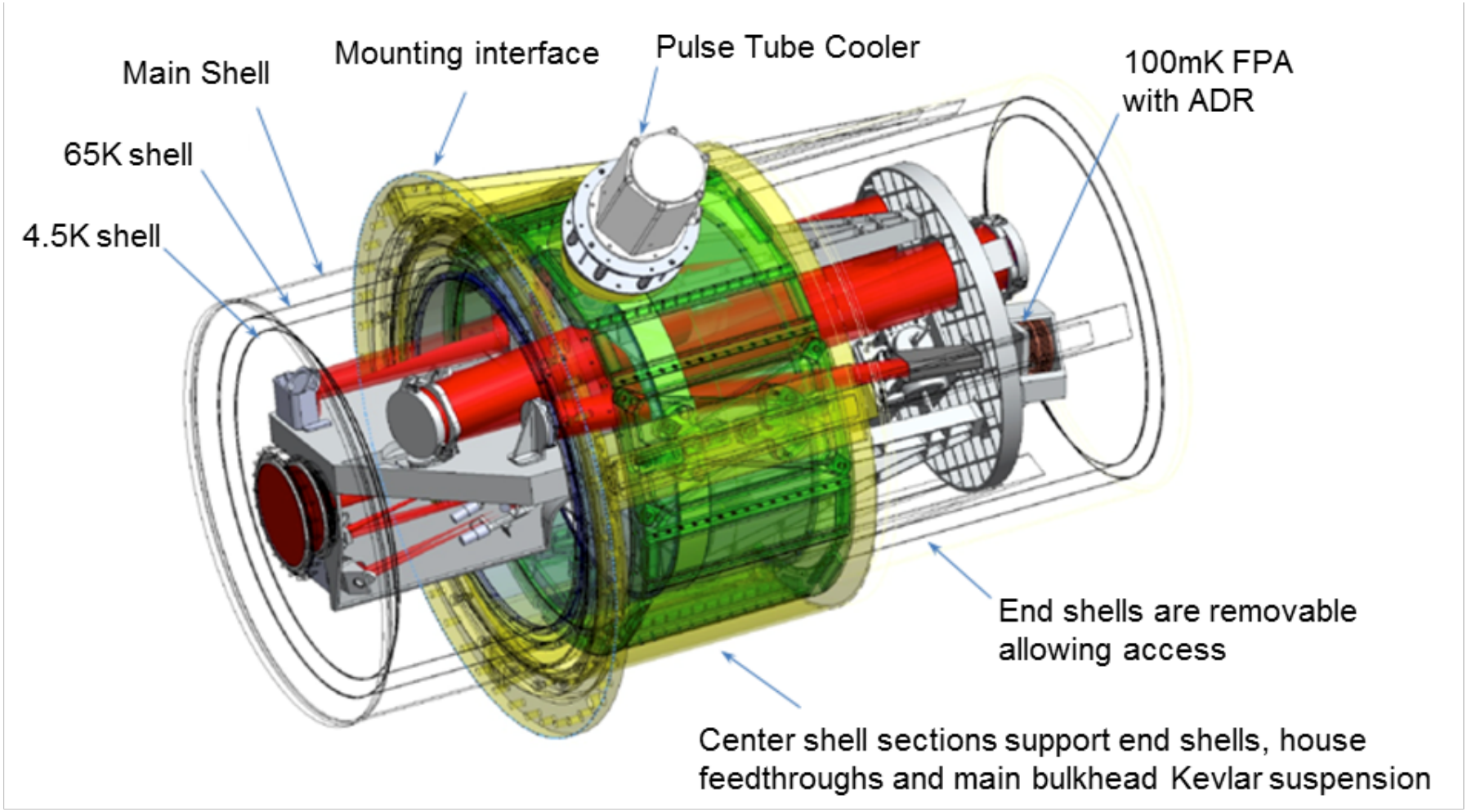
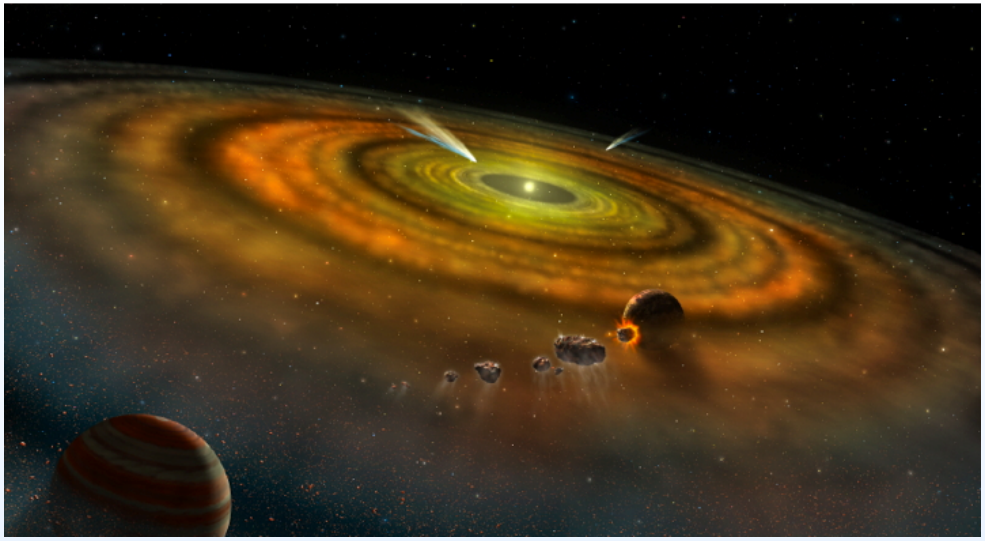
High Resolution Mid-infrared Spectrometer (HIRMES)

