Observing Disk Accretion in Action

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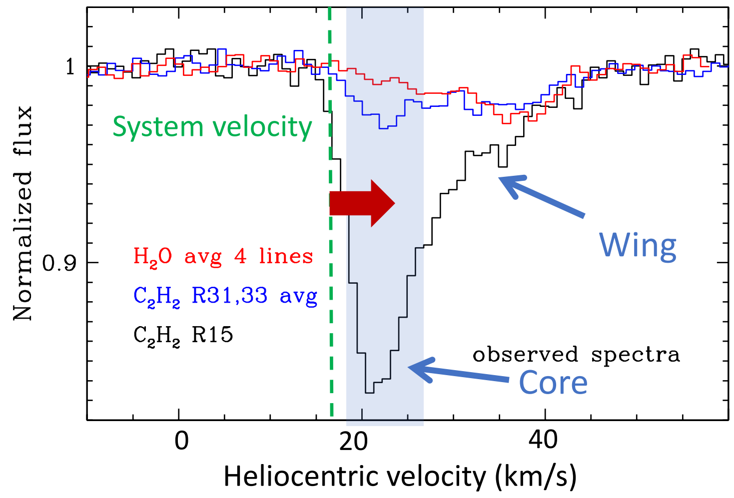
Summary

Physical processes that redistribute or remove angular momentum from protoplanetary disks can drive stellar accretion and affect the outcome of planet formation, although the process(es) responsible have been unclear. High resolution MIR spectroscopy of the Class I source GV Tau N appears to show disk accretion in action via *rapid inflow of molecular gas through the disk surface* (i.e., atmosphere). The flow carries an accretion rate comparable to stellar accretion rates of active T Tauri stars. The results may provide evidence for supersonic "surface accretion flows," which have been found in simulations of magnetized disks.

Observations

High resolution MIR spectroscopy of GV Tau N with Gemini/TEXES reveals a rich absorption spectrum of individual lines of C_2H_2, HCN, NH_3 and water, all redshifted by 4-20 km/s from the system velocity.

