Better Radial Velocity Measurement Precision Through Organic Chemistry: The GMT Consortium Large Earth Finder (G-CLEF)

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EPRV IV / Grindelwald
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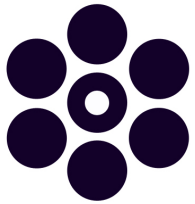


Harvard-Smithsonian Center for Astrophysics
Steward Observatory, University of Arizona
The Observatories of the Carnegie
Pontificia Universidad Catolica de Chile
University of Chicago

Korea Astronomy and Space Science Institute
Massachusetts Institute of Technology
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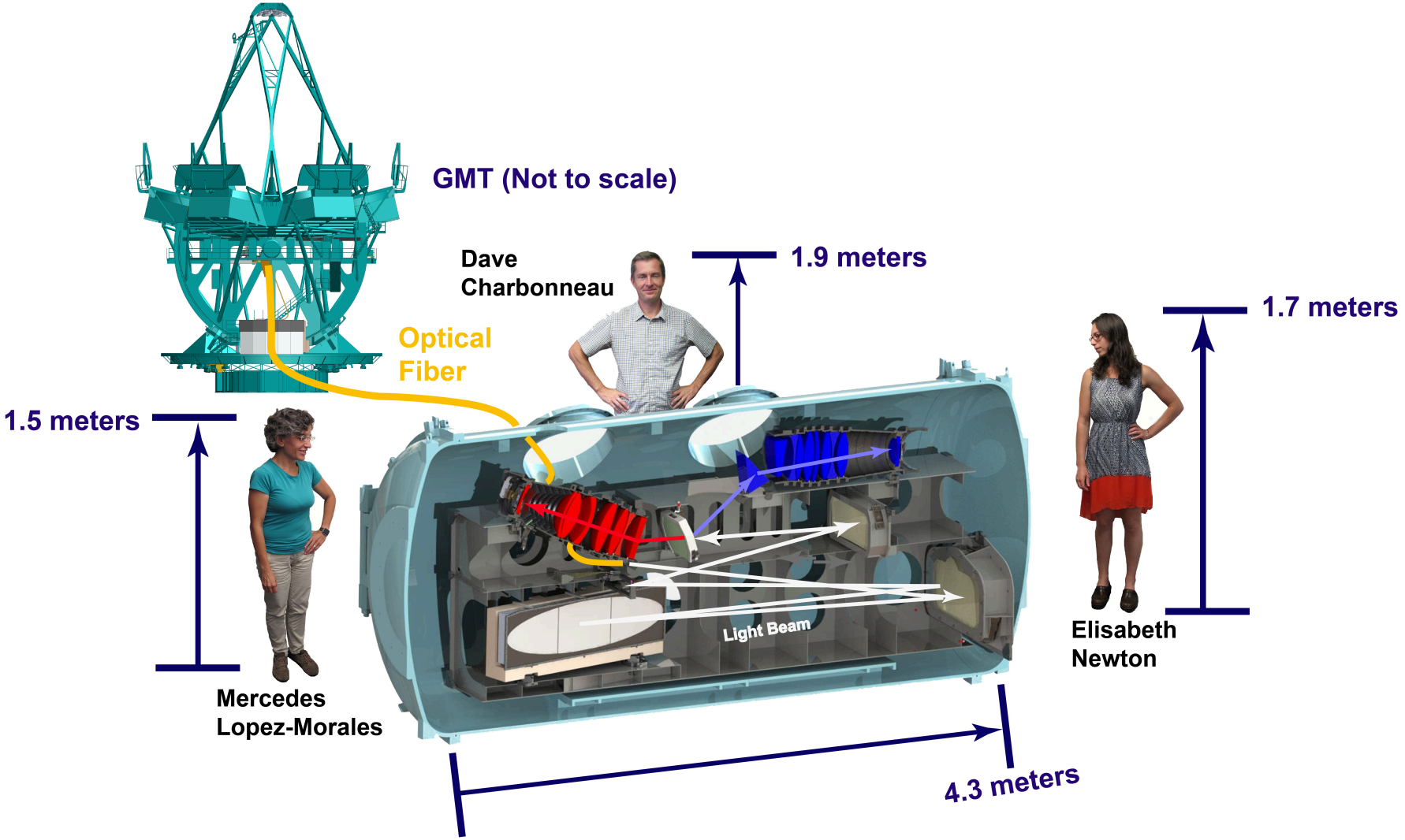
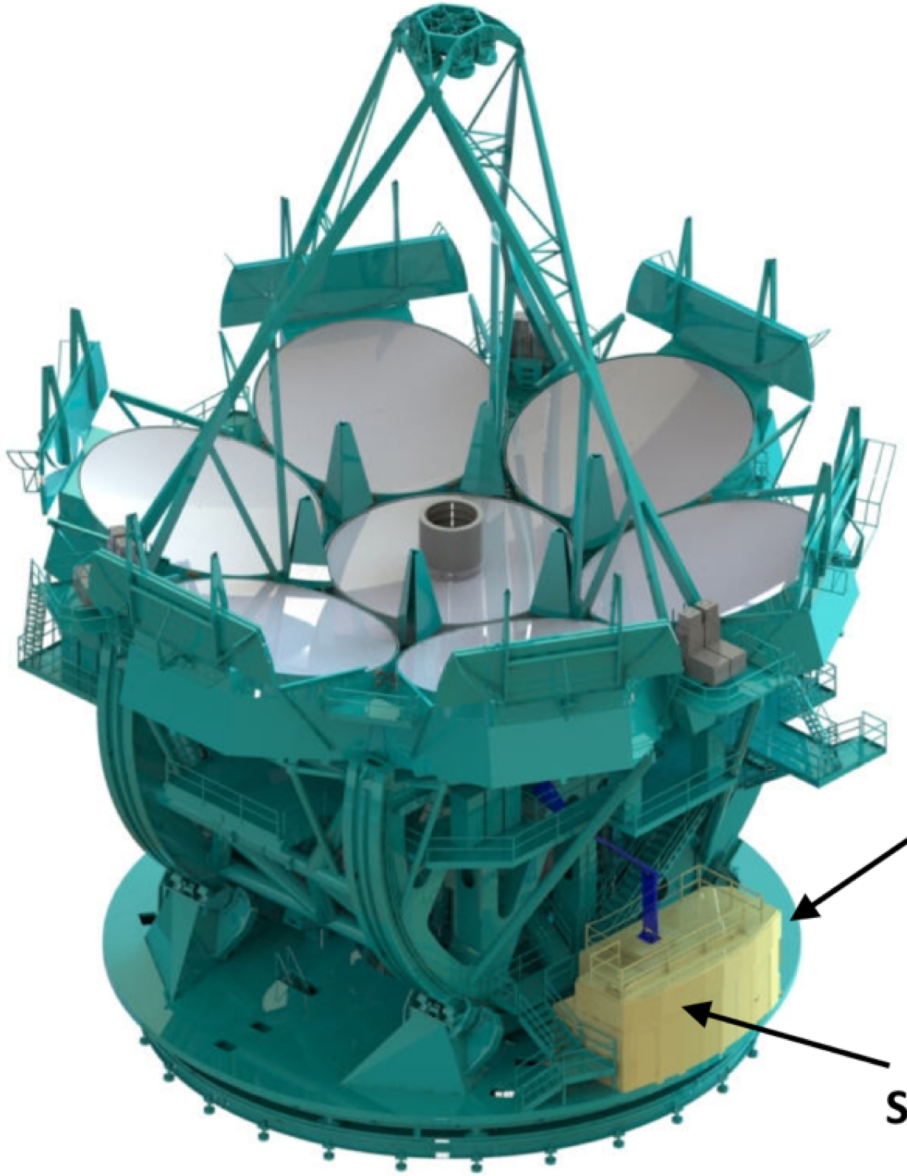
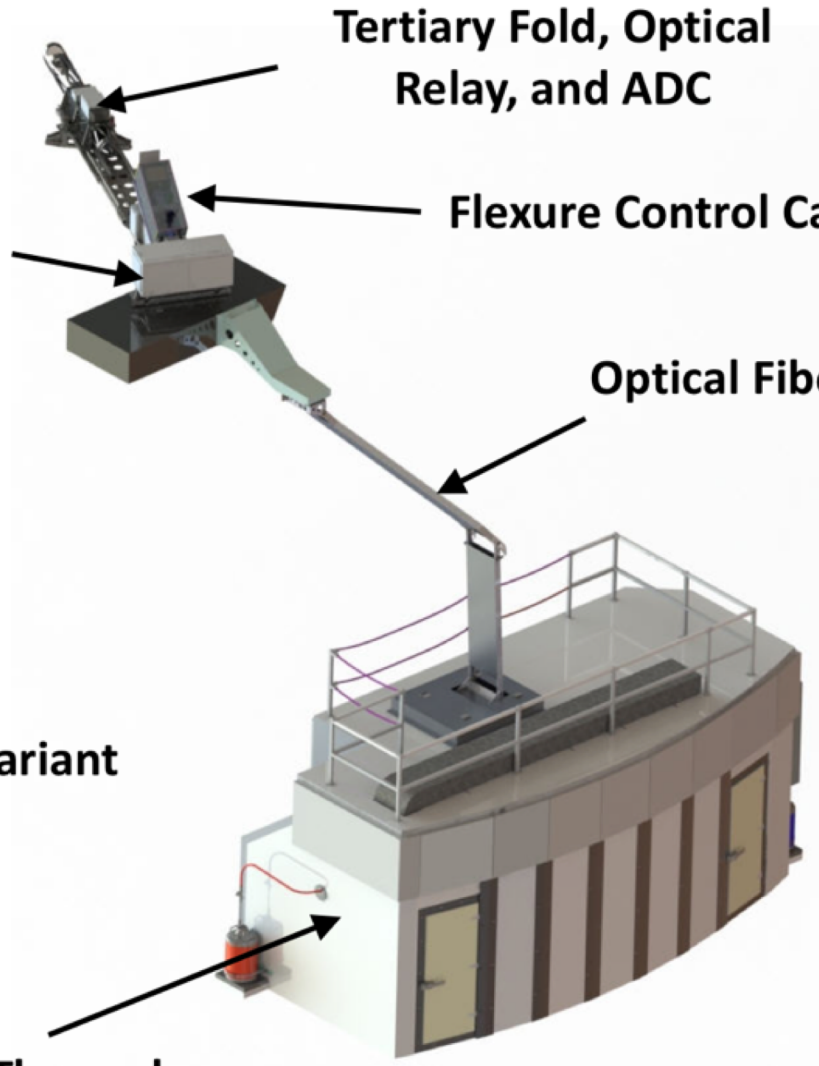
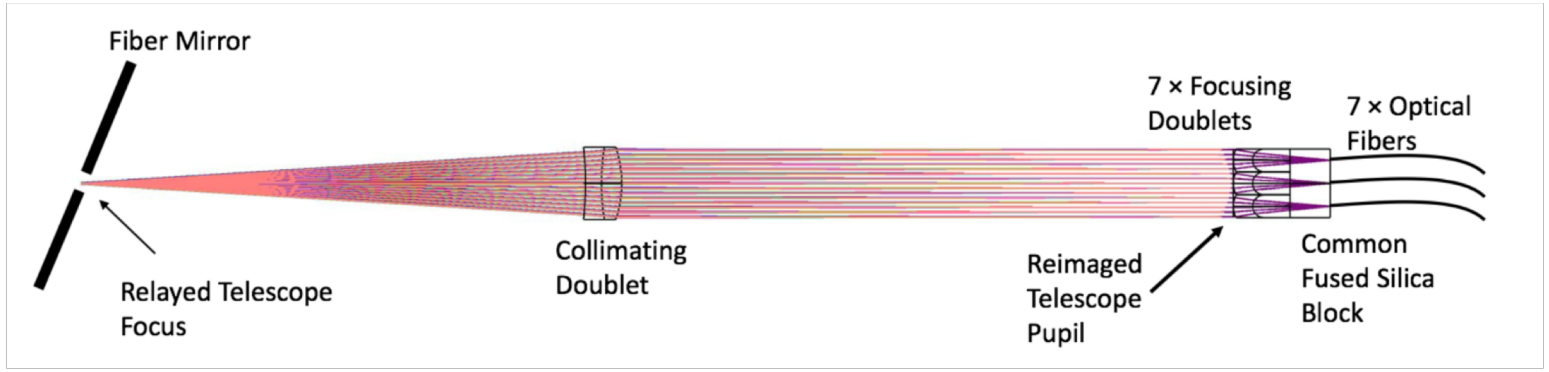
G-CLEF in Eight Slides

