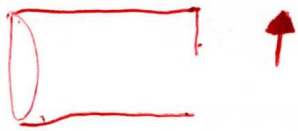
$$2062.65 \times 8.6 \times \frac{1}{60} = 295.6' \times \frac{1}{60} = 4.9^\circ$$

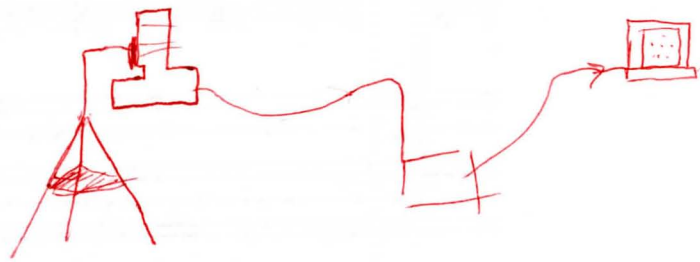
$$2062.65 \times 6.5 \times \frac{1}{60} = 223.4' \times \frac{1}{60} = 3.7^\circ$$

Field on Chip w/100mm Lens = $4.9^\circ \times 3.7^\circ$

- ST-6 - $3000
- 100mm Lens - 300
- V & B Filter - ? depends where we mt. it
- Adapter for Lens - $38







Very portable
Simple to use (Not necessary to acquire the same field)
Point at an altitude along a transect from Zenith to the South

We have

ST-6 w C5 + Focal Reducer

206265/787.5mm = 262 "/mm

$262 \times 8.6 \times \frac{1}{60} = 37.5'$

28.4'

David Crawford

How Faint you can see
Sky watch - looks at Pliedades

meapure sky directly
See how Faint you can see
Elaborate / Difficult to get Data

2nd wk of Nov. 9-10:30 Chamber of Commerces
Nov. 9

* Filters Visual Filter Blue Filter

50-100mm Eric Craine - 325-4505
Lenses

Not

Kitt Peak

OPTEC, Inc.

OPTICAL AND ELECTRONIC PRODUCTS

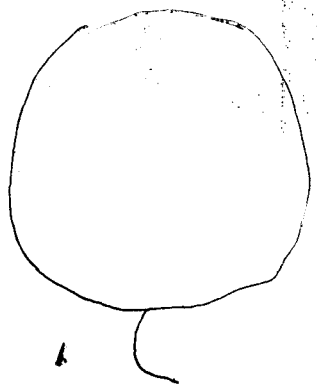
199 Smith Street
Lowell, MI 49331
U.S.A.
(616) 897-9351
(616) 897-8229 FAX

FAX MESSAGE

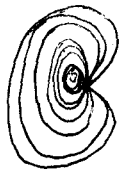
Number of Pages including this (2)

To: DENNIS CASPER

Fax No.: (602) 387-7661



602 622 8060



window 5.0 or greater







Rad
- Pixel Values

No Two dim info

Dave Crawford 11/29 1000



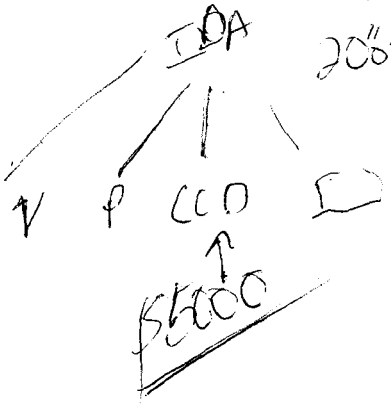
Not in



30" . 40" FOV

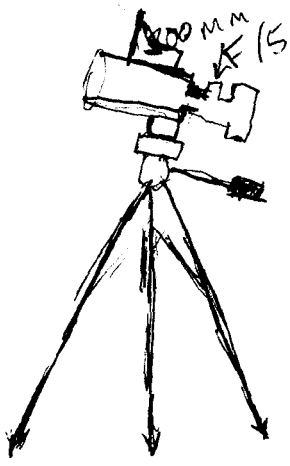
D.C. 11/29 1050

Not as sensitive
Simple to do reduct
.5x more sensitive
would do the job

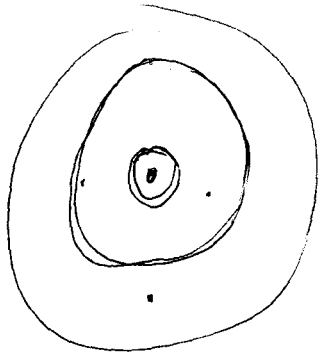




Accuracy
[warranty 1' of arc



4°



Optec V Filter Response

nm	U	B	V	R	I	DET. A/W
300	0.00	----	----	----	----	0.030
310	0.00	----	----	----	----	0.045
320	0.00	----	----	----	----	0.065
330	0.16	----	----	----	----	0.080
340	0.28	----	----	----	----	0.115
350	0.37	0.00	----	----	----	0.130
360	0.48	0.04	----	----	----	0.150
370	0.49	0.14	----	----	----	0.160
380	0.39	0.28	----	----	----	0.165
390	0.17	0.41	----	----	----	0.175
400	0.00	0.50	----	----	----	0.185
410	----	0.55	----	----	----	0.190
420	----	0.60	----	----	----	0.200
440	----	0.57	----	----	----	0.215
460	----	0.39	----	----	----	0.230
480	----	0.21	0.00	----	----	0.245
500	----	0.11	0.49	----	----	0.265
520	----	0.05	0.74	----	----	0.280
540	----	0.02	0.72	0.00	----	0.300
560	----	0.01	0.60	0.04	----	0.320
580	----	0.01	0.40	0.16	----	0.335
600	----	----	0.21	0.33	----	0.355
620	----	----	0.08	0.44	----	0.370
640	----	----	0.02	0.50	----	0.385
660	----	----	0.00	0.53	----	0.400
680	----	----	0.00	0.51	----	0.410
700	----	----	0.00	0.46	----	0.420
720	----	----	----	0.41	0.00	0.440
740	----	----	----	0.34	0.00	0.455
760	----	----	----	0.27	0.08	0.470
780	----	----	----	0.21	0.45	0.485
800	----	----	----	0.16	0.81	0.500
820	----	----	----	0.11	0.90	0.510
840	----	----	----	0.08	0.91	0.515
860	----	----	----	0.06	0.90	0.525
880	----	----	----	0.04	0.89	0.540
900	----	----	----	0.03	0.87	0.550
920	----	----	----	0.02	0.84	0.560
940	----	----	----	0.01	0.81	0.565
960	----	----	----	0.01	0.77	0.560
980	----	----	----	0.01	0.72	0.505
1000	----	----	----	0.01	0.66	0.430
1020	----	----	----	----	0.57	0.355
1040	----	----	----	----	0.49	0.270
1060	----	----	----	----	0.38	0.205
1080	----	----	----	----	0.28	0.140
1100	----	----	----	----	0.20	0.080
1120	----	----	----	----	0.14	0.040
1140	----	----	----	----	0.08	0.010

Table 6-4. Filter Transmission and Detector Responsivity in A/W.

perseptual

Mar1

Steve Howell 0930 11/22

Optec - Jerry was not in N.M 11/22 12:15

SSP-3 technical data They sent us a Manual of SSP-3

Price for whole system Scope Phot Filters

How do you aim the instrument

We need accuracy to .1 mag/(11)²

PFE Front



Bill Marline →

SSP-3?

