Linking Galactic structure to star formation in the Milky Way

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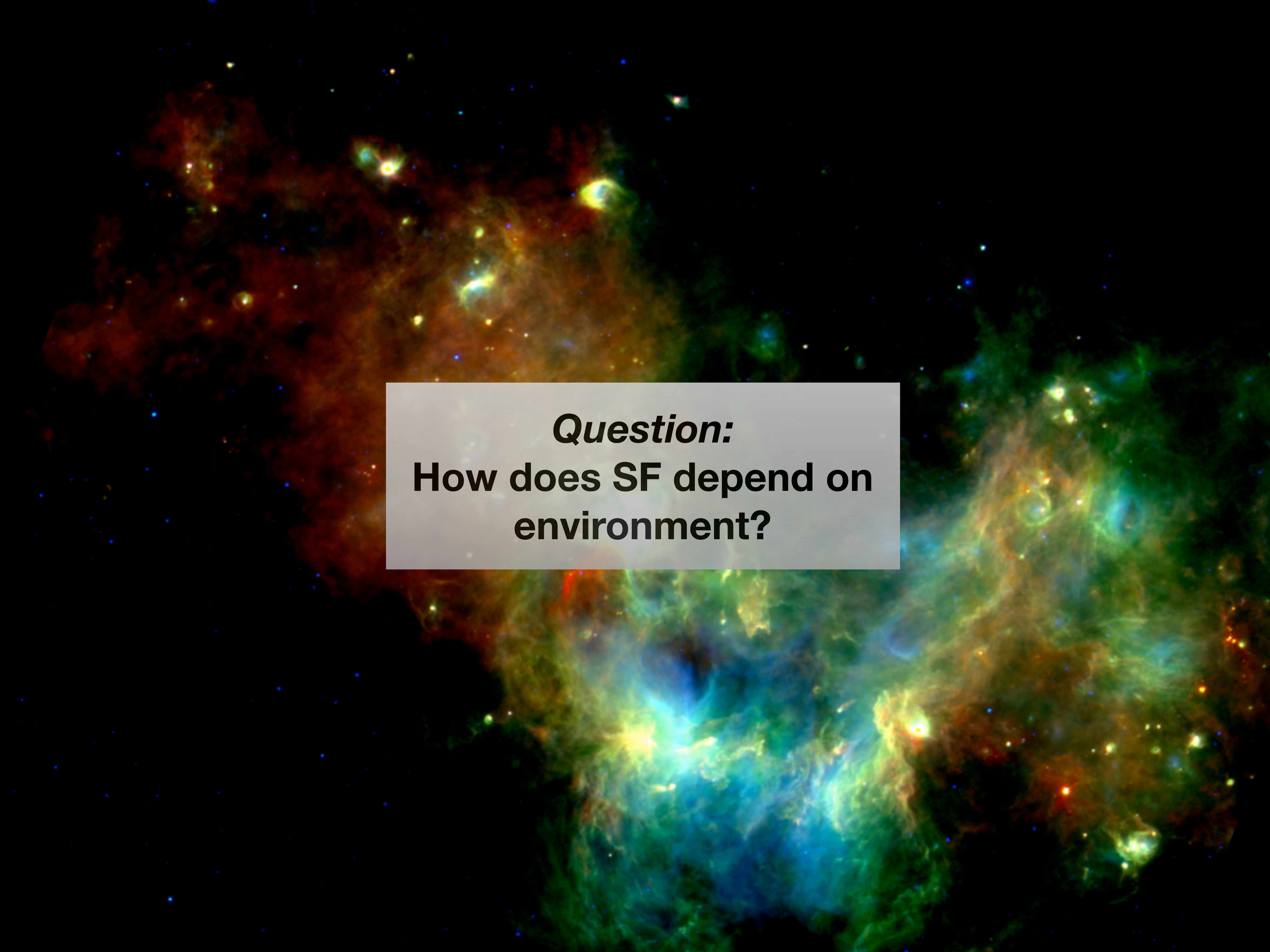
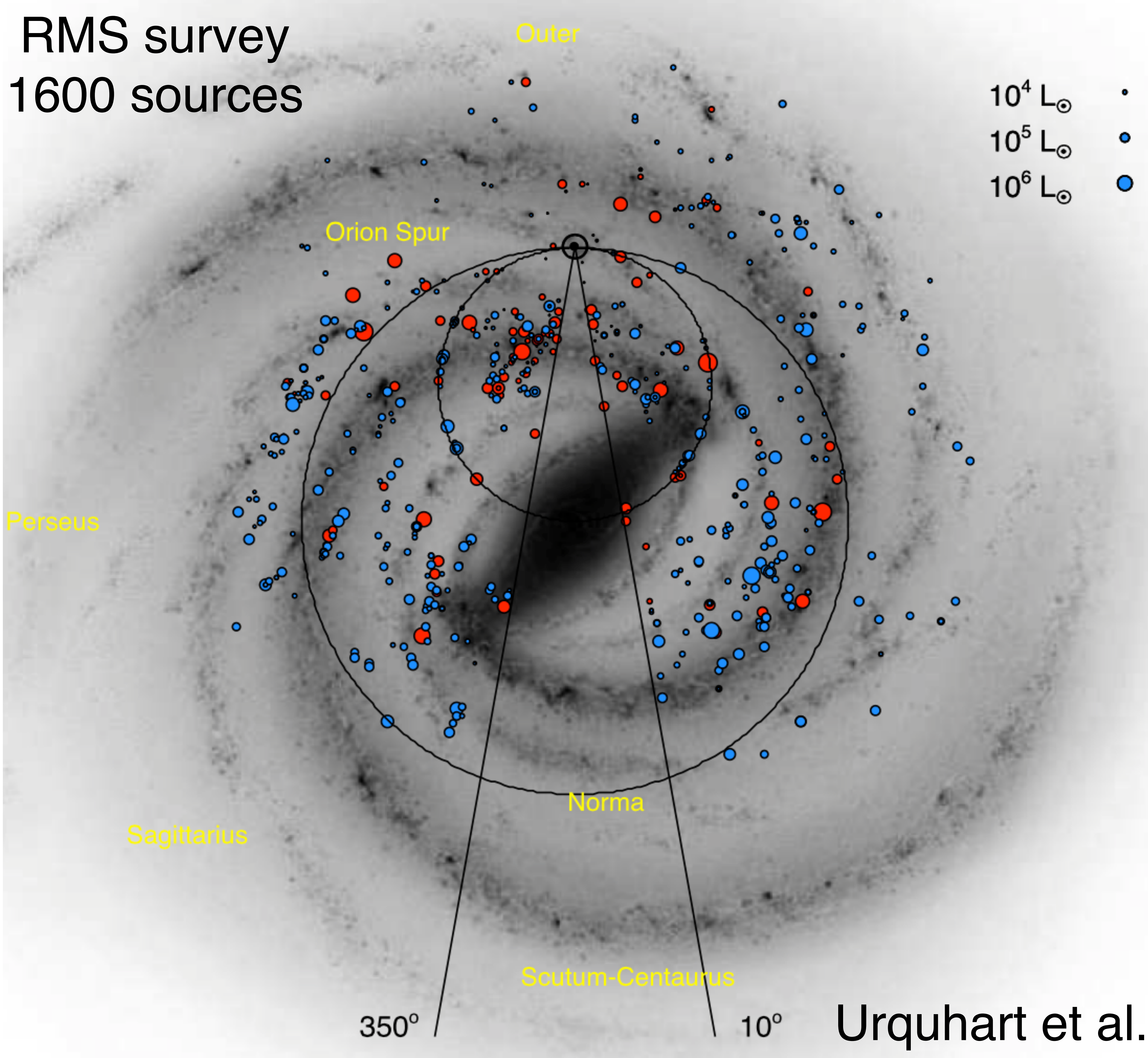
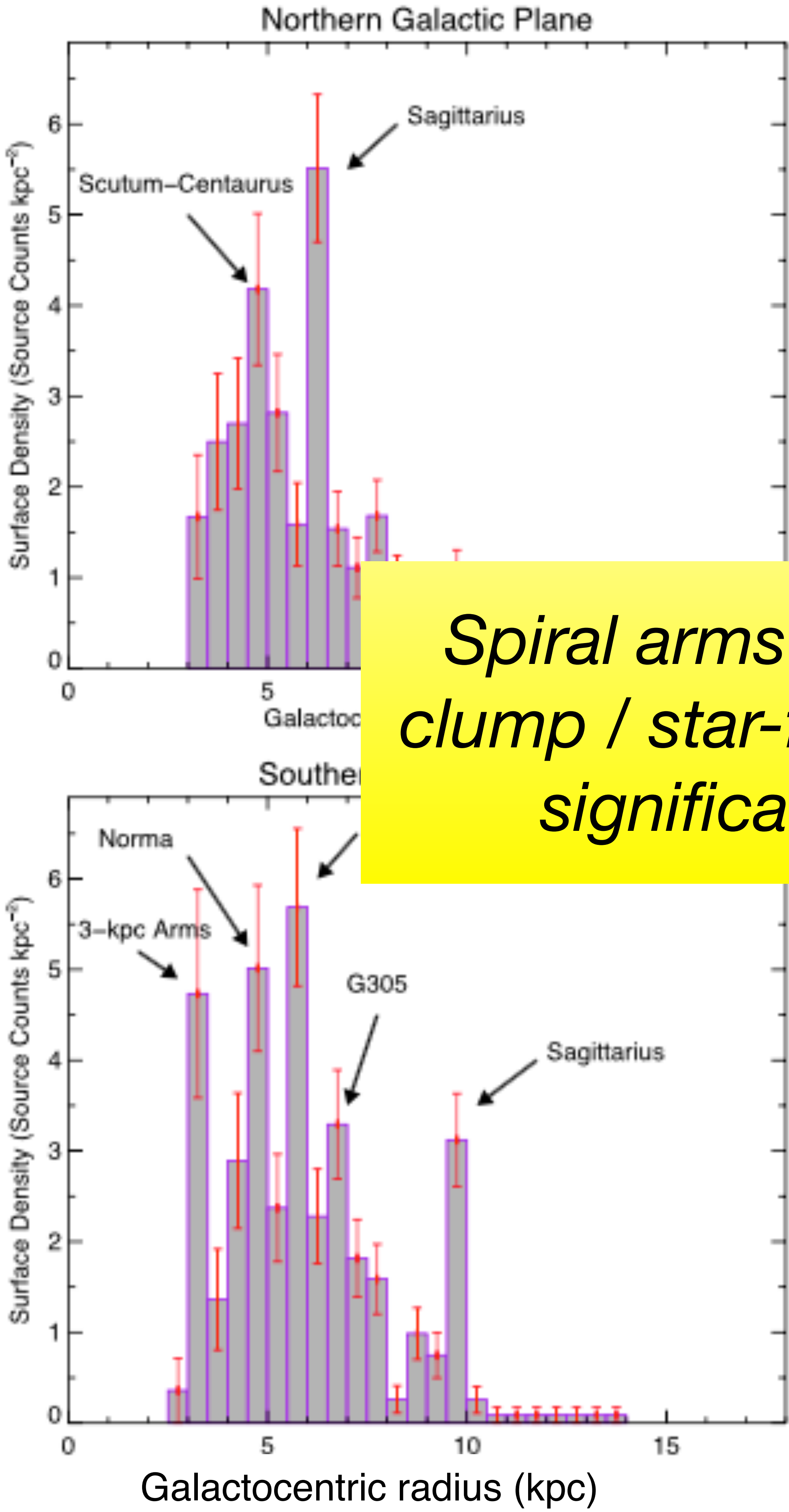

Question:
How does SF depend on environment?

