# F.S.I.: Flyby Scene Investigation


Nicolás Cuello

FONDECYT Fellow

Institute of Astrophysics

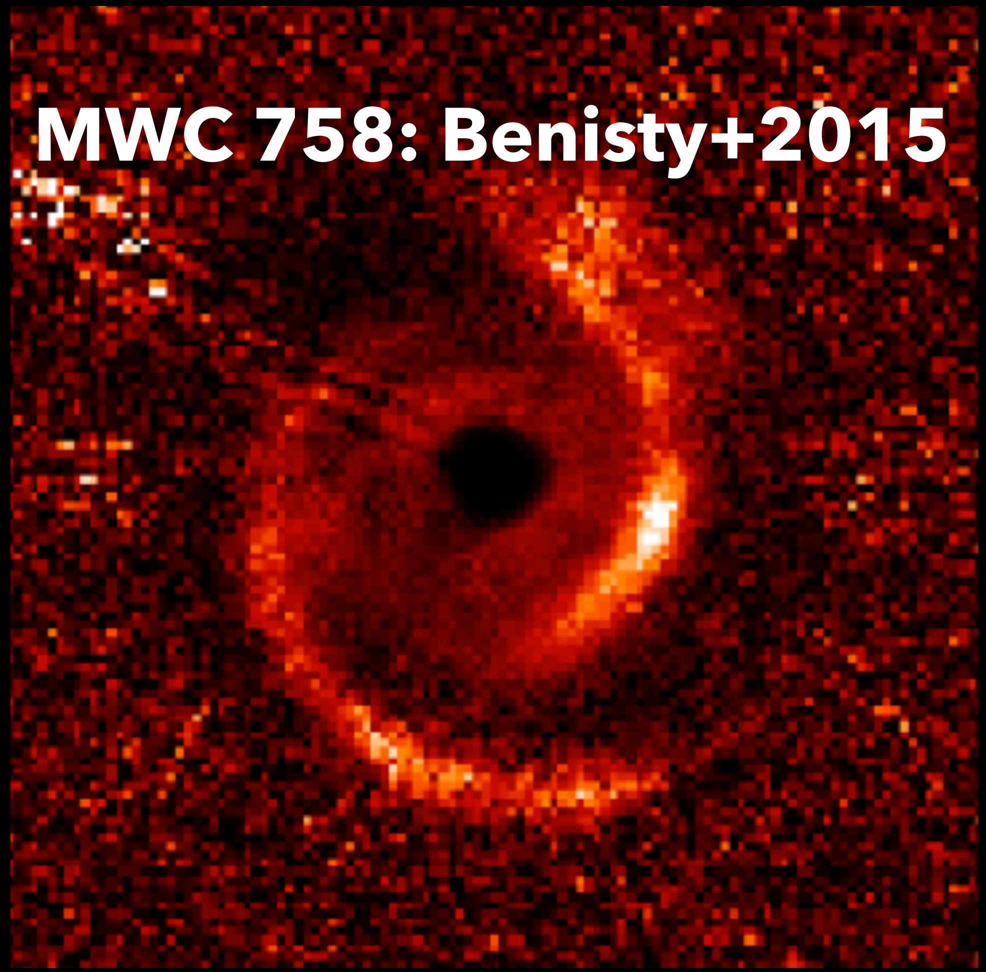
PUC, Santiago, Chile

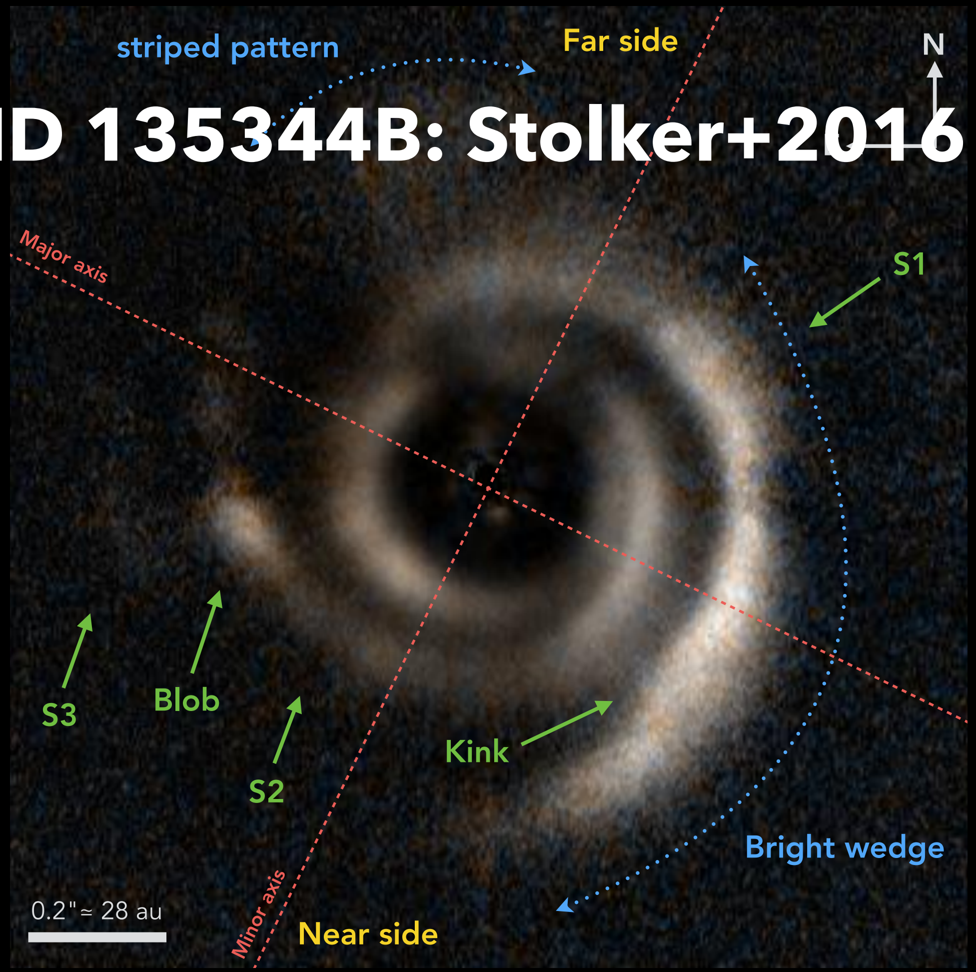

In collaboration with:

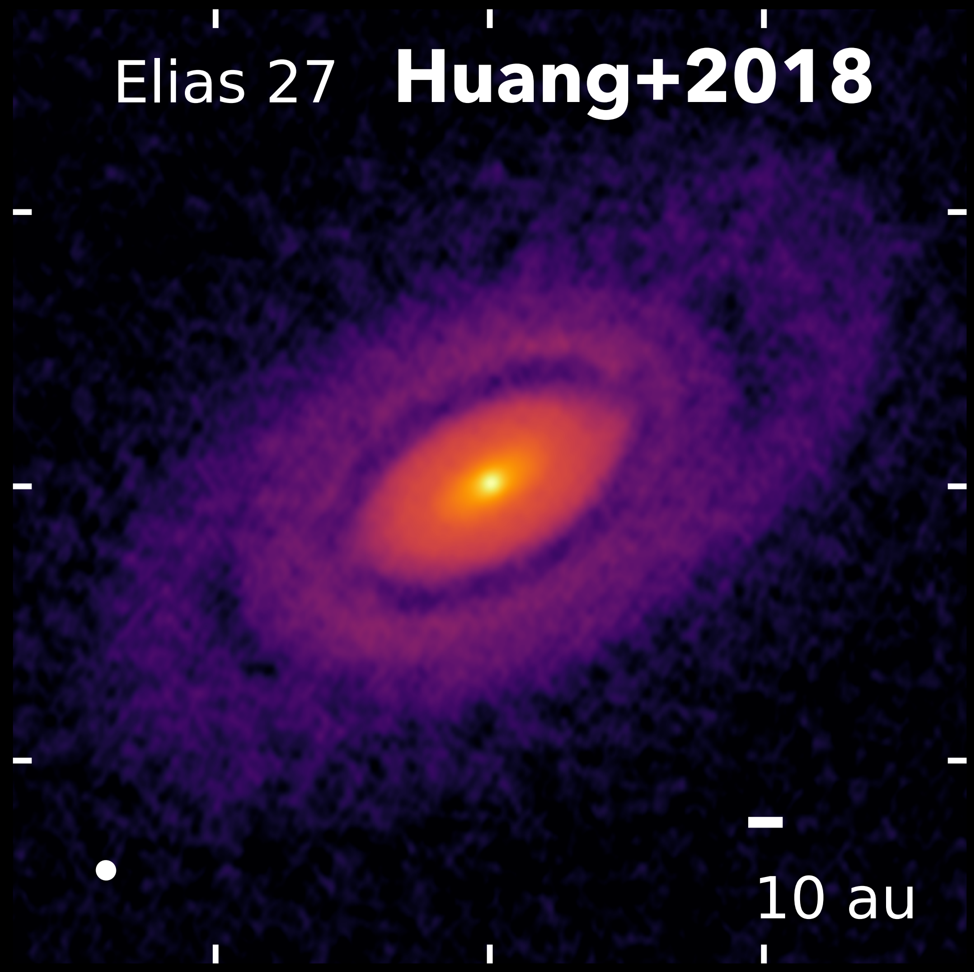
Giovanni Dipierro, Daniel Mentiplay, Daniel Price, Christophe Pinte, Fabien Louvet
François Ménard, Guillaume Laibe, Rebecca Nealon, Matías Montesinos,
Jorge Cuadra, Pedro Poblete, Sebastián Pérez, Valentin Christiaens

