MIRI European Consortium

MIRI
The Mid-Infrared Instrument for the JWST

ESO, Garching

13th April 2010

Alistair Glasse

(MIRI Instrument Scientist)

Summary

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- MIRI overview, status and vital statistics.
- Sensitivity, saturation and sub-arrays.
- ‘Special’ operating modes
- MIRI flight hardware

MIRI

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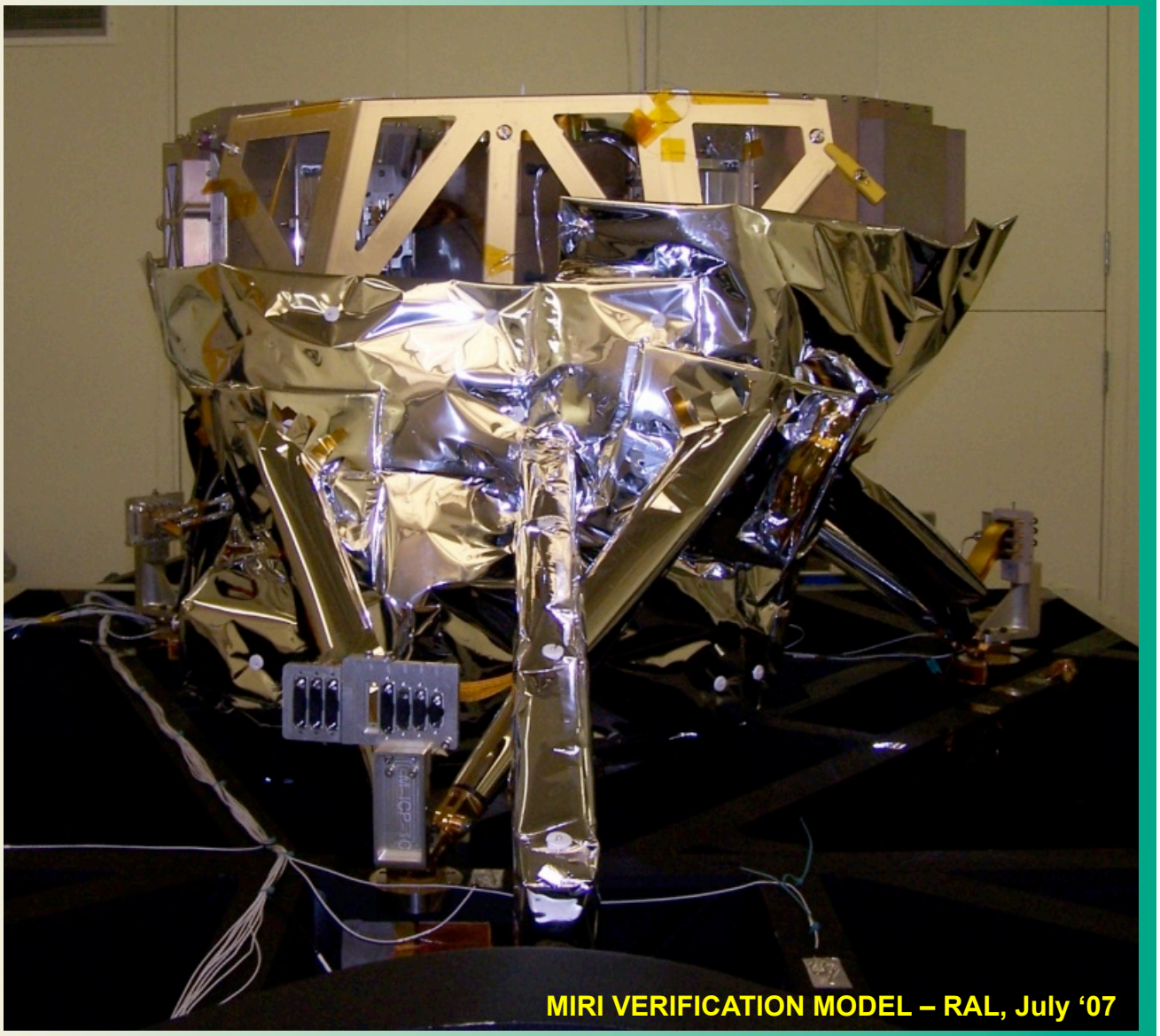
- A 5 to 28 μm imager and spectrometer
- Flight model systems now being delivered to RAL for integration and testing (late 2010)
- Delivery to NASA/GSFC in 2011
- JWST Launch in 2014
- Mission Lifetime
  - 5 years minimum
  - 10 years goal
- Built by a consortium of European Institutes
  - Plus JPL for the three 1024 x 1024 pixel Si:As IBC detectors

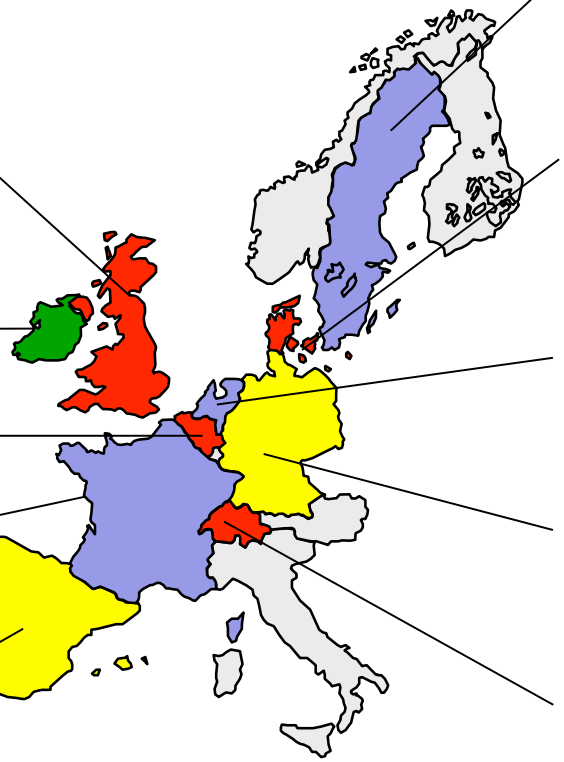


MIRI VERIFICATION MODEL – RAL, July '07

The MIRI European Consortium

MIRI European Consortium

UK-ATC		Principal Investigator Optical Engineering Spectrometer Pre-Optics (SPO) Calibration Sources
	Astrium Ltd.	Consortium Management PA Coordination System Engineering
	U. of Leicester	Mechanical Engineering Primary Structure MGSE
	RAL	Thermal Engineering & Hardware Optical Bench Assembly AIV
DIAS		Filters
CSL		Input, Optics & Calibration (IOC) Instrument Control Electronics (ICE) Imager Mirrors
	U. of Leuven	EGSE Software Support
CEA		Imager
	LESIA/LAM	Coronagraph
INTA		MIRI Telescope Simulator (MTS)



U. of Stockholm		Filters and Dichroics
DSRI		Hexapod
NOVA-ASTRON		Spectrometer Main Optics (SMO)
	U. Leiden	Spectroscopy Analysis
MPIA Heidelberg		Electrical Engineering Cryo Mechanisms
	U. of Köln	Low Resolution Spectrometer Double Prism
PSI		Contamination Control Cover Cryo Harness

NASA/GSFC		JWST Project Office Spacecraft Integrated Science Instrument Module (ISIM)
	JPL	Detector System Flight Software Cryo-Cooler
	Univ Arizona	Quick-look pipeline