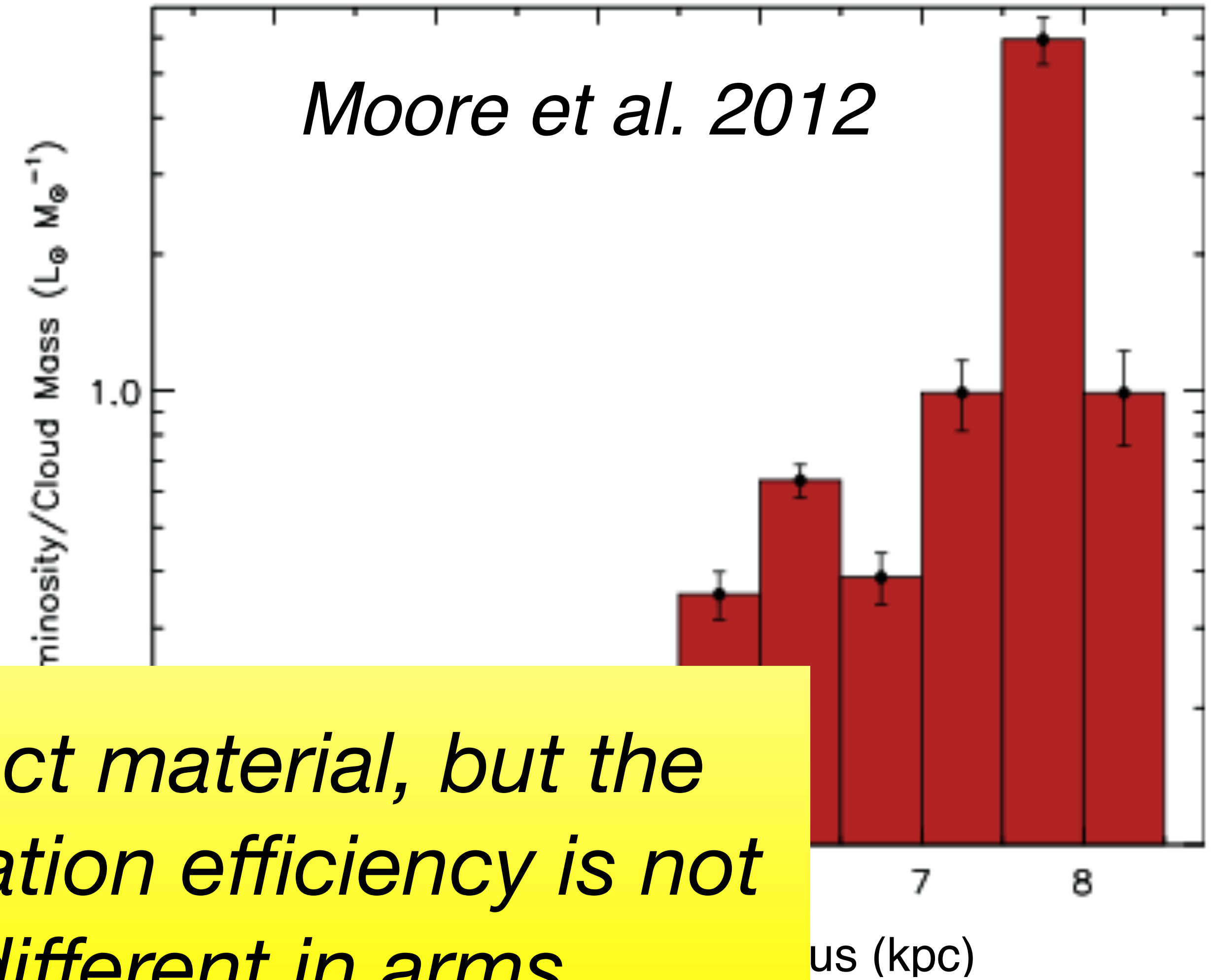
RMS survey
1600 sources



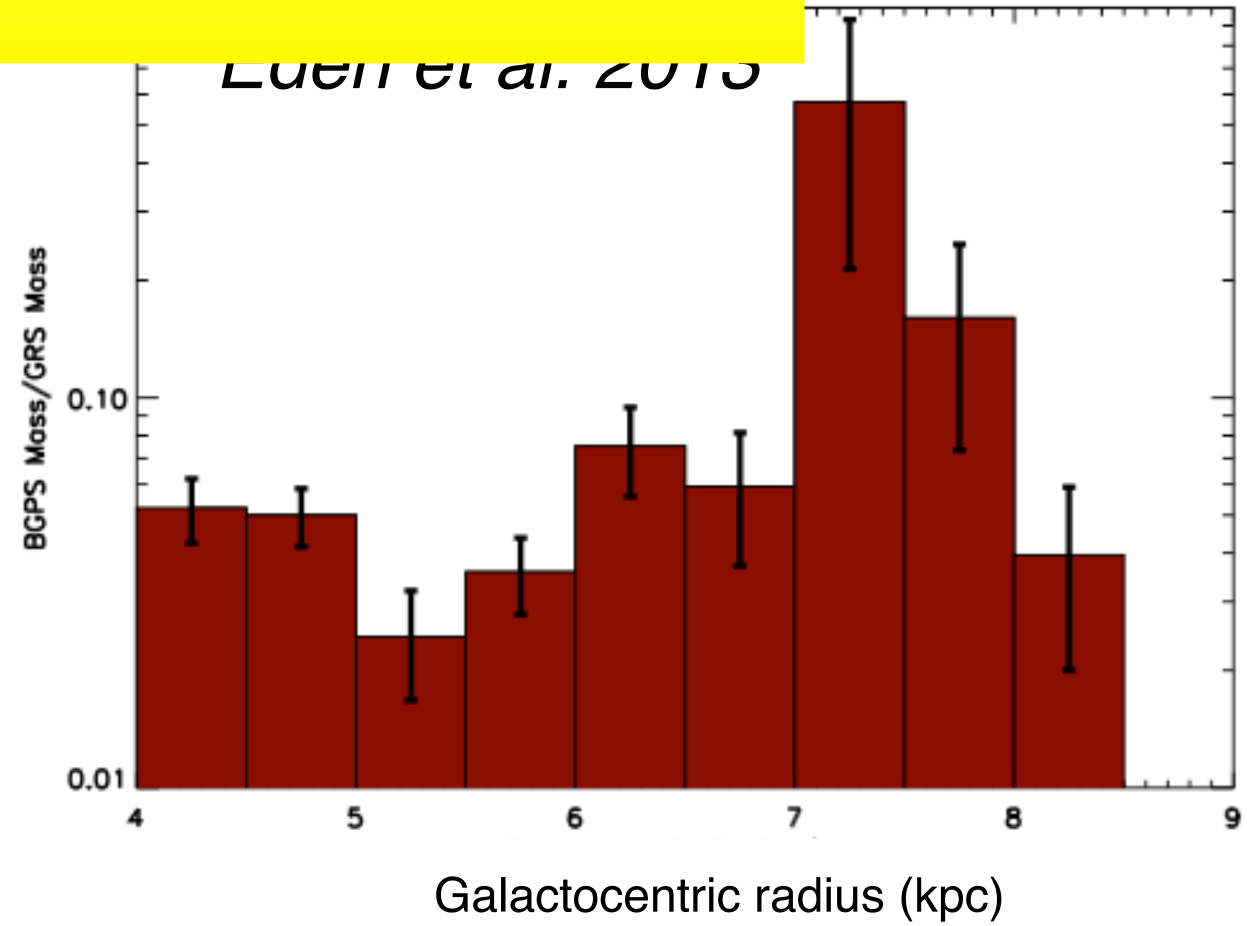
Urquhart et al. 2014



Urquhart et al 2014 (RMS)



Spiral arms collect material, but the clump / star-formation efficiency is not significantly different in arms.



Hi-GAL: *Herschel* Infrared Galactic Plane Survey

- Simultaneous five band (70, 160, 250, 350 & 500μm) continuum mapping of Milky Way plane ($|b| < 1^{\circ}$)
- 900h open time observations, PI: Sergio Molinari

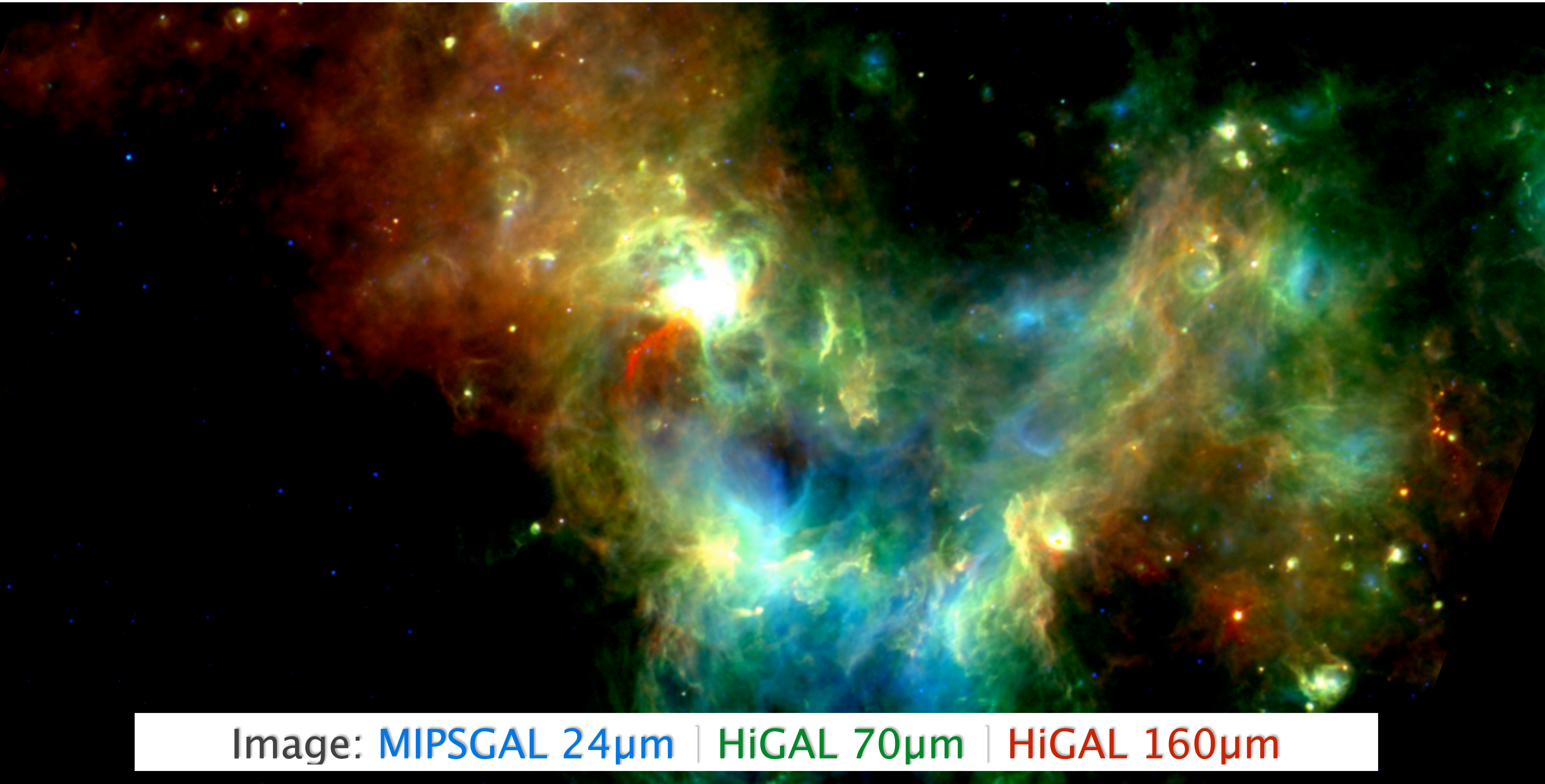
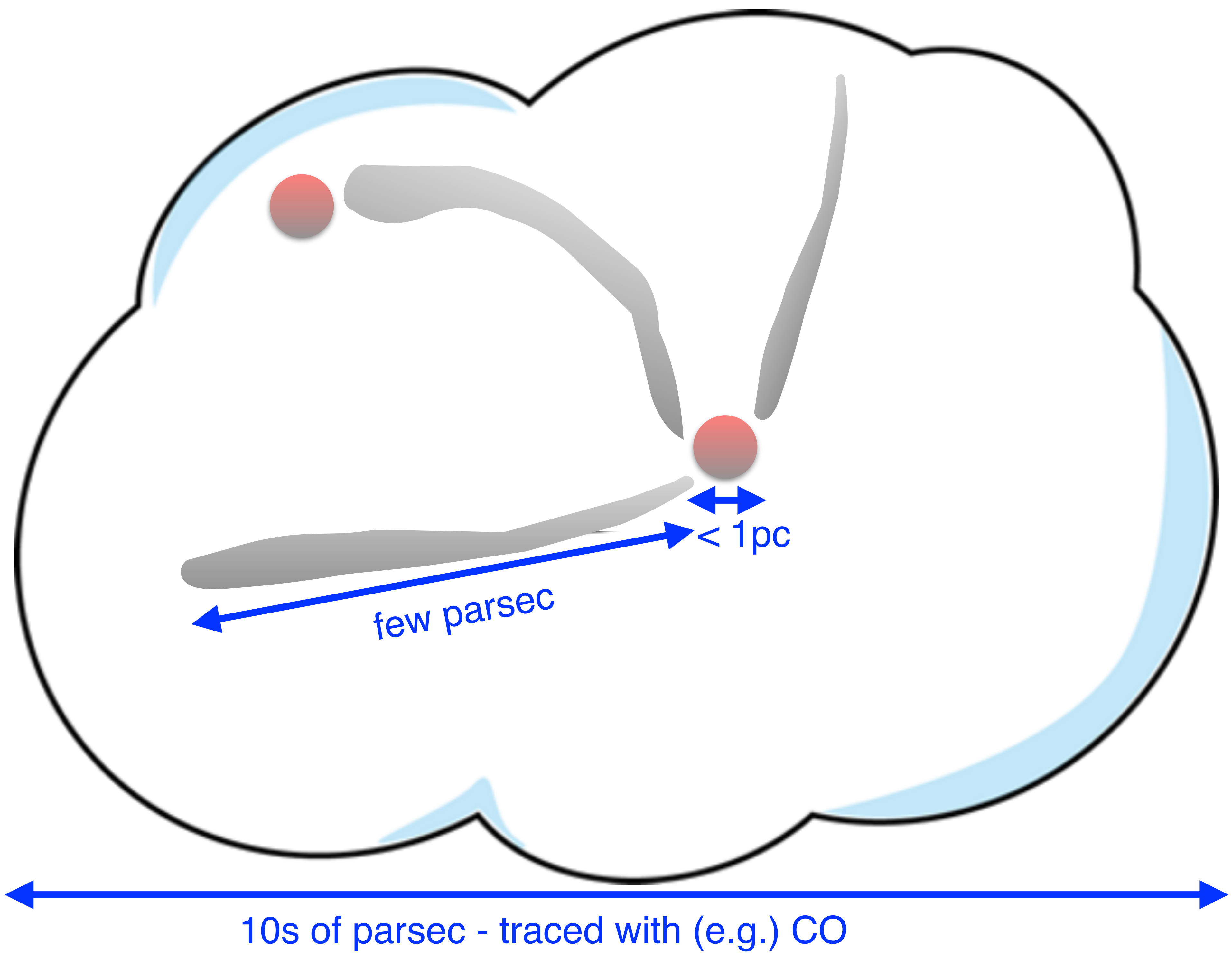


