INVESTIGATING THE PROTOPLANETARY DISK AROUND THE YOUNG STAR HD 163296

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Outline

- Introduction

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  - Brightness temperature profile

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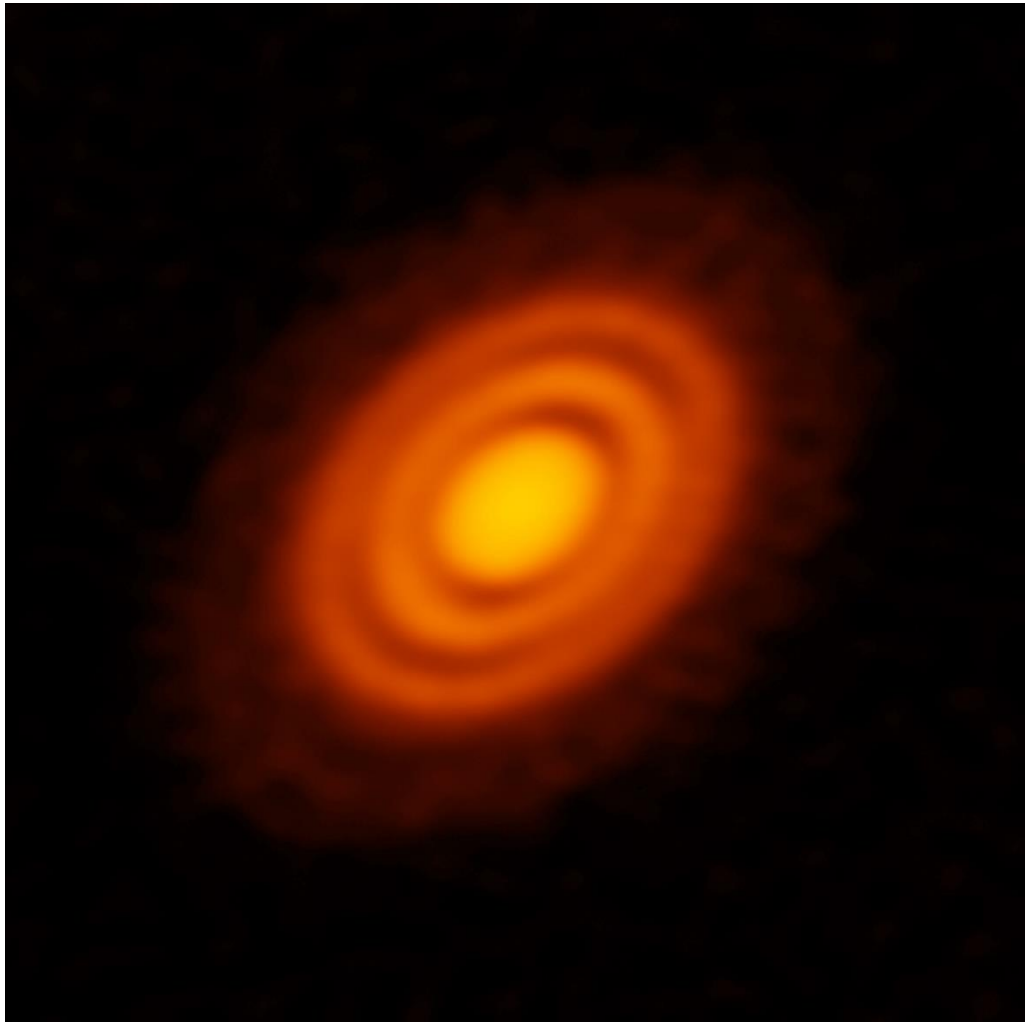


Credit: ALMA

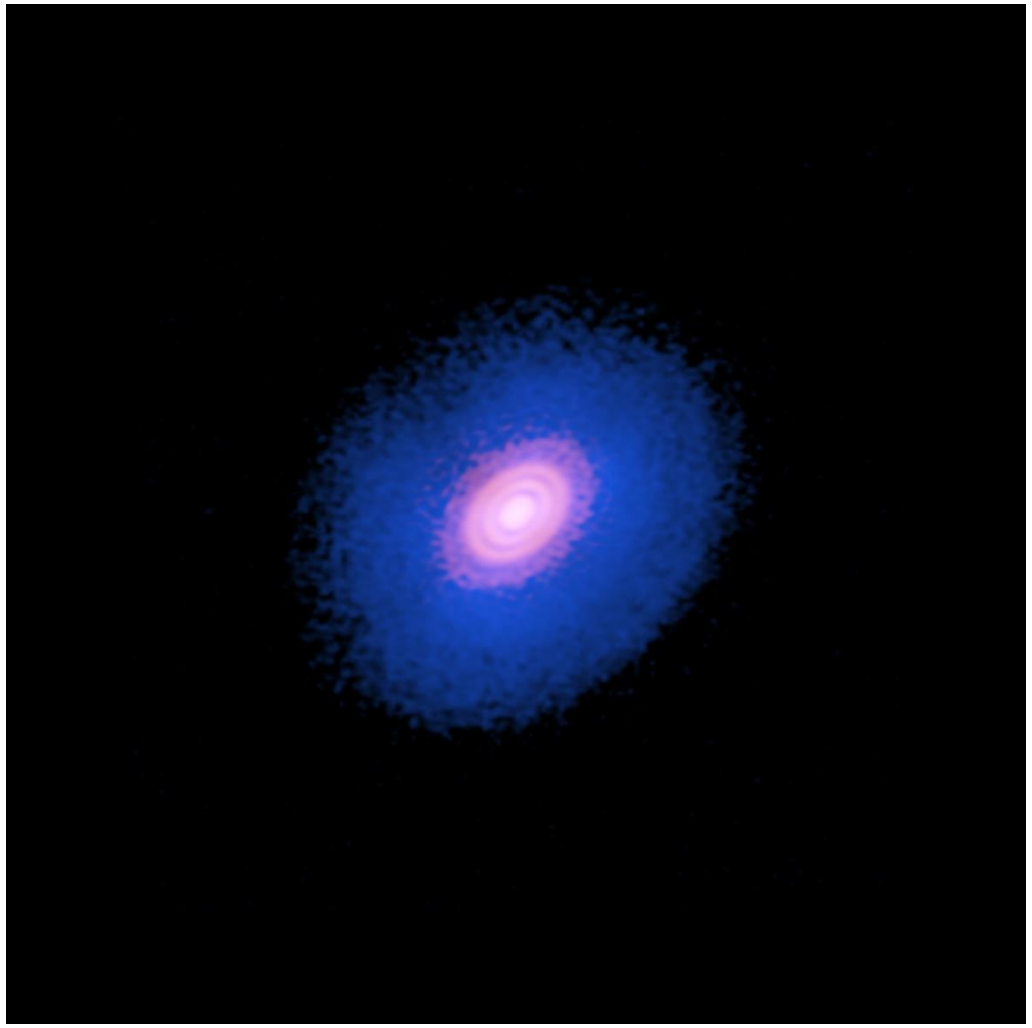
HD 163296

- Herbig Ae star
- Age: ~5 Myr
- Mass: 2.3 M_{Sun}
- Distance: 122 pc (Sagittarius)
- Disk radius: ~550 AU

(M.E. van den Ancker et al. 1997/A. Natta et al. 2004/NRAO)

