The ASTRA Spectrophotometer: Now Starting its Planned Operations

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and

the rest of the ASTRA Team

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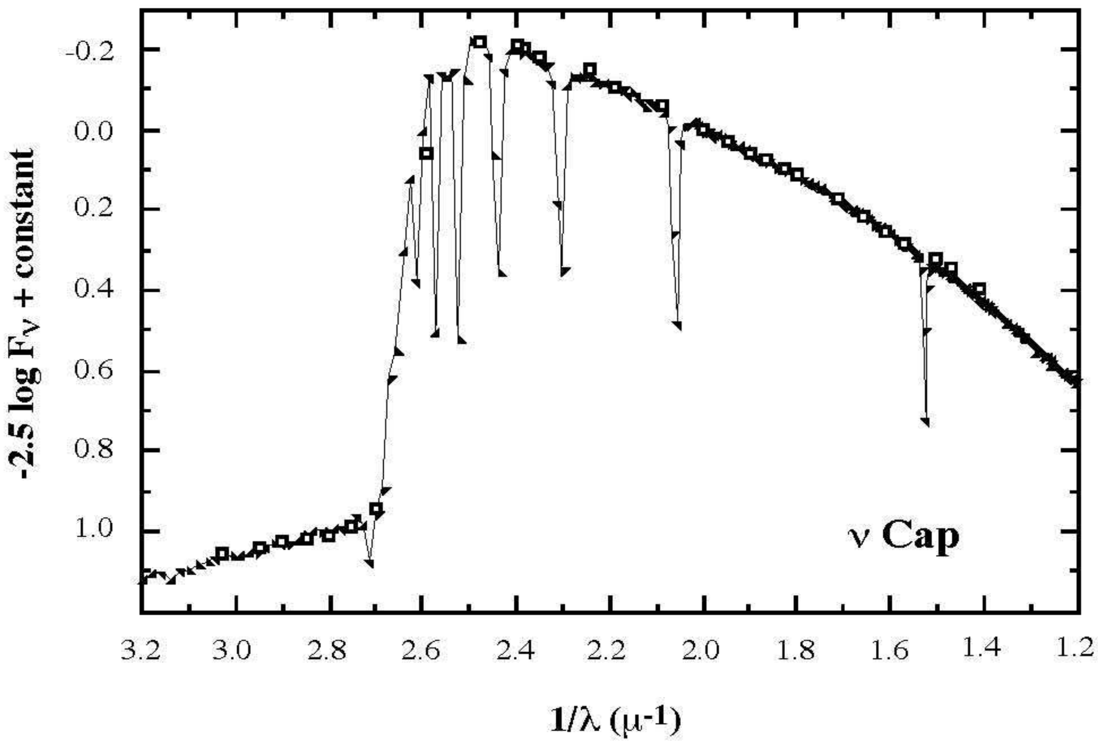
Historic Overview

The measurement of stellar fluxes by rotating grating scanners and other such devices was routinely done in the 1960's through the late1980's when these devices were retired. The data were used to determine the effective temperatures of hot stars and the gravities of cooler stars. Studies of stellar variability and of stellar physics were performed.

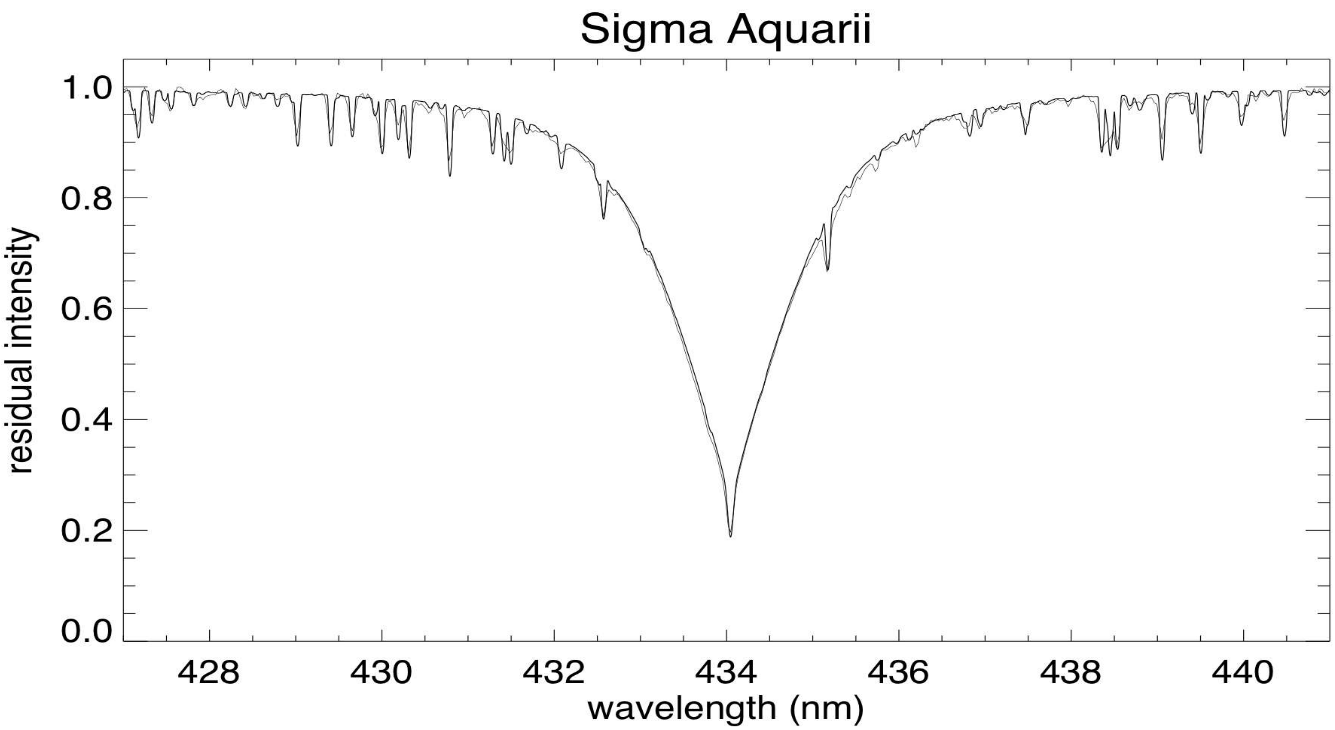
Problems with rotating scanners include:

