SOFIA Follow-up to Spitzer Observations of the North American Nebula

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Abstract

Much of our current knowledge regarding star-forming patterns and circumstellar disk evolution derives from study of molecular cloud complexes within a few hundred parsecs of the Sun, such as Taurus (140 pc) or Orion (400 pc). Studies of these two regions are the primary touchstones that inform our understanding of how stars form. However, the two environments are very different in many ways. Because the environment does matter, for a comprehensive understanding of star formation, it is important that we study more than just the nearest examples of the extrema of star formation modes. A good example of "mixed-mode" star formation is the relatively nearby (~600 pc) North American (NGC 7000) and Pelican (IC 5070) Nebulae complex (hereafter NAN). We observed the NAN with Spitzer (3.6 to 160 um), revealing a complex ISM distribution and more than 700,000 point sources. In particular, the "Gulf of Mexico" in "North America" is revealed to be a dramatic cluster of 100s of ob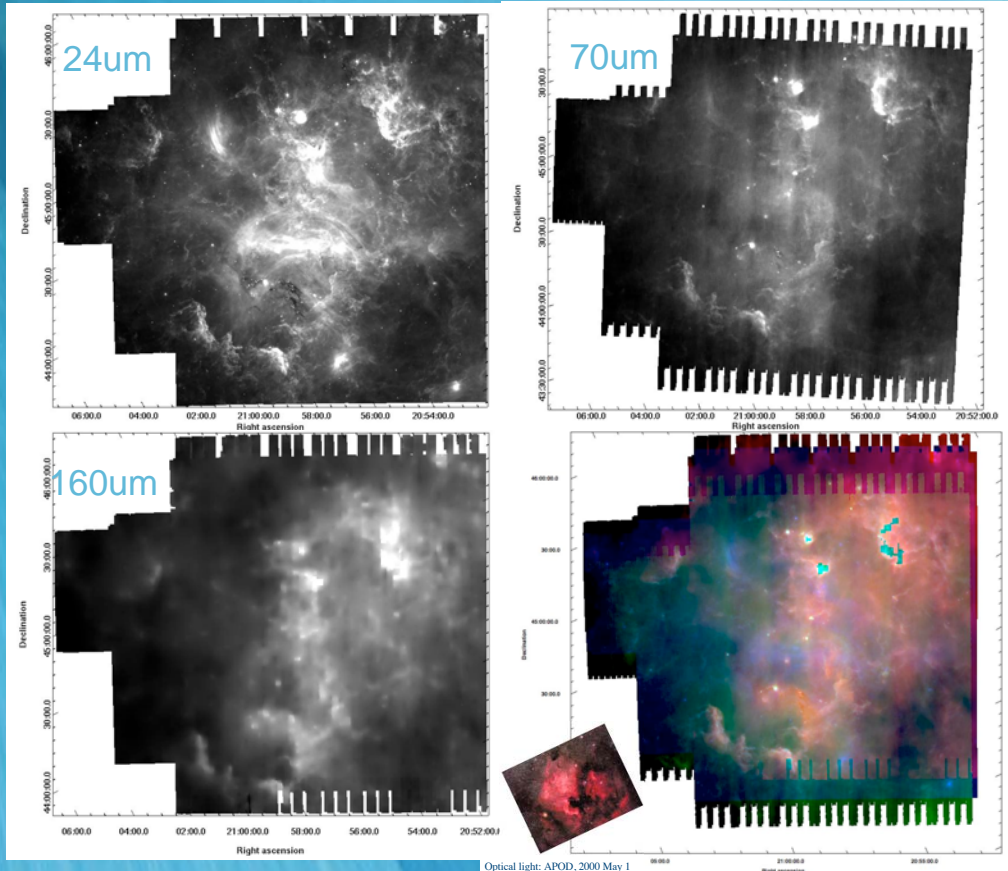jects, many seen at only 24 microns. *Using SOFIA would allow us to improve our resolution by a factor of 3, as well as extend our coverage at this resolution to at least 40 microns.* This should help us characterize the properties of the many YSOs here and give us insight into some of the youngest objects in the NAN, as well as improving understanding of the star formation process in dense regions such as this.