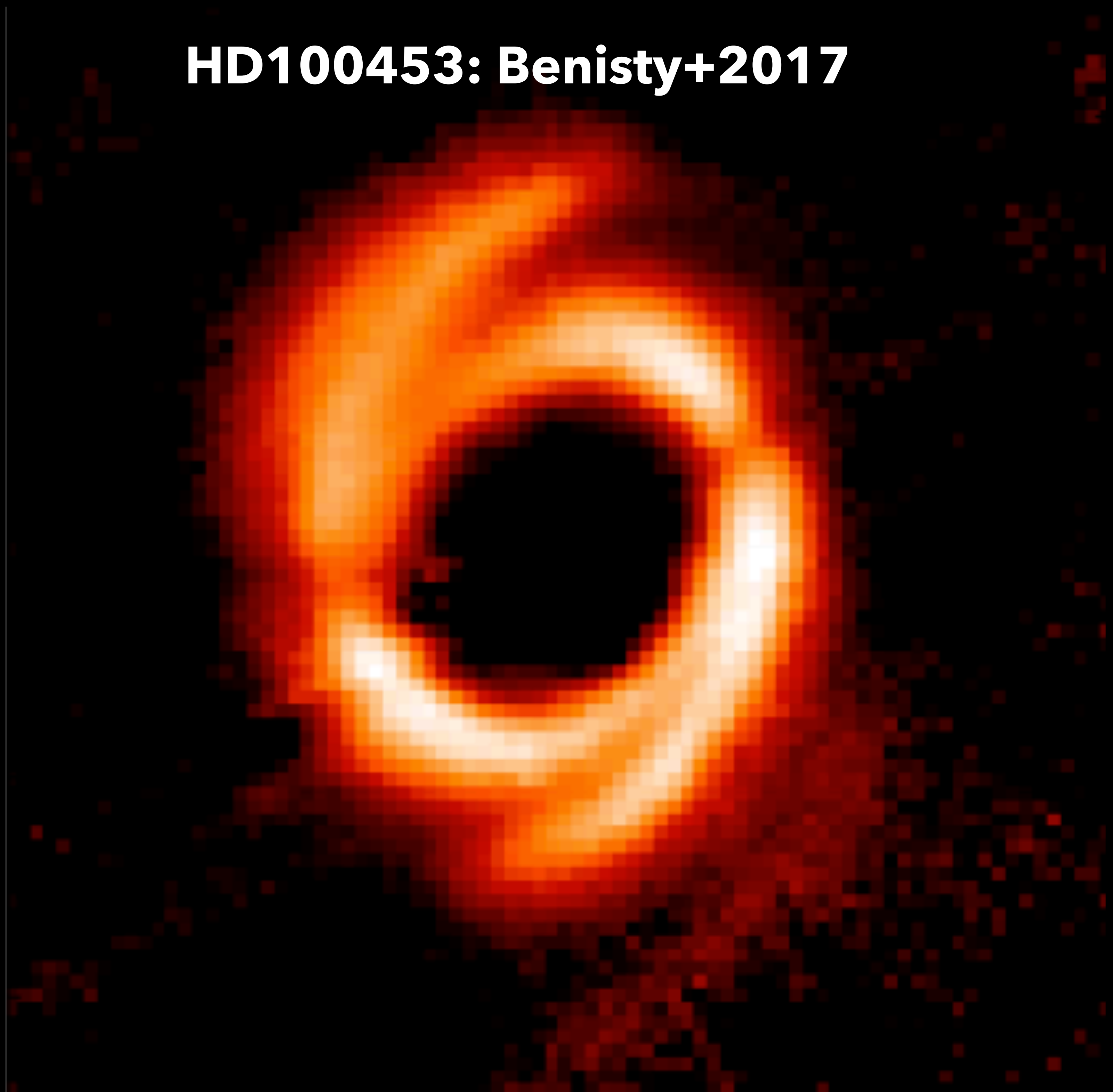
In memoriam **Giovanni Dipierro**

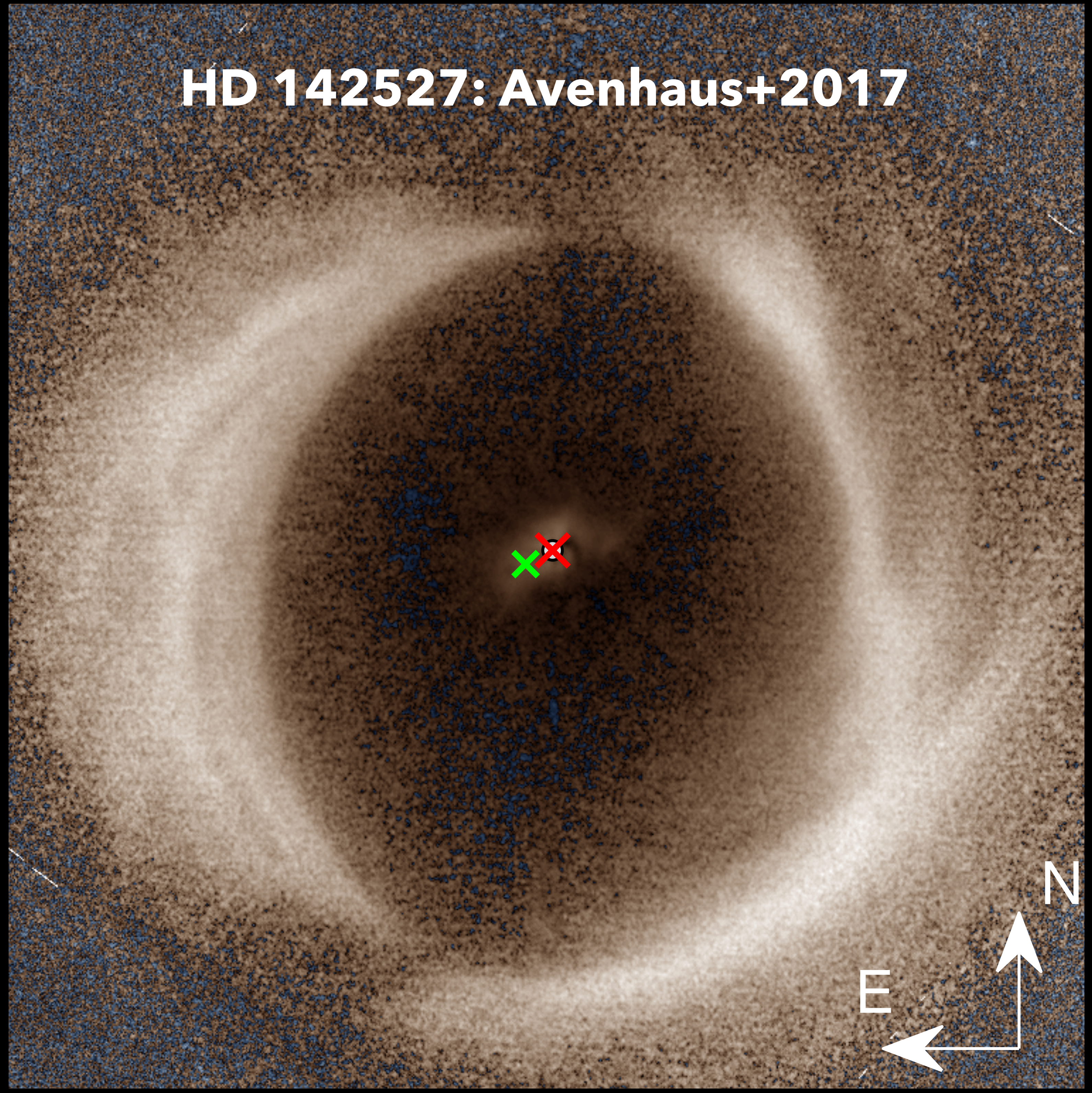
# ASTROPHYSICAL CRIME SCENES (1/2)



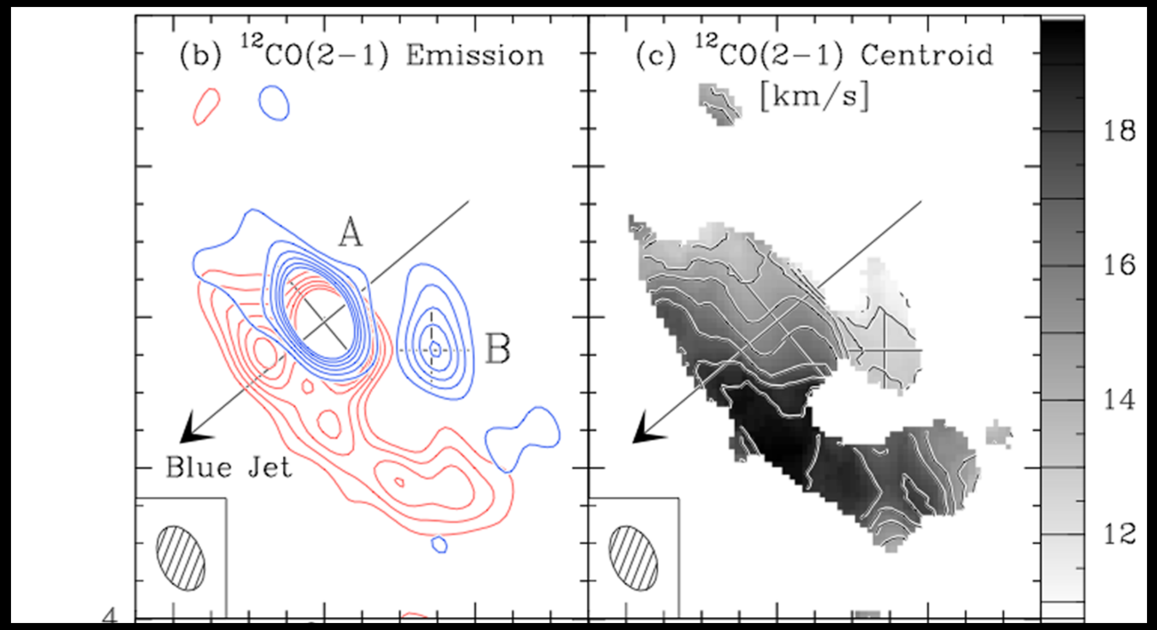



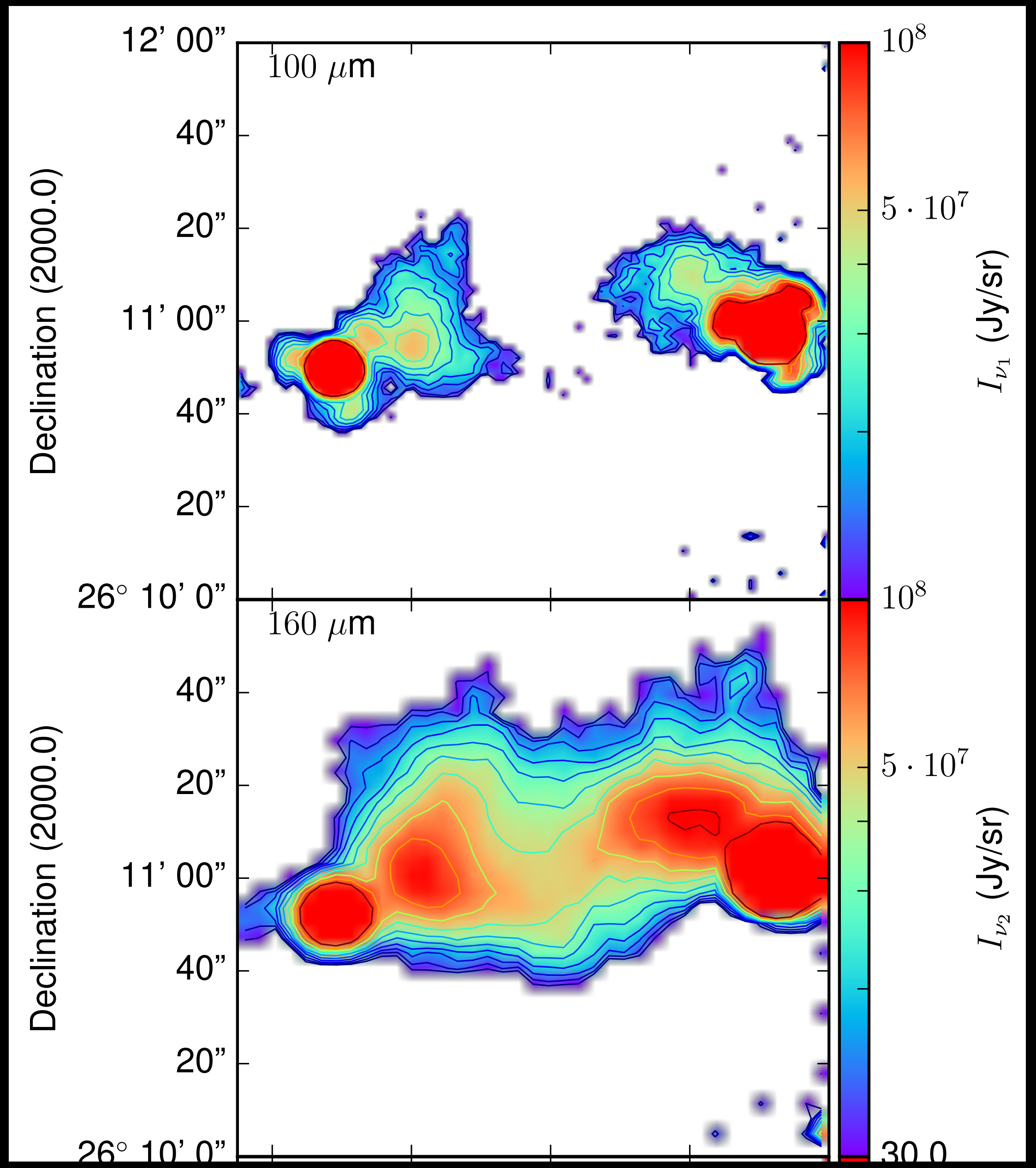




See talks by:
J. Huang
L. Pérez
N. van der Marel
E. Ragusa
M. Benisty
C. Dougados
A. Kóspál

