



Detecting Transport Processes in Protostellar Disks

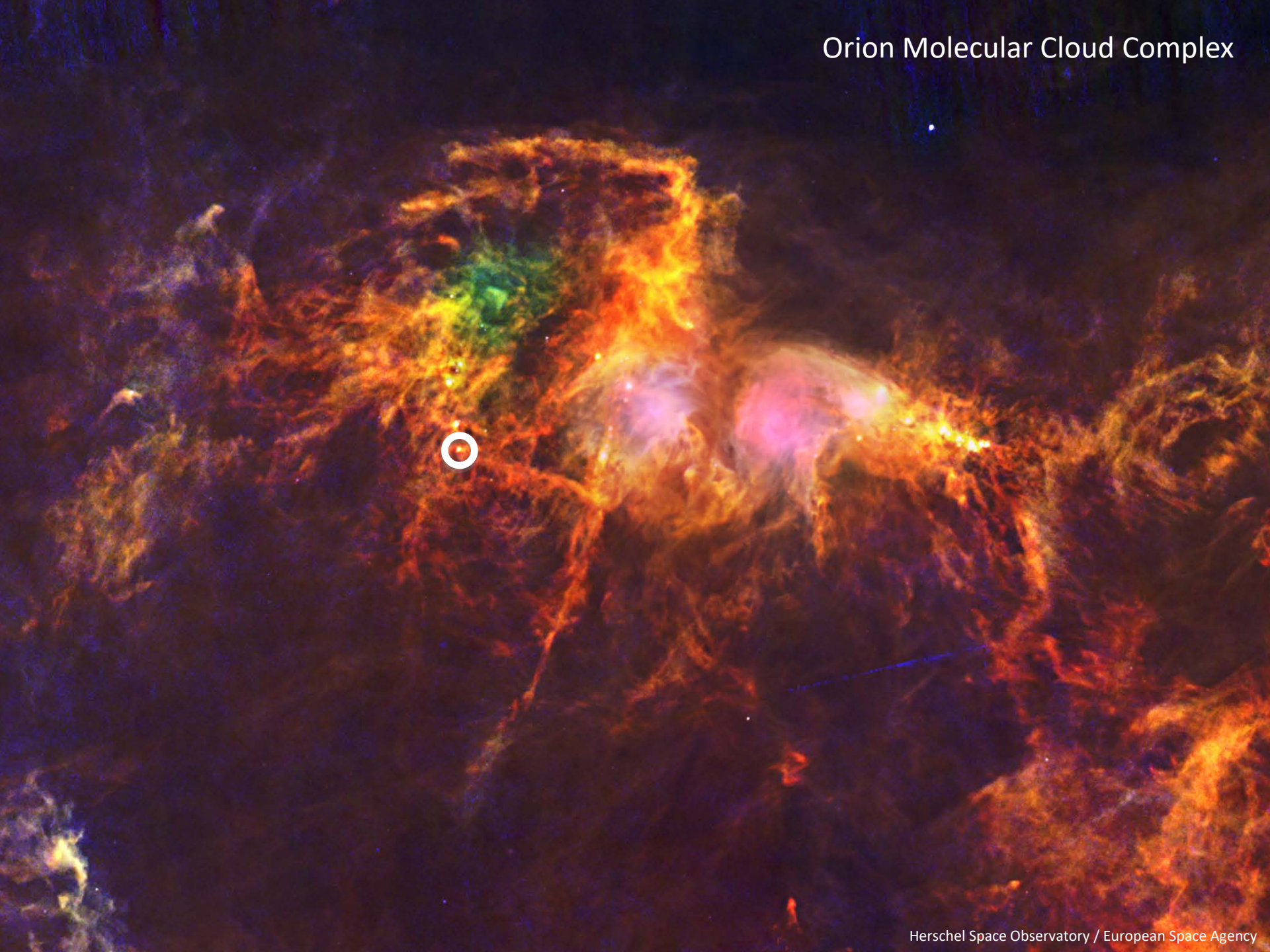
Neal Turner

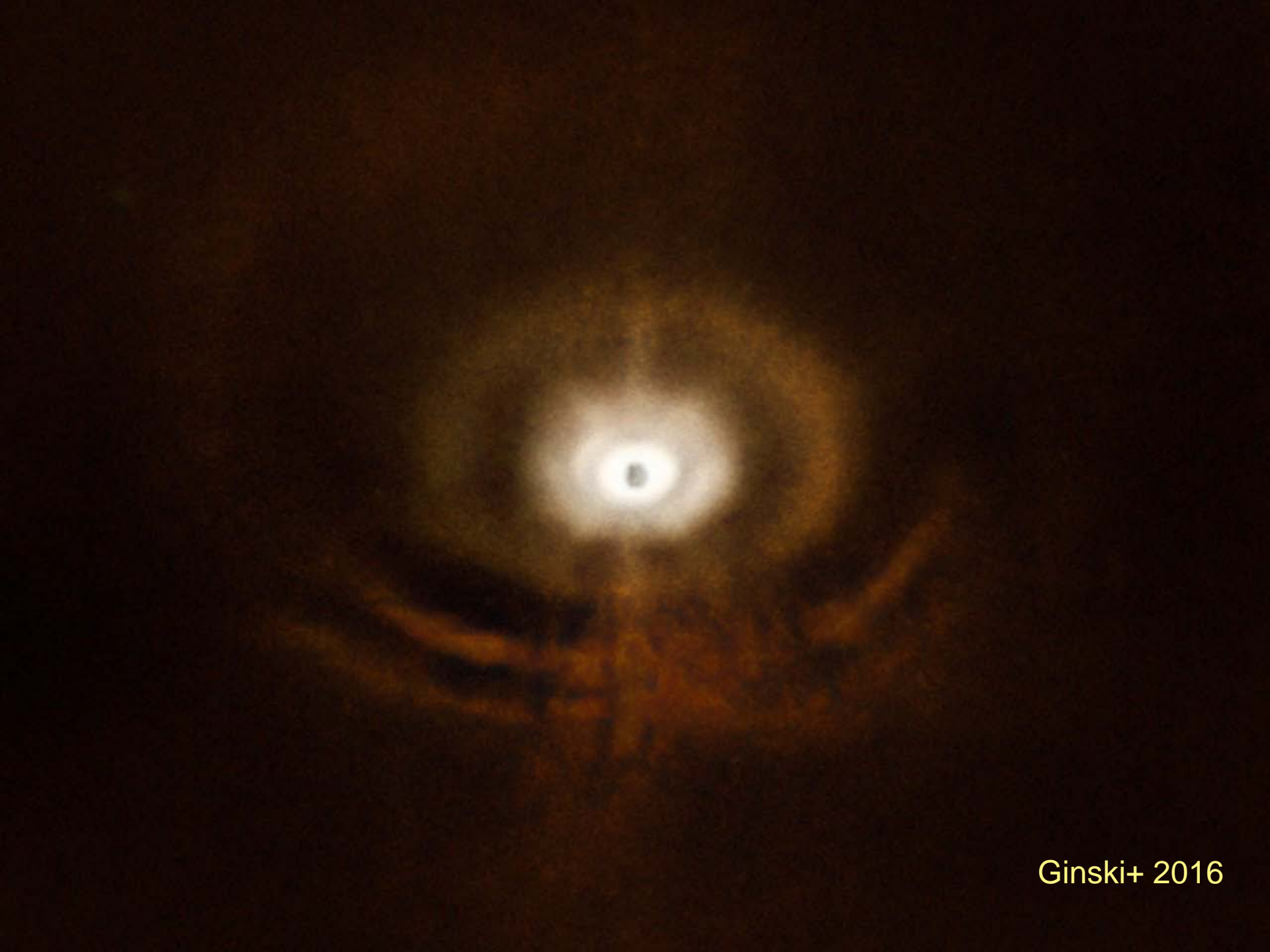
Jet Propulsion Laboratory, California Institute of Technology

