Star Formation at lower metallicity
A JWST view

DR OLIVIA JONES - STFC WEBB FELLOW
UK ASTRONOMY TECHNOLOGY CENTER
PRIMA - STARS AND STELLAR EVOLUTION WG CO-LEAD
@ANYWAYTHEWIND.BSKY.SOCIAL

Things should be different at low metallicity.

JWST enables detailed star-formation studies in other galaxies.

Lets see what we can observe in galaxies with 1/2 to 1/50 solar metallicity!


(Jones+2023)
(Zeidler+2024)
(Habel+2024)
(Bortolini+2024, Hirschauer+2024)
(Lenkić+2024, Nally+2024)
(Nayak+2024a,2024b)

Why extra-galactic star formation at Low Metallicity?

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

0.5 $Z_\odot$	0.2 $Z_\odot$	0.2 $Z_\odot$	0.03 $Z_\odot$
LMC-N79	NGC 6822	SMC-NGC 346	I Zw 18

Known Distance ➔ Known Luminosities

50 kpc	60 kpc	490 kpc	18 Mpc
LMC-N79	SMC-NGC 346	NGC 6822	I Zw 18

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

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

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	$0.2\ Z_\odot$ NGC 6822	$0.2\ Z_\odot$ SMC-NGC 346	$0.03\ Z_\odot$ I Zw 18

Known Distance ➔ Known Luminosities

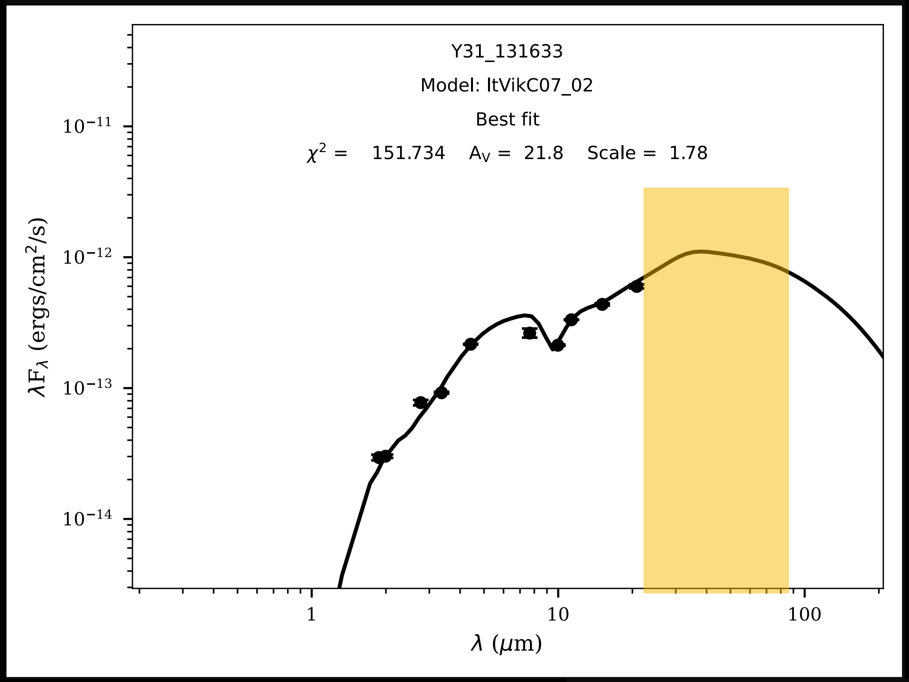
50 kpc LMC-N79	60 kpc SMC-NGC 346	490 kpc NGC 6822	18 Mpc I Zw 18

Maximize Statistics: 100s to 1000s of sources in

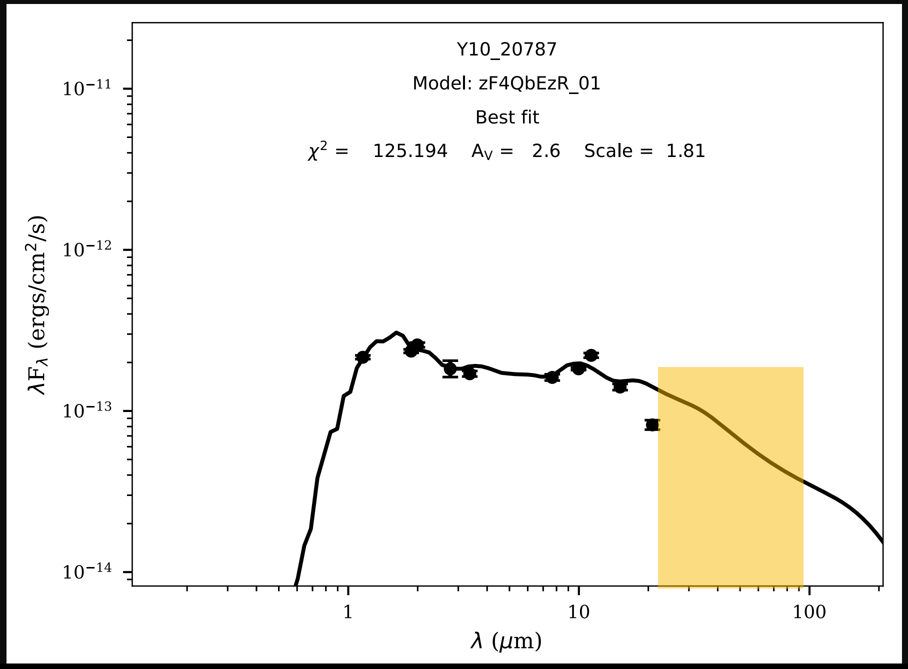
JWST Synergy with ALMA & HST enables udies
for first time.

THE DUSTIEST STELLAR OBJECTS IN THE MAGELLANIC CLOUDS

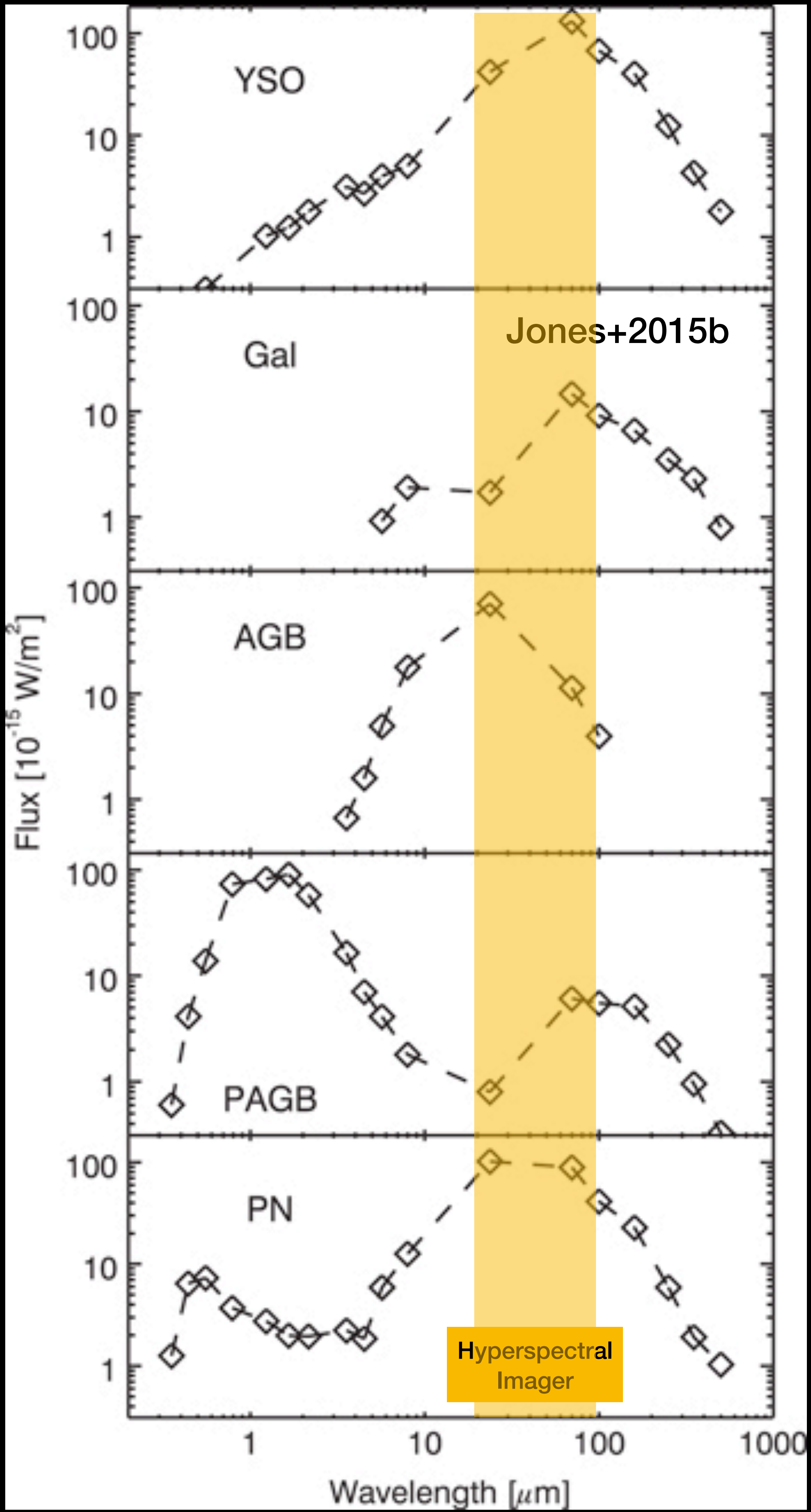
NGC 346: YSOs
Stage I embedded



Stage II disk prominent



Habel et al. 2024



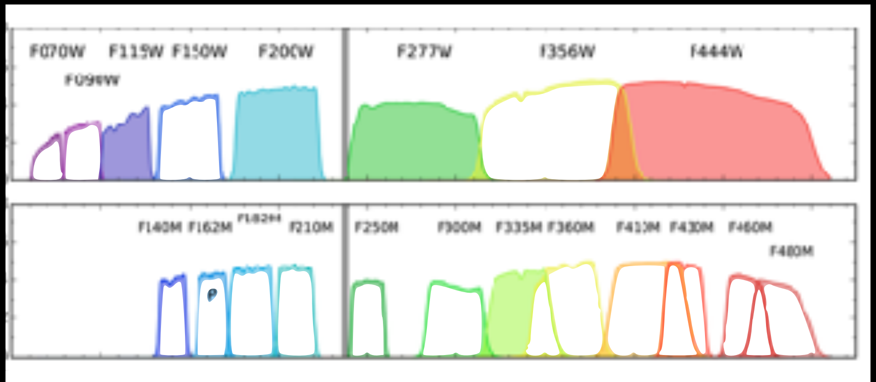
NGC 346 (epoch 1) was observed 2022-07-16

30h program - NIRCam, MIRI Imager, MIRI MRS & NIRSpec MSA spectroscopy.

