Detecting young (giant) planets in circumstellar disks

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Hydrodynamic & radiative transfer setup

(Mignone et al. 2007, Uribe et al. 2011, Ruge et al. 2013)

Central star

$$L = 0.35 \ldots 43\, L_\odot \qquad M_\star = 0.7 \ldots 2.5\, \mathrm{M}_\odot$$

$$T = 4000 \ldots 9500\, \mathrm{K}$$

Planet

$$L = 10^{-4}\, \mathrm{L}_\odot \qquad T = 1000\, \mathrm{K} \qquad M_\mathrm{P}/\mathrm{M}_\star = 10^{-3}$$

Scale free simulations

$$R_\mathrm{in} = 2 \ldots 50\, \mathrm{AU}$$

$$R_\mathrm{pla} = 5 \ldots 125\, \mathrm{AU}$$

$$R_\mathrm{out} = 9 \ldots 225\, \mathrm{AU}$$

Disk setup

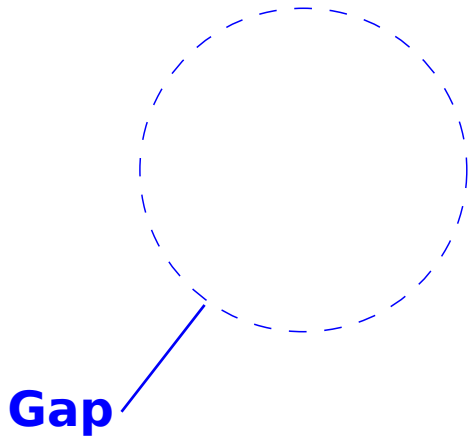
$$M_\mathrm{disk} \sim 10^{-6 \cdots -2}\, \mathrm{M}_\odot \qquad (M_\mathrm{dust}/\mathrm{M}_\mathrm{gas} = 1/100)$$

$$d = 140\, \mathrm{pc}$$

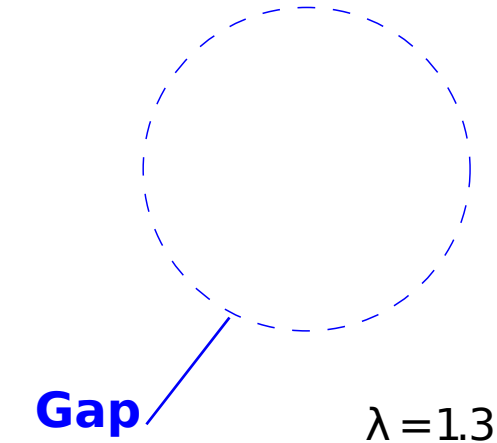
$$\lambda_\mathrm{scat} = 1 \ldots 5 \mu\mathrm{m}$$