Optec won't tell me what glass they use - They sell PFE Front End

Get back on Mon

Photons starting to become obso-

Older technology

More CCD

Pointing Problems

W/CCD can edit out stars

Base signal Level

$\frac{206\,265}{FL} = 1'/mm$ O.D.

Sorted by Item Name

$\frac{206265}{1000} = 206'/mm$

200

Jerry Persson 11/21
0900 Will call back in 2/hr.

Meade opens at 0930

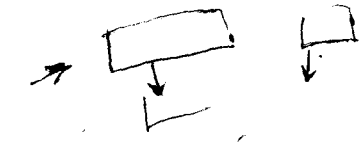
Superintendent Bryce Canyon 4-5 yrs ago
Air Water Quality
Sky & Tele.

Meade 1000
Left a message
Min Computer Requ -
Image Size

Bryce Canyon
NP
801 834 5322

Steve Howell (Meade Software is weak, but usable)
message received
11/21/94
Will be out of Office
but can be reach

test
test



Calc Error
Standard deviation
take root mean Square
SNR 100/1 → to 1%



Optec

Plate Scale - How to get an adequately small FOV

Dependent Focal Ratio

- System price
- SSP-3
- B-V Filters
- Telescope

- 895
- B- 80
V - 70
Position Filter 50
150 for 200mm F/5

26.95

w/ tripod Block

Each ☆ should be Sep. by at least 4hr Right ascension

~6☆

above 40° dec
10sec integration

2500 LX200 F/6.3

~1000 For photo

Jerry Pearman

Johnson UBV standard stars

2wks

200mm .28°
F/5

SA2000

extinction varies thru out night
Look at diff Standard stars w/ altitude

use A class stars

Pick sky Field w/o background ☆s

Astronomical Photometry

Tables of Extinction Stars

Between 1st & 3rd mag

Bryce Canyon ~1030 11/21

Nobody at R.M.

* Dan Foster ← Call back Tomorrow
801 834 5322

S.H. (will be back TOMORROW)

SSP-3 SNR 21.1 w/ ~~200~~ 191 mm 30 sec integ F/~~5~~ 4.3 43mm aperture V @ 10sec S/Noise 1 w/11 mag w/1" ap [SNR=1 w/ 7th mag w/1 10sec integ]

SSP-5 SNR w/ 200mm F/5 ◐ 100X more in B 20X more in V

↓ what accuracy in mag/(n)²

SSP-3 ——

SSP-5 —— .1 mag/(11)² guaranteed

◐ 4457

72°F 20e⁻/sec

Noise

1600

Tube 250

B/V Sider ~2000

40 40 tube

Power - Battery Charger 13.8V ~ 160 milli amp w 6' cable

10sec integration setting for ☆ 100 setting

Computer/Software -

Weight/Size - 1.5# more ↳ Bracket

Output - Digital readout

select ☆s w/ ~~4.5 mag~~ ↙ Saturate 0-2 mag

◐ Identical assembly

Instrument to stablize

1.0mm apt

Cold —
Dark —



Z

5%

.05 x 21.99 = 1.09
1.02

100 = 1

20

20 x

test

Steve Howell - ~1500 11/18

- Meade: Software performance
- Optec: ~1515

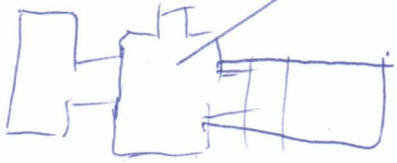


They are going to get back w/ him

Optec 11/18 8mm diag

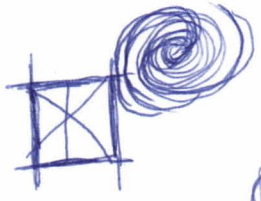
V Filter - 1/2" Filter $70
Matched to CCD Response
Better transformations

PFE - Front end

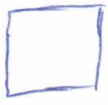


~$1000
SSP-3 photom

- F/5



* - Bryce Canyon 4yrs ago





~$2000
Single channel

Mag / π^2

SSP-3 ~100
SSP-5 ~2000

12V source

Raw Data →

Jerry Persson

Steve Howell 11/17/94 ~1540

Has not called Meade or Optec yet.

Will Call on 11/18

SSP-3 - ☐ Signal/Noise ratio ~ 20:1 ~ F/5

Accuracy -

How do you - Unit less # calibrate w/standard stars extinction of atmosphere
Flux

Mark Scruggs - SBI From San Raf

303-969-2077

1mm ~ 100/200mm F.L. Ha

Achromat Telescopes

Doctor Bill Malm

NPS Optics → he might have SSP-3

303-491-8292

- Telescopes → photometers
- Mag/$^{1/2}$ study at Bryce

- Whole System SSP-5

SSP-3 w/small Telescope ~ 100/200mm on Photo tripod

10sec integration

ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 2" RED
PAPER, LINEN BLUE STD W/W	1	3	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .25" BLACK
PAPER, LINEN MATTE BLACK	1	3	1 BOX			BLACK LINEN STATIONARY W/W
PLASTIC BINDINGS, 19R	1	3	100			SIZE: 1" RED
BATTERY, LARGE BLACK	2	1	1			DEAD
	2	1	1			GRAY ELEC. BOX W/LG PLUG, BLK AND RED ELECTRODES
BATTERIES, LARGE BLK AND GRAY	2	1	2			DEAD
	2	1	1			GREEN AND BLK CYLIN. DEVICE W/2 WIRES W/PLUGS
MANUAL, MODEL EA-136	2	1	6			OPERATORS MANUAL
WIRE, WHITE	2	1	1			

Publications ?

15m – 2000

Proven Methods? (Peer Reviewed)

CCD work
Analyze the data

Lens FL – image scale to Field of View

Sampling Methods

good data small view

pretty picture (May be difficult to measure brightness

CCD sensitivity ? dark current ? (thermal noise

cool enough -42°C and

Large chip or small chip?