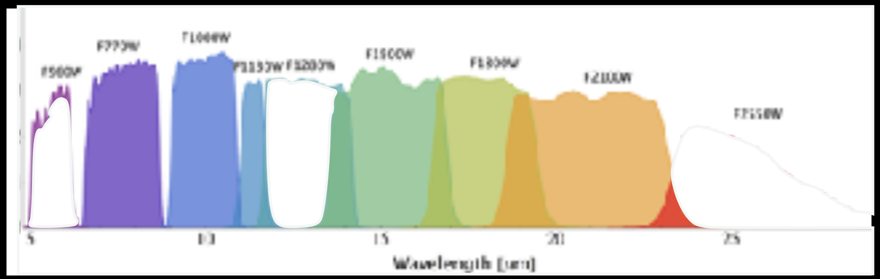
Epoch 1

- NIRCam

w. F187N - Pa alpha

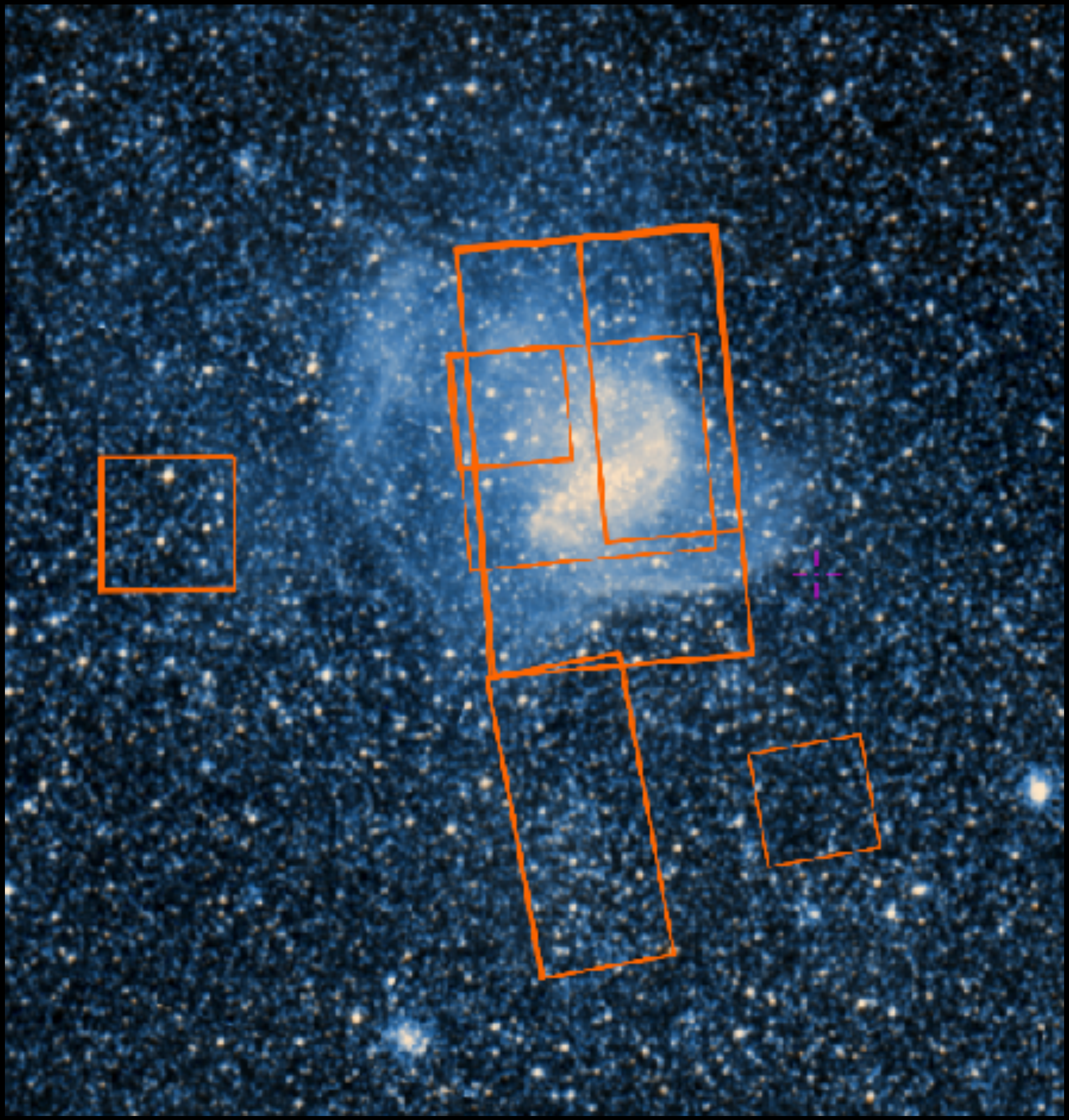


- MIRI



- NIRSpec MSA spectroscopy:

  40 sources - R~3000 -1.66–3.05 microns



Epoch 2

- NIRSpec MSA spectroscopy.
- MIRI MRS - 4 embedded YSOs
  - This is equivalent to spatial and spectral info for FOUR Orion-sized regions in ~5 hours.

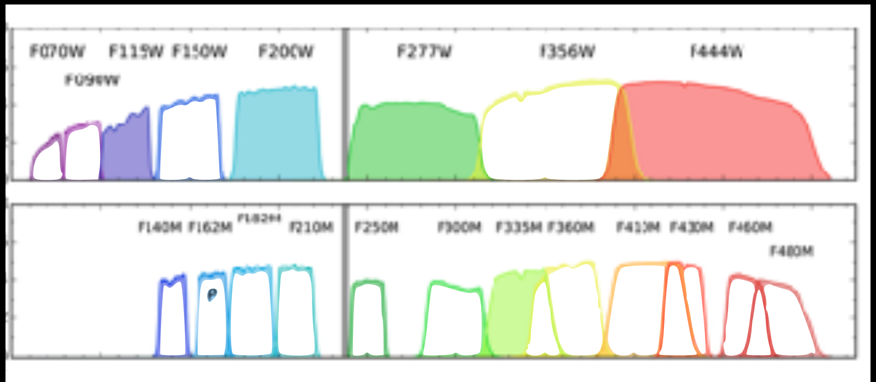
NGC 346 (epoch 1) was observed 2022-07-16

30h program - NIRCam, MIRI Imager, MIRI MRS & NIRSpec MSA spectroscopy.