# Astrophysical Crime Scenes (2/2)




**RW Aur: Dai+2015**



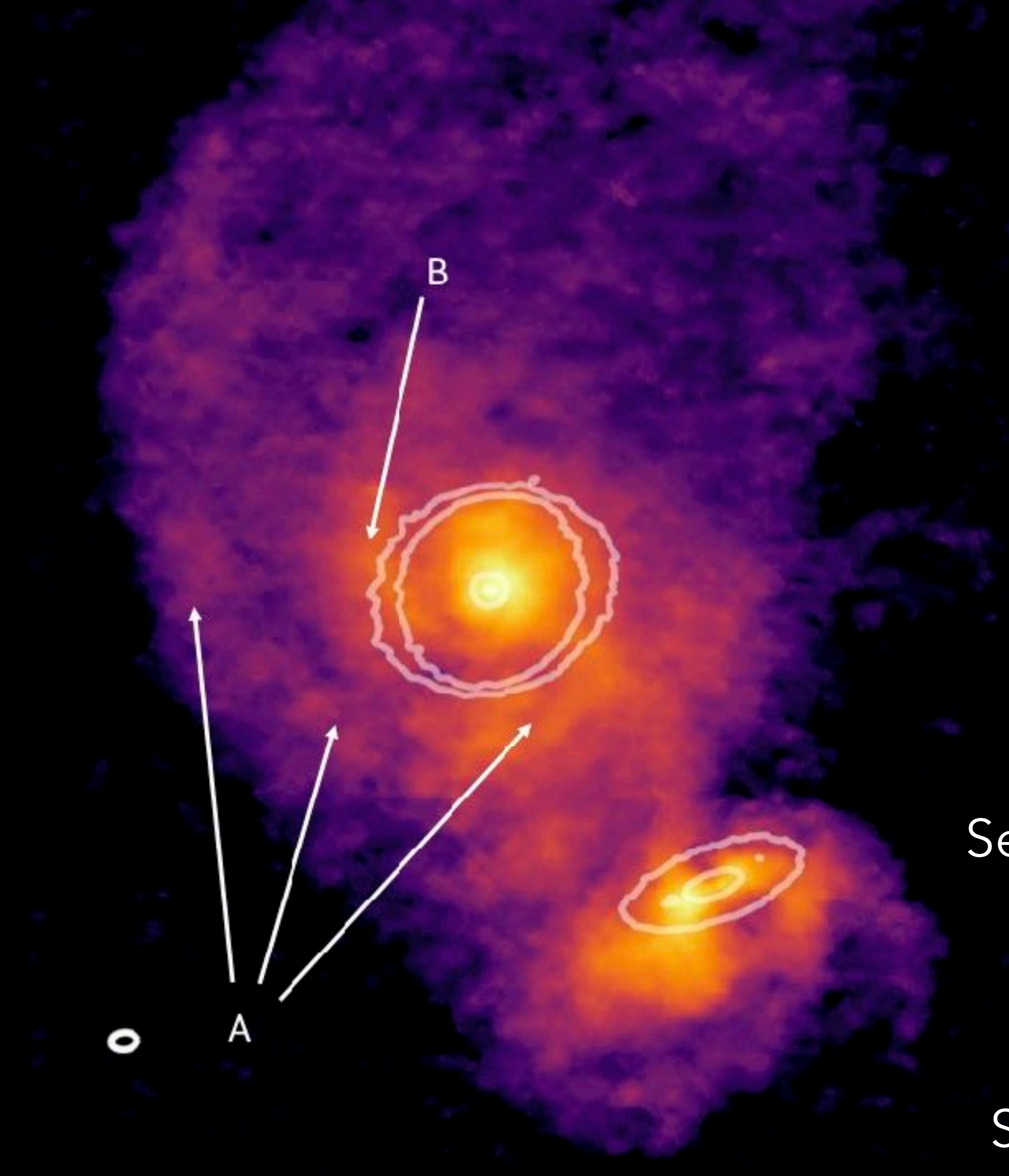

**HV & DO Tau: Winter+2018c**

Two stars in the field

Interacting objects

Puzzling structures:

- bridges
- warped discs
- spirals
- weird kinematics
- big mess

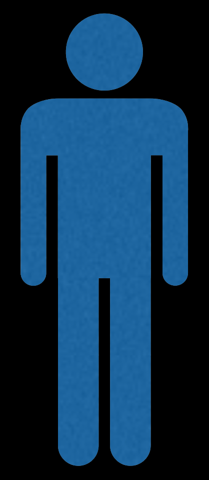



**AS 205: Kurtovic+2018**

See talks by:
L. Pérez
S. Pérez
R. Dong
S. Facchini
I. Czekala
R. Nealon

**Multi-wavelength observations are crucial**

# Type of Suspects

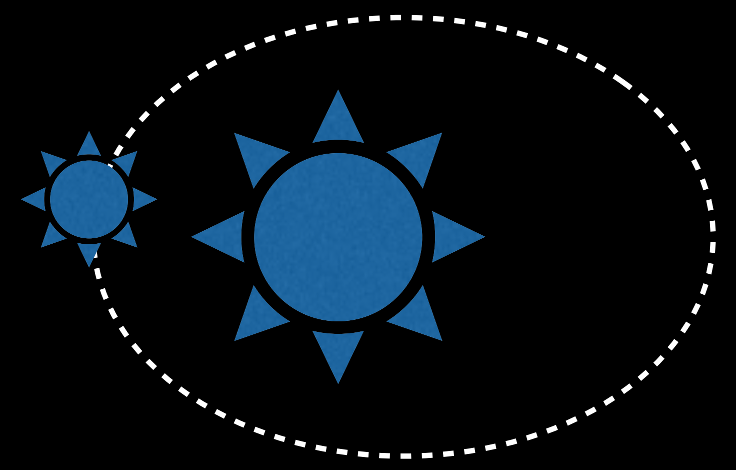


**Treacherous & vicious offenders**

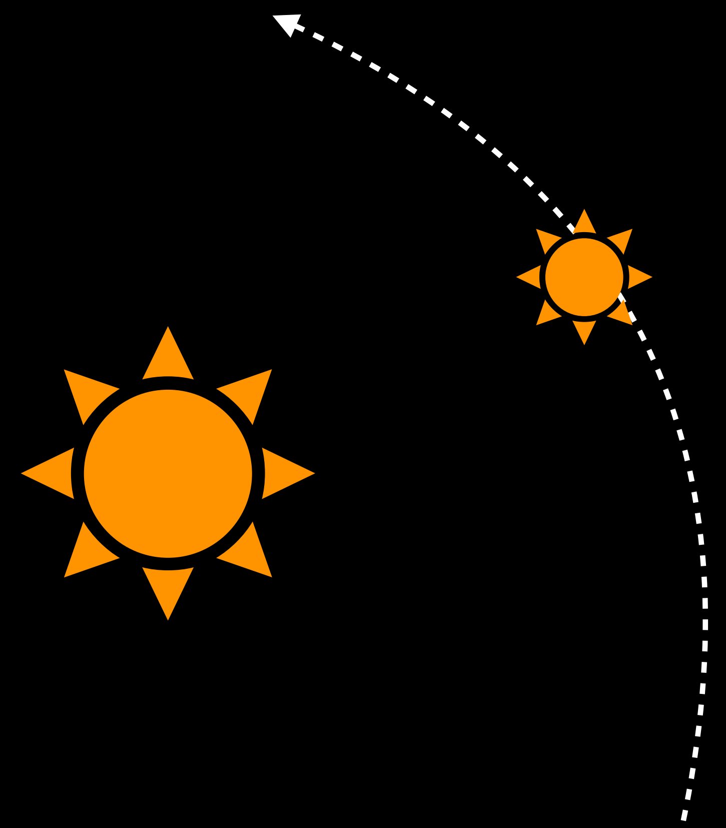
Potentially hidden
inside or outside the disc.
It's likely nearby…
but we do not where exactly

**Fast & strong delinquents**

Should be easy to notice,
but already gone…
Hit & run !
almost never caught red handed