ST-5 or ST-6 *Large

1500 / 3000

is a Telescope necessary?

Equatorial Drive ?

Is it necessary to acquire the same field year by year.

Zenith Meas. & transect protocol ?

Do you think this technology will work?
Will it be sensitive enough?
Will it be too complicated to implement?

SPECTRASOURCE INSTRUMENTS

CCD RTL DATA SHEET

CCD Imaging System Camera Control Library

The flexibility of the SpectraSource Imaging System allows for numerous applications, some of which may require capabilities not directly found in the standard camera application software that is included with the camera. To accomplish these tasks, SpectraSource Instruments has developed a standard procedural programming language camera control library. This library (generally referred to as a Run-Time Library, or RTL), allows for complete camera control from within a user-developed application. Designed to be linked into C and C++ application development projects, or projects that accept C/C++ standard libraries, this control library provides facilities to:

```
/********** EXAMPLE RTL APP **********/

#include <RTL.h>

int buffer[1024];           // line buffer

void main()
{
   CameraInitialize( 0x120 );
   CameraClearCCD();

   CameraOpenShutter();
   CameraExpose( 100,0,0 );
   CameraCloseShutter();

   CameraDigitizeArea( 0, 100,
                       0, 1,
                       0, 0, &buffer[0] );
}
```

- Initialize and configure the camera system
- Control all camera modes and options
- Set and read camera status
- Expose and acquire full and sub-frame images
- Perform on-chip binning and blooming control

Features:

- Borland C++ v3.1 library and Microsoft C v7.0 library formats supported at all memory models for both DOS and Windows (IBM host)
- Symantec THINK C library format supported (Macintosh Host)
- Optimized for each camera configuration
- Comprehensive error checking
- Very limited RTL overhead
- Small resultant application sizes
- Camera code portability between different host RTL's
- Complete, easy to use documentation

602 325 9346

D.C. ~0930 11/3/94

Meeting

TPCOLC 9:00-10:30

NP
- P.D. Steve → Lighting committee → Chamber of Commerce (By Ramada)
- E.C. → Lunch time discussion
- D.C.

Chris Lugmbuhl 1000 11/3/94

100 mm]
ST 6
B V
No drive

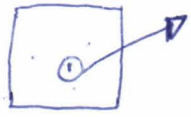


11 yrs cycle

*Pictures (Not calibrated)

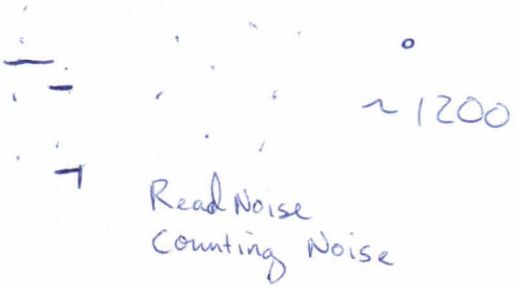


How it varies



50 mm
A few

Impact Visual → Not Photometric



~1200

Read Noise
Counting Noise

Calculate SNR For Camera
define protocal
Not guiding ? → Stars streaked too much
Not calibratable
The stars cover too much of the sky

BEAKER, 250 ML	WET LAB			1
BEE GLOVES	GARAGE			5 PAIR
BEE GLOVES	EQUIP. RM.	8	4	2
BEE HAT W/ VAIL	EQUIP. RM.	8	4	1
BEE SMOKER	EQUIP. RM.	7	2	1
BEE SMOKER	WET LAB	15	3	1
BEE SUIT	CONF. RM.			1
BELT POUCH, LEATHER	EQUIP. RM.	6	3	1
BELT, KLEIN TOOLS	EQUIP. RM.	2	3	1
BELT, SMALL W/ END CLIPS	EQUIP. RM.	4	2	1
BINDERS, 2PC. NARROW END	CONF. RM.	12	1	25
BINDERS, 3 RING	EQUIP. RM.	4	1	3
BINDERS, 3 RING	CONF. RM.	12	1	3
BINDERS, LOOSELEAF	CONF. RM.	12	4	1 BOX
BINDERS, THREE RING	SHED, R.C.	16	1	4
BINDER, 3 RING	CONF. RM.	12	4	5
BINDER, IBICO IBIMATIC	EQUIP. RM.	1	3	1
BINDER, LOOSELEAF	CONF. RM.	12	4	1
BINDER, POLLEN TRAP PROJECT	WET LAB	15	3	1
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	1	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	1	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	1	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	1	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	1	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	1	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	1	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	2	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	2	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	2	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	2	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	2	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	2	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	2	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	2	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	2	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	3	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	3	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	3	75
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	3	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	3	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	3	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	3	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	3	100
BINDINGS, 19R PLASTIC	EQUIP. RM.	1	3	75
BINDINGS, 19R PLASTIC	EQUIP. RM.	3	2	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	3	2	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	3	2	50
BINDINGS, 19R PLASTIC	EQUIP. RM.	3	2	50
BINOCULARS, BUSHNELL 7X26	EQUIP. RM.	4	2	1
BINOCULARS, NIKON 8X30E	EQUIP. RM.	4	3	1
BINOCULARS, NIKON 8X30E	EQUIP. RM.	4	3	1
BINOCULARS, NIKON 8X30E	EQUIP. RM.	4	3	1
BLINDS	SHED, R.C.			1
BOOK ENDS	CONF. RM.	13	5	12
BOOK POCKETS	CONF. RM.	13	2	2 STACKS
BORIC ACID	EQUIP. RM.	10	3	1 BOX

E. Cr. 10/25 1300

Too Wide – a lot of Variation across field

Long FL - Longer Integration site

Zenith - on camera tripod

100mm

(*No doubts about ST-6

Most difficult

-8.6mm x 6.5mm

16 bit

Cold camera - -42°C

dont worry

Sky transparency

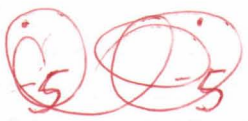
Strong seasonal variation

N-S BGround brightness

Cherry str. 2nd almost

Speedway 2 Cherry S. 2 blocks

950 S. Cherry



Calibration

Dark Frame - Produced by noise (part due to temp)

Correct for temp diff

- Set camera as cool as possible
- Close to dewpt. watch for frost on chip
- How to process images to get data out.

