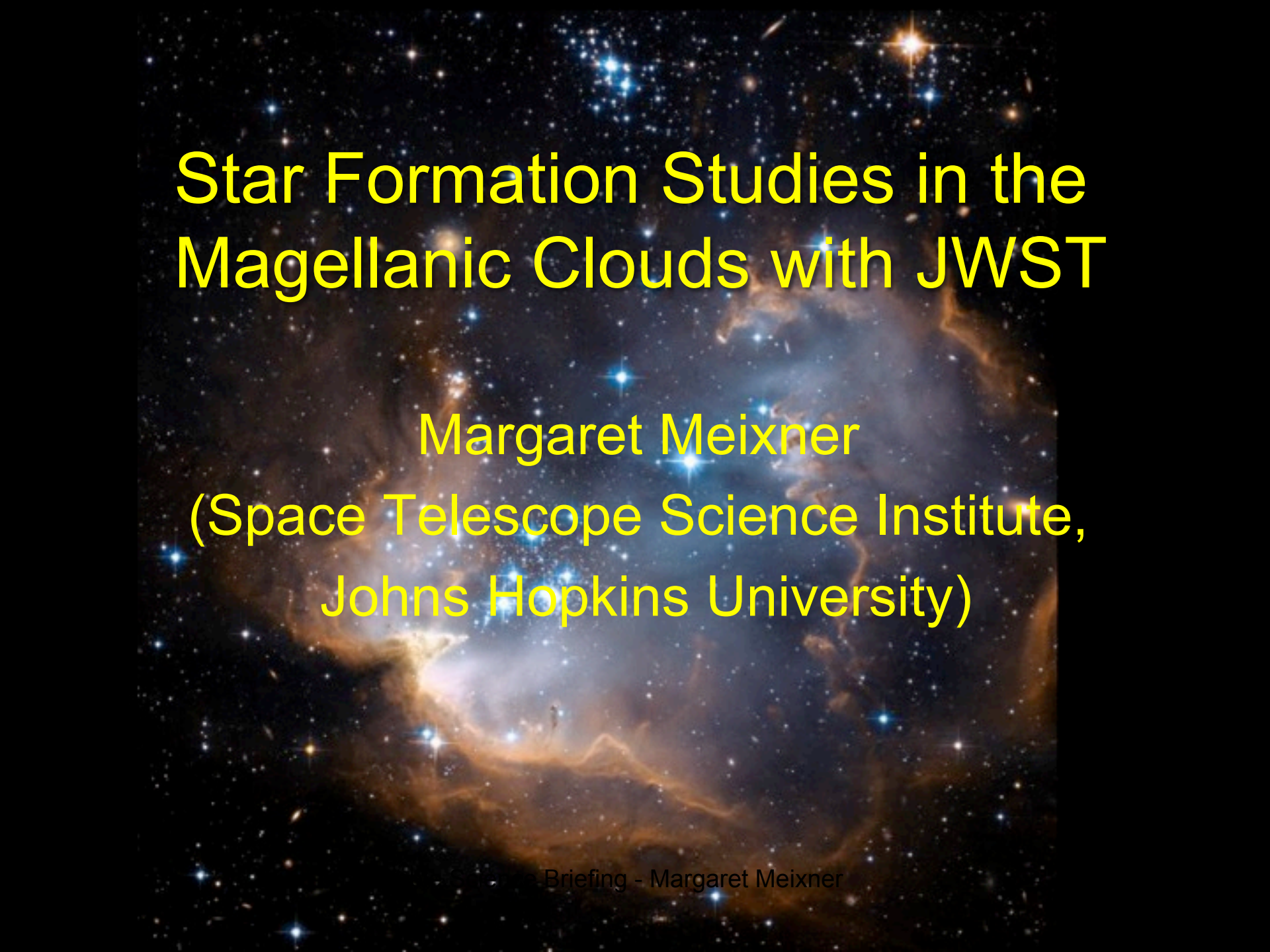


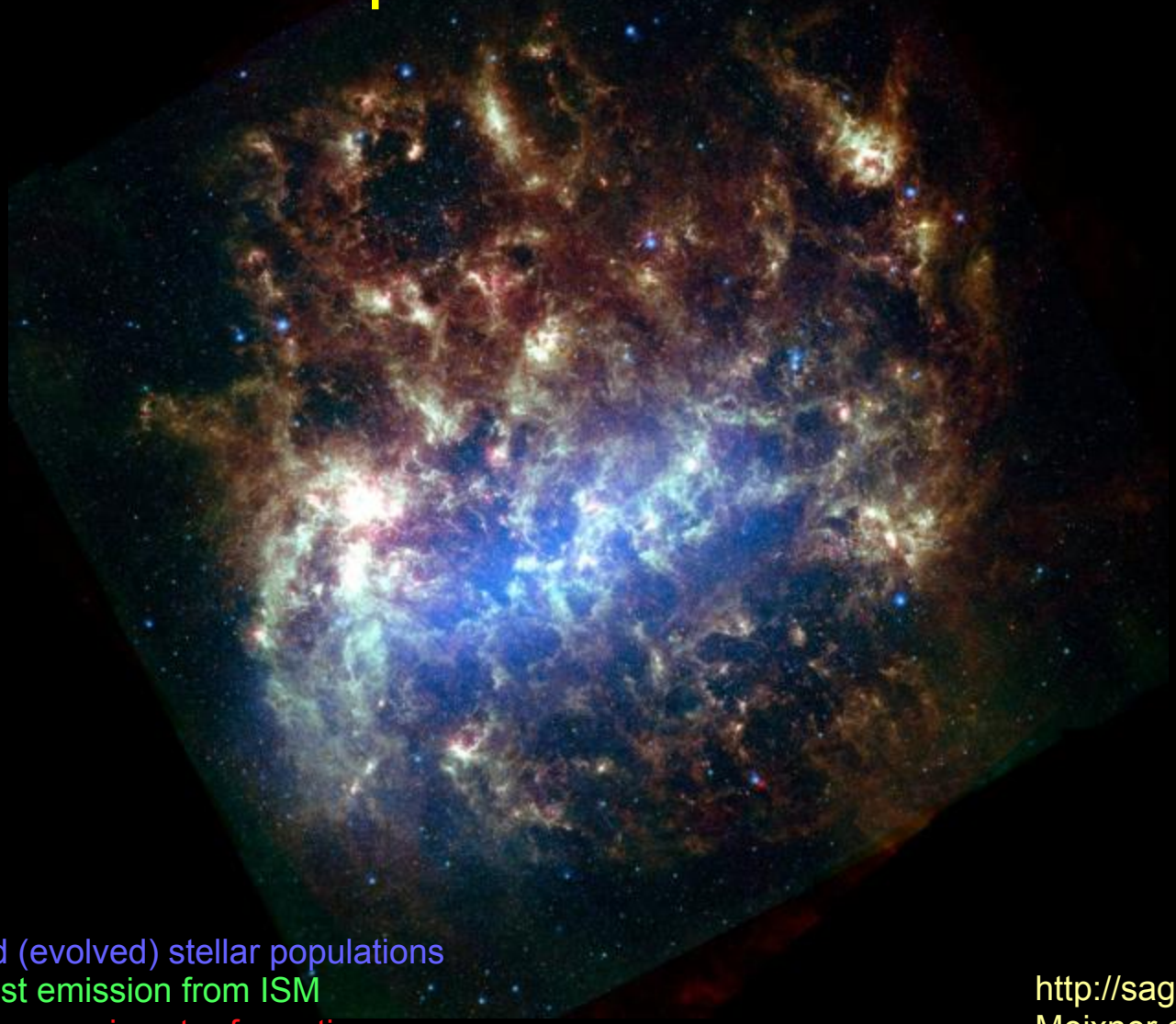
Star Formation Studies in the Magellanic Clouds with JWST

Margaret Meixner
(Space Telescope Science Institute, Johns Hopkins University)

Outline

- Discovery of Young Stellar Objects (YSOs) in the Magellanic Clouds
- Spitzer Spectroscopic followup programs: Ices and PAHs at low metallicity
- JWST potential for Magellanic Cloud star formation
- NIRCam/MIRI imaging of NGC 602
- Environments of YSOs in N159

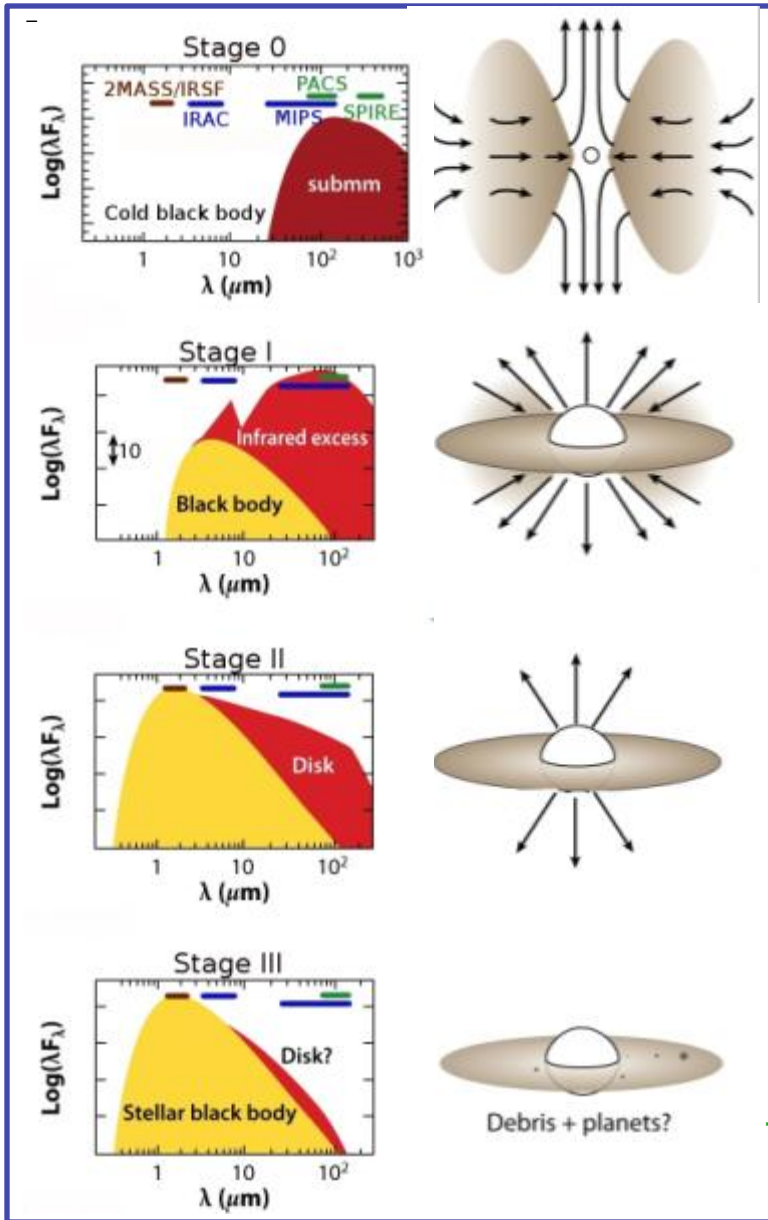
Large Magellanic Cloud (LMC), $Z \sim 0.5 \times Z_{\odot}$: Spitzer SAGE



IRAC 3.6 μm: old (evolved) stellar populations
IRAC 8.0 μm: dust emission from ISM
MIPS 24 μm: new massive star formation