ESA/ESTEC	JWST Project Office Prodex Office

MIRI Layout

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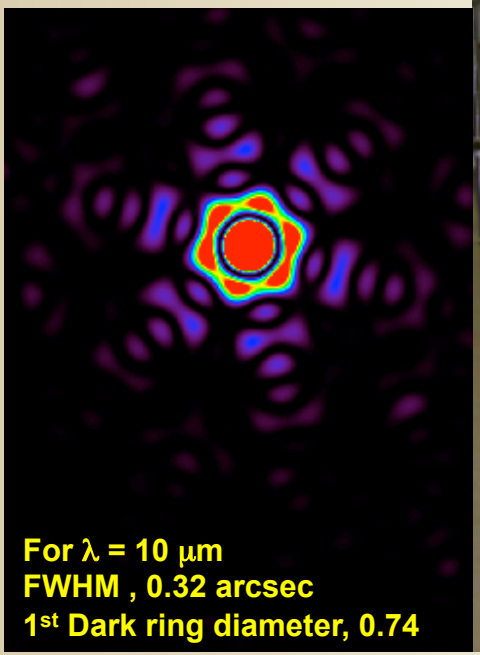
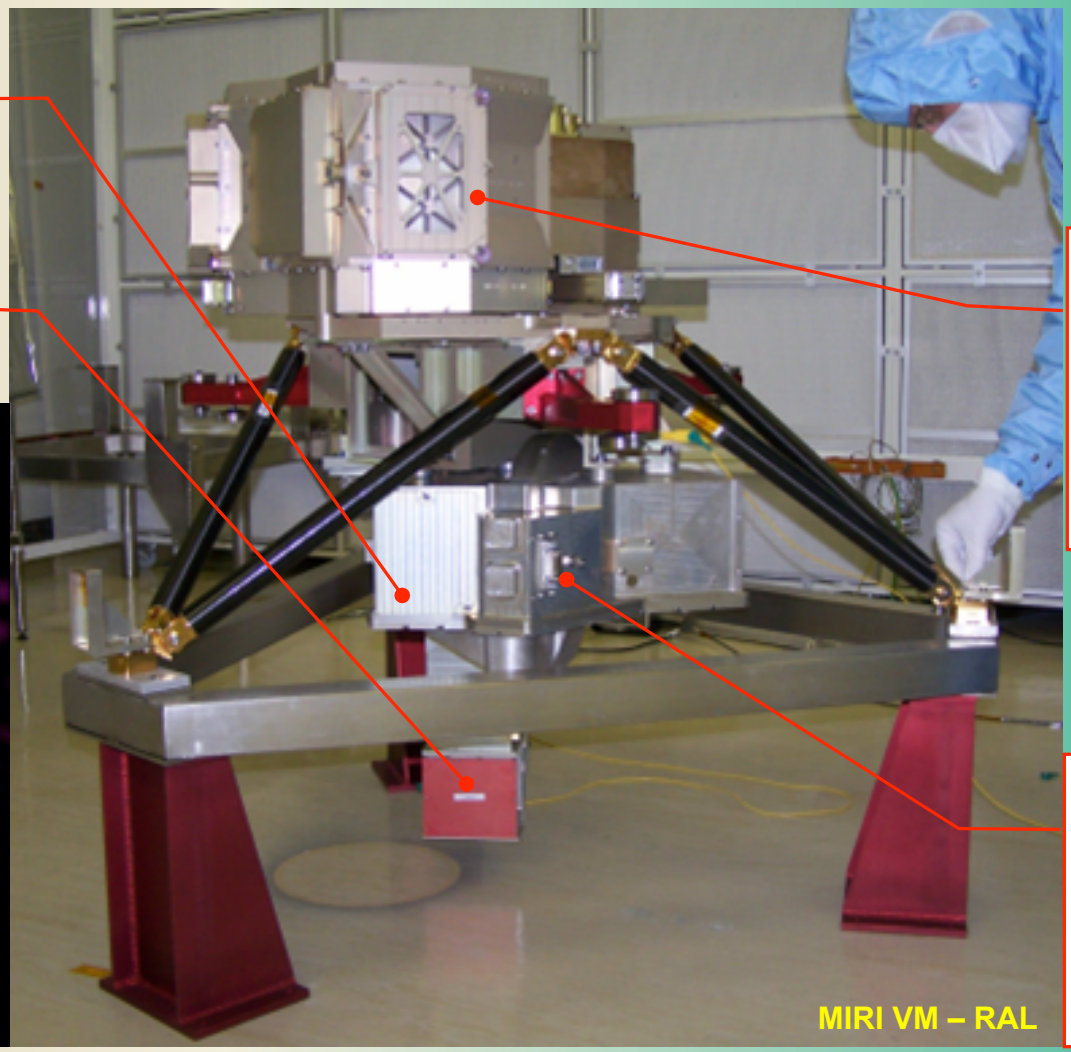
A carbon fibre truss isolates 7 K MIRI optics from the 40 K telescope

Light enters from the JWST telescope



For λ = 10 μm
FWHM , 0.32 arcsec
1st Dark ring diameter, 0.74 arcsec



MIRI VM – RAL

A 10 x 10 arcsec field passes through the deck into the R ~ 3000,
4 channel integral field spectrometer
2 detectors
2 channels per detector

A 115 x 115 arcsec region of the focal plane is directed into the imager
10 bandpass filters
4 coronagraphs
R ~ 100 slit spectrometer.

The MIRI Focal Planes (Entrance + Detector)

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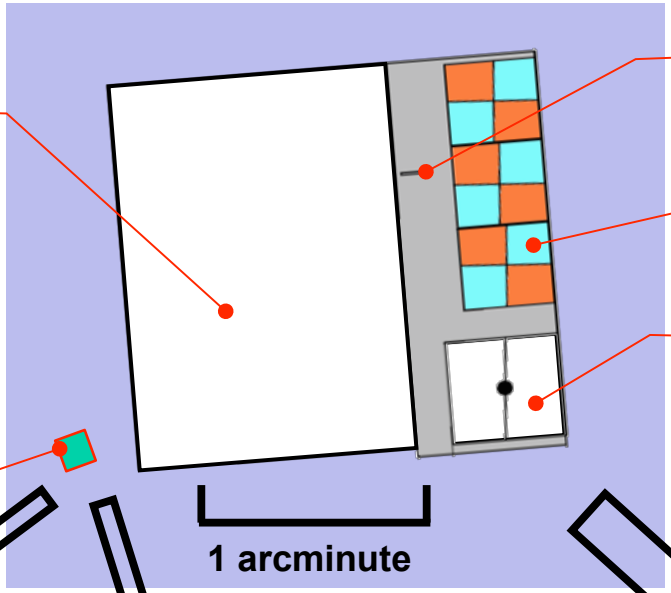
Imager
75 x 113 arcsec field
0.11 arcseconds/pixel
Nyquist sampled at 7 μm
It is not possible to simultaneously observe the same field with imager and spectrometer



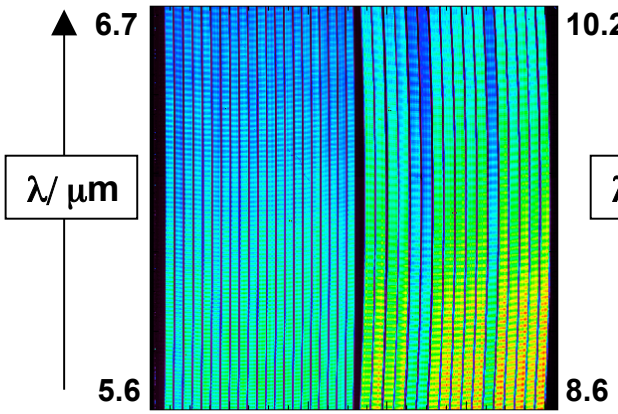
Low Resolution Spectrometer
5 x 0.6 arcsec

Three 4QPM Coronagraphs
24 x 24 arcsec

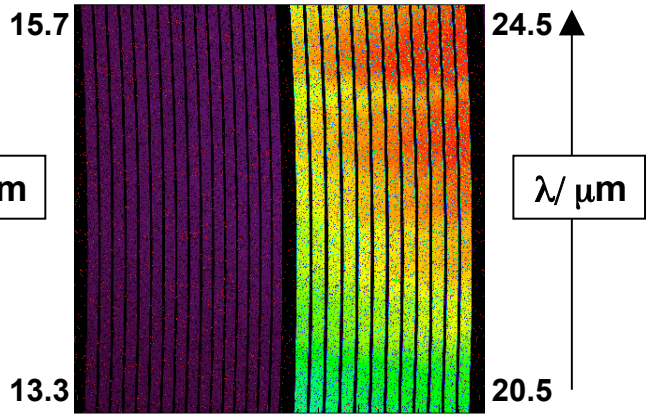
Lyot Mask 23μm
30” x 30”