- The absolute calibration of Vega which has errors at best of 1%, but often more.
- The ability to measure fluxes one 25-50 Å region at a time. The use of CCDs as detectors means one can measure many wavelength regions simultaneously.

**Decided to solve the relative calibration task and let others do the absolute calibration. But if needed we will do this.



-2.5 log Fν + constant
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1/λ (μ-1)
ν Cap



Sigma Aquarii
residual intensity
1.0
0.8
0.6
0.4
0.2
0.0
428
430
432
434
436
438
440
wavelength (nm)

The ASTRA Cassegrain Spectrophotometer is now working in a manual mode on the 0.40-m telescope of the Dominion Astrophysical Observatory, Victoria, BC, Canada.

Its automated 0.5-m f/16 telescope is almost completed at The Fairborn Observatory, Washington Camp, AZ, two hour's drive from Nogales, AZ, at an altitude of 5280 feet (1600-m) east of Nogales 3-4 km North of the US-Mexico border. We expect 120 to 150 photometric nights per year from experience with the Four College APT at this location.

It is the first spectrophotometer, built in 40 years, designed to measure in detail the optical energy distributions of stars with high precision.

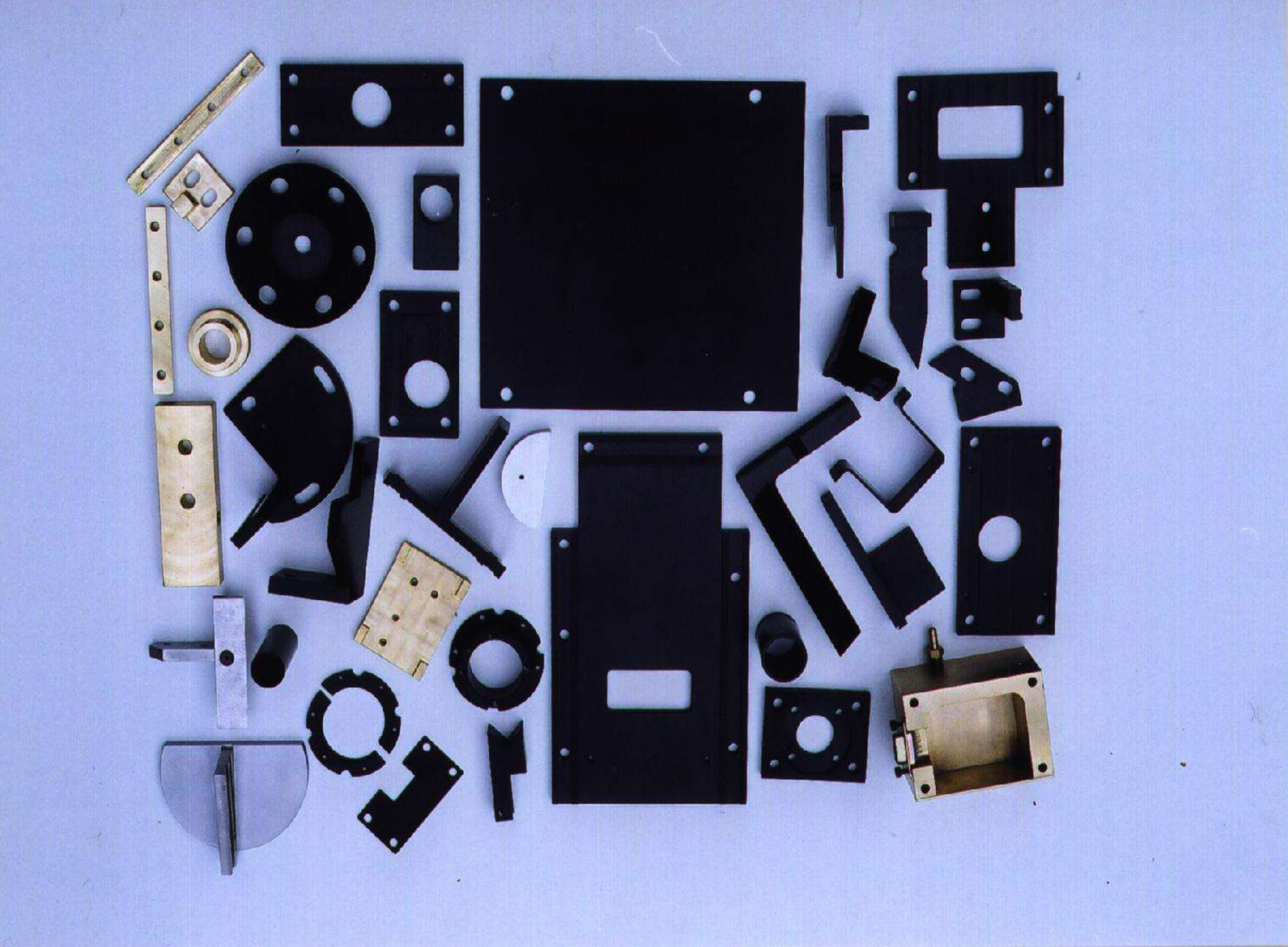
It is the first to use a back-illuminated uv-coated CCD as its detector.

