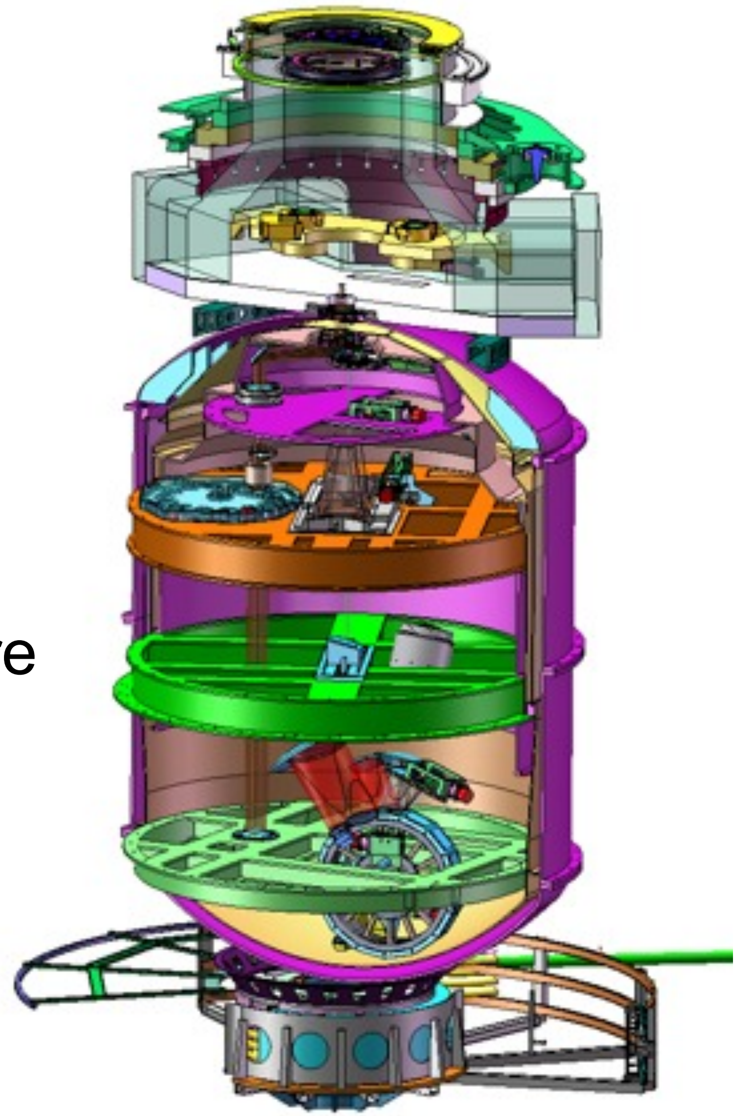
IRIS Status

James (詹姆斯) Larkin / Anna Moore
and over 50 collaborators

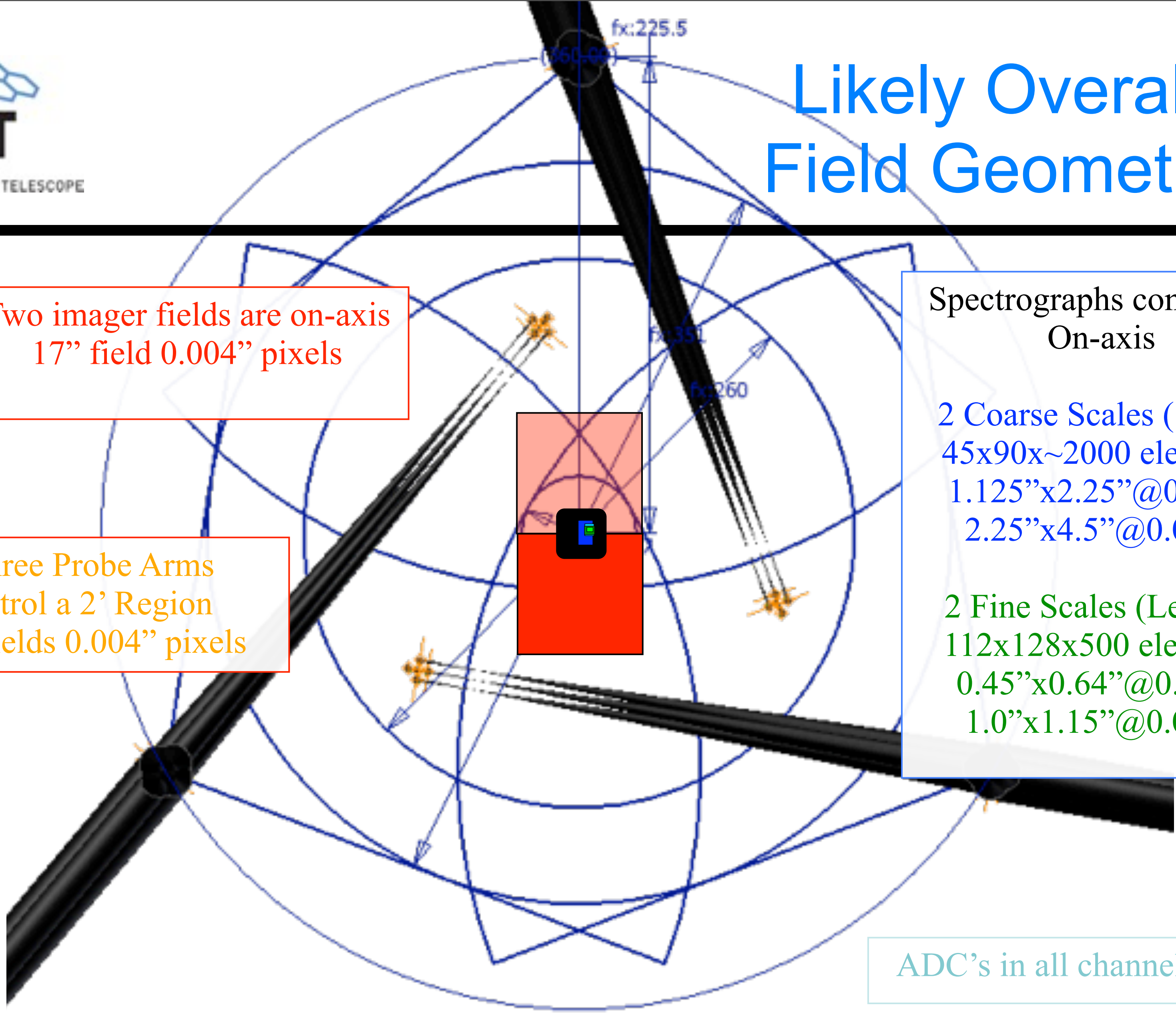


IRIS
(InfraRed Imaging Spectrograph)

- Diffraction limited integral field spectrograph and imager to work with NFIRAOS.
  - Wavelength Range 0.84-2.4 microns (based on Hawaii-4RG detectors)
  - Excellent image quality: Wavefront Error < 30 nm for fine scales
- On-Instrument deployable wavefront sensors (OIWFS)
  - Three sensors (one including focus) to measure tip/tilt, focus and distortion across field.
  - Near infrared to gain from NFIRAOS AO correction (works through K-short)
- Spectrograph
  - Spectral Resolution > 4000 (higher resolutions for limited cases)
  - IFS with Four Plate Scales (0.004, 0.009, 0.025, 0.050 arcsec per sample)
- Imager (probably 2 adjacent fields)
  - 16.4 arcsec field of view each (so likely 16.4”x32.8” field of view)
  - 0.004 arcsec plate scale
  - Pupil viewing mode

TMT
THIRTY METER TELESCOPE

Likely Overall Field Geometry



Two imager fields are on-axis
17” field 0.004” pixels

Three Probe Arms
Patrol a 2’ Region
4” Fields 0.004” pixels

Spectrographs concentric
On-axis

2 Coarse Scales (Slicer)
45x90x~2000 elements
1.125”x2.25”@0.025”
2.25”x4.5”@0.050”

2 Fine Scales (Lenslet)
112x128x500 elements
0.45”x0.64”@0.004”
1.0”x1.15”@0.009”

ADC’s in all channels

IRIS is versatile and covers a broad range of science cases

- Solar system
- Extrasolar planets
- Stellar structure & evolution (Microlensing)
- Star formation
- Galactic Center
- Nearby galaxies and stellar populations
- Supermassive black holes
- High-redshift galaxies
- First light galaxies

IRIS Technical Team

- James Larkin (UCLA), PI, Lenslet IFS
- Anna Moore (COO), co-PI, Slicer IFS
- Ryuji Suzuki (NAOJ), Imager Lead
- David Loop (HIA), PM, OIWFS
- Engineers at COO, HIA, UCLA, UCSC, TMT
  - Systems – Les Saddlemyer (HIA), Tony Travouillon (TMT)
  - Mechanical - Alex Delacroix (COO), Eric Wang, John Canfield (UCLA), Vlad Reshetov (HIA)
  - Optical - Drew Phillips(UCSC Faculty), Brian Bauman (UCSC), Murray Fletcher, John Pazder, Jenny Atwood (HIA)
  - Software – Jennifer Dunn, Bob Wooff (HIA), Jason Weiss, Chris Johnson (UCLA), David Hale (COO)
  - Detectors – Roger Smith (COO)
  - Electrical – Kris Caputa (HIA), Ken Magnone (UCLA)
- Strong heritage;
  - UCLA (OSIRIS, MOSFIRE, NIRC2, GPI)
  - COO (NIRC2, MOSFIRE, CWI)
  - NAOJ (MOIRCS, HiCIAO)
  - HIA (GMOS, Altair, GPI, NFIRAOS)
  - UCSC (MOSFIRE, GPI, DEIMOS)

