JEDI conference, June 25 - 28, Rome

CAN SPIRALS AND AXISYMMETRIC STRUCTURES GIVE US A PROXY FOR THE TOTAL DISC MASS?

THE CASE OF HD135344B

Benedetta Veronesi (UniMi)

Collaborators:
Giuseppe Lodato (UniMi, Italy)
Giovanni Dipierro (University of Leicester, UK)
Daniel Price (Monash University, Australia)

IN YODISH…

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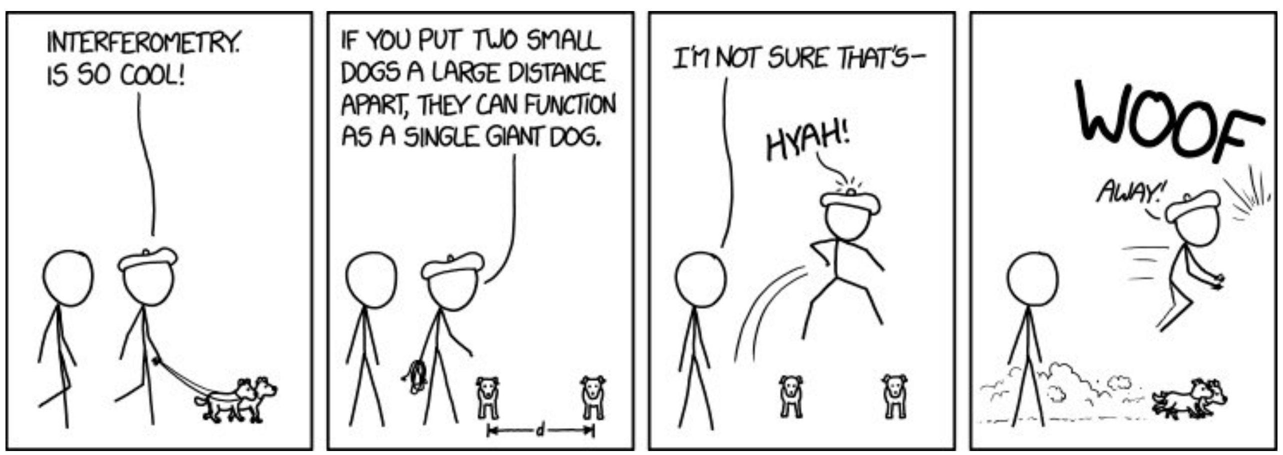
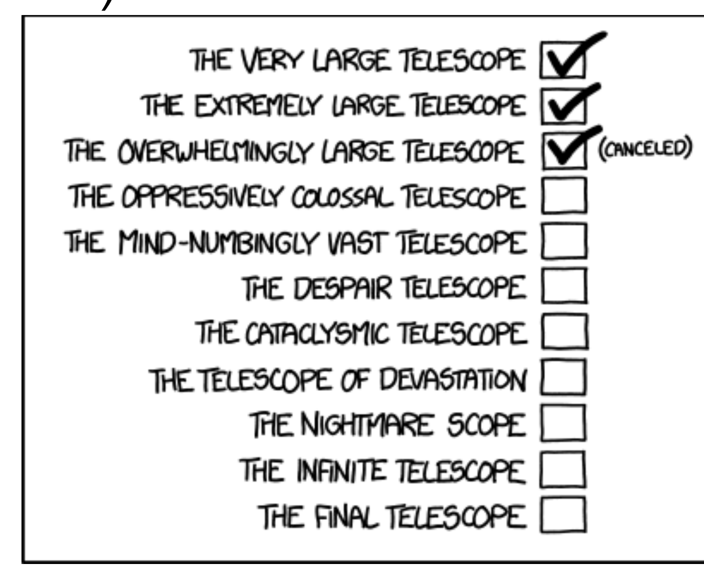
WHAT WE HAVE:

Telescopes:
ALMA (RADIO) and **SPHERE** (near-IR) high resolution images of protoplanetary discs

New powerful and fast computational tools:

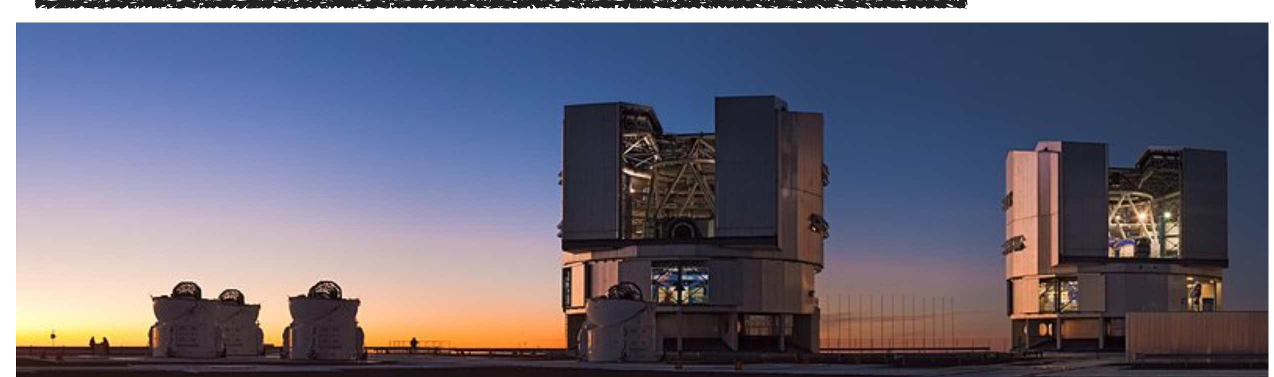
1. **S**moothed **P**article **H**ydrodynamics codes (**PHANTOM** - Price et al, 2017);
2. MonteCarlo Radiative transport codes (**RADMC-3D** - Dullemond et al, 2012; **MCFOST** - Pinte et al, 2006).