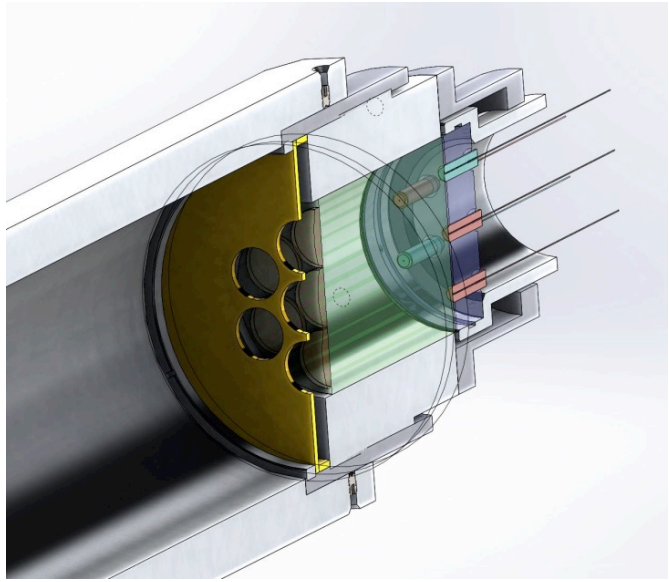
Group Portrait with G-CLEF



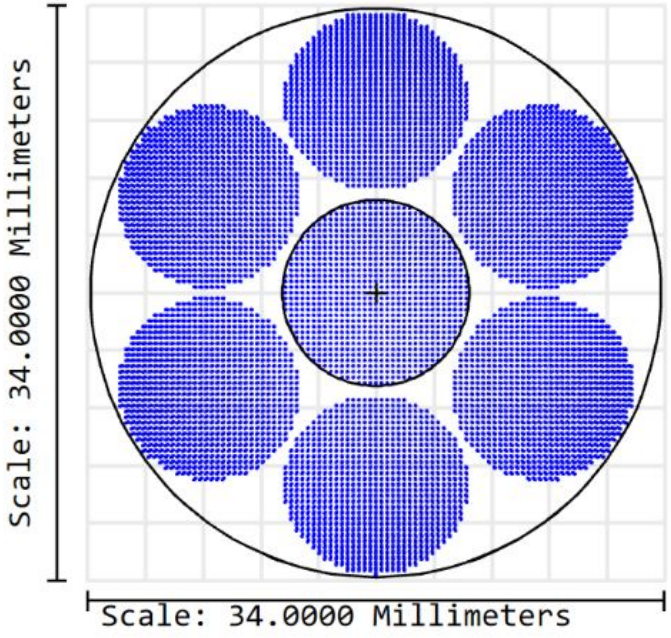


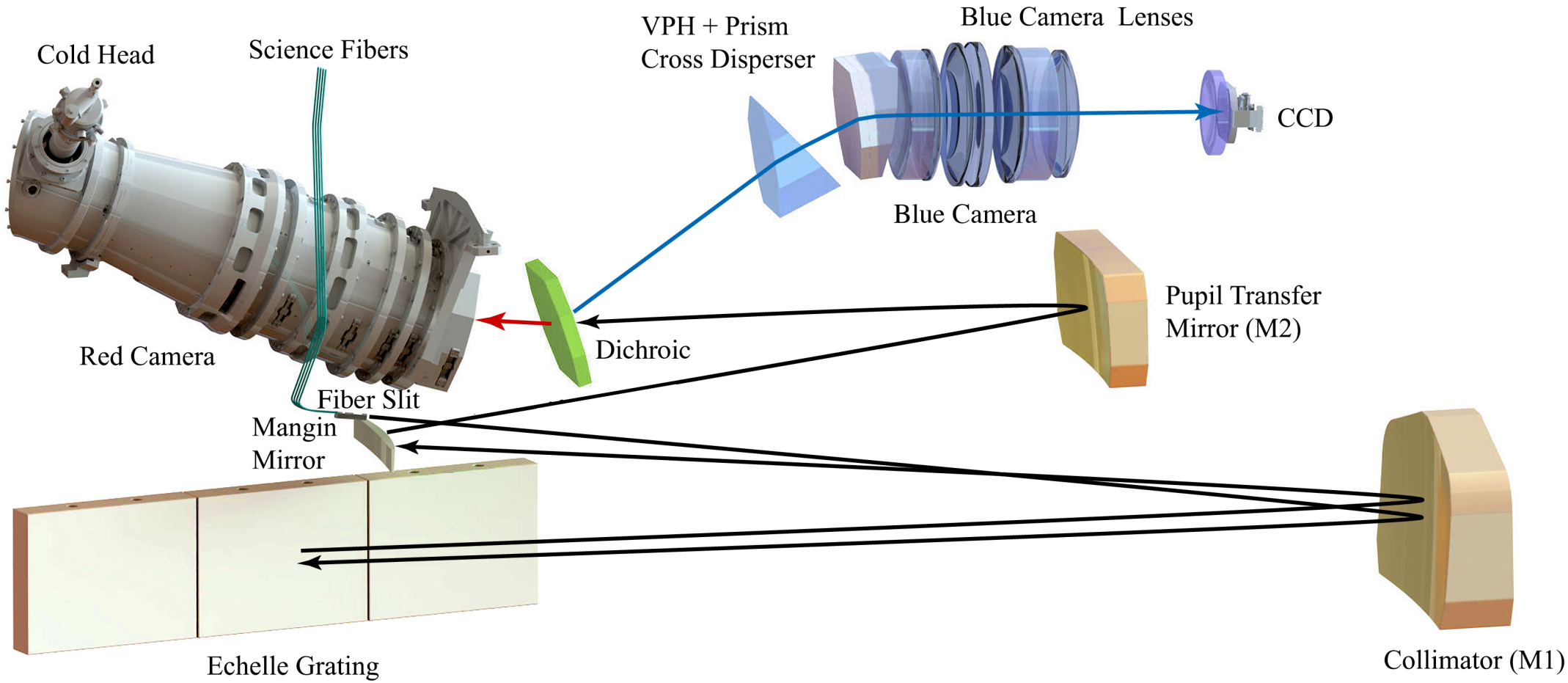

Tertiary Fold, Optical Relay, and ADC
Flexure Control Camera
Fiber Input
Optical Fiber Run
Gravity Invariant Station
Spectrograph Thermal Enclosure

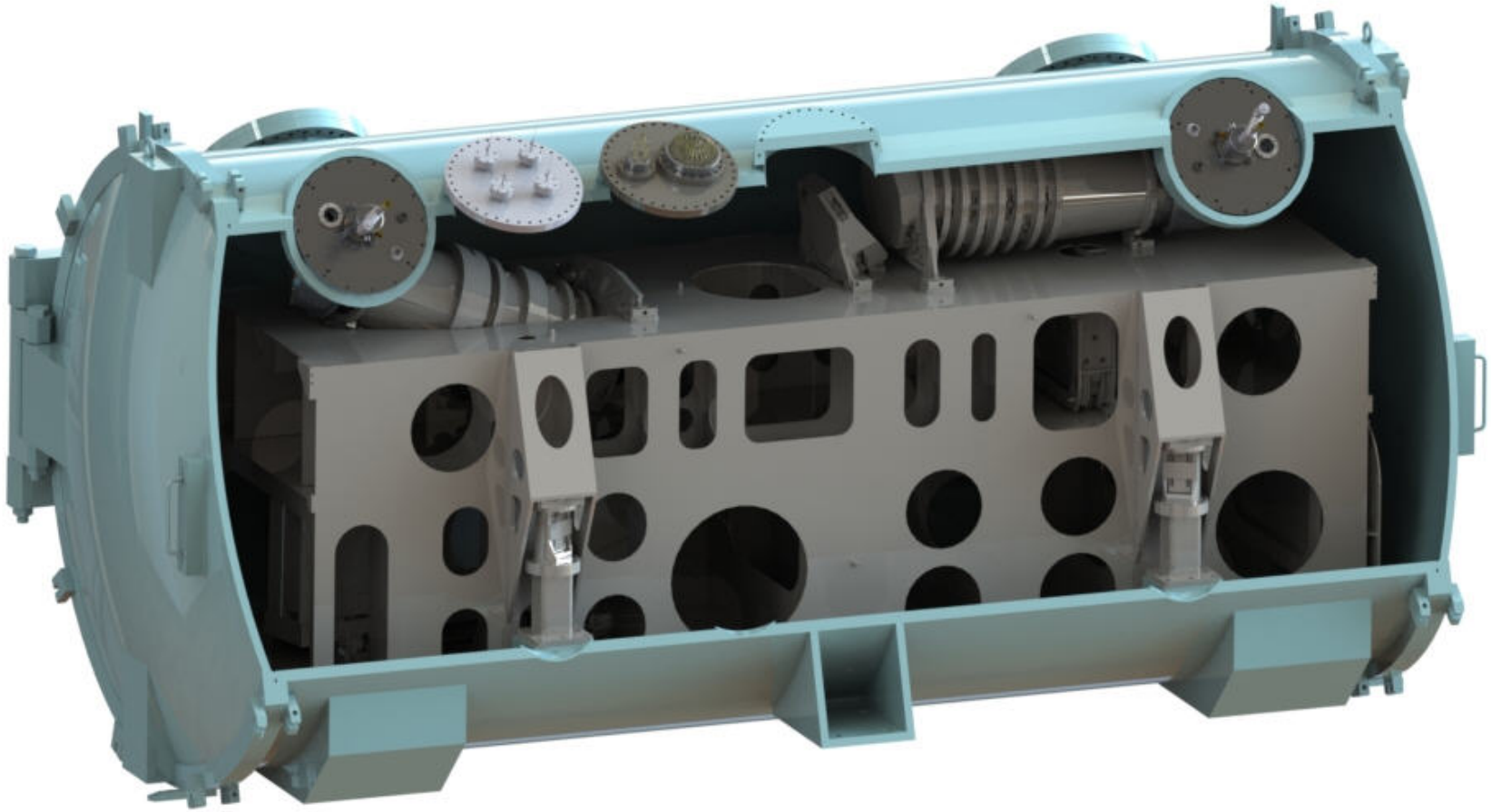




- Pupil Slicing is needed to get to R=108,000
- We treat the GMT as 7 x 8.4 m telescopes