Orion Molecular Cloud Complex

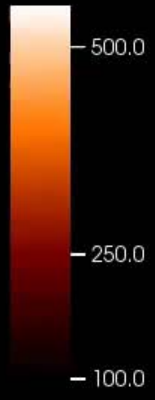


Orion Molecular Cloud Complex

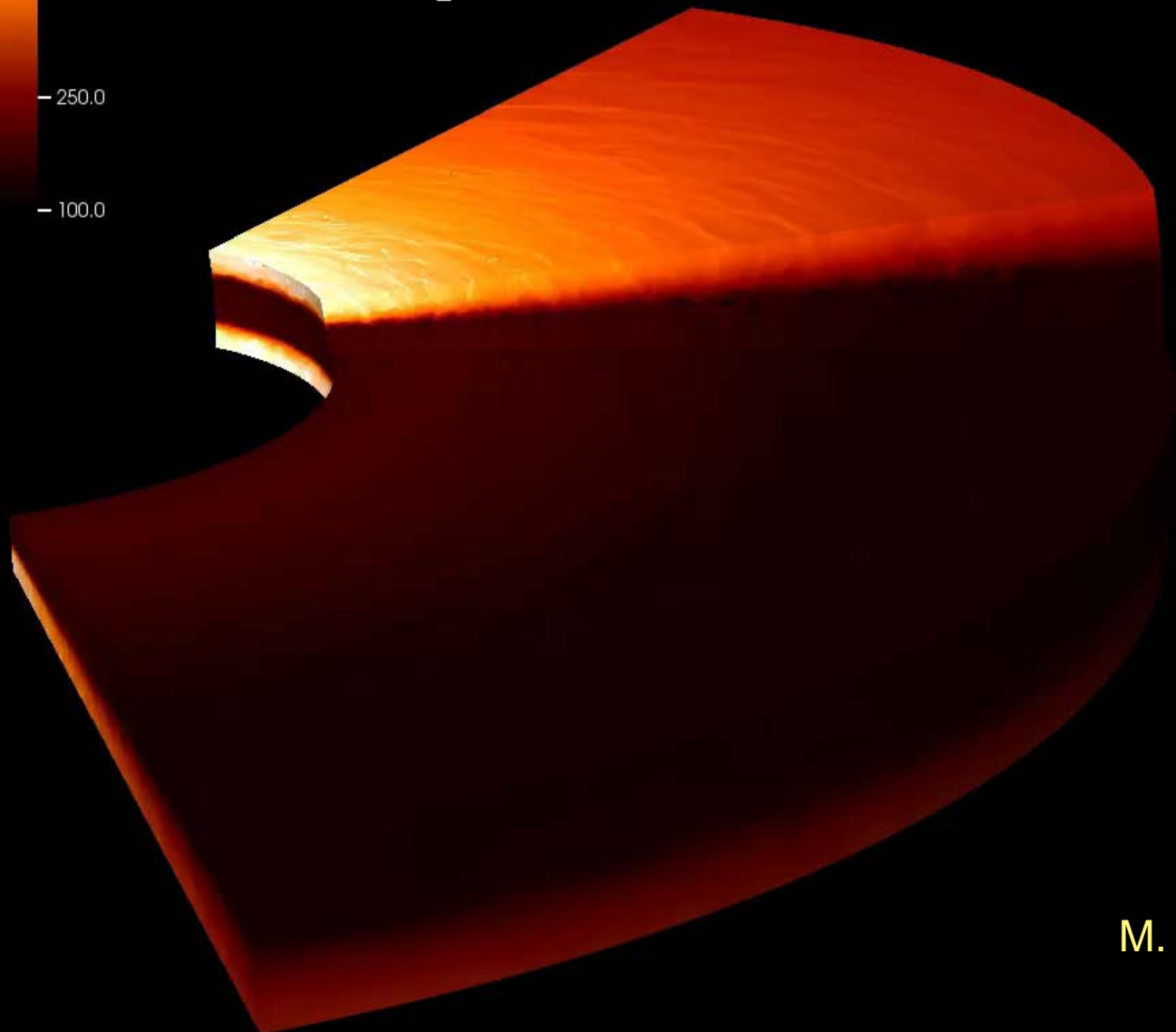


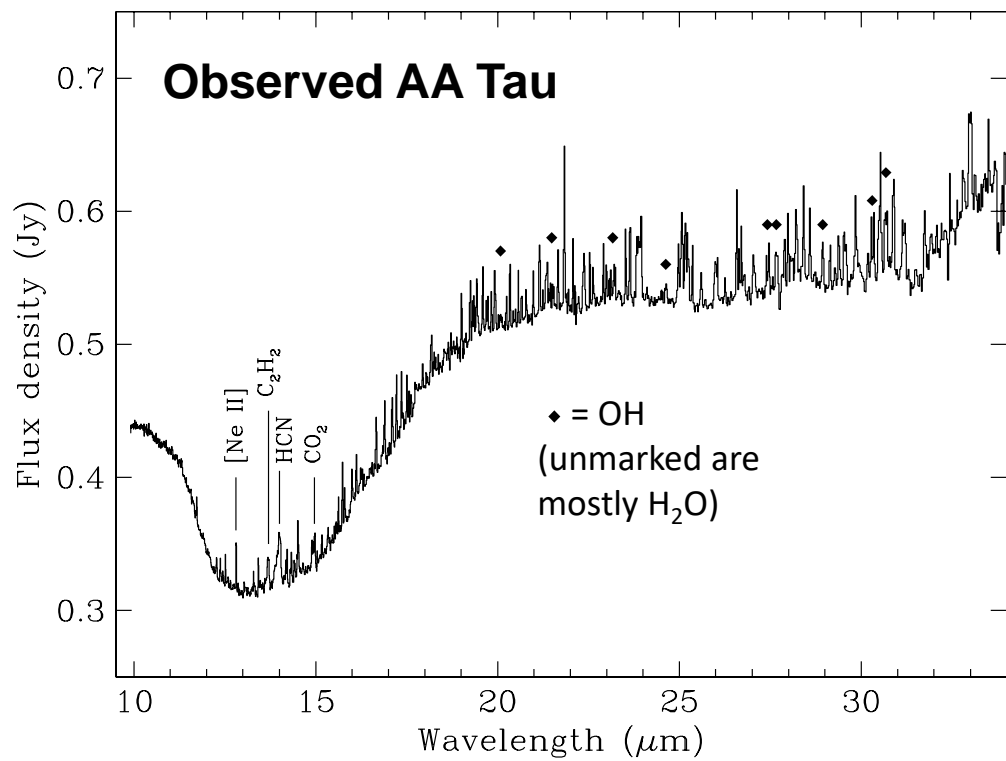


Ginski+ 2016

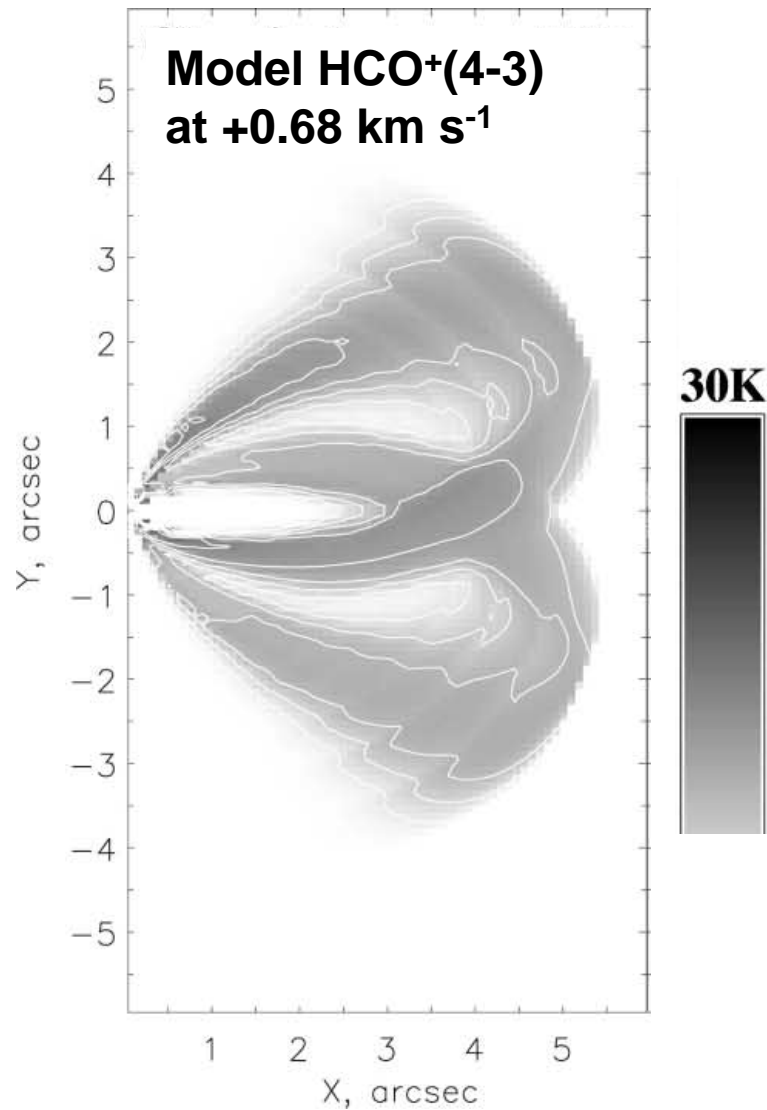


Temperature [K]