$$\lambda_\mathrm{reem} = 450\, \mu\mathrm{m} \ldots 2\, \mathrm{mm}$$

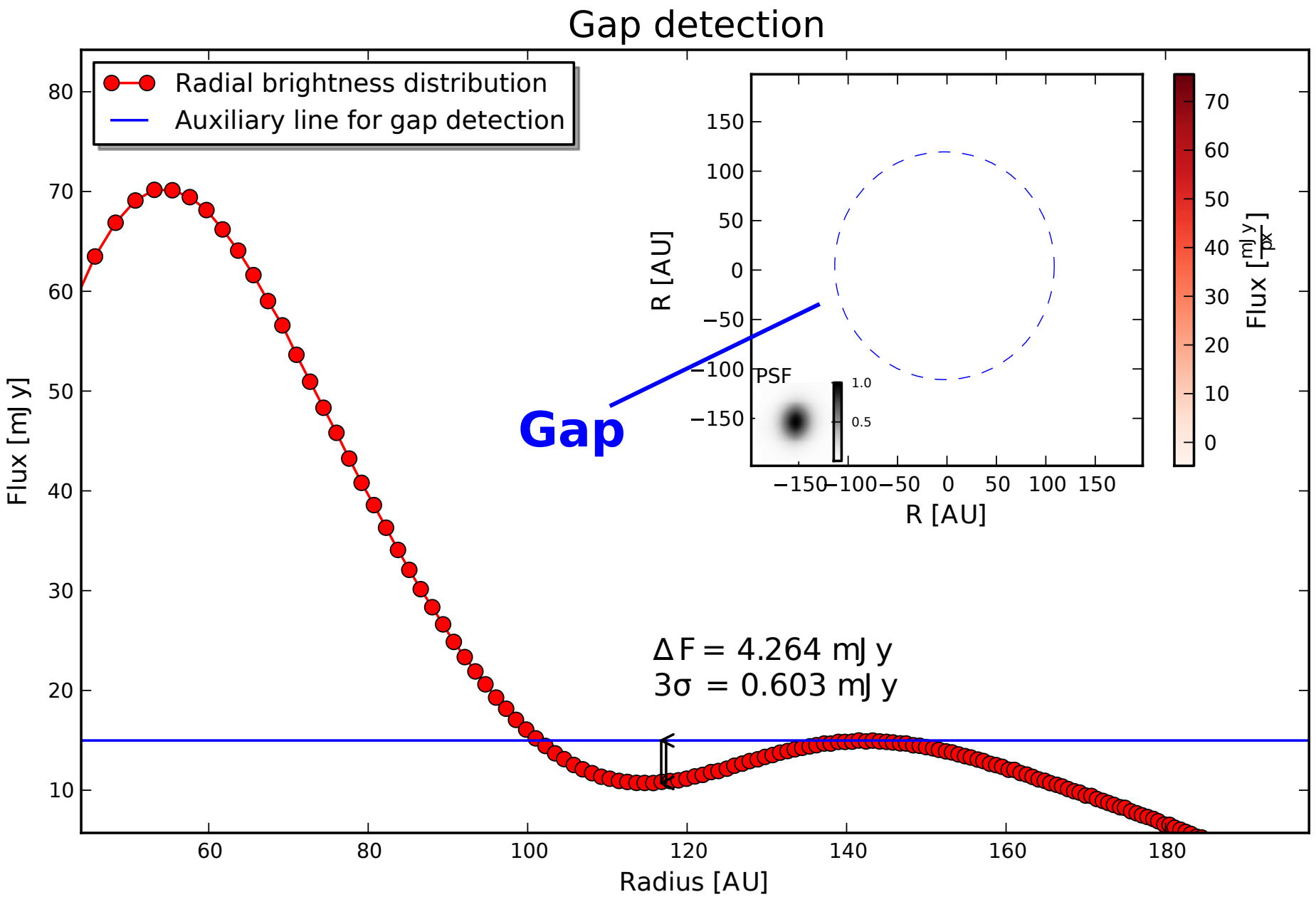
Density map