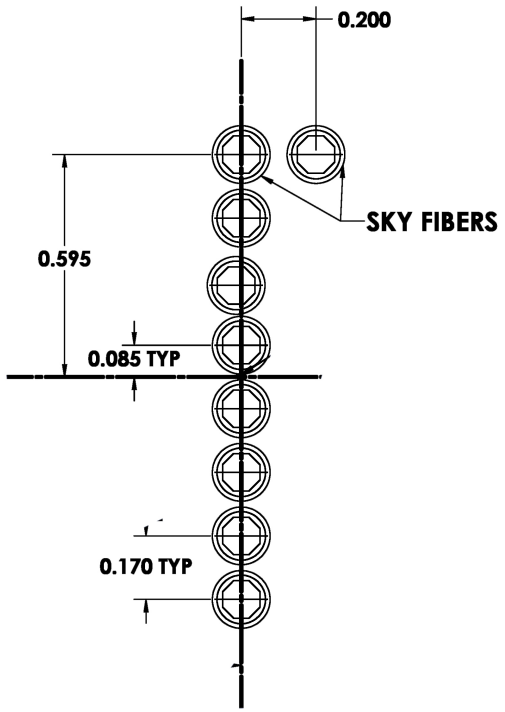



Cold Head
Science Fibers
VPH + Prism
Cross Disperser
Blue Camera Lenses
CCD
Blue Camera
Red Camera
Dichroic
Pupil Transfer
Mirror (M2)
Fiber Slit
Mangin
Mirror
Collimator (M1)
Echelle Grating



R = 108,000

PRV Mode

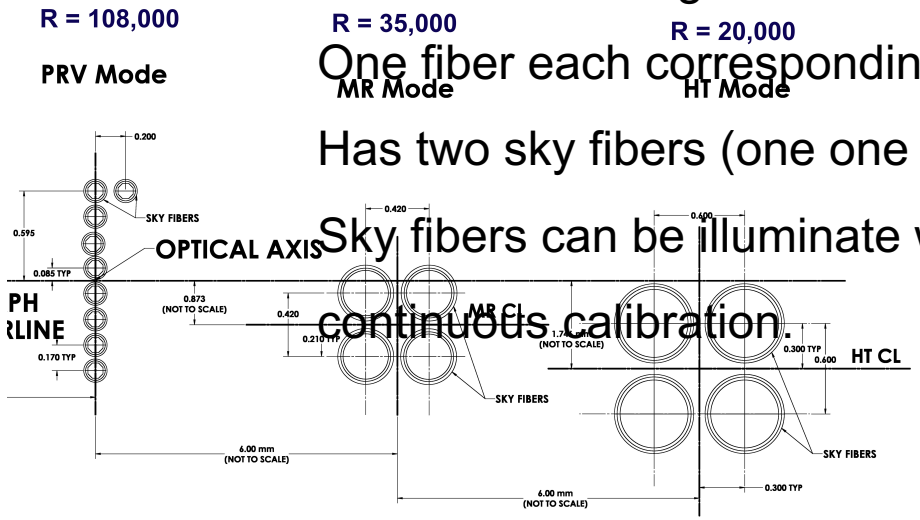


The precision radial velocity mode

R=108000

Is double scrambled

Fiber will be octagonal



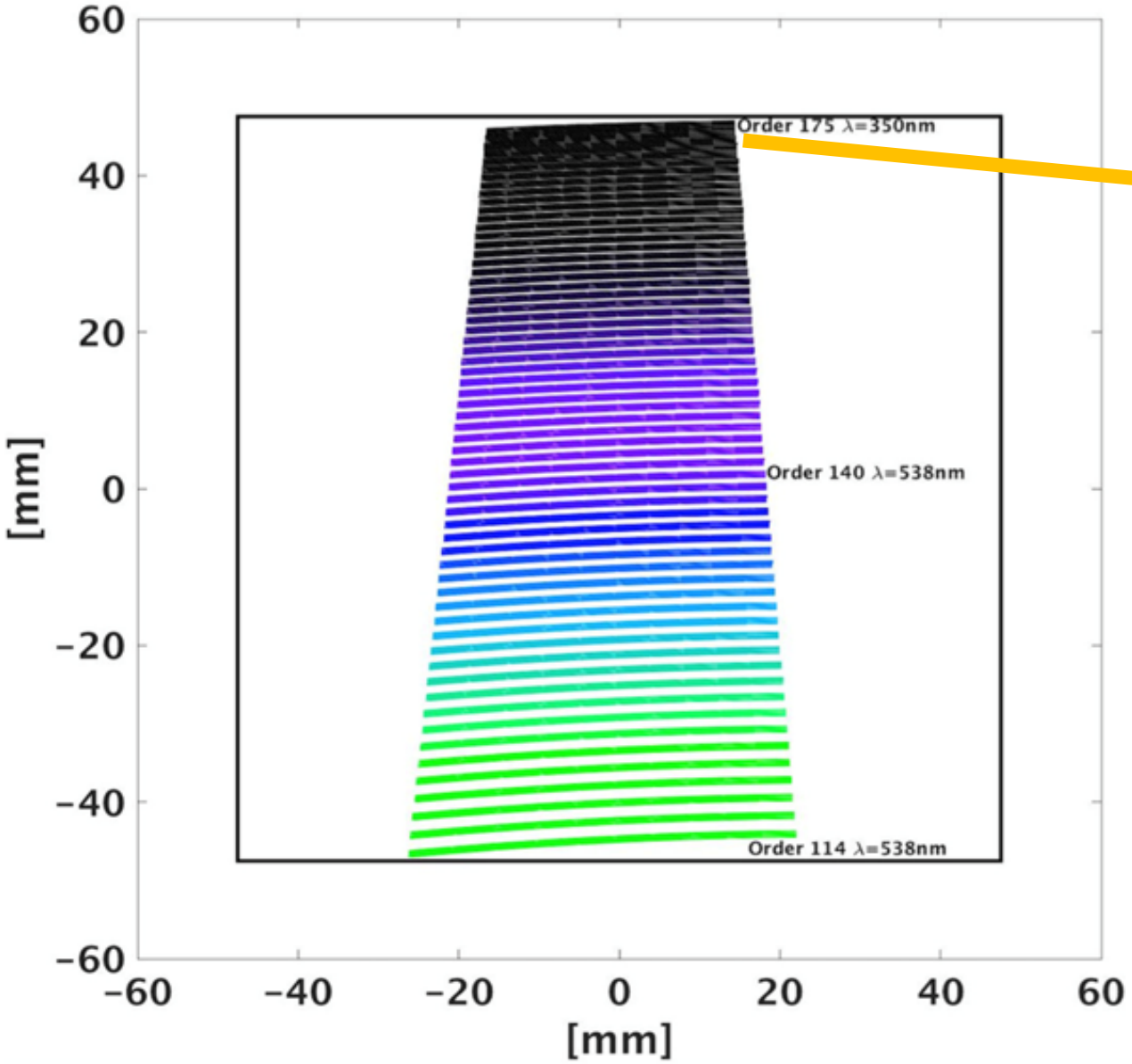
GHOST has many observing modes.

