Two types of protostellar evolution in the star forming cluster Serpens Main

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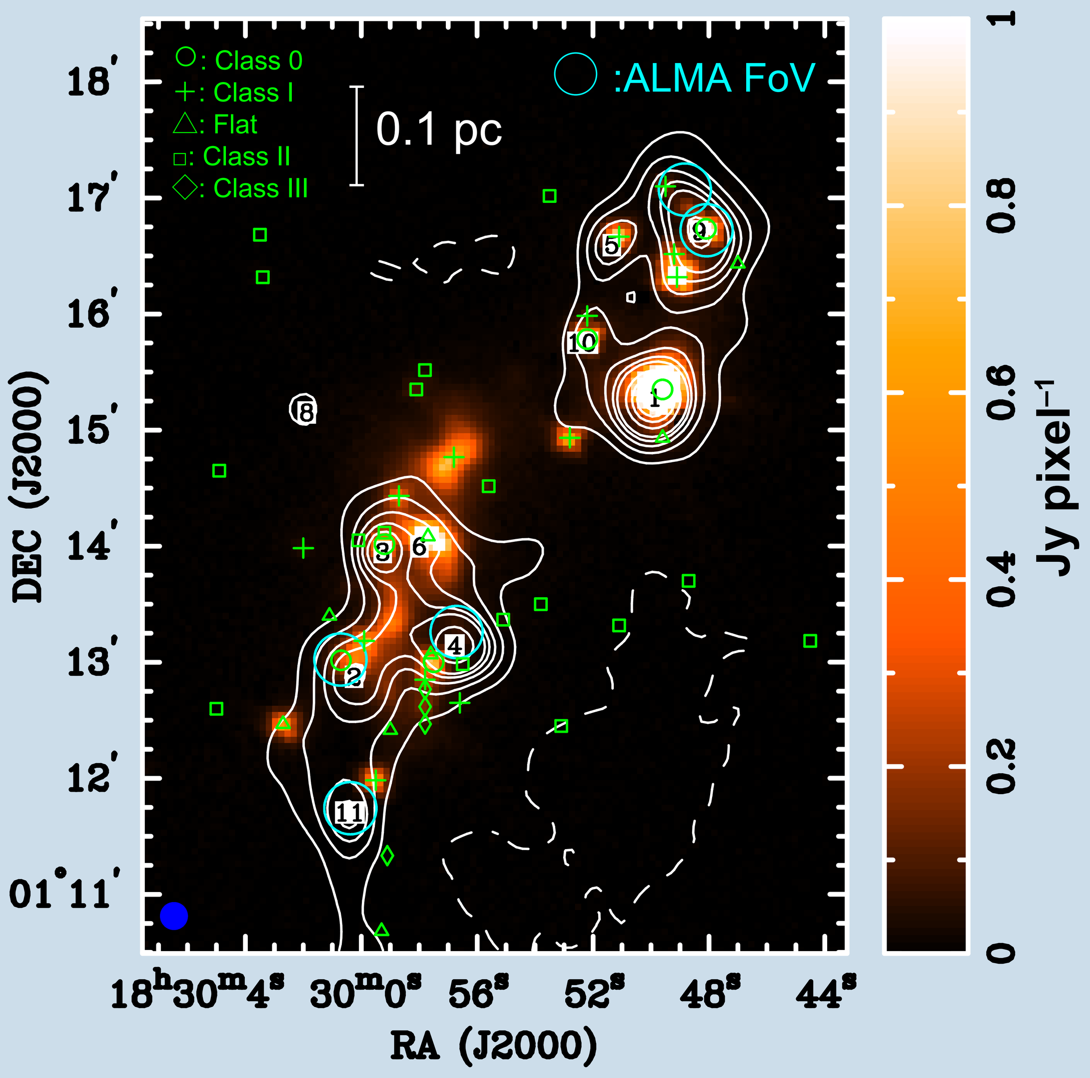


Figure 1. Serpens Main at JCMT 850 μm (contour) and at Herschel 70 μm (color). Blue filled ellipse is the JCMT beam ~14". YSO positions are derived by Spitzer[3].

Introduction —— disk-size diversity and protostellar evolution

T Tauri disks show radii from 10s to 100s au[1]. This diversity implies that some disks do not grow as largely as others in the protostellar phase.

To approach origins of disk-size diversity, we observed submillimeter condensations in a young star forming cluster[2], Serpens Main, using ALMA during Cycle 3 in Band 6.

Results —— two groups of 1.3 mm and ^{12}CO emission in Serpens Main

Regular (Fig. 1): Emission > 1000 au at 1.3 mm and mono/bipolar outflows in ^{12}CO $J = 2-1$.

