The interplay between X-ray photoevaporation and planet formation

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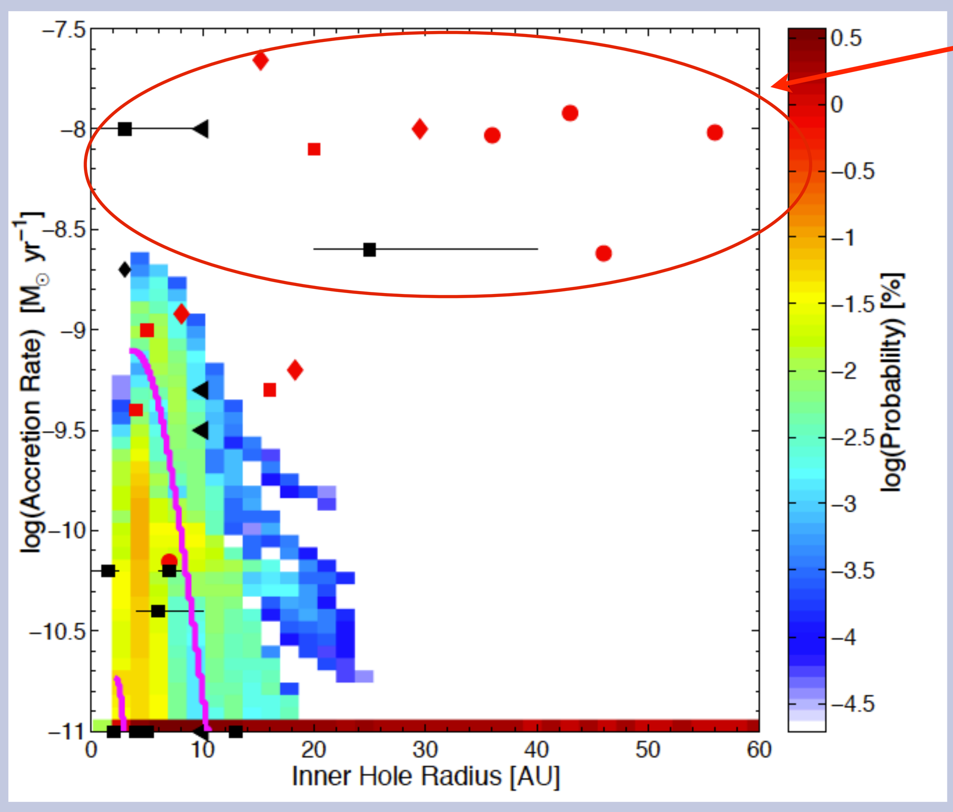
Abstract

Observations reveal that most (if not all) discs go through the "transitional disc" phase, which is currently interpreted as the last stage before the disc dispersal. Photoevaporation and planet formation have been studied as possible physical mechanisms responsible for the formation of these discs. While it is likely that more than one mechanism is at play, the interplay between them has until now not been studied in detail. We show results from 2d simulations of protoplanetary discs undergoing X-ray photoevaporation with an embedded giant planet. By reducing the mass accretion flow onto the star, discs that form giant planets will be dispersed at earlier times than discs without planets by X-ray photoevaporation. This process, planet formation induced photoevaporation (PIPE), is able to produce transition disc that for a given mass accretion rate have larger holes when compared to standard X-ray photoevaporation. This constitutes a possible route for the formation of the observed class of accreting transition discs with large holes, which are otherwise difficult to explain by planet formation or photoevaporation alone. Moreover, assuming that a planet is able to filter dust completely, PIPE produces a transition disc with a large hole and may provide a mechanism to quickly shut down accretion. This process appears to be too slow however to explain the observed desert in the population of transition disc with large holes and low mass accretion rates.