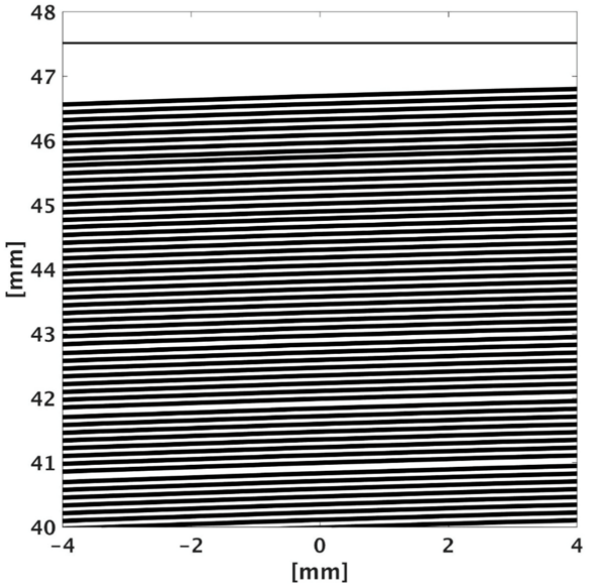
This is not all of them.

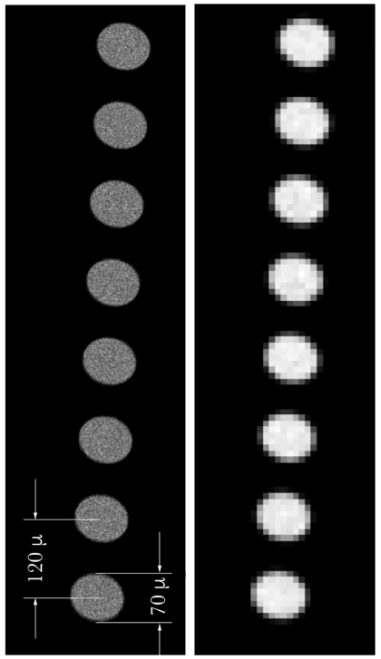
One fiber each corresponding to each primary mirror

Has two sky fibers (one one used at a time)

Sky fibers can be illuminate with calibration light for continuous calibration.


Order 175 λ=350nm
Order 140 λ=538nm
Order 114 λ=538nm
[mm]
[mm]
60
40
20
0
-20
-40
-60
-60
-40
-20
0
20
40
60


[mm]
[mm]
48
47
46
45
44
43
42
41
40
-4
-2
0
2
4


120 µ
70 µ

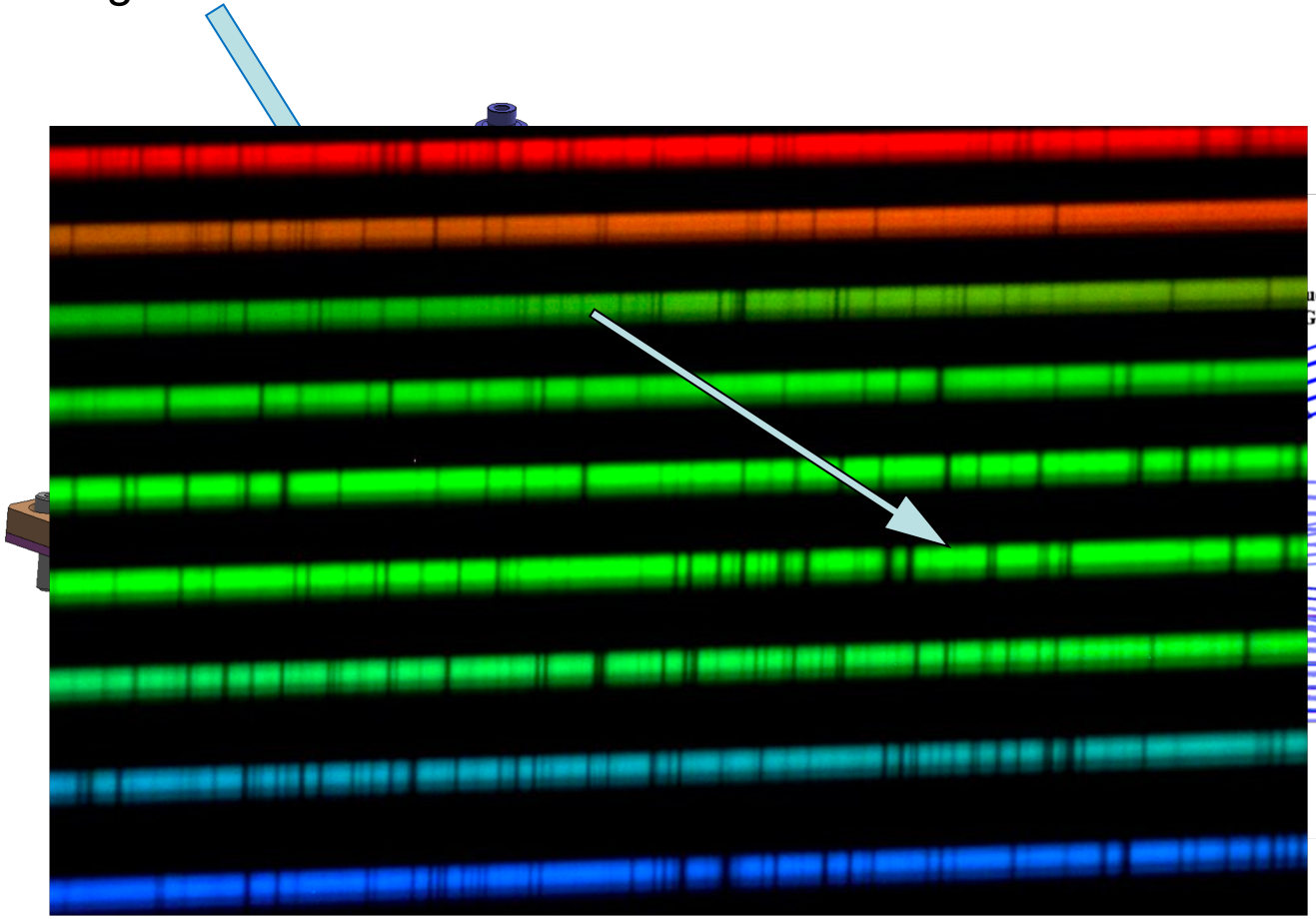
G-CLEF is the first major instrument for the GMT