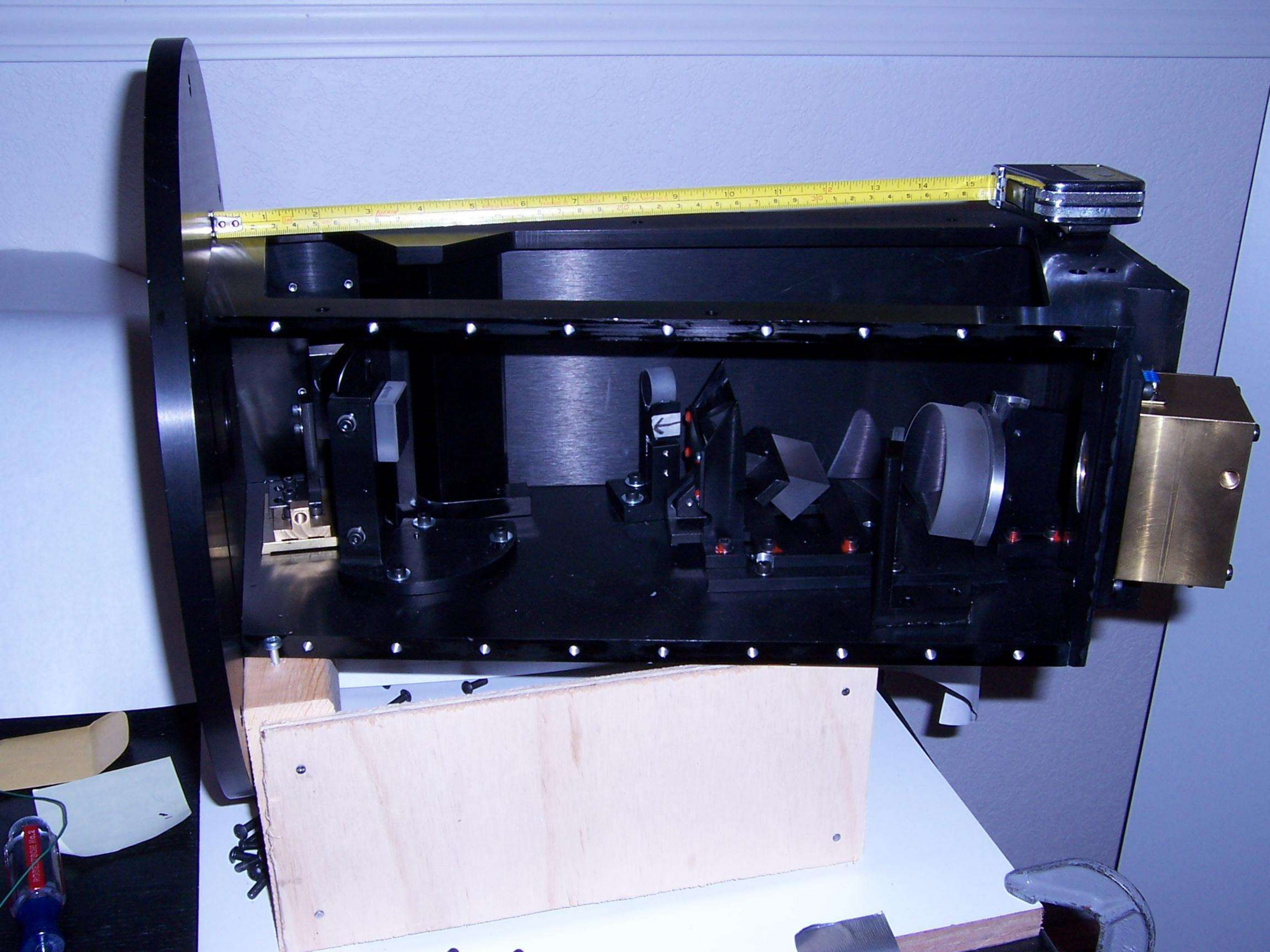
Automation helps achieve the uniform collection of data and minimizes the slew time without the need and the cost of a human observer.

