COUPLED OR NOT COUPLED, THAT IS THE QUESTION

AN IDEA TO INFER THE GAS DISC MASS

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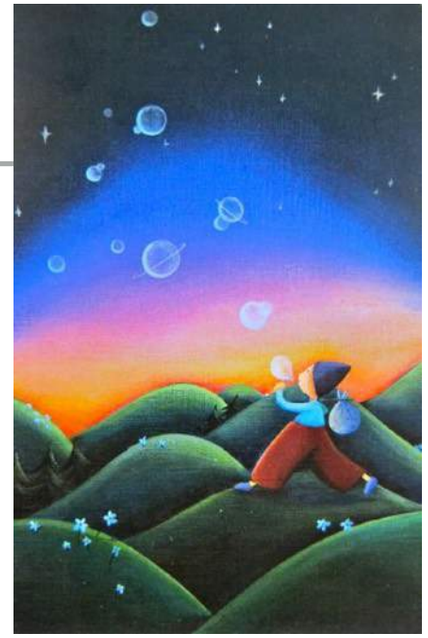
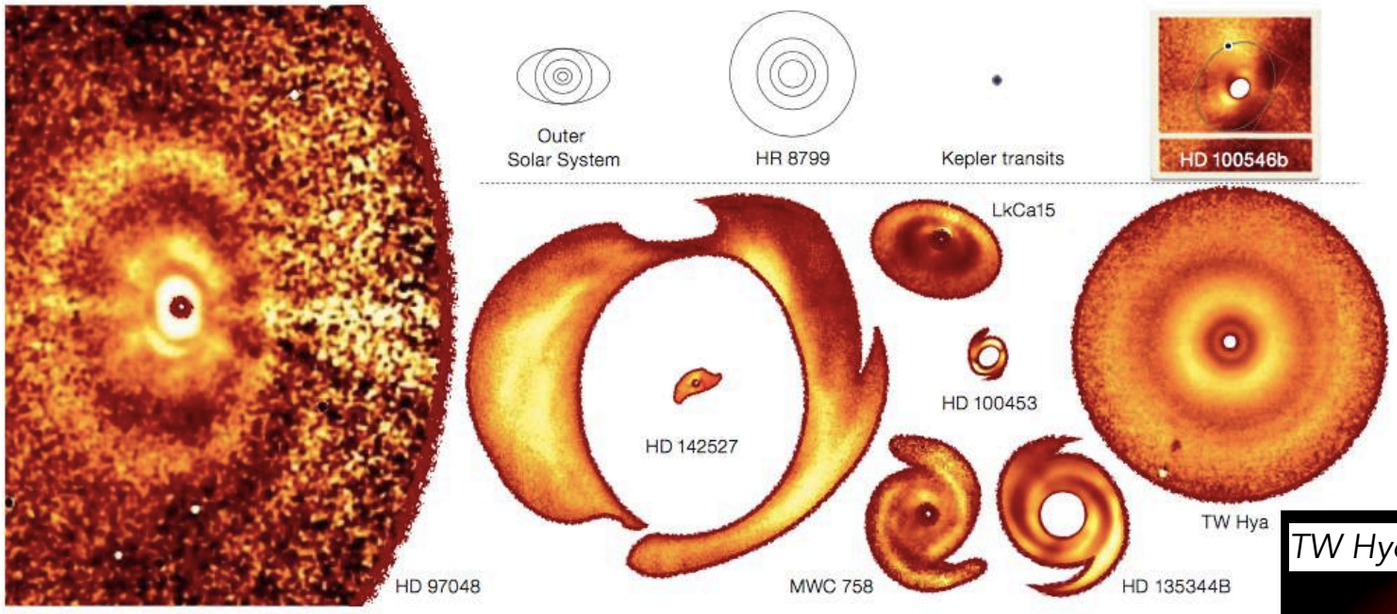
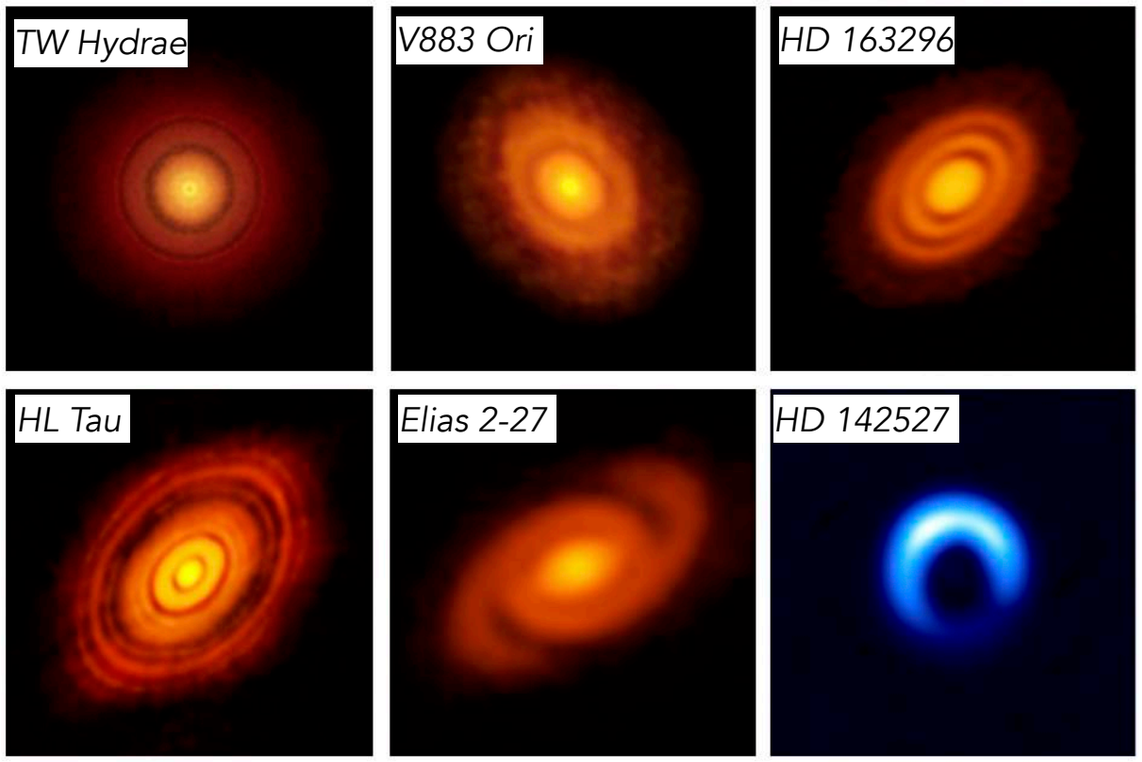
WHAT WE NEED: A THEORY ON PLANET FORMATION





Garufi et al. ESO Messenger

Andrews; ALMA (ESO/NAOJ/NRAO)



