Effects of X-ray photoevaporation on planetesimals formation by streaming instability

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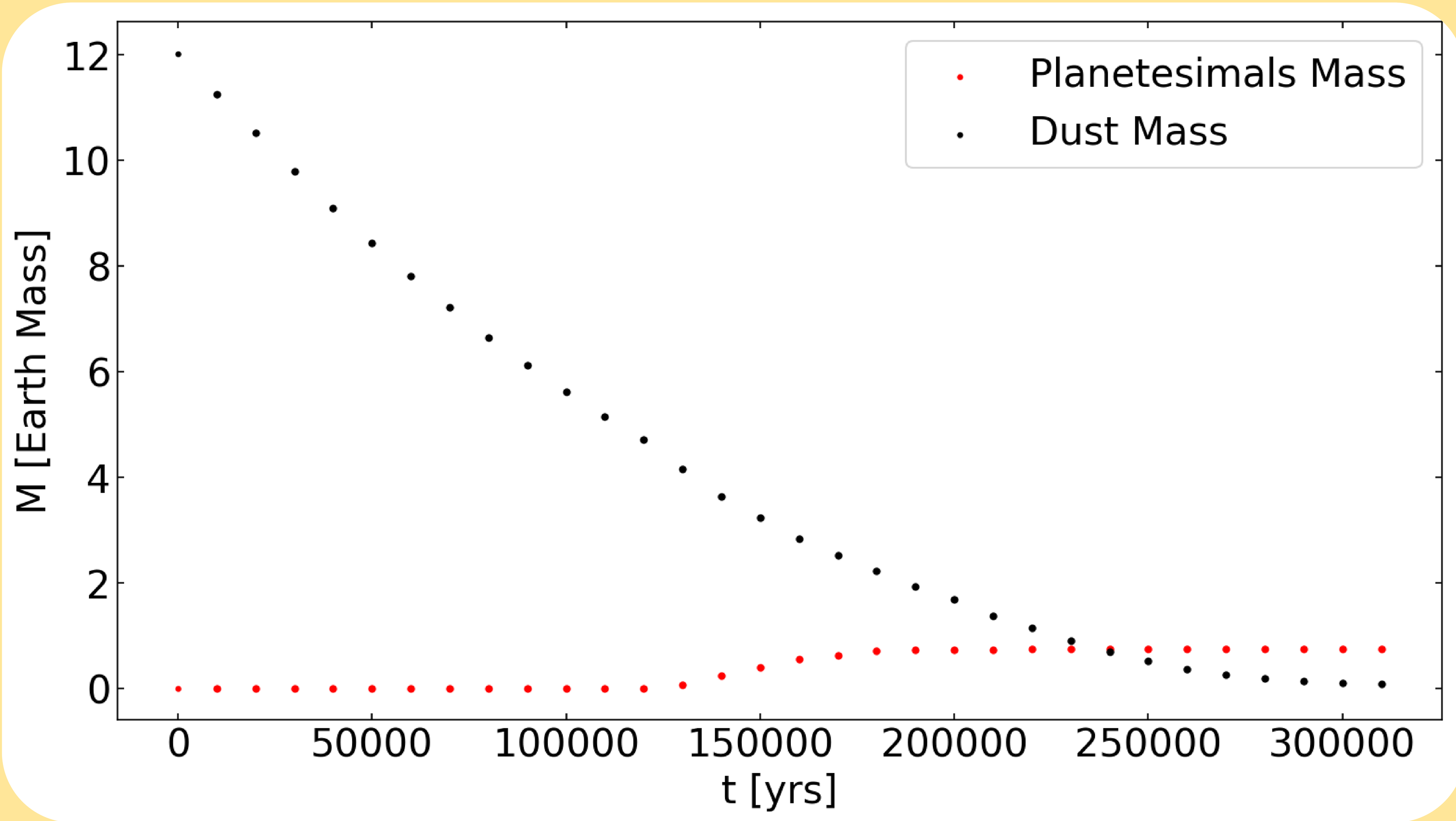
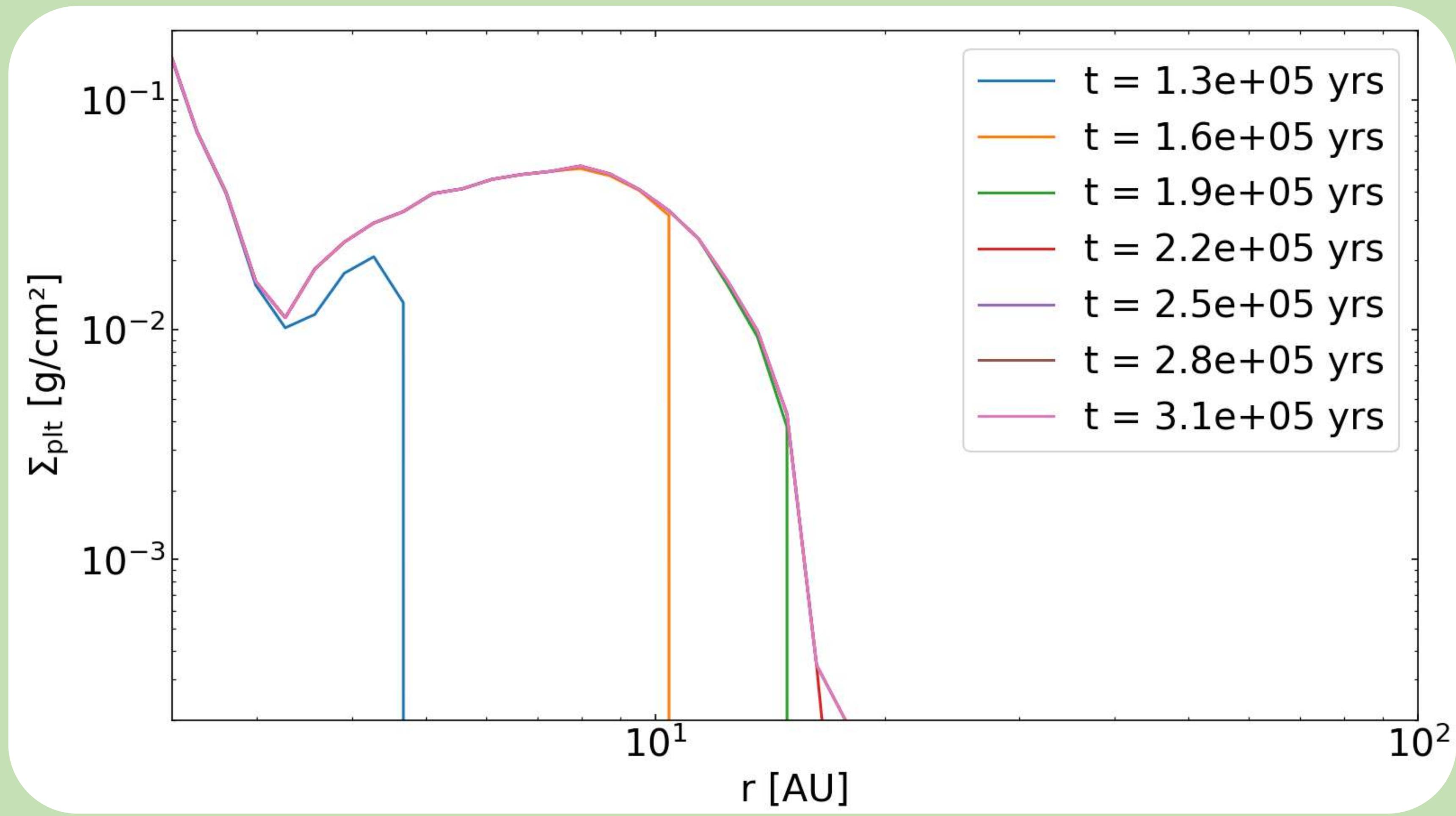
Abstract

