HIRMES capabilities and status

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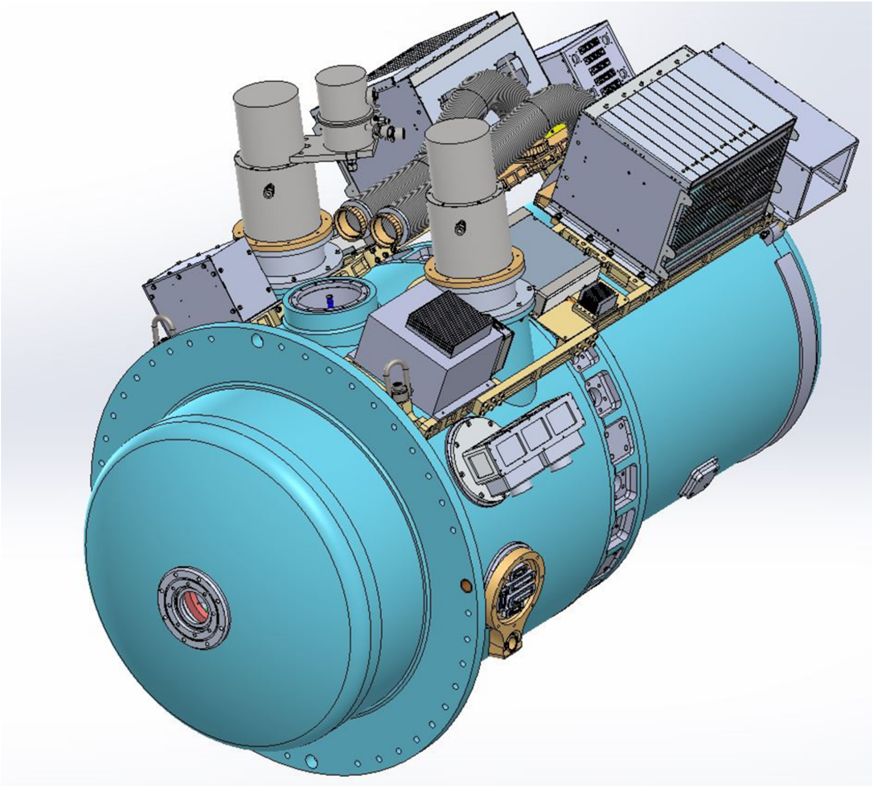
FY20 HIRMES Tele-Talks		
Instrument Overview	4 December	Matt Greenhouse
Protoplanetary Disks	11 December	Klaus Pontoppidan
Comets	15 January	Stefanie Milam
Deuterium in Giant Planets	29 January	Gordon Bjoraker
Debris Disks	5 February	Christine H. Chen

HIRMES Technical Capabilities

- HIRMES is a direct detection spectrometer covering the 25 to 122 μm spectrum in 4 operating modes optimized to deliver the maximum sensitivity achievable with SOFIA:

  1. High resolution spectroscopy: $50{,}000 < \lambda/\Delta\lambda < 100{,}000$
  2. Medium resolution spectroscopy: $\lambda/\Delta\lambda \sim 10{,}000$
  3. Low resolution spectroscopy: $\lambda/\Delta\lambda \sim 600$
  4. Spectral Imaging: $\lambda/\Delta\lambda \sim 2000$

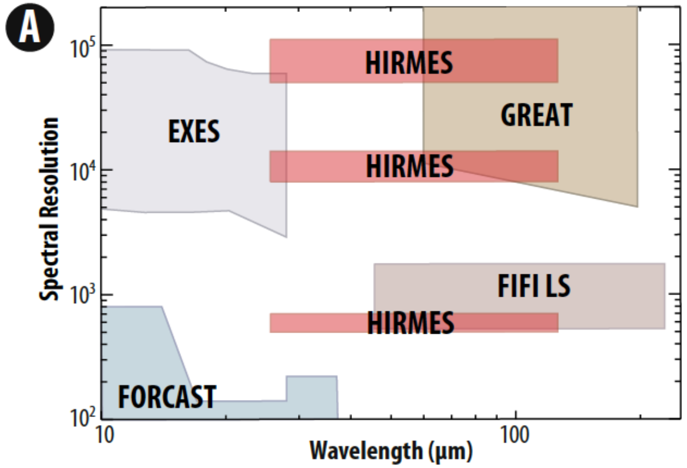
- HIRMES is a SOFIA facility-class instrument that is designed for use by the general astronomical community in support of a wide-range of exoplanet, planetary science, and astrophysics investigations



HIRMES transforms the science capability of the SOFIA mission bringing unique and new capability to the astronomical community

HIRMES fills-out the SOFIA mission discovery space with unprecedented capability:

- Approximately 14X more sensitive and ~200X faster than GREAT
- Acquires complete 35-70 micron spectrum and 10X faster than FIFILS



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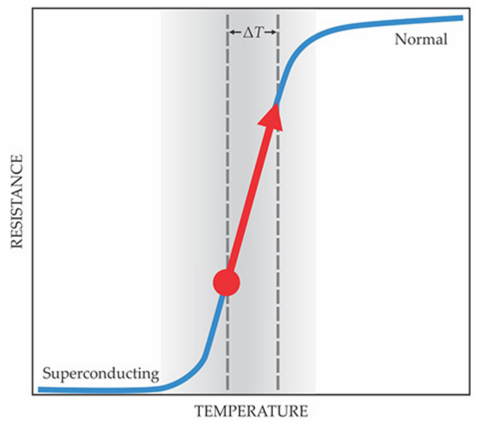
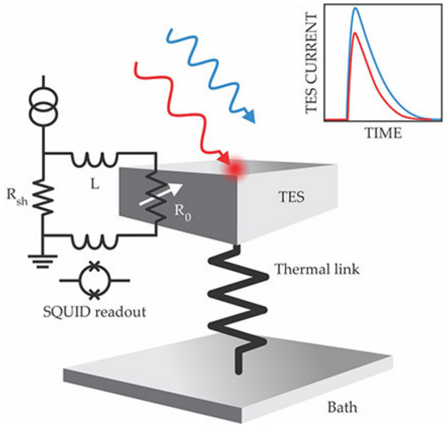
	O I Line (63 µm)			HD Line (112 µm)		
	NELF (Noise)	NELF Ratio	Obsv. Time Ratio	NELF (Noise)	NELF Ratio	Obsv. Time Ratio
HIRMES	2.1×10^{-18}	HIRMES is ~14x better	HIRMES is 205x faster	1.1×10^{-18}	HIRMES is ~14x better	HIRMES is 180x faster
GREAT	3.0×10^{-17}			1.5×10^{-17}		

NELF = Noise Equivalent Line Flux (W/√Hz)

Acquire complete spectrum from 35-70 µm range at R=100 with 0.04 Jy 1σ noise over full range.

HI2170





HIRMES utilizes Transition Edge Sensor bolometry to achieve the highest sensitivity possible with SOFIA

- This technology requires a mK cooling system.

The design development of HIRMES is guided by 4 specific science themes

- The design of HIRMES is guided by 4 specific science themes with science oversight provided by an AO-selected Science Working Group.
- These 4 investigations comprise the Level-1 science requirements for HIRMES

Table E-1: Science Traceability Matrix.

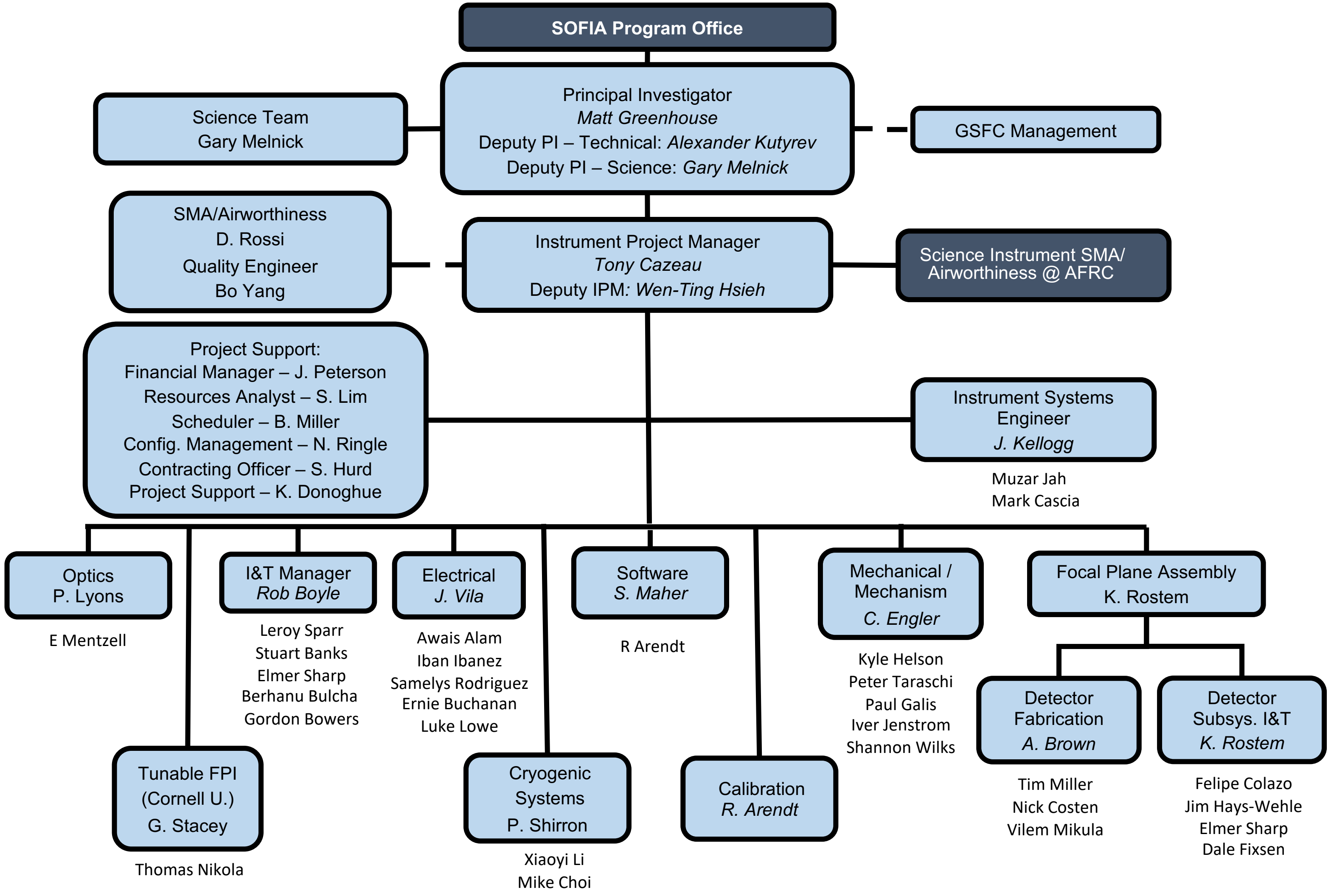
Driving Science Goal	Science Requirements	Required Measurement	Required Observations	Instrument Requirement
Study of Protoplanetary Disks • What are the processes through which protoplanetary disks evolve into nascent planetary systems? • What is the origin and ultimate fate of water in the planet forming regions of protoplanetary disks? • What is the spatial structure of protoplanetary disks in the region of planet formation?	**Measure the mass, composition, and kinematics of protoplanetary disks**	Determine the disk gas mass & kinematics	HD 1-0 R(0) line 112.0725 µm	R ~ 100,000 (3 km s^{-1}) Scan range: 15 km s^{-1} Sensitivity: $\leq 10^{-17}$ W m^{-2} 5σ in 1 hour Absolute λ accuracy: 0.1Δλ
		Determine the amount of O and H_2O inside snowline	[OI] line 63.1837 µm Warm H_2O 28-38 µm	R ~ 50,000 (6 km s^{-1}) Scan range: 30 km s^{-1} Sensitivity: ~10^{-17} W m^{-2} 5σ in 1 hour Absolute λ accuracy: 0.1Δλ
		Determine the amount of H_2O-ice beyond snowline	Measure the solid-state H_2O-ice features at ~43 µm and ~63 µm	Acquire complete spectrum from 35-70 µm at R = 100, with 0.04 Jy 1σ noise over full range Absolute λ accuracy: 0.2Δλ
H and D in the Solar System • What is the origin of the constituent materials of the Solar System? Does all of the material have common origin, or were there variations in characteristics across the Solar nebula?	**Determine the isotopic composition of the constituents giant planets**	Determine the H/D ratio	Measure: H_2 S(0) at 28.221 µm HD R(0) at 112.0725 µm HD R(1) at 56.2298 µm HD R(2) at 37.7015 µm HD R(3) at 28.5020 µm	R ~ 10,000 Sensitivity: < 5×10^{-16} W m^{-2} (Set by Neptune, the giant planet with the lowest flux density) Absolute λ accuracy: 0.1Δλ

HIRMES Science Working Group			
Investigator	Institution	Investigator	Institution
Arendt, Richard*	UMBC	Pontoppidan, Klaus	STScI
Bergin, Edwin	U. Michigan	Richards, Samuel*	USRA
Bjoraker, Gordon	GSFC	Roberge, Aki	GSFC
Chen, Christine*	STScI	Rostem, Karwan*	UMBC
Kutyrev, Alexander	U. Maryland	Stacey, Gordon	Cornell U.
Melnick, Gary	Harvard U.	Tolls, Volker*	Harvard U.
Milam, Stefanie	GSFC	Su, Kate*	U. Arizona
Moseley, Harvey	GSFC Emeritus	Watson, Dan	U. Rochester
Neufeld, David	Johns Hopkins U.	Wollack, Edward	GSFC
Nikola, Thomas*	Cornell U.		

* Investigator added via Legacy Science Investigation proposal

HIRMES Project Team Organization

Status as of: Nov 2019

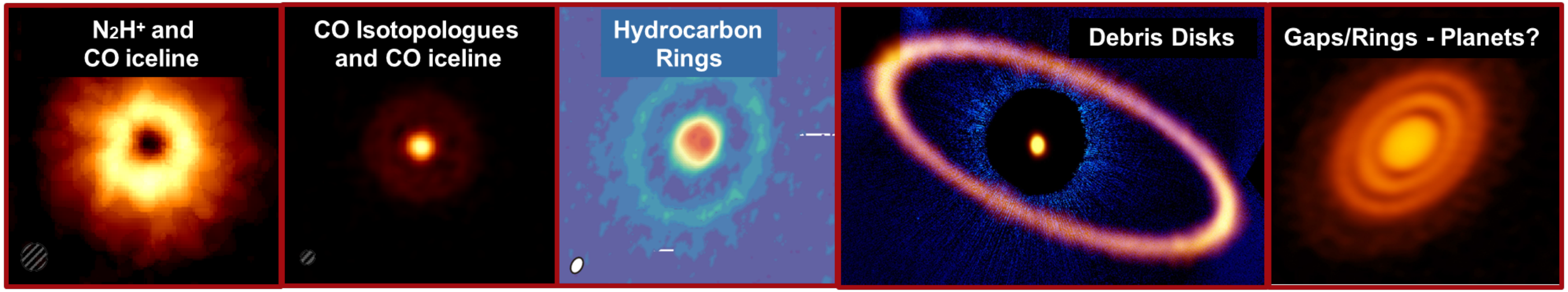


HIRMES enables SOFIA to uniquely address National science priorities in exoplanet and planetary science

- The overarching science theme is the study of the composition and evolution of protoplanetary systems
- HIRMES is designed to address key questions about protoplanetary disks :
  - What are their masses?
  - How are gas, water vapor, water ice, and dust distributed?
  - How is neutral oxygen distributed?
  - What is the deuterium abundance of the giant planets?
  - What is the abundance of: deuterium, amorphous water ice, and crystalline water in comets?
- HIRMES will measure the most important molecular species needed to address these questions
  - **Water and ice:** gas-phase water and water-ice play a critical role in the formation of giant planet cores and, producing habitable conditions in terrestrial planets
    - H_2O 34.9823 μm 6_{51}-6_{24} rotational line
    - Ice 43, 47, 63 μm amorphous & crystalline solid state feature
  - **Neutral Oxygen:** a tracer of disk chemistry and radial structure
    - [OI] 63.1837 μm $^2P_1$-$^3P_2$ fine-structure line
  - **Deuterated hydrogen:** a tracer of disk mass
    - HD 112.0725 μm J = 1-0 rotational line
    - HDO, $H_2^{18}O$ 112.1 and 109.3 μm (comets)
- No similar capability has or will be enabled by the Orbital Program through 2030.

HIRMES provides velocity-resolved spectra of these molecules enabling first determination of their radial distribution at different stages of disk evolution.

HIRMES will provide unique and foundational data sets for JWST and ALMA, without which their science impact will be diminished.



The synergy and value of HIRMES and ALMA in unlocking the secrets of the birth of habitable worlds

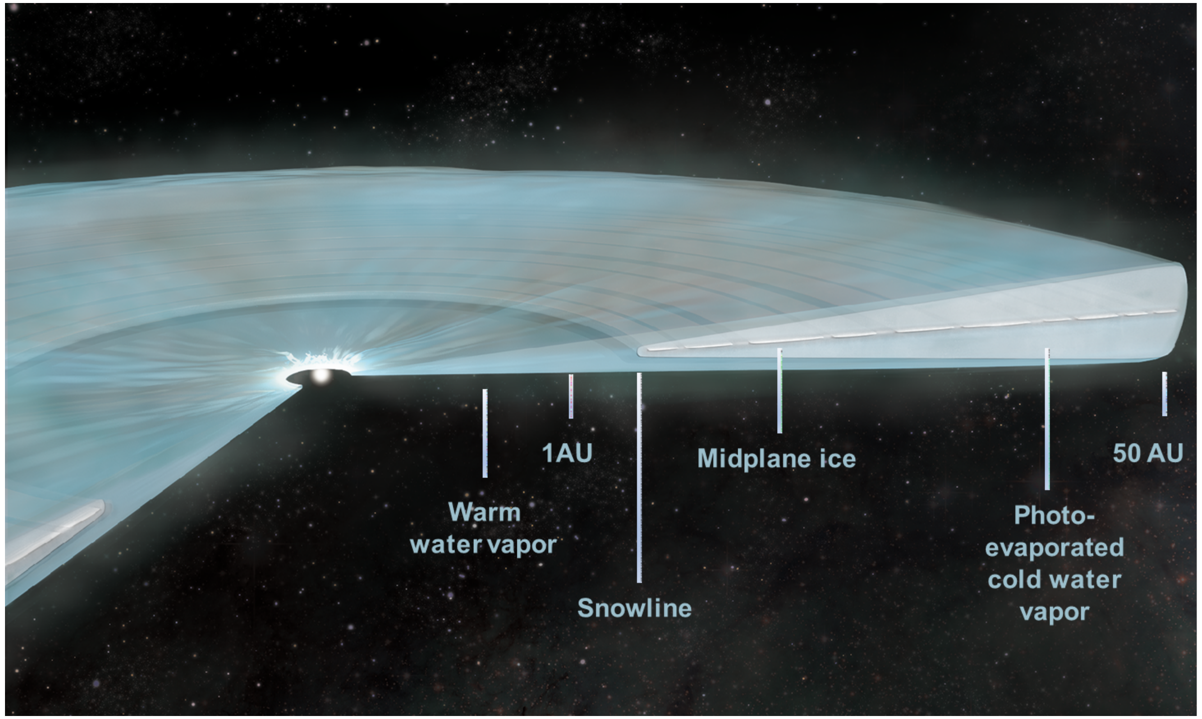
H_2O
Water Content and Snowline?
HIRMES can detect water and constrain its location.

