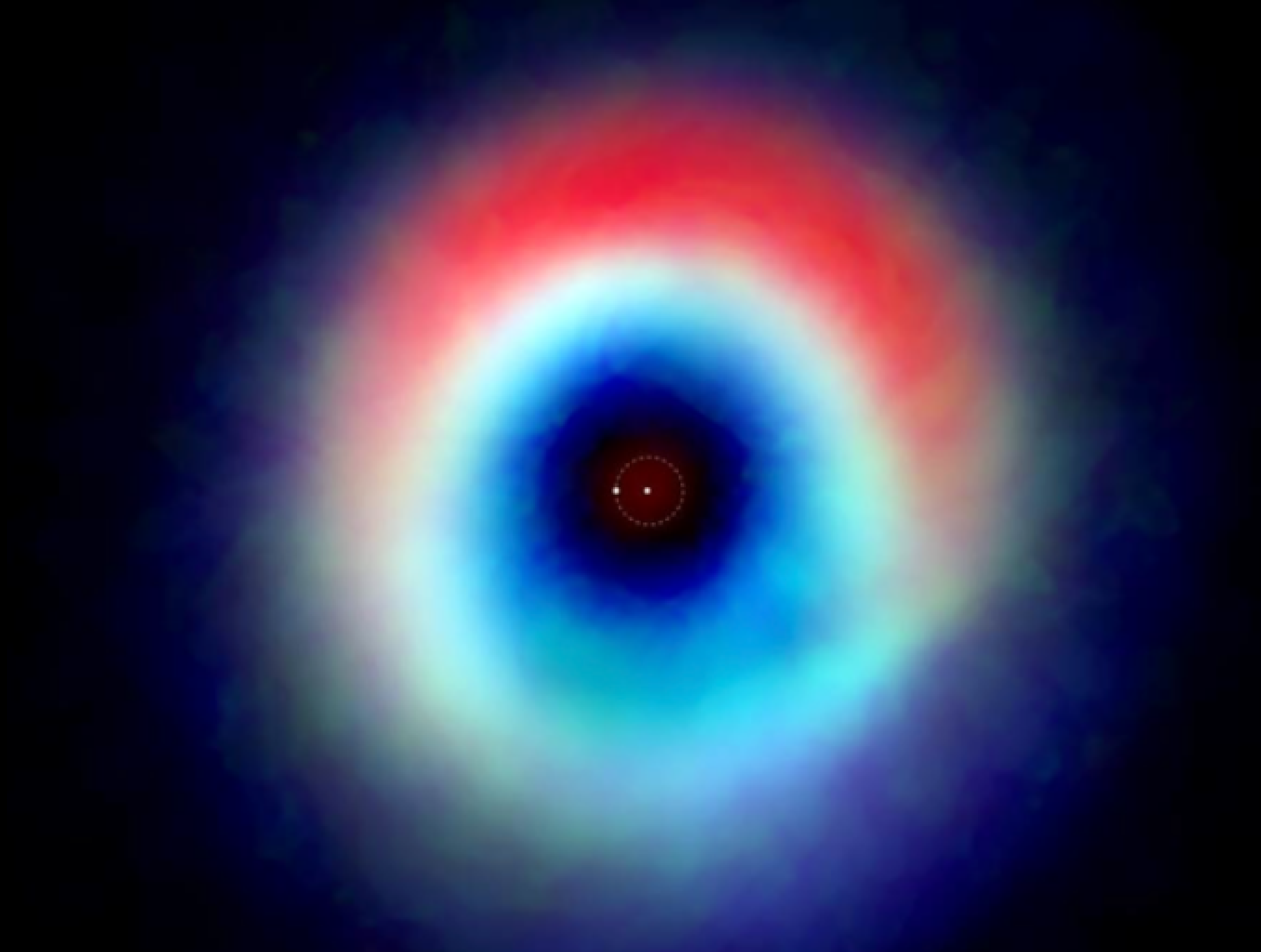
Vortex signature in the gas kinematics

Are asymmetries in protoplanetary disks explained by vortices ?



Yann Boehler

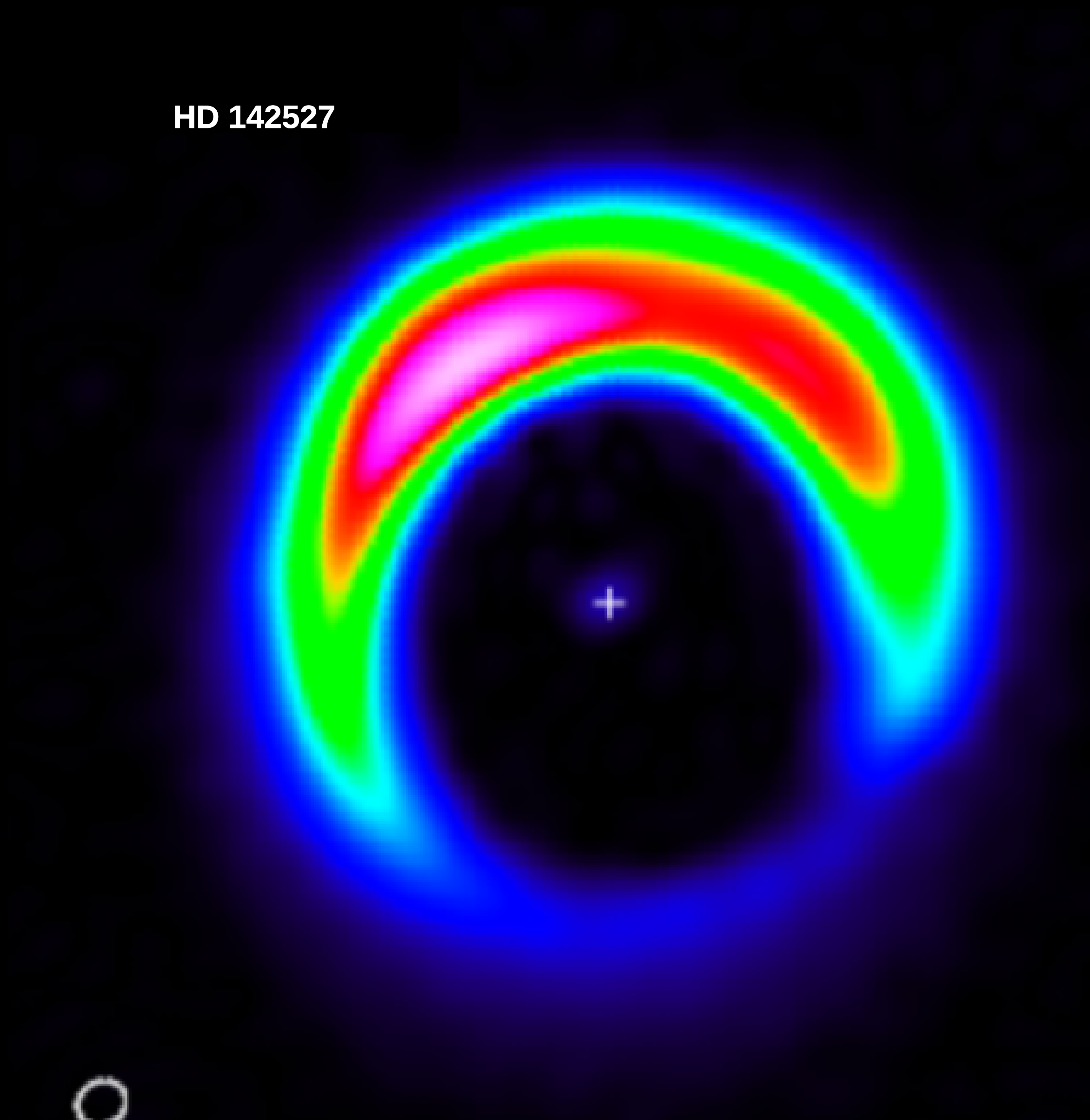
Institut de planétologie
et d'Astrophysique
de Grenoble

IPAG

With F. Ménard, A. Isella, C. Robert, C. Pinte, G. van der Plas,
E. Weaver, H. Méheut, J.-F. Gonzalez, G. Lesur

