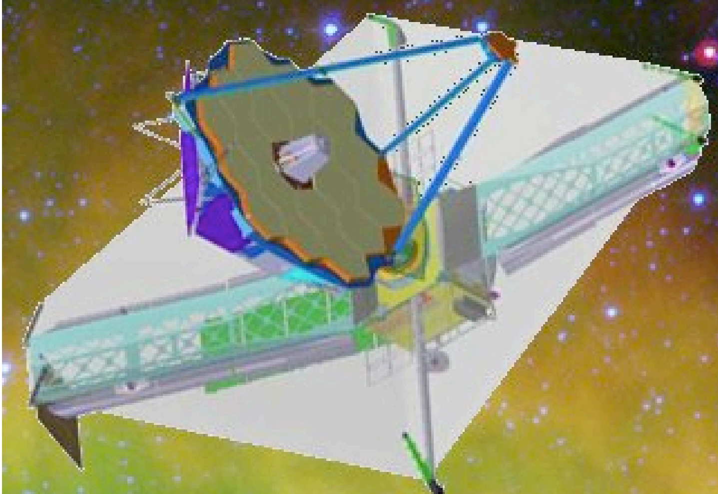
# James Webb Space Telescope (JWST) and Star Formation

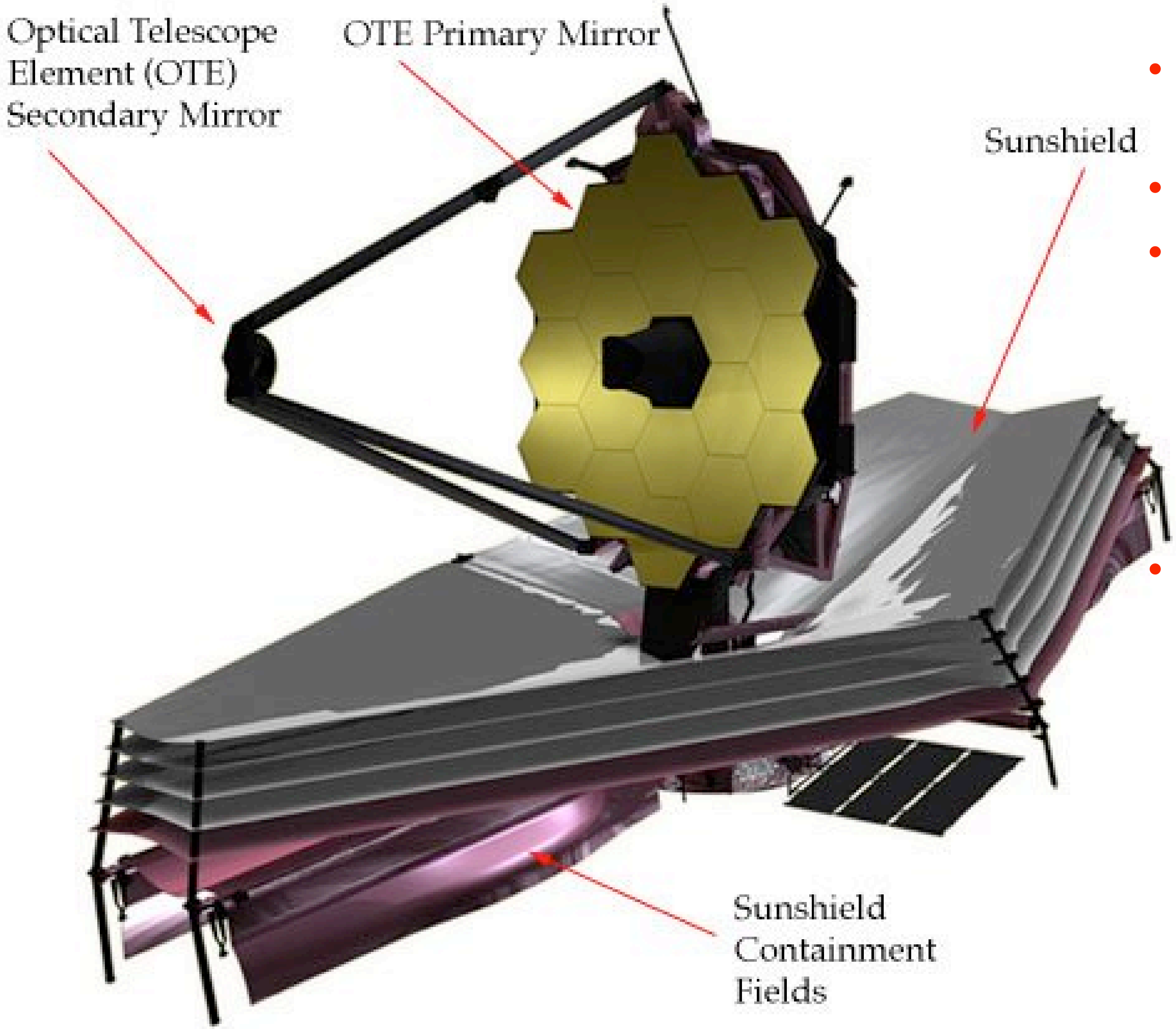
Zermatt ISM meeting
September 24, 2010

Tom Greene (NASA Ames)
& many other JWST scientists



Spitzer Serpens A image courtesy of NASA/JPL-Caltech/L. Cieza (UT)

