Massive Star Formation in the LMC

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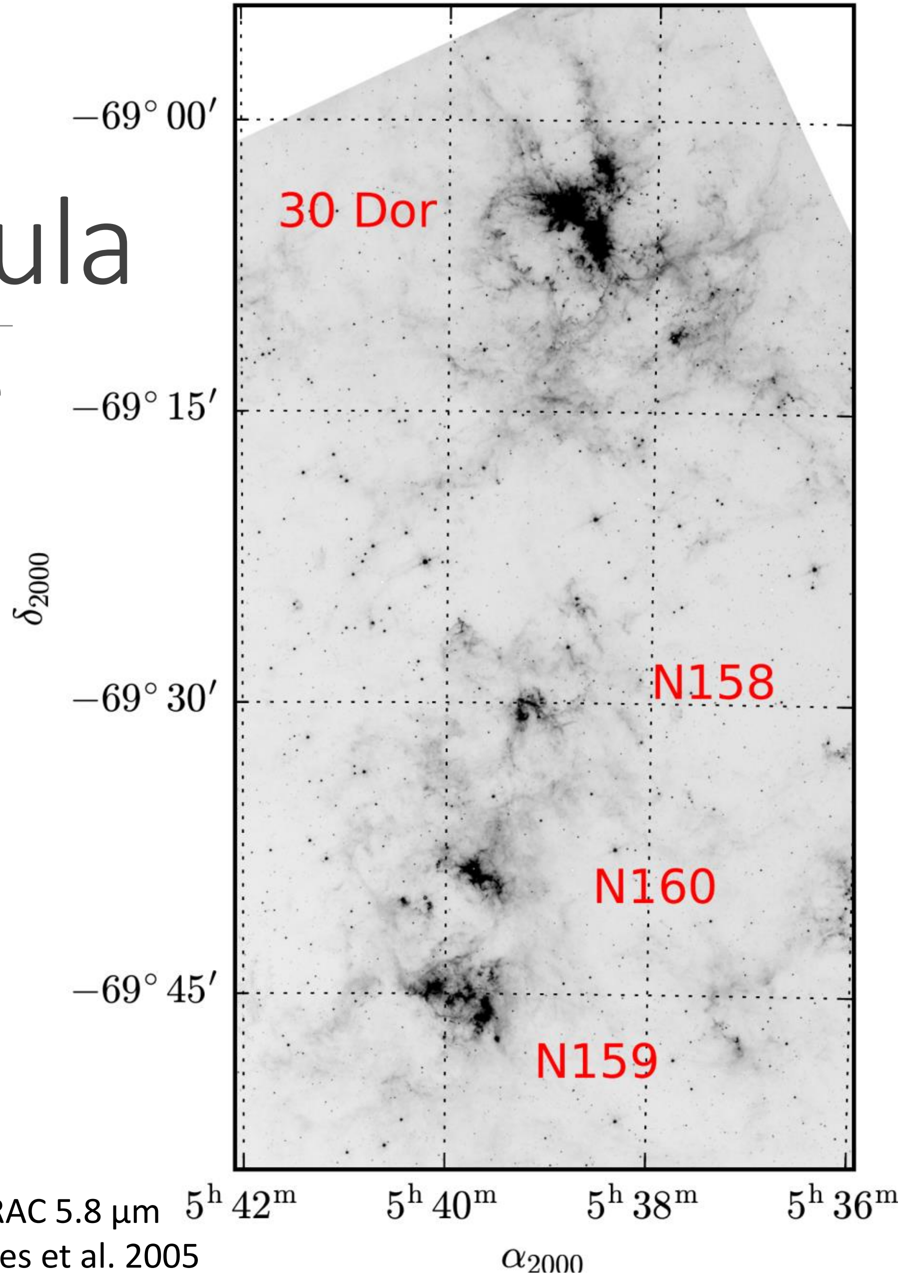
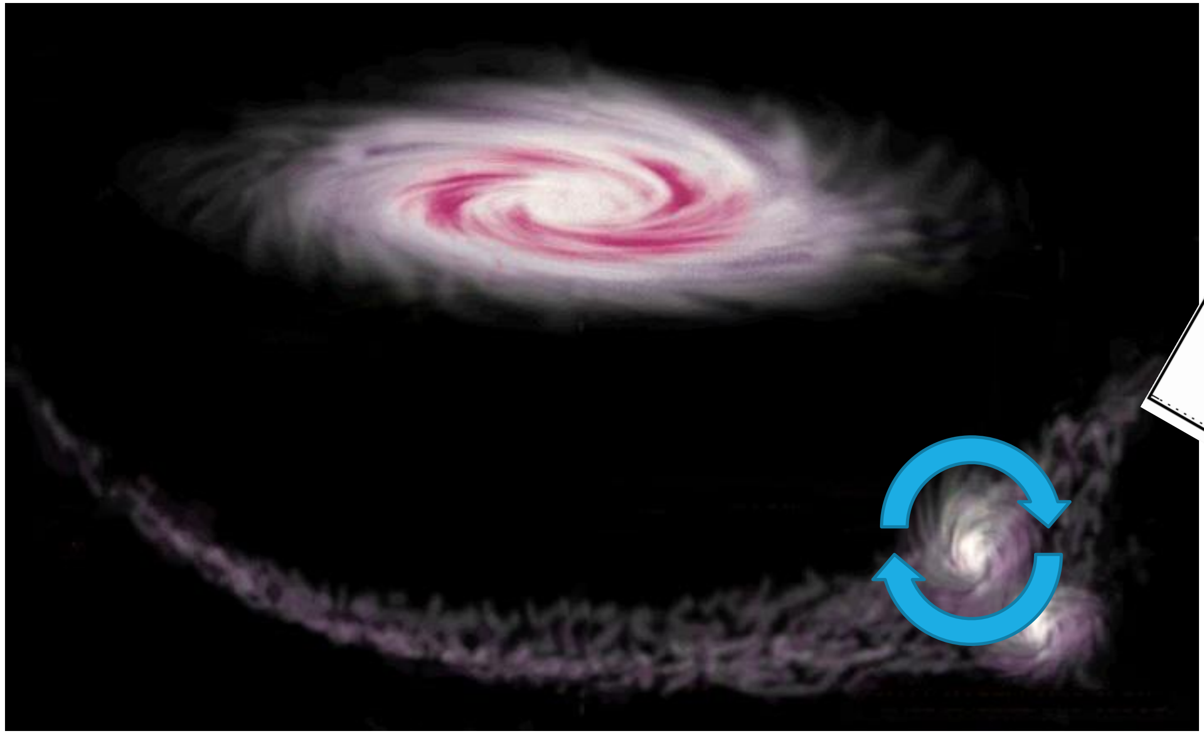
30 Doradus/Tarantula Nebula

