

ALMA Reveals Hot-Disk Kinematics and Protobinary Orbits in Massive Star Formation

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Questions

What happens inside the inner 100 au?

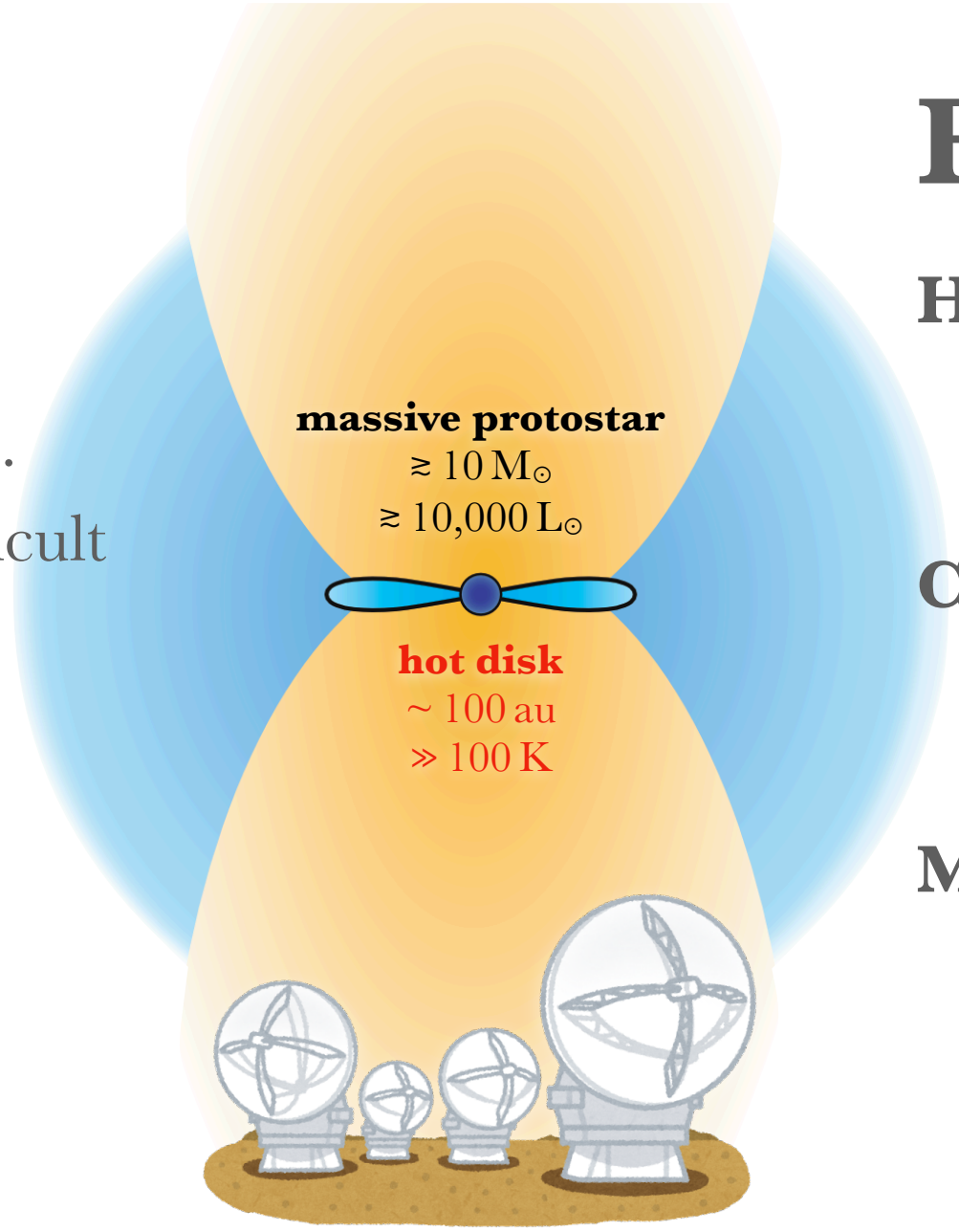
Massive stars form through disk accretion and commonly emerge in multiple systems. Yet their innermost disk kinematics and protobinary orbital architectures remain difficult to observe.

Where is the disk?

Traditional hot-core lines often trace the rotating envelope.

What are the orbital architectures of massive protobinaries?

Orbital motions are rarely measured in deeply embedded systems.



Findings

Hot-disk tracers reveal the inner 100 au

Hot water, refractory molecules, and hydrogen recombination lines trace hot-disk kinematics and protostellar motions.

Chemical tracers separate disks from envelopes

Hot-disk tracers isolate disk-scale kinematics, while CH₃CN and SO₂ mainly trace larger rotating envelopes.

