Star Formation at Low Metallicity: Studies with JWST

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Collaborators: Jones, Hirschauer, Nayak, Justtanont, De Marchi and many others

Process of selection and Planning

- Meixner's US MIRI GTO program is focusing on a range of lower metallicity extra-galactic star formation using MIRI MRS and Imager.

- Source selection based on prior Spitzer, Herschel, HST and ALMA work.

- Used ETC tool and the APT tool to scope the size of the program

- Use MIRI in conjunction with NIRCam and NIRSpec

- MIRI European Consortium is focusing on Galactic star formation: low and high mass.

Why extra-galactic star formation at Low Metallicity?

Metallicities similar to that of Universe's peak Star Formation Epoch

0.5 $Z_\odot$ LMC-N79

0.3 $Z_\odot$ NGC 6822

0.2 $Z_\odot$ SMC-NGC 346

0.02 $Z_\odot$ I Zw 18

Known Distance ➔ Known Luminosities

50 kpc LMC-N79

60 kpc SMC-NGC 346

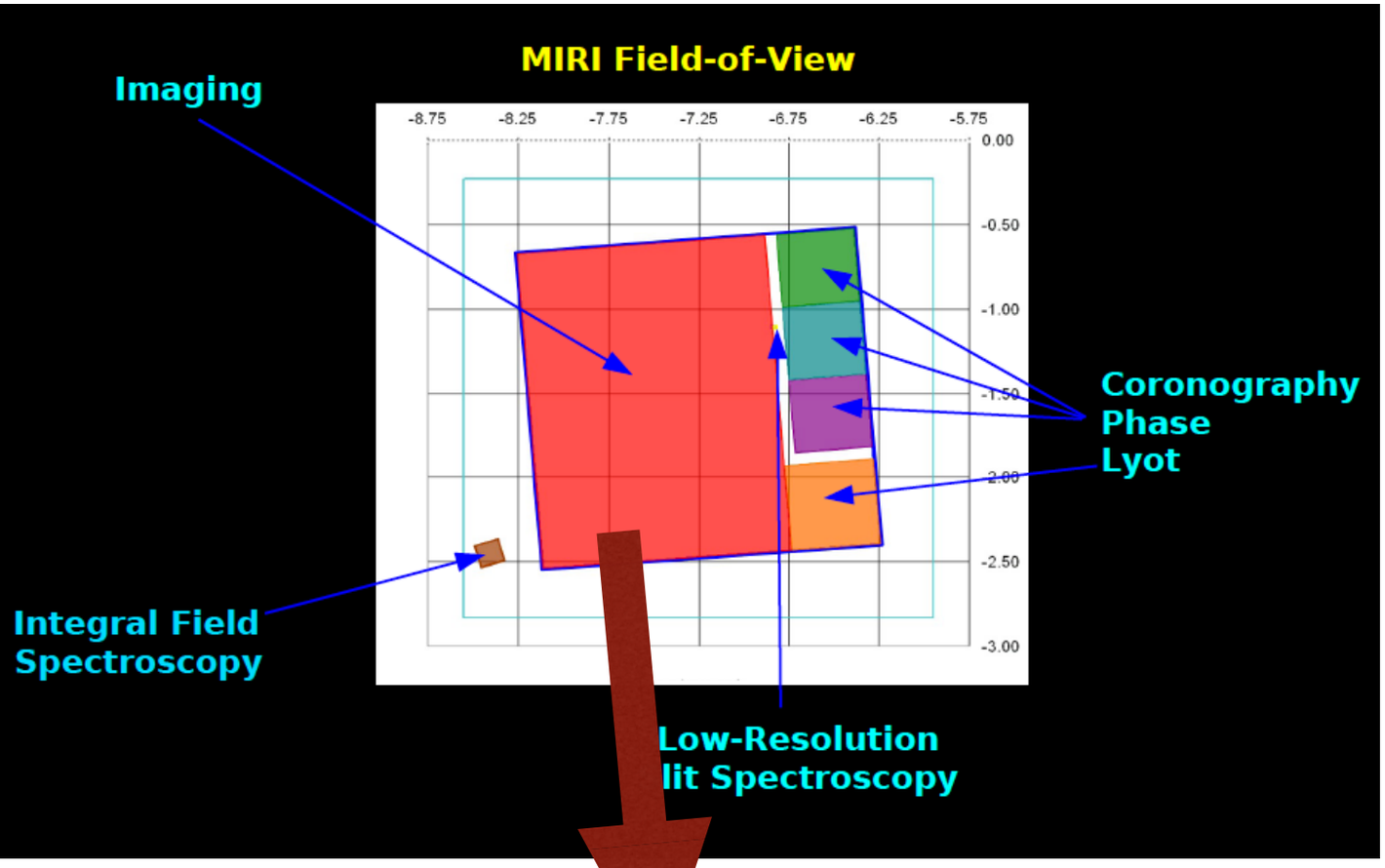
490 kpc NGC 6822

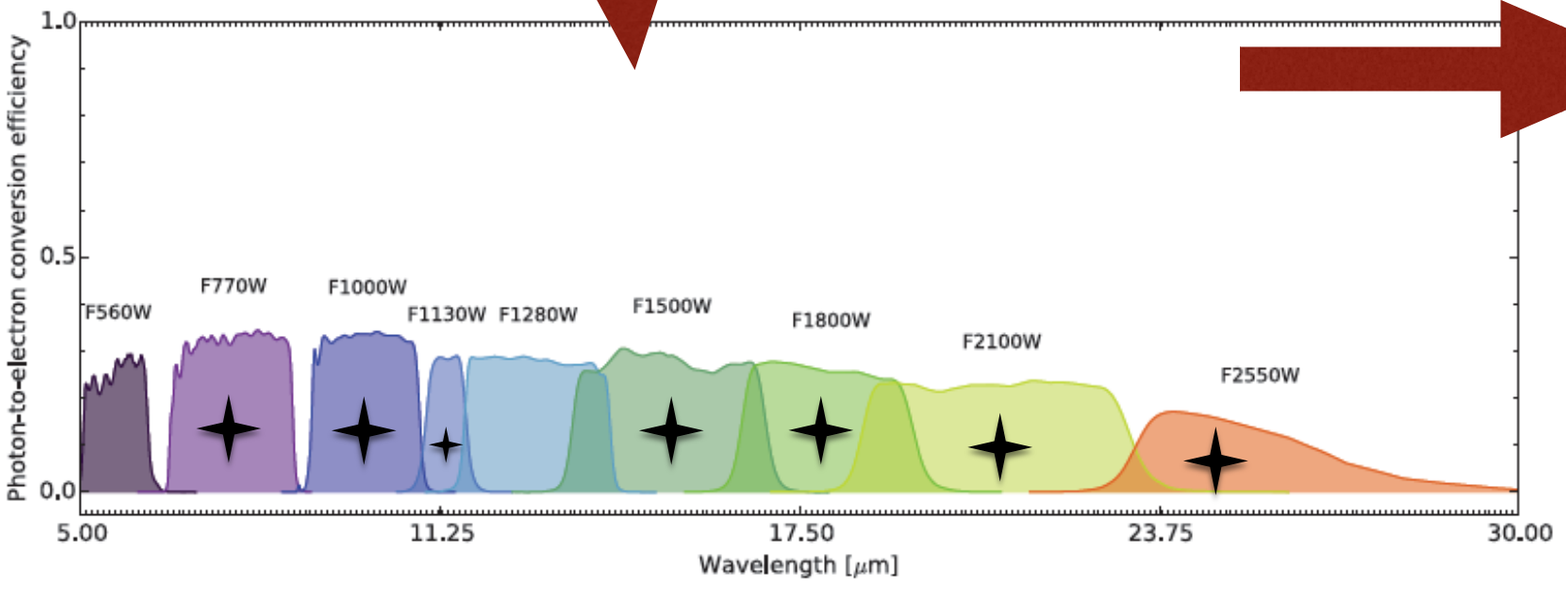
18 Mpc I Zw 18

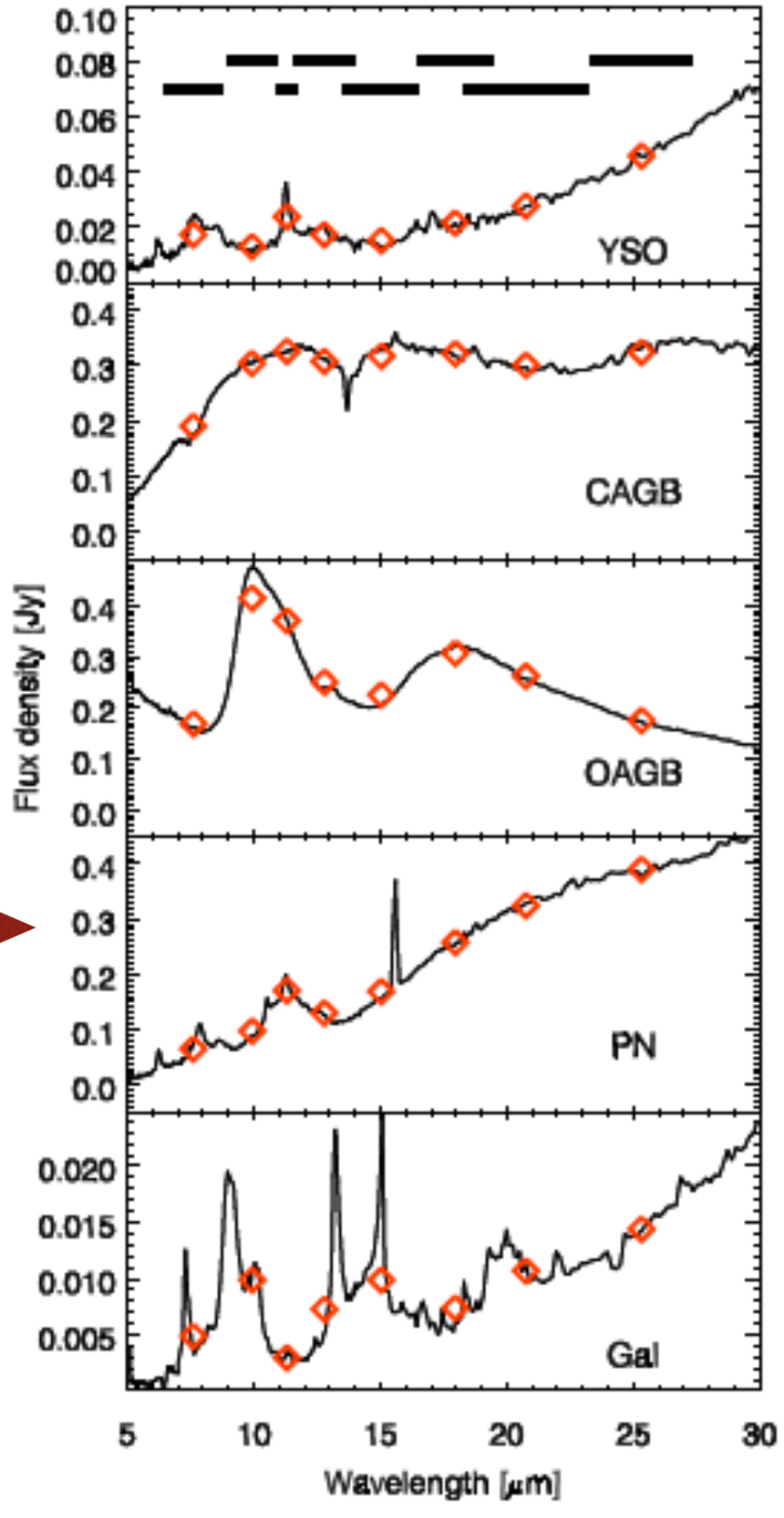
Maximize Statistics: 100s to 1000s sources in one image

