The Colorado High-resolution Echelle Stellar Spectrograph (CHESS) mission development.

Matthew Beasley

This work funded by NASA grant NNX10AC66G

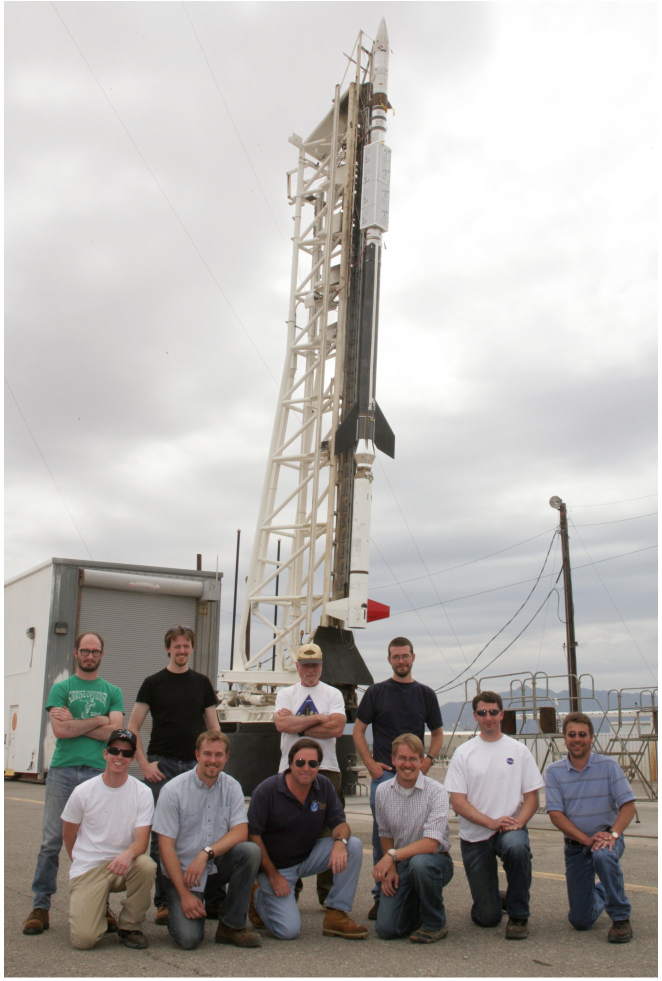
My Team

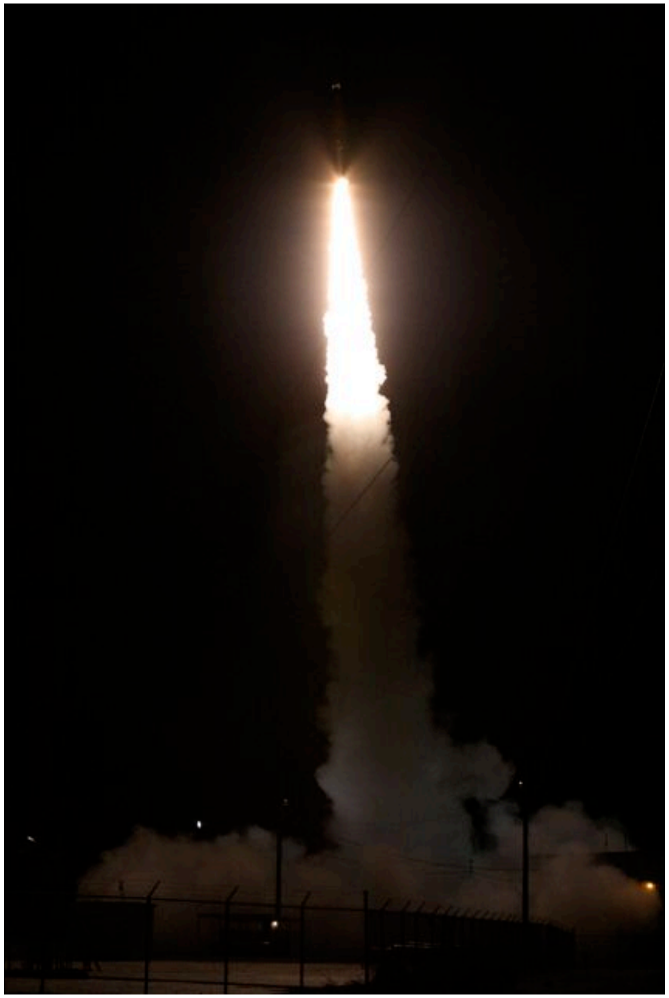
- Robert Kane
- Dr. Eric Burgh
- Dr. Kevin France
- Nicholas Nell
- Mike Kaiser
- Ted Schultz
- Professor James Green
- Graduate students who have launched but are still around:
  - Brennan Gantner
- Undergraduates too numerous to number