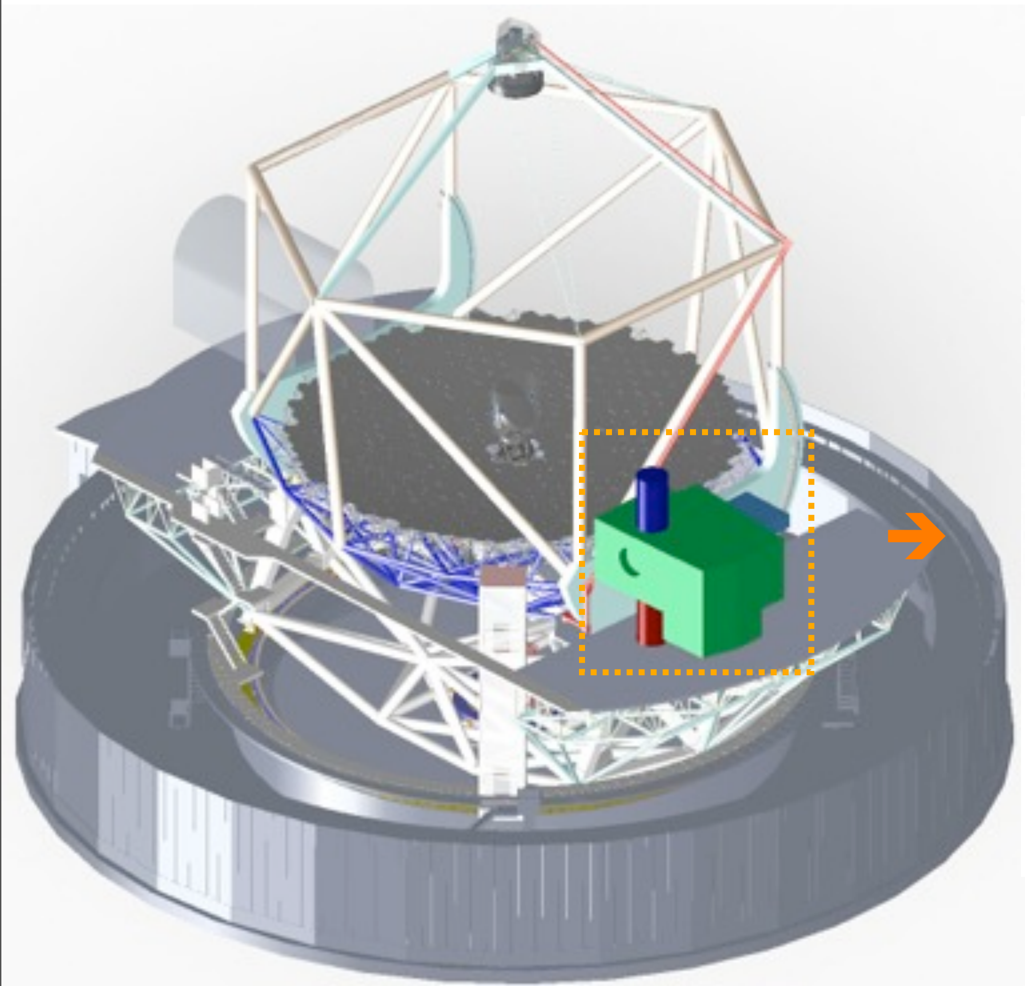
Luc Simard, David Crampton
TMT Instrumentation management

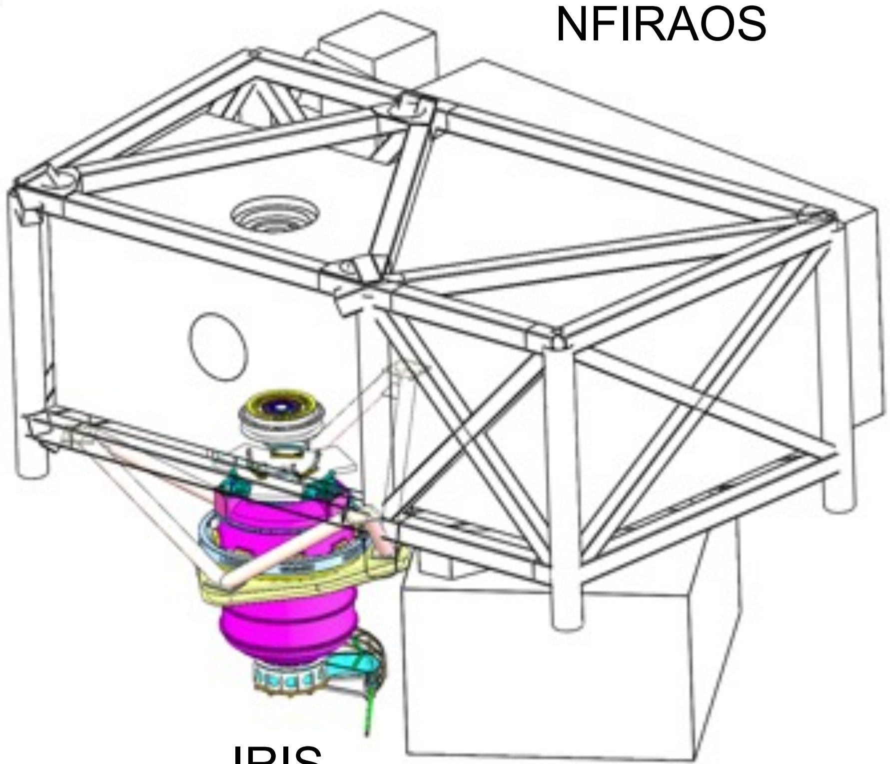
IRIS Science Team Members

12 Institutions (USA, Canada, Japan, China, Australia)

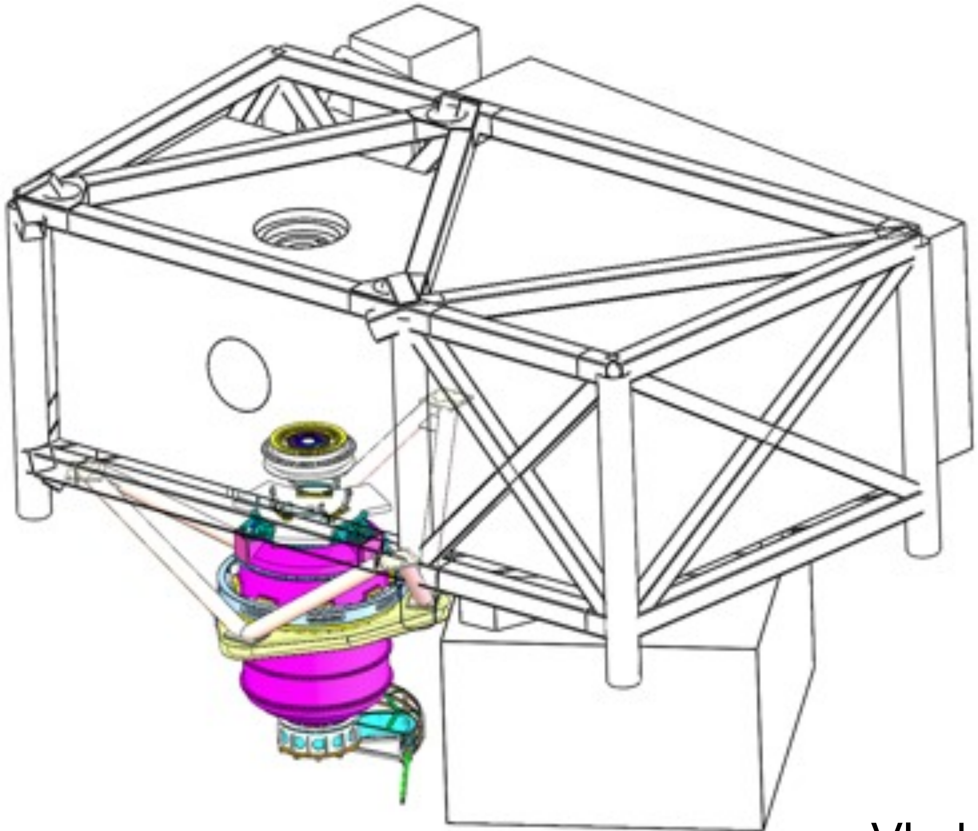
- Maté Adamkovics, Berkeley
- Lee Armus, IPAC
- Aaron Barth, UCI
- Joshua Bloom, Berkeley
- Will Clarkson, Indiana
- Jeff Cooke, Swinburne
- Pat Coté, HIA
- Tim Davidge, HIA
- Tuan Do, UCI
- Andrea Ghez, UCLA
- Miwa Goto, MPIA
- Nobunari Kashikawa, NAOJ
- Shri Kulkarni, Caltech
- David Law, Toronto
- Michael Liu, U Hawaii
- Jessica Lu, U Hawaii
- Bruce Macintosh, LLNL
- Shude Mao, NAOC
- Christian Marois, HIA
- Hajime Sugai, Kyoto
- Jonathan Tan, Florida
- **Shelley Wright (PS), Toronto**
- Tommaso Treu, UCSB
- Tomonori Usada, NAOJ