JWST Synergy with ALMA & HST enables Milky Way like studies for first time.

MIRI (only instrument observing from 5-28 microns)



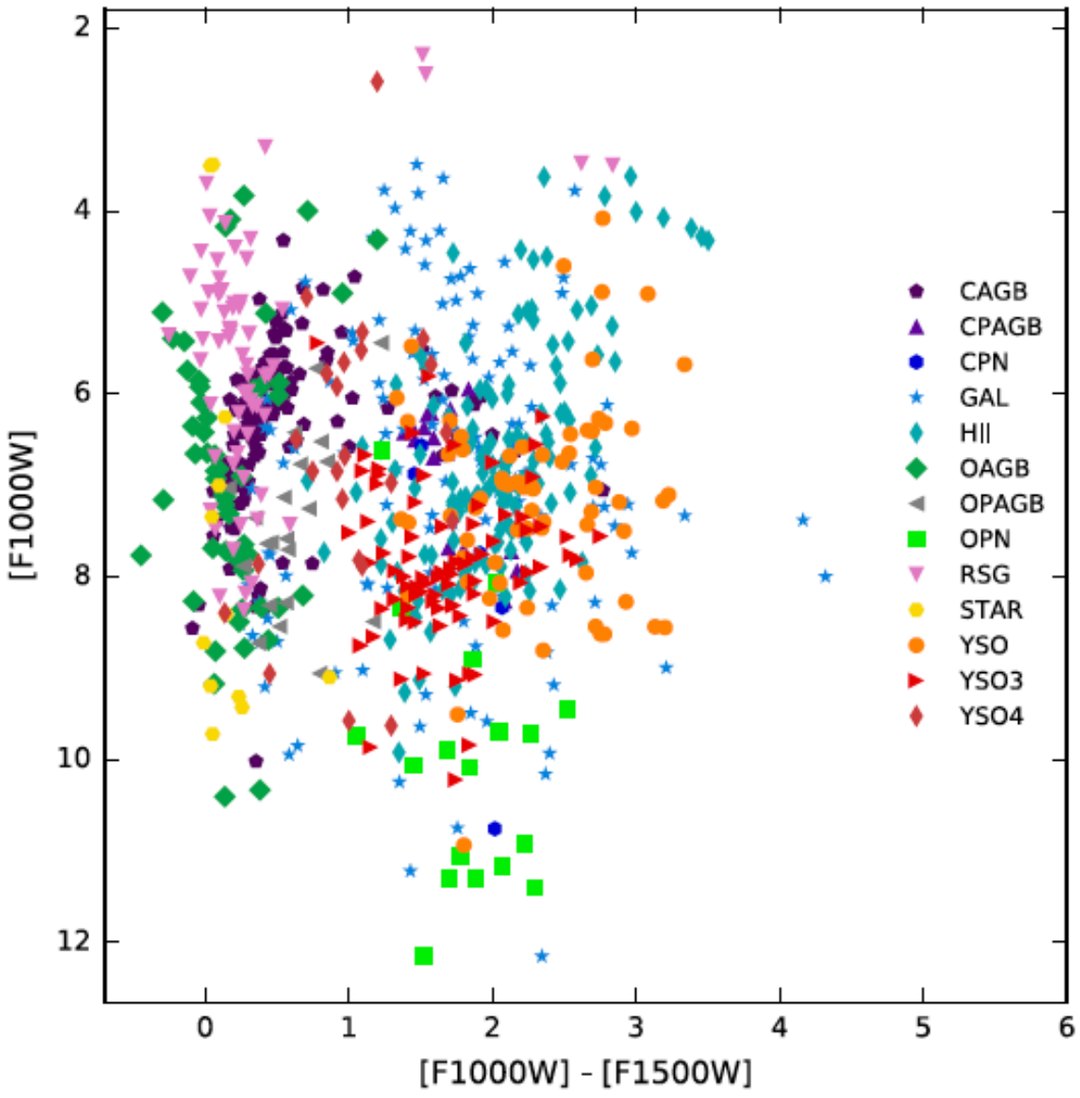


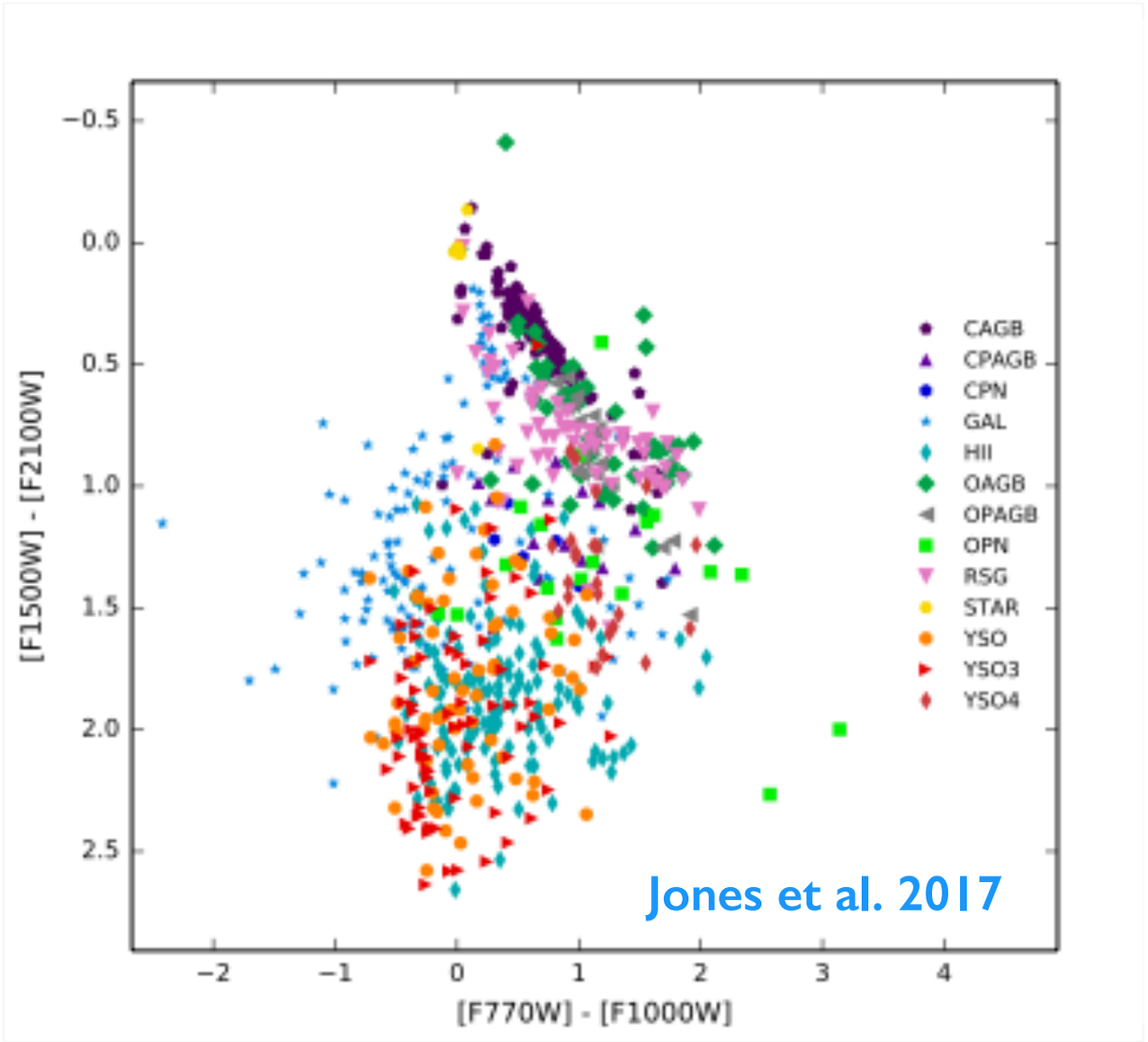


Glasse et al. 2015

Jones et al. 2017