J. Carr & J. Najita 2008



Ya. Pavlyuchenkov+ 2007

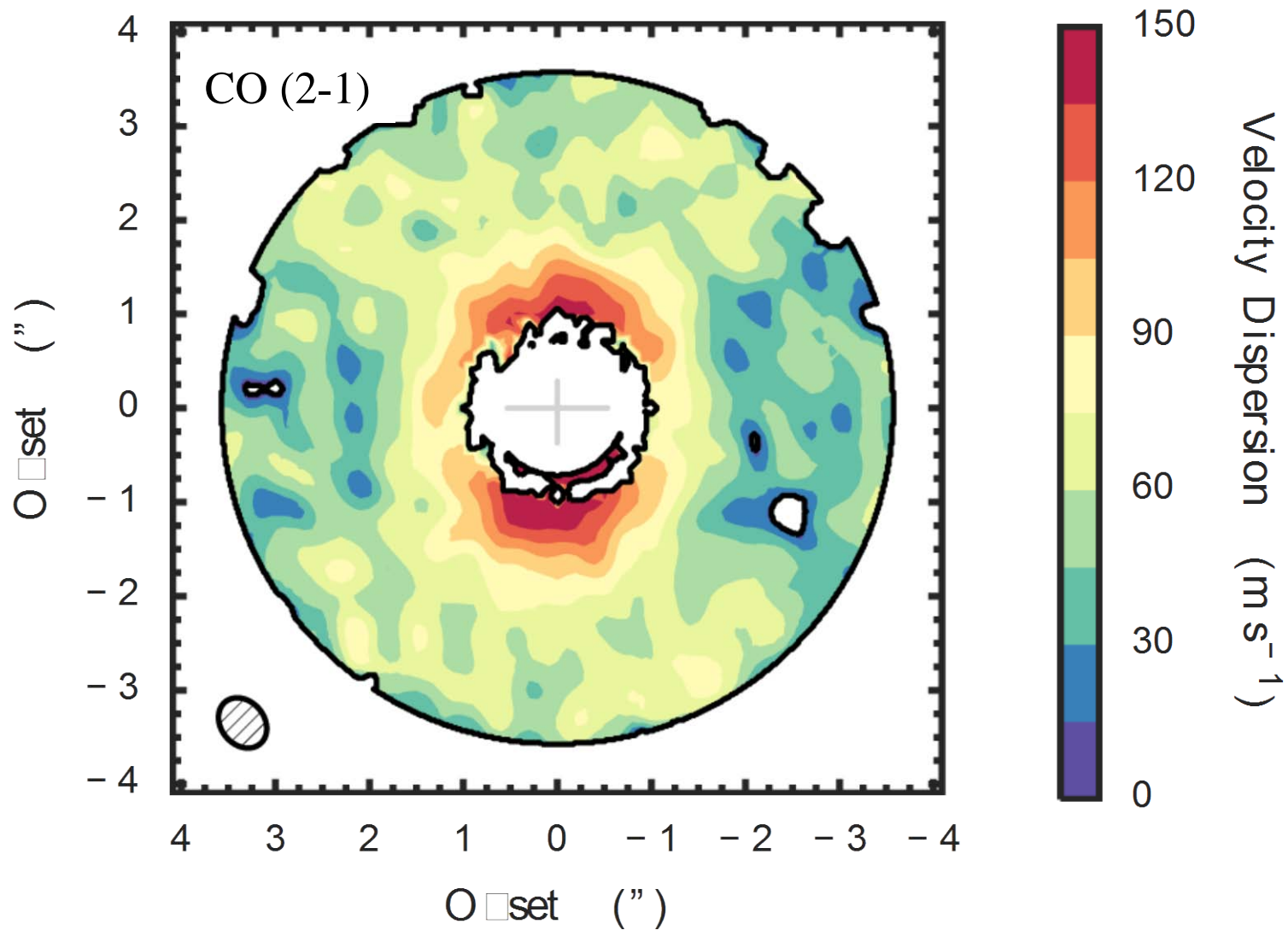
We can detect gas flows by

- 1. trace species' kinematics**
- 2. effects on trace species' abundances**
- 3. effects on solid particles**

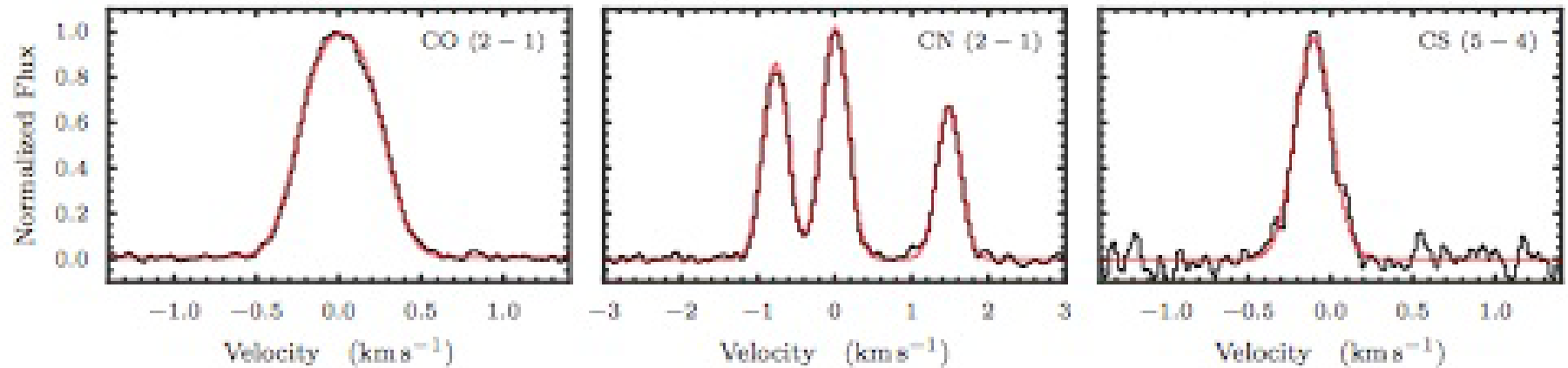
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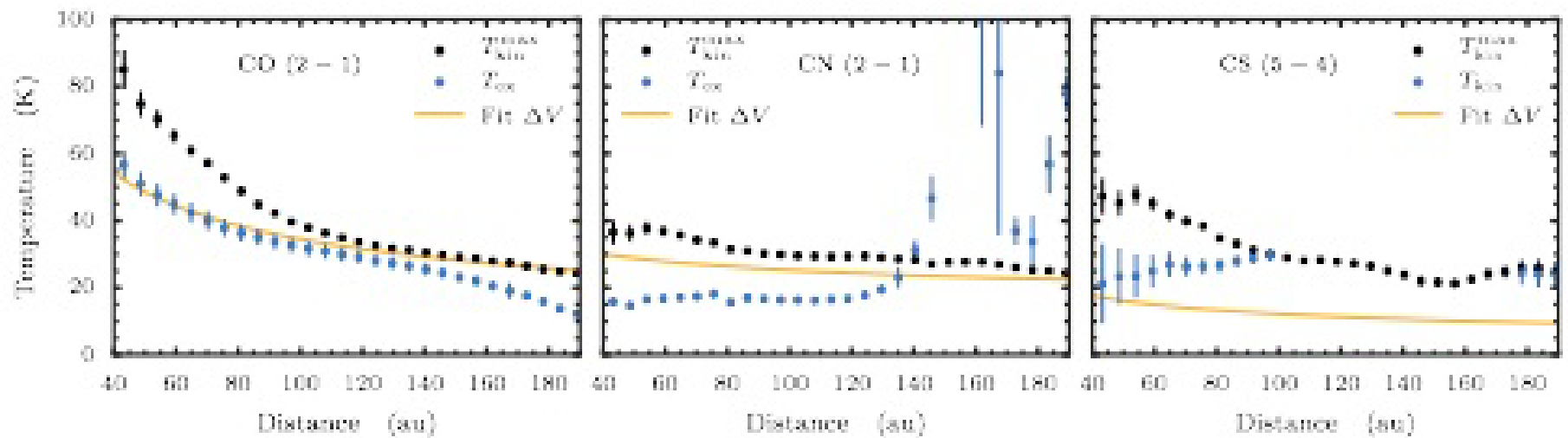
1. trace species' kinematics – from millimeter lines



