Galactic Star Formation in 2020: a White Paper

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Galactic Star Formation in the 2020s

- The last decade has seen a lot of progress in Galactic Star Formation, thanks mainly to the contribution provided by Spitzer and Herschel.

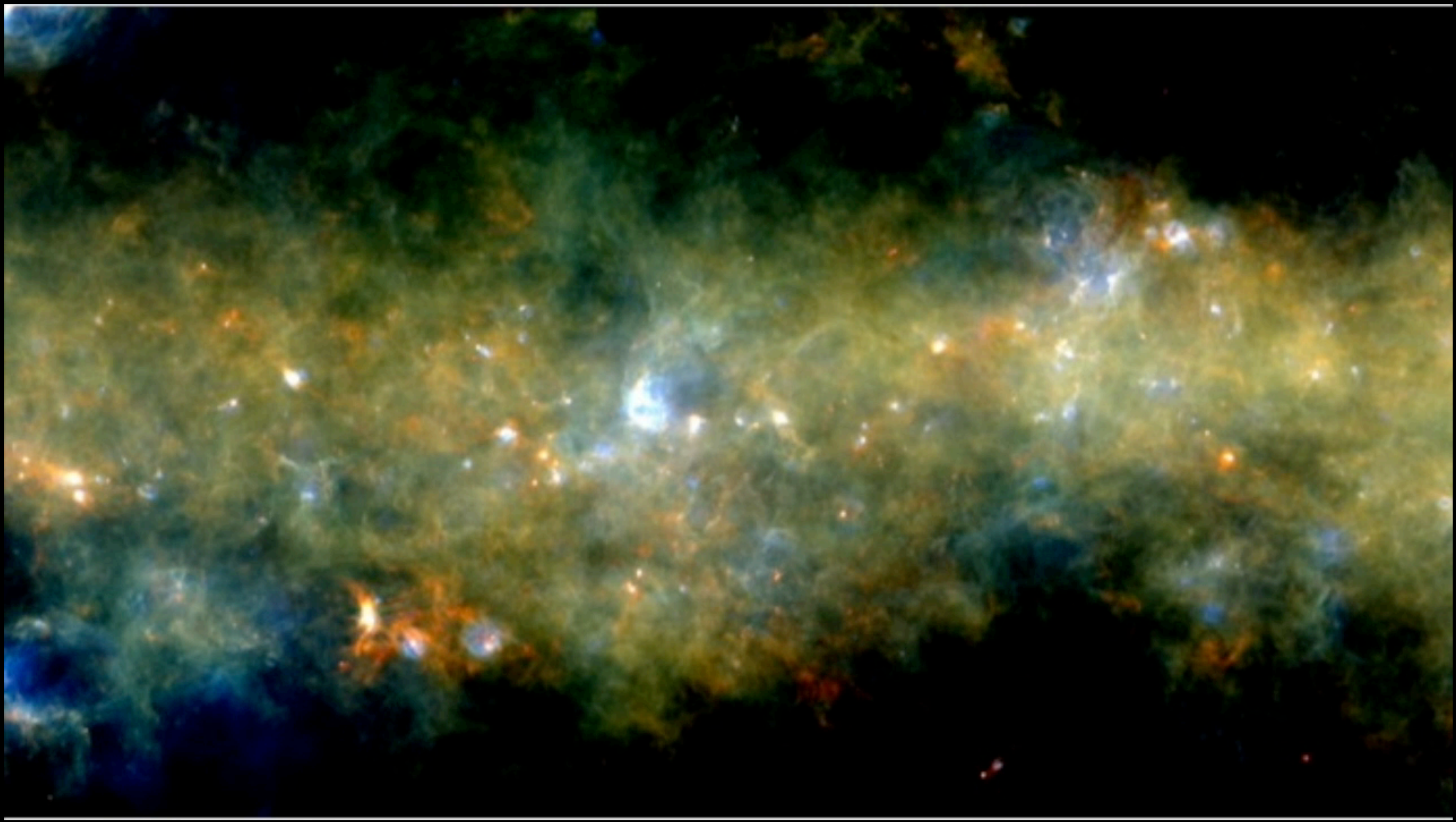
- However, some “old” (i.e., pre-Spitzer, pre-Herschel) questions are still standing, and new ones have risen.

Star Formation White Paper: Science Drivers

- From Clouds to Cores: global conditions for star formation
- Effect of environment and feedback
- Modes of star formation (low-, high-mass, isolated, clustered, etc.)