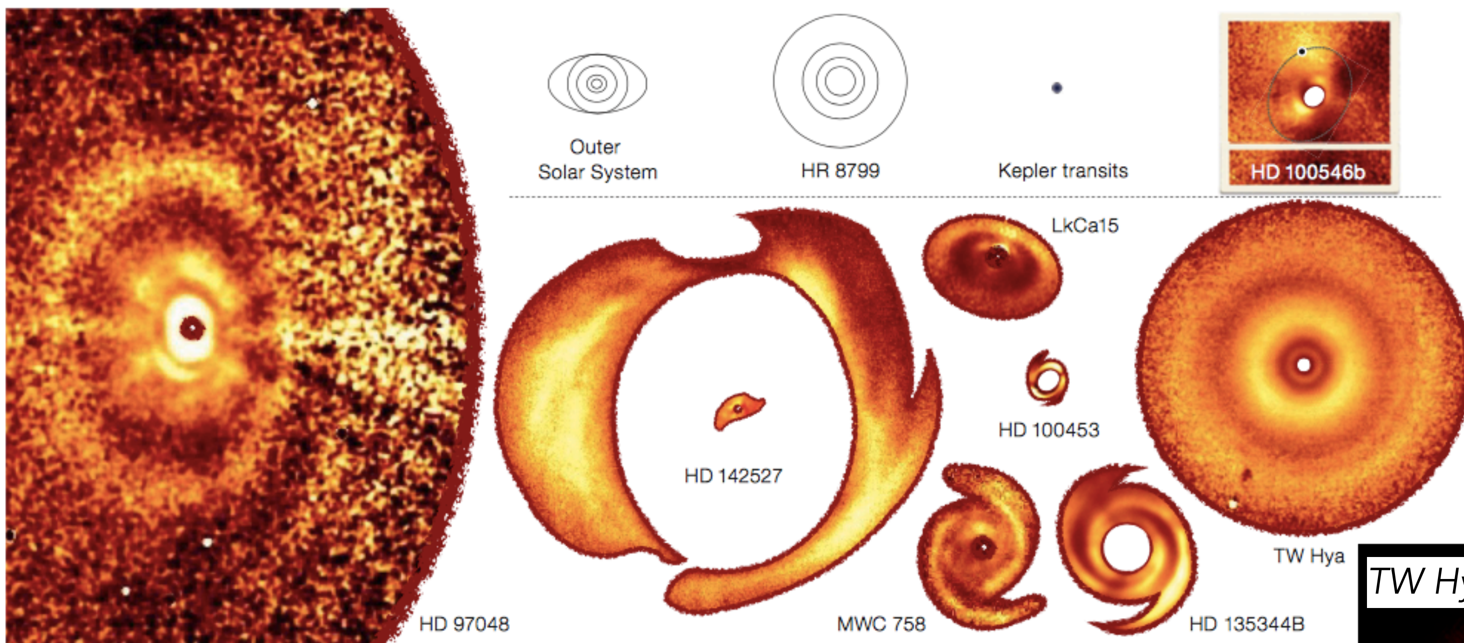


ALMA: Atacama Large Millimeter/submillimeter Array

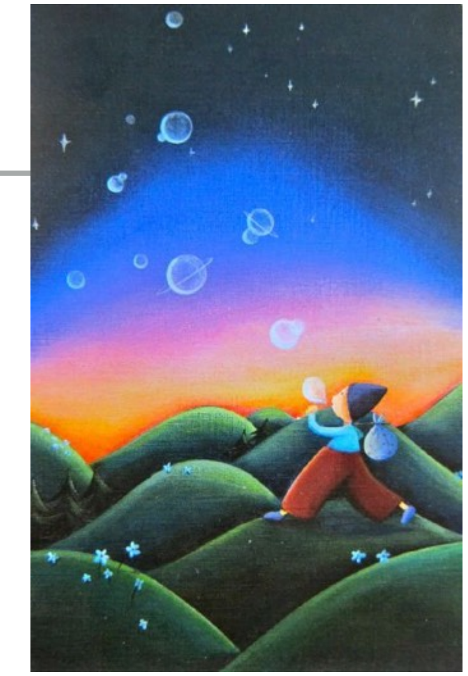
SPHERE at the Very Large Telescope



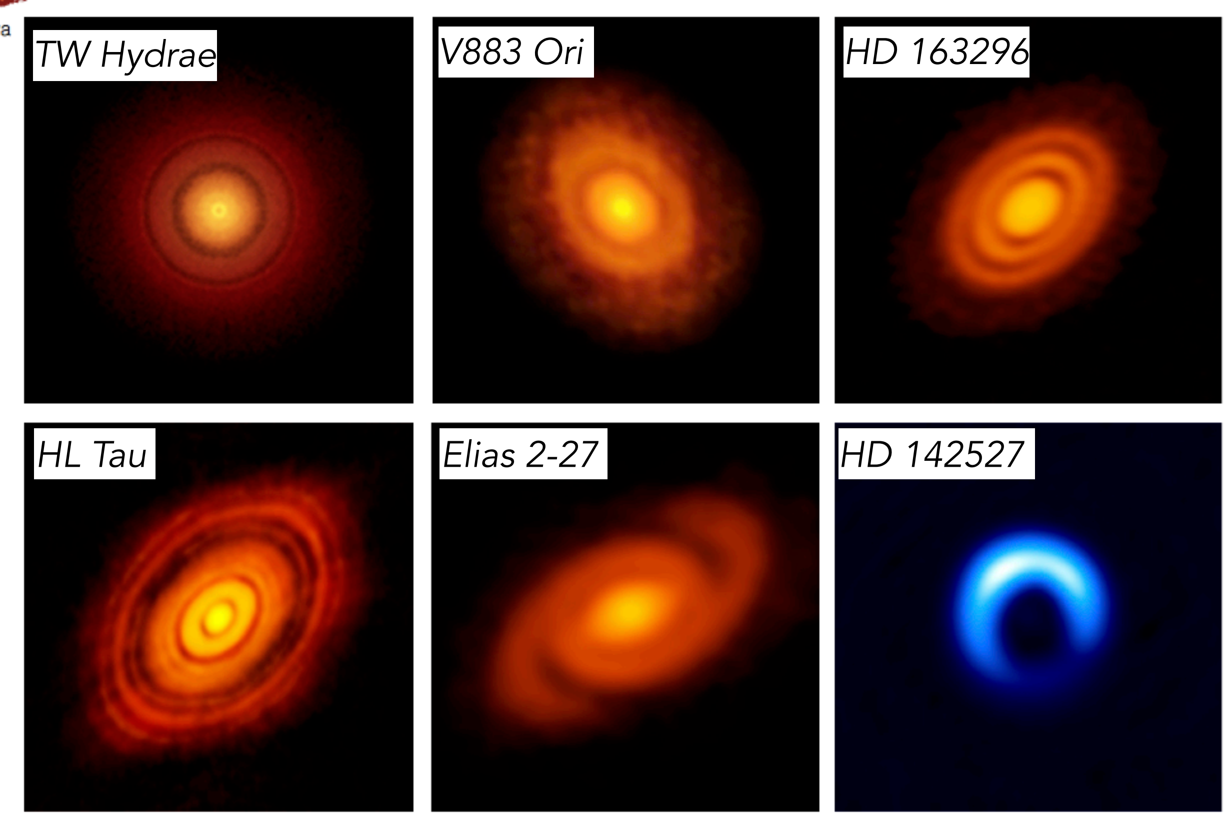
WHAT WE NEED: A THEORY ON PLANET FORMATION



Garufi et al., ESO Messenger



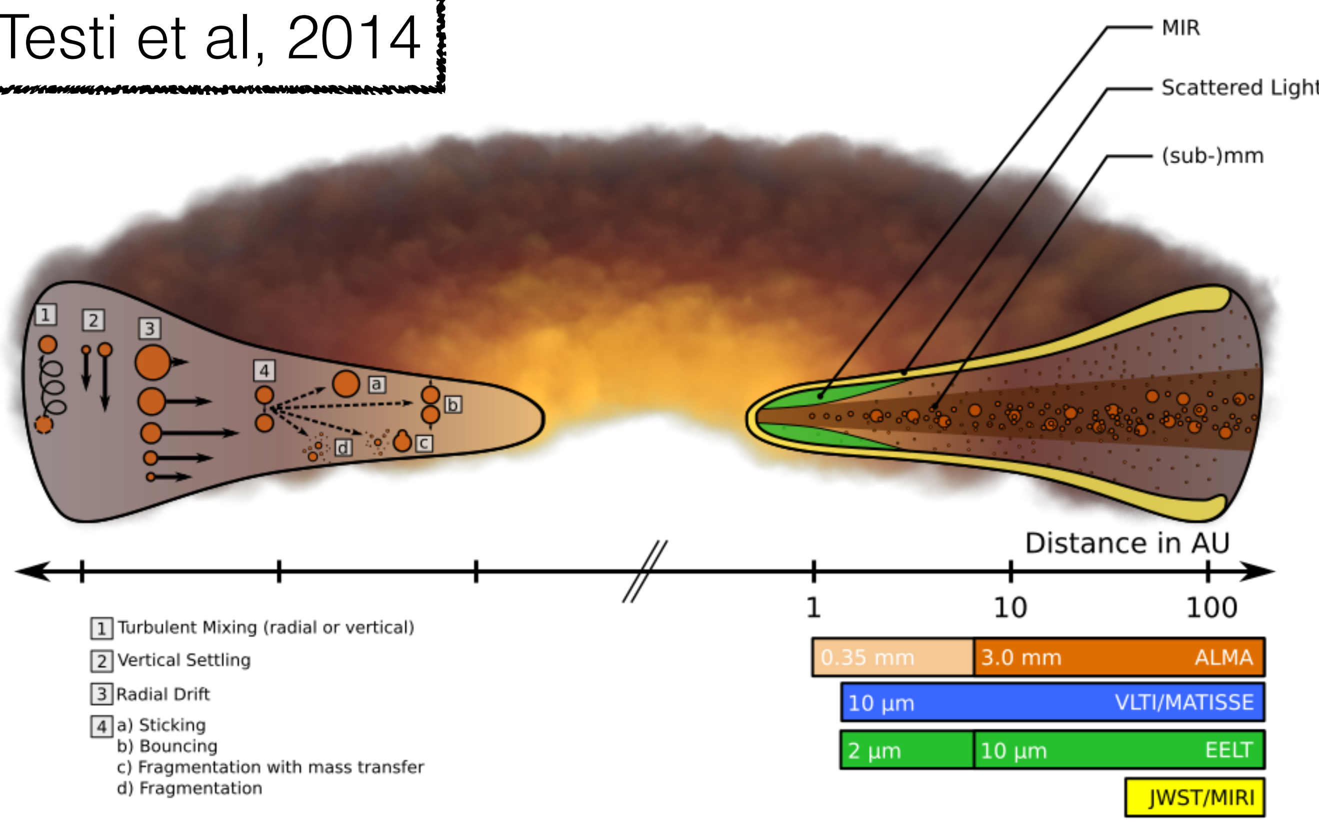
Andrews; ALMA (ESO/NAOJ/NRAO)



dust and gas interaction + planet and disc interaction + ? = Spirals, gaps, horseshoes…

AN INDICATOR OF GAS MASS IN DISCS

Testi et al, 2014



Dust dynamics:

- Aerodynamical drag
- Settling
- Coagulation
- Turbulence
- Particle concentration at pressure maxima