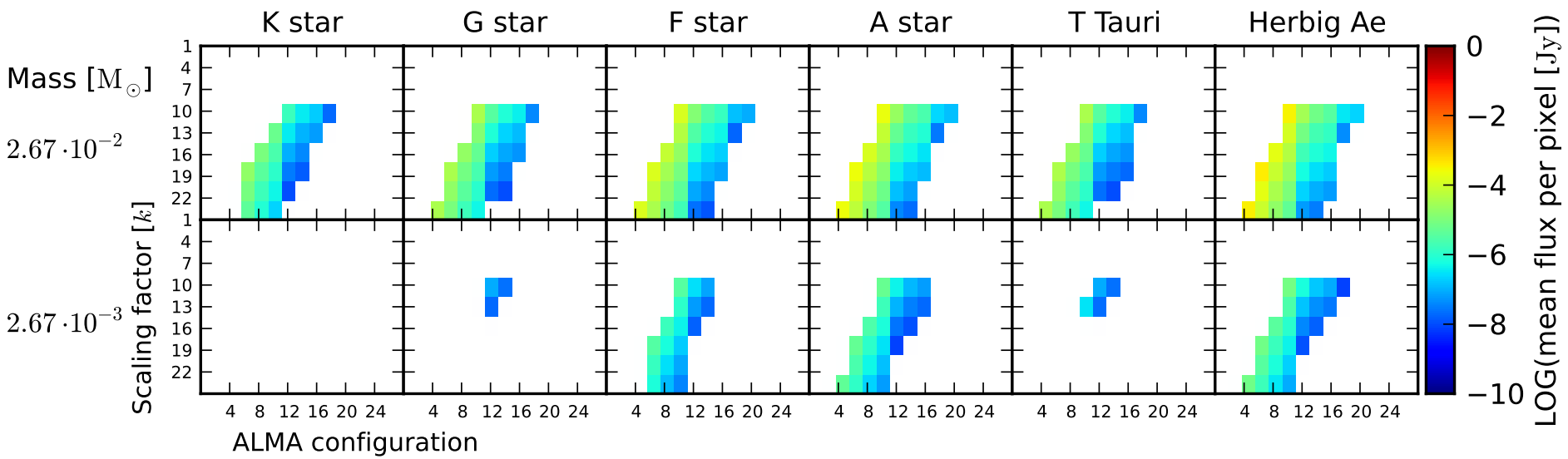
Re-emission map



How to detect a gap in thermal disk emission at 1.3 mm?