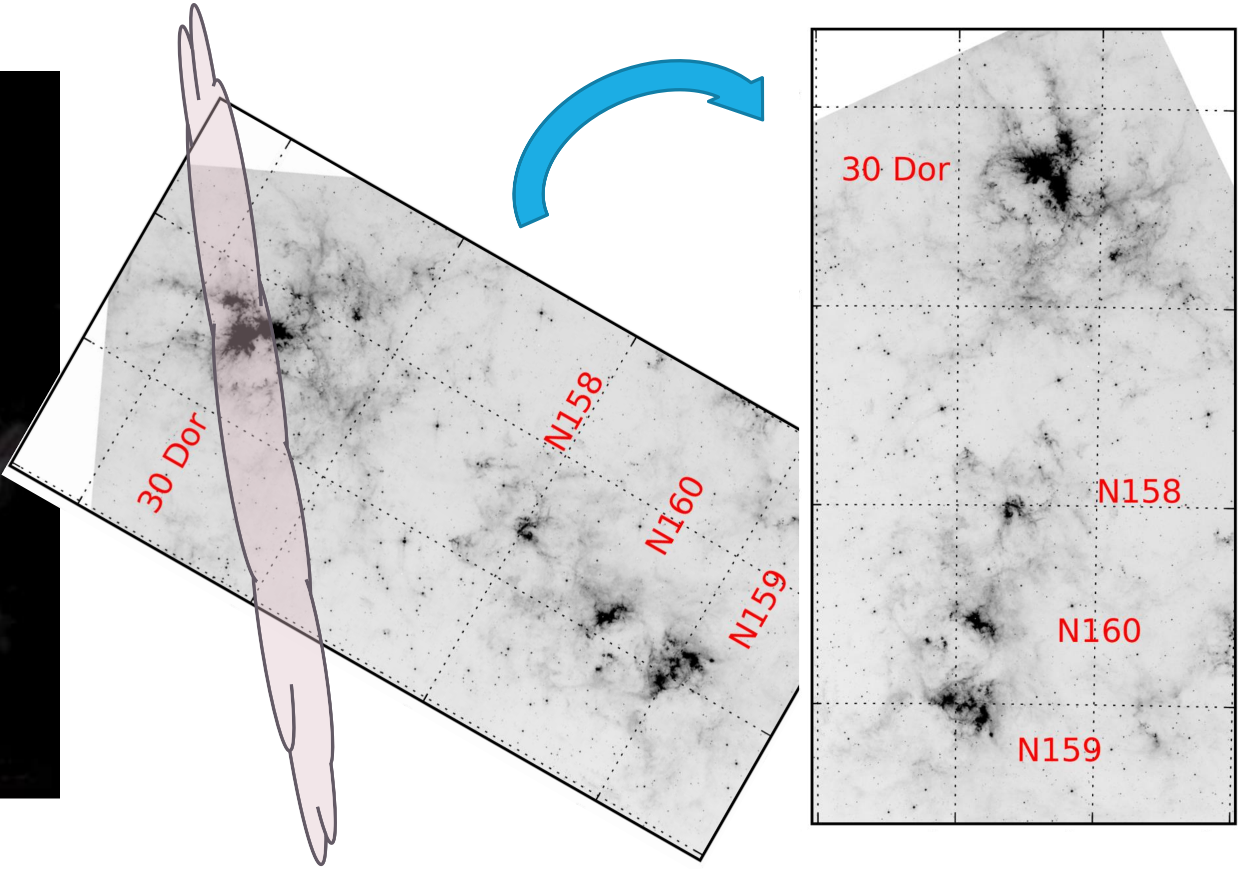
- Largest and most active star-forming region in the Local Group
- CO peak at N159—indicator of pre-star core
- Hosts extragalactic protostars, **P1** and **P2**
- Numerous HII regions and filamentary Hα emitting bubbles
- **Excellent laboratory for studying star formation**



