# Continuum Emission and Protostellar Clump Evolution

# Census of High- and Medium-mass Protostars (CHaMP)

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**Abstract:** The CHaMP survey attempts to characterize the gas properties and evolutionary timescales of all stages of massive star formation by creating the largest-yet compendium of high-resolution, unbiased observations of both line and continuum emission from molecular cloud clumps in the Milky Way. Here we present a snapshot of our ongoing follow-up of massive molecular gas clumps previously identified in the Mopra and Nanten maps of the 20° x 6° region of the galactic plane in Centaurus, Carina, and Vela (figs. 1 and 2). We have compiled and normalized continuum emission data from 3.4 to 870 μm at spatial resolutions of ~36" from the LABOCA bolometer array at APEX, the PACS and SPIRE photometers on the Herschel Space Observatory, the WISE cryogenic survey, and the MIPS and IRAC instruments on the Spitzer Space Telescope. We will fit pixel-by-pixel greybody spectral energy distributions (SEDs) to the clumps and their immediate surroundings to map the emissivity indices (β), effective temperatures, and peak fluxes (of each component where multiple temperature components are found). We also seek to compare these parameter maps to line emission maps of $^{12}$CO, as well as $^{13}$CO, C$^{18}$O, HCO$^{+}$, and other dense gas tracers where available, with an eye toward deriving clump masses, luminosities, sizes, distances, and evolutionary classes.