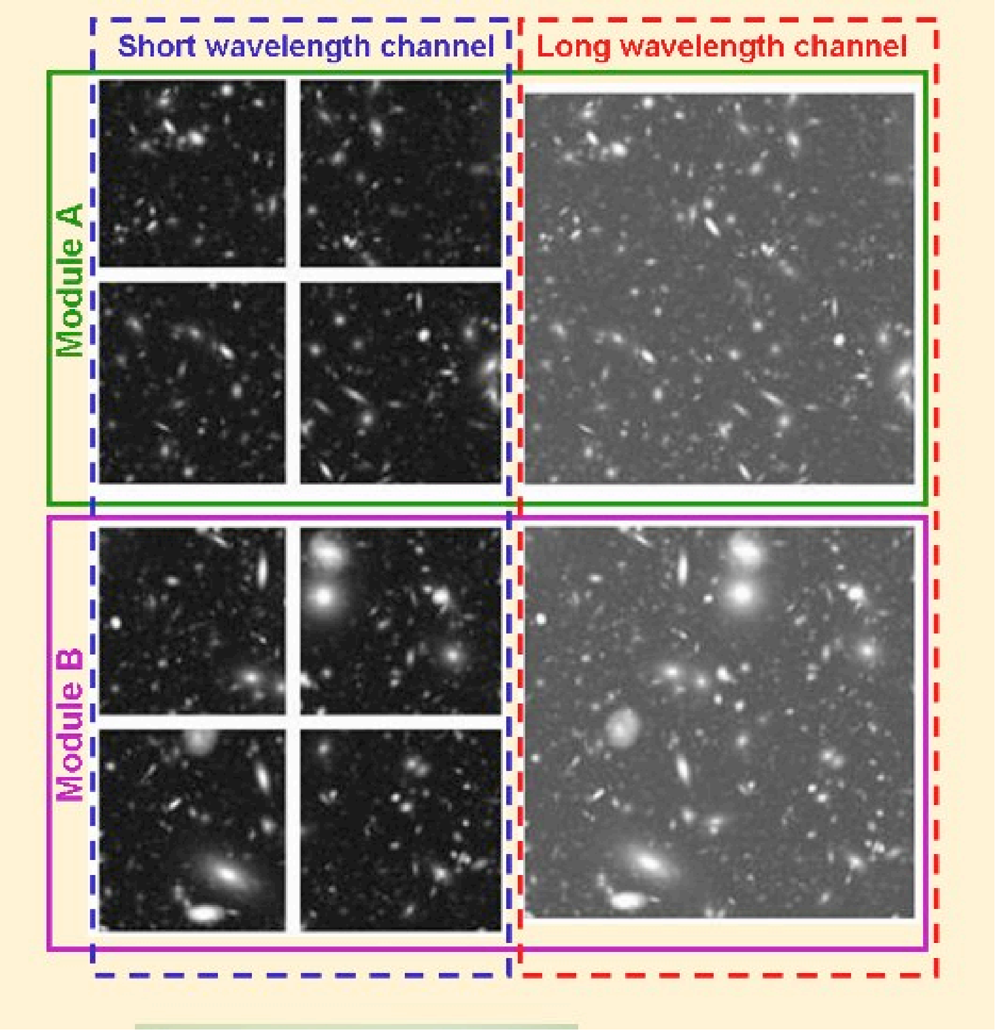
# JWST in a nutshell




- 6.5-m primary mirror; 18 segments
- $\lambda$ <1 - 28 $\mu$m
- Instruments:
  - NIRCam
  - NIRSpec
  - MIRI (cam + spec)
  - FGS w/TF
- ≥ 2014 launch
  - Arianne V to L2
  - 5 yr req life
  - 10 yr goal
  - No cryogens

# JWST Instruments: NIRCam (NASA)

- Images over 0.7 – 5 μm Nyquist sampled at 2 & 4 μm
  - Broad, medium, and narrow bands
  - R ~ 1700 slitless spectra 3 – 5 μm (series filter)
  - Coronagraphic imaging
- 2 identical modules, each with short and long wavelength dichroics: 2 x 2' x 2' FOV
- M. Rieke (U Arizona) is PI
- Filters and other information: http://ircamera.as.arizona.edu/nircam/

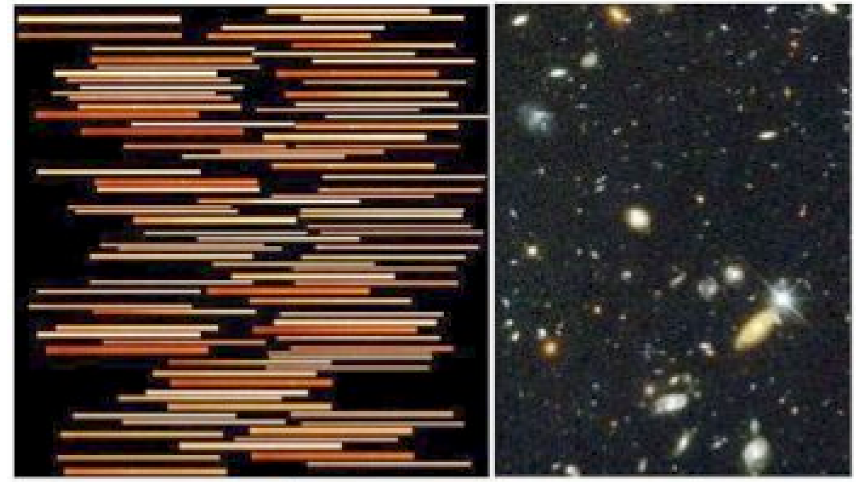


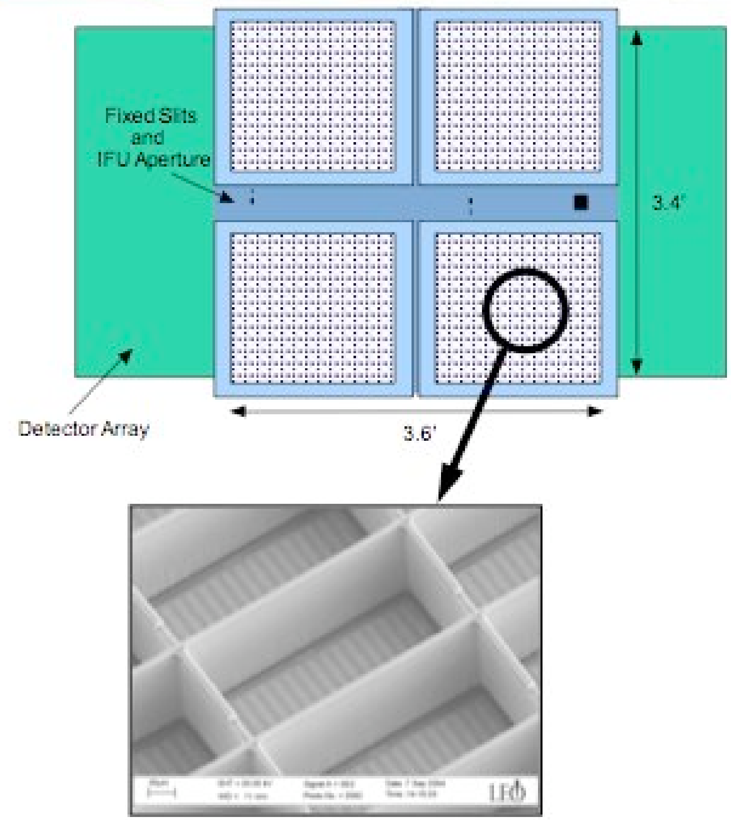
# FGS: Fine Guidance Sensor (CSA)

- 2 NIRCam-sized (2.3' x 2.3' adjacent FOVs)
  - $\lambda = 2\mu$m critical sampling
- $\lambda = 0.8 - 4.8\ \mu$m wide band guider imaging
- R=100 imaging with tunable filter (TFI) for science
  - $\lambda = 1.5 - 2.6\ \mu$m and 3.1 $- 5\ \mu$m operation
- Non-redudant mask for moderate contrast, high spatial resolution science imaging
- J. Hutchings (FGS) and R. Doyon (TFI) are PIs