MSG 2017, Spitzer/IRAC 5.8 µm reproduced from Jones et al. 2005

De Boer 1998, Bow-Shock Induced SF

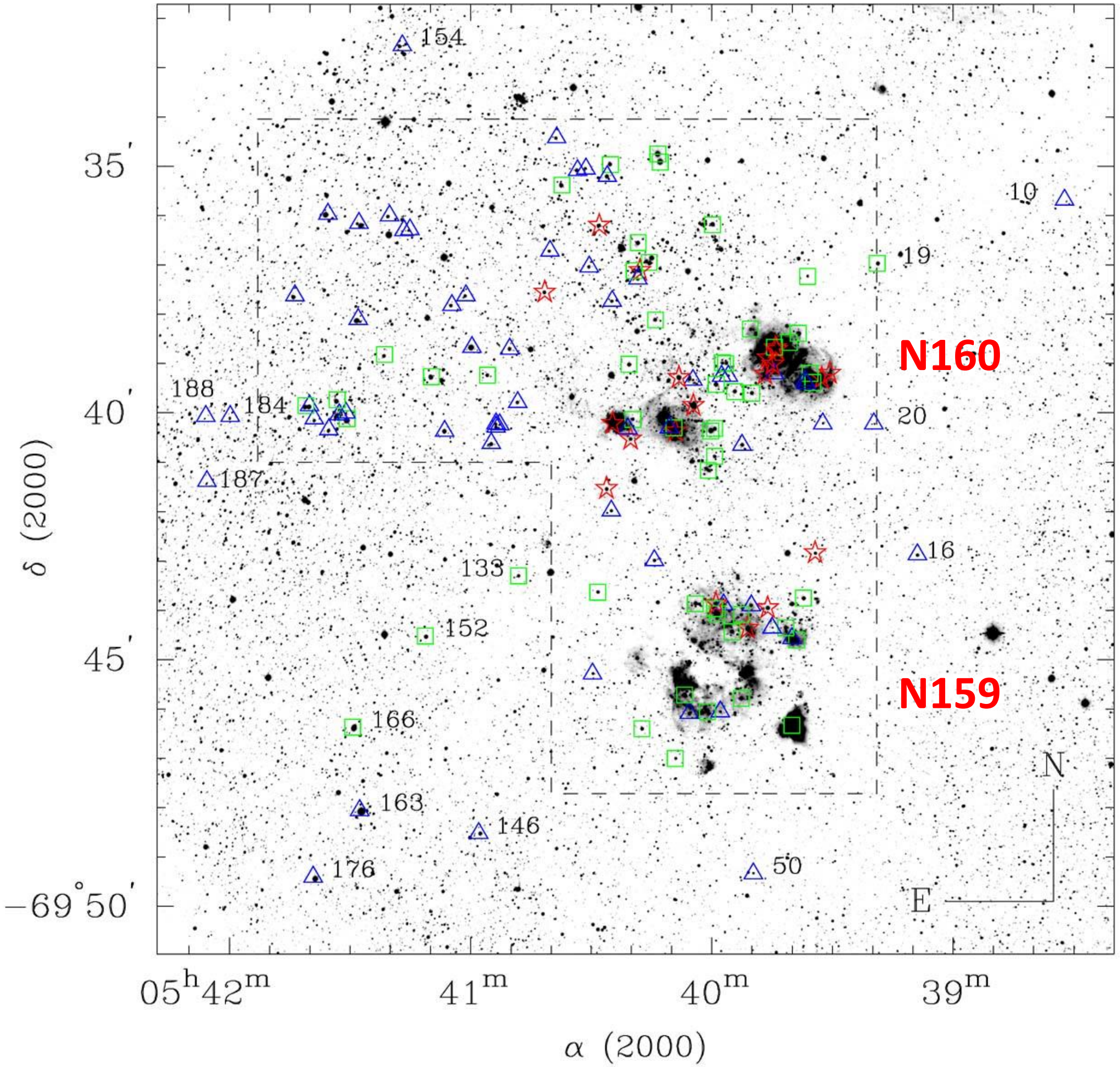




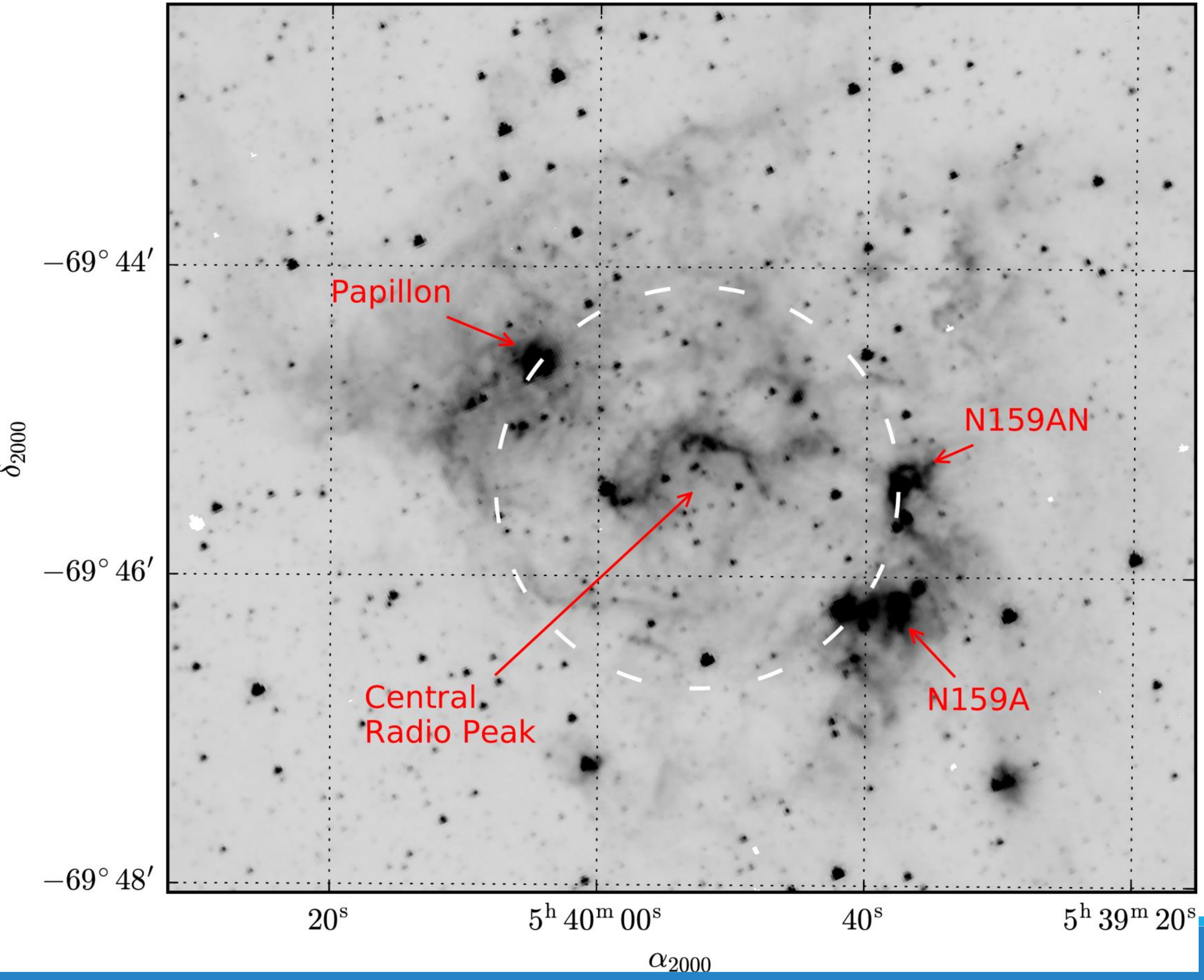
Age Gradient?