HD
Disk Gas Mass?
HIRMES will survey tens of systems and determine gas mass from HD.

HIRMES has potential to, on its own, transform our understanding of planet formation

Water is a key volatile in planet-formation theory

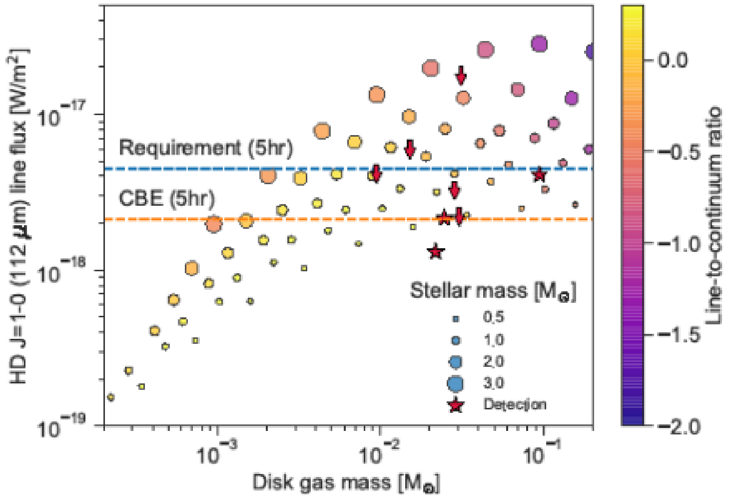
- Water content is central to understanding formation of habitable worlds.
- Water snowline (vapor-ice transition) is a region where giant planet formation predominantly occurs.
- *Disk water content - both gas/ice - and snowline locations are uncertain and poorly characterized*
- JWST and HIRMES can detect the water; only HIRMES can provide location information (e.g. snowline).



HIRMES ability to resolve water emission lines from 30-100 µm is unique.

HIRMES enables new discovery space to understand protoplanetary disk evolution

- HIRMES opens a portion of the infrared spectrum that contains fundamental tracers of protoplanetary disks
  - Unavailable since the end of the ISO, Herschel, and KAO missions.
  - HIRMES re-opens this spectrum with sensitivity needed to detect and velocity-resolve many disks
- HIRMES will produce the first accurate disk masses via velocity-resolved spectroscopy of HD
  - Planet-forming disks are thought to contain ~100X more gas than solids
  - This gas is too cold (10-30 K) for H_2 molecules to emit
  - As a consequence, disk masses remain uncertain by orders of magnitude despite decades of work
    - ALMA surveys show that masses derived from indirect tracers (CO, dust continuum) are systematically discrepant by 1-2 orders of magnitude
  - Uncertainty in HD-derived gas mass is much smaller (factor of a few)
    - Uncertainty driven by knowledge of: gas temperature which can be constrained with ALMA ^{12}CO and ^{13}CO data, and D/H ratio in the local interstellar medium which is known to ~50%

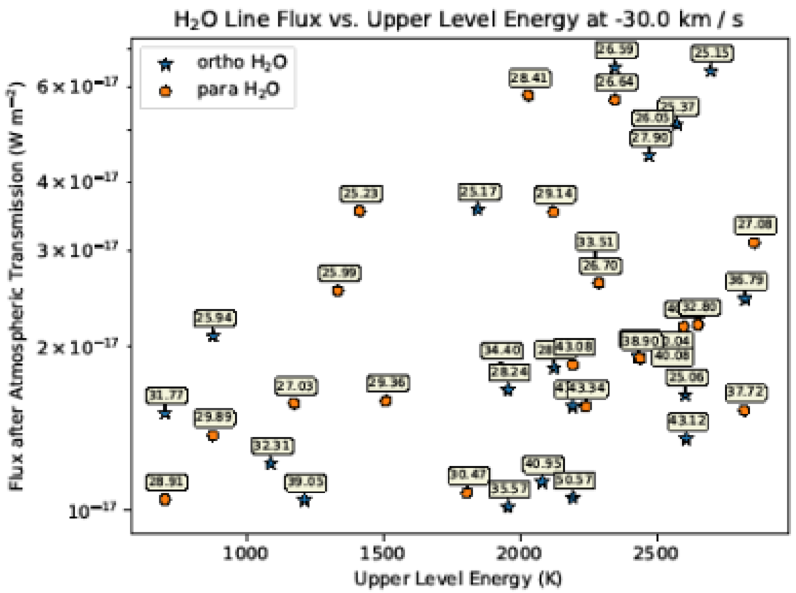


HIRMES will detect the HD 1 – 0 line at 112 μm in disks of masses >10³ M ☉ around stars of > 1 M ☉. The figure shows model predictions for HD 1–0 line fluxes (circles), along with detections (stars) and upper limits from Herschel-PACS. All models and data are scaled to a distance of 125 pc.

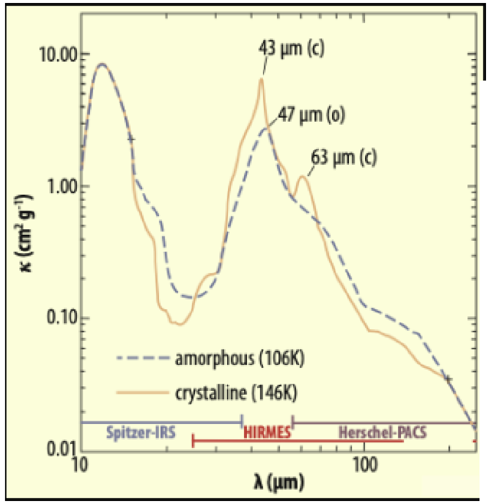
HIRMES will produce the first accurate measure of the cold gas mass in protoplanetary disks

HIRMES will enable the first velocity-resolved spectra of water vapor tracing the snowline region of protoplanetary disks

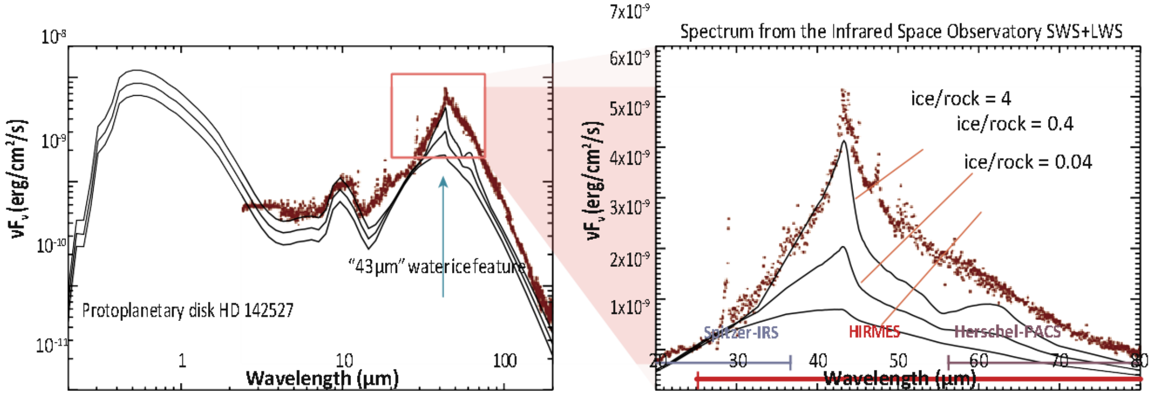
- Water traces the flow of volatile elements throughout the process of disk and planet formation
  - The region around the water snow line, where planets are thought to predominantly form, is key
  - Understanding the distribution of gas, ice, and dust in this region is necessary to understand the processes by which rocky and giant planets form



Several water vapor lines with upper level energy that can trace cold gas at the water snow line are available to HIRMES. Boxed numbers are the line wavelength in microns.



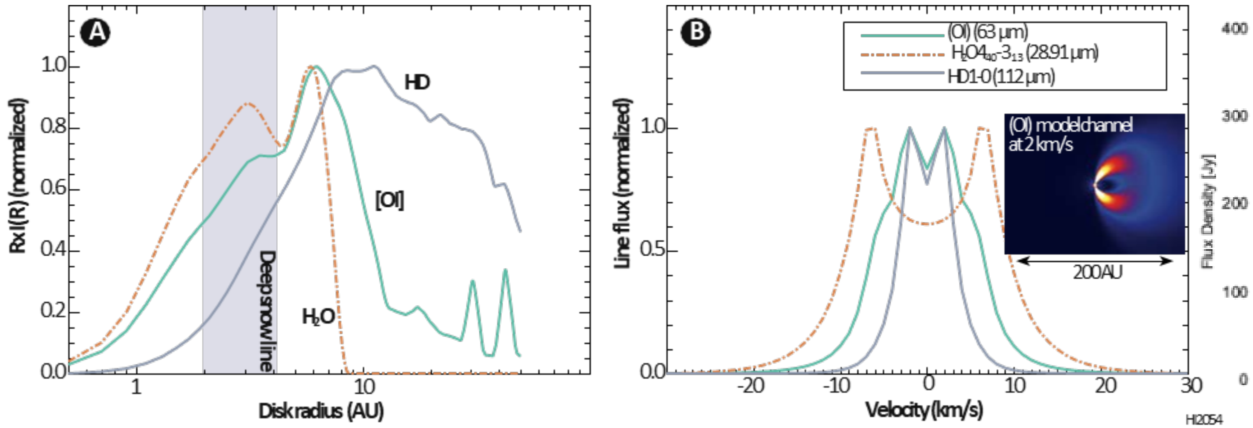
Several water ice lines with excitation temperature less than the desorption temperature will be seen in emission by HIRMES.



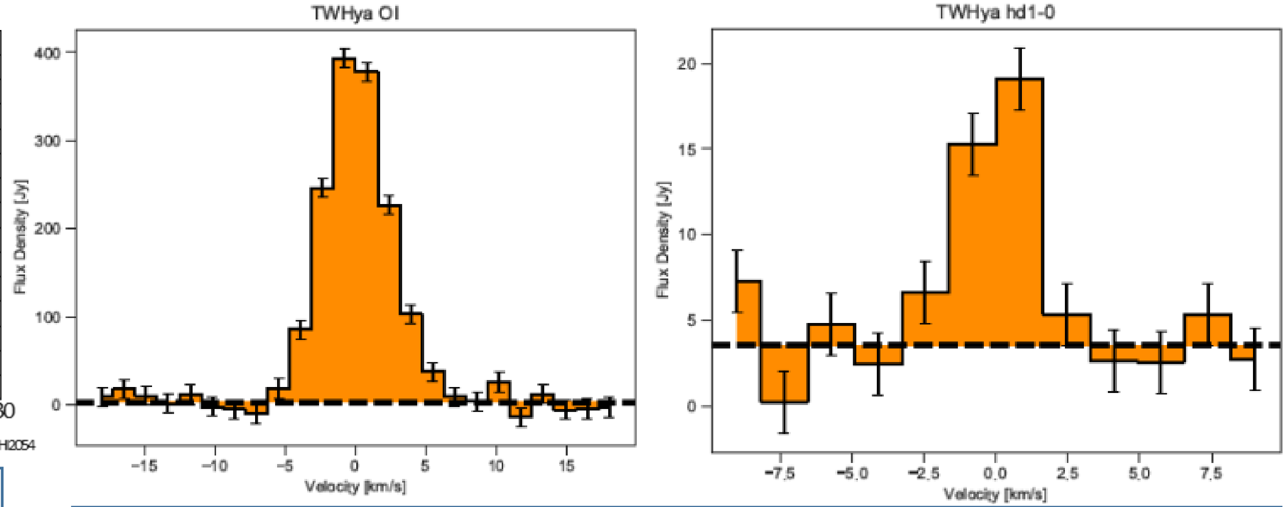
HIRMES will measure ice-to-rock ratios at high signal-to-noise in a large number of protoplanetary disks for comparison to Solar System comments and to determine if ice is a dominant solid mass reservoir for core-accretion.

HIRMES will resolve the radial surface energy balance in protoplanetary disks

- [OI] 63.2 μm is typically the most luminous emission line of protoplanetary disks
  - Most commonly detected line from disks by Hershel-PACS
    - Interpretation limited by lack of ability to distinguish ~10 km/s disk emission from 100 km/s outflows and shocks.
- HIRMES will produce velocity-resolved [OI] spectra of more than 30 protoplanetary disks
  - These data will, for the first time, enable determination of the radial surface energy balance from 1-100 AU.



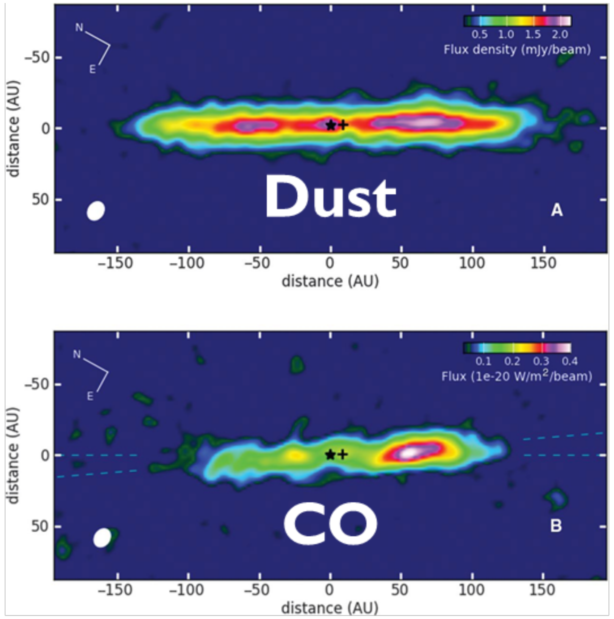
HIRMES measures the line profiles of HD, H20, and [OI] to determine the radial distribution of the emitting gas. Modeling (A) shows H2O and OI occupy the areas in and around the snow line. HIRMES spectra test this. (B) The lines arising from the inner planetary system are broad and easily resolved by HIRMES.



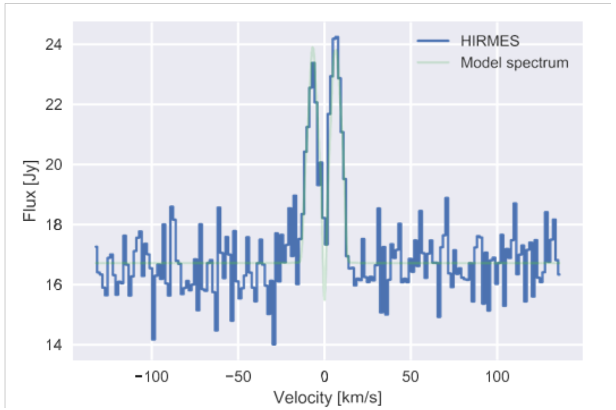
Simulated HIRMES spectra of TW Hya (a disk with typical line strengths). The signal-to-noise on [OI] 63.3 μm (left) and HD 1-0 (right) correspond to 1.5 and 10 hours of observing time with overheads

Water and neutral oxygen are modeled to occupy areas in and around the snow line. HIRMES velocity-resolved spectroscopy can test these models.