Overview

- What are sounding rockets anyway?
  - Introduction
- CHESS
  - Science Driver
  - Concept
  - Design
    - Optical
    - Mechanical
  - Issues
    - Known Unknowns

Sounding Rockets



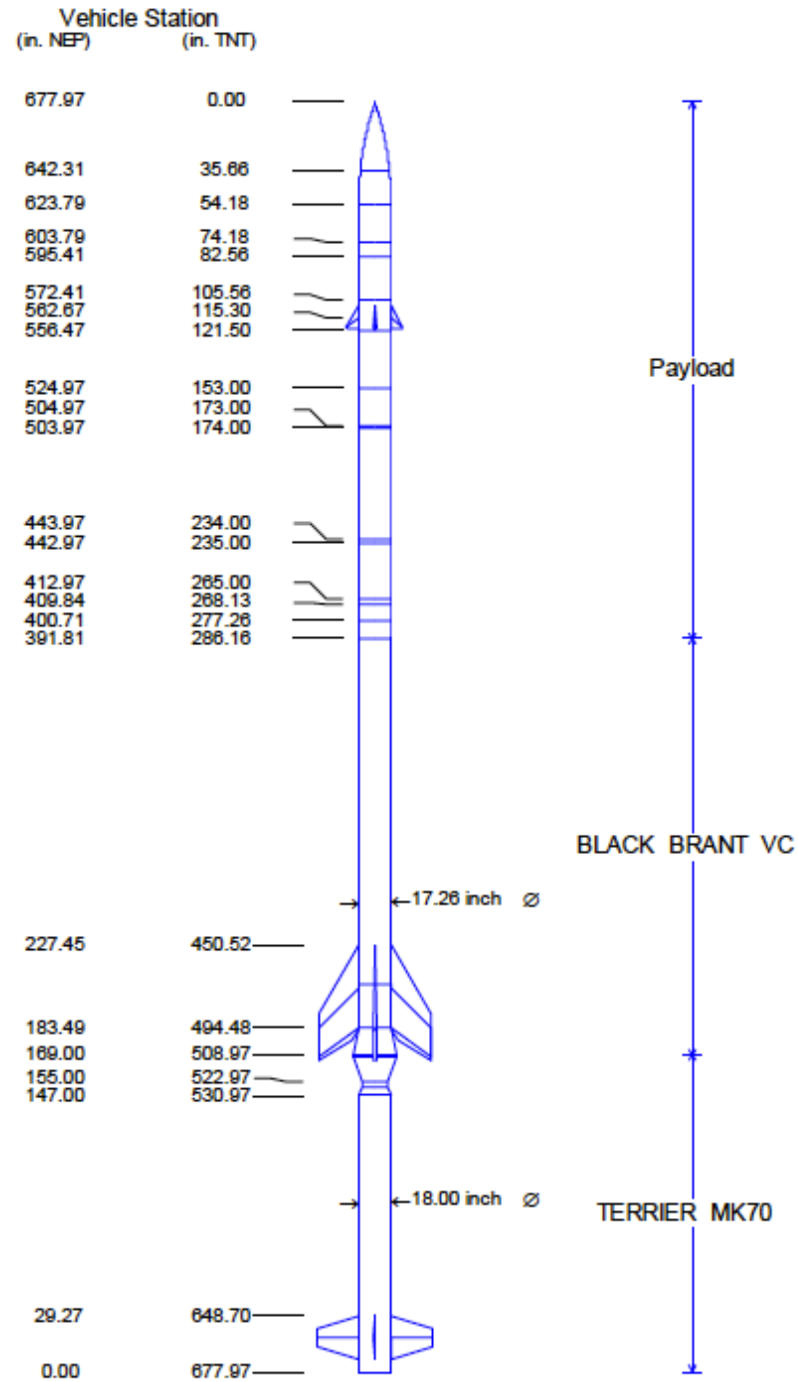


NASA Sounding Rockets

- Solid fuel, typically two-stage rockets (~55 feet long)
- Apogee at ~300 km
- Guided during boost (prevents large dispersion in landing area)
- Telemeter all data down (recovery is not critical)
- Normally deploy parachute and land (mostly) intact
- Capable of slightly better than arcsecond pointing (~0.6 arcsec)
- ~300 seconds of observing time (more or less)

Rocket

- Black Brant IX
- Payload ~25%



Motivation of CHESS

- Do some interesting, unique science
- Advance technologies
  - Either by refinements of existing technology, or drive new development
- Perform training
  - Teach students how to build space flight hardware and understand trades in the optical design

Motivation

Astrophysics is driven by spectrographic information

Generally the bluer the wavelength – the more available ground transitions per wavelength interval