Goal: S/N > 200 data and observe V= 9.5 mag A0 V stars in an hour.

Use 10 min/hour to observe secondary standards whose data will be used to calibrate the nightly extinctions.

The science E2V 30-11 CCD Alta system (Apogee Instruments) is liquid cooled to about -60°C for science observations. It has 1024 x 256 square 26-micron pixels.





Design Criteria

1. We designed our instrument for an average seeing of 1.5 to 2.0 sec of arc, appropriate to the Fairborn Observatory.
2. The spectroscope's zeroth order light guides the telescope during an exposure.
3. The science CCD has a high quantum efficiency for $\lambda\lambda$3200-9500 especially shortward of the Balmer Jump.

4. The spectrograph has good sensitivity for λλ3300-9000 with short- and long-wavelength extensions desirable. The grating used has 300 gr mm^{-1} and a 8600 Å blaze.

5. It obtains the entire desired spectral range(minimally λλ3300-9000) with one exposure by using a cross-dispersion prism.

6. To reduce light loss and scattering we minimized the number of optical surfaces.

7. To properly remove cosmic ray signatures we widen the spectrum to at least 5 pixels by rocking the telescope in Right Ascension.

8. The 2-pixel resolution is better than 15 Å. Achieved 14 Å in first order and 7 Å in second order.

9. We mount the optical components so that they will not drift out of alignment. We used solid mounts with tabs.

10. We control the spectrophotometer's temperature for stability.

11. We use a square projected aperture for accurate sky subtraction.

12. Our spectrophotometer is compact to reduce moments on the telescope.

13. We minimized cost by using simple optical and mechanical designs.

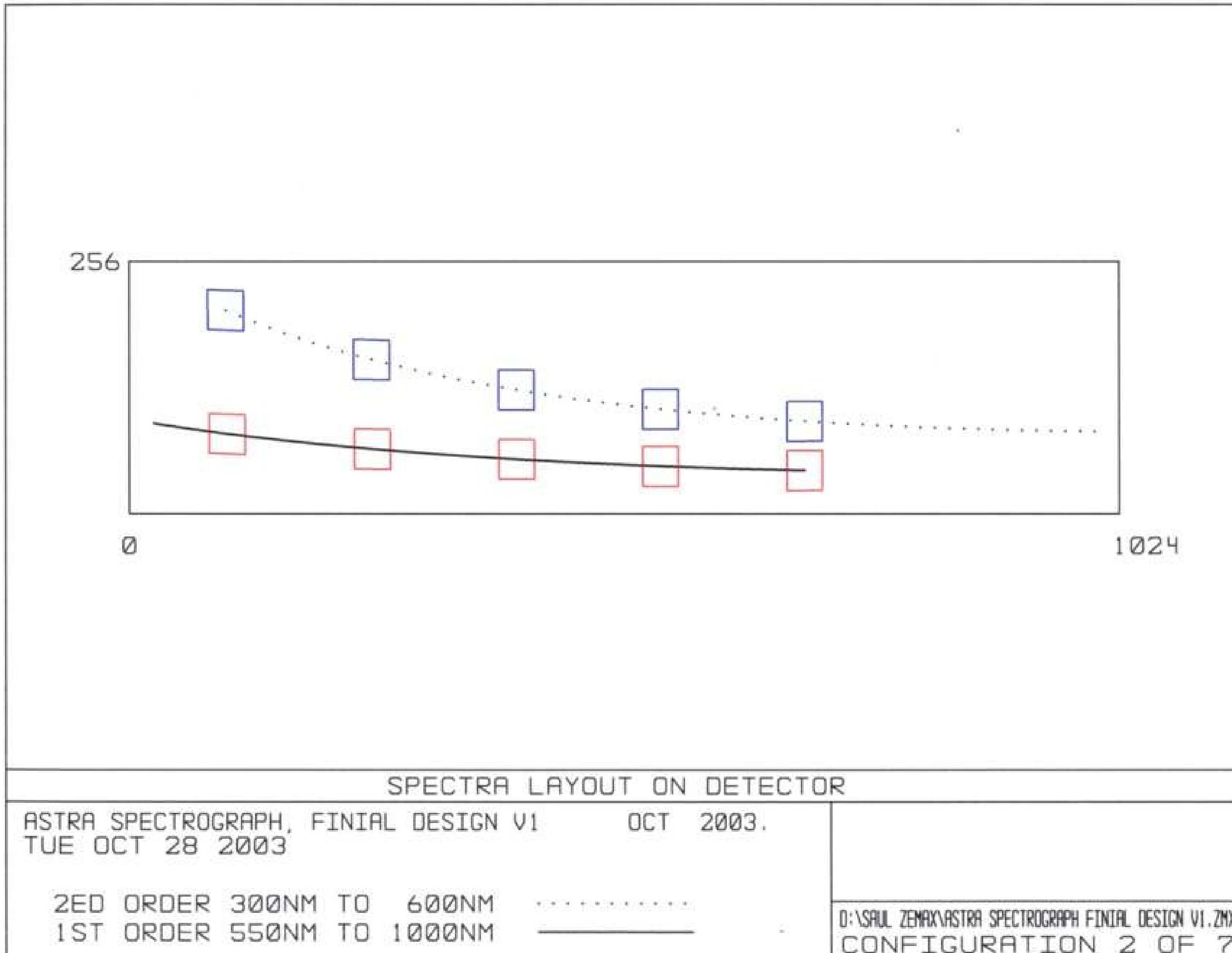
The case (approx. 38 cm x 28 cm x 14 cm) is a box, rectangular in cross-section covered by foam insultation and a steel box. The optical plate, made from 1.25 cm aluminum stock attaches to the telescope mounting collar.