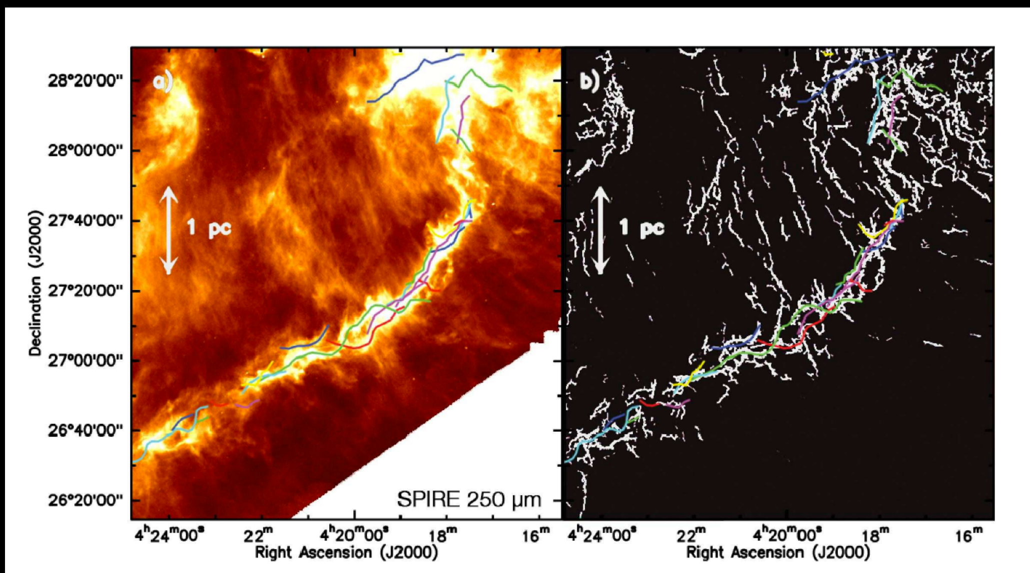
Theme # 1:
From Clouds to Cores

Courtesy: Hi-GAL Consortium



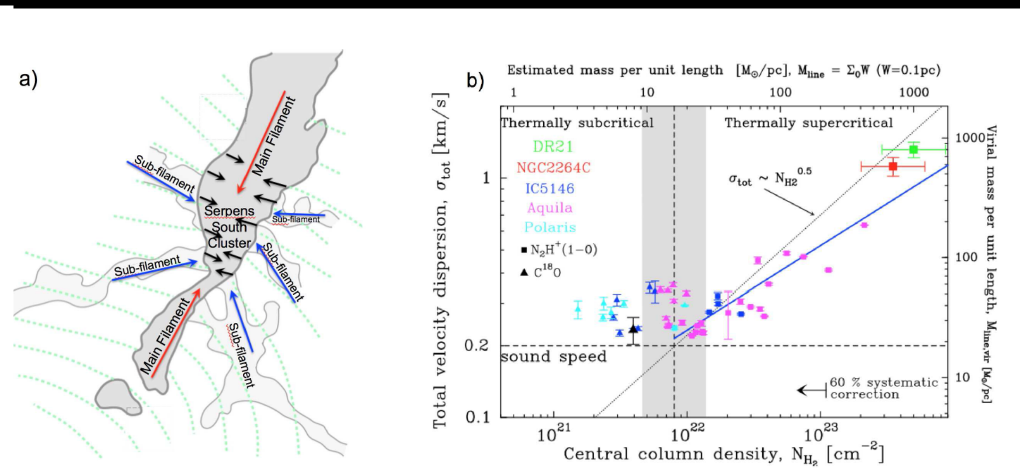
Theme # 1:
From Clouds to Cores

Taurus



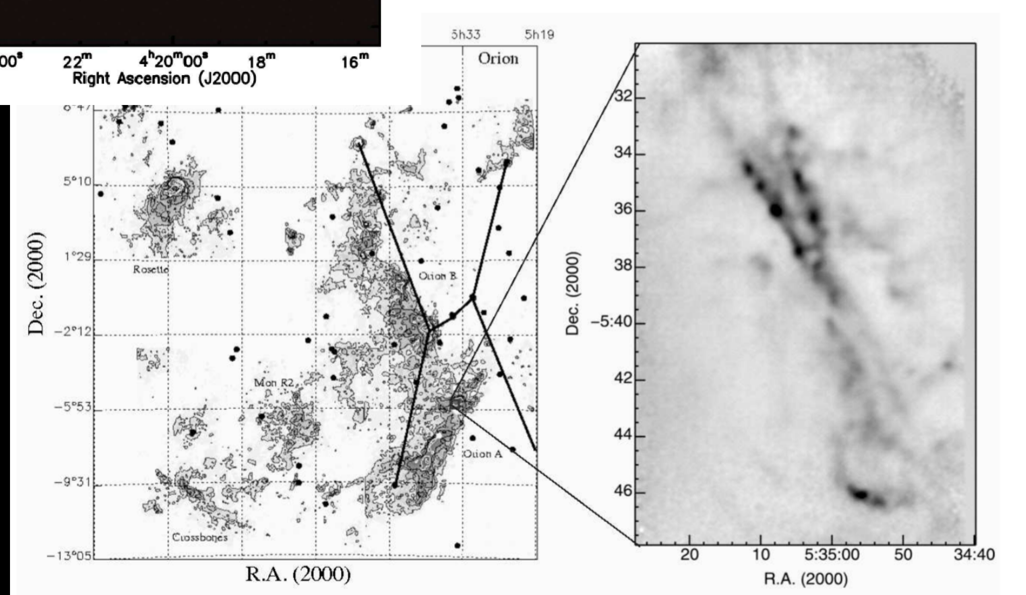
Andre' et al. 2014

Serpens



Andre' et al. 2014

Orion



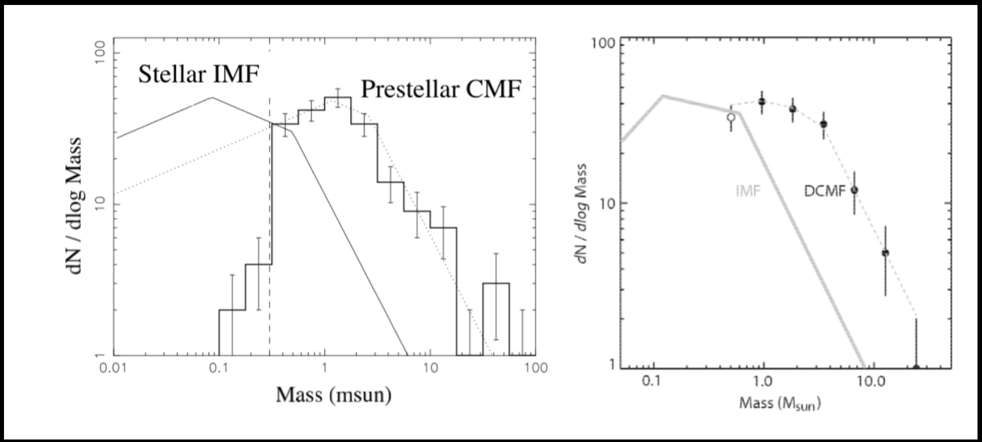
Carpenter et al. 2010

Theme # 1:
From Clouds to Cores

- Is there a universal threshold for star formation ?
- Are filaments necessary for star formation to occur ?
- What is the role of magnetic fields ?

Theme # 2:
The Effect of the Environment and Feedback

- The stellar Initial Mass Function (IMF) is remarkably consistent over a host of environments in the Galactic neighborhood.
- To make a definitive determination if the stellar IMF is imprinted in the cloud structure, future observations need to show 1) that the mass function of clumps in molecular clouds is similar to the stellar/substellar IMF down to ~$0.01M_\odot$, and 2) that the clump mass function is invariant to environment as is the stellar IMF.