Multi-epoch astrometry reveals their orbital architecture

Together with hydrogen recombination line velocities, it constrains three-dimensional orbital architectures and reveals strong disk-orbit misalignments.

Hot-Origin Tracer survey of DISKS of massive protostars

HOTDISK Survey

Kai Yang et al. 2026, ApJ

Just published!



A pilot ALMA Band 6 survey of 10 massive protostars selected from QUARKS. At ~0.05'' resolution, HOTDISK searches for compact disk-scale kinematics traced by vibrationally excited H₂O, NaCl, and SiS.

Hot-Disk Signatures Detected in 7 of 10 Sources

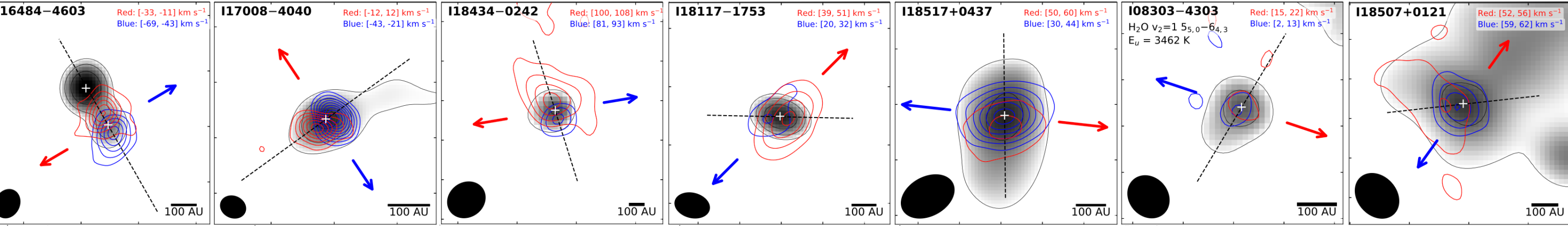
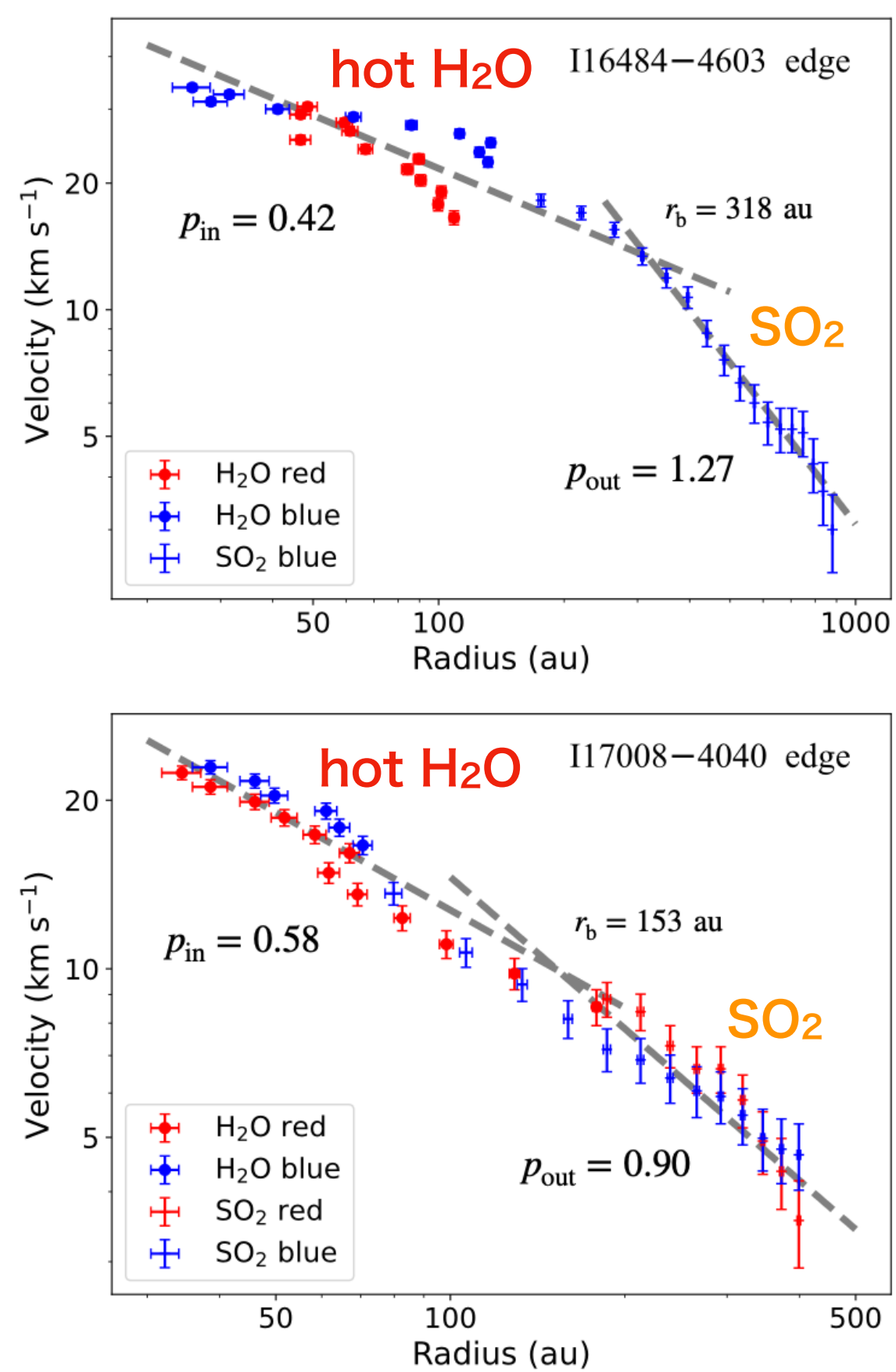
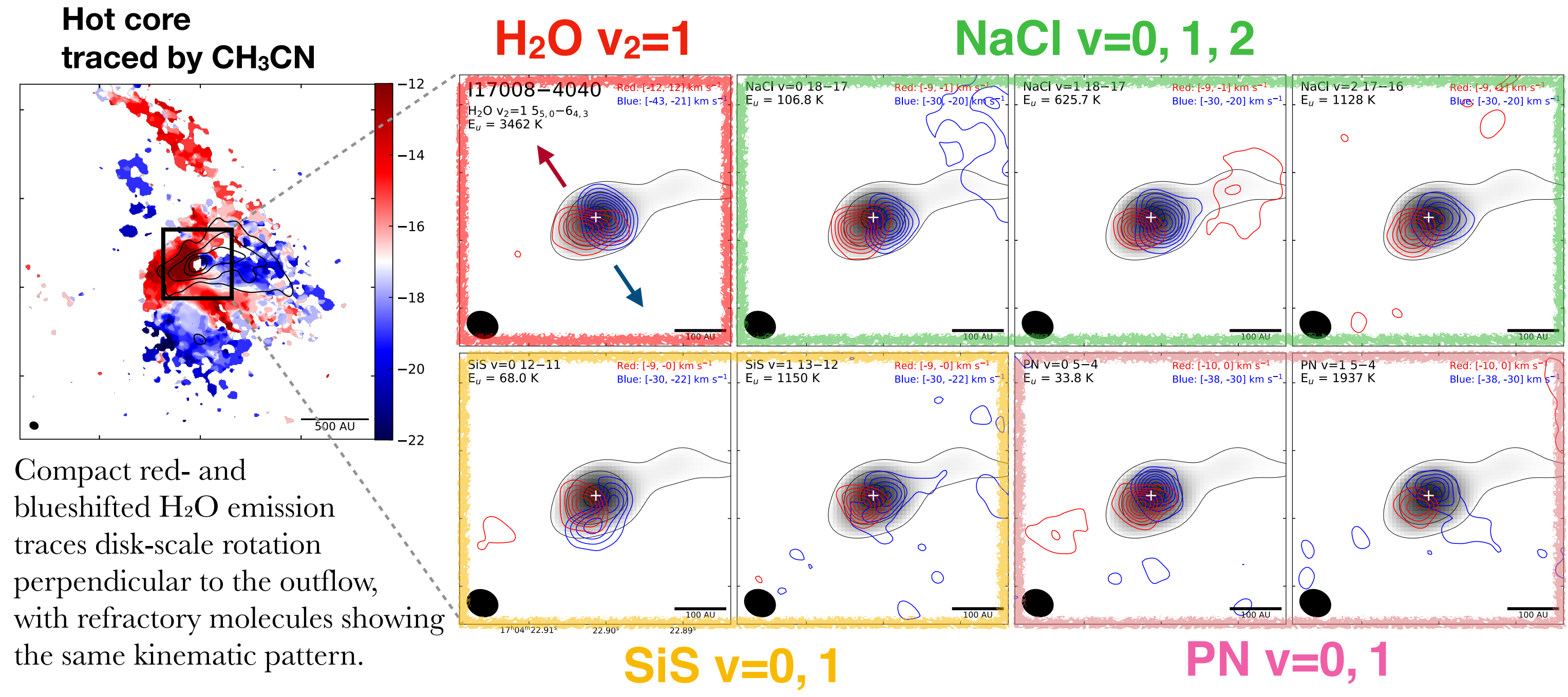