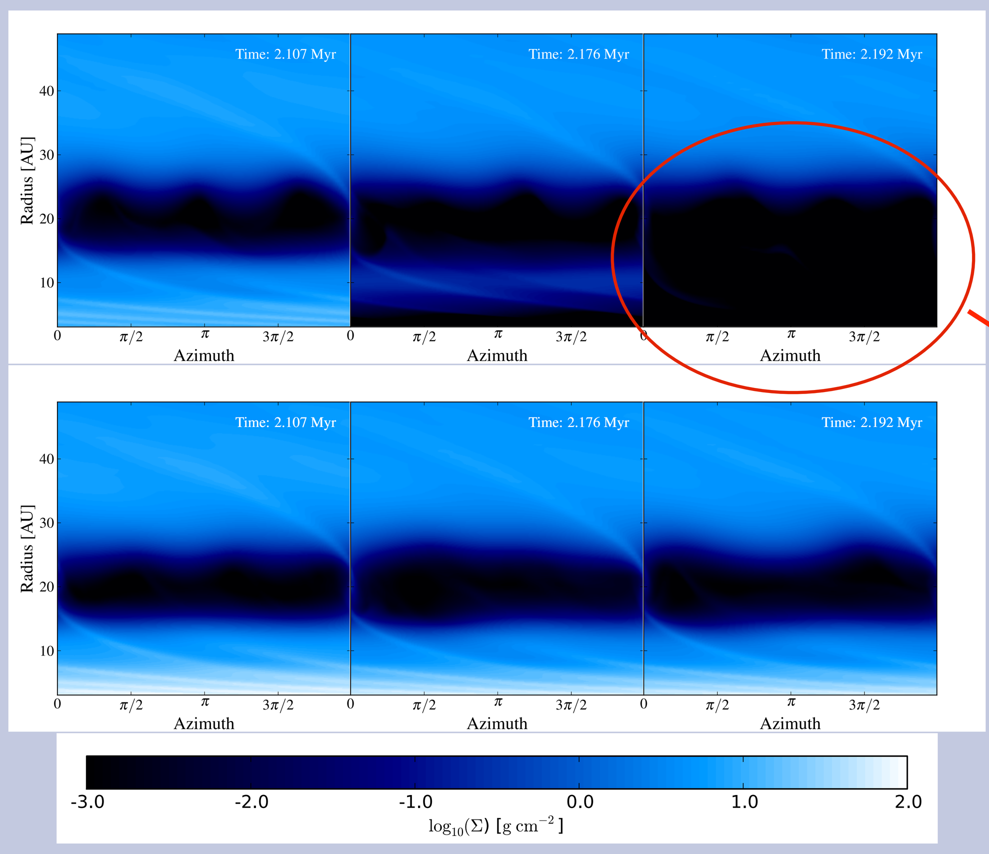
Motivation



X-ray photoevaporation cannot account for these.
Do they have a different physical origin?

From Owen+ 11. Points are observations, the colored region is where one expects to find transition discs according to X-ray photoevaporation theory.