http://sage.stsci.edu/
Meixner et al. 2006

Young Stellar Object Evolutionary Stages



Herschel/ALMA — Young Protostar: Main Accretion Phase

Spitzer — Evolved Accreting Protostar

Hubble & JWST — Thick disk, accreting, Herbig Ae/Be

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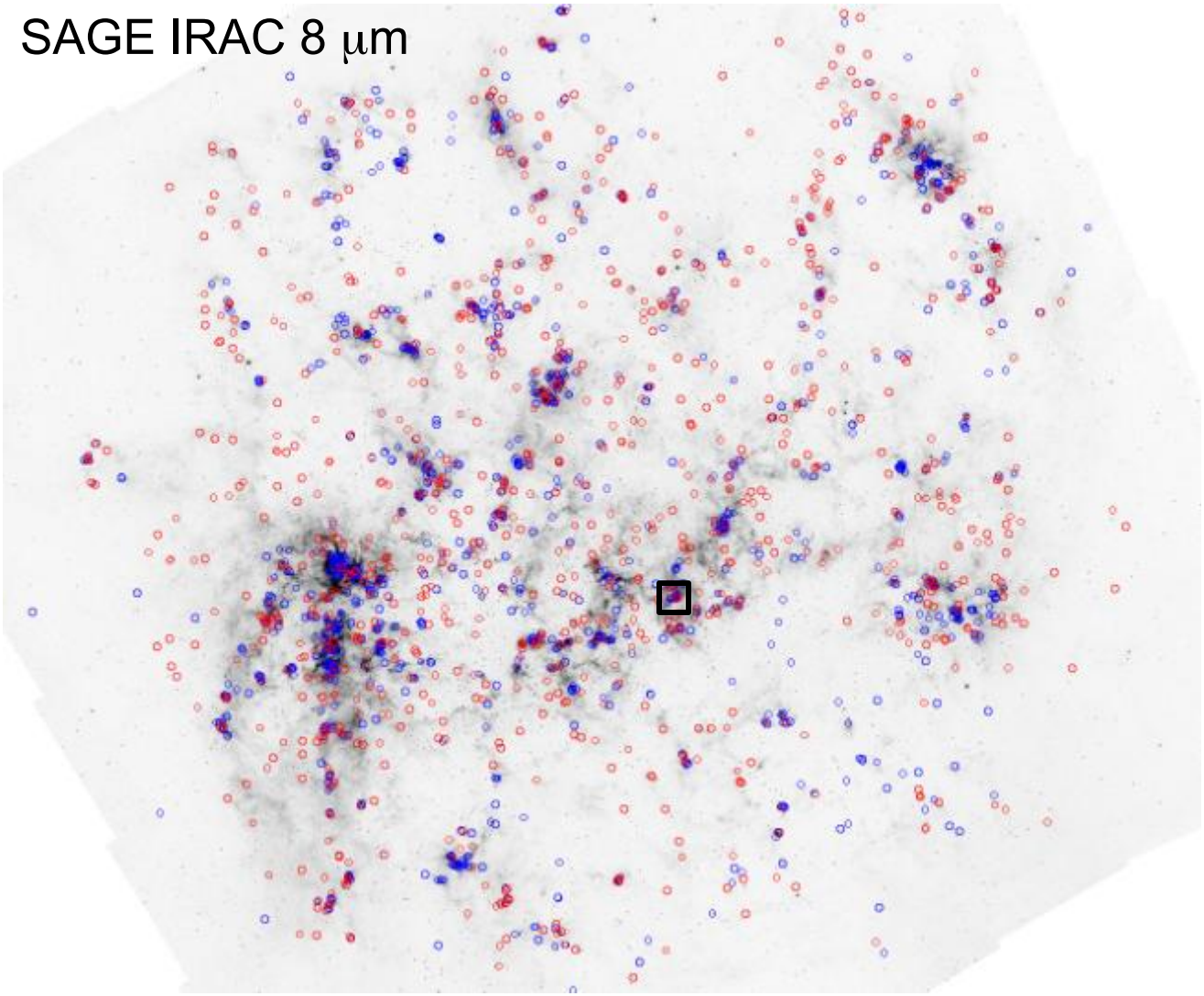
Spitzer Discovers Three Thousand Young Stellar Objects in the LMC



Pre-*Spitzer*:

~20 protostars known

Spitzer:

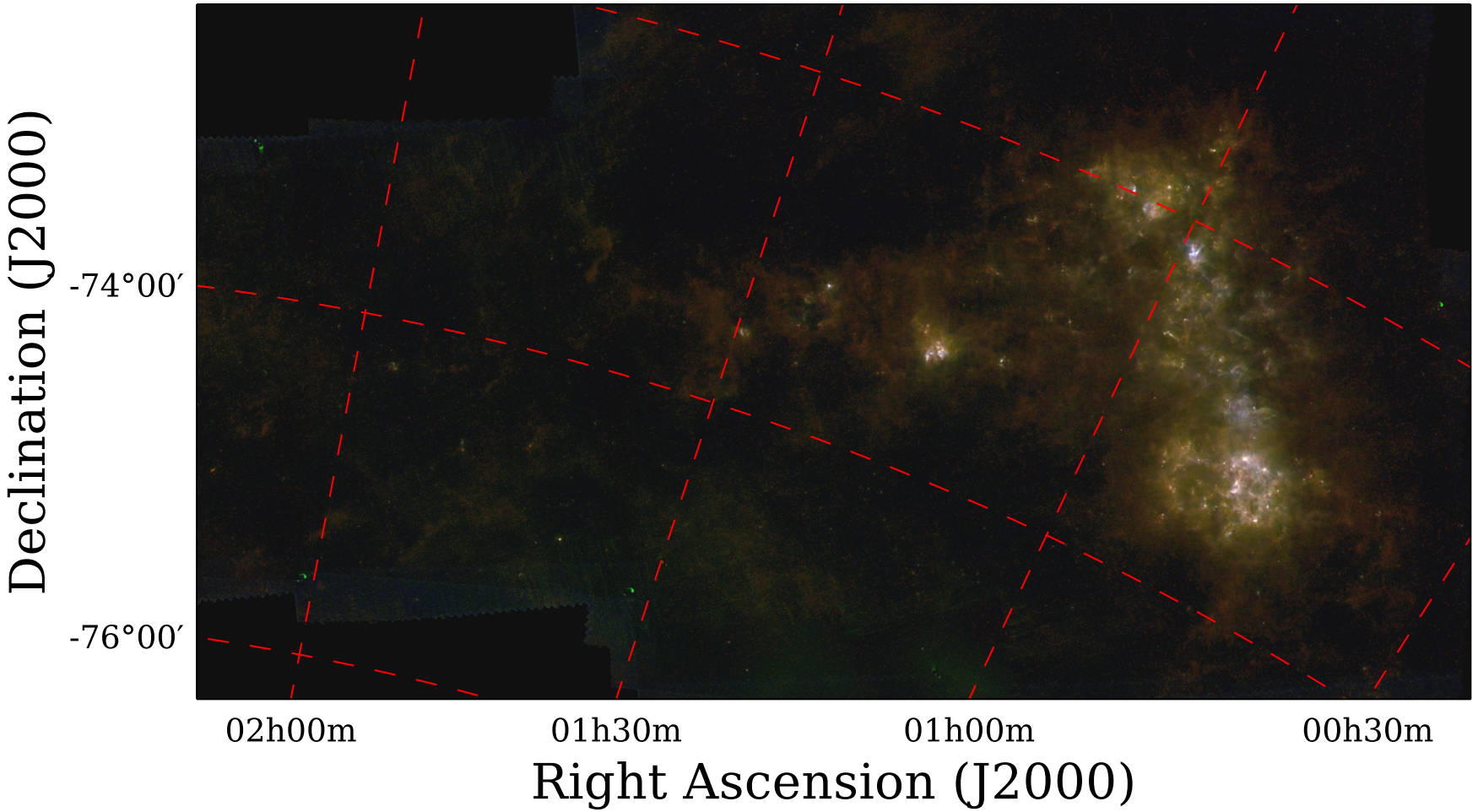
~1000 YSO candidates
Whitney, Sewilo et al. (2008)

~1200 YSO candidates
Gruendl & Chu (2009)

~1000 YSO candidates
In star forming clusters
Carlson et al. (2012)

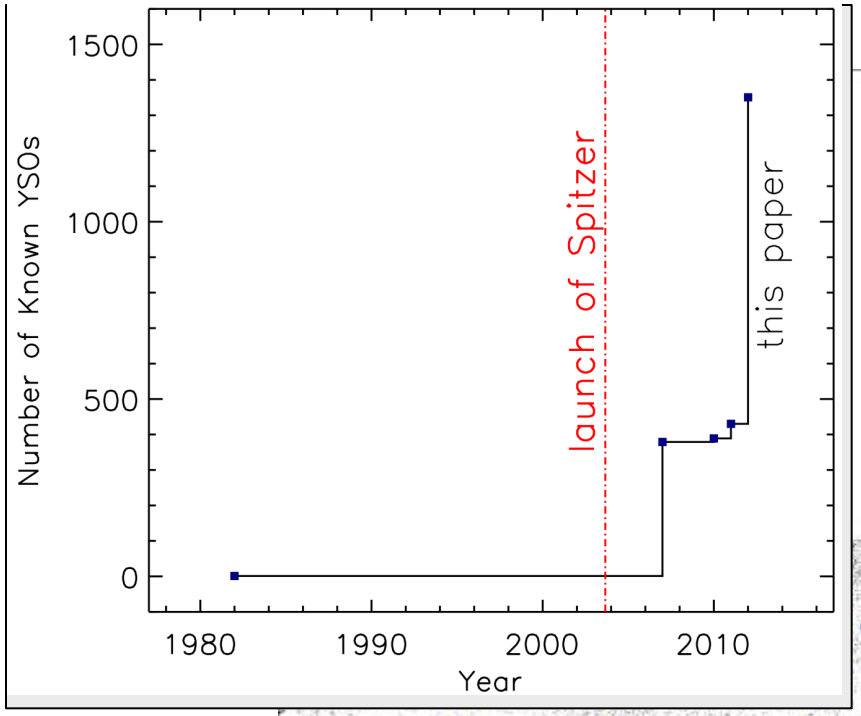
Small Magellanic Cloud (SMC) Z~0.2 $Z_\odot$: Herschel HERITAGE

SPIRE 250 μm PACS 160 μm PACS 100 μm

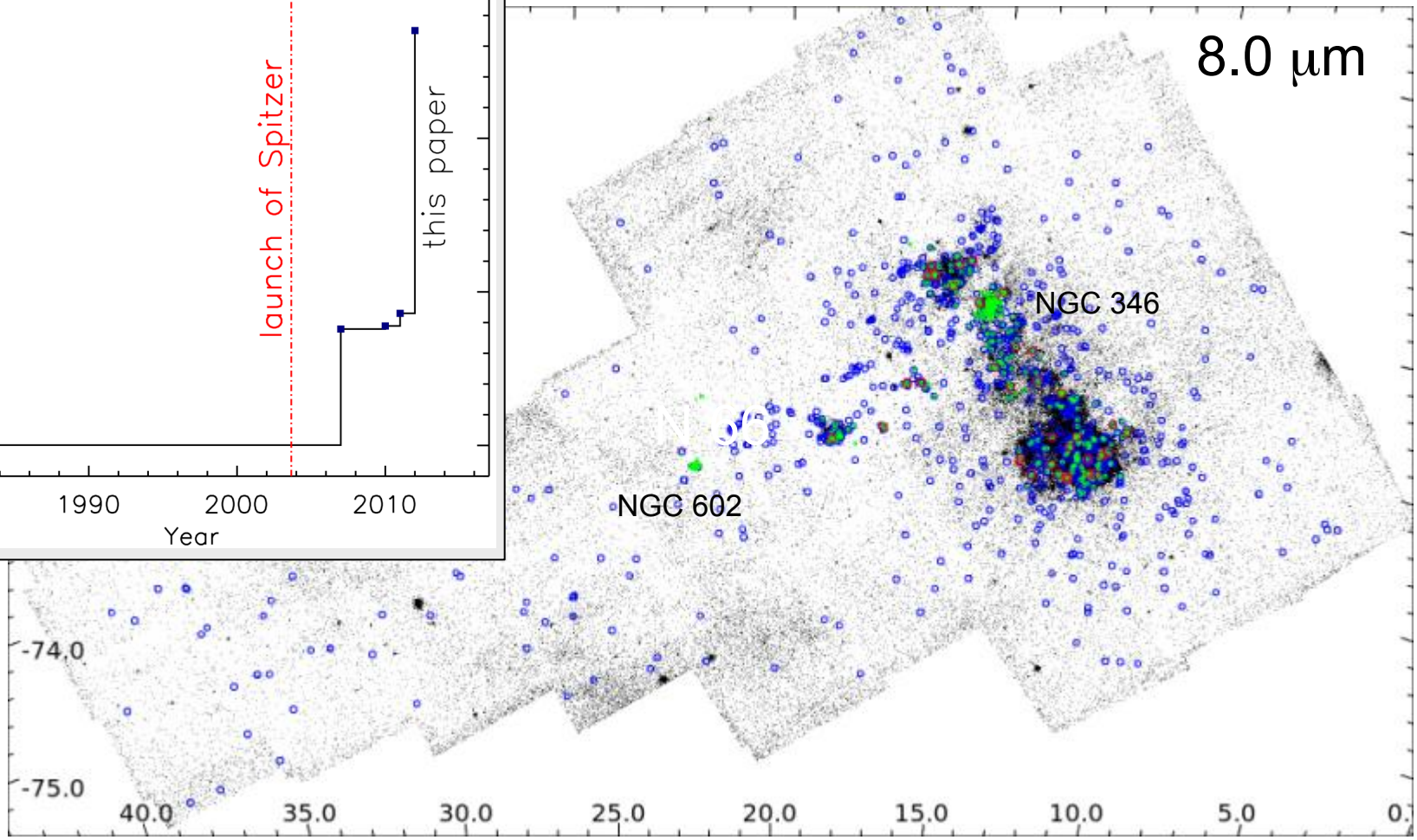


Meixner et al 2013

Spitzer Discovers One Thousand Young Stellar Objects in the SMC



~1100 YSO candidates; ~900 new

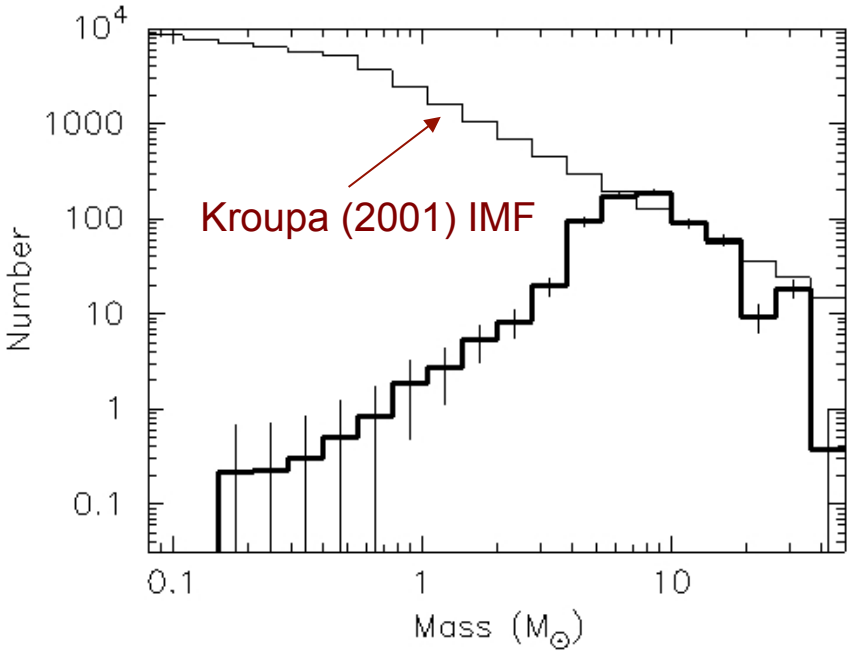


Sewilo et al. (2013)