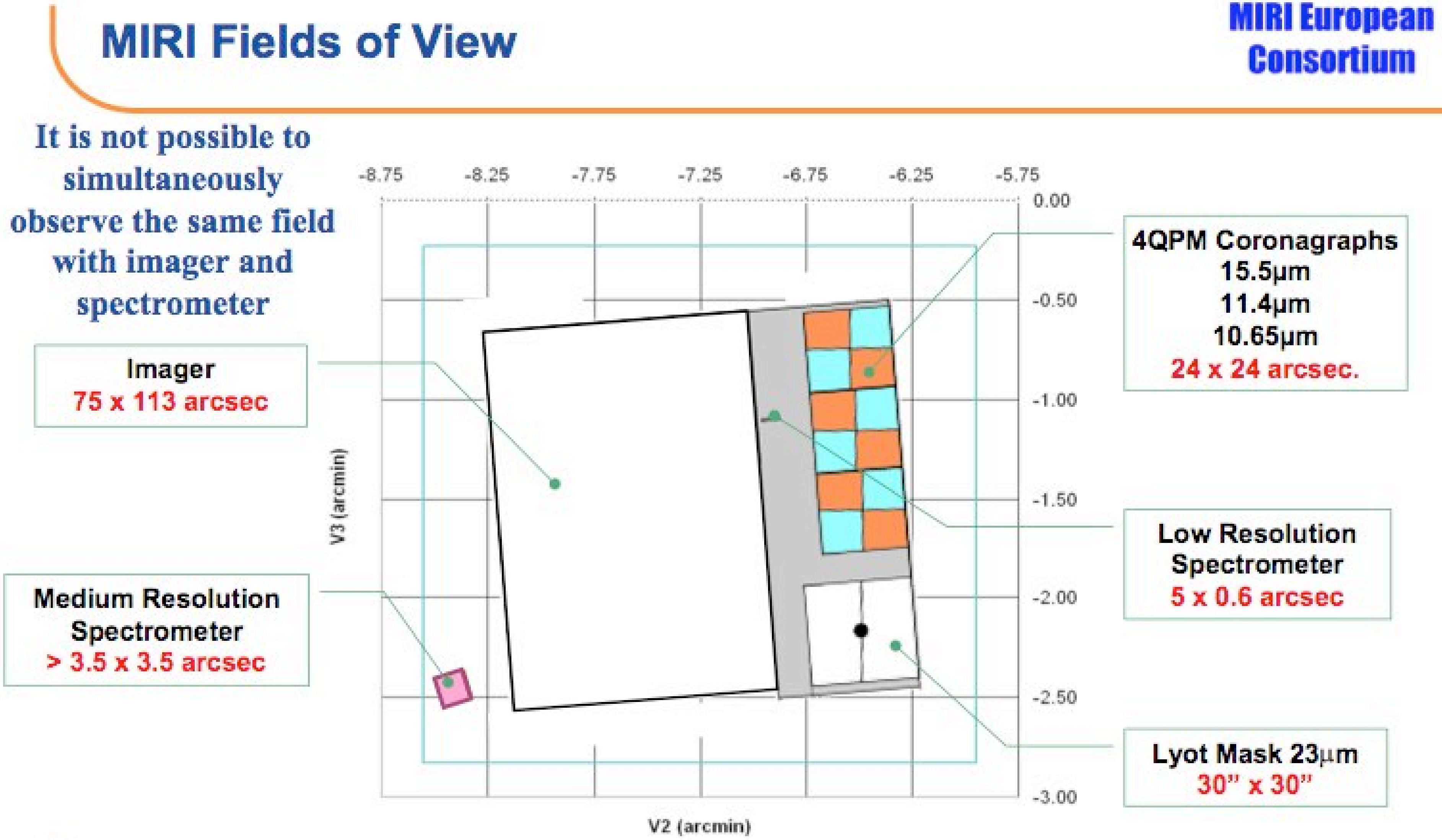
# NIRSpec (ESA): 1 – 5 μm spectra

- Multi-object spectrograph
  - 3.4' x 3.4' FOV
  - Mosaic of microshutter arrays (250,000 shutters, each 200 x 460 mas)
- Also has fixed slits and IFU
- R=100 (1 setting) and R=2700 (3 settings) spectroscopy with coarse (100 mas) spatial sampling for single or multiple objects
- R~100 prism covers 0.7 – 5μm
- P. Jakobsen science team lead





# MIRI: Mid-infrared instrument (EC/NASA)




- MIRI has an imager, F ~ 100 spectrograph, and R=3000 IFU spectrometer (G. Wright PI; G. Rieke science lead)

# Instrument Properties

**Key Instrument Characteristics** (as of Mar 06)

| Instrument | Channel/Mode | Wavelength (microns) | Typical Spectral Resolution ($\lambda/\Delta\lambda$) | FOV | Angular Resolution (arc sec) | Number of Sensor Chip Arrays | Mega Pixels | Detector Type / Format NIR=18 um pixels MIR=25 um pixels | Detector Temp (K) |
|---|---|---|---|---|---|---|---|---|---|
| NIRCam | Shortwave | 0.6 - 2.3 | 4,10,100 | 2.2' x 2.2' each of 2 modules | 0.032 / pixel | 8 | 34 | HgCdTe / 2048 x 2048 | 40 |
| | Longwave | 2.4 - 5.0 | 4,10,100 | 2.2' x 2.2' each of 2 modules | 0.065 / pixel | 2 | 8 | HgCdTe / 2048 x 2048 | 40 |
| NIRSpec | Multi-Object Spec | 1.0 - 5.0<br>0.6 - 5.0 | 1000<br>100 | 203 x 463 mas clear shutter aperture, 267 x 528 mas pitch, 4 x 171 x 365 shutter array format, 9.7 sq arcmin multi-object targetable solid angle | see FOV | 2 | 8 | HgCdTe / 2048 x 2048 | 37 |
| | Long Slits (5) | 1.0 - 5.0 | 100, 1000, 2700 | 200 x 3500 mas x 3, 400 x 4000 mas, 100 x 2000 mas | | | | | |
| | IFU | 0.7 - 5.0 | 2700 | 3 x 3 arc-sec | 0.10 slice width | | | | |
| MIRI | Imager | 5 - 27 | 4-6 | 1.9' x 1.4' | 0.11 / pixel | 1 | 1 | Si:As / 1024 x 1024 | 7 |
| | Low Res Slit | 5 - 11 | 100 | 5" x 0.6" | see FOV | 1 | 1 | Si:As / 1024 x 1024 | 7 |
| | Med Res IFU | 4.87 - 7.76<br>7.45 - 11.87<br>11.47 - 18.24<br>17.54 - 28.82 | 3000<br>3000<br>3000<br>2250 | 3.7" x 3.7"<br>4.7" x 4.5"<br>6.2" x 6.1"<br>7.1" x 7.7" | 0.18 slice width<br>0.28 slice width<br>0.39 slice width<br>0.65 slice width | 1 | 1 | Si:As / 1024 x 1024 | 7 |
| FGS-TF | | 1.6 - 2.5, 3.2 - 4.9 | 100 | 2.2' x 2.2' | 0.065 / pixel | 1 | 4 | HgCdTe / 2048 x 2048 | 40 |
| FGS-Guider | | 0.8 - 5.0 | 0.7 | 2.3' x 2.3' each of 2 modules | 0.068 / pixel | 2 | 8 | HgCdTe / 2048 x 2048 | 40 |