dust and gas interaction

$$St = t_s\Omega \approx \frac{\rho_d a}{\Sigma_g}$$

COUPLED

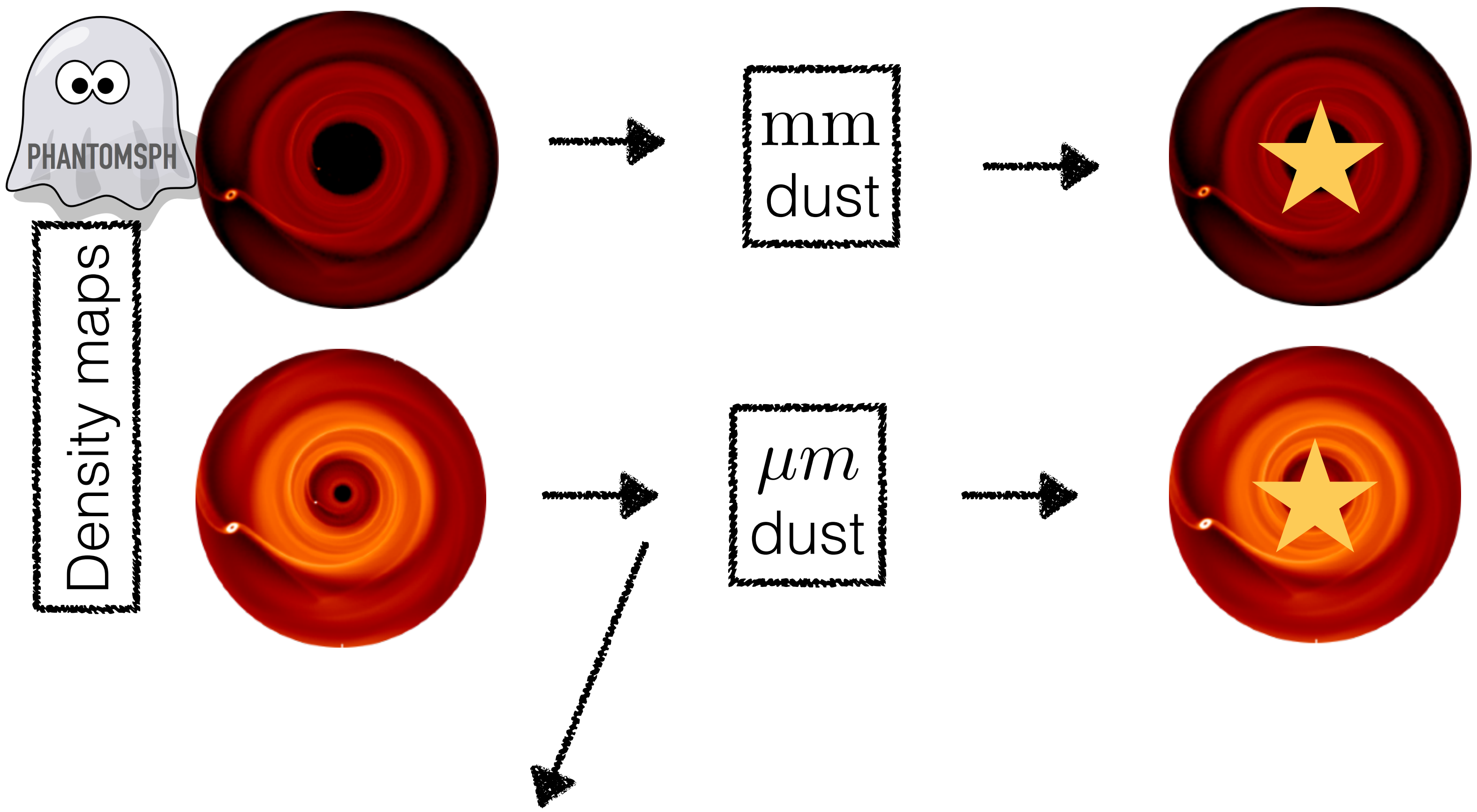
$$St \ll 1$$

NOT COUPLED

$$St \gg 1$$

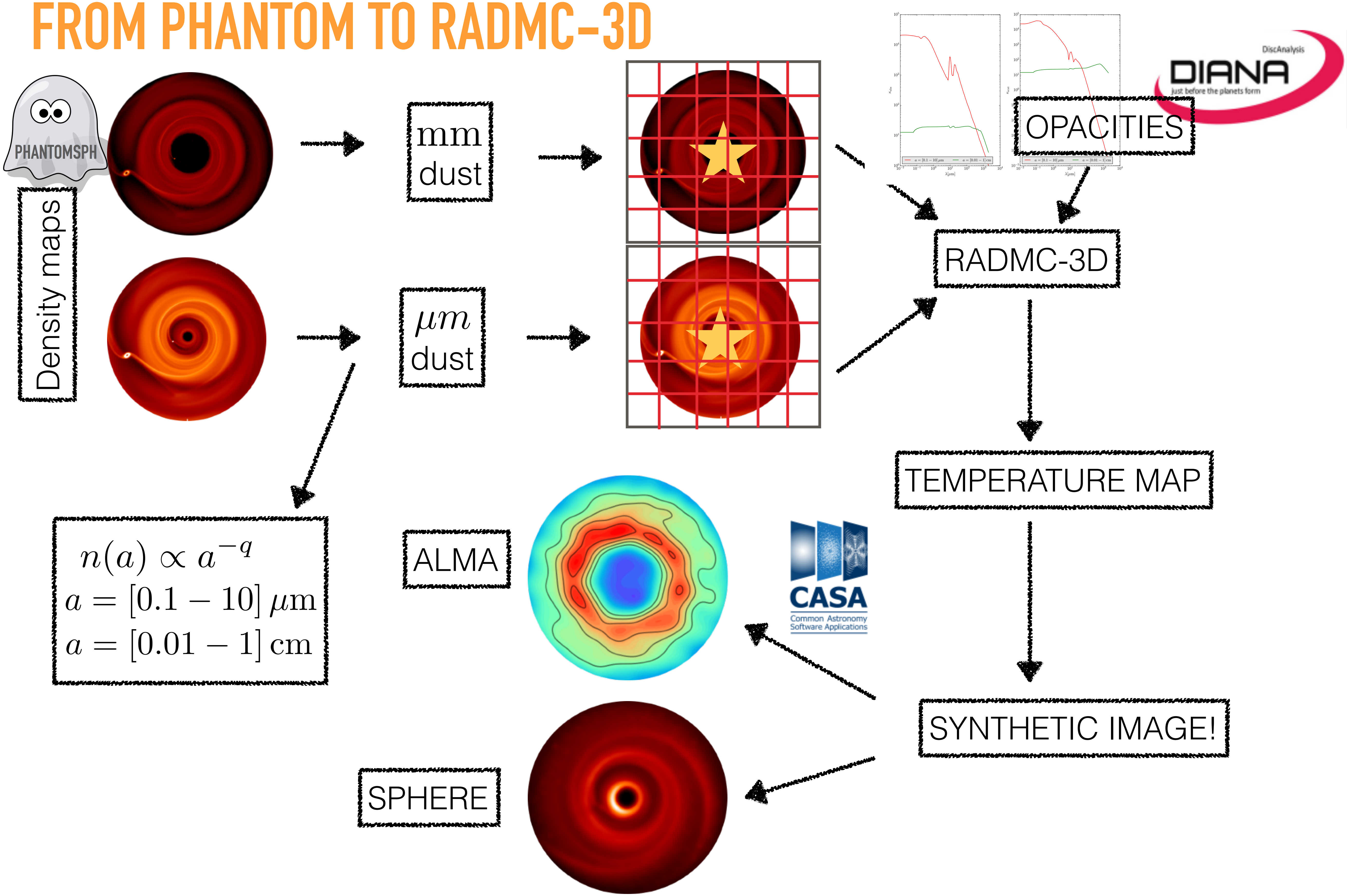
If the dust grain size is known…
we can **infer information on the gas disc mass**

FROM PHANTOM TO RADMC-3D

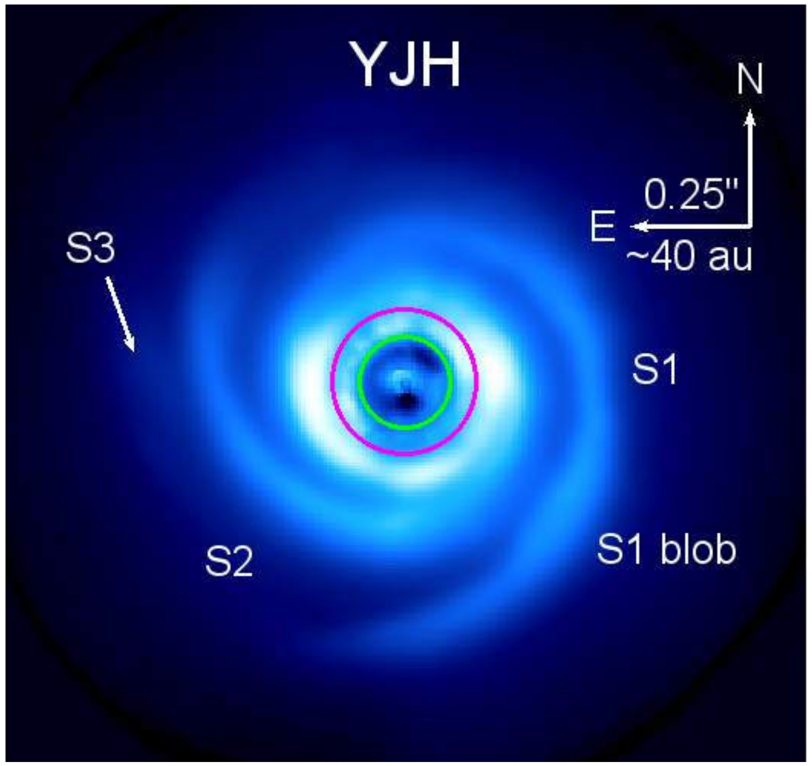


$$n(a) \propto a^{-q}$$
$$a = [0.1 - 10]\,\mu\text{m}$$
$$a = [0.01 - 1]\,\text{cm}$$

FROM PHANTOM TO RADMC-3D



ON THE ORIGIN OF THE SPIRALS



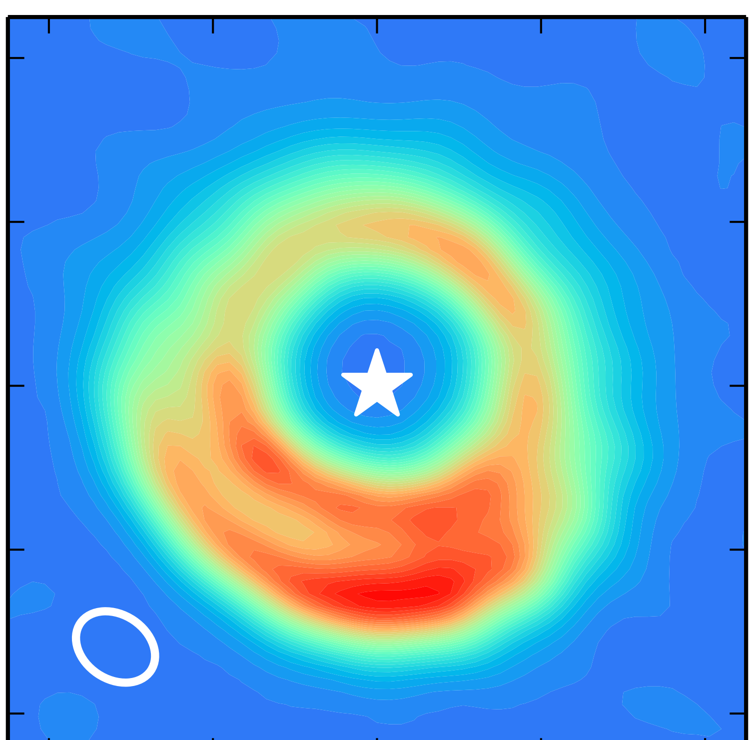
SPHERE: *0.95–2.3 μm, FWHM=37mas*

- scattered light, near-IR and visibile
- **small dust, coupled to gas**
- disc surface