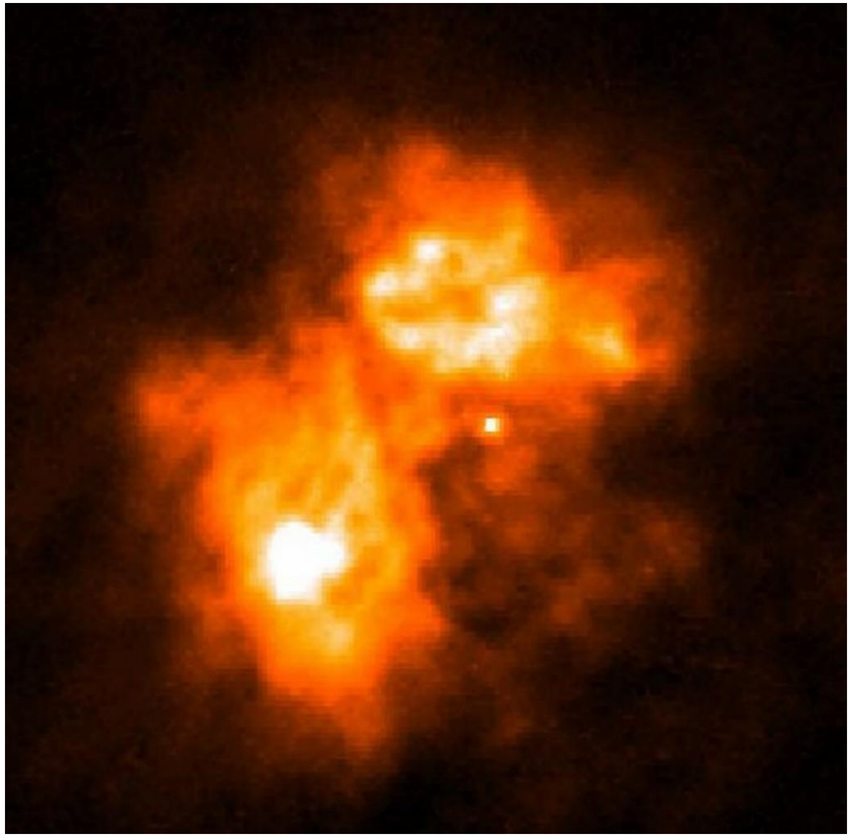
- De Boer et al. 1998; MW bow-shock scenario
  - Ages NW to SE as LMC rotates
  - Sequential, but not triggered (not self-propagating)

- Farina et al. 2009; common time origin for N159/N160
  - No specific N to S age gradient
  - Areas within HII regions may still have triggered star formation



Farina et al. 2009. O3-O5, O6-B0, B1-B8





"Papillon"—M. Heydari-Malayeri, HST WFPC2

"High-excitation blob" HEB

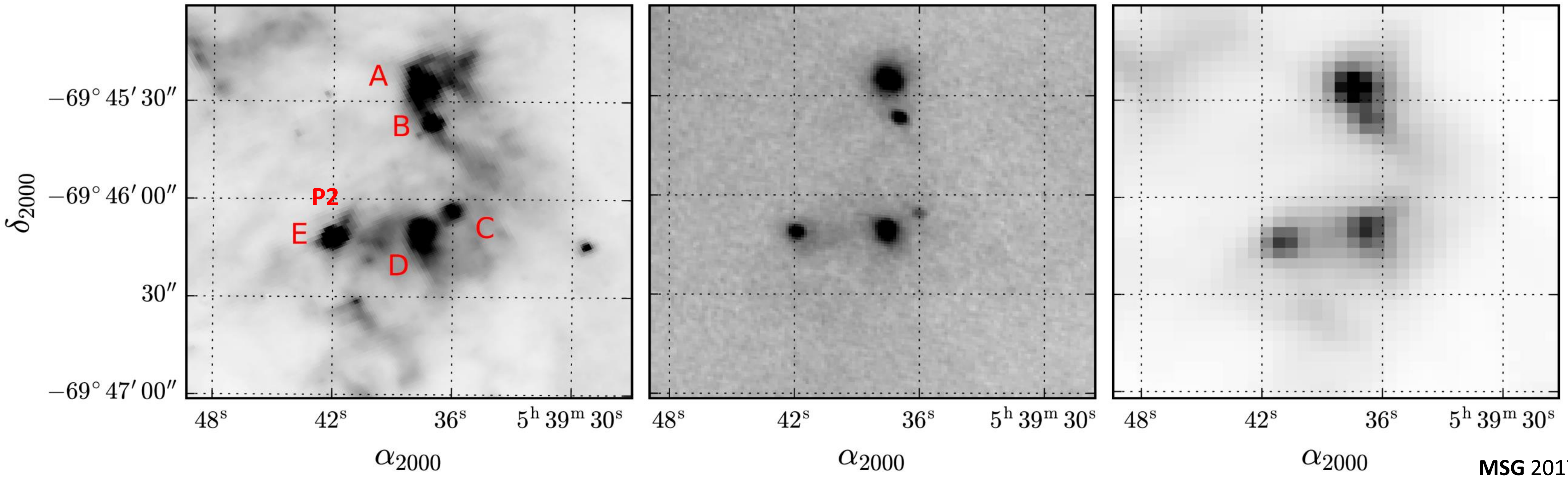
High excitation state, small size, high density, and large extinction compared to avg HII reg

MSG 2017, Spitzer/IRAC 3.6 µm reproduced from Jones et al. 2005

Goals

- Mid-infrared census of N159 and N160
- Spatially-resolve Spitzer/IRAC sources at $\lambda > 20$ microns (***requires SOFIA!***)
- Search for massive young stellar objects
  - embedded sources will be bright at 30 microns ***with no IRAC counterpart***
  - these would be analogous to Class 0 YSOs or young IRDCs
- Study local environment of massive star-forming regions
  - dust temperature
  - dust content
  - mass-accretion rates