R ~ 3000, 4 Channel Integral Field Spectrometer

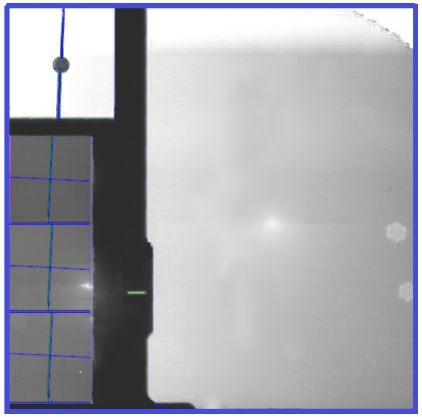
MIRI VM Spectral Image



Specsim simulated image



MIRI FM Imager (non-flight detector fitted)



MIRI Imager Filters

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CEA Saclay + MPIA

Filter name (and wavelength)	Pass band Δλ (μm)	Function
F560W	1.2	Imaging
F770W	2.2	
F1000W	2.0	
F1130W	0.7	
F1280W	2.4	
F1500W	3.0	
F1800W	3.0	
F2100W	5.0	
F2550W	4.0	
F2550WR	4.0	
P750L	5	R ~ 100 Spectroscopy
F1065C	0.53	Coronagraphy
F1140C	0.57	
F1550C	0.78	
F2300C	4.6	
FND	10	Target Acquisition
FLENS	N/A	Alignment
BLANK	N/A	Calibration

FM Estimated Photon Conversion Efficiency

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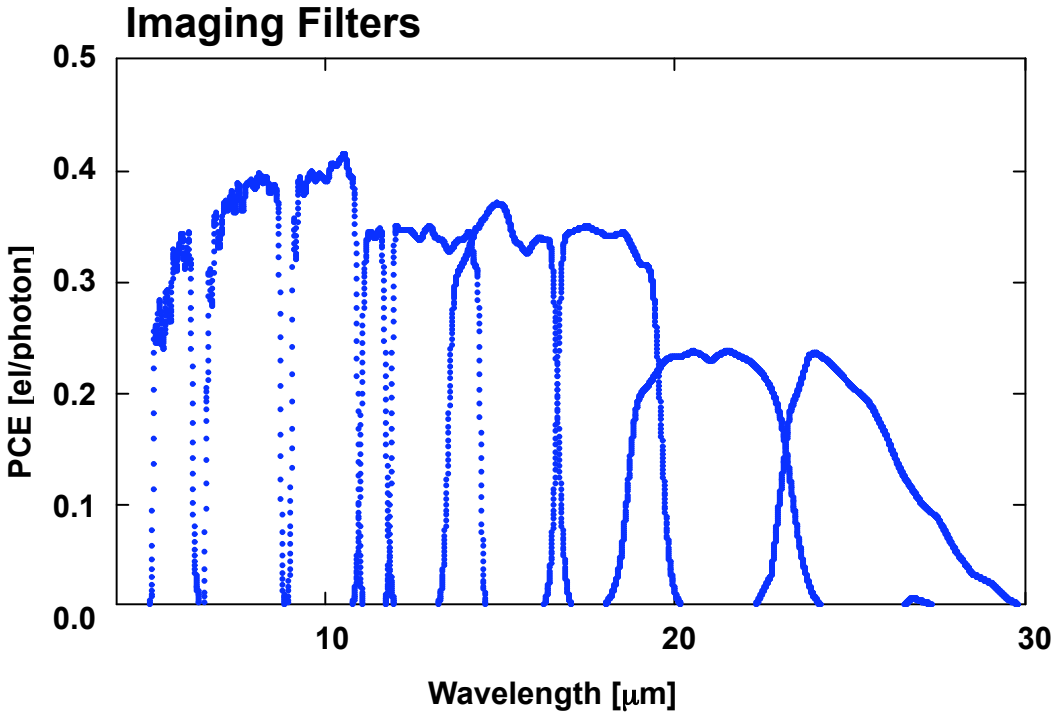
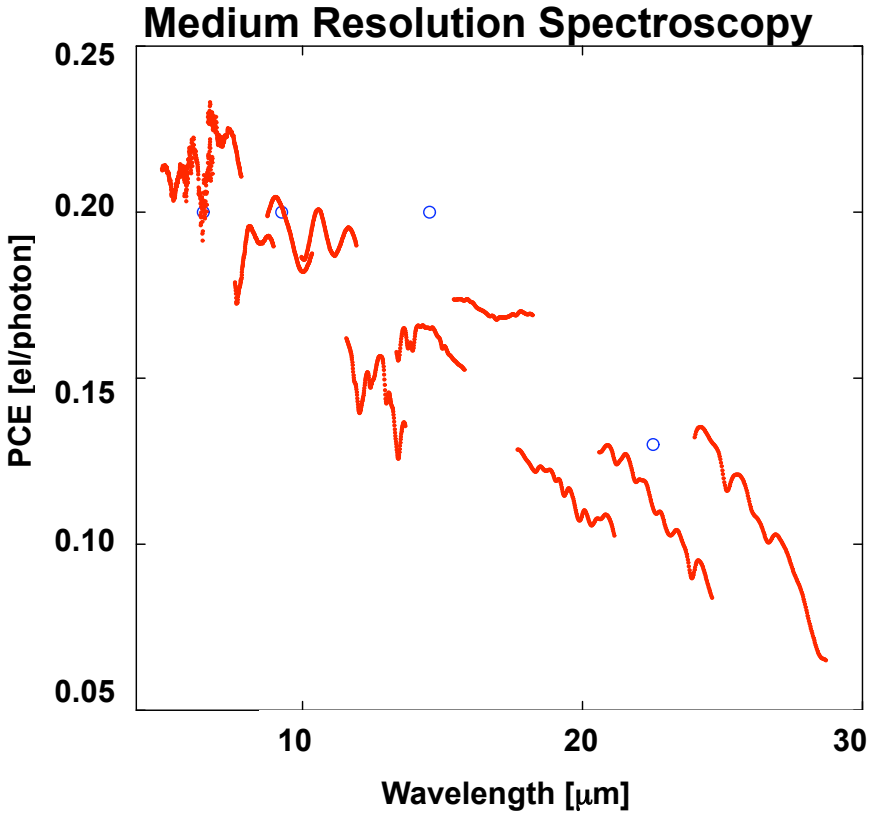
- Instrument throughput, decreases from short to long wavelengths
- Still some uncertainty in MRS Spectral Resolving Power