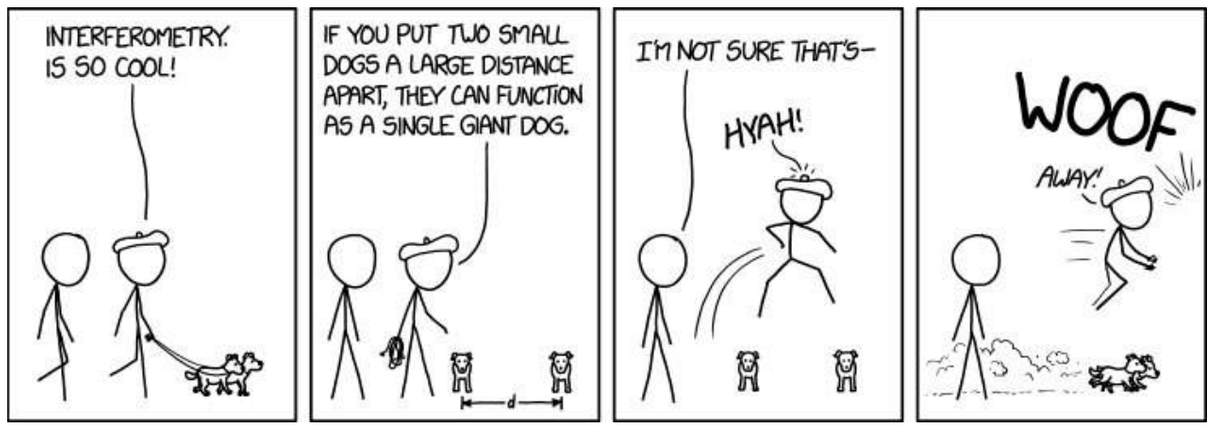
dust and gas interaction **+** planet and disc interaction **+** **?** **=** Spirals, gaps, horseshoes…

WHAT WE HAVE:

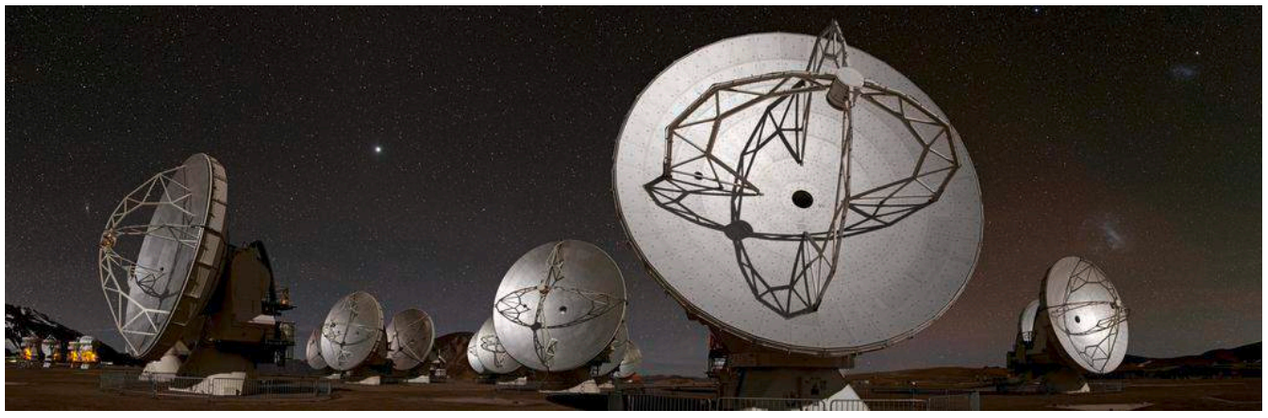
Telescopes:
ALMA (RADIO) and **SPHERE** (near-IR) high resolution images of protoplanetary discs

New powerful and fast computational tools:

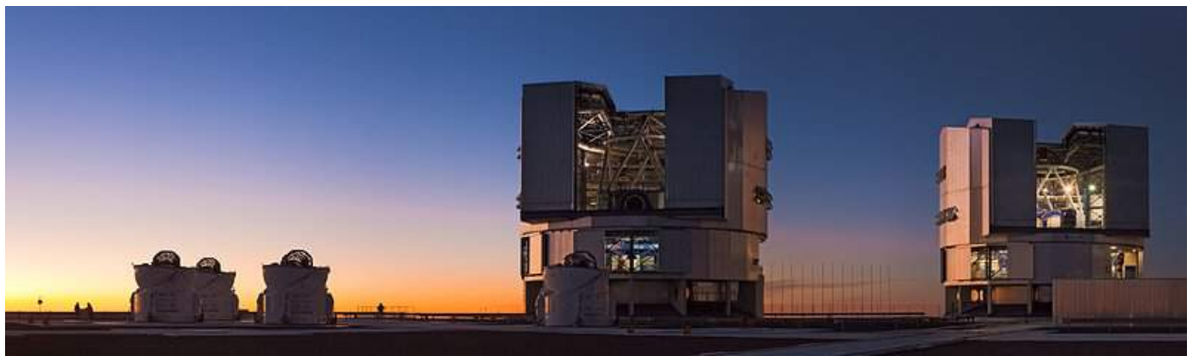
1. **S**moothed **P**article **H**ydrodynamics codes (**PHANTOM** - Price et al, 2017);
2. MonteCarlo Radiative transport codes (**RADMC-3D** - Dullemond et al, 2012; **MCFOST** - Pinte et al, 2006).