*Richard Berry - Cookbook CCD camera calibration images

- Camera power source, Laptop computer
- Public NIH IMAGE - Macintosh

IAPPP - Publish every 2 mo (Photometry) w/SBIG Camera

ATK with Pec Library in Tucson

ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 2" RED
PAPER, LINEN BLUE STD W/W	1	3	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .25" BLACK
PAPER, LINEN MATTE BLACK	1	3	1 BOX			BLACK LINEN STATIONARY W/W
PLASTIC BINDINGS, 19R	1	3	100			SIZE: 1" RED
BATTERY, LARGE BLACK	2	1	1			DEAD
	2	1	1			GRAY ELEC. BOX W/LG PLUG, BLK AND RED ELECTRODES
BATTERIES, LARGE BLK AND GRAY	2	1	2			DEAD

C.L. 602 779-5132

1330 -

10/19 @ Not in today → At Lowell Obs
For dedication of New interferometer
* Will be back tomorrow

SBIG

10/19 Has not sent the info
Will go out today in the mail
Info on ST-5 & ST-6 + Demo. Disk w/ image on it

C.L. 10/20/94 1610

→ :- Not in

D.D. 10/20/94 16:40
Message

C.L. 10/21/94
1120
602 526 8538

Home - 6.5mm 8.6mm

$250 brighter Stars

Not necessary

Standard stars

- ST-6
- 500mm F/5.6
- Stupid Guider
- Finder Scope 10-15X

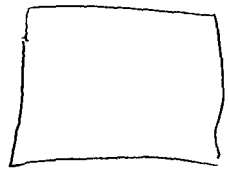






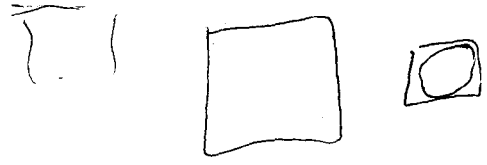
ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED

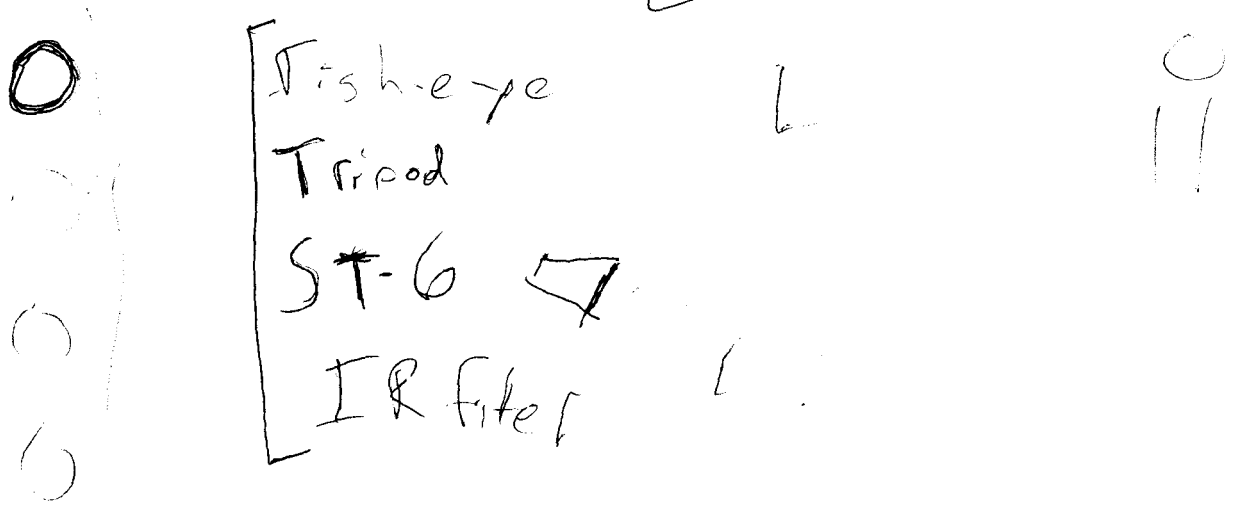
David Crawford



- Oct. 19 – He will be back

Not there





Chris Luginbuhl

Brightness at Zenith 1 m 800 x 800
Zenith & other Fields

Quantify ~~at~~ mag/per square arc sec

Photography (standard) wide angle
Along horizon

Fisheyelens - pretty picture (Qualitative)
Gate structure may interfere
Hard to calibrate
28-24 mm (Color) Film (Piers (Fixed))
IDA Visual Impact

ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 2" RED
PAPER, LINEN BLUE STD W/W	1	3	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .25" BLACK
PAPER, LINEN MATTE BLACK	1	3	1 BOX			BLACK LINEN STATIONARY W/W
PLASTIC BINDINGS, 19R	1	3	100			SIZE: 1" RED
BATTERY, LARGE BLACK	2	1	1			DEAD
	2	1	1			GRAY ELEC. BOX W/LG PLUG, BLK AND RED ELECTRODES
BATTERIES, LARGE BLK AND GRAY	2	1	2			DEAD
	2	1	1			GREEN AND BLK CYLIN. DEVICE W/2 WIRES W/PLUGS
MANUAL, MODEL EA-136	2	1	6			OPERATORS MANUAL
WIRE, WHITE	2	1	1			
WIRE, GRAY	2	1	1			