Image: MIPSGAL 24μm | HiGAL 70μm | HiGAL 160μm

A typical Hi-GAL “compact clump”



VIA LACTEA

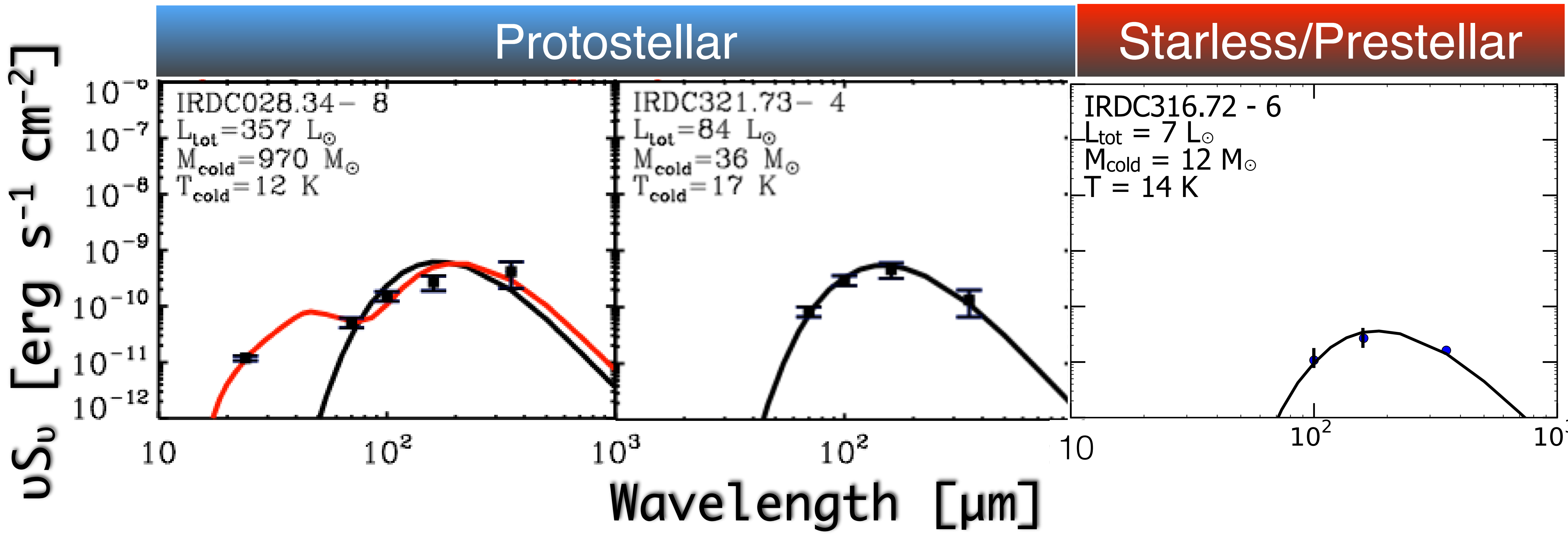
The Milky Way as a Star Formation Engine

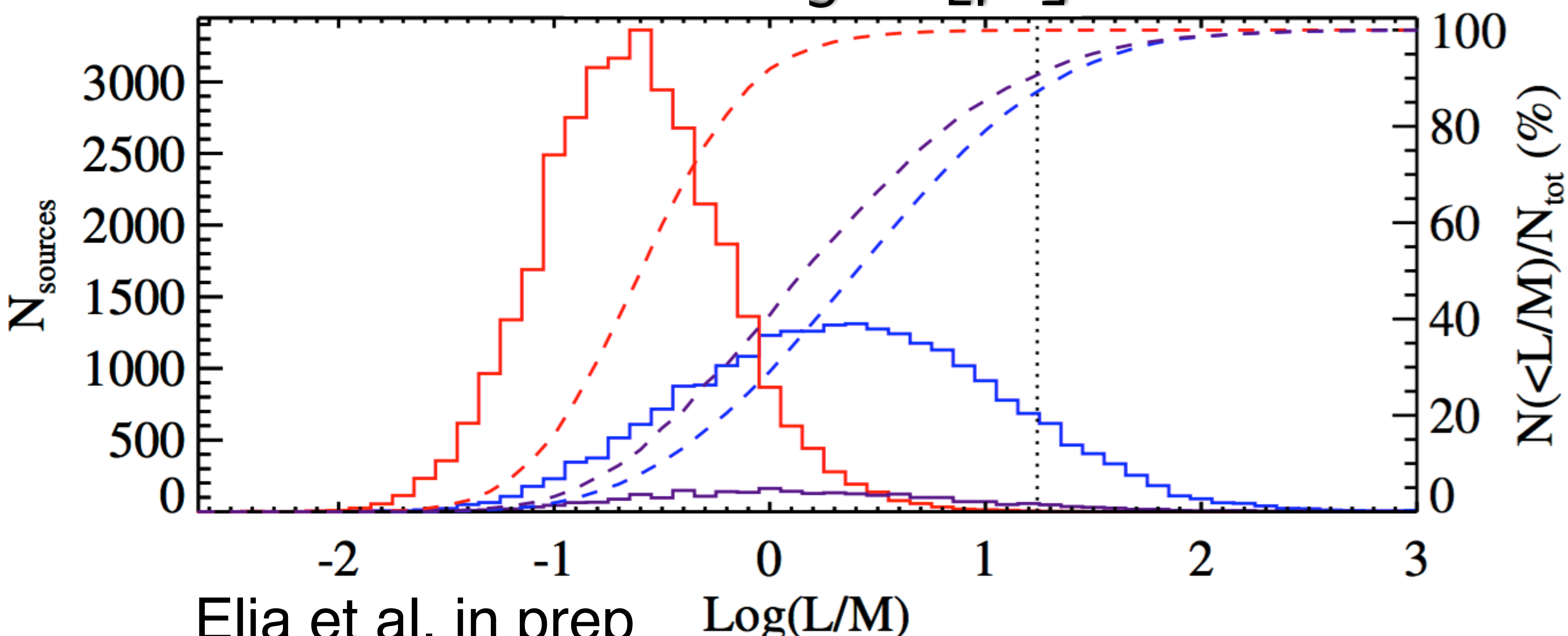
FP7-SPACE Project

- Multi-scale source (compact / filament / bubble) extraction
  Molinari et al. (2016)
- Homogeneous evolutionary classification of compact sources
  Elia et al. (2013 & in preparation)
- Source radiative transfer modelling (T_{dust} structure)
  PPMAP: Marsh et al. (2015, 2016)
- Distance estimations (kinematic, extinction-based)
  Russeil et al. (2011)
- Quantification of the role of spiral arms in star formation
  Ragan et al. (2016)
- Determination of star formation threshold / rate / efficiency
  Longmore et al. (2013)

FIR spectral energy distributions

Ragan et al. (2012b, A&A, 547, 49)
Ragan et al. (2013, A&A, 559, 79)





Elia et al. in prep

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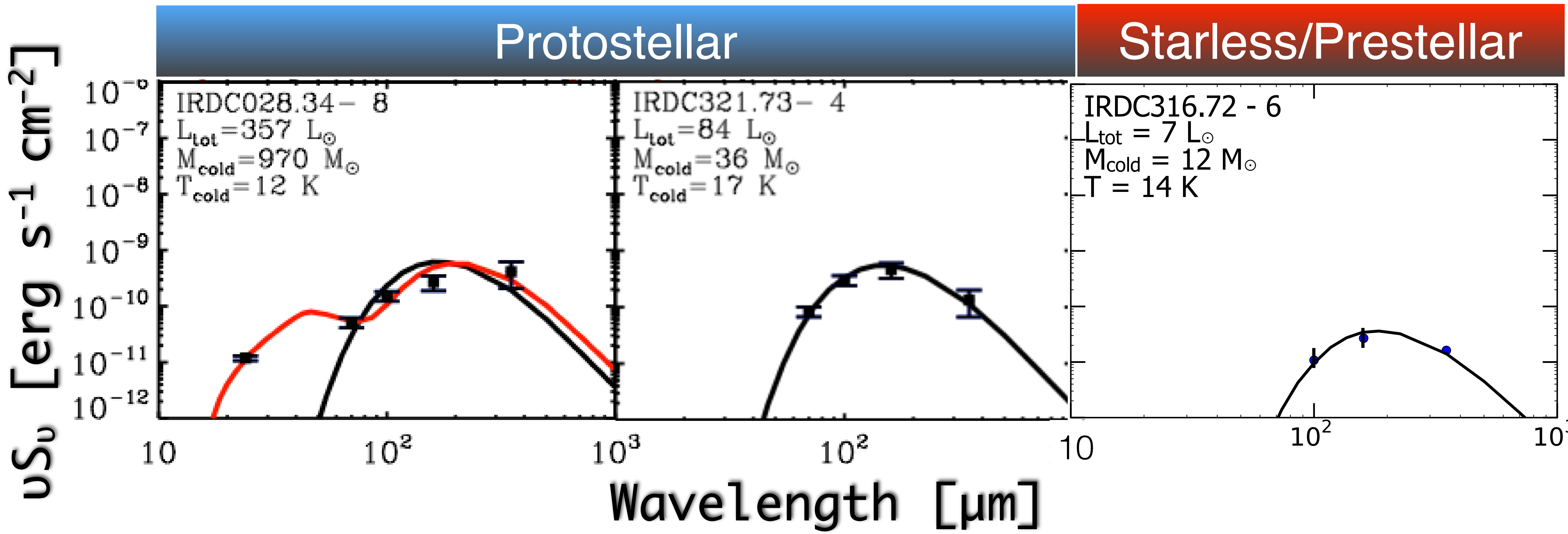
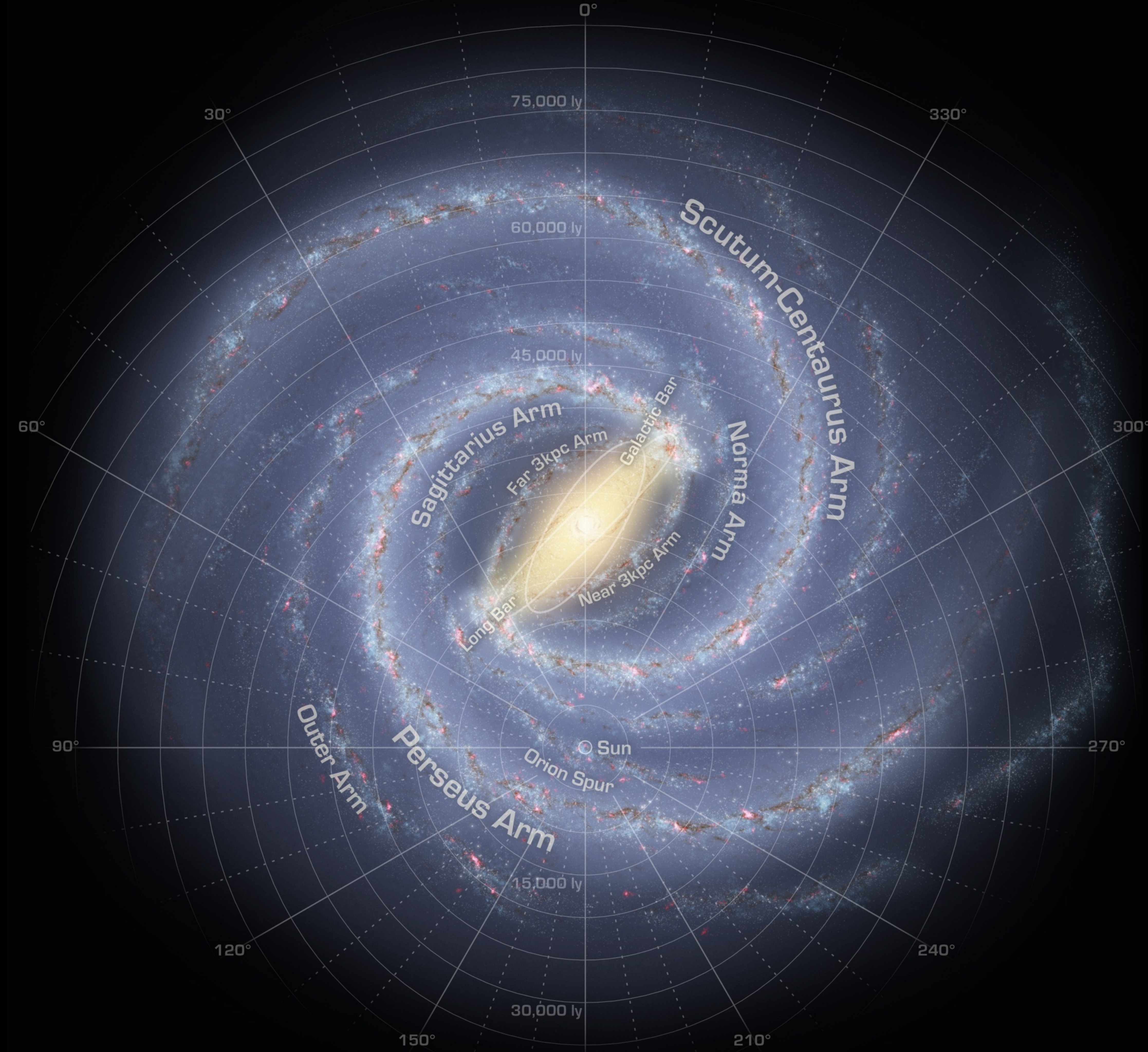