ALMA: Atacama Large Millimeter/submillimeter Array

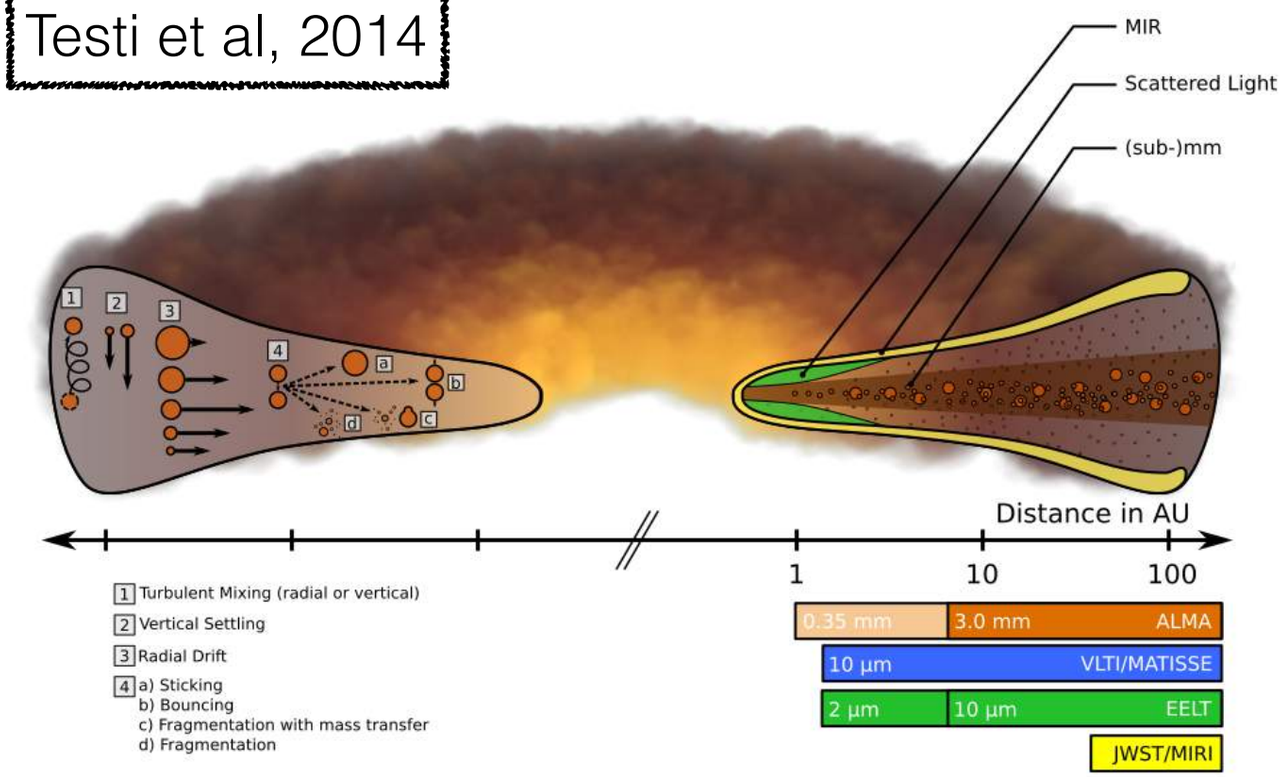


SPHERE at the Very Large Telescope



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

$$St = t_{\rm s}\Omega \approx \frac{\rho_{\rm d} a}{\Sigma_{\rm g}}$$

COUPLED

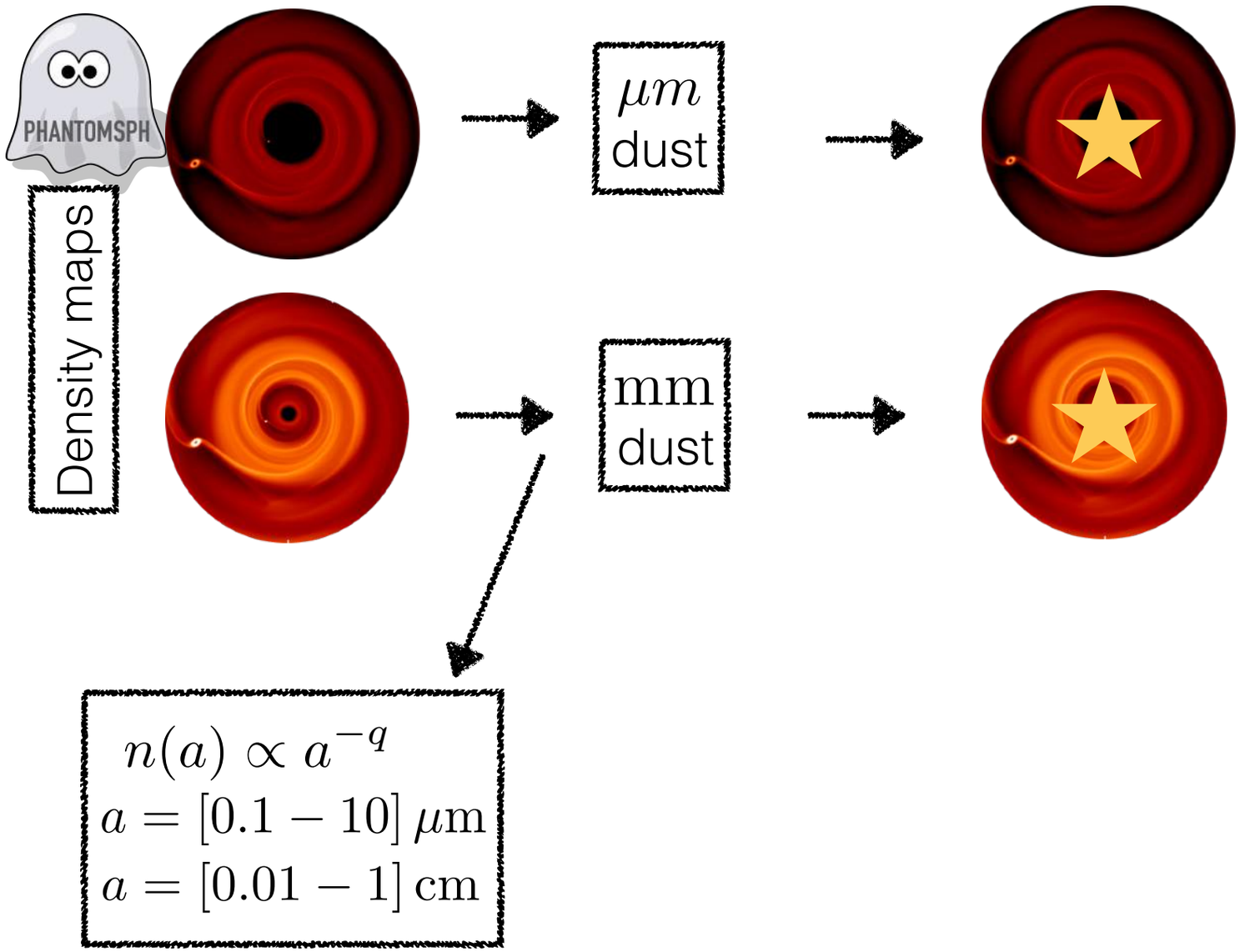
$$St \ll 1$$

NOT COUPLED

$$St \gg 1$$

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

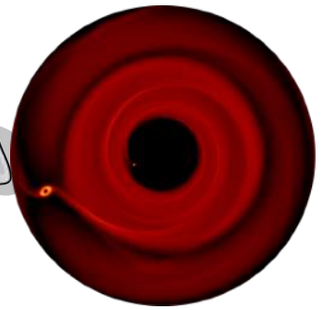
FROM PHANTOM TO RADMC-3D

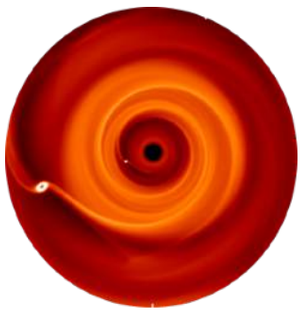


FROM PHANTOM TO RADMC-3D

PHANTOMSPH

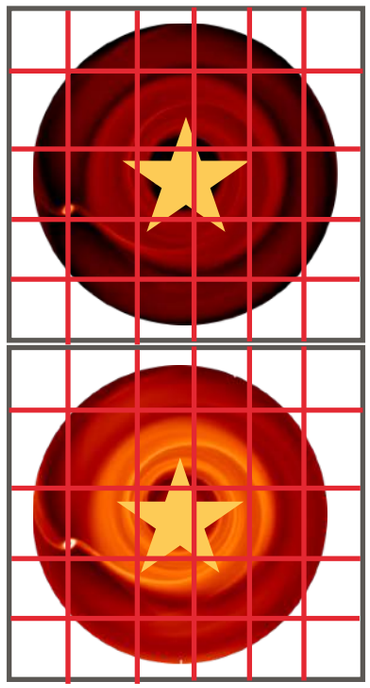
Density maps