N159A



Spitzer/IRAC 5.8 µm FORCAST 31.5 µm Herschel/PACS 100 µm

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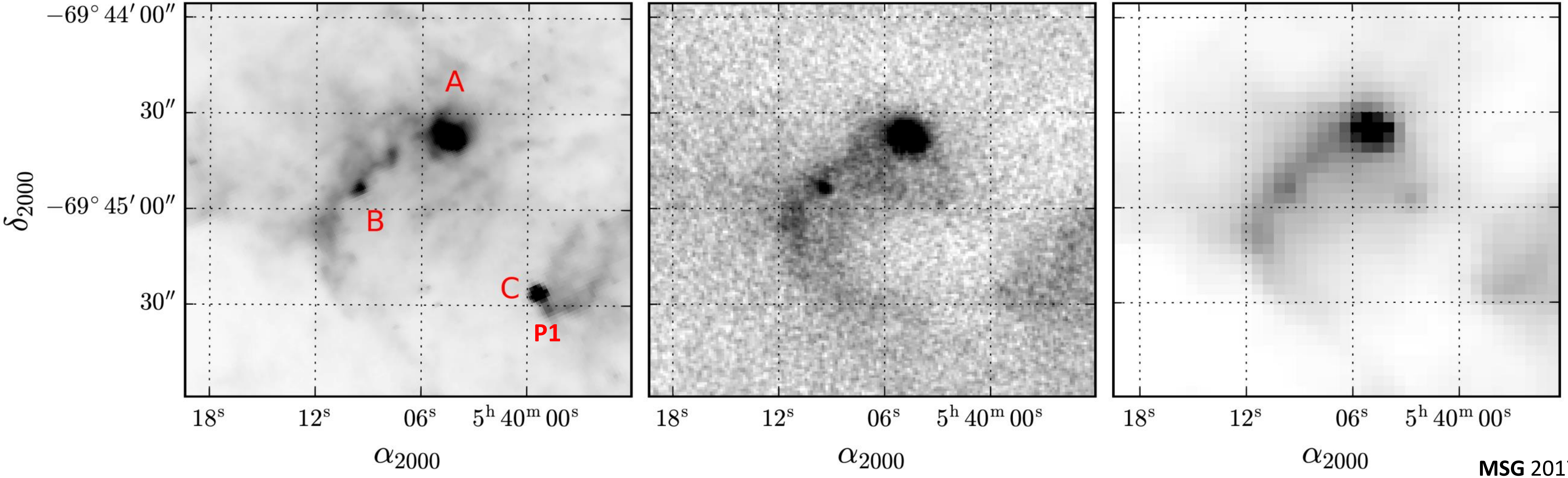
N159 Papillon



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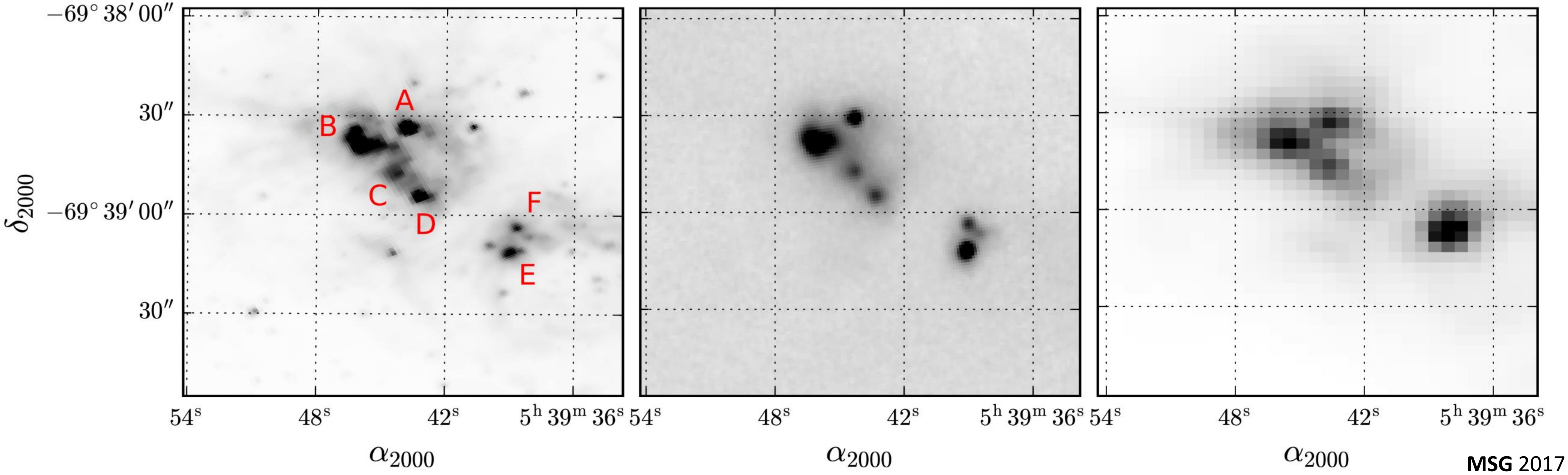
Spitzer/IRAC 5.8 μm