- At the same time, theoretical models show that the IMF is expected to vary with the density of the environment (Krumholz & McKee 2008), with the mass of the parent cluster (Bonnell et al. 2004), or essentially not at all (Elmegreen et al. 2008).
- Also, where do most disks/planets form ?



Carpenter et al. 2010

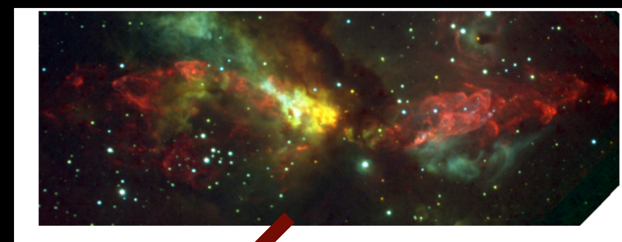
Theme # 3:
The modes of Star Formation

- The birth of massive stars is one of the fundamental unresolved problems in Astronomy

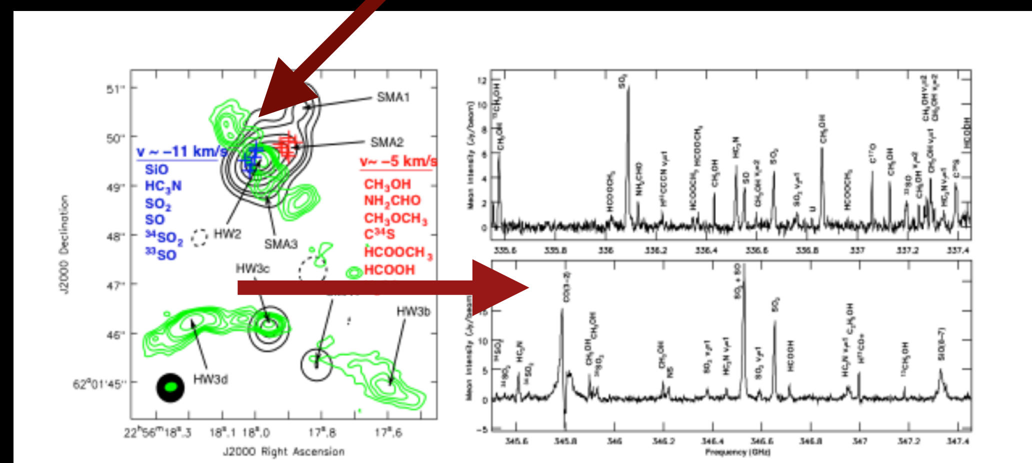
- Monolithic collapse scenario (McKee & Tan 2003) vs. competitive accretion (Bonnell, Bate & Zinnecker 1998)

- Why do some molecular cores produce massive stars while others do not ?

- Massive stars are found in highly clustered environments. What is the role of the environment for forming massive stars (see previous slide) ?



CepA-East



Bally et al. 2010

“*We believe that to understand and address star formation as a global system, we need to design and engage in a systematic program of imaging that covers a large number and variety of Galactic star forming regions.*