Our instrument will cover most of the FUV (100 – 160 nm) at 100,000 resolving power

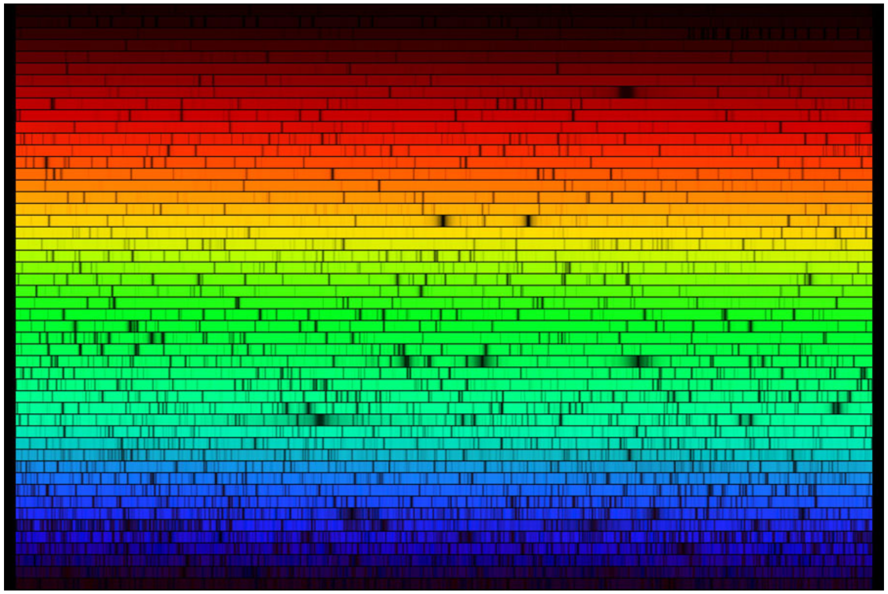
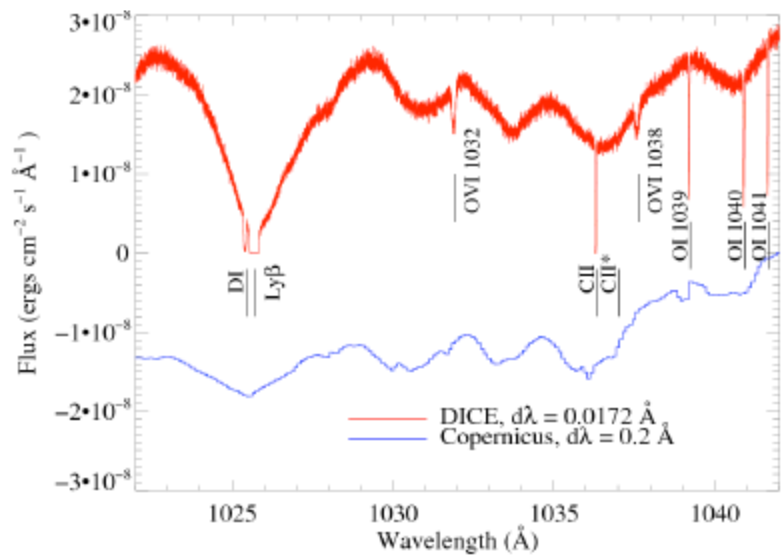


Image credit: Nigel Sharp (NSF), FTS, NSO, KPNO, AURA, NSF

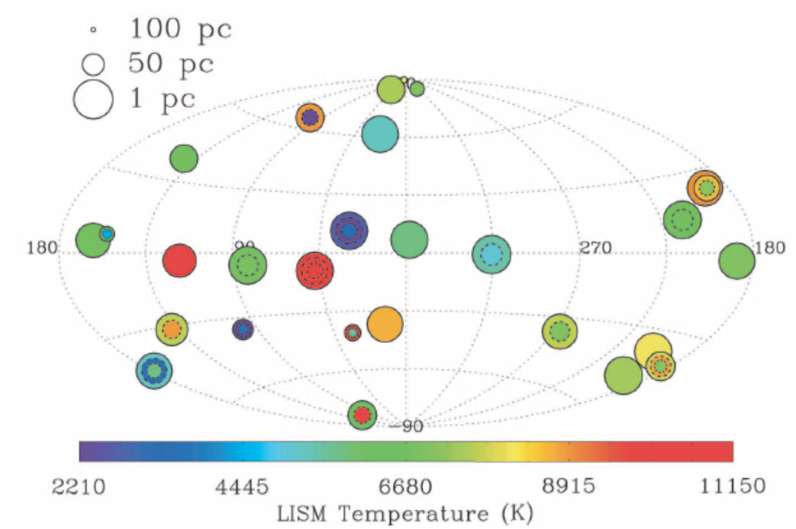
Resolution Comparison

- Resolution critical for studies of ISM



This target (δ Sco) is too bright to be observed by FUSE (now defunct) or other assets that work at 1030 angstroms

- CHESS Science goal
  - Study ISM within ~100 pc of the solar neighborhood
  - Clouds and gas properties near hot stars



Spatial temperature distribution in the local ISM (from Redfield & Linsky 2004).