The JWST Infrared Environment

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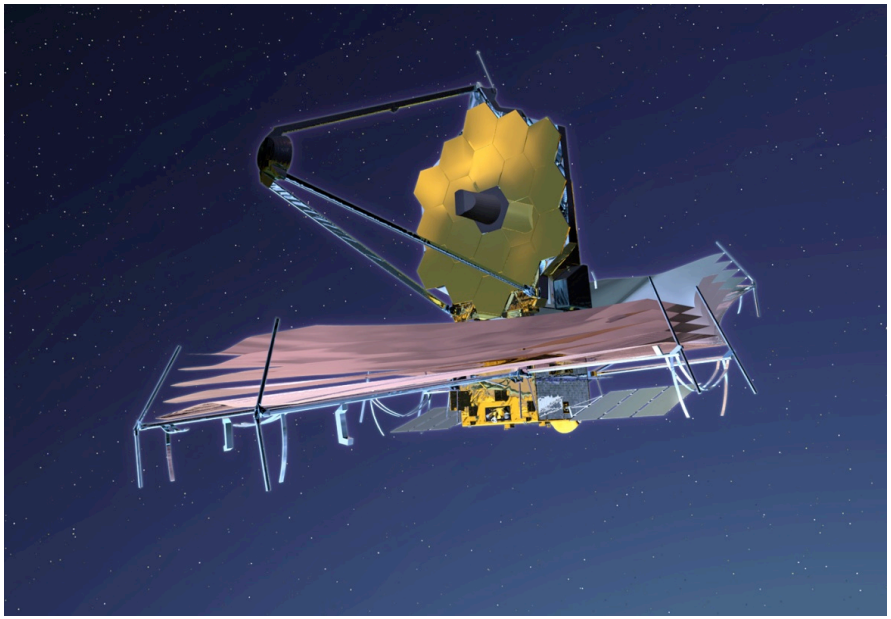
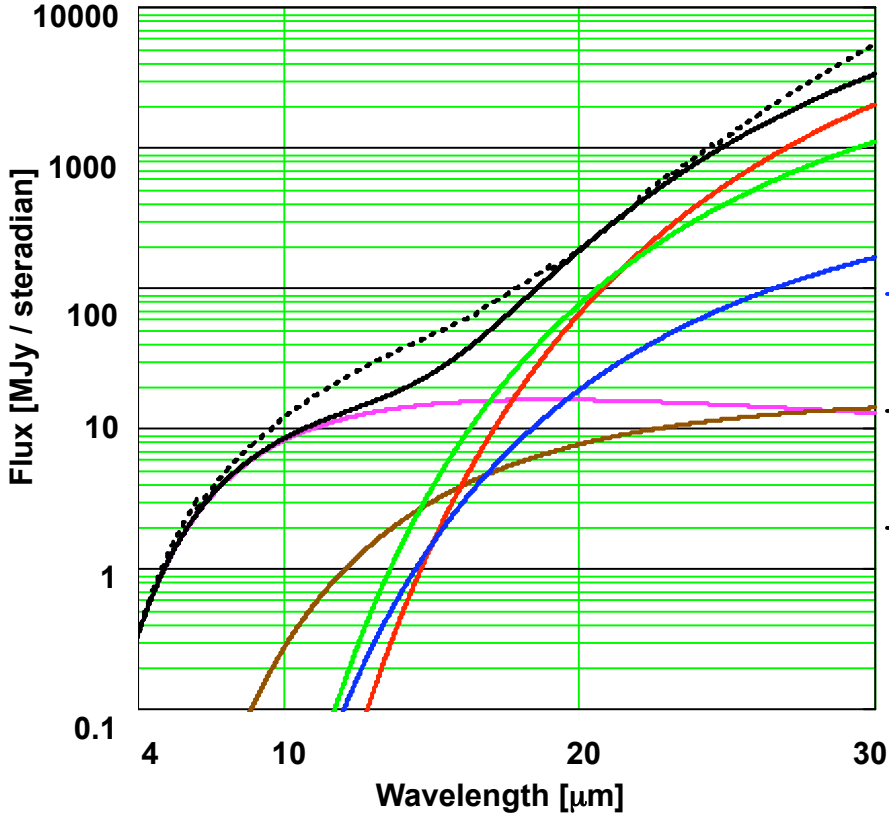
- **Photon background increases by > x1000 from short to long wavelengths.**
  - Zodiacal dust
  - Straylight from Sun/Earth/etc.
  - Telescope thermal emission
- **Cosmic ray flux expected to disturb > 50 % of pixels every 1000 seconds**





- **Aim to achieve shot noise limited sensitivity at all wavelengths and SRPs**
- **Need to make optimum use of detector**

Detector Readout Patterns

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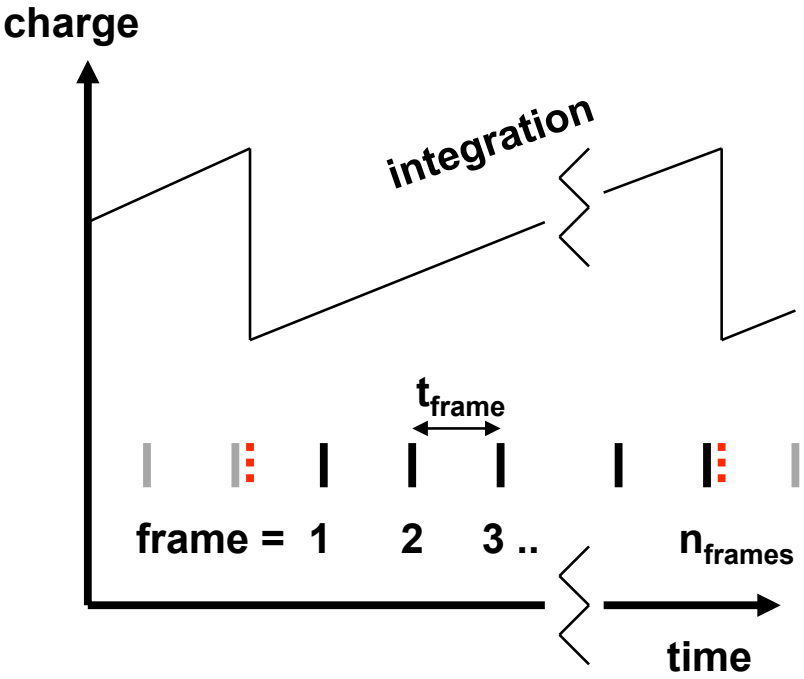

	t_{frame} [secs]	n_{frames}
FAST – Bright and extended objects (plus sub-arrays), Long wavelength imaging)	2.7	1 to 40
SLOW – Faint Objects, Deep Imaging, MRS Spectroscopy	27.6	1 to 40

- **Aim to fill the pixel capacitance**
  - measure plenty of frames to beat down the effective read noise.
- **SLOW mode averages 8 samples per frame to reduce the read noise**
  - t_{frame} is the minimum integration time. (No true dark)
- **Can estimate the sensitivity for these basic readout patterns…**

Sensitivity estimate

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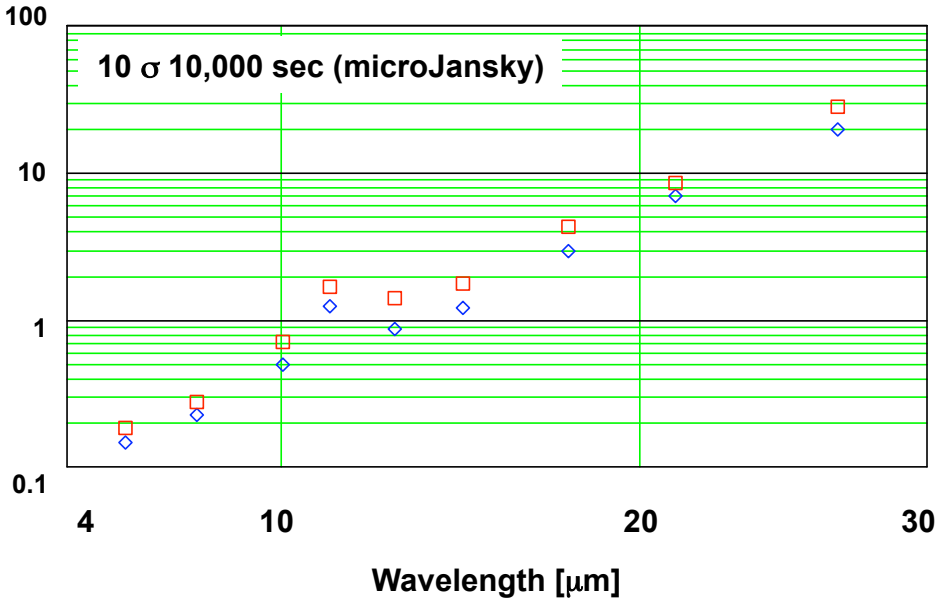
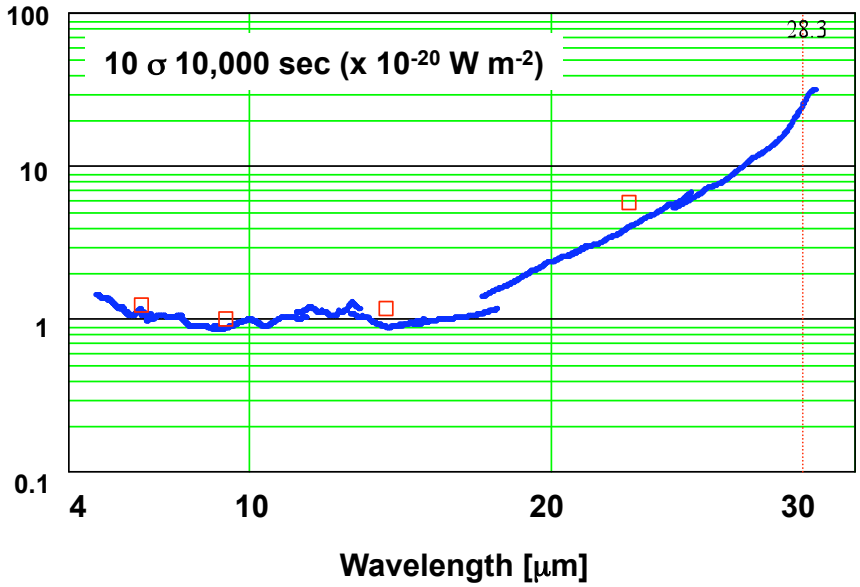
- Sample photocurrent with model detector (+ photometric aperture, FM estimated PCE, read noise, and FULL frame readout pattern).
- S/N = 10 in 10,000 second exposure for a faint point source





- Very sensitive, but finite detector dynamic range means that MIRI will saturate on targets which are faint on 8 m ground-based telescopes.