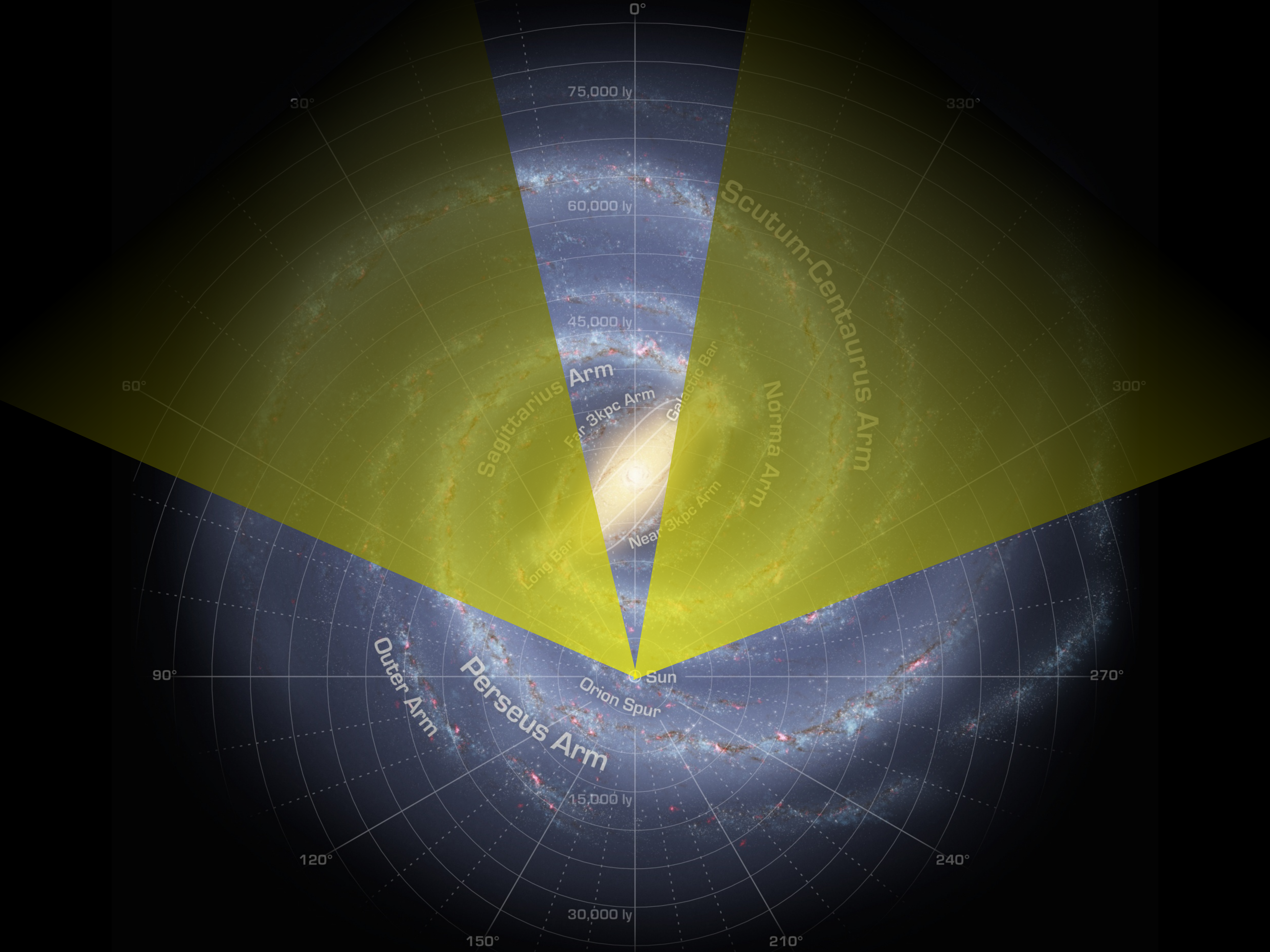
The star-forming fraction (SFF)

$$\mathrm{SFF} = \frac{N_{\mathrm{protostellar}}}{N_{\mathrm{total}}}$$

Ragan et al. (2016, MNRAS, arXiv:1607.07626)



0°
30°
330°
75,000 ly
60,000 ly
45,000 ly
Scutum-Centaurus Arm
Galactic Bar
Sagittarius Arm
Far 3kpc Arm
Norma Arm
60°
300°
Near 3kpc Arm
Long Bar
Outer Arm
Perseus Arm
Sun
Orion Spur
90°
270°
15,000 ly
120°
240°
30,000 ly
150°
210°



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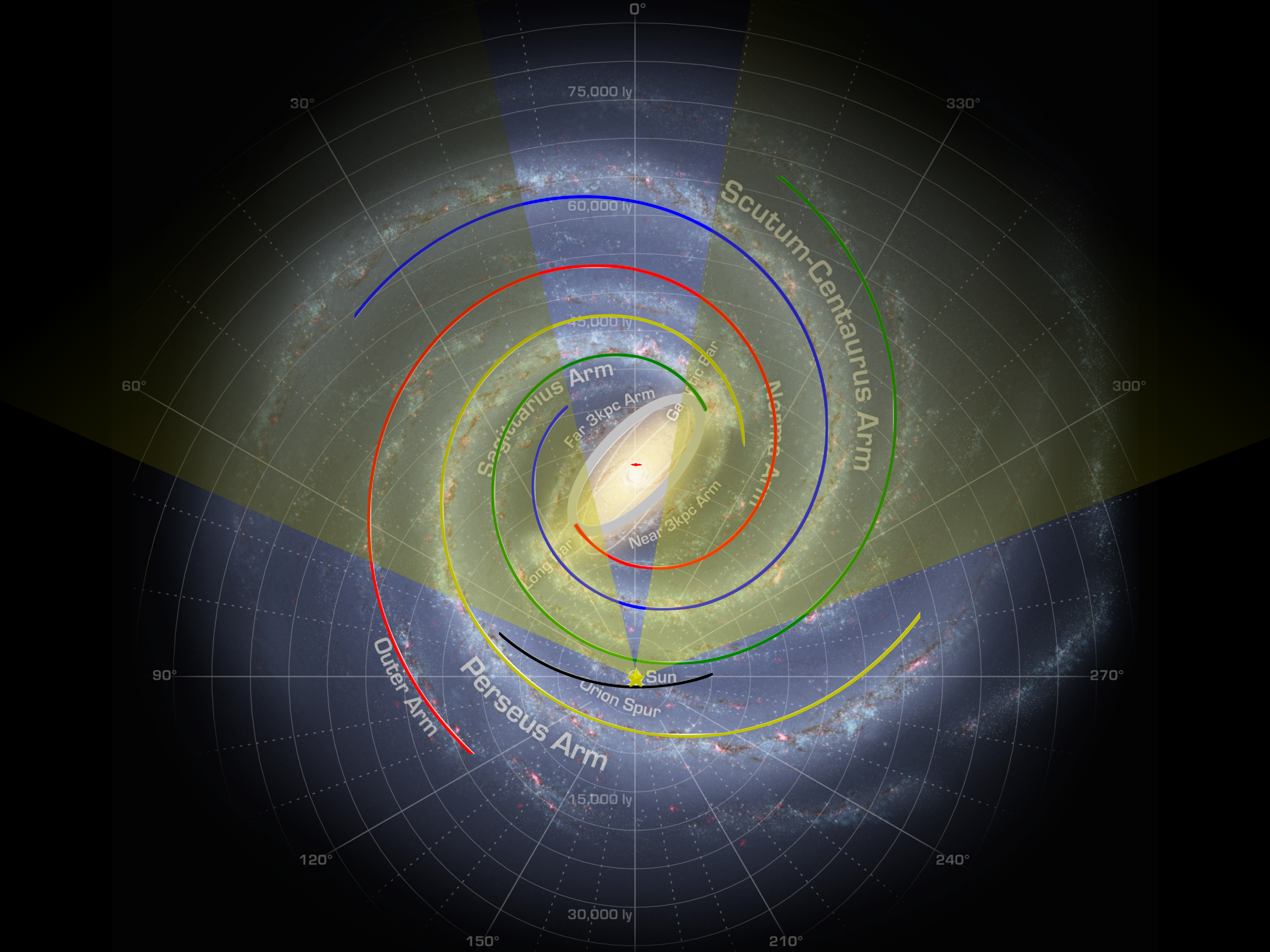