Table courtesy of Matt Greenhouse, JWST ISIM Project Scientist

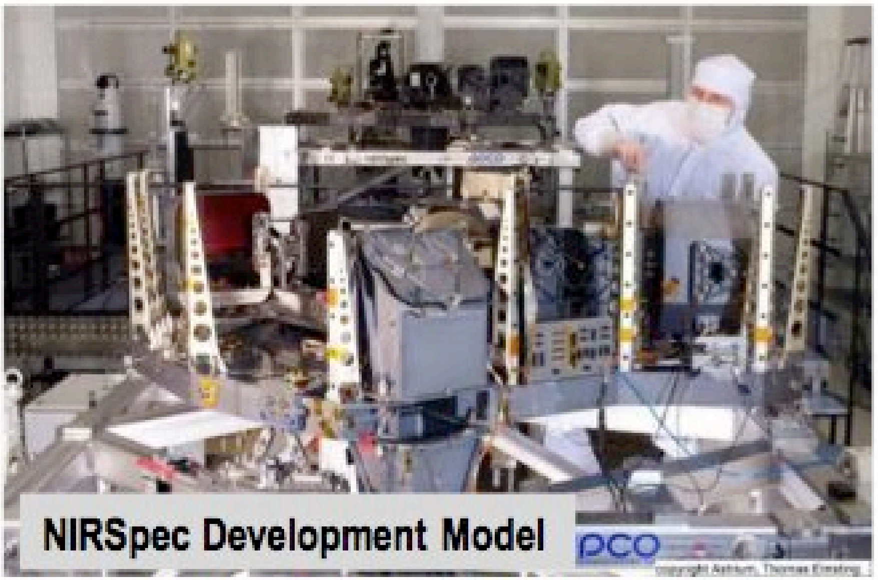
# Estimated Sensitivities

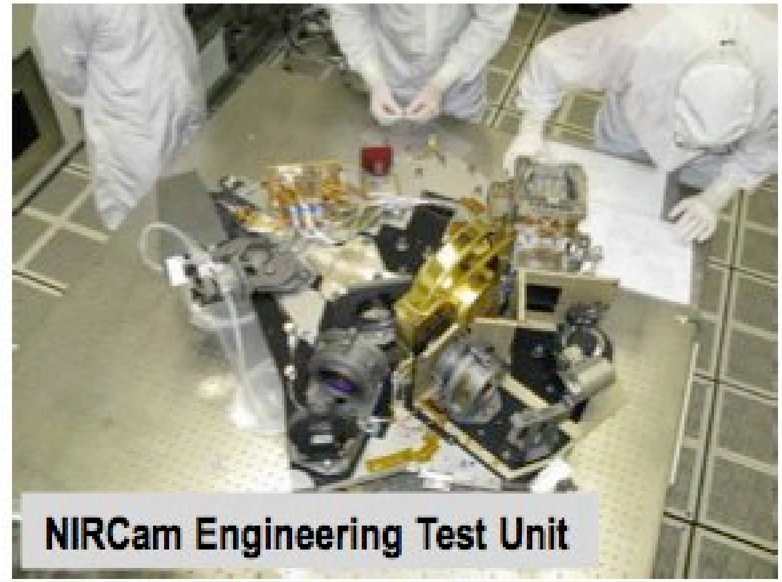
| JWST Sensitivity (JWST-RQMT-000634 Rev-M proposed) | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wavelength (microns) | Instrument/Mode | Bandwidth (l/Dl) | SNR | Maximum Wall Clock Time (s) | Continuum Flux Density (nJy) | Continuum Flux Density ($10^{-33}$ W m$^{-2}$ Hz$^{-1}$) | Unresolved Line Flux ($10^{-21}$ W m$^{-2}$) |
| 1.1 | NIRCam | 4 | 10 | 10,000 | TBD | TBD | NA |
| 2 | NIRCam | 4 | 10 | 10,000 | 10.40 | 0.10 | NA |
| 3.5 | FGS-TF | 100 | 10 | 10,000 | 126.00 | 1.26 | NA |
| 3 | NIRSpec/Low Res | 100 | 10 | 10,000 | 120.00 | 1.20 | NA |
| 2 | NIRSpec/ Med Res | NA | 10 | 100,000 | NA | NA | 1 |
| 10 | MIRI/ Broadband | 5 | 10 | 10,000 | 700.00 | 7.00 | NA |
| 21 | MIRI/Broadband | 4.2 | 10 | 10,000 | 8700.00 | 87.00 | NA |
| 9.9 | MIRI/Spectrometer | NA | 10 | 10,000 | NA | NA | 10 |
| 22.5 | MIRI/Spectrtometer | NA | 10 | 10,000 | NA | NA | 560 |

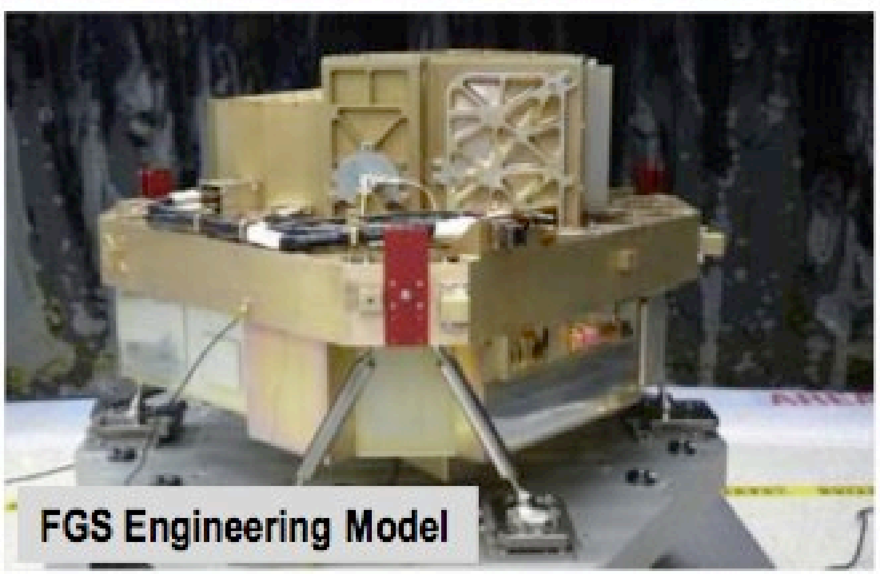
- MIRI R=3000 IFU is currently estimated to have point source sensitivity Fnu ~ 500 nJy @ S/N = 10 in 1E4 s in wide 10 μm filter
- Please take all values as estimates only: better values should be provided by June 2011