Effect of a giant planet on disc dispersal



including photoevaporation

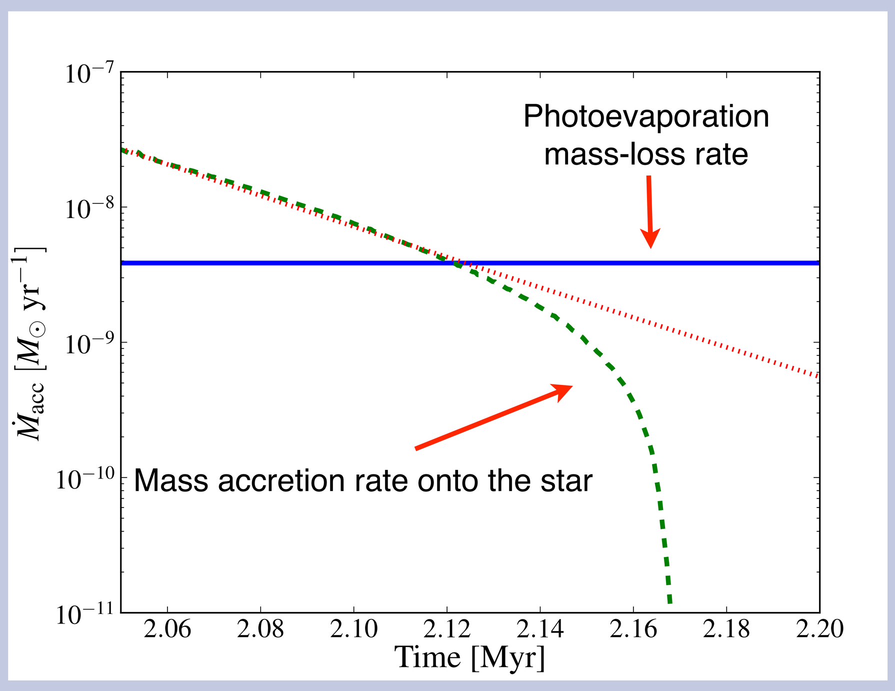
An inner hole has opened

no photoevap

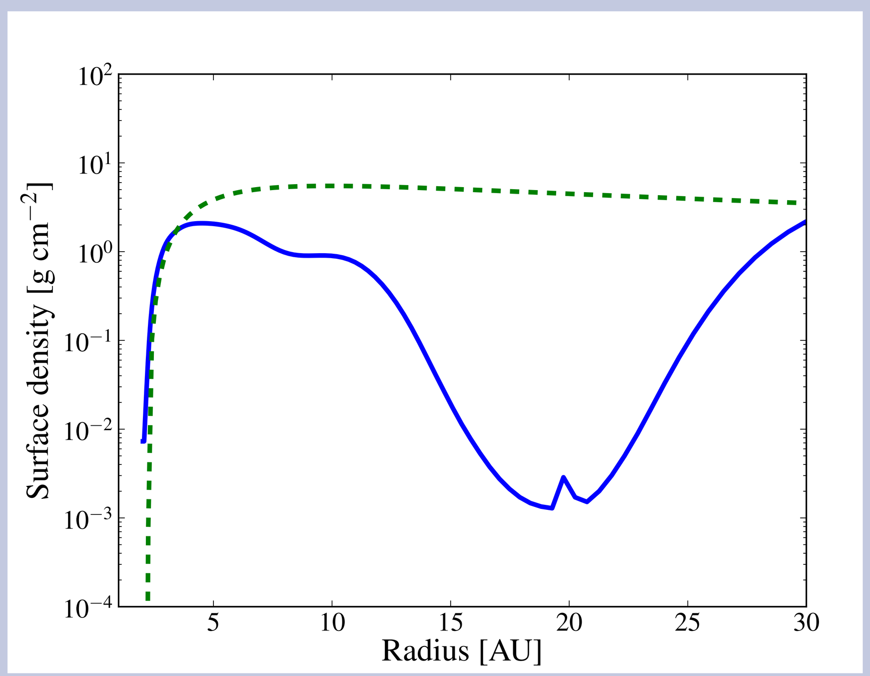
We run simulations **including the effect of photoevaporation with a giant planet embedded in the disc.** Comparing with a control run with no photoevaporation, the inner disc is dispersed at earlier times, giving rise to a transition disc.

We use the code FARGO to simulate the interaction. The initial mass of the planet is 0.7 M_jup and it is located at 20 AU from the star.