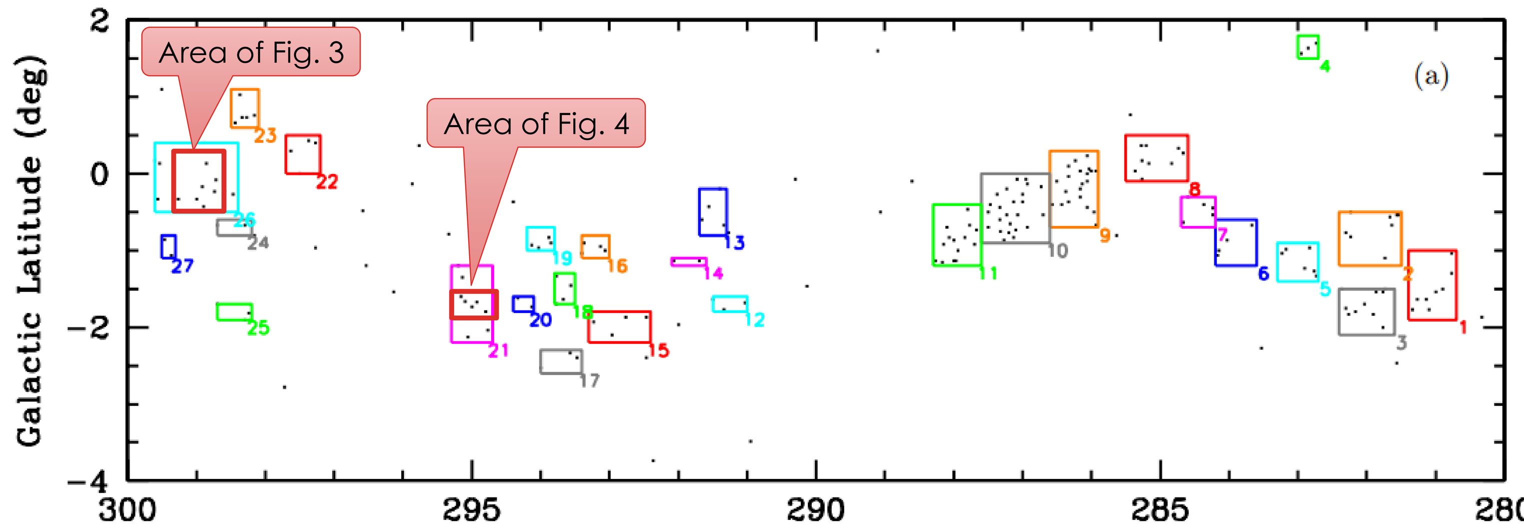

Fig. 1

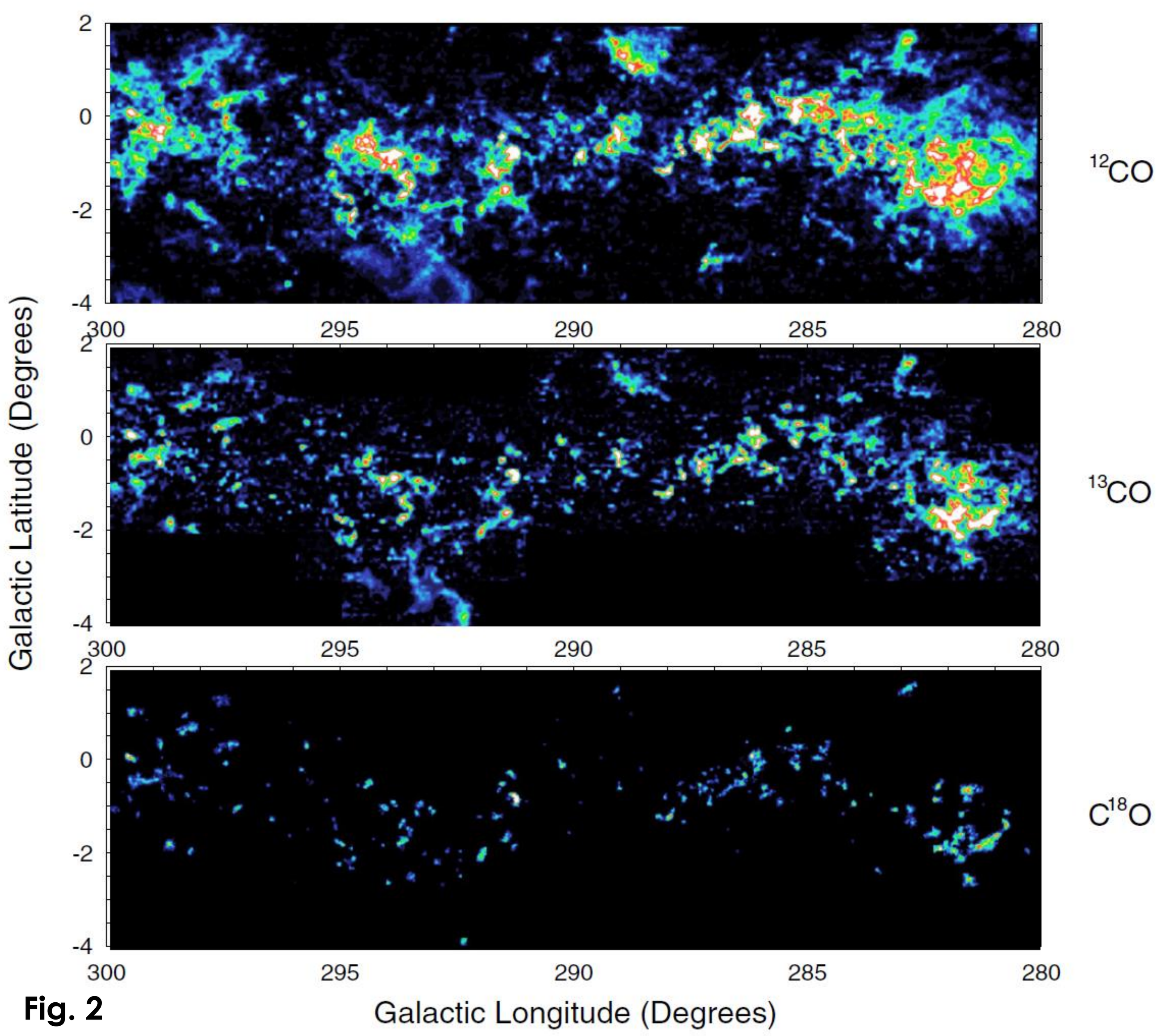

Fig. 2

## Recent Work

Preliminary population statistics from the CHaMP survey suggests that star-forming clumps may spend as much as 20 times longer idle than they do forming stars (Barnes 2011, Barnes 2013). However, these data are biased by the effects of abundance-altering chemical reactions particular to each gas tracer & its environment (see Barnes 2013), of which dust emission is believed to be independent. To expand upon this survey with unbiased data, we collected spacecraft images of continuum dust emission in the neighborhoods of such clumps, both star-forming & not, from 3.4 to 870 um. Currently we are finalizing the code to rotate, normalize, & convolve these data to a common grid with a resolution of 36" (equivalent to that of the Mopra antenna).

**Early findings:** regions 21 and 26 (see figs. 3 & 4) show multiple evolutionary stages of protostellar clumps in close proximity, & they appear to lie along filaments in agreement with conventional theories on massive star formation (Andre et al. 2010, Polychroni et al. 2013). If the chain of gas clumps shown in region 21 (fig. 4) are all part of the same filament as suggested by kinematic distances (Barnes et al. 2011), one may notice that the chain ends at its most evolved members. The structure of these filaments & locations of the most evolved clumps bear some cursory resemblance to the kpc-scale beads-on-a-string mode of star formation seen in interacting galaxies. We will be looking to see if physical & dynamical properties support or dismiss this triggered star-formation interpretation.