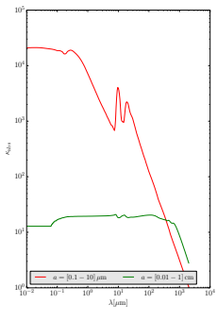


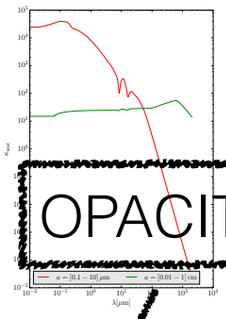


μm dust

mm dust







OPACITIES

DiscAnalysis DIANA just before the planets form

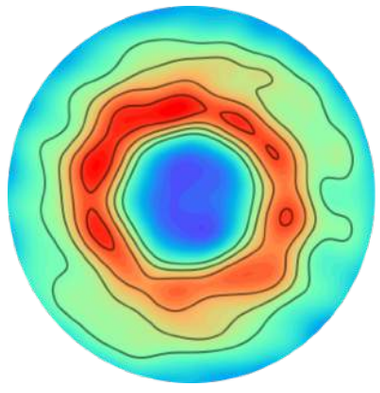
RADMC-3D

TEMPERATURE MAP

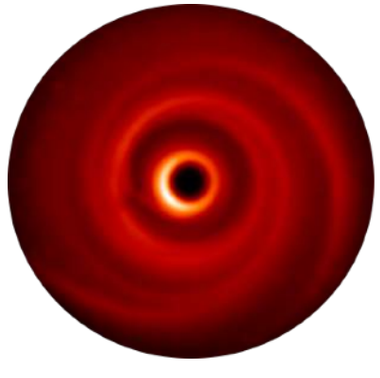
SYNTHETIC IMAGE!

CASA Common Astronomy Software Applications

ALMA

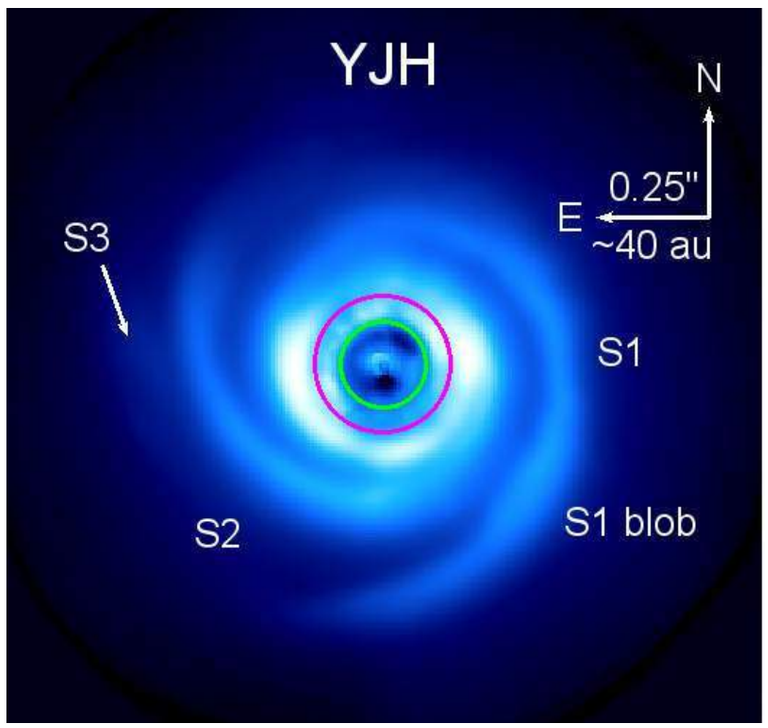


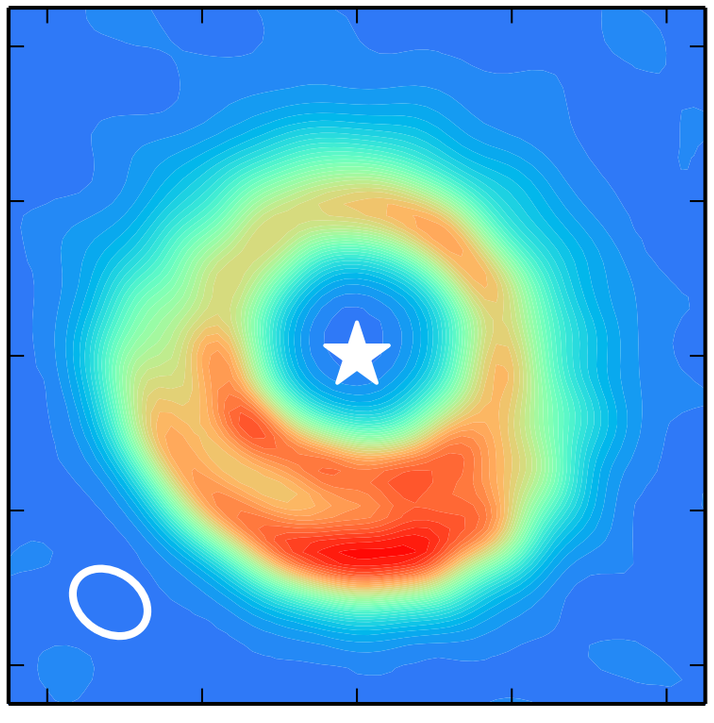
SPHERE



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

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

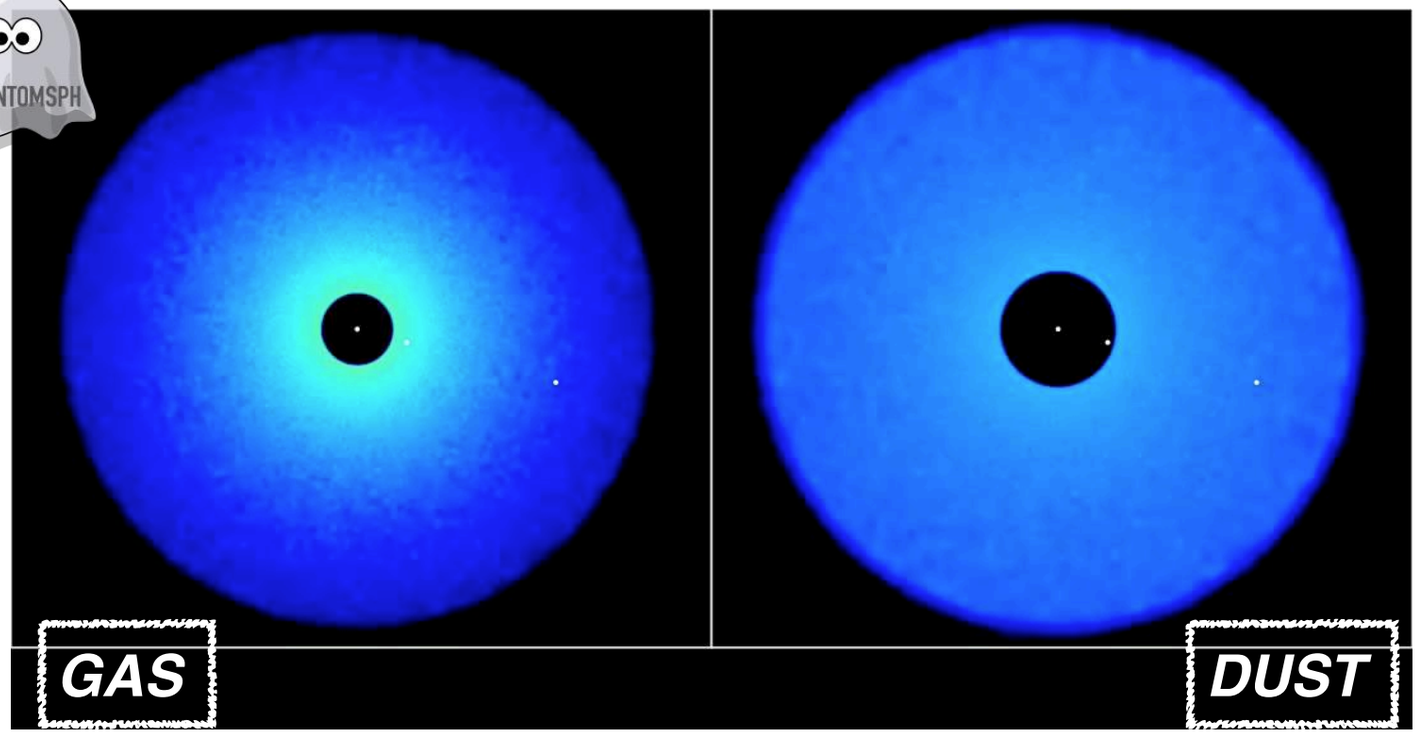
(van der Marel et al 2016)