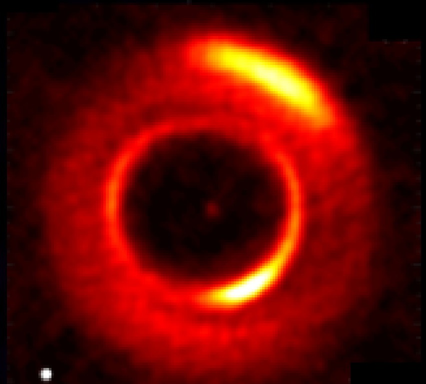
Asymmetries in the dust emission

HD 142527



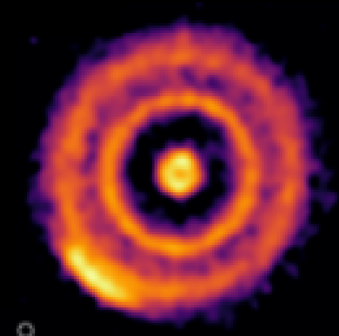
Boehler et al. 2017

MWC 758



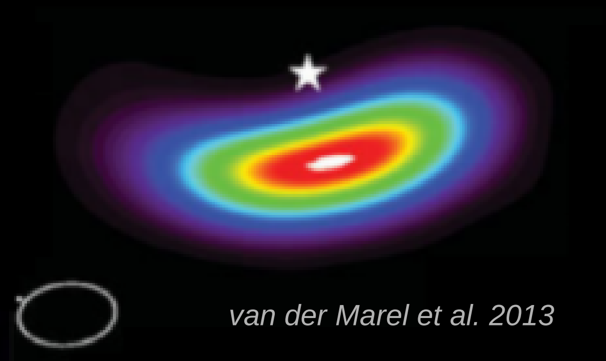
Dong et al. 2018

HD 143006



Huang et al. 2018

IRS 48



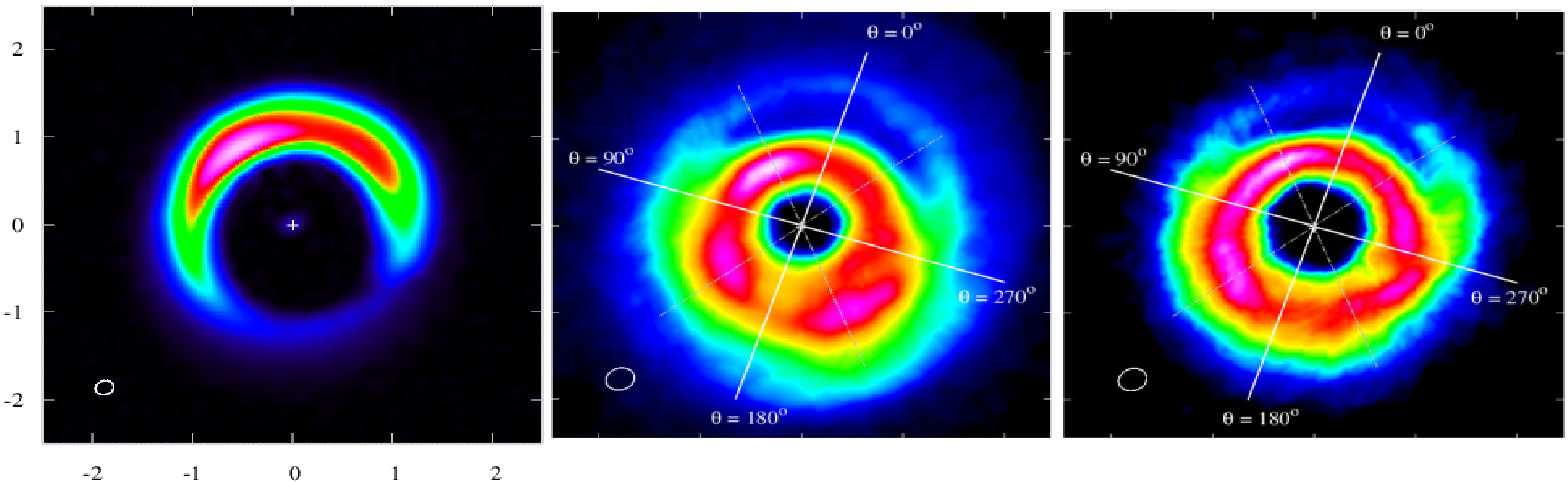
van der Marel et al. 2013

HD 142527 : A ideal target to study dust trapping

Binary system

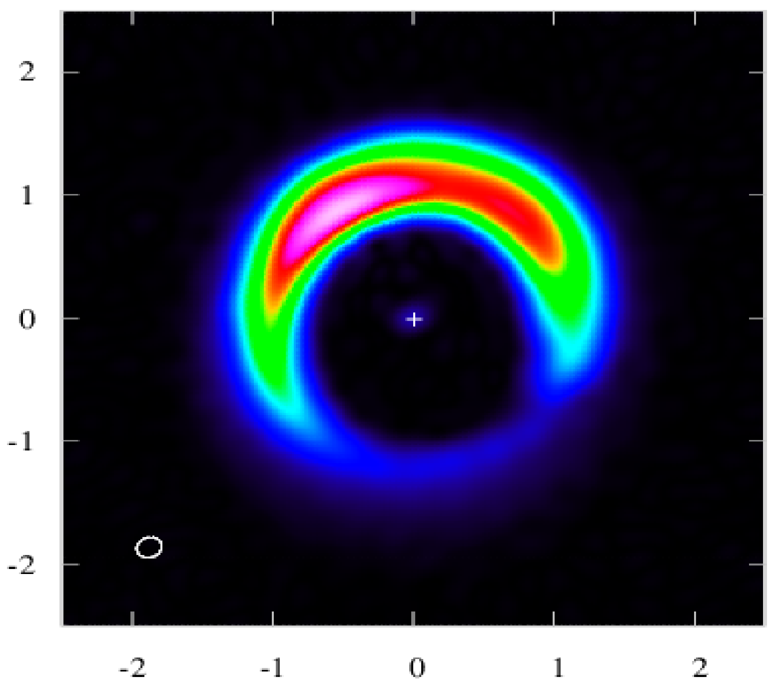
Close et al. 2014

Dust | 13CO J=3-2 | C18O J=3-2



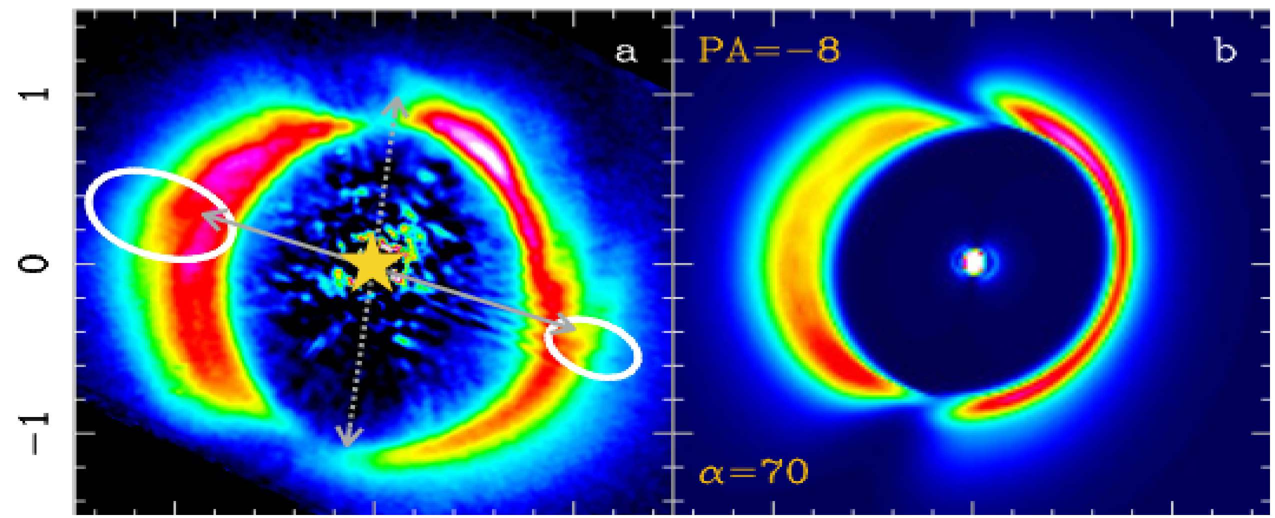
Azimuthal surface density contrast of ~ 50 in the dust and of 2-4 in the gas.