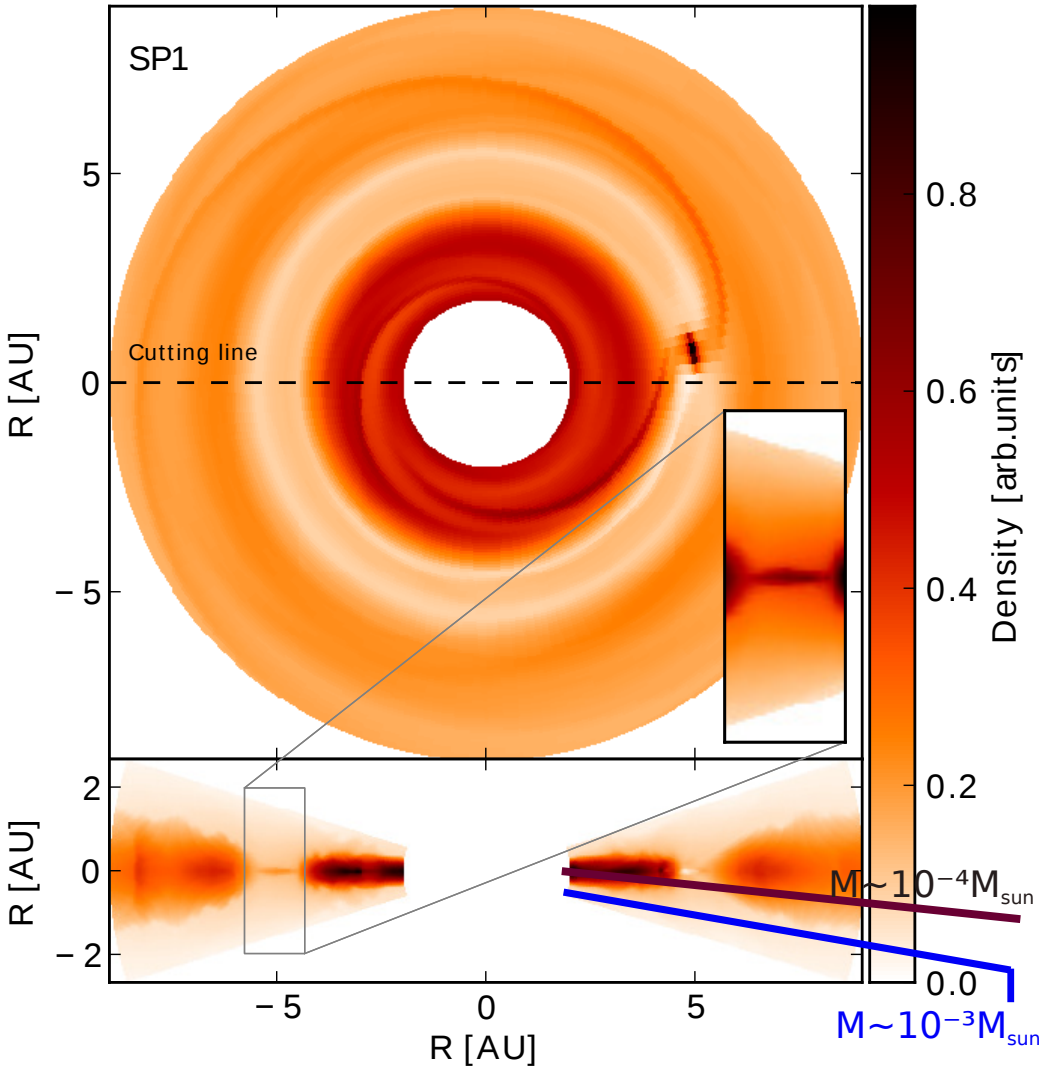
Trace a planet-induced gap at 1.3 mm



- 2 h exposure time
- Scaling factor k: measure for disk size
- CASA ALMA configuration number: measure for spatial resolution
- see Ruge et al, 2013 for details

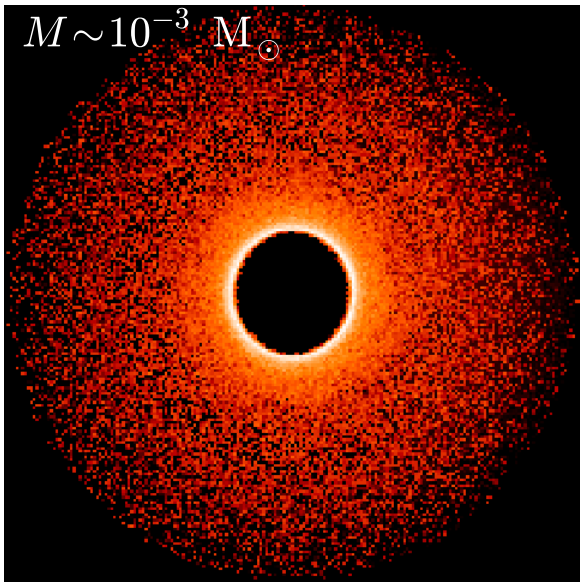
Gapped disks in scattered light at 2.2 μm