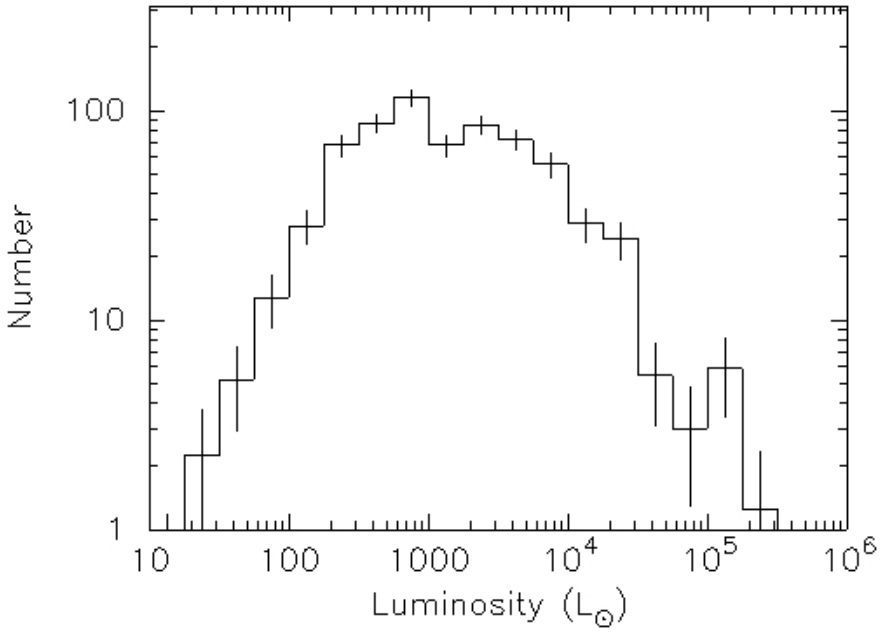
Sewiło et al. (2013)

SMC: YSO properties mostly Stage I

Histogram of Stellar Mass

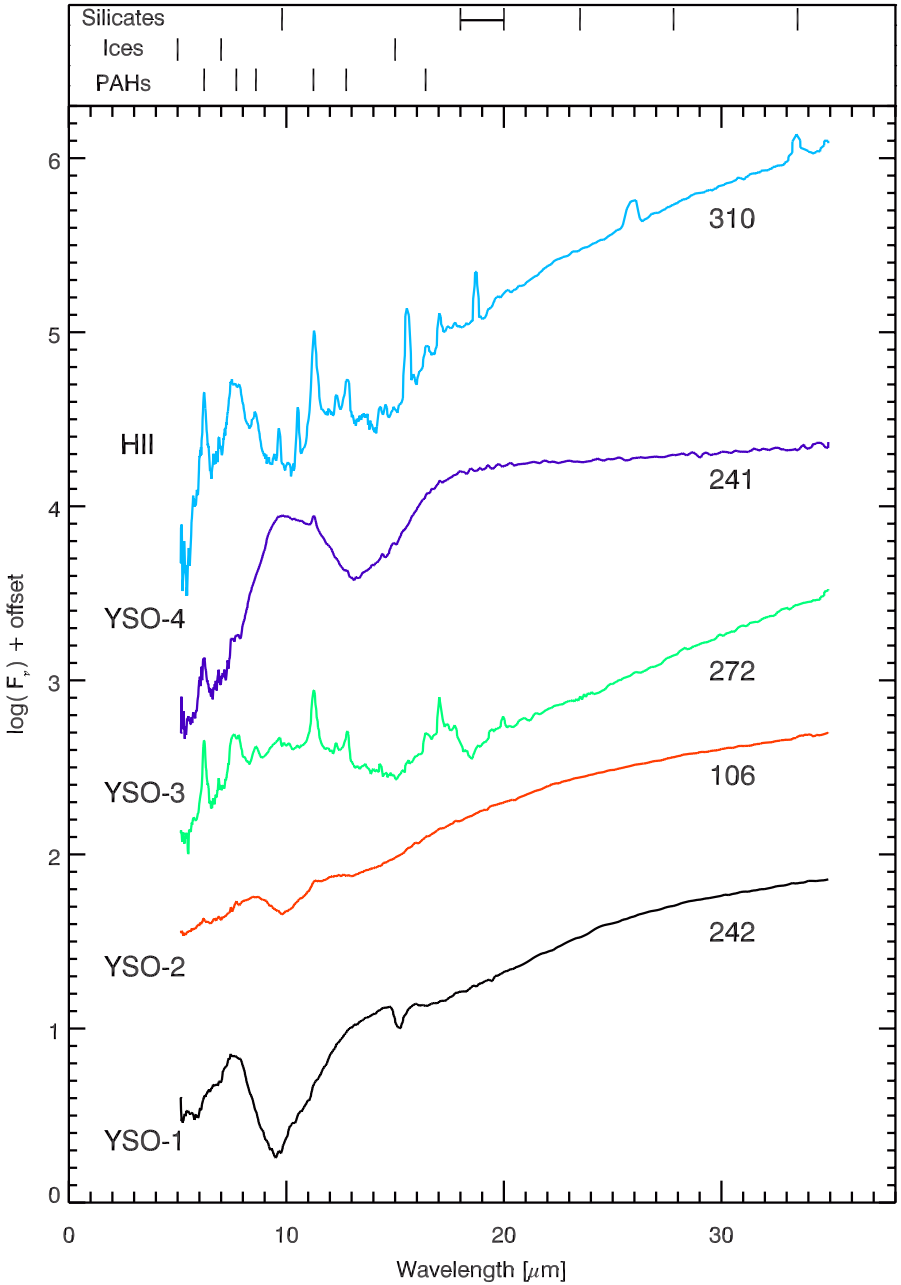


Luminosity Histogram



SFR ~ 0.06 M_{sun} / year

Sewilo et al. (2013)



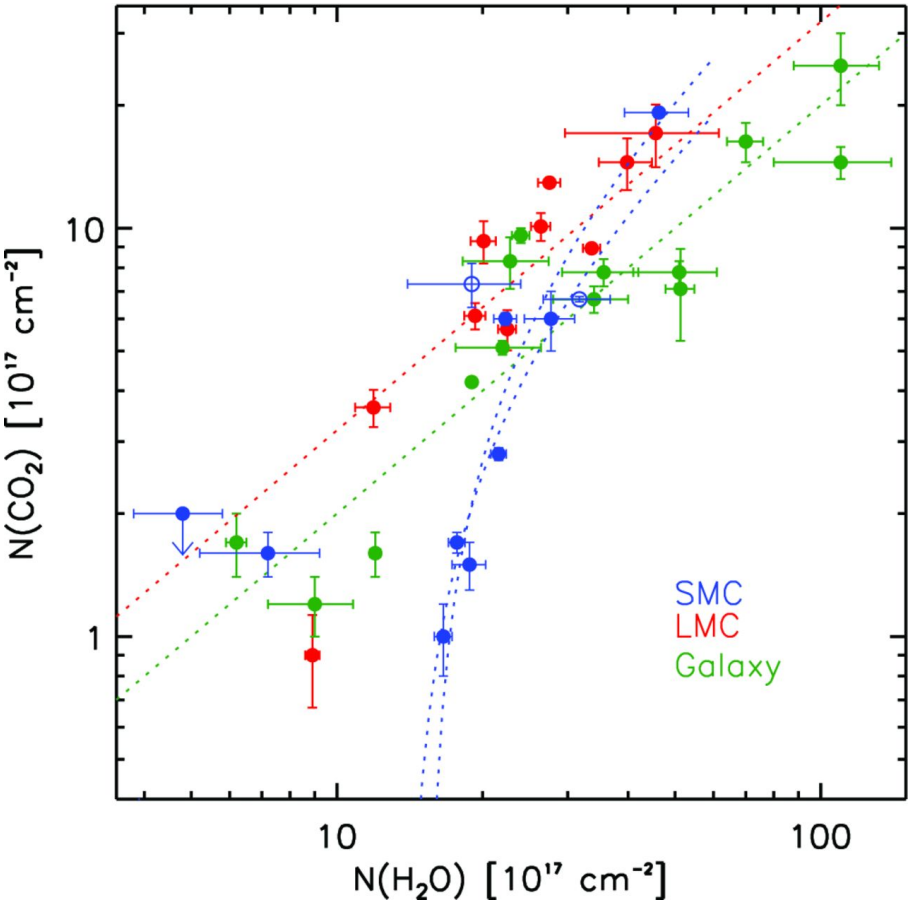
Spitzer Spectroscopy:

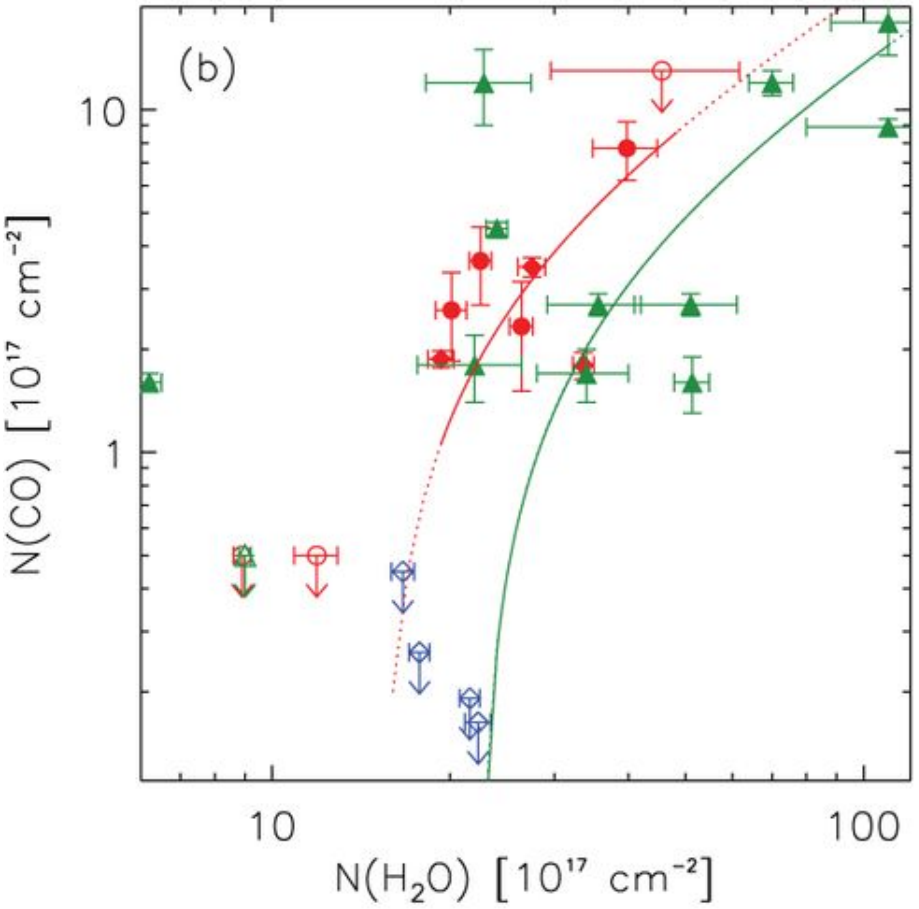
SAGE-Spec (PI: Kemper)
-sample of ~1000 all types of objects in LMC with Spitzer/IRS (Kemper et al. 2010; Woods et al. 2011)

-SMC-Spec: PI: Sloan,
IRS Spectra of ~hundreds

-IRS spectra of 294 Massive star YSO candidates: PI: Looney (Seale et al. 2009, 2011)