The expected CCD read noise is about 8 electrons/pixel.

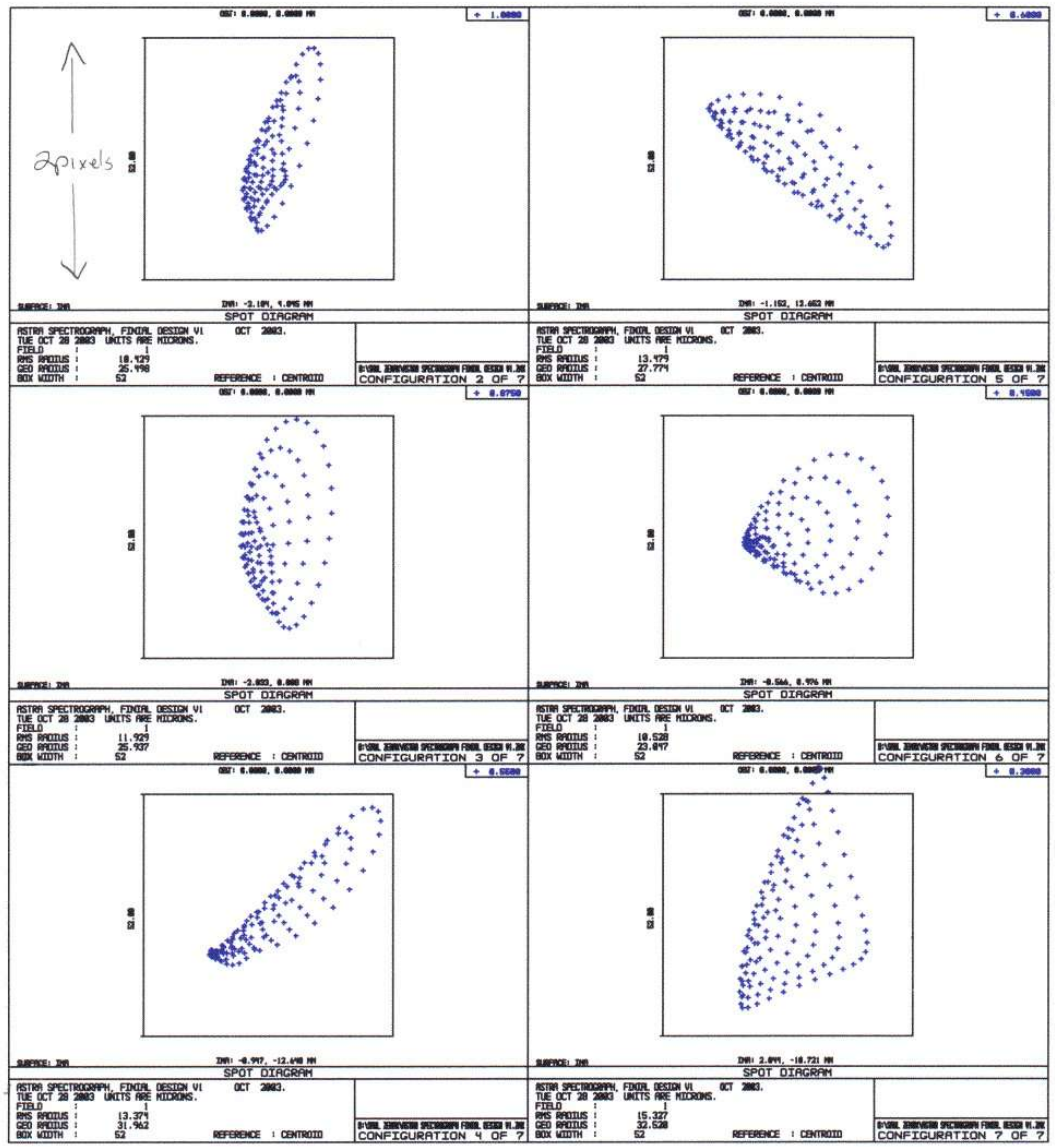
The instrument has very little scattered light. The mechanical parts and the insides of the case are anodized.

The separation of the two orders is sufficient that during the rocking of the telescope, the sky measurements of each order will not overlap.

We will call for collaborative proposals once we know when automated scientific observations will begin.


