MIRI

(& extragalactic science)

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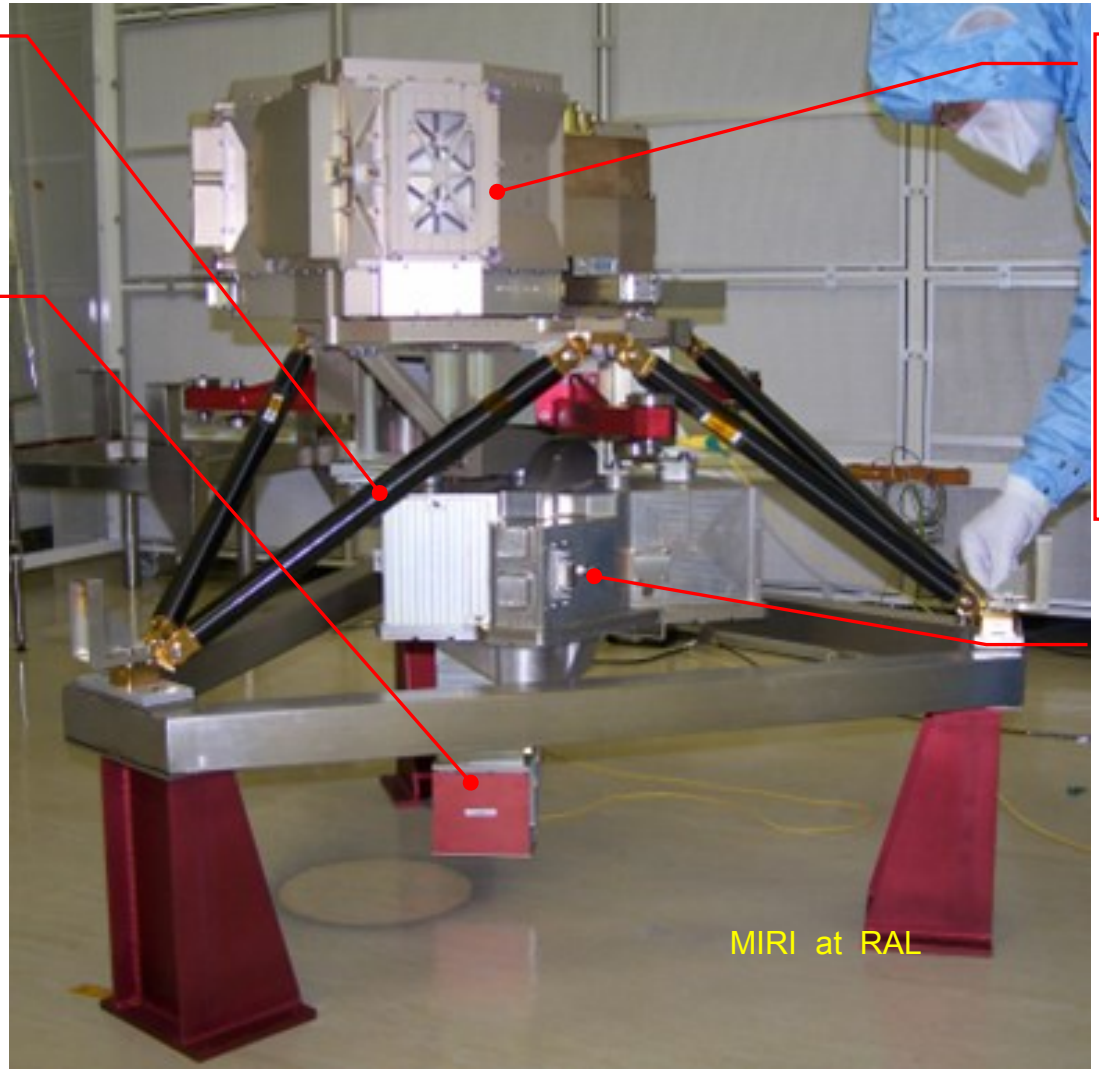
On behalf of the MIRI Team

MIRI is an Imager and a Spectrometer

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

Light enters from the JWST telescope

Not Shown:
The MIRI Cooer



Spectrometer

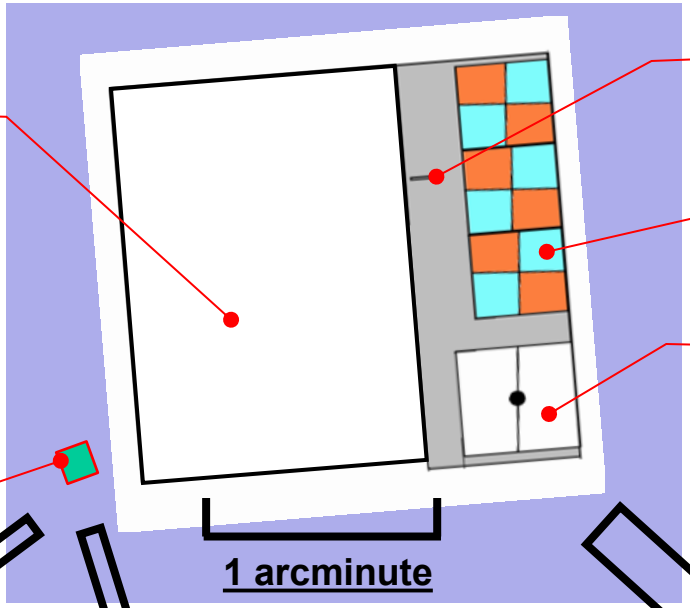
A 10 x 10 arcsec field passes through the deck into the R ~ 3000, 4 channel *integral field spectrometer*
2 detectors
2 channels per detector