**Figures (counterclockwise from above right)** – **1)** Map showing locations of clumps (black dots) identified in the Nanten & Mopra HCO+ maps, & regions into which they were grouped. Regions 21 & 26 were selected as test areas for analysis protocol development. **2)** Maps of 3 isotopologues of CO over the whole CHaMP survey area. $^{12}$CO traces the most diffuse gas & C$^{18}$O traces the densest gas. **3)** RGB images at several wavelength ranges of a subset of Region 26 encompassing BYF nos. 199, 201-203, & 208. Green contours are 870 emission (ATLASGAL) and magenta contours are 12CO emission (Mopra). **4)** Mopra map of Region 21 (left) with boxed area shown in WISE bands 2-4, plus Mopra & ATLASGAL contours.

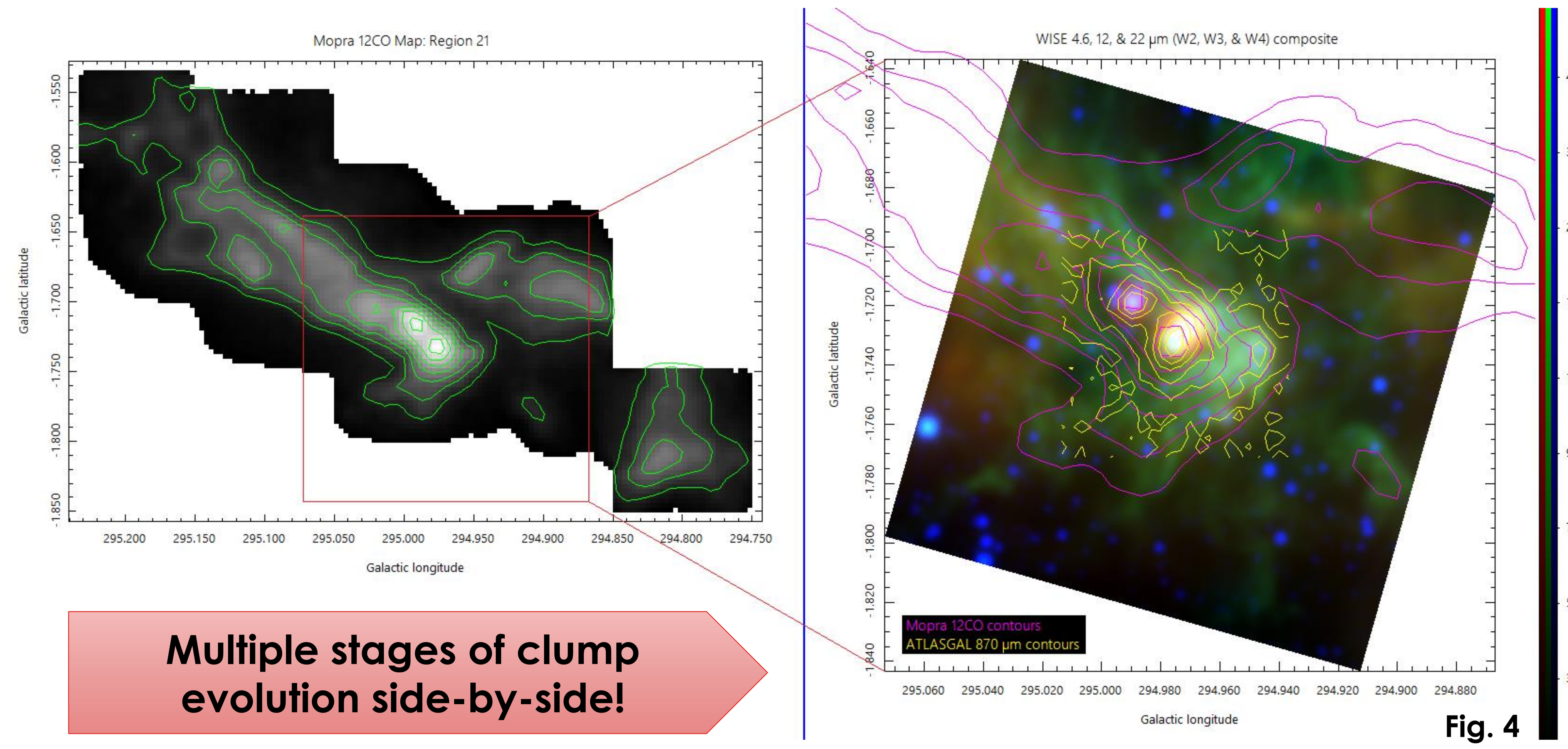

Fig. 4

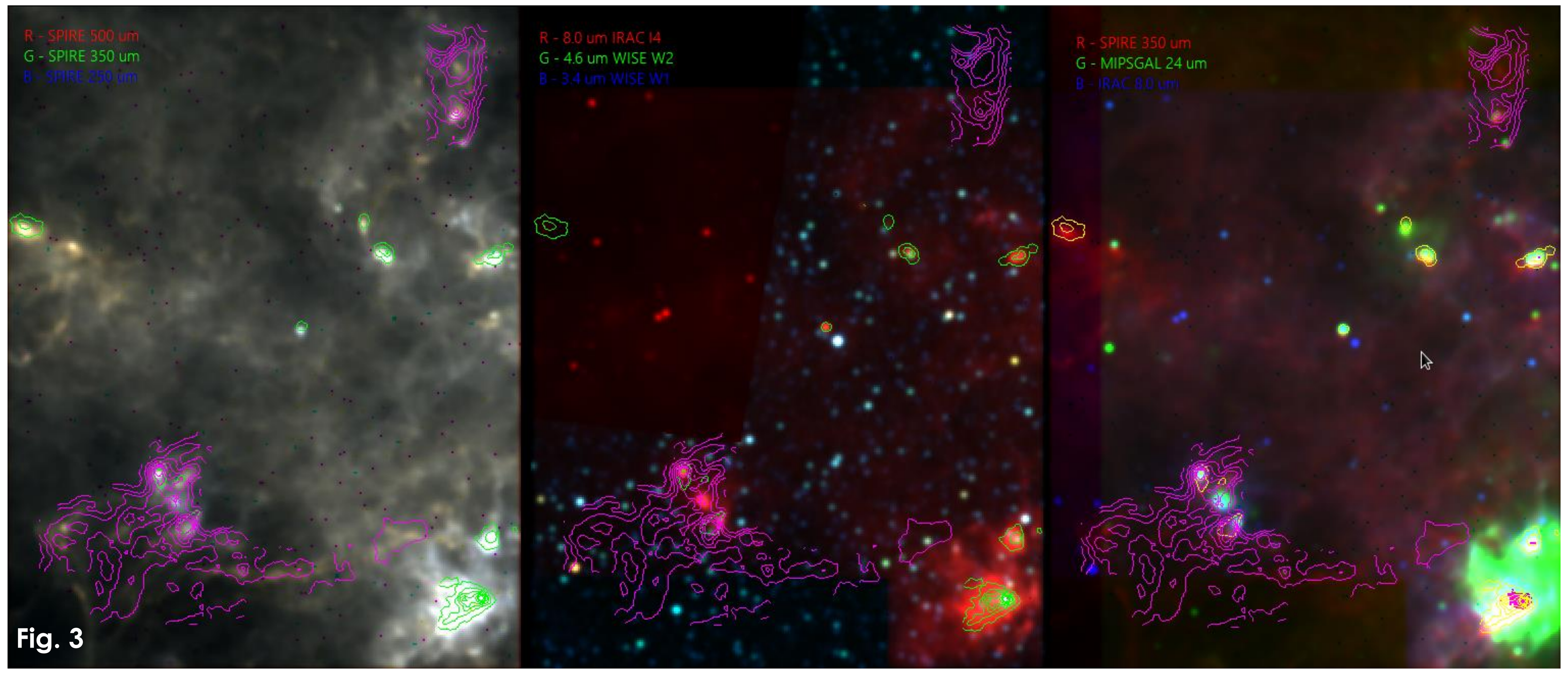

Fig. 3

## Future Work

Once final corrections to image alignment & convolution have been applied, we will fit modified Planck SEDs pixel-by-pixel using the Mosaic-Math routines of the MOSAIC-IDL package (F. Varosi, in preparation). Mosaic-Math assumes up to 3 temperature components—a hot source, a warm envelope, & cool foreground medium—plus a fixed fraction of silicates in the emitting dust & an initial distance estimate to compute 3 temperatures & peak fluxes, emissivity, & foreground extinction.

**Summary of goals:**

1. Use pixel-by-pixel SED fitting to create parameter maps of dust emissivity (β), grey-body temperatures & peak fluxes for up to 3 emitting components, & extinction along the line of sight. Spitzer IRAC bands 3 & 4, as well as WISE band 3, straddle several silicate & PAH emission features that need to be integrated over to be used reliably.
2. Define the boundaries of the clumps with the parameter maps to count clumps & determine their evolutionary classes (0-III), luminosities, sizes, distances, & gas masses. Numbers of clumps in each evolutionary class will be used to estimate the typical time spent of each stage.
3. Use gas masses & luminosities to compute star formation rates for each nascent cluster, & compare the gas mas derived from continuum emission to that found using gas tracers like CO, HCO+, & N2H+ as a measure of the bias in these tracers, assuming the dust emission is an unbiased gas tracer.

## References

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