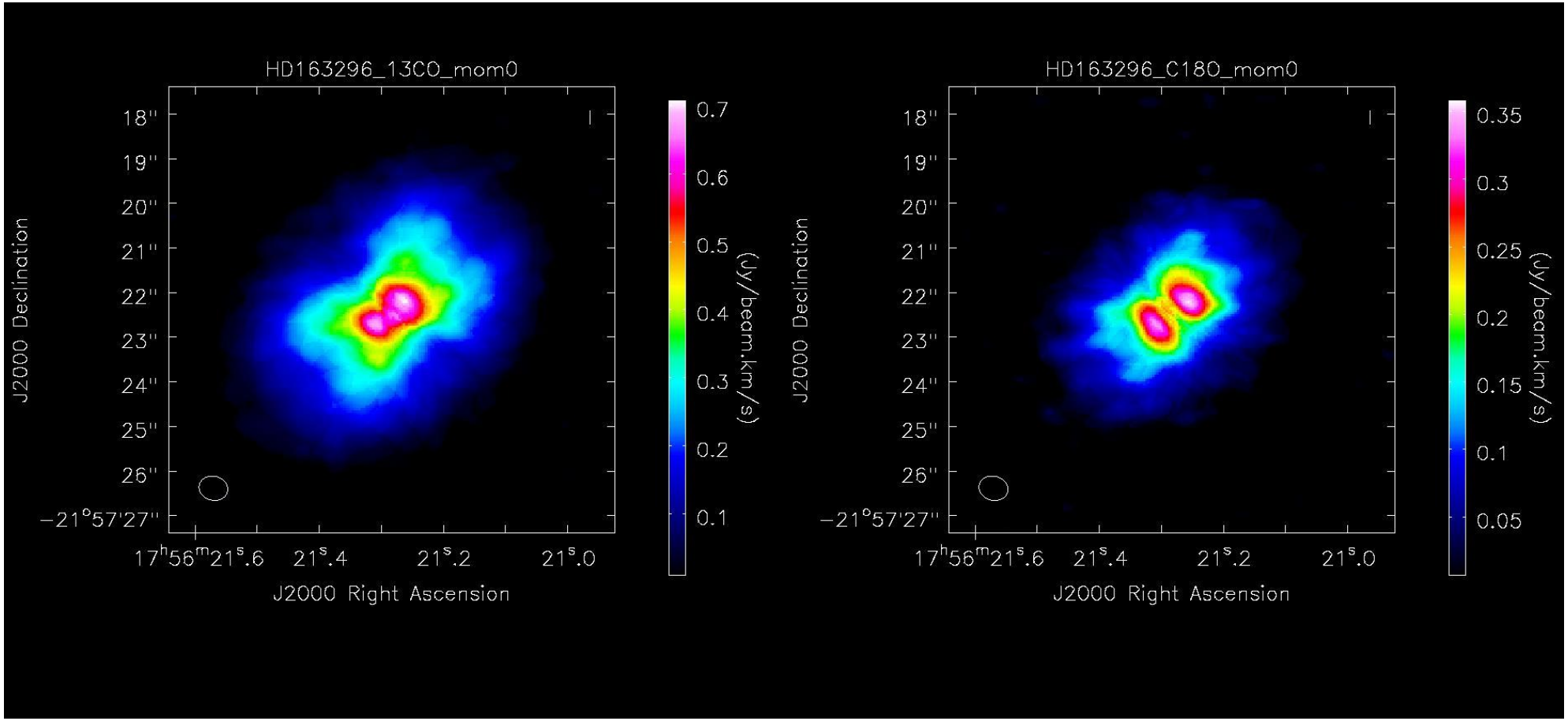
- Herbig Ae/Be star is usually 2 to 8 M_{Sun}
- There is a close relation between protoplanetary disk and star formation.

- HD 163296 represents the condition of lower-mass Herbig star.



