Conceptual Design of a Low Resolution Spectrograph for the Astronomical Observatory of Córdoba

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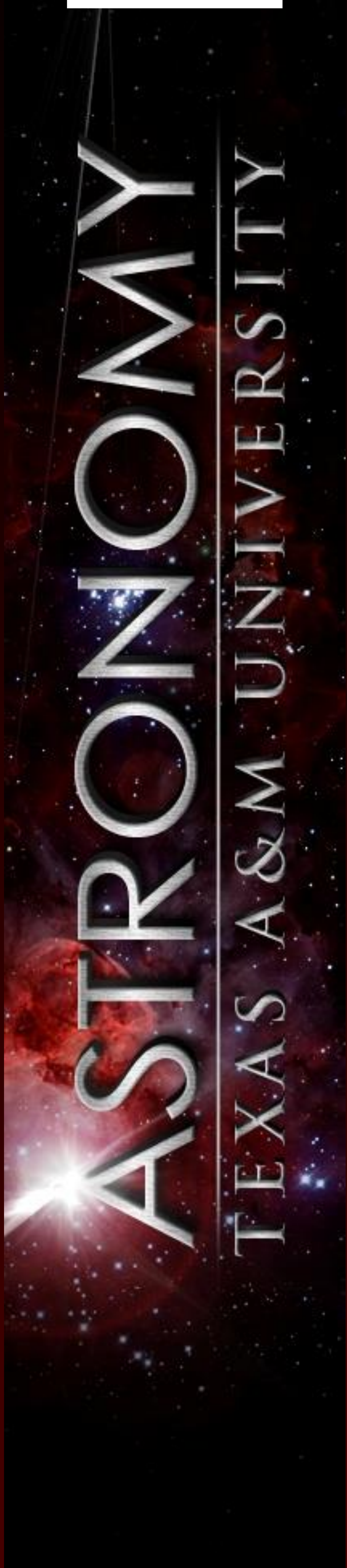


Abstract

We present a conceptual design for a low resolution optical spectrograph for the Astronomical Observatory of Cordoba 1.54m telescope. The simple instrument is required to cover a broad wavelength range (4000A< λ <9000A with 3000A simultaneous coverage) at a resolution of R= λ/Δλ ~ 500, allowing its use as a versatile astronomical spectrograph. In particular, we explore the use of inexpensive commercial off-the-shelf lenses, gratings, and a CCD system to create a small and simple spectrograph that has reasonable performance. We carefully measure properties of the lenses and demonstrate that they have excellent image quality and high throughput.

Introduction

The field of modern astronomy is focused on studying the universe at large and small scales. Several large scale surveys are currently underway or planned, particularly in the southern hemisphere. These surveys, such as DES and LSST, will discover enormous numbers of interesting targets that require spectroscopic follow-up. Furthermore, various planetary transit and variability surveys are currently in operation that identify relatively bright objects. These sorts of surveys, among many others, require spectroscopic follow-up studies in order to realize their full scientific potential.

We describe a conceptual design for a simple spectrograph for the 1.54m, *f*/4.9 telescope at the Astronomical Observatory of Córdoba in Argentina. We concentrate on an instrument with moderate resolution and relatively wide wavelength coverage. The budget of the instrument is small; as a result, we have carefully investigated the use of commercial-off-the-shelf components in the design of the instrument.

Science Goals and Preliminary Design

We desire a spectrograph that would allow the 1.54m telescope at Córdoba to be used for initial spectroscopic classification of interesting or unusual objects found in imaging surveys. Optical spectroscopy at low-to-moderate resolution opens a few avenues of exploration, including but not limited to identification of quasi-stellar objects (QSO's) and spectral types of variable stars.

We have chosen for this project to use the following commercial-off-the-shelf (COTS) components:

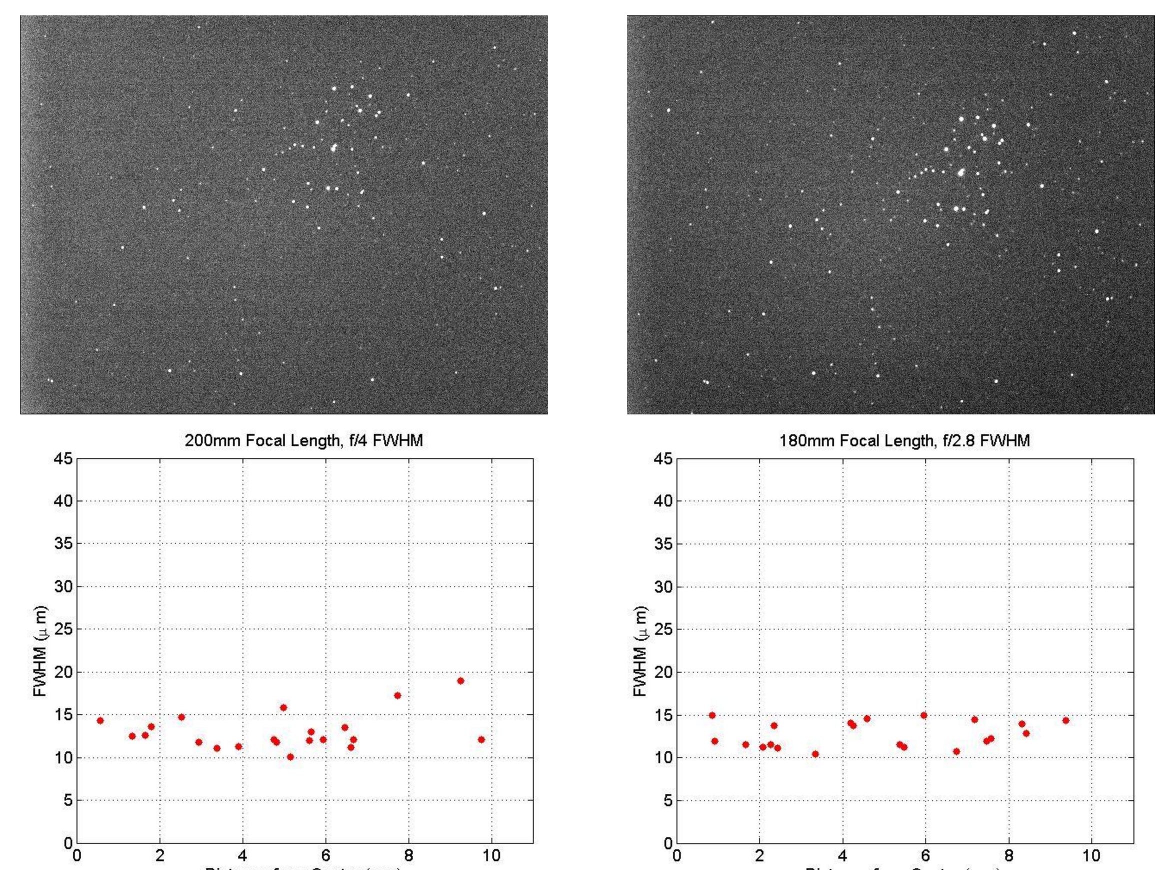
- Nikon 200mm focal length, f/4 photographic lens (collimator)
- Nikon 180mm focal length, f/2.8 photographic lens (camera)
- 300 line/mm, 8000Å blazed Shimadzu holographic grating
- Santa Barbara Group (SBIG) ST8300M 3326x2504 pixel (5.4μm x 5.4μm) CCD

The combination of optical components yields a theoretical resolution of R = 793 at a wavelength of 7846Å and simultaneous coverage of 3200Å.

Lens Image Quality Tests

To ensure that these lenses could take science-quality astronomical data, we attached the collimator lens and the camera lens to the selected CCD to perform observations of the Pleiades star cluster (RA: 03:47:24, DEC: +24°07'00"). The pixel scale for the collimator and camera were 5.5"/pixel and 6.2"/pixel respectively. Since seeing conditions were smaller than 1 pixel (~ 2"), this provides a direct probe into image quality.