Target flux sensitivity limits

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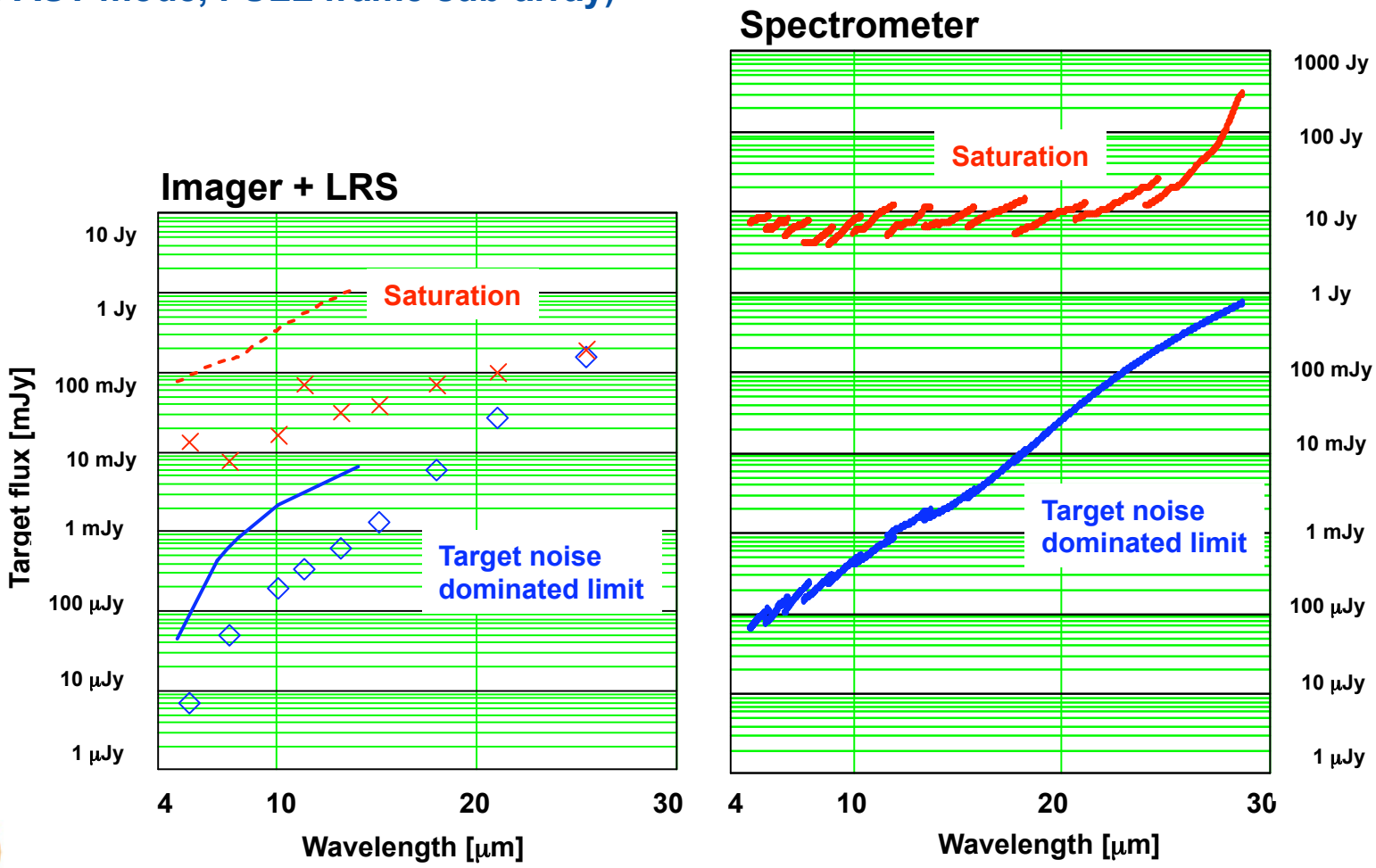
- Target noise dominates for target photocurrent > background + dark
- Saturation (1/8th of flux in brightest pixel at 8 microns, 80,000 el (1/3rd full well), FAST mode, FULL frame sub-array)



Imager Readout Patterns

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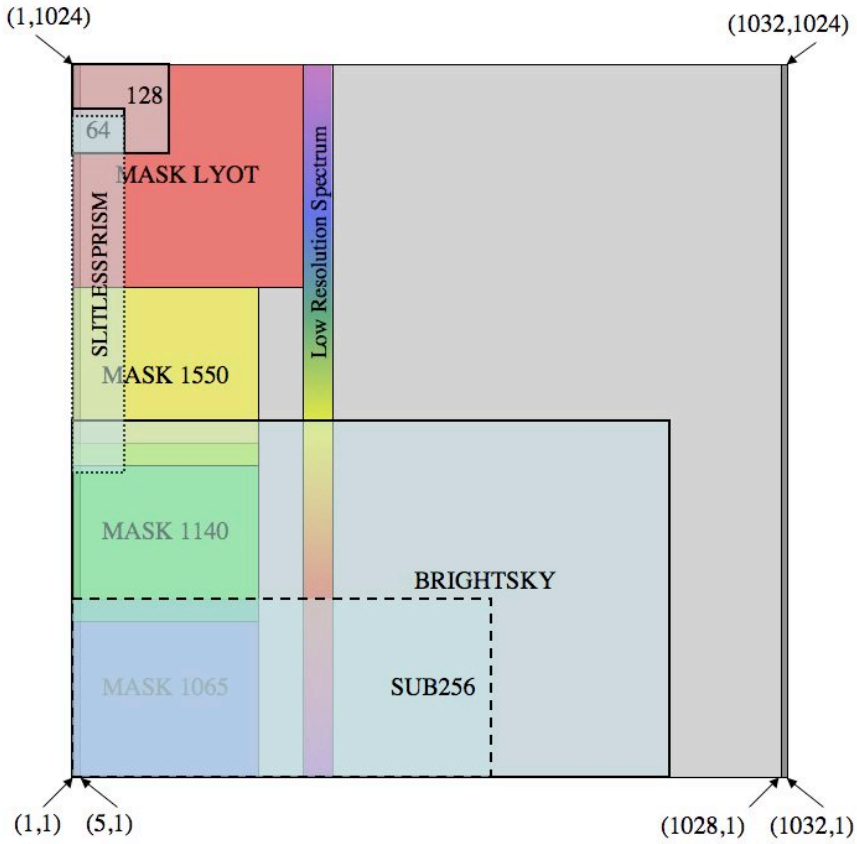
- **Extend the saturation limit using sub-arrays to trade field of view for faster frame rates.**
  - For example, a 0.5 Jy source will not saturate the F1000W filter using the SUB128 sub-array with its 14 x 14 arcsecond field.
  - Note the SLITLESSPRISM sub-array's specific capability for transit spectroscopy.