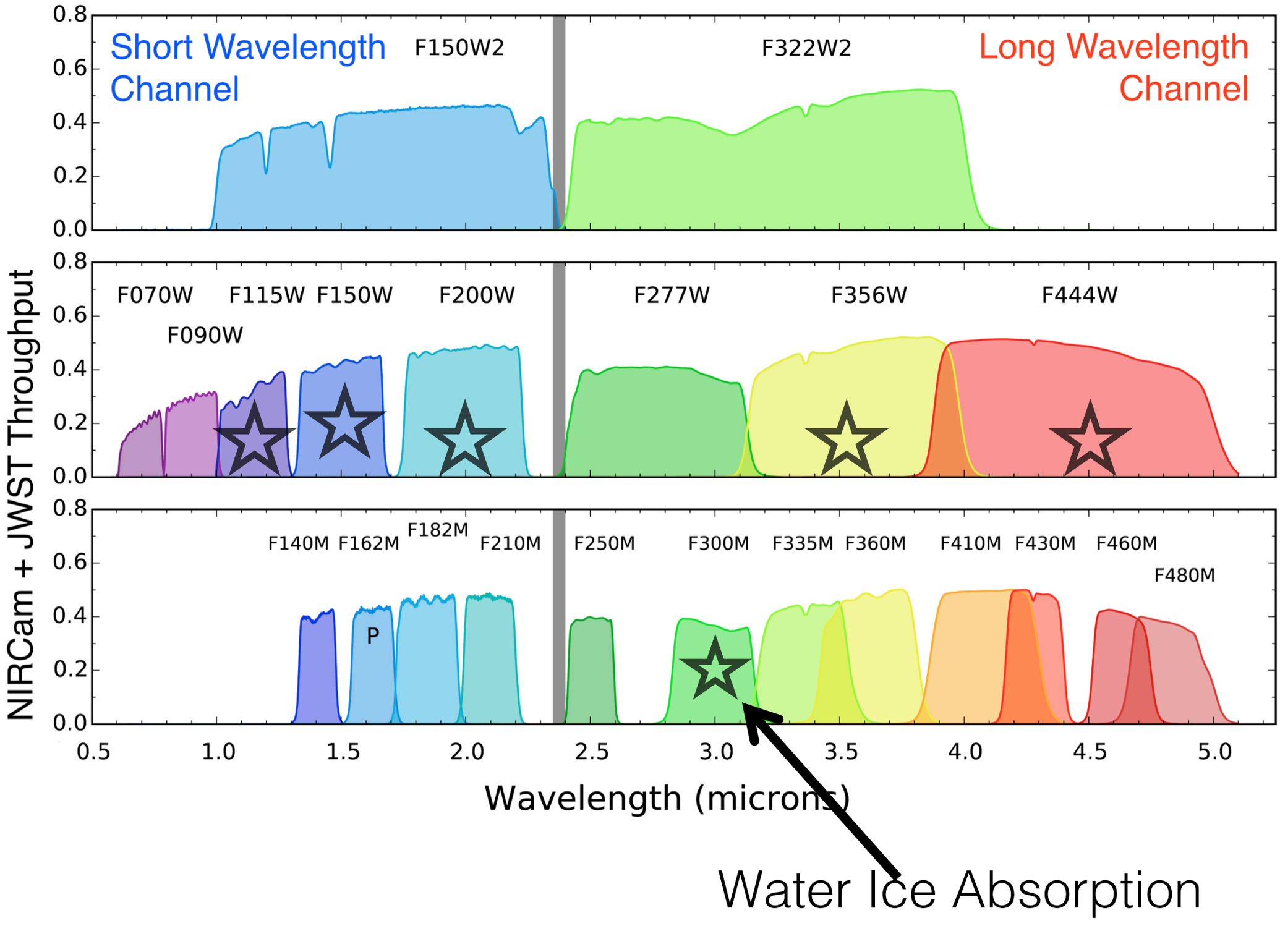
Choice of MIRI filters for stellar populations



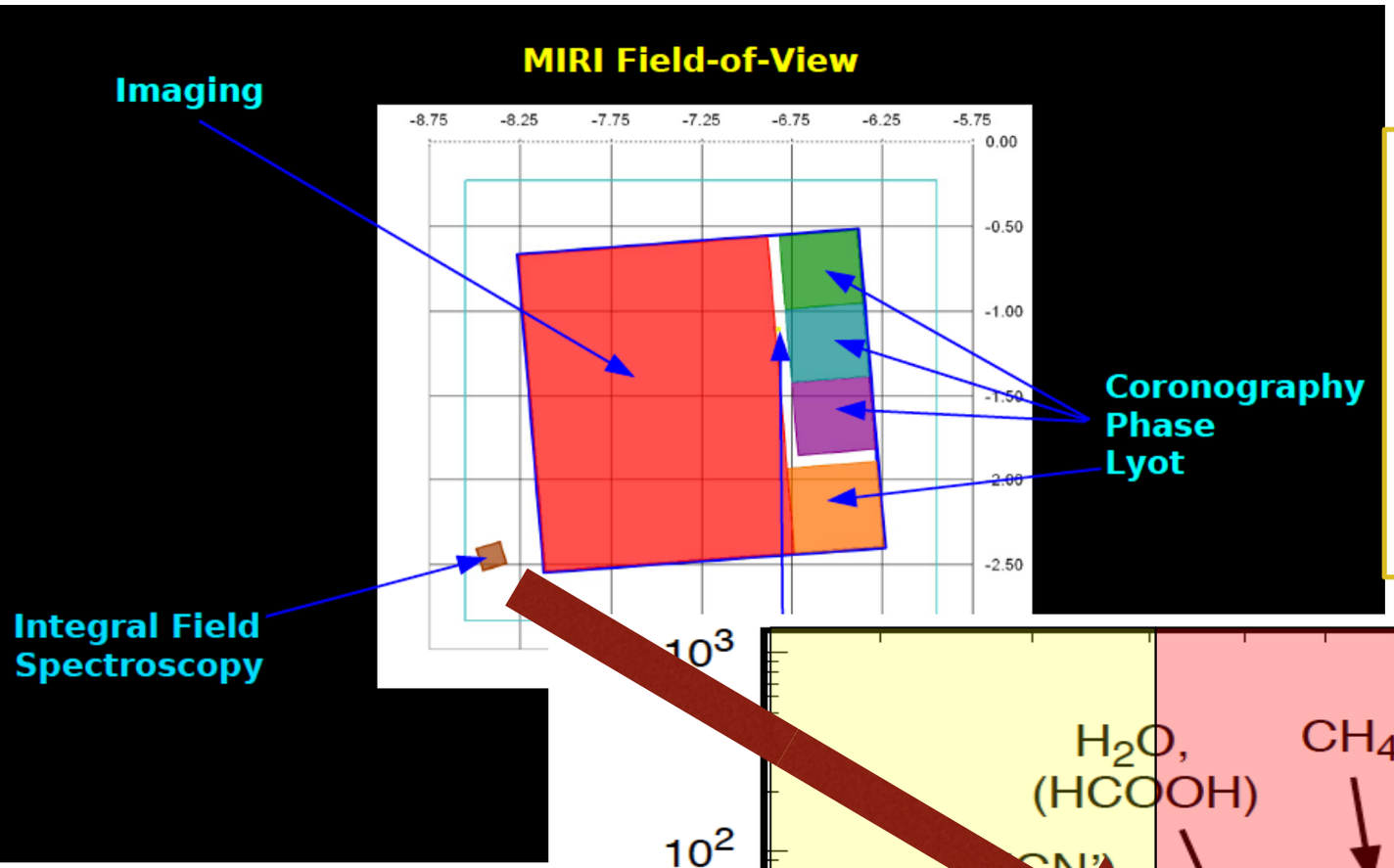


Filter selection depends on the science goals but the [F770W], [F1000W], [F1500W] and [F2100W] filters are a good bet for stellar populations!