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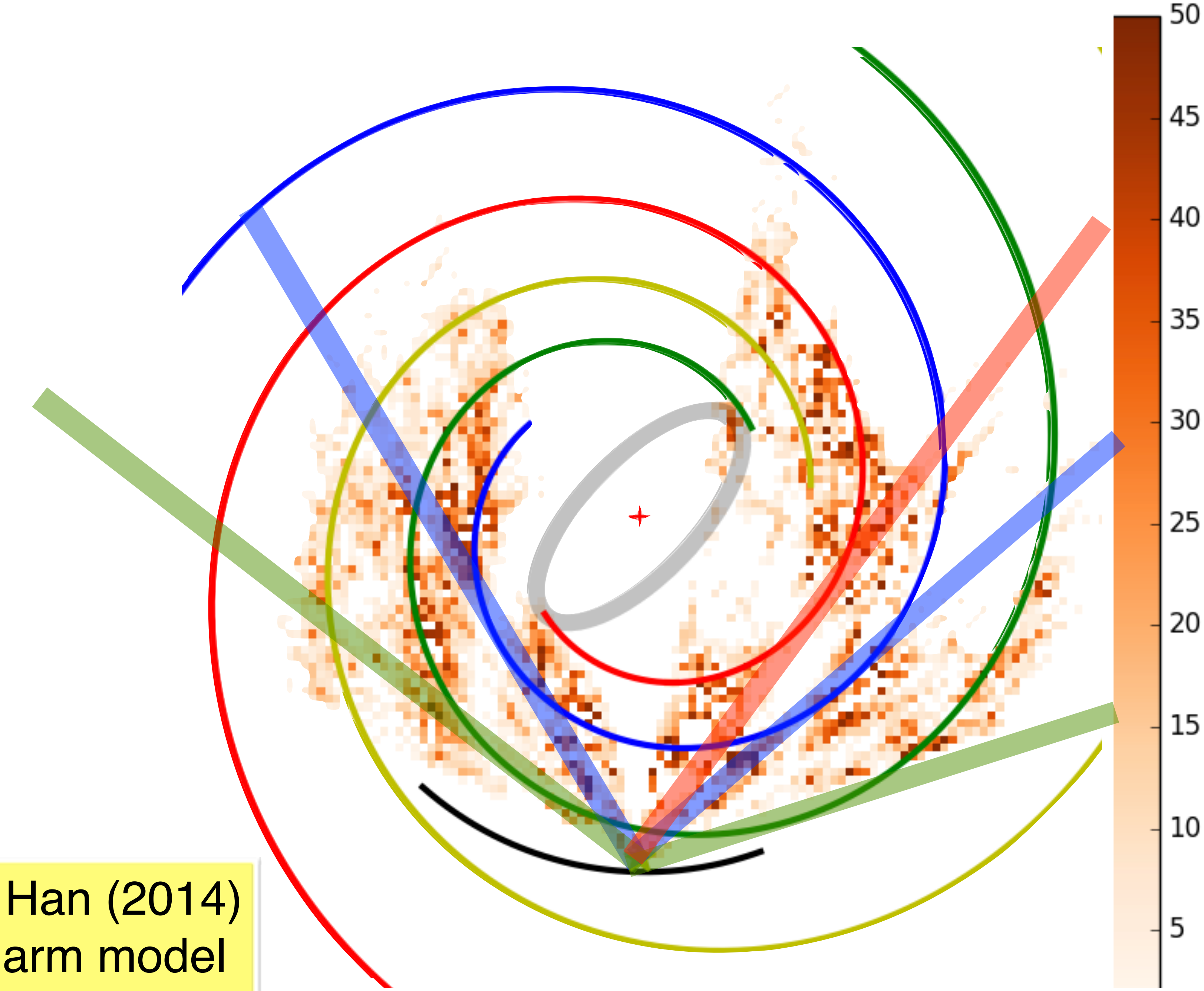
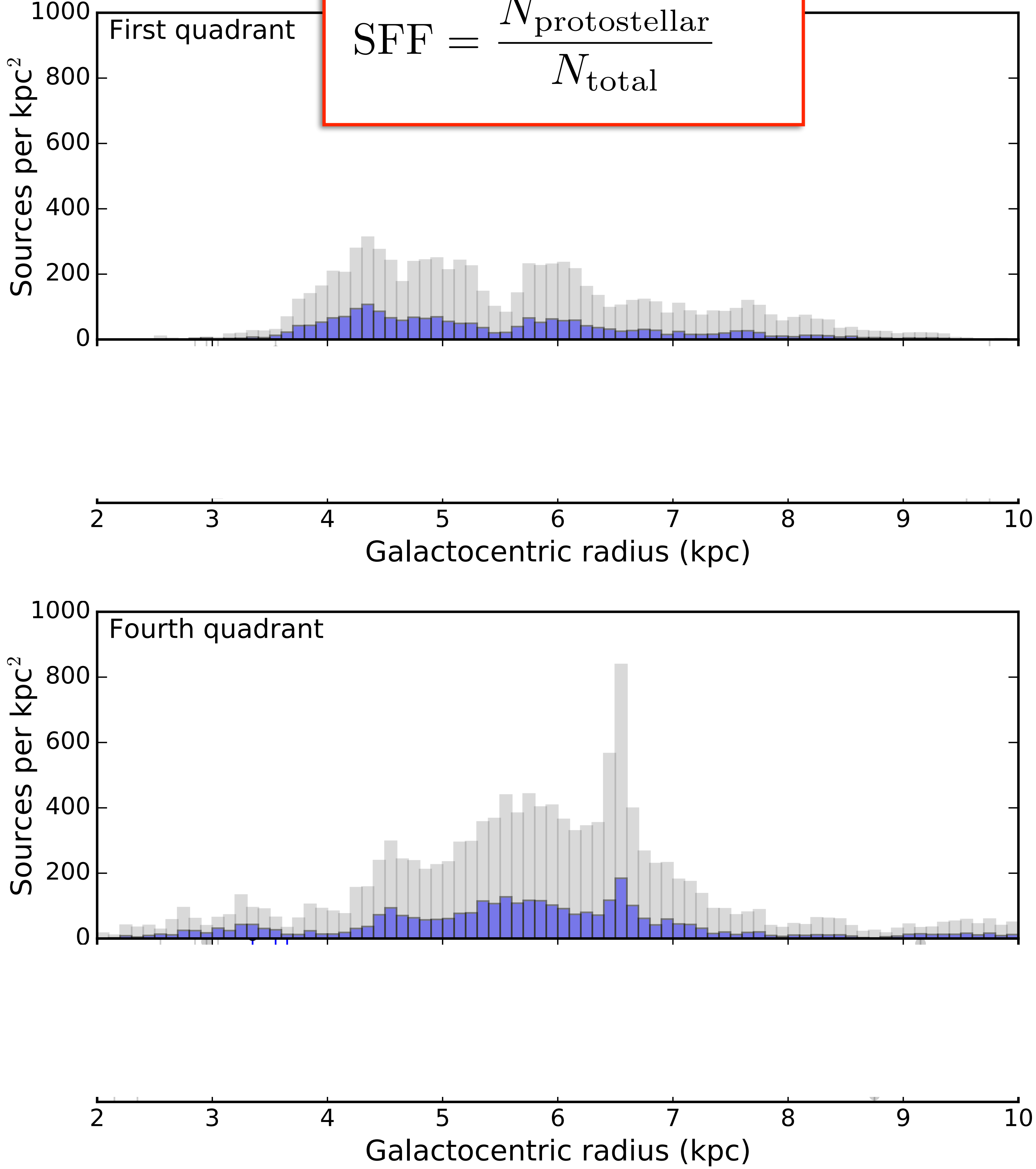


Hi-GAL sources with “good” SED

Hou & Han (2014) spiral arm model fit to HII region distribution

100922 sources!

$$\mathrm{SFF} = \frac{N_{\mathrm{protostellar}}}{N_{\mathrm{total}}}$$



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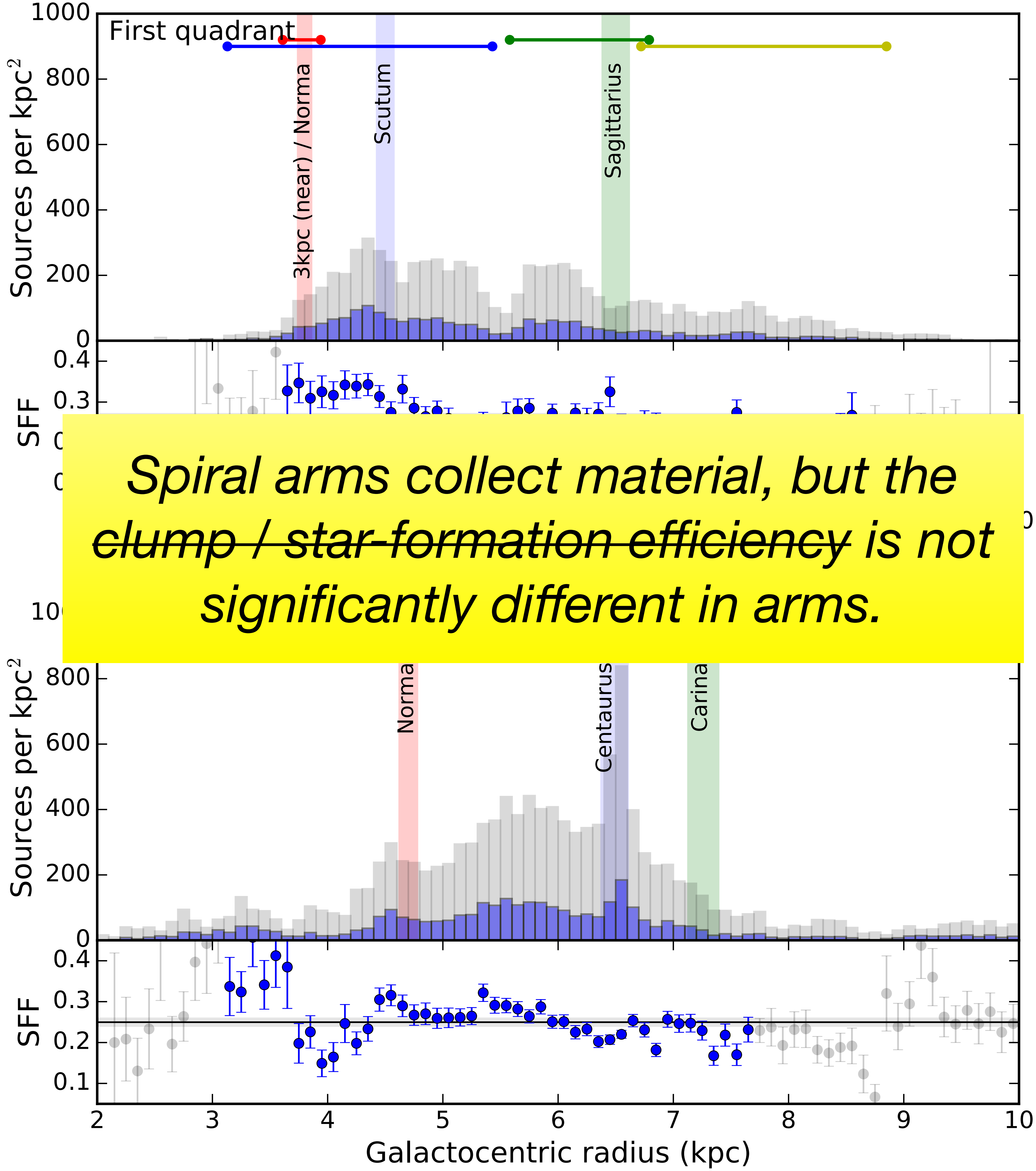

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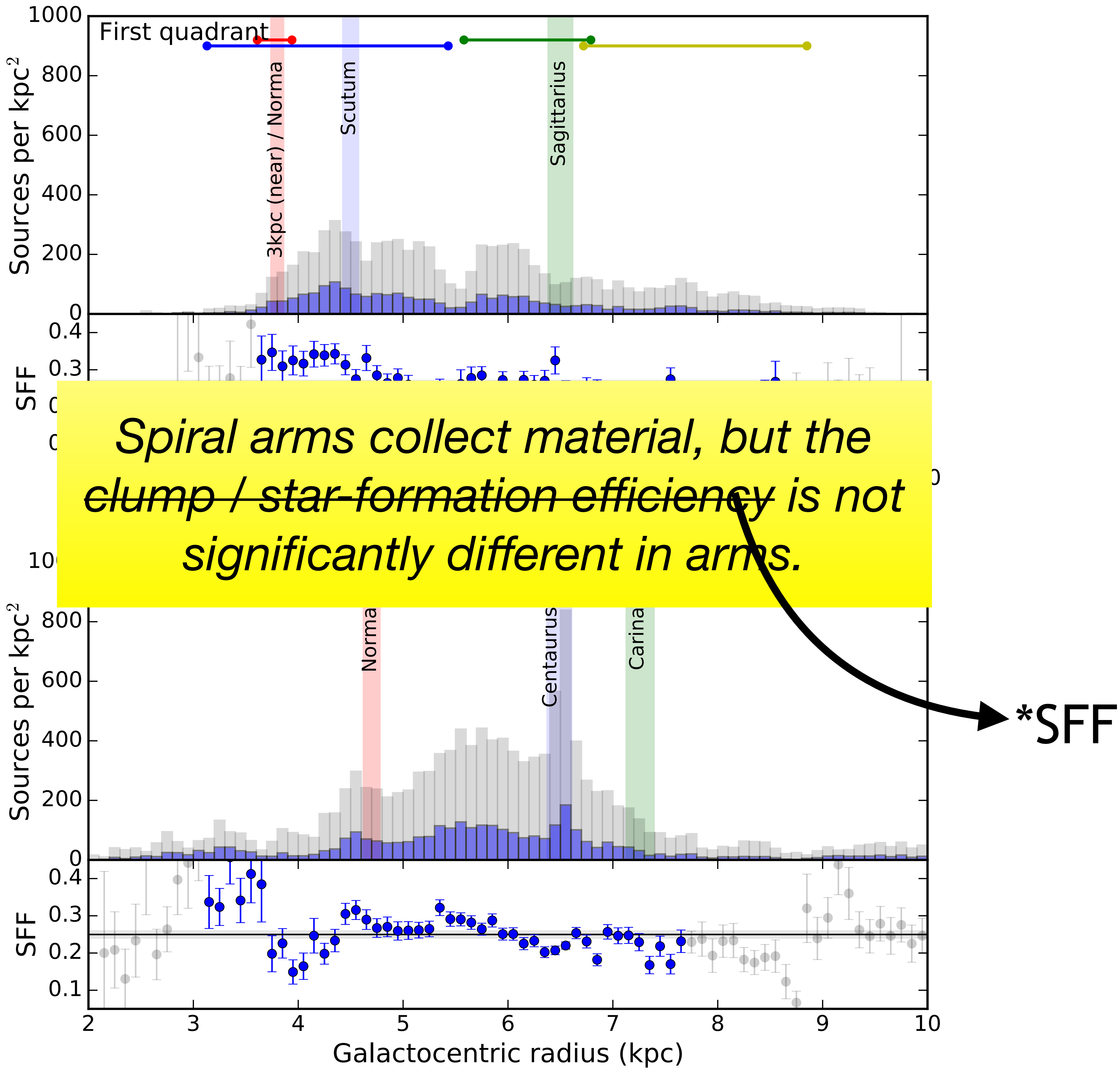