SOFIA's 3rd Generation Instrument



Scientific Motivation for HIRMES

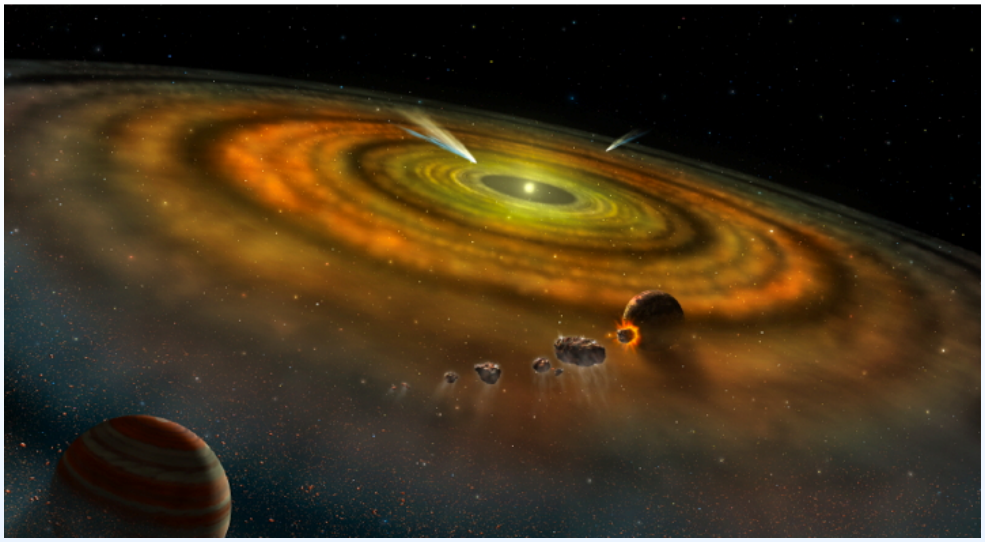
- Over ~10 million years, protoplanetary disks evolve into young planetary systems
- Bulk of mass is gas and ice, and both hard to observe
  - This hinders testing & development of planet formation theories



PI: Harvey Moseley (Goddard)

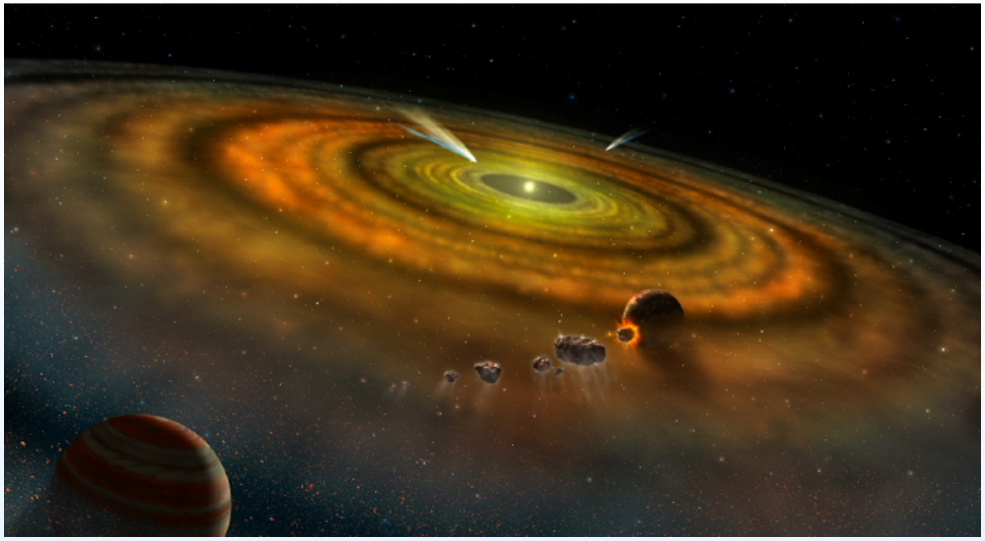
Science team:
D. Neufeld (JHU)
G. Melnick (SAO)
D. Watson (Rochester)
G. Stacey (Cornell University)
K. Pontoppidan (JHU)
E. Bergin (Univ. of Michigan)
J. Staguhn (JHU/GSFC)
S. Rinehart (GSFC)
A. Roberge (GSFC)

Scientific Motivation for HIRMES



- Primary science is to investigate proto-planetary disk physics and addresses the questions:
  - How does the disk mass evolve during planetary formation?
  - What is the distribution of oxygen, water ice, and water vapor in different phases of planet formation?
  - What are the kinematics of water vapor and oxygen in protoplanetary disks?

Scientific Motivation for HIRMES



- Primary science will be to investigate proto-planetary disk physics and addresses the questions:
  - How does the disk mass evolve during planetary formation?
  - What is the distribution of oxygen, water ice, and water vapor in different phases of planet formation?
  - What are the kinematics of water vapor and oxygen in protoplanetary disks?