256
0
1024
SPECTRA LAYOUT ON DETECTOR
ASTRA SPECTROGRAPH, FINIAL DESIGN V1 OCT 2003.
TUE OCT 28 2003
2ED ORDER 300NM TO 600NM
1ST ORDER 550NM TO 1000NM
D:\SAUL ZEMAX\ASTRA SPECTROGRAPH FINIAL DESIGN V1.ZMX
CONFIGURATION 2 OF 7

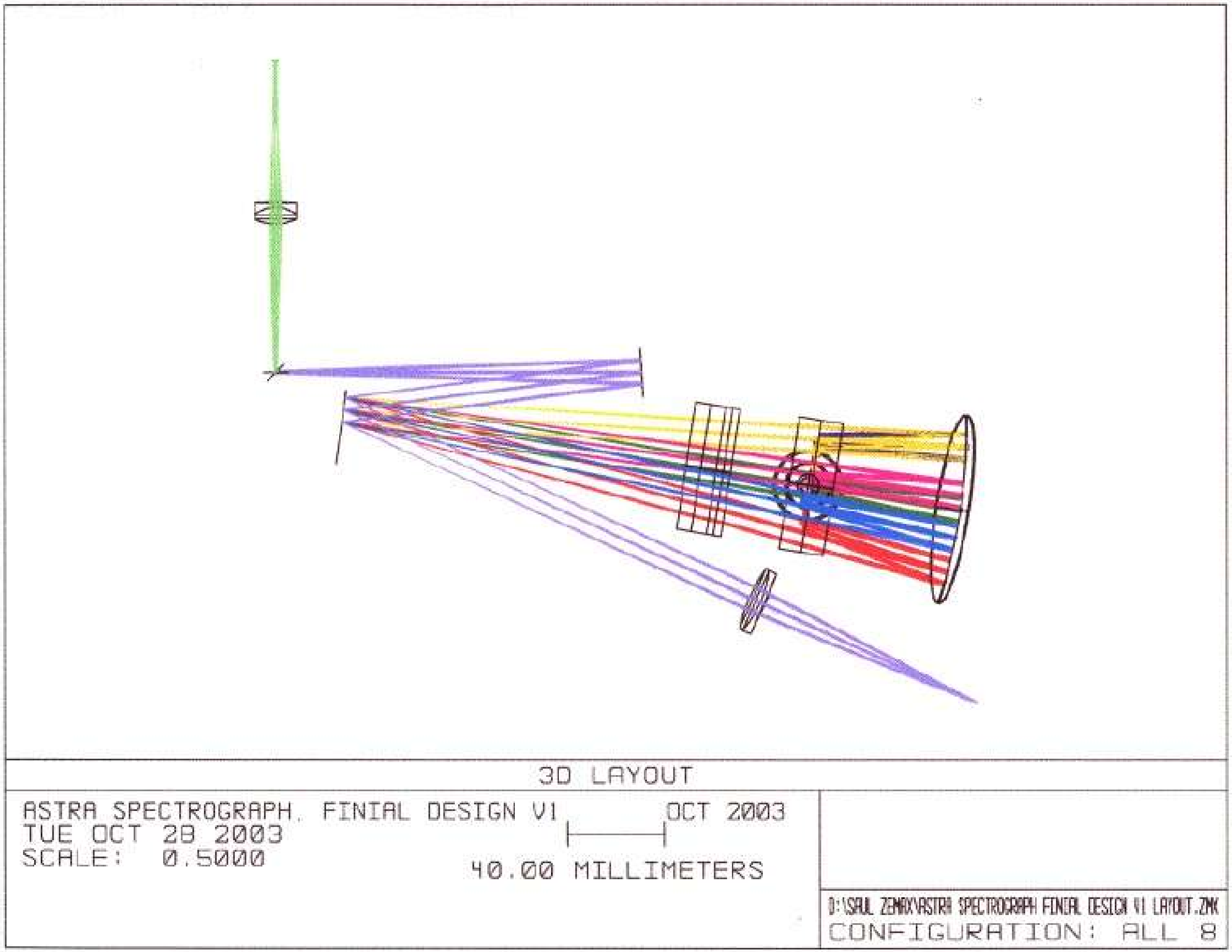
(pixel size = 26μ)