Table 1 Target Properties and Detection Summary of Disk-tracing Lines										
Source ^a	R.A. ^b (J2000)	Dec. ^b (J2000)	Distance ^c (kpc)	V _{sys} ^d (km s ⁻¹)	Disk-tracer Detection				V _{rot} ^e (km s ⁻¹)	M _{disk} ^f (M _J)
					H ₂ O	NaCl	SiS	SiO		
I08303-4303	08:32:08.34	-43:13:54.0	2.35	14.3	✓	✓	✓	U	...	13.2
I16484-4603	16:52:04.29	-46:08:30.1	2.20	-33.0	✓	✓	✓	D+O	✓	33.0
I17008-4040	17:04:23.03	-40:44:24.9	1.33	-18.0	✓	✓	✓	D+O	✓	16.0
I17016-4124	17:05:11.02	-41:29:07.8	3.16	-27.1	...	...	...	O	...	...
I18117-1753	18:14:39.14	-17:52:01.3	2.40	38.0	✓	✓	✓	D	✓	36.4
I18134-1942	18:16:22.12	-19:41:27.0	1.25	10.6	...	...	...	D	...	...
I18434-0242	18:46:03.51	-02:39:36.7	5.26	97.2	✓	✓	✓	D+O	✓	99.4
I18469-0132	18:49:33.15	-01:29:04.2	4.91	97.0	...	...	...	O	✓	...
I18507-0121	18:53:18.12	-01:25:22.7	3.03	37.9	✓	✓	✓	D	...	58.0
I18517-0437	18:54:14.13	-04:41:46.2	1.88	43.9	✓	✓	✓	D+O	...	43.2

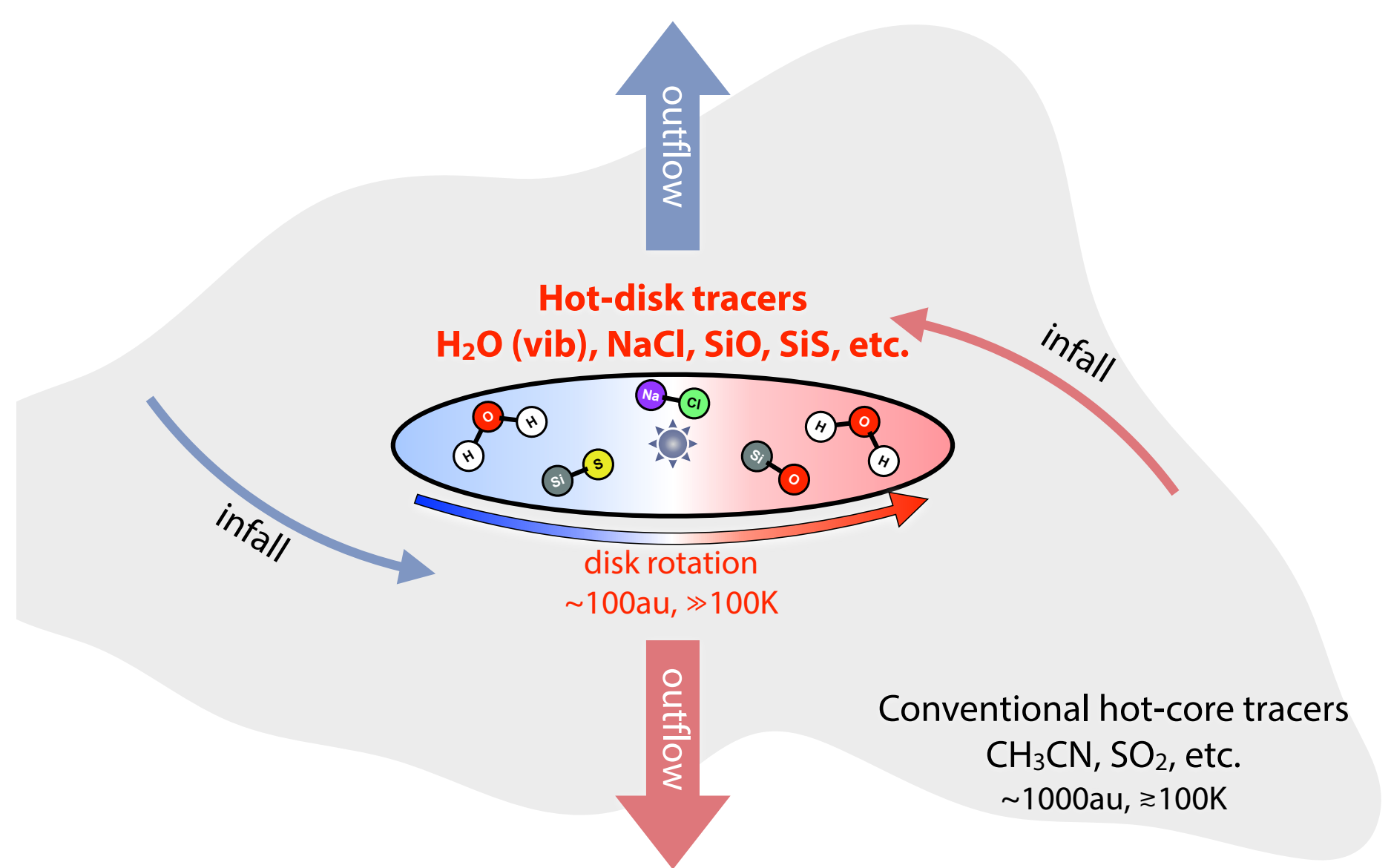
Vibrationally excited H₂O is detected in 7 of 10 sources, with NaCl and SiS in 5 of those 7, demonstrating that hot-disk tracers are common rather than exceptional.