Over-arching theme is discover how protoplanetary systems evolve

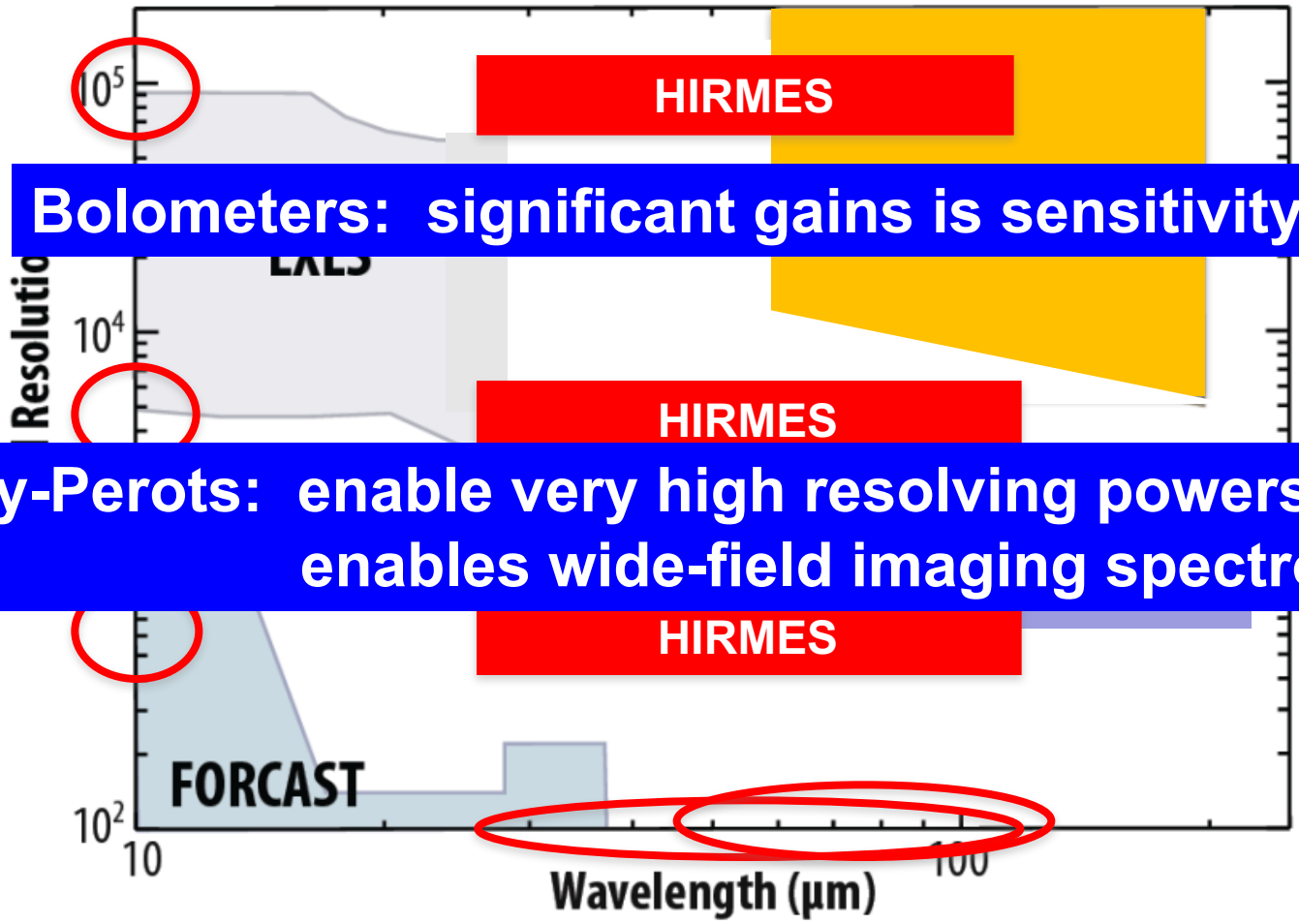
How is the Science Achieved

- HIRMES is a direct detection spectrometer covering the spectral range from 25 to 122 μm
- There are four spectroscopic modes to HIRMES
  - High-res mode R ~ 100,000
  - Mid-res mode R ~ 10,000
  - Low-res mode R ~ 600
  - Imaging spectroscopy mode: R ~ 2000
- The modes are optimized to deliver the maximum sensitivity achievable with SOFIA. HIRMES uses:
  - Background limited bolometers
  - Combination of Fabry-Perot Interferometers and gratings

HIRMES covers an important wavelength range for protoplanetary disk science

- **Water and ice:** water and ice play a critical role in the formation of giant planet cores and, producing habitable conditions in terrestrial planets
  - H_2O 34.9823 μm 651-624 rotational line
  - Ice 43, 47, 63 μm
- **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 = 2-0 rotational line
  - HIRMES resolves these narrow lines and determines their origins from velocity profiles

HIRMES bridges the spectroscopic gap between EXES/FORCAST and GREAT/FIFI-LS



Comparision with upGreat

- Coherent detection fundamentally limited in sensitivity by the quantum noise limit inherent in the detection of phase
- Direct detection in principle wins by factors of 12 (122 μm) to 58 (26 μm) over coherent detection

Sensitivity ratio estimates based on public upGREAT sensitivities:

[OI] 63 μm 10:1
HD 112 μm 10:1

Comparisons with FIFI-LS

- Both are direct detection spectrometers, so they do not suffer from quantum noise limit, so in terms of sensitivity:

HIRMES Spectral Imaging Mode ≈ FIFI-LS IFU Mode

- For lines, it is anticipated that the factor ~100 better spectral resolution than FIFI-LS will lead to better line sensitivity for HIRMES Hi-Res Mode

Other HIRMES Instrument Specifications

Parameters	Note
Spectral range	25-122 μm
Angular resolution	Diffraction limited @ λ=45 μm
Number of det. modules	2
Detector format	16 x 64 mid/low-res, 8x16 high-res
Detector technology & operating temperature	TES bolometers @ 0.1 K
Detector sensitivity	NEP ~ 1 x 10^{-18} W/√Hz including photon noise
Detector cold readout	SQUID
Detector warm readout	UBC Multichannel Electronics (MCE)
Cooler	Pulse tube cooler and adiabatic demagnetization refrigerator (ADR)

Development Schedule

- PDR: November 2016
- CDR: May 2017
- I&T at GSFC: November 2017
- Delivery to Armstrong: December 2018
- First Flights: Spring 2019
- Re-introduce selves to families: Summer 2019

HIRMES Instrument Scientist Position Advertised

Position already advertised on the USRA website

Just posted on the November AAS Job Register

http://jobregister.aas.org/job_view?JobID=56886

Help us recruit!

Embedded Team Engagement (*Notional*)

from Mark Mckelvey

Embedded Team Goal

Successful 3rd Gen SI Development

- How can the Embedded Team help to make this a reality?
  - From the beginning of 3rd Gen SI development, embed SOFIA team members within the HIRMES team
  - Use the expertise, talents, and experience of the embedded team members to help the HIRMES team succeed
  - Communicate program oversight, quality assurance and documentation requirements, and all review stage entrance and exit criteria for HIRMES reviews early
  - Start positive, but know from experience things can go wonky
  - Document lessons learned to help with the 4th Gen SI team succeed

Embedded Team Membership

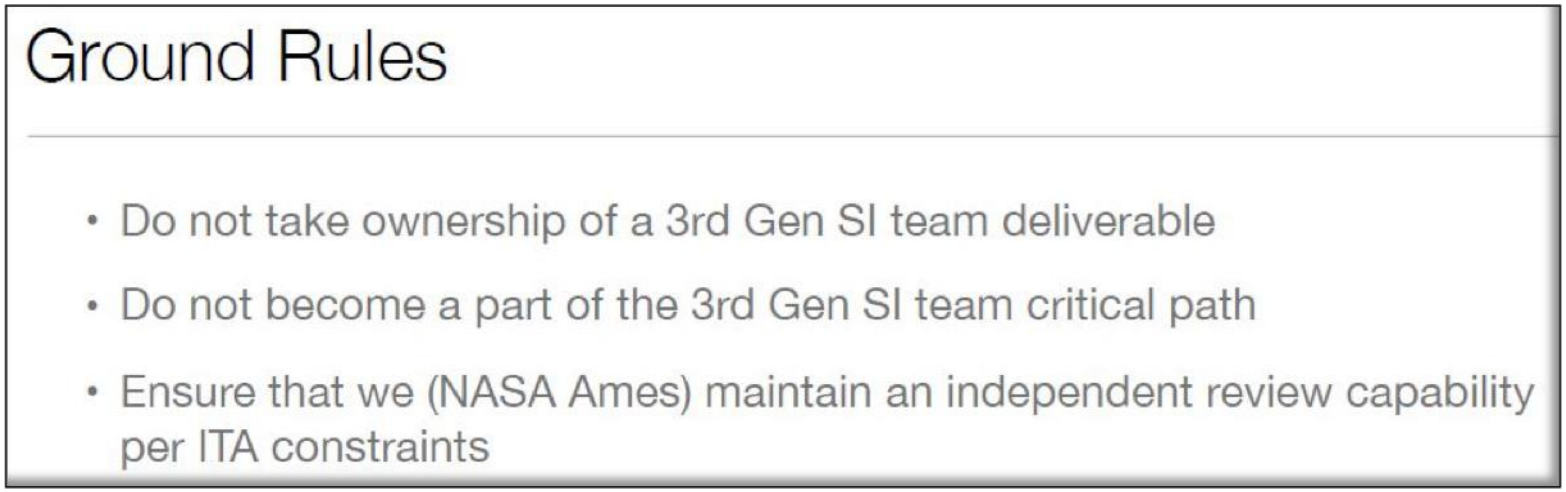
Area of Representation	*Embedded Team*	*FTE / WYE*	*Tech Authority*
SI Dev Management			OSD/M. Gaunce
			Mark McKelvey
SE&I	Jeff Huang	1	Jonathan Brown
Airworthiness	Mo Hanna	0.5	Tim Krall
S&MA	Leonard Hee	0.5	Ed Ingraham
Engineering	Paul Lam	0.3	Jeanette Le
	Stefan Rosner	0.5	
Pipeline	Eric Omelian	0.5	Pam Marcum
USRA/SI Dev	Eric Burgh Marissa Ortiz	1.6	Mark McKelvey
TBD Misc. Support	TBD	0.3	
Total		5.1	

- SOFIA Program Office has approved ~5 full time equivalent (FTE) / work year equivalent (WYE) to support HIRMES. WBS leads have proposed names for participation in ET.
- This level of staffing provides us an opportunity to help the HIRMES team succeed given a very aggressive development timeline.