Spectra Source - Got info catalogue sent

Dave Crawford
10/19 - What he think
1000 Not in → Call back in 1 hr

1100
1105 - He will call me back
~1200 -

Dan Duriscoe
10/21/94 @ 1420

C5+ -

Tripod - $239.95

Astro
1249 $1529 w/Tripod

Nobody Home

PLASTIC BINDINGS, 19R	1	3	50		SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	3	100		SIZE: .25" BLACK
PAPER, LINEN MATTE BLACK	1	3	1 BOX		BLACK LINEN STATIONARY W/W
PLASTIC BINDINGS, 19R	1	3	100		SIZE: 1" RED
BATTERY, LARGE BLACK	2	1	1		DEAD
	2	1	1		GRAY ELEC. BOX W/LG PLUG, BLK AND RED ELECTRODES
BATTERIES, LARGE BLK AND GRAY	2	1	2		DEAD
	2	1	1		GREEN AND BLK CYLIN. DEVICE W/2 WIRES W/PLUGS
MANUAL, MODEL EA-136	2	1	6		OPERATORS MANUAL
WIRE, WHITE	2	1	1		
WIRE, GRAY	2	1	1		
	2	1	1	PY5426	GRAY AND BLK CORD W/PLUG AND SENSOR, 50'
PHOTOCOPY OF REL. HUM. TABL.	2	1	1		PAPER COPY OF HUM. TABLE
RELATIVE HUMIDITY TABLE	2	1	1		PLASTIC, 2 SIDED; PART OF BELT WEATH. KIT
FIELD ENCLOSURE, MODEL EA-120	2	1	6		OPERATORS MANUAL
ALUMINUM CONDUIT COVERING	2	1	1		SMALL LENGTH
MANUAL, DP217	2	1	3		OPERATORS MANUAL
MANUAL, DP 214	2	1	18		OPERATORS MANUAL
INSTRUCTIONS, PORTASOL	2	1	1		
MANUAL, 5RG40 TIPPING BUCKET	2	1	5		OPERATORS MANUAL
MANUAL, DP101	2	1	2		OPERATORS MANUAL
MANUAL, DP113	2	1	1		OPERATORS MANUAL
MANUAL, ES-060 SW THERMISTOR	2	1	1		OPERATORS MANUAL
MANUAL, DP230	2	1	9		OPERATORS MANUAL
MANUAL, DP220	2	1	7		OPERATORS MANUAL
MANUAL, DP211	2	1	2		OPERATORS MANUAL
MANUAL, TP10 THERMISTOR	2	1	8		OPERATORS MANUAL
PORTASOL, SOLDERING PEN	2	1	1		LARGE, BLACK, PEN-LIKE

Dan Duriscoe

Busy 10/19

1445

Dave Crawford

1600 10/19

(602) 327-9331

Tim Hunter

602 626 7402

D.C. Home

1610

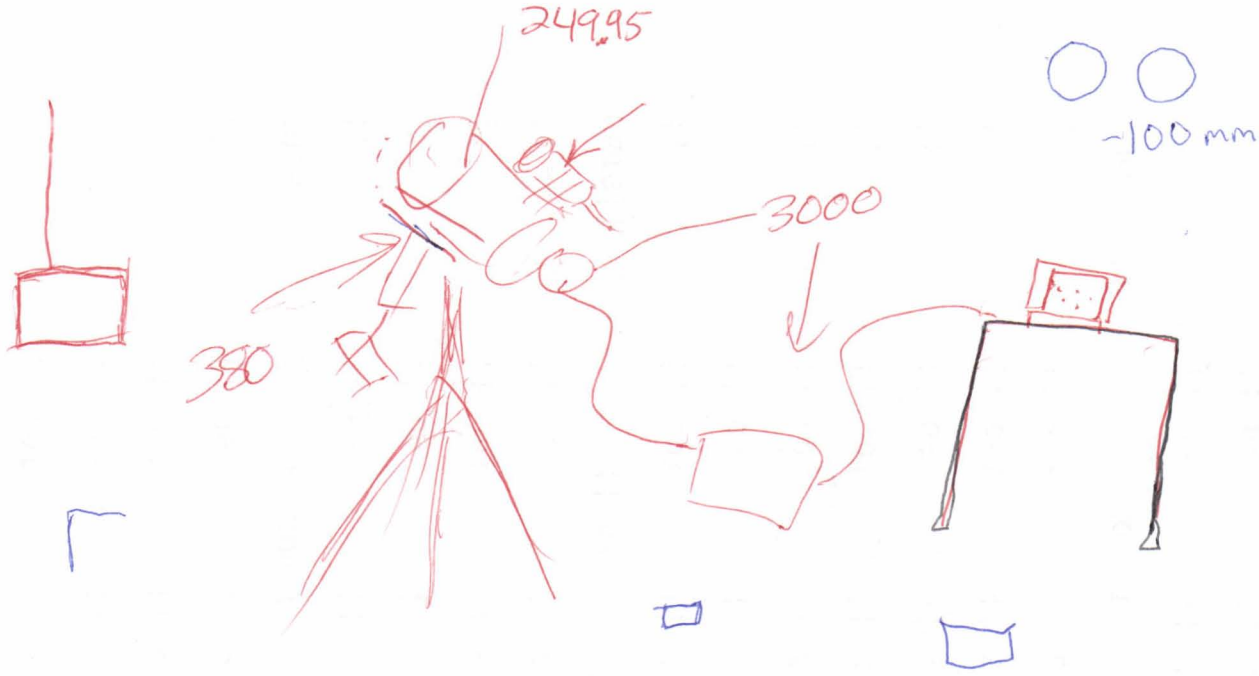
1548
133
1681
3000
4681

T. H.

Not here out rest of wk.

Back Mon.

ITEM NAME	CAB #	SHLF #	QUANTITY	#	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 2" RED
PAPER, LINEN BLUE STD W/W	1	3	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .25" BLACK
PAPER, LINEN MATTE BLACK	1	3	1 BOX			BLACK LINEN STATIONARY W/W
PLASTIC BINDINGS, 19R	1	3	100			SIZE: 1" RED
BATTERY, LARGE BLACK	2	1	1			DEAD
	2	1	1			GRAY ELEC. BOX W/LG PLUG, BLK AND RED ELECTRODES
BATTERIES, LARGE BLK AND GRAY	2	1	2			DEAD
	2	1	1			GREEN AND BLK CYLIN. DEVICE W/2 WIRES W/PLUGS
MANUAL, MODEL EA-136	2	1	6			OPERATORS MANUAL
WIRE, WHITE	2	1	1			
WIRE, GRAY	2	1	1			
	2	1	1	PY5426		GRAY AND BLK CORD W/PLUG AND SENSOR, 50'
PHOTOCOPY OF REL. HUM. TABL.	2	1	1			PAPER COPY OF HUM. TABLE
RELATIVE HUMIDITY TABLE	2	1	1			PLASTIC, 2 SIDED; PART OF BELT WEATH. KIT
FIELD ENCLOSURE, MODEL EA-120	2	1	6			OPERATORS MANUAL
ALUMINUM CONDUIT COVERING	2	1	1			SMALL LENGTH
MANUAL, DP217	2	1	3			OPERATORS MANUAL
MANUAL, DP 214	2	1	18			OPERATORS MANUAL
INSTRUCTIONS, PORTASOL	2	1	1			
MANUAL, 5RG40 TIPPING BUCKET	2	1	5			OPERATORS MANUAL
MANUAL, DP101	2	1	2			OPERATORS MANUAL
MANUAL, DP113	2	1	1			OPERATORS MANUAL



Possible List	Price
ST-6 CCD Camera	$300.00
Pro-Optic 500mm F/5.6 Lens	249.95
? Vista Instr. Sky track 3	380.00
- T-Tread Adapter	32.00
IR Filter	? 15.00
Finder/Guide Scope 6x30 - 8x50	? $40-80
	~ 3736.95

S-VHS Cam

Corrector Reducer 114.95

ST-6 3000

C5+ w/Tripod 1529 → gives 787.5mm FL

IR Filter 15.00

~~$ [illegible]~~

Will it swing thru w/ corrector + camera place?