FORCAST 37.1 μm

Herschel/PACS 100 μm

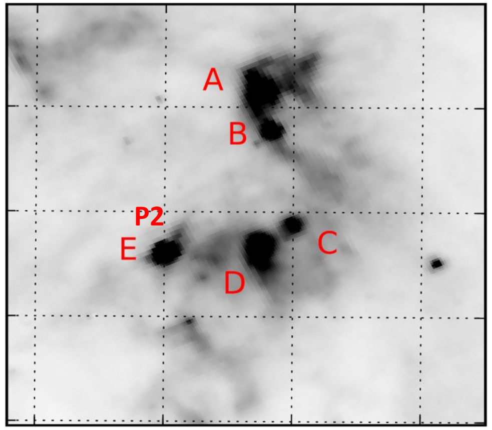
N160



Spitzer/IRAC 3.6 µm

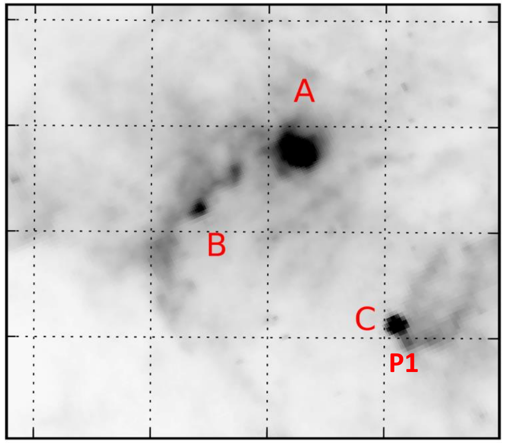
FORCAST 31.5 µm

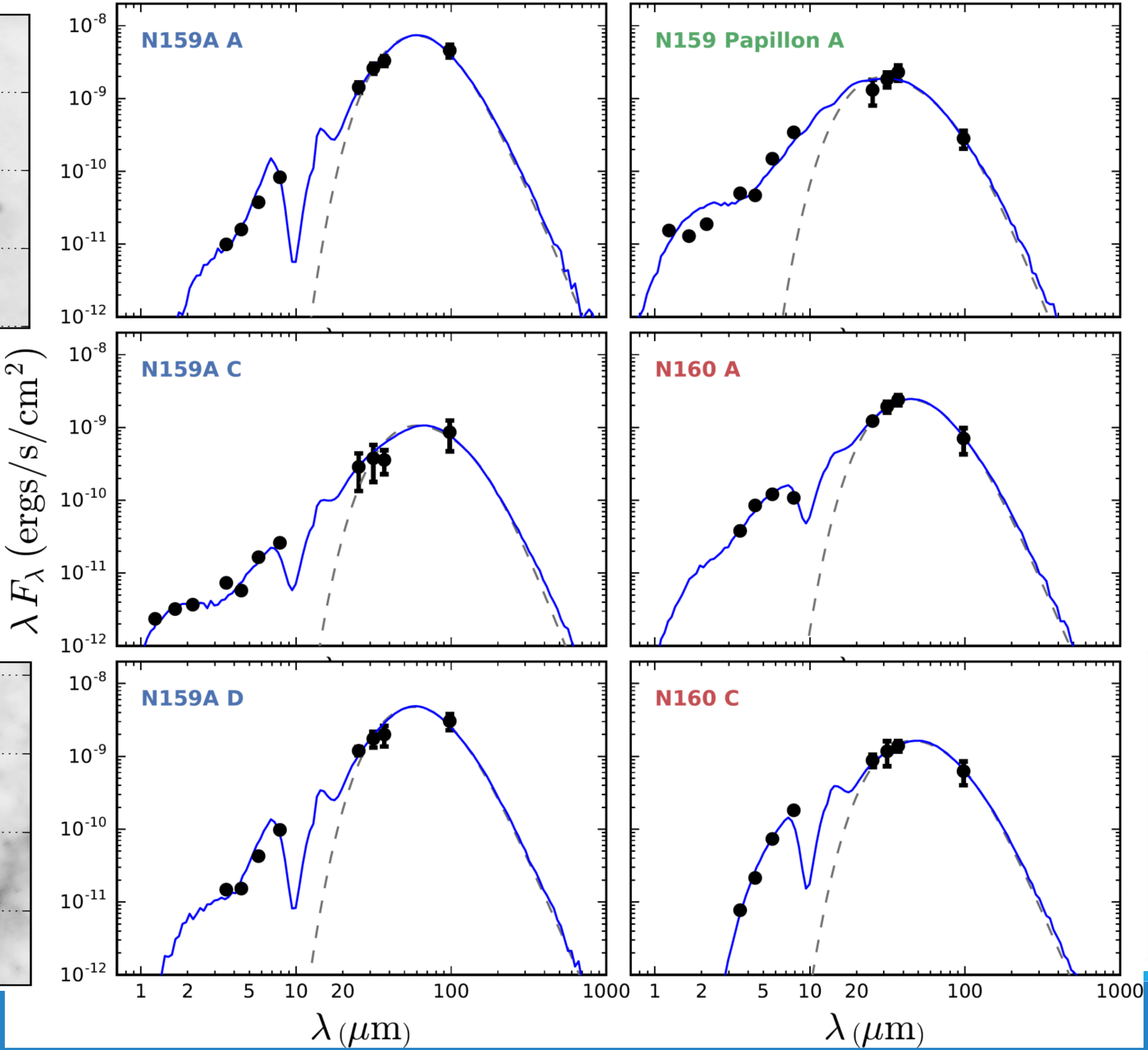
Herschel/PACS 100 µm



N159A

N159 Pap





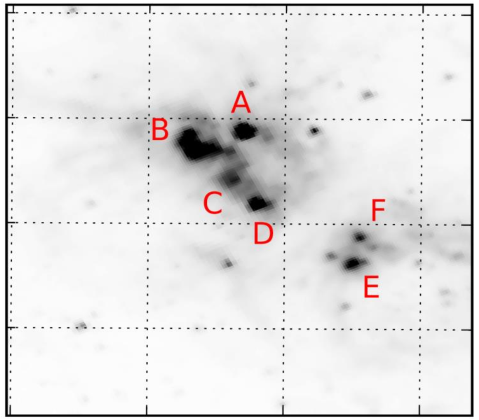
MSG 2017,
SED models from
Robitaille et al. 2007

