7735-164

A radial velocity spectrometer for the Automated Planet Finder Telescope at Lick Observatory

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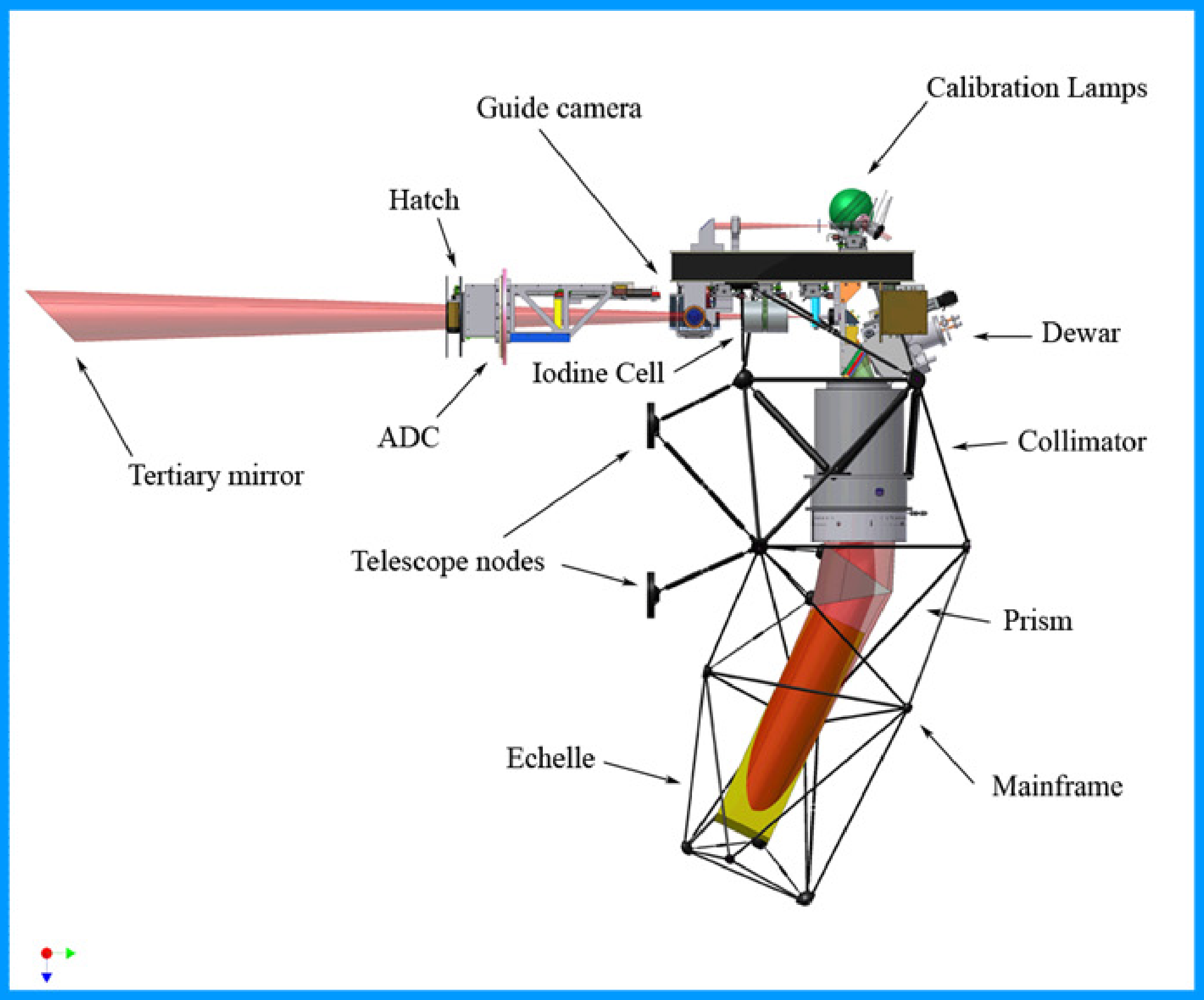
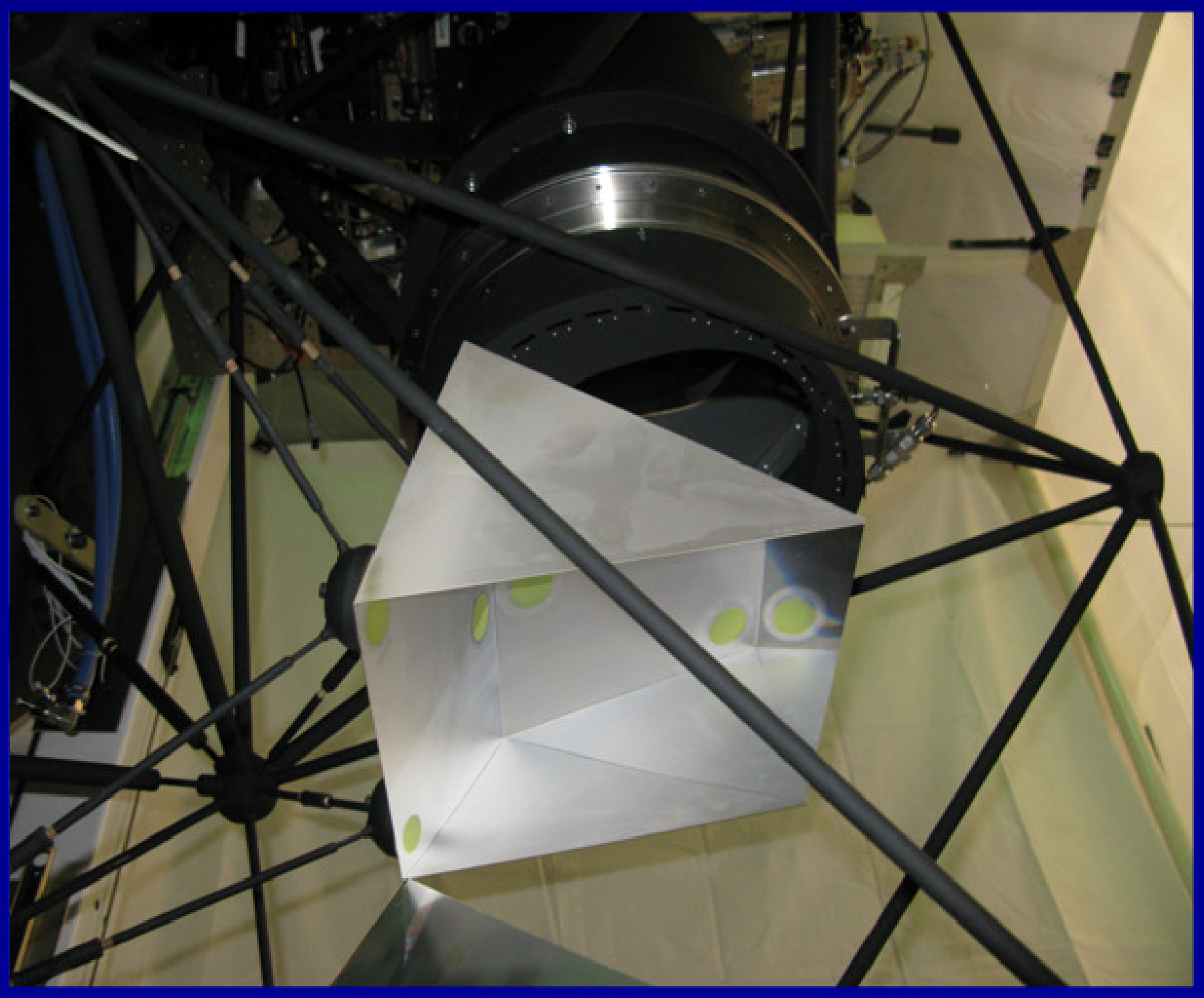
ABSTRACT