Starless (no figure): no infrared nor associated ^{12}CO emission.

Compact (Fig. 3): FWHM < 120 au at 1.3 mm and compact ^{12}CO outflows.

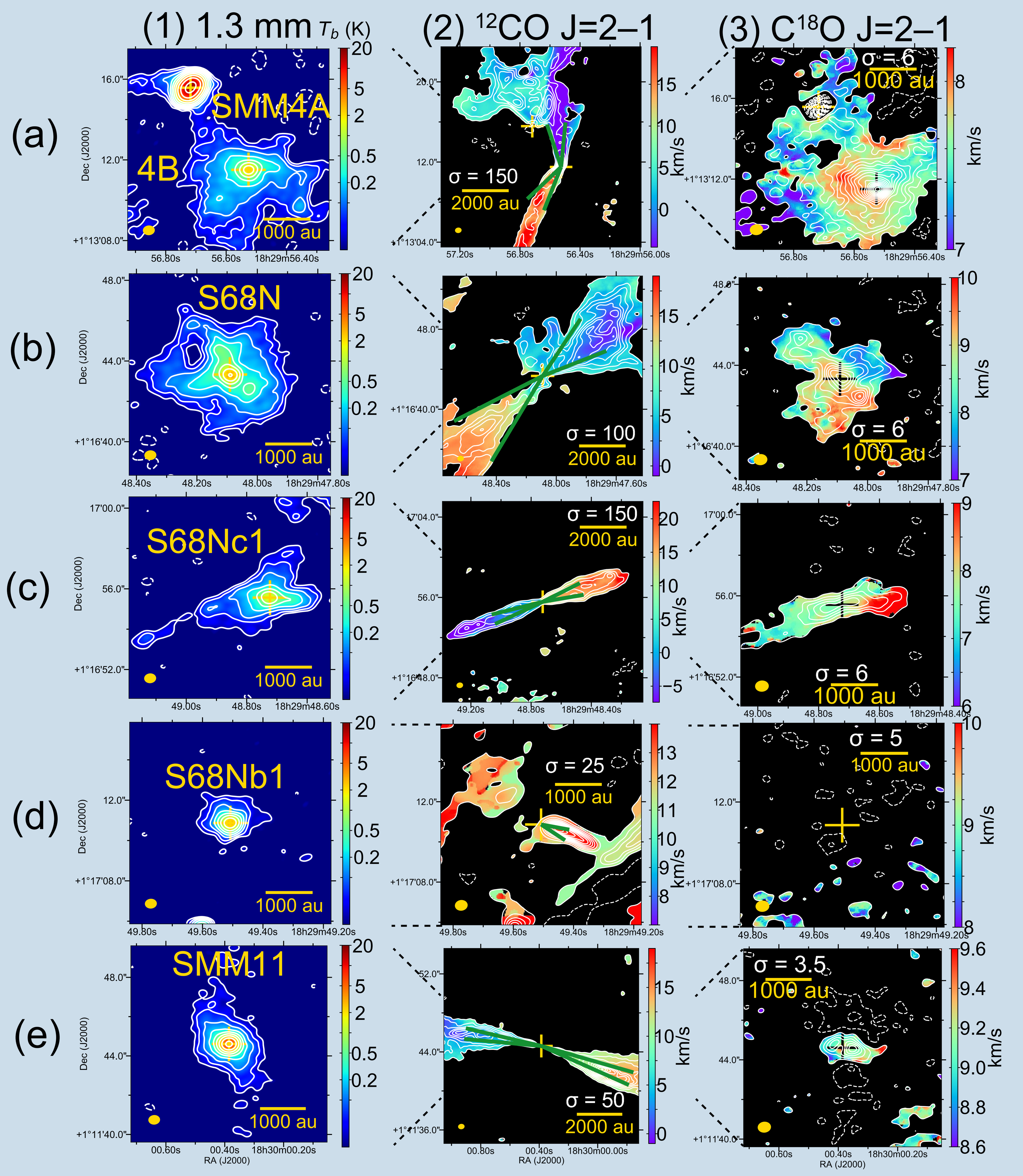


Figure 1. ALMA results of **the regular group**. 1σ in the continuum images are 0.1 mJy b^{-1}. Green lines in column (2) denote intensity-weighted mean radii and opening angles.

Discussion —— Evolutionary trends in the regular group

Class 0 protostars ($T_{bol} < 60$ K & $L_{bol}/L_{submm} < 15$)[3], [4], [5].

- outflow dynamical time (+ possibly widening[6], [7]) (Fig. 2a).
- $C^{18}O$ freeze-out/desorption over the three groups[7], [8] (Fig. 2b).
- Central compact components (disks) in 4B, S68N, and c1[4] (Fig. 1).