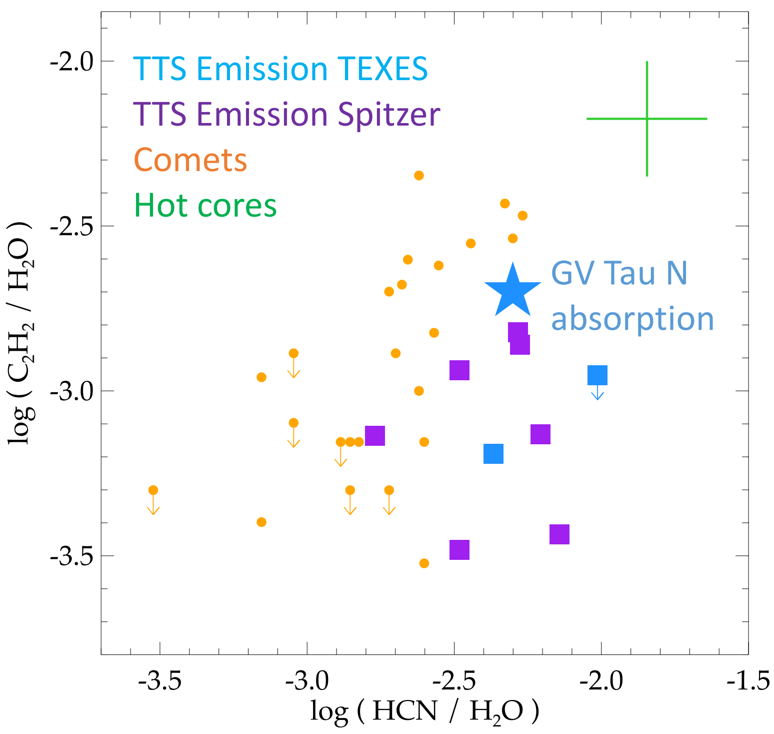


Results

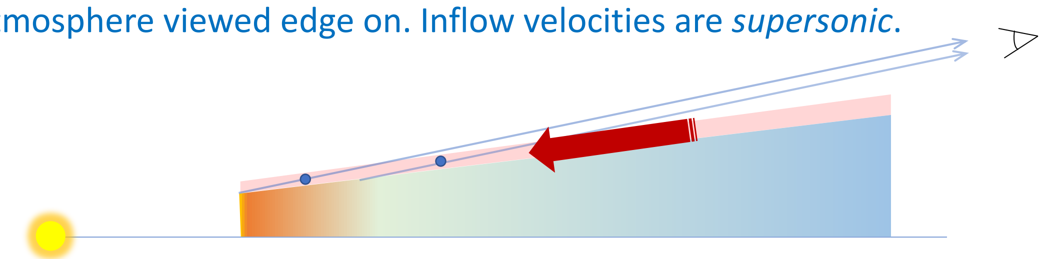
Table 1. Derived properties of absorption components

	Temp	N_{abs} / cm^{-2}	N_{perp} / cm^{-2}	V_{in}	Mdot
Core	450 K	$7x10^{16}$ (HCN)	$7x10^{21}$	4 km s^{-1}	$7x10^{-9}$ M_{sun}/yr
Wing	450 K	$6x10^{19}$ (H2O)	$6x10^{22}$	20 km s^{-1}	$1x10^{-7}$ M_{sun}/yr

1. Molecular abundances and temperature of the absorber are consistent with inner disk atmospheres at ~ 1au.



2. High absorption column densities are consistent with an inner disk atmosphere viewed edge on. Inflow velocities are *supersonic*.



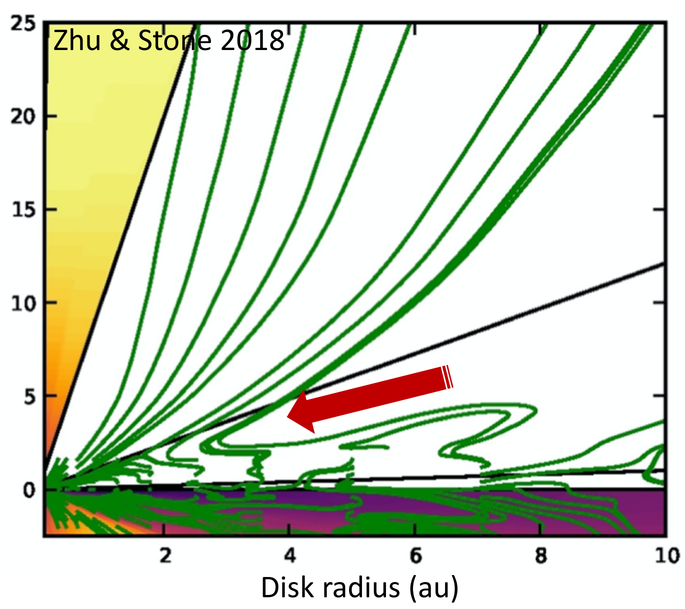
3. Implied mass inflow rate is comparable to T Tauri stellar accretion rates.

$$Mdot = 2\pi r\, m_H\, v_{in}\, N_{perp}$$

$$N_{perp} \sim 0.1\, N_{abs} / x_{mol}$$

Discussion

Supersonic "surface accretion flows" like that seen in GV Tau N are found in simulations of magnetized disks. In Zhu & Stone (2018), magnetic fields connect the disk surface to the midplane at larger radii and spin down the disk surface, generating supersonic inflow at velocities similar to those observed.



Conclusions

The low ionization fraction of protoplanetary disks restricts accretion toward the disk surface if accretion is related to disk magnetic fields. Spectroscopy of GV Tau N appears to confirm this picture, but in a surprising way. We find that *accretion occurs primarily in the disk atmosphere*, i.e., in the familiar region that produces the observable emission lines from protoplanetary disks.

References

Najita et al. 2020, "High-Resolution Mid-Infrared Spectroscopy of GV Tau N: Surface Accretion and Detection of Ammonia in a Young Protoplanetary Disk," accepted for publication in ApJ

Zhu & Stone 2018, "Global Evolution of an Accretion Disk with Net Vertical Field," ApJ, 857, 32