- 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 $[M_\odot]$	$\gtrsim 2.4 \times 10^{-2}$
Dust Mass $[M_\odot]$	$\gtrsim 1.7 \times 10^{-4}$

Miotello et al. 2017

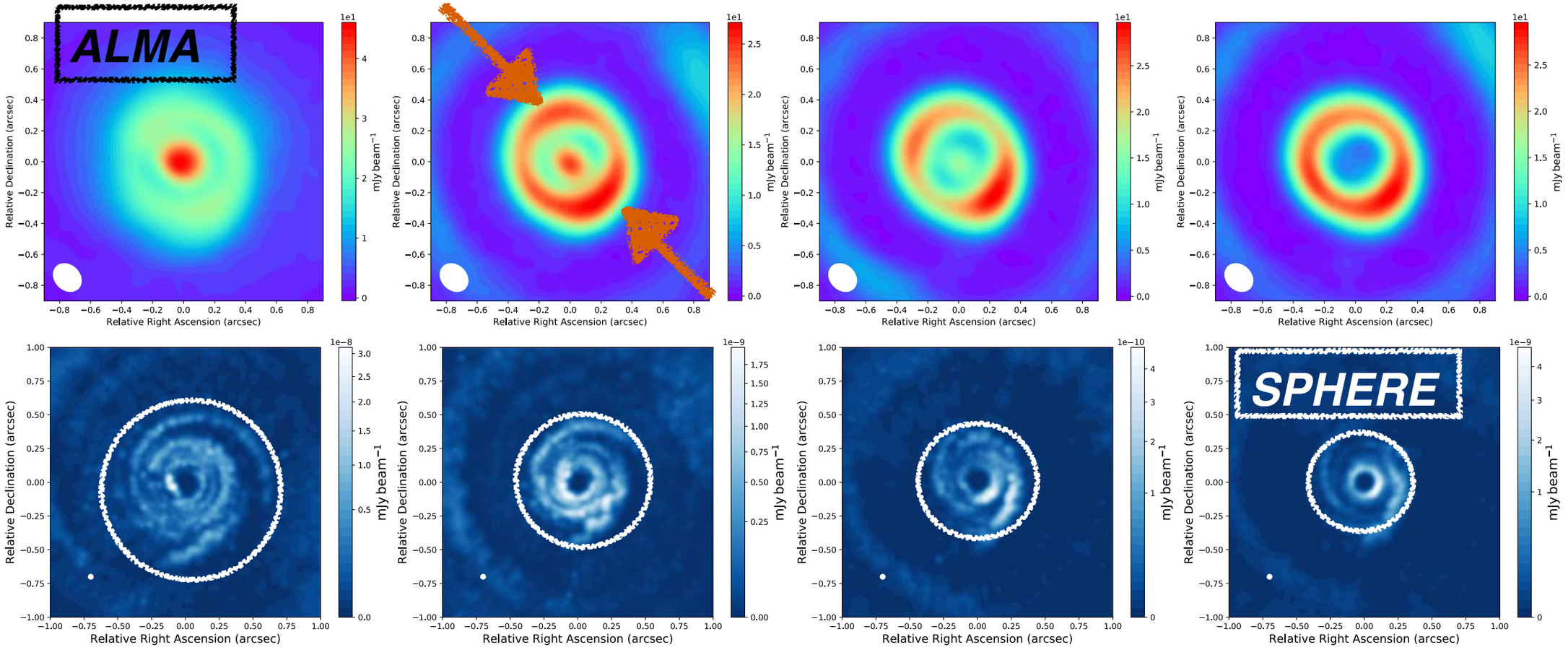
THE BEGINNING: HD135344B

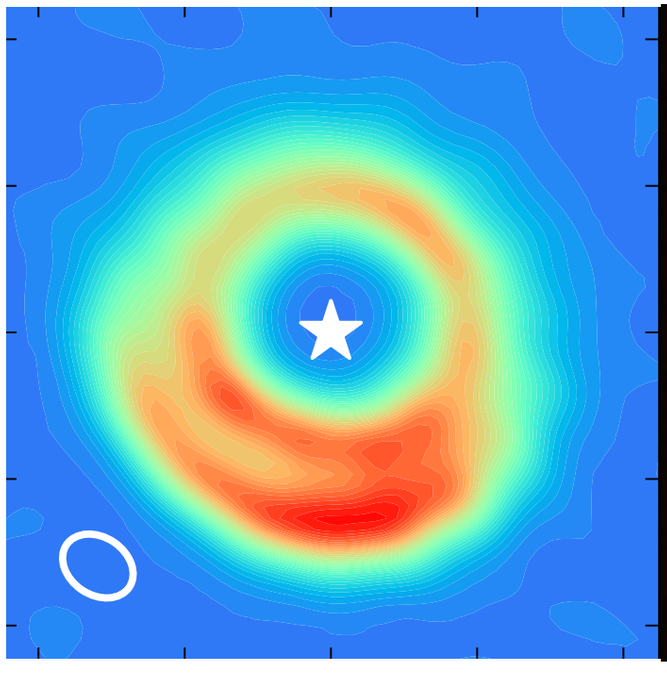


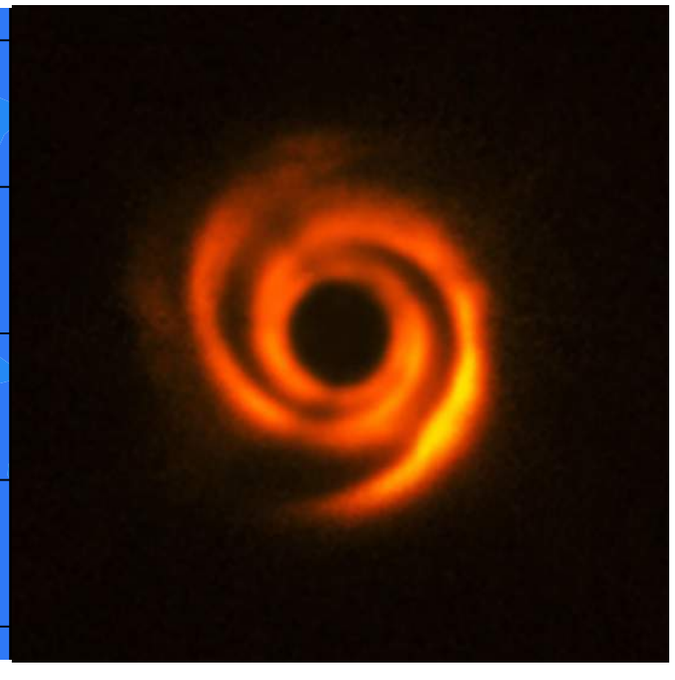
$R_{\mathrm{out,gas}} = R_{\mathrm{out,dust}} = 200\,\mathrm{au}$