The Ken and Gloria Levy Spectrometer is being constructed at the Instrument Development Laboratory (Technical Facilities) of UCO/ Lick Observatory for use on the 2.4 meter Automated Planet Finder Telescope at Mt. Hamilton. The mechanical design of the instrument has been optimized for precision Doppler measurements. A key component of the design is the space-frame structure that contains passive thermal compensation. Determinate hexapod structures are used to mount the collimator, prism, and echelle grating. In this paper we describe the instrument mechanical design and some features that will help it detect rocky planets in the habitable zone.

LEVY SPECTROMETER

The Levy Spectrometer is a high-resolution prism-cross-dispersed single object spectrometer designed to function at the Nasmyth focus of the 2.4 meter Automated Planet Finder Telescope. The instrument structure is a determinate space-frame made from Invar 36® with an Invar 36® optical table. The optical table is attached to the space-frame with six adjustable struts. The optical table provides the attachment points for all the small optics and stages. The space-frame also provides the attachment points for the collimator, the cross-dispersion prism, and the R-4 echelle. All three of these major components attach to the main structure via adjustable hexapod assemblies. The CCD dewar houses a 42-90 E2V CCD that is cooled with a Brooks Automation Cryotiger®. Signal from the CCD is recorded through the Lick Observatory Universal Camera (UCAM) controller. The optical instrument is housed in an enclosure composed of fiberglass over 3” [75 mm] thick extruded polystyrene foam. The enclosure is sealed and positively pressurized with active thermal control. The total instrument volume is 112” x 48” x 50” [2.85 x 1.22 x 1.27 m].





Cross dispersion prism and collimator inside the Invar 36 Mainframe structure.

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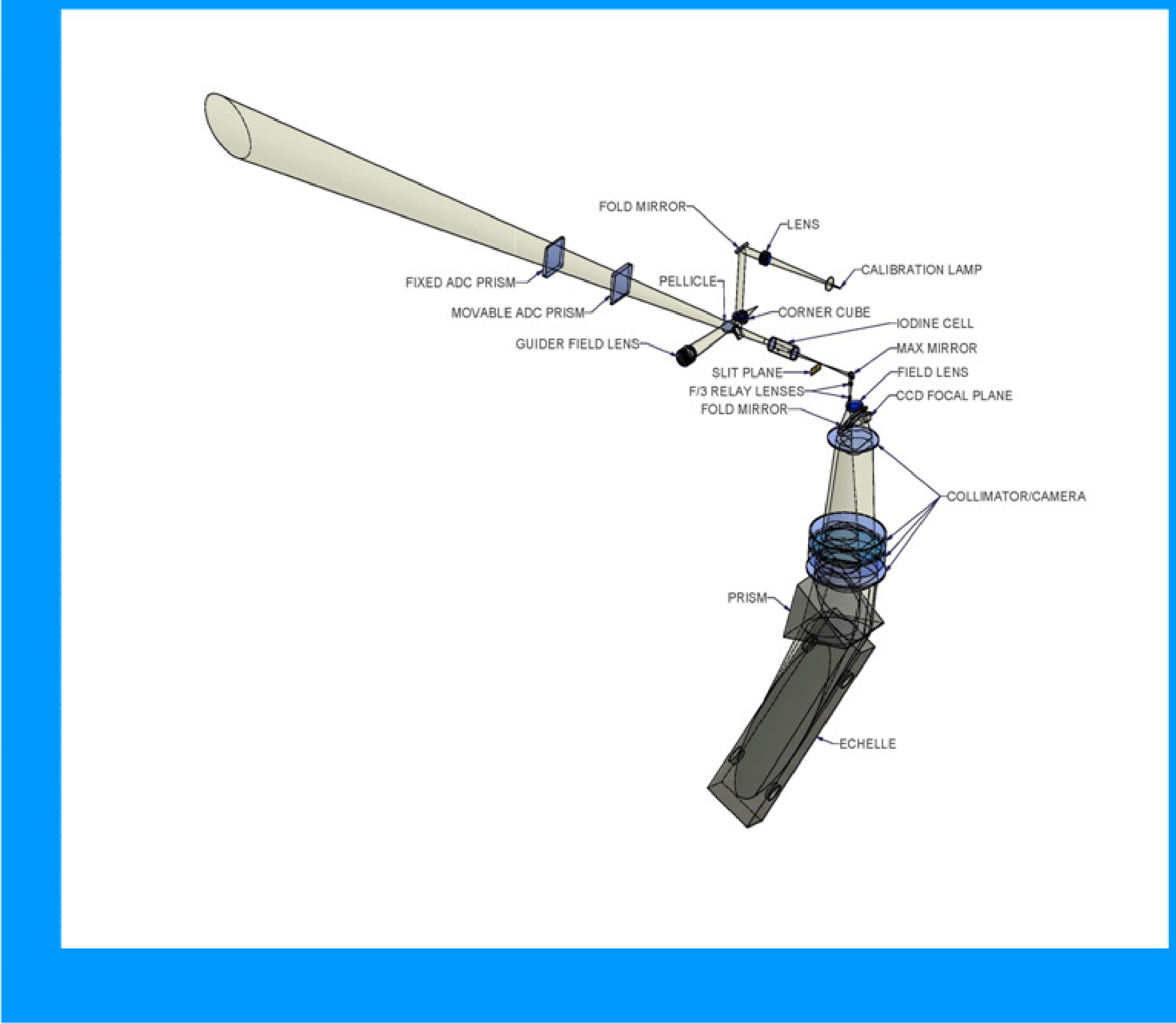
Optical Layout