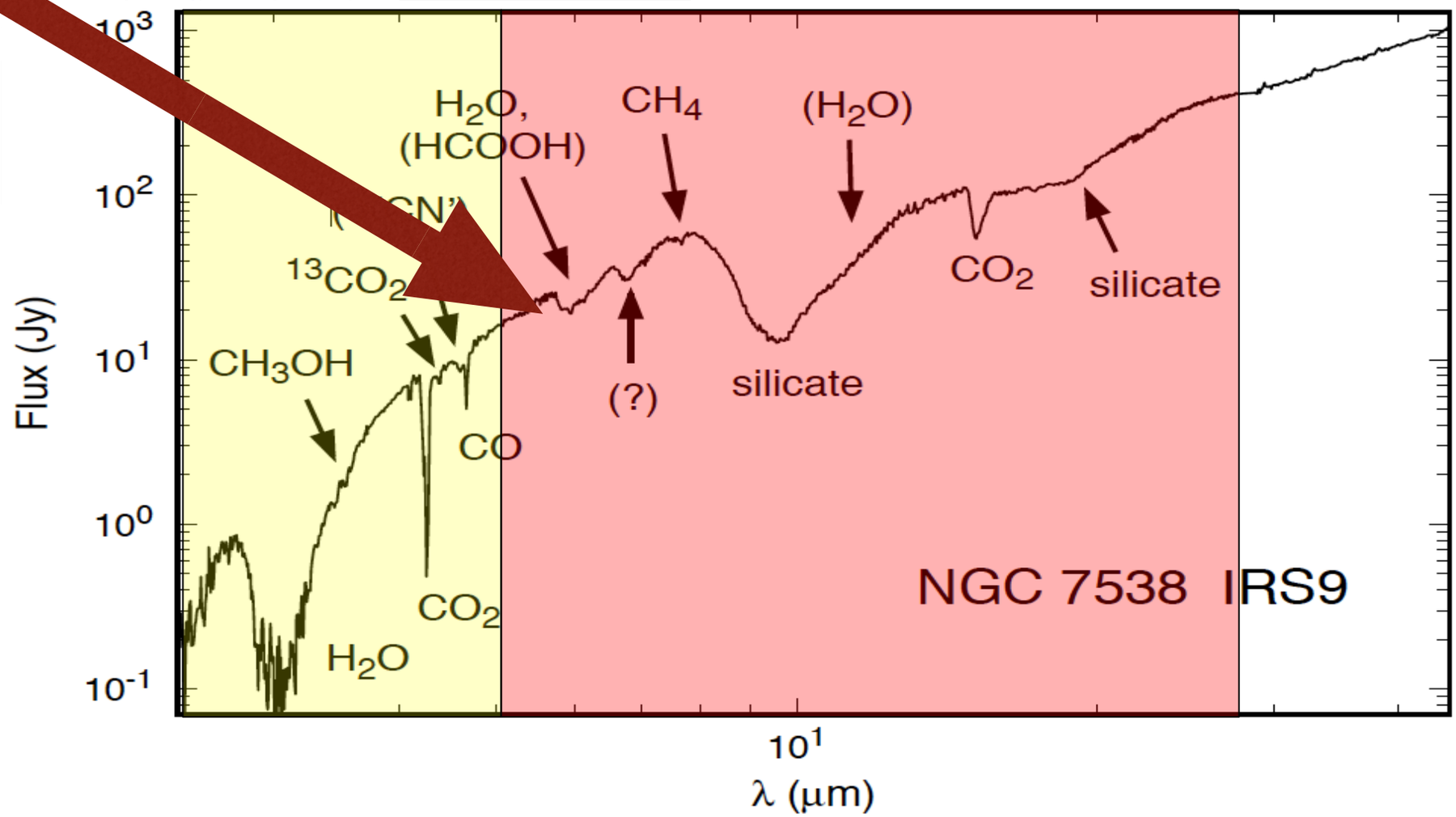
NIRCam filters for stellar populations



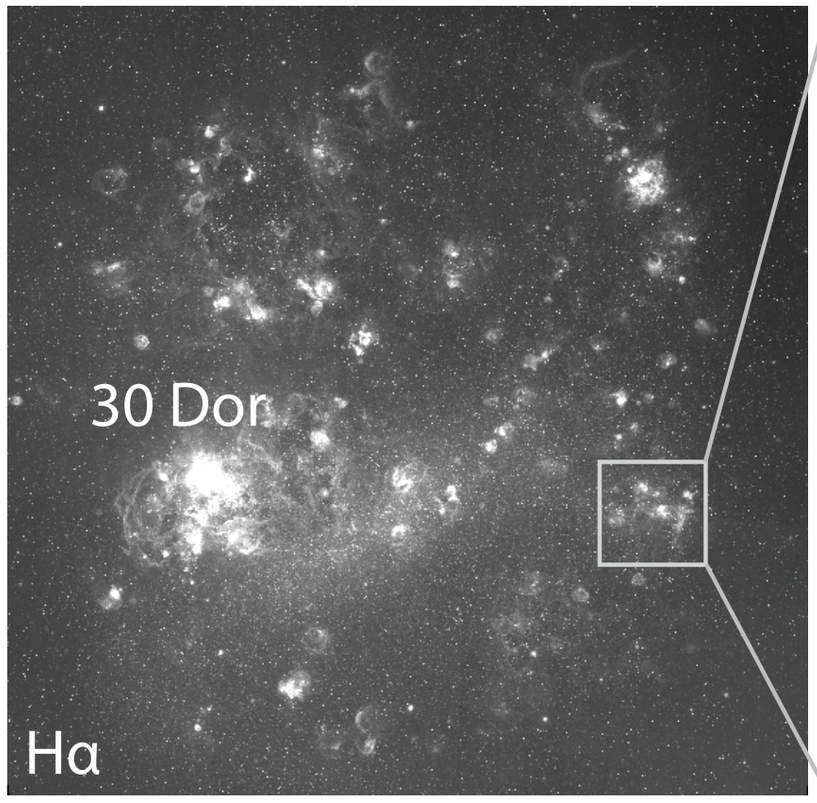
MIRI (only instrument observing from 5-28 microns)

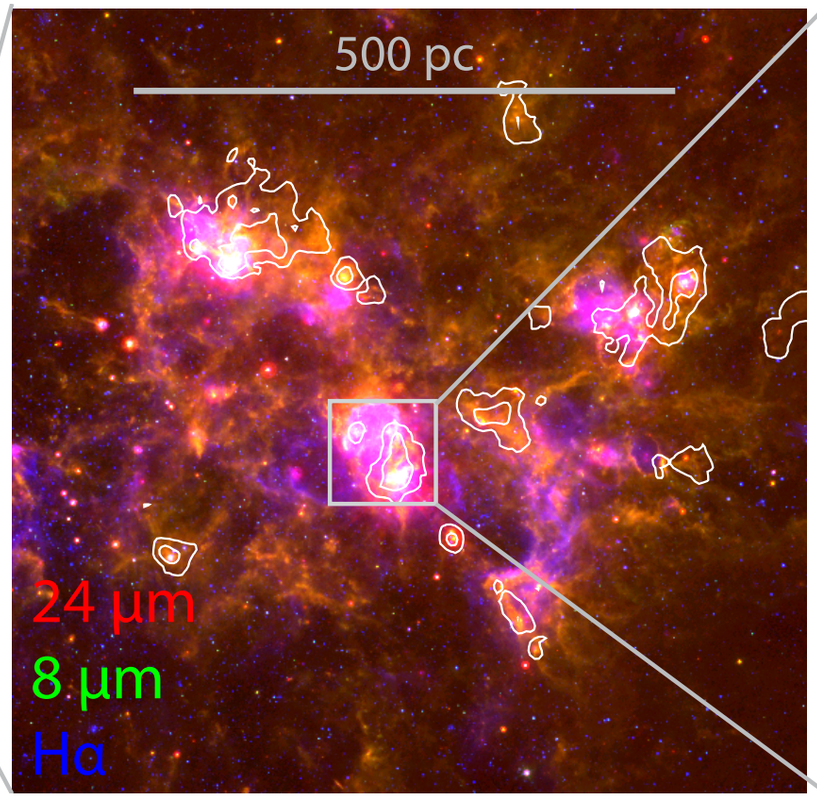


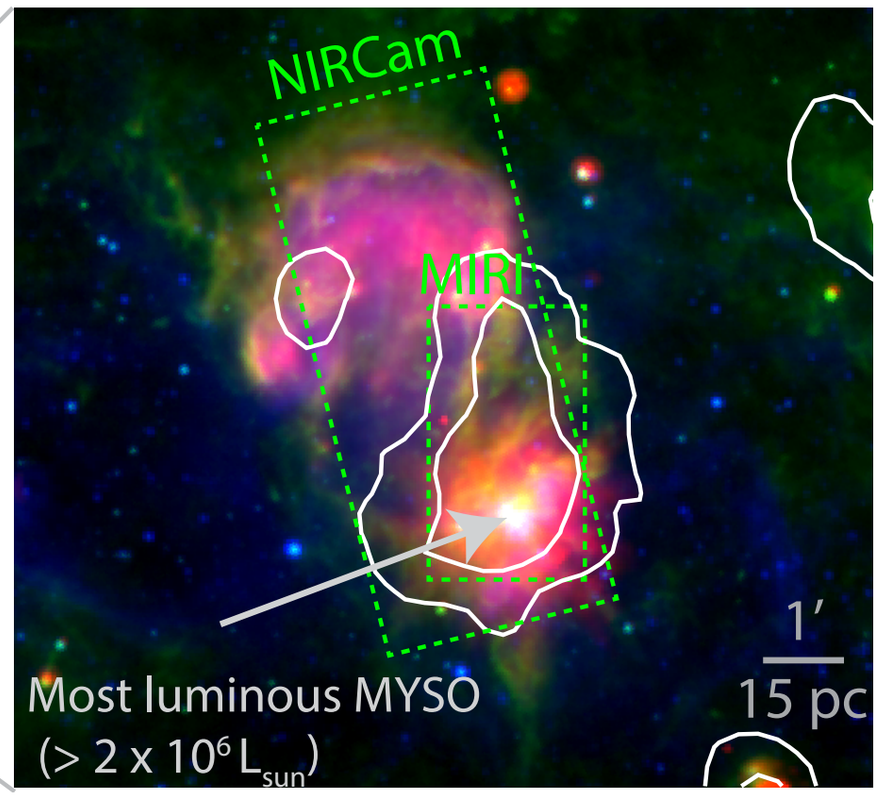
JWST: NIRSpec & MIRI IFU spectroscopy reveals the environmental composition of forming stars



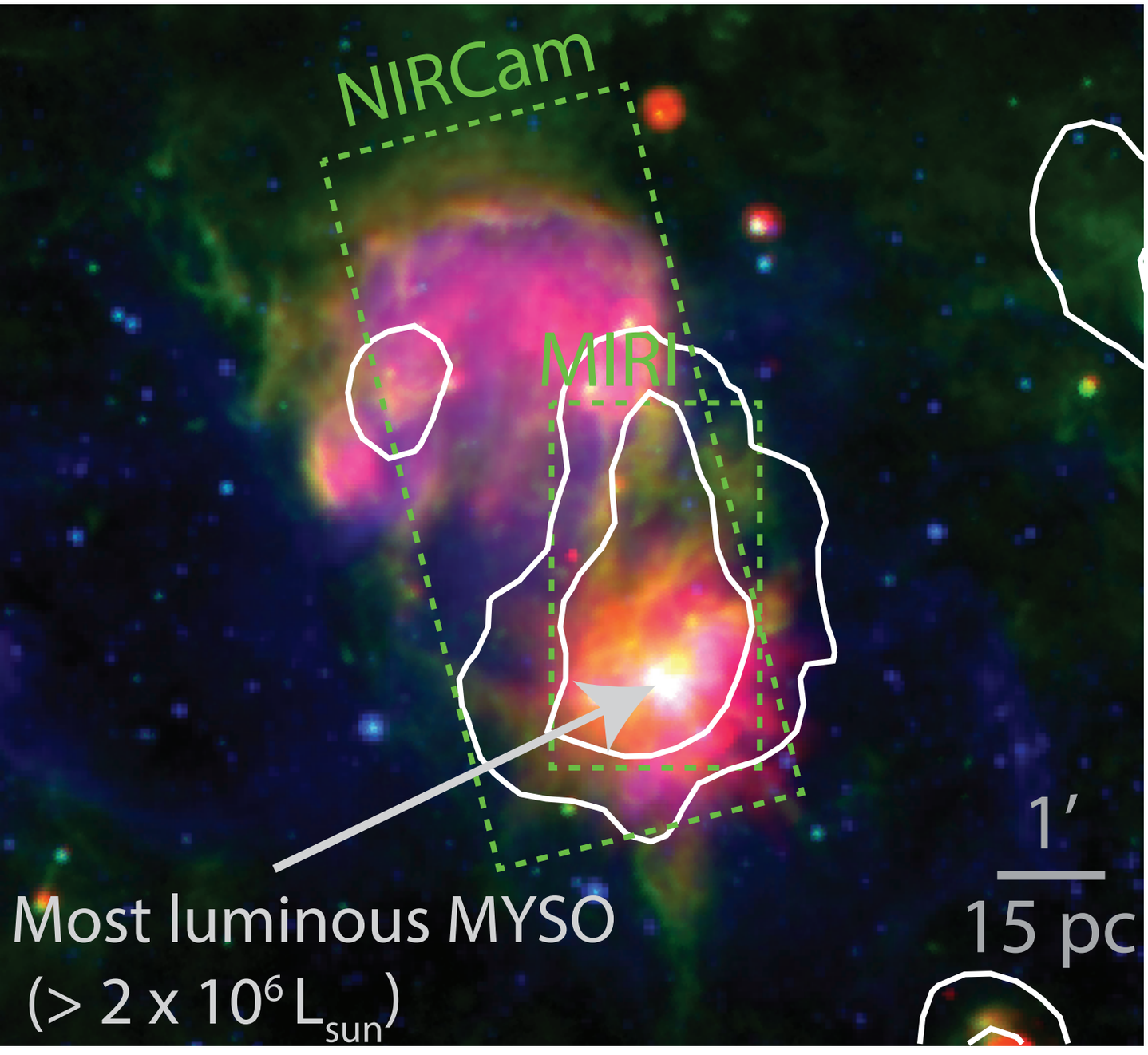
Large Magellanic Cloud: N79
Investigating super-star cluster formation







