Initial Conditions of Disk Formation:
The Class 0 Envelope Structure

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Asymmetric Envelopes

In our *Spitzer* IRAC study of protostars associated with scattered light nebulae, we found many protostars have large envelopes that are extincting the background ISM emission in their vicinity. These envelopes in extinction have enabled us to study their structure at 2'' resolution. ***Most envelopes that we find are not spherical and even asymmetric!*** A subset of detected envelopes is shown in Figure 1, the images are 3.6 micron IRAC images and the white contours trace the optical depth of the envelopes.

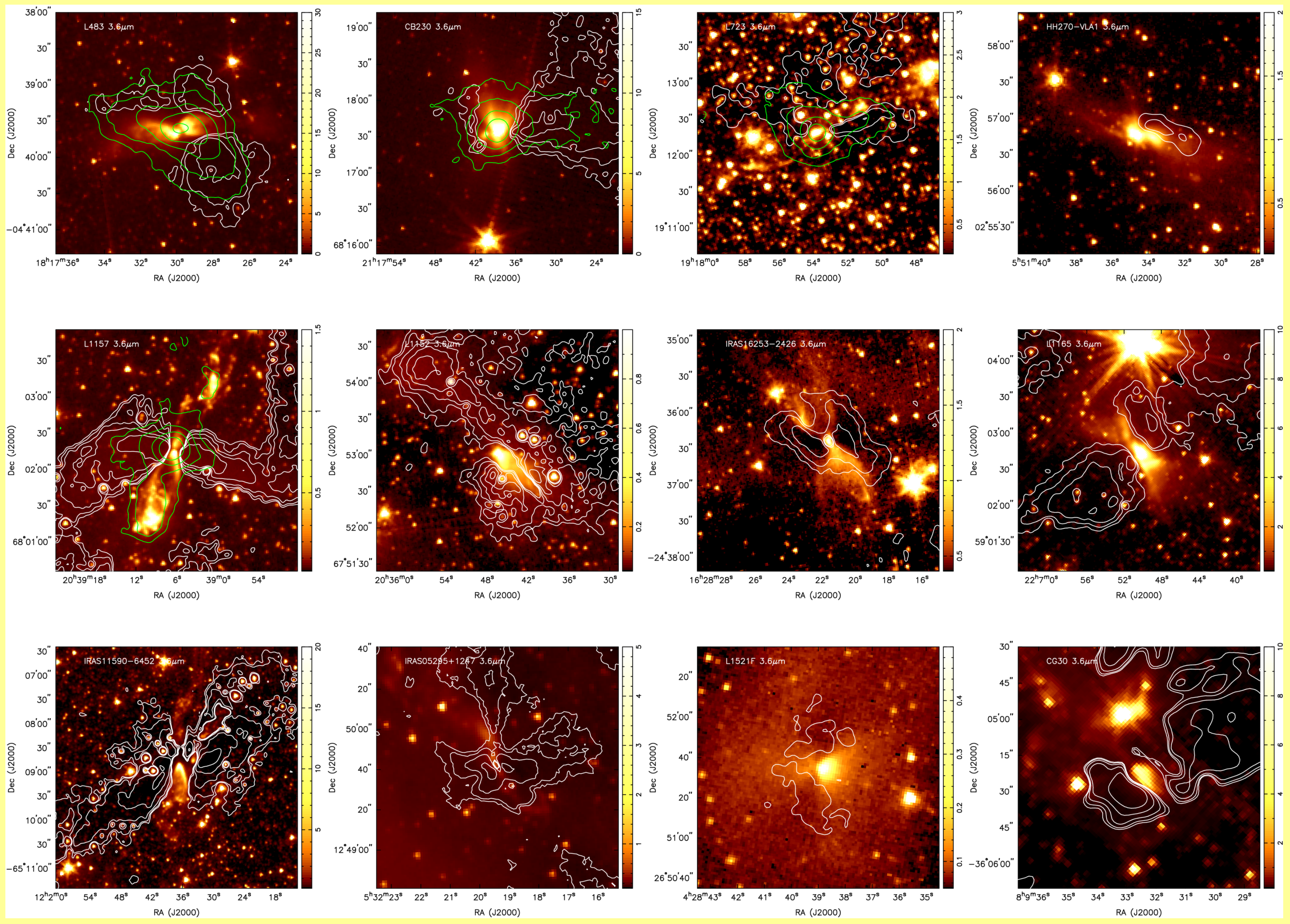

Figure 1: IRAC 3.6 micron images of protostars with 8.0 micron optical depth contours (white) and SCUBA 850 micron contours (green) overlaid.