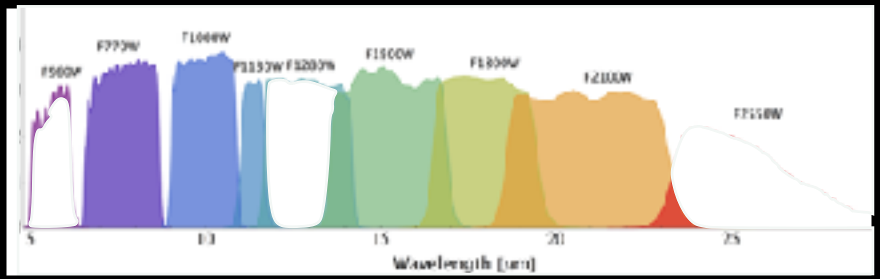
Epoch 1

- NIRCam

w. F187N - Pa alpha



- MIRI

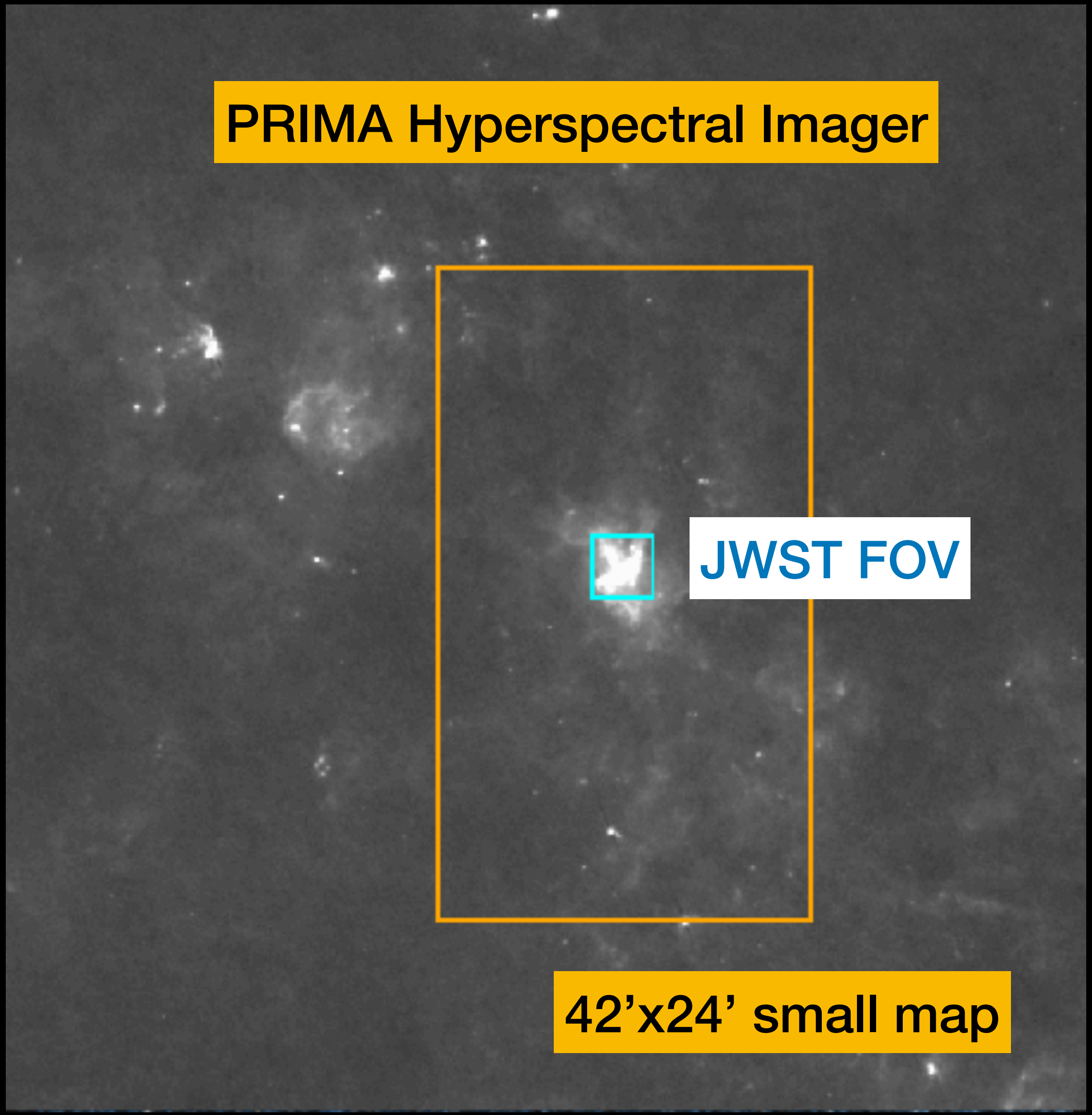


- NIRSpec MSA spectroscopy:

  40 sources - R~3000 -1.66–3.05 microns

Epoch 2

- NIRSpec MSA spectroscopy.
- MIRI MRS - 4 embedded YSOs
  - This is equivalent to spatial and spectral info for FOUR Orion-sized regions in ~5 hours.