A more detailed look

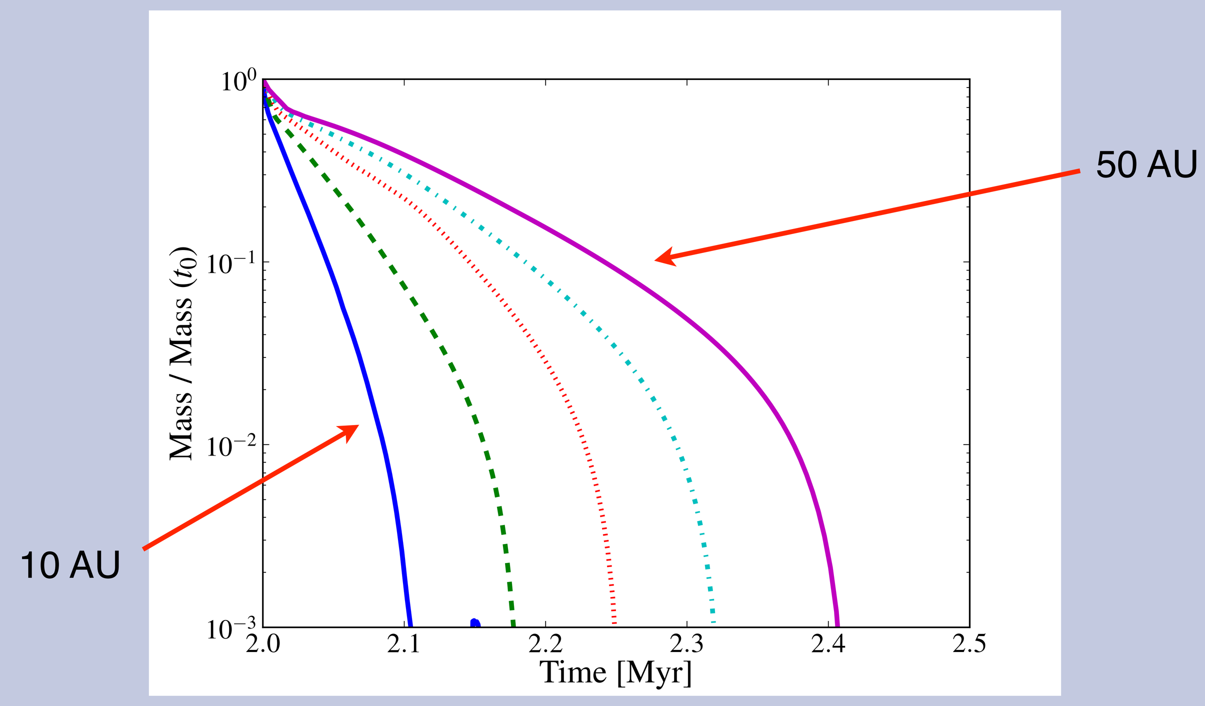


The planet disconnects the outer from the inner disc. The inner disc is cleared when the mass accretion onto the star falls below the mass-loss rate from photoevaporation in the inner disc. After that, the mass accretion rate has a sharp drop.



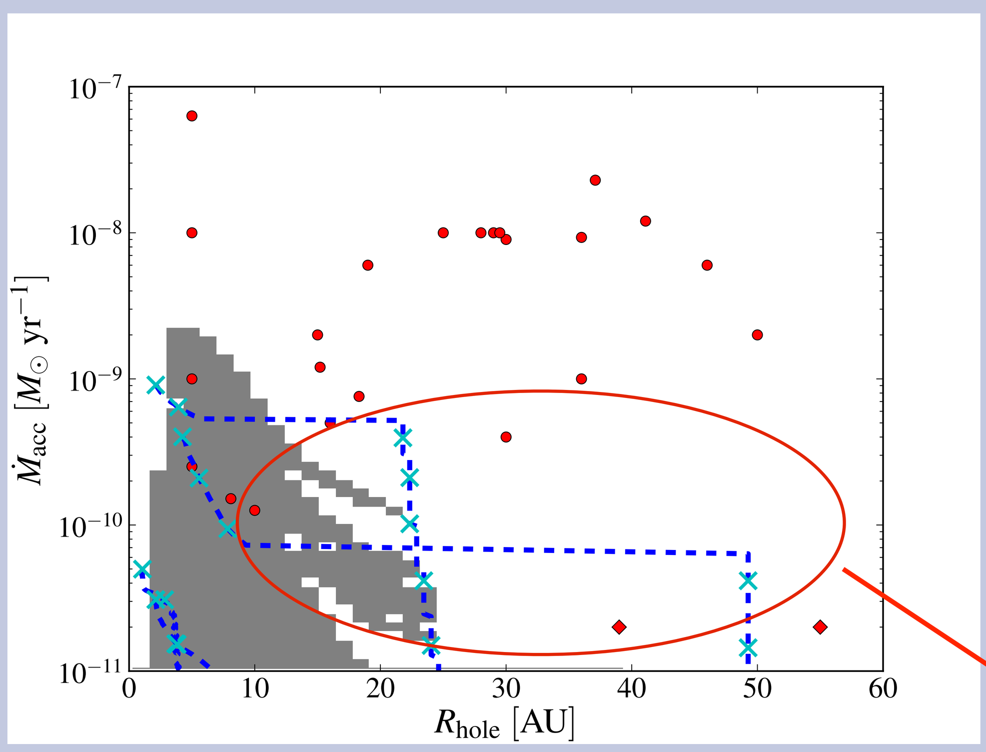
Green: surface density at gap opening in a model with photoevaporation only.
Blue: surface density at gap opening in our model.