Ochsendorf et al. 2017



Comprehensive study of Most luminous YSO:
-ALMA CO, HCN, HCO+
-Magellan-FIRE spectra
-Herschel HERITAGE photometry
-Spitzer-SAGE photometry
-SAGE-Spec spectra
-near-IR photometry
-SOFIA spectroscopy

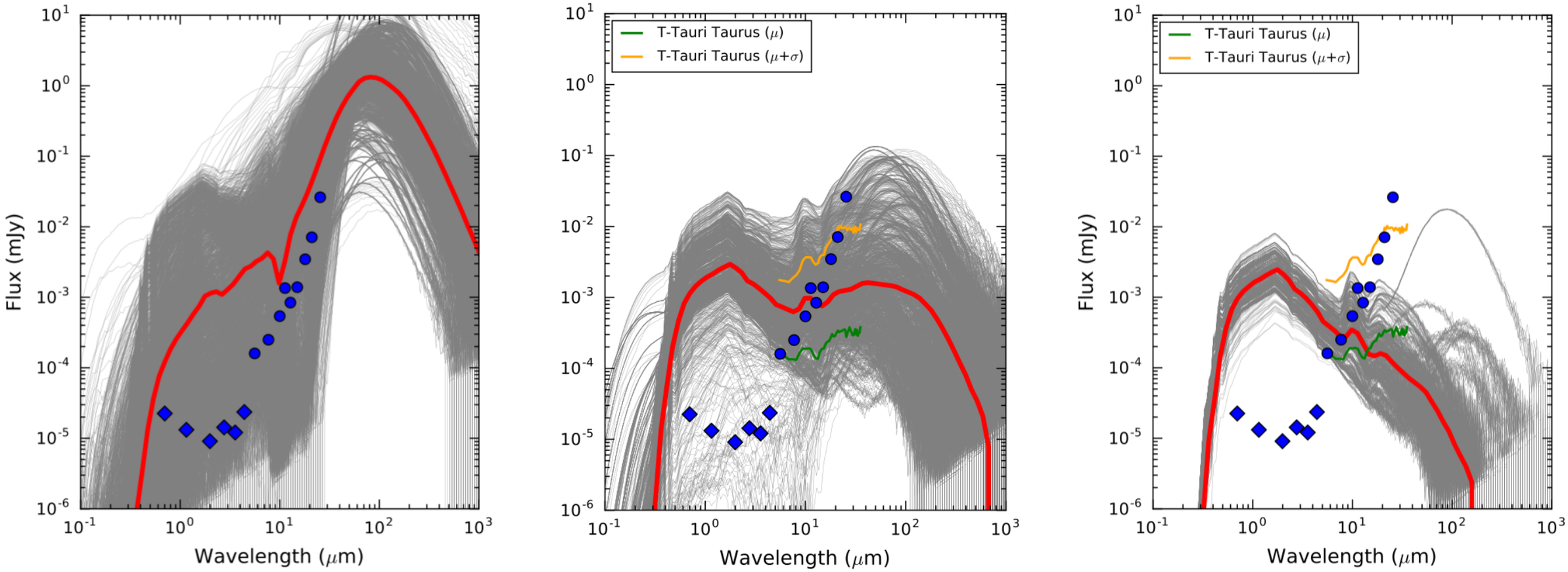
Nayak et al. 2019 & submitted.

Evolution of Young Stellar Object (YSO)

Stage 1

Stage 2

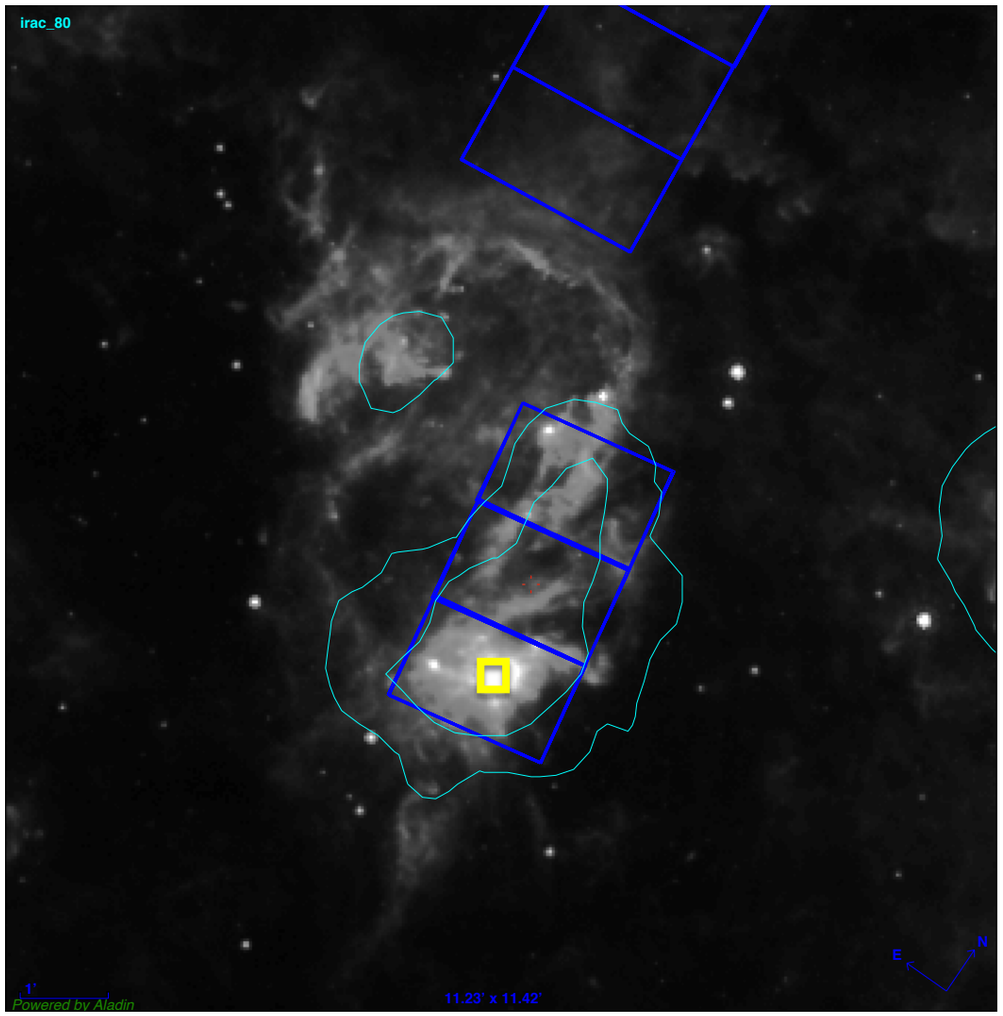
Stage 3



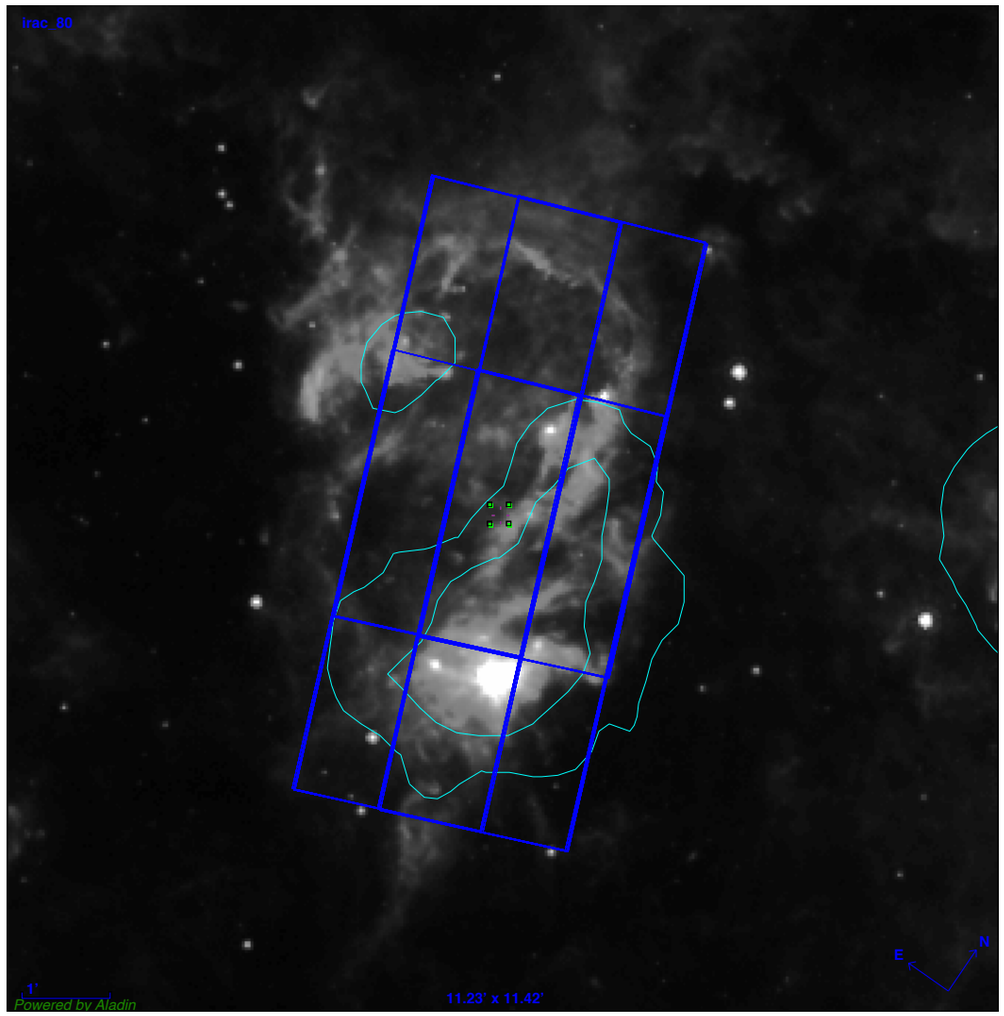
1 $M_{\odot}$ models, red line is median model spectra blue diamonds are JWST 10 σ sensitivity limits in 3 minutes