(Stolker et al 2016, Maire et al 2017)

↓

- inner cavity: $R \simeq 25\,\mathrm{au}$
- m=2 spiral structure



ALMA: *Band7 (335 GHz or 896 μm) FWHM=0.20 x 0.16''*

- mm/sub-mm wavelenghts
- **dust**
- disc midplane

(van der Marel et al 2016)

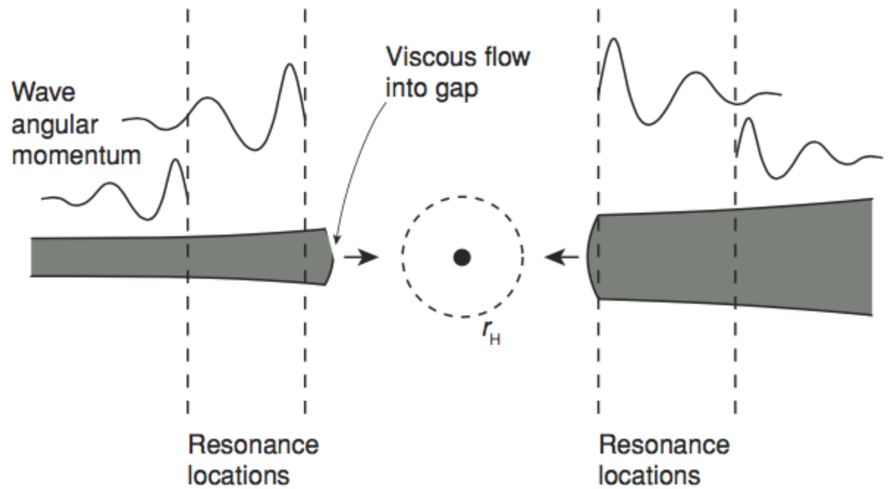
↓

- inner ring
- inner cavity: $R \simeq 40\,\mathrm{au}$
- southern overdense region

Parameter	Value
Age [Myr]	8^{+8}_{-4}
$M_\star$ $[M_\odot]$	1.7
d [pc]	156 ± 11
Disc inclination	11°
Gas Mass $[M_\odot]$	$\gtrsim 2.4 \times 10^{-}$
Dust Mass $[M_\odot]$	$\gtrsim 1.7 \times 10^{-4}$

Where is the gas mass?
Miotello et al. 2017

ONE PLANET: TWO SPIRALS!



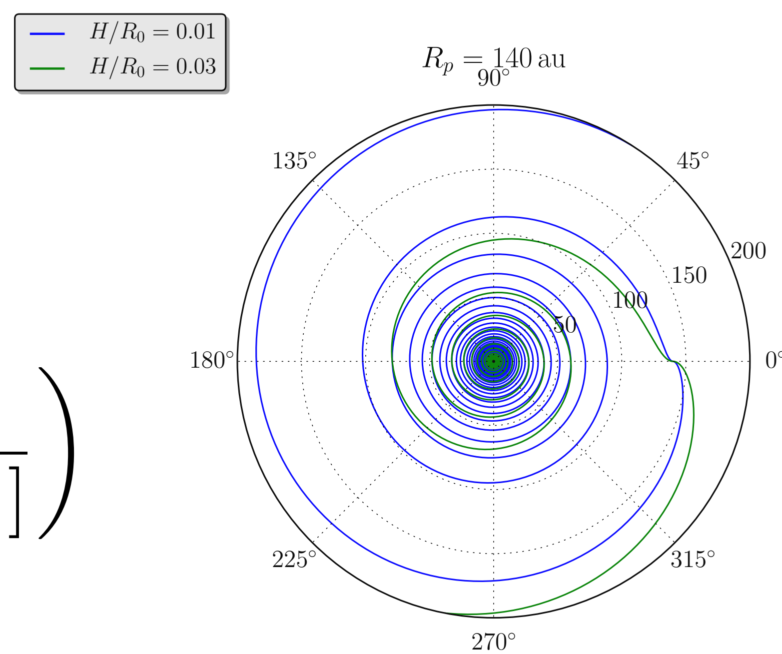
Tidal torques+viscous torques = Gap formation

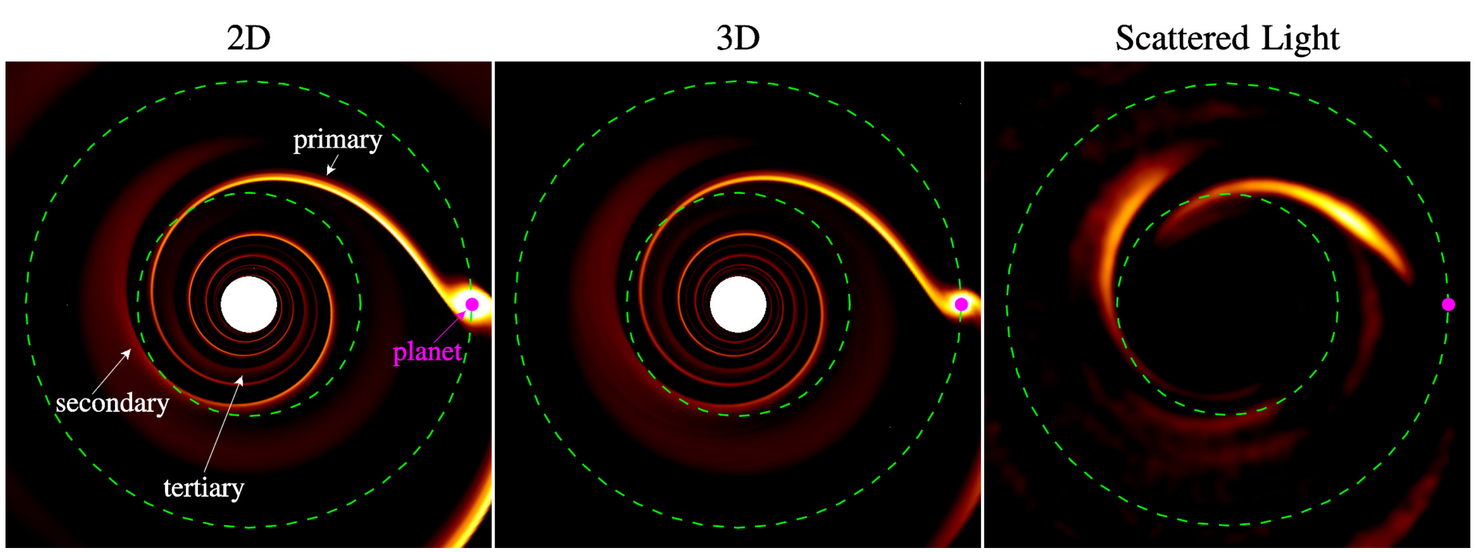
Constructive interference of density waves: SPIRAL ARMS

1) ***Linear regime***:
one planet excites one spiral arm (Rafikov 2002)

Pitch angle

$$i \approx tan^{-1}\left(\frac{c_s}{[r|\Omega_k - \Omega_p|]}\right)$$

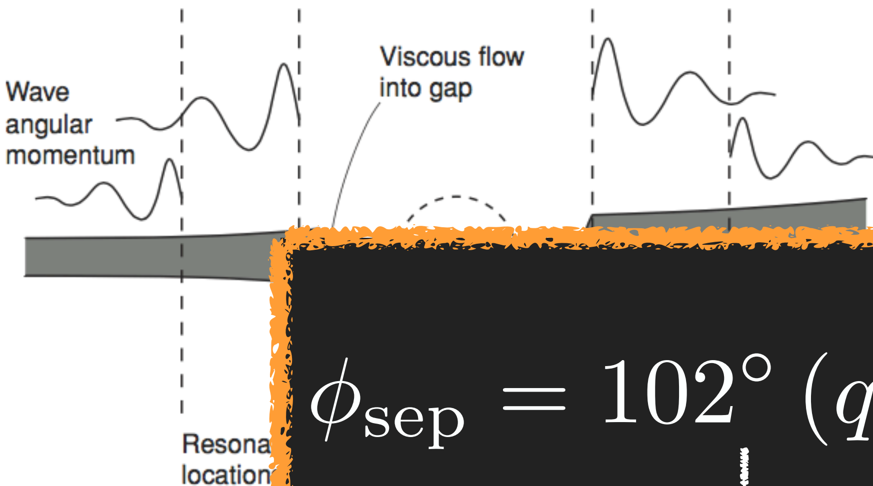




2) ***Non Linear regime***:
one planet excites $m > 2$spiral arms (Zhu et al 2015b, **Fung & Dong 2015**, Bae et al 2017), with

$$M_{\rm p} > (H/R)^3_{\rm p} M_{\star}$$

ONE PLANET: TWO SPIRALS!