Velocity resolved [OI] spectra can carry a wealth of information

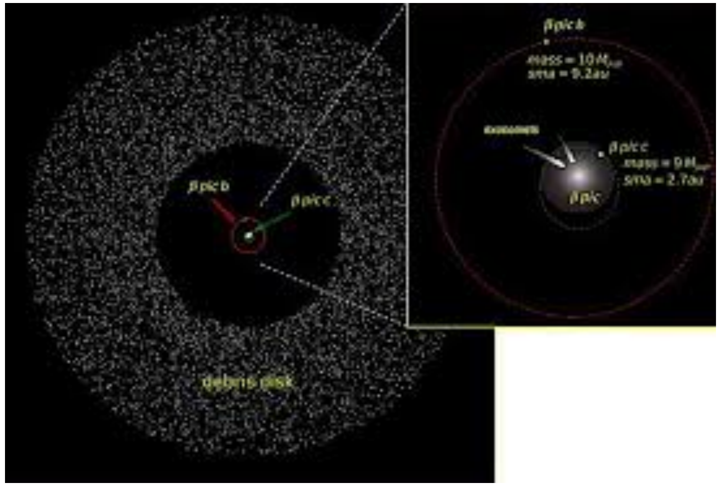


Dent et al., Science (2014)



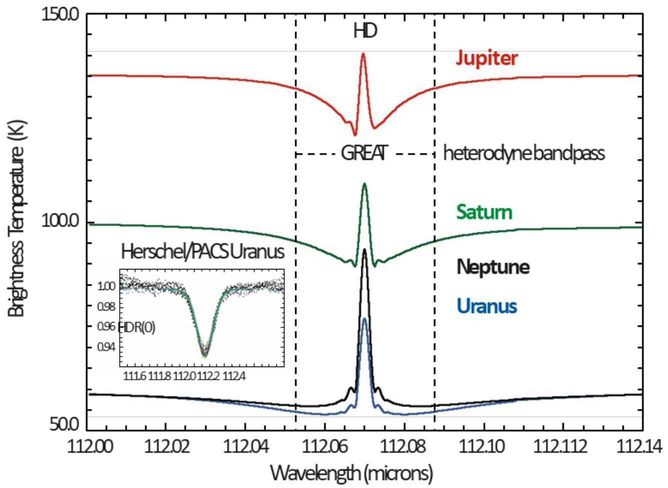
Example: Beta Pic

- CO and CI emission from ALMA are spatially resolved and asymmetric – there's a clump!
- HIRMES can get spatial info on [OI]
- Asymmetric OI line profile should show if [OI] is also in clump
  - If yes, recent massive collision
  - If no, planetesimal shepherding

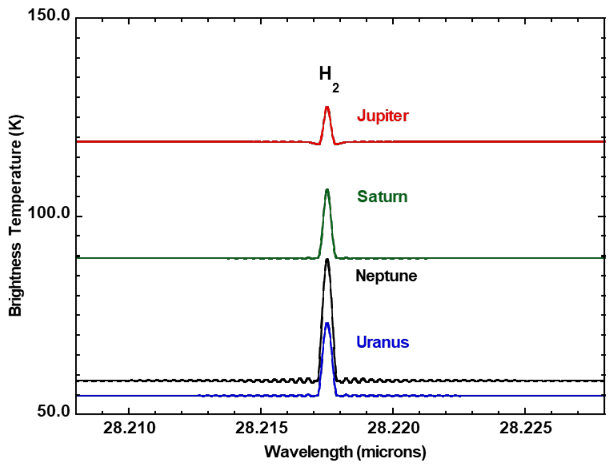


HIRMES will spectrally resolve HD in all of the giant planets

- Deuterium is an important indicator of the formation mechanism for the giant planets
  - Jupiter and Saturn are expected to exhibit the protosolar value of D/H
  - Uranus and Neptune are expected to exhibit D/H of the icy planetesimals where they formed
    - Comets are the closest analog to the icy planetesimals that we can measure today
    - 11 comets have been measured revealing D/H at 8-32 times the protosolar value
    - Herschel-PACS measurement on Uranus and Neptune show D/H at 2X the protosolar value
  - Either the measured D/H in Uranus and Neptune is wrong or planetary formation models are incomplete



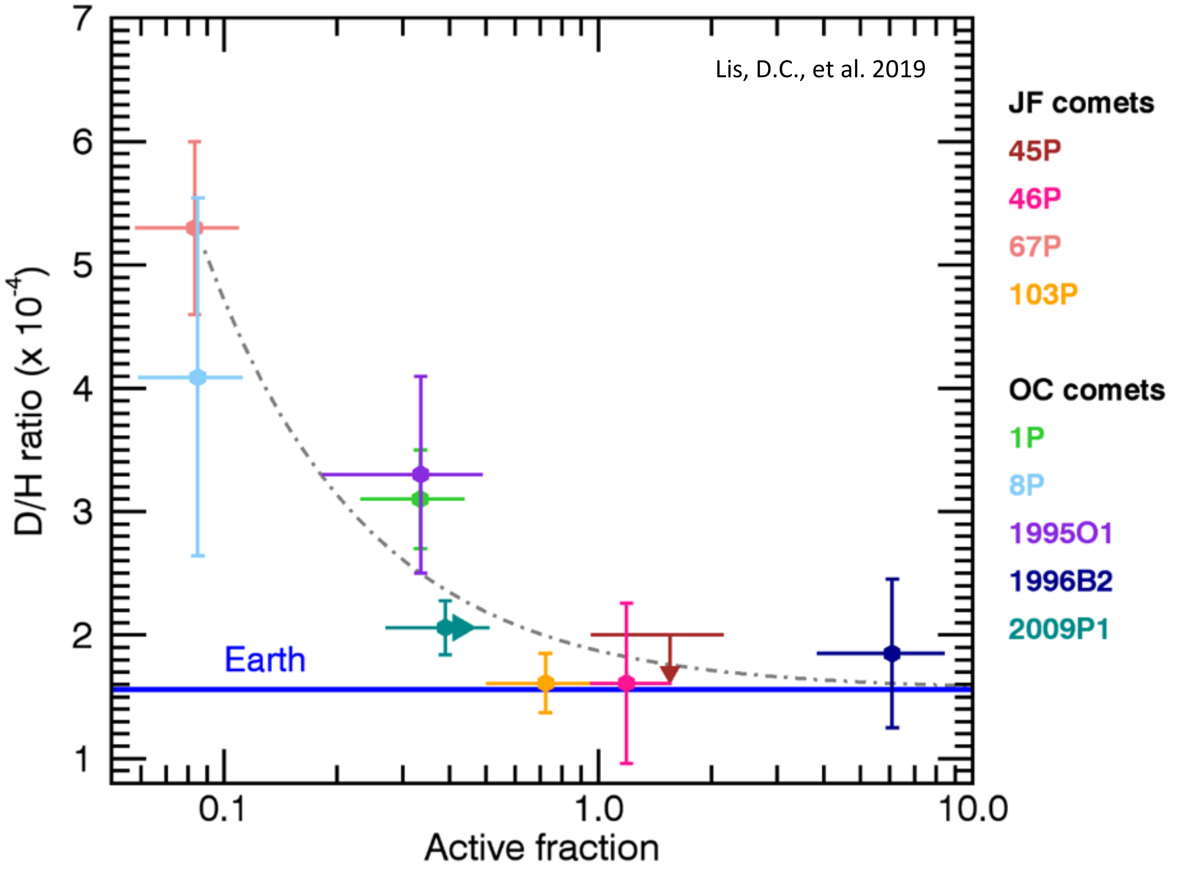
HIRMES will resolve the emission line core of HD in all 4 Giant Planets, which probes their stratospheres. The broad bandpass of HIRMES will be used (in medium-resolution mode) to reveal HD absorption in the wings, which probes their tropospheres.



HIRMES will derive stratospheric temperature profiles for all 4 Giant Planets using the S(0) quadrupole line of H_2 at 28.2 µm. Accurate temperature profiles obtained with the same instrument and for the same geometry as HD measurements are essential in order to derive HD mole fractions from the 112-µm line.

HIRMES is unique in its ability to constrain the chemical evolution of comets

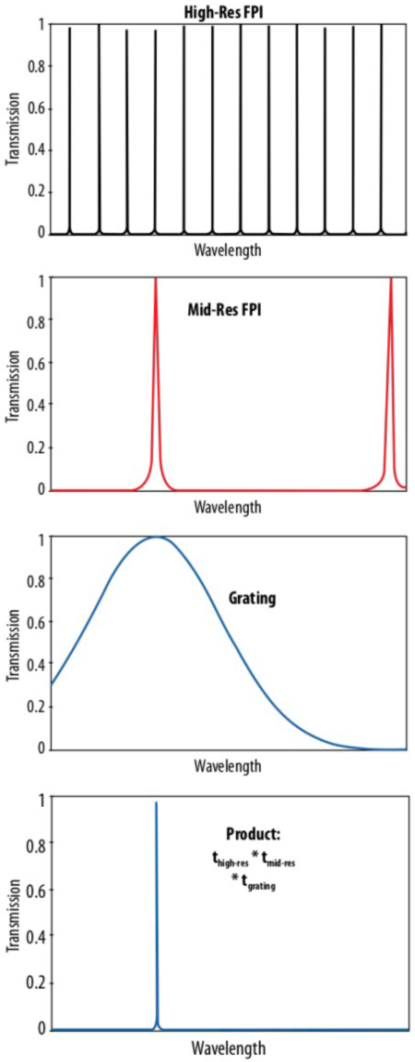
- HIRMES will measure the amorphous-to-crystalline water ice and D/H ratio in comets
  - HDO and $H_2{}^{18}O$
- Important for understanding the chemical evolution of comets, and their potential as a source for the Earths' oceans.

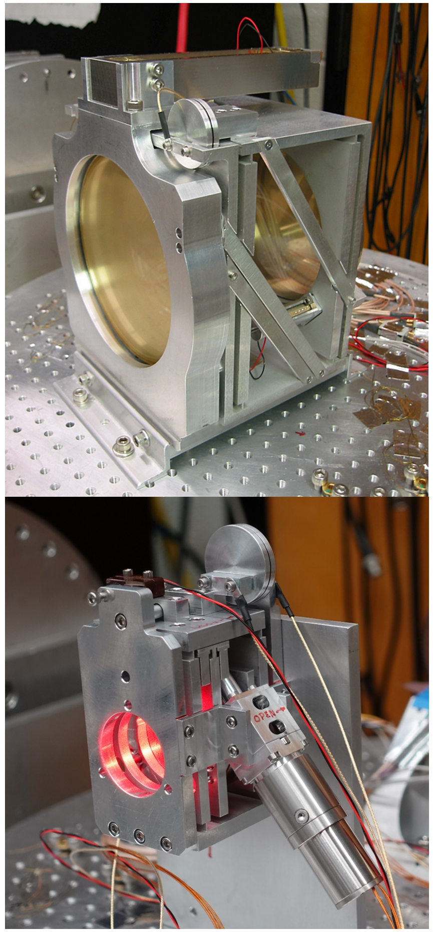


The D/H ratio in cometary water as a function of the active fraction, the ratio of the active surface area to the total nucleus surface. Hyperactive comets with high active fractions have a D/H ratio consistent with the value found in the Earth's oceans, which is shown as the blue line.

How HIRMES works

- Tandem scanning Fabry-Perot etalons are used to achieve high spectral resolution.

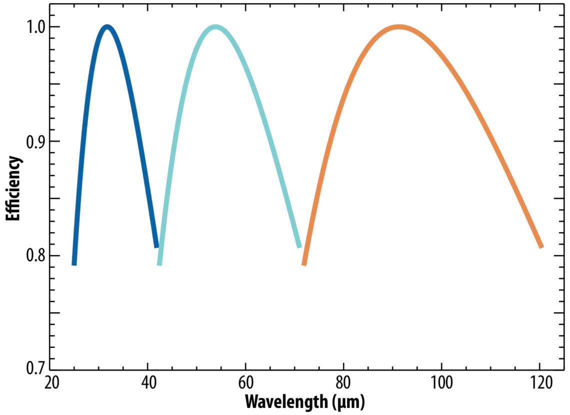




HIRMES high (top) and low (bottom) resolution scanning etalons

Mode	Scanning FPI	Central Wavelength	Wavelength Range	Resolving Power	Etalon Diameter
slit	high-R LW	112 μm	86-122 μm	100,000	100 mm
slit	high-R MW	63 μm	50-86 μm	100,000	90 mm
slit	high-R SW	35 μm	25-36 μm	50,000	90 mm
slit	mid-R LW	112 μm	86-122 μm	12,000	90 mm
slit	mid-R MW	63 μm	50-86 μm	12,000	90 mm
slit	mid-R SW	35 μm	25-36 μm	12,000	90 mm
imaging	low-R SW	57 μm	50-70 μm	2000	30 mm
imaging	Low-R LW	102 μm	80-125 μm	2000	30 mm

HIRMES fixed etalon imaging filters

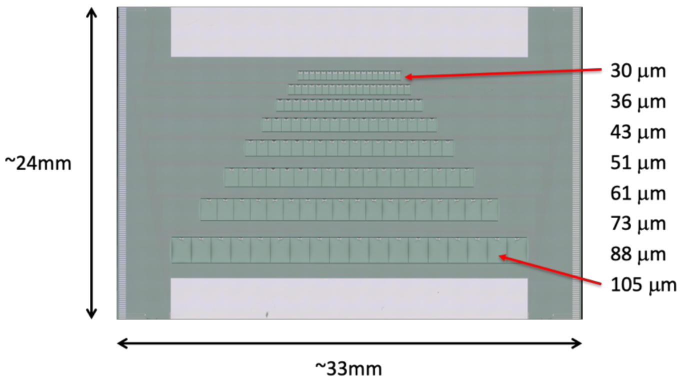


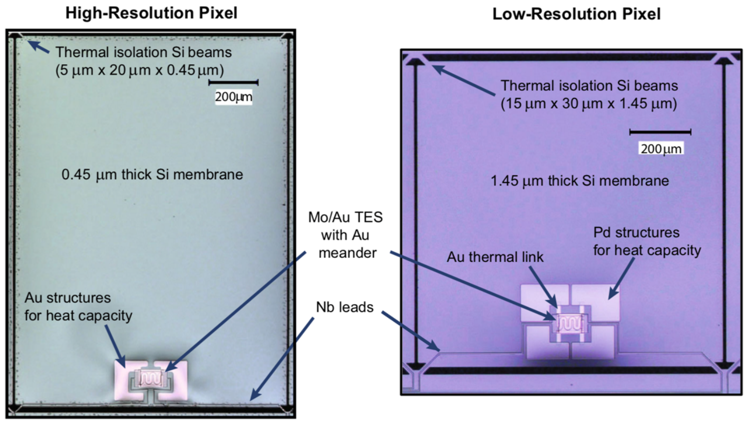
HIRMES diffraction gratings

How HIRMES works continued …

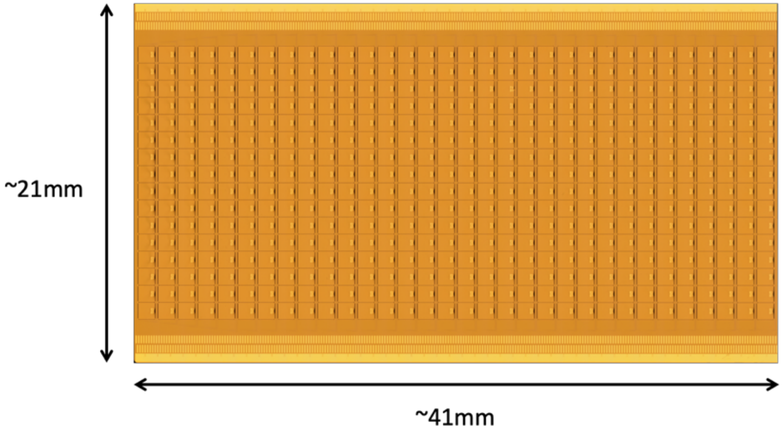
- HIRMES utilizes MoAu Transition Edge Sensor photon-counting bolometers requiring mK cooling

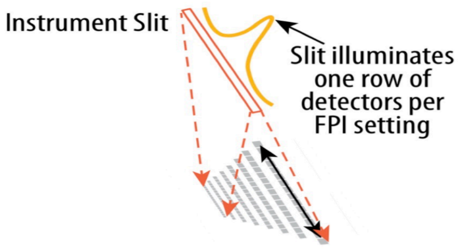
128 Pixels, 2.5-8.5 arcsec/pixel



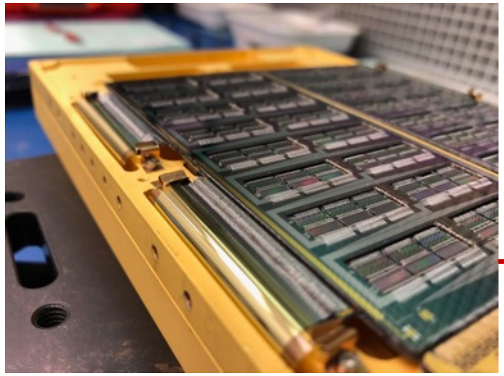


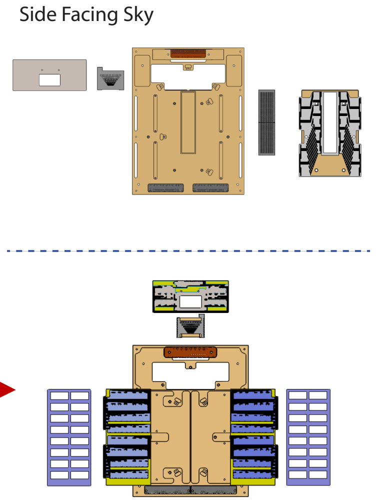
16 x 64 pixel format 6.1 arcsec/pixel

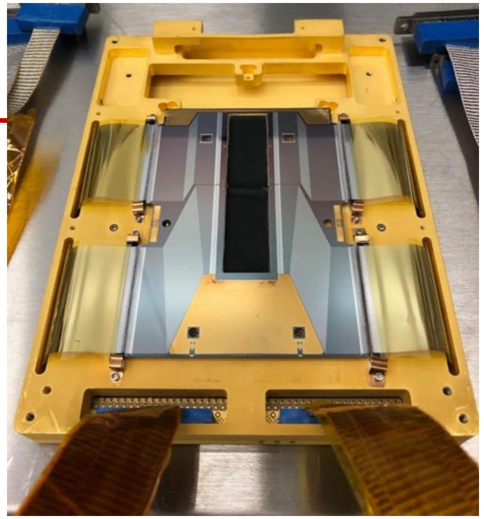




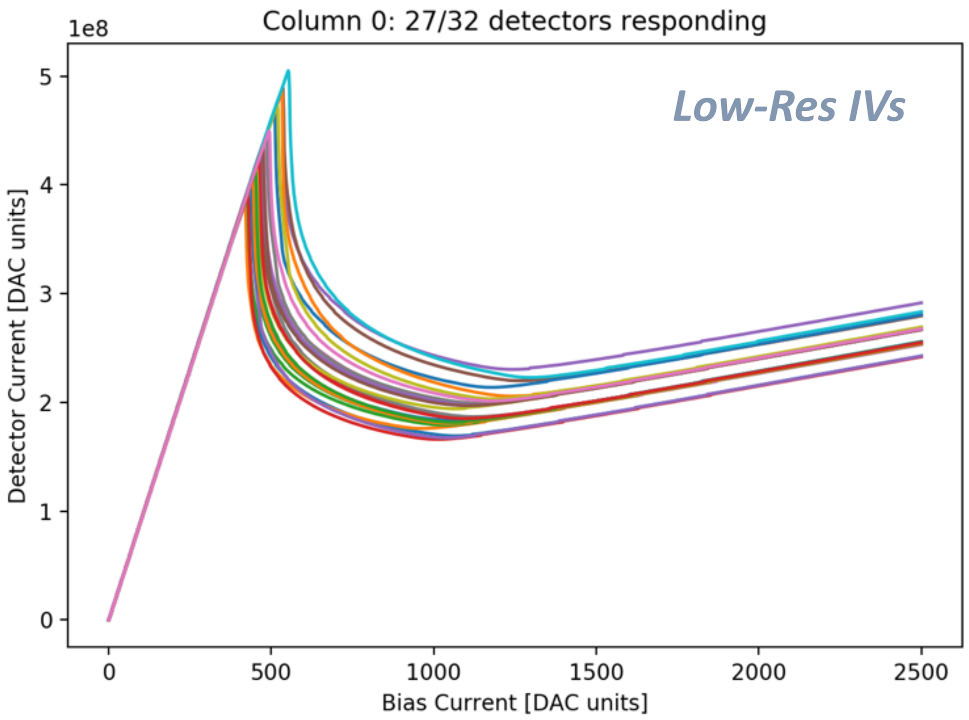
Dark Detector NEP 10^{-18} W $Hz^{-1/2}$	
Low Resolution	20
High Resolution	3