- ***Challenge is to ensure that the embedded team is meaningfully engaged while adhering to ground rules***

Embedded Team Ground Rules

- From 8/18/2016 Embedded Team Kickoff Meeting:



ET Governance

- Embedded Team Chair: Jeff Huang
- Primary function of ET is not oversight (though review/ITA has to be respected).
  Program oversight functions remain intact, but are not an ET responsibility.
- Internal to the embedded team:
  - Following consultation with the HIRMES team, determine and document who on the embedded team does what, who has decisional authority, and who someone goes to for a specific answer.
- Between the embedded team and the HIRMES team:
  - Repeat the process for the internal team except that the HIRMES team is responsible for all products and therefore is the decisional authority.
- Once embedded with the HIRMES team, continue to assess the workload and effectiveness of each team member.
  - Perform this assessment periodically to ensure that the embedded team

Potential Areas Embedded Team Can Help (1/2)

- Facilitate the review and closure of System Requirements Review (SRR) Requests For Information (RFIs)?
- Evaluate the feasibility of conducting a Single Design Review instead of separate PDR and CDR, including identifying the Entrance and Success/Exit Criteria for such a single review?
- Identify roles, responsibilities, and expectations of SOFIA Program and HIRMES team for HIRMES pipeline development?
- Collect good representative examples of documentation from existing instruments to provide as guidance for HIRMES team?
- Provide guidance on capabilities, performance, and interfaces for Phase 1 Cryocooler System (and Phase 2 as information matures and becomes available), and certification of HIRMES cryocooler components including qualification and acceptance testing?
- Provide additional hazard report examples that are applicable to HIRMES (e.g., Cryocooler, ADR), beyond the generic four hazard reports included in the in the SI Developer's Handbook?

Potential Areas Embedded Team Can Help (2/2)

- Develop hazard reports?
- Write procedures?
- Design Installation Cart?
- Design Load Test Fixture for Installation Cart?
- Coordinate procurement of SOFIA CWR and PI Racks?
- Correct and update HIRMES SE01-2028/ICD V&V Compliance Matrix?
- Develop Physical Configuration Audit (PCA) Procedure and formulate schedule for inspections
- Others?

Regular Site Visits to HIRMES

- Possible rotation of Embedded Team personnel, travel to NASA Goddard (Maryland) to work with the HIRMES team
  - SOFIA Program is considering this plan with associated travel expenses
  - If approved, visits would nominally be a week
  - Goal would be to establish closer working relationships with HIRMES team
  - HIRMES team is open to this discussion, and is eager to have the help of the ET

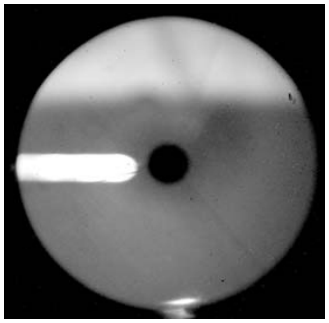
SOFIA Telescope Assembly: Black Spider Baffles Overview

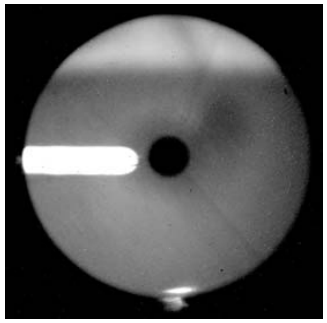
Patrick Waddell, Eric Becklin, Ryan Hamilton, Bill Vacca

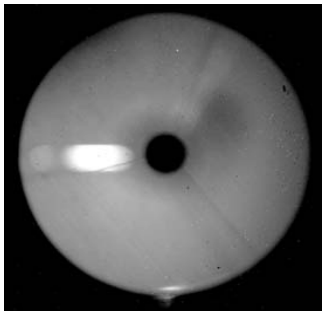
02, November 2016

Black Spider Baffles

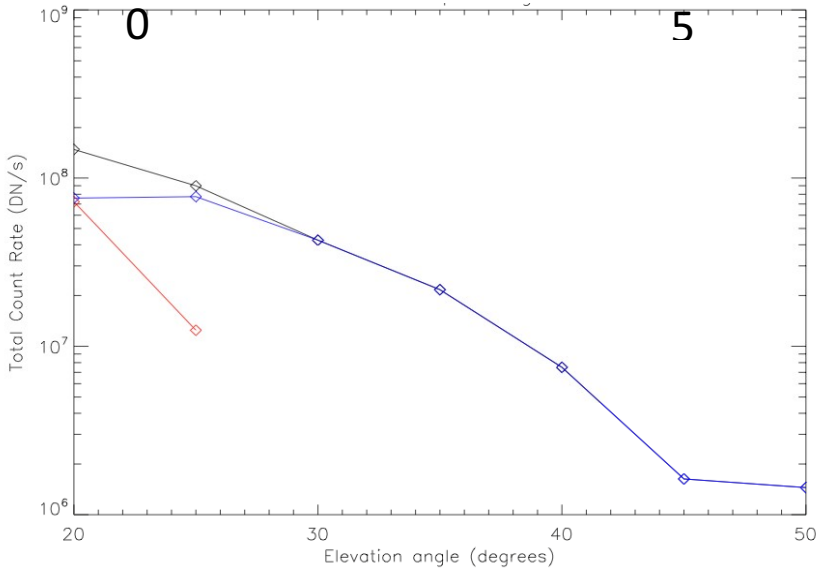
- Background illumination sourced from SOFIA #1 Engine; problem captured in Pupil Images during 2015 occultation campaign