HD 142527 : A ideal target to study dust trapping



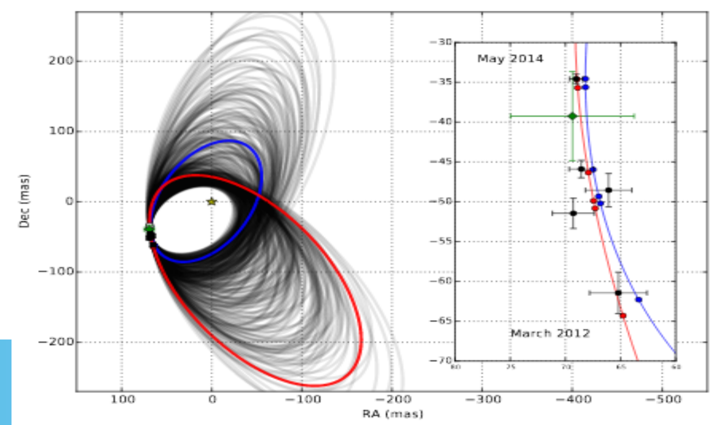
Boehler et al. 2017

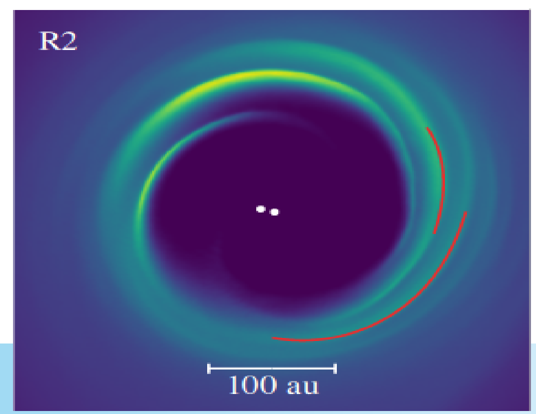
Near-IR scattered light



Marino, casassus et al. 2015

Companion orbit and simulations

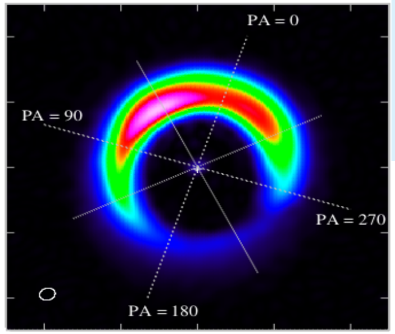




Lacour et al. 2016

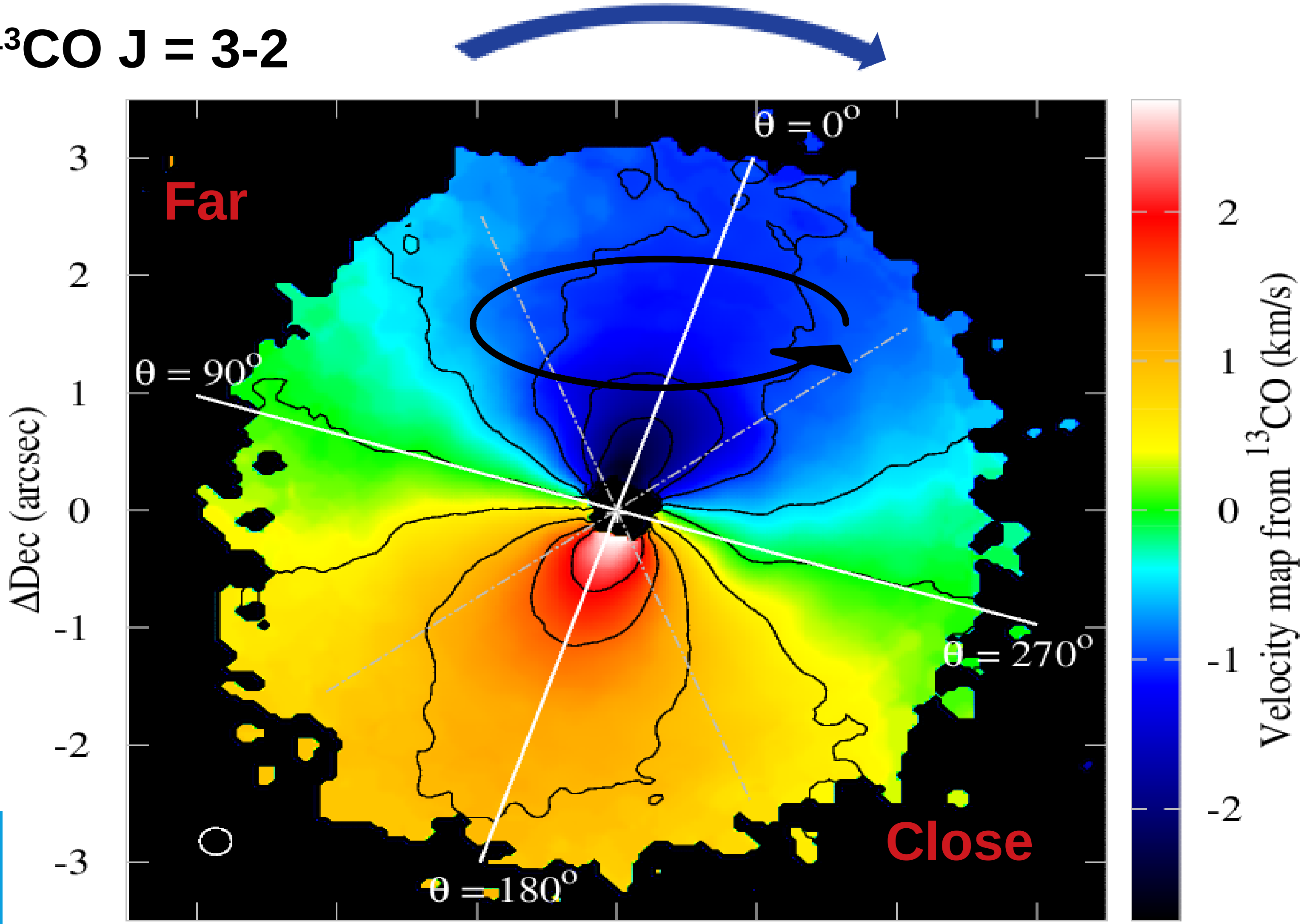
Price et al. 2018

Gas kinematics



Clockwise rotation

^{13}CO J = 3-2

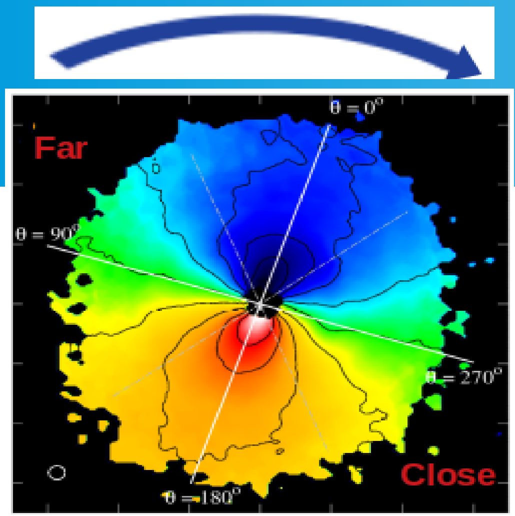


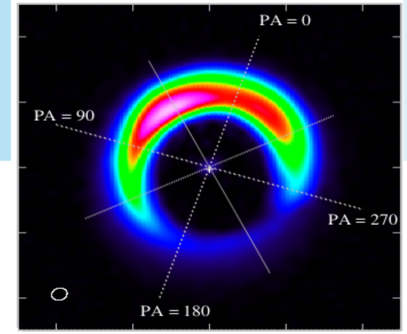
Extends up to 500 au

Inc ~ 27 degrees

Vsys = 3.75 km/s

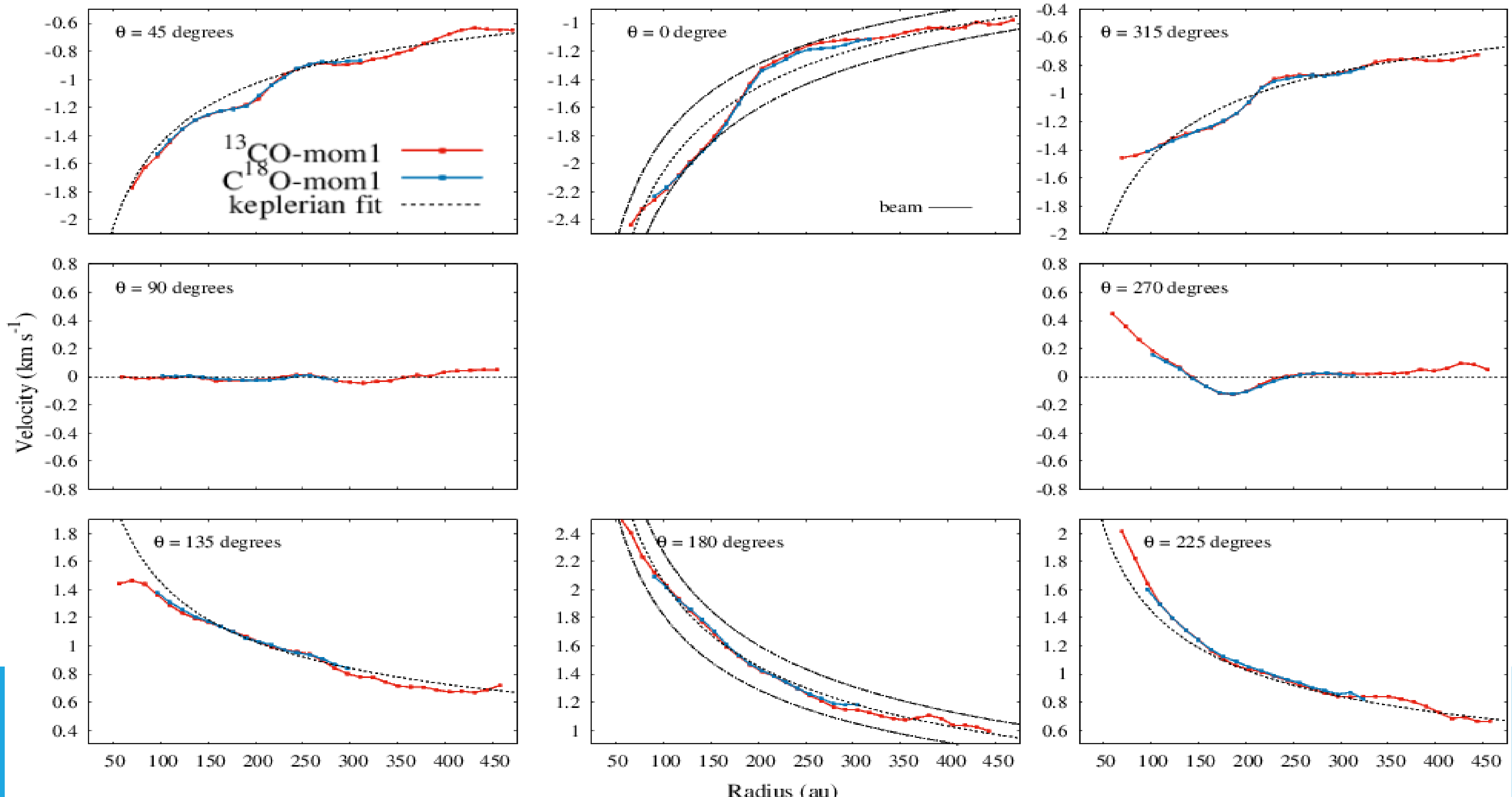
Gas kinematics



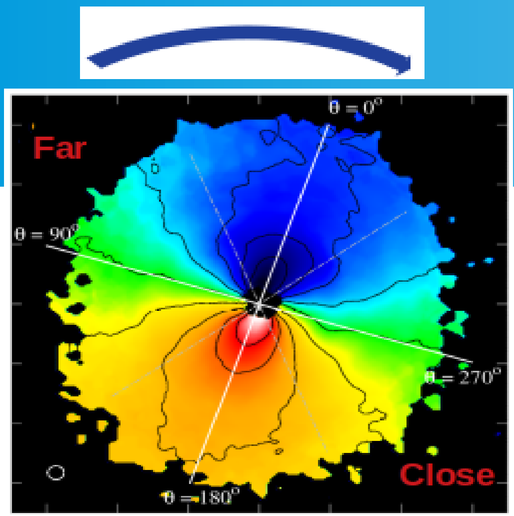


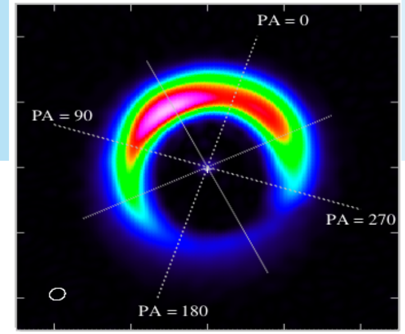
Radial profiles of the velocity

V_{obs} Vs V_{Kep}

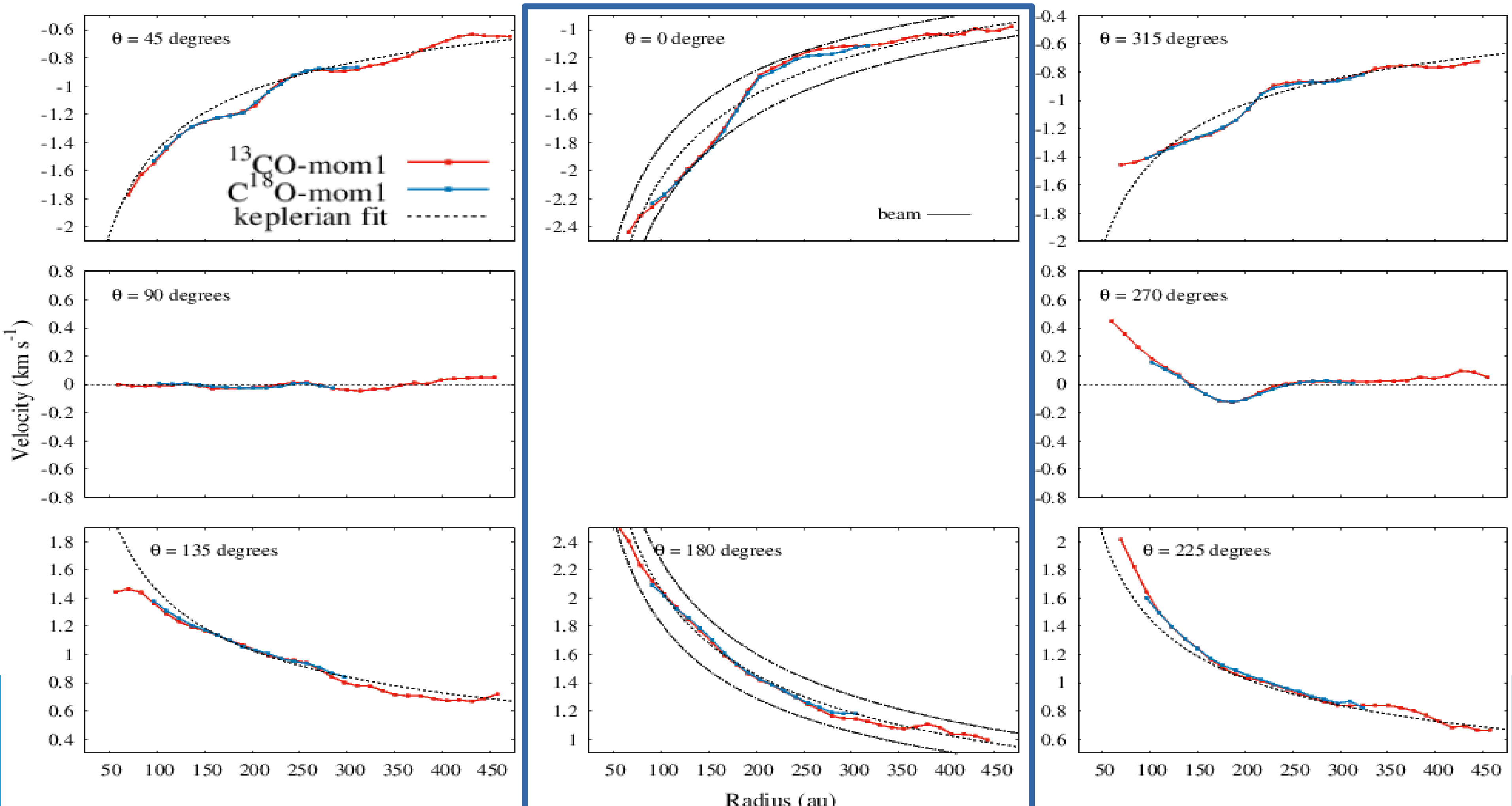


Gas kinematics