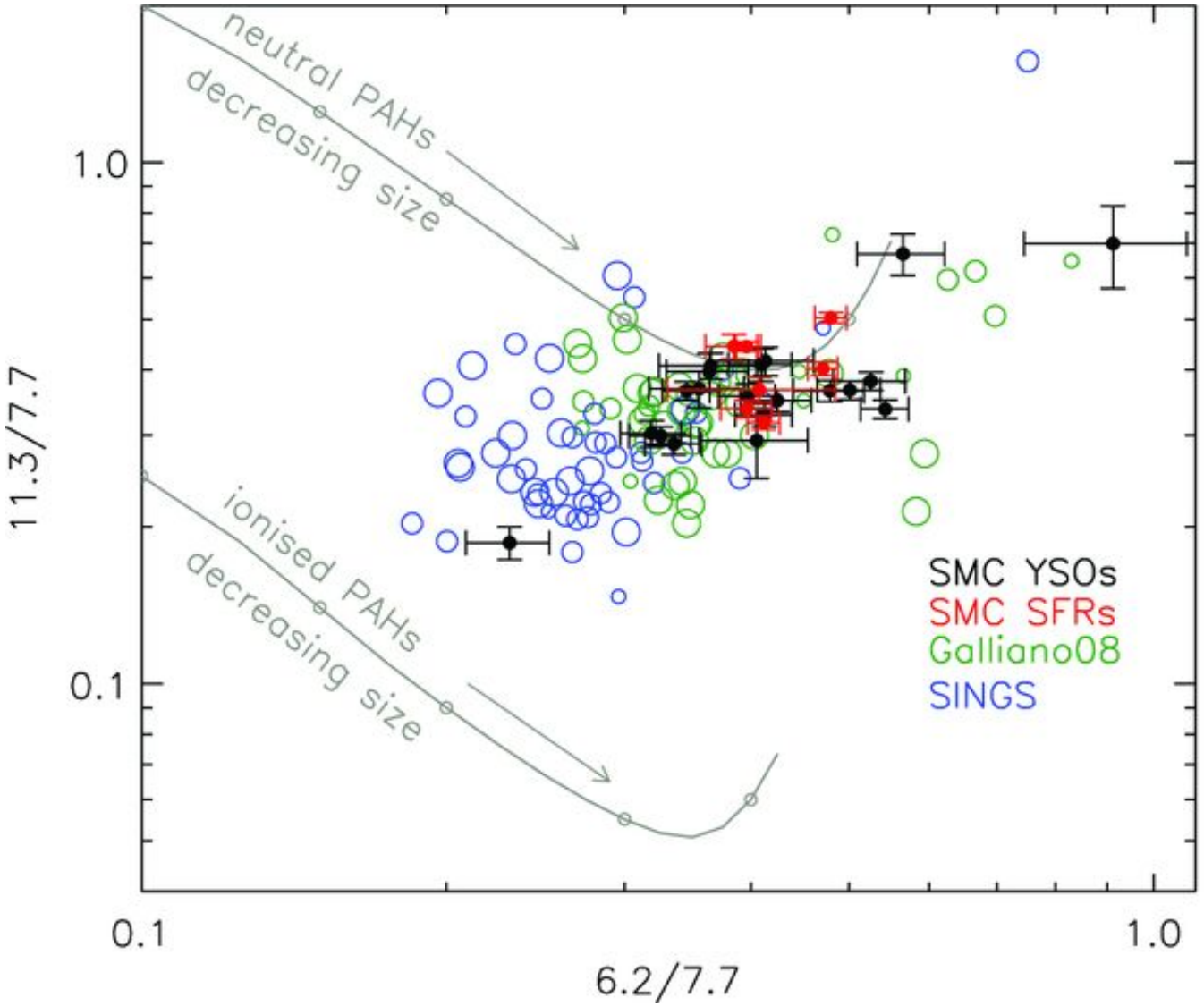
Ices in LMC & SMC





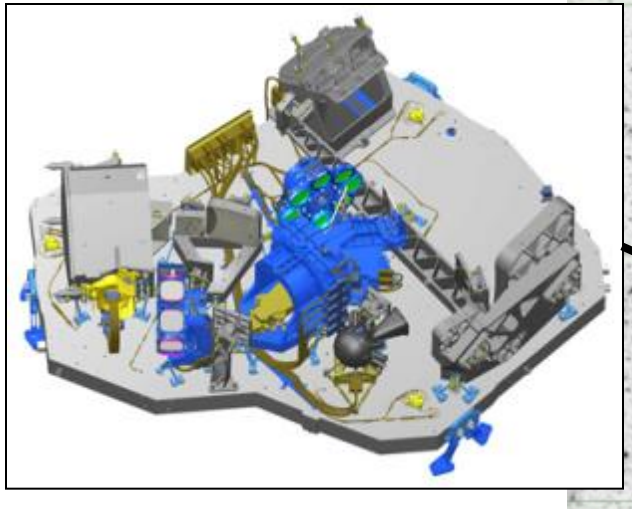
Oliveira et al. 2009; 2011, 2013
Seale et al. 2011