Echelle motivation

- With high resolution over a large bandpass and efficient use of 2D detector space
- Although they require more reflections – which comprise efficiency at short wavelengths the trade is still worthwhile for certain science goals

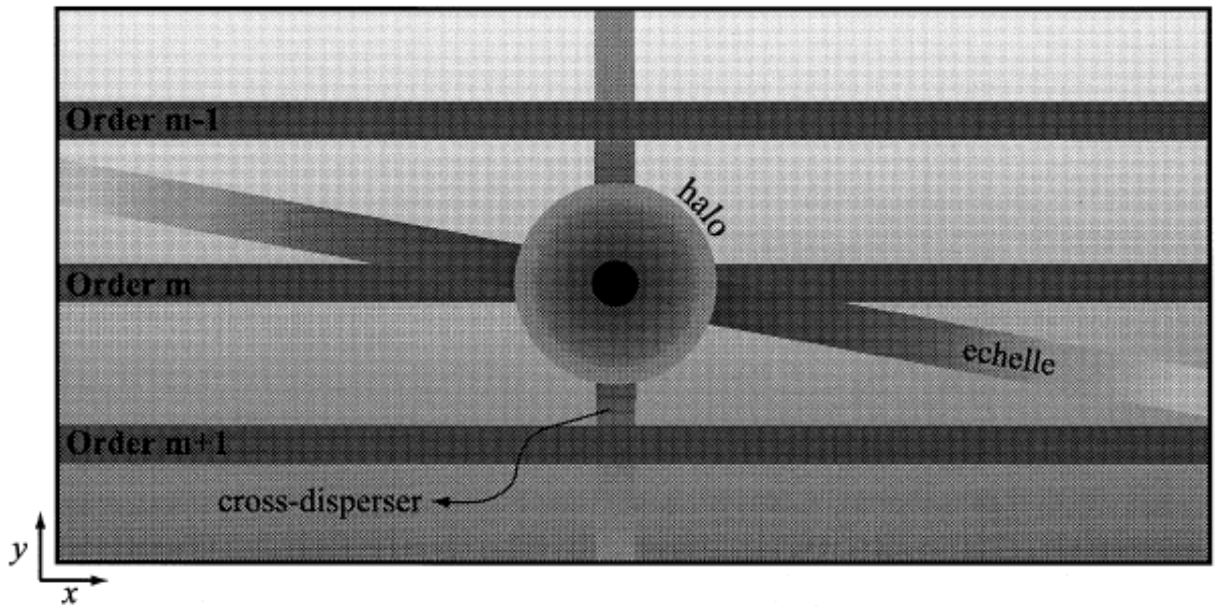
State of the art

- Space Telescope Imaging Spectrograph's echelle modes are the only FUV echelle operating in space
  - Resolving power >40,000
- Mechanically ruled gratings
- Detector is a MAMA device

Current Issues

- Scatter is a significant problem from STIS
  - Product of mechanical gratings
  - Also holds the echelle to modest incident angle (i.e., R < 2)
- Not related to the scatter is the background from the MAMA window
  - Plus small format (1k x 1k)