**Observational signatures?**
Interpretation?
Planet formation in
multiple systems?



# ASTROPHYSICAL CLUEDO


**Who?** Massive (stellar or planetary) body

**How?** Weapon: gravitational torque

Modus operandi: type of orbit

**Where?** Inside or outside the disc

**When?** During the disc lifetime ~ few Myrs

**Eccentric Dan 1.0**

Inner companion eccentric and/or inclined

**The French Chris**

Massive planet embedded in the disc

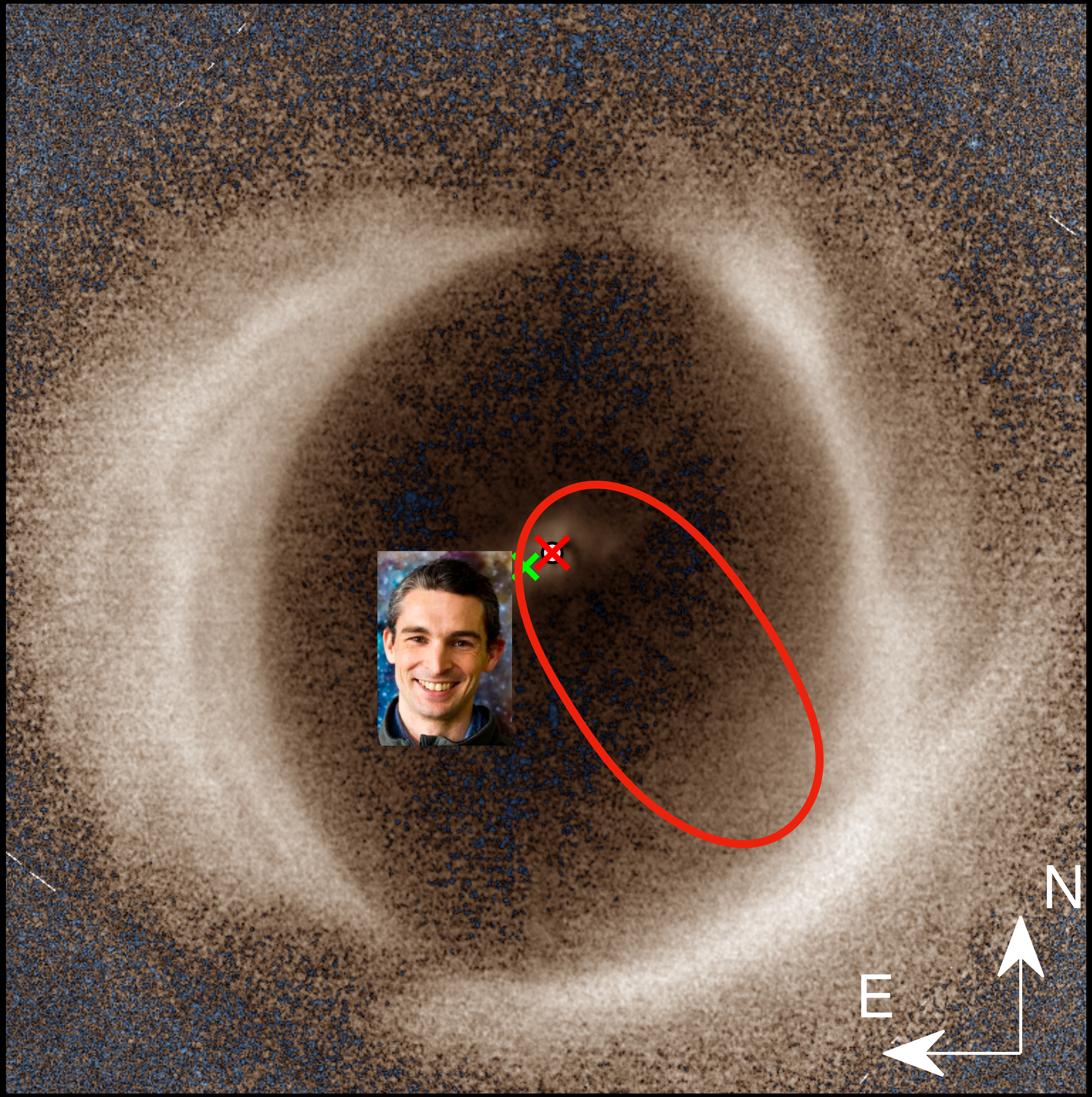
**Treacherous Dan 2.0**

Massive companion wandering in the outer disc regions

**Fearless Valentino**

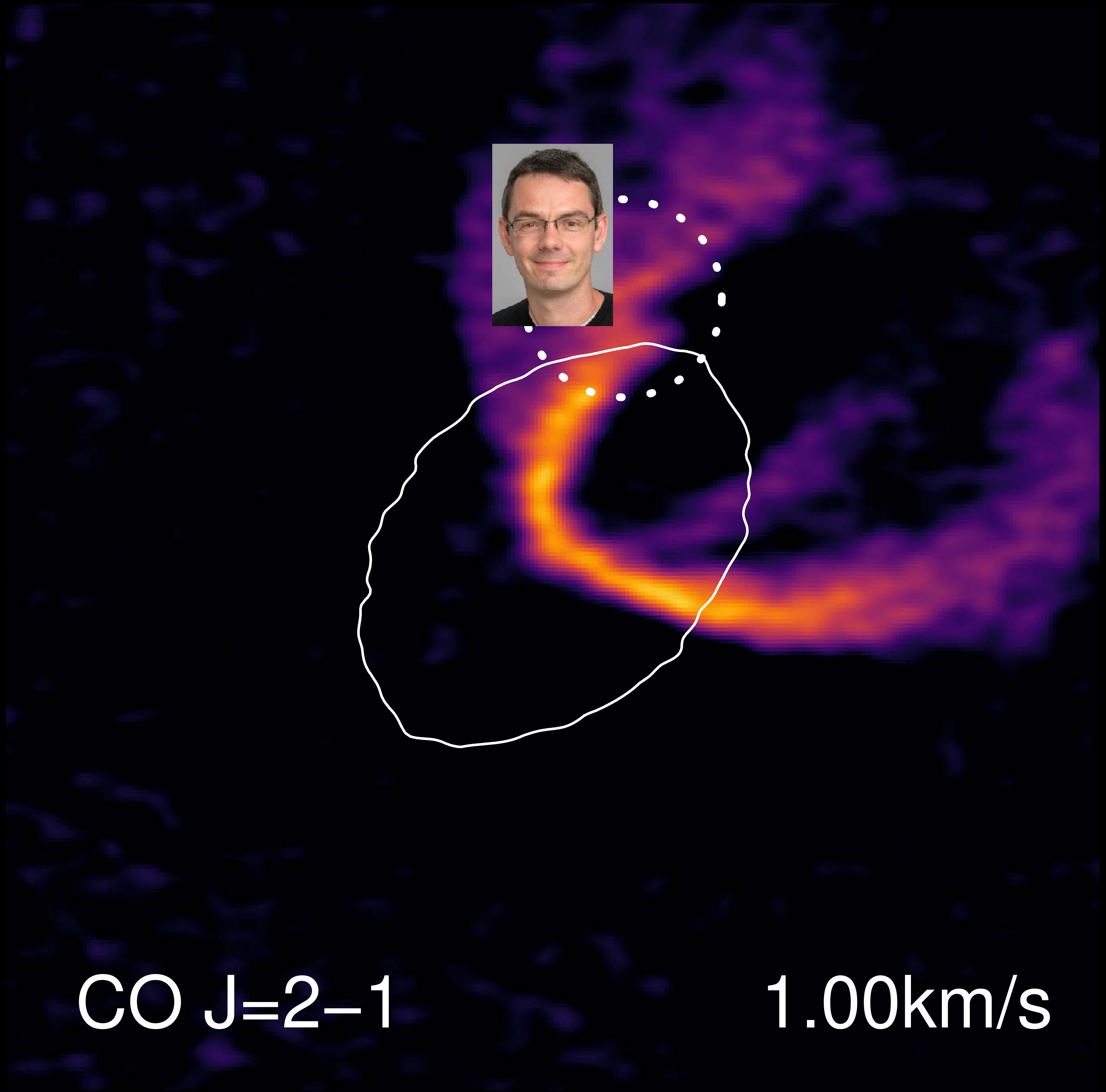
Fast & furious! Extremely dangerous

# Eccentric Dan 1.0: Stellar Inner Companion




Price, Cuello, Pinte et al. (2018)

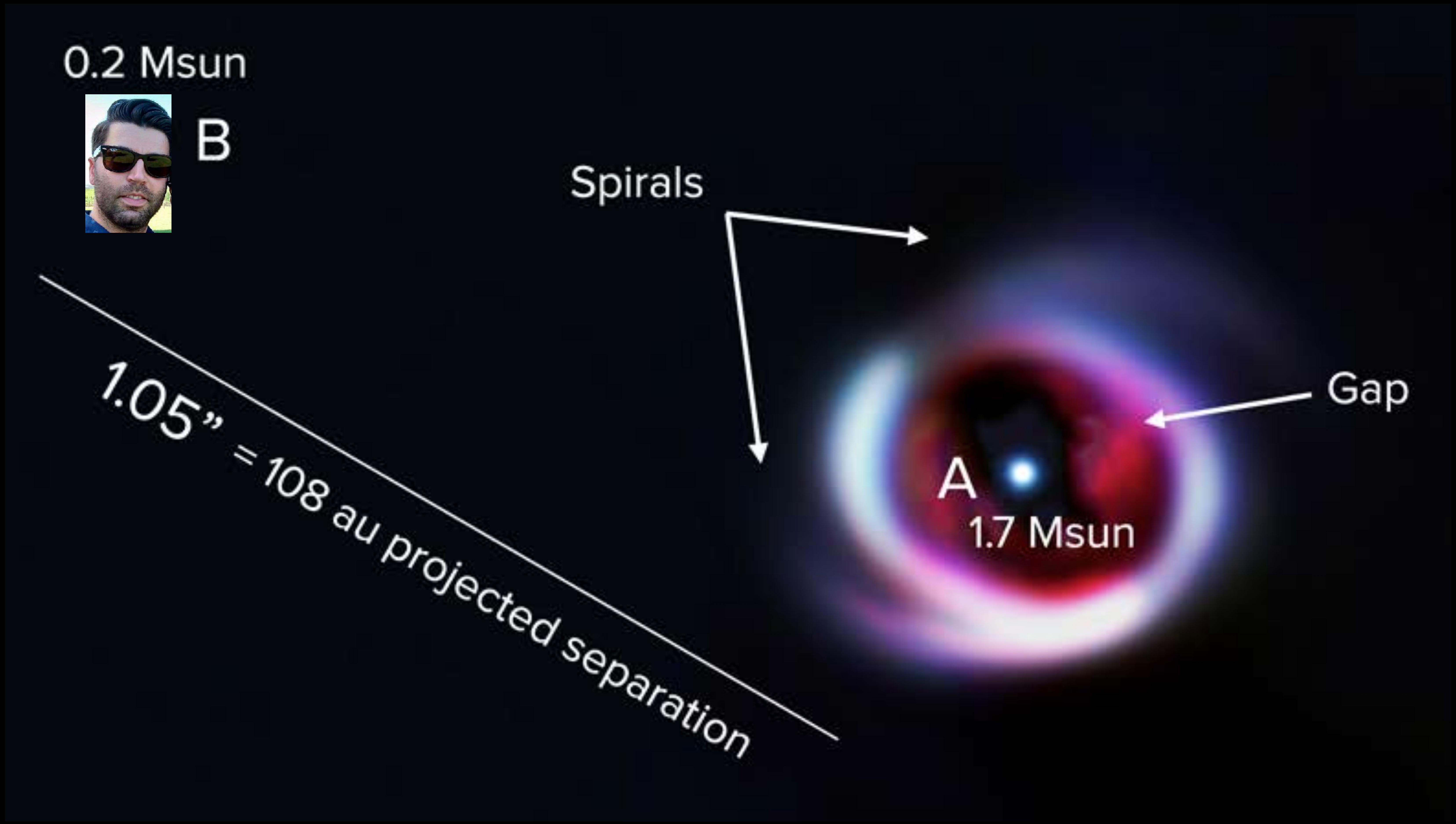
# The French Chris: Embedded Kinky Planet




**Pinte, Price, Ménard et al. (2018)**

See talk by
S. Pérez
See posters by
C. Pinte

# Treacherous Dan 2.0: Bound Companion

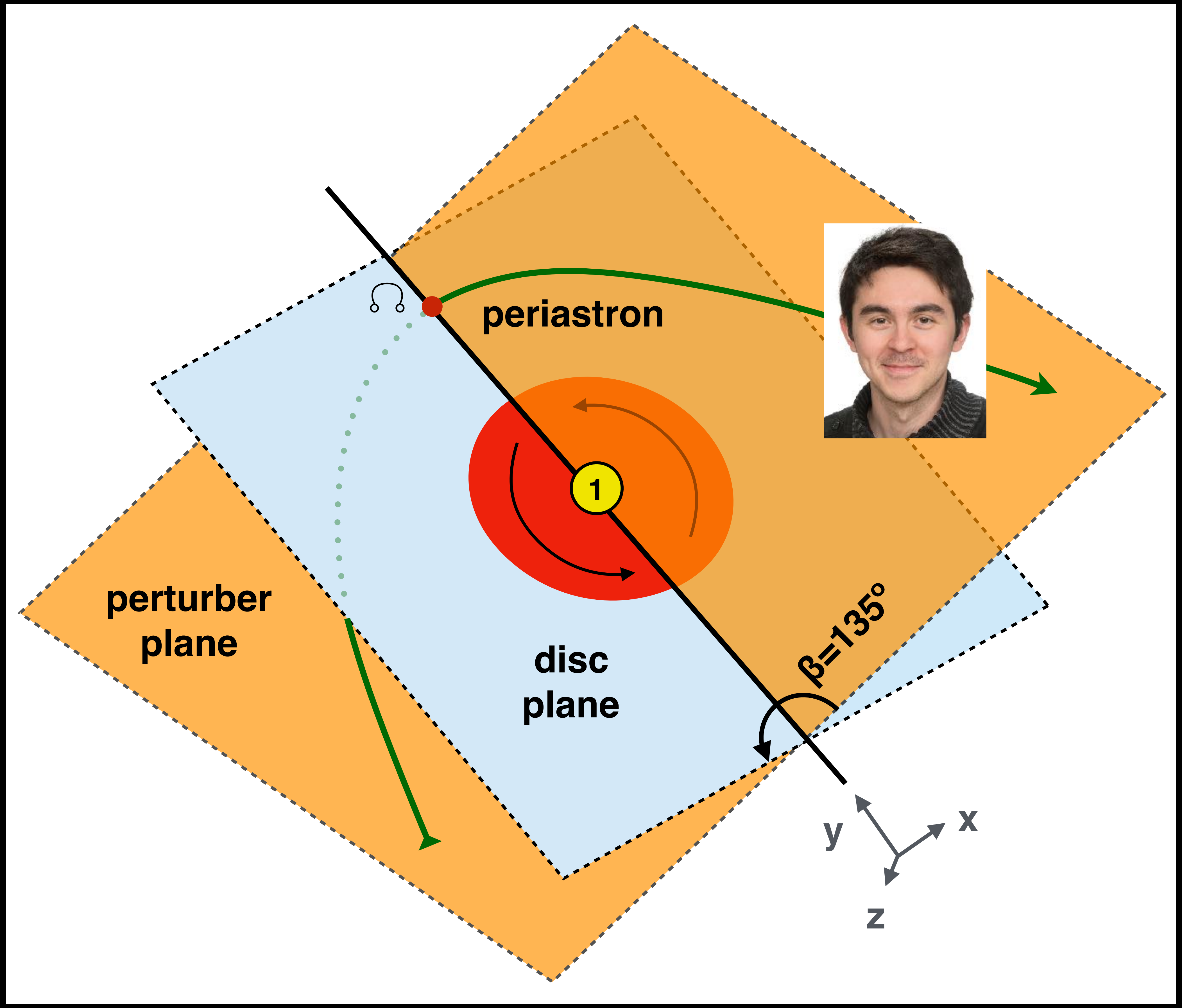



**Wagner, Dong, Sheehan et al. (2018)**
**van der Plas, Ménard, Gonzalez et al. (2019)**

# Discs & Flybys Modeling

Degenerate problem: infinite ways to chose a flyby orbit
however: **orbit <–> disc structure**