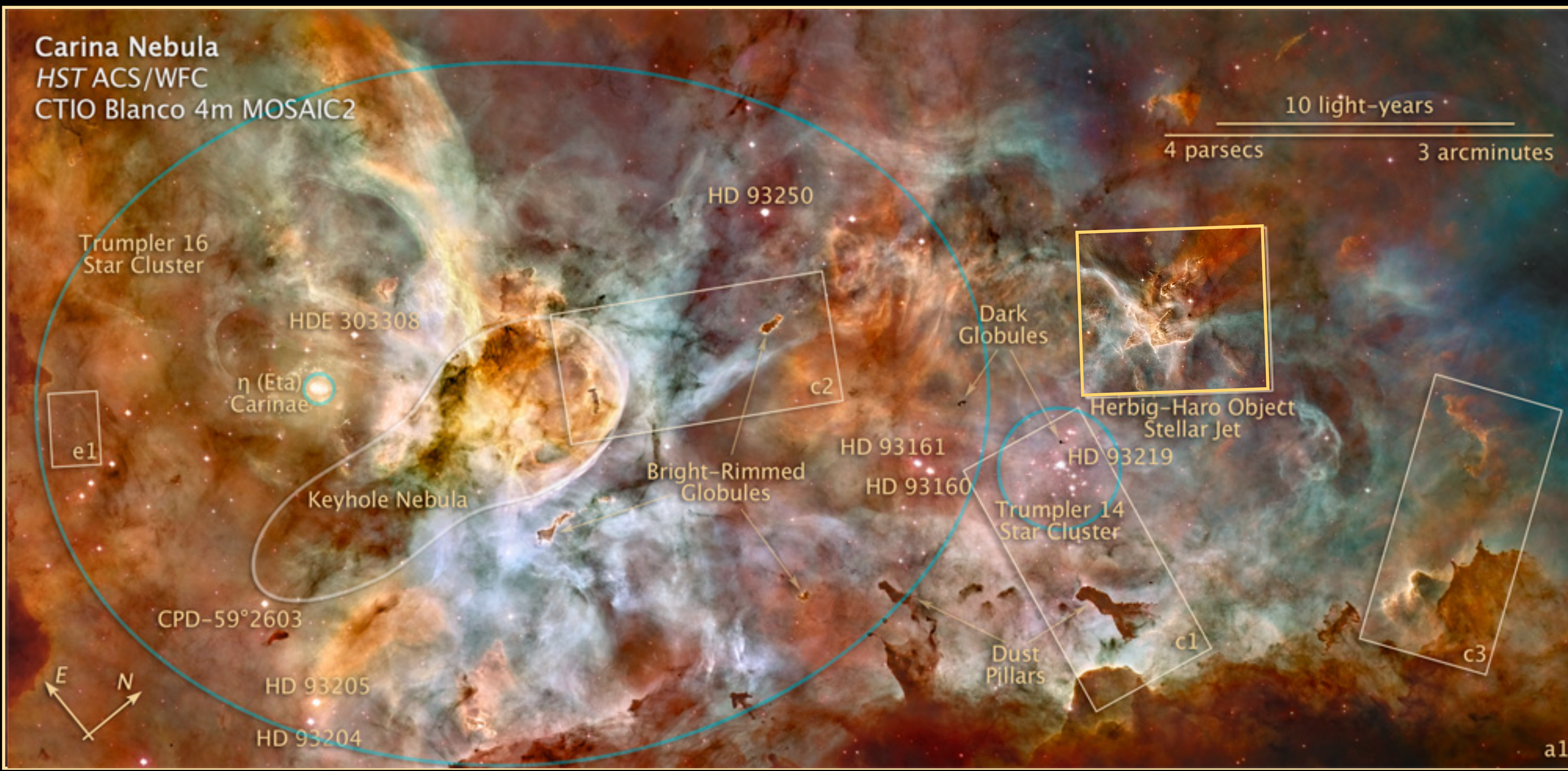
To understand star birth in the early Universe, to understand galaxy formation and evolution, to understand the origin of the stellar mass spectrum, to understand the formation of planets, and to understand feedback, we must treat star birth as an integrated systemic process.”