PAHs in SMC



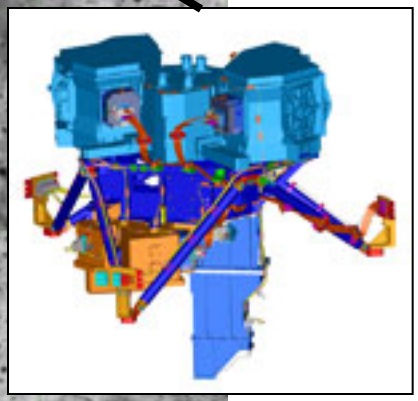
Oliveira et al. 2013

James Webb Space Telescope: Webb ~2018

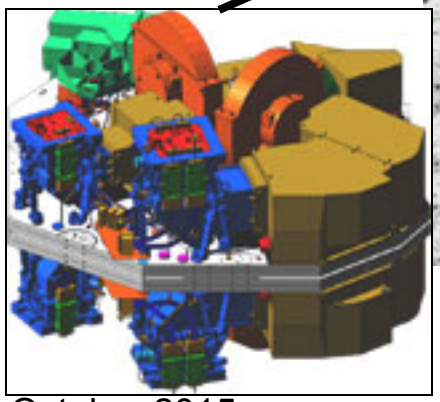


NIRSpec

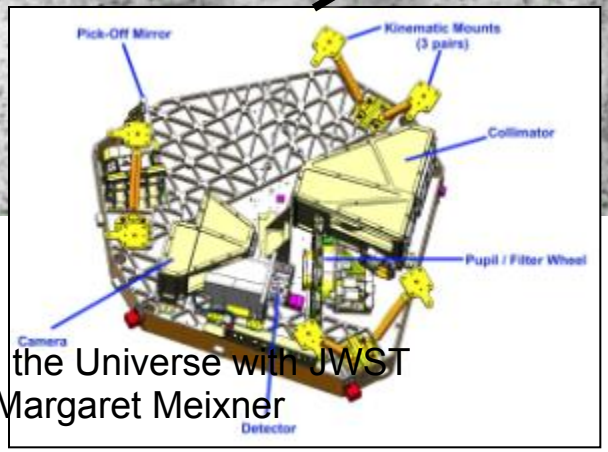
MIRI



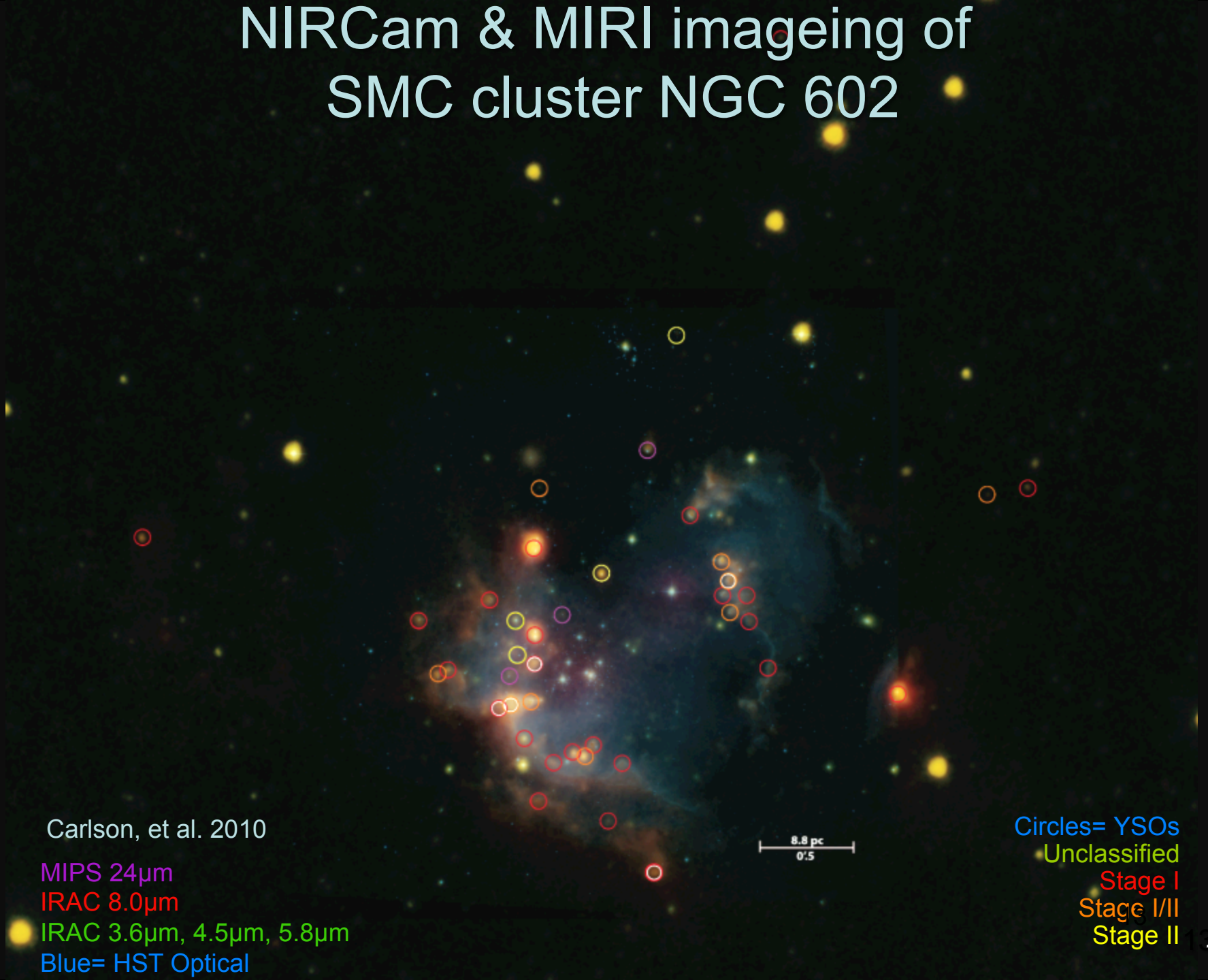
NIRCam



NIRISS



NIRCam & MIRI imageing of SMC cluster NGC 602

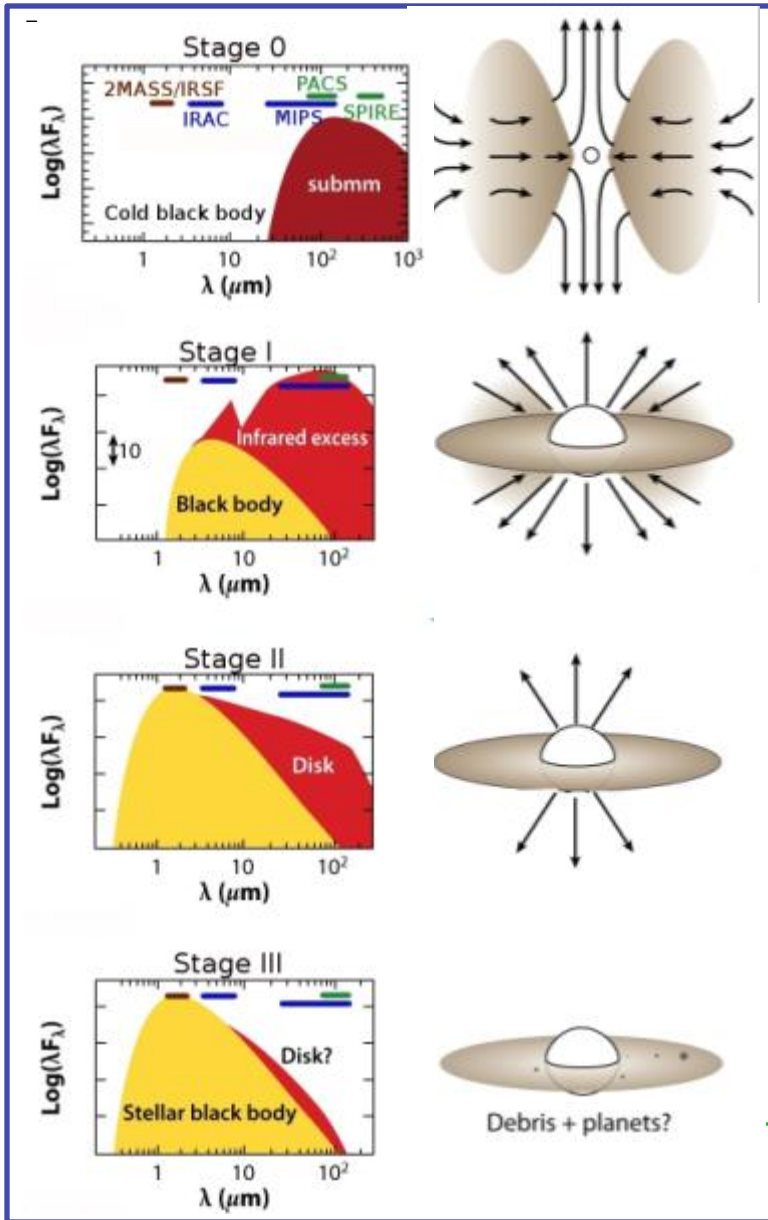


Carlson, et al. 2010

MIPS 24μm
IRAC 8.0μm
IRAC 3.6μm, 4.5μm, 5.8μm
Blue= HST Optical

Circles= YSOs
Unclassified
Stage I
Stage I/II
Stage II

Young Stellar Object Evolutionary Stages



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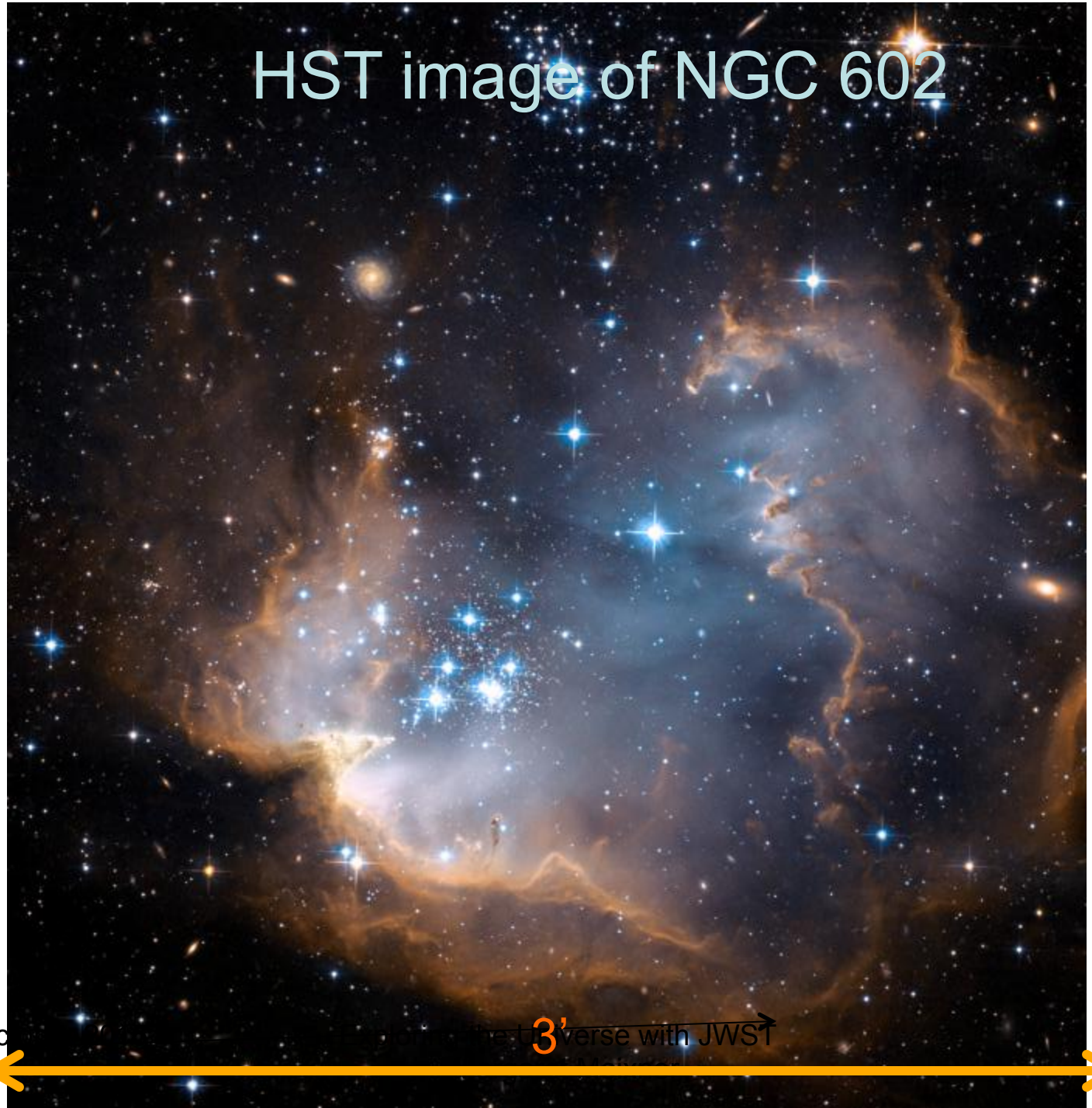
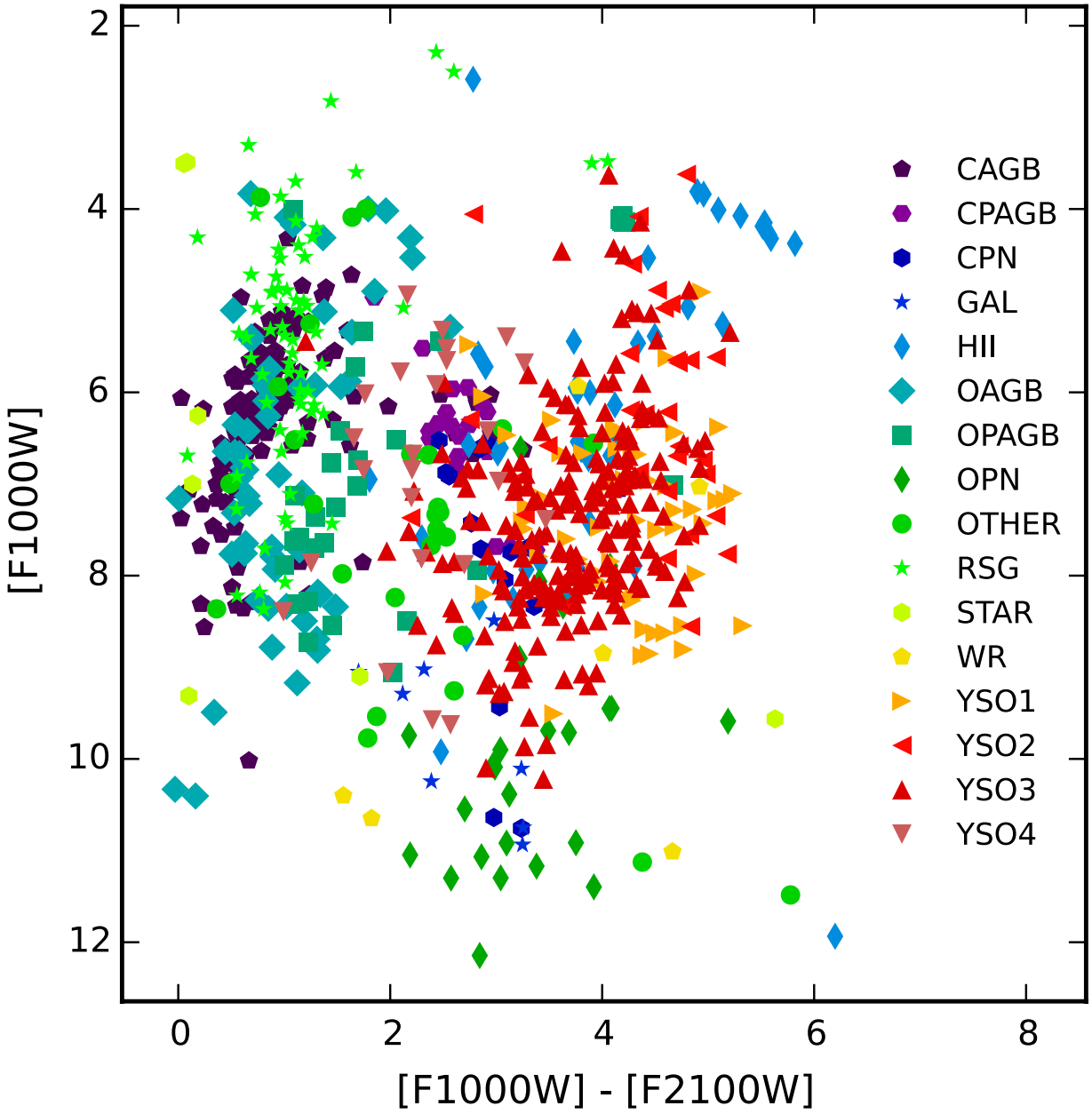
HST image of NGC 602



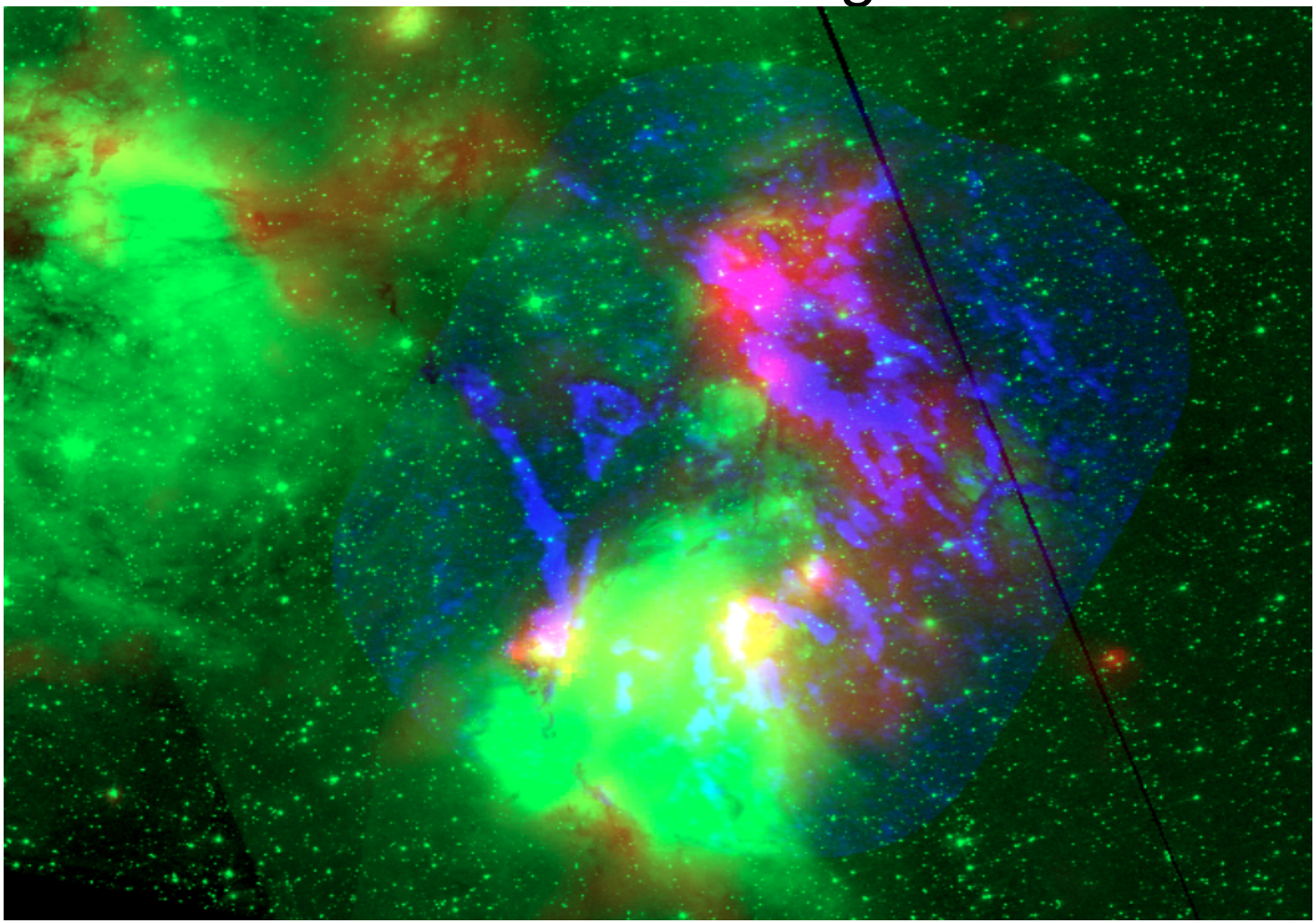
15

MIRI predictions for LMC YSOs, etc.