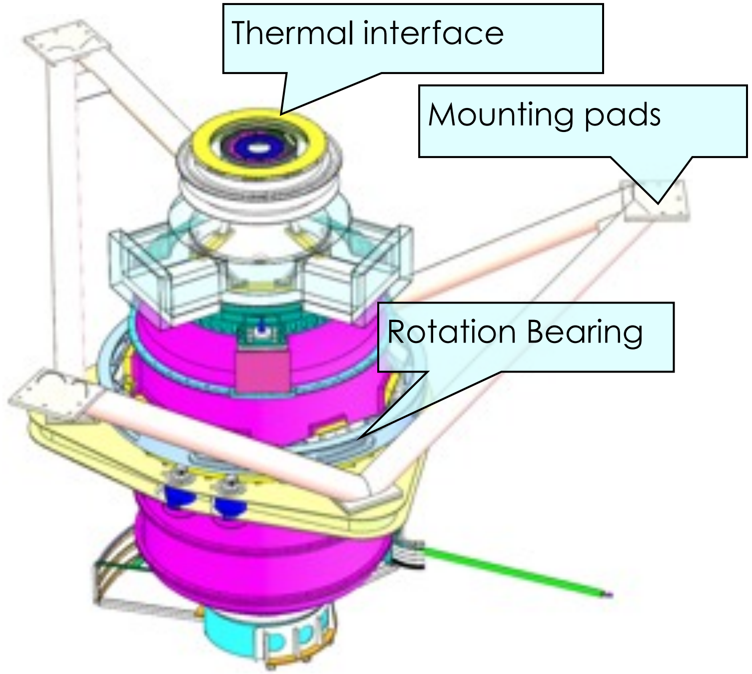
IRIS on TMT





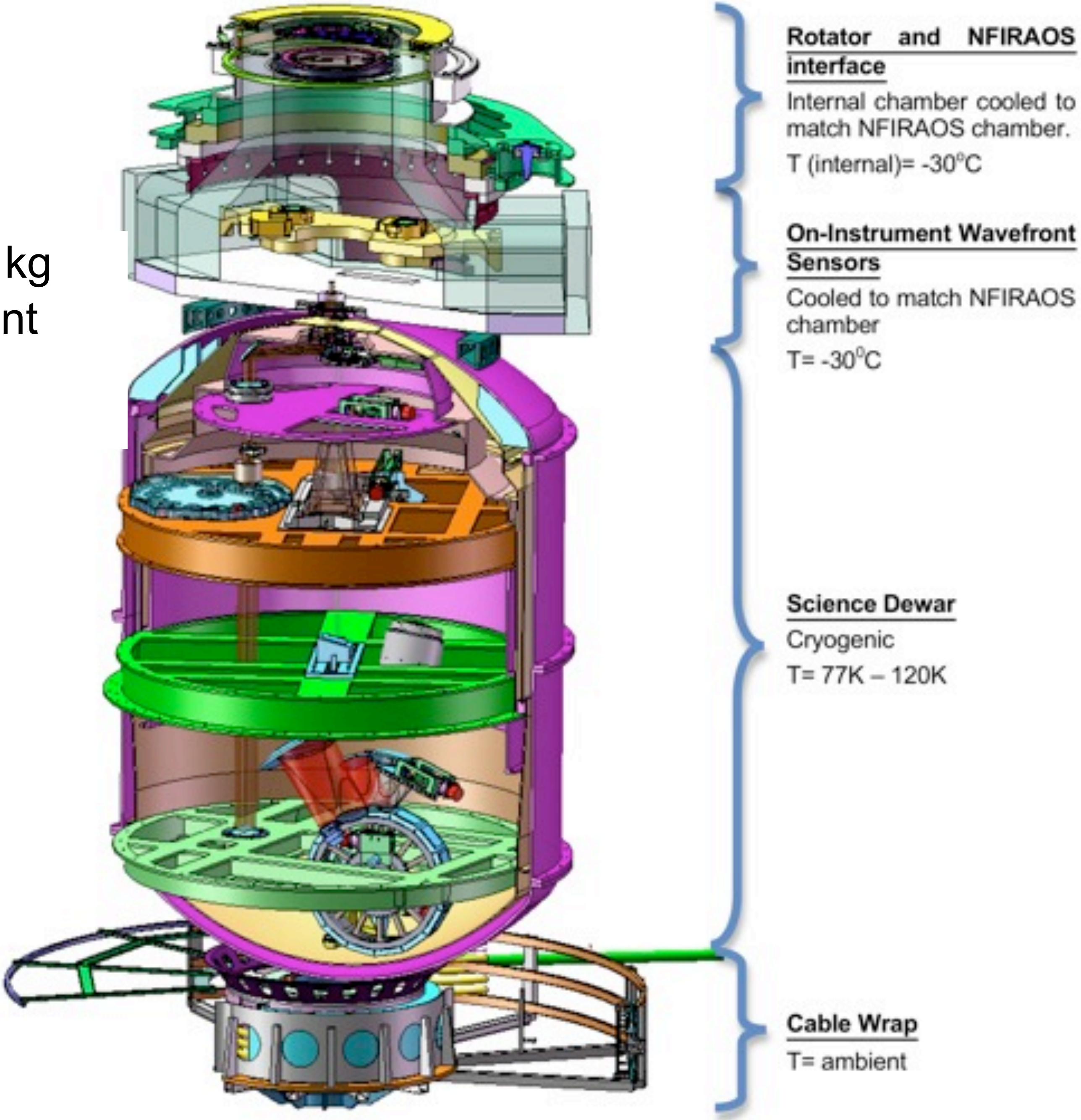
POSITION OF IRIS RELATIVE TO NFIRAOS





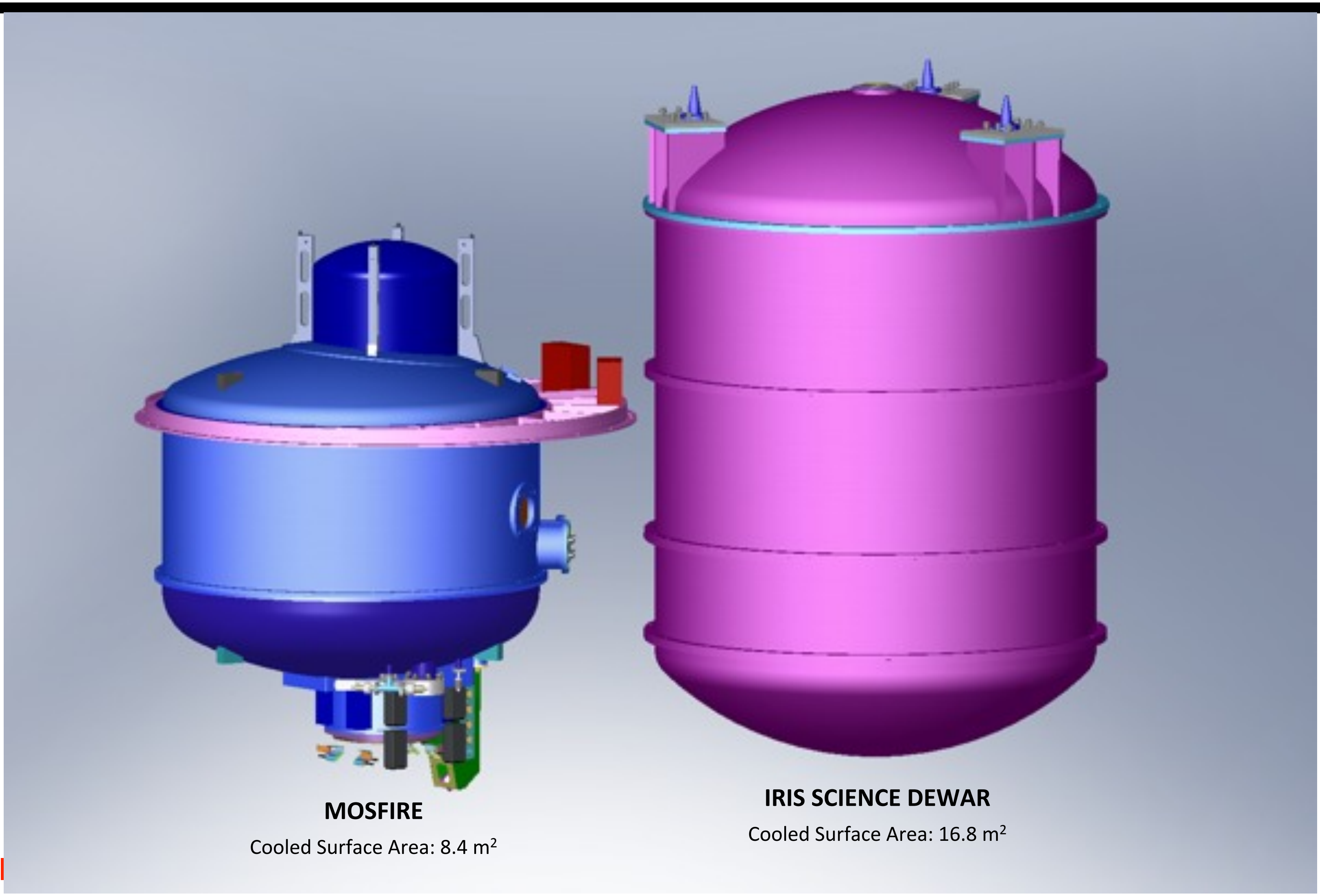
Vlad Reshetov - External Design

- Total mass: 6300 kg
  - Includes Mount
- Height ~4m



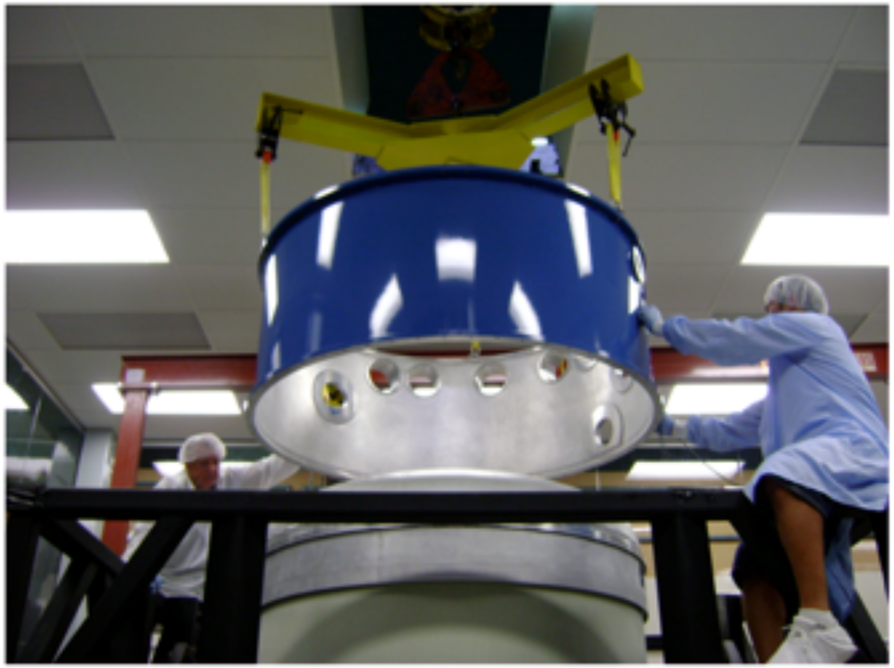
July 23, 2013

COMPARISON WITH MOSFIRE (IRMS)
But IRIS has fixed gravity orientation



Jul

MOSFIRE Dewar Assembly



- An excellent collaboration between UCLA, Caltech, UCSC, Keck Observatory and international industry.
- Dewar has about ½ IRIS volume and many comparable challenges. On sky in 2012, performing very well.

Big Dewars (MOSFIRE)

History of IRIS development

- CELT – In some ways IRIS started around 1998
  - Discussion of deployable IFU's in 2000
- Feasibility Study – co-led: Larkin, Taylor
  - IRIS contract started in March 2005 (UCLA, Caltech) one month after first light with OSIRIS (Similar instrument for Keck)
  - Competition and Collaboration
  - Tim Davidge served as Project Scientist
  - Successful Review March 7, 2006


OSIRIS – First light Feb 2005

- Chief concerns in 2006 – no design for OIWFS, Instrument rotation, mounting, or ADC and no decision on slicer or lenslet (both had advantageous)

History of IRIS development