$ 4658.95 (ego)

37.5 x 28.4 / 86 * LINE

261.9 "/mm 60'

2252.5"

To Access messages

PLASTIC BINDINGS, 19R || 1 || 2 || 50 ||
||SIZE: 2" BLUE
PLASTIC BINDINGS, 19R || 1 || 2 || 50 ||
||SIZE: .25" BLUE
PAPER, LINEN EGG SHELL || 1 || 2 || 1 BOX ||
WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R || 1 || 2 || 100 ||
||SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R || 1 || 2 || 100 ||
||SIZE: 1" BLUE
PLASTIC BINDINGS, 19R || 1 || 2 || 50 ||
||SIZE: 1" WHITE
PLASTIC BINDINGS, 19R || 1 || 2 || 100 ||
||SIZE: .75" WHITE
PLASTIC BINDINGS, 19R || 1 || 2 || 100 ||
||SIZE: .75" RED
PLASTIC BINDINGS, 19R || 1 || 2 || 50 ||
||SIZE: 1" BLACK
PLASTIC BINDINGS, 19R || 1 || 3 || 100 ||
||SIZE: .5" BLUE
PLASTIC BINDINGS, 19R || 1 || 3 || 75 ||
||SIZE: .75" BLACK
PLASTIC BINDINGS, 19R || 1 || 3 || 75 ||
||SIZE: .5" BLACK
PLASTIC BINDINGS, 19R || 1 || 3 || 100 ||
||SIZE: .5" RED
PLASTIC BINDINGS, 19R || 1 || 3 || 50 ||
||SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R || 1 || 3 || 50 ||
||SIZE: 2" RED
PAPER, LINEN BLUE STD W/W || 1 || 3 || 1 BOX ||
LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R || 1 || 3 || 50 ||
||SIZE: 1" WHITE
PLASTIC BINDINGS, 19R || 1 || 3 || 100 ||
||SIZE: .25" BLACK
PAPER, LINEN MATTE BLACK || 1 || 3 || 1 BOX ||
||BLACK LINEN STATIONARY W/W
PLASTIC BINDINGS, 19R || 1 || 3 || 100 ||

Dave Harvey

~~10/14~~

~~1540~~ -

Rich Cromwell (did site testing at Mt. Graham)

602-621-3976

602-621-5338

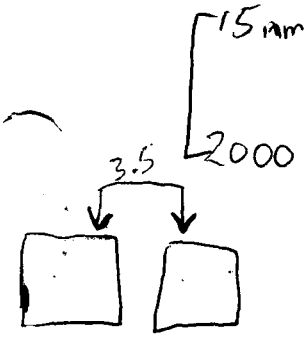
[• • •]

(R.C.

10/14

1550-

- Low Noise-
- Filtered to responds) Like human eye
  [IR Filter
- Measuring S.B. of sky Varies



S. FL - large area shows how it varies

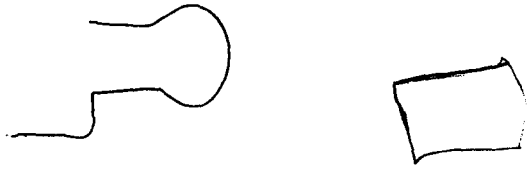
L. FL - Point in diff dir

Brighter image w/ ~~2~~ Fast lens - less crucial noise requ

$3000

Chairman of IDA

D. Crawford



ITEM NAME	CAB	SHLF	QUANTITY	ID #	C?	REMARKS
	2	1	1			GREEN AND BLK CYLIN. DEVICE W/2 WIRES W/PLUGS
MANUAL, MODEL EA-136	2	1	6			OPERATORS MANUAL
WIRE, WHITE	2	1	1			
WIRE, GRAY	2	1	1			
	2	1	1	PY5426		GRAY AND BLK CORD W/PLUG AND SENSOR, 50'
PHOTOCOPY OF REL. HUM. TABL.	2	1	1			PAPER COPY OF HUM. TABLE
RELATIVE HUMIDITY TABLE	2	1	1			PLASTIC, 2 SIDED; PART OF BELT WEATH. KIT
FIELD ENCLOSURE, MODEL EA-120	2	1	6			OPERATORS MANUAL
ALUMINUM CONDUIT COVERING	2	1	1			SMALL LENGTH
MANUAL, DP217	2	1	3			OPERATORS MANUAL
MANUAL, DP 214	2	1	18			OPERATORS MANUAL
INSTRUCTIONS, PORTASOL	2	1	1			
MANUAL, 5RG40 TIPPING BUCKET	2	1	5			OPERATORS MANUAL
MANUAL, DP101	2	1	2			OPERATORS MANUAL
MANUAL, DP113	2	1	1			OPERATORS MANUAL
MANUAL, ES-060 SW THERMISTOR	2	1	1			OPERATORS MANUAL
MANUAL, DP230	2	1	9			OPERATORS MANUAL
MANUAL, DP220	2	1	7			OPERATORS MANUAL
MANUAL, DP211	2	1	2			OPERATORS MANUAL
MANUAL, TP10 THERMISTOR	2	1	8			OPERATORS MANUAL
PORTASOL, SOLDERING PEN	2	1	1			LARGE, BLACK, PEN-LIKE

	#	#				
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 2" RED
PAPER, LINEN BLUE STD W/W	1	3	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS



OPCNM

A

10/13 Brian Skiff



774 3358 call back Later
He works part time



10/13 Dave Harvey
Not in ~1030
1530 → Not in

~1530

Not cool enough
Noise
- Cooler time of year
- Calibrate on stars
Standard
- Roy Garstangs
model
Kitt Peak