Paul Scowen, AstroData2010

Example:
the Carina Nebula

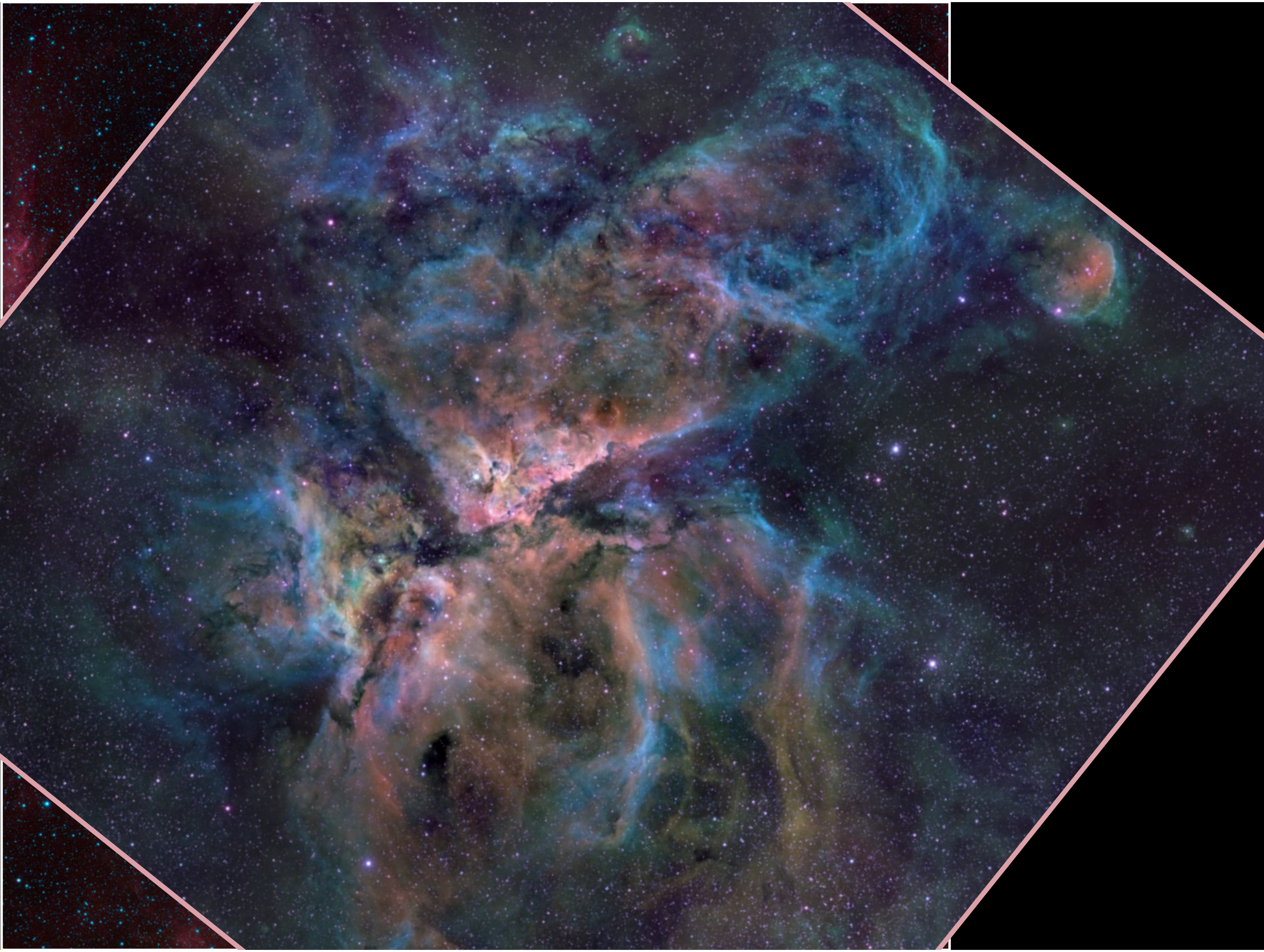
Hubble Space Telescope image of Herbig-Haro jets and pillars in the Carina Nebula

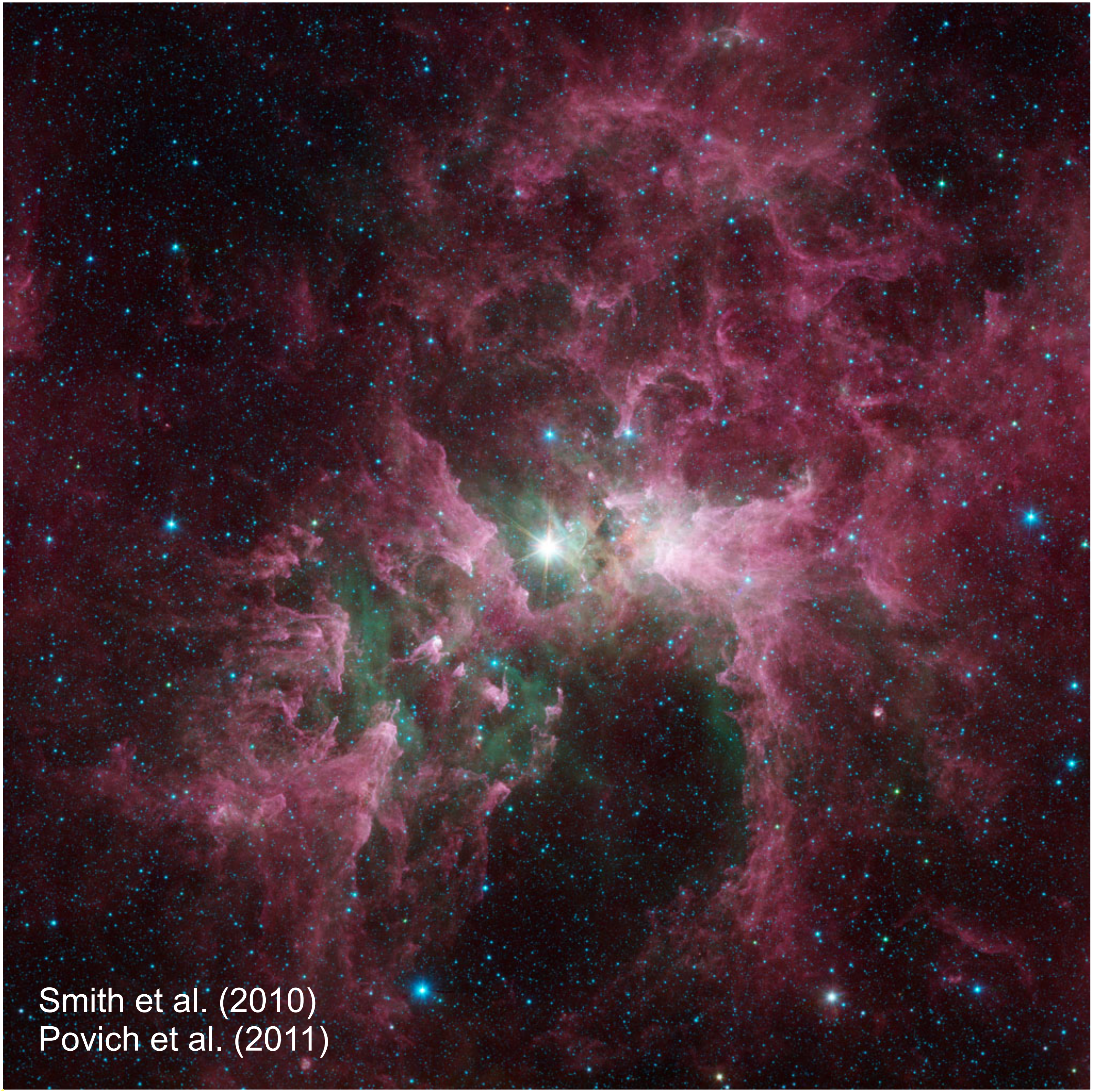
Hubble Space Telescope ~6′×12′ mosaic of the Great Nebula in Carina