- TMT - Conceptual design phase started in May, 2008
  - Proposed Hybrid model combining a slicer and a lenslet array
  - Anna Moore took over lead on slicer and co-lead role
  - Ryuji Suzuki (NAOJ) joined as lead of the Imager
  - Betsy Barton (UCI) became new Project Scientist
  - Dave Loop (HIA) served as Project Manager
  - HIA led design of On Instrument Wavefront Sensors, Dewar mount and rotation.
  - Drew Philips (UCSC) led ADC design.
  - New team included UCLA, Caltech, HIA, NAOJ, UCSC and UCI…
  - Emphasis on maturing all aspects, but focused on issues not addressed by Feasibility study.

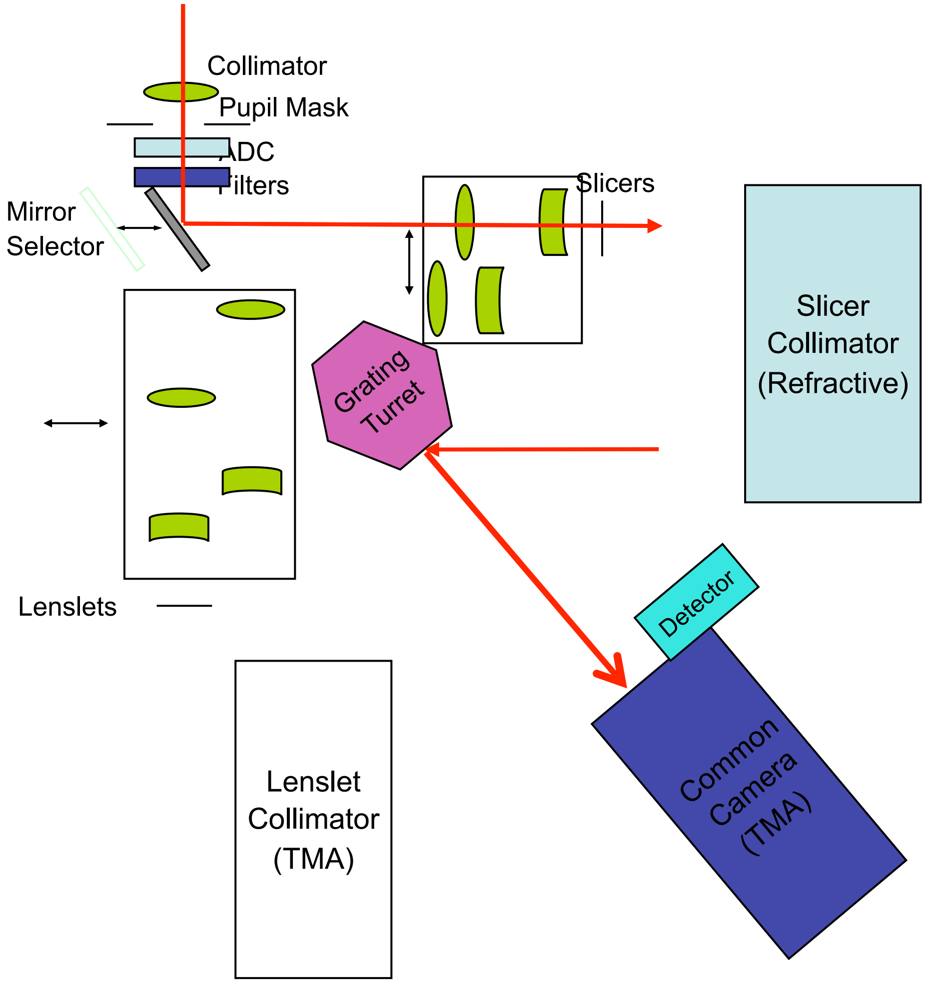
IRIS is one spectrograph with two slicing techniques

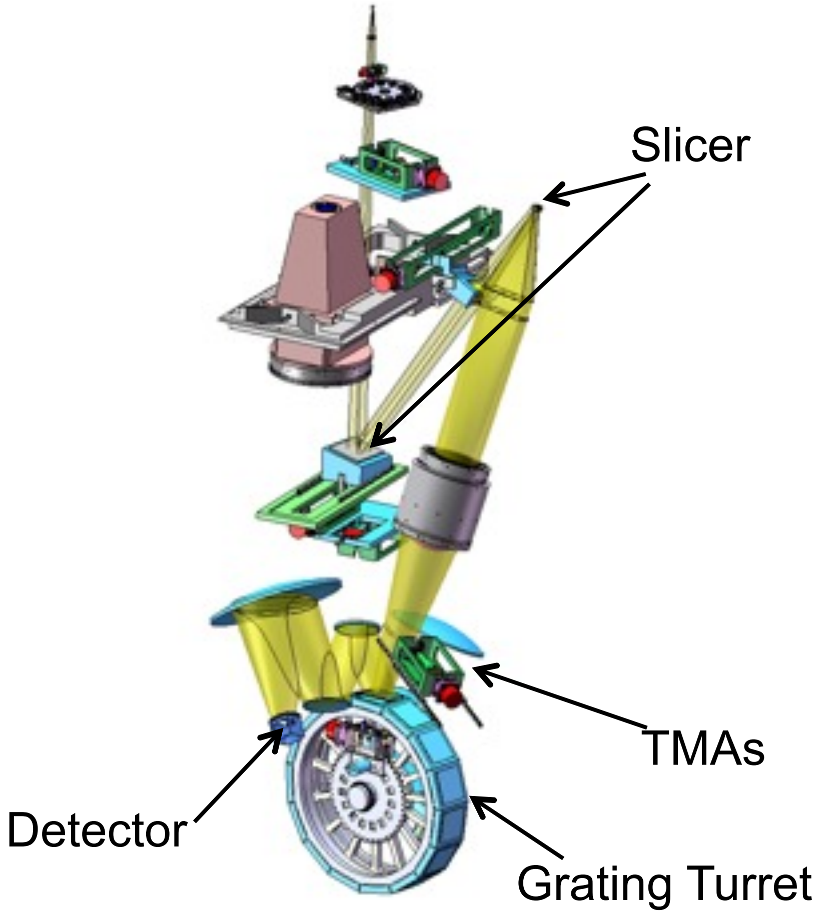
- Lenslet arrays (e.g. OSIRIS, GPI) are excellent for finest plate scales
  - Easy to expand spatially to >100x100 to sample most of the PSF even at 4 mas scale.
  - Intrinsically low wavefront error since lenslets sample image plane.
    - OSIRIS has undetectable image degradation at ~25 nm rms WFE
    - GPI selected lenslets and existing camera has <25 nm of WFE.
- Slicer IFUs (e.g. SINFONI, NIFS) are excellent for coarser plate scales
  - Easy to expand wavelength coverage once sufficiently large field is achieved in coarse scales.