24um / 70um / 160um

Optical light: APOD, 2000 May 1

What is this Region?

- The North American Nebula and Pelican Nebula complex appears to exhibit "mixed mode" star formation, e.g., low and high mass, clusters and distributed populations.
- ~10^5 Msun in molecular gas, ~10^4 Msun in stars.
- Ages <~1 Myr to <~10 Myr. (See Guieu et al., 2009, ApJ, 697, 787.)
- ~6-700 pc away. (only ~30% more than ONC.)
- Why hasn't it been better studied to date?
- It's in the galactic plane (b~-0.53 deg) and along a spiral arm! More sources in ~7 square degrees here than in ~44 square degrees in Taurus.
- Contamination is …problematic. Spitzer finds the stars with IR excesses.
- *Spitzer data have taken us from ~200 previously known YSOs to ~2100 new YSOs in this region (see Rebull et al. 2010, in prep). Most of them are Class II, and about half are found within newly-defined clusters.*

The "Gulf of Mexico"

- Multi-wavelength views are below. *"Herbig's cluster" is on the north end; these objects were identified in the literature, but the rest are new Spitzer discoveries. Note some regions are opaque even at 70 microns.*
- ~270 MIPS-24 sources can be identified as part of the cluster. ~0.67 deg across; at 600pc, ~7pc.
- ~60% of the MIPS-24 sources have Ks counterparts, ~90% of the MIPS-24 sources have IRAC counterparts.
- ~10% of the MIPS-24 sources have 70 counterparts.
- The objects have a wide range of colors, from photospheres to very red (deeply embedded). The more-embedded objects are more clustered. Sample SEDs are to the right.
- This is probably the youngest region of the NAN complex.

With SOFIA…

Using 900 sec exposures, 40% of the Gulf of Mexico M24 sources are detectable (S/N=4) using FORCAST at 24 um. All of those sources will also be detectable at 11 um. 10% of the M24 sources have measured 70 um, with flat or rising SEDs. Most of those will be detectable at 37 um. SOFIA's spatial resolution allows better flux apportionment, and SOFIA's wavelength coverage allows a better understanding of exactly where the IR excess starts, both of which lead to a better understanding of the mass function and disk properties in this very young cluster.

RIGHT: SEDs for 16 selected objects from the Gulf. Symbols denote photometry: X/Δ/+= optical; ◆=2MASS, O=IRAC, □=MIPS. Some objects are undetected (or inseparable from neighbors) at MIPS wavelengths, some objects are essentially photospheric, and some objects are deeply embedded. LEFT/BELOW: multi-wave views of the Gulf of Mexico. Note high Av, and some portions dark at 70.
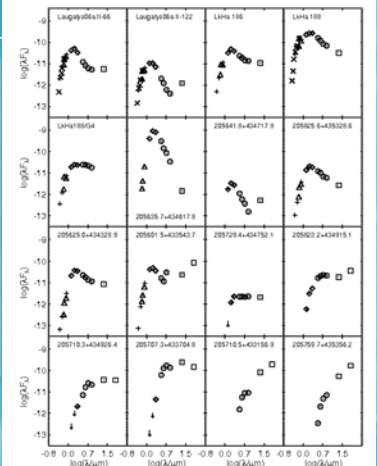
Want more information on the Spitzer observations of the NAN? See Rebull et al. (2010) in prep and Guieu er al (2009).

POSS / 2MASS-J / 2MASS-H / 2MASS-Ks

IRAC-1 (3.6 um) / IRAC-2 (4.5 um) / IRAC-3 (5.8 um) / IRAC-4 (8 um) / MIPS-1 (24 um) / MIPS-2 (70 um) / MIPS-3 (160 um)