Non-penetrating encounters: R_peri > R_d

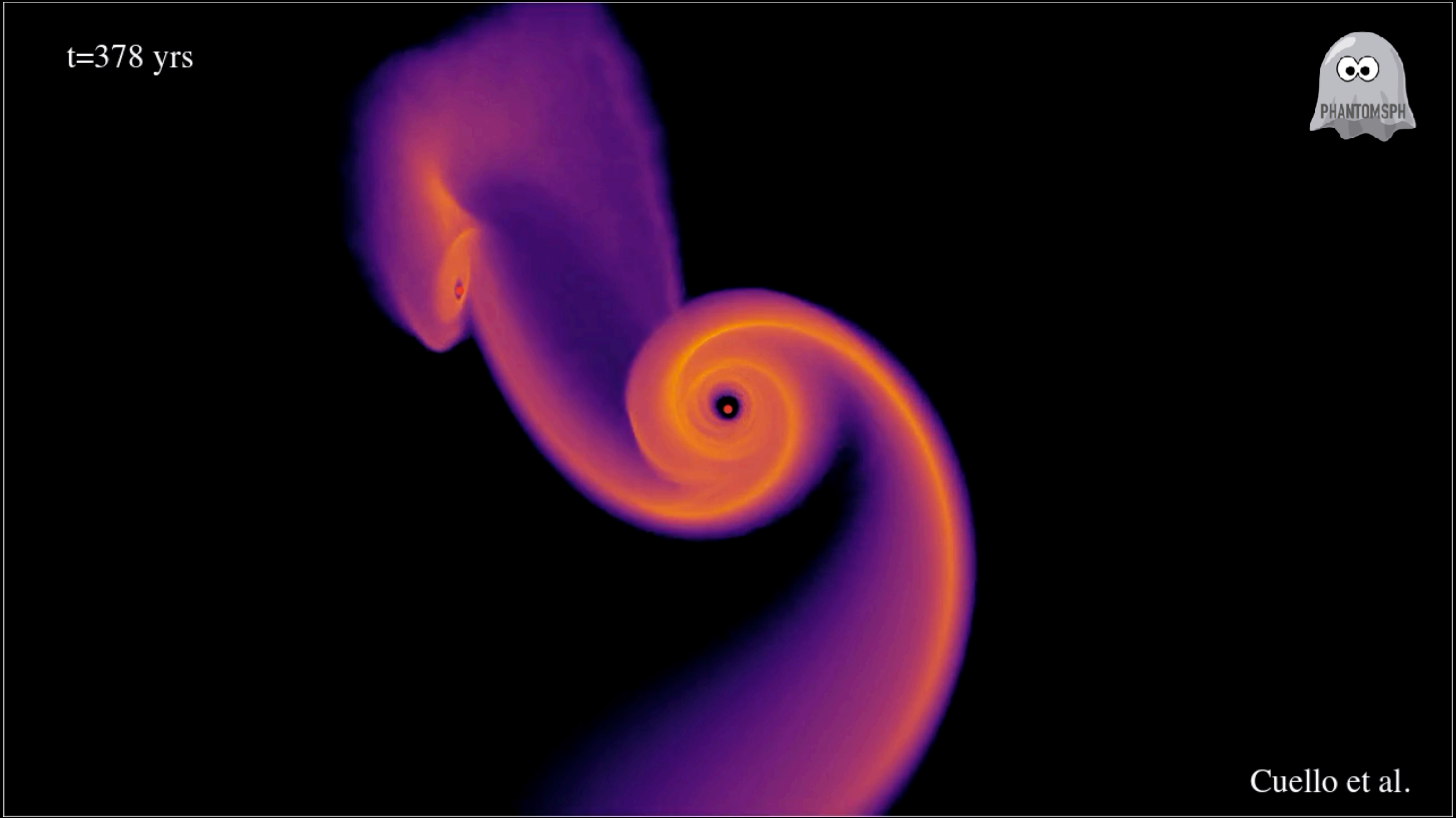



**ß45: inclined prograde**

**ß135: inclined retrograde**

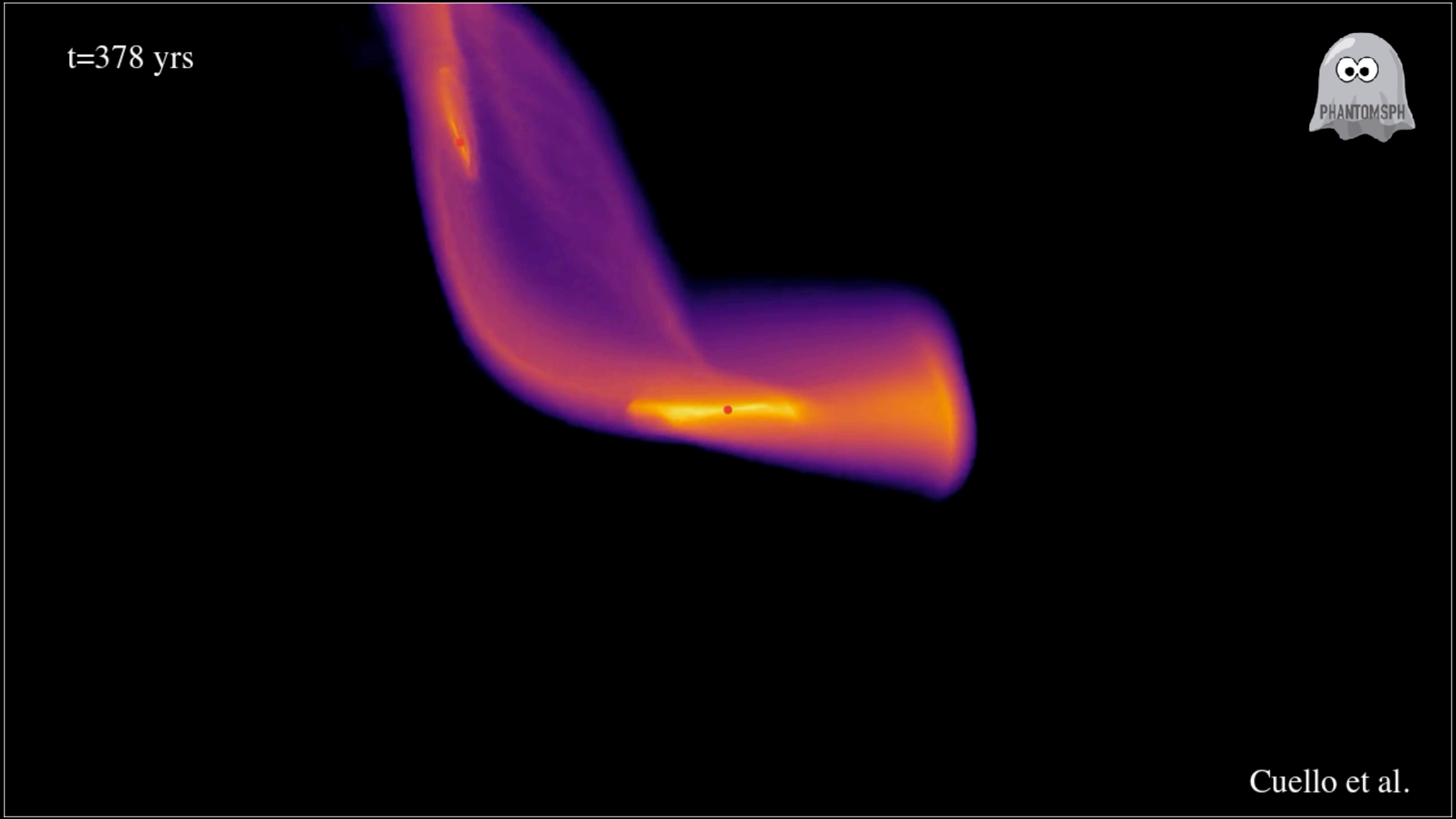
q=M2/M2=1, R_d=150 au, R_peri=200 au
**inclination:** ß= 0° (P), **45° (P)**, 90° (polar), **135° (R)**, 180° (R)

# FLYBYS: DYNAMICAL SIGNATURES




Inclined prograde (ß=45°) encounter
GAS – Face-on view

# Flybys: Dynamical Signatures

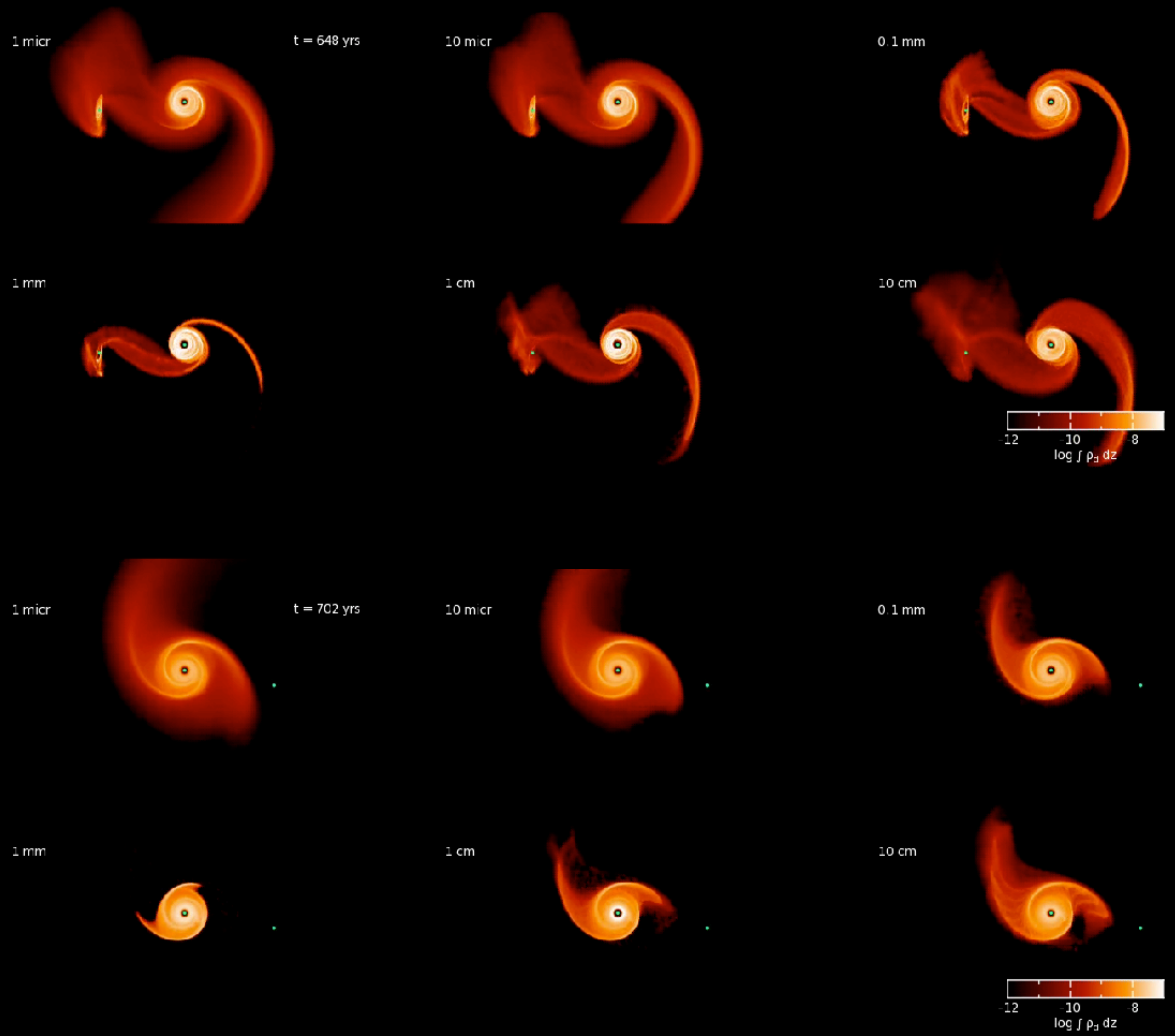



Inclined prograde (ß=45°) encounter
GAS – Edge-on view

# DUST DYNAMICS

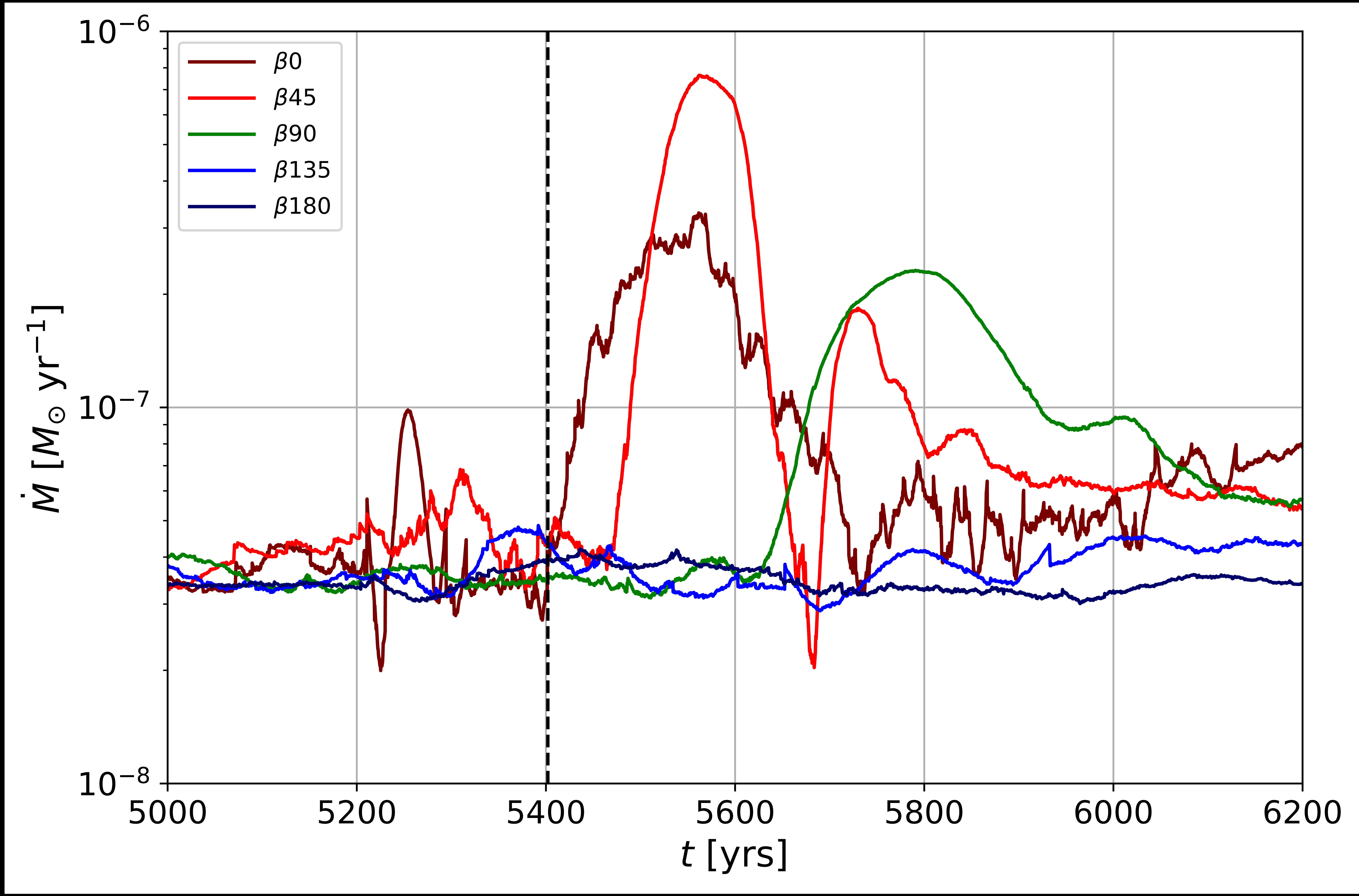
**ß45 inclined prograde**

**ß135 inclined retrograde**




Cuello, Dipierro, Mentiplay et al. (2019)