Imager

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

MIRI focal plane

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



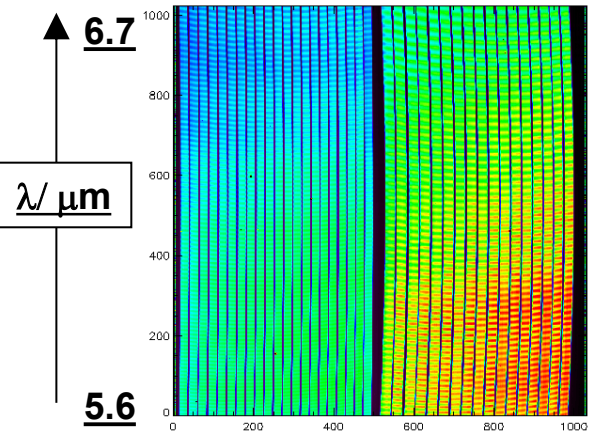
Low Resolution Spectrometer
5 x 0.6 arcsec

Three 4QPM Coronagraphs
24 x 24 arcsec

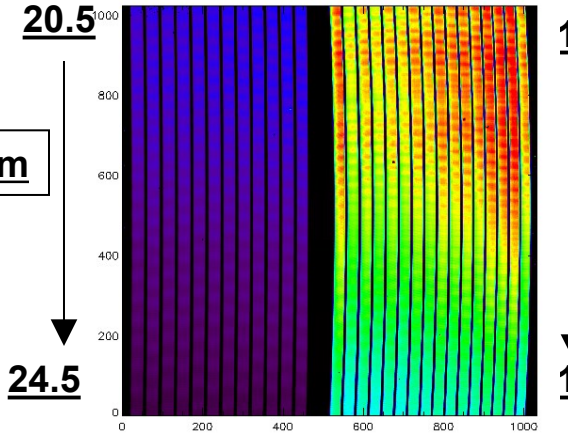
Lyot Mask 23μm
30" x 30"

R ~ 3000, 4 Channel Integral Field Spectrometer

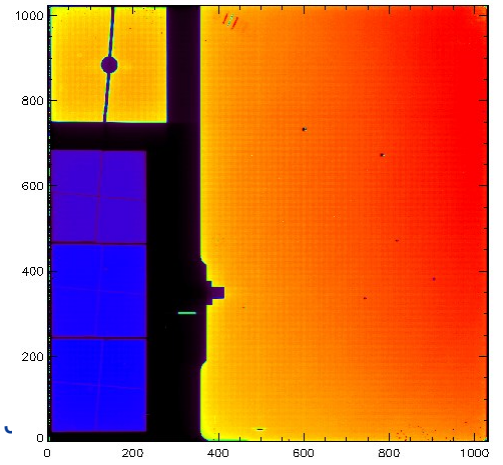
Channels 1 and 2



Channels 3 and 4



MIRI FM Imager



For detailed information about MIRI capabilities:

PASP Volume 127, Issue 953 (2015)

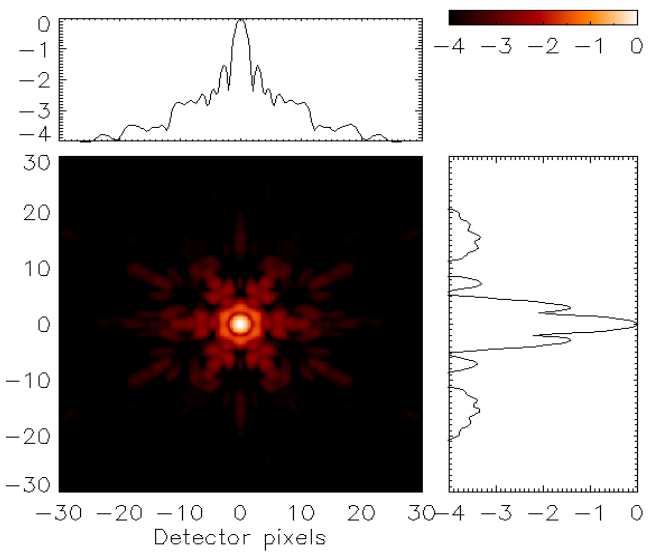
Papers are available on the MIRI team website

http://ircamera.as.arizona.edu/MIRI/index.htm

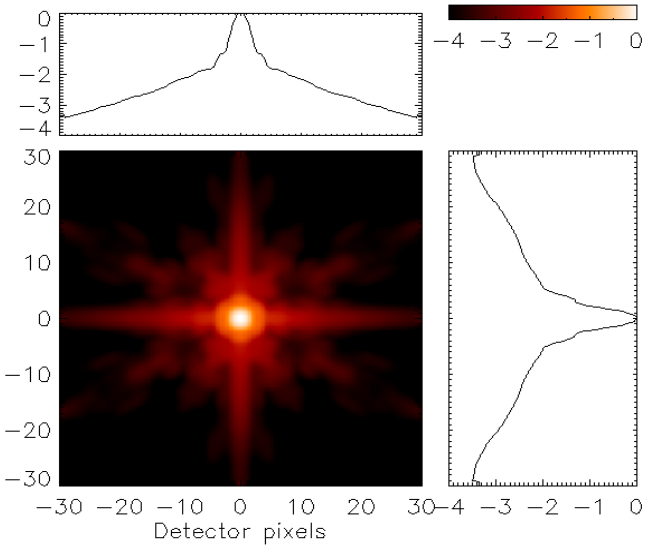
MIRI Pocket Guide available from
http://www.stsci.edu/jwst