Density distribution

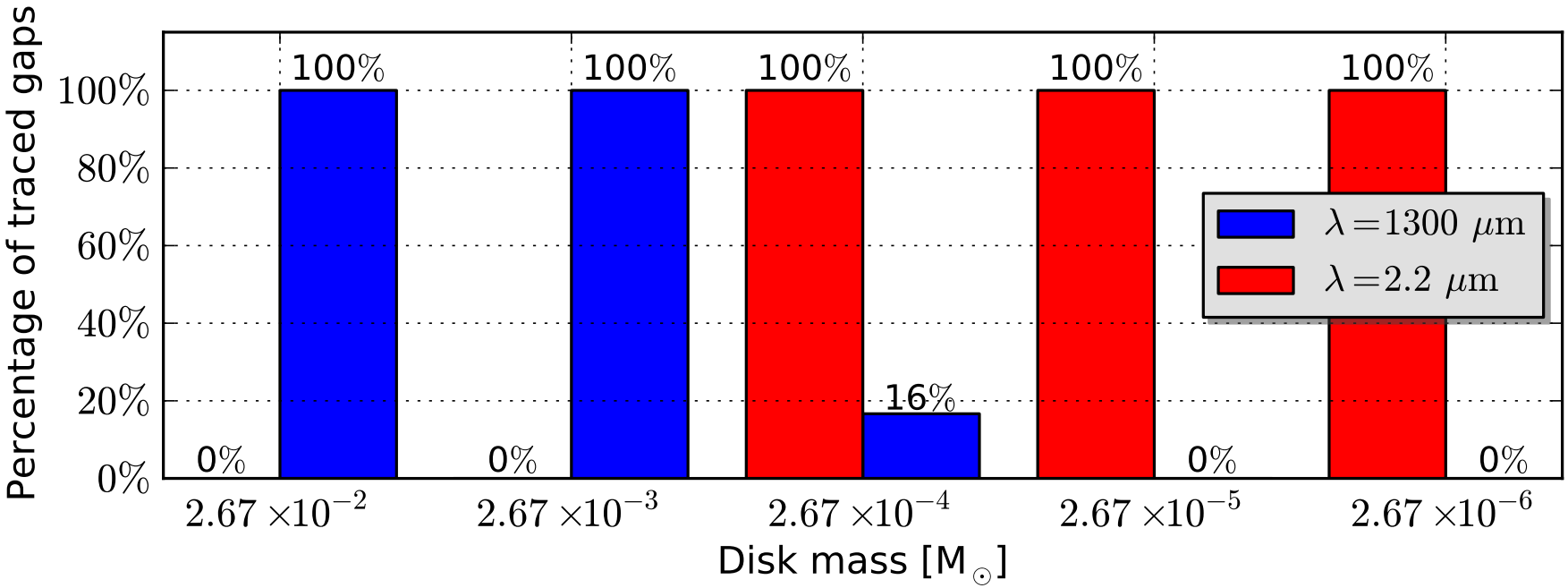


From: Ruge et al., subm. to A&AL

2.2 μm scattered light maps



Results ($\lambda = 2.2\,\mu\mathrm{m}$)



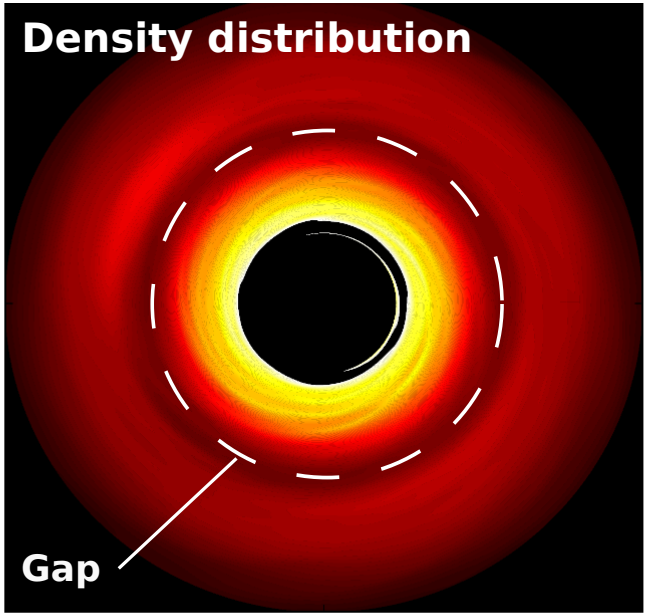
Traced gaps:

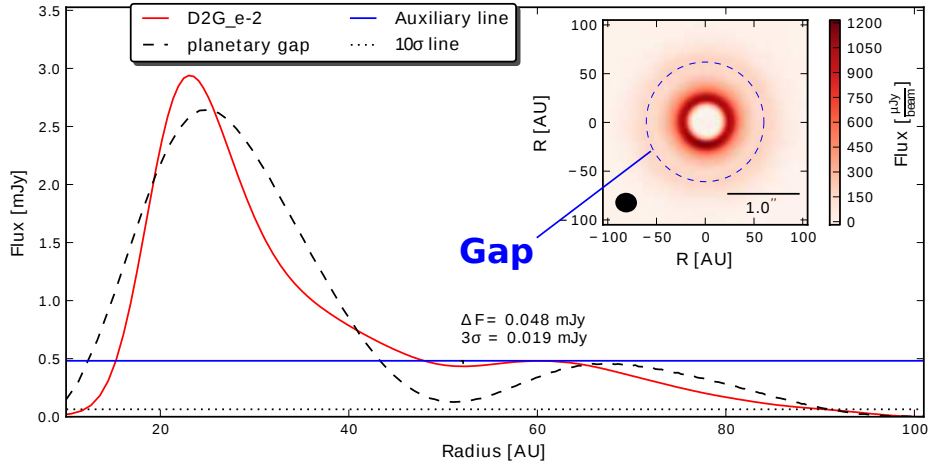
- $\cdots$ only for $M_{\mathrm{tot}} \leq 10^{-4}\,\mathrm{M}_\odot$
- $\cdots$ either in scattered light or thermal disk emission