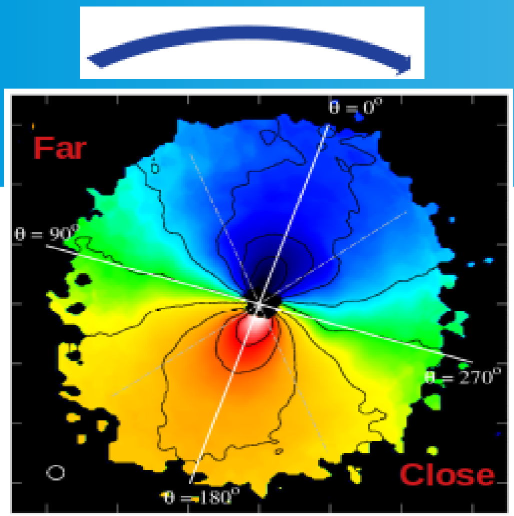


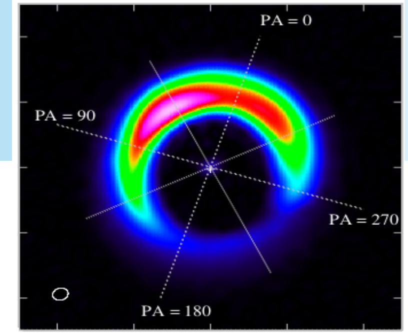


Radial profiles of the velocity V_{obs} Vs V_{Kep}

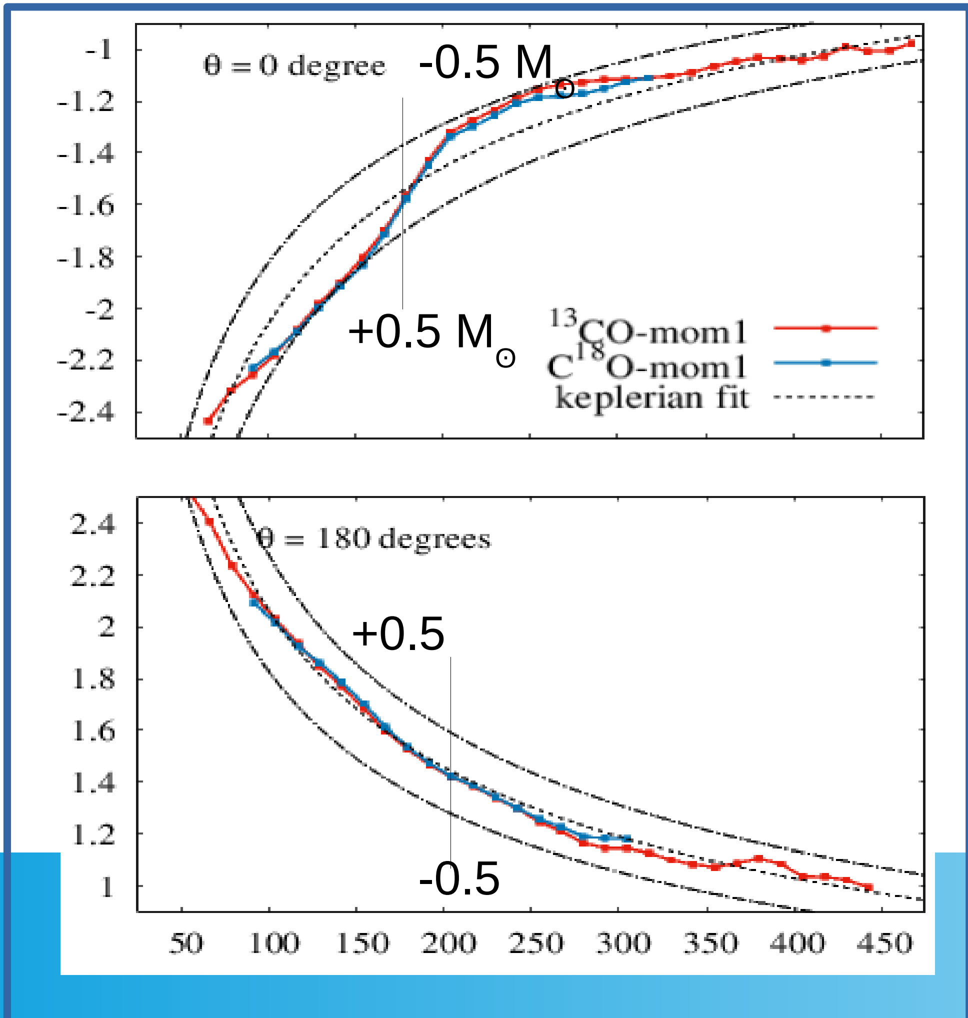


Gas kinematics





Radial profiles of the velocity along the **major** axis



Sensitive to azimuthal velocities
gives a mass of 2.32 Msun for the binary

Origin of these deviations :

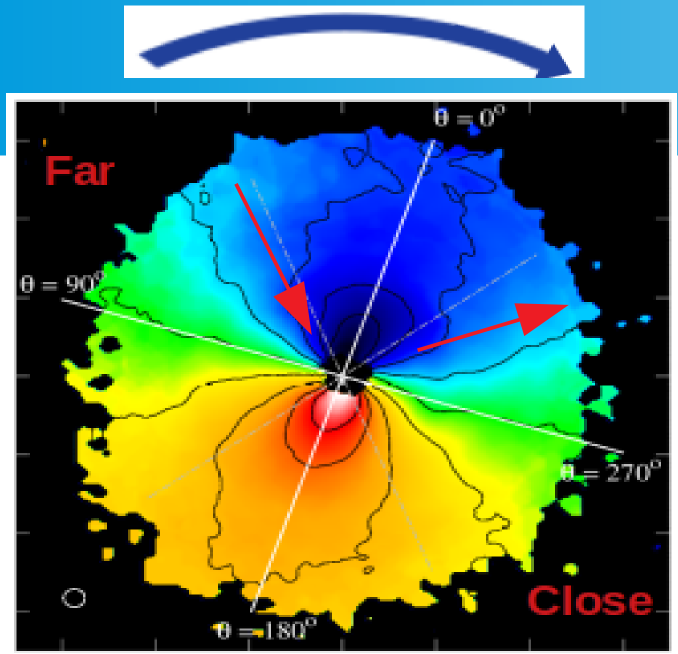
- anticyclonic vortex

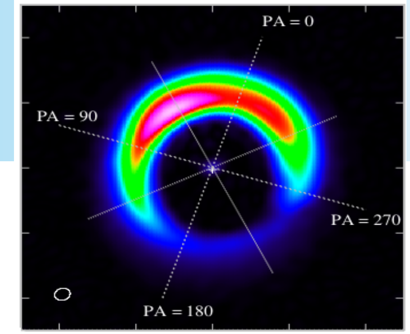
- radial pressure gradient across the ring position

dP/dr > 0 Super-keplerian velocity

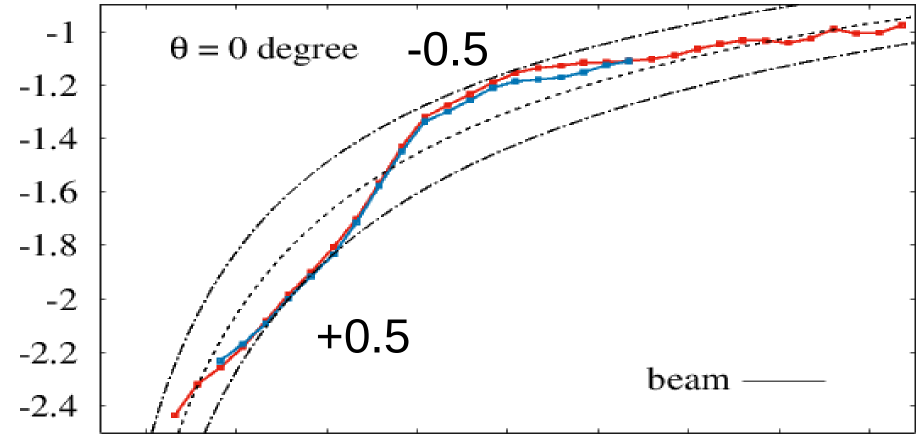
dP/dr < 0 Sub-Keplerian velocity

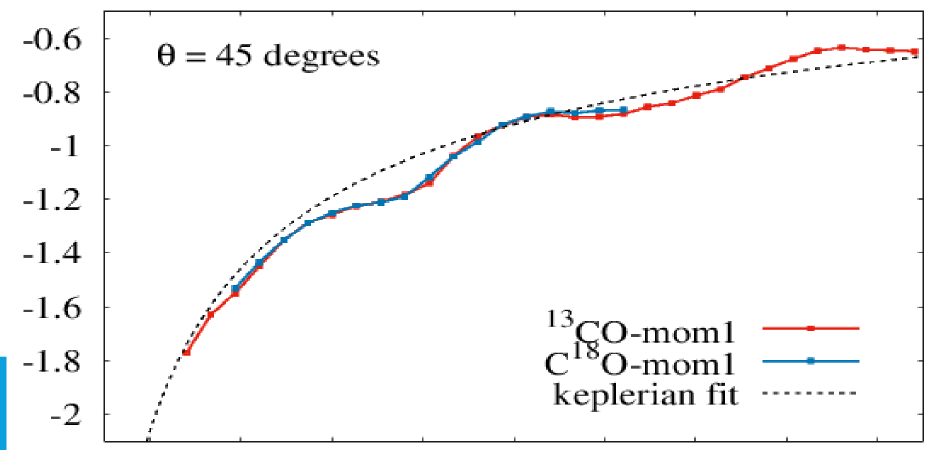
Gas kinematics

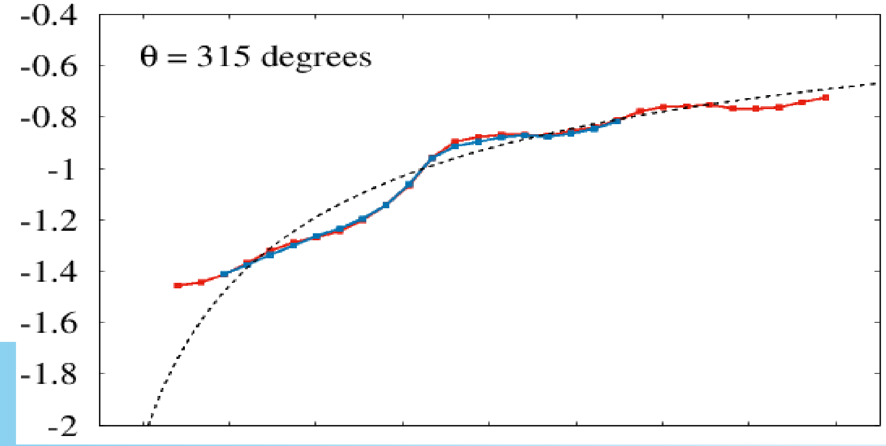




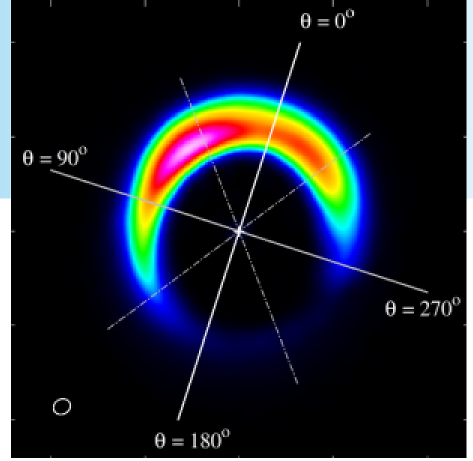
Radial profiles of the velocity V_{obs} Vs V_{Kep}