Imager Image Quality

- **MIRI's short wavelength PSF is well described by a diffraction limited profile which is then convolved with a detector (internal) scattering profile.**
- **Model PSF derived from test data**
  - predicts that 22 % of the point source light at F560W is scattered (11 % for F770W).
- **MIRI has diffraction limited image quality for all longer wavelengths**



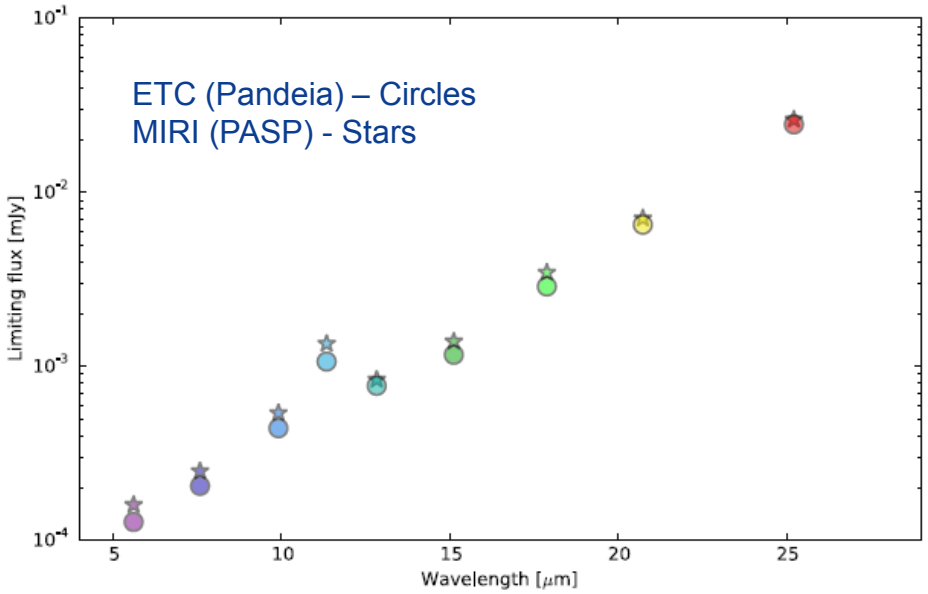
Model JWST diffraction limited PSF

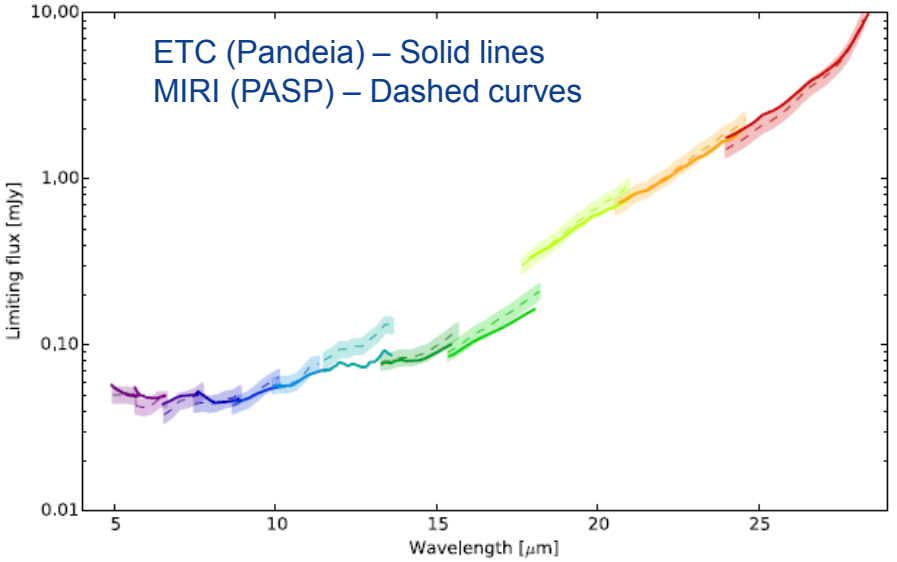


Expected (model) MIRI PSF, including det. scattering.

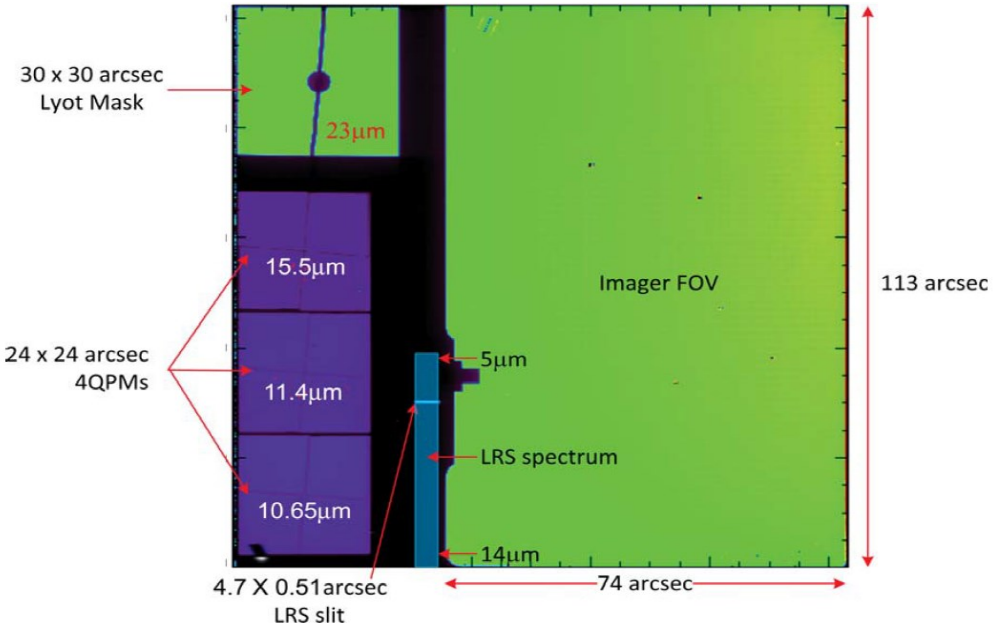
Sensitivity

- **MIRI's unprecendented sensitivity in the mid-IR means it can provide critical data for the study of galaxy evolution**
- **At long wavelengths MIRI sensitivity is limited by telescope background radiation**
  - Therefore for deep imaging of very faint high redshift sources the filters at 5.6, 7.7, 10.0 microns are of most interest
- **Plots show current best understanding of MIRI sensitivity**
  - Caveats : still some work in progress, telescope thermal background, still working to understand all detector features