IRIS is one spectrograph with two slicing techniques

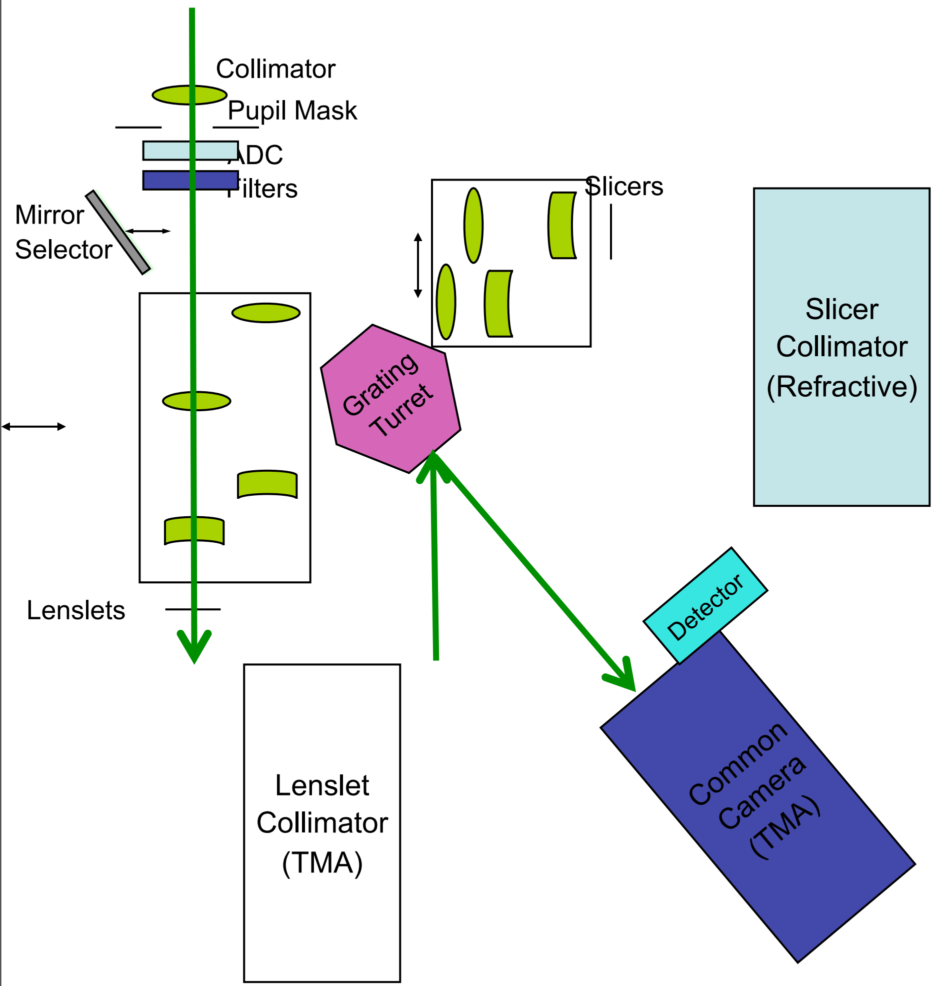
- Either technique has compromises when you attempt to cover all scales, fields of view and bandpasses.
  - Example: Factor of 12.5 in plate scale requires roughly factor of 12.5 in focal ratios to the detector and similar changes in footprint on grating and similar changes to reimaging optics.
- As planned in IRIS, both have a camera focal ratio at the detector of F/4.
  - And this is then only changed by a factor of two in spectrograph focal ratios between all four scales.
- All four scales share filters, atmospheric dispersion corrector, tracked cold pupil, gratings and camera optics to the H4RG detector.

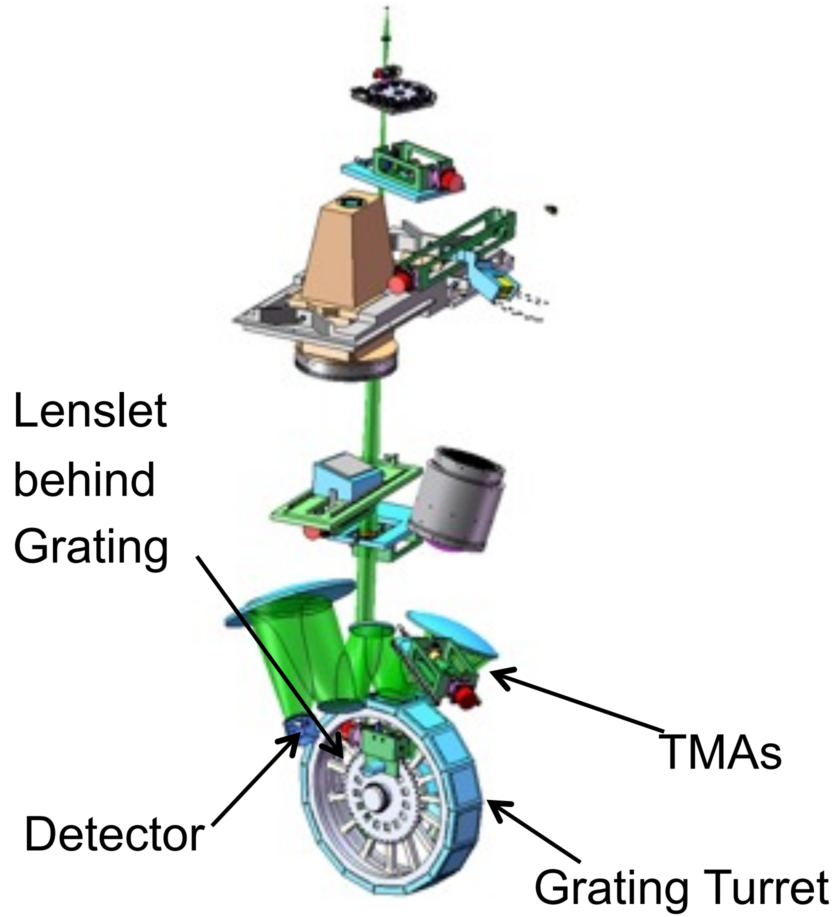
Folded Geometry (25 mas scale)





Folded Geometry (9 mas scale)





Modes

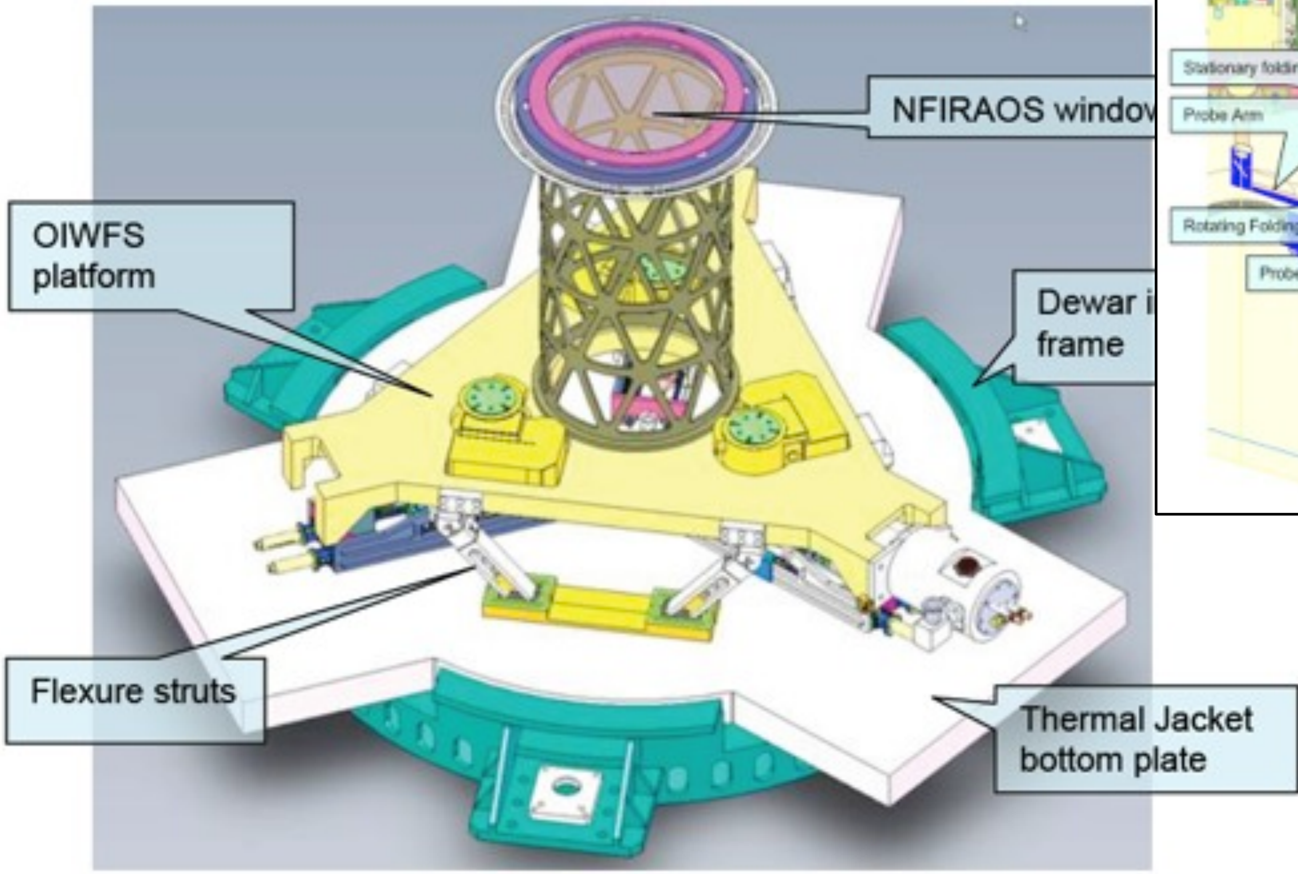
- Slicer
  - 1.125"x2.2" @ 0.025" scale
  - 2.25"x4.4" @ 0.050" scale
    - 45 x 88 x 1600(λ) elements
      - R=4000 – 20% bandpasses
    - 45 x 88 x 800(λ) elements
      - R=8000 – 5% bandpasses
- Lenslet
  - 0.45"x0.51" @ 0.004" scale
  - 1.01"x1.15" @ 0.009" scale
    - 112 x 128 x 500(λ) elements
      - R=4000 – 5% bandpasses
    - 16x128 x 4000(λ) elements
      - R=10,000 – 20% bandpass

Each mode has between 6,000,000 and 7,000,000 independent spaxels.