# Flyby-induced Accretion Events




If we assume that
$L_* \propto M \, \dot{M}$

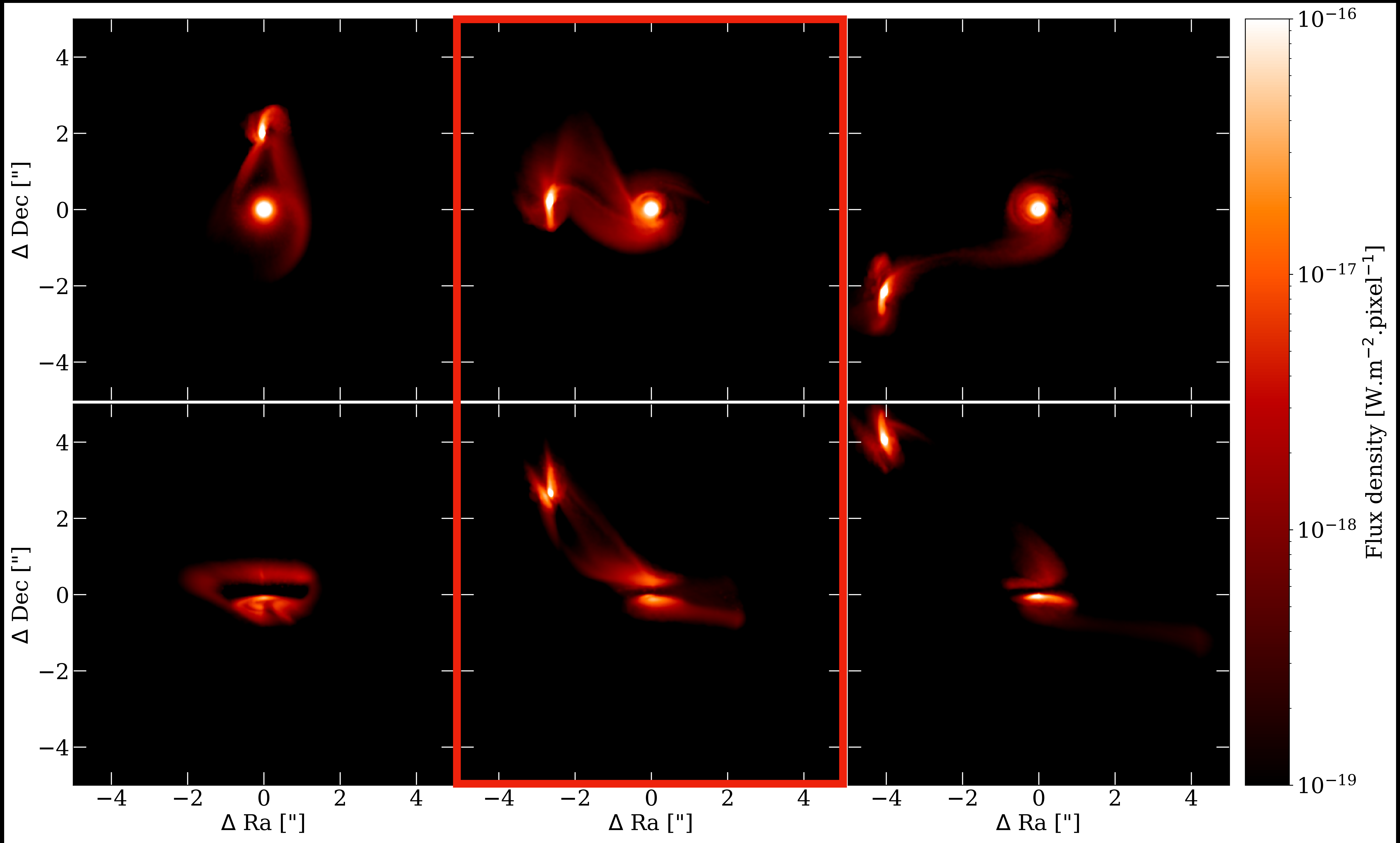
L suddenly x2 x10
L↗ with ↗q

**–> FU Ori events?**

# Flybys in Scattered Light

Emission at 1.6 μm with MCFOST

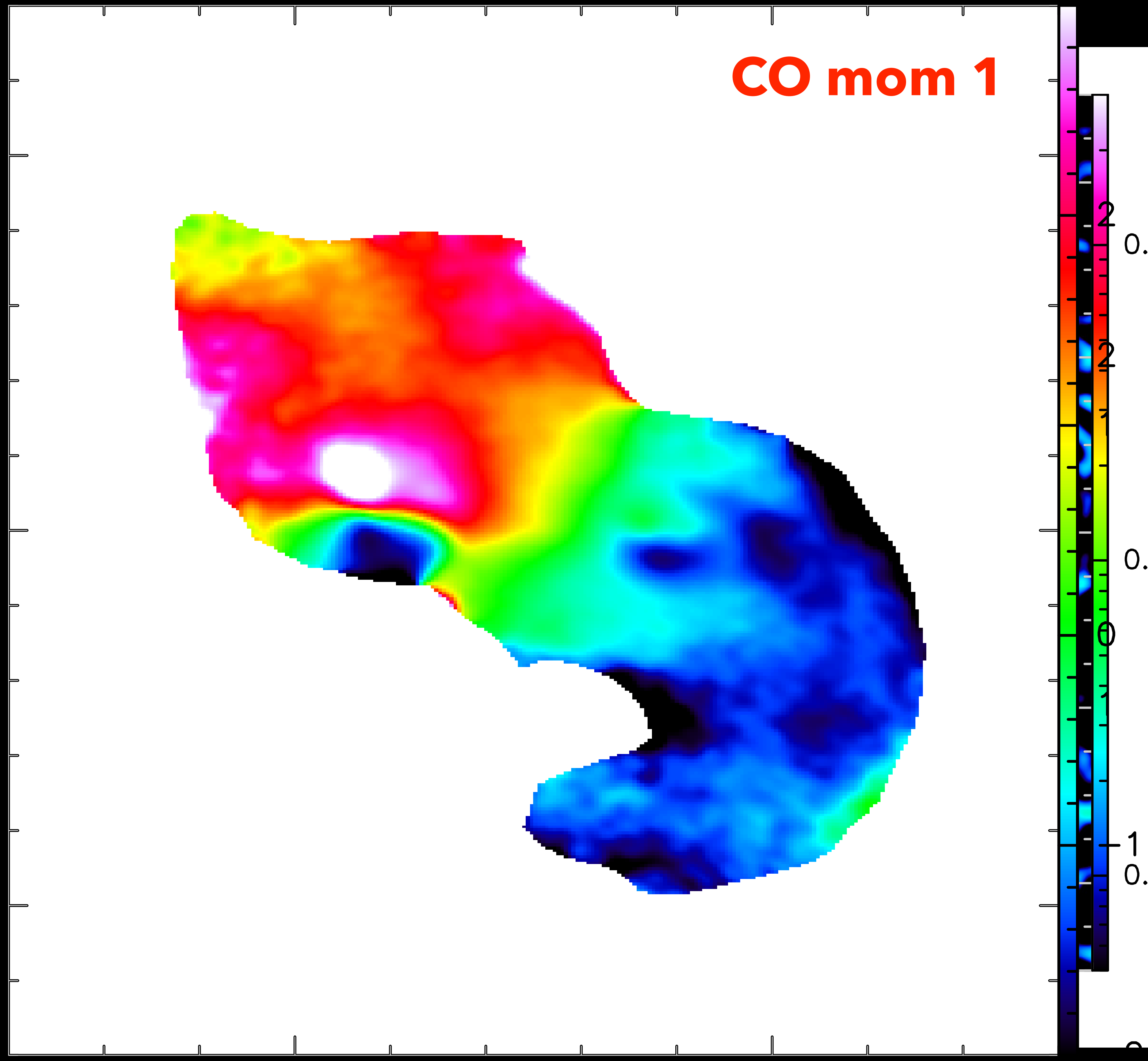
**ß45**
inclined
prograde
orbit

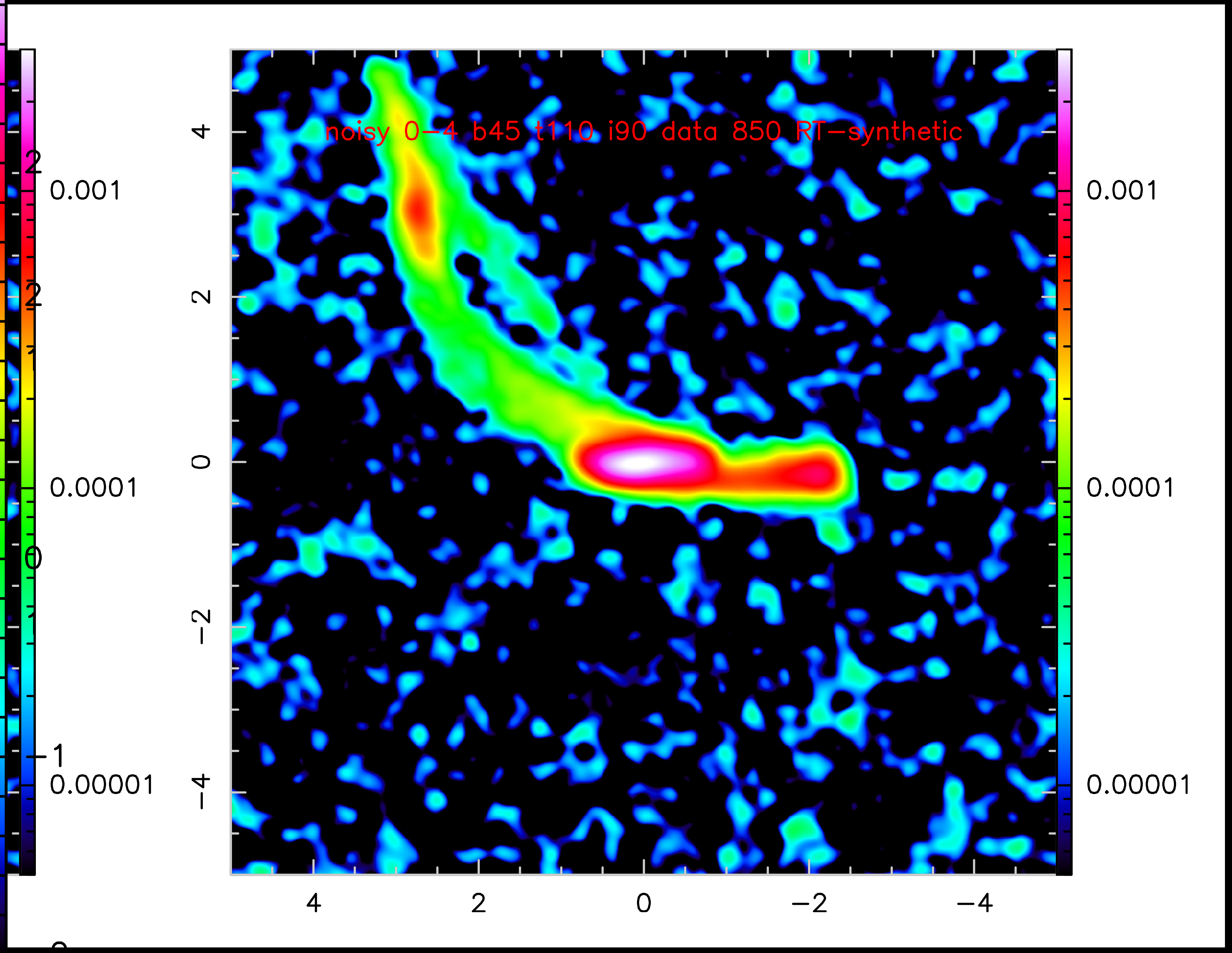