Meanwhile, it is not trivial whether these regular Class 0 protostars will obtain large disks as SMM4A did ($r \sim 240$ au)[7].

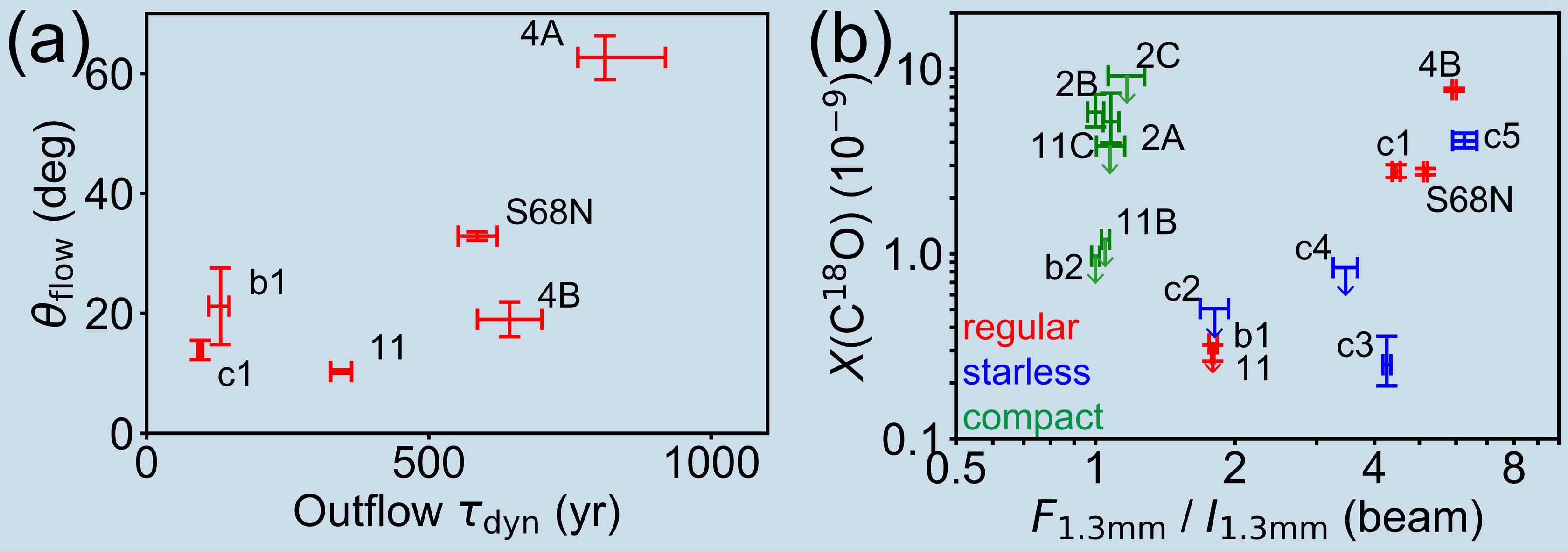
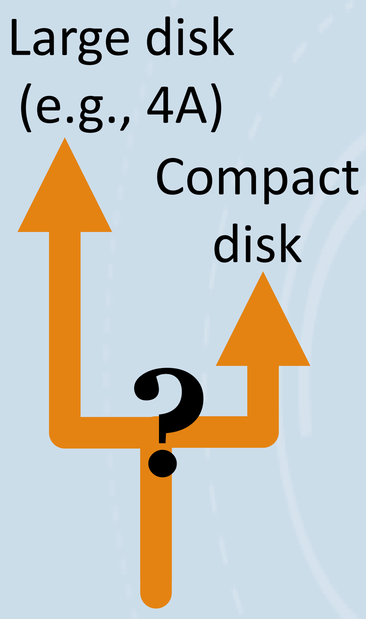


Figure 2. Evolutionary indicators of the regular group. θ_{flow} and τ_{flow} are inclination corrected. Estimate of $X(C^{18}O)$ assumes $T = 20$ K[9]. 4A shows absorption in the $C^{18}O$ line.

Table 1. Evolutionary scores of the regular group.