Gray body fits to
characterize thermal dust
emission

$$\epsilon_\lambda \propto \lambda^{-\beta}$$

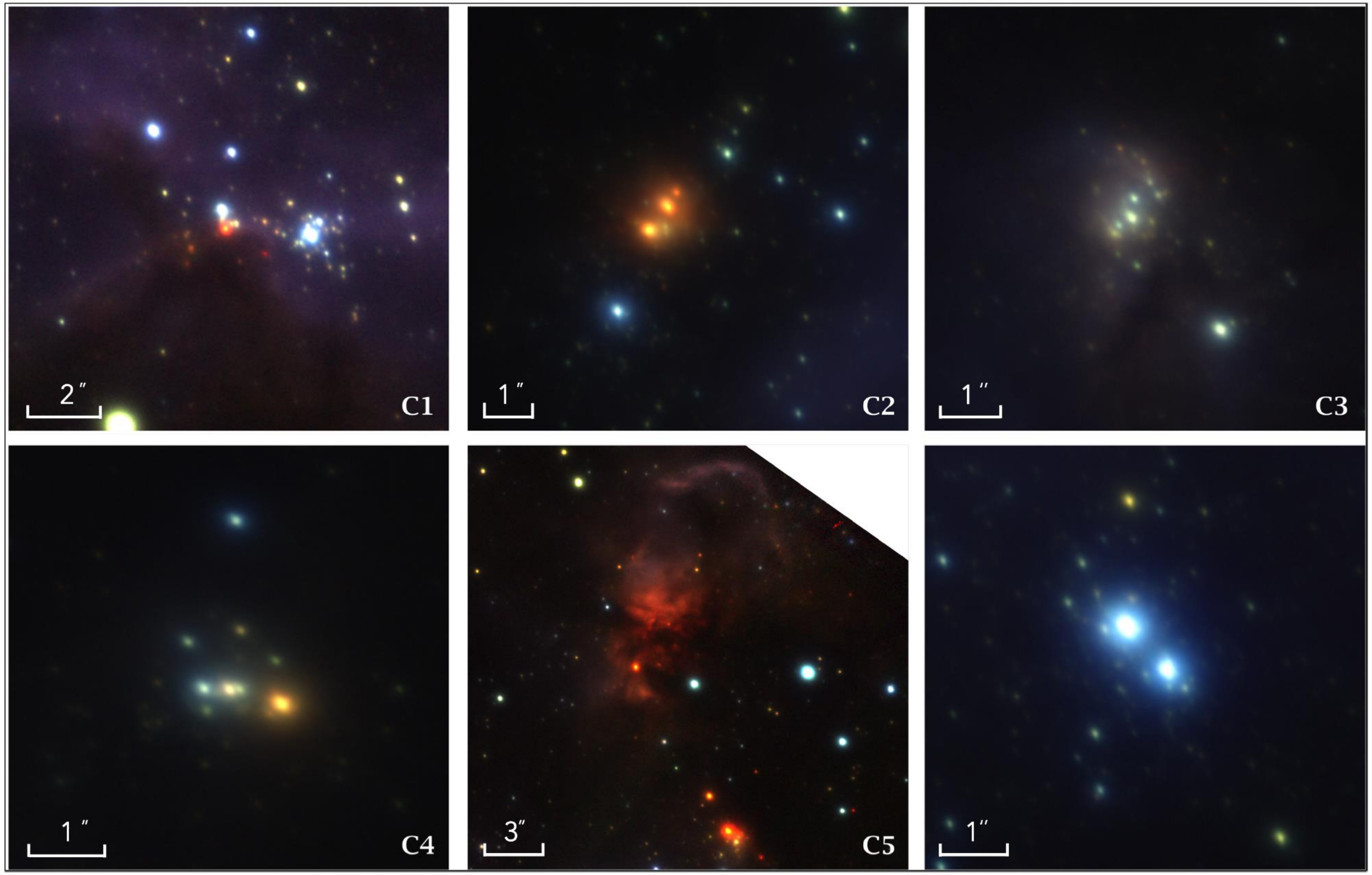
(Rathborne 2010,
Jones, **MSG** 2016)