Scatter



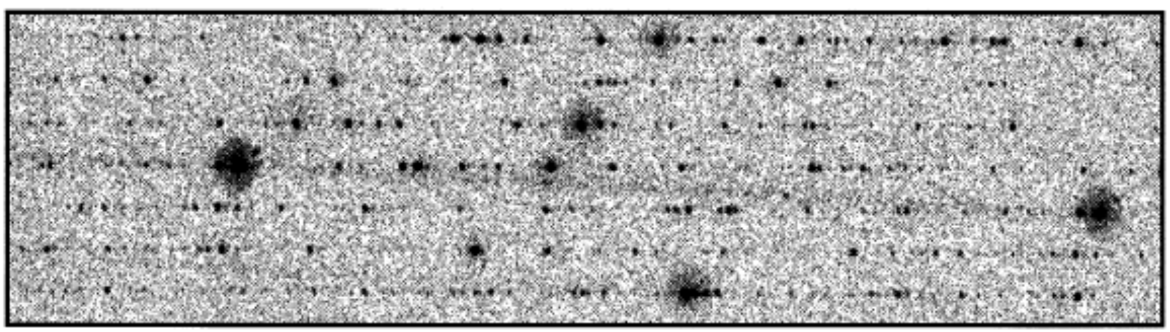
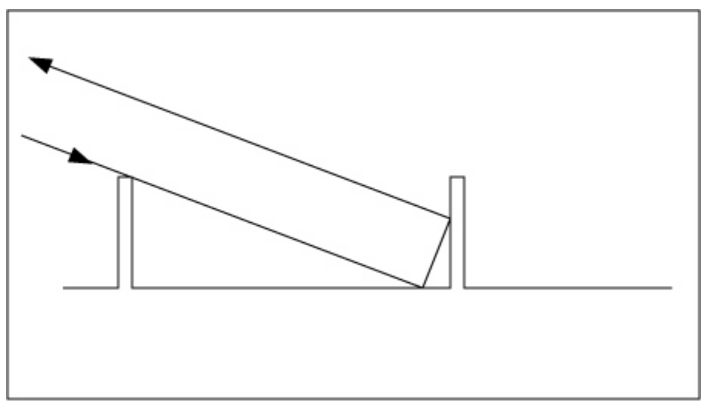


Image Credit: Howk and Sembach, 2000

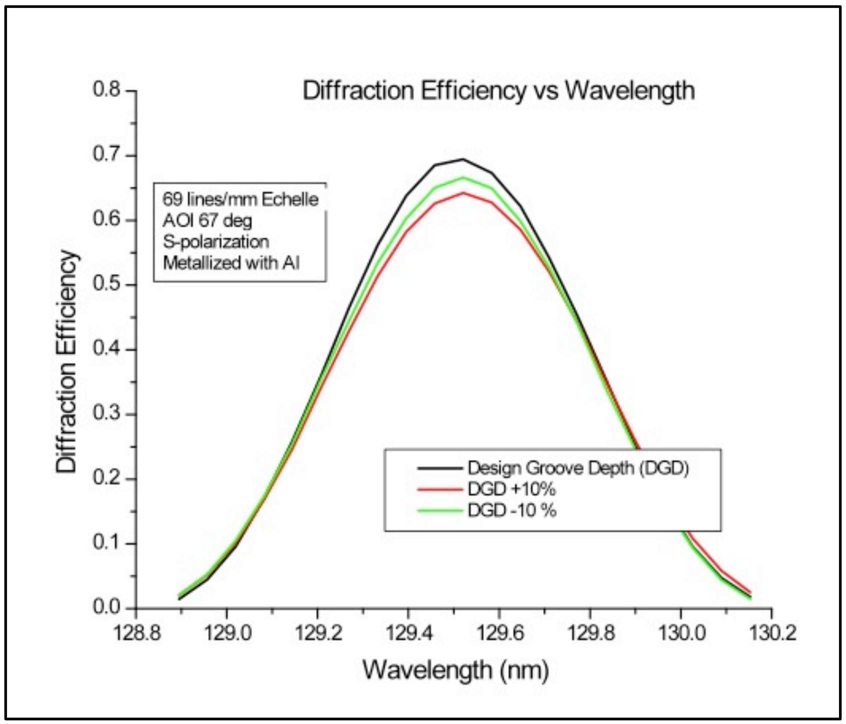
New Echelle

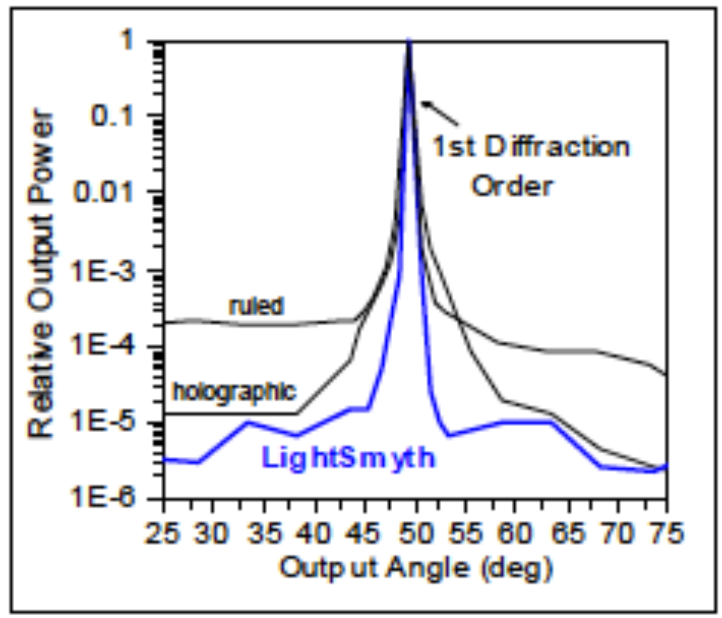
- Several groups have developed new types of echelle grating technology.
- New FUV detectors have larger format and/or better resolution



