Density Distribution and Grain Growth of Class 0 YSOs

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Abstract

Circumstellar envelopes of young stellar objects (YSOs) at the earliest stage, the so-called Class 0 YSOs, harbor conditions of star formation. Recently, we studied the density distribution and the dust opacity spectral index (β) of three Class 0 YSOs (Kwon et al. 2009): L1448 IRS 2, L1448 IRS 3B, and L1157. Through visibility modeling of the continuum data at λ = 1.3 mm and 2.7 mm taken by the Combined Array for Research in Millimeter-wave Astronomy (CARMA), we found that β is around 1 indicating significant grain growth at the earliest stage already and that there are two types of density distribution: density power-law index p = 1 in L1448 IRS 2 and L1157 and p = 2.6 in L1448 IRS 3B. Since L1448 IRS 3B is a binary system and younger in terms of the bipolar outflow (Shu 1977) or radial dependent (this new model) is required.

Class 0 YSOs are the youngest protostellar systems in the low mass star formation, which have massive envelopes and well-developed bipolar outflows (Andre et al. 1993). The envelopes have the conditions of the preceding molecular cores, the natal places of star formation.

Density distribution shedding light on star formation... 

Motivation: results of Kwon et al. 2009

1. Image comparison

β = a - 2 + log(F_α/ν)^(-1) - 2 (i.e., F_α ~ ν^2)

Optically thin and Rayleigh-Jeans approximations

Dust continuum (λ = 1.3 and 2.7 mm) and dust opacity spectral index (β) maps of three targets. The synthesized beams are the same in the bottom right of the β maps. Note: mostly β < 1 and β variation along radius.

2. Visibility comparison

Visibility amplitude averaged in annuli (upper panels) and dust opacity spectral index β plots (lower panels) of the three targets as a function of separation. Note that larger uv distances correspond to smaller scales. Error bars indicate standard errors in both bin. Solid points on the β plots delimit the range of values expected based on absolute flux calibration uncertainties (15% at λ = 1.3 mm and 10% at λ = 2.7 mm). The curves in upper panels present the best-fit models.

3. Modeling in uv space

Color composite images taken by Spitzer IRAC L1448 region (Tobin et al. 2007) and L1157 (Looney et al. 2007).

4. Radial dependence of β : L1448 IRS 3B

No good fit with a constant β for L1448 IRS 3B (below left). Optically thick point source ("3. Modeling", but no point source feature detected Looney et al. 2009) or radial dependent (this new model) is required.

A new model based on grain growth by gas accretion (Spitzer 1978) β(r) = β_{opt} + (p-1) log r / r_{ref} where r < r_{ref}

Observations and data


Survey

Flux calibrator: Uranus for all data

The rest of 3-mm data toward Perseus will be taken in the next D configuration (from 2010 April 9).

Preliminary results 1.

Based on the total fluxes of targets at λ = 1.3 and 2.7 mm, β is likely around unity. Note that β < 1, when assuming optically thin and Rayleigh-Jeans approximations (Table: β = α - 2). Models... in each bin. Solid points on the plots delimit the range of β in each bin. Solid points on the plots delimit the range of values expected based on absolute flux calibration uncertainties (15% at λ = 1.3 mm and 10% at λ = 2.7 mm). The curves in upper panels present the best-fit models.

Preliminary results 2.

Current "eye" fitting results suggest that there are still two types of density distribution in Class 0 YSOs: p = 1.8 and p = 2.0. Caveat: a larger parameter space has not been searched.

References:


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