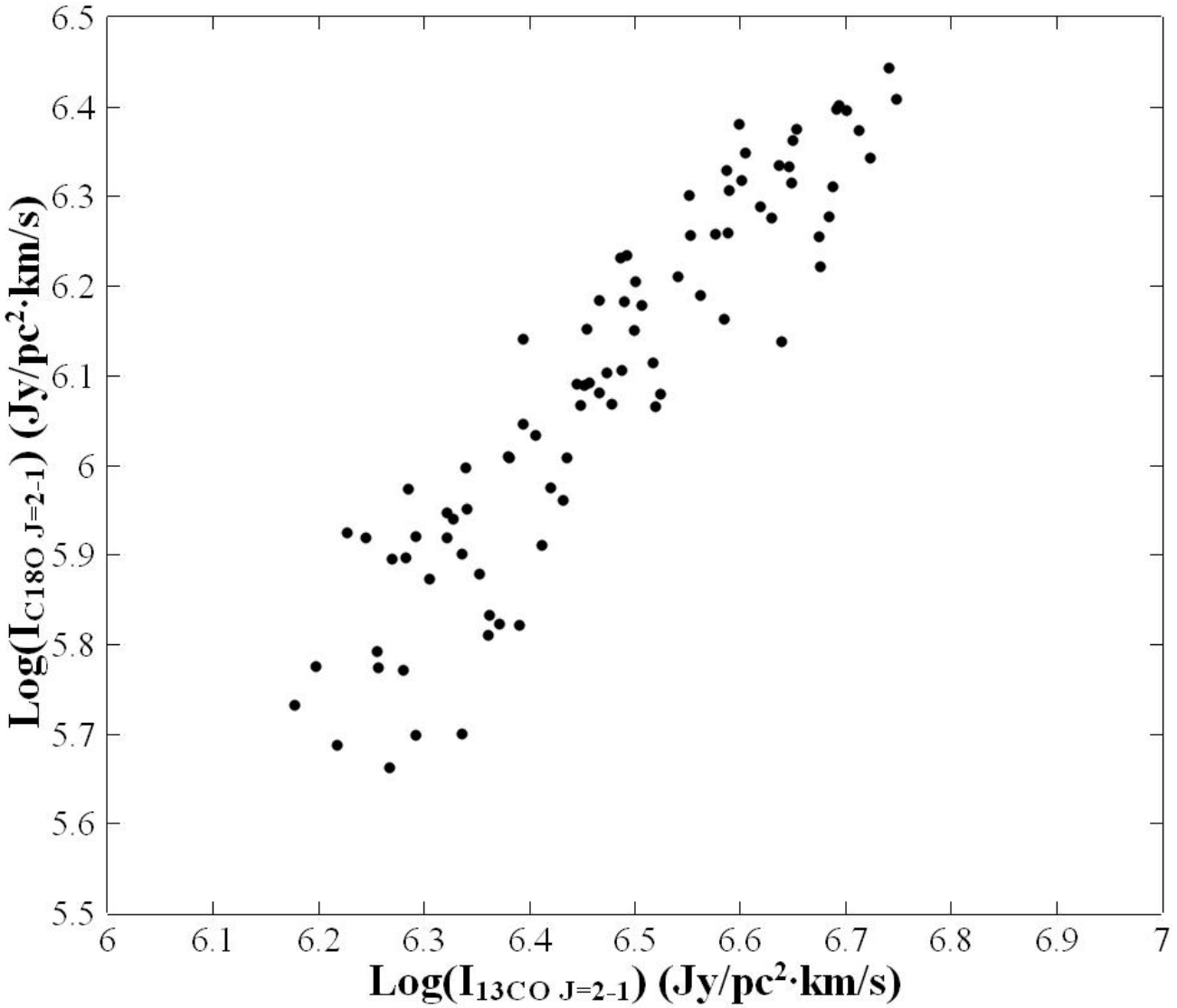
Credit: ALMA

Disk mass

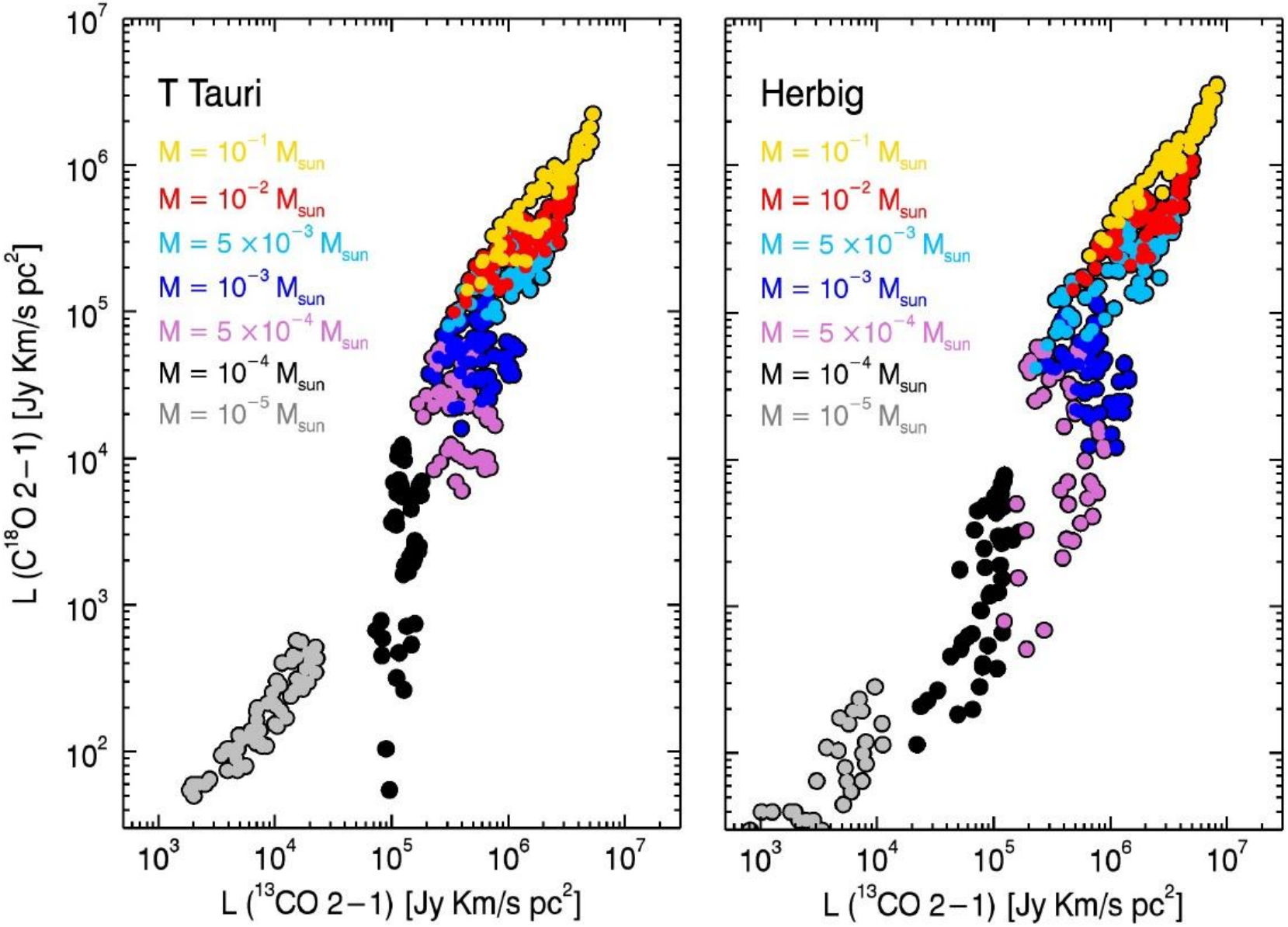


$^{13}CO(J=2-1)$ $C^{18}O(J=2-1)$

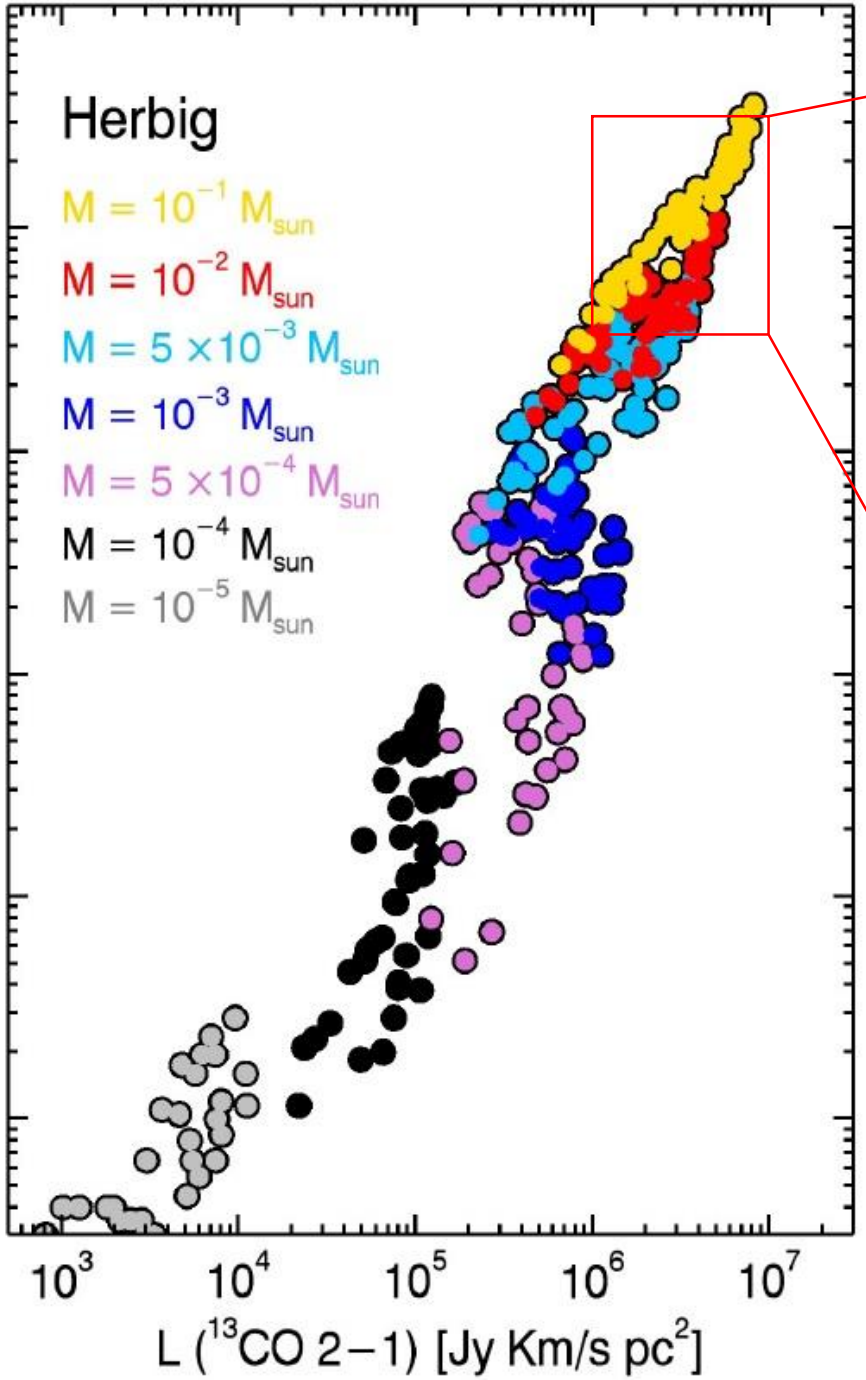
Sample 100 points from zeroth moment of $^{13}CO(J=2-1)$ and $C^{18}O(J=2-1)$