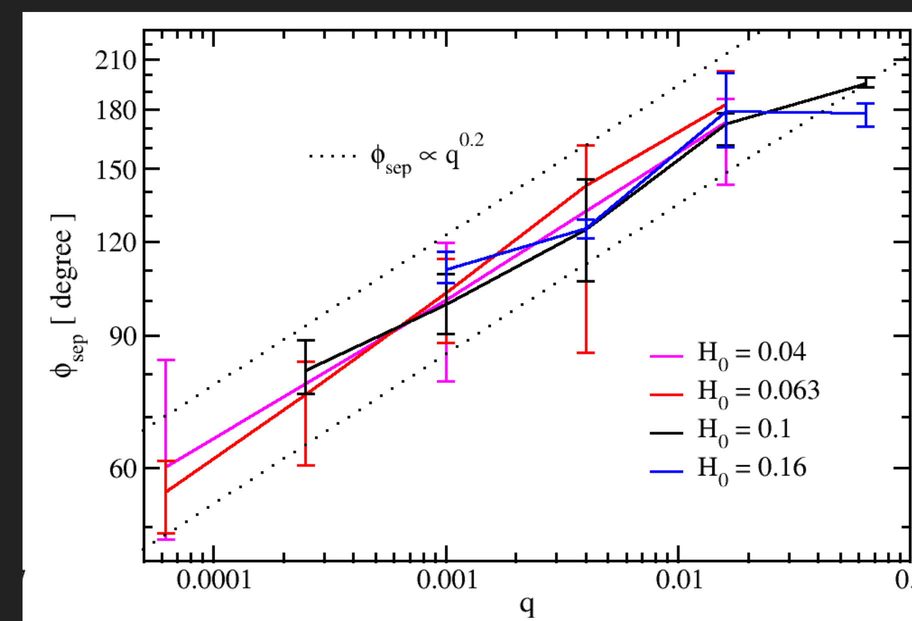


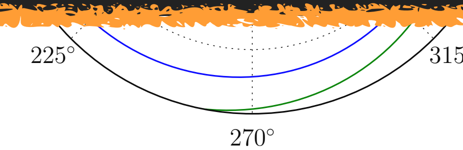
Tidal torques+viscous torques =
Gap formation

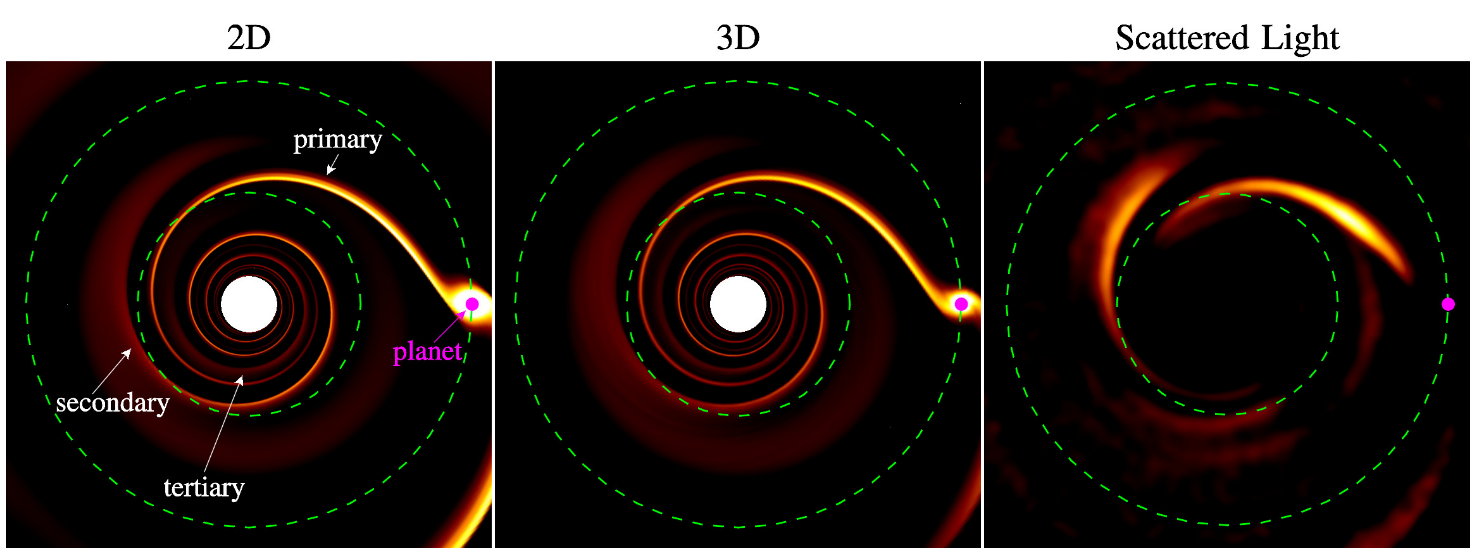
$$\phi_{\rm sep} = 102^\circ \, (q/0.001)^{0.2}$$

$$M_{\rm p} = 6\, M_j$$

30% accuracy







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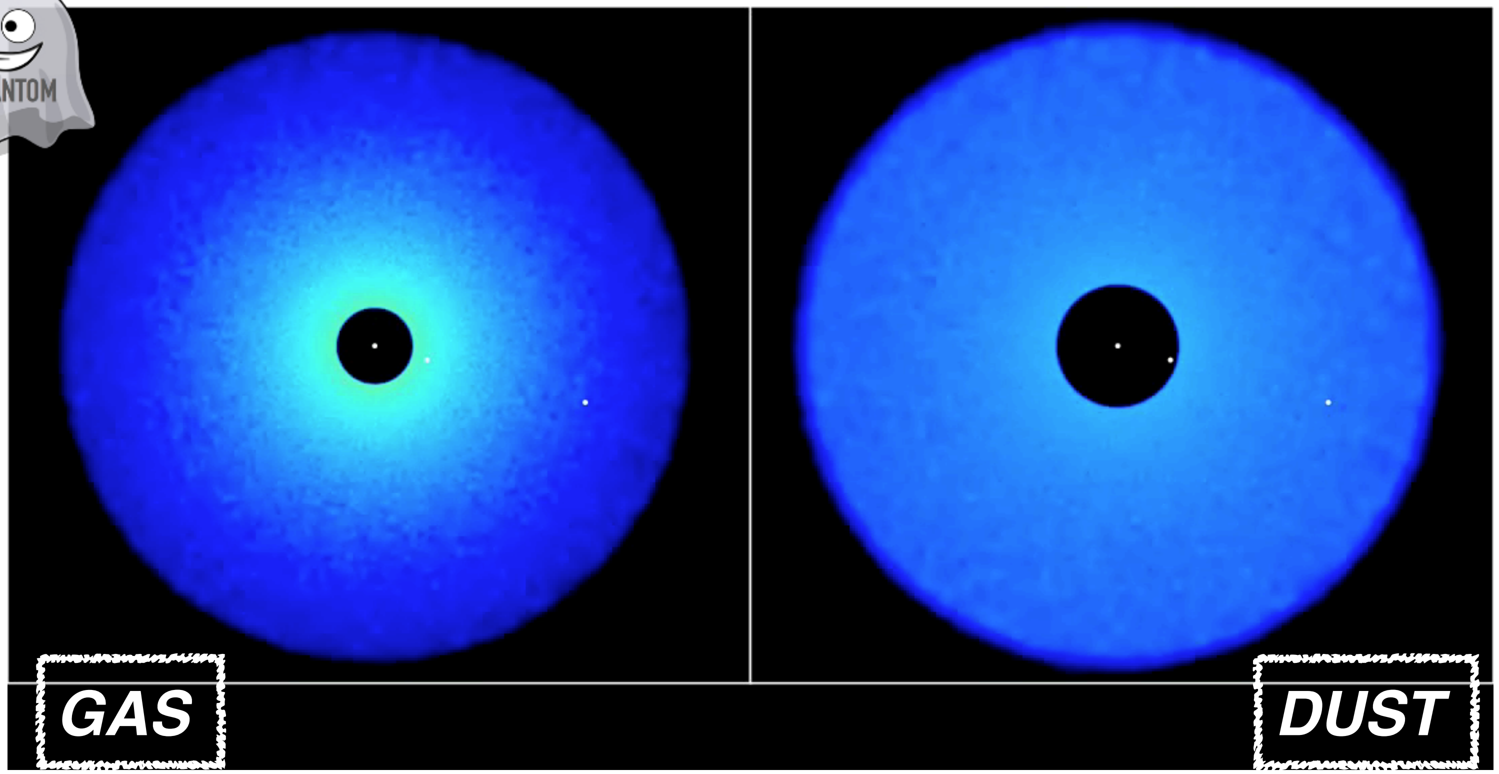
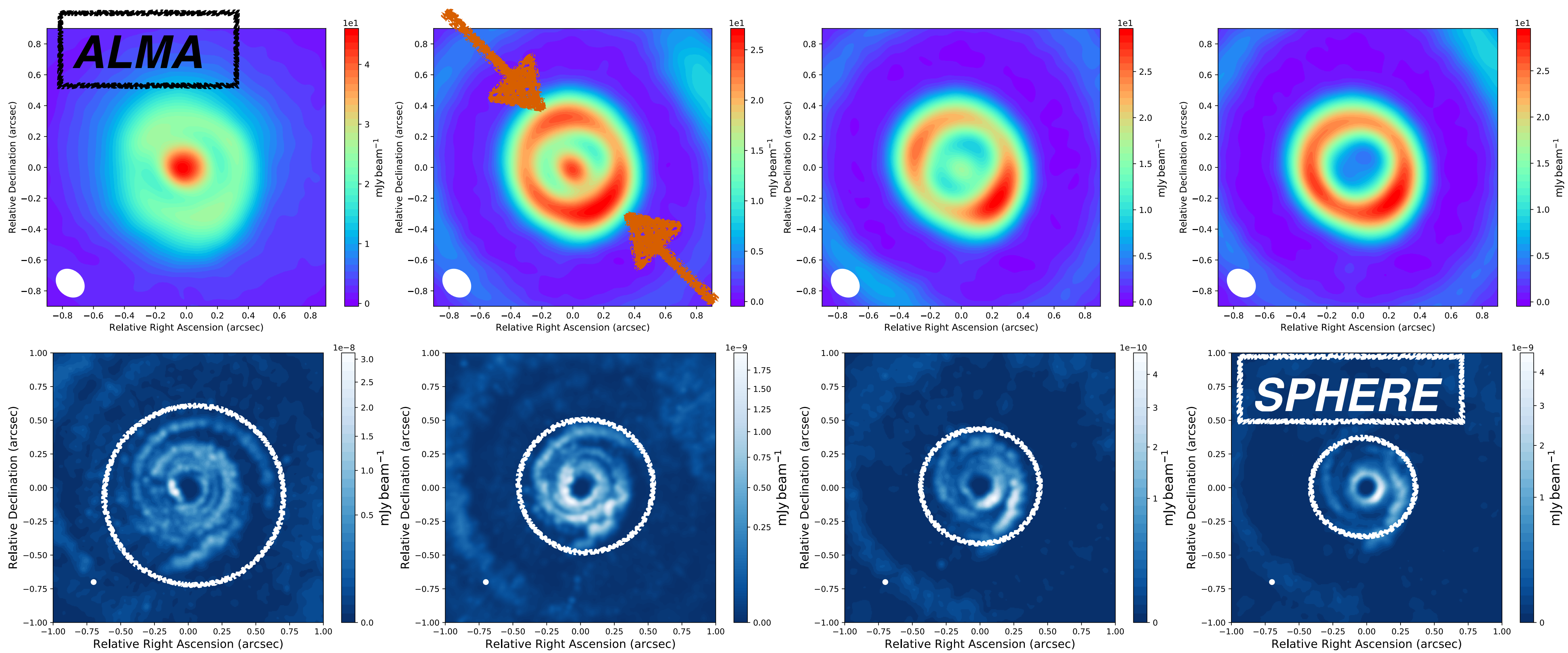
THE BEGINNING: HD135344B