SUB-ARRAY	FAST frame time	SLOW mode frame time	Purpose
	sec	sec	
FULL	2.775	27.105	Full frame imaging + nominal LRS spectroscopy
BRIGHTSKY	1.183	11.274	Imaging at 2.3 x FULL frame saturation limit
SUB256	0.453	4.024	6.1 x FULL frame saturation
SUB128	0.100	0.515	28 x FULL frame saturation
SUB64	0.065	0.180	40 x FULL frame saturation
MASK1065	0.228	1.772	Coronagraphy
MASK1140	0.228	1.772	
MASK1550	0.228	1.772	
MASKLYOT	0.228	1.772	
SLITLESSPRISM	0.164	1.430	Slitless LRS spectroscopy

Sub-arrays and exoplanet imaging

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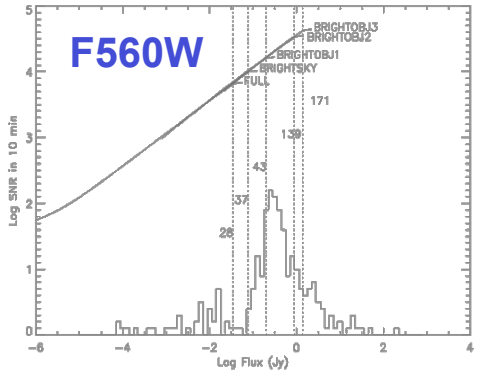
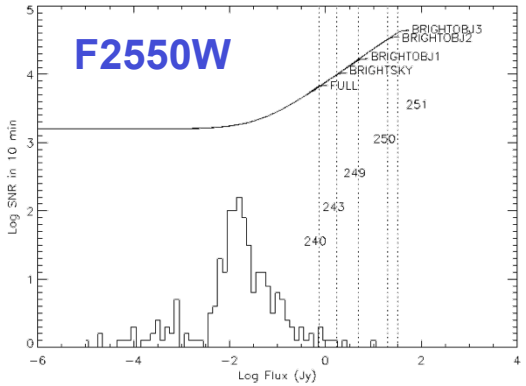
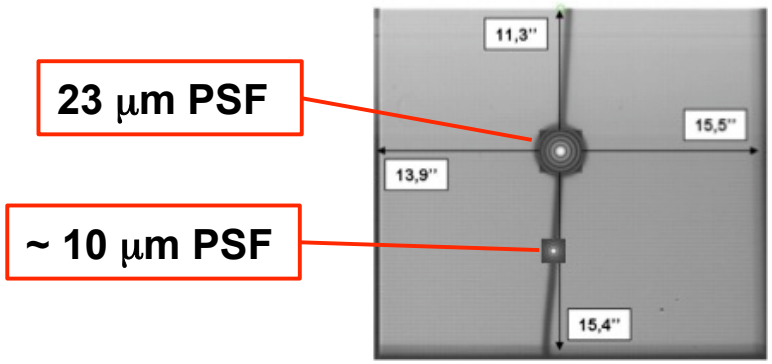
- Modelling sub-array impact on S/N for exoplanet parent star imaging. (Christine Chen, STSci)





- Proposal (Anthony Boccaletti, Meudon) to use Lyot bar for > 10^5 contrast using short wavelength filters.



- See Eric Pantin's talk for more about coronagraphy with MIRI.

Low Resolution Spectrometer

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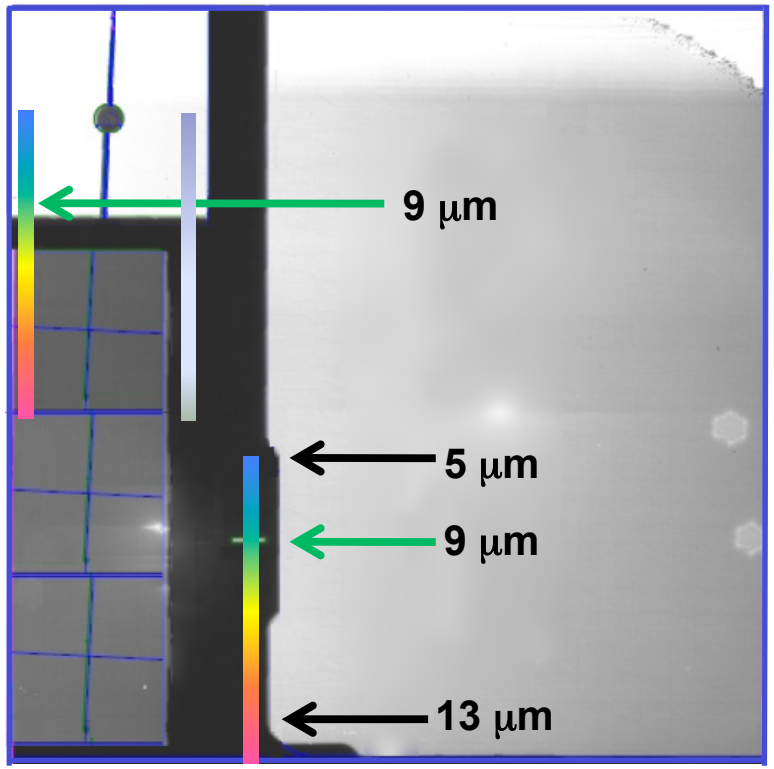
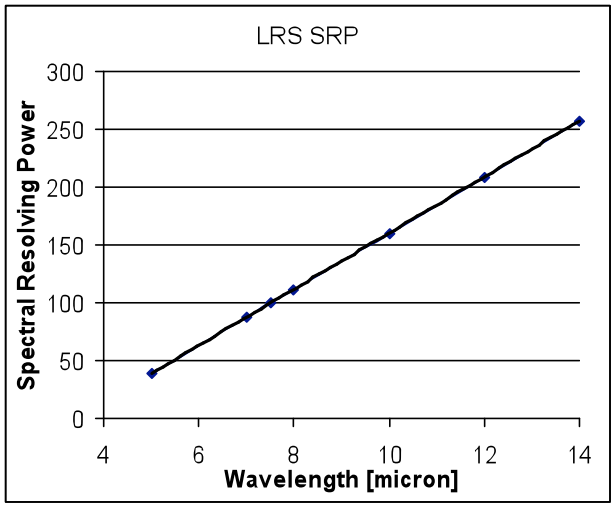
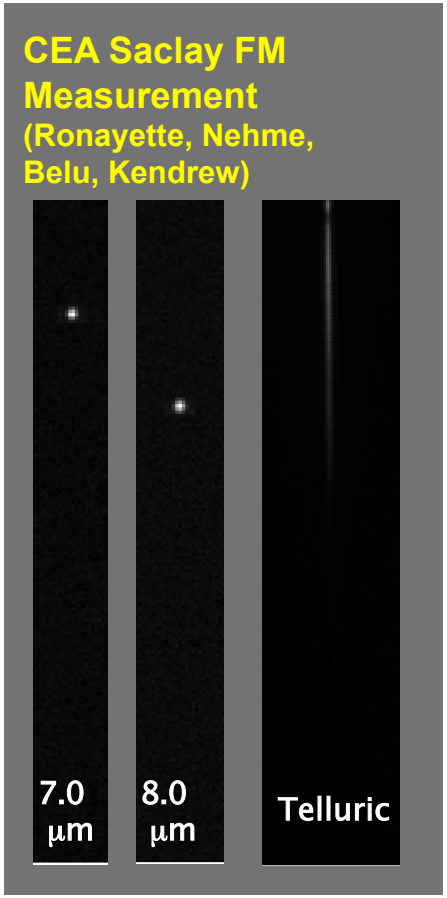
- **Slit and slitless locations**
  - Cusp at 5 μm in slitless spectra
  - Possible alternate slitless location (currently unsupported)