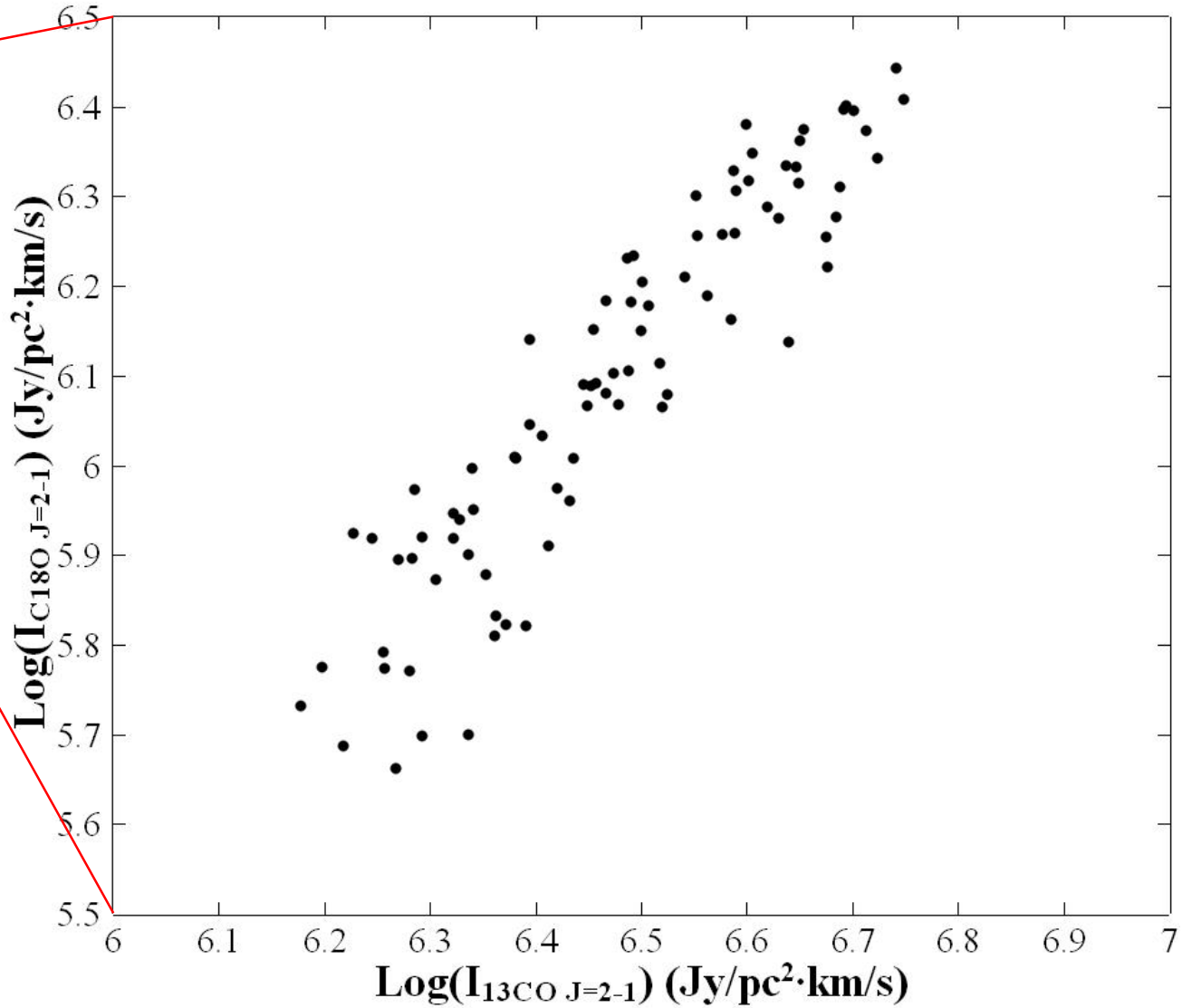


Total intensity of $C^{18}O$(J=2-1) vs. total intensity of ^{13}CO(J=2-1) in logarithmic coordinates.



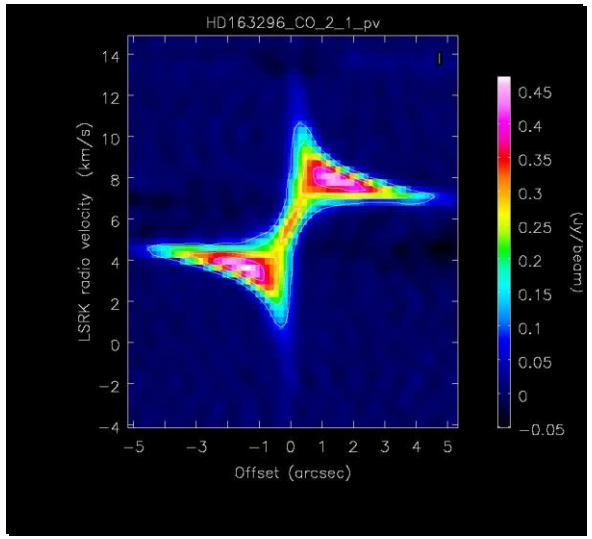
Model for estimating disk mass (A. Miotello et al. 2016)



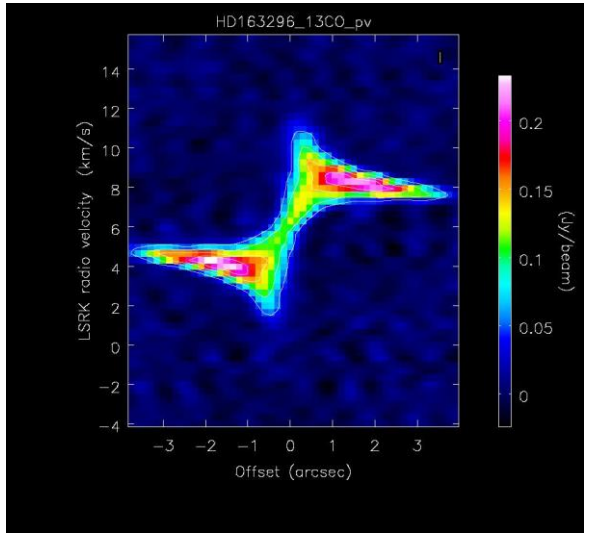


→ The disk mass of HD 163296 is about 0.1 M_{Sun}

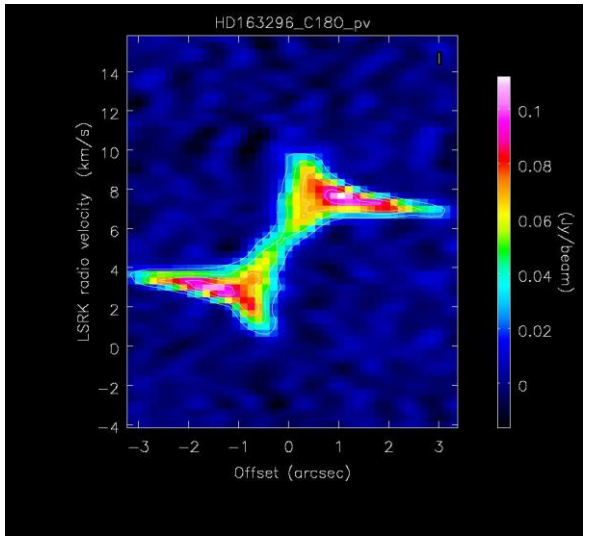
Central mass



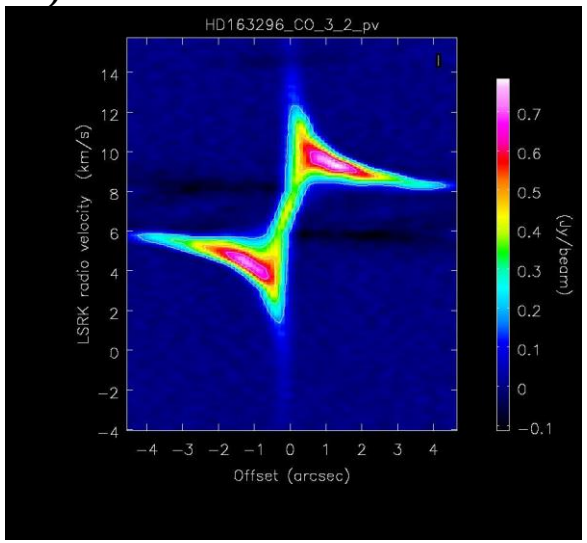
CO(J=2-1)