JWST program: LMC-N79

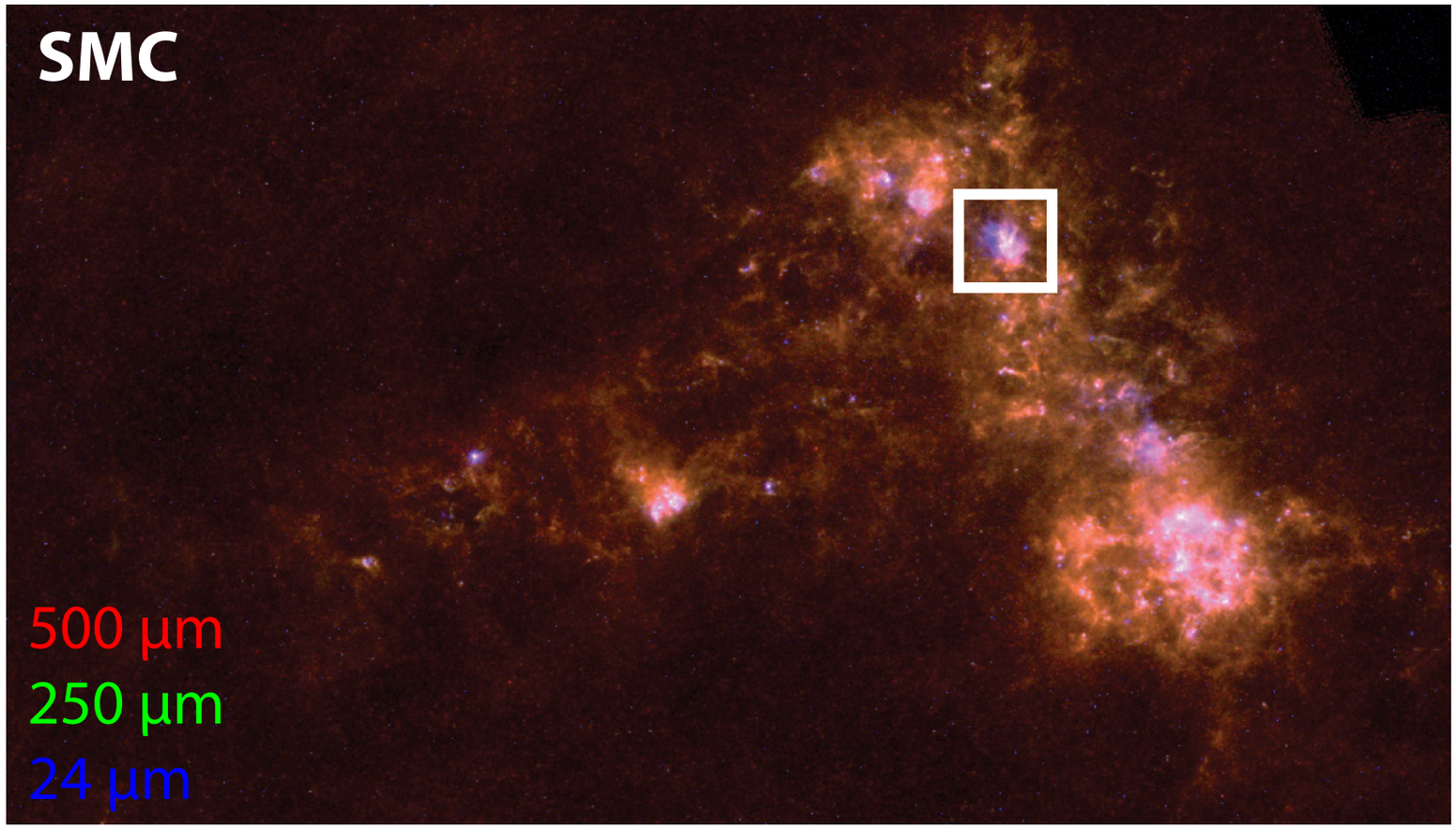
Importance of combined MIRI & NIRCam imaging, ~8 hrs



MIRI imaging 3 fields:
F770W, F1000W, F1130W,
F1500, F1800W, F255W



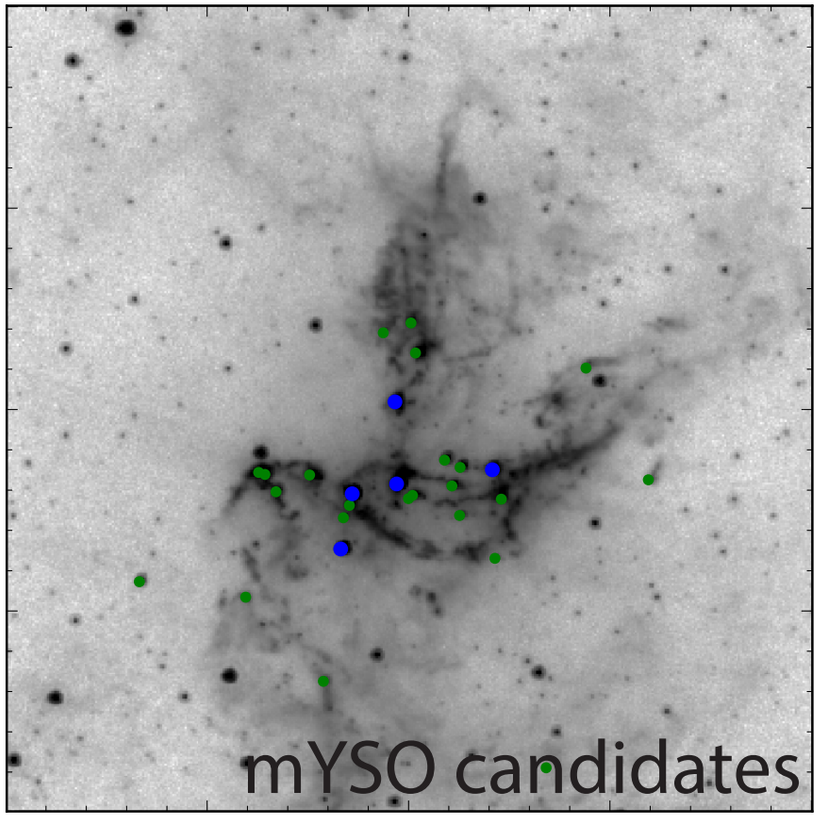
NIRCam imaging 4 fields:
F150W/F356W, F200W/F444W,
F115W/F300M



