Early Planet Formation in Embedded Disks (eDisk): Program overview and first results

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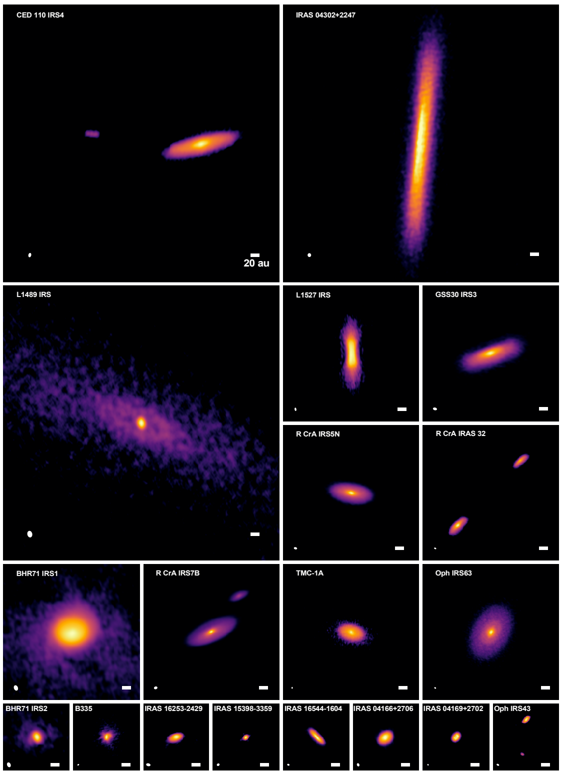
ABSTRACT

We have carried out an ALMA Large Program, Early Planet Formation in Embedded Disks (eDisk), to observe 12 Class 0 and 7 Class I protostars within a distance of 200 pc at a resolution of ~7 au in 1.3 mm continuum emission, searching for substructures in embedded disks around the sampled protostars. The first results show that the continuum emission, mostly arising from dust disks around the sample protostars, has relatively few distinctive substructures, such as rings and spirals, in marked contrast to Class II disks. The dramatic difference may suggest that substructures rapidly develop in disks when the systems evolve from protostars to Class II sources or alternatively that high optical depth of the continuum emission could obscure internal structures. Kinematic information obtained through CO isotopologue and other lines reveals the presence of Keplerian disks around sampled protostars, providing the dynamical mass of central protostars. An overview paper was submitted to the ApJ (Ohashi et al. 2023).



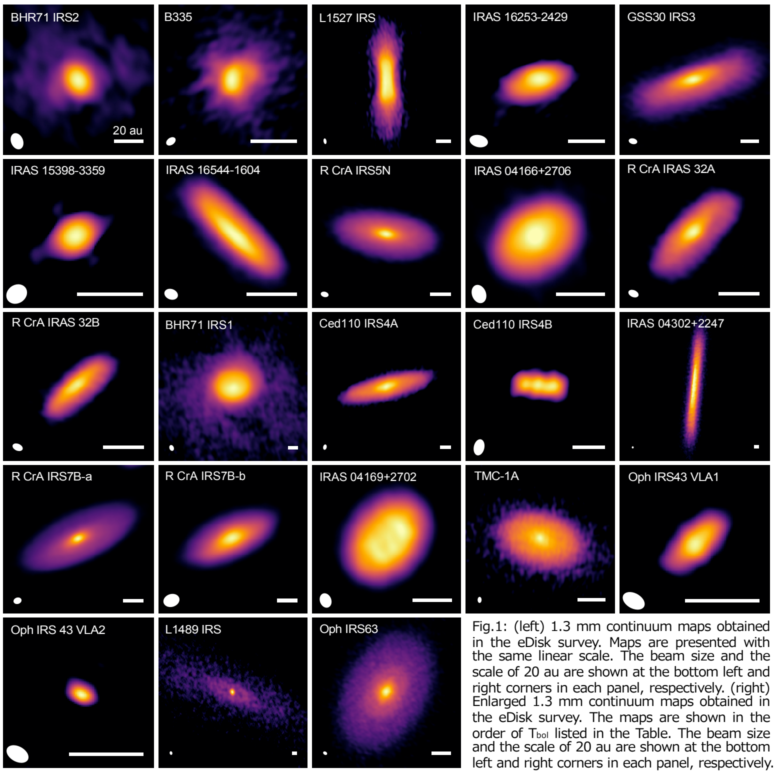


Fig.1: (left) 1.3 mm continuum maps obtained in the eDisk survey. Maps are presented with the same linear scale. The beam size and the scale of 20 au are shown at the bottom left and right corners in each panel, respectively. (right) Enlarged 1.3 mm continuum maps obtained in the eDisk survey. The maps are shown in the order of T_{bol} listed in the Table. The beam size and the scale of 20 au are shown at the bottom left and right corners in each panel, respectively.