N160

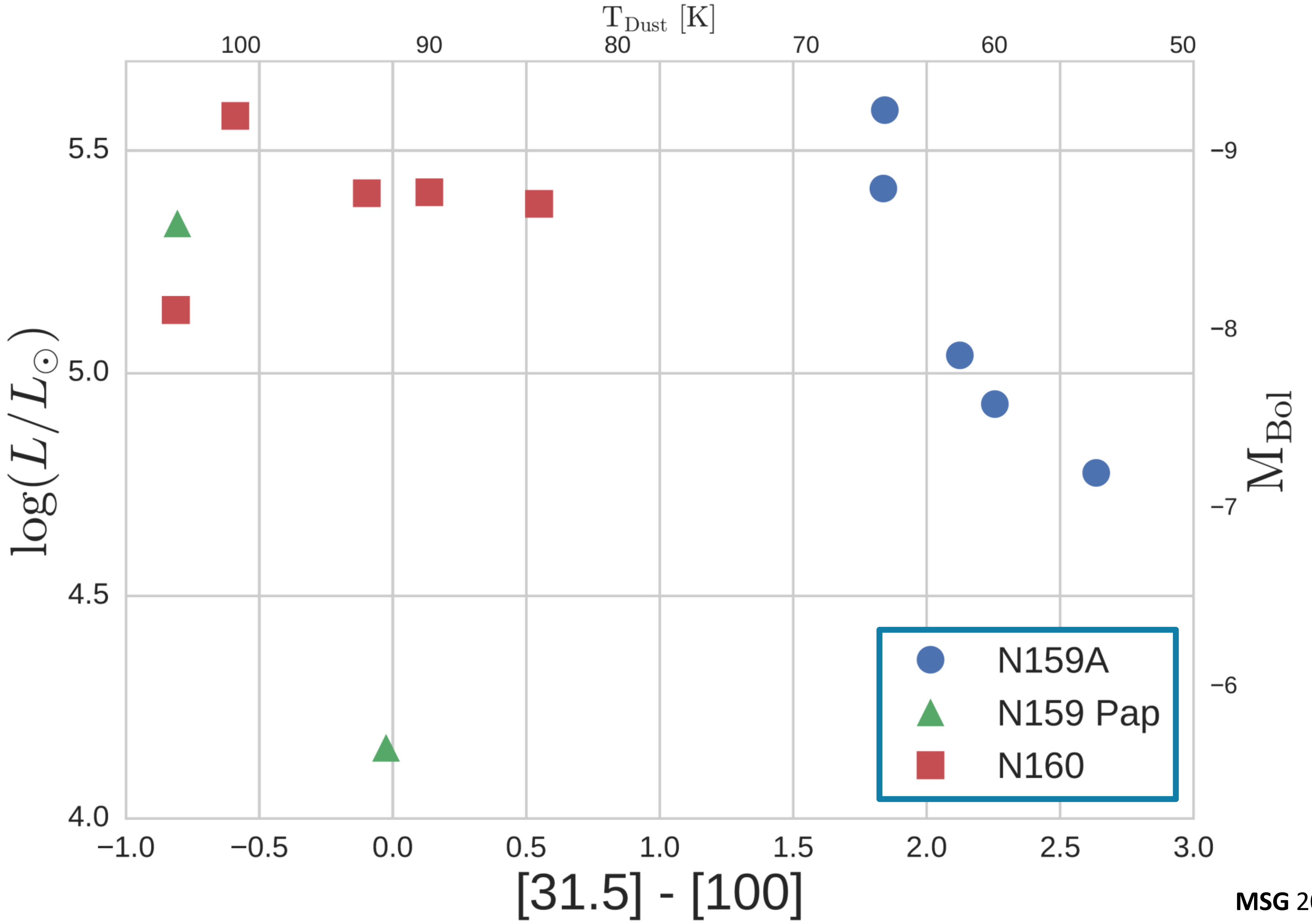


Caveats

- Multiplicity!
- Even at diffraction limit, cannot separate sources at 30 µm
- Varied populations in N159/N160 suggest that ***only one massive YSO will contribute to mid-IR flux*** (Chen 2010, Bernard 2016)
- Isochrones in models were scaled up low-mass PMS stars



N159A, J—Ks image, Bernard et al. 2016. GeMS/GSAOI. Compact clusters with multiple components revealed.



T_{Dust} [K]
100
90
80
70
60
50
5.5
5.0
4.5
4.0
$\log(L/L_{\odot})$
−9
−8
−7
−6
M_{Bol}
N159A
N159 Pap
N160
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
[31.5] - [100]

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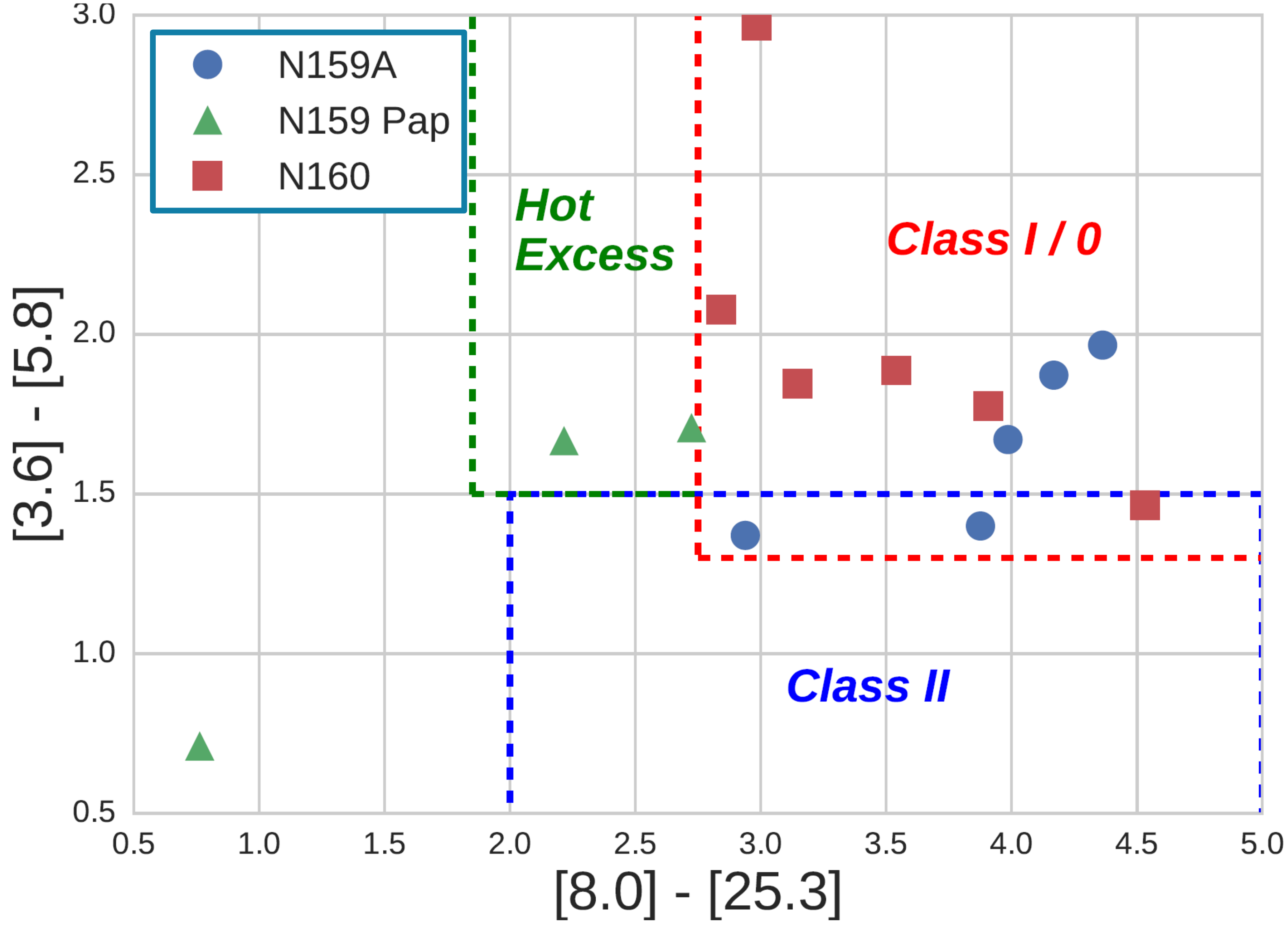

MSG 2017, classification scheme from Reach (2004) & Rho (2006)

"Hot excess"

1. Herbig Ae/Be stars
2. Active accretion
3. HEBs

Conclusions

- Confirmed increased dust obscuration in N159A compared to N160
- Models and dust temp. suggest N160 is older than N159A
- Papillon consistent with “high-excitation blob”
  - suggests internal triggered star formation in N159
- FORCAST provides complete census of protostars in these regions
- No new, undiscovered Class 0 YSOs
- P1 *not* a protostar—no mid-IR emission
- P2 has strong emission out to 37 μm

Future Work

- Cycle 5 observations of N158
- N158 potentially old enough to host very young massive stars
  - Testor & Niemela 1998—two OB associations between 2 and 8 Myr

- References

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