The instrument optical layout is shown below. Light enters the spectrometer through the fixed prism of the linear ADC, which also functions as a window to seal the instrument. 96 % of the photons pass through the pellicle and into the iodine cell and on to the slit plane of the instrument.

The remaining 4% of photons is reflected to the guider field lens to adjust the plate scale, and into a Princeton Scientific Photon Max 512® camera. The guider system also includes a corner cube and shutter that make it possible to see the slit plane and the 4% star image simultaneously. This feature is used for guider alignment only, so the corner cube shutter is closed during normal observation.

The slit stage has a single decker plate with a variety of rectangular apertures. The instrument shutter (not shown) is behind the slit plane and in front of the MaxMirror®4 fold flat. After the native f/15 beam from the telescope is folded it enters a relay system whose purpose is to speed the beam up to f/3. The f/3 beam then enters the field lens and collimator off-axis. After passing through the five-element, all-spherical collimator, the beam passes through the prism to the echelle and back through the prism a second time. The second pass through the collimator brings the beam to focus on the CCD after it is folded by a flat mirror.

The instrument has a calibration system with quartz lamps and thorium hollow cathode lamps filled with a mixture of 90% argon and 10% neon gas for wavelength calibration. A movable mirror (not shown) blocks the incoming beam from the telescope and directs the light from the calibration lamps into the iodine cell, after it is folded from the plane above the breadboard down into the main instrument optical axis.



Conclusion

The Levy Spectrometer has been designed to produce the highest possible spectral stability. The space-frame structure is used in new ways to create passive compensation for the residual errors that have been predicted from an integrated optical and mechanical analysis. We expect to achieve radial velocity measurement accuracies better than 1 meter per second on the 2.4 meter Automated Planet Finder Telescope. In fall of 2010 this facility will begin dedicated observing to find earth analogs