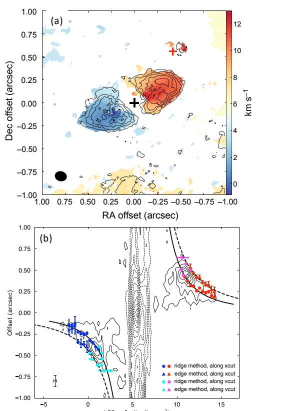


Fig. 2: (a) $C^{18}O$ 2-1 moment 0 and 1 maps of R CrA IRS7B are shown in contours and color, respectively. Contours are drawn every 2σ from 3σ (1σ=2.9 mJy beam^{-1} km s^{-1}). The black and red crosses show the positions of IRS7B-a (primary) and IRS7B-b (secondary), respectively. The beam size (0.13" x 0.11", PA=78°) is shown at the bottom left corner. (b) PV diagram cutting along the major axis of $C^{18}O$ around IRS7B-a. Contours are drawn every 2σ from 3σ, while dashed ones are drawn from -3σ to -15σ every -3σ and less every -5σ. 1σ=1.2 mJy beam^{-1}. Emissions at the ridge (circles) and edge (triangles) are fitted with power-law functions, suggesting that the velocity structure can be explained as Kepler motion. The dynamical mass of the central star was estimated to be ~2.1 – 3.2 Mo.

RESULTS

1. All the detected 1.3 mm continuum emissions were spatially resolved and show elongated structures, suggesting that the continuum emission most probably arises from disks around the sample protostars (see Fig. 1).
2. Three new binary systems were found; Ced 110 IRS4A/IRS4B, R CrA IRS7B-a/IRS7B-b, and R CrA IRAS32A/IRAS32B (See the left of Fig.1 and also posters PF-04-4006, 4007, and 4009).
3. The extent of the continuum emission varies significantly from source to source; the largest one is ~3.9" x 1.3" from L1489 IRS, while the smallest one is ~0.019" x 0.016" in the companion of Oph IRS43 VLA2.
4. Only two sources, L1489 IRS and Oph IRS63, show substructures that can be identified by eyes in their continuum disks, and these substructures are not as distinctive as those seen in Class II disks (see Fig.1 and also posters PF-04-4013 and 4014). This could suggest that substructures are formed in disks quickly when Class 0/I protostars evolve to Class II sources or otherwise that high optical depth of dust emission may obscure such features.
5. More continuum emission shows brightness asymmetry, particularly along its minor axis. This brightness asymmetry may reflect the dust optical thickness and the disk vertical thickness (see posters PF-04-4004 and 4007).
6. $C^{18}O$ 2-1 emission often shows elongated disk-like structures with velocity gradients along elongated structures (see Fig. 2a). PV diagrams cutting along the elongated structures show velocity structures suggesting differential rotation. Rotation curves obtained from fittings of PV diagrams with power-law functions suggest that rotation can be explained as Keplerian motions (see Fig. 2b and also eDisk posters).

Table: eDisk sample

Source name	Class	Distance (pc)	T_{bol} (K)	L_{bol} (Lo)
L1489 IRS	I	146	213	3.4
IRAS 04166+2706	0	156	61	0.4
IRAS 04169+2702	I	156	163	1.5
IRAS 04302+2247	I	160	88	0.43
L1527 IRS	0	140	41	1.3
Ced 110 IRS4	0	189	68	1.0
BHR71 IRS2	0	176	39	1.1
BHR71 IRS1	0	176	66	10
IRAS 15398−3359	0	155	50	1.4
GSS30 IRS3	0	138	50	1.7
Oph IRS43	I	137	193	4.1
IRAS 16253−2429	0	139	42	0.16
Oph IRS63	I	132	348	1.3
IRAS 16544−1604	0	151	50	0.89
R CrA IRS5N	0	147	59	1.4
R CrA IRS7B	I	152	88	5.1
R CrA IRAS 32	0	150	64	1.6
TMC-1A	I	137	183	2.3
B335	0	165	41	1.4

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