Small Magellanic Cloud: NGC 346

-Most active massive star formation in SMC

- 19 MYSOs above 8 solar masses
33 spectroscopically confirmed O-stars

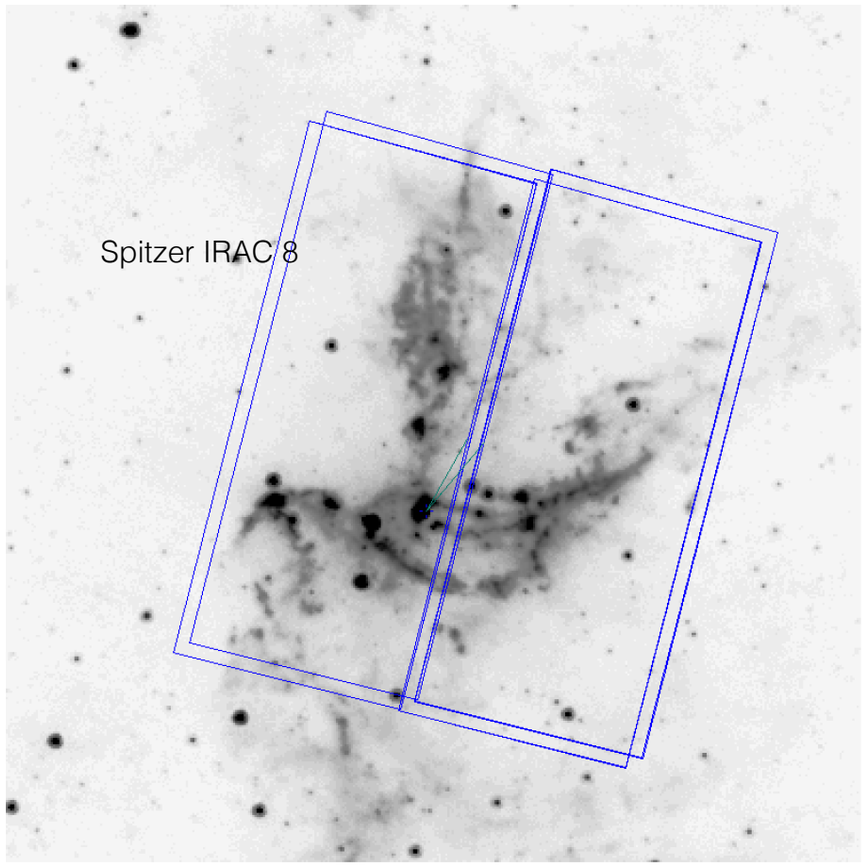


-HST study
-ALMA planned
-Spitzer – IRS

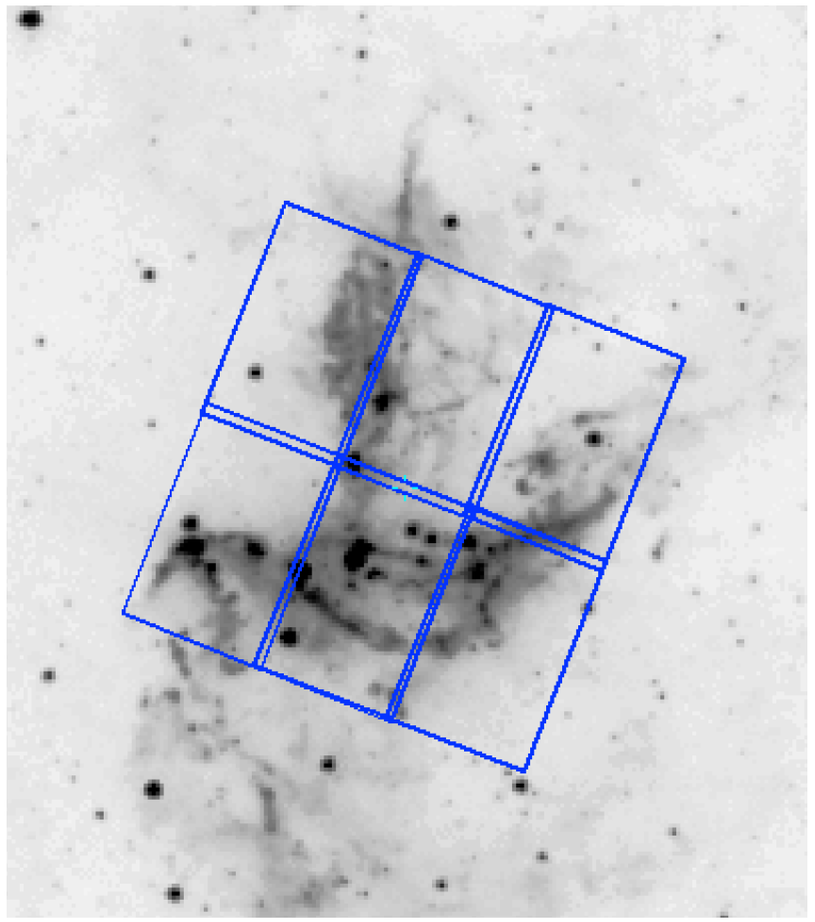
JWST GTO: collaboration with NIRSpec team

Flexible Mosaicks: ~10 hrs

NIRCam

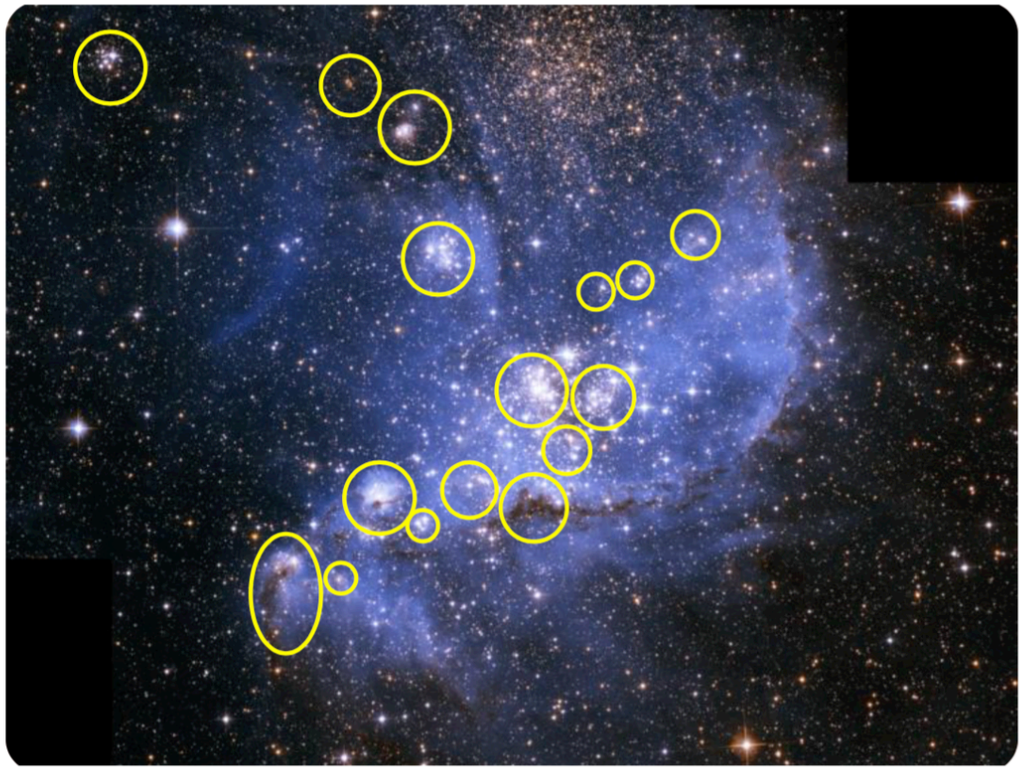


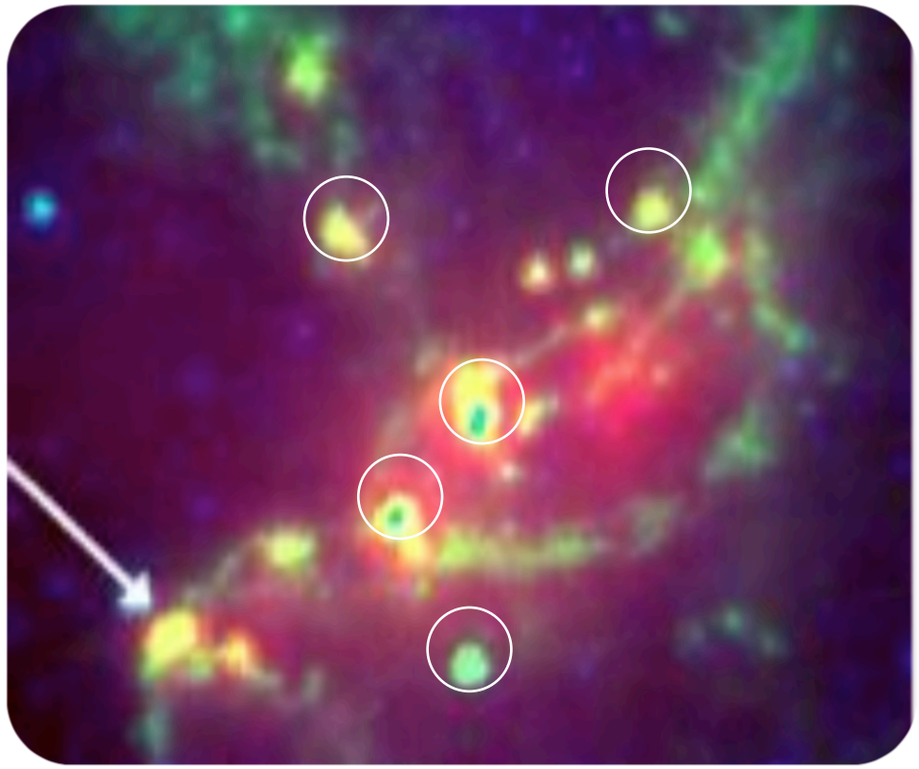
MIRI



SMC-NGC 346 MIRI-MRS of YSOs:
get spatial and spectra information
on an Orion-size region, ~5 hrs

Final selection will be based
on first visit imaging study



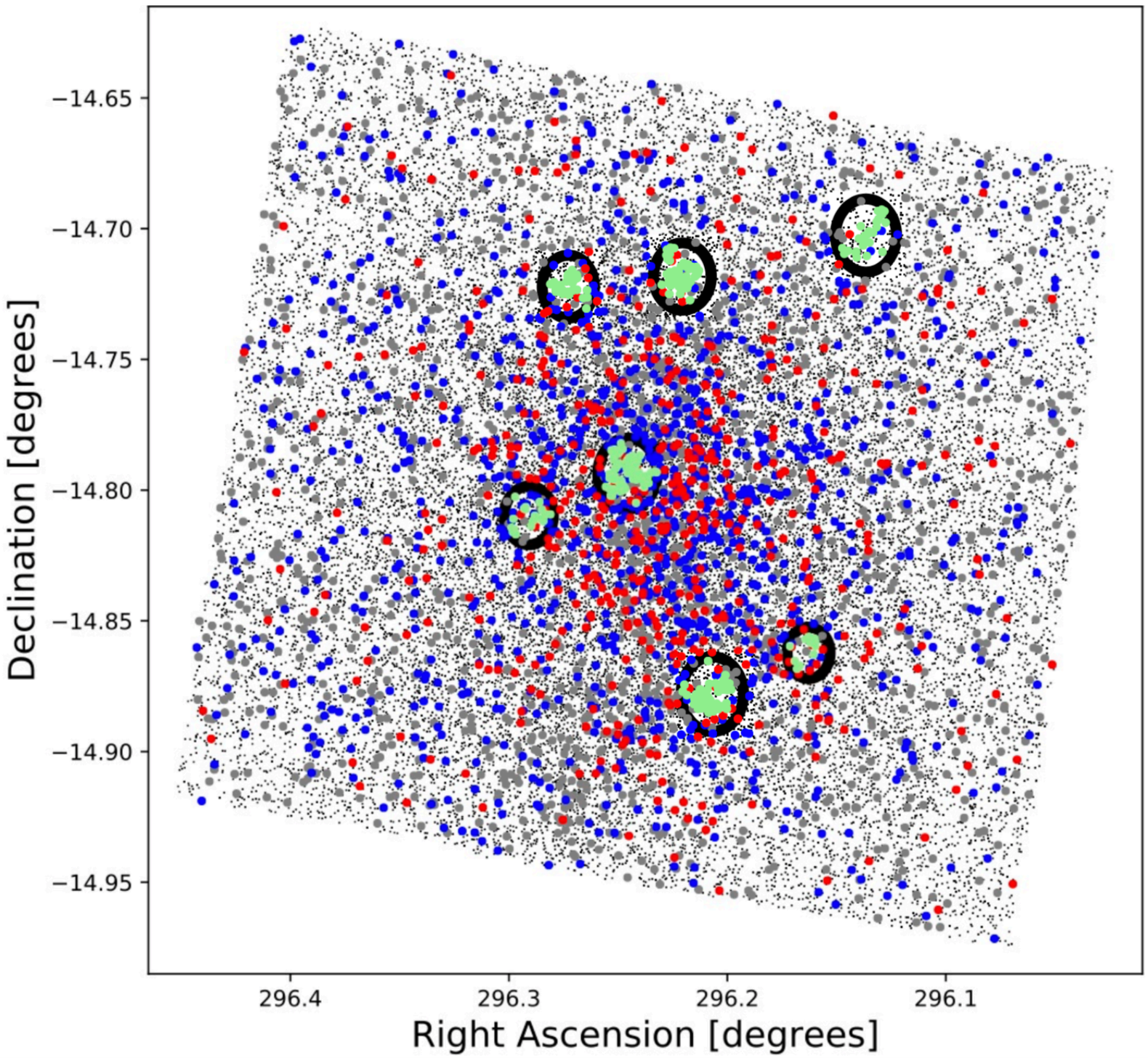


NGC 6822: ~17 hrs

- MIRI imaging: F770W, F1000W, F1500W & F2100W
- NIRCam Imaging: F115W/F356W & F200W/F444W


ALMA observations have targeted the brightest star-formation regions.