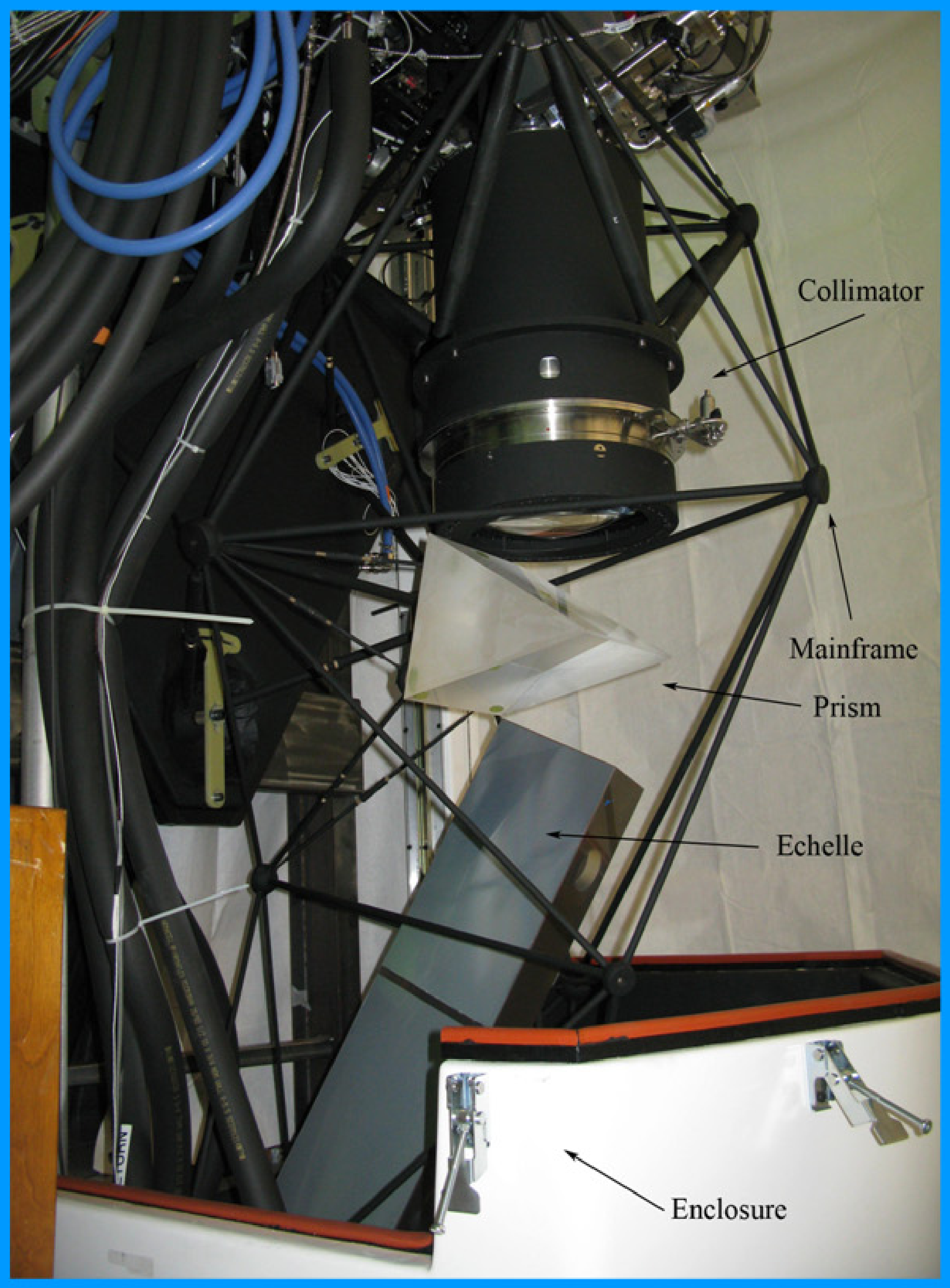
Design Philosophy

The scientific requirement for radial velocity accuracy less than 1 meter per second drove all aspects of the mechanical design. The goal of this effort was to build a spectrometer with the highest possible spectral stability at the CCD.

To meet this requirement we set out to build the stiffest and most thermally invariant structure possible. The structural design drew on experience gained building the Echellette Spectrograph and Imager (ESI) for the Keck Telescope. ESI was the first attempt by UCO Technical Facilities to use this construction technique to build a spectrometer, and has been discussed in papers by Bigelow1, Sheinis2, and Radovan3. The Levy Spectrometer represents a major advancement for UCO because most of the structure is constructed from Invar 36® to improve thermal stability.

Recognizing that there would be limitations of the design because materials other than Invar 36® are necessary for construction, we also designed a high-efficiency enclosure with active cooling control. The enclosure is sealed and positively pressurized to keep the instrument clean. It also contains multiple coolant circuits to address the unavoidable heat sources within the spectrometer.

The mechanical design of the instrument was integrated with the optical model to predict the thermal residual scale and focus changes. The details of this process will be the subject of a paper to be presented at a later date by Professor Steven S. Vogt. The result was a passive solution using some of the hexapods to correct for the subtle changes to the optical components that are temperature dependant. This had a profound impact on the camera and prism hexapod structure as described in this paper.



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[3] Sheinis, A.I., Nelson, J.E., Radovan, M.V.,”Large prism mounting to minimize rotation in Cassegrain instruments”, Proc. SPIE 3355, 1998

Acknowledgements:

We would like to thank the United States Naval Observatory, The National Aeronautics and Space Administration (NASA), The University of California Observatories (UCO), National Science Foundation, Ken and Gloria Levy, and Professor Geoff Marcy (U.C. Berkeley) for their support of the Automated Planet Finder (APF).

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