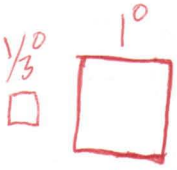
Reg Fisheye lens
15mm lens

Fisheye Lens
2000mm

going to be hard



Photomultiplier Tube Not readily available



Short F.L. - standard Stars + Large dark Image scale 206265/FL mm give arcsec/mm

Chris Lugtenburh
Naval Obs.
779 5132

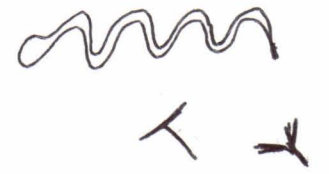
Flat Fields
bias Field

Chip 10mm

¦¦SIZE: 1" RED							
	BATTERY, LARGE BLACK	¦¦ 2 ¦¦	1 ¦¦	1 ¦¦		¦¦	¦¦DEAD
		¦¦ 2 ¦¦	1 ¦¦	1 ¦¦		¦¦	¦¦GRAY
ELEC. BOX W/LG PLUG, BLK AND RED ELECTRODES							
	BATTERIES, LARGE BLK AND GRAY	¦¦ 2 ¦¦	1 ¦¦	2 ¦¦		¦¦	¦¦DEAD
		¦¦ 2 ¦¦	1 ¦¦		1 ¦¦		¦¦
¦¦GREEN AND BLK CYLIN. DEVICE W/2 WIRES W/PLUGS							
	MANUAL, MODEL EA-136	¦¦ 2 ¦¦	1 ¦¦		6 ¦¦		¦¦
¦¦OPERATORS MANUAL							
	WIRE, WHITE	¦¦ 2 ¦¦	1 ¦¦	1 ¦¦		¦¦	¦¦
	WIRE, GRAY	¦¦ 2 ¦¦	1 ¦¦	1 ¦¦		¦¦	¦¦
		¦¦ 2 ¦¦	1 ¦¦	1 ¦¦	PY5426	¦¦	¦¦GRAY
AND BLK CORD W/PLUG AND SENSOR, 50'							
	PHOTOCOPY OF REL. HUM. TABL.	¦¦ 2 ¦¦	1 ¦¦		1 ¦¦		¦¦
¦¦PAPER COPY OF HUM. TABLE							

	RELATIVE HUMIDITY TABLE	¦¦ 2 ¦¦	1 ¦¦		1 ¦¦		¦¦
¦¦PLASTIC, 2 SIDED; PART OF BELT WEATH. KIT							
	FIELD ENCLOSURE, MODEL EA-120	¦¦ 2 ¦¦	1 ¦¦		6 ¦¦		¦¦
¦¦OPERATORS MANUAL							

C.L.



10/13
1610 - Not in (Left message)



10/13
SBIG Called back ~ 1630

Friends of Pine Mt. Obs is the probable Candidate for the N-S B. study in Oregon. SBIG is not sure who did it. They left a message at Pine Mt. Obs. I will inquire if they are the ones who did the study. They will get back with us soon.

10/13 Larry Pratt Office phone
1650 503-593-4442
Not in - will be back tomorrow at 1000

Consistency

Jan

10/14 Recording at 4442 #
1030 - Speech in Bend (Will be back around 1:00pm Will call me back
CATHY - Passed legislation in Deshutes Co. Oregon. due to N-S B measurements.

Comparison photos
ORION/60m
-Close Zenith
30° & 20° above horiz
5 - 1 min exp.
set background at zero
Calibrate to know stars - det limiting mag. town & rural area
8" Meade LX100

ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 2" RED
PAPER, LINEN BLUE STD W/W	1	3	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .25" BLACK

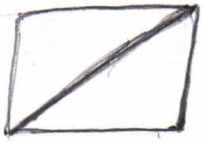
ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1.5" WHITE

Kitt Peak

602
Dan Brose 791-4259
Dick Guthry → 791 2518
3191

Stars drop. 8-9 FOV Rich Hi
Electrim Lunar Plan LAB AAVSO
Comparison Image
New Moon Exact FOV & Focus
Clear
-smoke
dark frame
raw to raw

Planetary Sciences Institute
I.D.A. Don Davis 602-622-6300

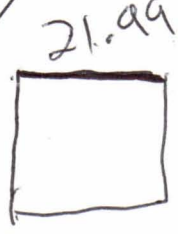


*Steve Howell - Board of Advisers CCD Astron. mag
Get Back to us next wk

10/11 D.D. →

Tumoc Hill Tucson
Test Camera
Steve Larsson → Diego Garcia

Fax - 622 8060
Camera Spec.





(((

ALUMINUM CONDUIT COVERING ¦¦ 2 ¦¦ 1 ¦¦ 1 ¦¦ ¦¦
¦¦SMALL LENGTH
MANUAL, DP217 ¦¦ 2 ¦¦ 1 ¦¦ 3 ¦¦ ¦¦
¦¦OPERATORS MANUAL
MANUAL, DP 214 ¦¦ 2 ¦¦ 1 ¦¦ 18 ¦¦ ¦¦
¦¦OPERATORS MANUAL
INSTRUCTIONS, PORTASOL ¦¦ 2 ¦¦ 1 ¦¦ 1 ¦¦ ¦¦ ¦¦
MANUAL, 5RG40 TIPPING BUCKET ¦¦ 2 ¦¦ 1 ¦¦ 5 ¦¦ ¦¦
¦¦OPERATORS MANUAL
MANUAL, DP101 ¦¦ 2 ¦¦ 1 ¦¦ 2 ¦¦ ¦¦
¦¦OPERATORS MANUAL
MANUAL, DP113 ¦¦ 2 ¦¦ 1 ¦¦ 1 ¦¦ ¦¦
¦¦OPERATORS MANUAL
MANUAL, ES-060 SW THERMISTOR ¦¦ 2 ¦¦ 1 ¦¦ 1 ¦¦ ¦¦
¦¦OPERATORS MANUAL
MANUAL, DP230 ¦¦ 2 ¦¦ 1 ¦¦ 9 ¦¦ ¦¦
¦¦OPERATORS MANUAL
MANUAL, DP220 ¦¦ 2 ¦¦ 1 ¦¦ 7 ¦¦ ¦¦
¦¦OPERATORS MANUAL
MANUAL, DP211 ¦¦ 2 ¦¦ 1 ¦¦ 2 ¦¦ ¦¦
¦¦OPERATORS MANUAL
MANUAL, TP10 THERMISTOR ¦¦ 2 ¦¦ 1 ¦¦ 8 ¦¦ ¦¦
¦¦OPERATORS MANUAL
PORTASOL, SOLDERING PEN ¦¦ 2 ¦¦ 1 ¦¦ 1 ¦¦ ¦¦
¦¦LARGE, BLACK, PEN-LIKE
BUNGEE CORD ¦¦ 2 ¦¦ 1 ¦¦ 1 ¦¦ ¦¦ ¦¦
BUTANE FUEL ¦¦ 2 ¦¦ 1 ¦¦ 1 ¦¦ ¦¦
¦¦SMALL ARESOL CAN, NOT FULL
ANEMOMETER CUP ¦¦ 2 ¦¦ 1 ¦¦ 1 ¦¦ ¦¦ ¦¦RED,

Tom —

598.1

598.1f An

598.1f Sidney

DENNIS 10-24

DAVE CRAWFORD WILL BE IN HIS OFFICE TUESDAY (10-25) from 0930 - 1200. (325-9346)

Don Davis, Tucson
622-6300

D.C.