The Great Nebula in Carina

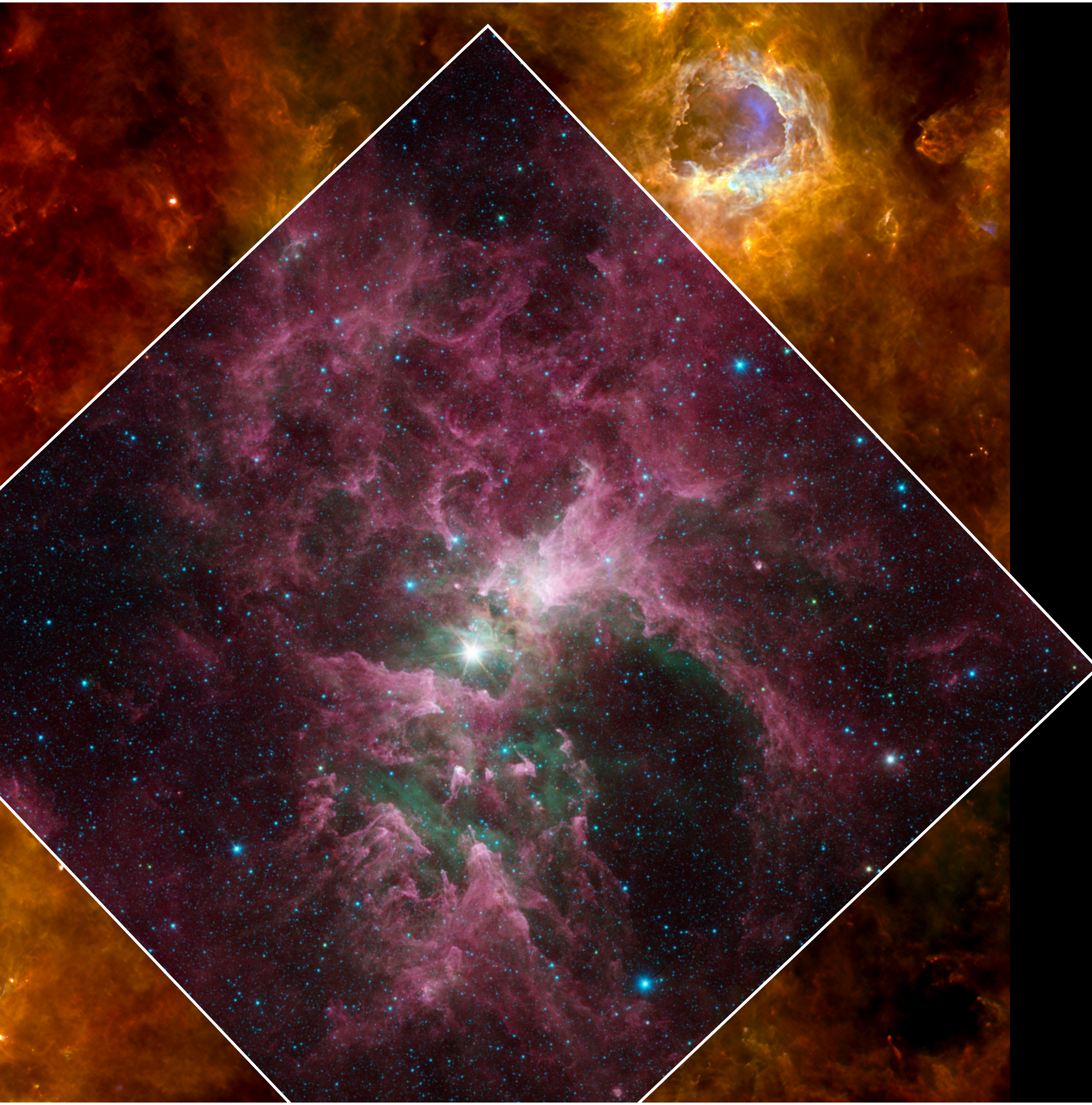
- Carina is a "starburst region," an example of the large-scale star formation seen in starburst galaxies.