EL (deg): 20 25 40



2.2 micron Background In Pupil:

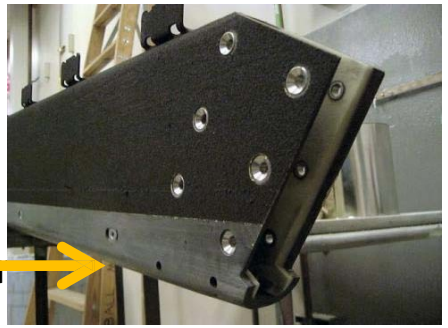
Spider emission [BLUE]

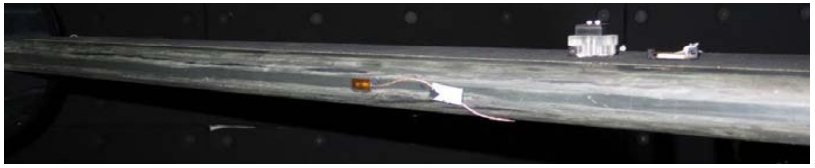
Primary Mirror surface emission

Engine 1 Illumination Path

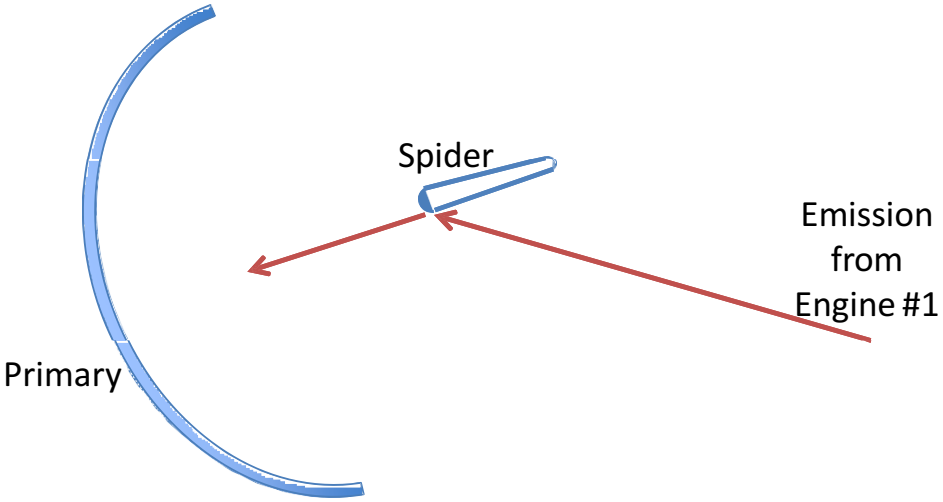
- **Engine #1 has direct line of sight into the Cavity.** The TA Spiders receive hot engine tail cone flux, even at fairly high elevations.

- **Current state of Spiders:**
  - Unfinished, large radius, rounded edges
  - Reflect 10% (min.) broad band IR
  - Intent was to accept Reflecting Spider Cover





Stray Light Geometry & Blocking Concept

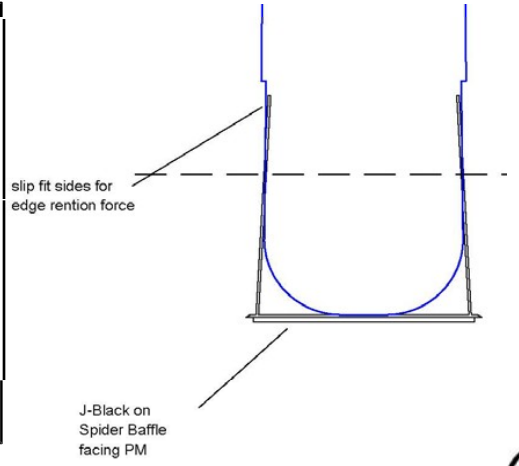


Knife-edge outer baffle, formed as sharply as possible

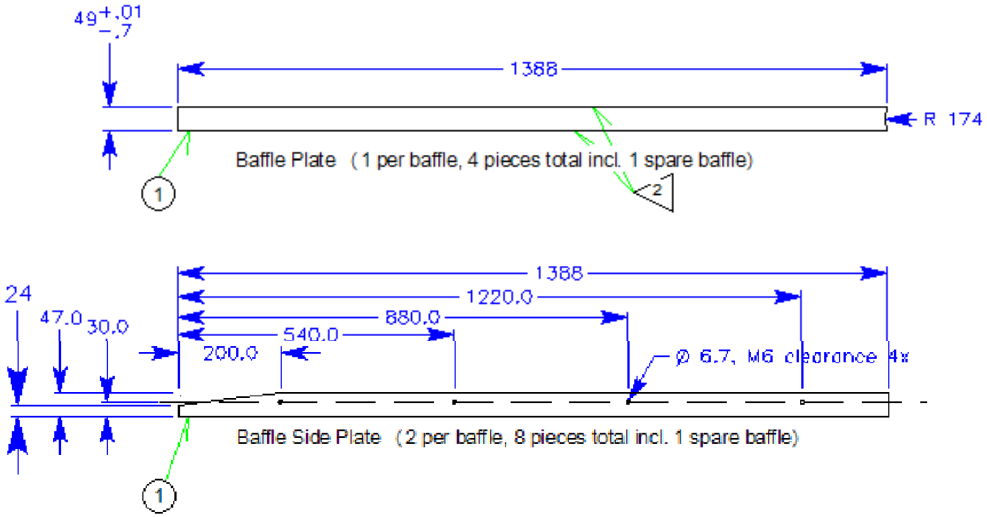
Stray light coating on surface facing Primary Mirror to prevent second reflection