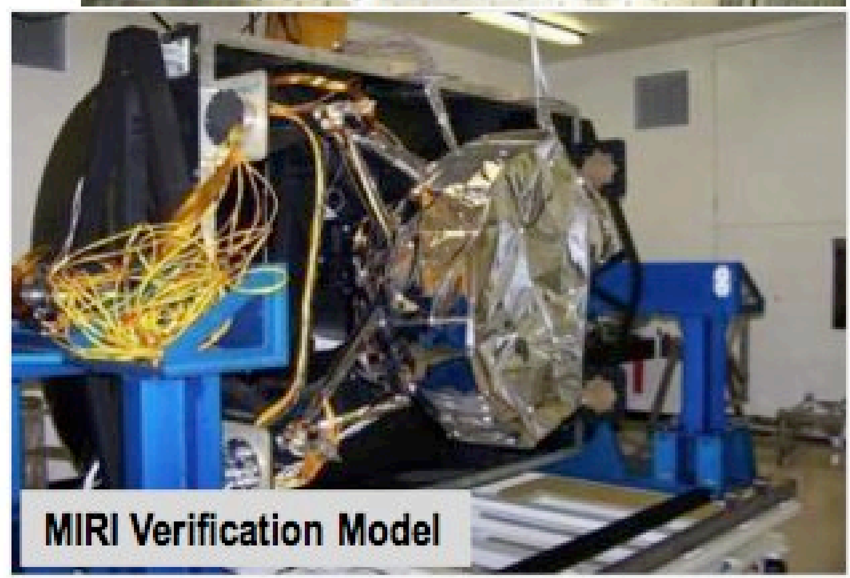
# Status

- All instrument engineering models built, flight models to be delivered in 2011

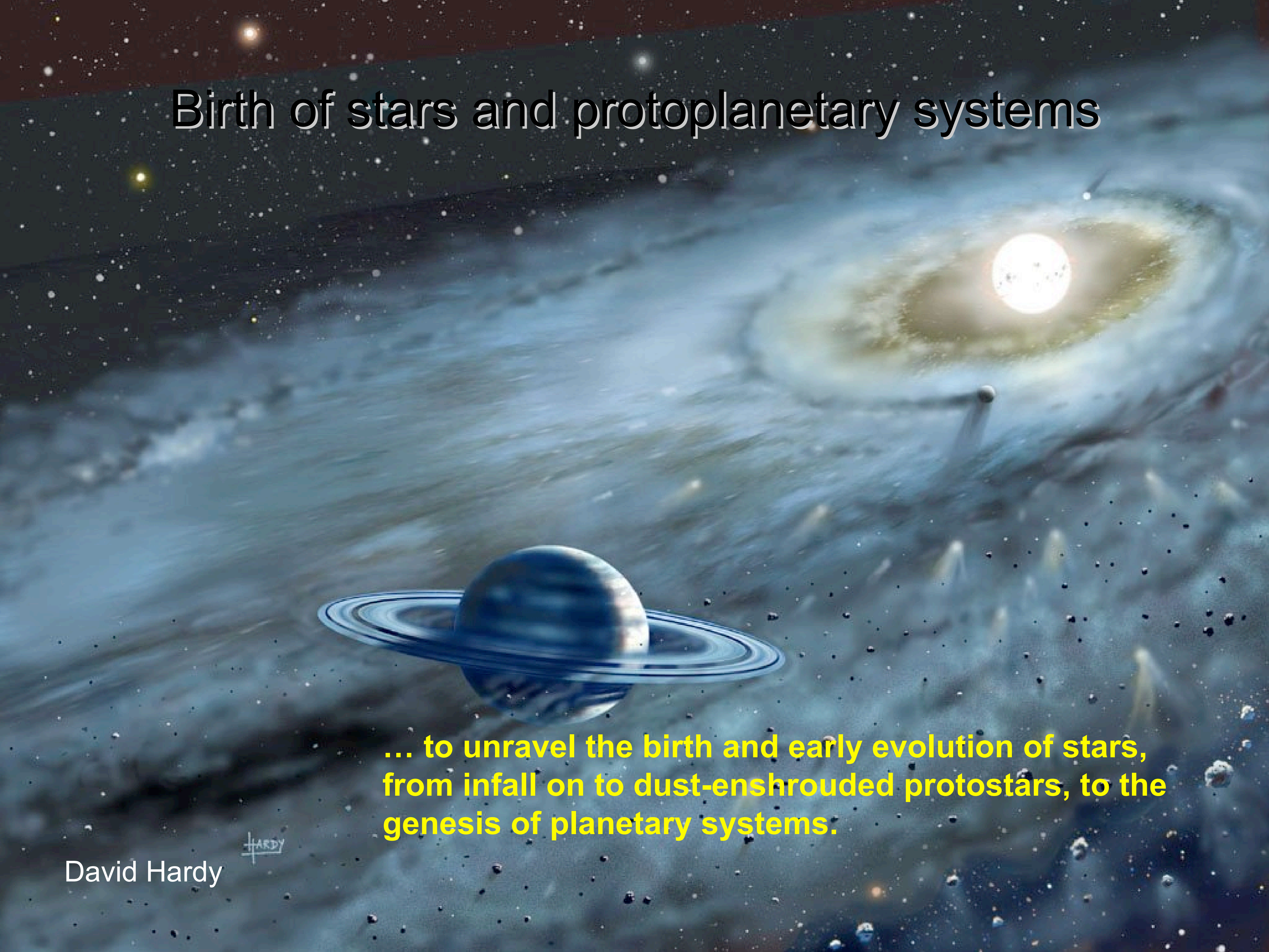


# Birth of stars and protoplanetary systems

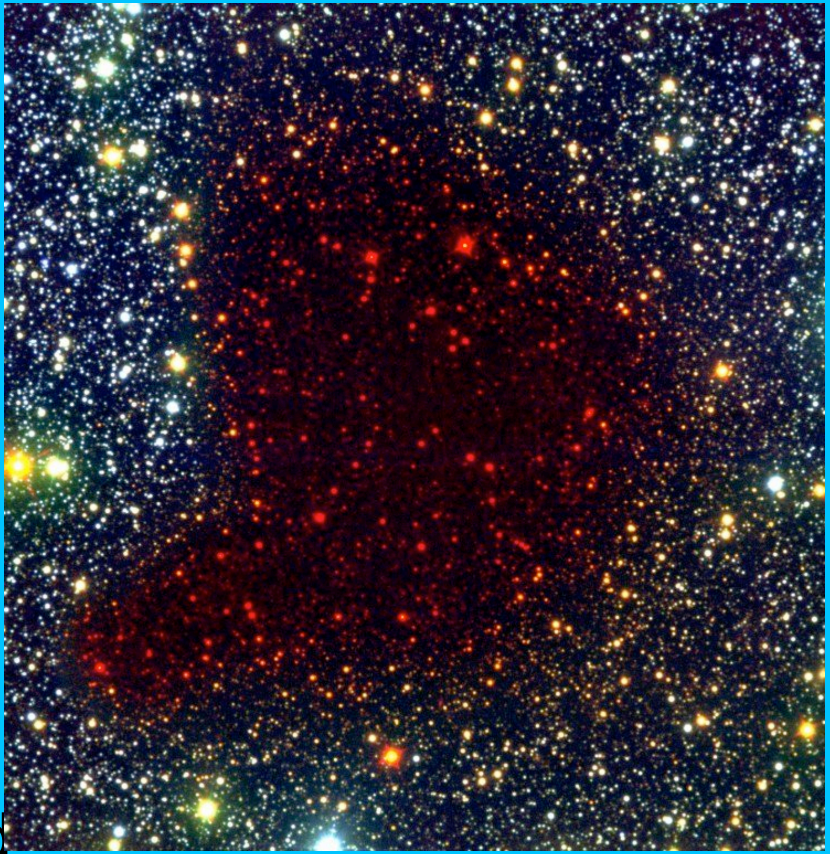



… to unravel the birth and early evolution of stars, from infall on to dust-enshrouded protostars, to the genesis of planetary systems.

David Hardy

# How do proto-stellar clouds collapse?

- Stars form in small regions collapsing gravitationally within larger molecular clouds.
- We can see through thick, dusty clouds in the infrared.
- Protostars begin to shine within the clouds, revealing temperature and density structure.
- Observations consist of near- and mid-IR images that are used to create extinction maps via color and number information of background stars