Some of the envelopes are also highly flattened or filamentary; L1157 (Looney et al. 2007) and L723 are particularly dramatic examples. We compare the dust extinction to submillimeter emission where observations are available, see Figure 1 (green contours). The submillimeter emission traces the same structures as the extinction, though the extinction tends to show even more extended structure. An advantage of the extinction mapping over dust emission is that we can determine masses without assuming a dust temperature and/or temperature distribution.

These envelopes imply that infall is going to be complex, if not non-axisymmetric. This has important implications for early disk evolution as infalling mass will be unevenly distributed in the disk. ***Thus, non-axisymmetric infall may play a key role in the formation of multiple systems as these highly non-uniform structures are falling in*** (e.g. Boss 1995). We also see that protostars form within envelopes with a variety of structures. However, do these envelopes reflect the initial conditions of the cloud or are they the product of large scale collapse and fragmentation of the molecular cloud? Hartmann (2002) pointed out that large scale sheets will collapse into filaments which fragment into individual protostars. This may be the case for many of our protostars which seem to be part of a larger filament (e.g. L1152, L1157, IRAS 11590-6452, L1165).

References

Boss, A. P. 1995, RMxAC, 1, 165
Hartmann, L. W. 2002, ApJ, 578, 914
Looney, L.W., Tobin, J. J., Kwon, W. 2007, ApJL, 630, 131
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Modeling Results: L483

Modeling of these sources is quite complicated by the asymmetric envelopes and complex inner envelope morphology. We approximate the inner structure in L483 as a dual-cavity, similar to the case of L1527 (Tobin et al. 2008). Our models replicate the central source well, but fall short in outer cavity brightness a short distance from the center. Also, the models constrain the centrifugal radius to be less than 200AU and the Gemini 7.7 micron image requires the disk to be less than 50AU at 80 degrees inclination. Also, the disk wall is preferred to be 2x thick as normal hydrostatic equilibrium to increase the observed near to mid-IR scattered light. Relevant parameters of the model are given in Table 1.