NGC 6822- JWST observing strategy
Hirschauer AAS talk, Monday Jan. 6 2-3:30 pm Room 322AB



Hirschauer et al. (*submitted*)

Spatial distribution plot of RSGs (gray), O-rich AGBs (blue), C-rich AGBs (red), and YSOs (green)

NGC 6822- JWST observing strategy
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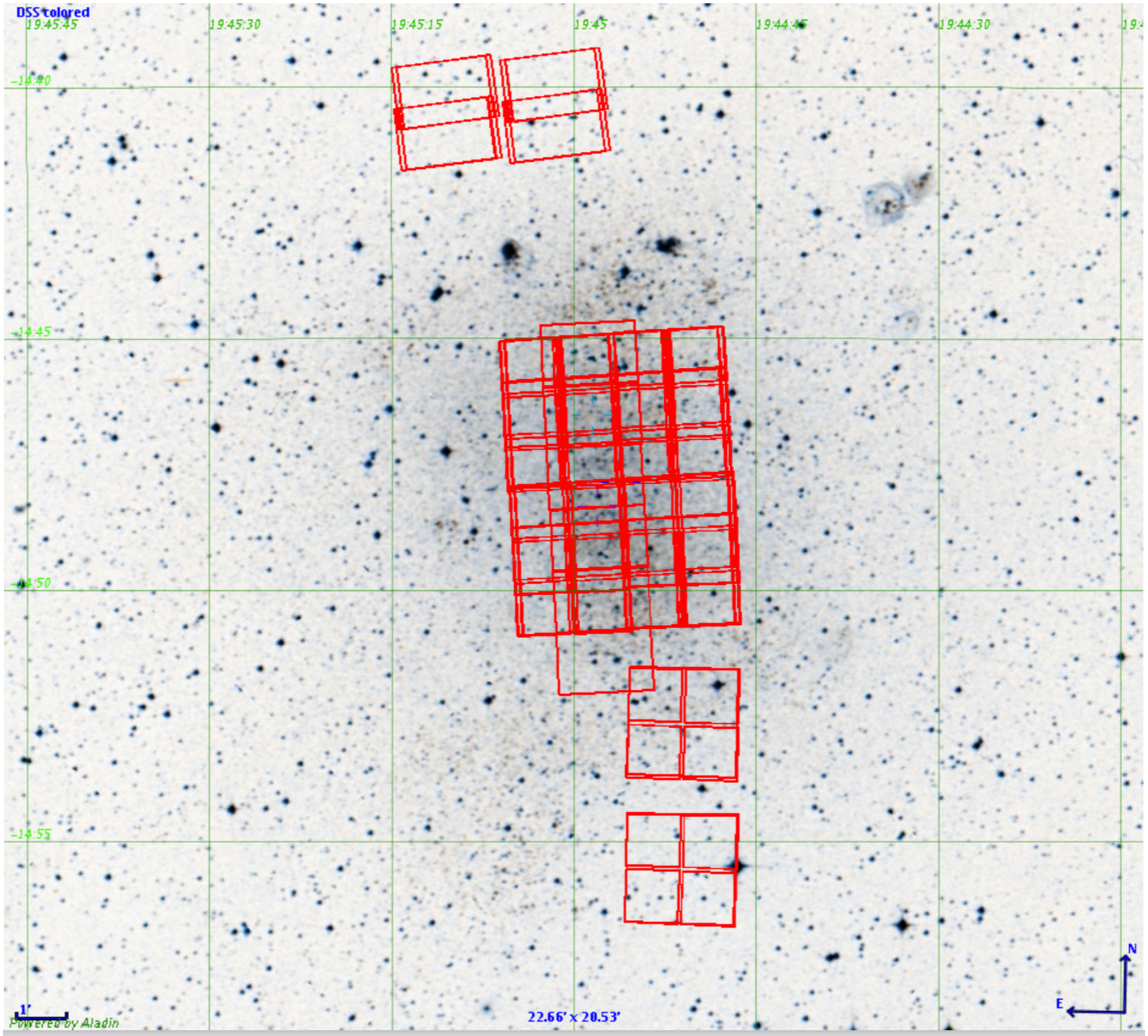


JWST – stellar population imaging

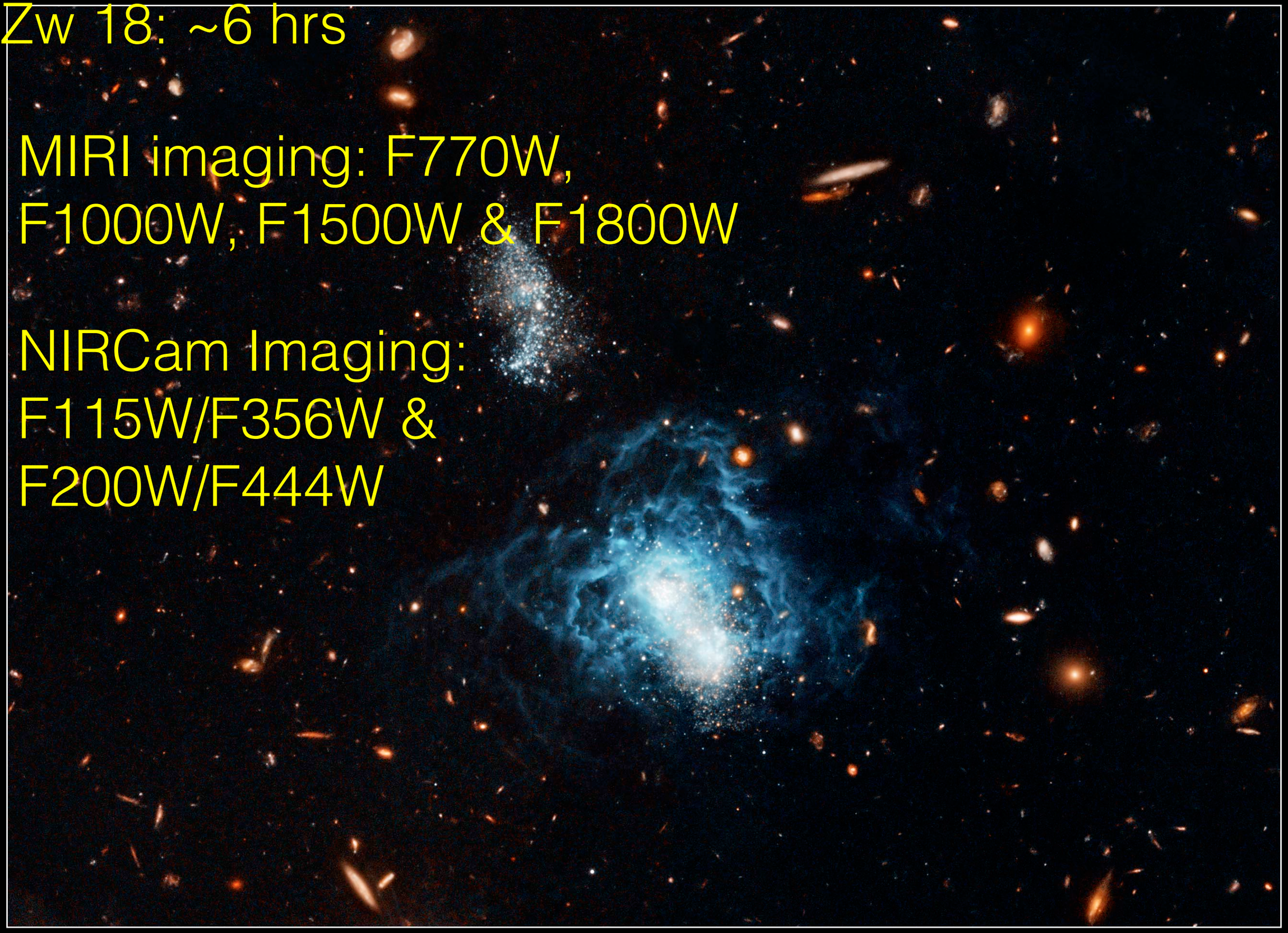
- Exquisite resolution in the infrared (0.6-28 microns)
  — Accurately resolve stars & background galaxies.

- Sensitivity — detect faint emission from massive YSOs and high & intermediate mass evolved stars.

- Plus parallel observations with MIRI/NIRcam
  - Background field to correct for galaxy & foreground contamination.

I Zw 18: ~6 hrs

- MIRI imaging: F770W, F1000W, F1500W & F1800W
- NIRCam Imaging: F115W/F356W & F200W/F444W



Galaxy I Zwicky 18

Hubble Space Telescope • ACS/WFC

I Zw 18:

Galaxy I Zwicky 18

Hubble Space Telescope • ACS/WFC

Take Aways

- JWST has orders of magnitude more sensitivity than prior facilities in the Mid-IR.

- Think of new science or at least new objects (old, overly studied objects may saturate)

- Use ETC & APT to plan and optimize your program

- Parallel NIRCam and MIRI imaging is wise technically and scientifically

- JWST spectroscopy is powerful… use it.

- Use prior work, Spitzer, HST, Herschel & ALMA, to select your targets - nice to have ancillary data