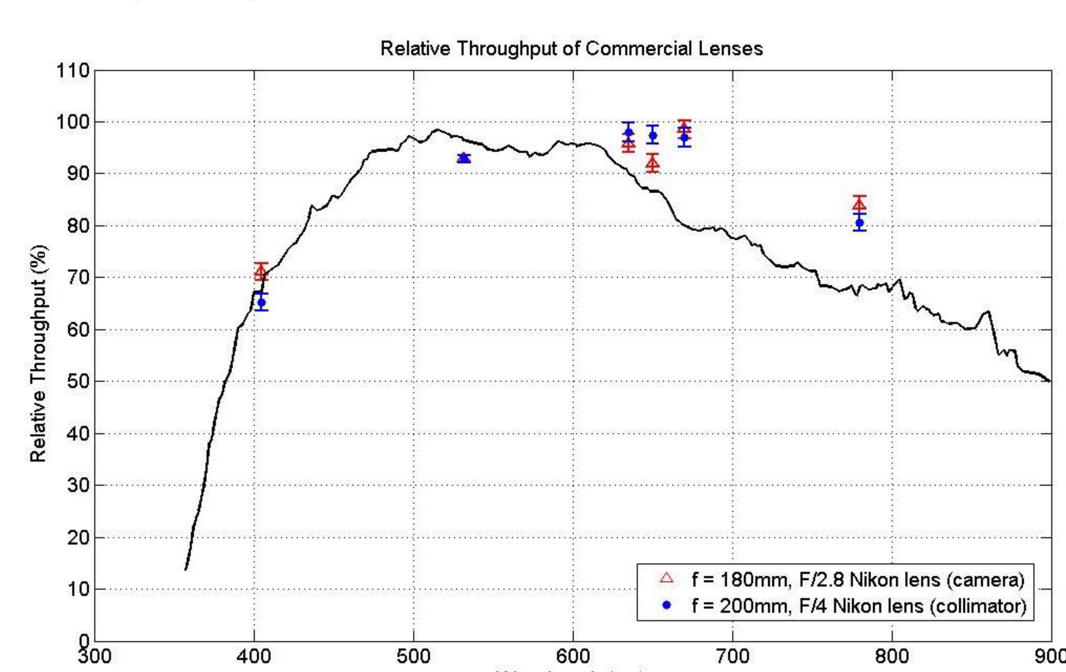
The mean FWHM of the stars in the image was 12μm. In order to see if this degraded as a function of distance from the center of the CCD, we plot the FWHM of each star against its distance from center of our image. We measure no significant change in the FWHM over a 10mm field radius, which was to be expected given these lenses' use for 35mm film photography.



Throughput Analysis

We also wanted to test the throughput of each of these lenses to ensure there were no significant losses in our wavelength range of interest. We used several laser diodes and a laser power meter with a Si photodiode to measure incident power through open air and though the collimator and the camera lenses individually. A separate system was used to measure relative throughput of a separate Nikon 50mm focal length lens for comparison.

We expect that, assuming the behavior of all Nikon lenses are similar, that the throughput will never drop >50% for our wavelength range of interest.