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

MASTER THESIS RESULT





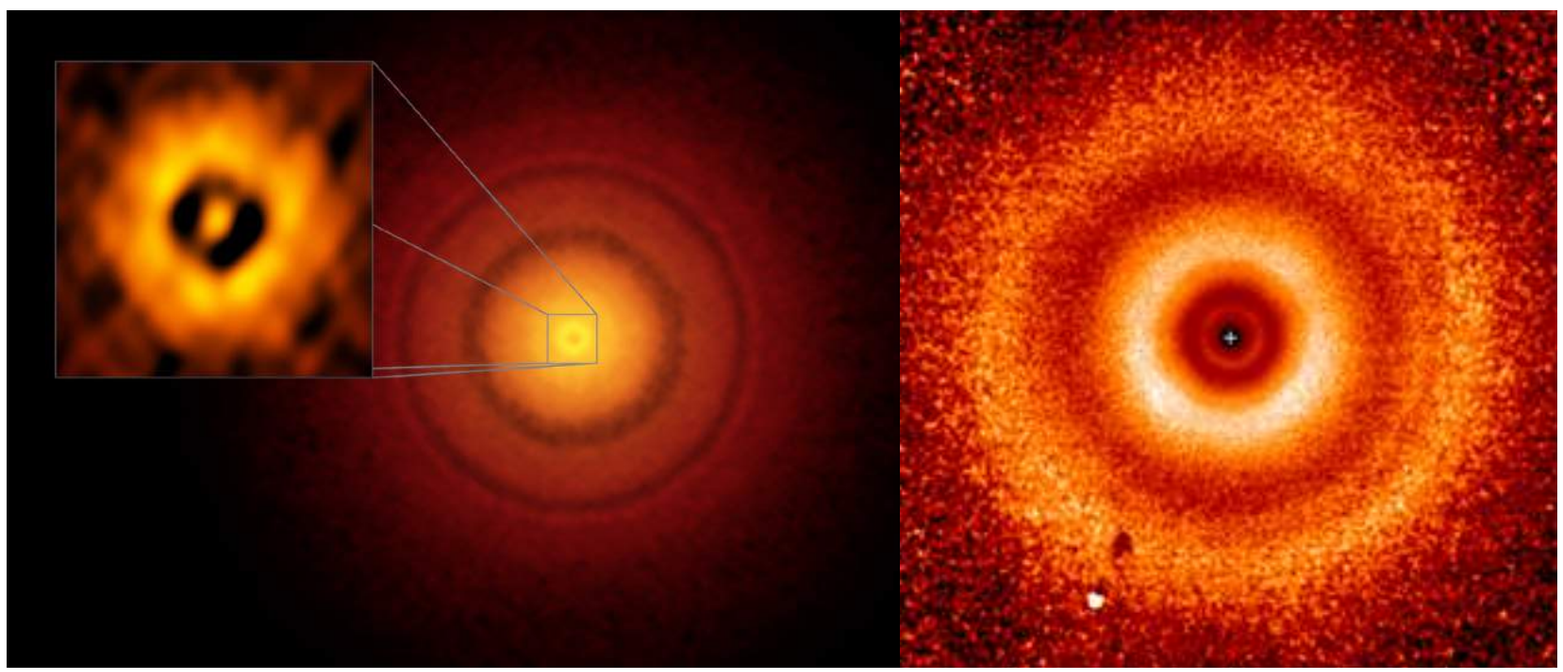


HD 135344B
Van der Marel et al. 2016
Stolker et al. 2016

ALMA & SPHERE OBSERVATIONS

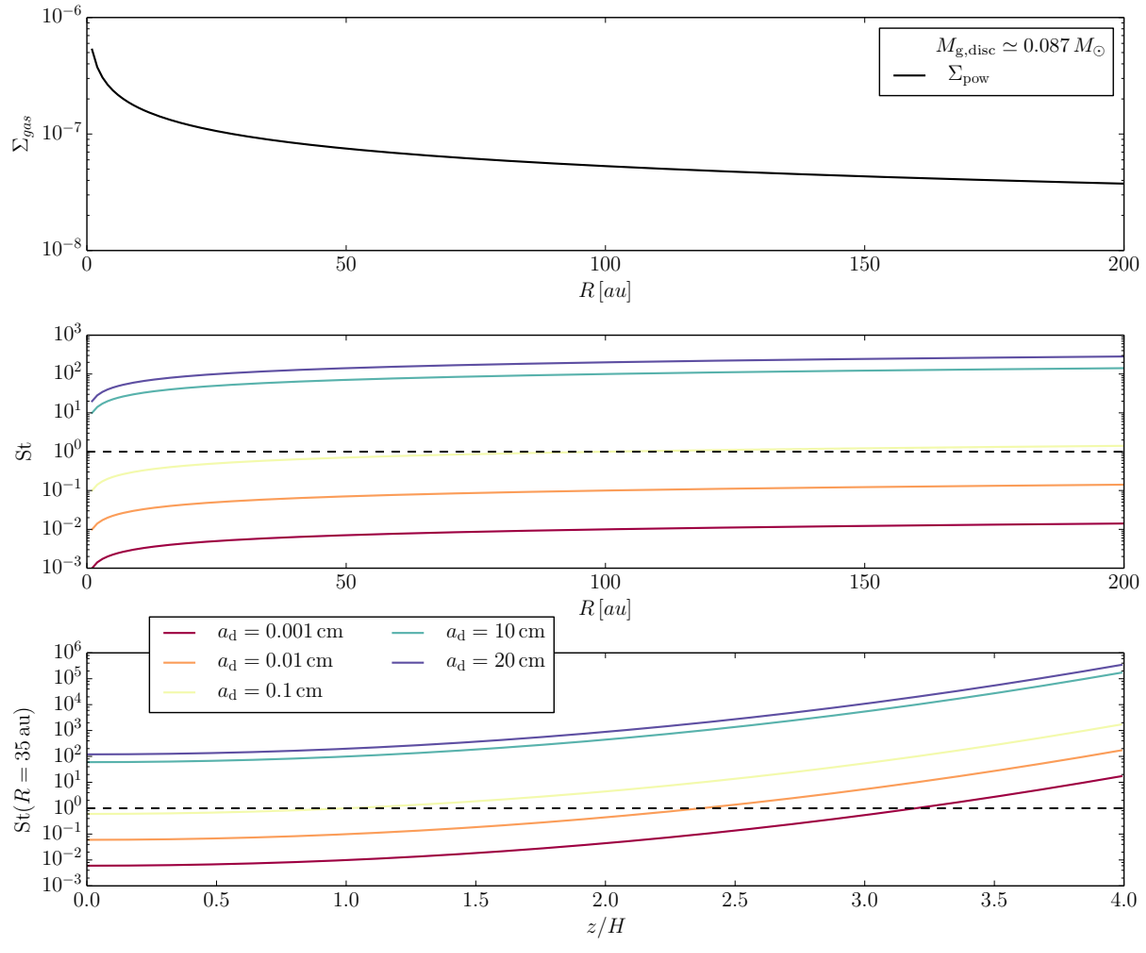
HINT ON THE GAS DISC MASS

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

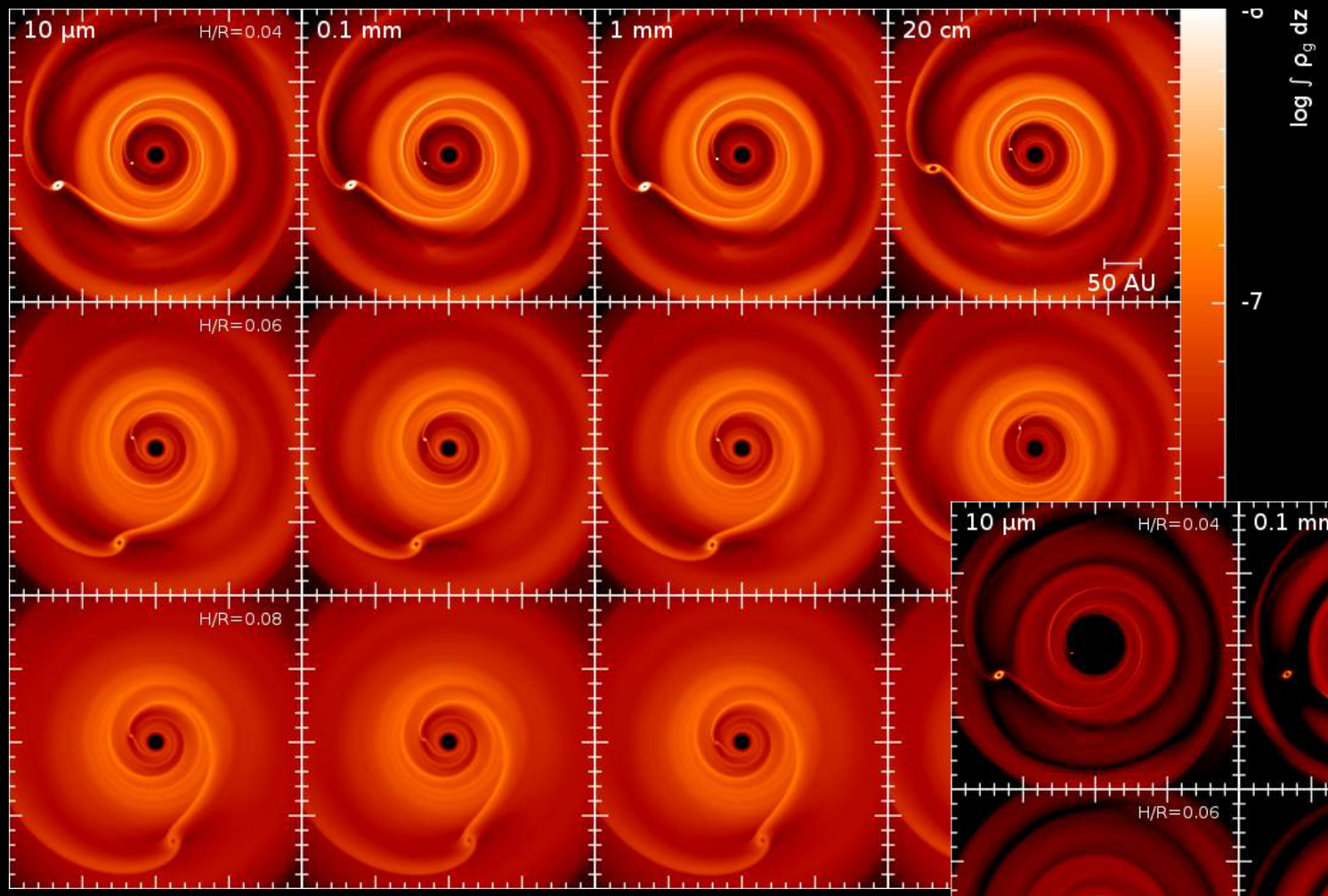


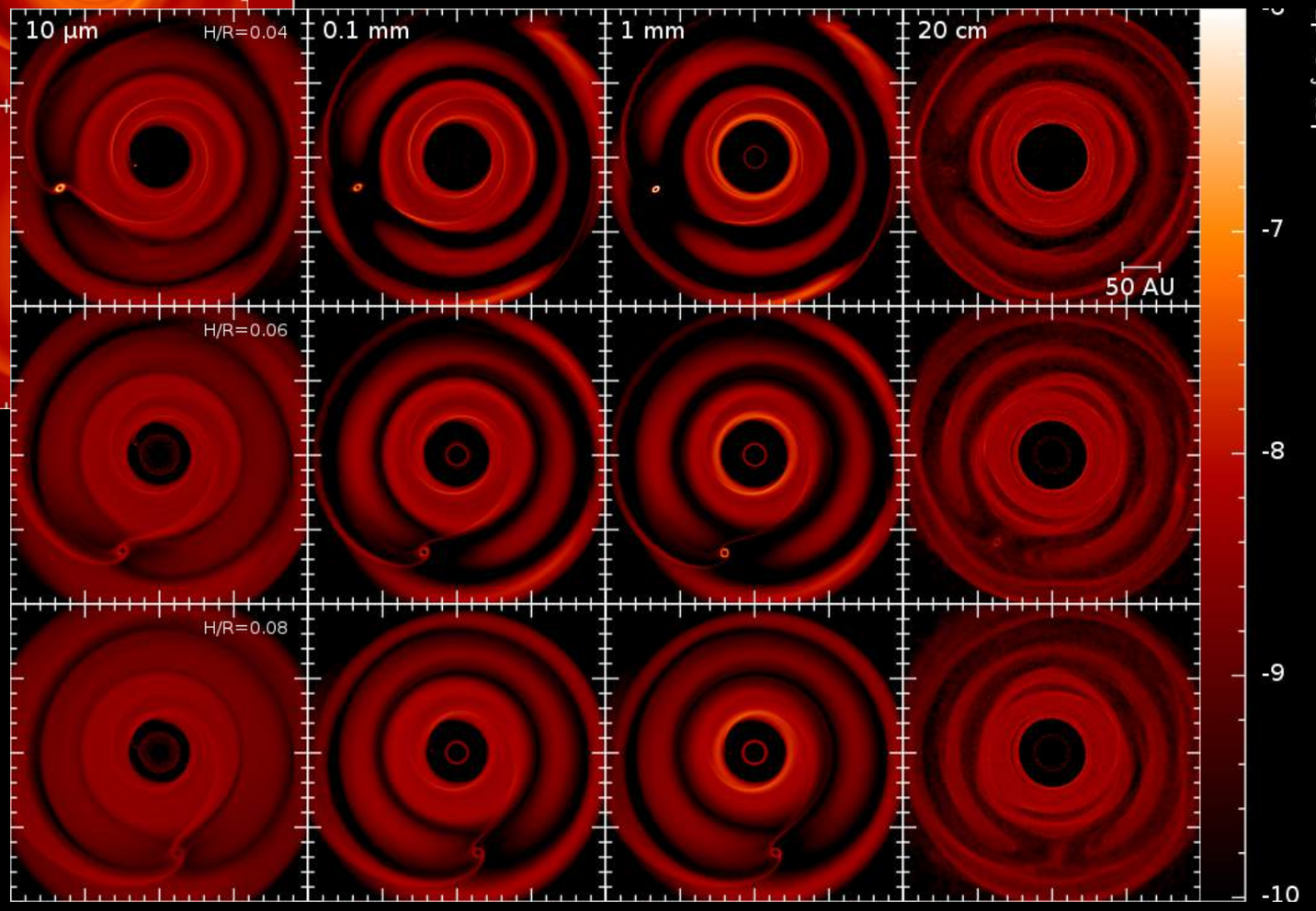