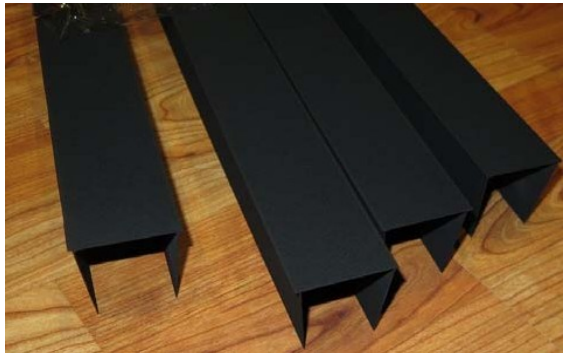
Mitigate increase in obscuration: ≤ 0.5%

Lowest profile fasteners (1.2 mm)



BSB Drawings Excerpts

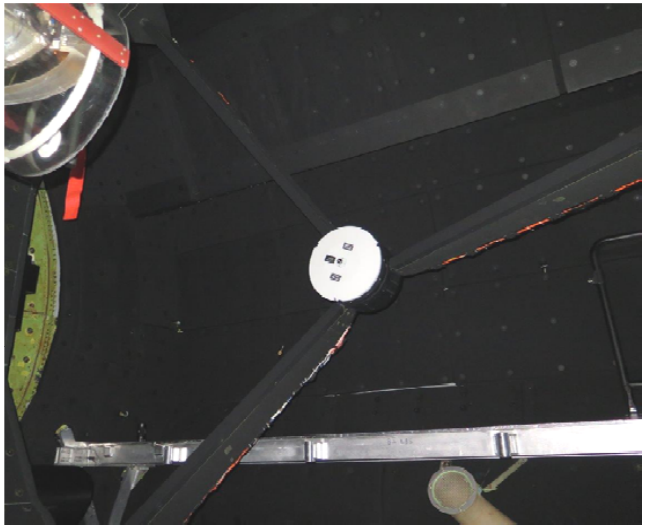


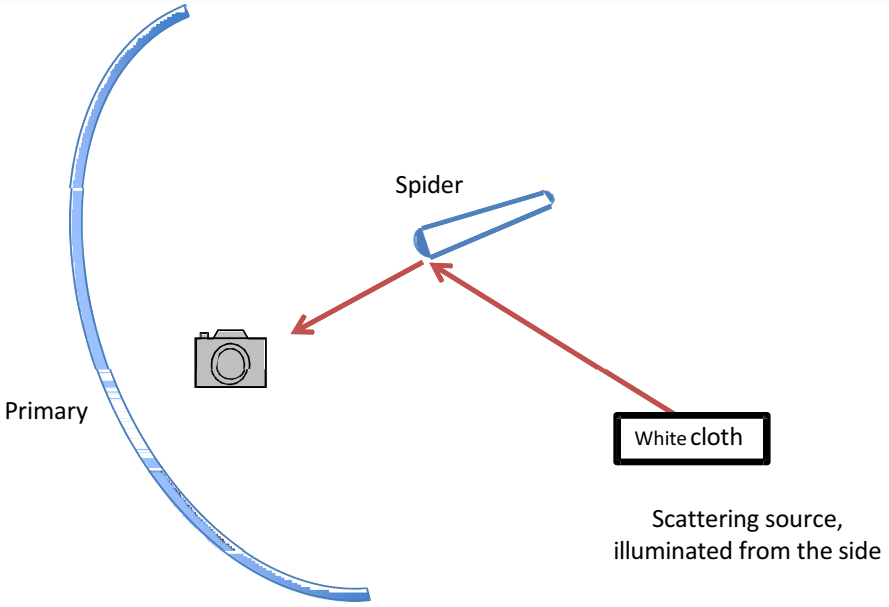


Carbon Fiber, for Spider CTE match

Each weighs ~300 g incl. fasteners

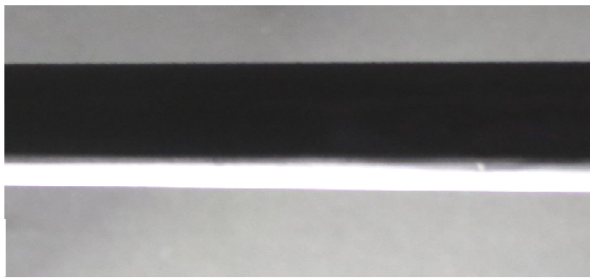
Black Spider Baffles – on-ground Verification