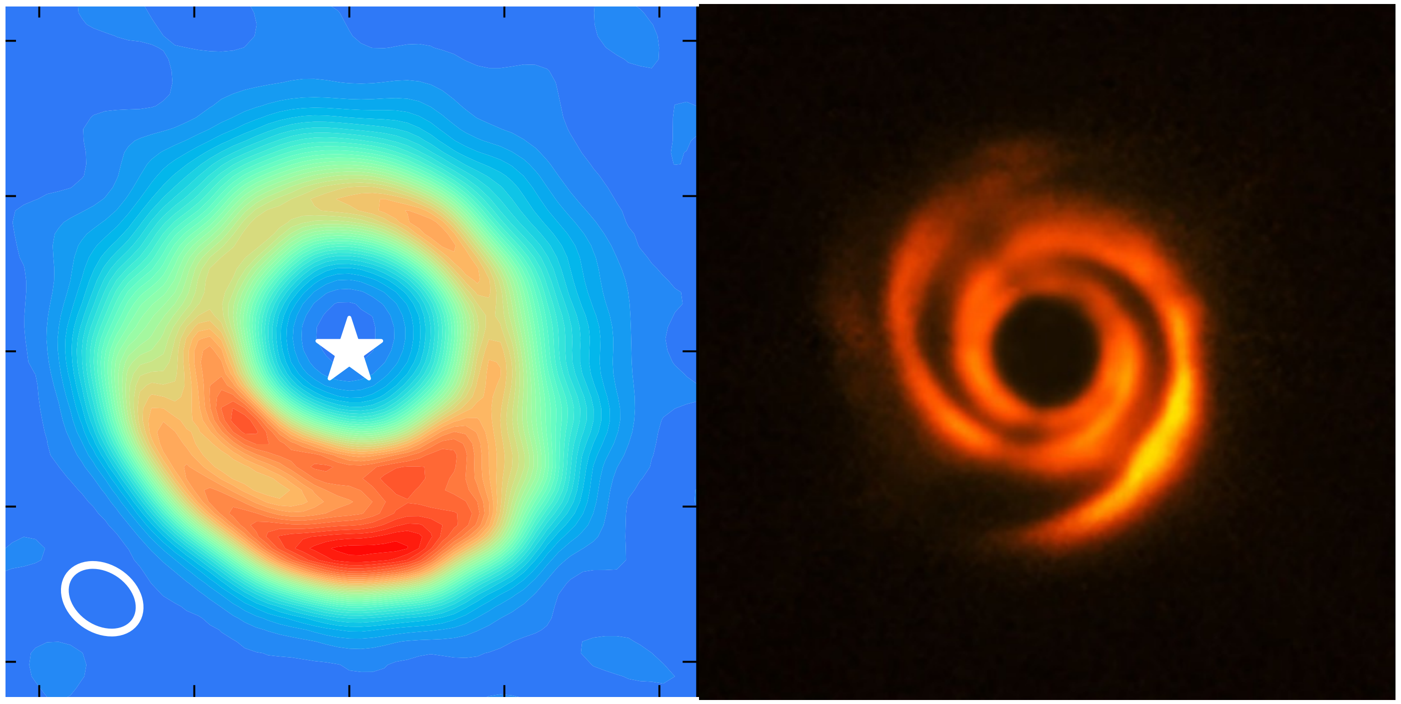


$$R_{\rm out,gas} = R_{\rm out,dust} = 200\ {\rm au}$$

Parameter	Value
$R_{\rm in,gas}$ [au]	25
$R_{\rm in,dust}$ [au]	40
$M_{\rm gas,disc}$ $[M_\odot]$	0.1
dust/gas	0.01
$(H/R)_0$ $[R_0 = 25\ {\rm au}]$	0.048
$M_{p,({\rm in,out})}$ $[M_j]$	(4,6)