Herschel/PACS 100 micron

JAMES WEBB SPACE TELESCOPE

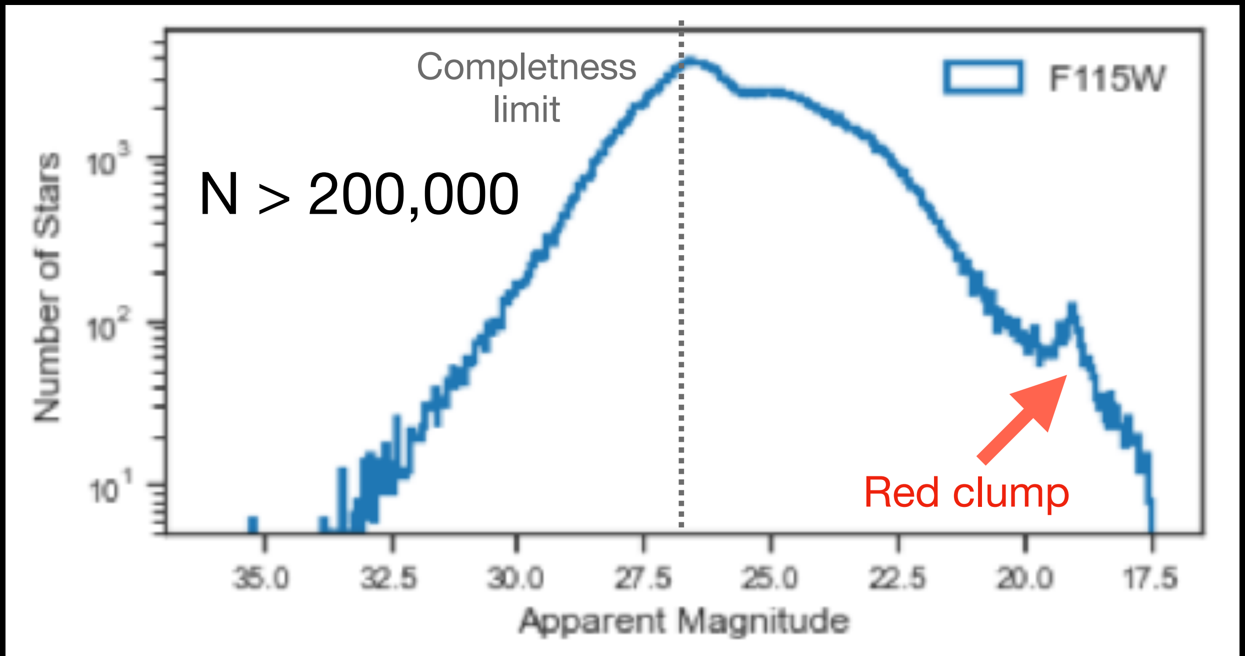
SMALL MAGELLANIC CLOUD | NGC 346

NIRCam Filters | F200W F277W F335M F444W

JAMES WEBB SPACE TELESCOPE

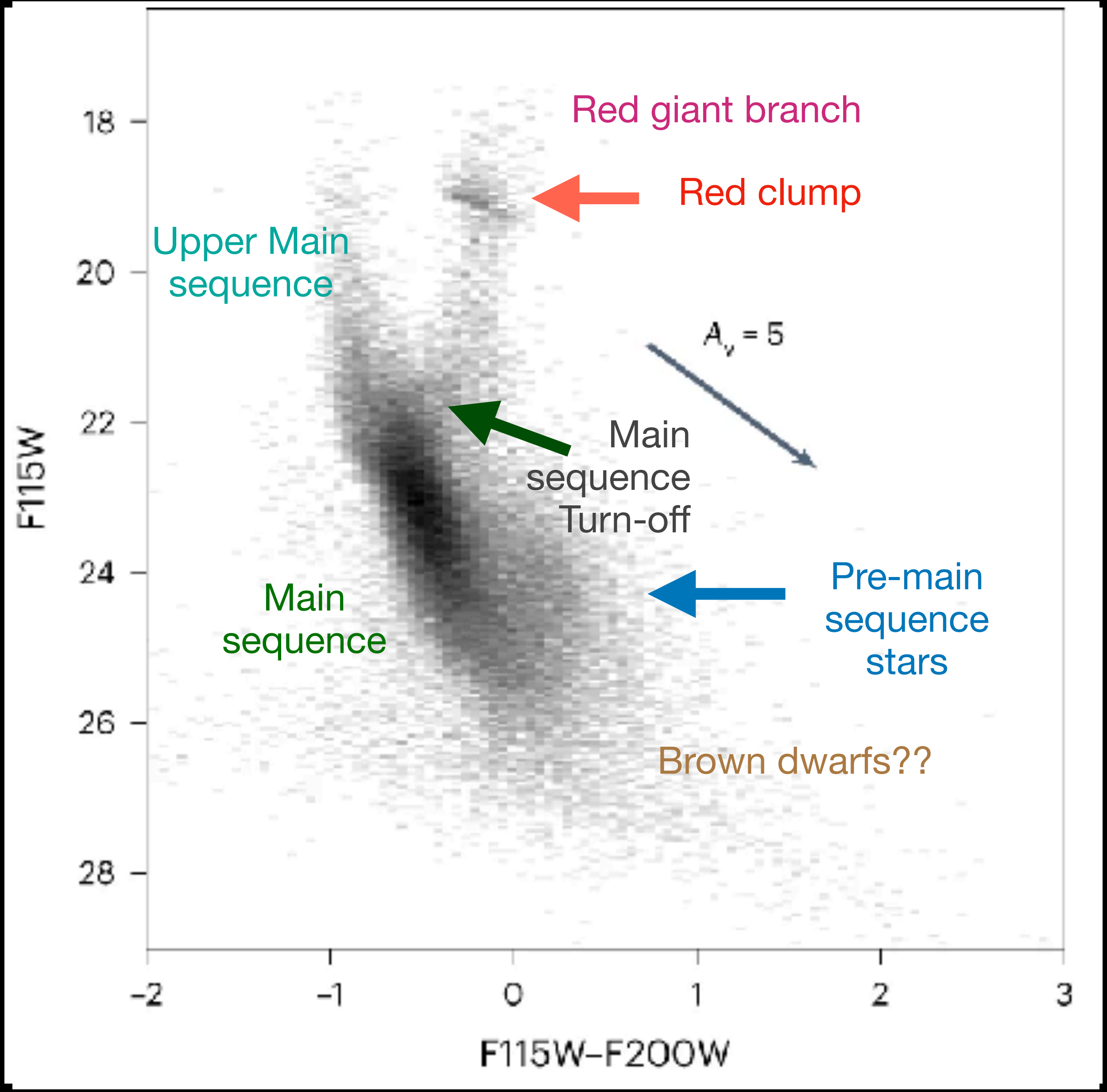
SMALL MAGELLANIC CLOUD | NGC346

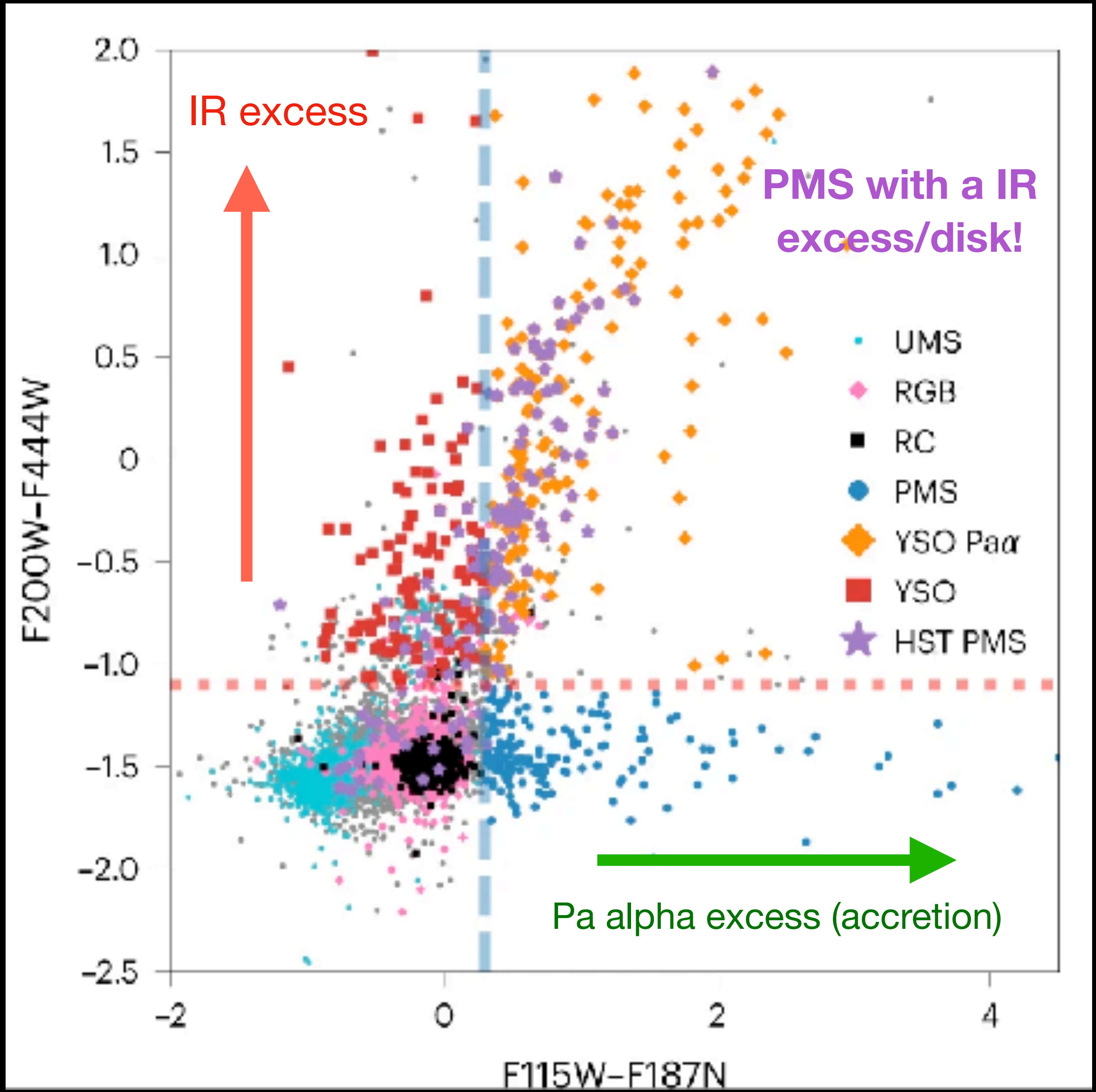
MIRI Filters | F770W F1000W F1130W F1500W F2100W



1st extragalactic detections of sub-solar mass YSOs

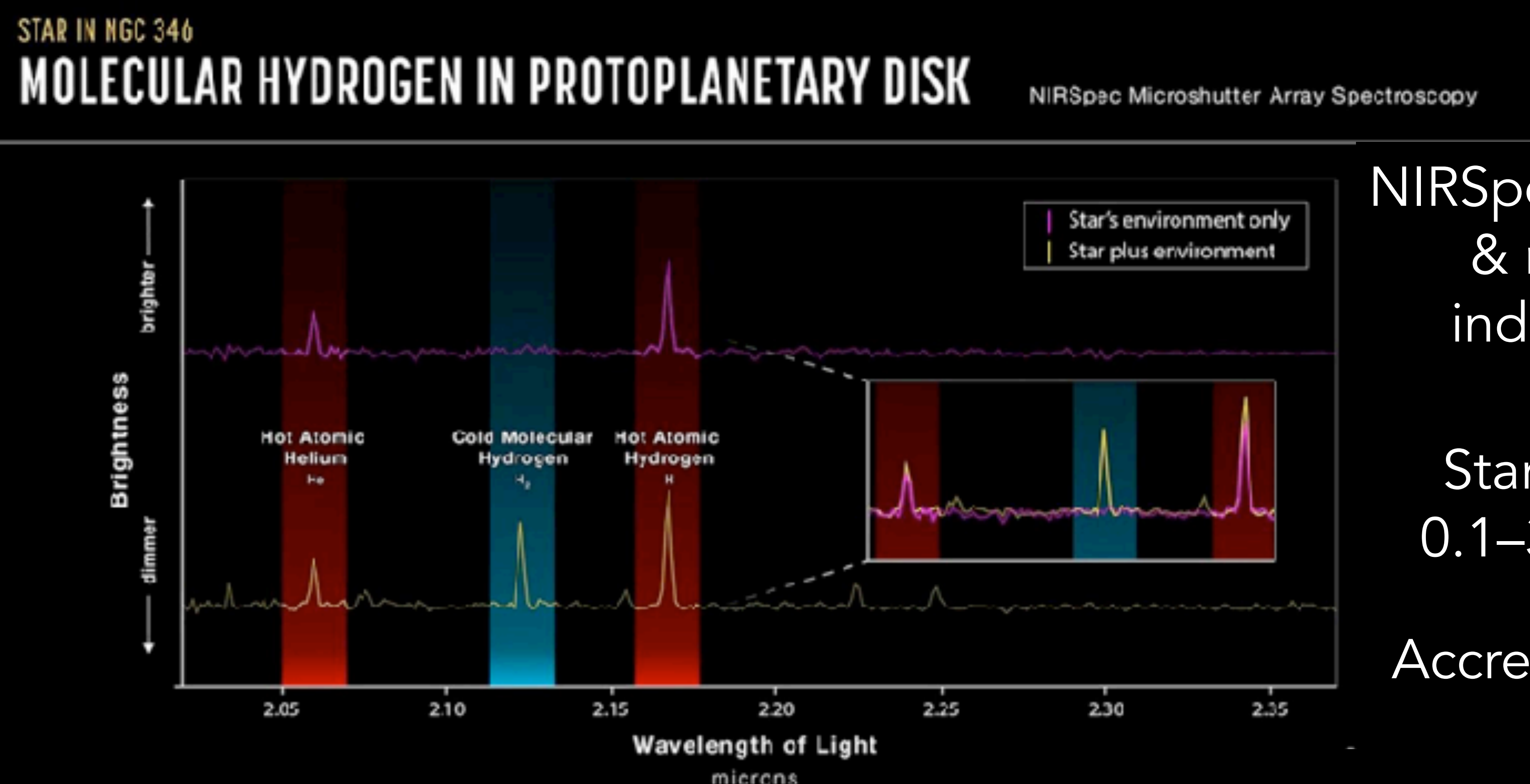
IR excesses suggests the dust required for rocky planet formation is present at 0.2 $Z_\odot$





Jones et al. Nature Astro. 2023a

PROTOPLANETARY DISKS AROUND SUN-LIKE STARS APPEAR TO LIVE LONGER AT LOW METALLICITY



NIRSpec data have a near-IR excess & molecular hydrogen lines indicative of long-lived discs.

Stars in NGC 346 with ages 0.1–30 Myr are still accreting!

Accretion rates ~10^-8 *Msun*/yr lasting over 20 Myr!

Disc lifetimes are longer than in nearby star-forming regions.

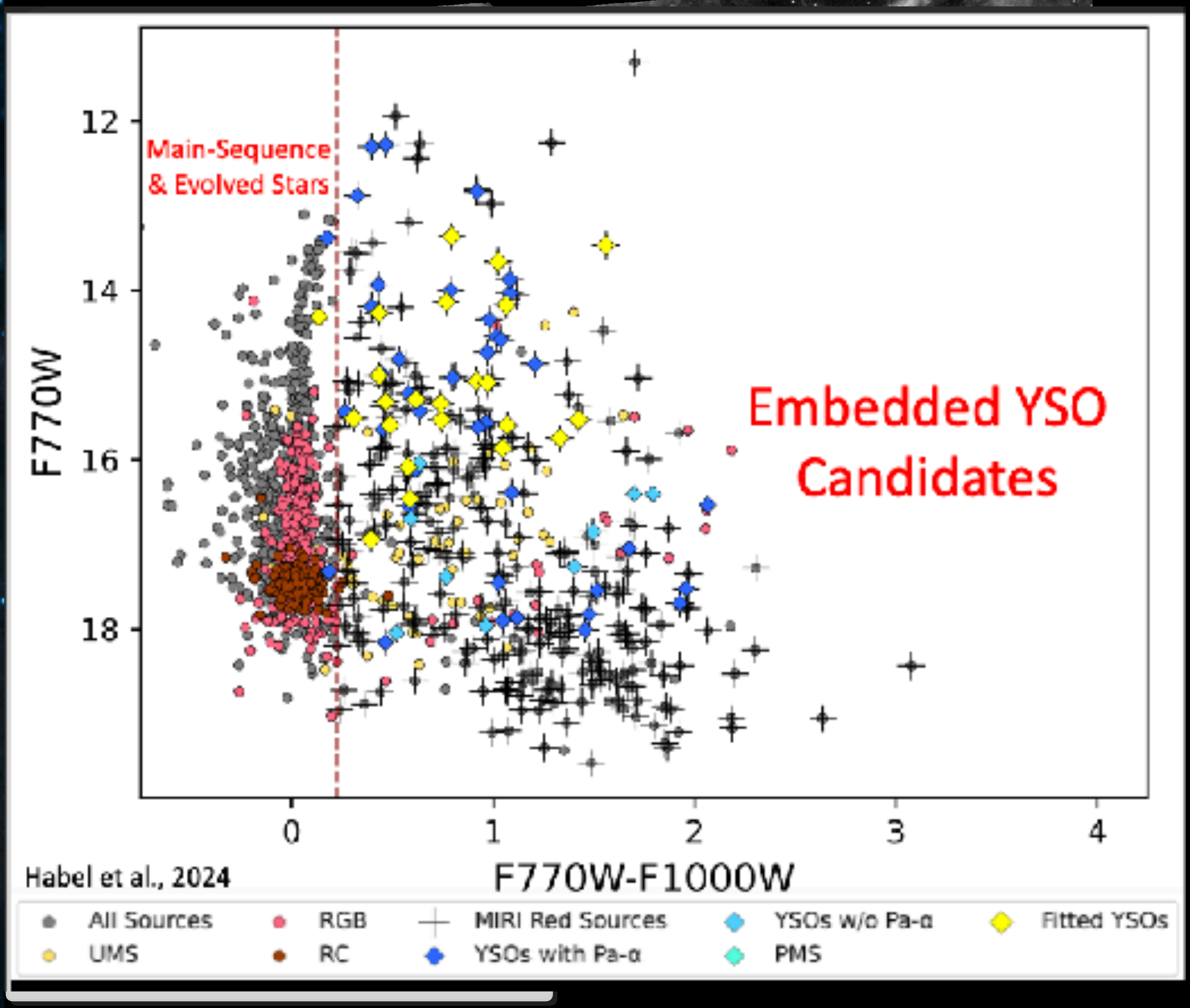
Significantly more time for giant planets to form & grow than in higher-metallicity environments.