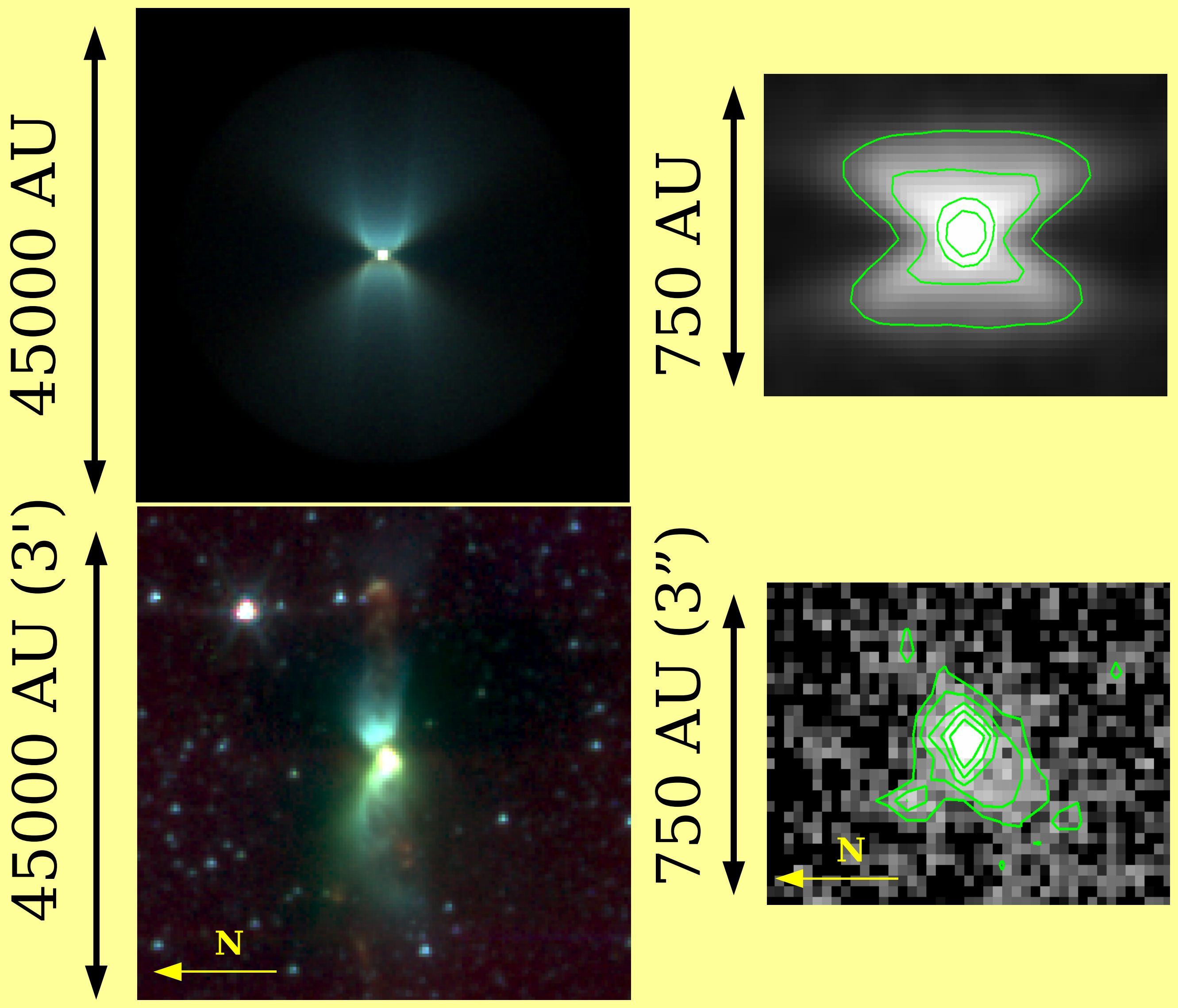

Figure 2: Modeling (Top) results for L483 (Bottom). Color images are IRAC channels 1, 2, and 4. Right panels are 7.7 micron images of the central 3" x 4" of the top images. The bottom right panel was observed with Michelle on Gemini-North. Model images are produced by Monte Carlo code of Whitney et al. (2003).

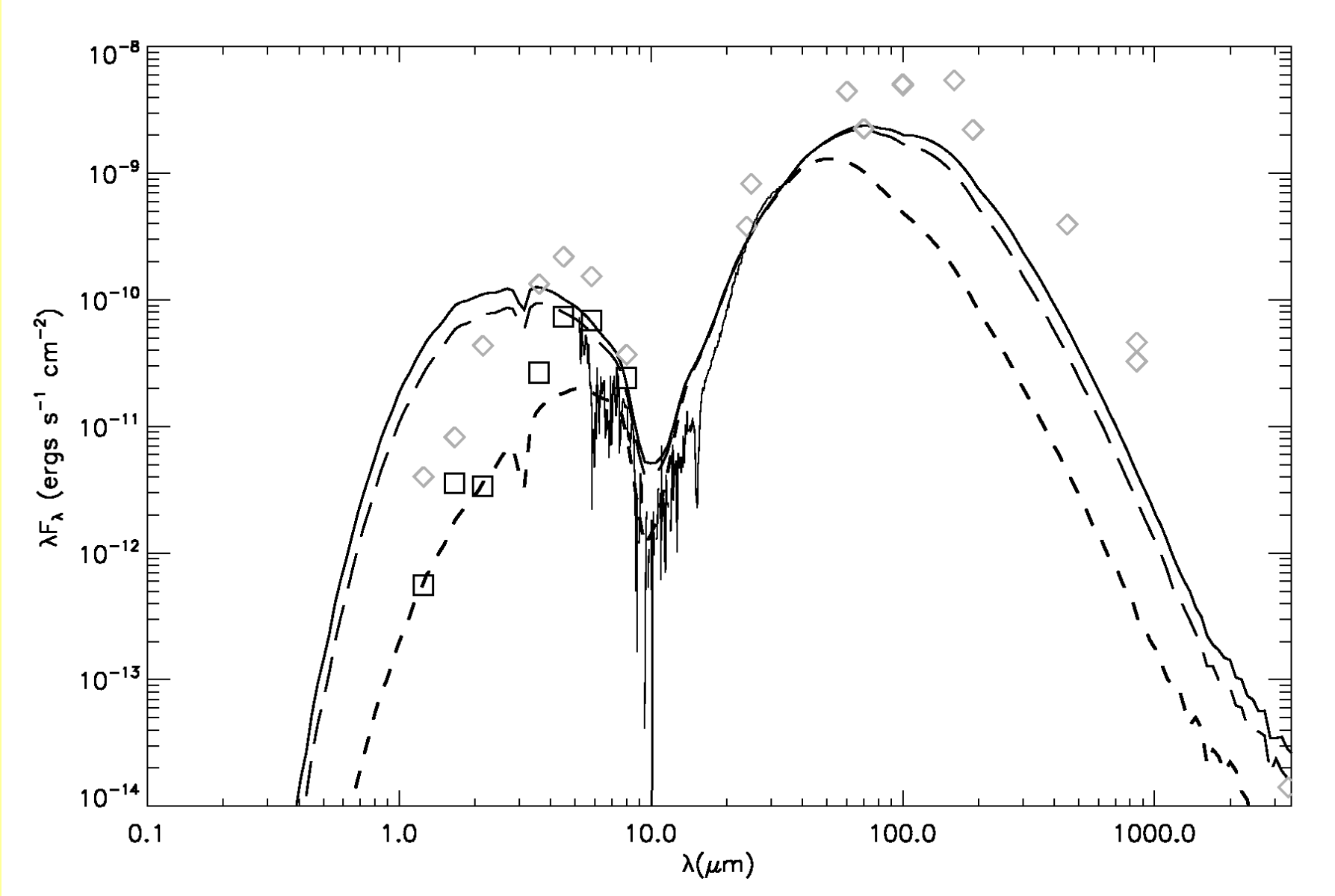

Figure 3: Model SED of L483 plotted with NIR to mm photometry and Spitzer IRS spectrum. Models require a disk less than 75 AU around central source.