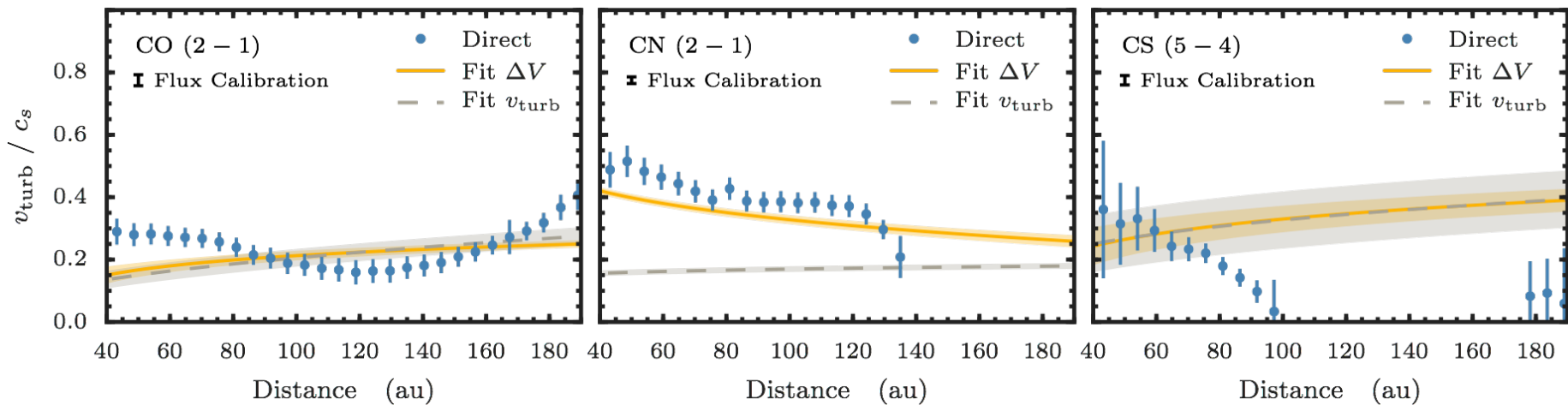
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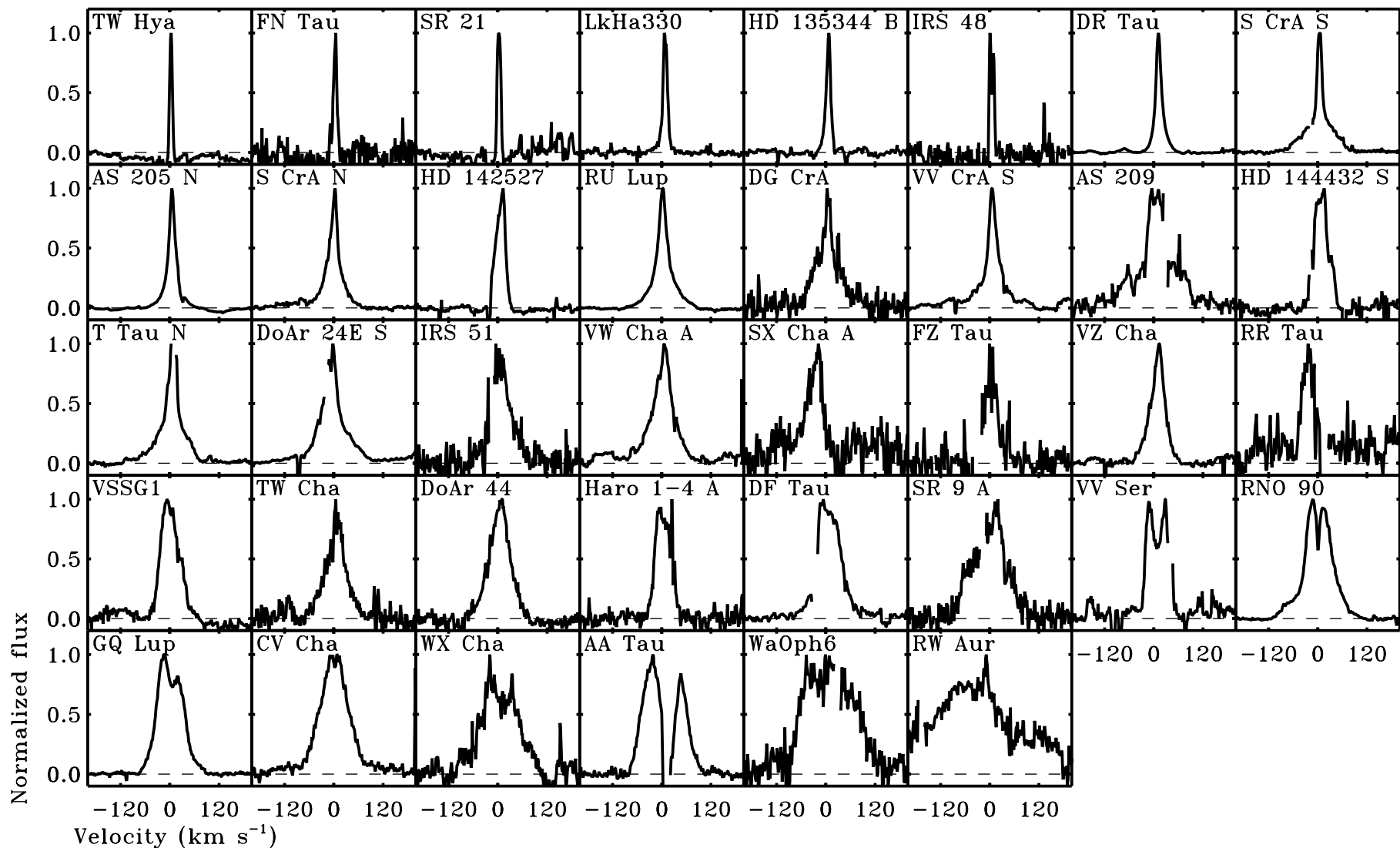
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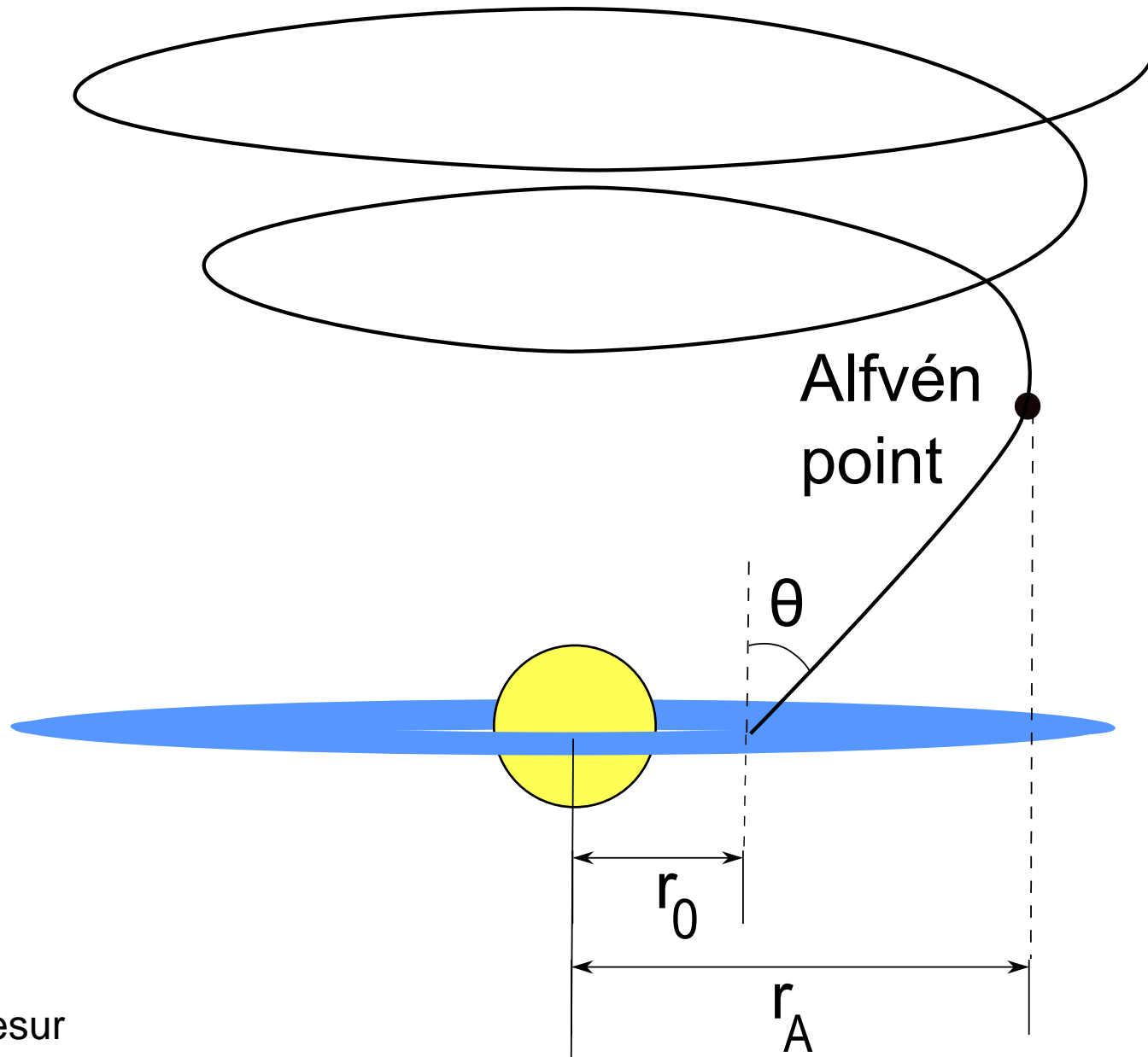
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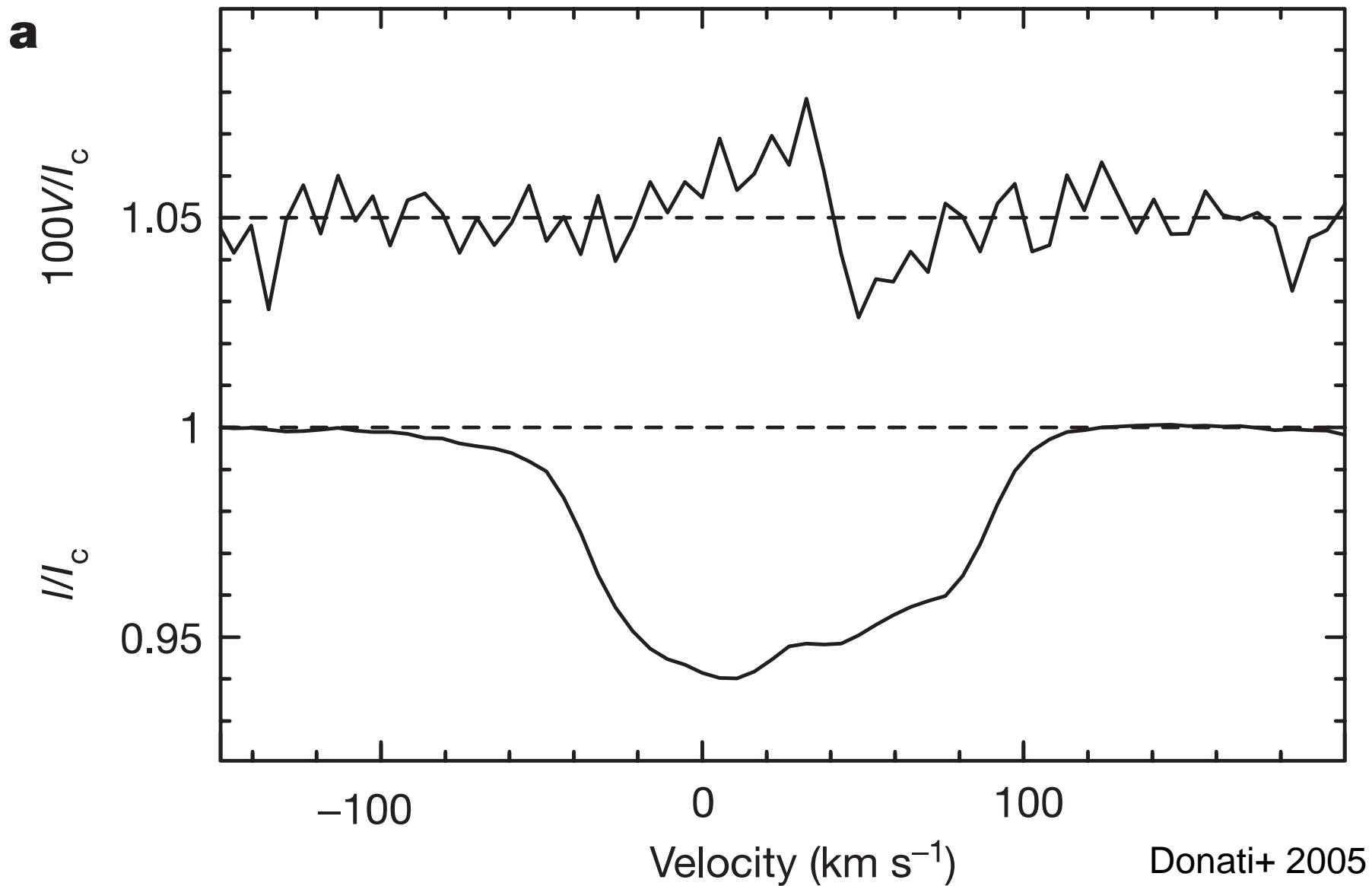
1. trace species' kinematics – from infrared lines