**Cuello, Mentiplay, Louvet et al. (almost submittable)**

# FLYBYS IN THE CONTINUUM AND CO LINES

ALMA Band 7 with MCFOST and then CASA



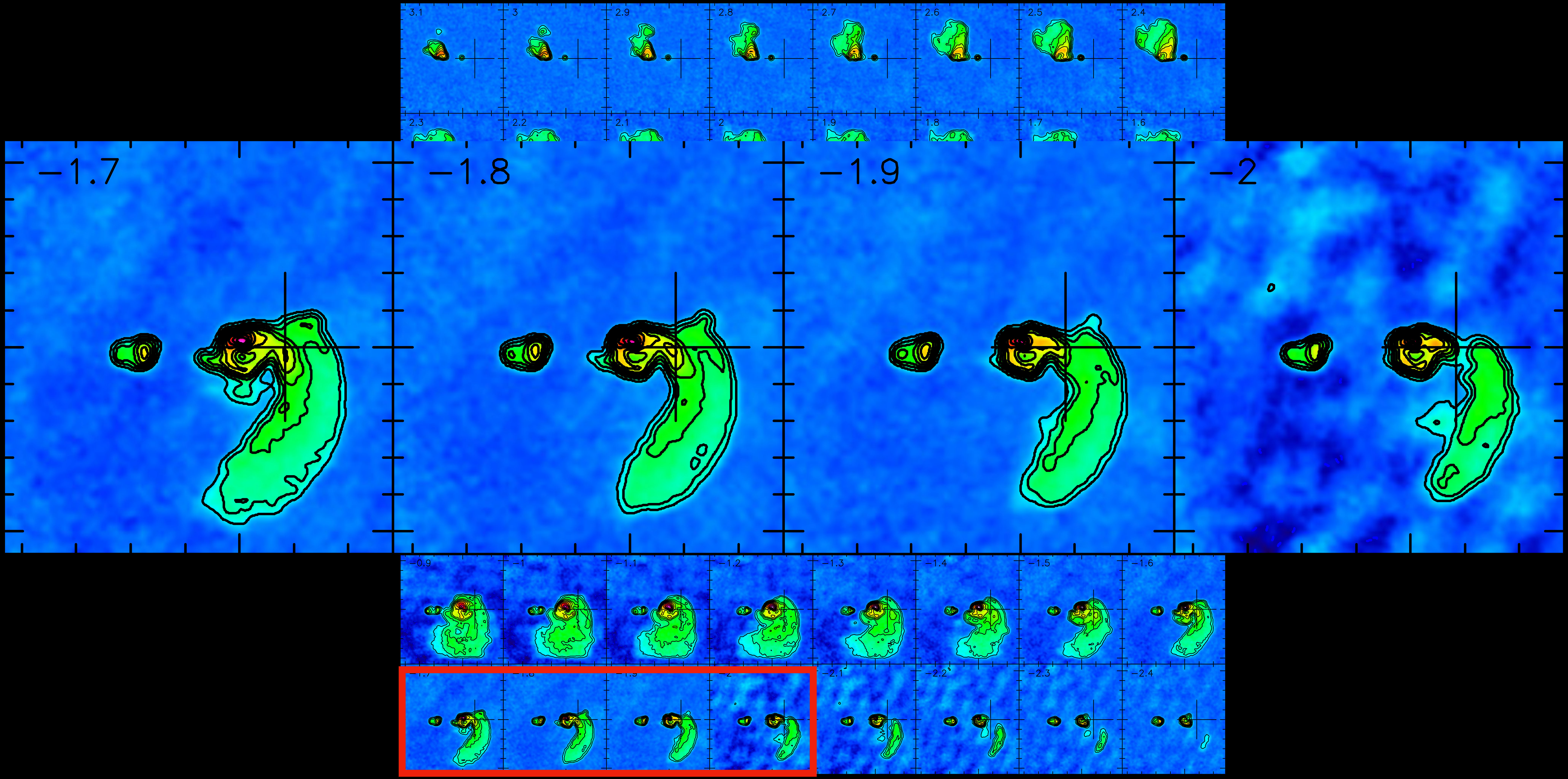




Kinematics = information about disc orientation

**Cuello, Mentiplay, Louvet et al. (almost submittable)**

# Flybys in through the channels

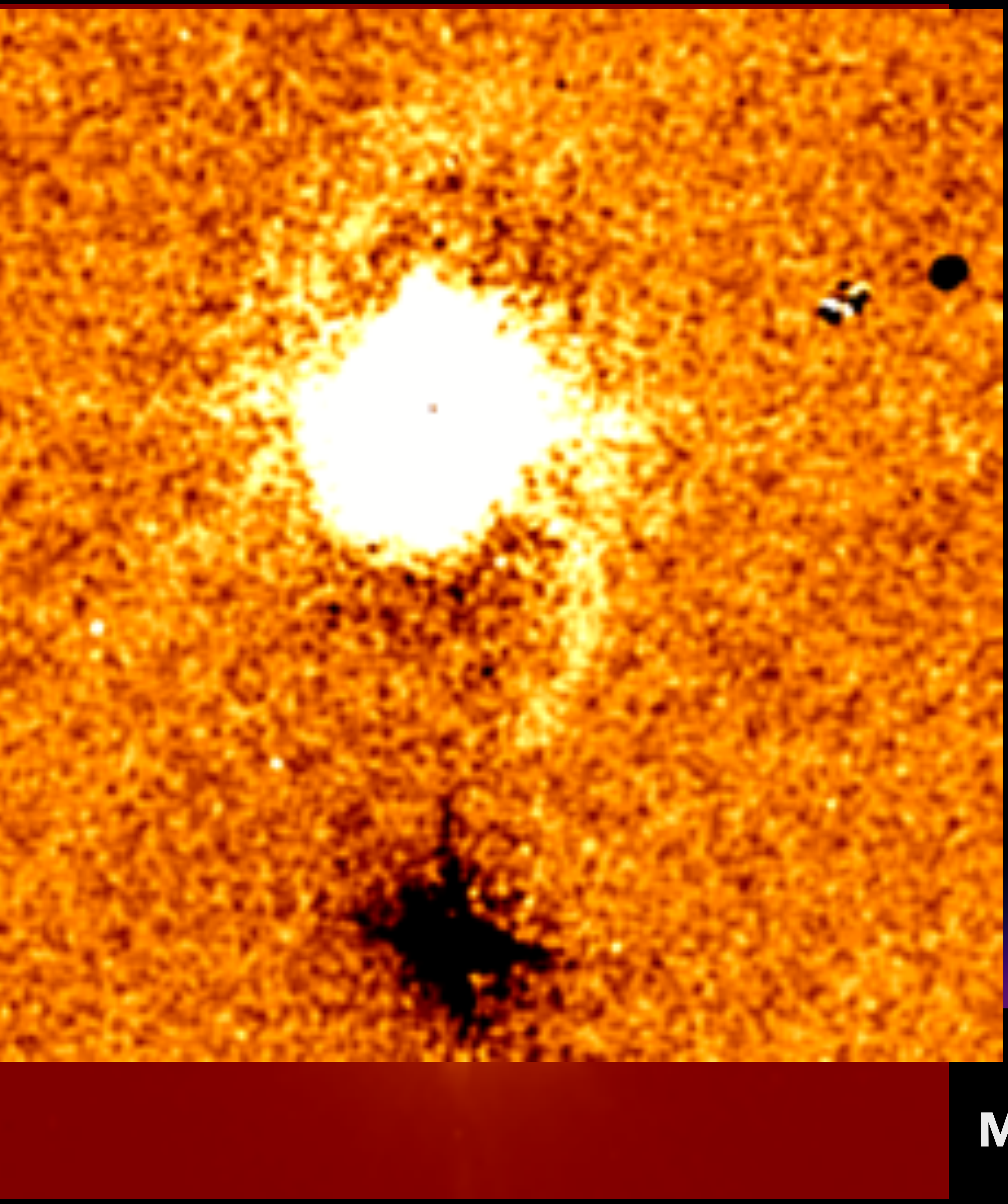
CO channel maps for the inclined prograde case