MIRI Capabilities for Deep Imaging



MIRI provides diffraction limited images of FWHM 0.32 arcsec at 10um sampled with 0.11 arcsec pixels

The field for imaging is 74x113 arcsec

To obtain the best sensitivity observations are taken using a pre-defined dither pattern

JWST instruments do not simultaneously image the same field

The relatively small field size of MIRI means that it is not well suited to wide area searches /surveys
=> study areas already well studied or follow-up known or suspected very high redshift sources to constrain their properties

Example MIRI Deep Imaging of HUDF

Number of sources per MIRI FOV as function of 5.6 μm detection limit (AB mag)

B1: Bouwens et al. (2015), F: Finstein (2015), B2: Bowler et al. (2015)

Redshift	< 27.0 B1+F+B2	< 27.5 B1+F+B2	< 28.0 B1+F+B2	< 28.5 B1+F+B2
4.5 – 5.5	13 - 29	18 - 38	34 - 81	49 – 132
5.5 – 6.5	4 - 16	13 - 28	23 - 81	33 – 73
6.5 – 7.5	2 - 15	5 - 18	11 - 37	26 – 45
7.5 – 8.5	1 - 6	1 - 8	4 - 13	8 – 22
> 9	0 - 0.6	0 - 1	0 – 7	5 – 13

Assumptions:

Extrapolation assuming faint – end slopes for flat to -2

Photo-z errors typically affect number densities making them smaller by 10-20 % z>5

Very blue sources ([5.6] – H < 1) missed-> 30 % less sources than LF, effect included

~80h to reach 5sigma 28.5 at 5.6um

Galaxy sizes – evolution with z

- MIRI 6-8 um imaging : first time direct high resolution observations morphology of old (>100Myr) stellar populations
- MIRI data provide unique information for establishing relationship between assembly of stellar mass and size growth for z>3