New Echelle Grating

- The theoretical performance looks good
- Corner-cube reflection seems to work





MCP Detectors

- Large format (~ 40 mm diameter)
- Good spatial resolution (~ 30 microns)
- High global counting rates (~ MHz)
- Photon counting

- Should be receiving our new device in the next few months

CCDs

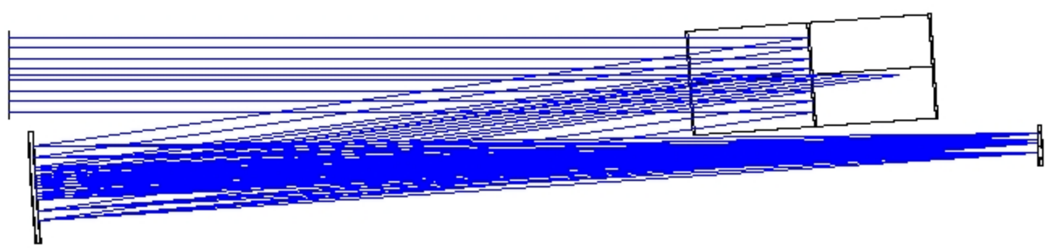
- FUV CCDs have promise of good broadband efficiency and large format
  - Fixed pixels over a large (~40 mm) format
- Not photon-counting in large formats
- Hopefully taking delivery of a delta-doped CCD built here sometime later this year

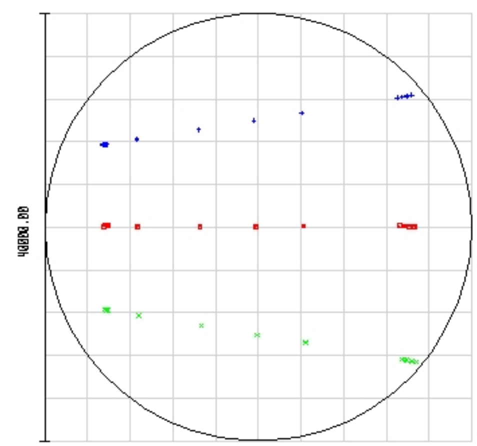
Rocket Instrument

- Keep it as simple as possible
- Only one focusing optic
- Robust for launch survival and only target very bright stars
  - Our targets are blue to the naked eye

Our instrument

- Mechanical Collimator feeds objective echelle, cross disperser is new type of grating optimized using techniques for synchrotron systems





CHESS Prescription

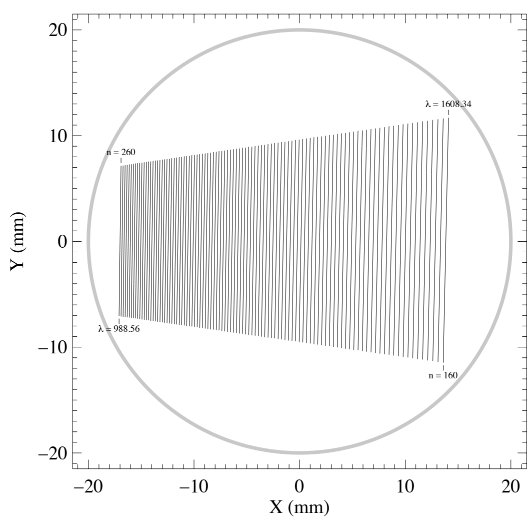
- Echelle (100 x 100 mm silicon wafer)
  - 69 grooves/mm
  - 67 degrees alpha/beta (4 degree turn)
  - Orders 156 - 266