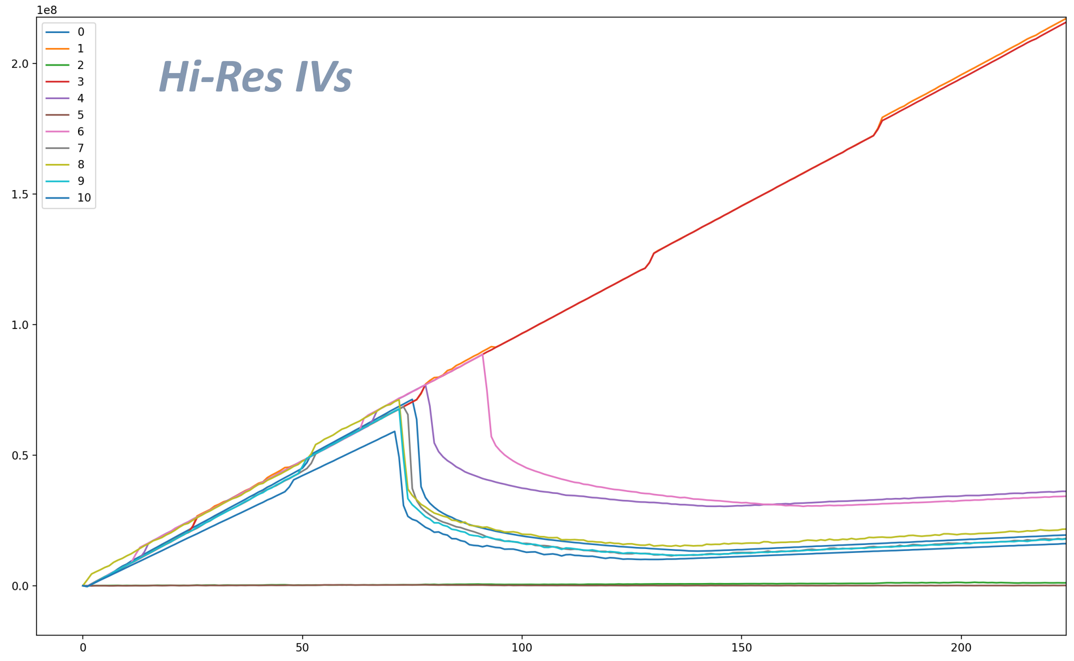






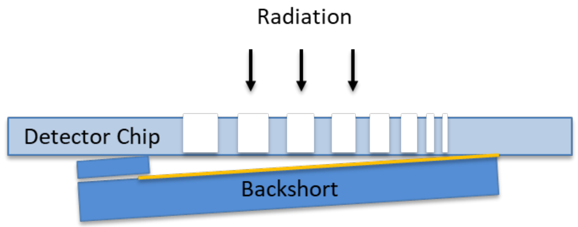
Detector readout has been demonstrated in a test Dewar on ETU arrays and a high fidelity flight-like signal chain



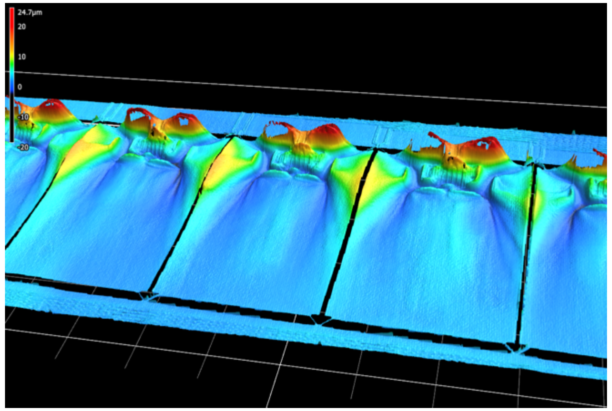


How HIRMES works continued …

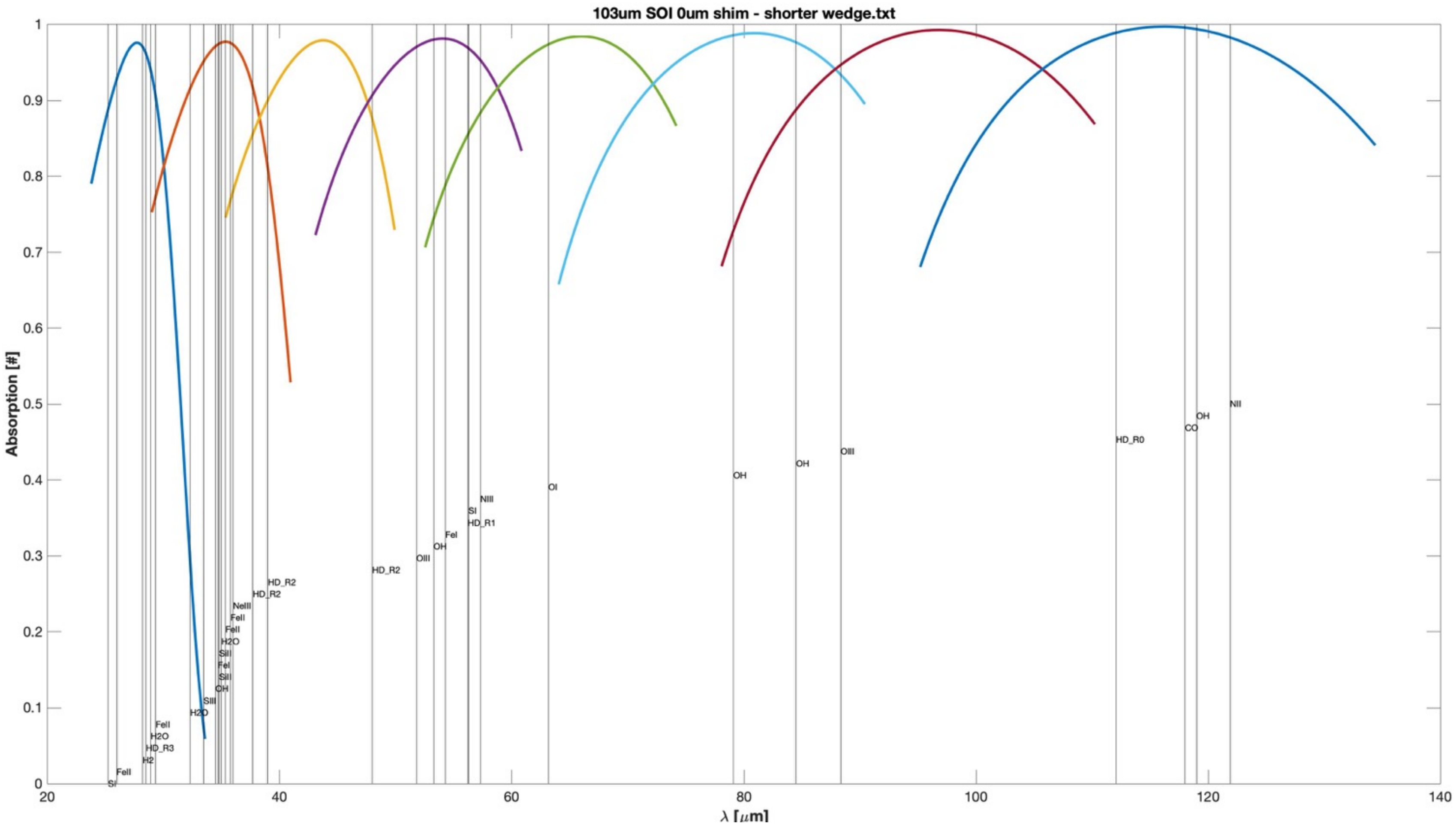
- A 3λ/4 reflective back-short is used to optimize the quantum efficiency of the high resolution detectors
  - Initial instrument commissioning may utilize an absorptive back-termination -- TBD



A tilted mirror is used to create an integrating cavity that is tuned to 3λ/4 at the center of each pixel



Cryogenic metrology of the detector pixels is needed to design and verify the back-short spacing.



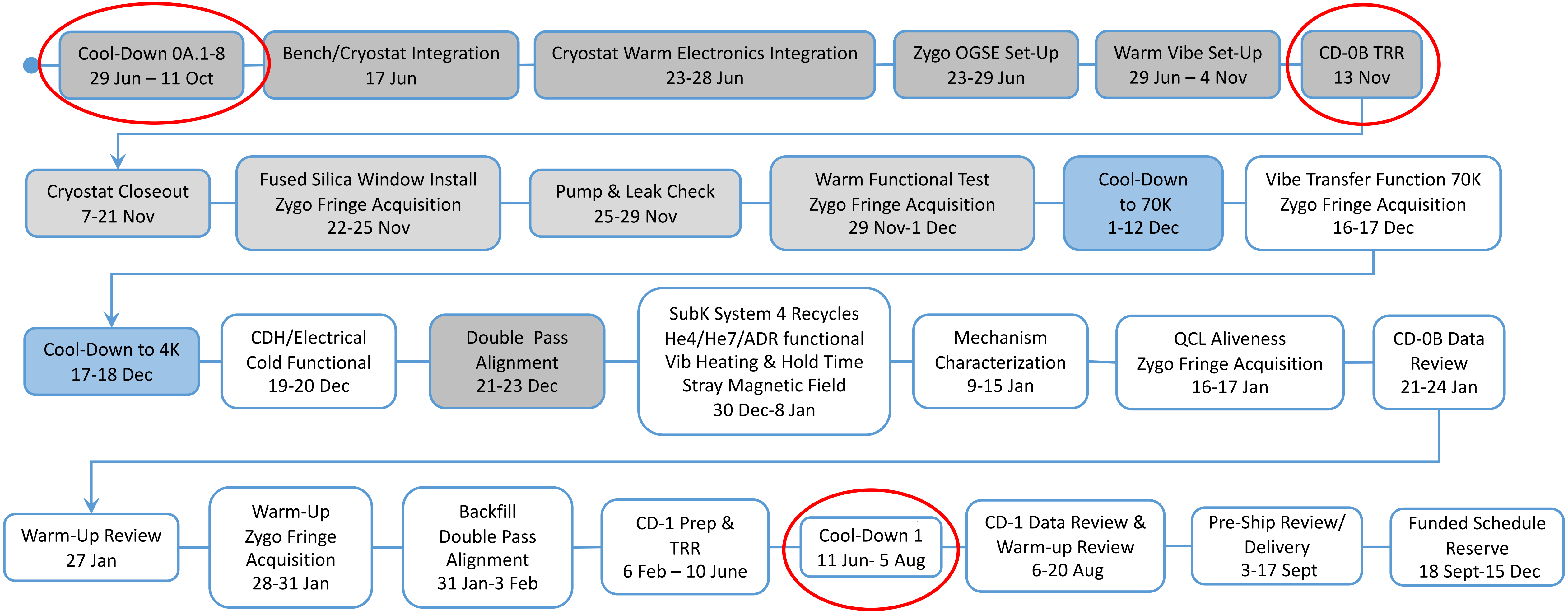
The bandwidth of the back-short is sufficient to optimize the most important lines for HIRMES science

HIRMES is in I&T and on schedule for Dec 2020 shipment to AFRC

Status as of 19 Nov 2019

2 Dec Update: Currently running ~ 10 days ahead of schedule

- Completed
- In Work
- To Go



Cool-Down 0A test series was completed on 11 Oct 2019

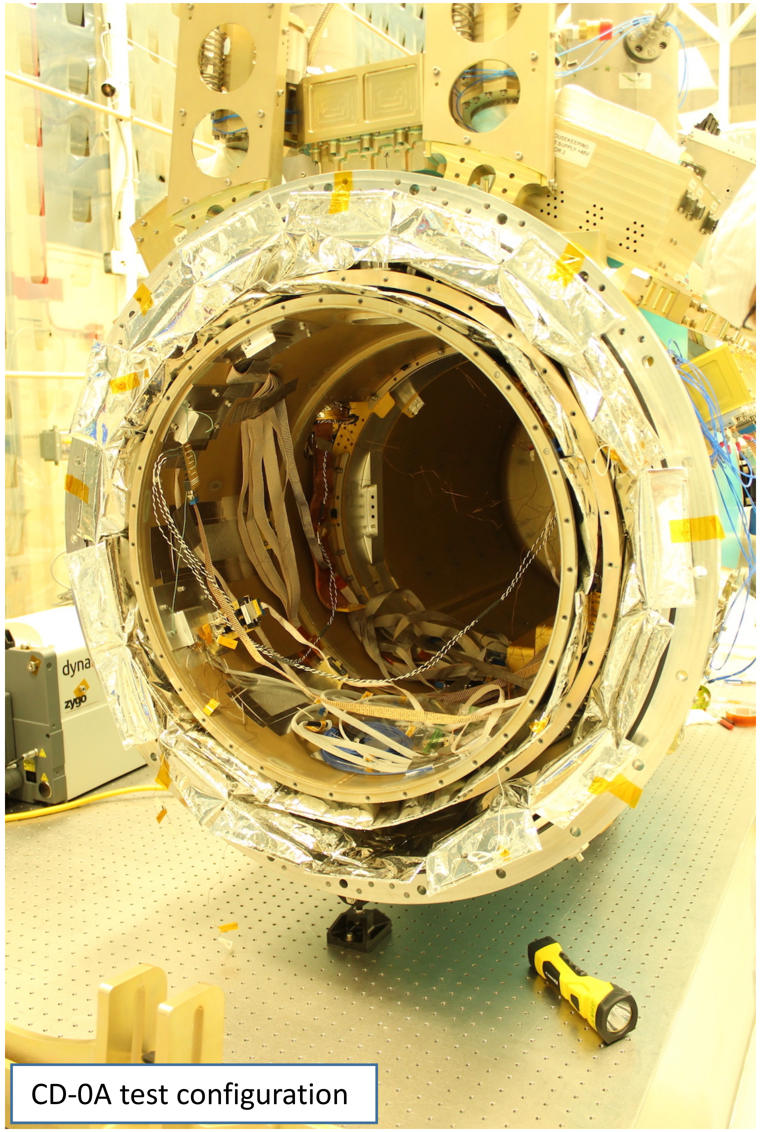
CD-0A provided verification of:

- Cryostat vacuum performance
- Cryostat thermal performance
    - First anchor point for thermal model
- Full thermal transition harnessing
- 4K cooling system
- QCL laser system

Test configuration includes:

- Full thermal transition harness (1,743 wires)
- Full blanketing
- Inner and outer radiation shields
- PTC cryo-cooler system
- Housekeeping electronics

Test required 8 thermal cycles (2 aborted)



CD-0A test configuration

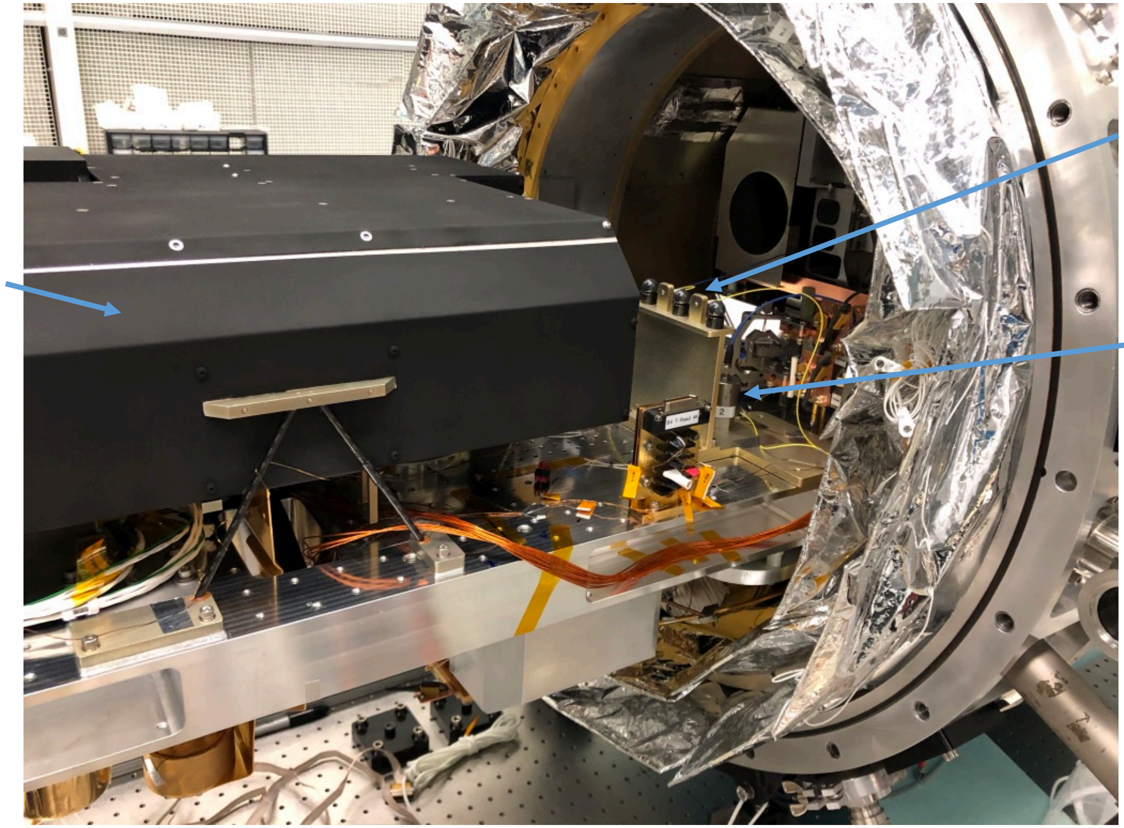
CD-0B test provides verification of 14 functional requirements with focus on mK cooling system and cryogenic optics alignment