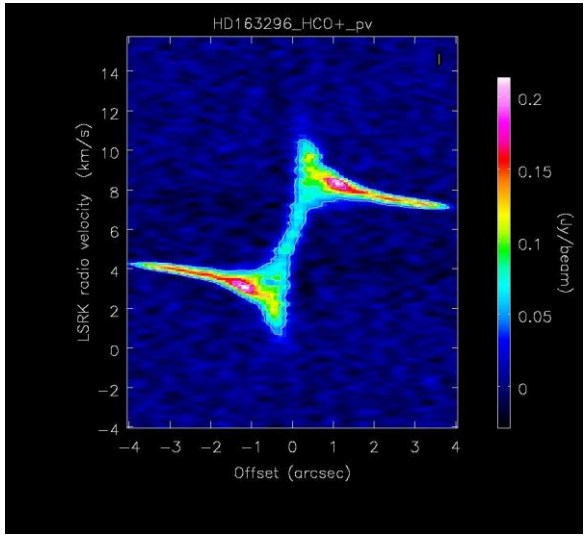
^{13}CO(J=2-1)



C^{18}O(J=2-1)

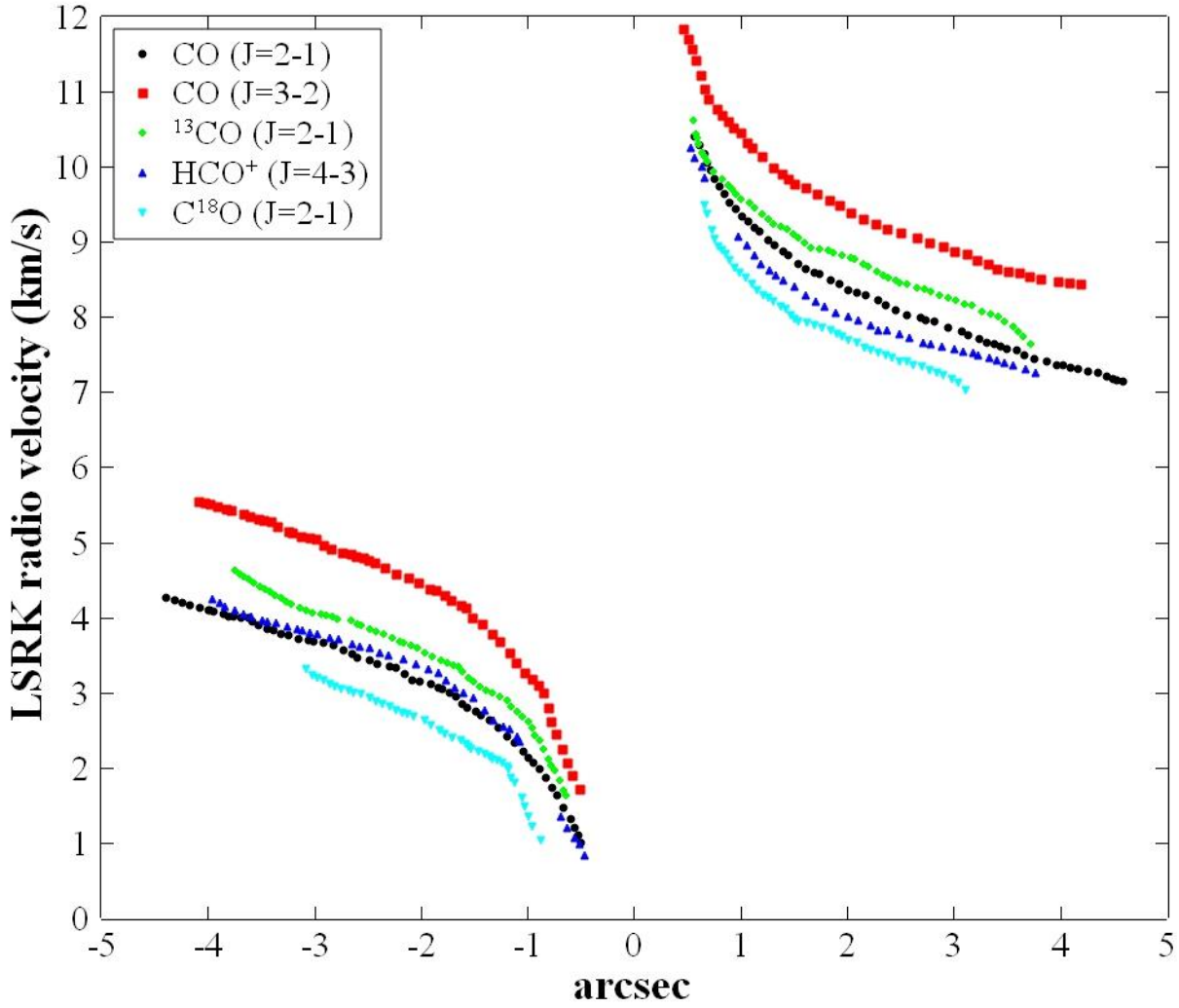


CO (J=3-2)