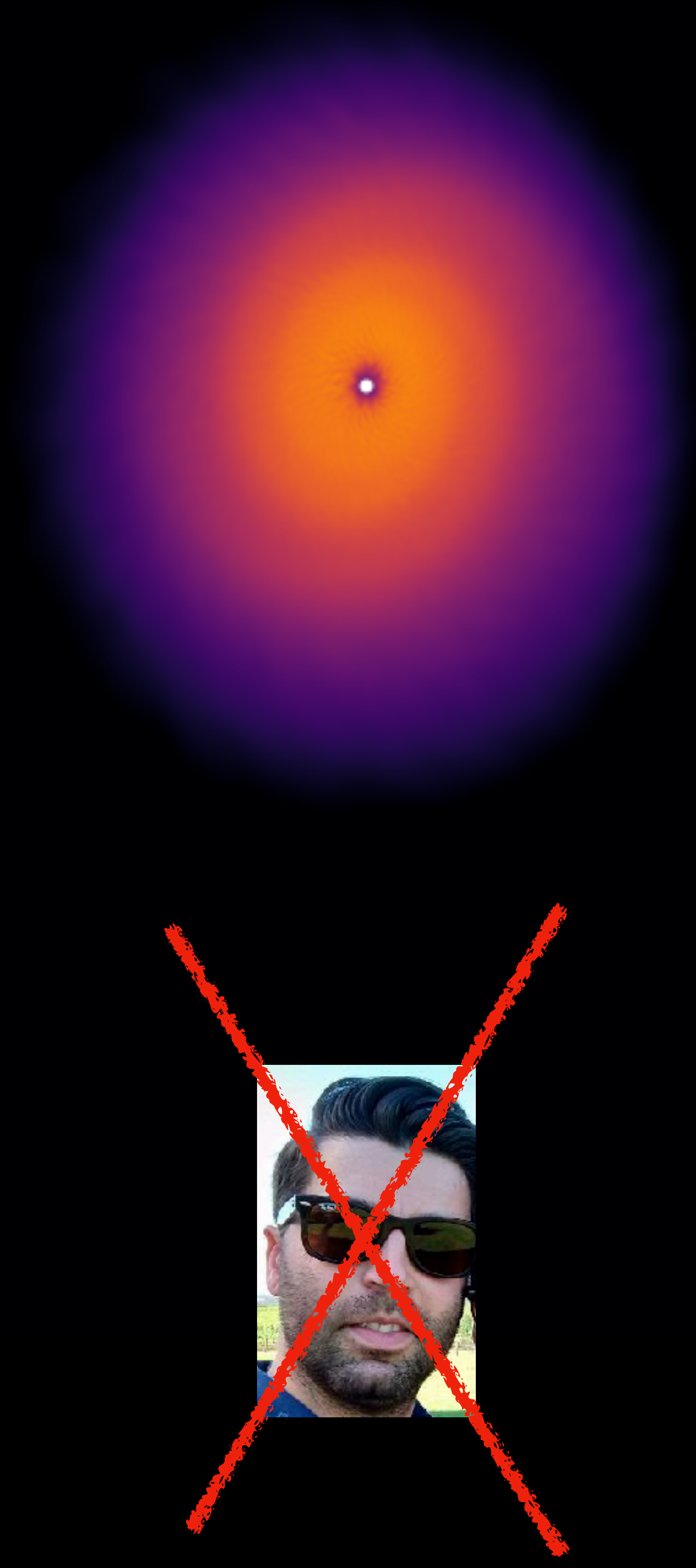



**Cuello, Mentiplay, Louvet et al. (almost submittable)**

# FLYBY VICTIM I: UX TAU

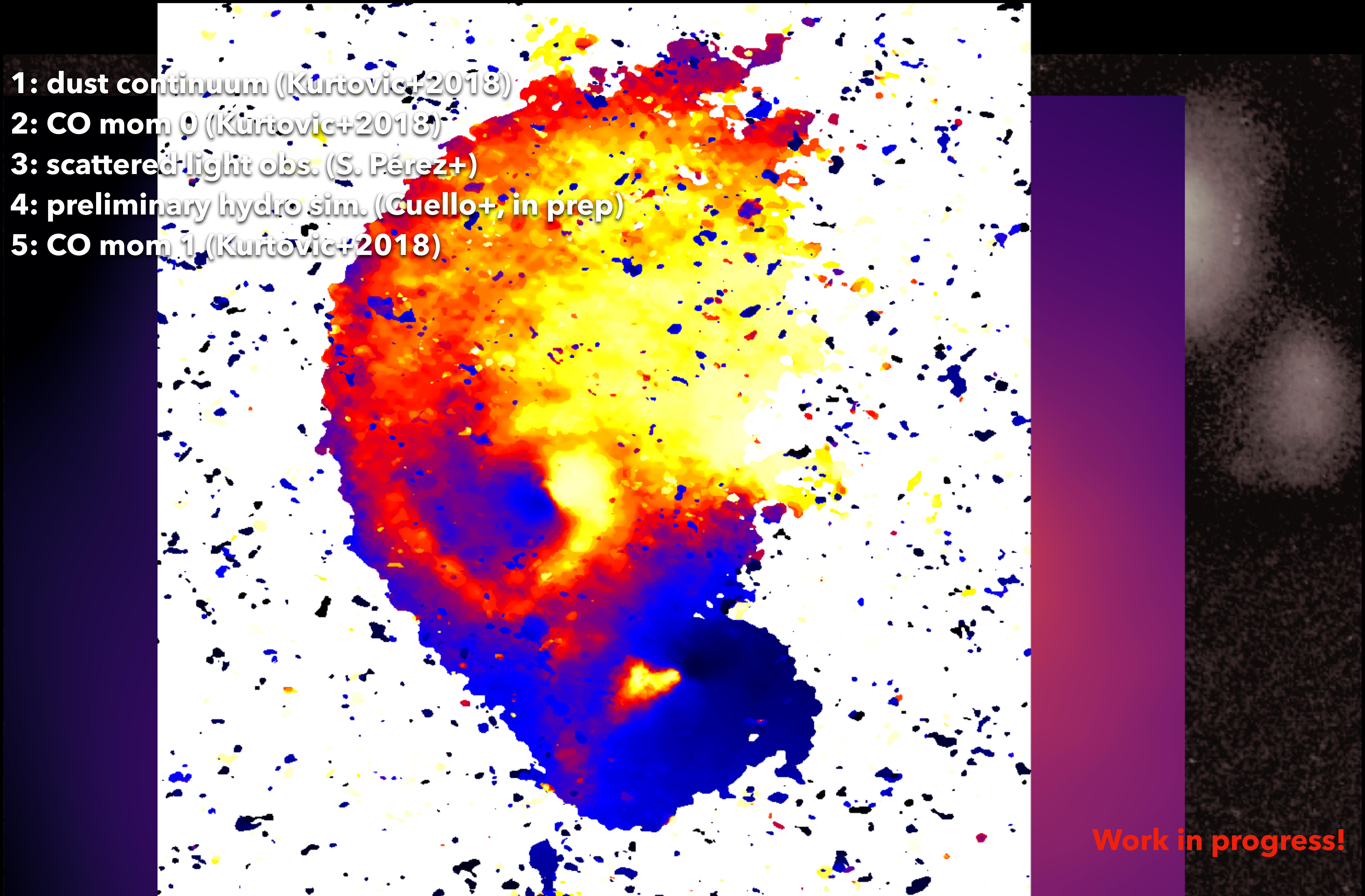
Based on dynamical arguments, the orbit should be prograde.
But, is it bound or unbound?





**Ménard, Cuello, Gonzalez et al. (in prep)**

# Flyby Victim II: AS 205

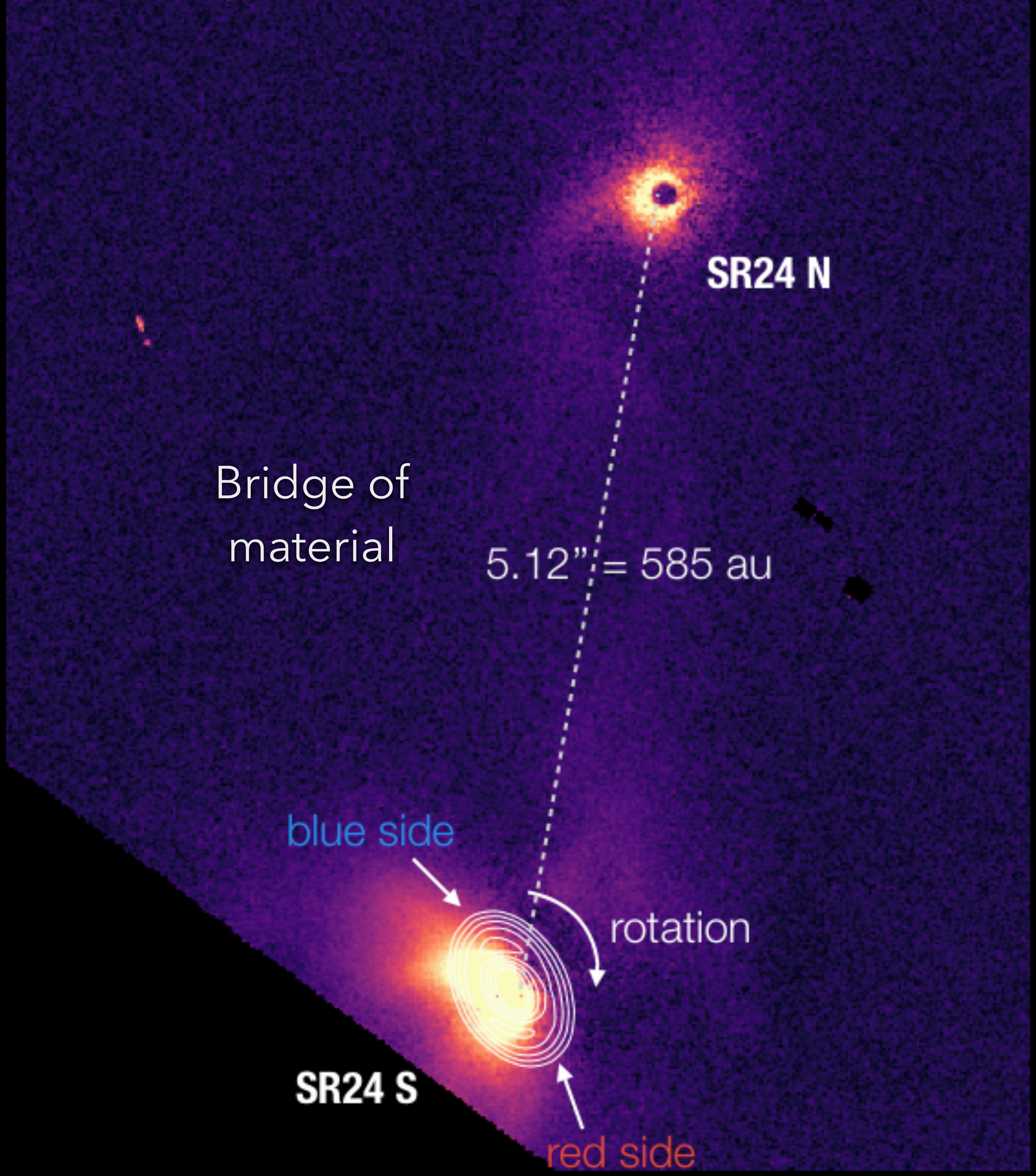


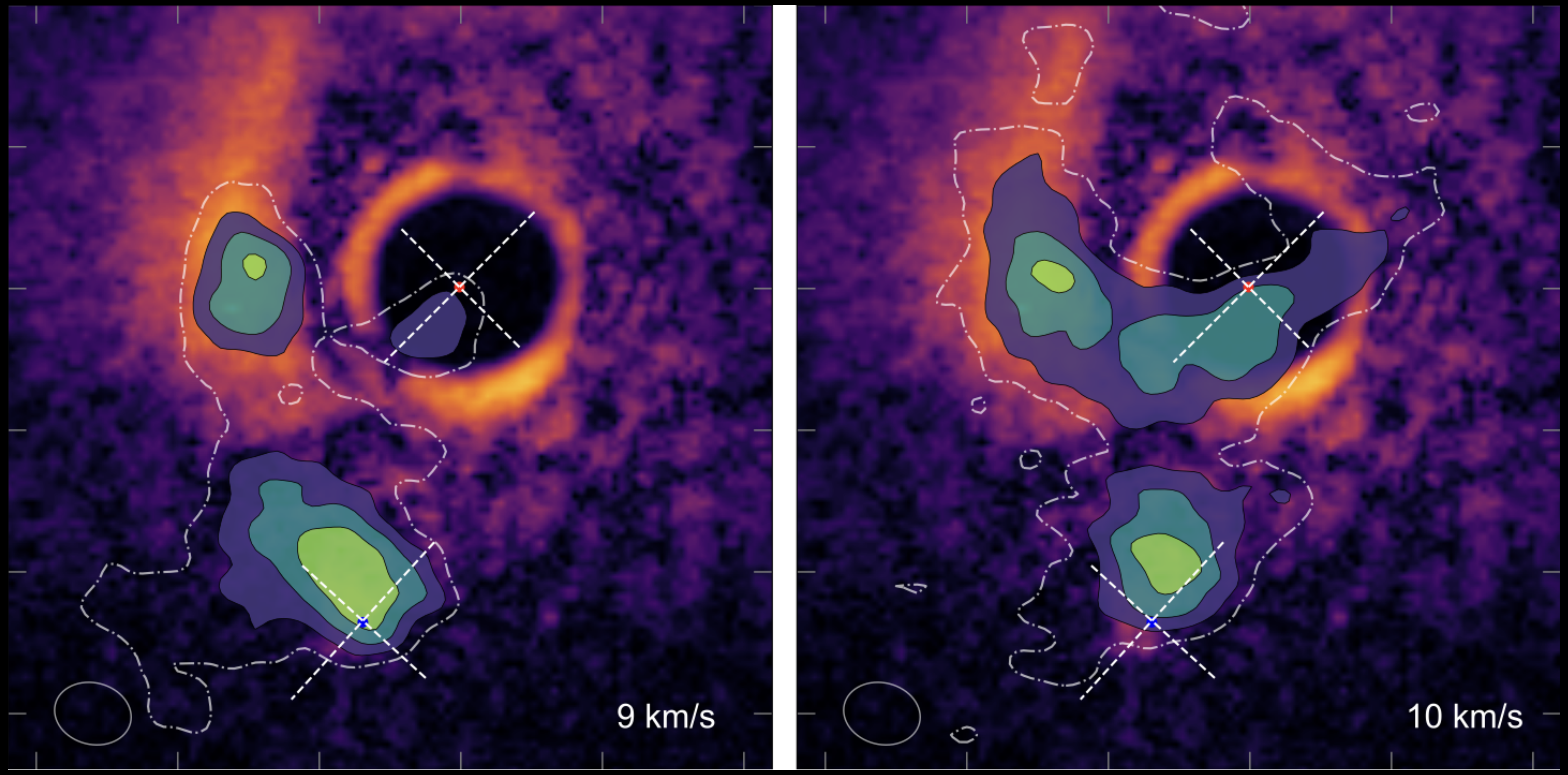
1: dust continuum (Kurtovic+2018)
2: CO mom 0 (Kurtovic+2018)
3: scattered light obs. (S. Pérez+)
4: preliminary hydro sim. (Cuello+, in prep)
5: CO mom 1 (Kurtovic+2018)

**Work in progress!**

# Flyby Victims III & IV: SR24 & FU Ori (?!)

**S. Pérez, Cuello, Avenhaus et al. (in prep)**




**S. Pérez, Hales, Liu et al. (submitted)**

In SR24: bridge between both stars
surprisingly no mm disc around SR24N

In FU Ori: non-coplanar spiral
excellent match with scattered light spiral!
—> non-coplanar interaction!

# When should you suspect a Flyby?

| PROGRADE? | OBSERVATIONAL SIGNATURES | RETROGRADE? |
|---|---|---|
| Yes | Bridges & spirals with large pitch angles | ~ |
| Yes | Dust trapping in the spirals | Yes |
| Yes | Disc truncation | No |
| ~ | Warped discs | Yes |
| Yes | Diffuse halo | No |
| Yes | Accretion events / outbursts ? | No |

**Cuello, Mentiplay, Louvet et al. (almost submittable)**

# FINAL WORDS

**Disc structure <–> Flyby parameters**

1) Do we observe stellar flybys?
2) How does the disc react to a flyby?
3) How does a flyby look like?
4) Can we identify flyby suspects?
5) Implications for planet formation?

OPEN QUESTIONS

- disc long-term evolution after the encounter?
- planet formation in perturbed/multiple systems?
- connexion with the Solar & exoplanetary systems?

**14 DRINKS**