Jones & Meixner poster –GA14

NIRSpec & MIRI spectroscopy of LMC star formation region N159



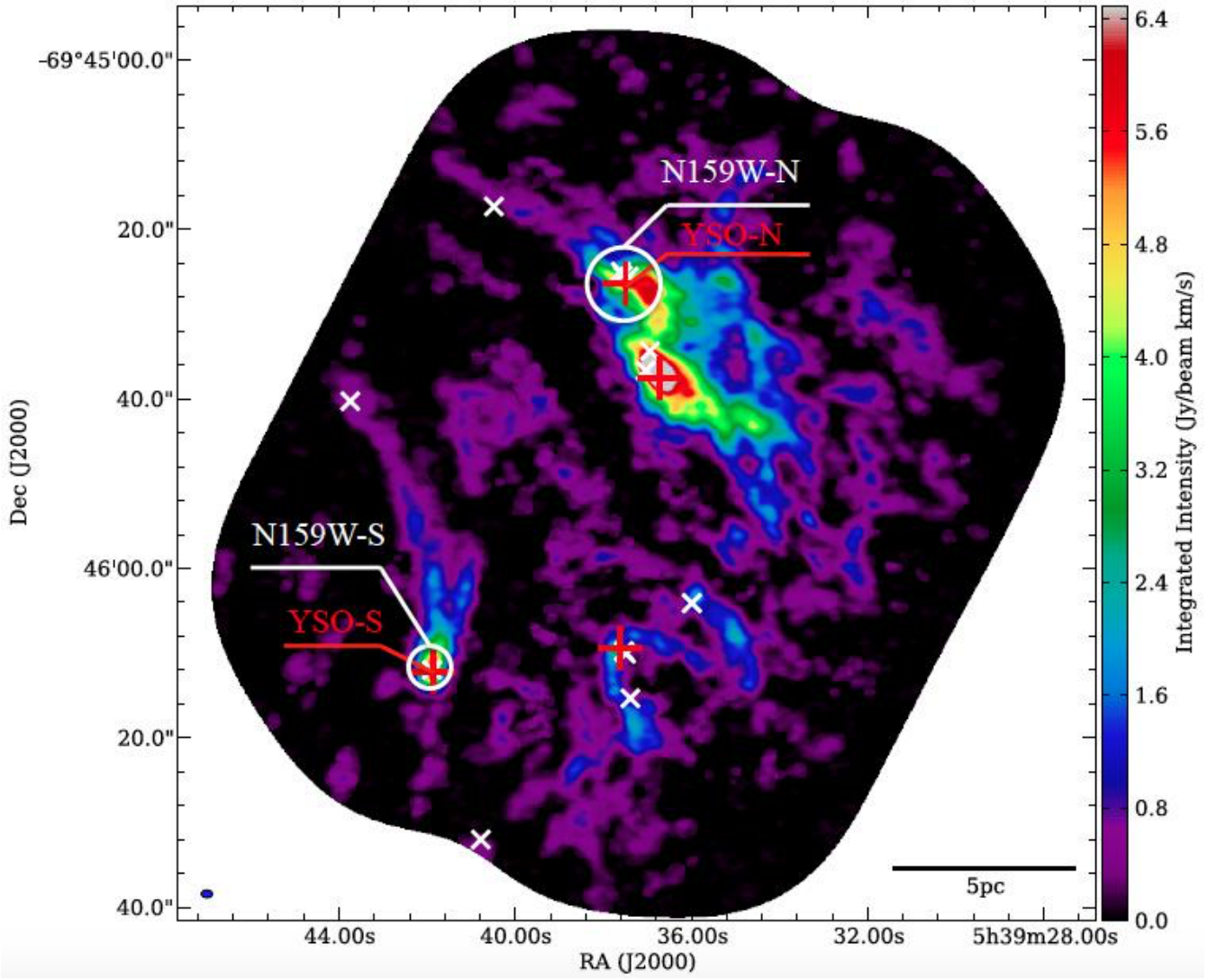
R: Spitzer 8 micron, G: HST F555W, B: ALMA 13CO(2-1)

HST PI: R. Indebetouw ALMA PI: Y. Fukui

Filaments Revealed in ALMA 12 m Array 13CO (2-1)

White X's: YSOs
(Chen et al. 2010)

Red Crosses: 1.3mm
continuum peak



Fukui et al. 2015

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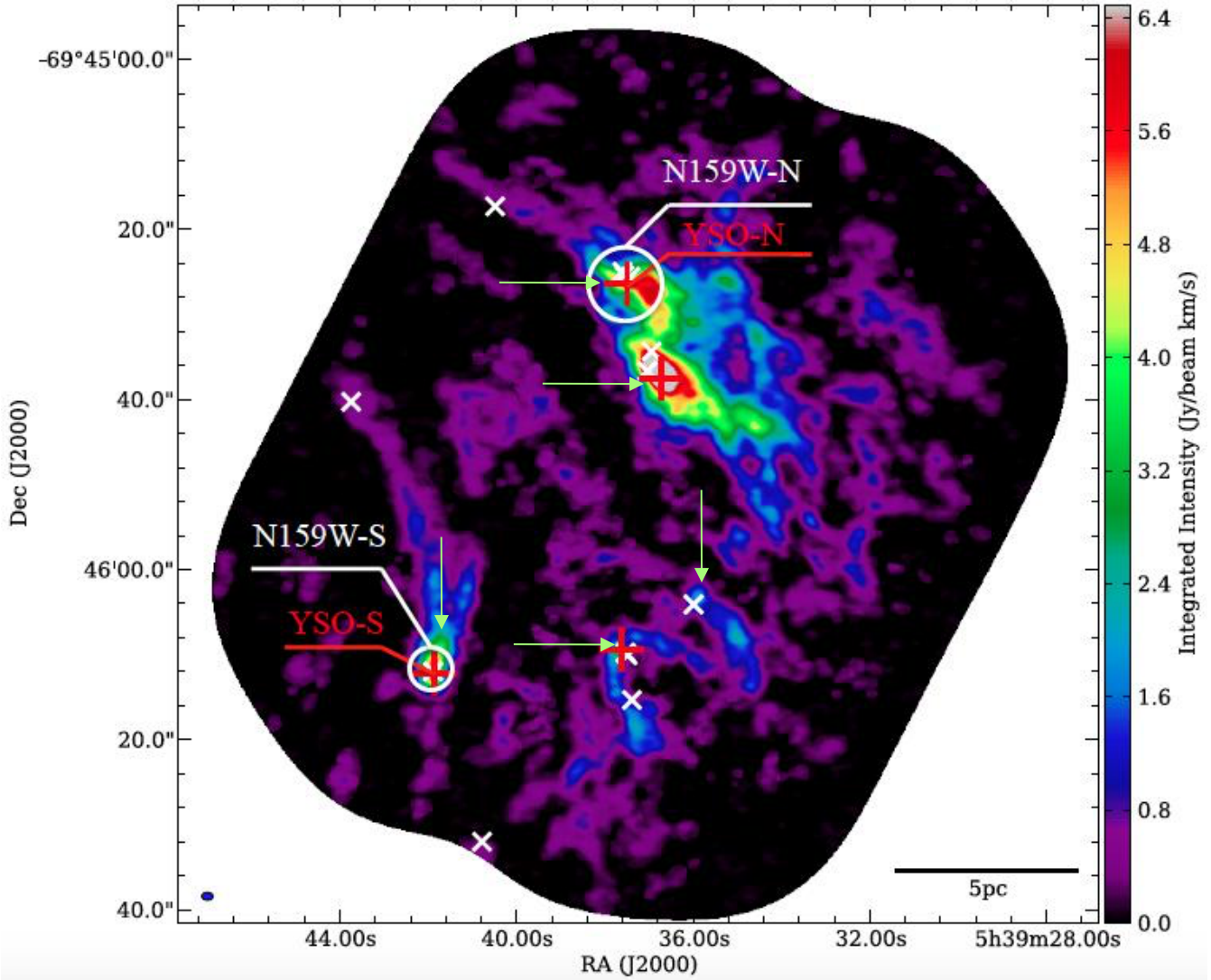
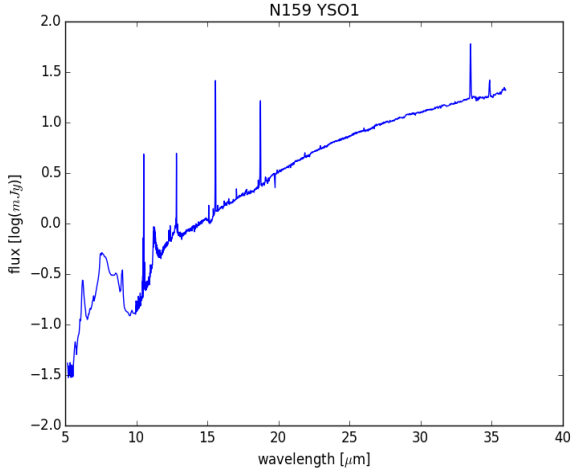