I17008-4040: A Representative Hot Disk



From Hot Core to Hot Disk A Chemical and Kinematic Transition

Toward smaller radii, conventional hot-core tracers give way to H₂O, NaCl, and SiS, revealing a transition from envelope-scale rotation to disk-scale kinematics.



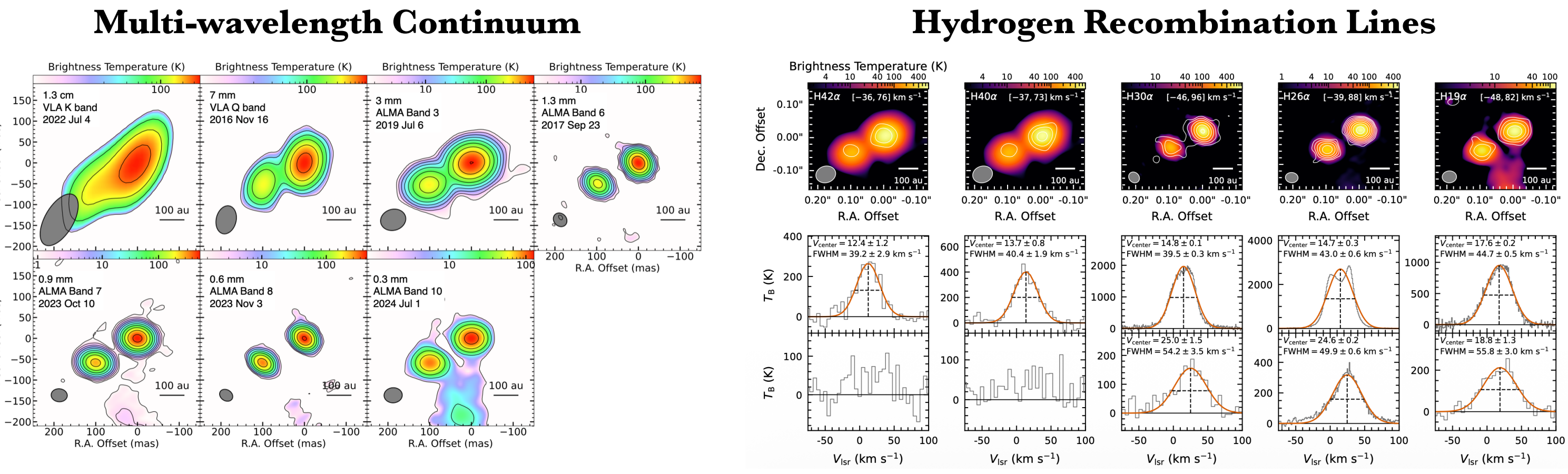
Protobinary Architecture

Yao Wang et al., accepted by Nature Astronomy

Multi-wavelength ALMA and JVLA observations resolve two massive protostars, each surrounded by a compact ionized circumstellar disk.