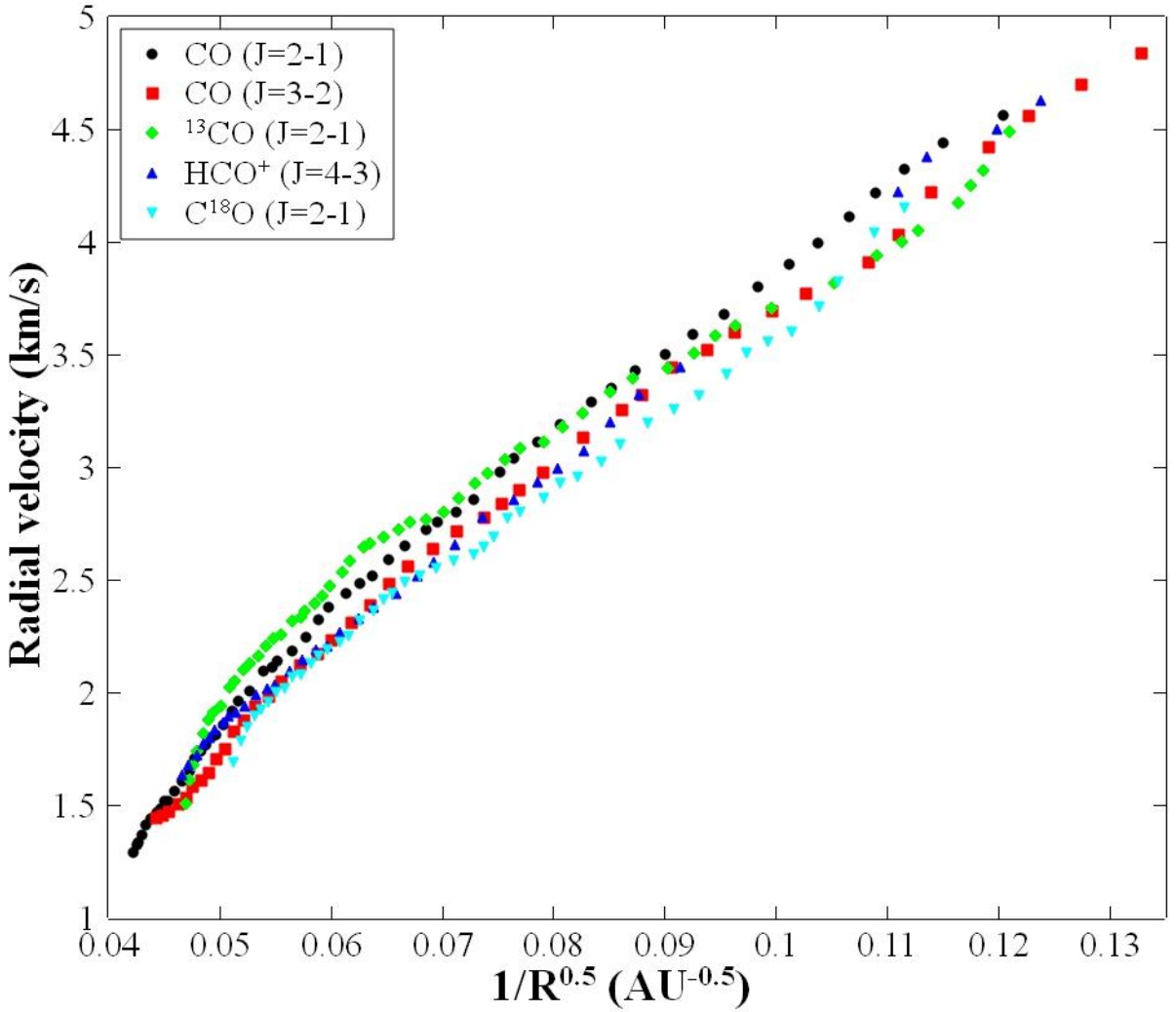


HCO$^+$(J=4-3)

PV cut
Position angle: ~130°
Width: 5 pixels



Keplerian curve from each PV diagram



Radial velocity vs. $1/\sqrt{\text{Radius}}$ diagram

$$v = \sqrt{\frac{GM}{r}} \rightarrow M = \frac{(Slope)^2}{G}$$

- Do linear analysis with the points from each emission line

Spectral Line	Central mass (M_{sun})
CO (J=2-1)	1.98
CO (J=3-2)	1.68
^{13}CO (J=2-1)	1.33
HCO^+ (J=4-3)	1.68
$C^{18}O$ (J=2-1)	1.49