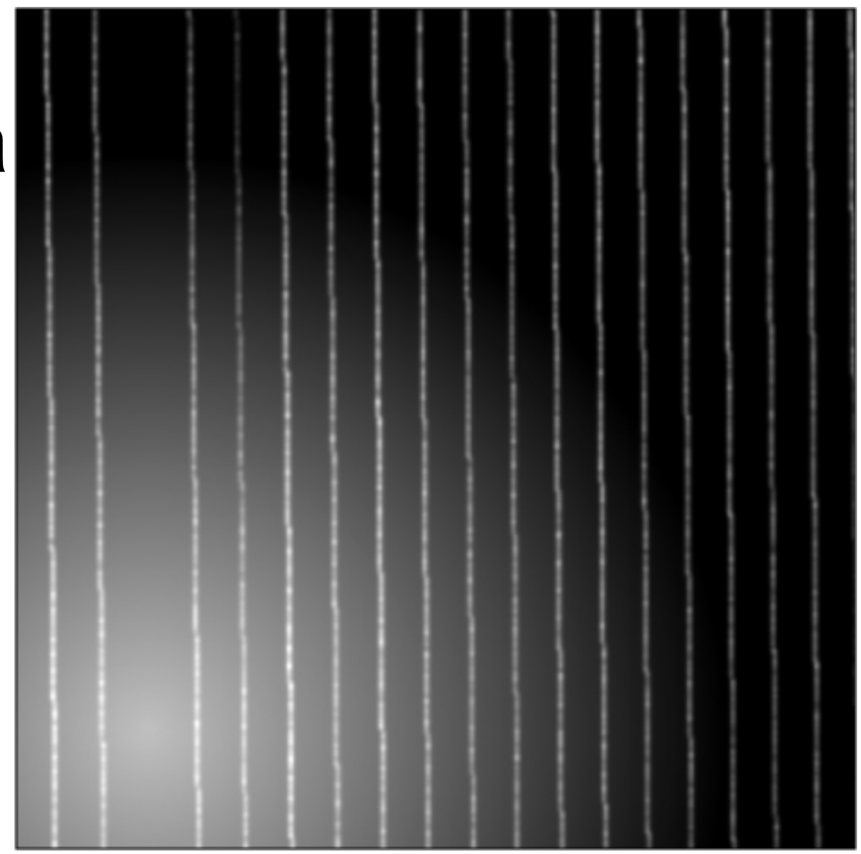
- Cross disperser (100 x 100 mm fused silica)
  - 571 grooves/mm
  - Alpha ~2.3 degree

- Effective focal length: 1250 mm

CHESS Performance

- 100 to 160 nm @ 100,000 resolving power
- 1 cm^2 effective area
- ~ 0.25 degree FOV





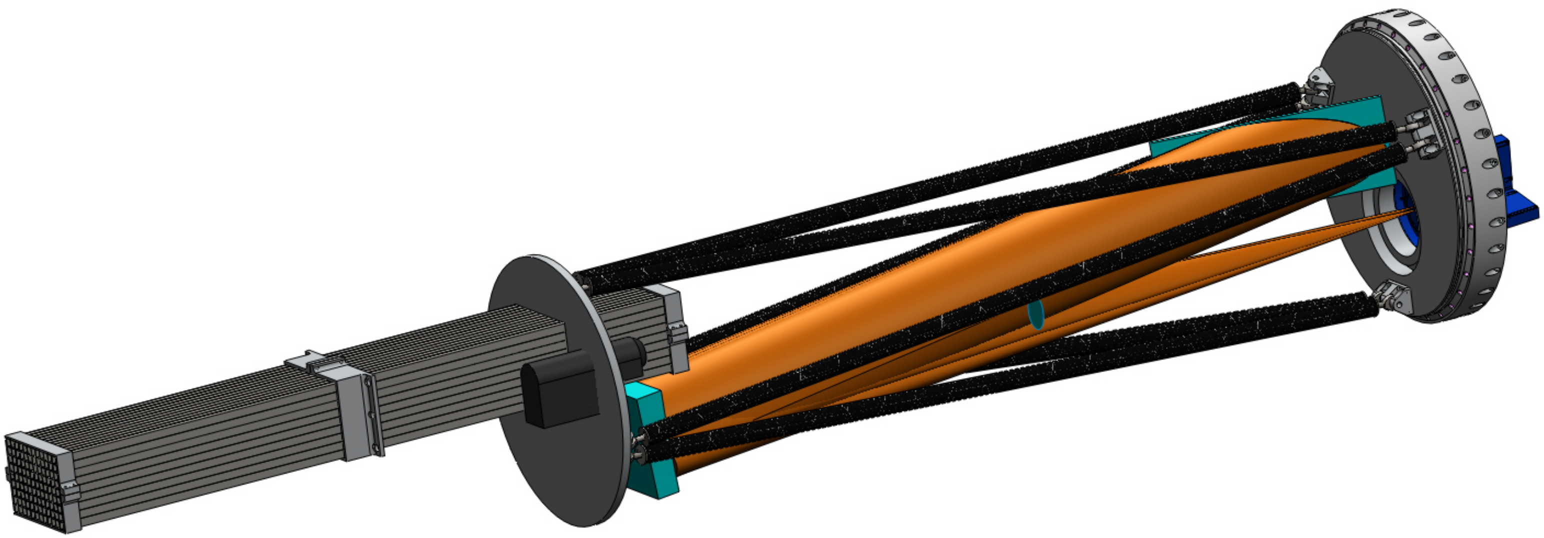
Advantages

- CHESS eliminates much of the issues with FUV echelle spectrographs
  - Large detector format improves background subtraction and inter-order confusion
  - Low scatter echelle grating permit the construction of high R (>2) system (high resolution, compact)