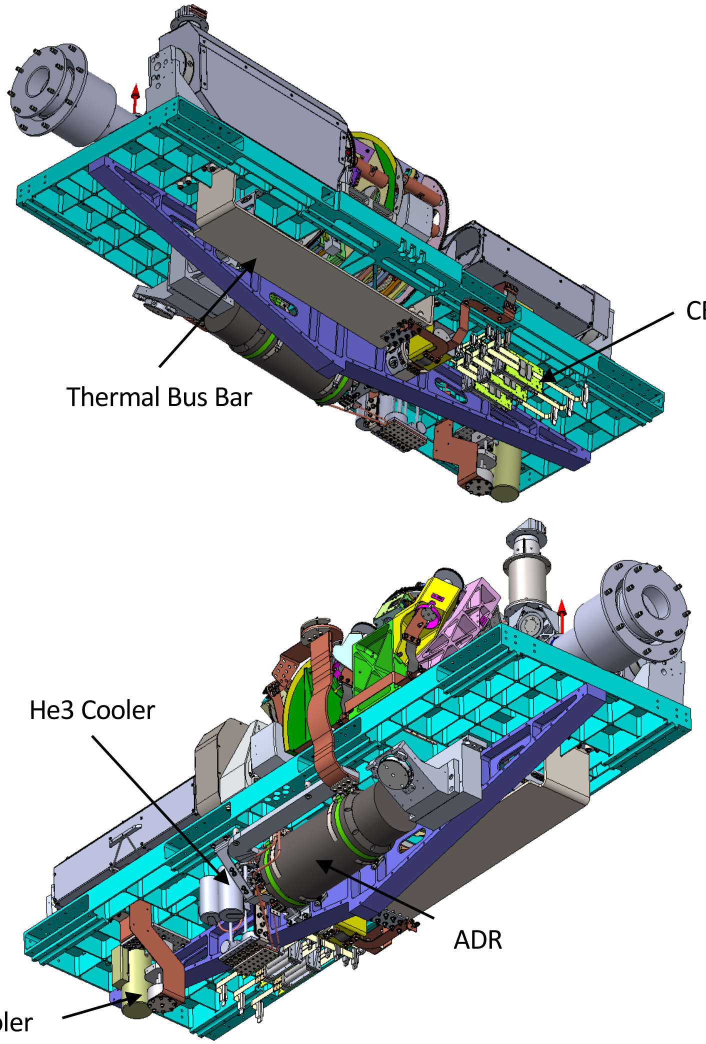
Goal	Description	Requirement Verification
1	Verify HIRMES optical bench, optics and OB components can be cooled to ≦ 4K using 2 PTCs	✓
2	Characterize cooldown time from 300K to 4K	✓
3	Verify He Sorption cooling performance: He7 (He3/He4) Fridge: from 4K to 350mK and 1K He4 Fridge: from 4K to 1K	
4	Verify the FPA thermal interface can be cooled to 70 mK using the ADR and He7 cooler	
5	Verify ADR hold time is ≧ 16 hours under flight thermal and vibration load profile	
6	Verify the He7 cooler has sufficient capacity to support ADR recycling	
7	Verify 1K baffle can be maintained at ≦ 1K by He4 cooler for the duration of ADR operations	
8	Verify the ADR, He7 cooler and He4 cooler recycle timeline performance and duration	
9	Characterize impact of SOFIA vibration environment on thermal performance	
10	Operate mechanisms (Heat Switch, Grating Mechanism, PAM) at cryogenic temperatures	
11	Correlate thermal model with test results	
12	Verify optical system performance at 4K (via Double Pass Test)	
13	Verify Cryostat vacuum performance (i.e. hold vacuum cold for 1 month) and pumpdown time	
14	Perform aliveness test of QCL lasers at cryogenic temps Verify QCL temperature and stability	✓

Initial results look good (→ 12)

Cool-Down 0B Provides verification of the mK cooling system and cryogenic optics alignment

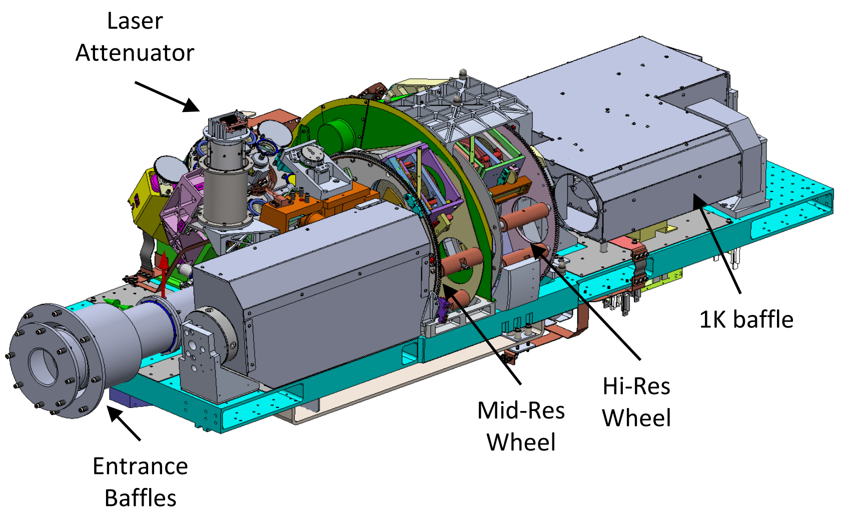
- Test began on 29 Nov
- In the CD-0B level of assembly, the optical bench is added to the CD-0A assembly level

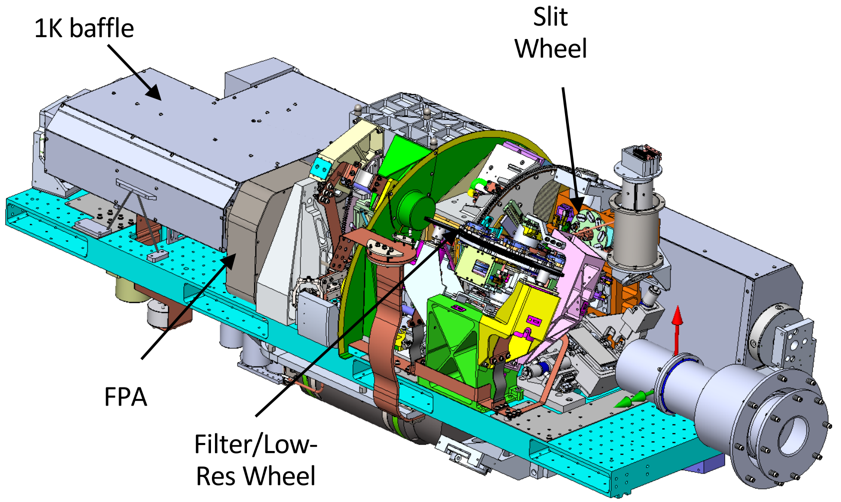


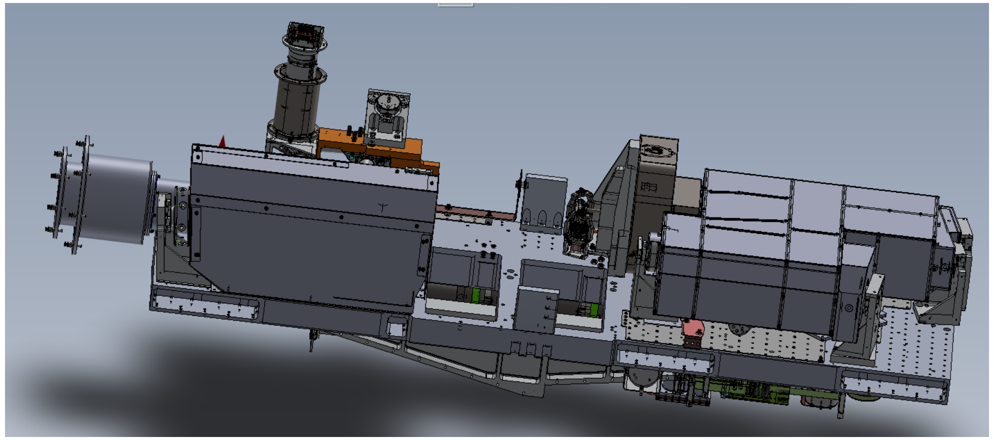


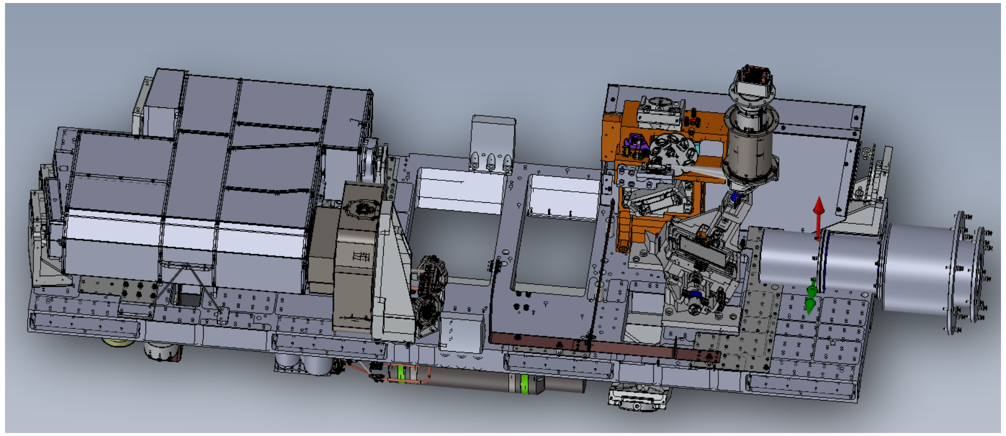
Optical Bench Configuration (Bottom Side) for CD-0B

CD-0B bench assembly level omits FPA and 4 mechanisms in order to enable cryogenic optics alignment test





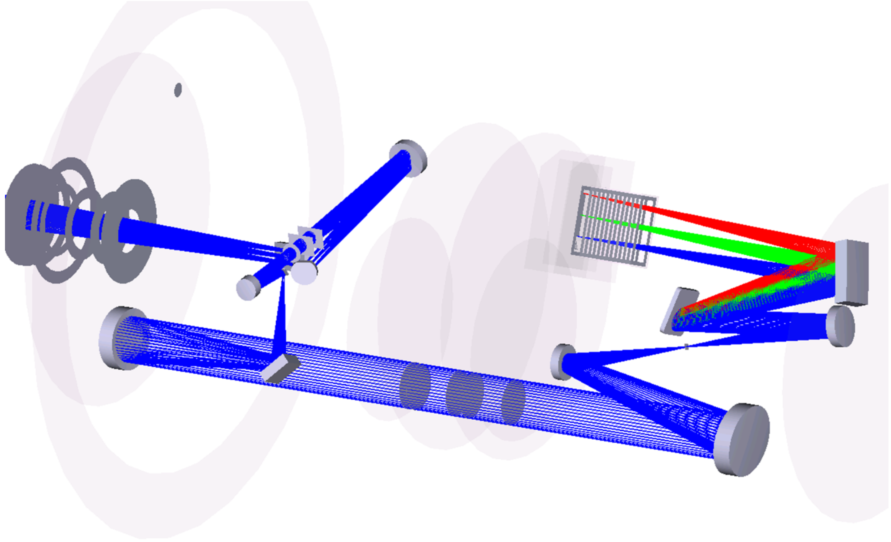


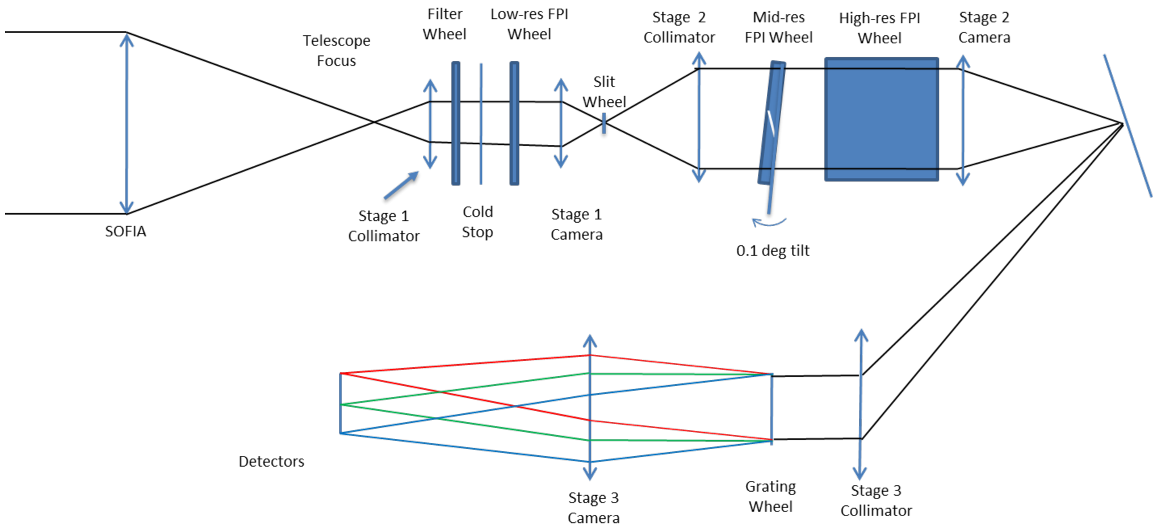


Optical Bench Configuration (Top Side) for CD-0B

HIRMES utilizes a three stage optical system

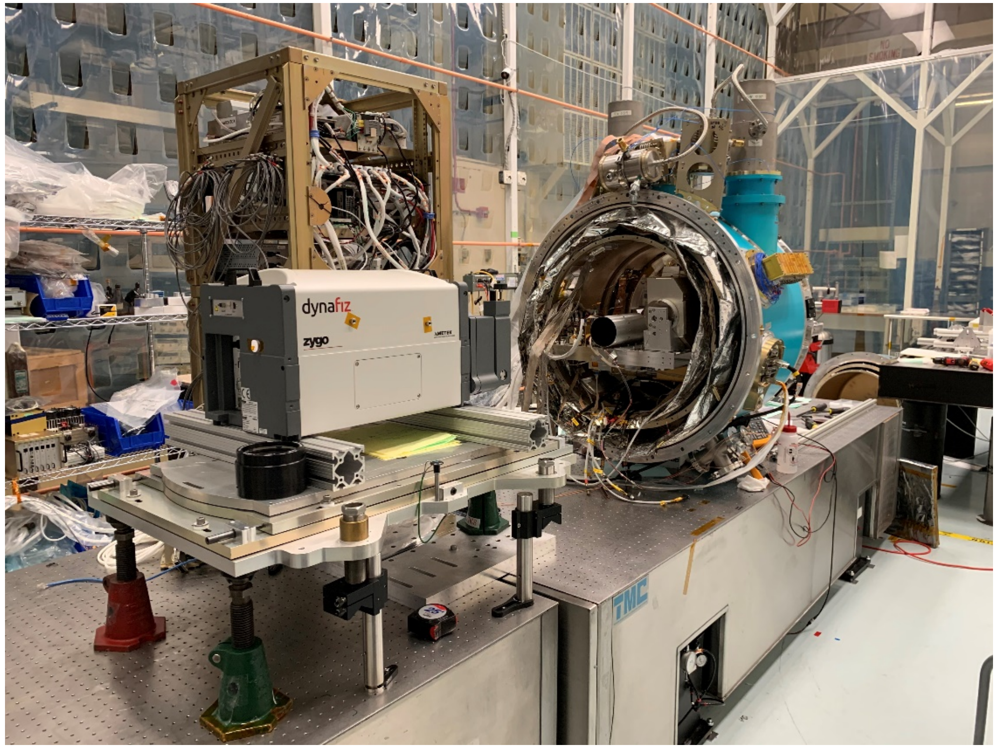
- Pupil imaging
  - HIRMES re-images the SOFIA exit pupil onto a cold (4K) pupil with masking for the secondary mirror spider vanes.
  - Steering mechanism on flat mirror to align HIRMES entrance pupil to telescope exit pupil in two-axes.
- FOV: Slit widths 2.8-11.4 arcsec x 140 arcsec long or 100 x 100 arcsec imaging
- Plate scale, F/#
  - HIRMES re-images to f/13.3 to set a 6.2 arcsec per mm plate scale
  - 8 high-res pixel sizes range from 0.4 to 1.4 mm, to match λ/D for 30 – 105 μm
- Wavelength coverage 25 – 122 μm



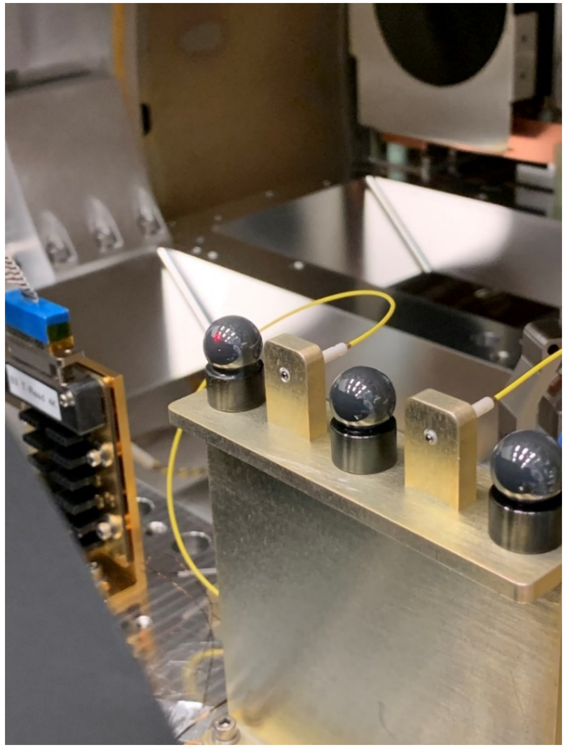


Cryogenic optics alignment is verified during the CD-0B test

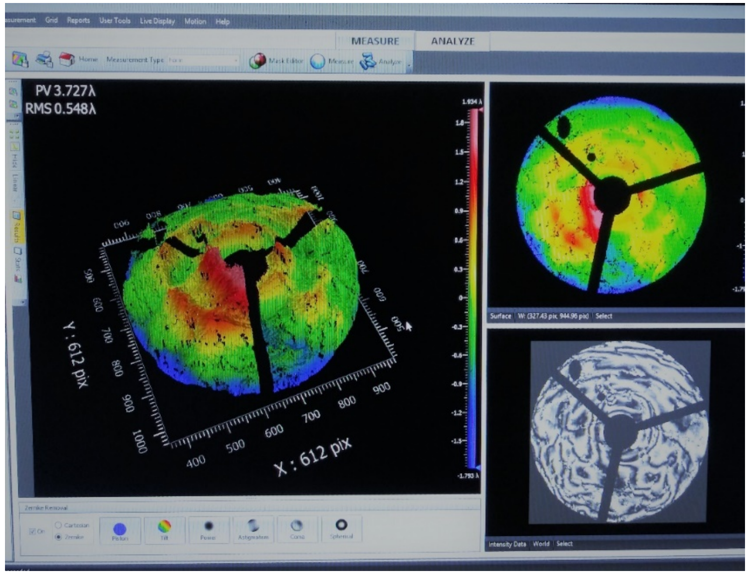
- Test approach:
  - Measure wavefront at ambient temperature, and in same configuration at 4K. Then, the observed change of wavefront is added to ambient wavefront to provide actual performance at 4K