Since the planet already started to clear the inner disc, photoevaporation has less material to remove, so that for the same accretion rate the resulting transition disc will have a larger hole.



The distance of the planet controls the speed of the process. The further out the planet is, the bigger the mass reservoir in the inner disc is, so that photoevaporation takes longer to dissipate the disc

Observable consequences



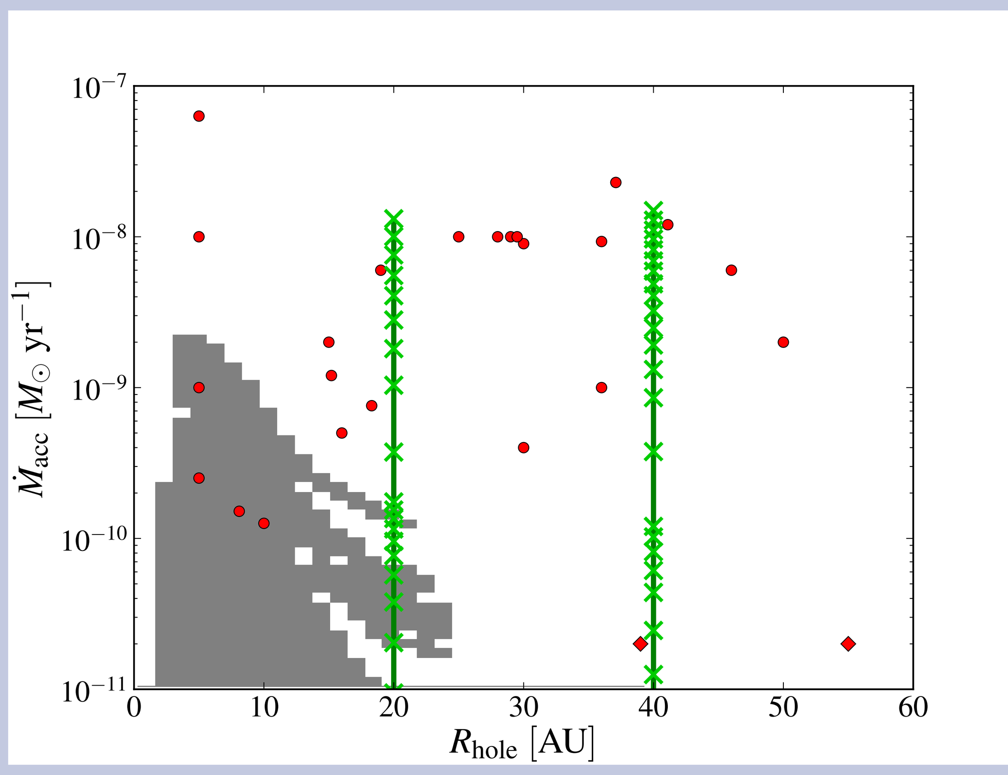
For the same mass accretion rate, PIPE produces transition discs with bigger holes

The region of the parameter space where transition discs are predicted gets wider, but only in the horizontal direction

Our model is gas only, so we have to make assumption about the dust. We make two different limiting assumptions: on the left we assume that dust and gas are fully coupled as they leak through the gap.
On the right, we assume that the planet is 100% efficient at filtering dust at its location.

We plot crosses on the tracks every 10^4 years to show how fast the disc proceed along the track. Different tracks are for different planet locations and X-ray luminosities.

We are currently working to include a more detailed dust treatment in our modeling.



Photoevaporation provides a mechanism to “shut down” accretion and modifies the evolution of the disc. In this scenario, transition discs with different mass accretion rates are interpreted as progressively older discs.