JN

assistance with the reveg program. Most notably was the borrowing of Art's truck several times to haul the water trailer while the RM 4x4 was down.

4. Reviewed:

- WRO Revegetation guidelines.

- Interp. Exhibit Plan (FY93 & FY94).

5. Drafted much correspondence.

6. - Draft GPS Work Plan.

Also identified equipment needs, conducted product research and prepared product requisitions using PPFS software.

A.6. Assist with all Aspects of the Natural and Cultural Resources Management Plan Revision

1. I did no additional writing during this period.

2. I did not assist in coordination of planning meetings during this appraisal period.

3. Reviewed draft project statements and narratives and provided comments.

B.1. Responsible for complying with Occupational Health and Safety

1. I adequately performed this in accordance with the four specified performance standards.

B.2. Performs other duties to meet the goals and objectives of the park

- Conducted weekly museum inspections during GIS position vacancy.

- Organized and managed all in-coming library materials to be accessioned when the new GIS position is filled.

- Served as Acting Chief of Resources Management on a regular basis.

- GIS - See other sections above.

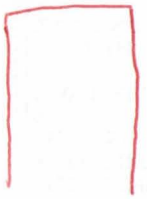
B.3. Supports monument's E.E.O.

- I carried this out.

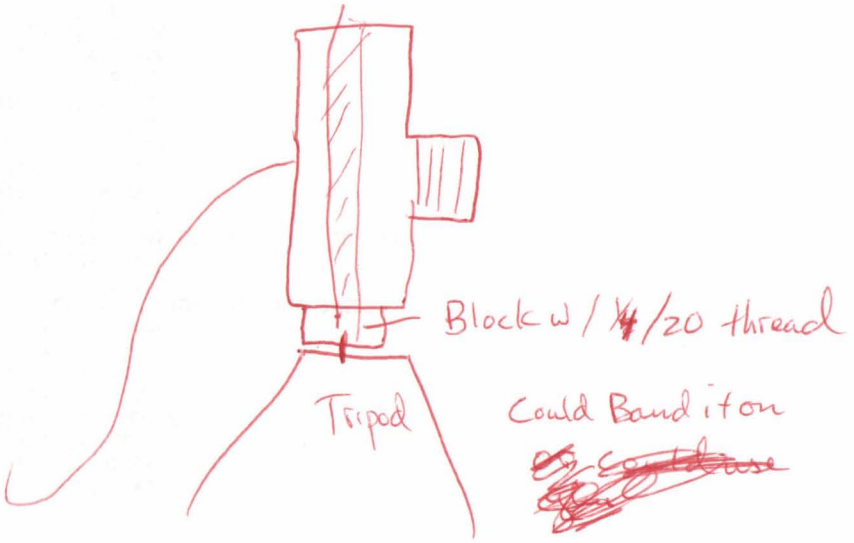
28 mm wide angle Lens

17.6° x 13.3° FOV
Easy Field aquisition
Large Picture of sky
Have the lens already
Very portable

No sophisicated Mounting needed



* Might not be enough image scale to have good messurable data.



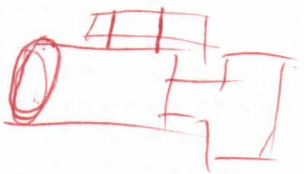
ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
MANUAL, DP 214	2	1	18			OPERATORS MANUAL
INSTRUCTIONS, PORTASOL	2	1	1			
MANUAL, 5RG40 TIPPING BUCKET	2	1	5			OPERATORS MANUAL
MANUAL, DP101	2	1	2			OPERATORS MANUAL
MANUAL, DP113	2	1	1			OPERATORS MANUAL
MANUAL, ES-060 SW THERMISTOR	2	1	1			OPERATORS MANUAL
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
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PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
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PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 2" RED
PAPER, LINEN BLUE STD W/W	1	3	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	3	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .25" BLACK
PAPER, LINEN MATTE BLACK	1	3	1 BOX			BLACK LINEN STATIONARY W/W
PLASTIC BINDINGS, 19R	1	3	100			SIZE: 1" RED
BATTERY, LARGE BLACK	2	1	1			DEAD
	2	1	1			GRAY ELEC. BOX W/LG PLUG, BLK AND RED ELECTRODES
BATTERIES, LARGE BLK AND GRAY	2	1	2			DEAD
	2	1	1			GREEN AND BLK CYLIN. DEVICE W/2 WIRES W/PLUGS
MANUAL, MODEL EA-136	2	1	6			OPERATORS MANUAL
WIRE, WHITE	2	1	1			
WIRE, GRAY	2	1	1			
	2	1	1	PY5426		GRAY AND BLK CORD W/PLUG AND SENSOR, 50'
PHOTOCOPY OF REL. HUM. TABL.	2	1	1			PAPER COPY OF HUM. TABLE
RELATIVE HUMIDITY TABLE	2	1	1			PLASTIC, 2 SIDED; PART OF BELT WEATH. KIT
FIELD ENCLOSURE, MODEL EA-120	2	1	6			OPERATORS MANUAL

Camera trackers

Sky track 1 AC - Other DC
gel cell battery 12-6 Amp

2 Solar/Sideral

3 sideral



$380

get info

<5 min tracking

N.M. OP . . . N.M.

1 Cactus
Cactus

ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED

ITEM NAME	CAB #	SHLF #	QUANTITY	ID #	C?	REMARKS
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: .25" BLUE
PAPER, LINEN EGG SHELL	1	2	1 BOX			OFF WHITE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1.5" BLUE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: 1" BLUE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" WHITE
PLASTIC BINDINGS, 19R	1	2	100			SIZE: .75" RED
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" BLUE
PLASTIC BINDINGS, 19R	1	3	75			SIZE .75" BLACK
PLASTIC BINDINGS, 19R	1	3	75			SIZE: .5" BLACK
PLASTIC BINDINGS, 19R	1	3	100			SIZE: .5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" RED
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1" BLACK
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" BLUE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" WHITE
PLASTIC BINDINGS, 19R	1	1	50			SIZE: 1.5" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: 2" RED
PLASTIC BINDINGS, 19R	1	1	100			SIZE: .25" WHITE
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 1.5" BLACK
PAPER, LINEN BLUE STANDARD	1	2	1 BOX			BLUE LINEN STATIONARY, ~500 SHEETS
PLASTIC BINDINGS, 19R	1	2	50			SIZE: 2" BLUE