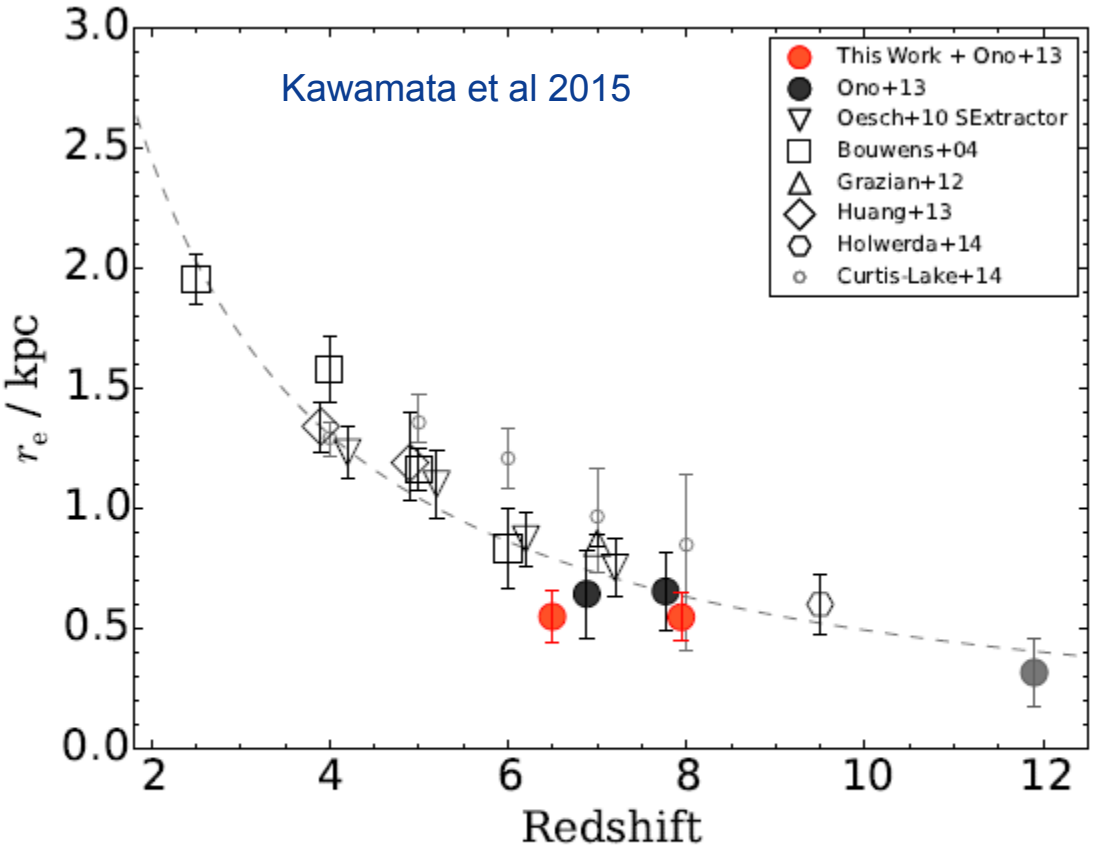
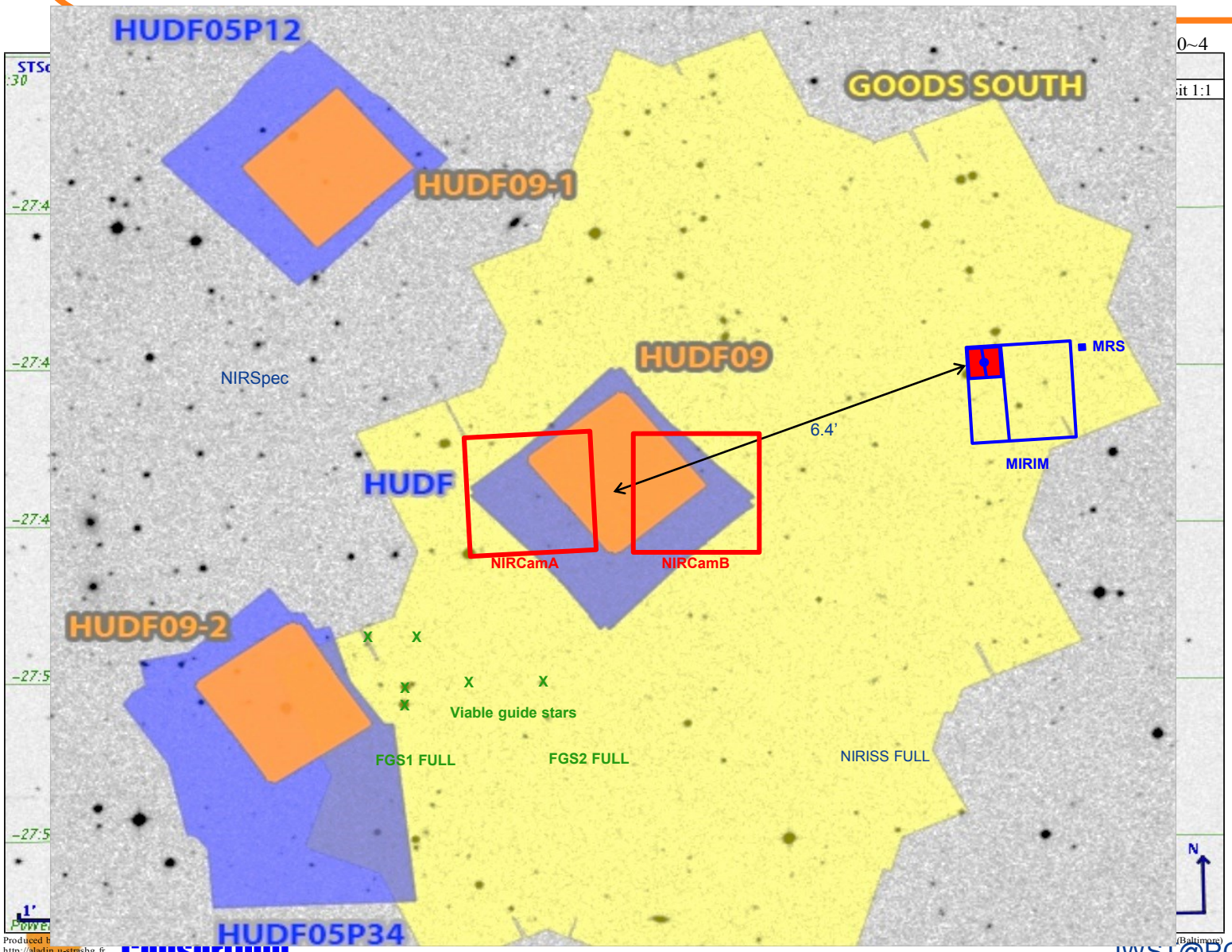


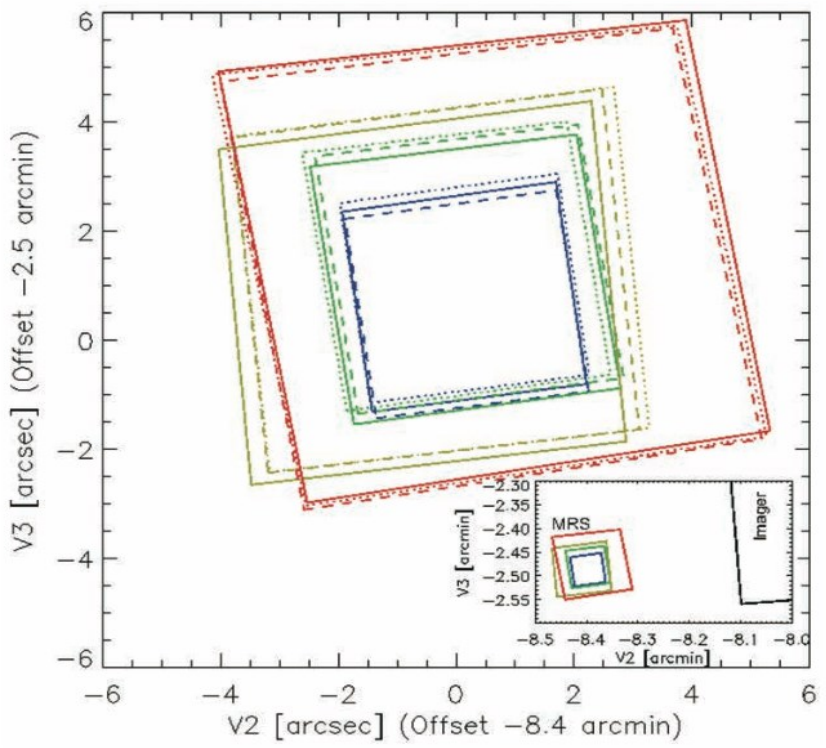
Figure 6. Redshift evolution of the average size of bright galaxies. The red circles show the weighted-average radii of our samples combined with Ono et al. (2013)'s, while the black circles are for Ono et al. (2013)'s. The error bars show the 1σ standard error.