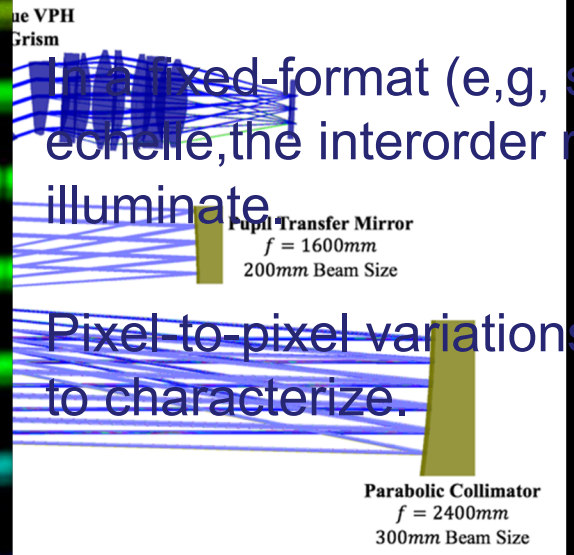
First light is in 2028

The Spectrograph passed CDR Dec 2018

Some Innovations in the G-CLEF Design

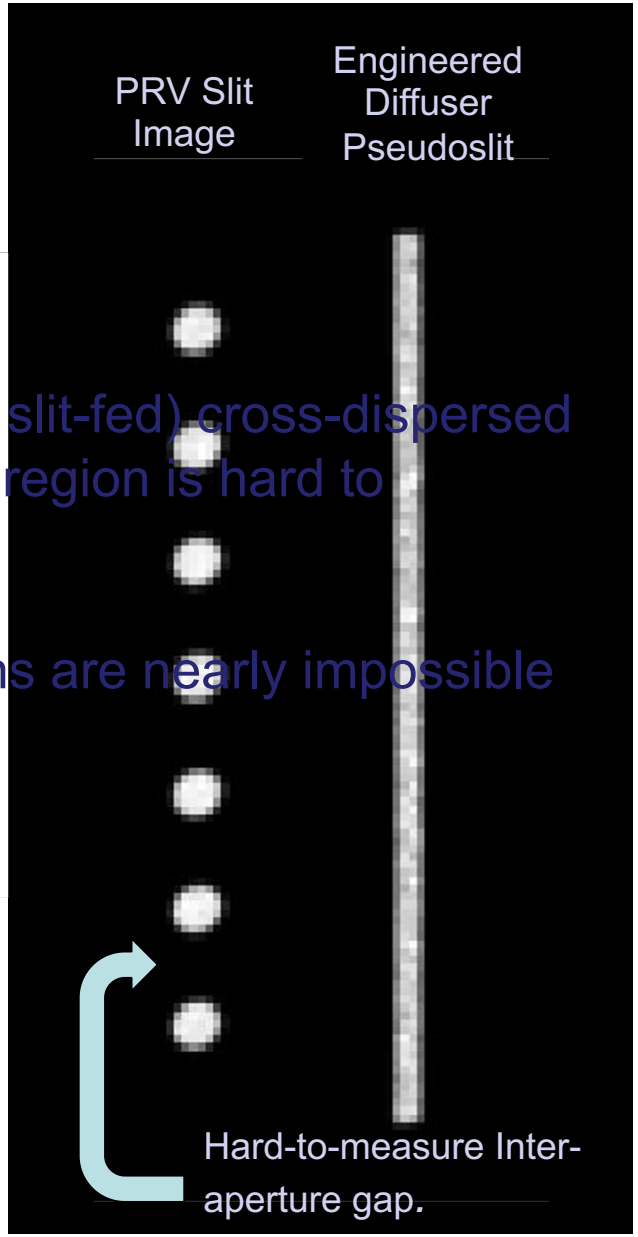
Engineered diffuser

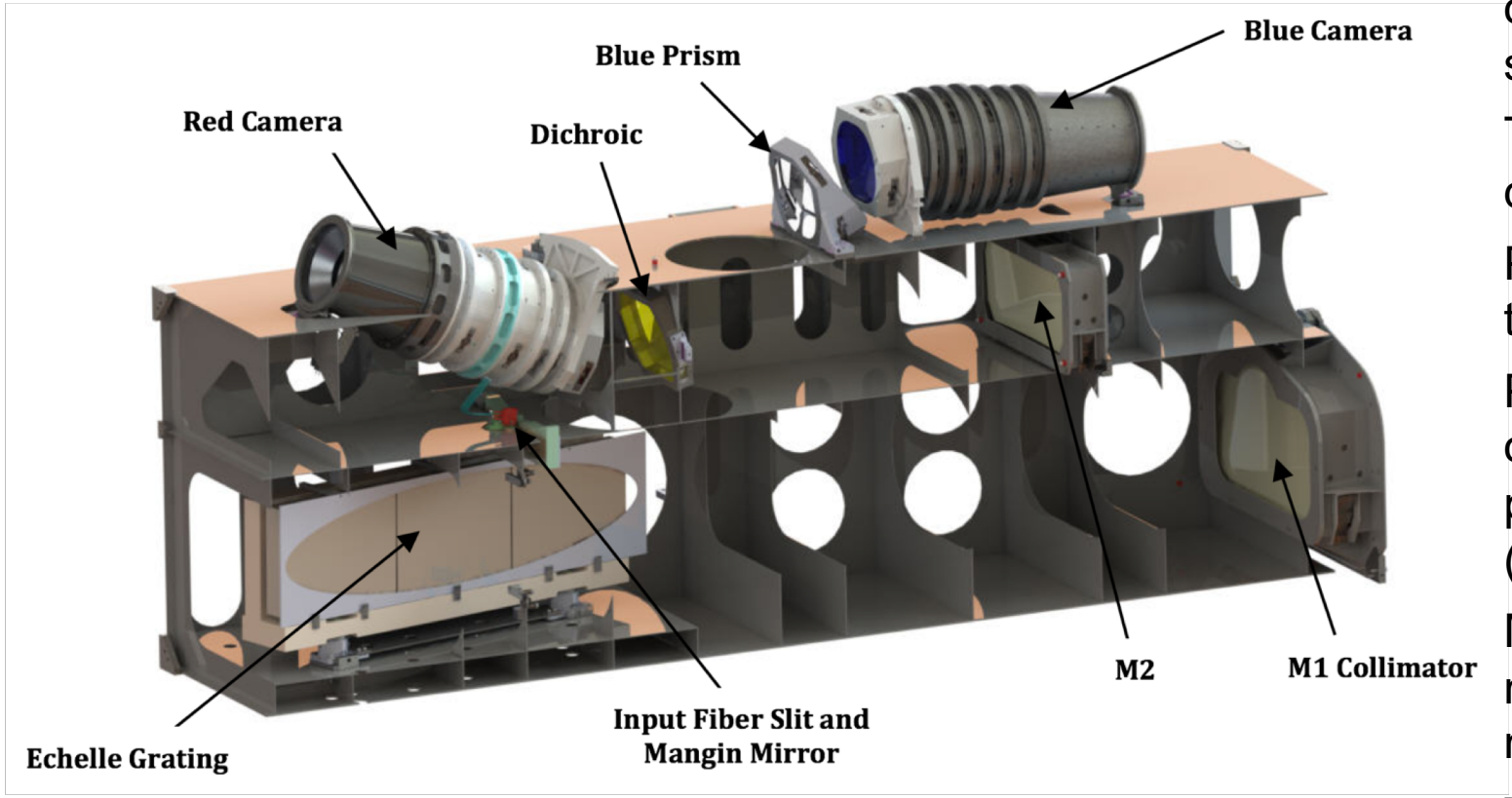




In a fixed-format (e,g, slit-fed) cross-dispersed echelle,the interorder region is hard to illuminate.

Pixel-to-pixel variations are nearly impossible to characterize.





The mechanical stability of the spectrograph optics is paramount for a stable wavelength scale.

Time-varying thermal gradients flex and distort the the position and shape of optics.

Plan A: Keep the optomechanics, especially the optical bench thermally stable.

Plan B: Make everything, especially the optical bench out of material with the lowest possible coefficient of thermal expansion (CTE) material possible.

Most previous optical benchs were made of mild steel - cheap, easy to manufacture, moderate CTE.