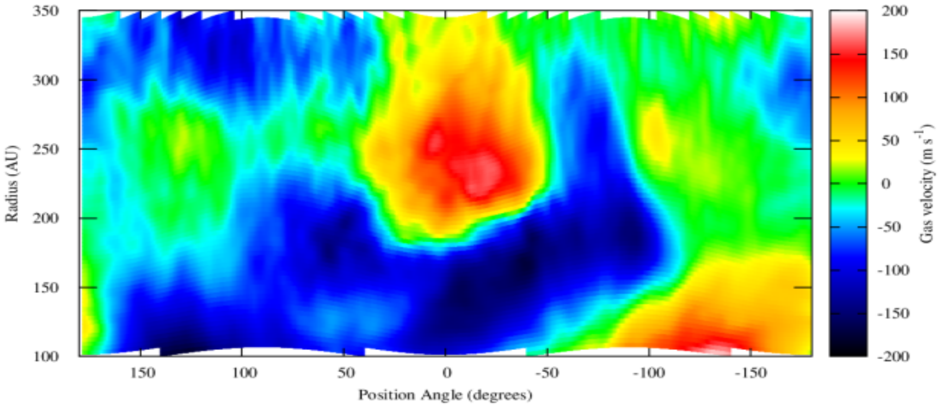


Gas kinematics



Observations

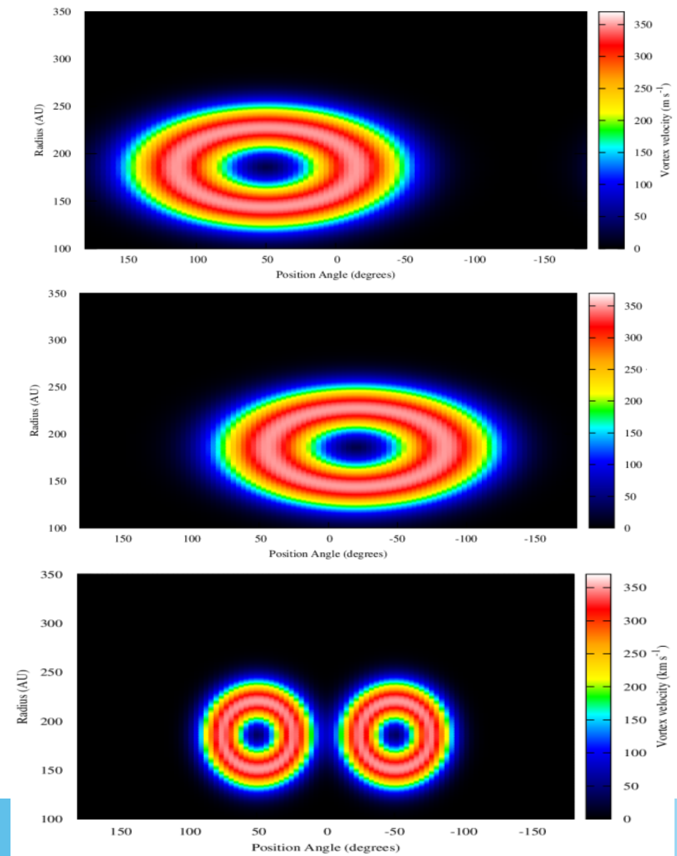
Deviation to the Keplerian Rotation



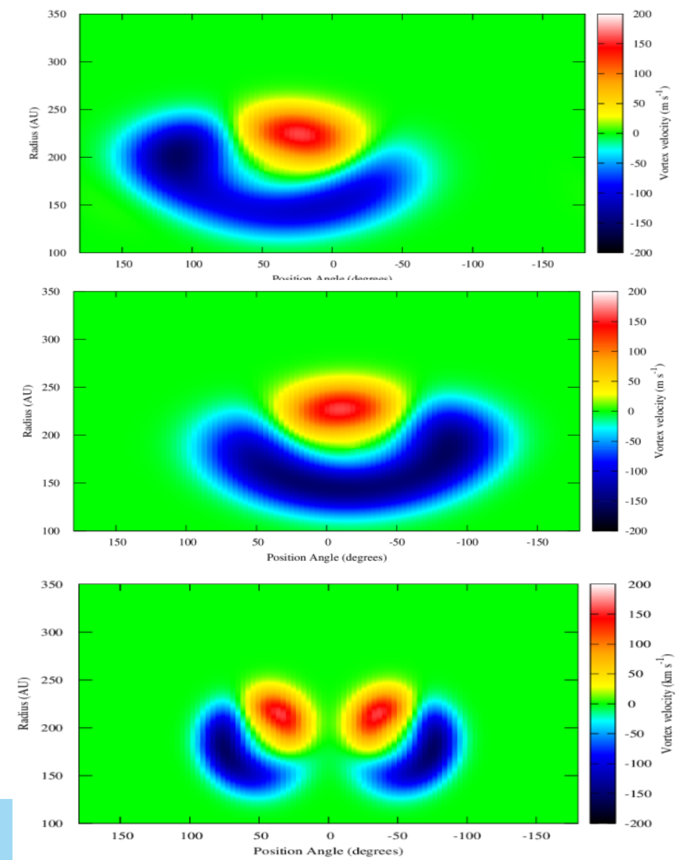
	Model A	Model B	Model C	
			V1	V2
R_0 (au)	185	185	185	185
θ_0 (degrees)	-20°	50°	-50°	50°
χ_A (aspect ratio)	5	5	2.4	2.4
V_{max} (m s^{-1})	350	350	350	350
R_v (au)	42	42	35	35
w_v (au)	26	26	22	22

Modeling

Absolute velocity

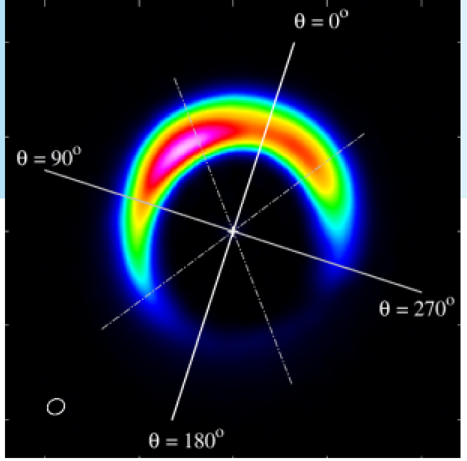


Projected velocity



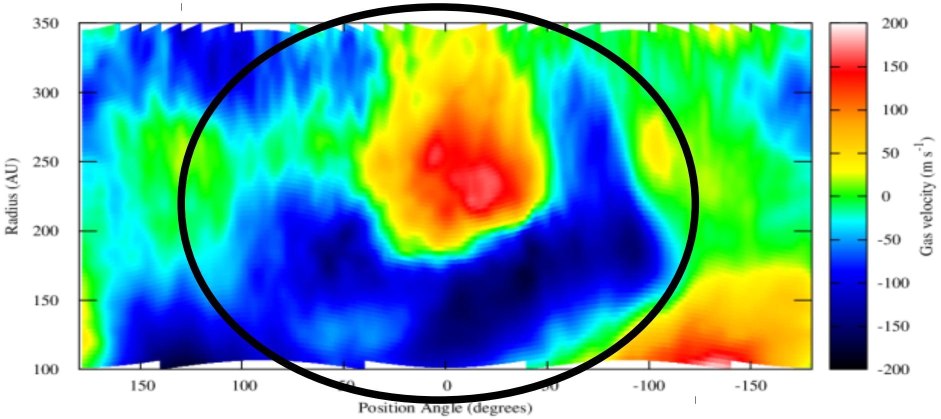
Boehler et al. (in preparation)

Gas kinematics



Observations

Deviation to the Keplerian Rotation



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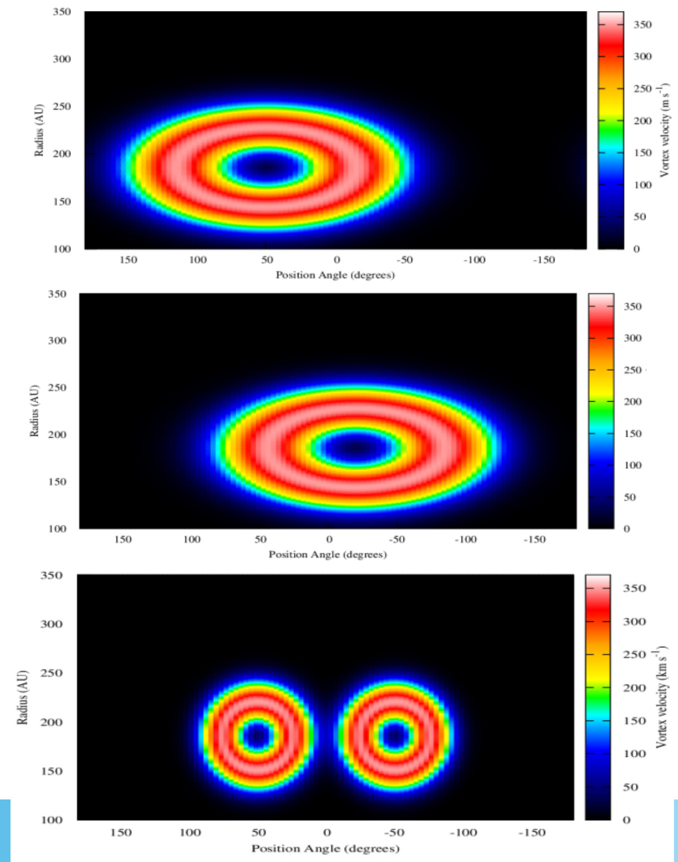
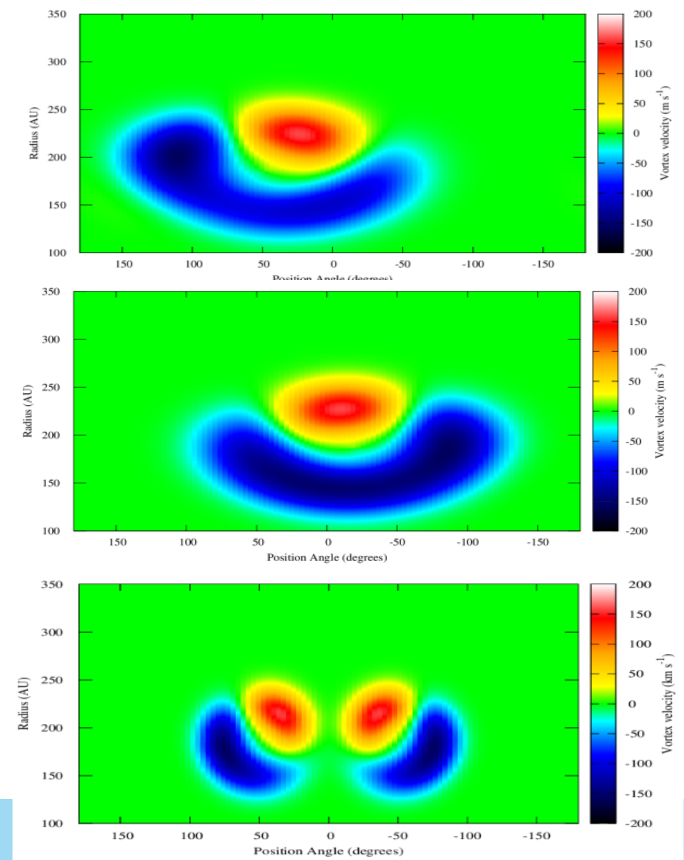
Modeling