NIRCam-MIRI Parallels : powerful capability



With this configuration MIRI observes a field from GOODS south.

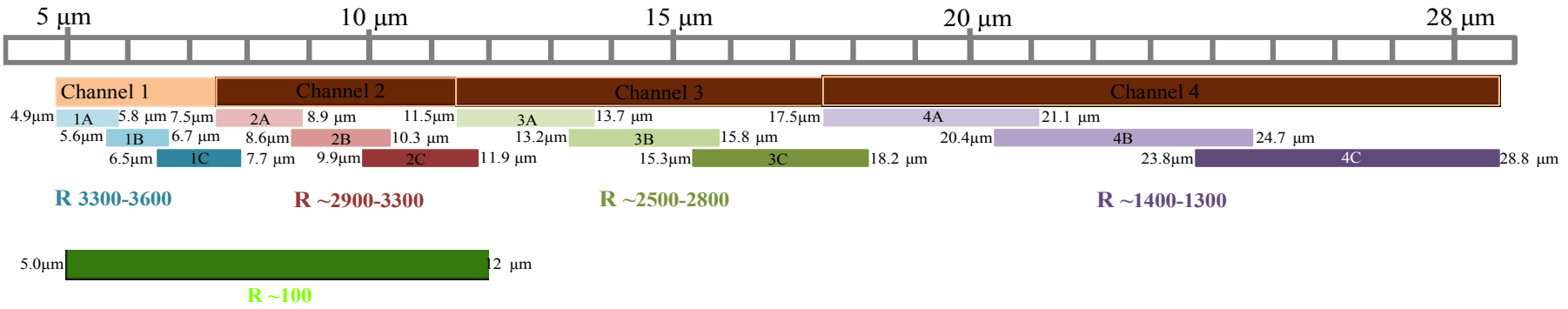
MIRI MRS: Spectrscopy with MIRI



MRS: diffraction limited integral field spectrograph from 5 to 28.5 µm.

The light get s split into 4 channels, each with 3 sub-bands.

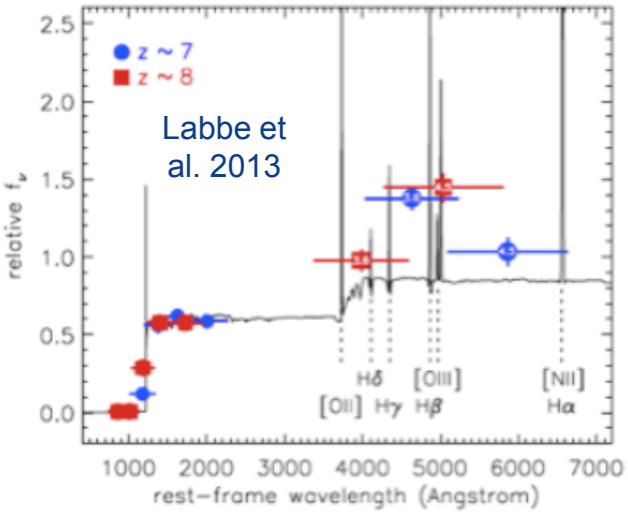
Concentric FOVs on the sky ranging from 3.7”x3.7” to 7.7”x7.9”, and slice widths from 0.18” to 0.64”
(scales with diffraction limit)



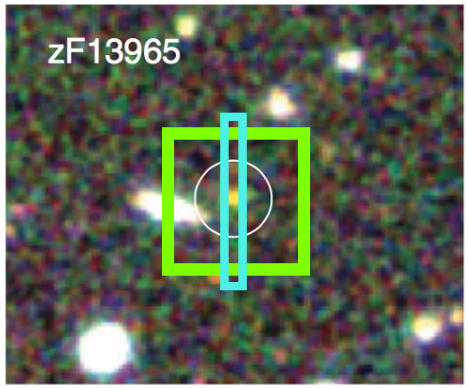
Spectroscopy of high redshift galaxies

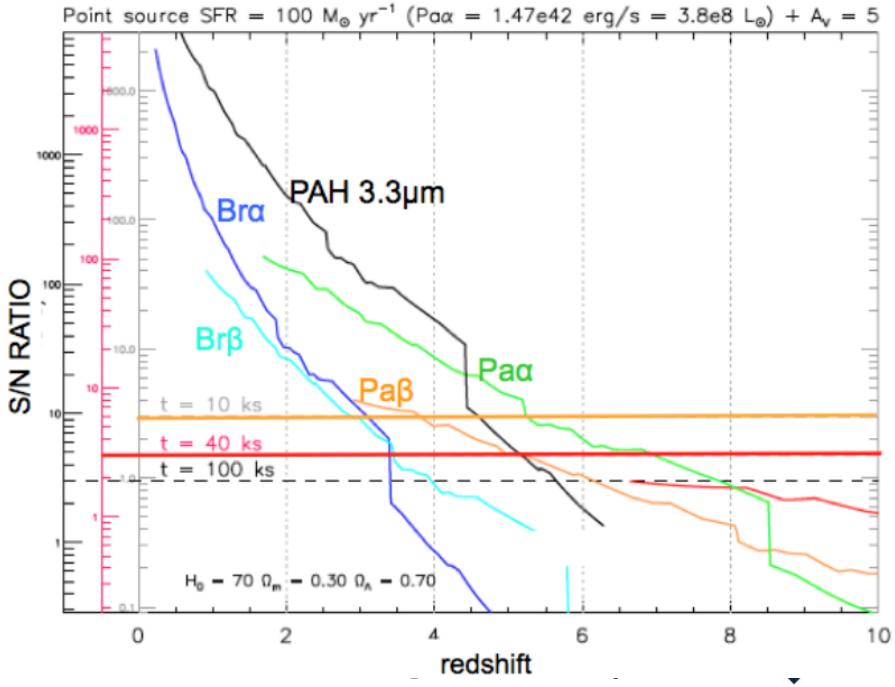
- **Galaxies in the epoch of re-ionisation z ~6-9**
- **Detection of strong nebular (rest frame optical) emission lines**
  - Key properties such as ionisation escape fraction, star formation rates, dust content, metallicity
  - Mid-IR for the highest redshifts