MASTER THESIS RESULT



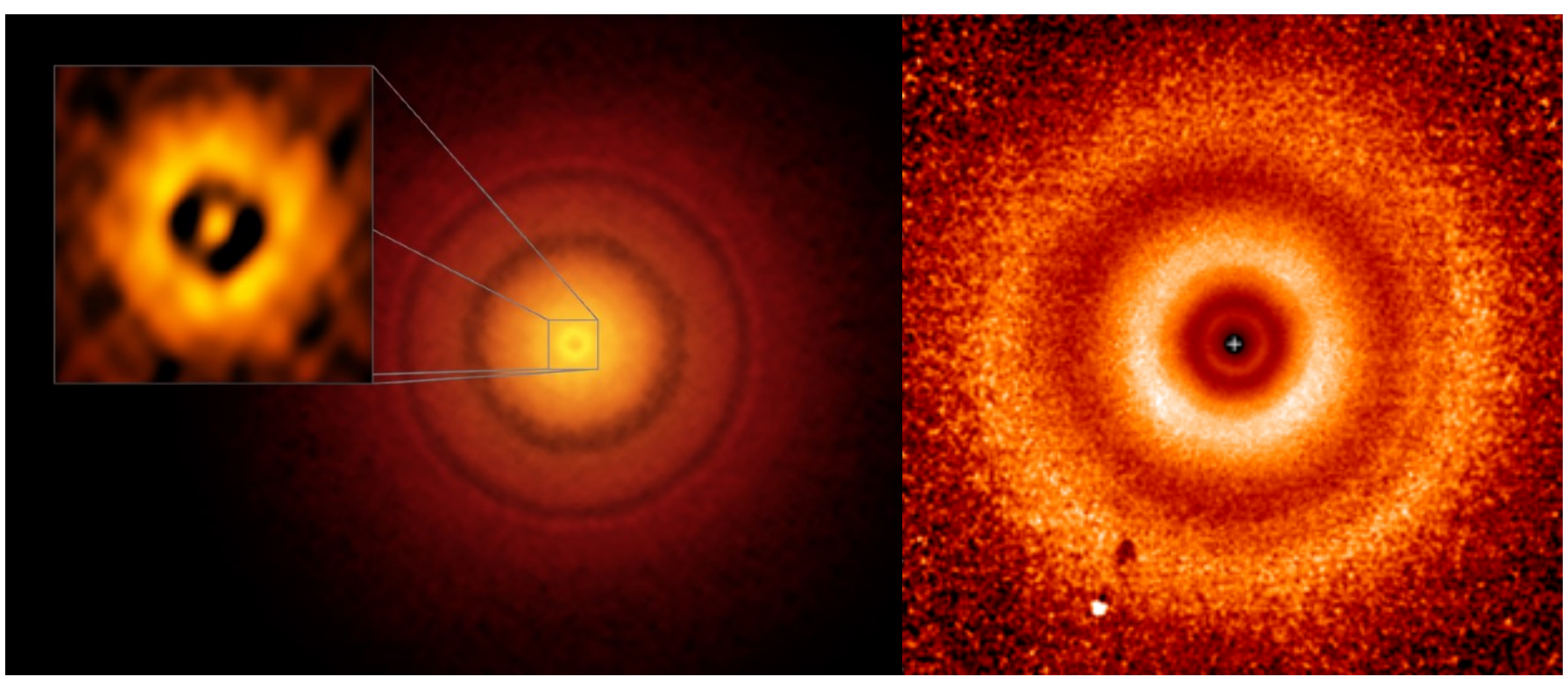


HD 135344B
Van der Marel et al. 2016
Stolker et al. 2016

ALMA & SPHERE OBSERVATIONS

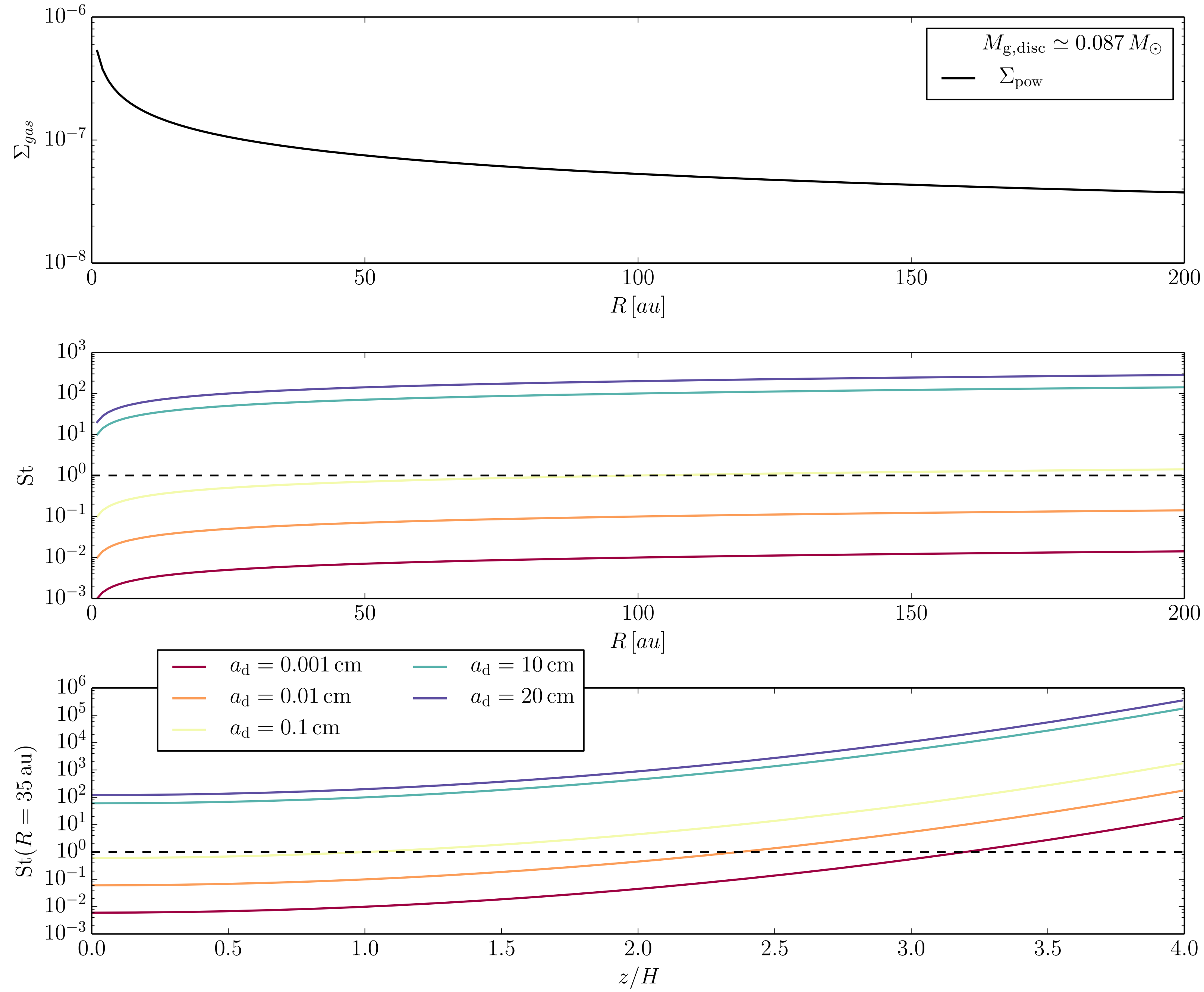
HINT ON THE GAS DISC MASS

TW Hydrae
S. Andrews, B. Saxton, ALMA (ESO/NAOJ/NRAO)
van Boekel et al. 2017

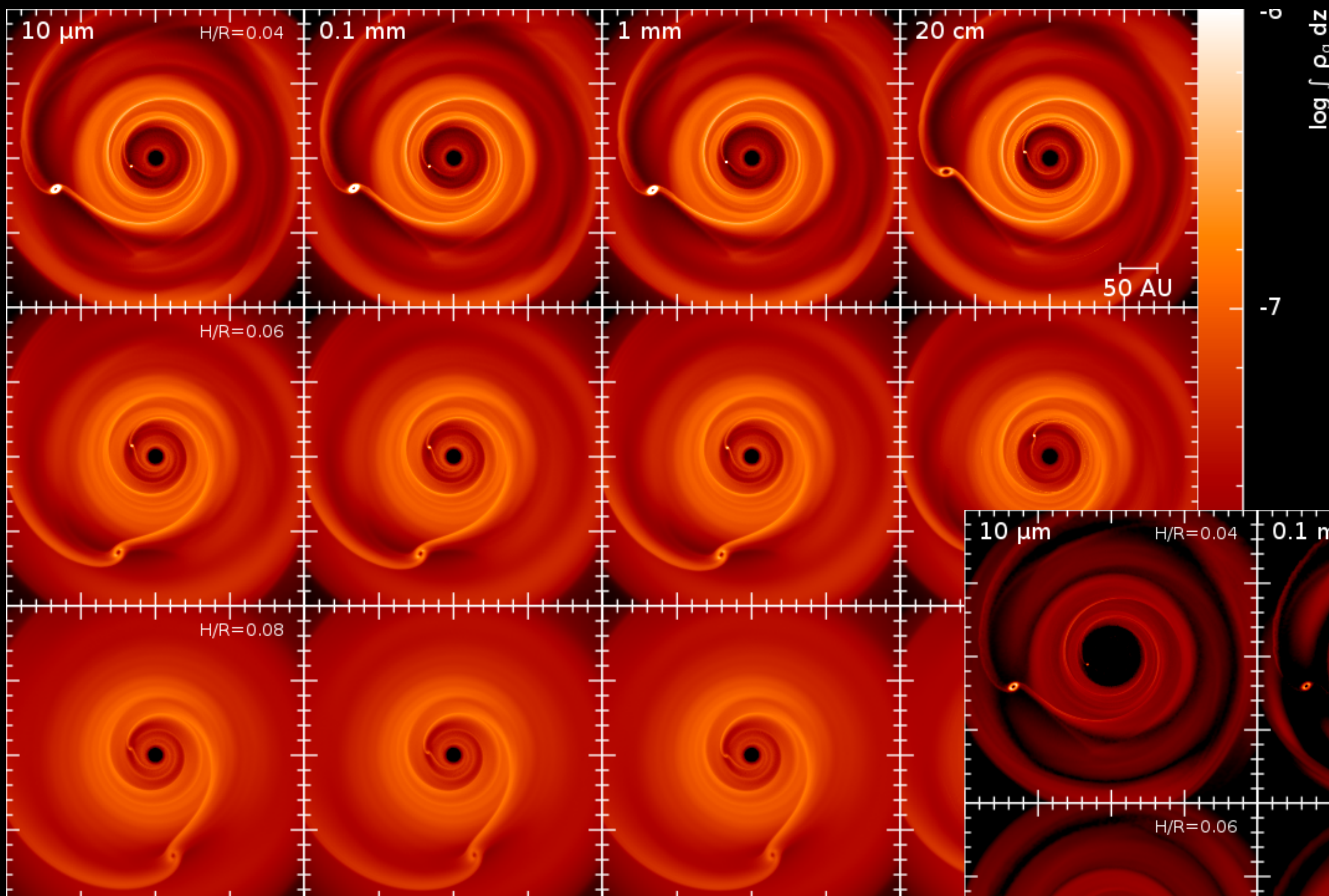


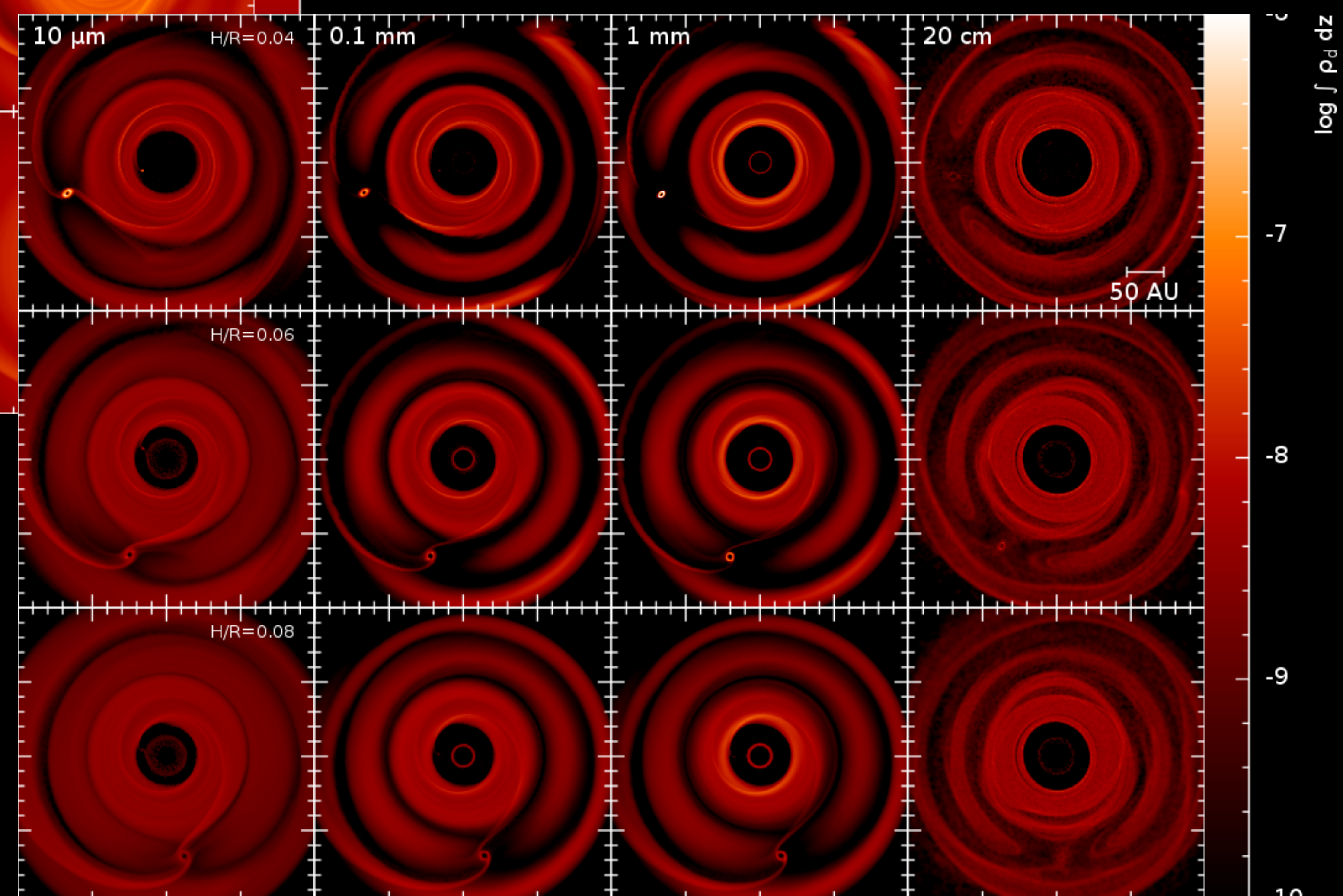
DUSTYDISC SETUP

- Different gas disc masses → in SPH different grain size → St !!
- One fluid + Two fluids
- 2 planets: $M_p \simeq 3 - 5\, M_j$ first idea: to model HD135344B
- Power-law density profile (both dust and gas)