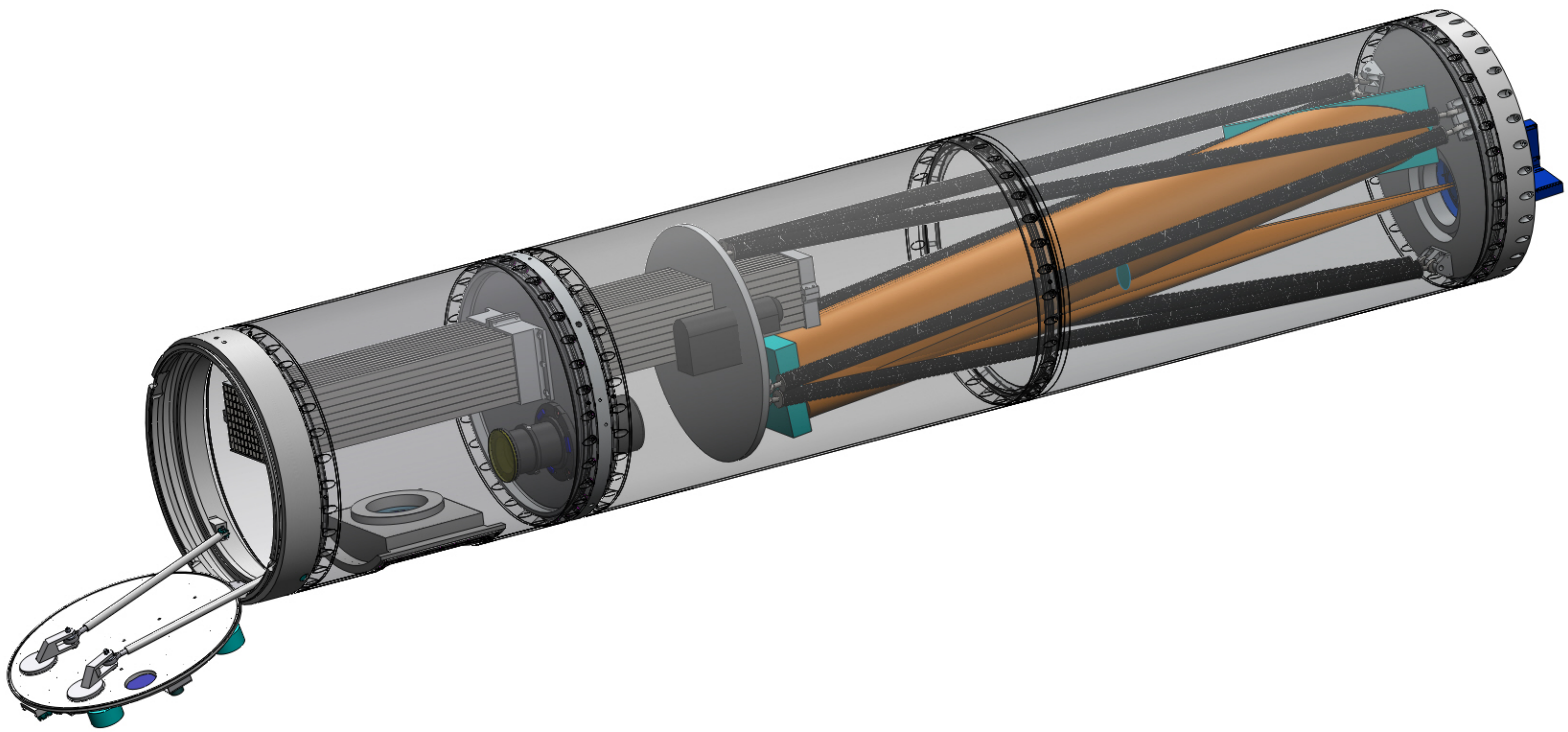
Mechanical Design

- Rockets are a rough ride
- Precision optical alignment + robust do not go together gracefully
- Clean, not expensive, athermal, vacuum compatible, tough as nails, capable to micron level adjustment

Mechanical Design



Mechanical Design



Known Issues

- The gratings are printed on a silicon wafer (700 microns thick)
  - How to mount grating without distorting it?
  - Thickness variations may be important
- Each grating is 2 bounces (corner cube) but … one is a graze. We'll examine the impact on efficiency

Known Issues Con't

- With a face profile like corner cubes, coating with reflective material may be a problem
- How to coat without screwing up the straightness of the wall
  - The perpendicularity of the reflective wall directly impacts diffraction efficiency
  - Do we risk softening the "blaze" function
    - Significant consequences across the instrument

Future

- Design and fabrication proceeding.
- Hope for launch in 2012, 2013 and onward