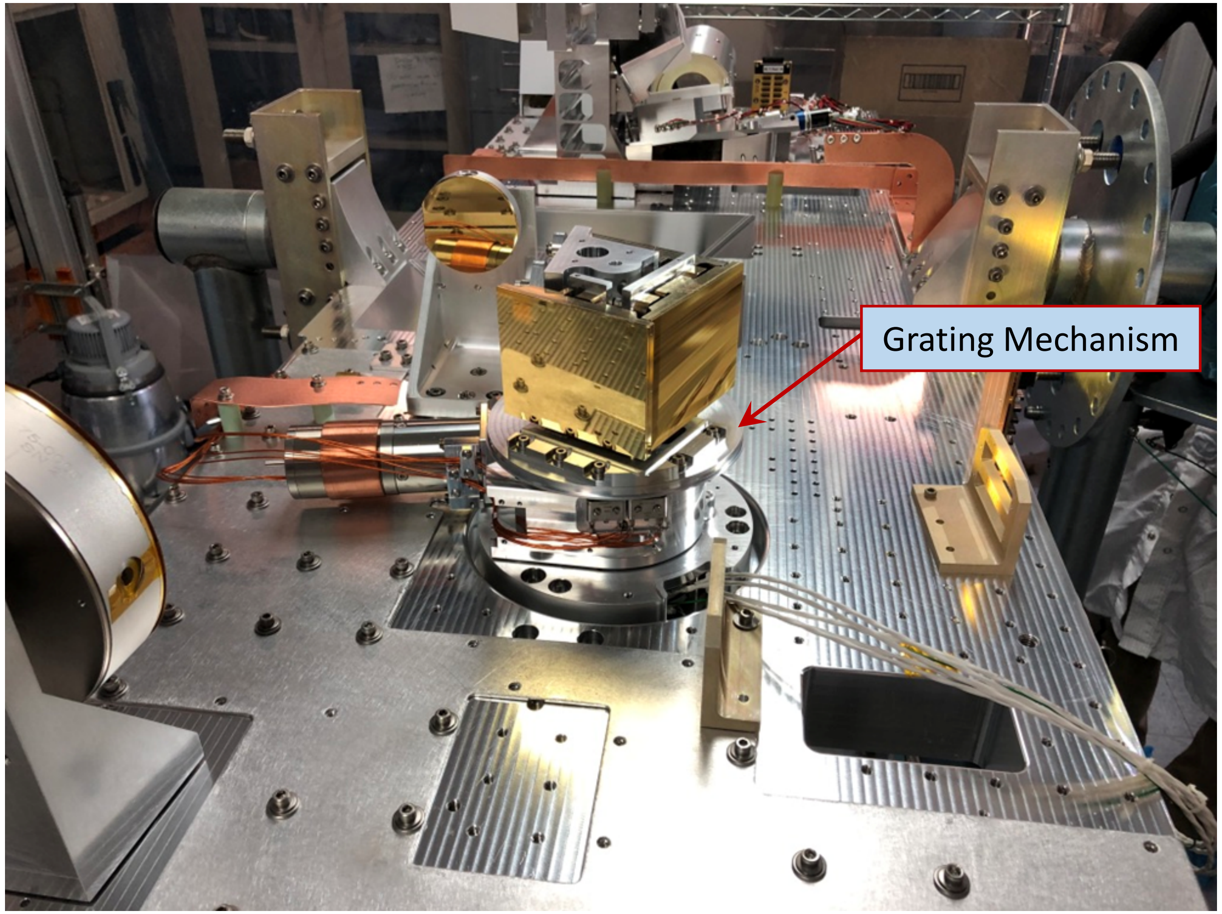
Warm test set-up. Cryogenic test is performed using a fused silica cryostat pressure window.



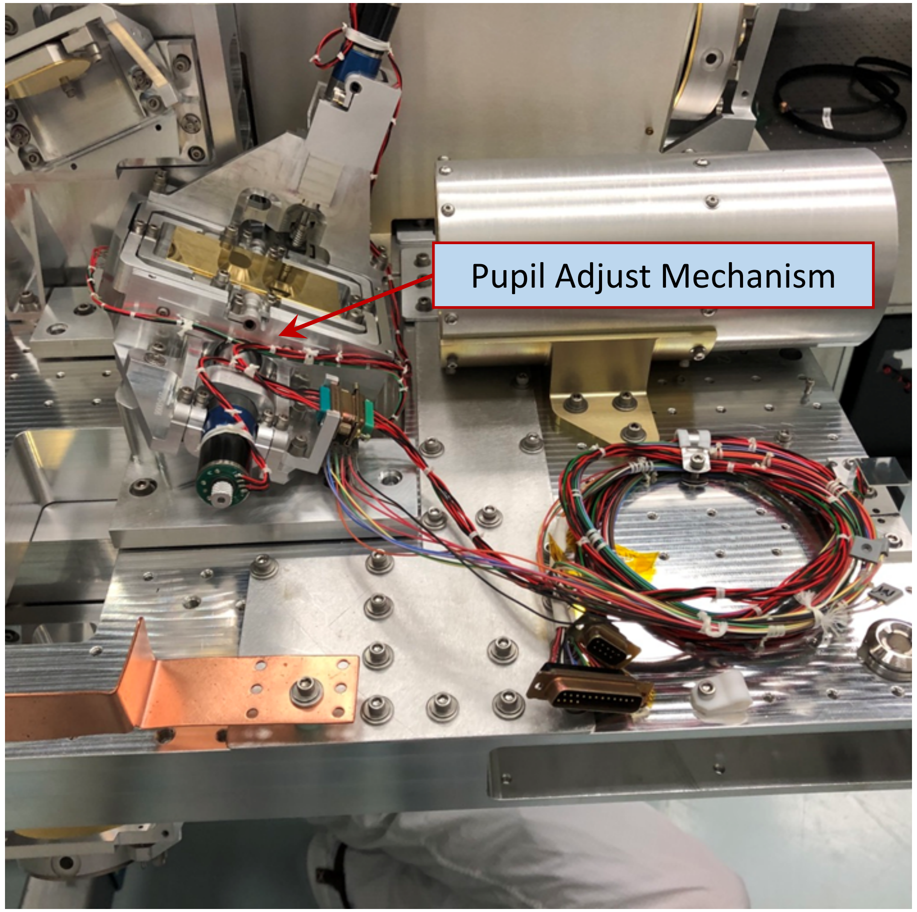
Cryogenic OGSE (tooling balls and fiber sources) is located in place of the FPA to support the double pass test



Two optics mechanisms are included in CD-0B to support the double-pass alignment test



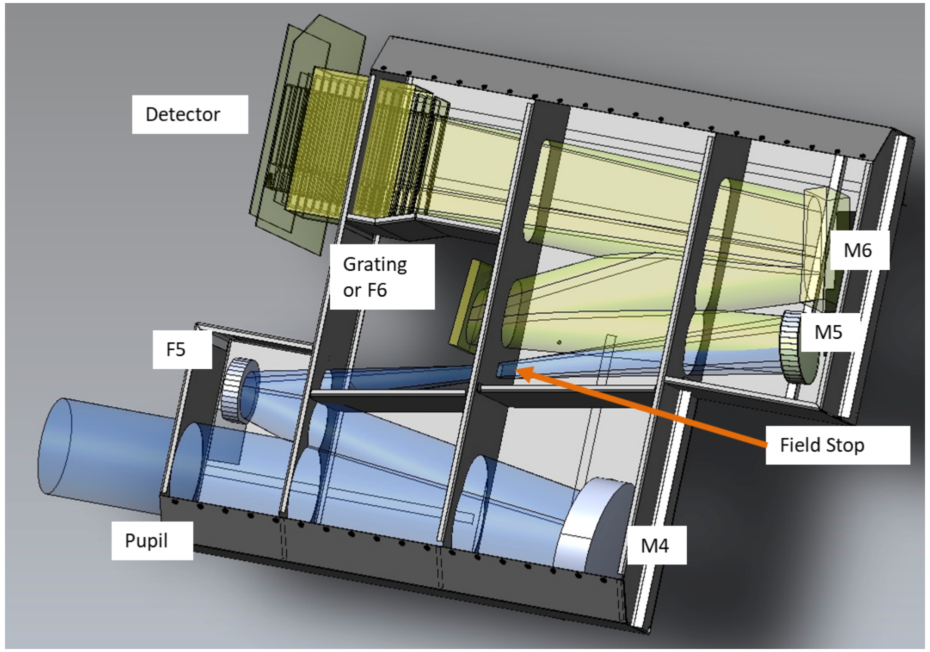
The grating mechanism carries 3 diffraction gratings and 1 mirror. It provides +/- 180 degree rotation with 8 arc-sec precision and stability

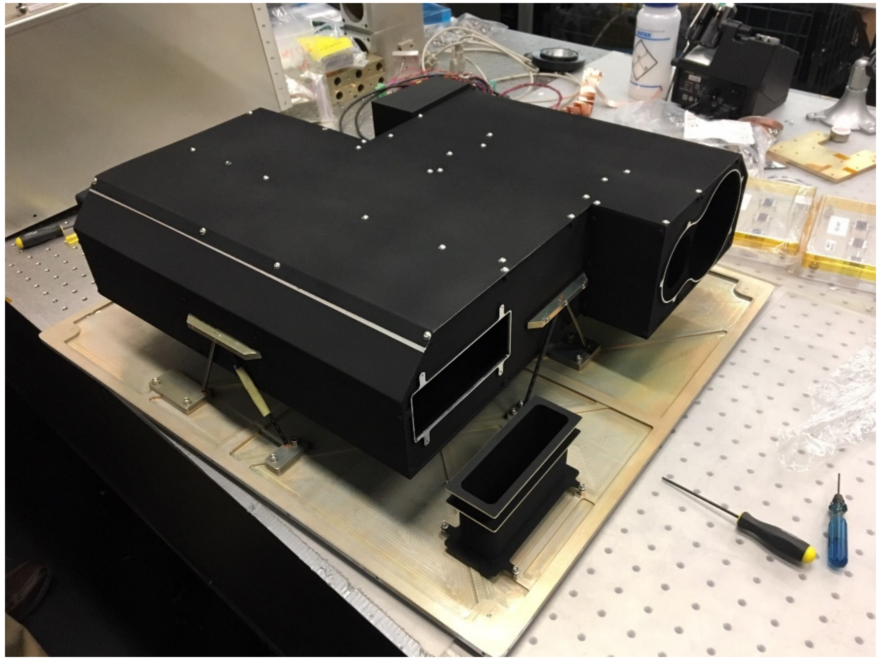


The pupil adjust mechanism enables alignment of the HIRMES entrance pupil with the telescope secondary mirror. It provides +/- 3 degrees tile in two axis with 1 arc-min precision and stability

Control of stray light from thermal self emission is critical to HIRMES performance

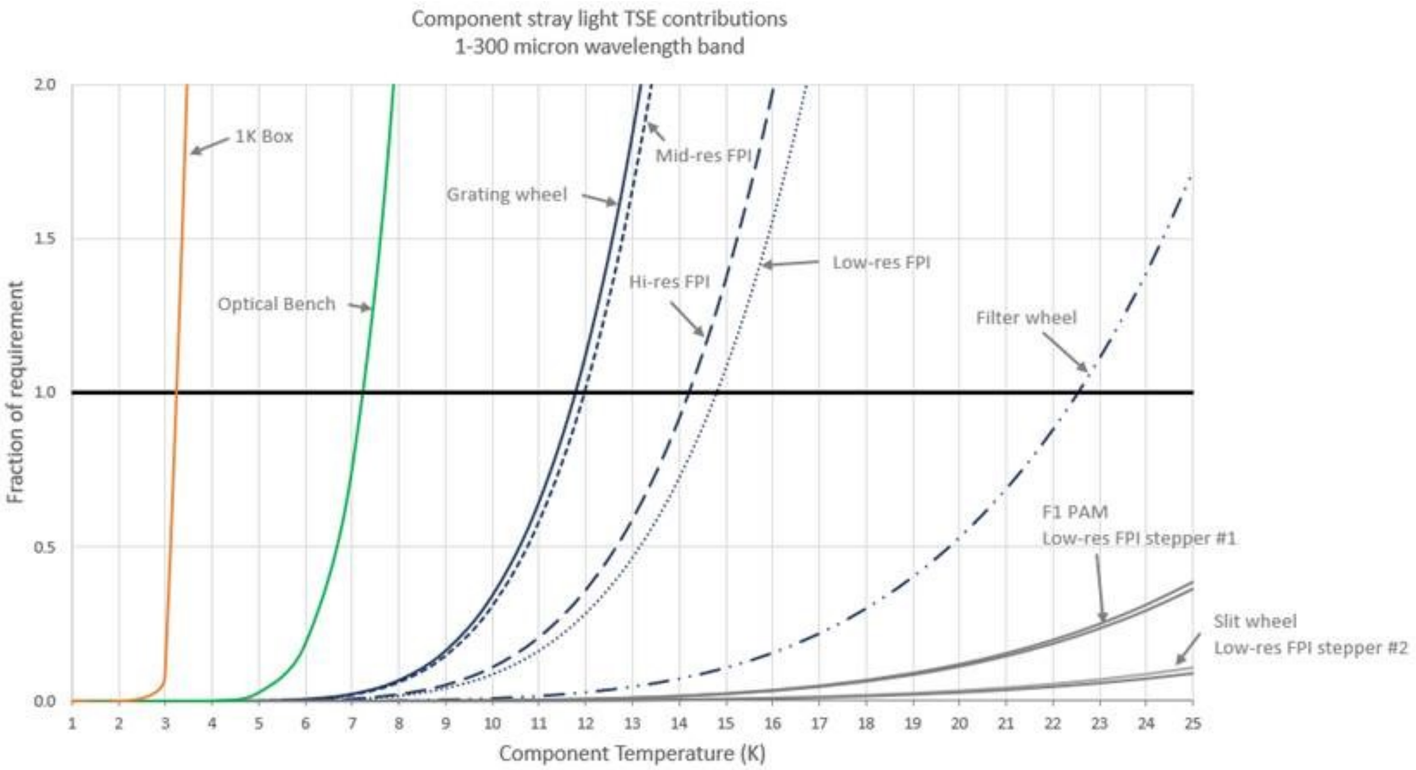
- HIRMES High Resolution detectors can detect 4K light
- Stray light model developed by Photon Engineering from detailed CAD model
- A VBX-2 coated baffle operated at 1K is used to terminate 4K TSE
  - Aeroglaze Z306 and Nextel coatings used in less critical locations



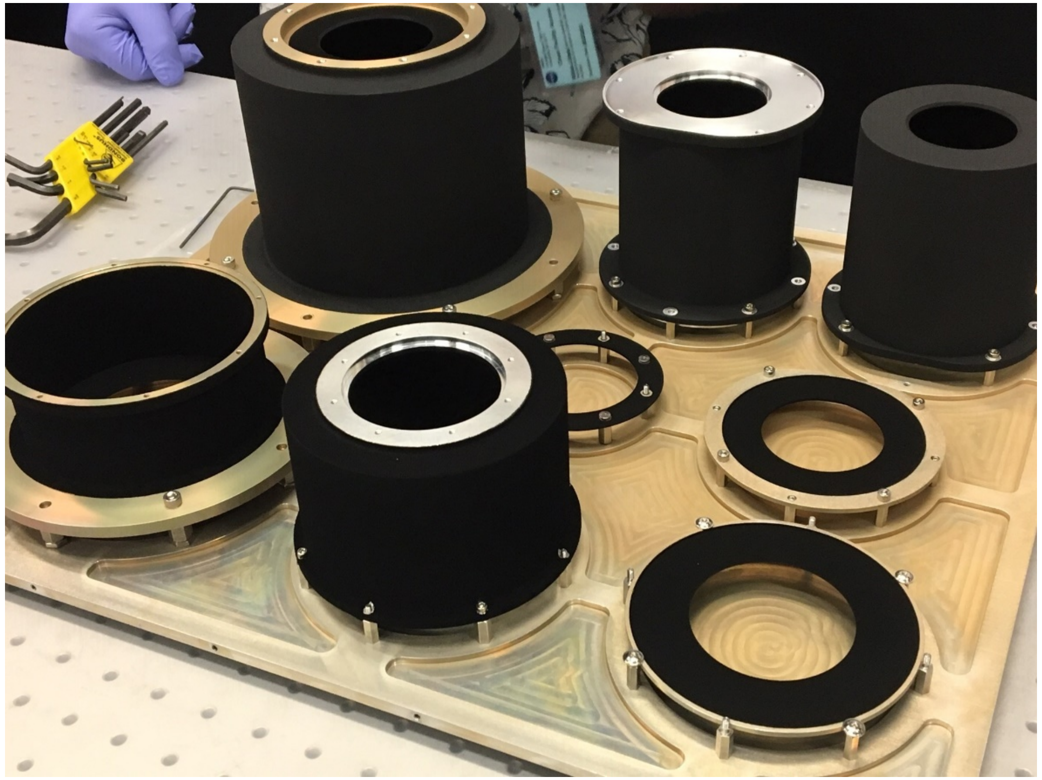


Stray light from 4K thermal self emission is terminated by a VBX-2 coated baffle assembly that is cooled to 1K by a He^4 sorption cooler