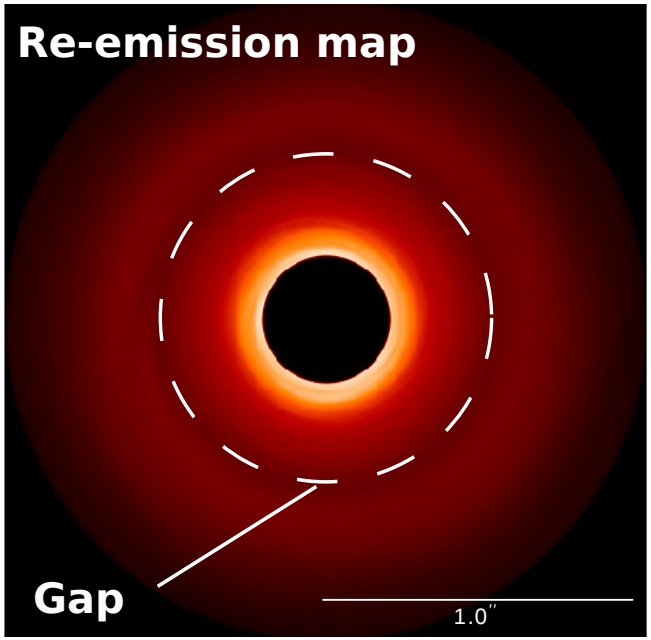
Influence of hydrodynamic simulation setup is small

From: Ruge et al., subm. to A&AL

Gaps – but no planet (see also talk by M. Flock)







Expected significances of gap detections in simulated ALMA observations

λ [μm]	75 pc	100 pc	120 pc	140 pc
441	5.0σ	3.9σ	2.6σ	2.2σ
871	11.7σ	6.4σ	4.2σ	4.2σ
1303	7.7σ	4.8σ	3.3σ	2.4σ

From: Flock et al., subm. to A&A

Conclusions

- We explore the observability of (planet-induced) gaps in circumstellar disks
- We predict:
  - ALMA traces (measures) gaps of several sizes
  - Gap origin: planet or zonal flow $\Rightarrow$ differentiation not possible on base of re-emission maps
  - In scattered light: upper mass limit around $\approx 10^{-4}\,\mathrm{M}_{\odot}$ for tracing gaps
  - A mutual gap detection with ALMA in thermal dust re-emission and scattered light may not possible