	CO outflow τ_{dyn}	SO jet?	$X(C^{18}O)$	$PA_{flow} - PA_{cont}$	Total score
4B	1 (>500 yr)	1 (no)	1 (>1e9)	1 (>70°)	4
S68N	1	1	1	1	4
c1	0	1	1	0 (<20°)	2
b1	0	0 (yes)	0	0	0
11	0	0	0	0	0



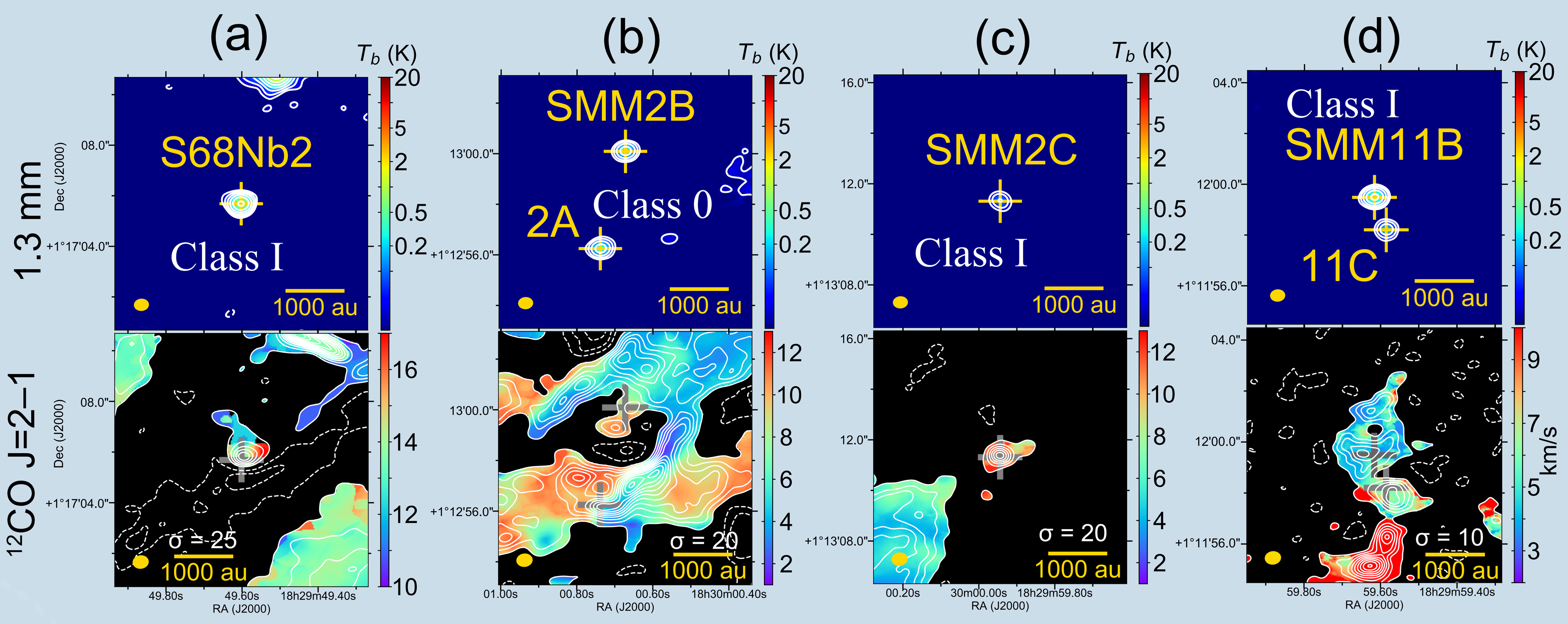


Figure 3. ALMA results of **the compact group**. Their 1.3 mm and ^{12}CO emission are much more compact than those of the regular group.

Discussion —— What is the compact group?

Smaller $M_{gas} < 0.05\ M_\odot$ than the regular group has ($M_{gas} \sim 0.2$-$0.4\ M_\odot$), as well as less clear outflows.

→ Envelopes are dissipated, and thus disks will not grow anymore ($r \lesssim 60$ au).

→ **One origin of compact T Tauri disks ($r \sim 10$s au).**

Possible mechanisms: impact by outflows (SMM2?), truncation by binary motion (11B/C?), Hall effect, etc.

Conclusions —— diversity of protostellar evolution in Serpens Main

We have revealed evolutionary trends among six Class 0 protostars. Other six protostars appear to be terminating mass accretion before acquiring large disks ($r > 100$ au). The difference between Class 0 sources, SMM2A/B ($r < 30$ au) and SMM4A ($r \sim 240$ au), may imply diversity of evolution toward large or compact disks in a protostellar phase as early as the Class 0 phase.

References [1] Najita et al. 2018, ApJ, 864, 168 [2] Li et al. 2019, ApJ, 871, 163 [3] Dunham et al. 2015, ApJS, 220, 11 [4] Aso et al. 2018, ApJ, 863, 19 [5] Aso et al. 2017, ApJL, 850, L2 [6] Machida & Hosokawa 2013, MNRAS, 431, 1719 [7] Arce & Sargent, ApJ, 646, 1070 [8] Aikawa et al. 2012, ApJ, 760, 40 [9] Lee et al. 2014, ApJ, 797, 76