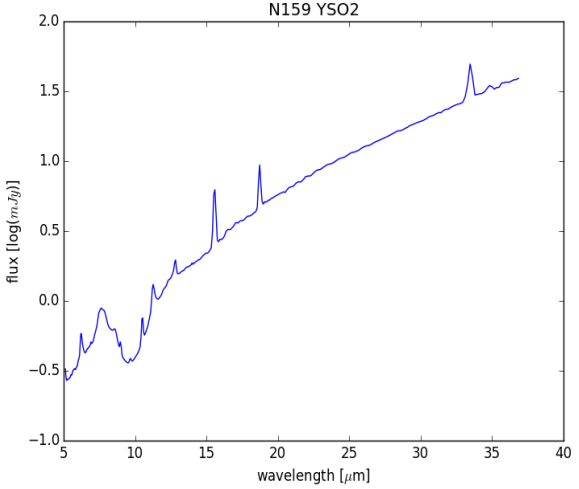
Fukui et al. 2015

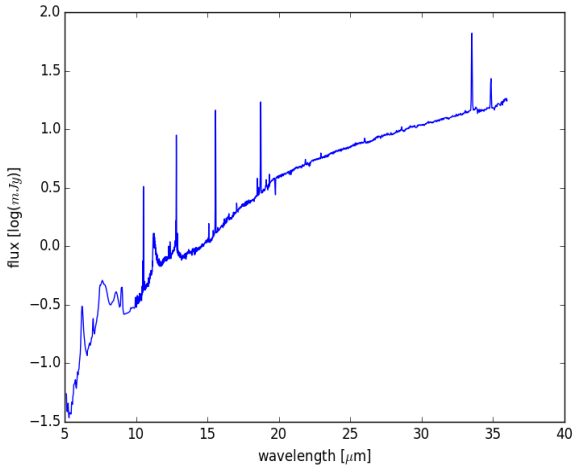
Spitzer IRS Spectra of YSOs in N159W

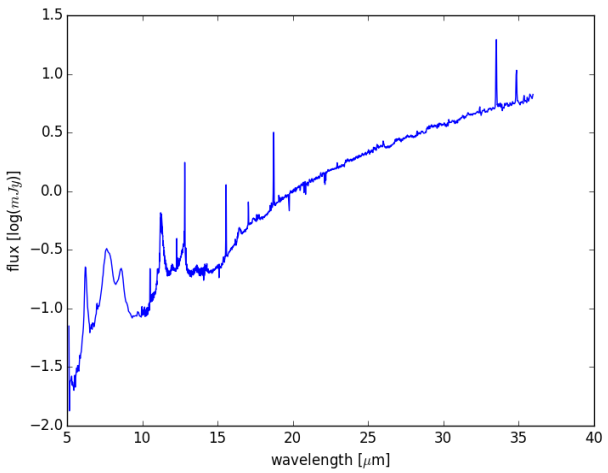
N159W YSO-N

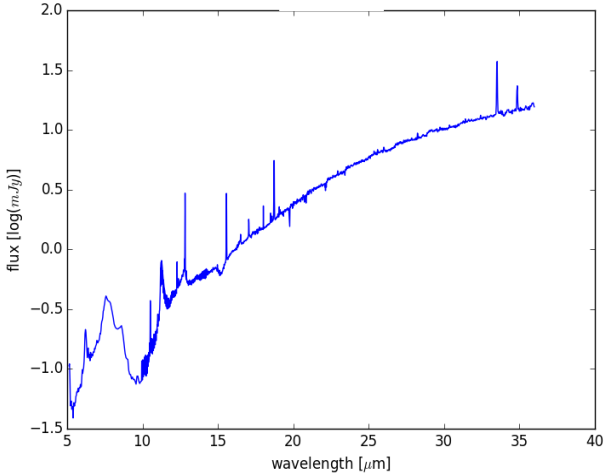


N159W YSO-S





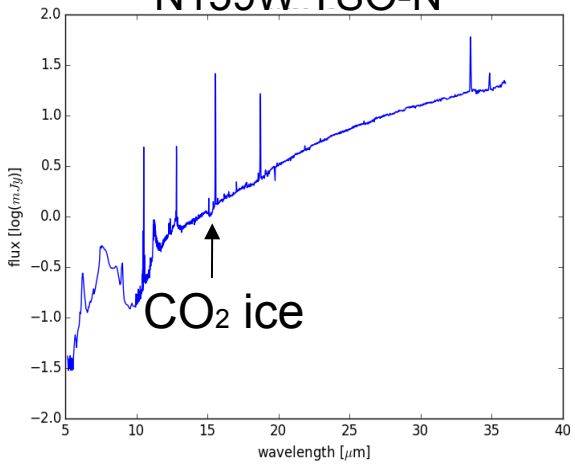




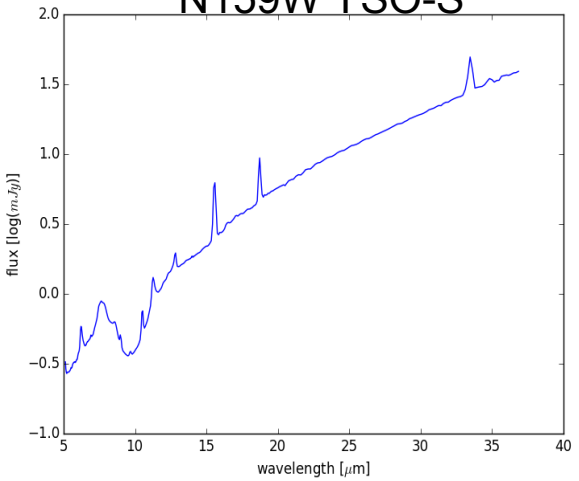
Nayak et al. in prep

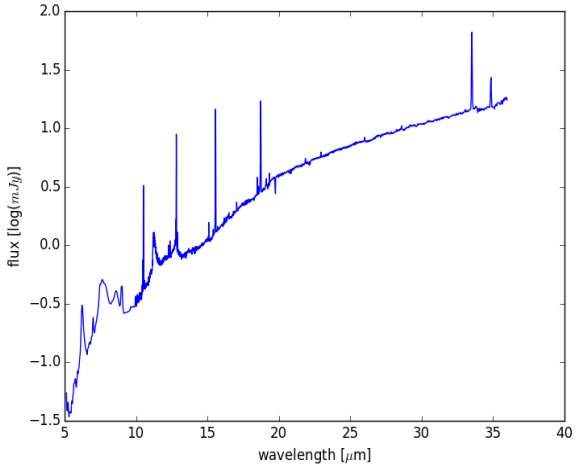
PAH and Ices in N159W YSOs

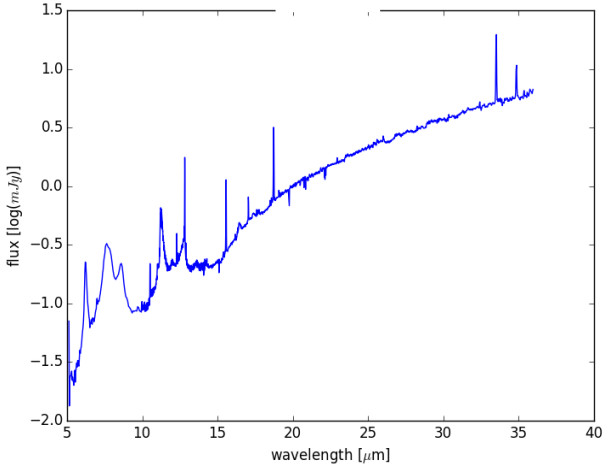
N159W YSO-N

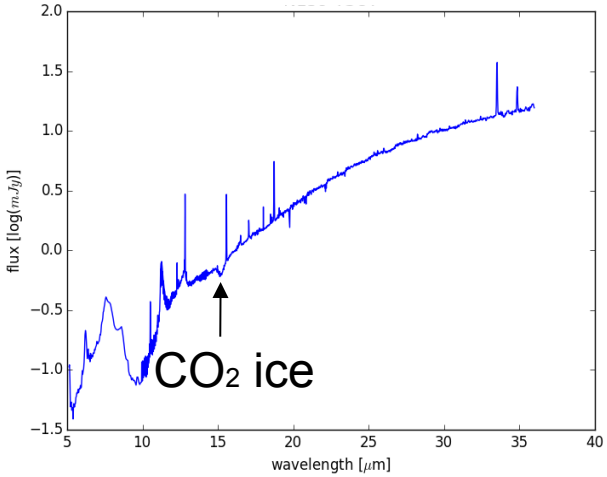


N159W YSO-S



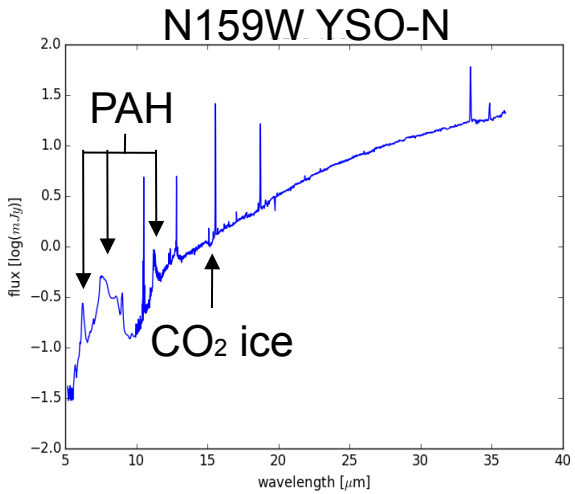


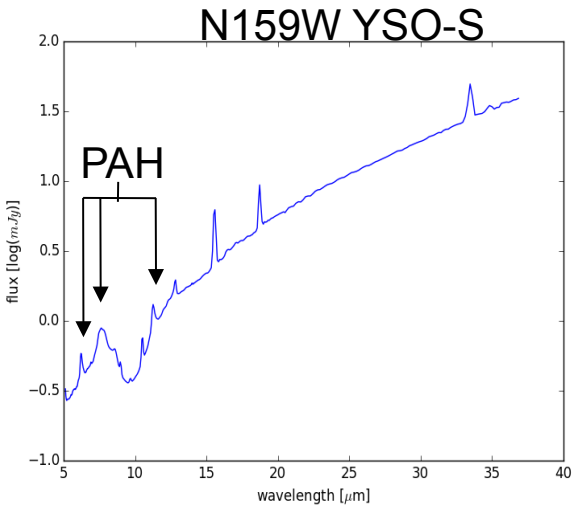


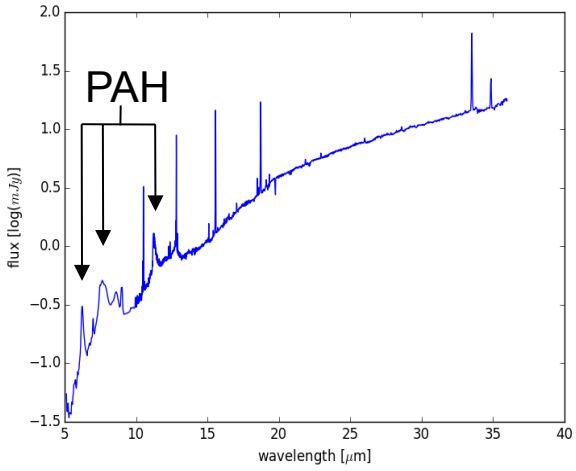


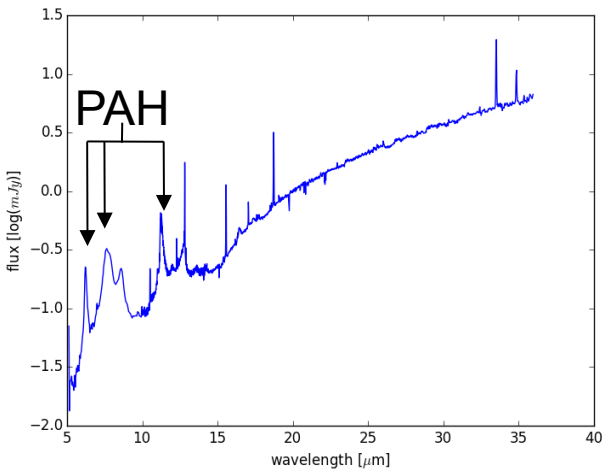
Nayak et al. in prep

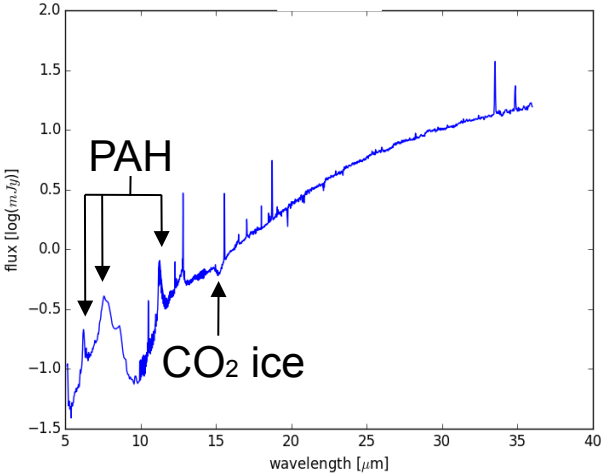
PAH and Ices in N159W YSOs





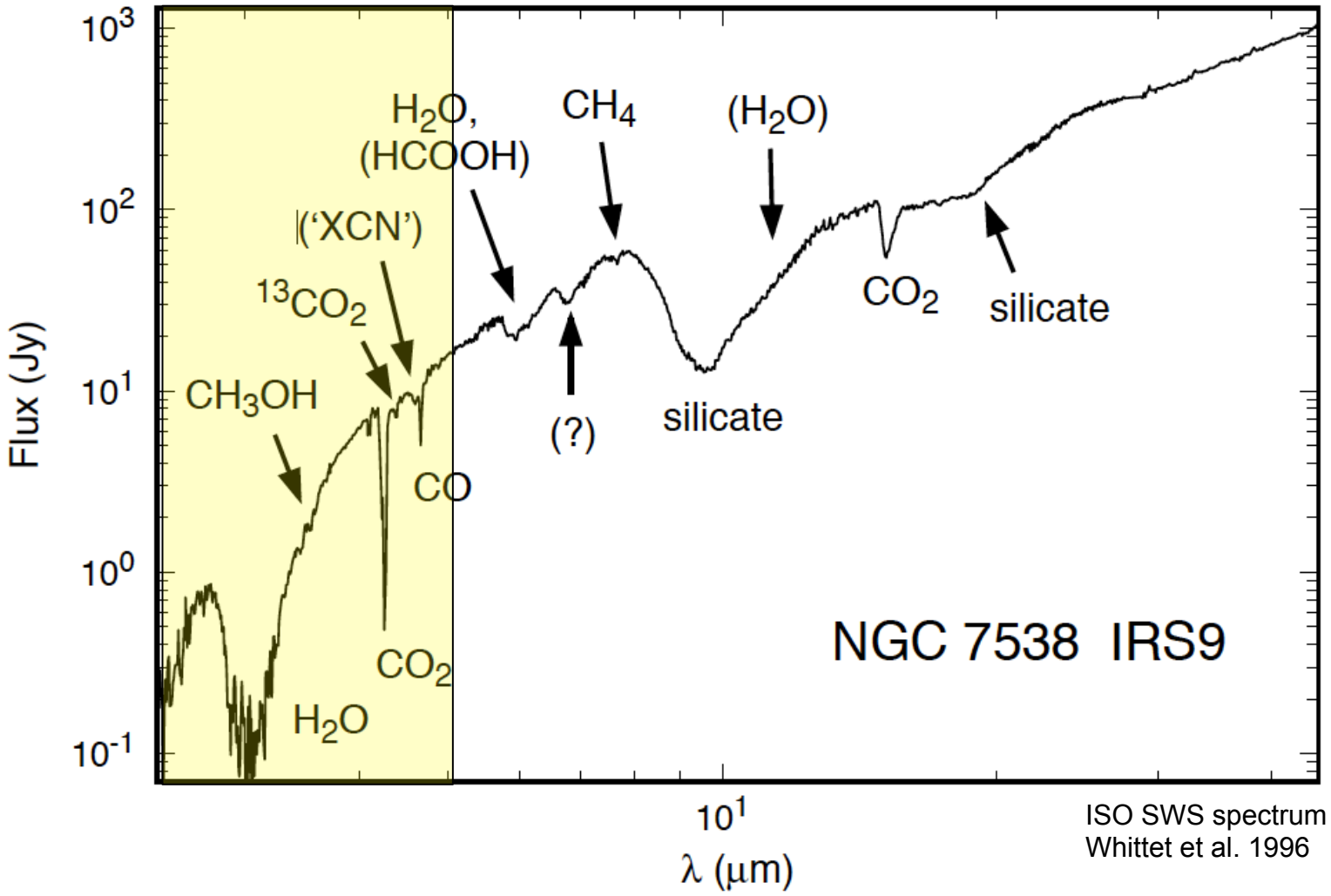






Nayak et al. in prep

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



ISO SWS spectrum
Whittet et al. 1996

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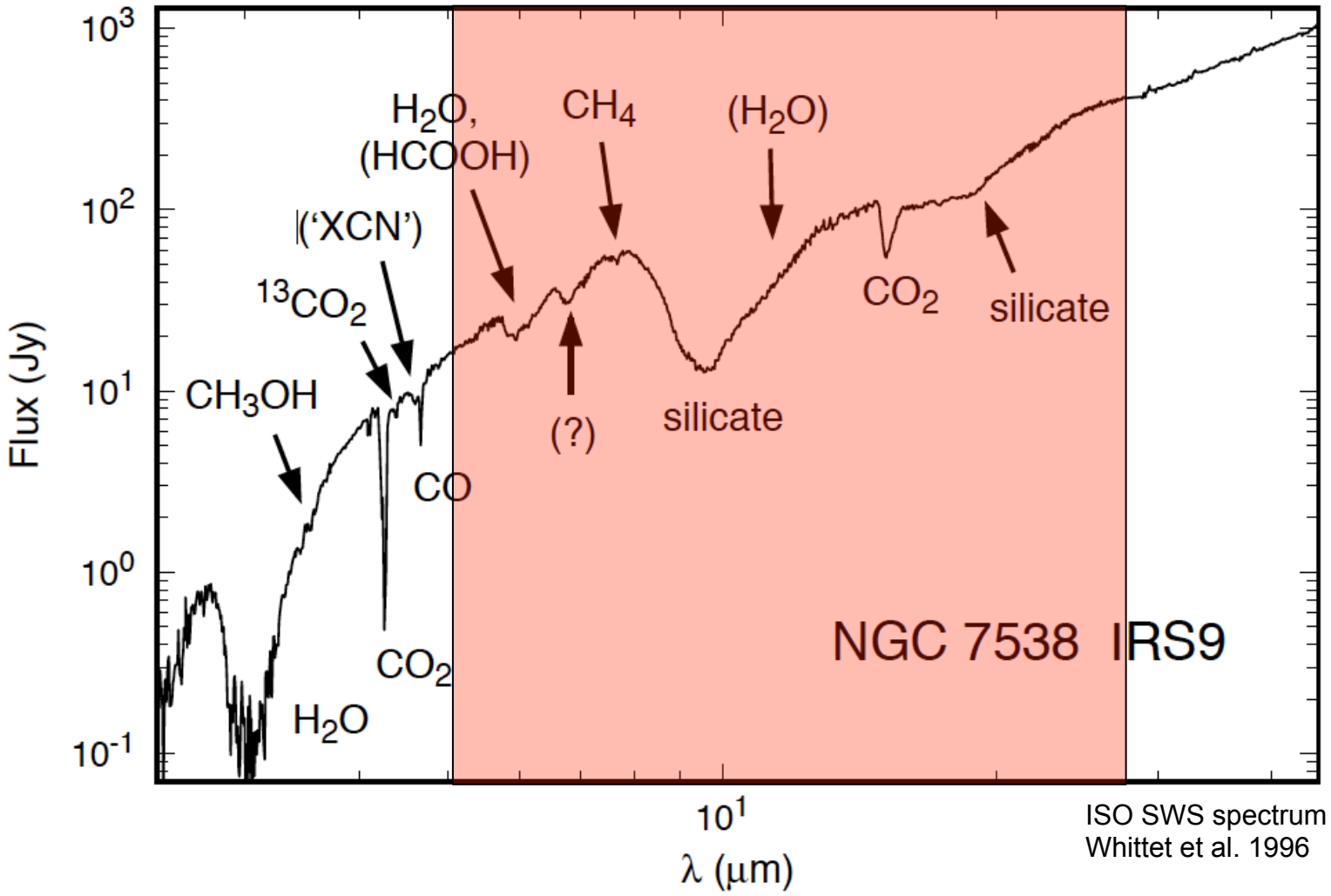