To ensure background-limited sensitivity, the design of HIRMES stray light control is informed by a detailed stray light model that is anchored to the instrument mechanical CAD model

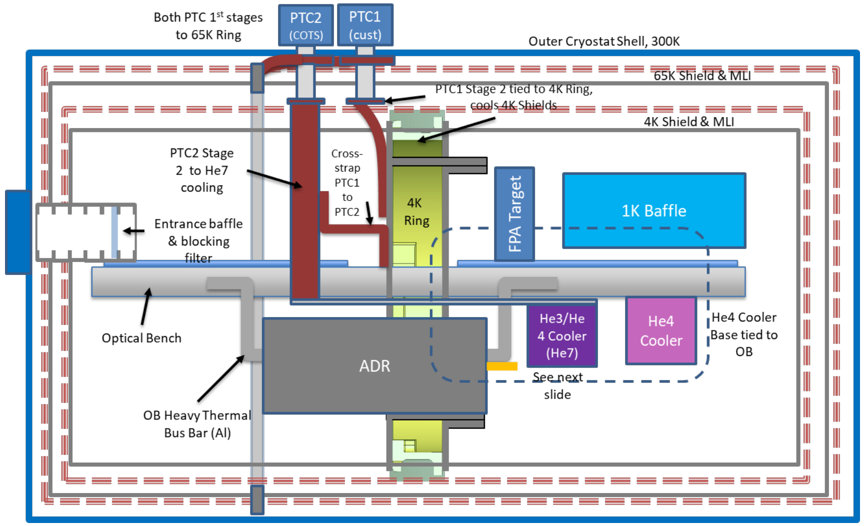


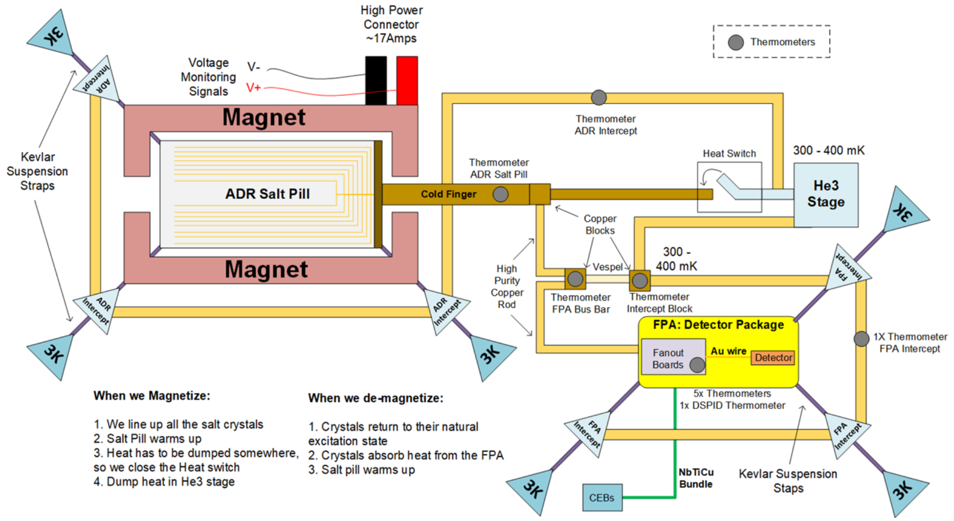
Model susceptibility to transient sources of thermal stray light is shown.



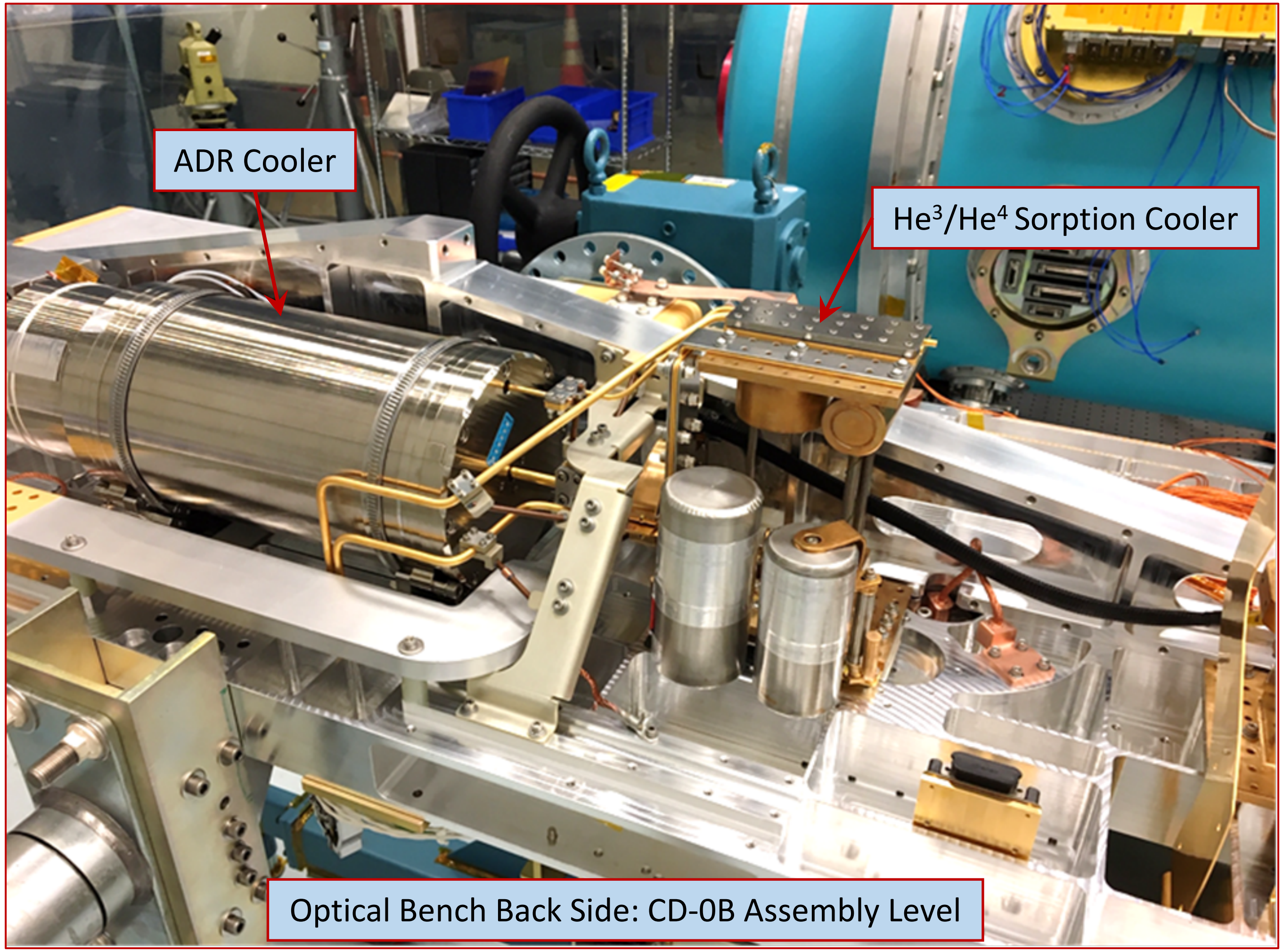
HIRMES utilizes closed-cycle cooling

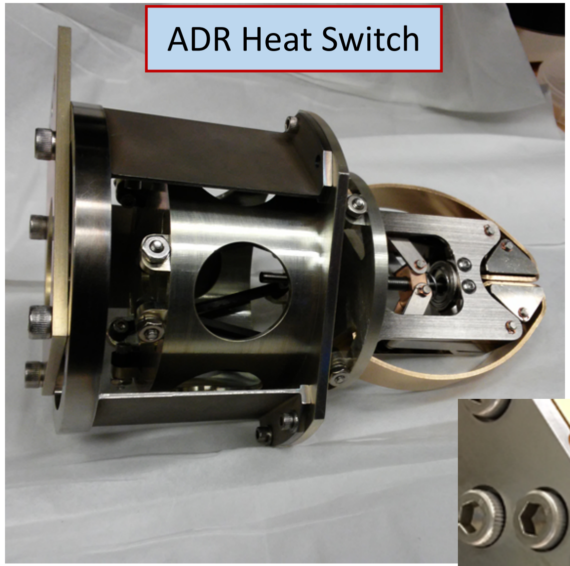
- HIRMES cryogenic system uses multiple stages of refrigeration to meet cooling requirements (temperature and operational time)
  - ADR to cool FPA to 70 mK
  - 3He/4He (7He) sorption cooler
    - 3He portion of cooler used as heat intercept for Kevlar suspension assemblies that support the ADR salt pill and FPA
    - 4He portion of cooler is used to precool the ADR salt pill to 0.8 K before demagnetization
  - 4He sorption cooler to cool the 1 K baffle
  - Two pulse tube cryocoolers (PTC) to cool the optical bench to 4 K and act as heat sinks for recycling the ADR and 4He & 7He sorption coolers

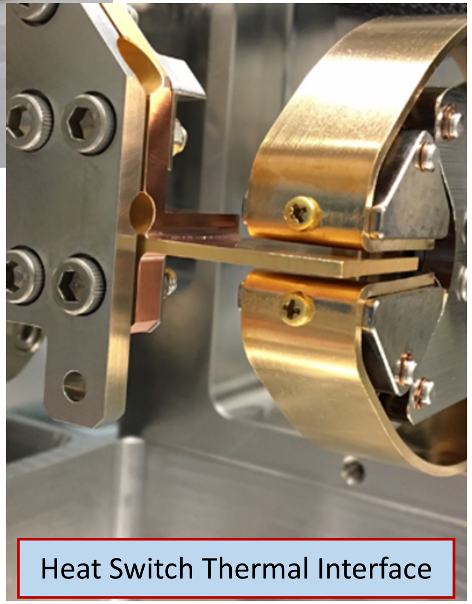




Key elements of the HIRMES mK cooling system







CD-1 (Jun – Aug 2020) is final test prior to Pre-ship Review for December 2020 delivery

- Cool-Down One (CD-1)
  - Full flight configuration
    - CD-0B assembly + Fabry-Perot etalons + etalon/filter/slit selection mechanisms + flight Focal Plane Assembly (FPA)
  - Comprehensive Performance Test (CPT)
  - Full instrument calibration

- A CPT will be performed at AFRC to verify shipment

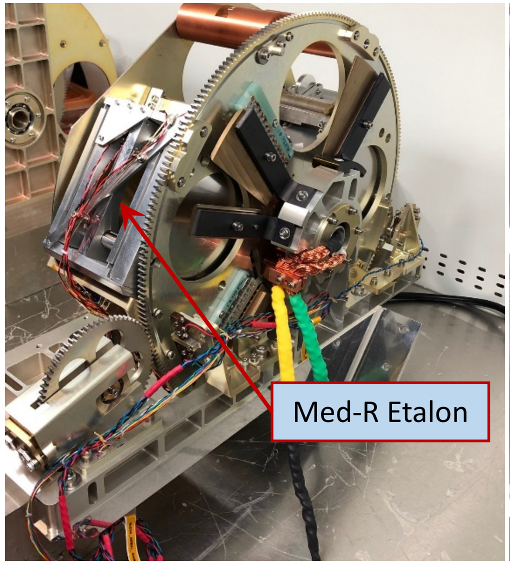
- A Hanger-Op will be performed to verify aircraft interfaces

- Acceptance anticipated ~July 2021 following a 7 month in-flight commissioning period

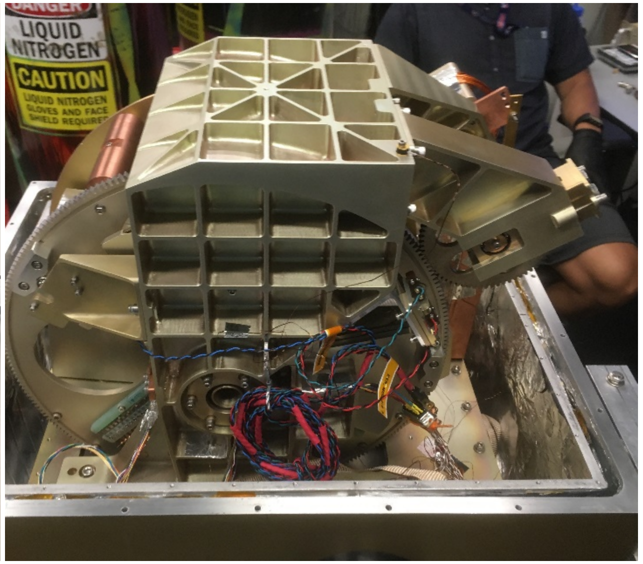
Mechanisms are used to configure beam line elements for HIRMES observing modes

- Each observation requires setting 6 mechanisms

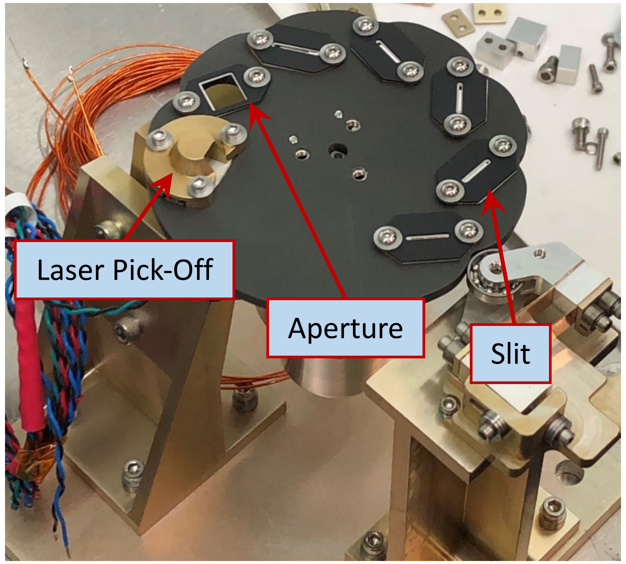
Spectroscopy Mode	X Denotes Element in Beam Line					
	HR Scanning FPI	MR Scanning FPI	LR Scanning FPI	Grating	Filters & Fixed FPI	Slit
High Resolution	X	X		X	X	X
Medium Resolution		X		X	X	X
Low Resolution				X	X	X
Imaging			X		X	