Absolute velocity



Projected velocity



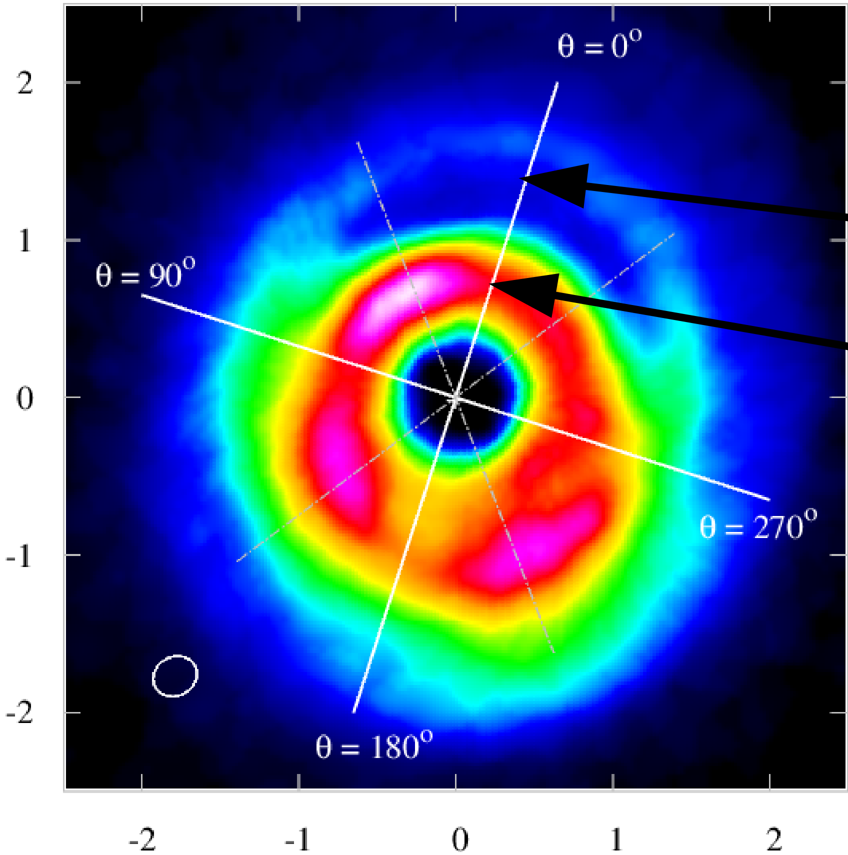
Boehler et al. (in preparation)

Happy ending ?!

Or might this feature be an artifact ?

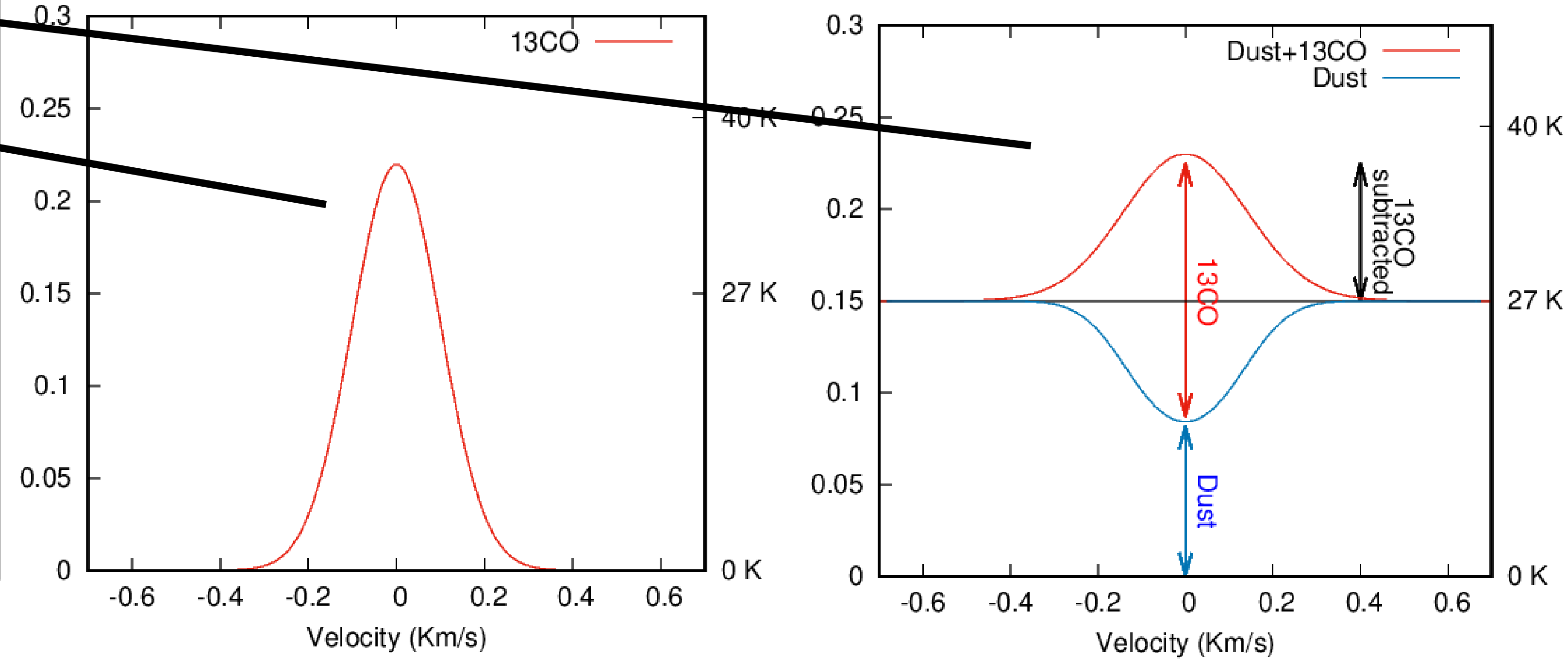
Effect of the dust optical depth on the Integrated emission

13CO Integrated emission



Line alone

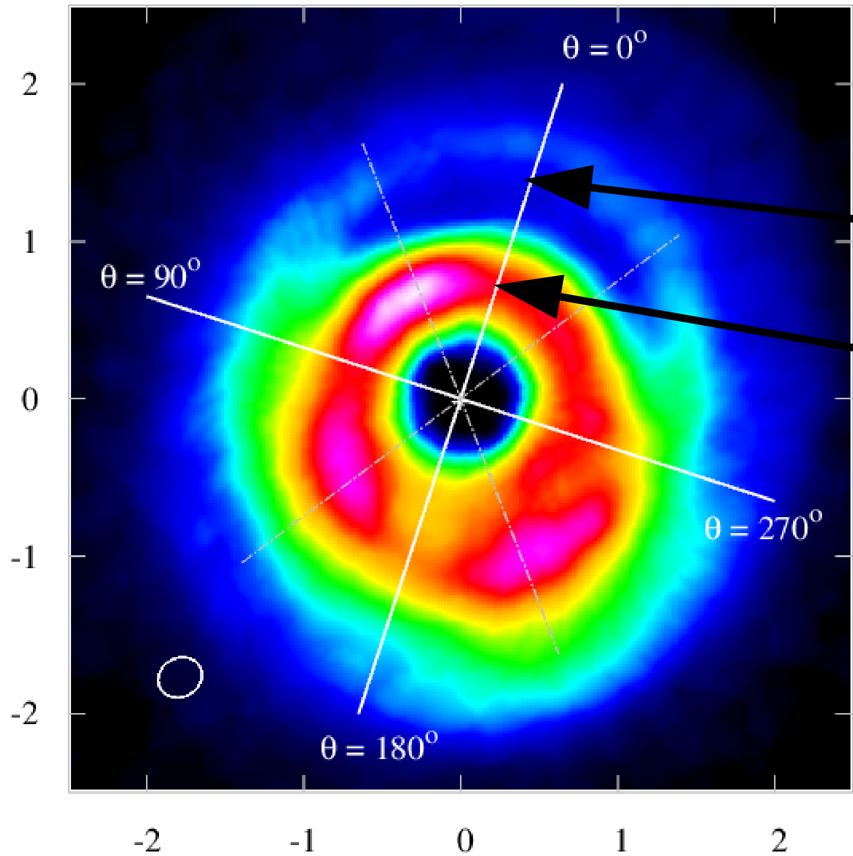
Line + dust



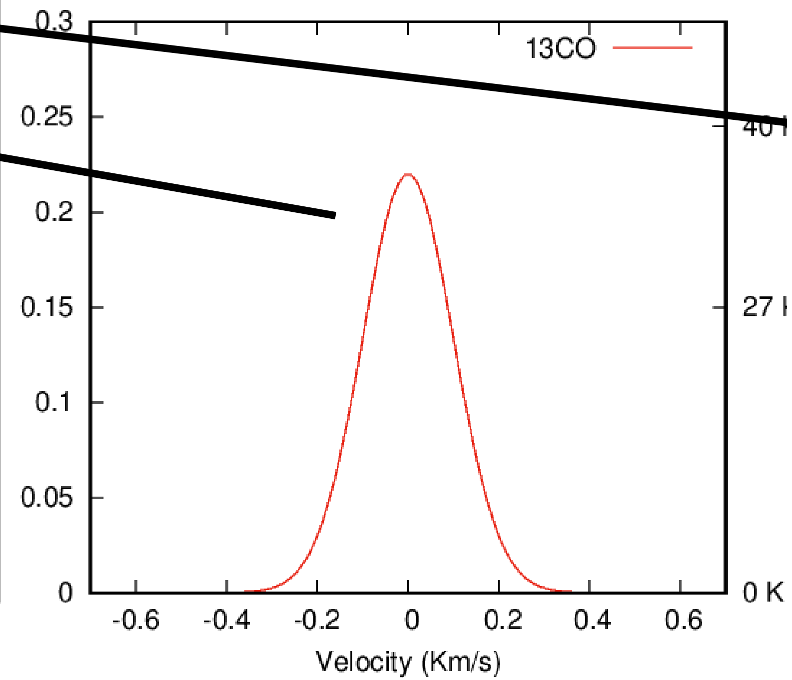
The presence of dust can create artificial cavities in the gas