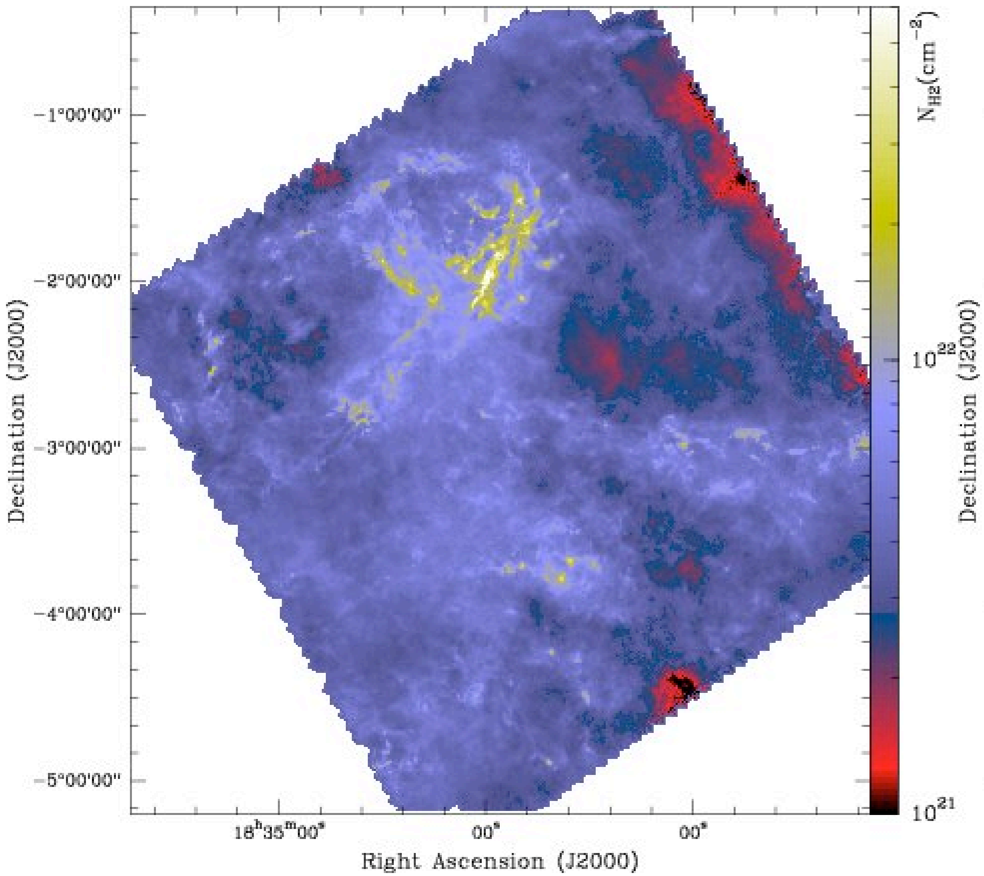


Barnard 68 in visible light
Barnard 68 in infrared light

# Emission vs. Extinction maps

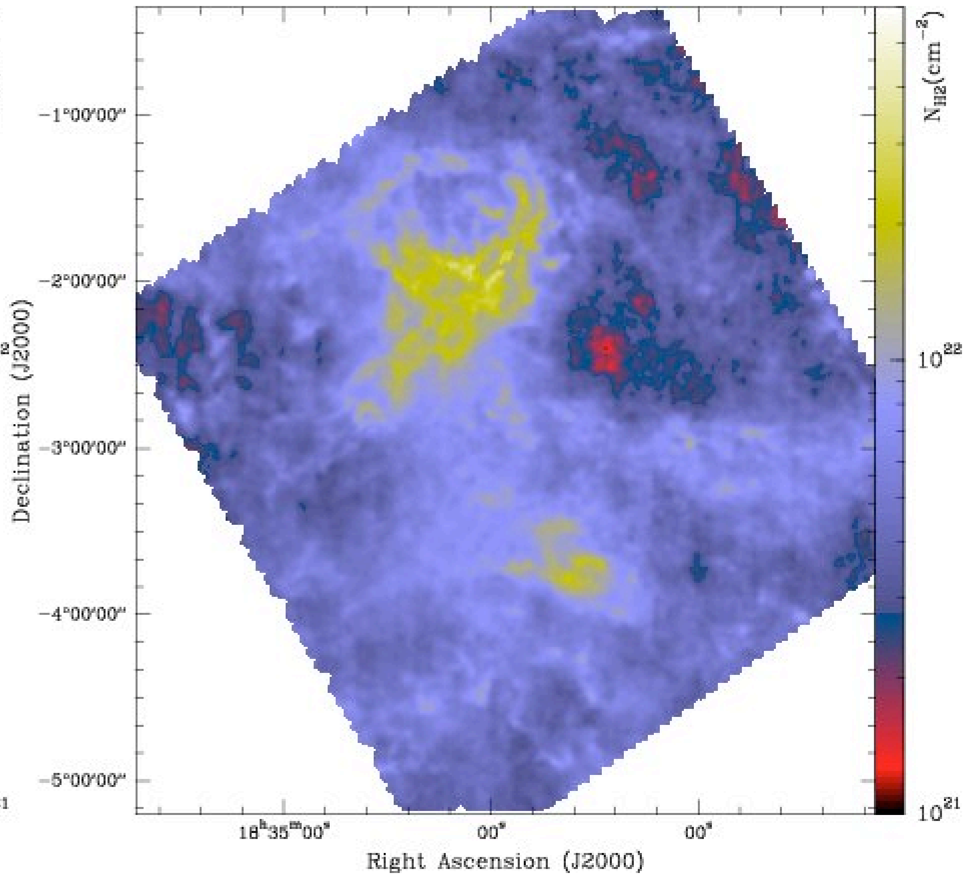
- High JWST sensitivity allows much deeper penetration and much finer sampling than ground-based extinction mapping:

Herschel Column Density of Aquila




Könyves et al. 2010

2MASS extinction map of Aquila




Könyves et al. 2010 / Bontemps et al. 2010

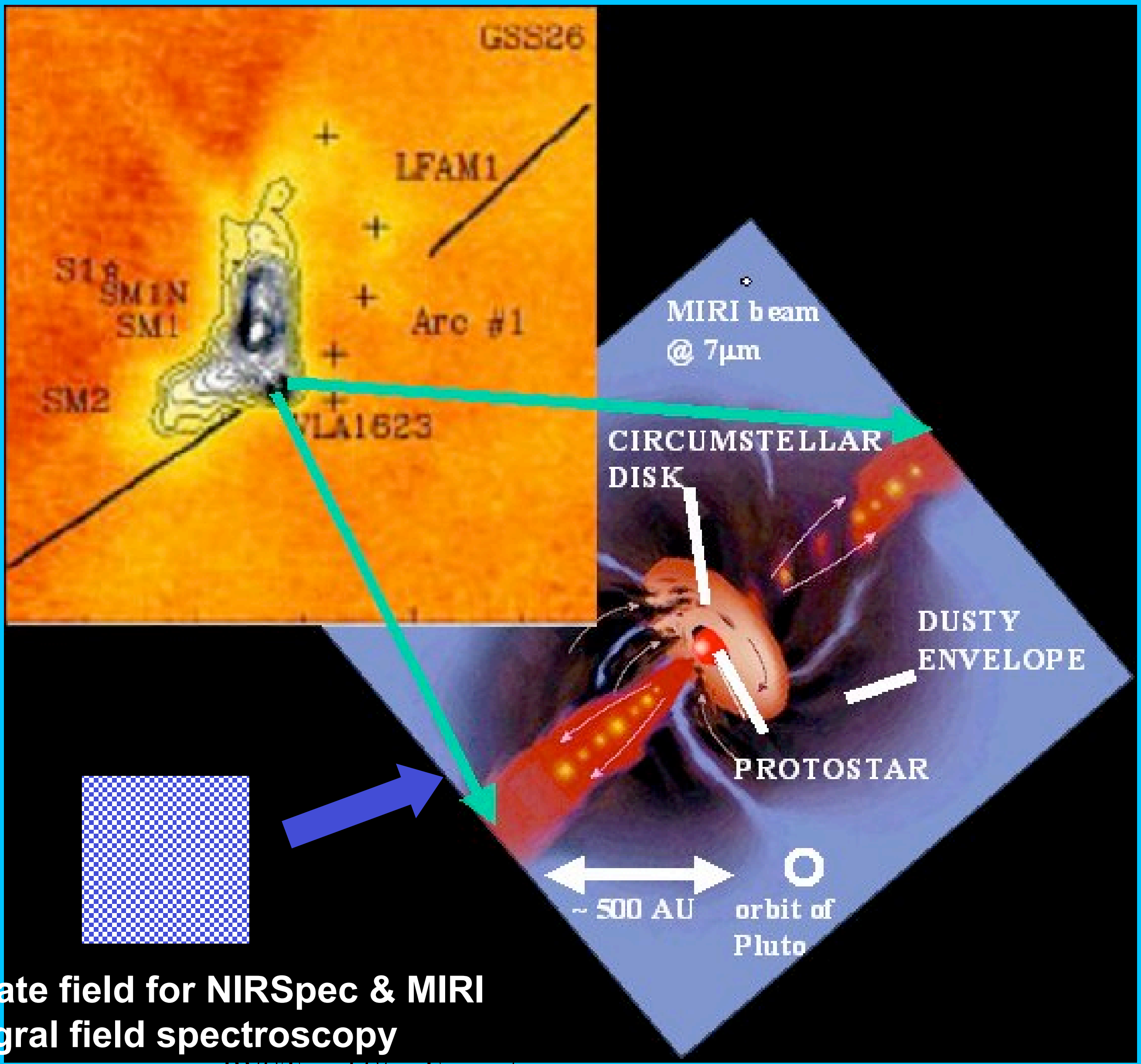
# How do planets form?

