Back-reaction of dust on gas in protoplanetary discs: crucial, yet often overlooked

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Gas and dust dynamics

- Sub-Keplerian gas drags Keplerian dust ⇒ dust settling and drift

gas
$$v_{\mathrm{g},r} = -\frac{\epsilon \mathrm{St}}{(1+\epsilon)^2 + \mathrm{St}^2} v_{\mathrm{drift}} + \frac{1+\epsilon+\mathrm{St}^2}{(1+\epsilon)^2 + \mathrm{St}^2} v_{\mathrm{visc}}$$

radial velocities

dust
$$v_{\mathrm{d},r} = \frac{\mathrm{St}}{(1+\epsilon)^2 + \mathrm{St}^2} v_{\mathrm{drift}} + \frac{1+\epsilon}{(1+\epsilon)^2 + \mathrm{St}^2} v_{\mathrm{visc}}$$

$$\frac{v_{\mathrm{drift}}}{v_{\mathrm{visc}}} \sim \frac{1}{\alpha}$$

optimal drift velocity *(Nakagawa+1986)*

gas viscous velocity *(Lynden-Bell+Pringle1974)*

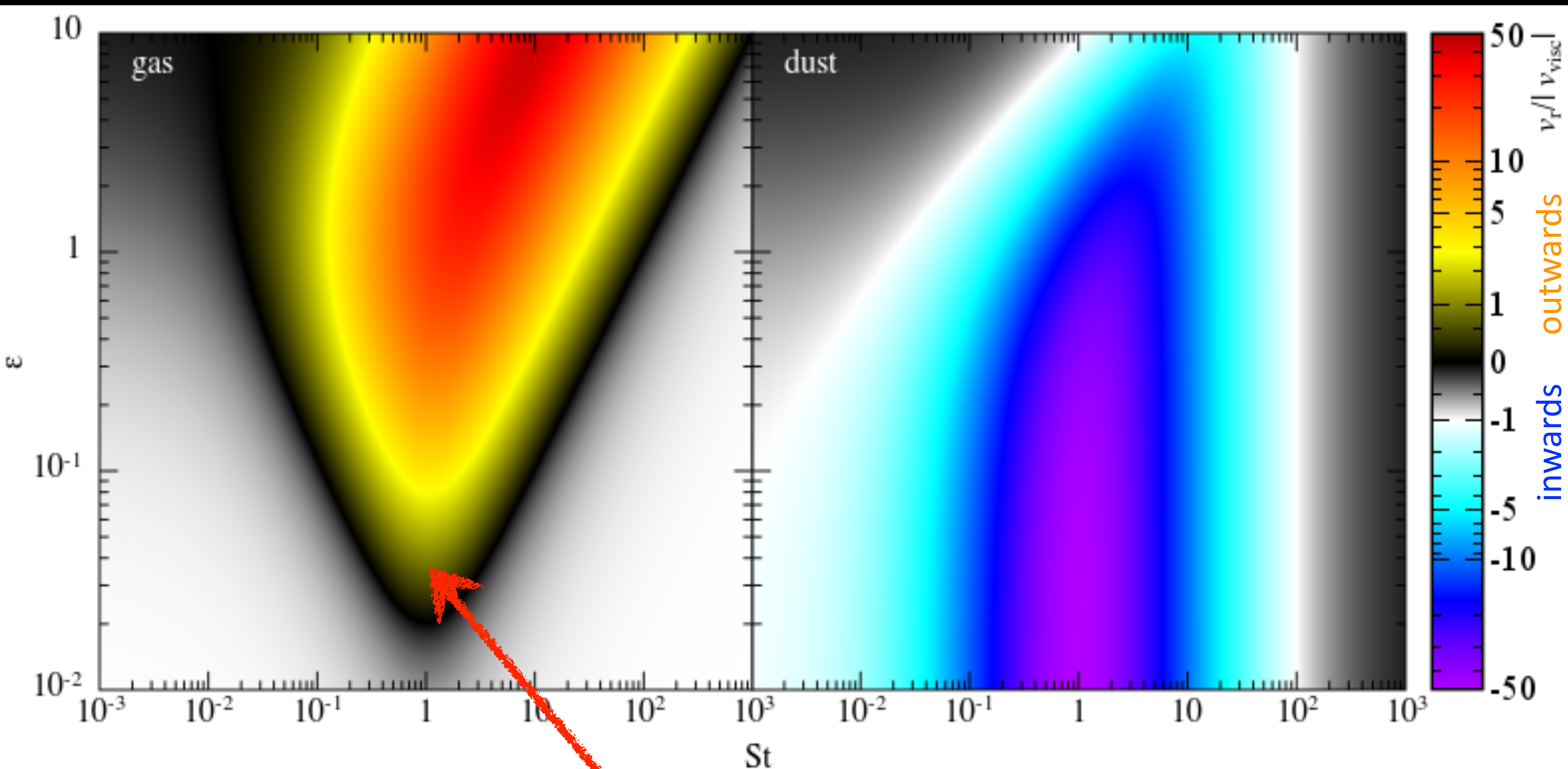
- Dynamics controlled by the Stokes number $\mathrm{St} = \frac{\Omega_{\mathrm{K}} \rho_{\mathrm{s}} s}{\rho_{\mathrm{g}} c_{\mathrm{s}}}$ and $\epsilon = \frac{\rho_{\mathrm{dust}}}{\rho_{\mathrm{gas}}}$
- $\epsilon = 0$ ⇒ equations without back-reaction
- $\epsilon \neq 0$ ⇒ effects of back-reaction
  - slows down dust radial drift
  - modifies the gas motion
- Consequences
  - Streaming instability
  - Self-induced dust traps