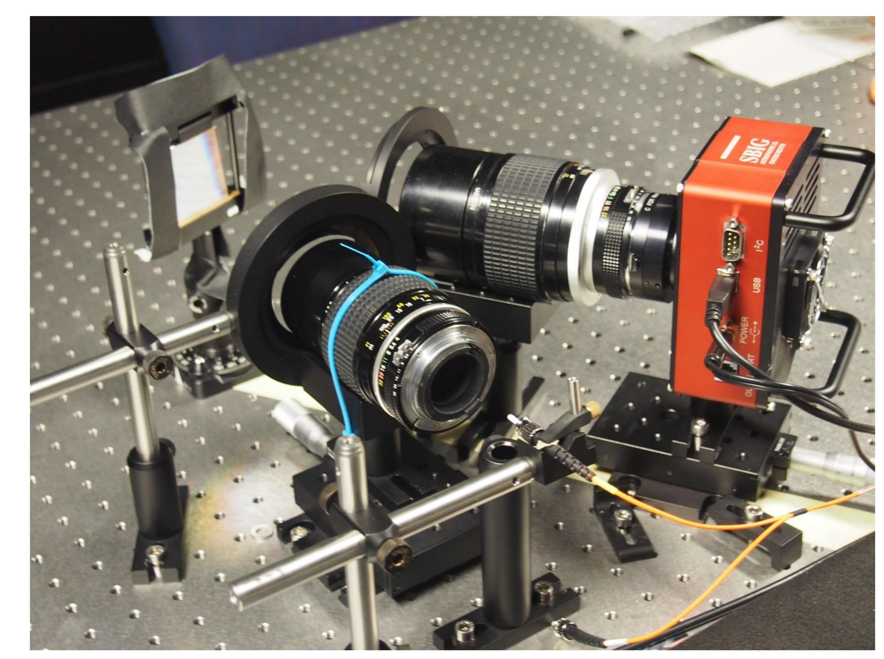


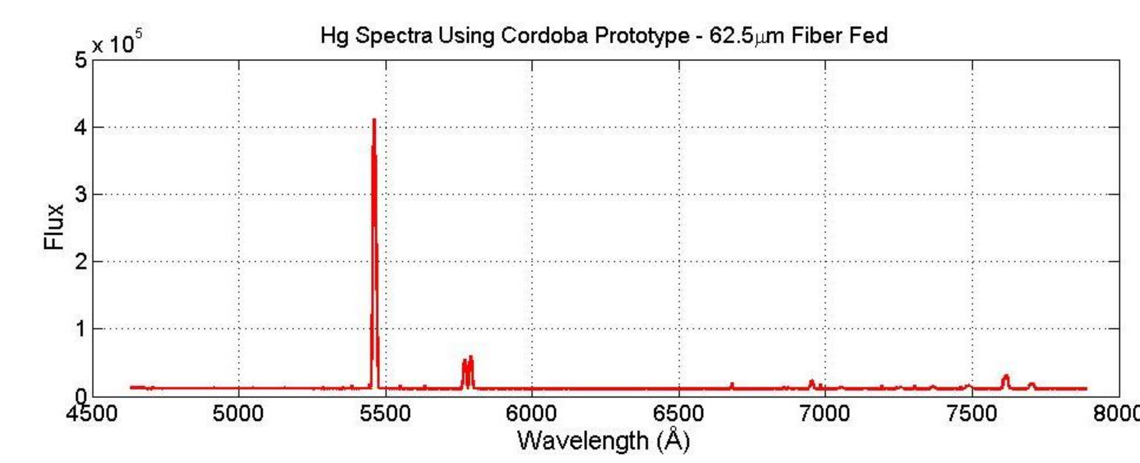
Prototype System Tests

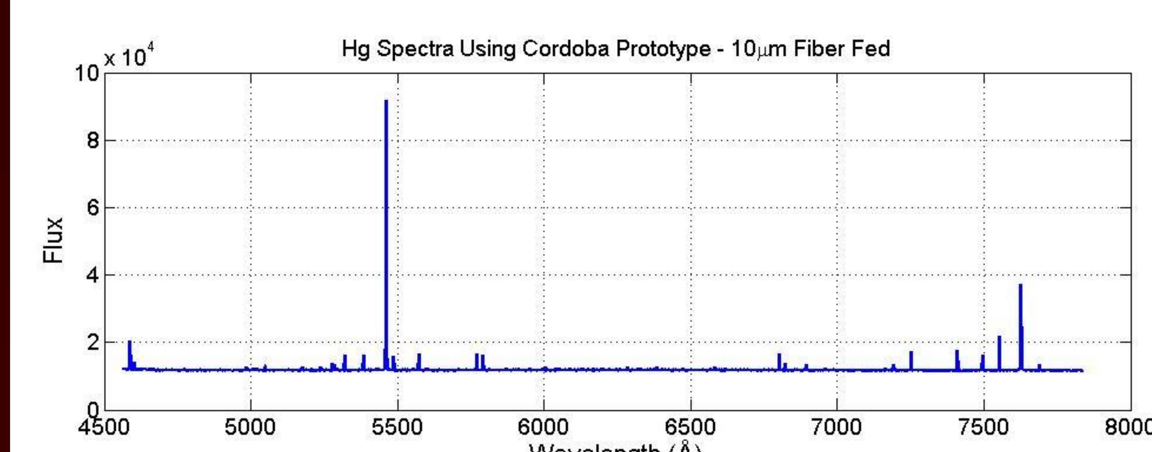
The selected COTS components were assembled into a spectrograph on an optical bench; this spectrograph was fed using a 62.5μm fiber optic cable illuminated by an f/4.9 telescope simulator fed by an integrating sphere. Light from an Hg arc lamp was fed into the integrating sphere. The fiber size in this simulated system would correspond to 1.725" in the sky.

We note that, using this system, we achieved a FWHM of 8.5Å for the Hg lines are 5769Å and 5790Å and simultaneous coverage of 3200Å, both as predicted.

In the extreme case of a 10μm spot corresponding to 0.275" in the sky (if higher resolution was desired at the expense of throughput), we can achieve a FWHM of ~1Å for the same lines. We conclude that even in the extreme case, we are not limited by the quality of the optics in our prototype but rather by slit width.







Conclusion

Using custom optics for this system could probably perform a COTS system but there would be a significant increase in both cost and complexity. We therefore conclude that, based on these tests, that the use of commercial lenses in this project is both scientifically adequate and financially preferable, though much engineering progress remains before full deployment of this system.

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