Models of planet formation predict disks should dissipate after 2-3 million years!

De Marchi et al. 2024

NGC 346: WHAT MIRI REVEALS

Background: MIRI F770W



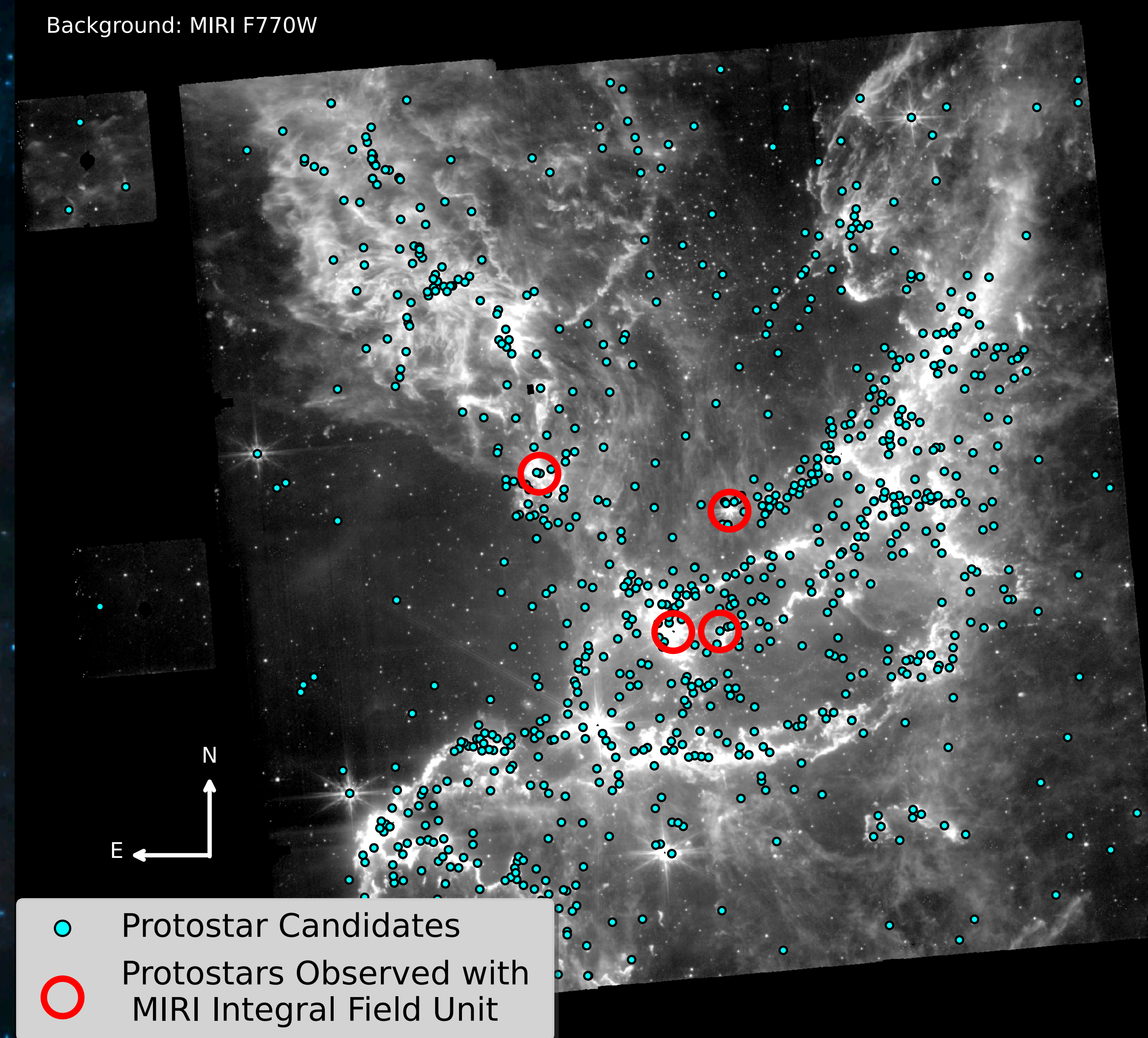
MIRI traces the structure of diffuse emission from cooler gas and dust.

Deeply embedded YSOs shine brightly - hundreds are present.

Redder, deeply-embedded sources lie along filaments of gas and dust.

Habel et al. 2024

NGC 346: WHAT MIRI REVEALS



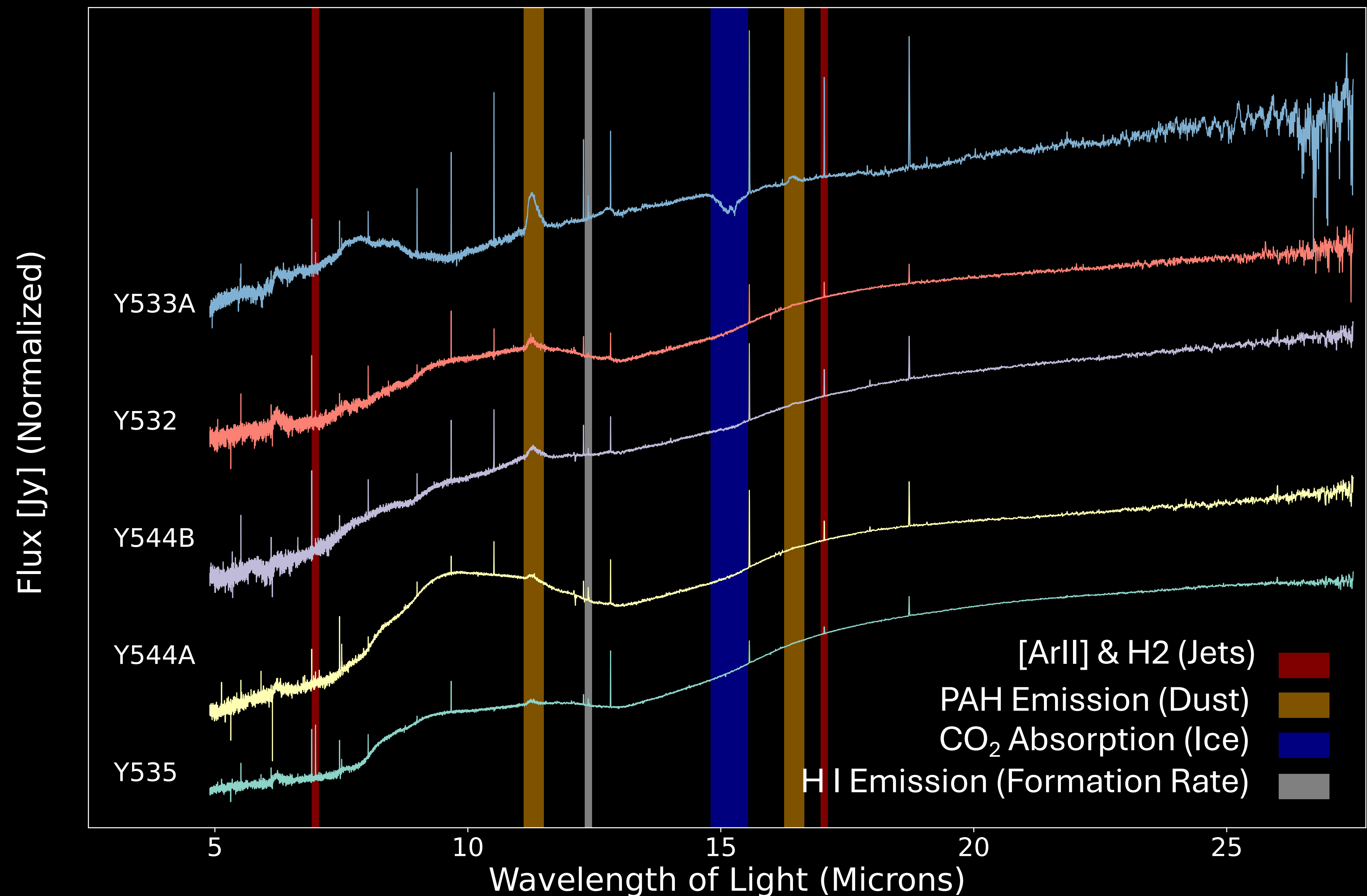
MIRI traces the structure of diffuse emission from cooler gas and dust.

Deeply embedded YSOs shine brightly - hundreds are present.

Redder, deeply-embedded sources lie along filaments of gas and dust.

Habel et al. 2024

With **MIRI**, JWST can probe the environment and formation processes of individual stars in nearby galaxies.