→ Average central mass is 1.63 M_{Sun}

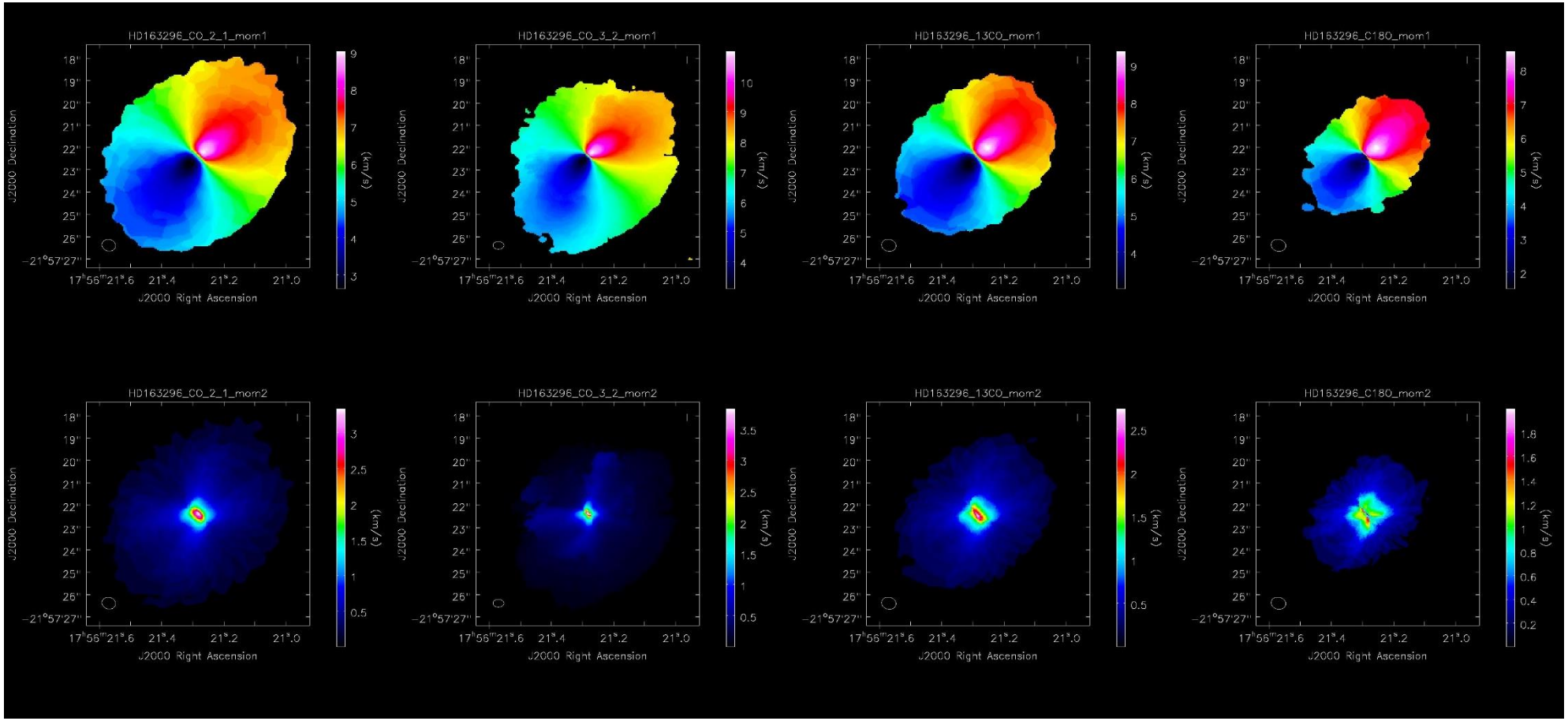
- Use full points to do linear analysis

→ Central mass is 1.57 M_{Sun}

The area is not rotation dominated

1st moment

2nd moment

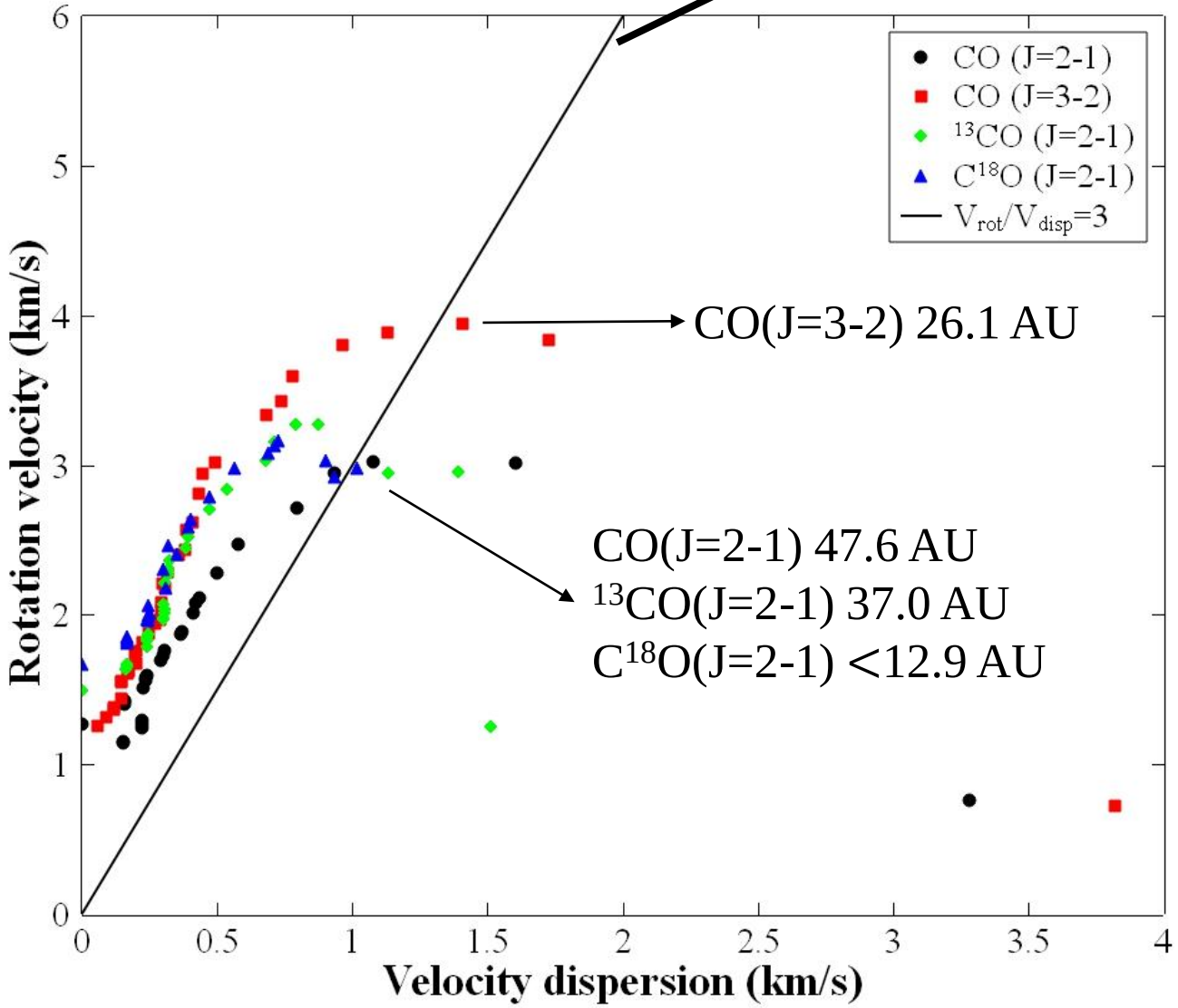


CO(J=2-1) CO(J=3-2) ^{13}CO(J=2-1) C^{18}O(J=2-1)

Get points from center to outer disk with position angle ~310°

Rotation velocity $> 3\sigma$

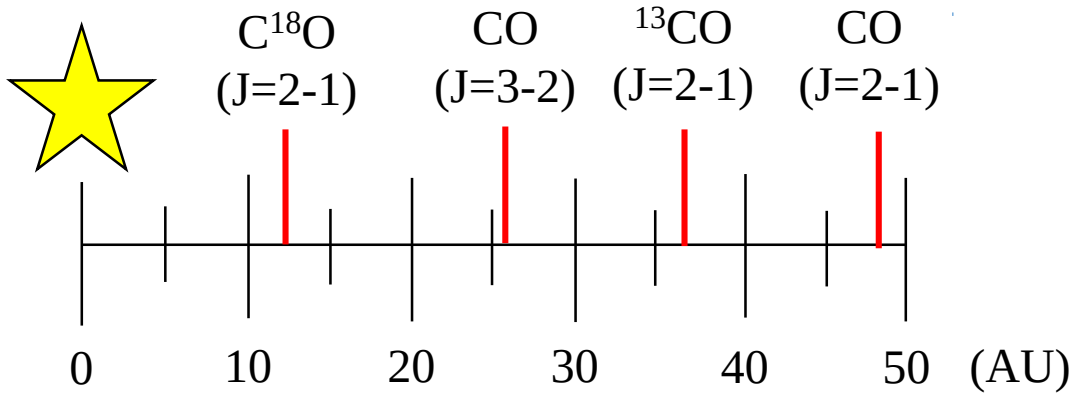
$$\frac{v_{rotation}}{v_{dispersion}} = 3$$