Effect of the dust optical depth on the Integrated emission

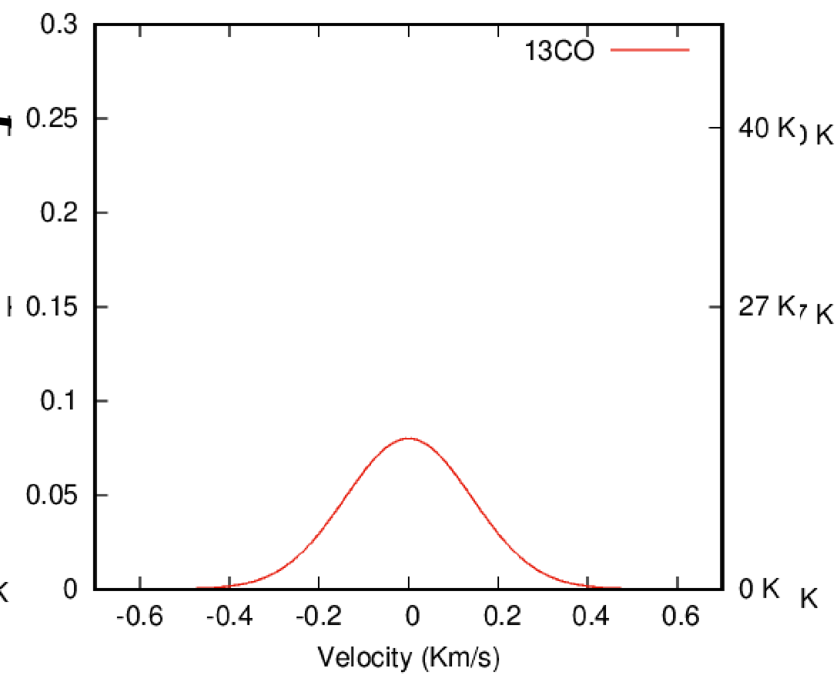
13CO Integrated emission



Line alone

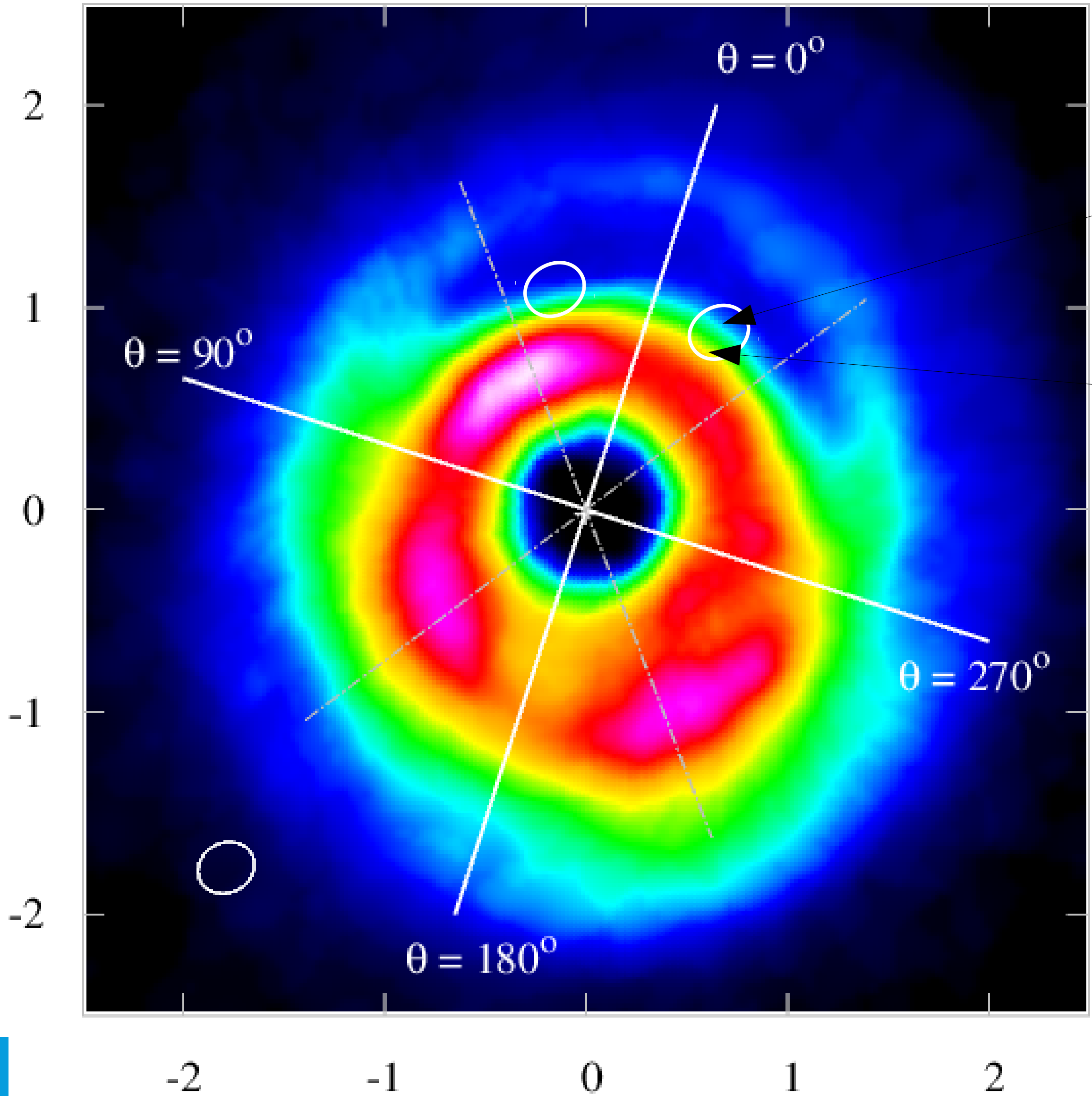


Line after Dust subtraction

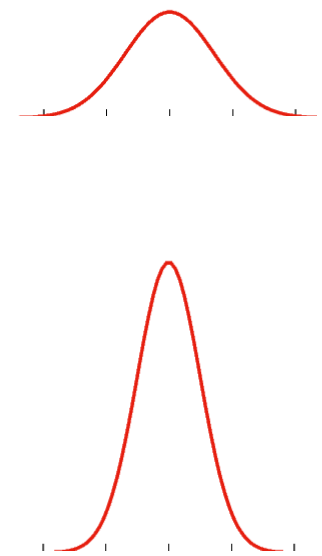


The presence of dust can create artificial cavities in the gas

Effect of the dust optical depth on the measured velocity

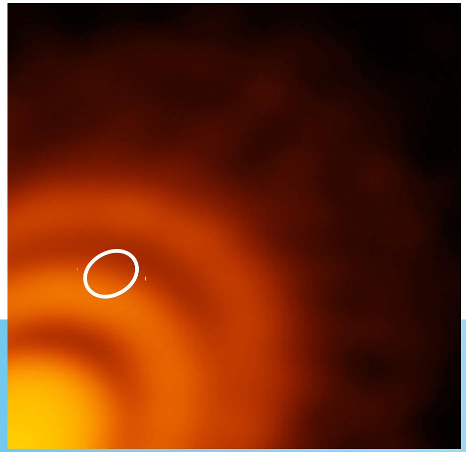


Bad effect ...



Super-Keplerian Velocity

Very bad effect ...



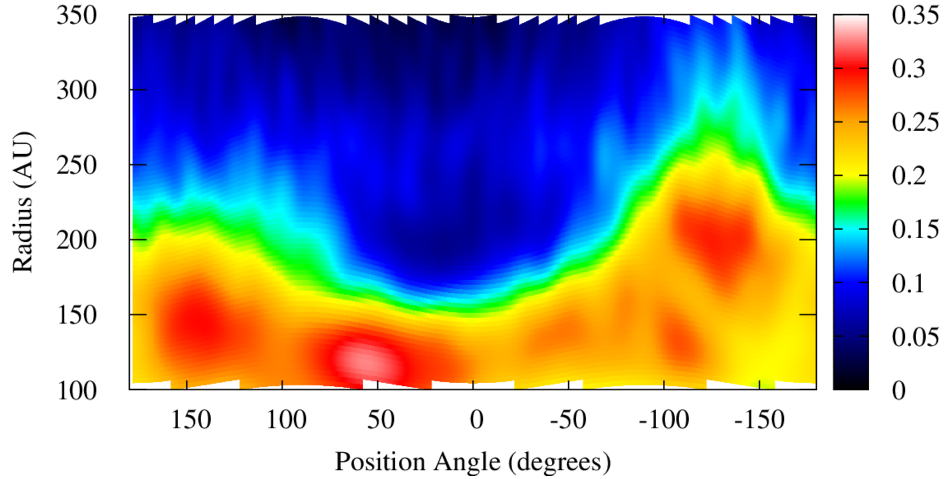
Effect also for the rings :

- sub-keplerian on the inner edge of the gap

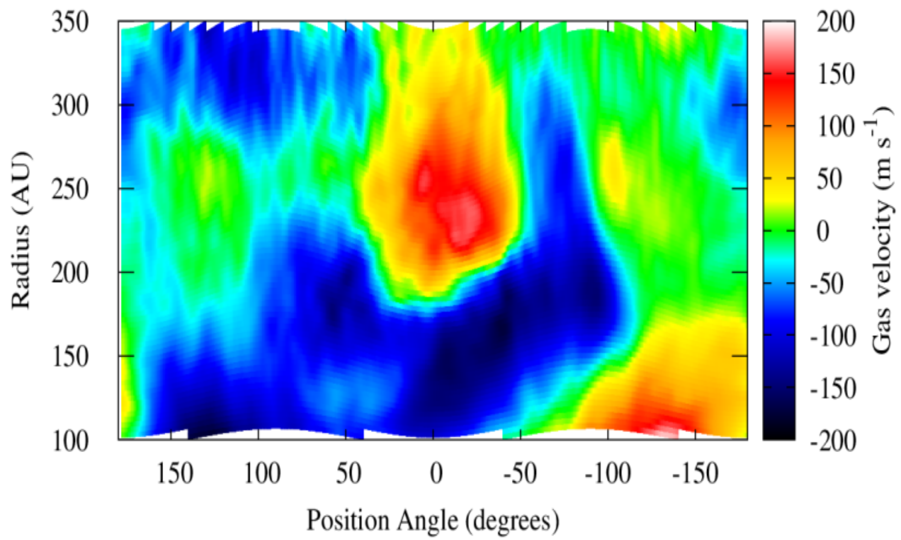
- super-keplerian on the outer edge of the gap