Youdin+Goodman2005, Johansen+2007, Bai+Stone2010, Yang+Johansen2014, Drążkowska+Dullemond2014

Gonzalez+2017a,b

Gas and dust radial velocities

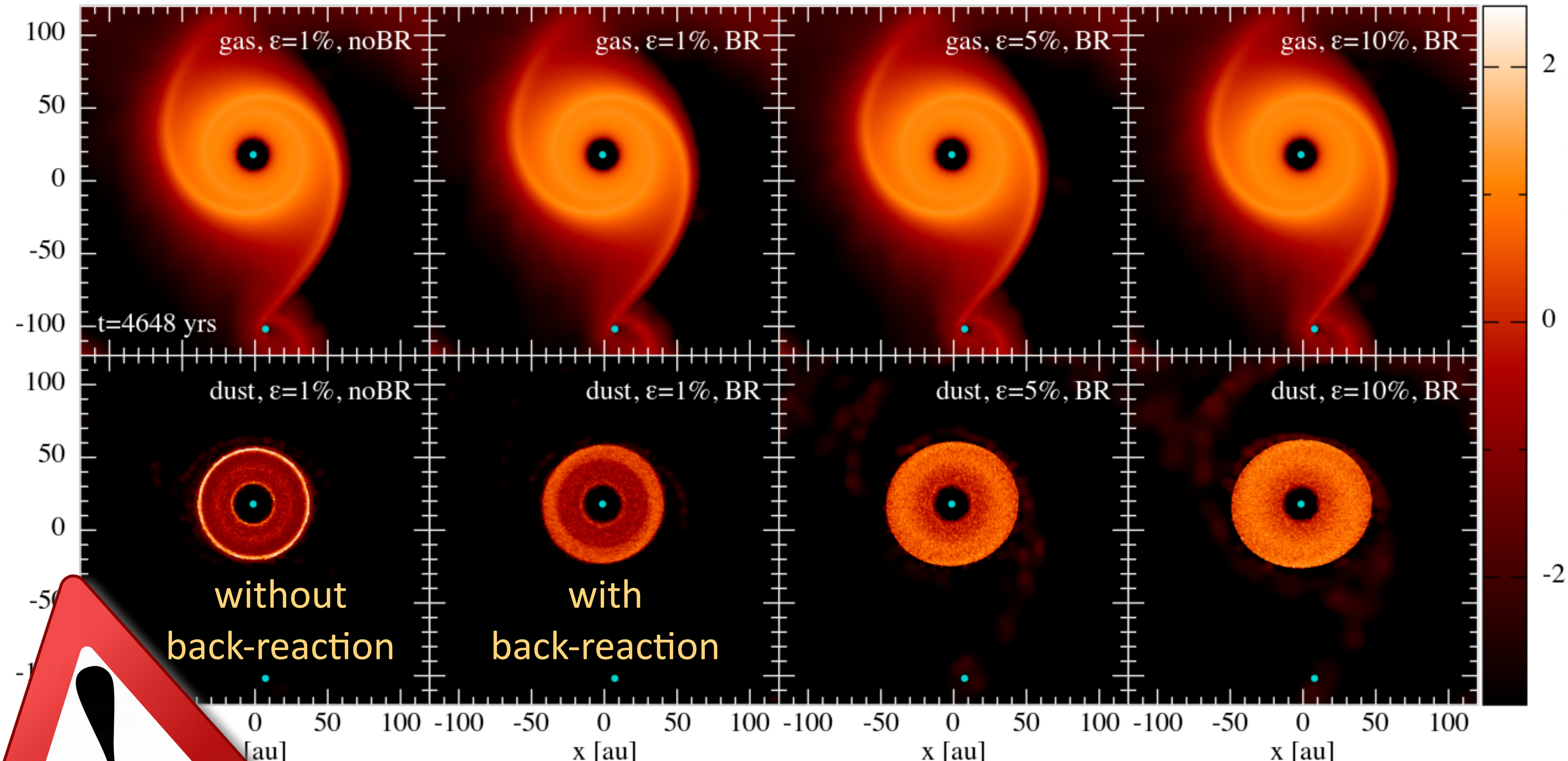
Maps of $\frac{v_r}{|v_{\rm visc}|}$ for α = 10^{-2}



Gas can drift OUTWARDS for $\epsilon = \rho_{\rm dust}/\rho_{\rm gas}$ of a few %!

Practical case: a circumprimary disc in a binary star system

SPH simulations, gas + 1 mm grains



Careful when interpreting observations!