$$M_2 = \sqrt{\frac{\int I(v)(v - M_1)^2 dv}{\int I(v) dv}}$$

→ velocity dispersion

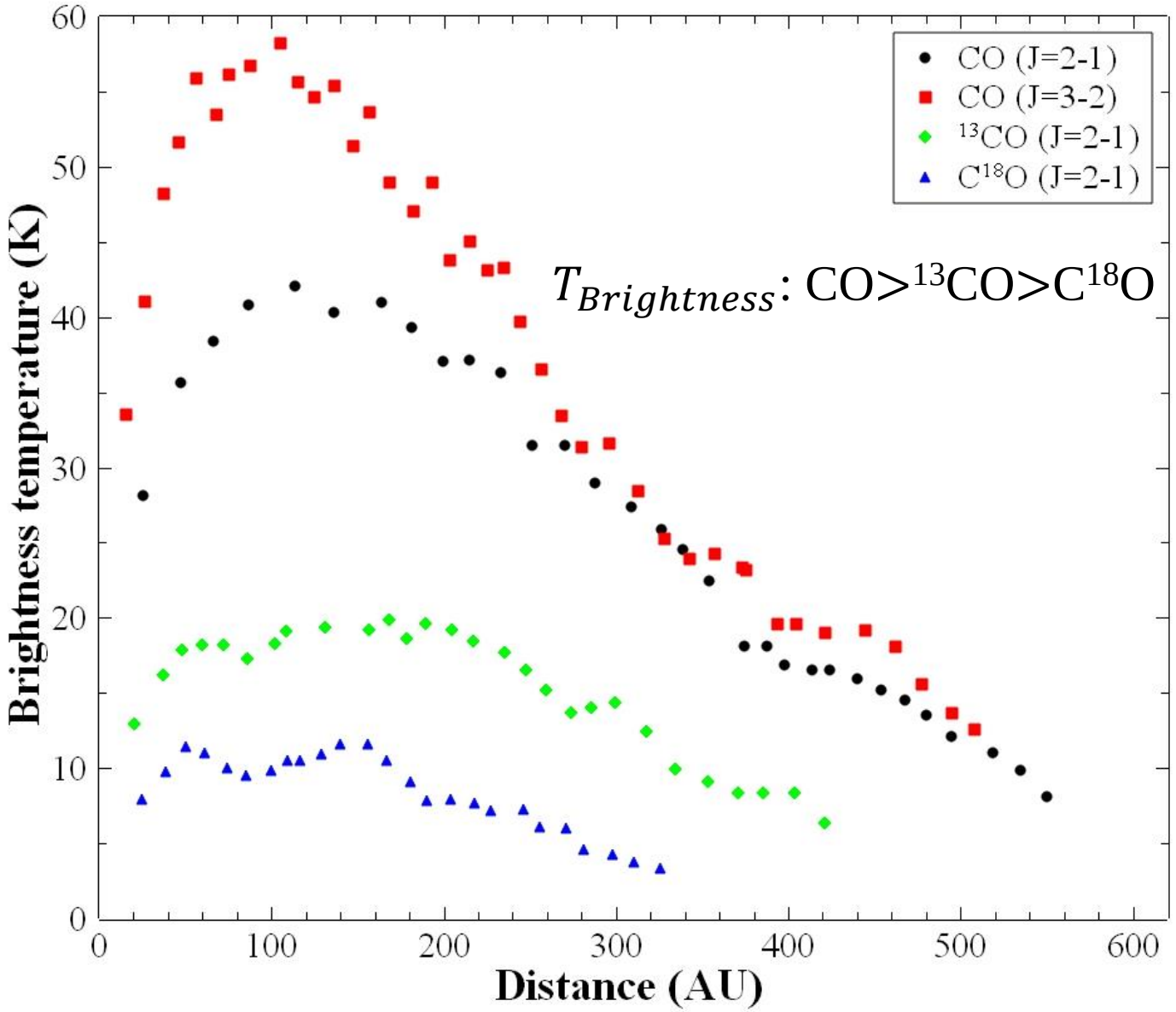
→ standard deviation (σ) of velocity

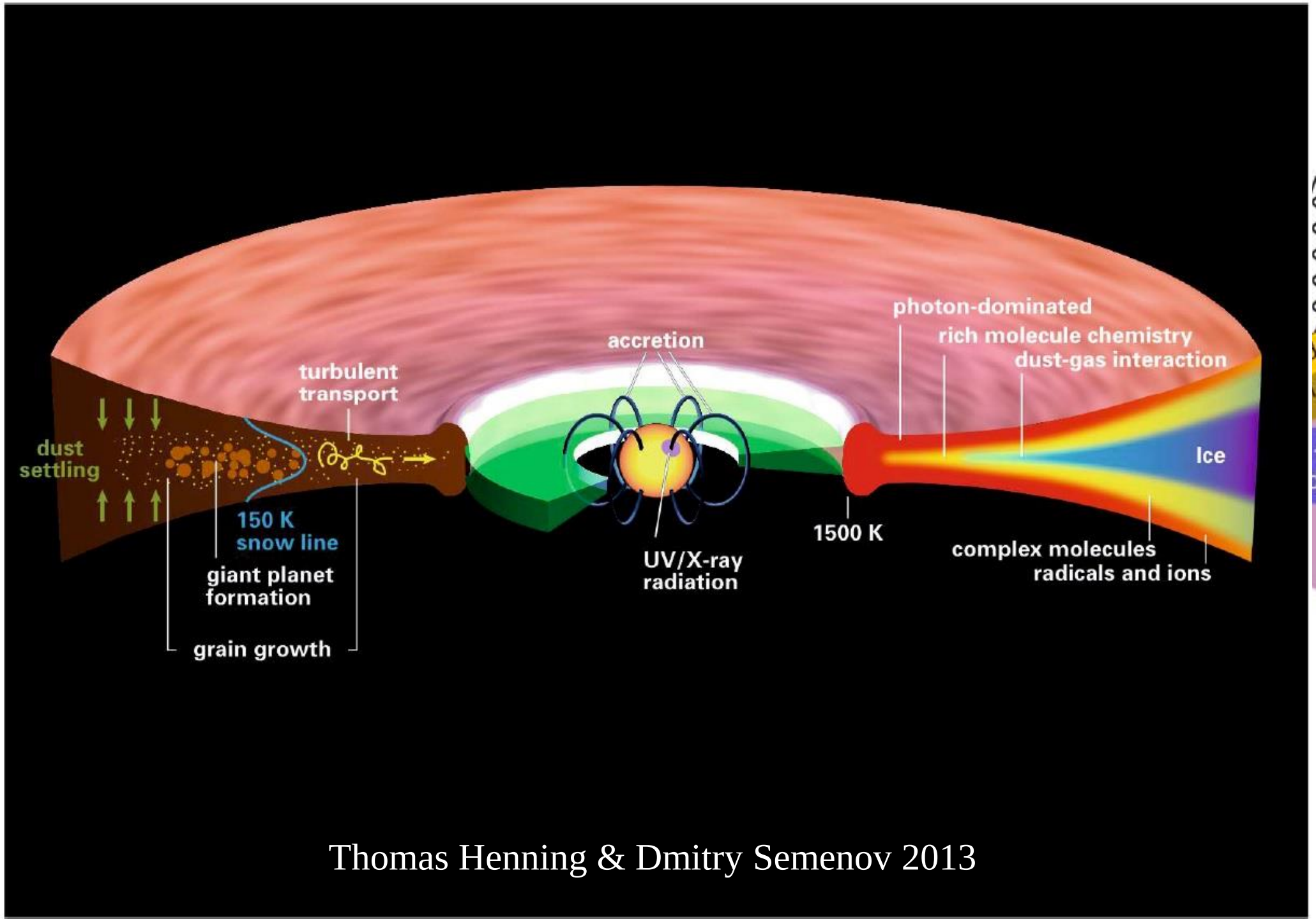


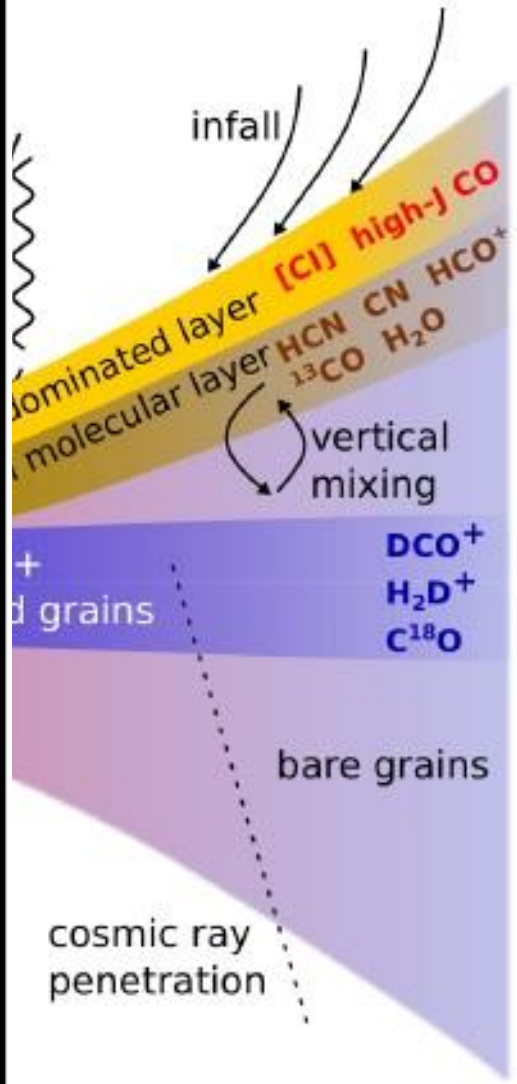
Full disk radius is about 550 AU

→ Less than 1% area of the disk is not rotation dominated.

Brightness temperature profile







Thomas Henning & Dmitry Semenov 2013

Conclusions

- Use total intensity of $C^{18}O$(J=2-1) vs. ^{13}CO(J=2-1) diagram, and compare the model for estimating disk mass (A. Miotello et al. 2016), the disk mass of HD 163296 is about 0.1 M_{Sun}.

- The central mass I calculated from PV diagram is about 1.6 M_{Sun}, but the mass of HD 163296 is 2.3 M_{Sun} (M.E. van den Ancker et al. 1997).

- There is surely an area being not rotation dominated, but it only takes less than 1% of the protoplanetary disk.

- The brightness temperature of CO isotopes show the vertical temperature structure of the protoplanetary disk.