- **Continuum sensitivity**
  - ~3 microJansky 10 σ 10000 sec at 7.5 μm

- **Spectral Resolving Power**





MIRI Medium Resolution Spectrometer

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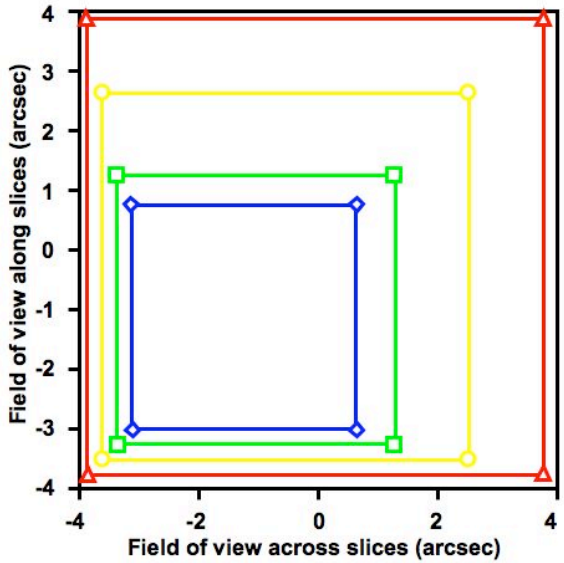
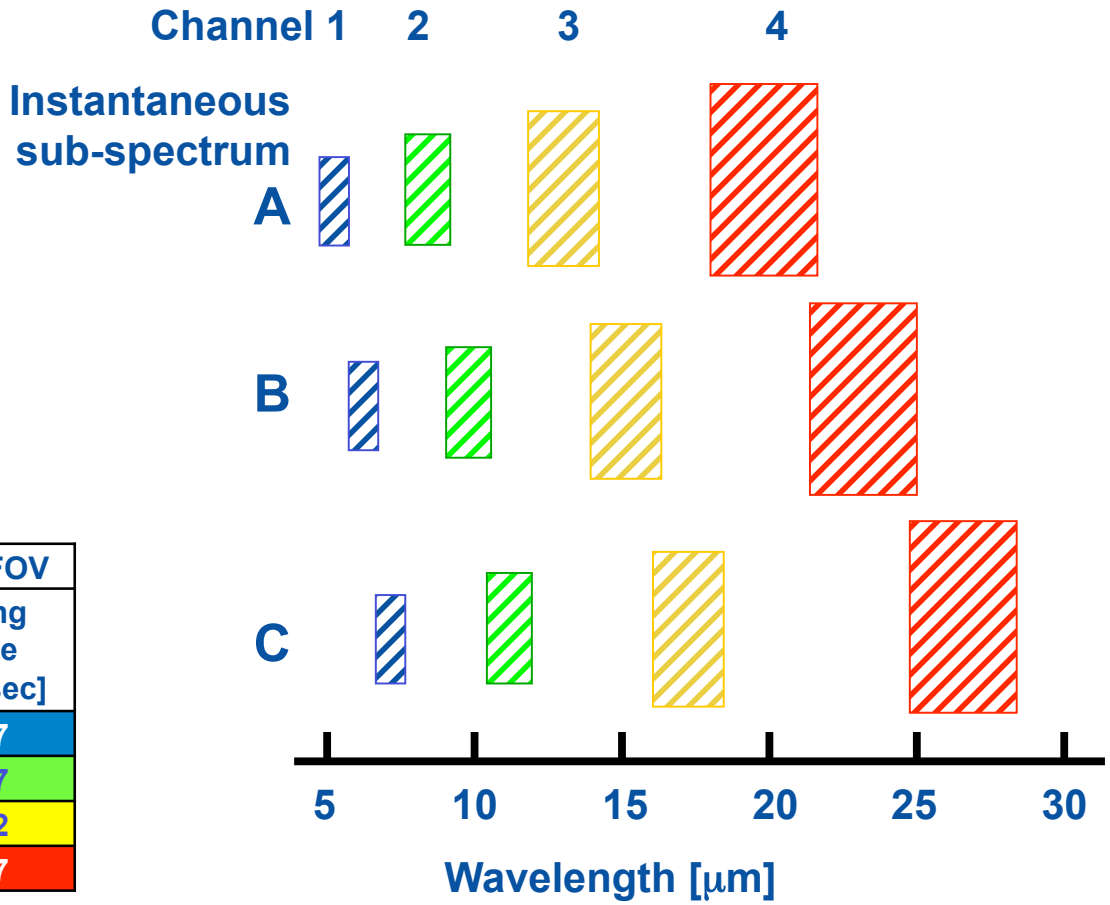
- 4 Spectral Channels with concentric fields of view



Channel Name	Spatial sample dimensions		Instantaneous FOV	
	Across slice (Slice width) [arcsec]	Along slice (Pixel) [arcsec]	Across slice [arcsec]	Along slice [arcsec]
1	0.18	0.20	3.7 (21)	3.7
2	0.28	0.20	4.5 (17)	4.7
3	0.39	0.25	6.1 (16)	6.2
4	0.64	0.27	7.9 (12)	7.7

- 3 mechanism selected sub-spectra per channel with dedicated dichroic and gratings



MIRI MRS Flight Hardware – The SPO

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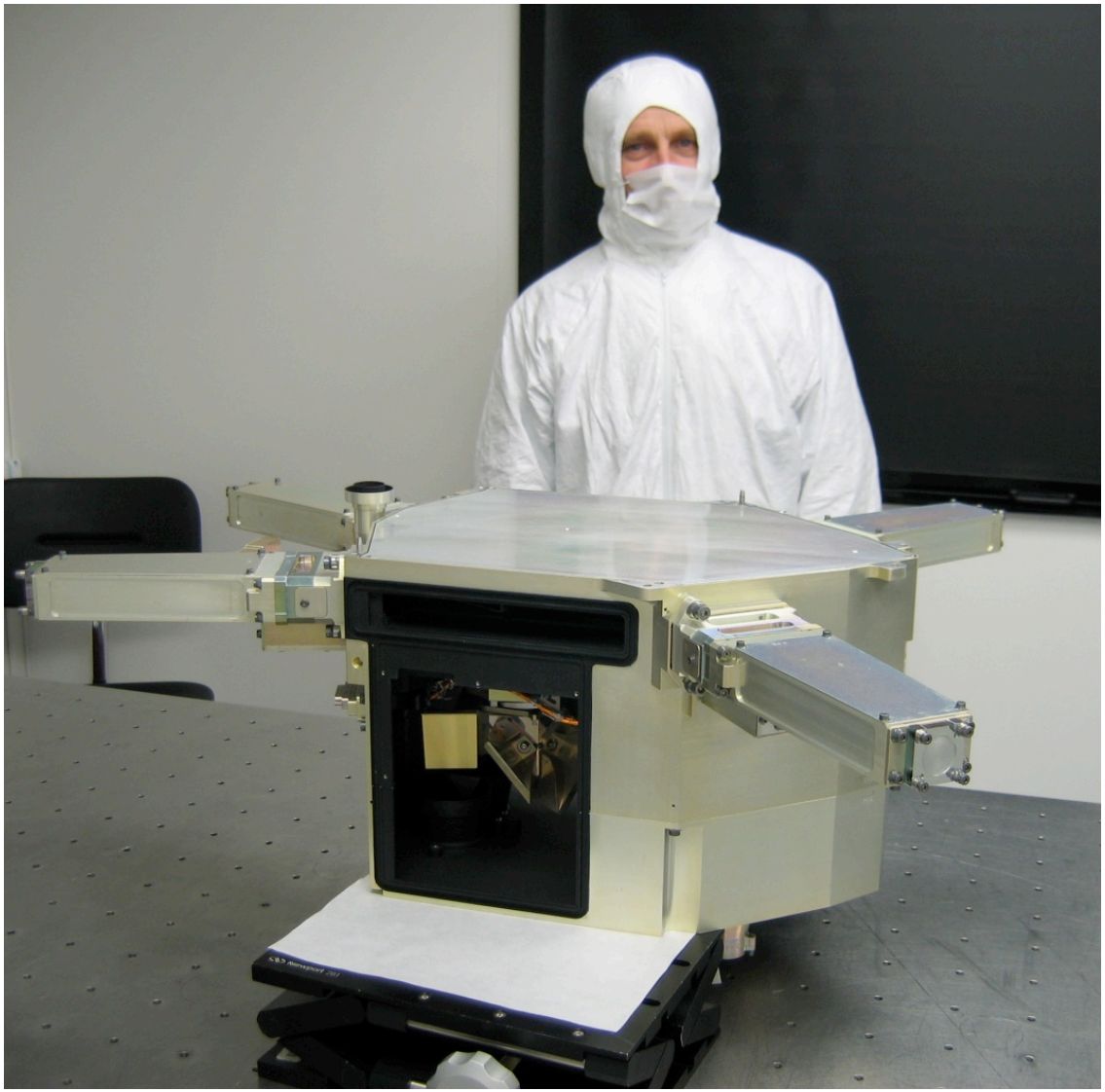
- Spectrometer Pre-Optics
- Separates the 4 spectral channels x 3 sub-spectra using 9 dichroics mounted in 2 mechanisms.
- 4 IFUs image slice the fields and present them to the spectrometer cameras.
- Spectra dispersed using 12 diffraction gratings.
- Pupil and field filtering provided throughout for straylight control.