- Giant planets could be signpost of process that creates Earth-like planets
- Solar System primordial disk is now in small planets, moons, asteroids and comets

- Observations:
  - Coronagraphic imaging of very young exosolar planets
  - Compare spectra of comets and circumstellar disks

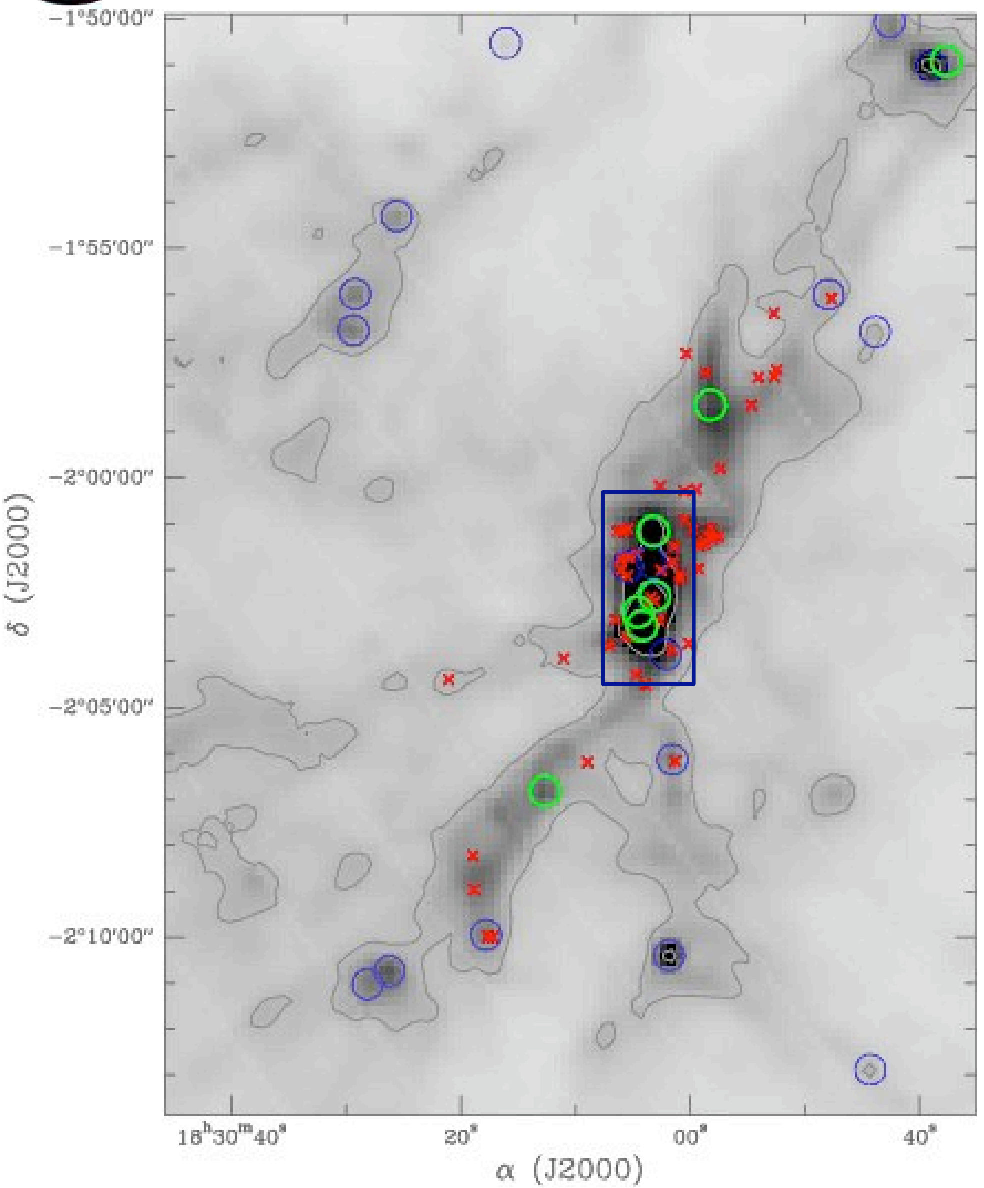
# How are circumstellar disks like our Solar System?