1. trace species' kinematics – from infrared lines



1. trace species' kinematics – and magnetic fields!



- We can detect gas flows by
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2. effects on trace species' abundances – water

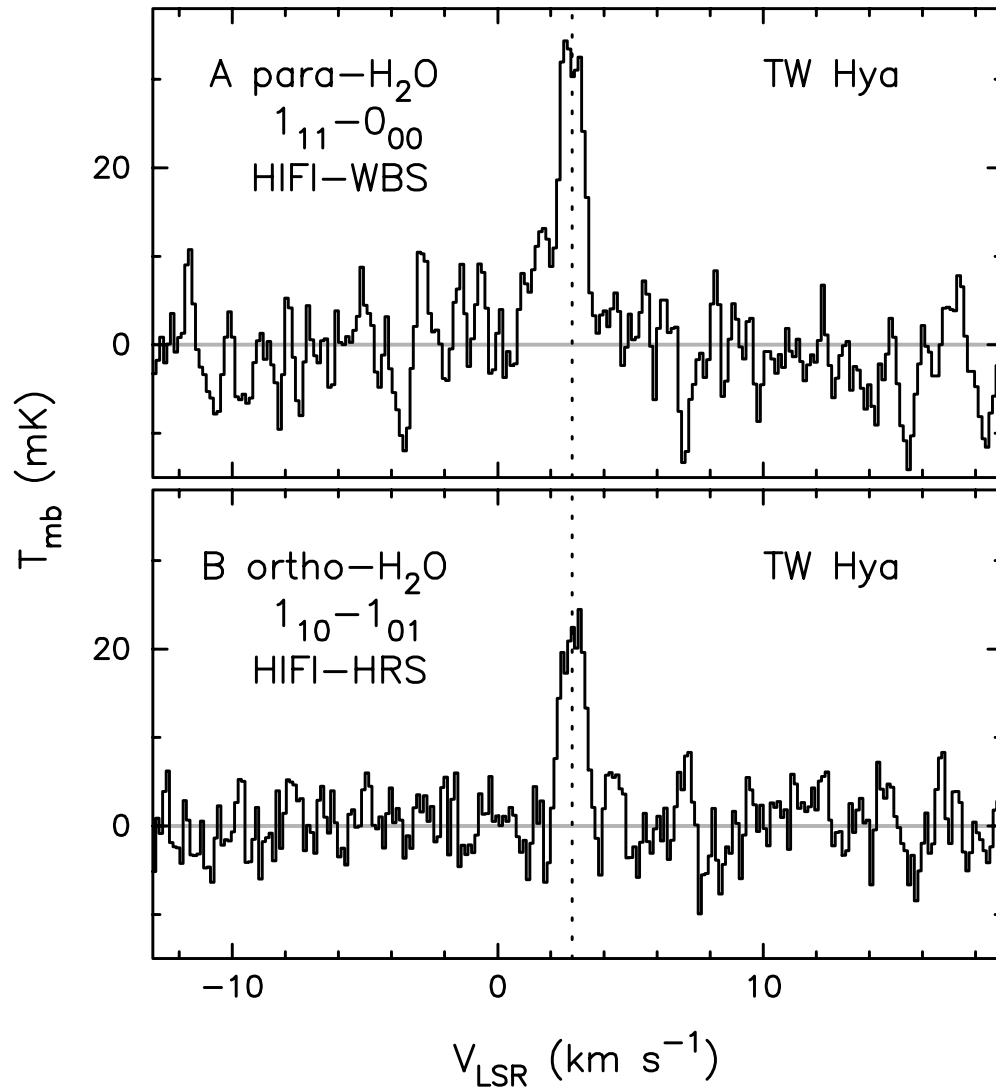
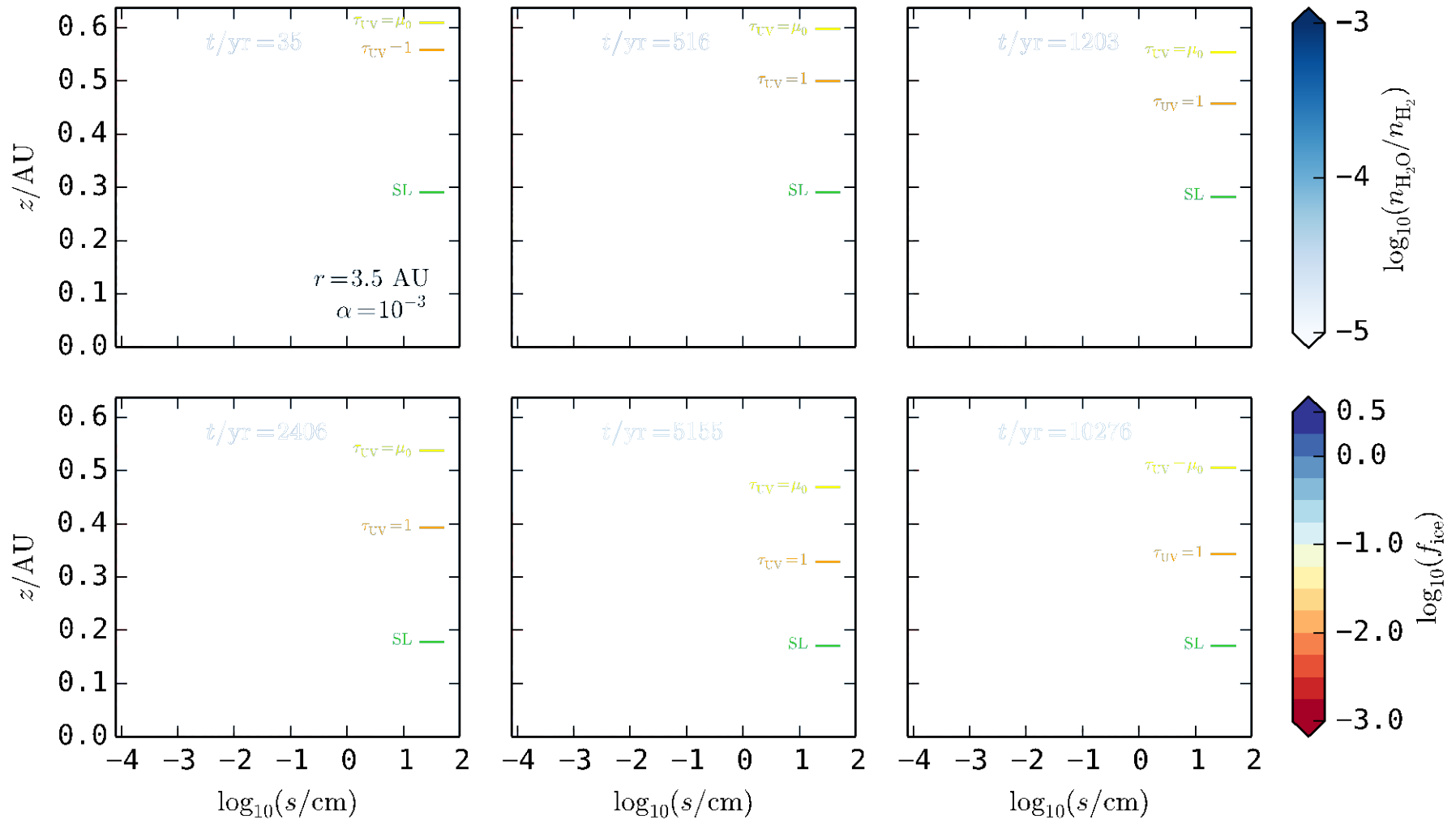