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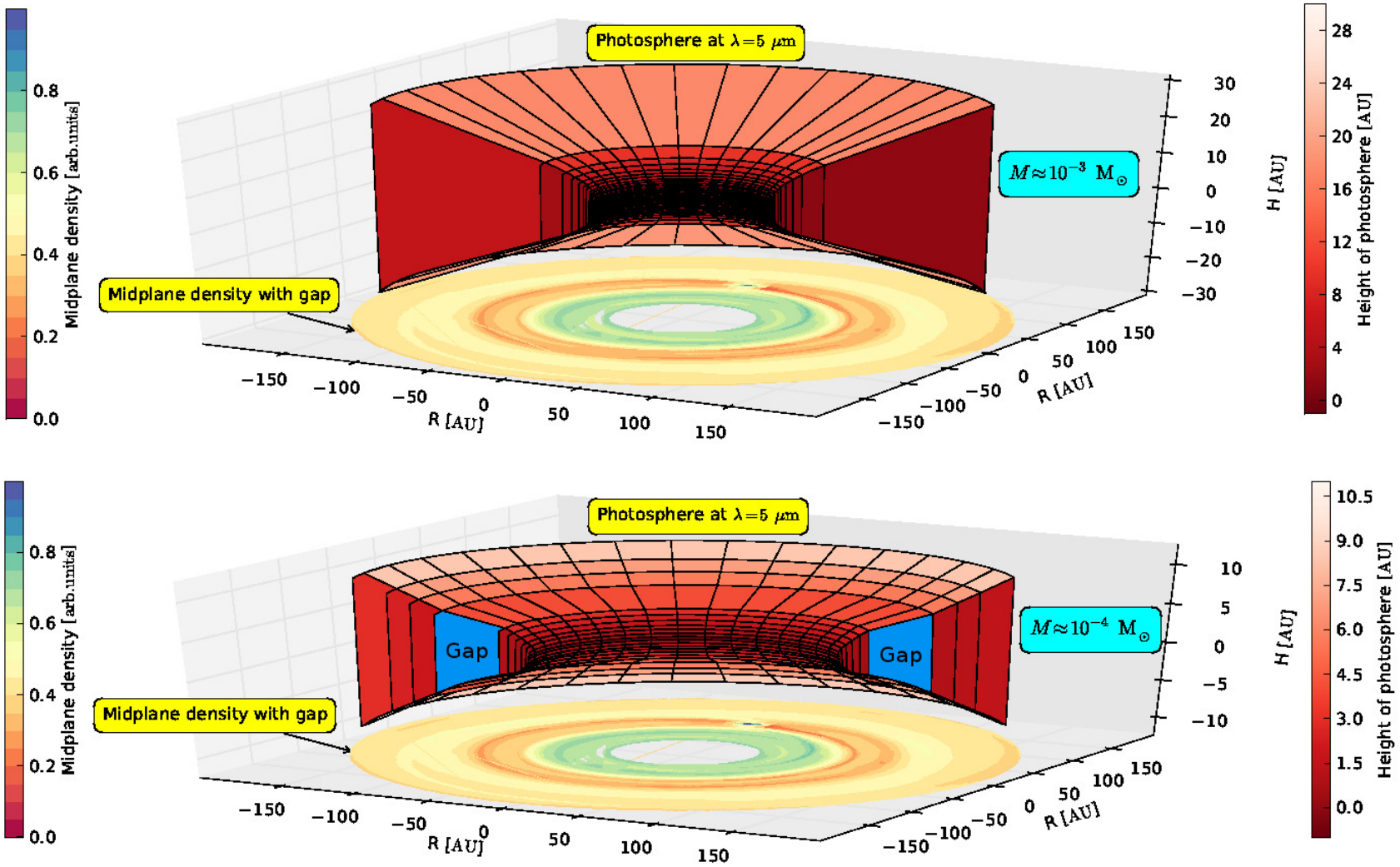
Thank you.