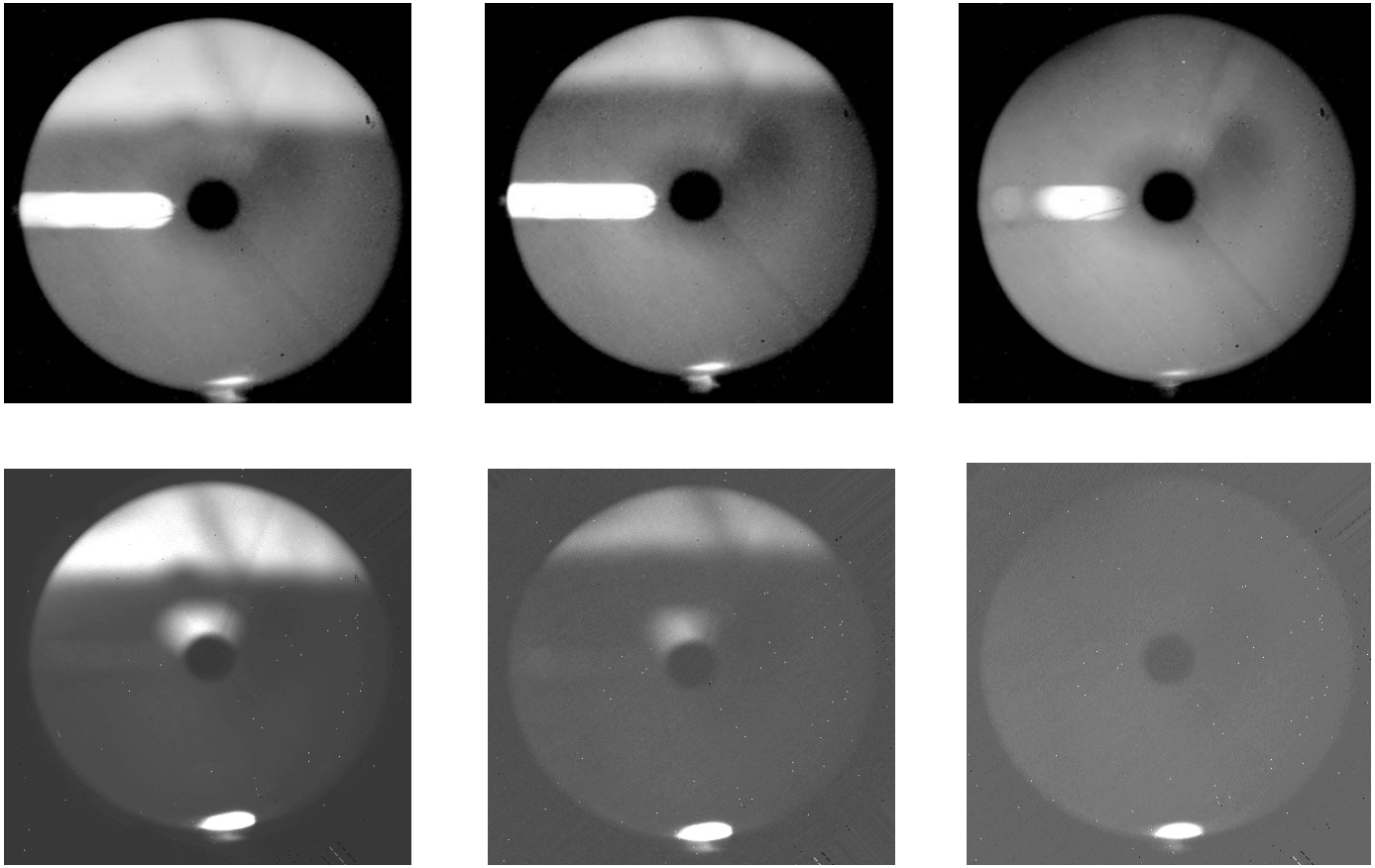
Test fit &

First stray light, 10aug2016



Black Spider Baffles

- Previous FLITECAM pupil images vs new pupil images (with baffles)



20 deg EL

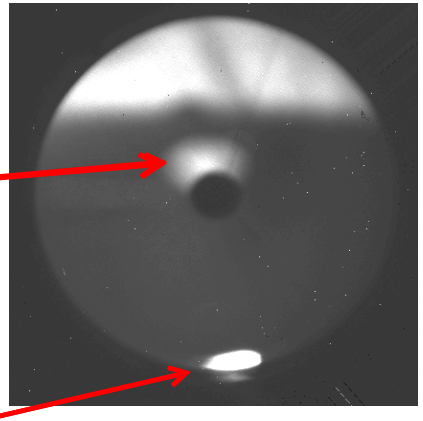
25 deg EL

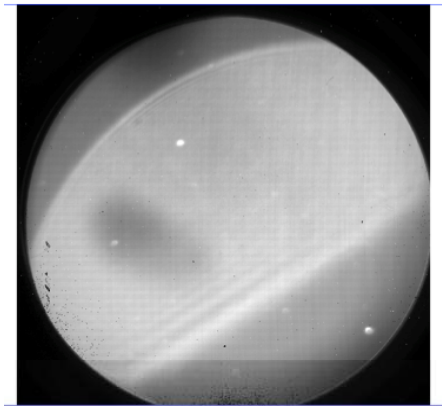
40 deg EL

Additional Artifacts

"New" item is M2 button reflecting scattered Primary Mirror emission

"Old" item, and next problem to fix, is now believed to be Engine #1 glint from edge of the Secondary Mirror. If so, this might be solved via steady hand and a *Sharpie!*





Pupil

Focal Plane