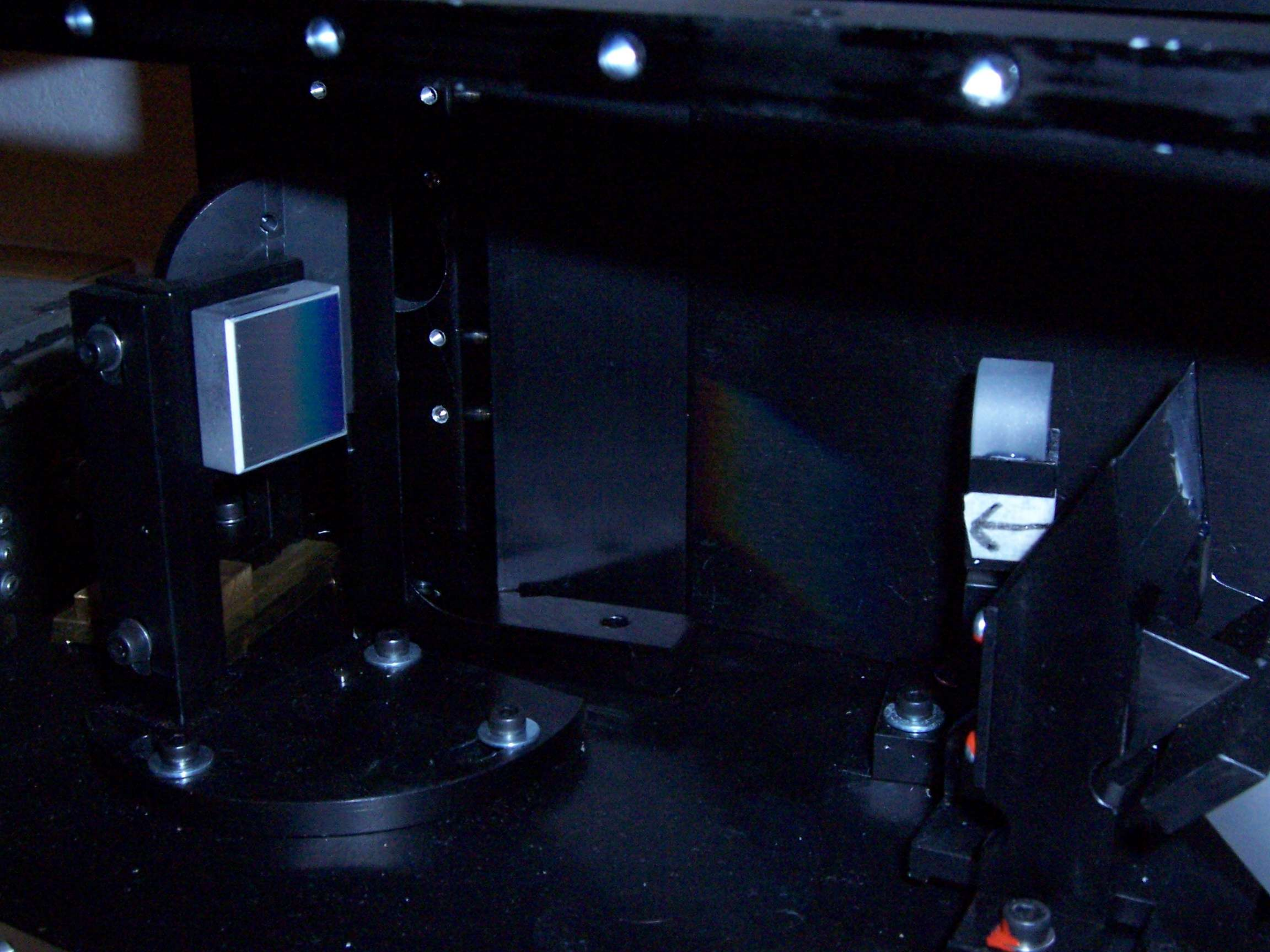


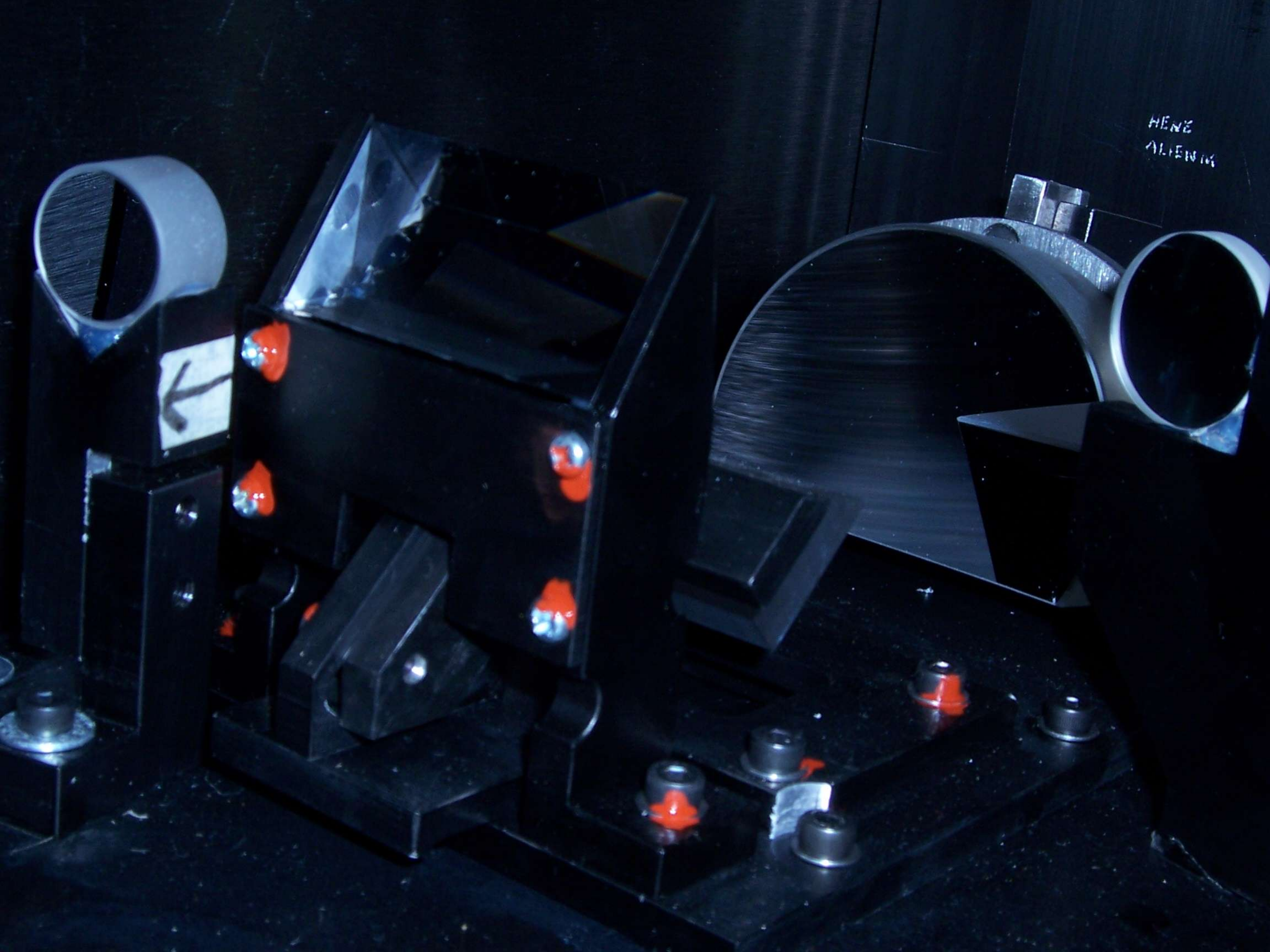
At the focus, a flat mirror with a projected mounted hole is placed in the beam at a 45° angle. The light reflected from this mirror is focused upon a small CCD video camera for target acquisition. When the star is found, the telescope moves so that the starlight falls through the hole in the mirror and enters the spectrograph. The zeroth order light is focused onto a second small CCD video camera. The image center is kept at a particular pixel by an automated guider.