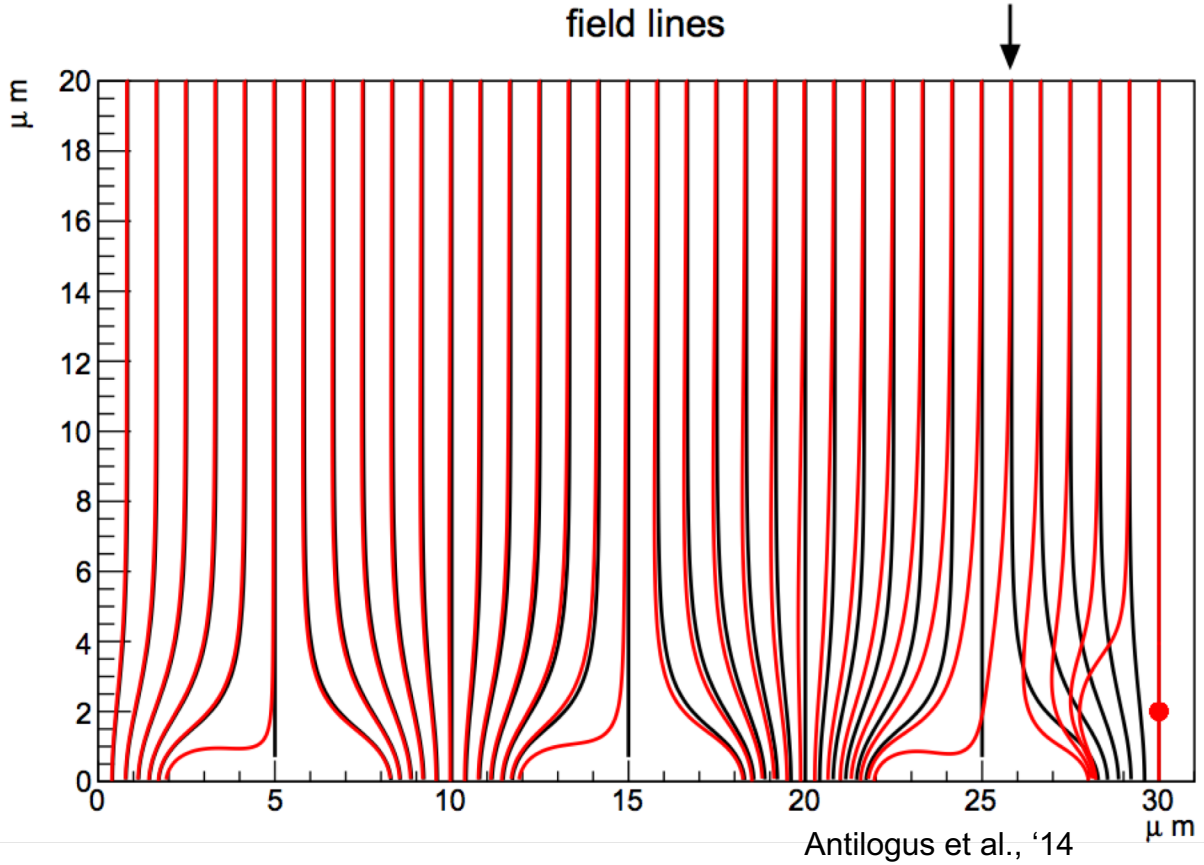
The G-CLEF bench will be made out of Carbon Reinforced Fiber Polymer* (CFRP) – expensive, tricky to fabricate, among the lowest CTE structural materials available.

*An organic material.

An Example of Issues That Wake a Priincipal Investigator Up at 3 am.*

*With Heartburn.

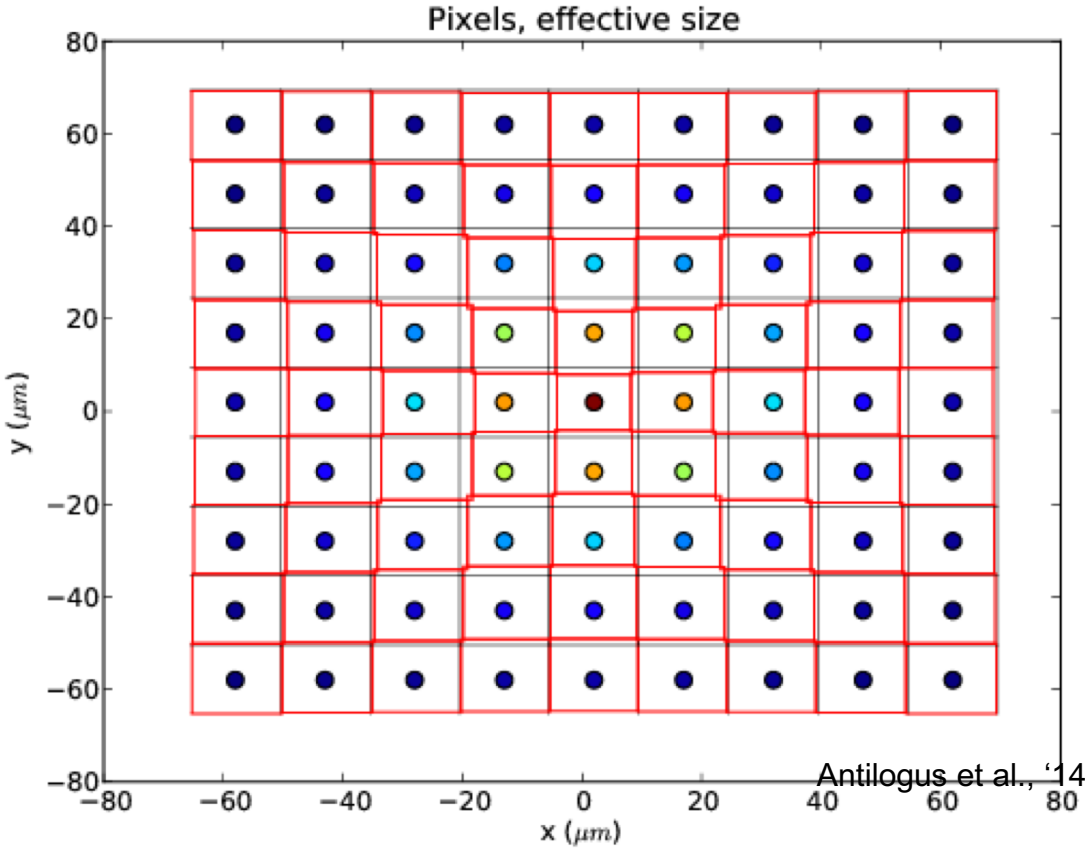
The field structure defining a pixel is distorted by the charge it contains.
More charge → More distortion.