DUSTYDISC SETUP

- 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 was to model HD135344B
- Power-law density profile (both dust and gas)



DENSITY MAPS...





...AND (PRELIMINARY) MOCK IMAGES

SPHERE

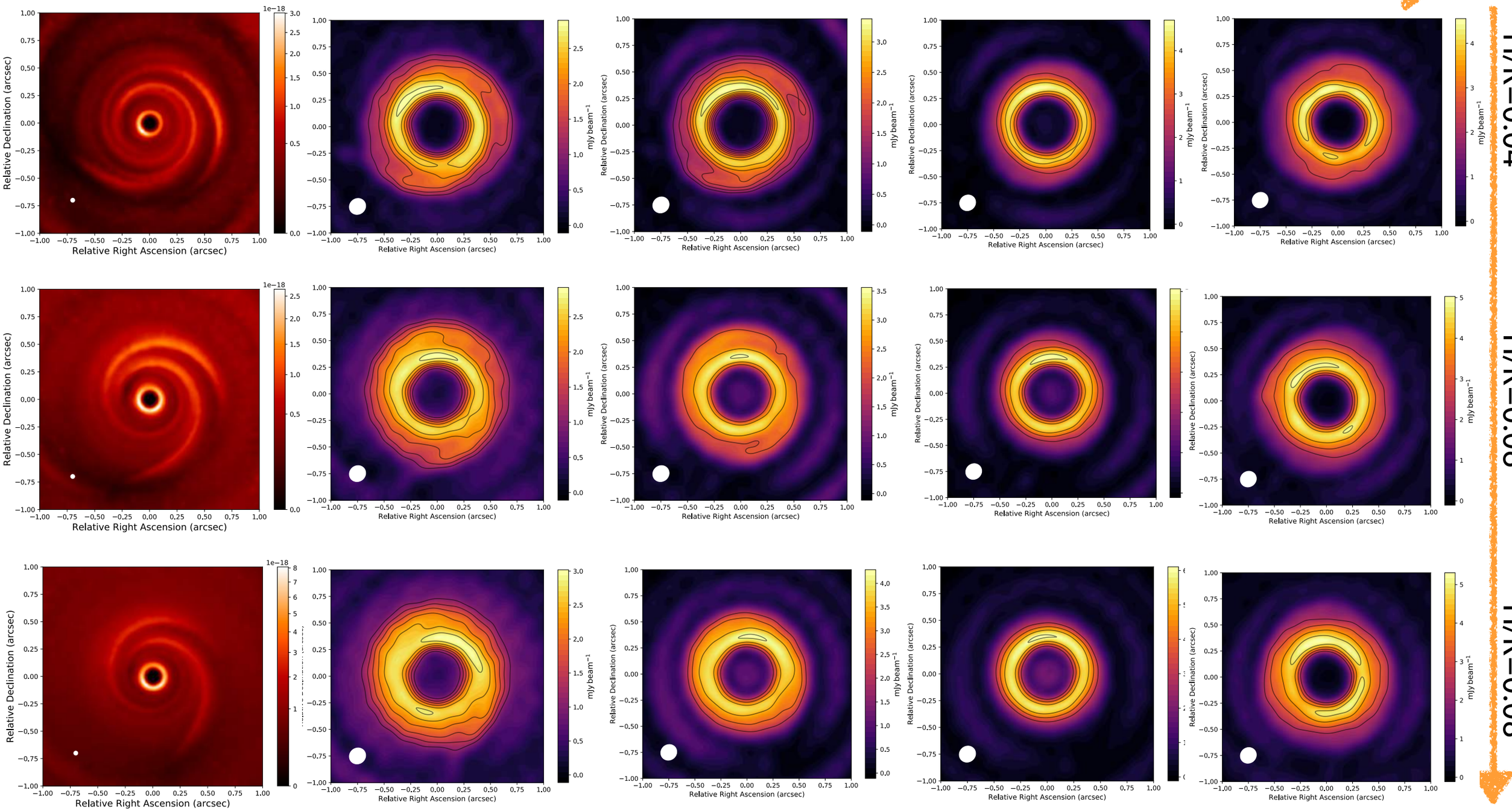
ALMA

$St = 10^{-2}$ $St = 10^{-1}$ $St = 1$ $St \approx 10^{2}$

H/R=0.04

H/R=0.06

H/R=0.08



...AND (PRELIMINARY) MOCK IMAGES

SPIRALS!

SPHERE

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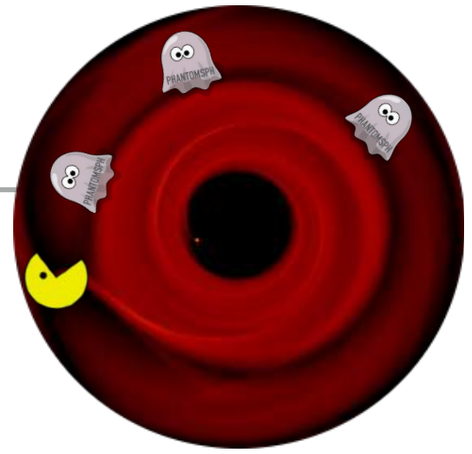

TAKE HOME MESSAGES

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

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?
- Put in a more quantitative way the relation between the Stokes number and the (ALMA-SPHERE) residuals.

MULTIGRAIN+MCFOST!!

THANKS FOR THE ATTENTION!
QUESTIONS?