PRIMA FIRESS should also be able to get spectra of extragalactic medium- to high mass protostars in nearby galaxies

Far-IR rotational bands of CO, H_2O, & OH, Atomic lines of [O I], [O III] & [C II] key for efficient cooling of the hot dense gas - see e.g. Oliveira+2019 Nayak+2021

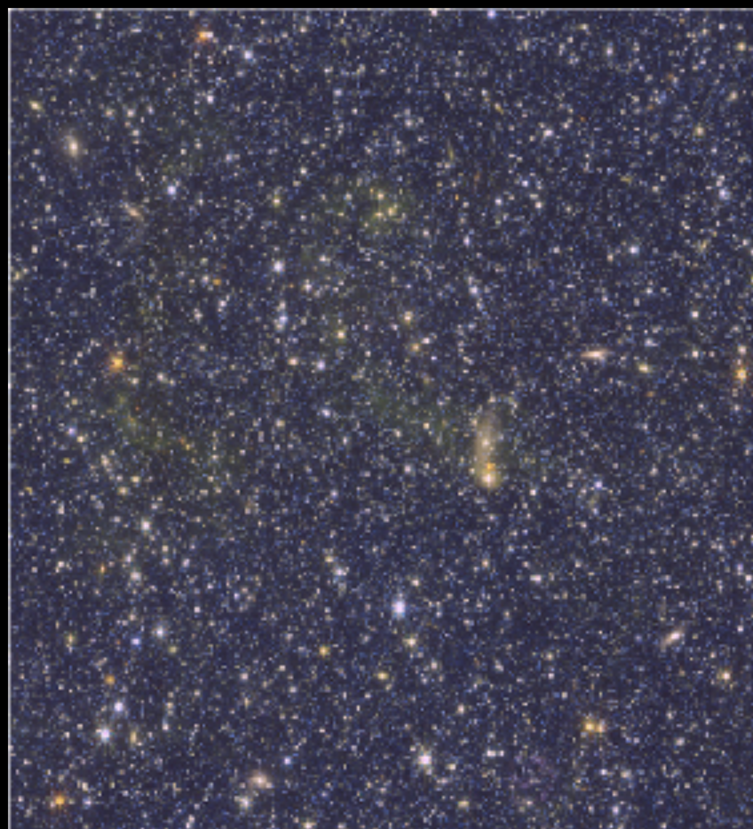
Dusty Stellar Birth & Death in the isolated galaxy NGC 6822

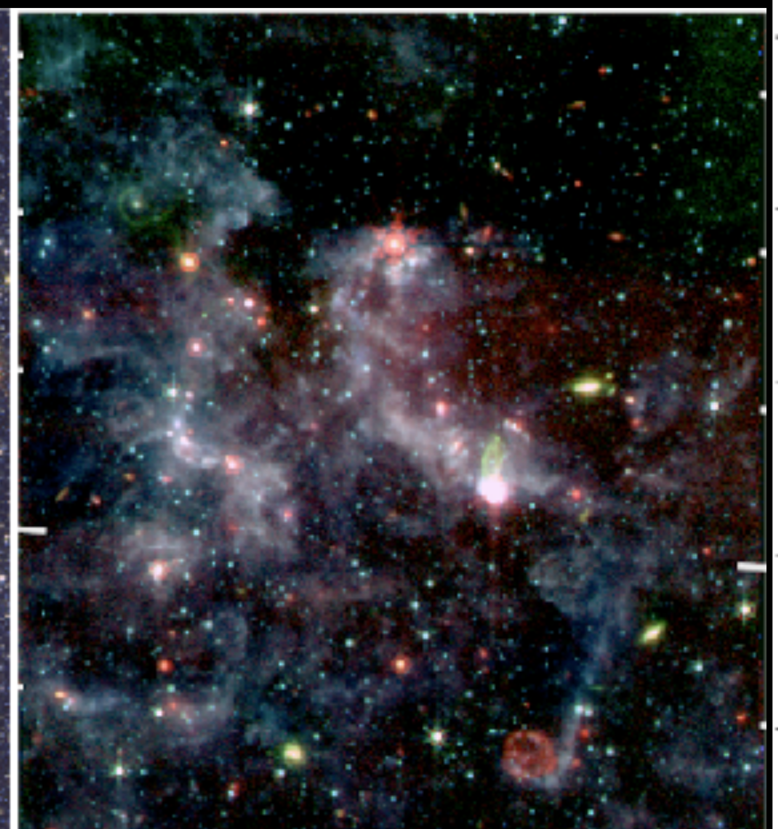
D = 490 Kpc   Z ~30% Zsun

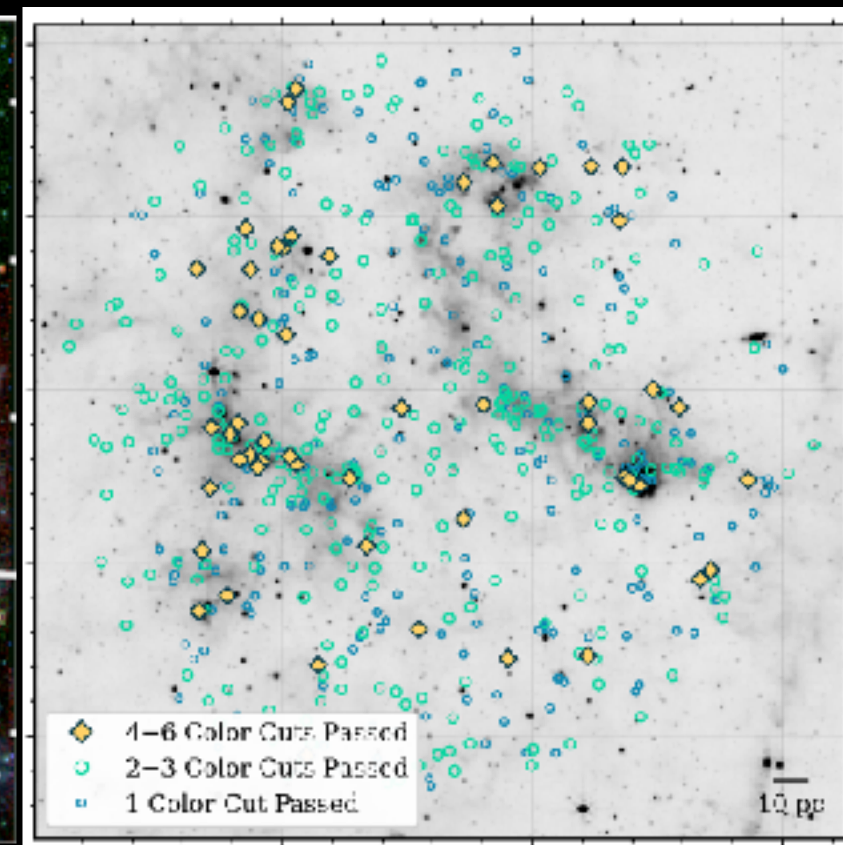
Unusual H I distribution.   Bright HII regions

Nally et al. (2024)

~82,000 POINT SOURCES IN SPITZER I: ~140 ARE YSOS!

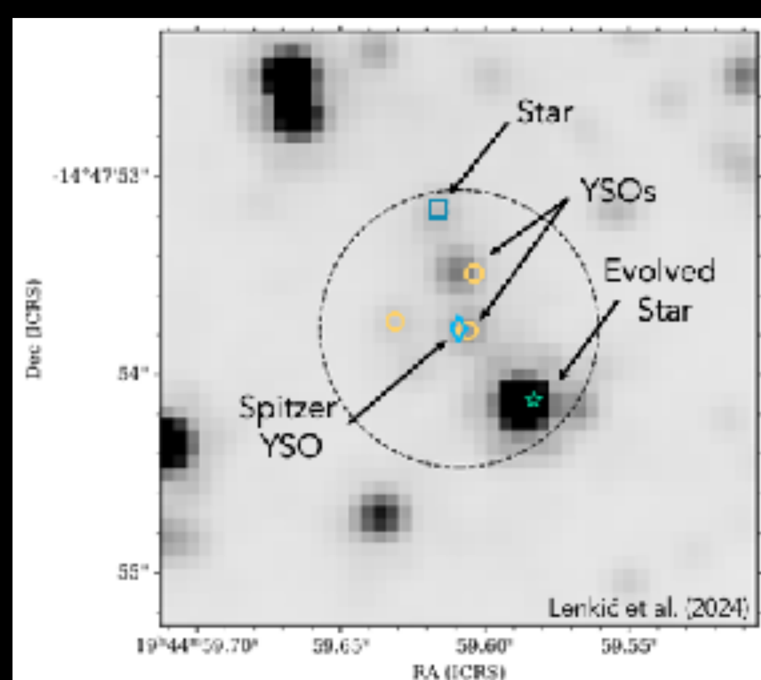


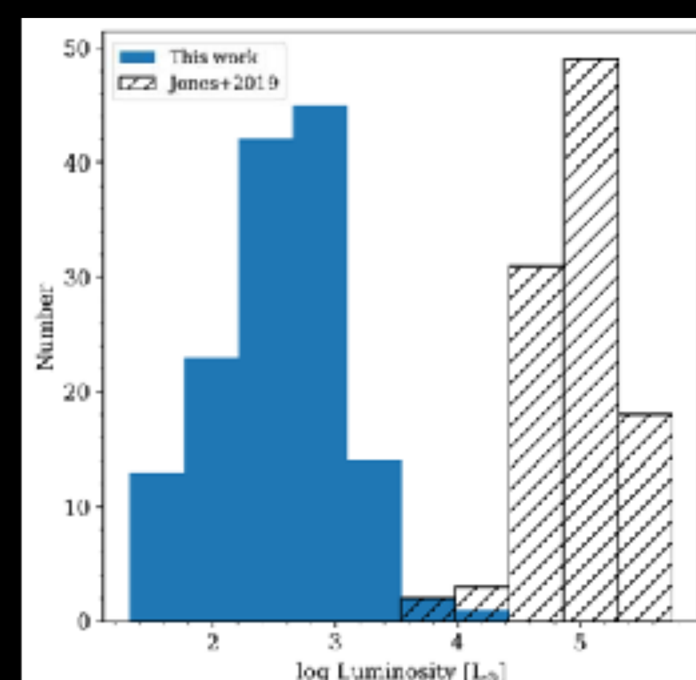




Sources that pass multiple colour cuts, are well fit by YSO SEDs & are point-like are concentrated along dusty filaments.