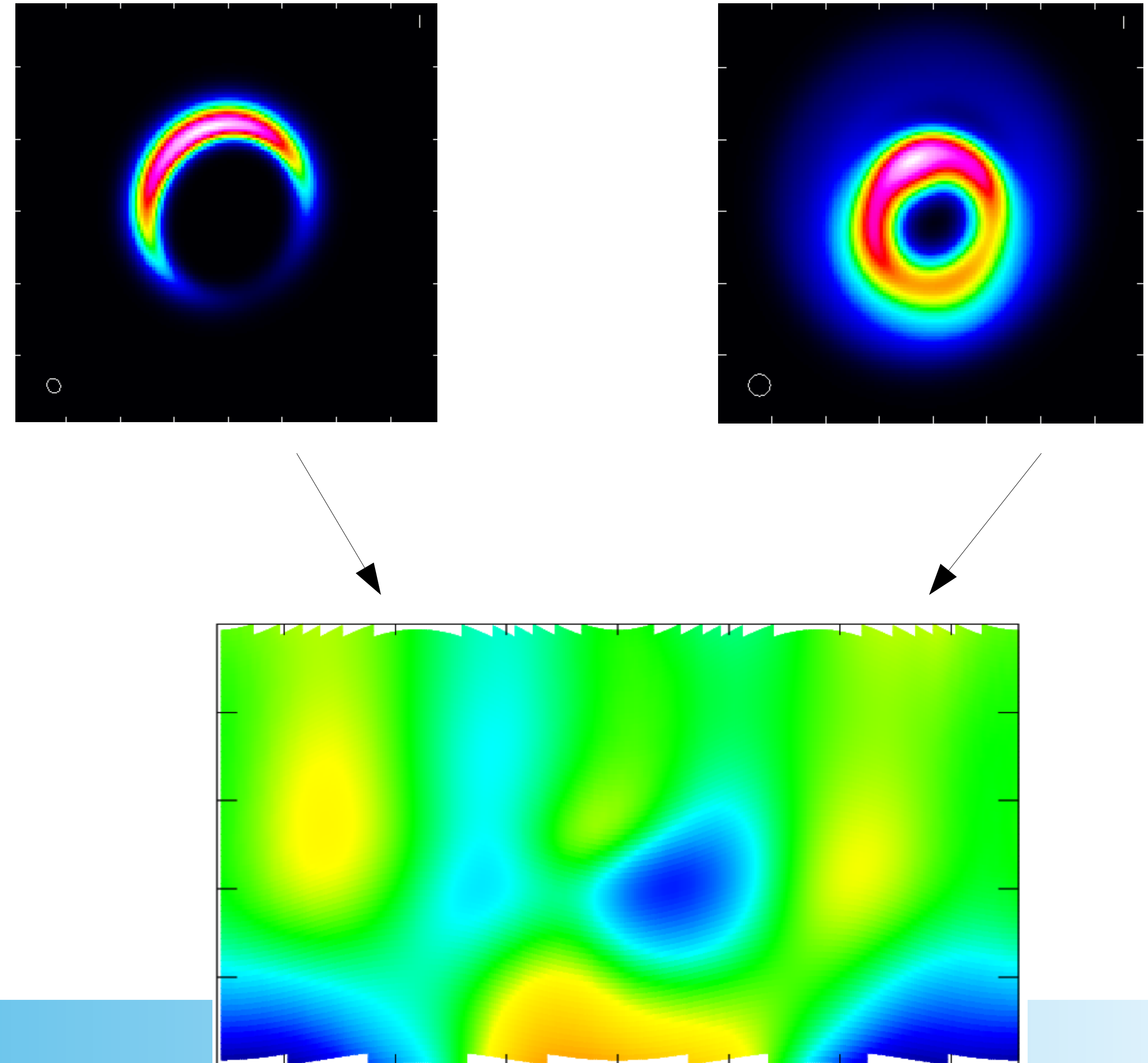
Observation and toy model

13CO Integrated emission



Deviation to the keplerian rotation





Conclusion

Detections of deviations to Keplerian rotation start to become common ... but Determining their origin reveals to be complex

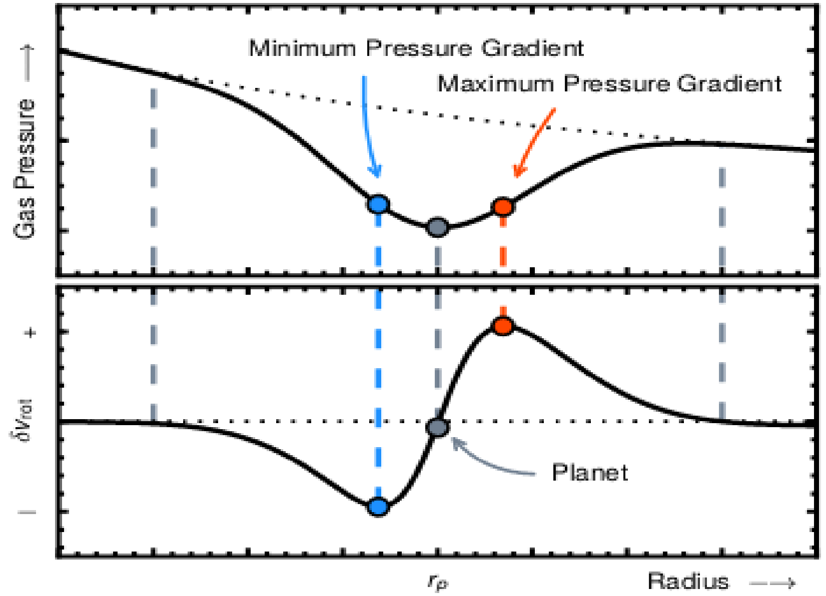
Are the vortices responsible for the dust asymmetries ?
Well … We still do not know

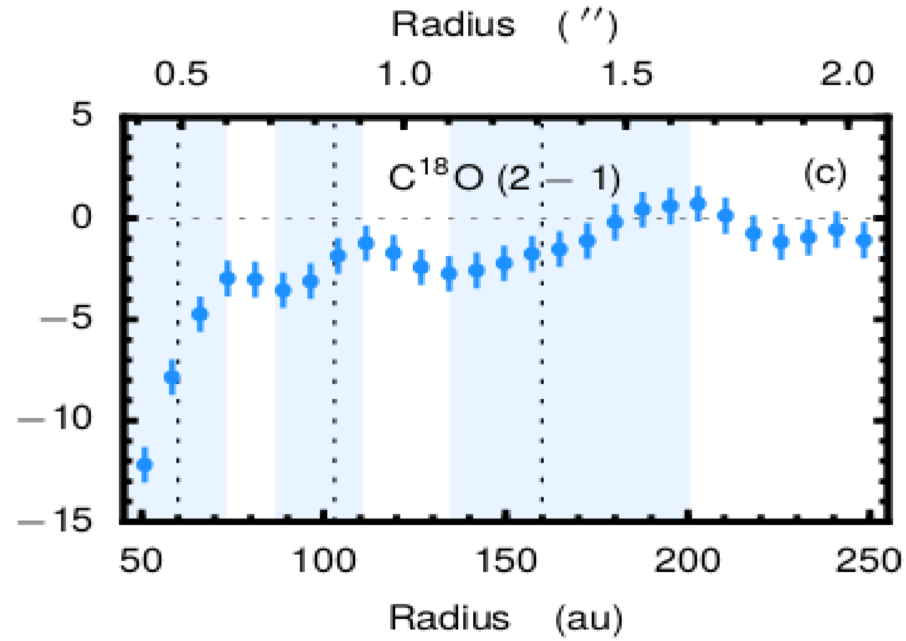
Good news :
These artifacts will diminish with the spatial resolution while the signal of real signatures will be better resolved and more visible.

Thank you for your attention !

HD 163296 : Deviations to the Keplerian rotation

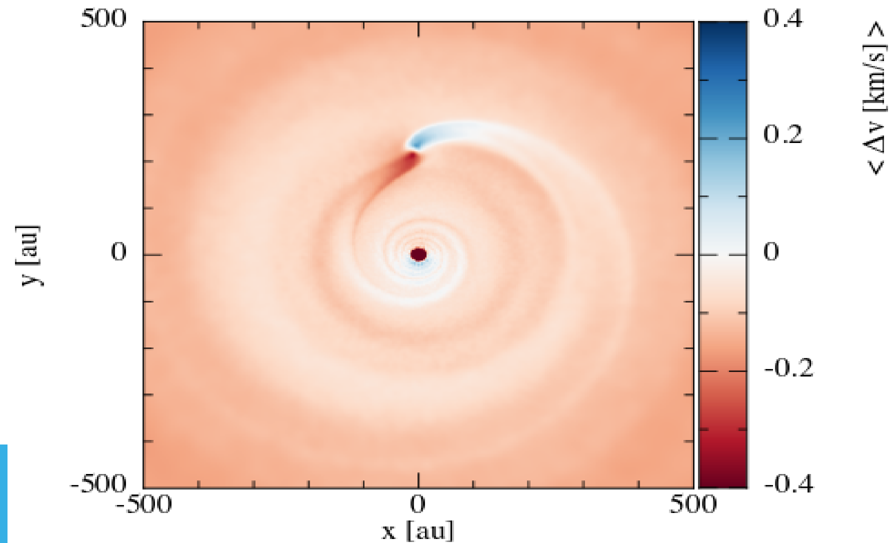
Rings in the gas ?

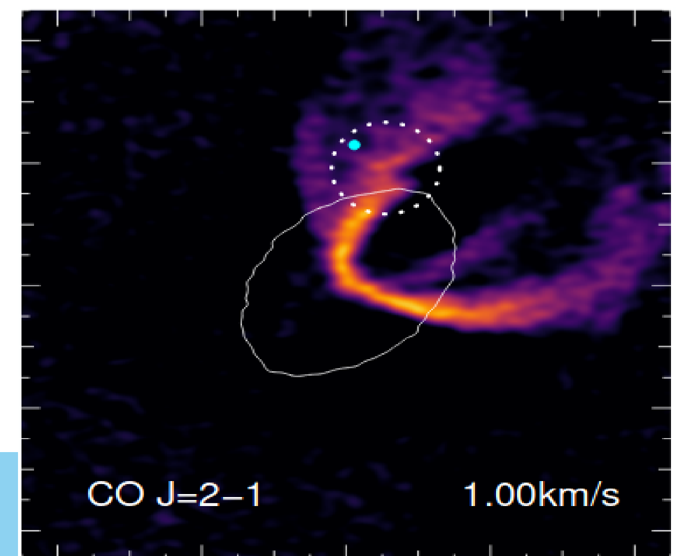




Teague al. 2018

Gas perturbed by a massive planet?





Pinte et al. 2018

Dust trapping

However, dust grains can be maintained inlocalized particle traps (pressure maxima) which allow them to efficiently grow . In addition to concentric rings, azimuthal asymmetries have also been observed, in particular in protoplanetary disks with dust-depleted large cavities .

They are interpreted as azimuthal dust trapping , possibly in a vortex due to the Rossby wave instability. Such an instability can be generated at the edge of a gap created by a massive planet (, or at the edge of a dead zone.

Three separate peaks that are unresolved in the radial direction. During their lifetime, vortices may never reach a stable equilibrium. For example, simulations have shown that when the back-reaction of the dust onto the gas is taken into account, vortices may trap particles not in a single but in multiple structures, and it is this dust feedback that would eventually lead to the destruction of the vortex.

We note that the vortex-like structure is not associated to spiral arms in scattered light (Benisty et al. 2018), unlike the well-studied cases of MWC 758 (Dong et al. 2018), HD 142527 (Avenhaus et al. 2014) and HD 135344B (Stolker et al. 2016), which in addition are classified as transition disks from their spectral energy distribution and whose central stars are Herbig ABe objects.