**Here is an illustration of what MIRI might find within the very young core in Ophiuchus, VLA 1623**




**approximate field for NIRSpec & MIRI integral field spectroscopy**

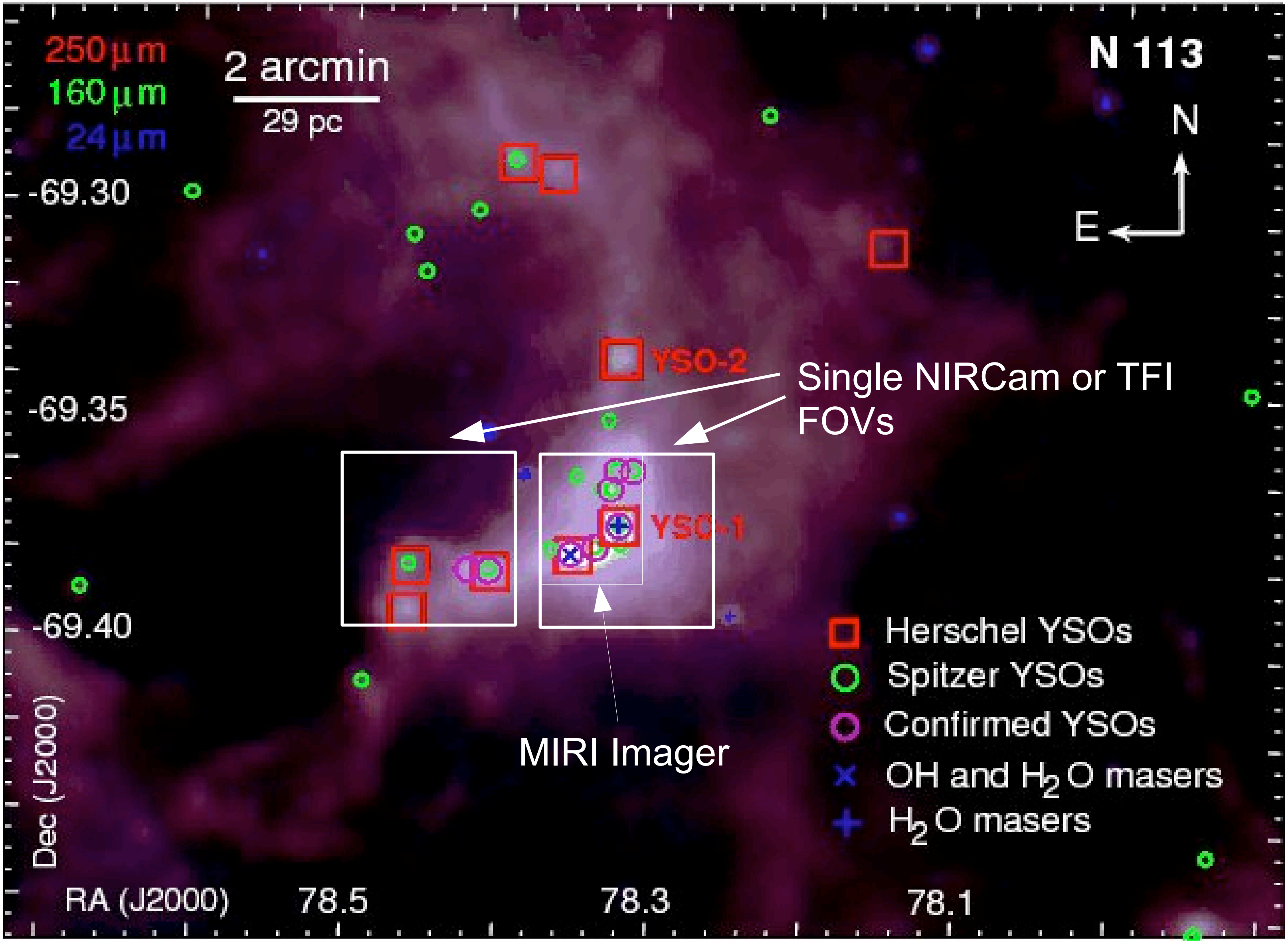
# JWST and Herschel: nearby dark clouds




- Herschel PACS & SPIRE find the most embedded objects
- JWST will observe those protostars in detail:
  - Both NIRCam fields shown
  - TFI line imaging
  - NIRSpec MOS R=3000 spectra
  - MIRI images and IFU spectroscopy

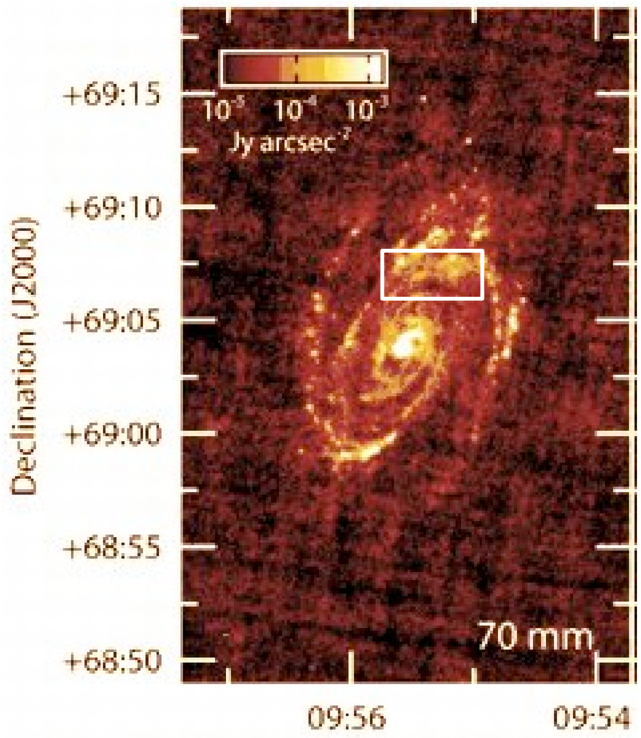
Serpens Herschel SPIRE 350 μm image & protostars (green) Bontemps et al. 2010

# JWST and Herschel: LMC

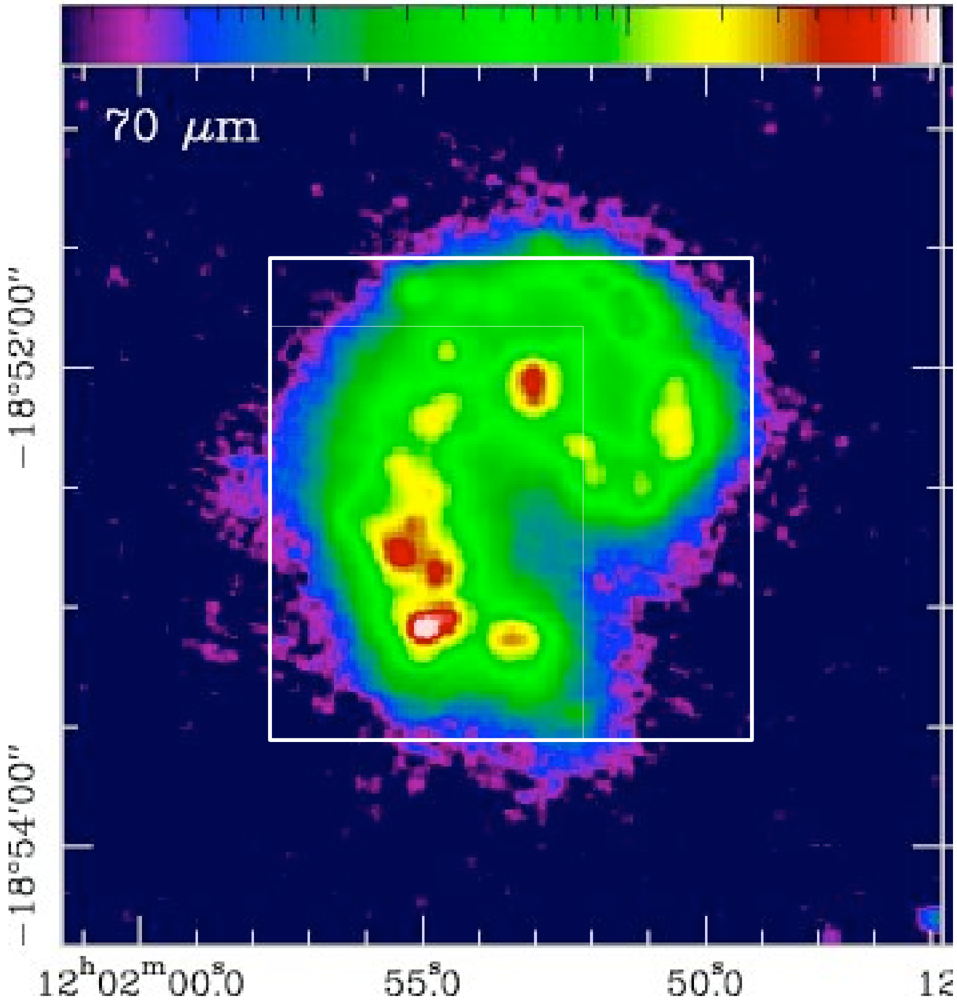



Sewiło et al. (2010): SPIRE, PACS, and Spitzer MIPS. Herschel objects in red boxes

# JWST and Herschel: Nearby Galaxies




Bendo et al. (2010) PACS M81
- Dual NIRCam fields shown
- Can map star formation in a few pointings




Klaas et al. (2010) PACS Antennae
- single NIRCam / TFI field shown
- MIRI field inset

# Other JWST Star Formation/ ISM thoughts

- Probe structure of protostellar envelopes with deep mid-IR imaging
- Chemistry of circumstellar envelopes with mid-IR spectra
- Probe "bottom end" of the initial mass function with multi-object spectroscopy of young clusters
- Images and spectra of jets in high and low mass star formation regions to study cessation of infall and entrainment of outflows
- Multi-epoch images to search for jet & stellar variability and investigate dynamical motions
- Tunable filter imaging of H2, PAH, HI Br, and other line emission