Spectral Filtering by Dichroic Chain

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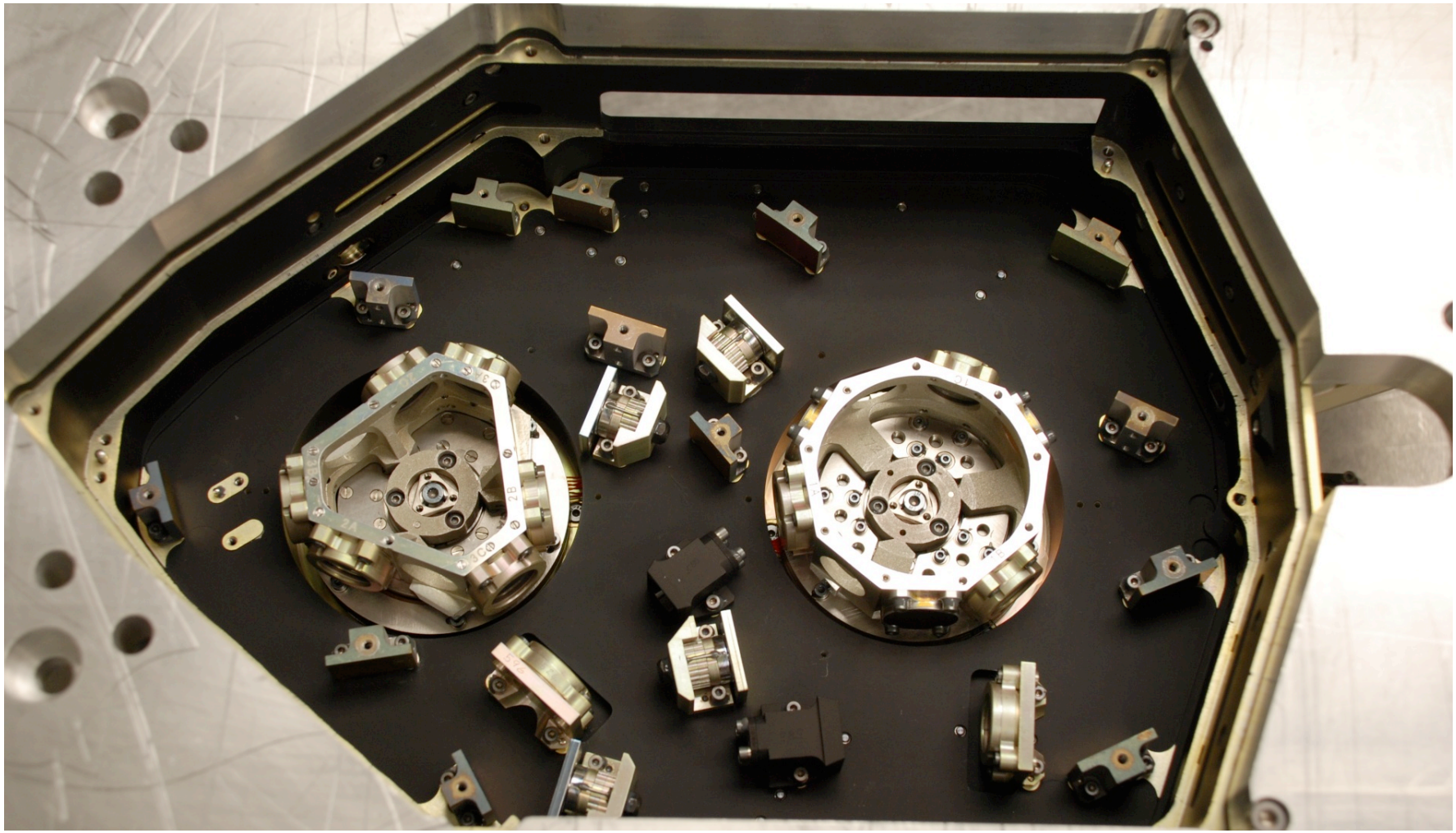

Grating Wheels

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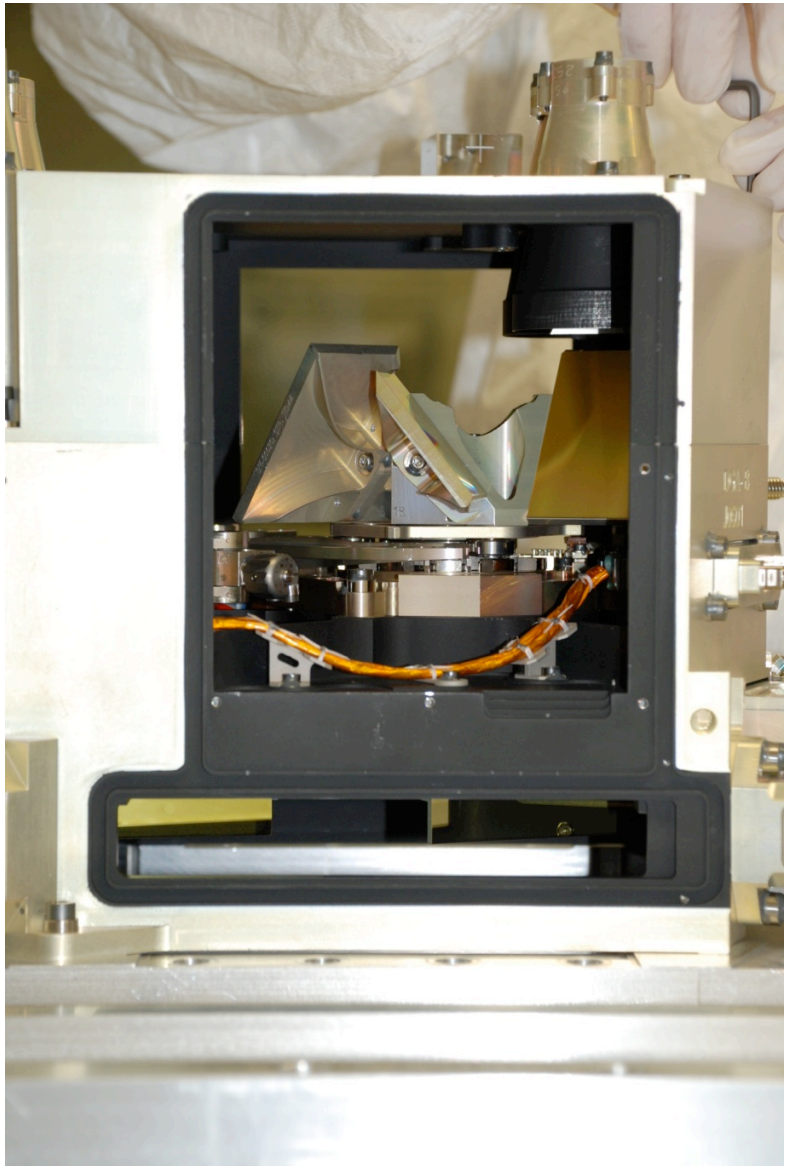
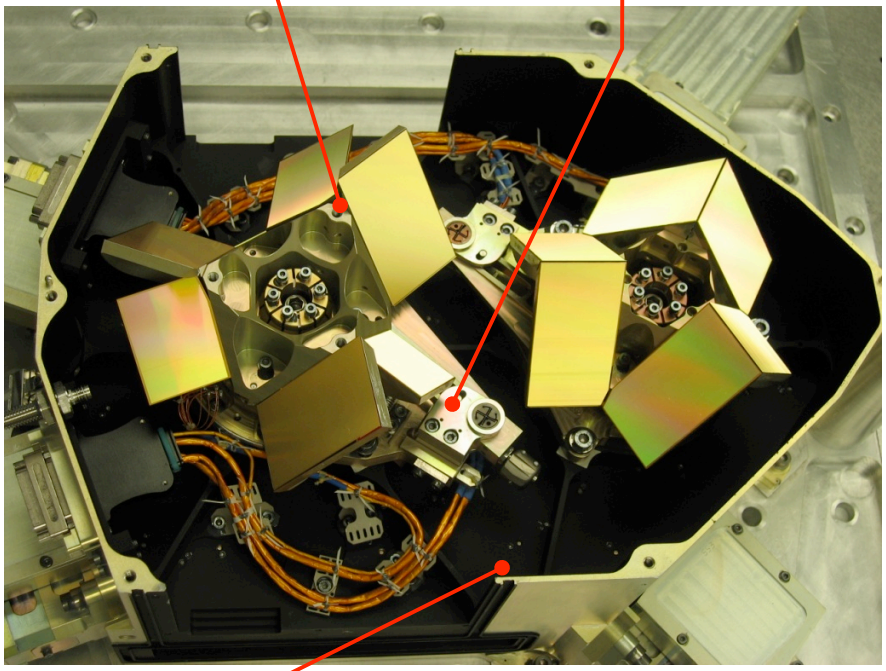


Astron, Netherlands

MPIA, Germany



UKATC, Scotland