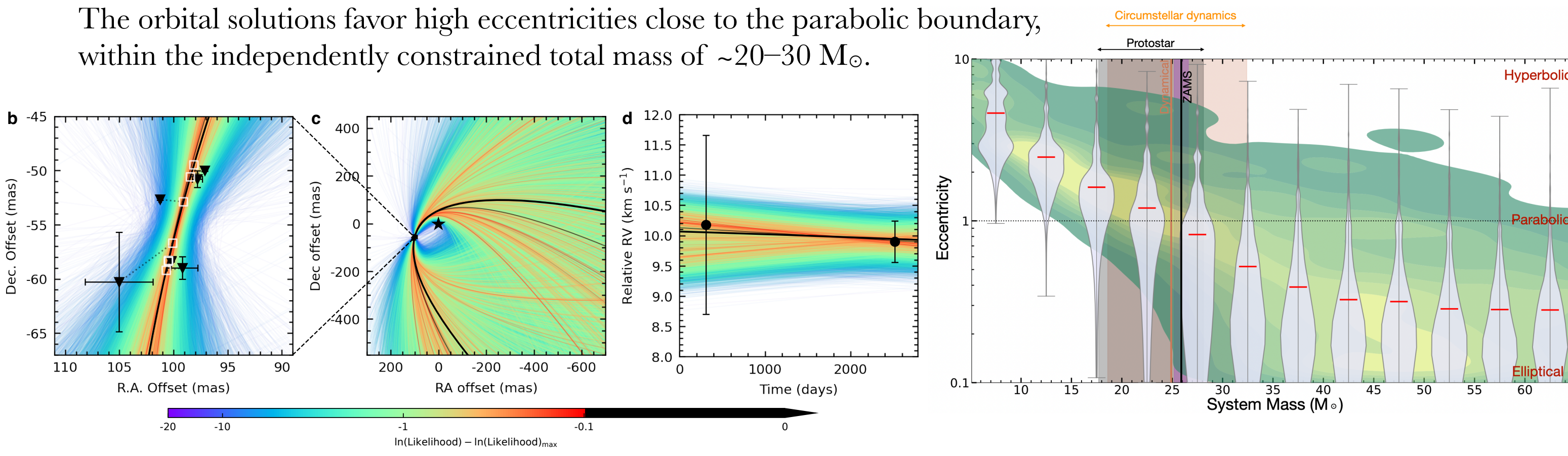
Multi-epoch View of the Massive Protobinary IRAS 07299-1651

ALMA and JVLA observations from 2016 to 2024 resolve two compact ionized sources across 1.3 cm to 0.3 mm, while multiple hydrogen recombination lines provide their line-of-sight velocities.



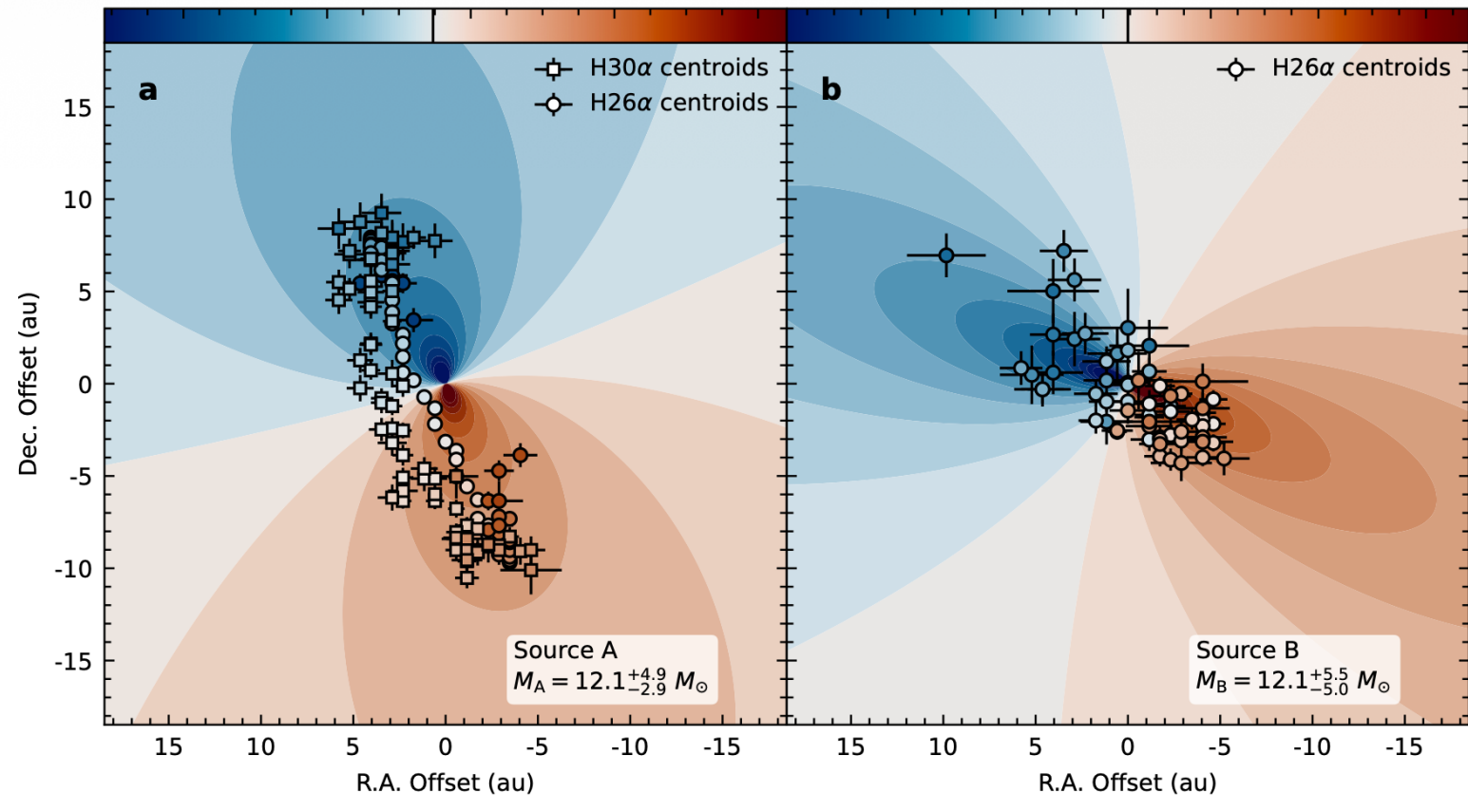
Astrometry & LOS Vels. Reveal 3D Orbital Motion