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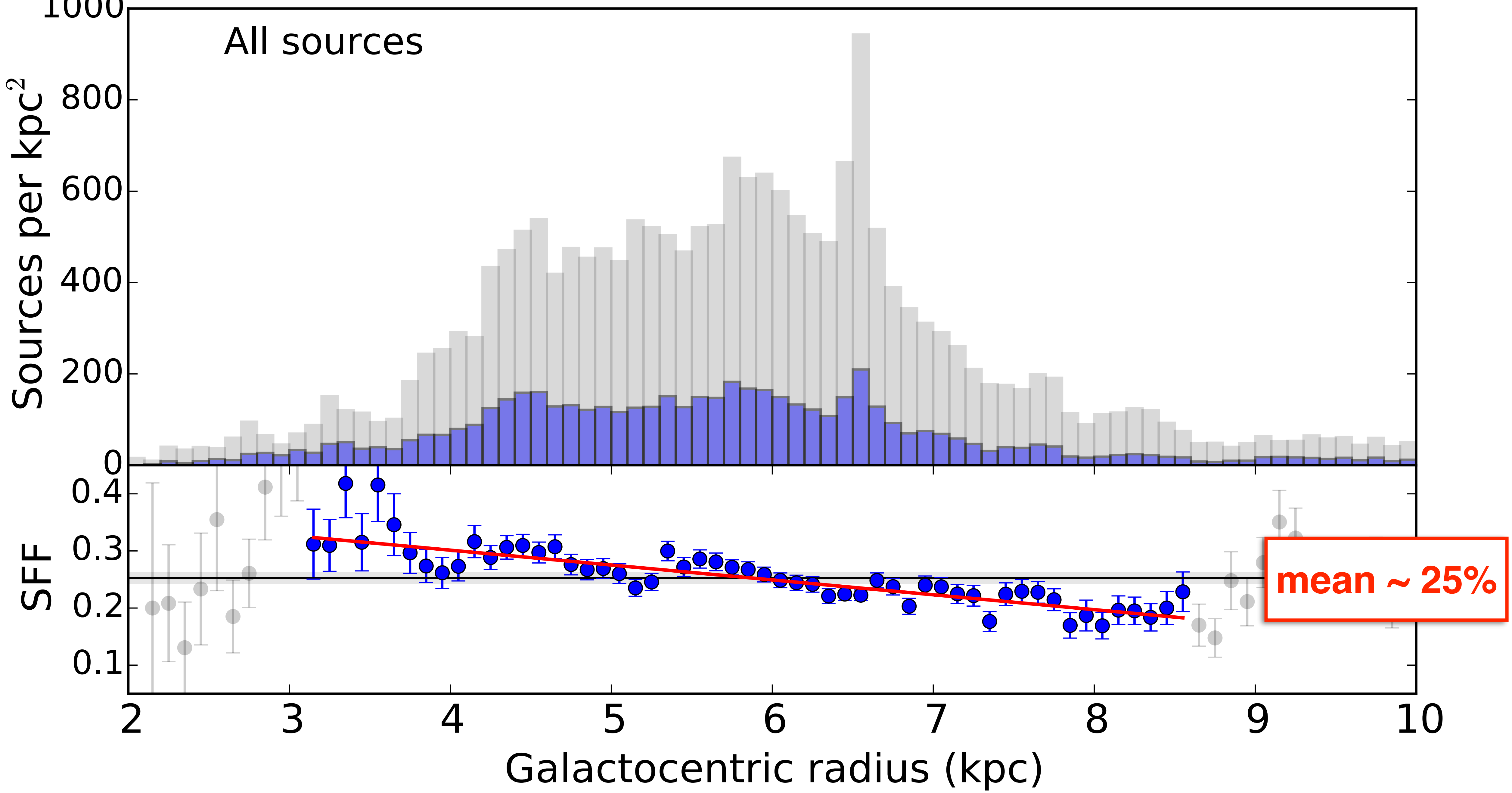
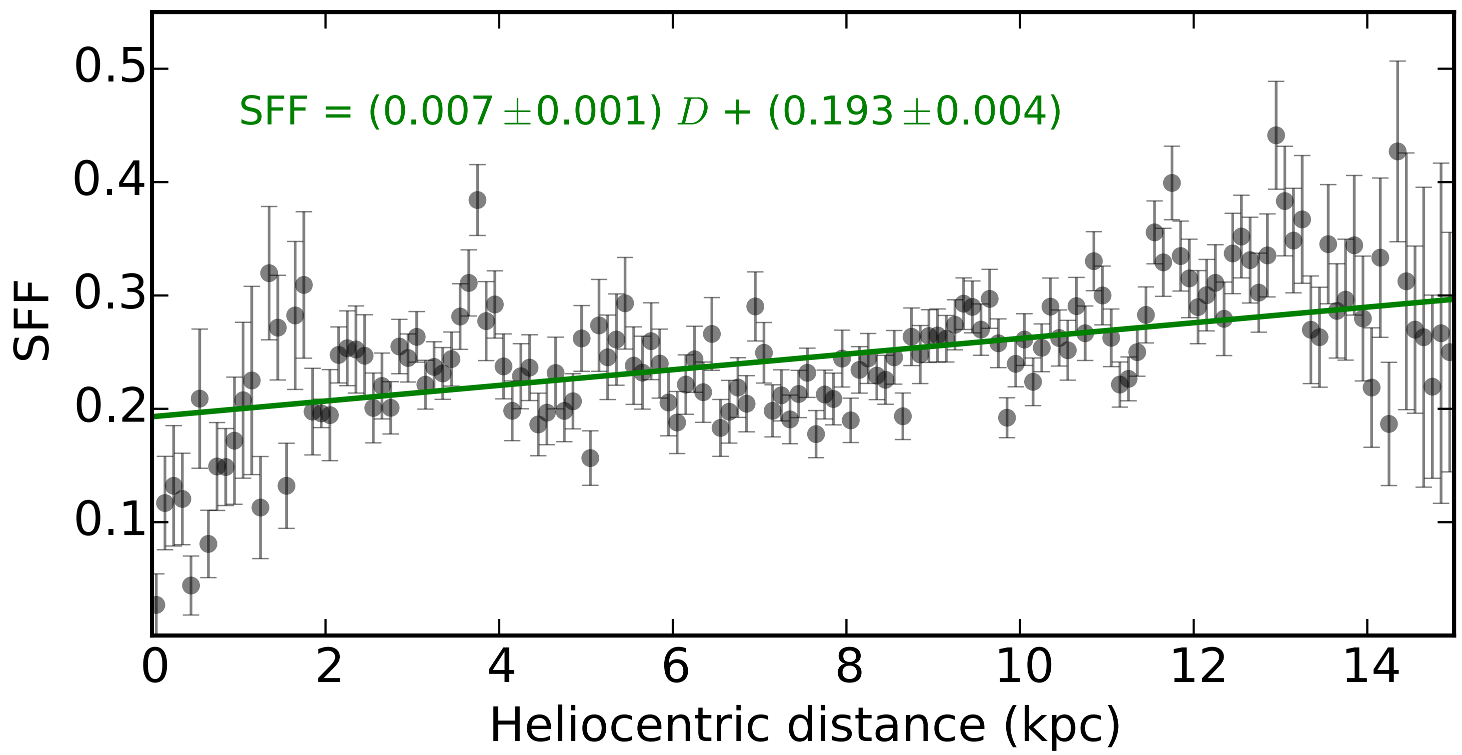


$$SFF = (0.406 \pm 0.003) - (0.026 \pm 0.002) R_{\rm GC}$$

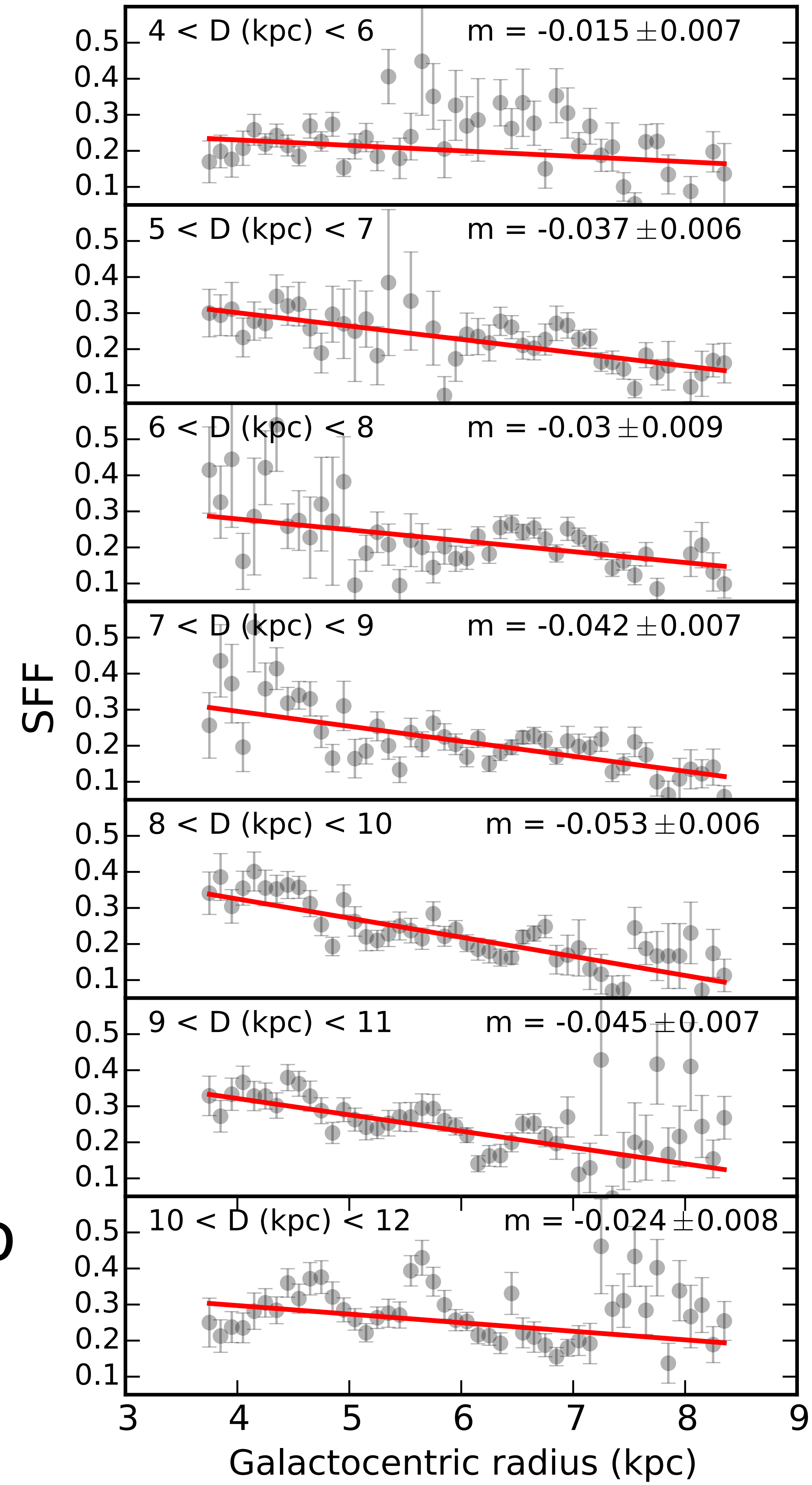
$$\rho_S = -0.91$$

Ragan et al. (2016, MNRAS, arXiv:1607.07626)

Know thy biases



- Sensitivity to low-mass clumps decreases with distance
- More distant clumps more likely to overlap with 70μm component