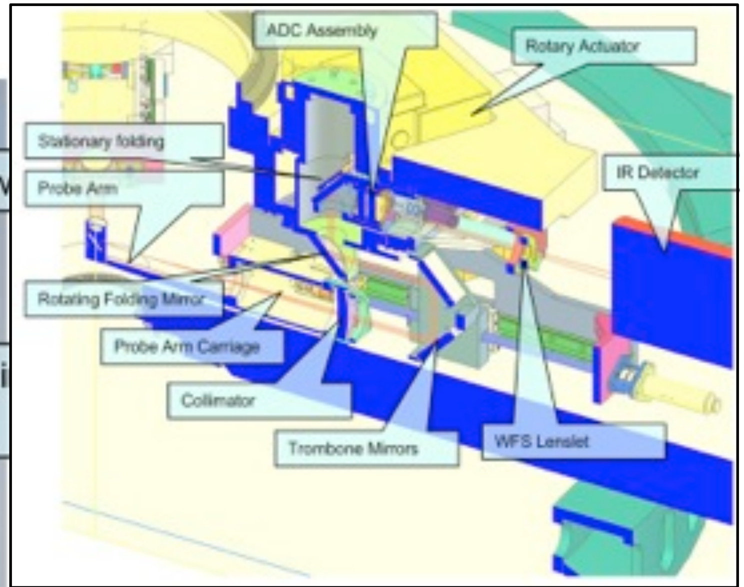
Most hardware is shared between all modes

We require very precise (micron level) large grating turret

OIWFS (HIA) – Probe Arms



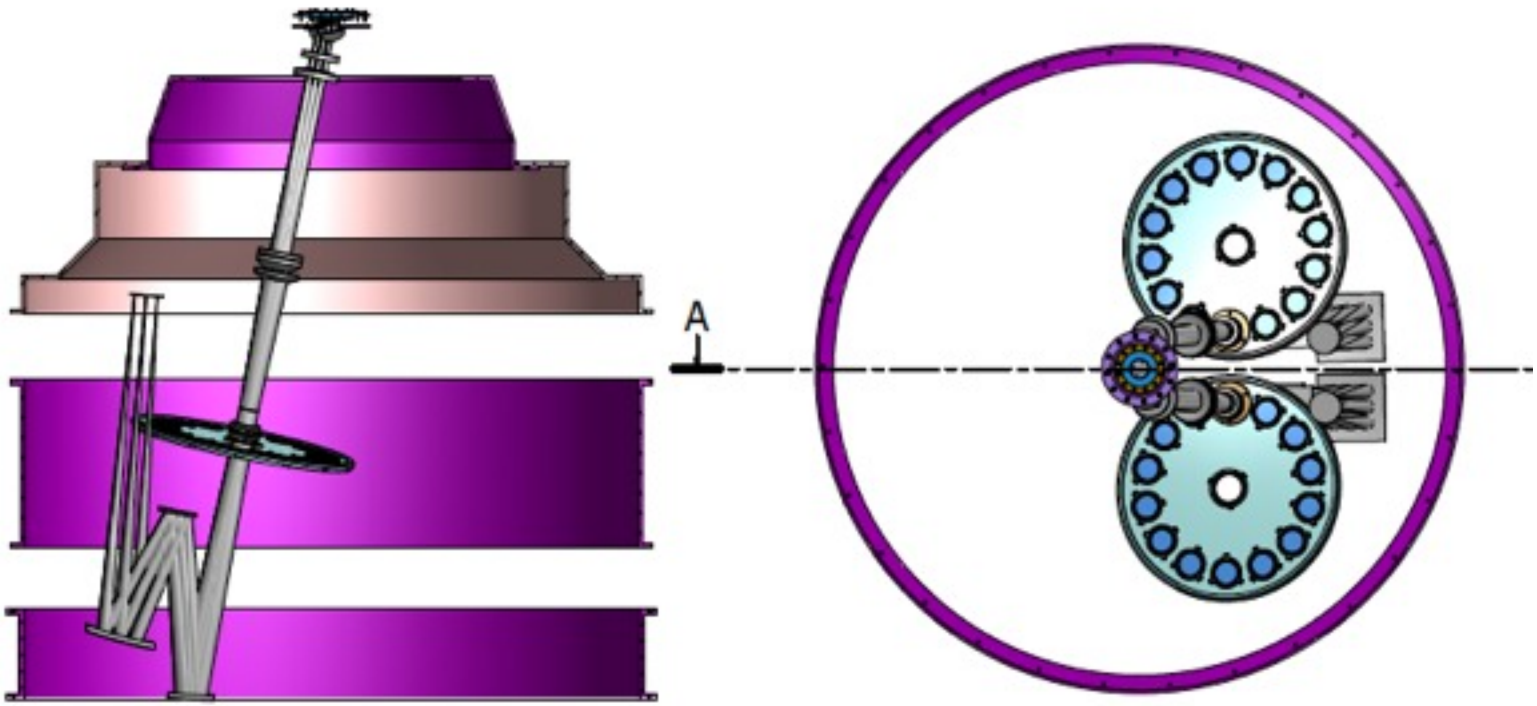
Probe arm



Mature mechanical design
Prototype probe arm almost complete
Arms can perform TT or Focus measurements

IRIS Imager (0.004” scale)
(Ryuji Suzuki – NAOJ)

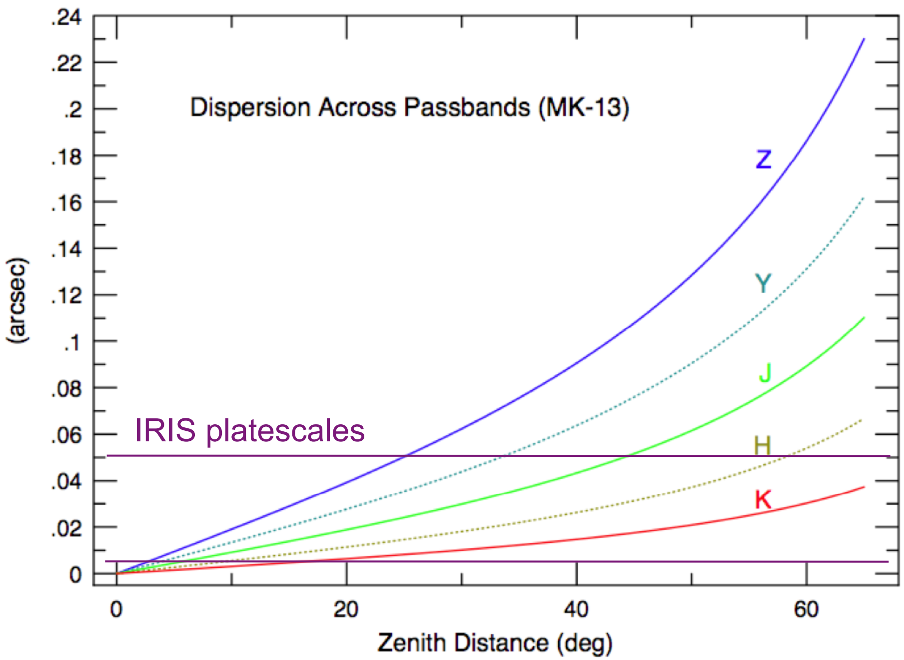
- Refractive Apochromatic Triplet + Three Mirror Anastigmat (Five other design families were considered).
- Below 30nm of WFE in almost all positions and bands.
- Supports a Pupil Viewing Mode



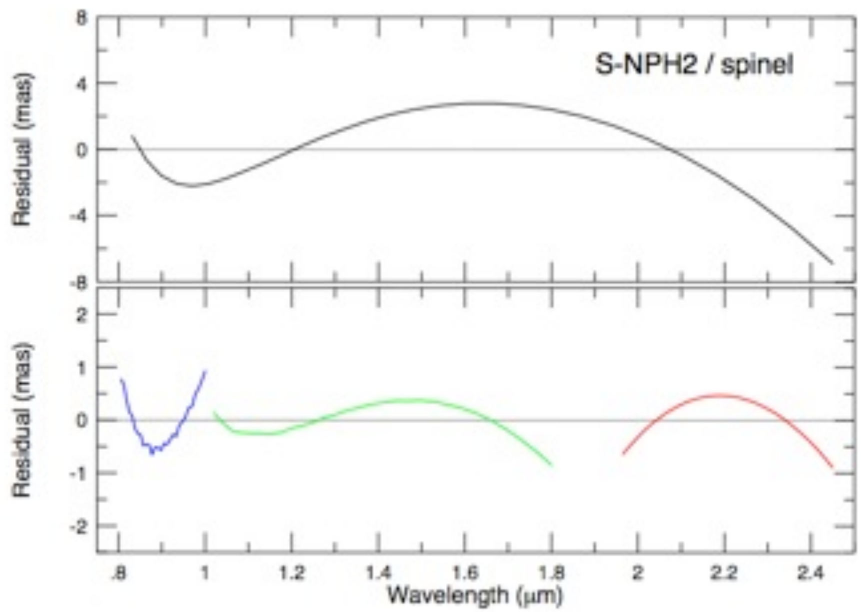
July

Atmospheric Dispersion Corrector

- Within a 20% band, dispersion can reach 0.2”
  - This rotates during an exposure making ADC essential for most observations.
- Knowledge must be <0.001”
- Drew Phillips (UCSC) investigated over 240 glass combinations for all of our ADC needs.