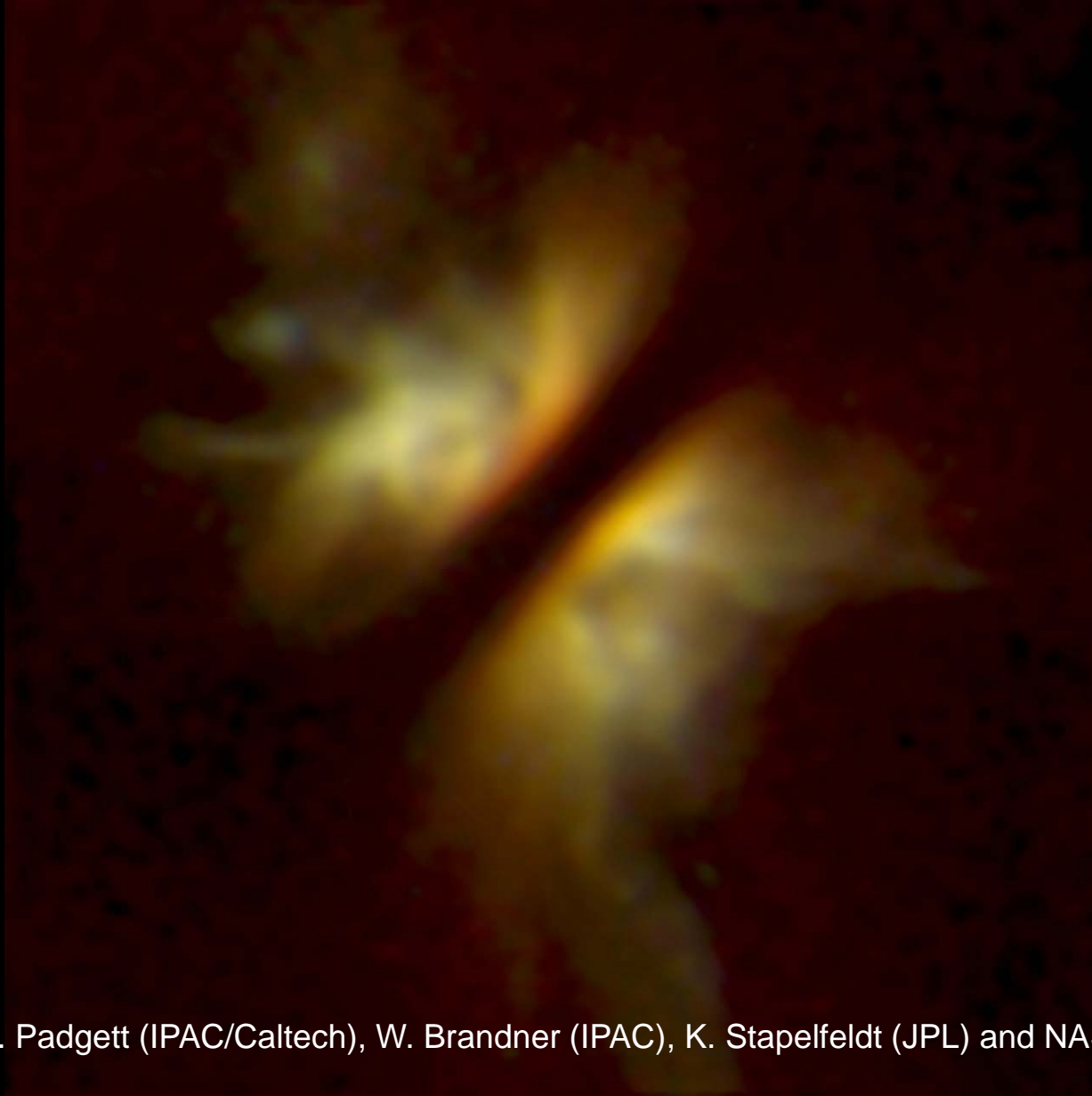
Fig. 1. Spectra of para-H₂O $1_{11}-0_{00}$ (A) and ortho-H₂O $1_{10}-1_{01}$ (B) obtained with HIFI on the Herschel Space Observatory toward the protoplanetary disk around TW Hya after subtraction of the continuum emission. The vertical dotted lines show the system's velocity of $+2.8 \text{ km s}^{-1}$ relative to the Sun's local environment (local standard of rest).

2. effects on trace species' abundances – water



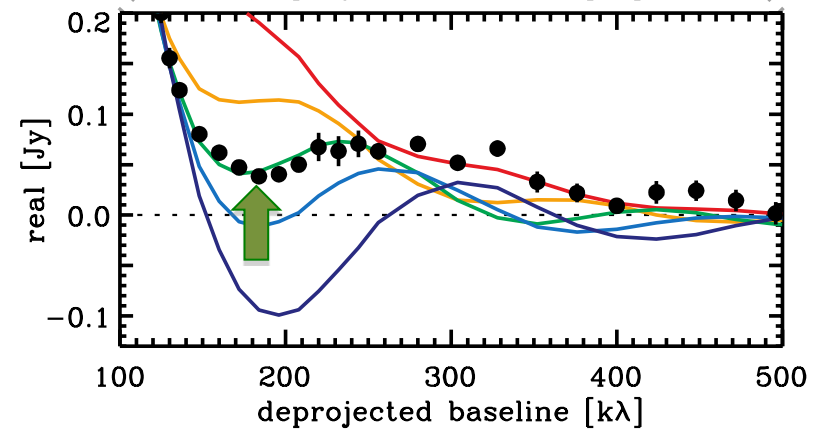
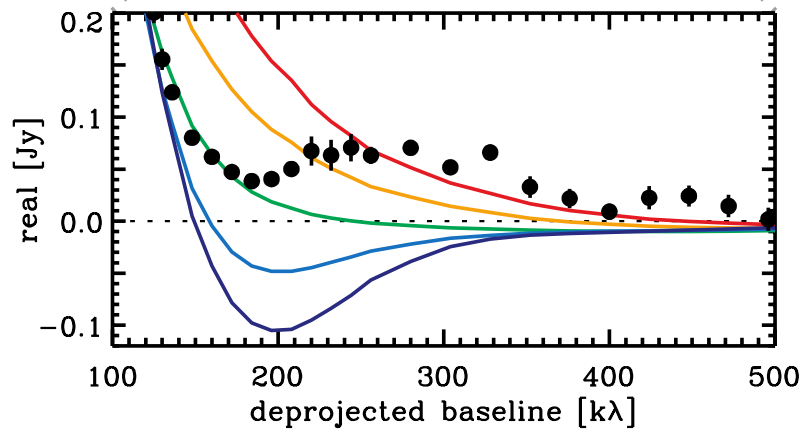
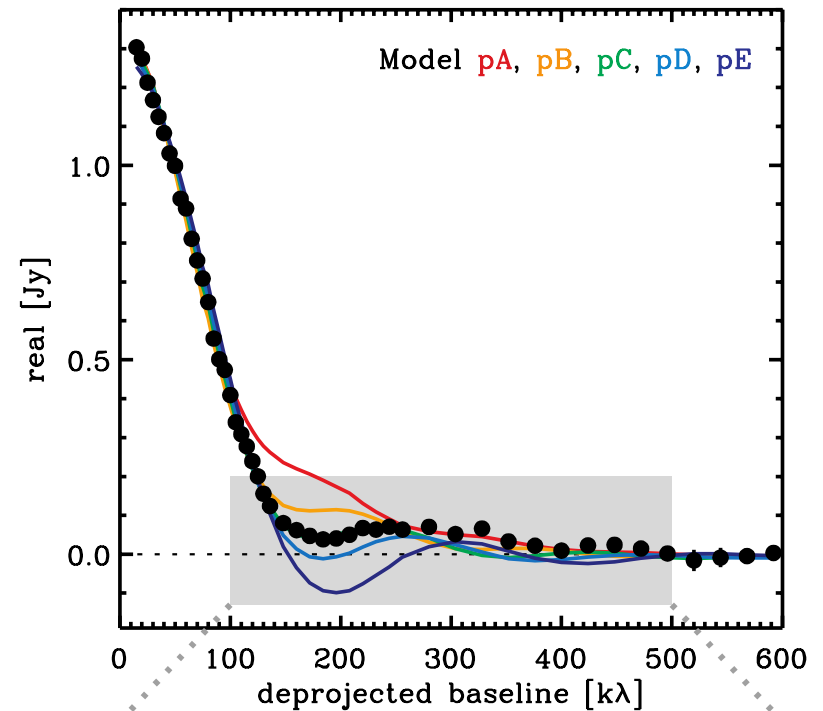
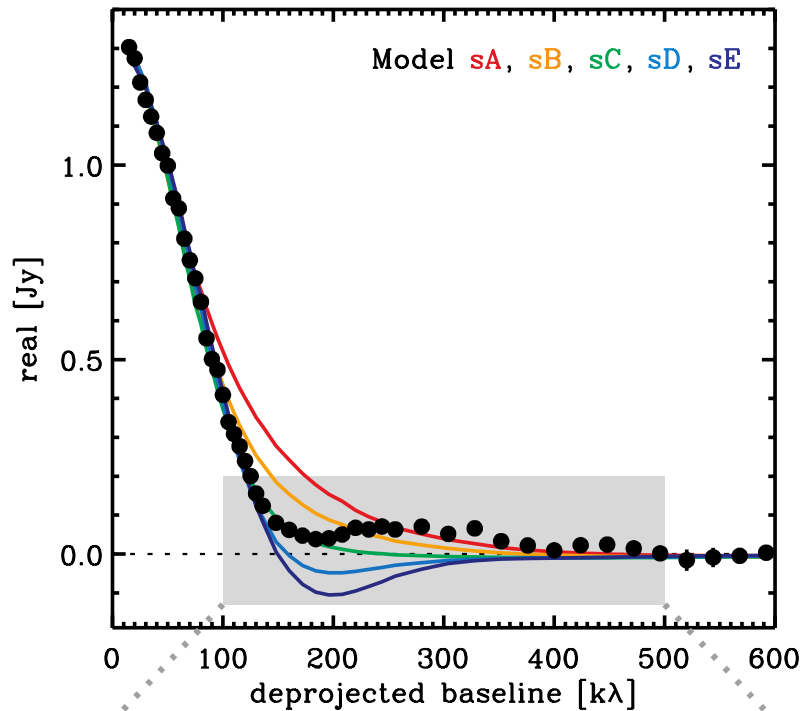
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3. effects on solid particles – NIR scattered starlight