Photosphere of the disks



From: Ruge et al., subm. to A&AL

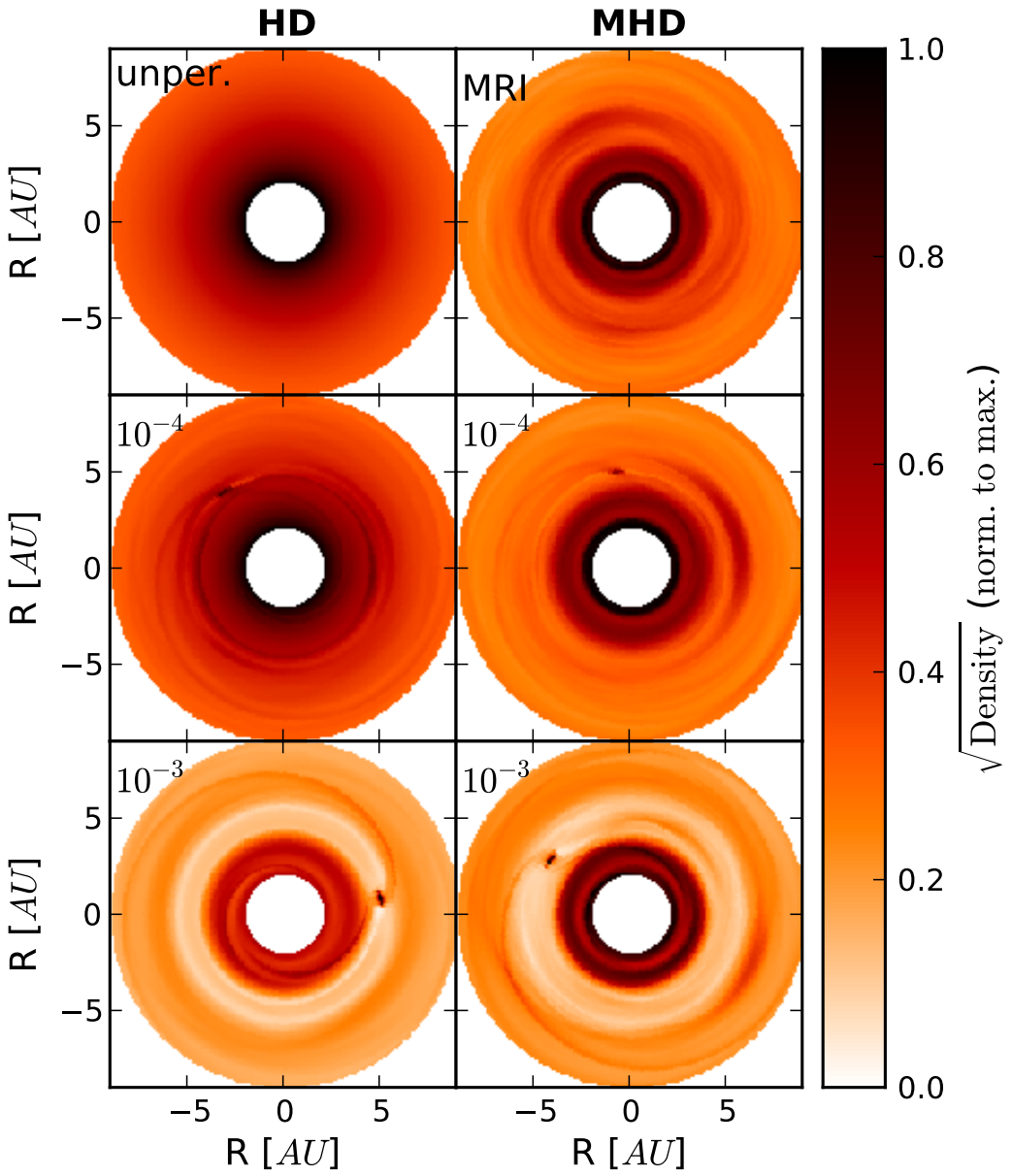
Additional information on the model setup

Hydrodynamics

Parameter	Value
Snapshot	$\approx 100\,\mathrm{T_P}$
ϑ-area	$\pm 0.3\,\mathrm{rad}$
Cells $(n_\mathrm{r}, n_\vartheta, n_\varphi)$	$(200, 128, 256)$

Radiative Transfer

Parameter	Value
Photons (reem.)	101000
Photons (scat.)	10^8
i (scat.)	15°,30°,45°
	60°,75°
Cells $(n_\mathrm{r}, n_\vartheta, n_\varphi)$	$(100, 341, 128)$



Continuum radiative transfer and dust composition

(Wolf et al. 1999, Wolf 2003)

Setup

Parameter	Value
Dust	62.5% Astr. silicate
	37.5% Graphite
Dust density	$2.7\,{}^{\mathrm{g}}/_{\mathrm{cm}^3}$
Grain size distr.	$n(a) \propto a^{-3.5}$
Large dust	$a \in [5\,\mathrm{nm}, 100\,\mu\mathrm{m}]$
Small dust	$a \in [5\,\mathrm{nm}, 0.25\,\mu\mathrm{m}]$
i (reem.)	5°