For flat fielding, we will use Lou Boyd's new 0.5-m telescope. His photomultiplier detector and our flat field optics share the same space. We will point the telescopes at one another just before and after observing.

An alternative is to have the flat field light hit a flat screen and be reflected into our telescope. Either way the fringing will be that of a star rather than that of the sky aperture.


3D LAYOUT
ASTRA SPECTROGRAPH. FINIAL DESIGN V1
OCT 2003
TUE OCT 28 2003
SCALE: 0.5000
40.00 MILLIMETERS
D:\SAUL ZEMAX\ASTRA SPECTROGRAPH FINIAL DESIGN V1 LAYOUT.ZMX
CONFIGURATION: ALL 8

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Our Data Reduction Pipeline

1. The data from the Science CCD will be pushed by FTP from the Fairborn Observatory to The Citadel.
2. A version of CCDREDUCE by Austin Gulliver & Graham Hill will convert the 300-700 1 Mbyte CCD exposures for a night to 1-d spectra.
3. Then the 1-d spectra will be pushed by FTP from The Citadel to the University of Keele, England.

4. Barry Smalley will derived the atmo-spheric extinction and determine the fluxes above the Earth´s atmosphere.

5. Then Barry will calibrate the fluxes using observations of the secondary standards.

6. As part of the pipeline, we plan to calculate values for each stellar exposure in as many useful photometric systems as possible.

7. As photometric systems often can be used to calculate the interstellar reddening, it should be possible to deredden the fluxes and hence derive interstellar reddening from them. Wahlborn's O stars are our initial choices for such a study, but there are not enough of them. We plan to use bright early-type non-variable supergiants (mainly of luminous class II) to supplement them.

8. The absolute calibration of Vega is at best good to 1%, but the errors are often worse. It needs to be properly redone. We could use the ASTRA system, except it is not an optimum solution. Project ACCESS (of John Hopkins University, Mary Beth Kaiser, PI) is planning to do this study using sounding rockets We will be able to simply change the Vega data to account for any new absolution calibration.

Initial Observing Programs

Major Projects

1. Revision and Extension of the Secondary Standards
2. Sample Fluxes of Population I and II Stars

Auxiliary Projects

- Model Atmospheres Comparisons
- Synthetic Colors, Line Indices, and Reddening from Spectrophotometry

Collaborative Projects

We want to work with other astronomers interested in starting a variety of projects and soon getting initial results. We are particularly interested in those which find stellar parameters and/or study physical processes in stellar atmospheres.

We are willing to obtain simultaneous as well as phase dependent observations.

- With 150 photometric nights and our relatively short observing times for bright stars, we should obtain about 30,000 flux observations per year. 5000 will be for standards and 25000 will be of targets. Austin Gulliver, Barry Smalley , and I cannot analyze that much data per year. So we need collaborators.
- Collaborators can help us finish our initial projects in a reasonable time.

Plans for Next Year

Fall 2010-Spring 2011. Observe in a manual mode on the DAO's 0.40-m telescope. Learn to use spectrophotometer and to get good quality data.

Spring & Summer 2011. Take the instrument to its 0.5-m telescope at Fairborn Obseratory. Finish telescope and get automated operations running.

Fall 2011. Begin automated observations. Concentrate initially on standards and then our first major projects and initial projects.