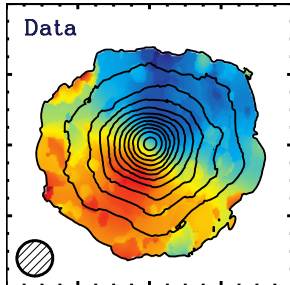


D. Padgett (IPAC/Caltech), W. Brandner (IPAC), K. Stapelfeldt (JPL) and NASA

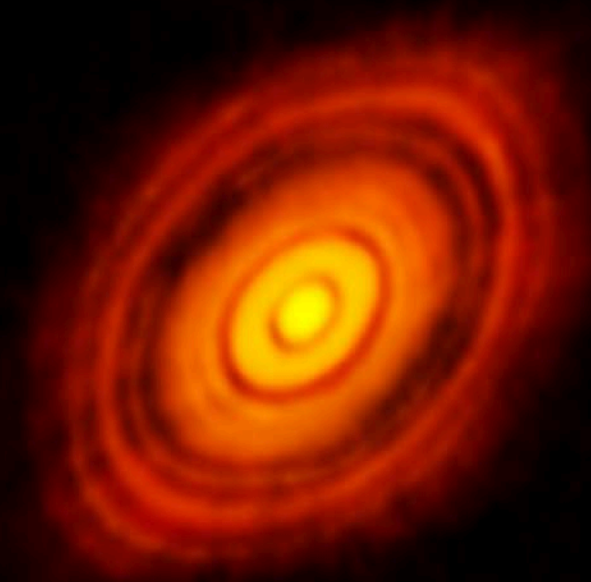
3. effects on solid particles – millimeter continuum



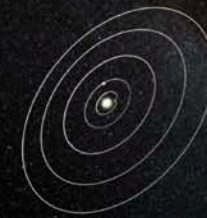
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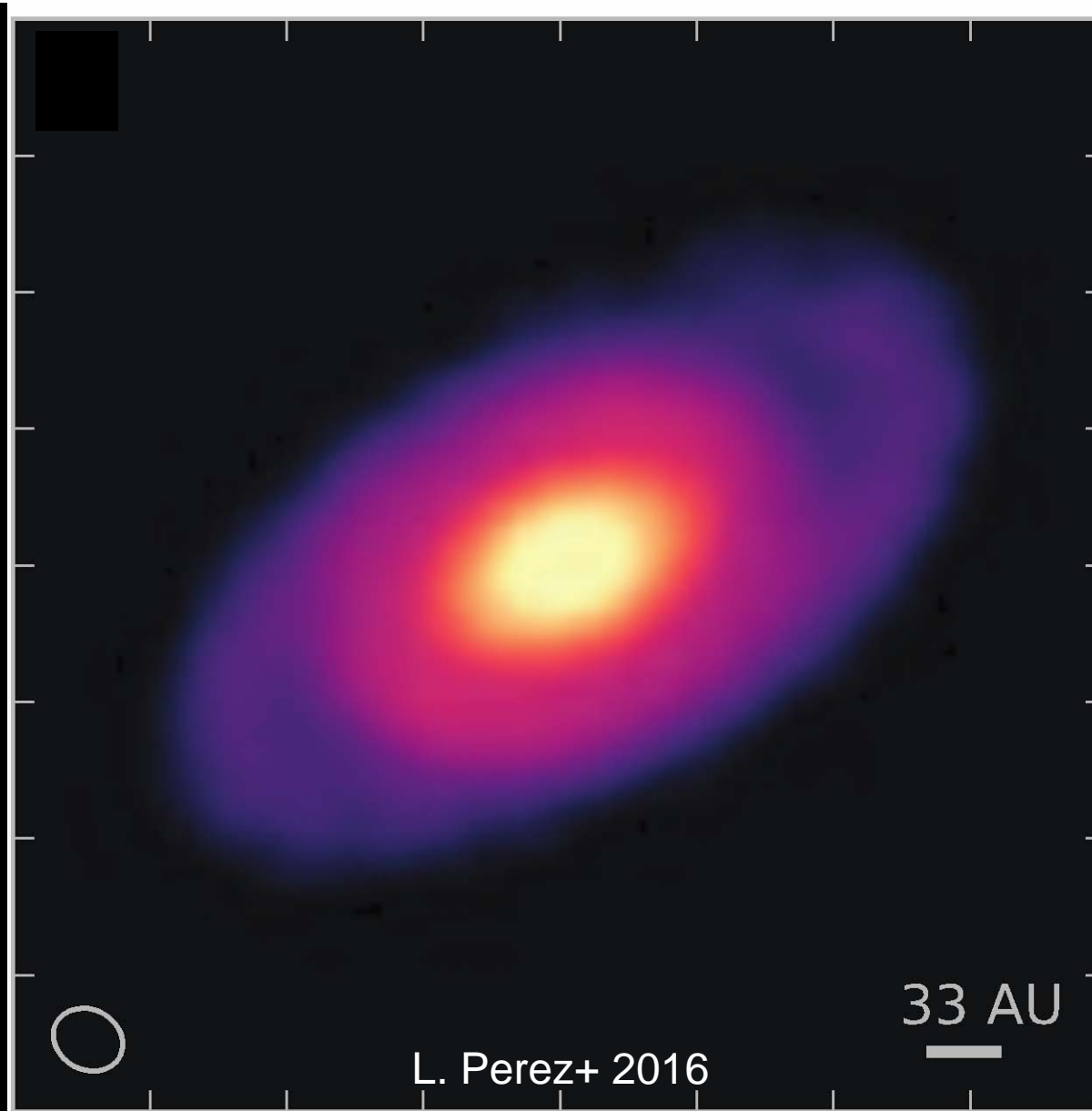