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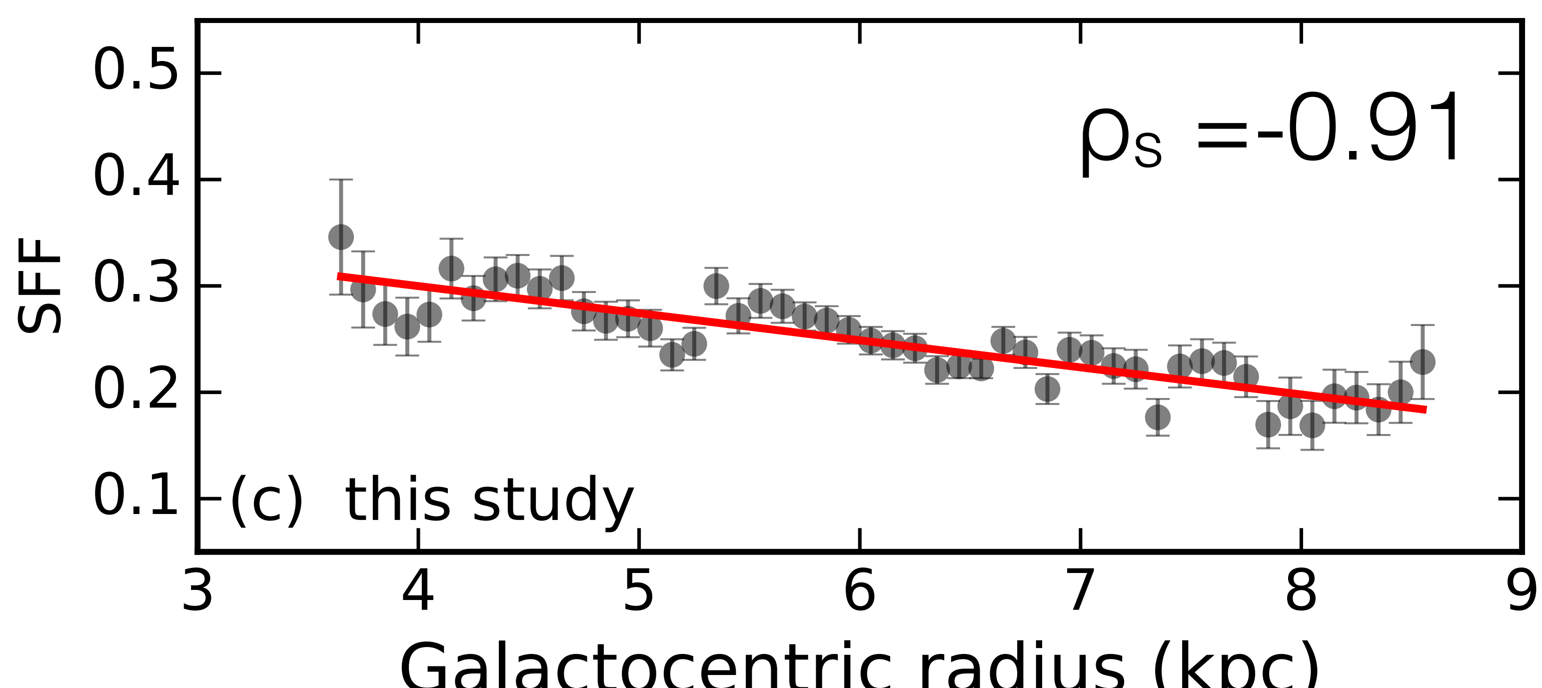
How does the SFF relate to the gas distribution?

$$\mathrm{SFF} = \frac{N_{\mathrm{protostellar}}}{N_{\mathrm{total}}}$$



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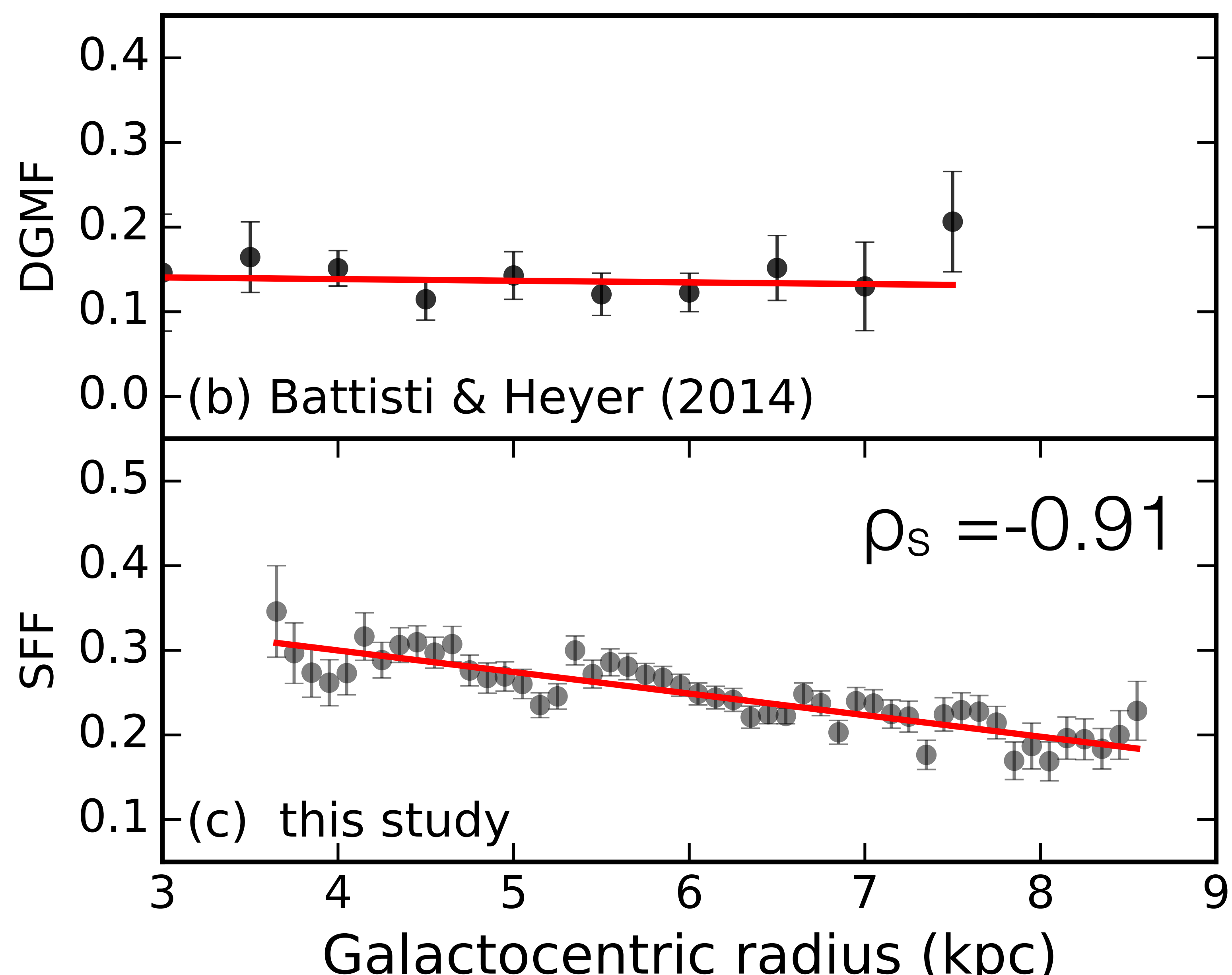
How does the SFF relate to the gas distribution?

$$\frac{M_{\rm sub-mm}}{M_{\rm 13CO}}$$

$$\mathrm{SFF} = \frac{N_{\rm protostellar}}{N_{\rm total}}$$



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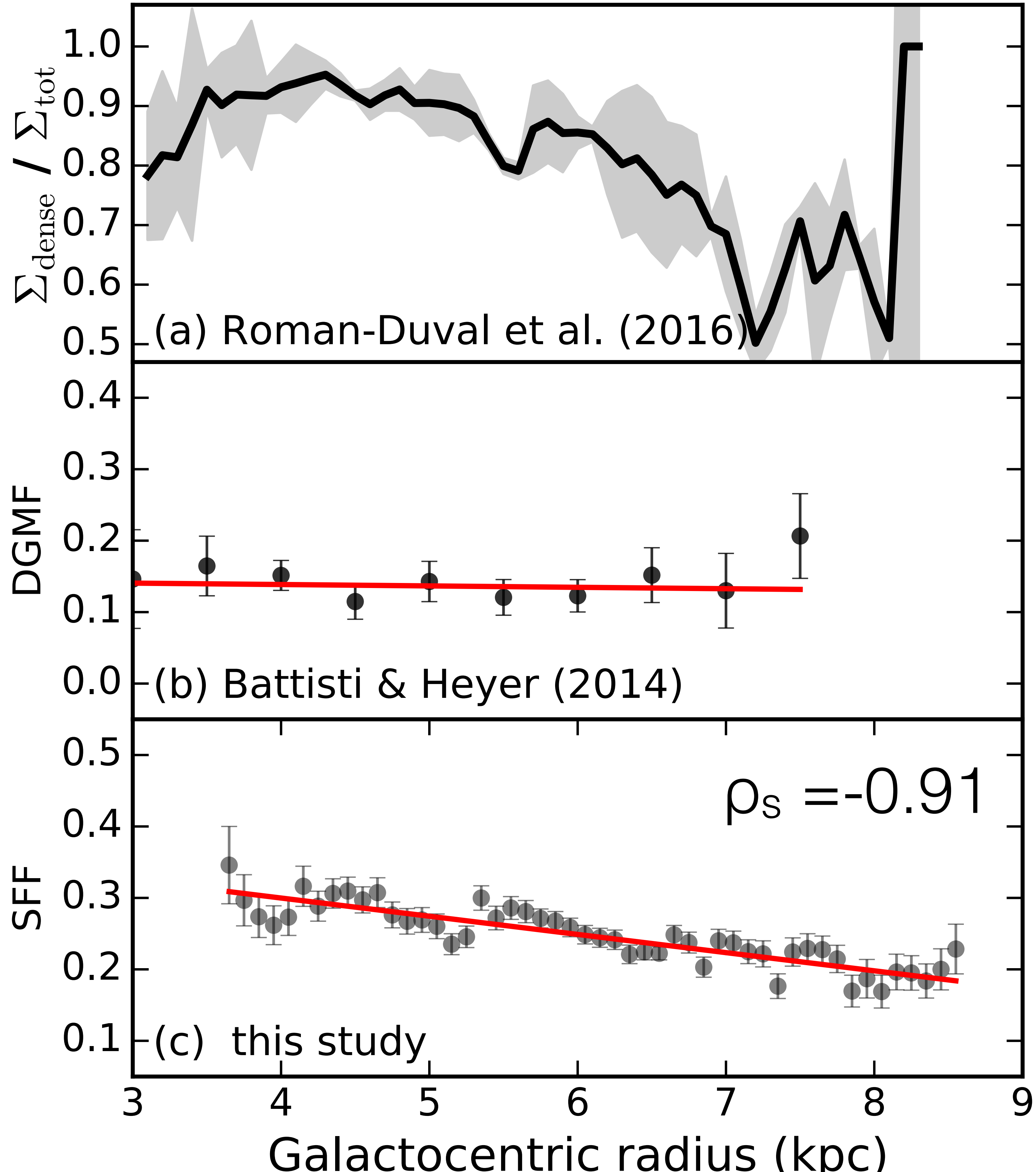
How does the SFF relate to the gas distribution?

$$\frac{\Sigma(^{12}\mathrm{CO})}{\Sigma(^{12}\mathrm{CO} + {}^{13}\mathrm{CO})}$$