The orbital solutions favor high eccentricities close to the parabolic boundary, within the independently constrained total mass of ~20–30 M_⊙.



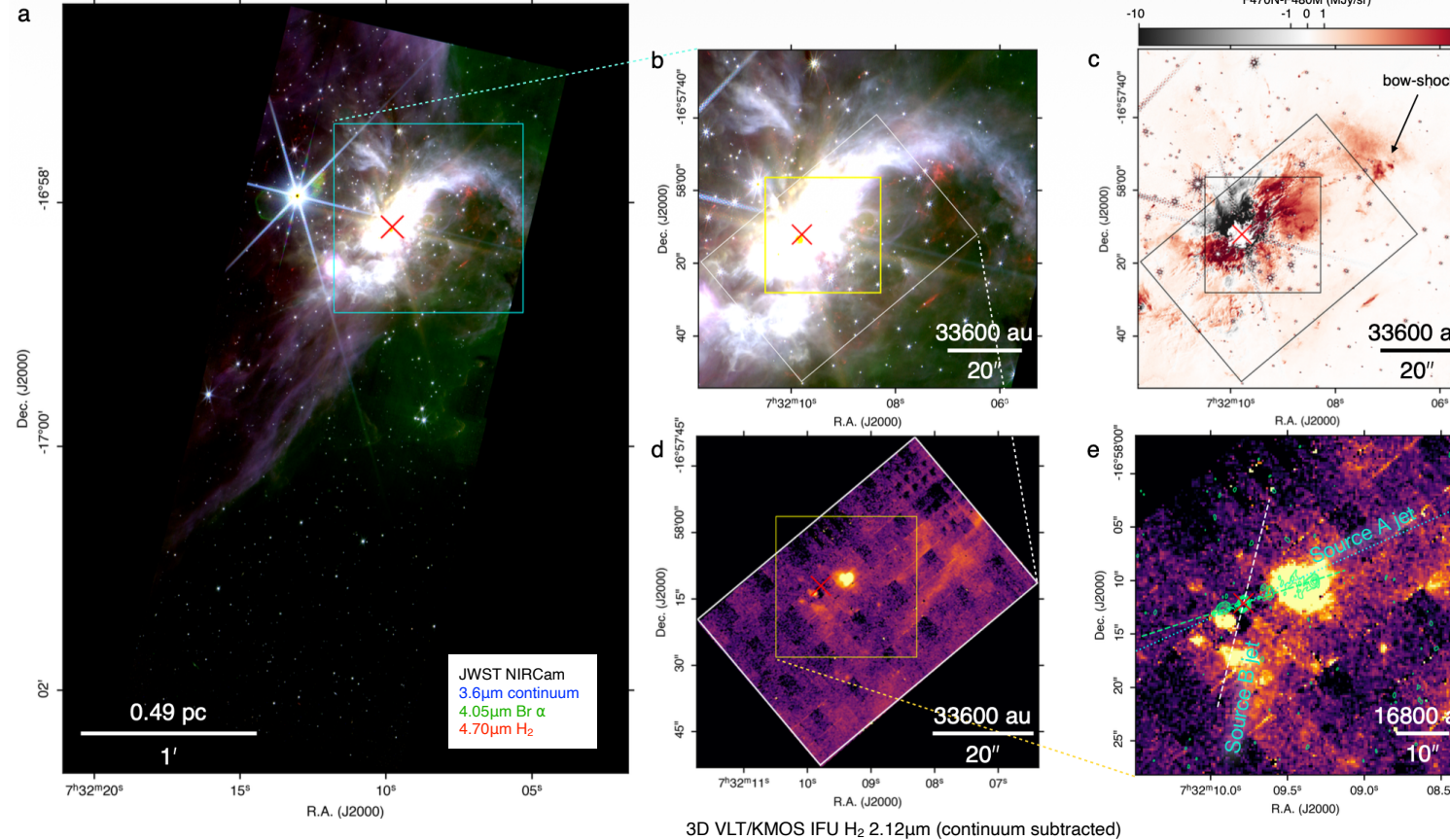
HRLs Trace Disk Rotations

HRL centroids trace ~10 au disk rotation, constraining disk orientations and dynamical masses.