HL Tauri disk with ALMA

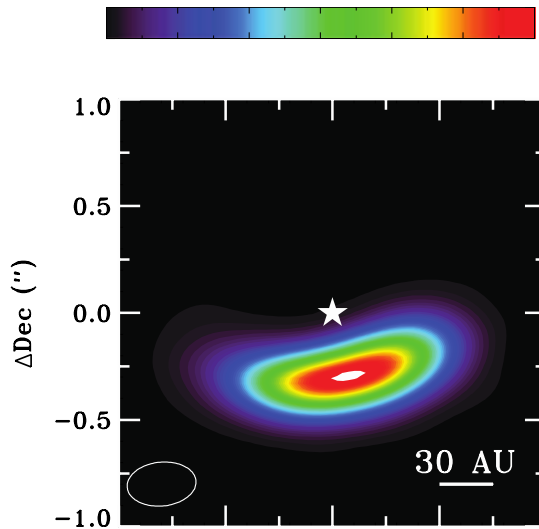


Solar System to scale

3. effects on solid particles – millimeter continuum



3. effects on solid particles – millimeter continuum



**440 μm
continuum**

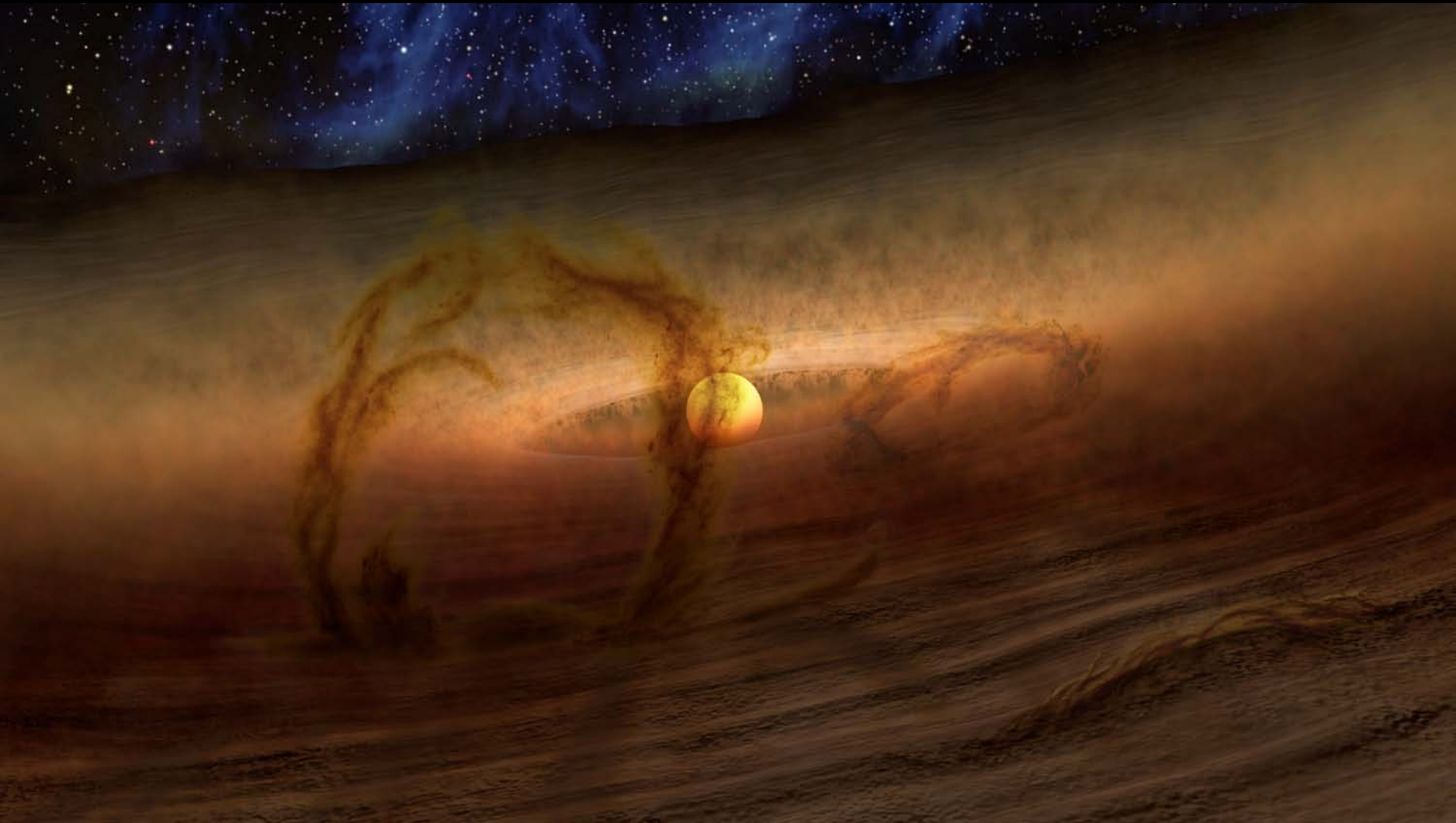
**CO 6-5 blue & red wings,
440 μm continuum**

**18.7 μm ,
440 μm continua**

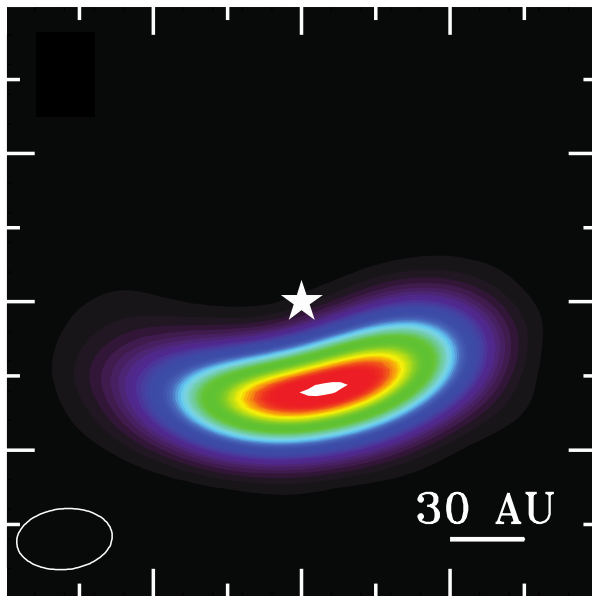
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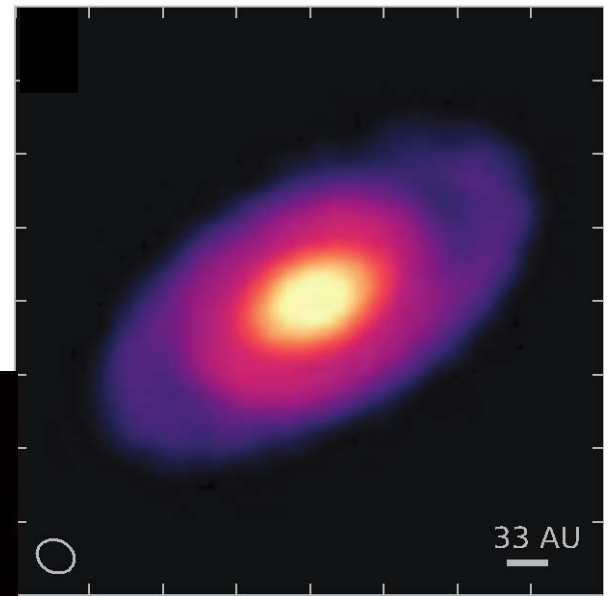
**How to recognize each
transport process?**



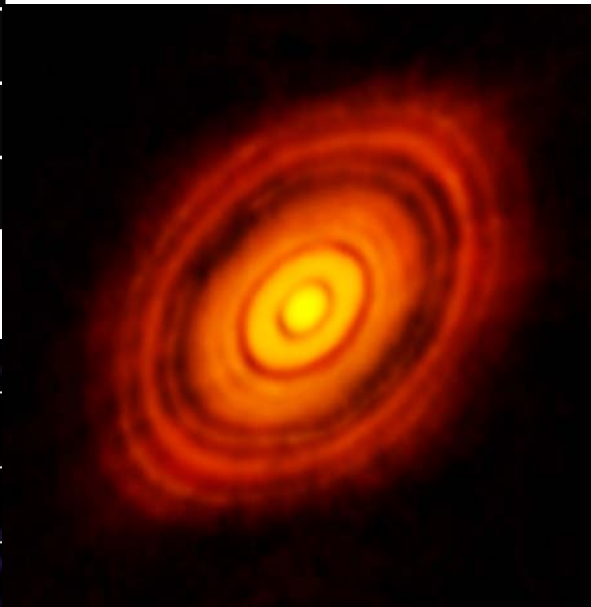
Artwork by Robert Hurt (IPAC/Caltech)



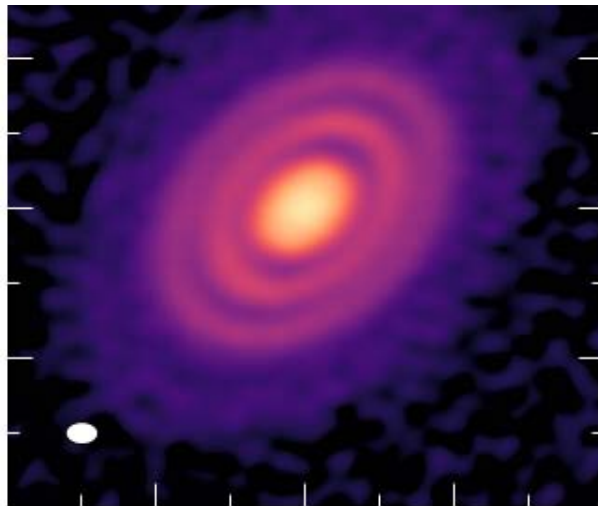
van der Marel+ 2013



Perez+ 2016

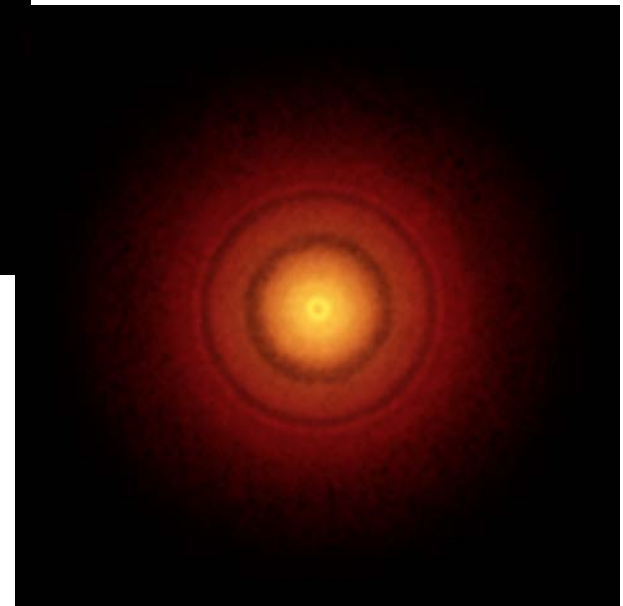


ALMA Partnership, Brogan+ 2015



^{13}CO flux density [Jy/beam km/s]

Isella+ 2016



Andrews+ 2016

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