$$\frac{M_{\mathrm{sub-mm}}}{M_{13\mathrm{CO}}}$$

$$\mathrm{SFF} = \frac{N_{\mathrm{protostellar}}}{N_{\mathrm{total}}}$$



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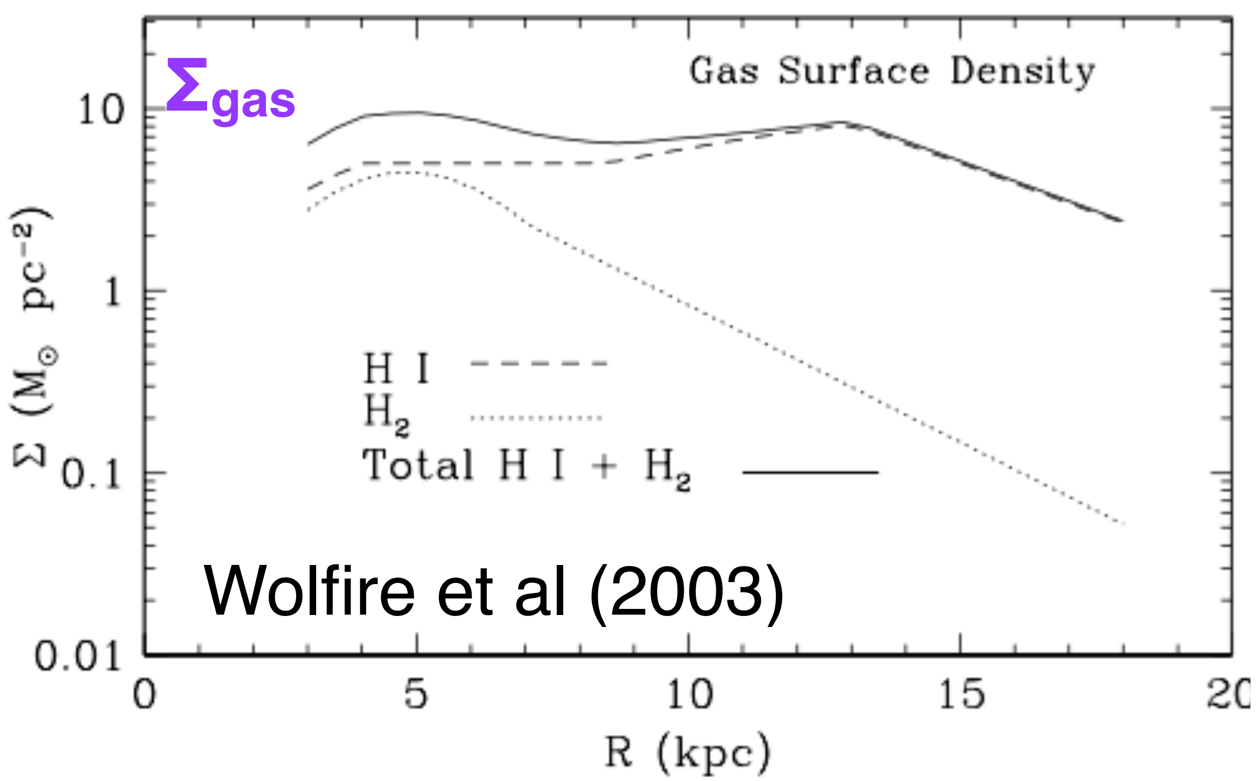
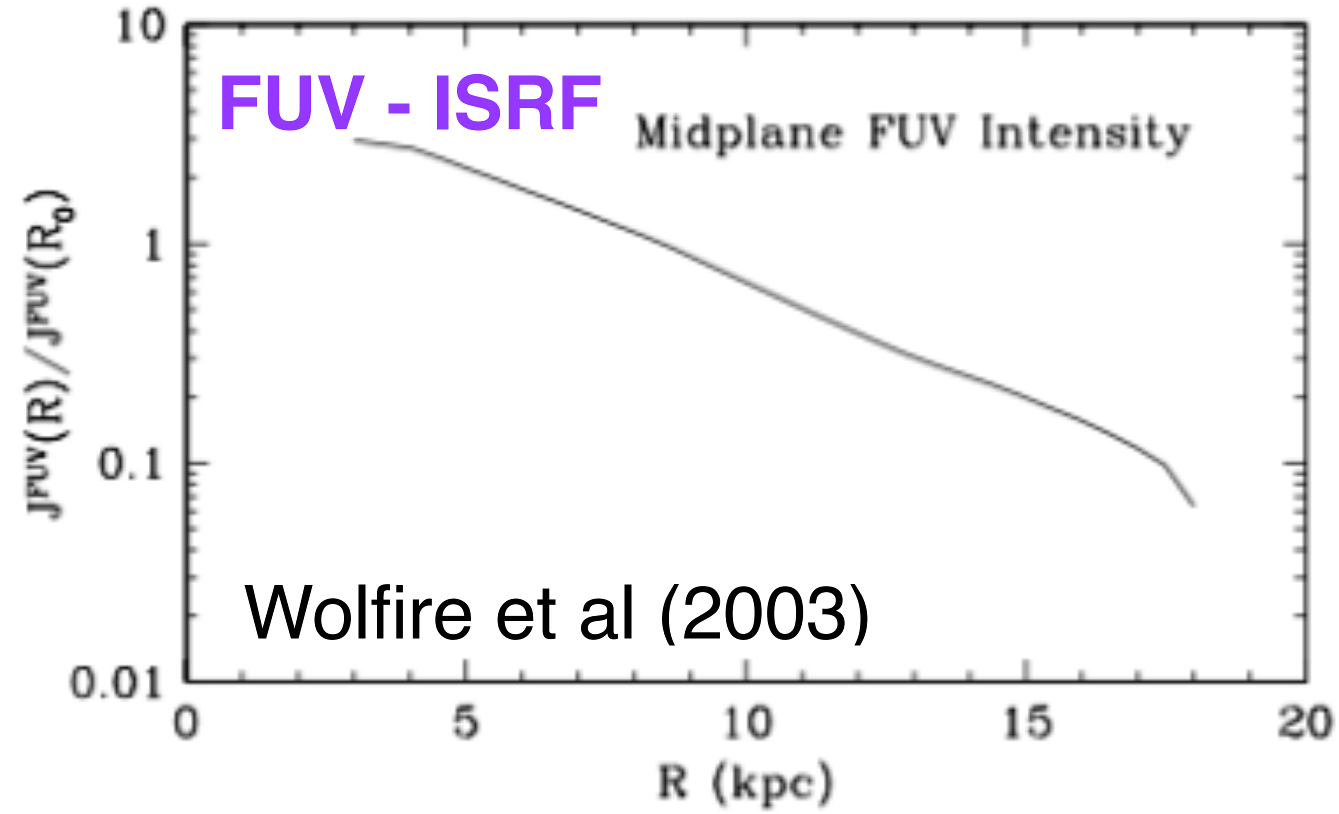
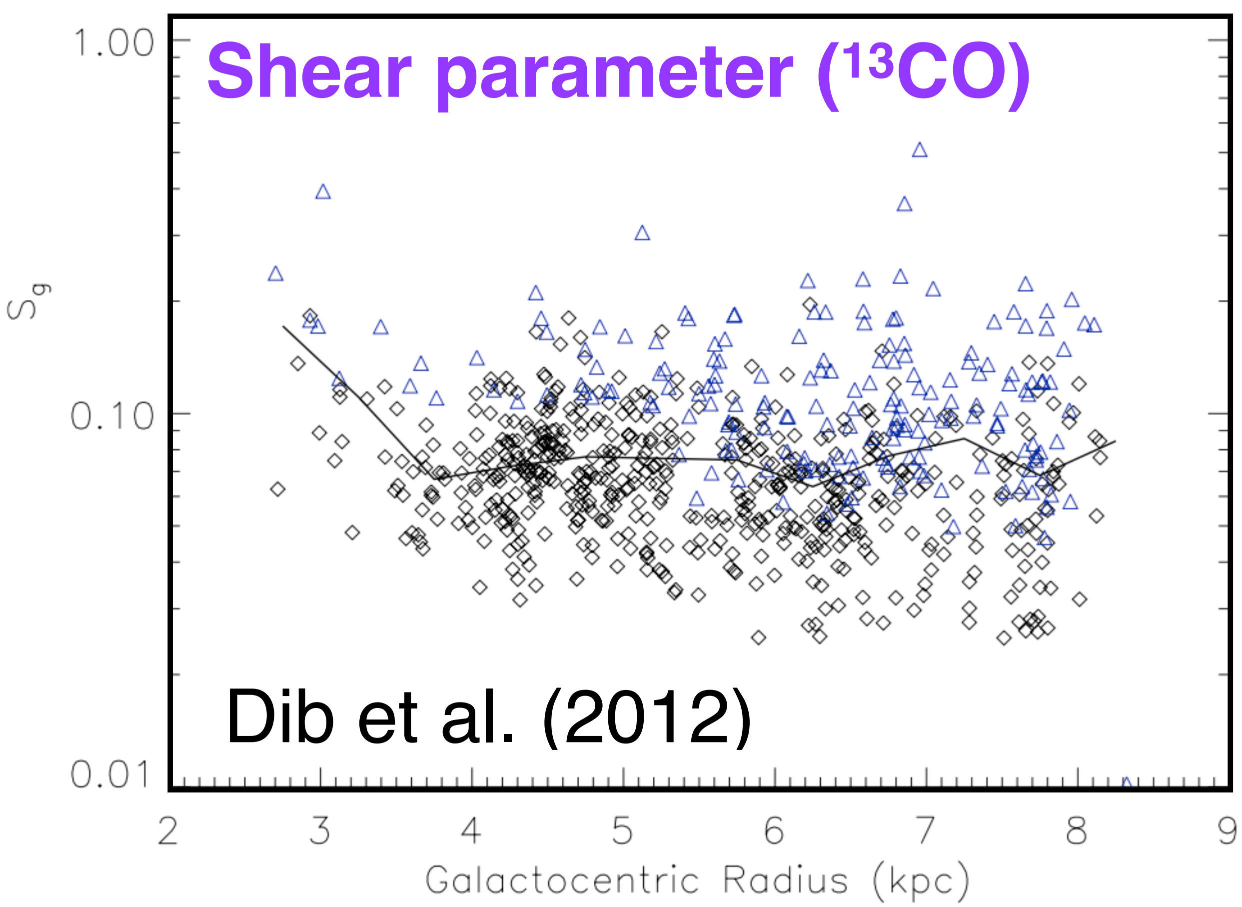
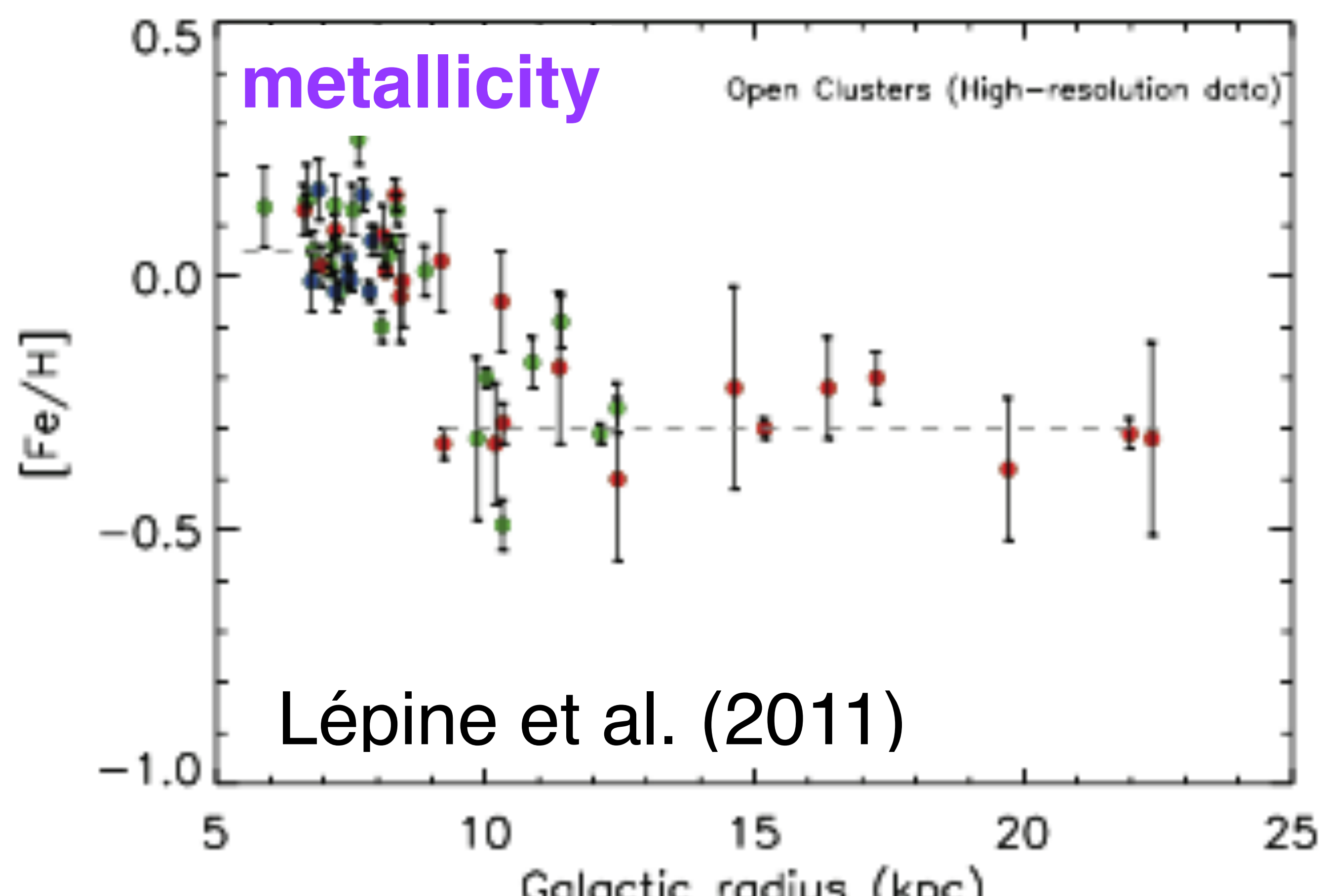
Connecting to large scale trends…









Summary

- 1 / 4 Hi-GAL clumps has a 70μm counterpart.
- Spiral arms are where Hi-GAL sources are concentrated, but there is no enhancement of the star-forming fraction
- The fraction of Hi-GAL clumps with 70μm counterpart decreases gradually with R_{gc} by ~2.6% per kpc
- No *single* large-scale driving mechanism obviously determines SFF trend
- SFF trend serves as a useful benchmark for simulations including the multiple galactic-scale effects