Example Correction @ 45



History of IRIS development

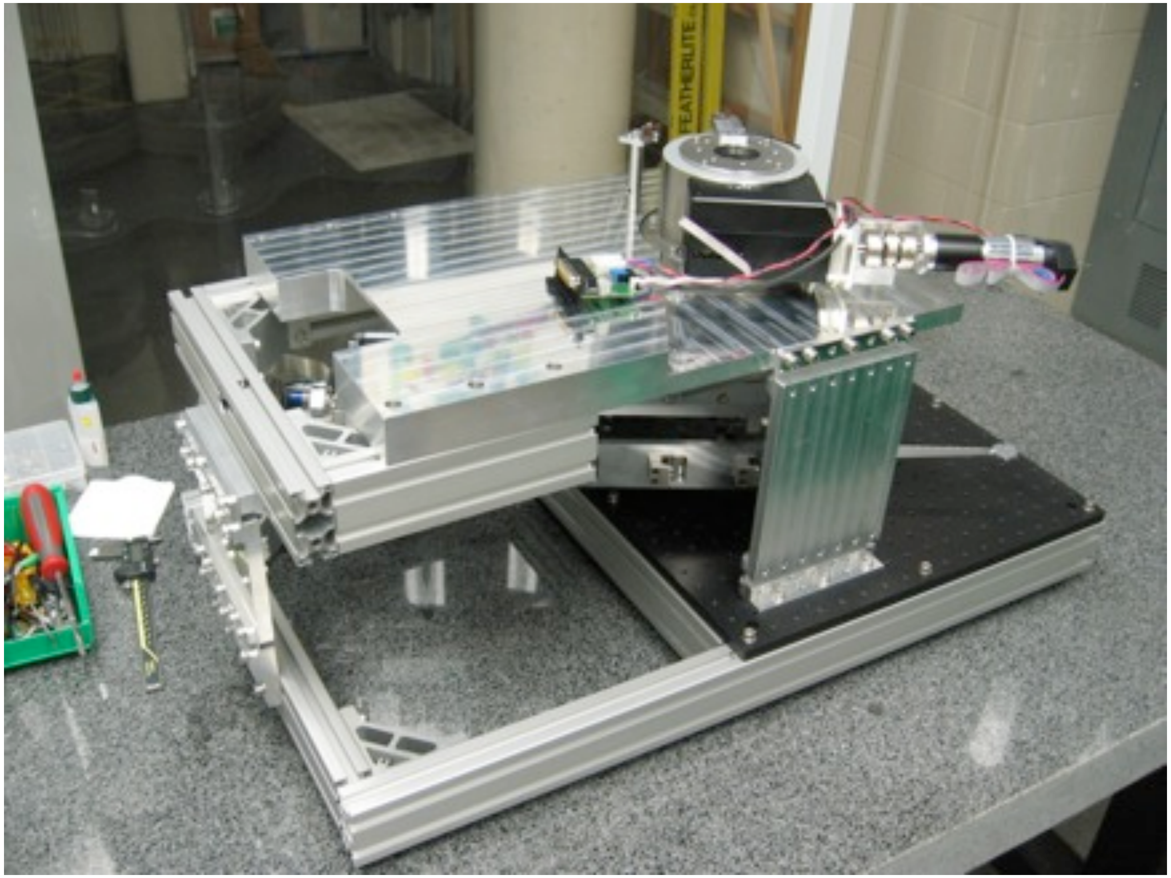
- Conceptual Design Phase
  - We had two internal interim reviews
  - Complete cost/schedule review mid 2011
  - Main Review Dec 8-9, 2011
    - Passed the review with many compliments
    - Concerned that some additional capabilities were still being discussed which could affect the design.
    - Suggested a more rigorous flow down of requirements to subsystem components – esp. astrometry, photometry

History of IRIS development

- During Conceptual Design we identified several technical challenges.
- After Conceptual Design Review we began a one-year Prototyping Phase which ended in Dec 2012.
  - New Project Scientist Shelley Wright (U. Toronto) organized the enlarged science team and formed subgroups on astrometry and photometry. Also working on final decisions of spectral resolutions and field of view.
  - Three primary prototypes:
    - Fully functional mechanical OIWFS probe arm
    - Large fully cryogenic grating turret prototype
    - Optical tests of preferred ADC glass material – Spinel

PROBE ARM PROTOTYPE (Vlad Reshtekov-HIA)

- Successful tests with coordinate measuring machine.
  - Rotary actuator ±2.6mm (3s) Linear actuator ±8mm (3s)
  - Requirement is ±13.2mm (3s) which is 2 mas rms



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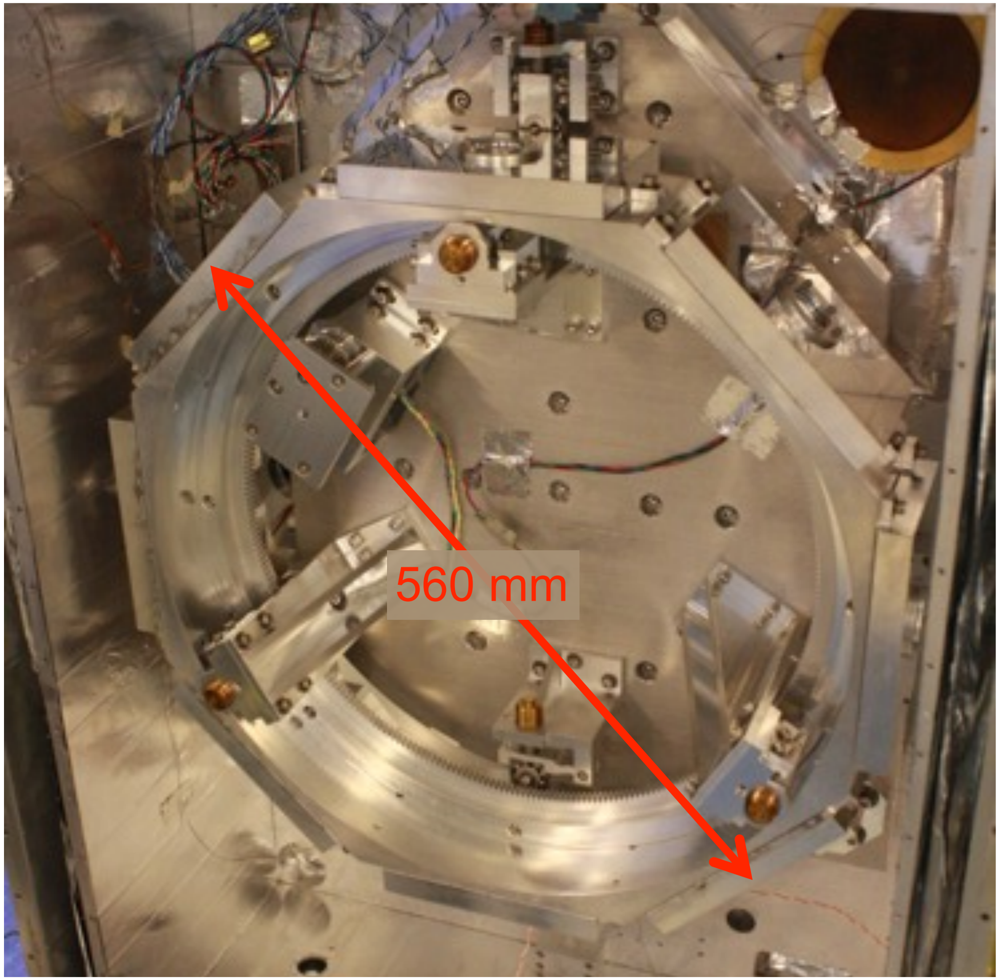
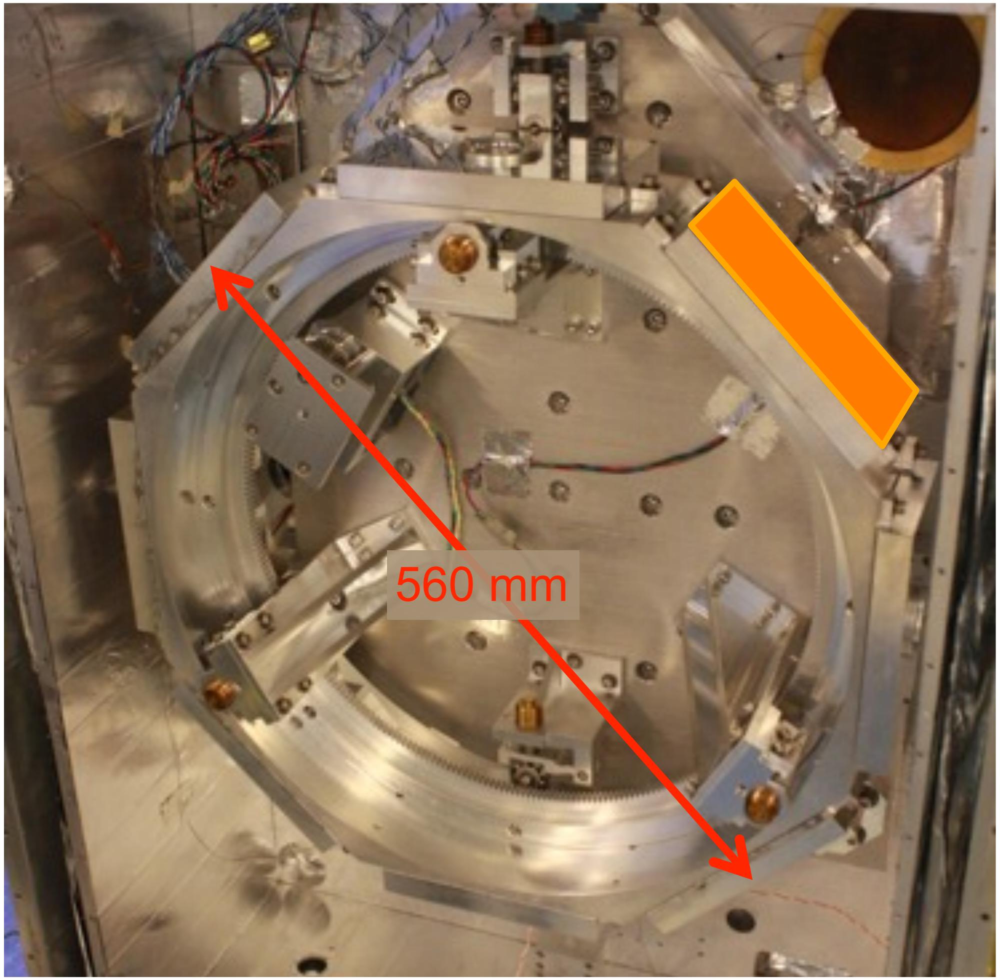
Cryogenic Grating Turret Prototype (2/3rds full size)



- 8 Full size “Gratings”
  - Each 100x150 mm
  - 25mm precision mirror mounted in each
- From any position to any position in less than 30 seconds.
- Repeatability very good in crucial axis (<20mradians), new detent still creates about 0.5 pixel offsets in dispersion axis.