Previously identified YSOs are resolved into multiple sources…

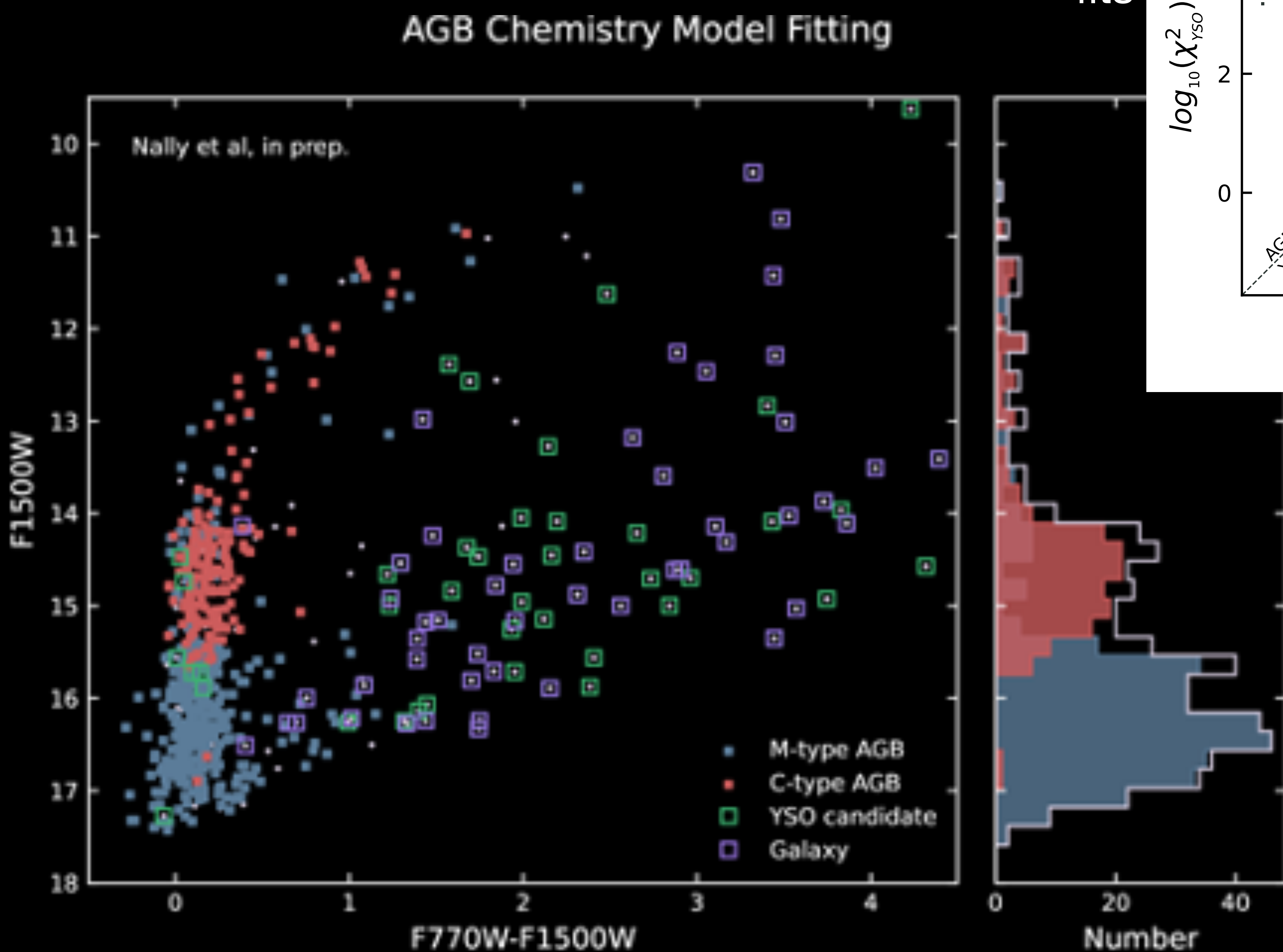




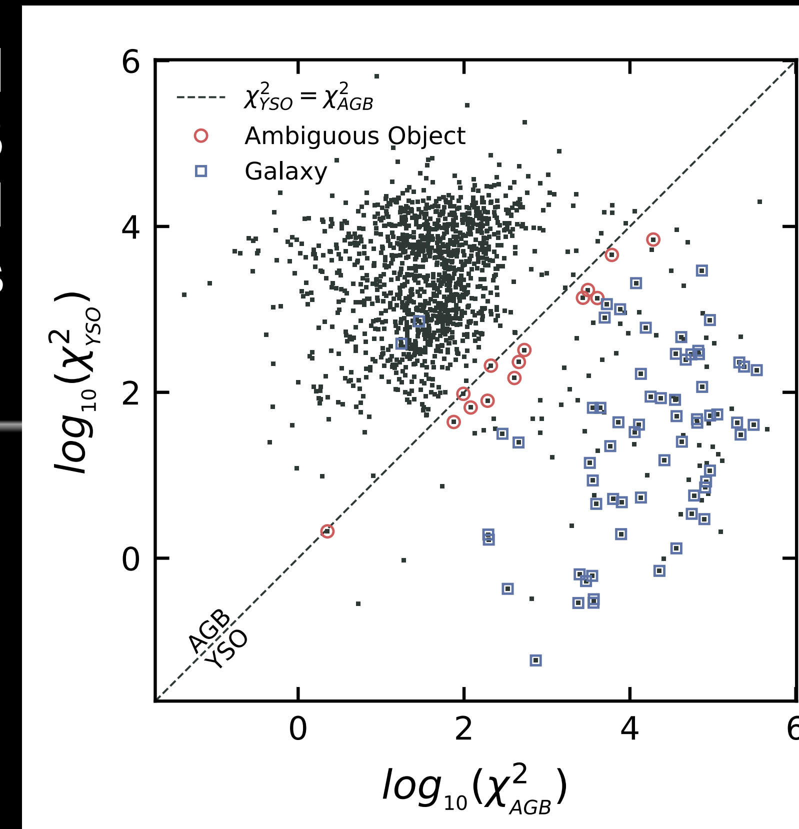
that are less luminous & massive than previously thought.

Lenkić et al. (2024)