Table 1:
Modeled Physical Parameters

Stellar Temperature	4800 K
Stellar Radius	3.64 R_{sun}
System Luminosity	8.86 L_{sun}
Envelope Radius	20000 AU
Disk/Centrifugal Radius	25 AU
Mass Infall Rate	2.0×10^{-5} M_{sun}/yr
Disk Accretion Rate	2.0×10^{-7} M_{sun}/yr
Disk Mass	0.01M_{sun}
Inner Cavity Opening Angle	10°
Outer Cavity Opening Angle	10°
Outer Cavity Shape Exponent	3.5
Inner Caviy Shape Exponent	1.75
Outer Cavity Offset	200AU

Probing Kinematics with N$_2$H$^+$

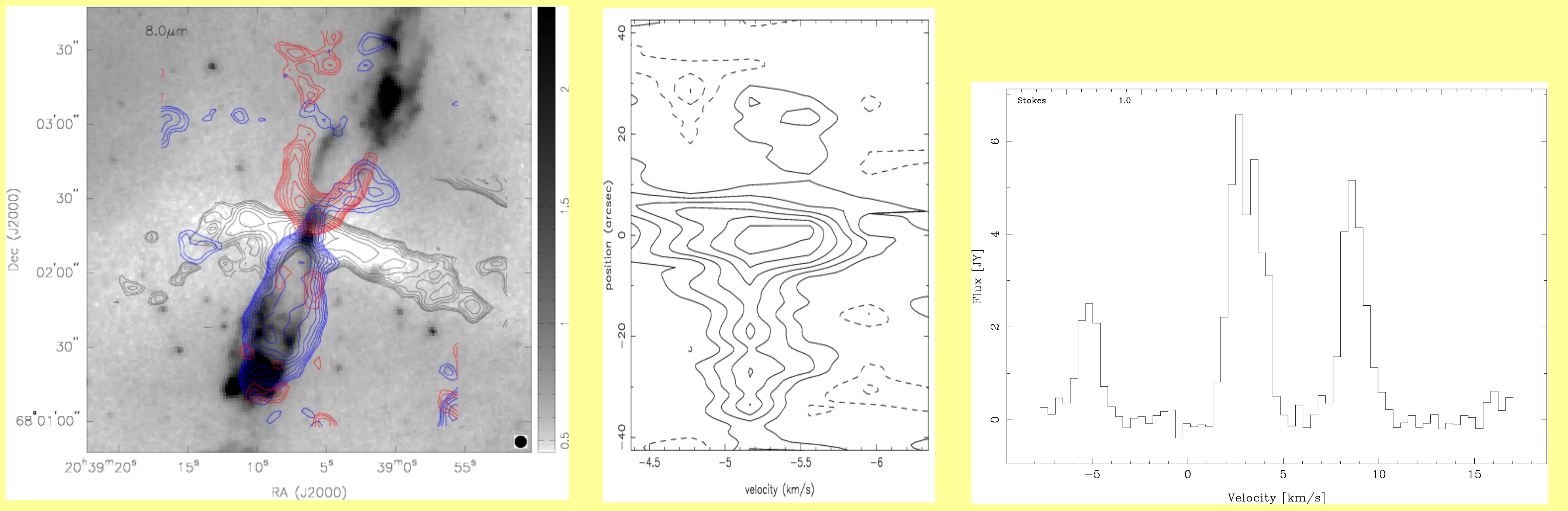

Figure 3: Left: IRAC 8.0 micron image with N2H+ (black contours) and HCO+ (red/blue) overlaid. Middle: Position-velocity plot of L1157 across the extended envelope. Right: N2H+ spectrum of L1157 at 0.4 km/s resolution.

We have found that high density tracers such as N2H+ and ammonia correlate very well with the 8.0 micron extinction. We are observing more protostars in the sample with N2H+ and ammonia at 0.1 km/s velocity resolution to determine the kinematic structure of these asymmetric envelopes and study the effects of infall from these envelopes onto disks. In Figure 3, we show an N2H+ image and spectrum of L1157 taken with the CARMA array as well as a position-velocity plot across the flat envelope. We detect a slight gradient with a velocity resolution of 0.4 km/s. This may be indicative of large scale rotation.