Cryogenic Grating Turret Prototype (2/3rds full size)



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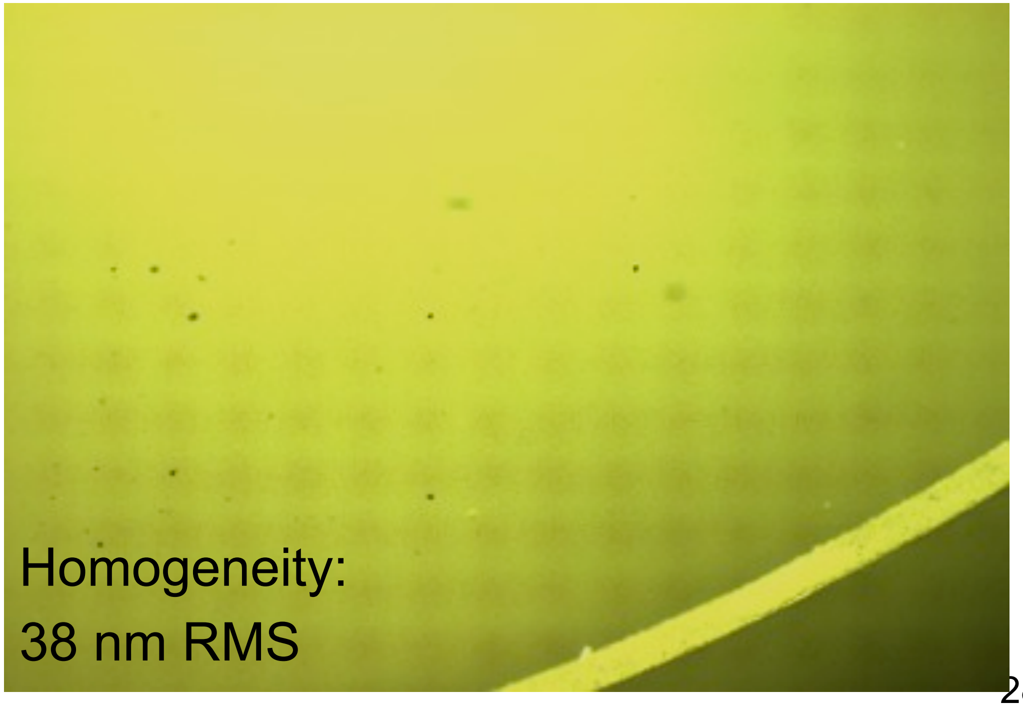
  - 25mm precision mirror mounted in each
- From any position to any position in less than 30 seconds.
- Repeatability very good in crucial axis (<20mradians), new detent still creates about 0.5 pixel offsets in dispersion axis.

Spinel (ADC glass) Testing

- Led by Jenny Atwood (HIA)
- Successful tests, but material had too many internal defects and surface irregularities.
- Spinel (originally 1st choice) is not currently a viable option for our ADC.



Currently in Light Preliminary Design Phase (L-PDP)

- April 1, 2013 – July 31, 2014
- Many sub-systems will be completed to PDP level
  - Optical layout
  - OIWFS
  - Dewar mechanical, internals
  - Opto-mechanical interfaces
- Some aspects will be only at `LPDP` level
  - Electronics
  - Software

Major Decisions

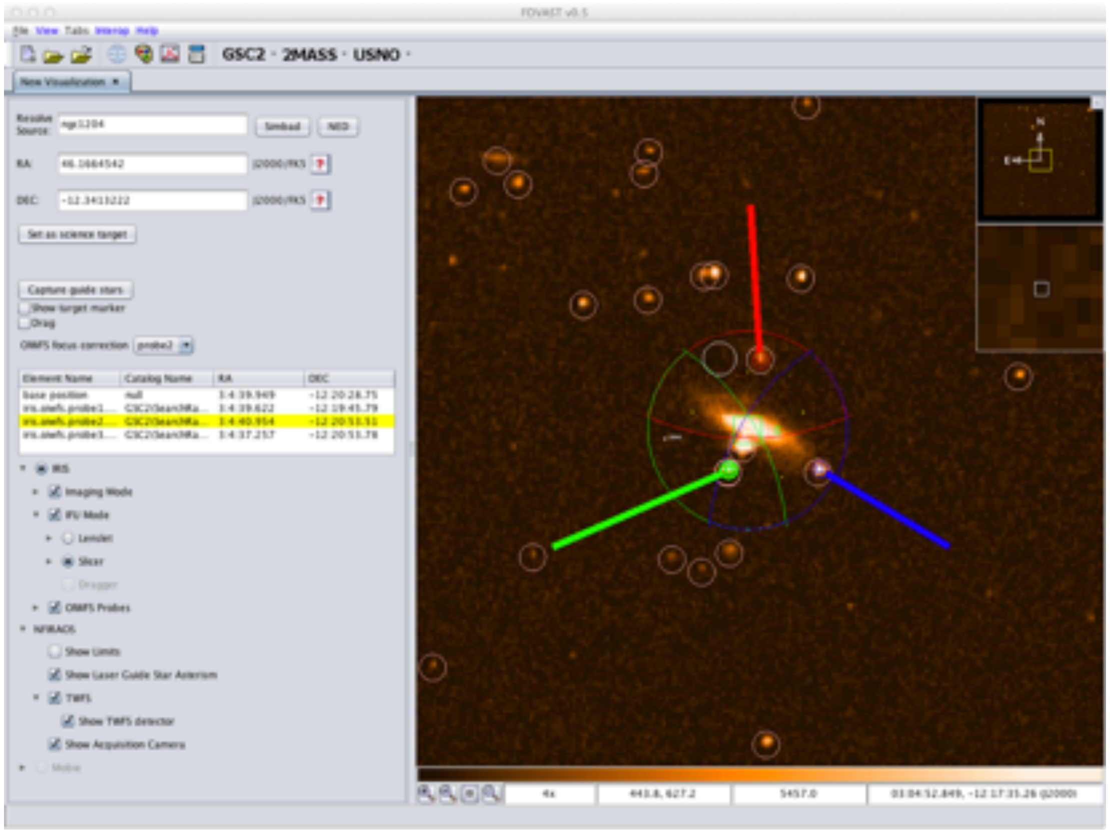
- Use of VPH or Ruled gratings
  - Transmission vs. Reflection
- ADC glass choices and distortion issues
  - Could force growth in reimaging optics
- OIWFS wavelength range
- Science field of view
  - Two contiguous imager fields?
  - On-axis or off-axis spectrograph
- Other science options
  - High contrast (non-redundant mask)?
- Common test chambers for subsystems?

VPH vs. Ruled Gratings (Throughput, Complexity)

- Shelley and Anna are procuring comparison ruled and Volume Phase Holographic gratings.
  - Includes ruled gratings from CIOMP in Changchun, China
- Shelley will use her infrared test facilities in Toronto to directly compare throughputs.
- If we switch to VPH
  - Gratings are transmissive so turret's design and position must change.
  - Current spectrograph pupil likely too small so TMAs need redesign for larger field angles
  - Internal steering mirrors or articulation are needed.

Software Acquisition Development

- Kim Gillies working with Indian scientists on focal plane visualization tool and guide star selection
- Prototype to understand observing planning issues with OIWFS, IRIS imager, IFU, and NFIRAOS



IRIS Schedule

Tight to make integration with NFIRAOS

Co-Design Review	December 2011
Prototype Review	December 2012
L-Preliminary Design Review	June 2014
Detailed Design Review	February 2016
OIWFS Integrates with NFIRAOS	May 2018
Science dewar with OIWFS	January 2020
Combine Science Dewar, OIWFS and NFIRAOS	March 2020
AIV at TMT	December 2020
Begin Commissioning	December 2021

THIRTY METER TELESCOPE

Summary

- IRIS will be a revolutionary diffraction limited instrument.
- We have designs for all components with existing technologies
  - Lenslet and Slicer Spectrographs
  - Wide-field AO imager
  - OIWFS probe arms
  - Atmospheric Dispersion Correctors
  - Field Rotation
  - Detectors
- We have identified the most challenging components and prototyped them
  - Probe Arms prototype has passed many early tests
  - Grating Turret is undergoing warm tests
  - ADC modeling is very advanced and starting to include distortion and SED effects.
- Dedicated and very active science team.
  - Competing scientific capabilities
  - Very active modeling program – astrometry, photometry, etc…
  - Helping derive subsystem requirements