Antilogus et al., '14

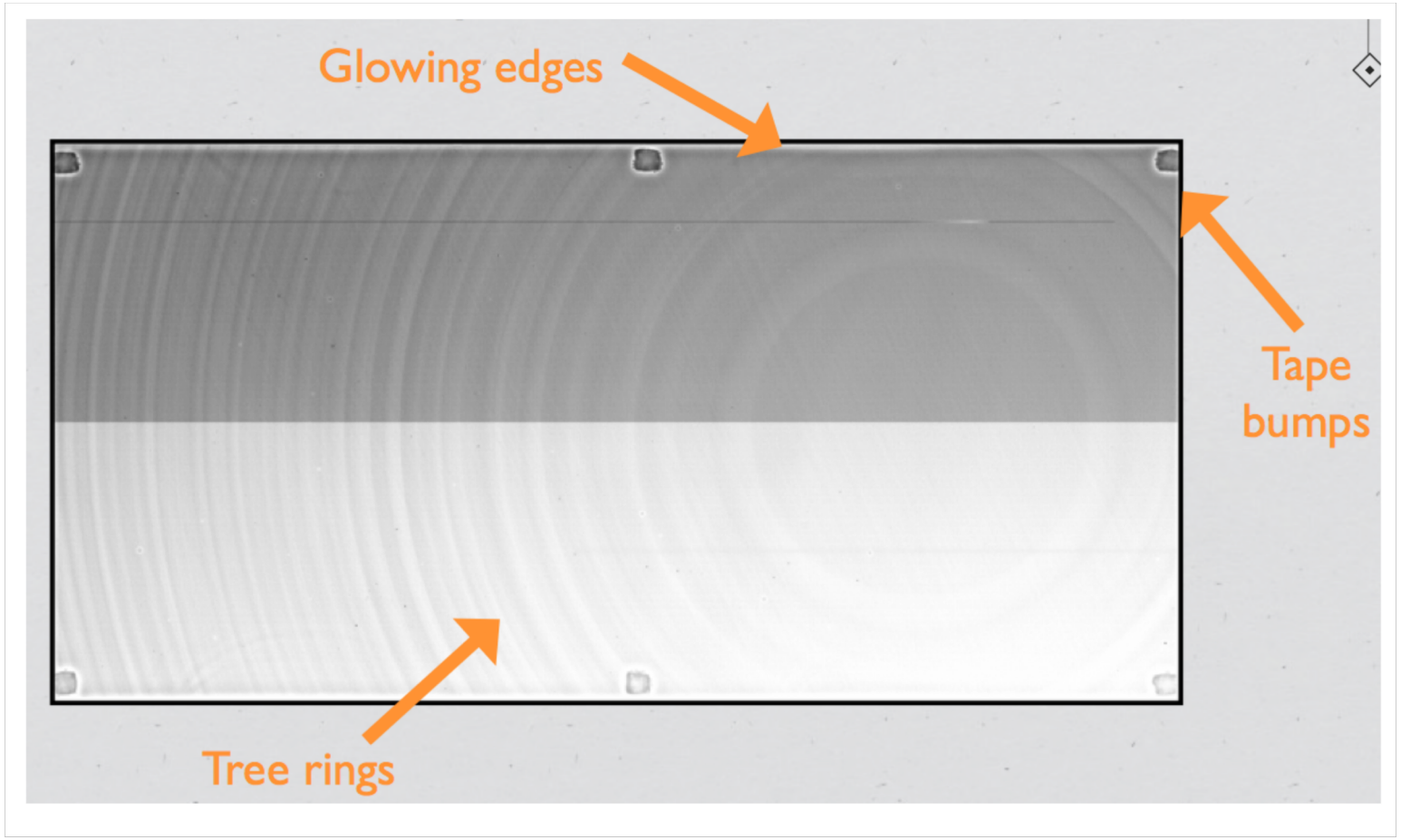
Simulation of field structure in E2V CCD 250
Red field lines: charge present
Black field lines: no charge present

Fuller pixels are physically smaller.
Fuller pixels appear bigger.



Antilogus et al., '14

Bluer – Less full Redder – more full

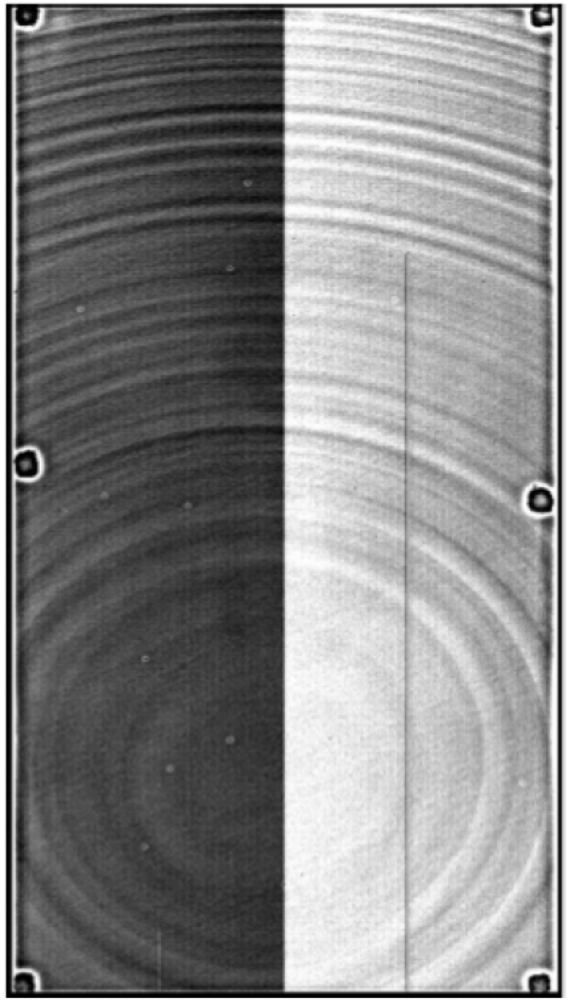


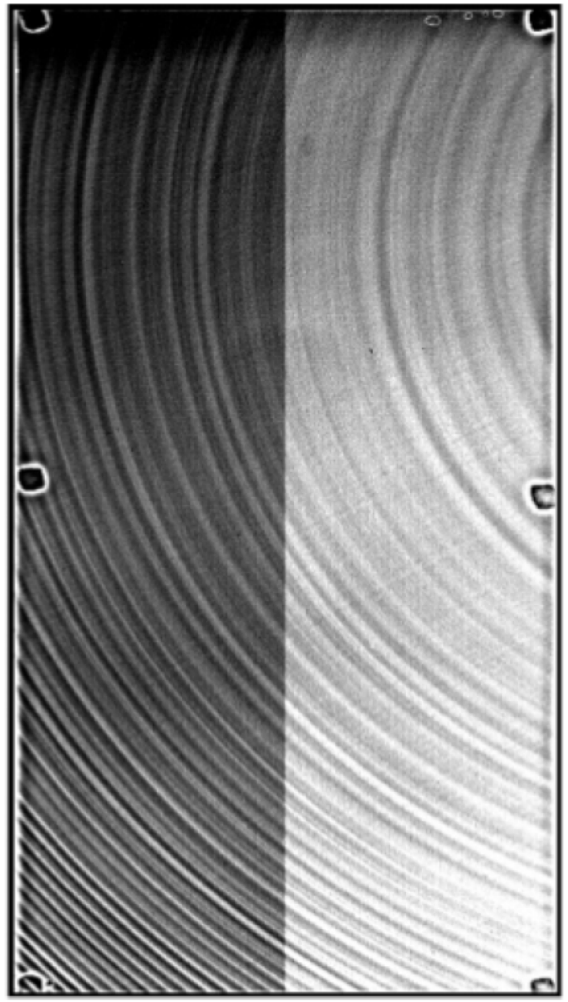
Electric fields in CCD are inhomogeneous and anisotropic due to:

- “Tree Rings” due to imperfect doping of the silicon boule wafers are diced from.
- “Glowing edges” due to larger field structures at CCD periphery.
- Tape bumps due to attachment technology for back-side (thinned) CCDs.

Electric field anisotropies distort the pixel grid.

These distortions are not regular or easily characterized.





Plazas et al., ‘13

Calibration is Done with Emission Features, Data is in Absorption