Advances in Star Formation with ALMA

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Opportunities with ALMA
- Full-synthesis imaging
- Great sensitivity
  - detection experiments
  - quick sampling/band scans
- High angular resolution
  - small but important structures

Stages of Star Formation

Full-Synthesis Imaging
- G0.253+0.016
  - located in CMZ
  - \( P/k > 10^7 \text{ K cm}^{-3} \)
  - \( T \sim 20 \text{ K} \)
  - \( \rho > 10^4 \text{ cm}^{-3} \)
  - \( M \sim 2 \times 10^5 M_\odot \)
  - lack of prevalent star formation
SF affects by Environments

- Lack of star formation in high-pressure regime
- Star formation threshold depends on environment
- Higher $p_{\text{crit}}$ in CMZ w.r.t. solar neighborhood

Virial Ratio over Scale

- Kinematics in G0.253+0.016
  - Outer layers likely unbound and expanding
  - Central region likely bound and collapsing
- Insufficient central mass to form an Arches-like cluster within 0.5 pc

Tracers over All Spatial Scales

Fragmentation to Cluster Formation

- SMA (2 sub+2 com+2ext)
- ALMA-29 1.5 hr
Core Mass Function

- Lack of distributed low-mass cores
- $M_{\text{core}} > 10 M_{\text{f 16}}$
- turbulence and perhaps B fields important
- $\alpha_{\text{vir}} < 0.47$
- cores NOT in viral equilibrium
- dynamical process

Zhang et al. 2015

Dynamical Cluster Formation

- IRDC G33.92+0.11 (face-on)
- spiral streamers feeding not yet virialized cores

Liu et al. 2015

Chemical Differentiation

- B335
  - redshifted absorption w.r.t. the $v_{\text{LSR}}$
  - Strong evidence of infall motions
  - explained by inside-out collapse

Zhang et al. 2015

Inverse P-Cygni Profile
Always a (Large) Disk?

- B335
- No sign of Keplerian rotation > 10 AU
- Magnetic braking suppress disk formation?

Disk around Protostars

- L1489 IRS (Class I)
  - Keplerian disk ~ 700 AU, 0.005 M⊙
  - Streamers feeding to the disk from the envelope

Rotation of Disk or Envelope?

TMC-1A

Peak position-velocity (PPV)

Disk/Envelope Interface

- IRAS 04368+2557
  - Chemical contrast highlight the disk/envelope interface
  - cyclic-C₃H₂ vs SO
  - absorption against continuum
Early Phase of Episodic Outflows

The loss of mass from protostars, in the form of a jet or outflow, is a hallmark of star formation. While the protostar is still obscured by the surrounding envelope via a disk, with the envelope providing the main mass reservoir for the star. While the protostar is still obscured by the surrounding envelope via a disk, with the envelope providing the main mass reservoir for the star. When the protostar's mass is sufficiently large, it becomes unstable due to gravitational forces, leading to the formation of a circumstellar disk. Material accretes onto a protostar from an infalling envelope, and the protostar evolves into a young stellar object.

Episodic molecular outflow in the very young protostellar phase (the early accretion stage) can be observed through the detection of outflow features with velocities greater than a few kilometres per second, and a minimum of about 23° (at 10/8, respectively). Outflow features near the origin are only around 1–2°.

The C18O intensity (moment 0, σ00) near the class 0 source is found closest to C7 (Fig. 2a, b). The Early Phase of Episodic Outflows (Héctor G. Arce et al., 2015) of 8.6 to 12.7 km/s at velocities of a few kilometres per second, and a minimum of about 23° (at 10/8, respectively). Labels B1–B11 and 0.9 to 5.7 km/s, respectively. The C18O intensity (moment 0, σ00) near the class 0 source indicates the presence of redshifted and blueshifted emission coinciding along the outflow axis (see Fig. 1). Points correspond to velocity maxima where we can observe the presence of redshifted and blueshifted emission coinciding along the outflow axis. The C18O intensity (moment 0, σ00) near the class 0 source indicates the presence of redshifted and blueshifted emission coinciding along the outflow axis. Points correspond to velocity maxima where we can observe the presence of redshifted and blueshifted emission coinciding along the outflow axis. The C18O intensity (moment 0, σ00) near the class 0 source indicates the presence of redshifted and blueshifted emission coinciding along the outflow axis. Points correspond to velocity maxima where we can observe the presence of redshifted and blueshifted emission coinciding along the outflow axis.