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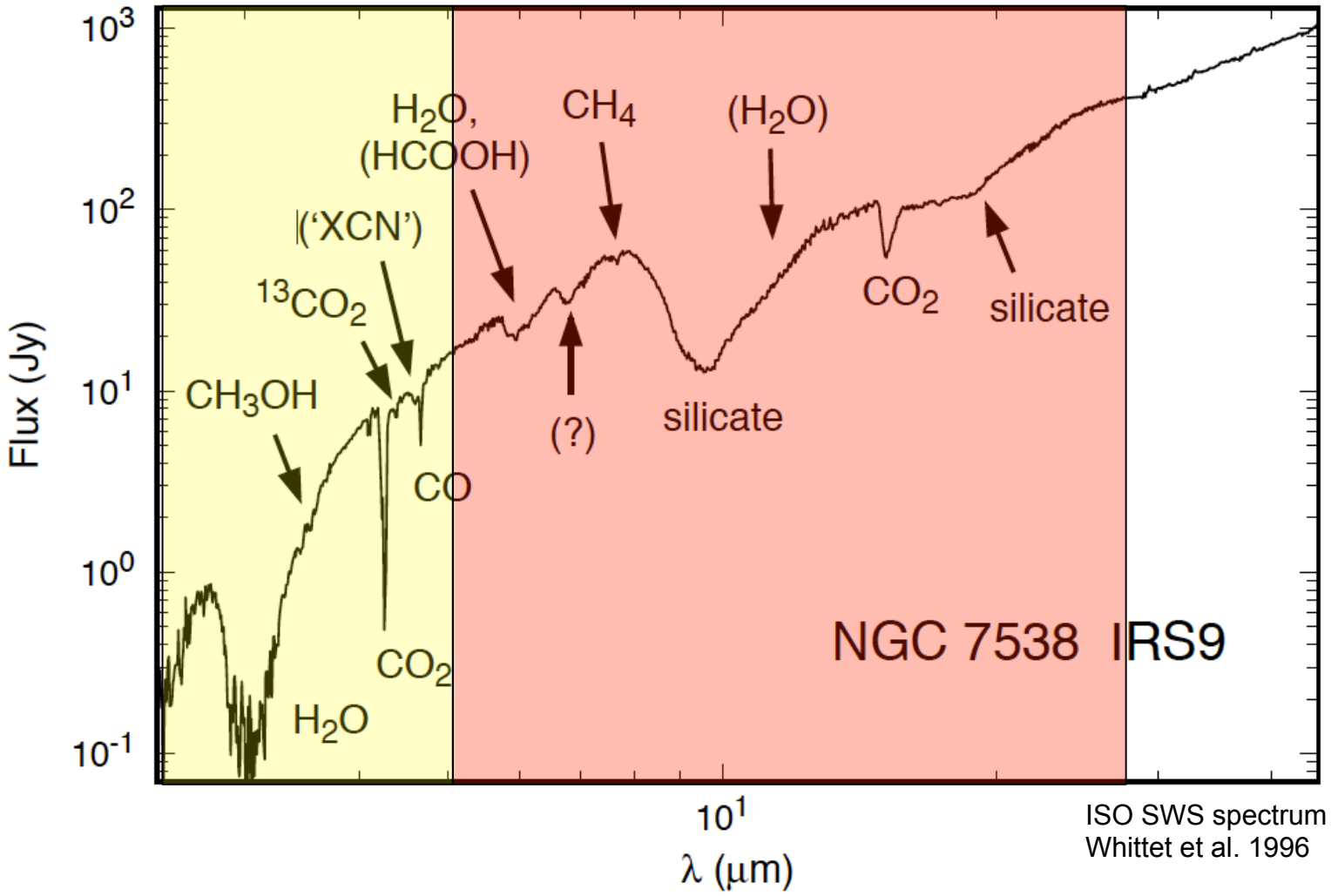

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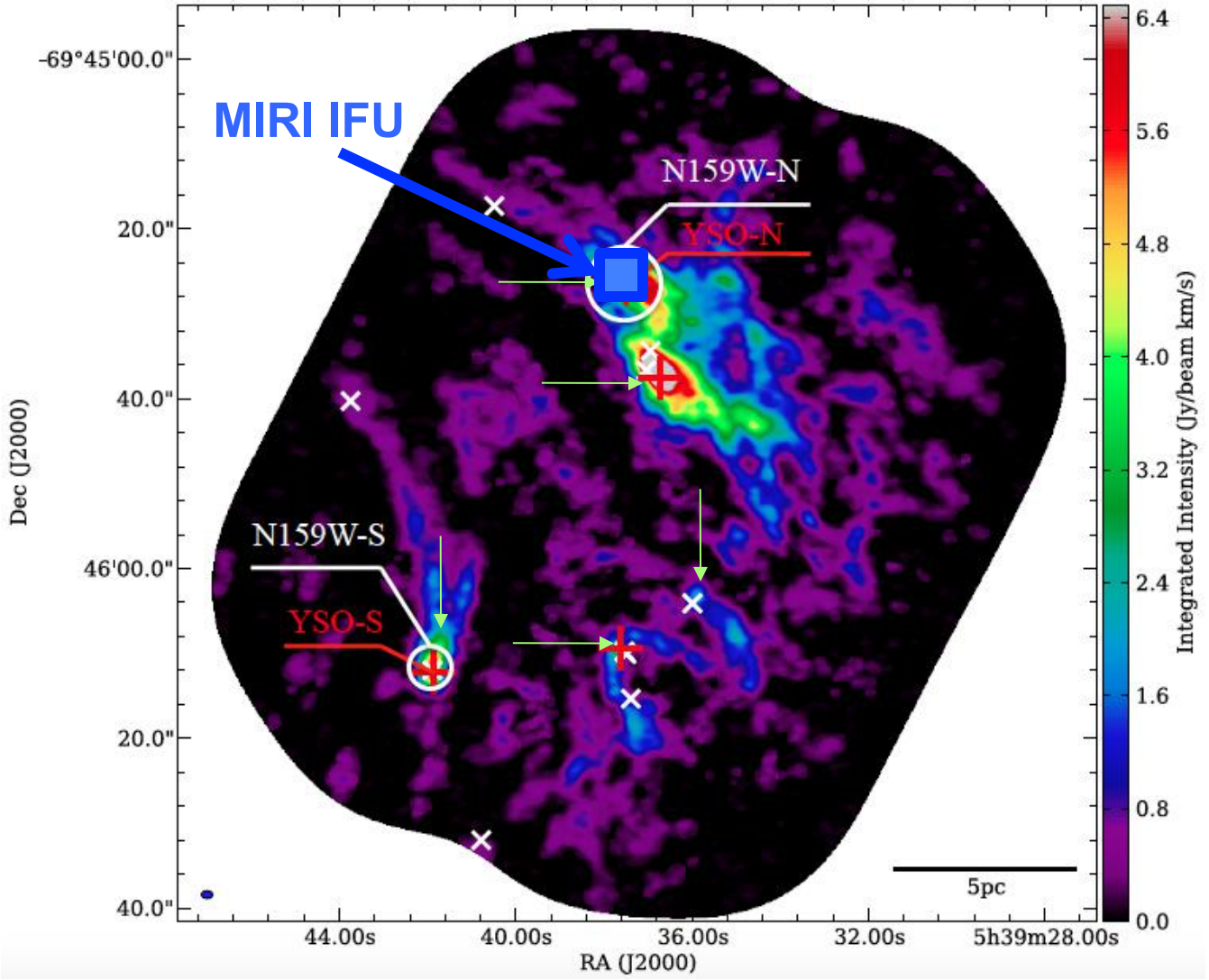

Fukui et al. 2015

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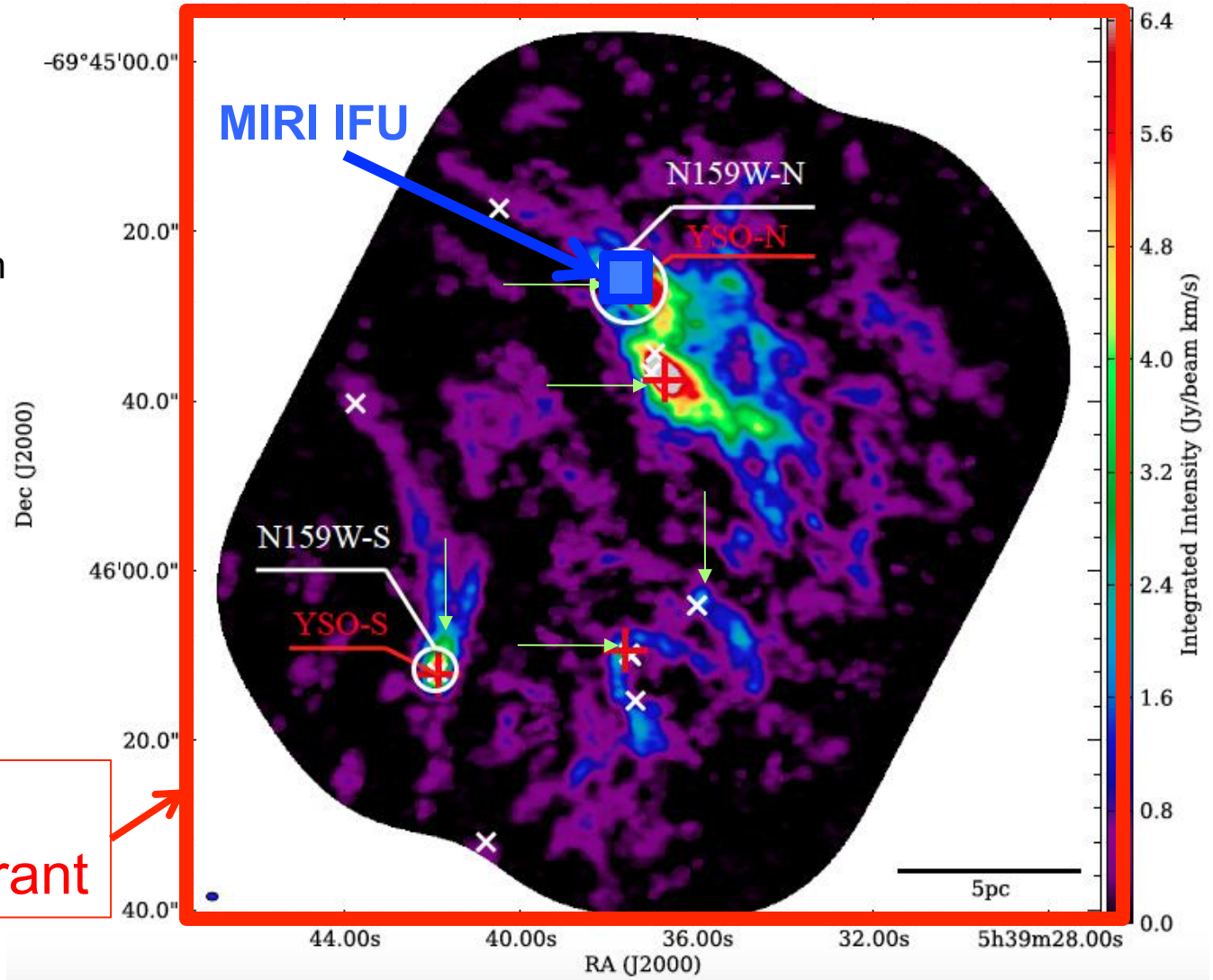
NIRSpec:
MSA – 1 quadrant



Fukui et al. 2015

Summary:

- Thousands of mostly massive, YSO candidates in LMC & SMC.
- Hundreds of Spitzer spectra of Massive YSO's in LMC & SMC:
  - Classification using PAHs & Ices
  - Differences with Ices and metallicity/environment: low CO & CO_2 in SMC, high CO & CO_2 in LMC

- JWST will enable Galactic type star formation studies in the low metalicity environments of the LMC and SMC
  - MIRI & NIRCam imaging of HST studied clusters will reveal the Stage II and III YSOs down to 1 $M_{\odot}$, SMC/NGC 602
  - NIRSpec & MIRI spectroscopy to investigate nature of YSOs, potential for discovery, e.g. ice chemistry at low metallicity, LMC/N159