Can gap-edge illumination excite spirals in protoplanetary disks?

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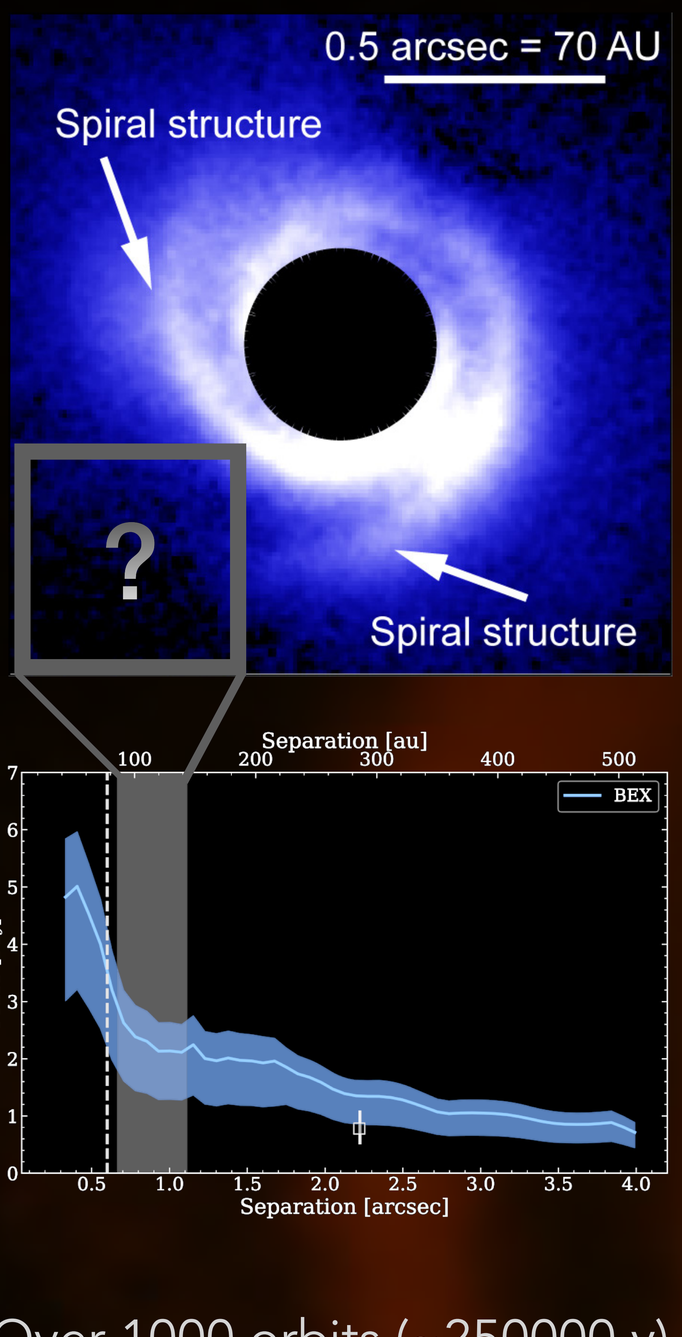


Near-infrared (NIR) imaging has revealed **prominent spiral structure** in a number of protoplanetary disks [1, 2].

- Consistent with **inner Lindblad spirals** of multi-Jupiter-mass planets, in classical theory of disk-planet interaction [3, 4].
- But to date, JWST observations offer **no conclusive evidence** for such widely separated super-Jupiter companions! [5, 6]

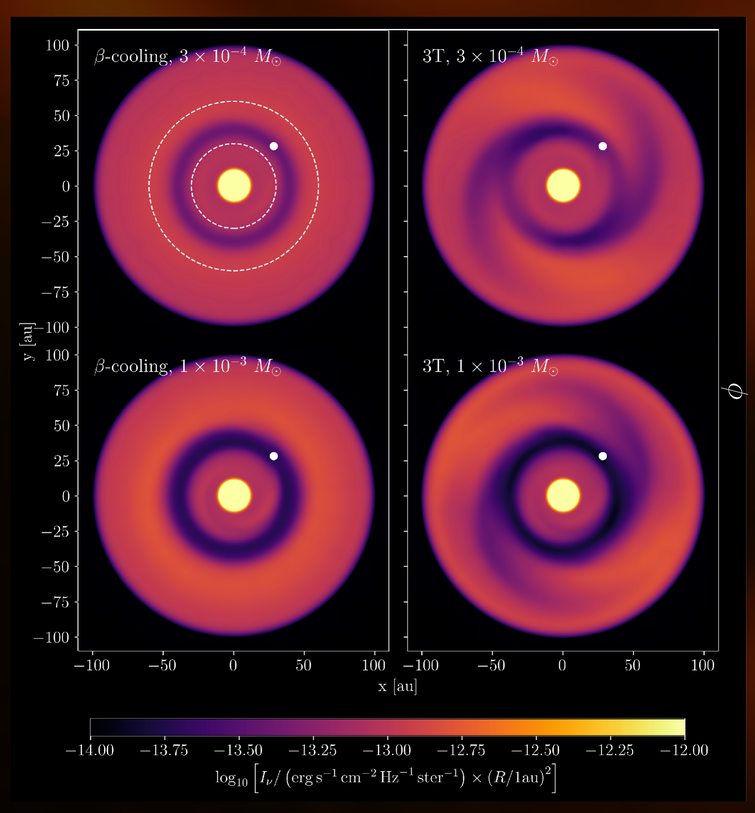
To study this question, we ran 3D hydrodynamic simulations with PLUTO [7] and used RADMC3D [8] for mock images, with