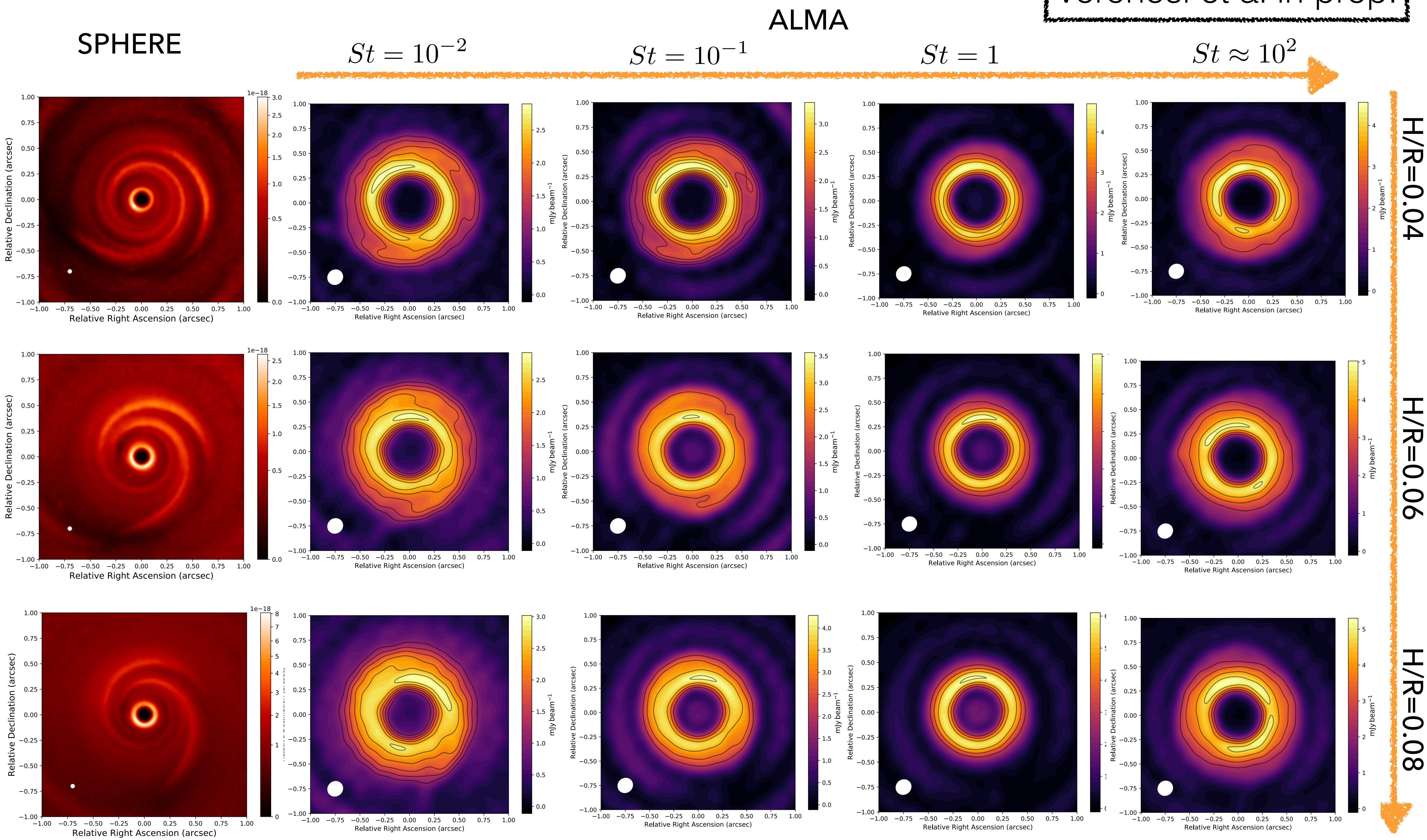
DENSITY MAPS…





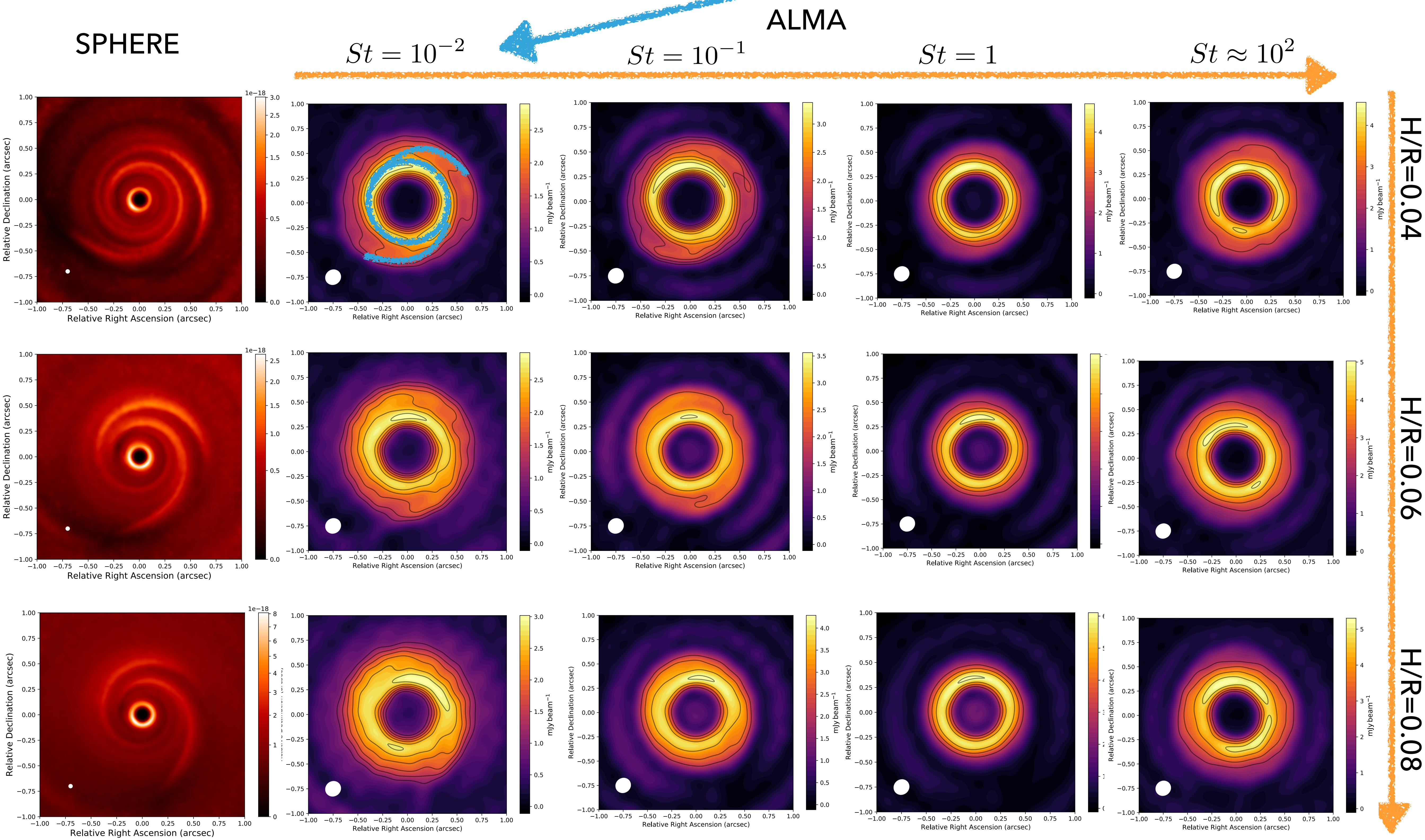
...AND (PRELIMINARY) MOCK IMAGES

Veronesi et al in prep.



…AND (PRELIMINARY) MOCK IMAGES

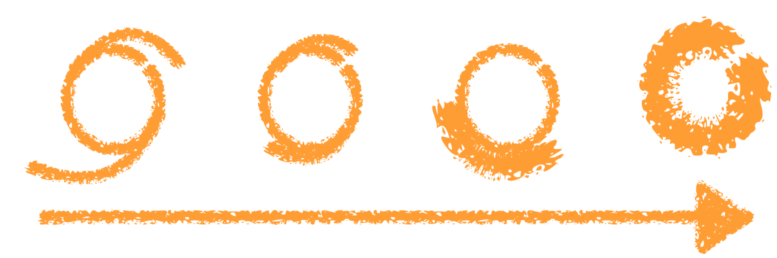
SPIRALS!



TAKE HOME MESSAGES

- Different Stokes number are observable through ALMA and SPHERE images;
- The more coupled the dust and the gas, the more asymmetric are the structures → **spirals** both in ALMA and SPHERE images;
- Given the observed grain size, the sub-structures in the ALMA image compared to the ones in the SPHERE image can give us an **hint on the gas disc mass** (see St definition).

+ Miotello's talk



IN PROGRESS + TO DO

- Try with different q for the grain size distribution;
- Check the temperature map + optical depth → are the spirals a density or temperature perturbation? Both?

MULTIGRAIN in PHANTOM!

THANKS FOR THE ATTENTION!

QUESTIONS HAVE YOU DO?

HMMMM!