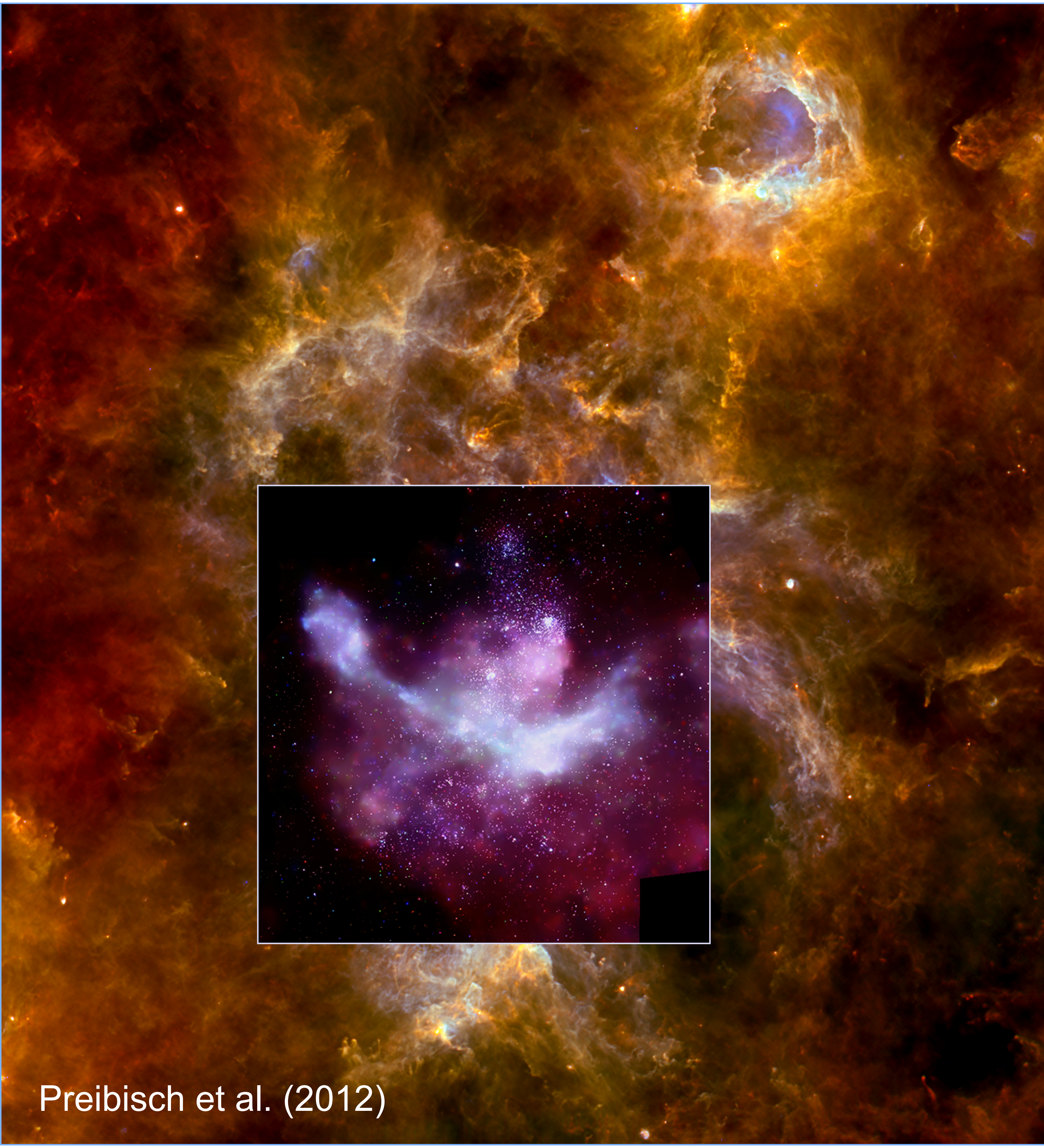




Spitzer/IRAC

8.0 μm
4.5 μm
3.6 μm

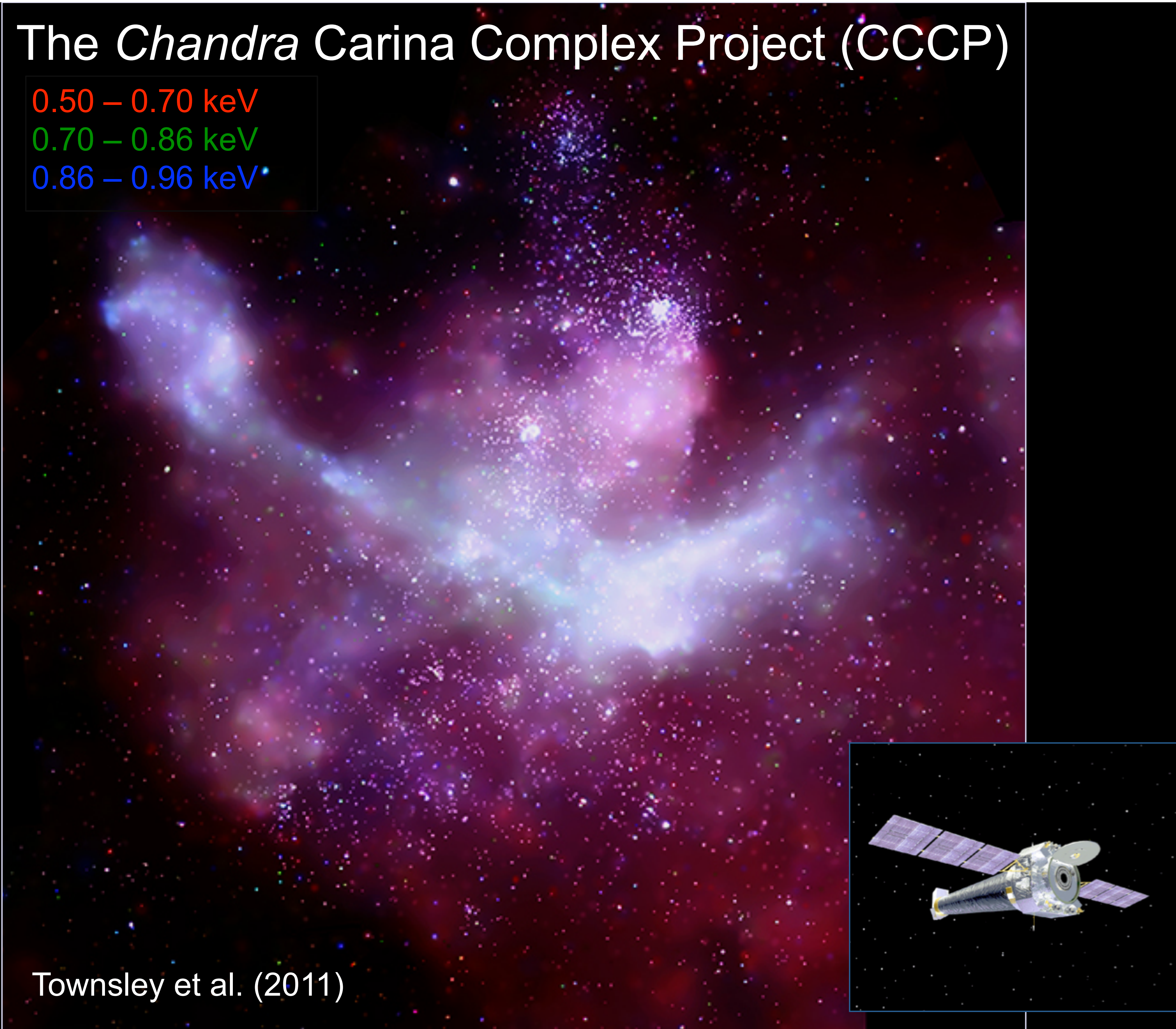




Herschel

SPIRE 250 µm
PACS 160 µm
PACS 70 µm

The *Chandra* Carina Complex Project (CCCP)



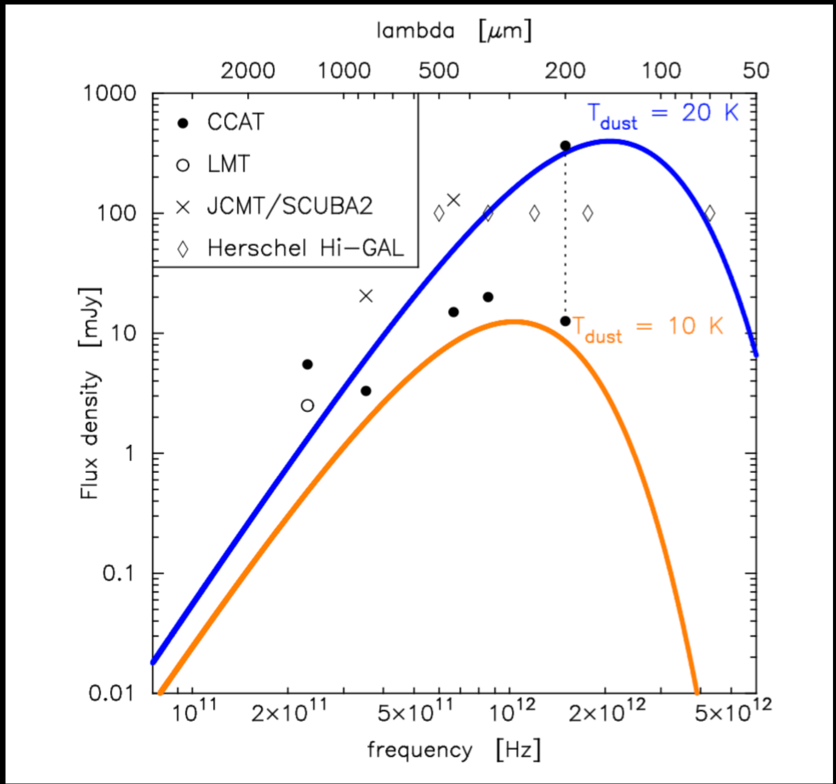
Recommendations

1. Need for large-area surveys: to capture "complexity" of star formation process (see Carina Nebula Example): WFIRST, LSST, Euclid… Origins Space Telescope ?

2. Resolution: need ~5" to allow resolving FIR clumps into cores, and to resolve filamentary networks at distances of several kph (e.g. across the Galaxy).

3. Sensitivity: Assuming a 30% "efficiency" in converting clump mass into stellar mass, observations of the clump mass function need to be complete for masses greater than 0.03 M⊙.

4. Multi-wavelength observations: observations from X-rays (YSOs) to cm-wavelengths (cores), to capture multi-faceted aspect of SF process



From Astro2010 Carpenter et al.'s White Paper

Archive and computing needs

Example:

- Hi-GAL is ~400 GB of data in one band.
- If we double the resolution, we quadruple the size , 400 GB X 4.
- If we have more than one epoch, we have to multiply for the numbers of N epochs, i.e., 400 GB X 4 X N.
- then, if we want more than 1 band, we need to multiply by the number of bands, M: 400 GB X 4 X N X M.
- we quickly arrive at several TBs of data.

Needs:

- Easy access and visualization to multi-wavelength data
- Cloud computing re-sources for handling (and possibly reprocessing) large-area surveys data
- Spectroscopic Database and Tools (-> Galactic Astrochemistry)
- Polarization Database and Tools (-> role of magnetic fields)