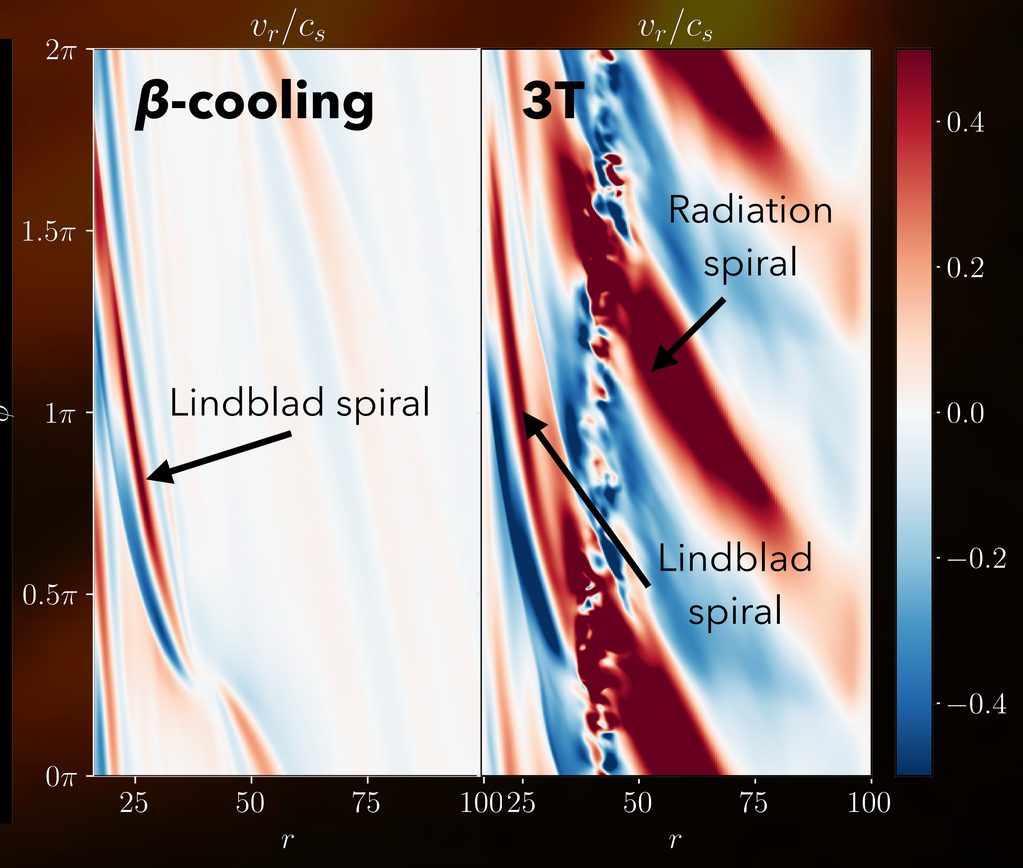
- Two planet masses (**Saturn-mass**, **Jupiter-mass**), below typical JWST detection limits at ~100 au.
- Two thermodynamic prescriptions (***β*-cooling** to initial background temperature, **three-temperature [3T] scheme** [9] with energy exchange between gas, dust, and radiation)
- Viscous $\alpha = 1 \times 10^{-3}$ in all simulations.

Over 1000 orbits (~250000 y), the planet carves a gap in disk:

- *β*-cooling: Rossby wave instability (RWI) asymmetries excited at outer gap edge, but damped rapidly by α-viscosity.
- 3T: **stellar irradiation onto RWI asymmetries** creates non-axisymmetric temperature at outer gap edge. This **generates strong spirals** in the upper atmosphere [10, 11].

In agreement with observations, simulated radiation-induced spirals are **prominently visible in NIR** and **do not require** a multi-Jupiter-mass driver!





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12. [background image] Adapted from ESO from Stolker, T., Dominik, C., Avenhaus, H., et al. 2016, *A&A*, 595, A113