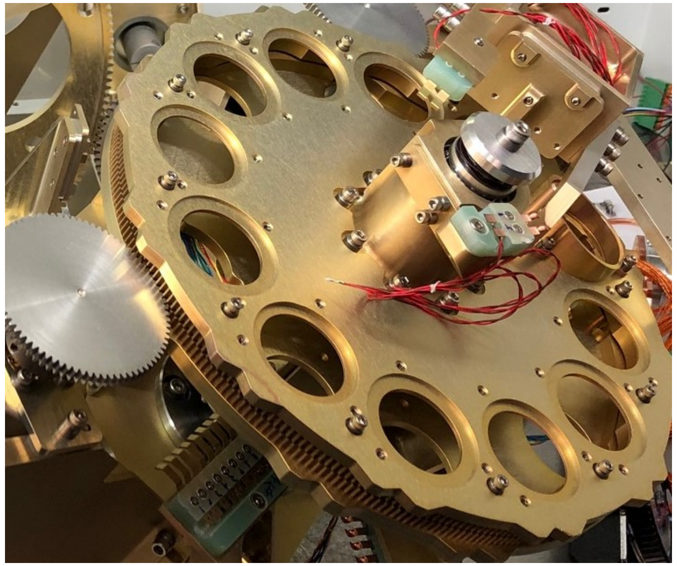
Medium-R FPI selection wheel



High-R FPI selection wheel in test

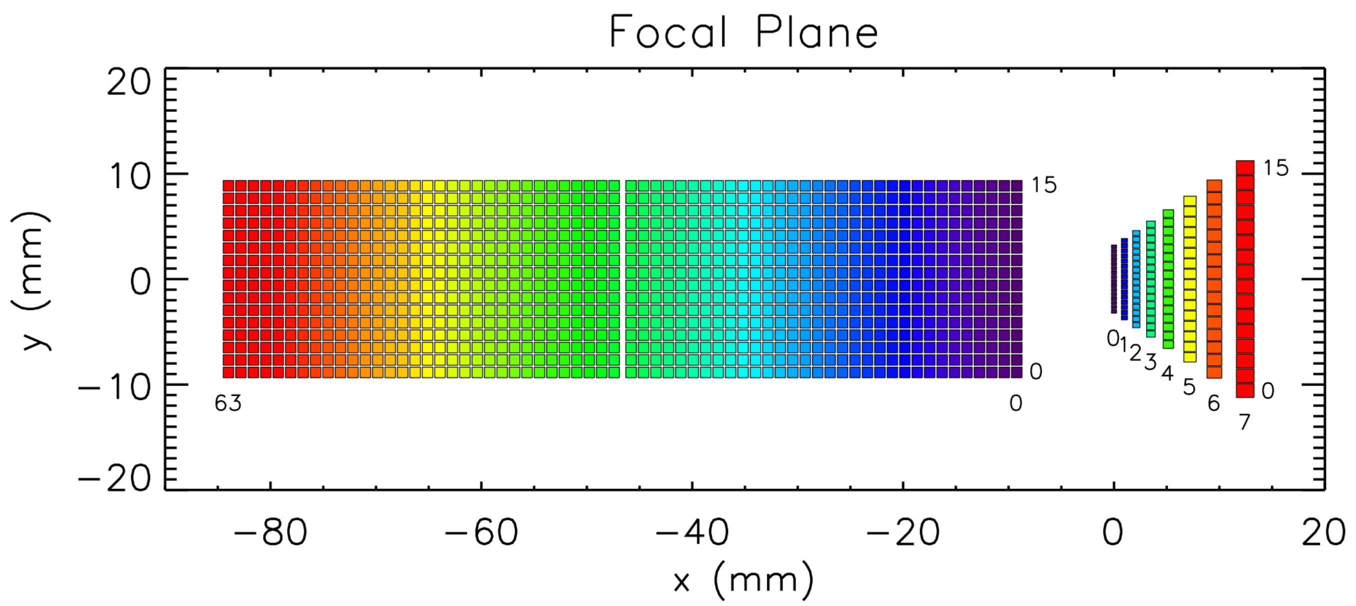


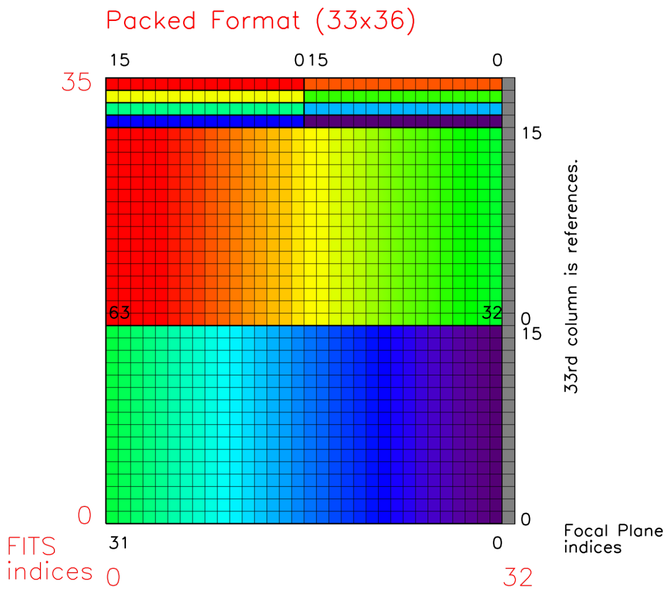
Slit selection wheel


Filter selection wheel

Each exposure is packaged into a single image

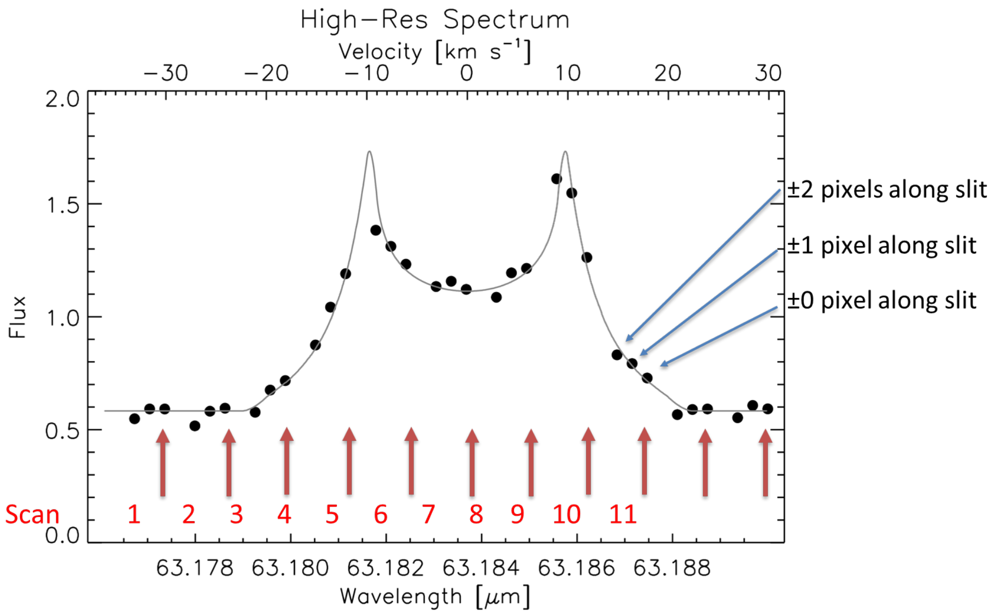
- All pixels are read-out regardless of the observation details
- Exposures are packaged into data cubes: 33 x 36 x n
  - CRUSH (customized for HIRMES) is used for data analysis
- Data processing to Level-3 is performed by the SOFIA Science Center



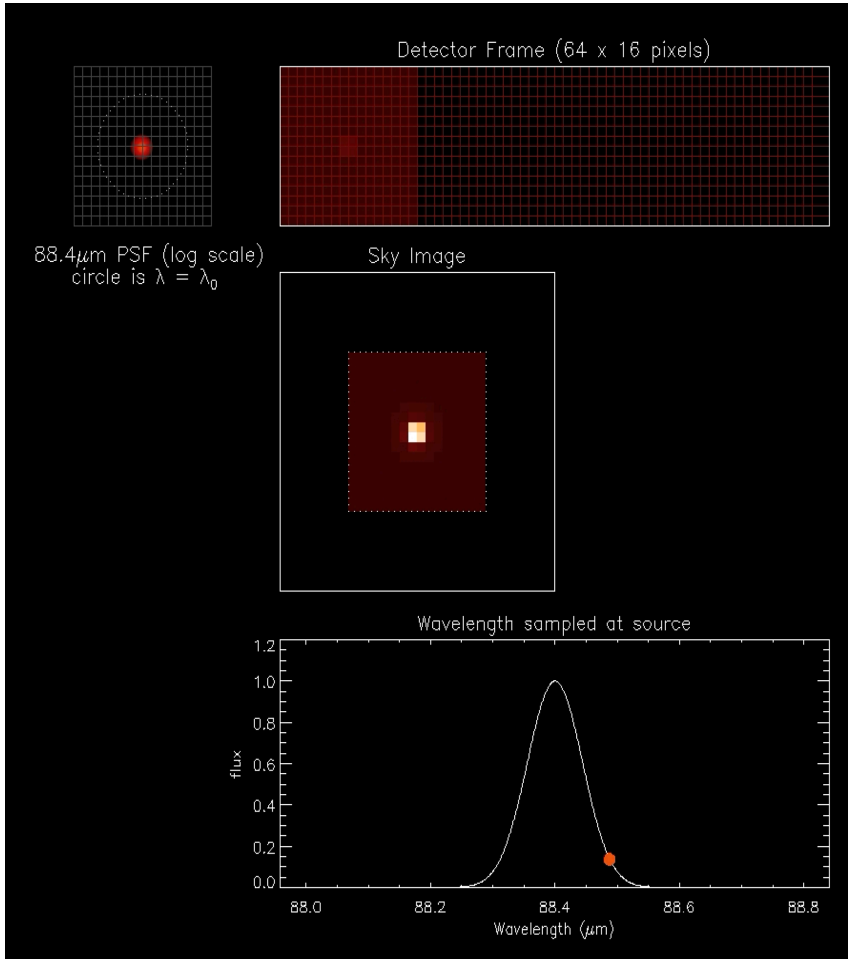


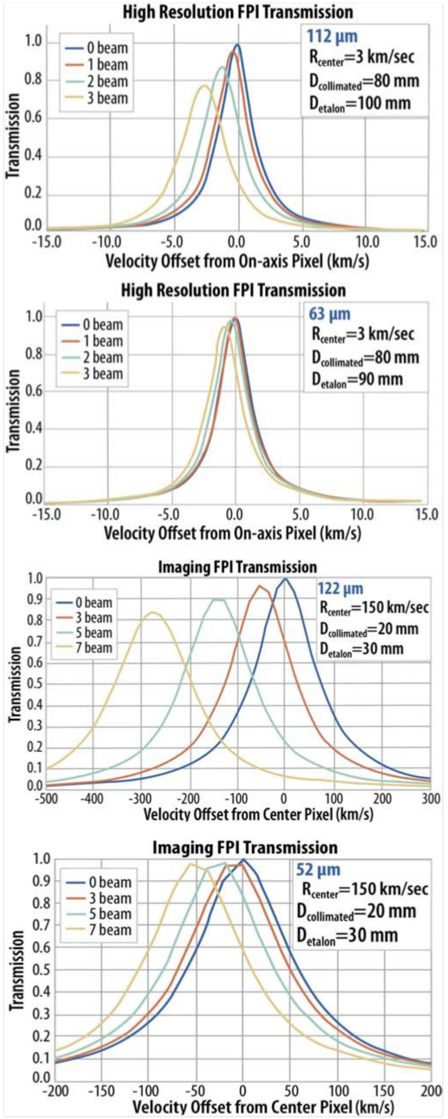
Data are collected using spatial scanning

- Spatial scanning allows separation of source from other signals (a.k.a. noise)
- The Fabry-Perot wavelength varies slightly with position of the source
    - Hence, Lissajous or Box scan patterns can improve spectral sampling

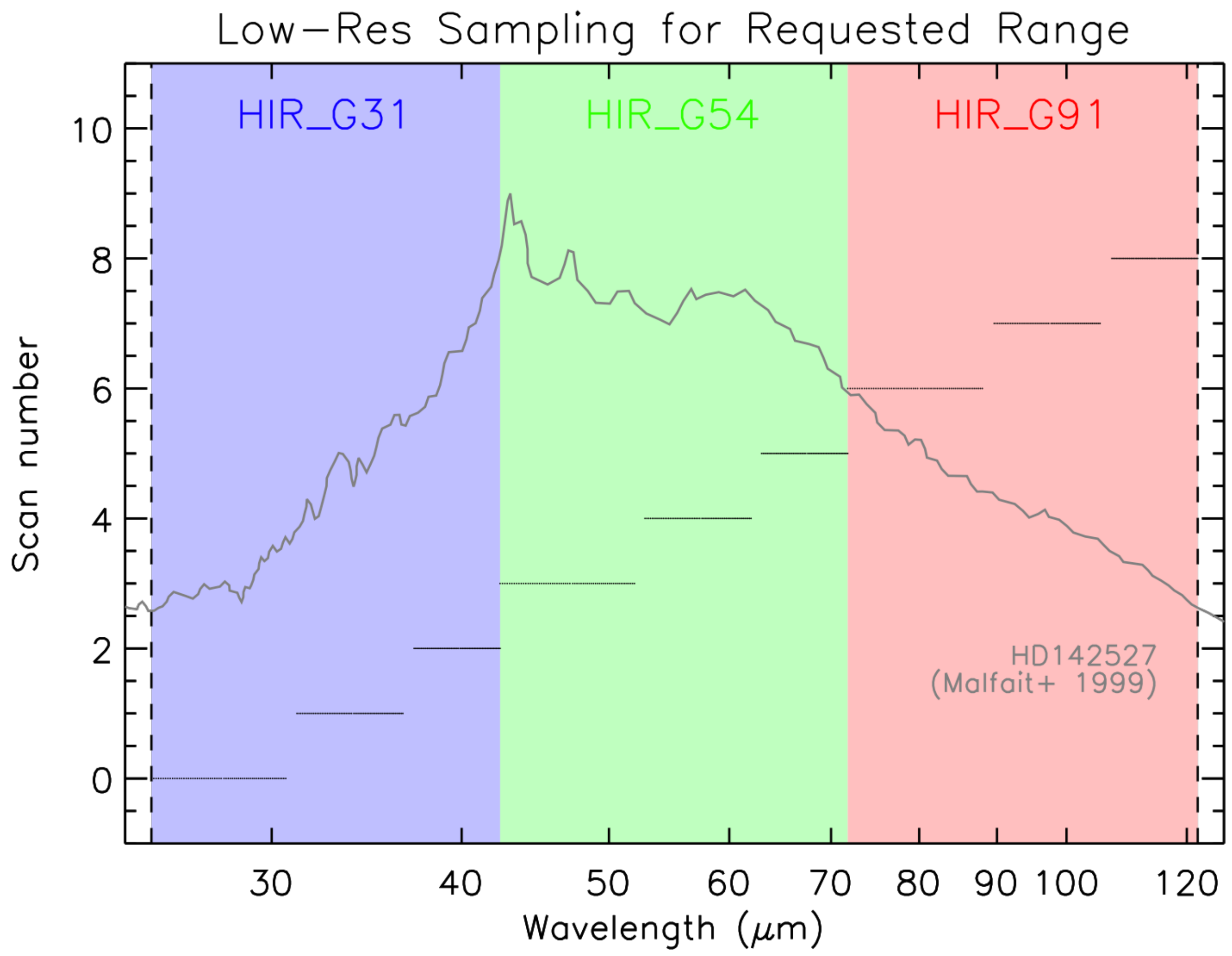


Simulated line profile of a rotating disk showing 11 scans at nominal wavelengths to sample the line profile. Additional sampling appears as the source is scanned up and down the slit by ±2 pixels.





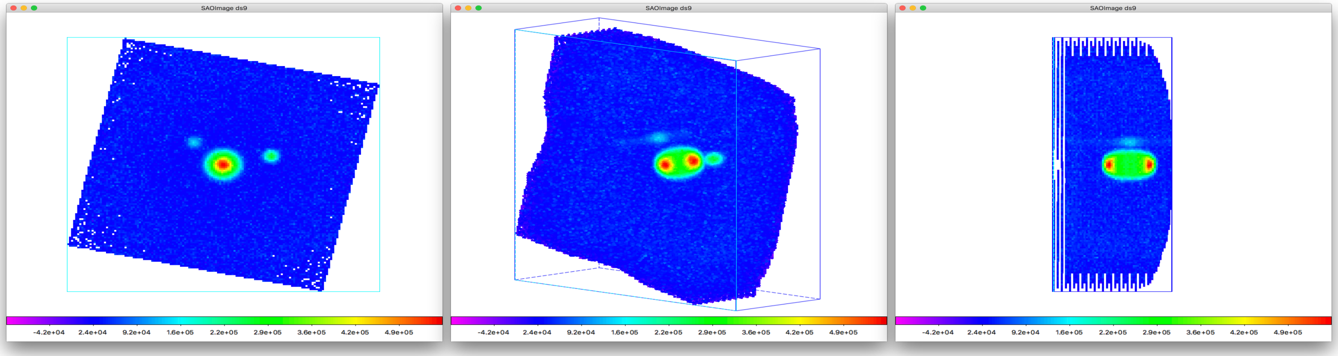
Full wavelength coverage in low-res spectroscopy requires use of 3 wavelength settings for each of the 3 gratings



CRUSH will be used for data analysis

- Developer: Attila Kovacs, now at the CfA.
- Adapted to process data from many different TES bolometer instruments (e.g. SHARC-2, GISMO, HAWC+).
  - HIRMES required adaptation for spectral data and data cubes instead of monochromatic single-band imaging.
- Processing to Level-3 will be performed by the SOFIA Science Center
- Any Level-4 tools developed by the HIRMES team will be made available to the community

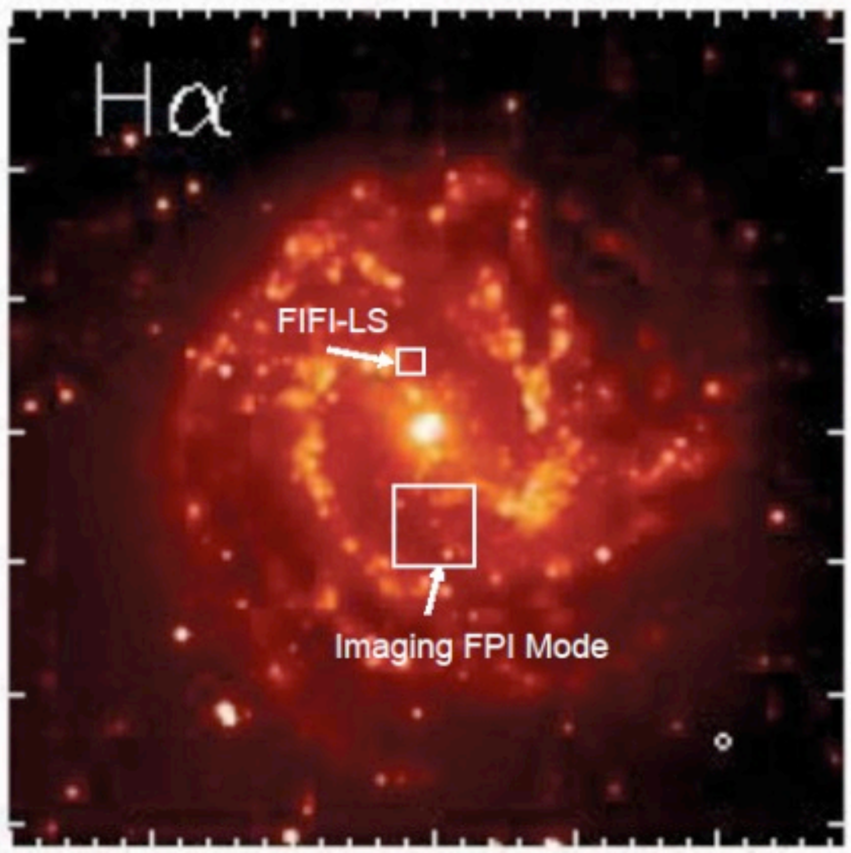
0°, 0° (x-y) 45°, 10° 90°, 0° (λ-y)



- Simulated data set processed with CRUSH
- Simulated sky includes 3 sources with line and continuum emission. Central source is a small expanding shell.
- Simulated observations include 11 scans with different target wavelength settings.
- [164,154,60] data cube

HIRMES enables broad science capability beyond planet-forming discs

- **Galactic chemistry, radiation fields, shocks:** [SI] 25.25 μm; [FeII] 25.99, 35.35 μm, [SIII] 33.48 μm, [SiII] 34.81 μm; [NeIII] 36.0 μm, [OIII] 51.81, 88.36 μm, [NIII] 57.30 μm, [OI] 63.18 μm
- **Extragalactic lines** resolved with mid-res, imaged with low res
- **SEDs** with grating mode
- **O/H in HII regions:** [OIII] 51.81, 88.36 μm



HIRMES is on course and on time for shipment to AFRC during Dec 2020

Learn more:
Current instrument paper
How Fabry-Perot tunable filters work
How Transition Edge Sensors work
How Adiabatic Demagnetization Refrigerators Work

FY20 HIRMES Tele-Talks		
Instrument Overview	4 December	Matt Greenhouse
Protoplanetary Disks	11 December	Klaus Pontoppidan
Comets	15 January	Stefanie Milam
Deuterium in Giant Planets	29 January	Gordon Bjoraker
Debris Disks	5 February	Christine H. Chen

HIRMES is coming soon to this space