SED MODELLING USED TO SEPARATE YSOS & EVOLVED STELLAR POPULATIONS



Good AGB model fits



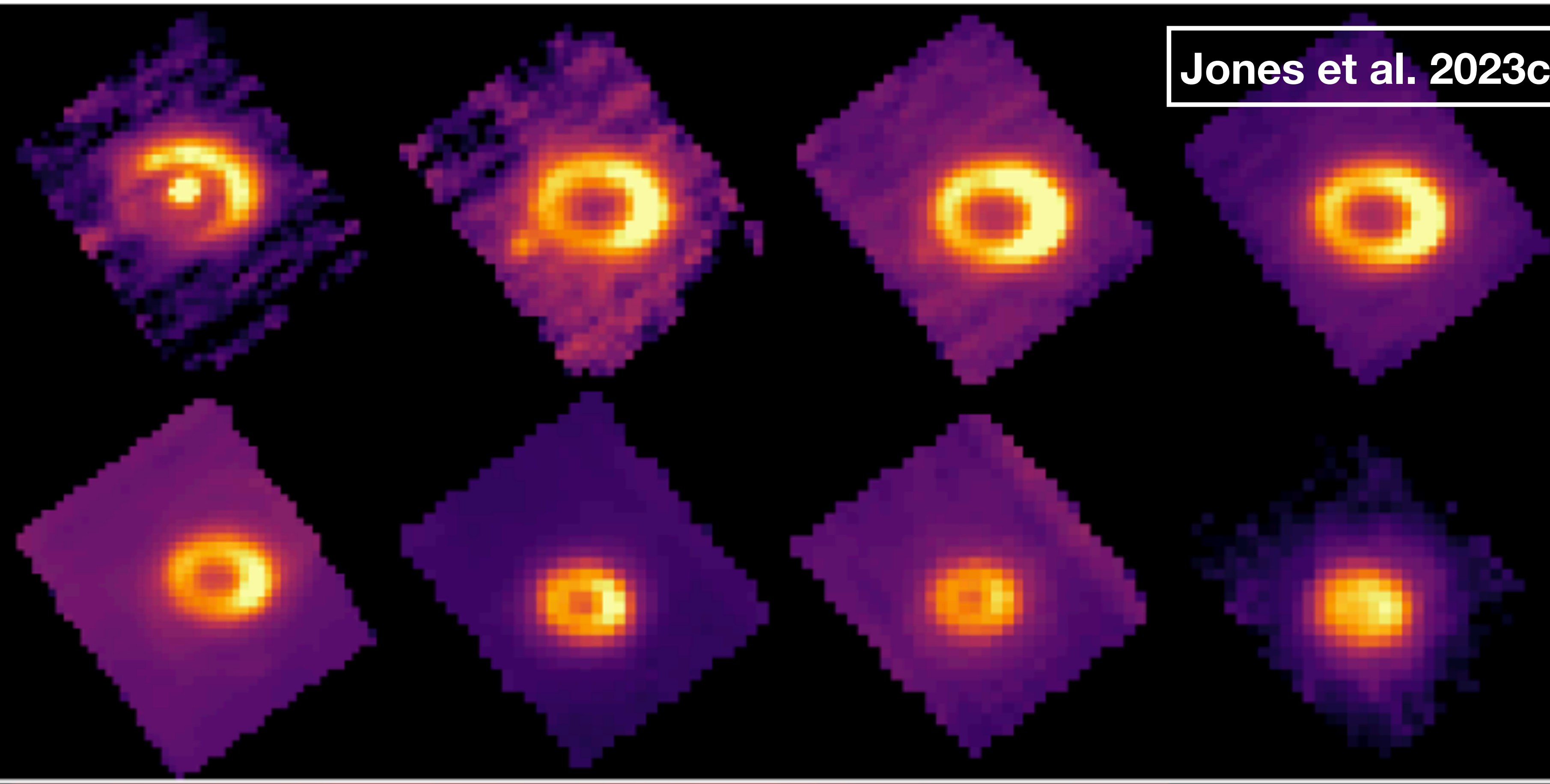
Good YSO model fits

Nally et al. in prep

A Supernova Tangent

EJECTA, RINGS, AND DUST IN SN 1987A WITH JWST

Matsuura et al. 2024



Jones et al. 2023c

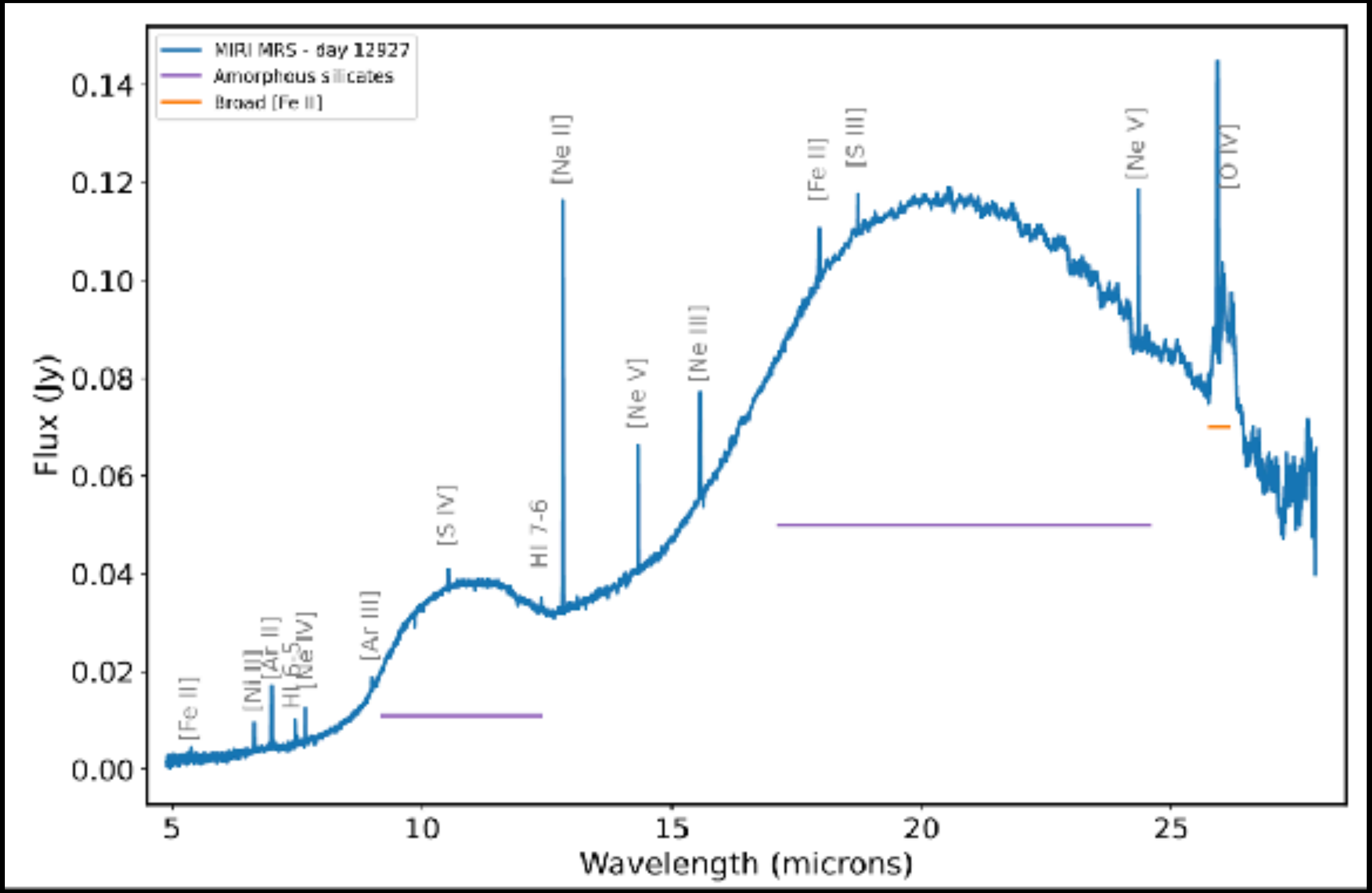
First spatially resolved spectral maps in the 1 to 28 μm wavelength region.

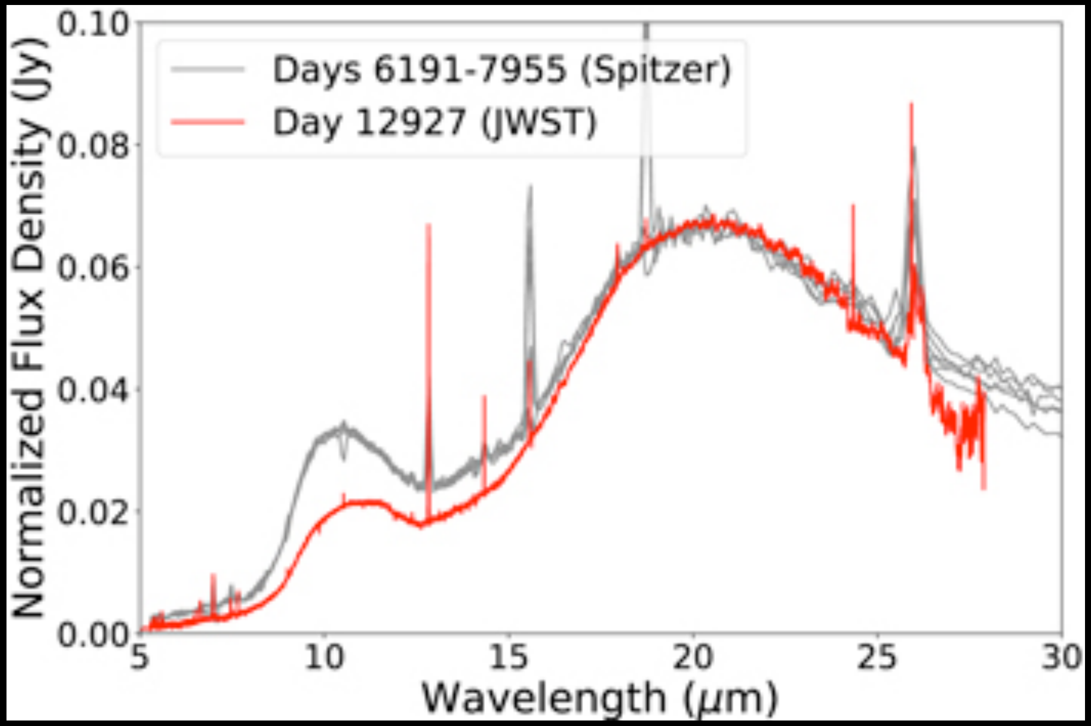
Gas emission lines arise in the Equatorial Ring, the ejecta, the outer rings, & the region between the Equatorial Ring and the outer rings.

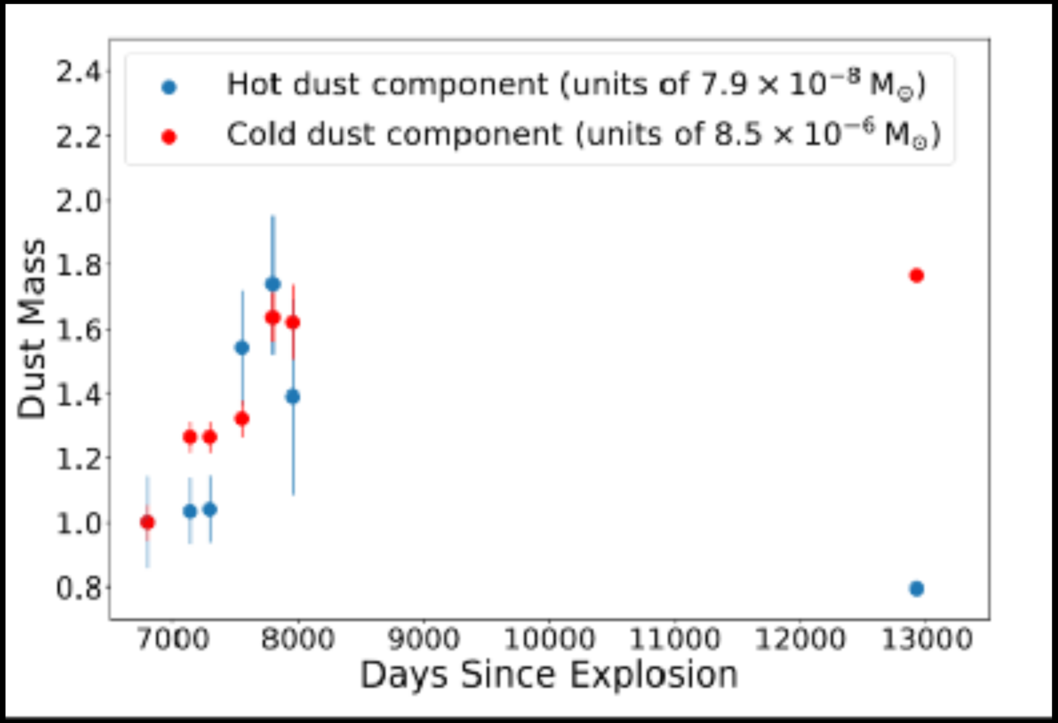
The continuum is dominated by dust emission mostly from the Equatorial Ring.

Jones et al. 2023c   Larsson et al. 2023

EJECTA, RINGS, AND DUST IN SN 1987A WITH JWST







Currently no evidence of ejecta dust in MRS spectrum.

Large progenitor dust grains preferentially survive the SN explosion & processing by shocks.

Jones et al. 2023c

Conclusions

- ★ JWST has opened up a new window for observation of star formation in the local volume. Many very exciting results!
- ★ In the Magellanic Clouds is it now possible to observe YSOs in a manner comparable to studies of similar objects in the Milky Way.
- ★ MIRI/MRS provides high spatial & spectral resolution. Observations of lines previously only detected in the Milky Way are now possible in other galaxies.
- ★ PRIMA Hyperspectral mapping and spectroscopic followup would be the perfect complement to the red JWST sources.
- ★ I would also REALLY like far-IR spectra of evolved stars and supernova remnants. Especially covering the crystalline silicate features & dust mineralogy.