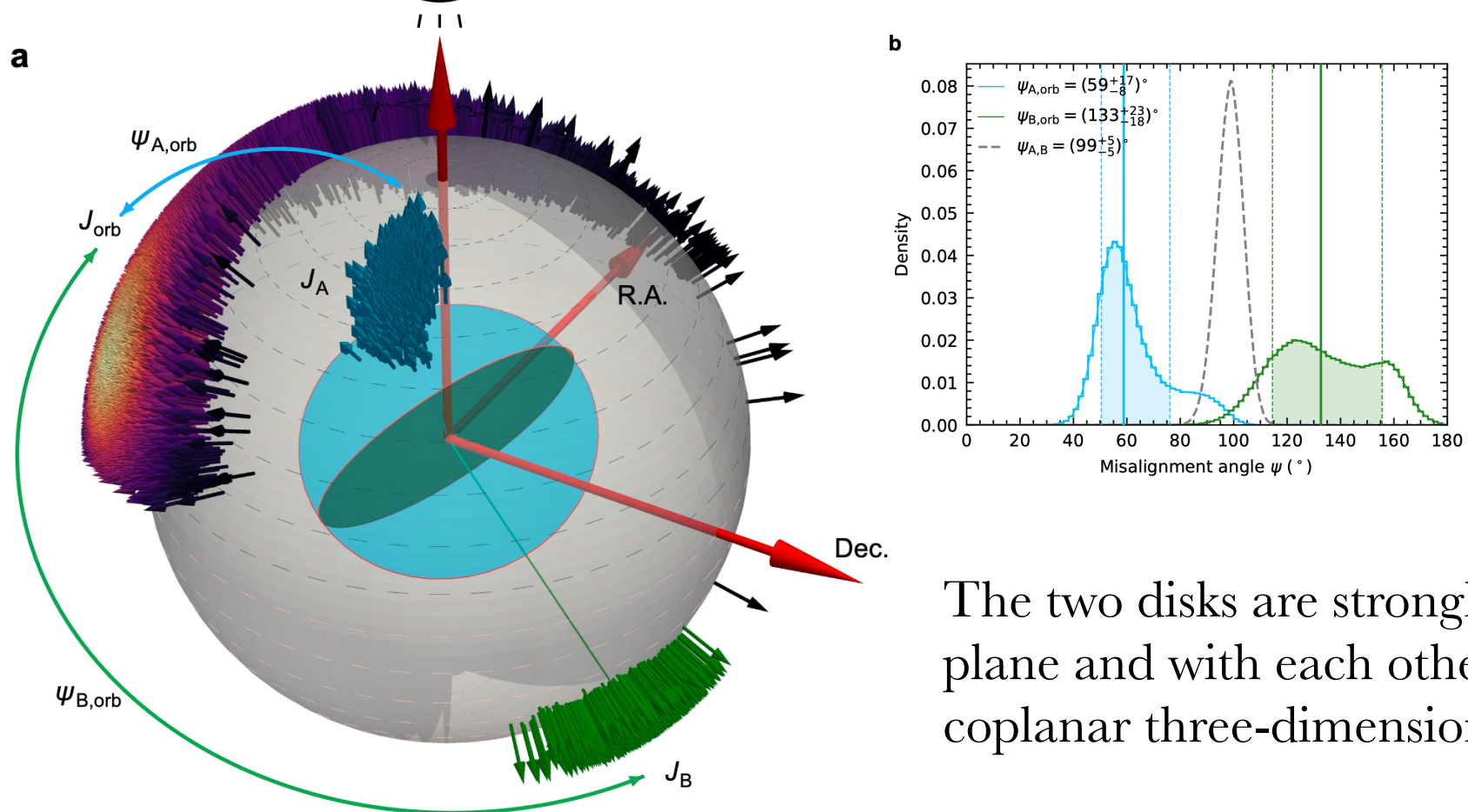


Jets Constrain Disk Orientations

JWST and VLT H₂ emission traces both jets, helping constrain the 3D disk orientations.



A Strongly Misaligned Protobinary Architecture



The two disks are strongly misaligned with the orbital plane and with each other, revealing a highly non-coplanar three-dimensional architecture.

Multi-epoch astrometry and hydrogen recombination lines enable a direct reconstruction of the three-dimensional motion and disk-orbit architecture of an embedded massive protobinary.

HOTDISK establishes hot H₂O and refractory molecules as powerful tracers of the innermost ~100 au of massive protostellar disks, revealing disk-scale kinematics that are often hidden in conventional hot-core tracers.