- **Population of dusty IR luminous galaxies at z ~ 3-6 found in large surveys (ALMA, Herschel, Spitzer)**
- **Rest frame near-IR spectra key diagnostic lines**



Tilvi et al. 2003, z~7

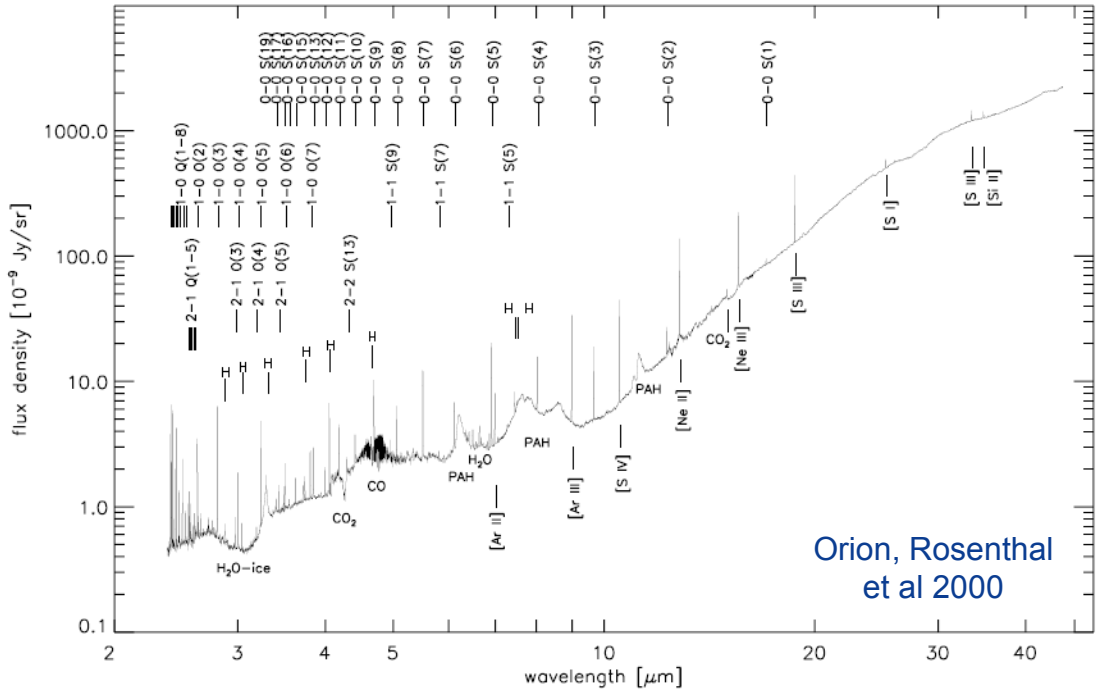




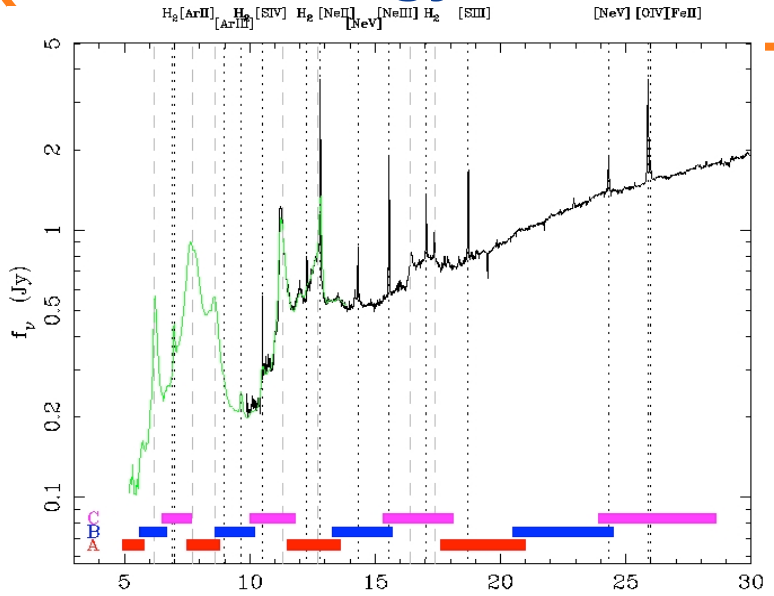
Spectroscopy

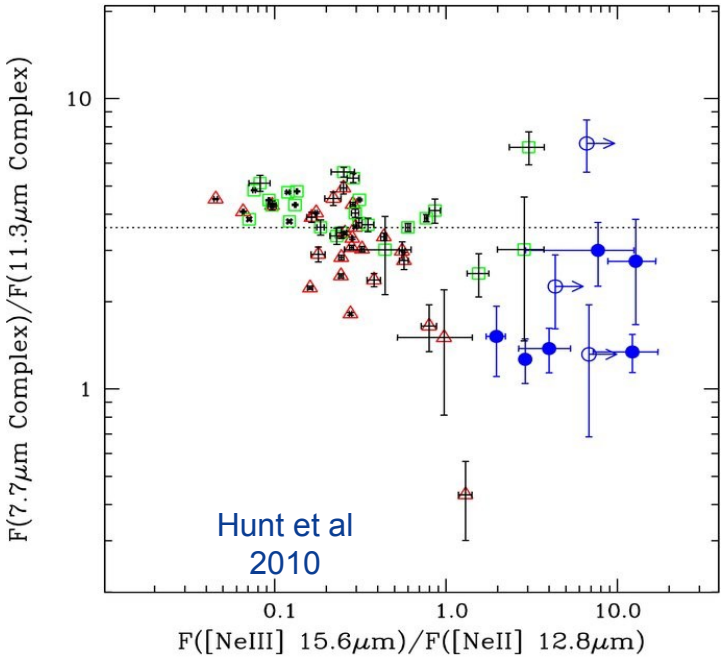
- **Mid-IR wavelength range has many key diagnostic lines for physical/excitation conditions in galaxy nucleii**
  - **PDR lines**
  - **Stellar HII lines**
  - **AGN tracers**
  - **Coronal lines**

- **Line ratios – give**
  - excitation and
  - ionisation state, hence
  - the shape of the SED responsible
- **NIRSpec and MIRI IFUs are well matched in field and resolution**



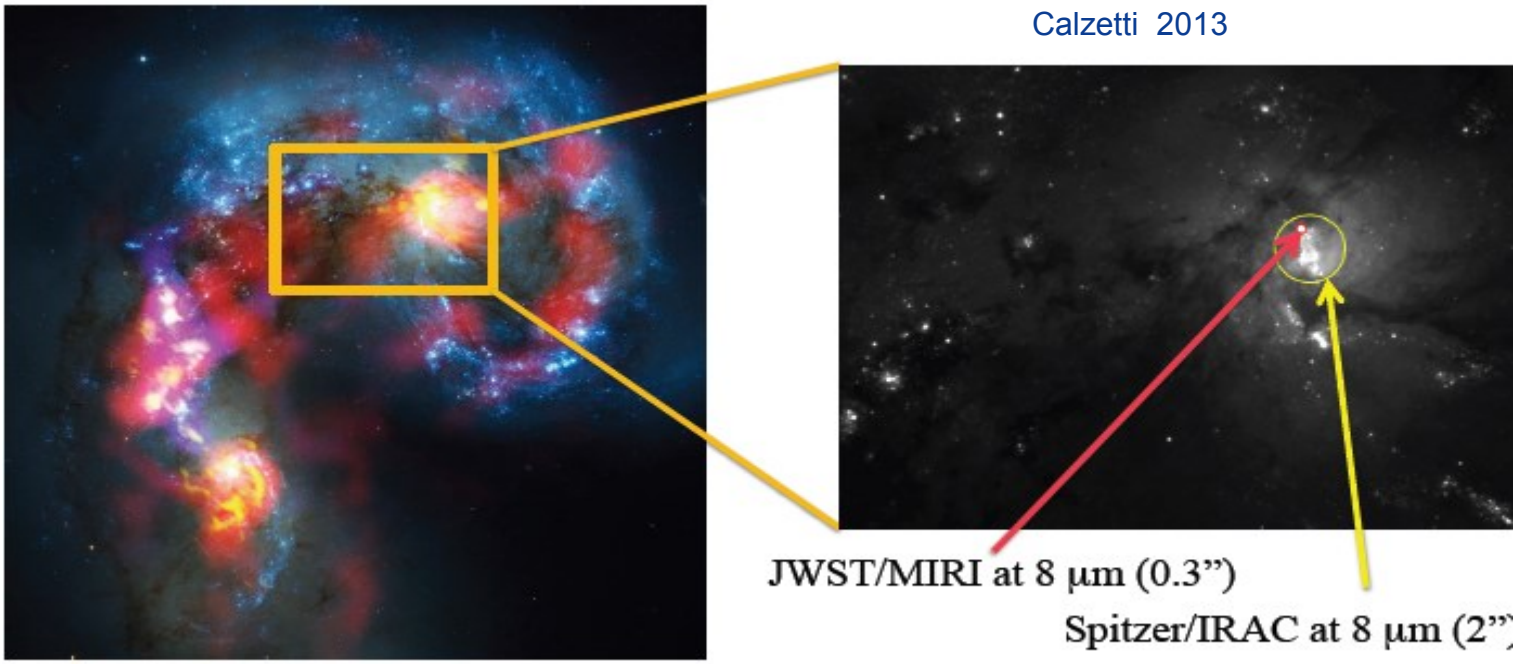
Mass-energy-chemical cycles in galaxies





- **NGC5135, mix of AGN and starburst type spectral features**
- **MIRI IFU capabilities will be key for understanding the differences in gas excitation and dust heating of star formation and AGNs. Able to separate them spatially**
- **Spatially resolved PAH spectra across a range of physical and chemical conditions**
  - Dust enshrouded star formation and SFR at high redshift

Nearby Galaxies …



Antennae Galaxies ~ 18 Mpc: HST (blue)+ALMA(yellow+red)

- MIRI PSF at 10um is comparable to the size of a small molecular cloud in local galaxies (out to 5Mpc)
- MIRI PSF corresponds to size of bright nuclear starburst (150pc) for galaxies as far away as Coma cluster

Conclusions

- **MIRI on JWST will provide a unique capability for extragalactic science**

- **Unprecedented combination of sensitivity and spatial/spectral resolution**
  - Discovery space !

Thanks to the MIRI team !!