In the core accretion model of planet formation, how dust and pebbles in the protoplanetary discs cross the 'meter barrier' to build planetesimals is an important problem to be solved. Streaming instability is often considered an effective way to solve this problem, the SI produces strong particle clumping if the ratio of solid to gas surface density—an effective metallicity—exceeds a critical value. In the protoplanetary discs, there are many scenarios that can trigger SI, such as the snow line, the boundary of the planetary groove, and the boundary of the dead zone. We suggest that X-ray photoevaporation is a possible mechanism for triggering SI in the late lifetime of protoplanetary discs, which removes relatively dust-free gas and increases effective metallicity around the edge of gap. Using a one-dimensional viscous evolution model of a disc subject to internal X-ray photoevaporation, we explore the efficacy of this process to build planetesimals. We found that after the photoevaporation groove, the solid is relatively enriched at the edge of the gap, which is sufficient to trigger SI to build planetesimals, and finally build planetesimals with 1 Earth mass within the range of tens of AU. We have only completed the preliminary work, and there are still several physical processes that may promote planetesimal formation that have not been considered, and the actual rate of planetesimal formation should be higher.

Main Results

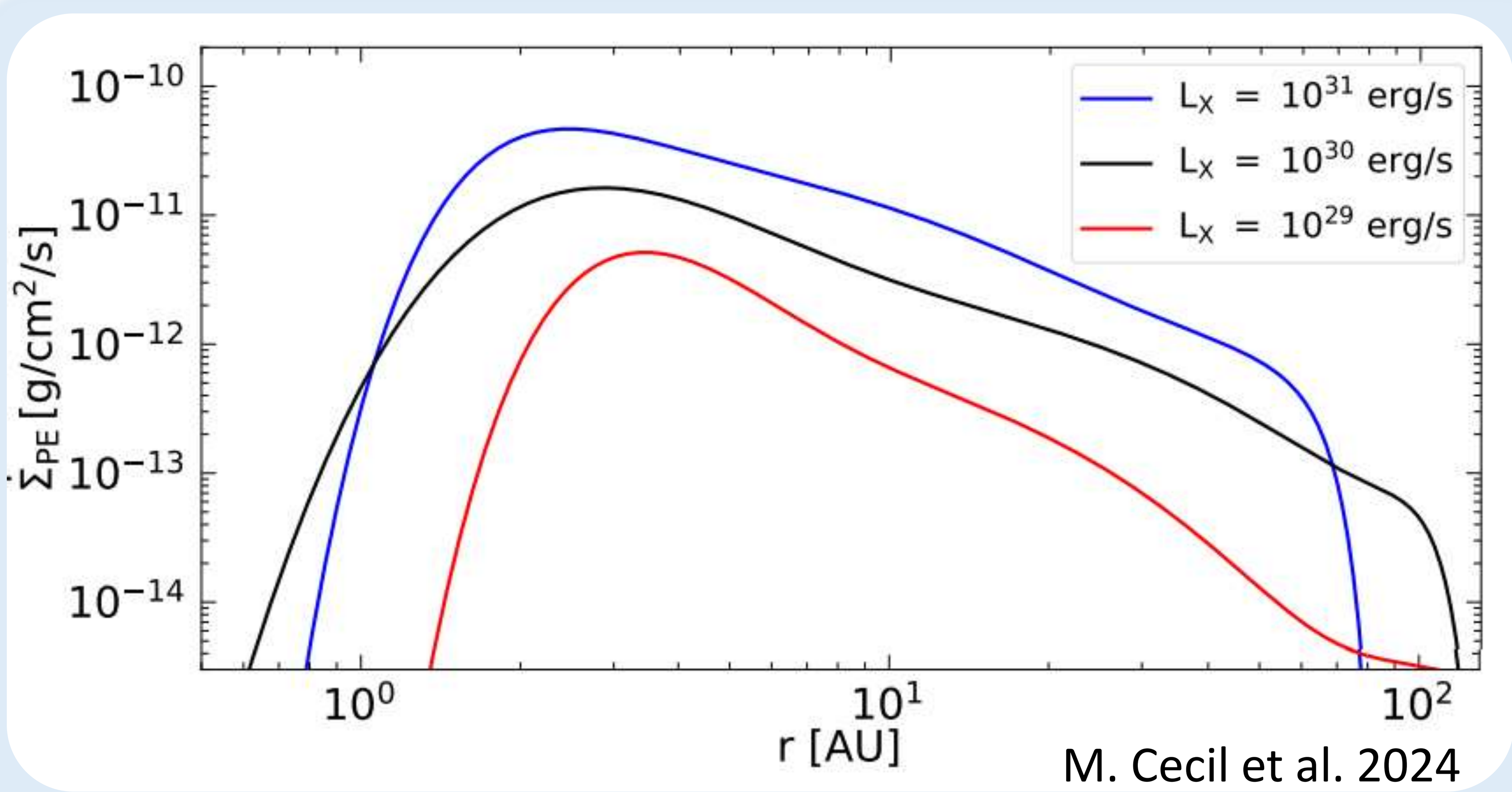


- Fiducial Model: $\alpha_t = 10^{-3},\ Z = 10^{-2},\ L_X = 10^{30}$ erg/s
- X-ray photoevaporation initiated gap formation at ~130,000 years, leading to planetesimals formation. By 210,000 years, the process was completed, producing planetesimals with a mass of 0.94 Earth mass.

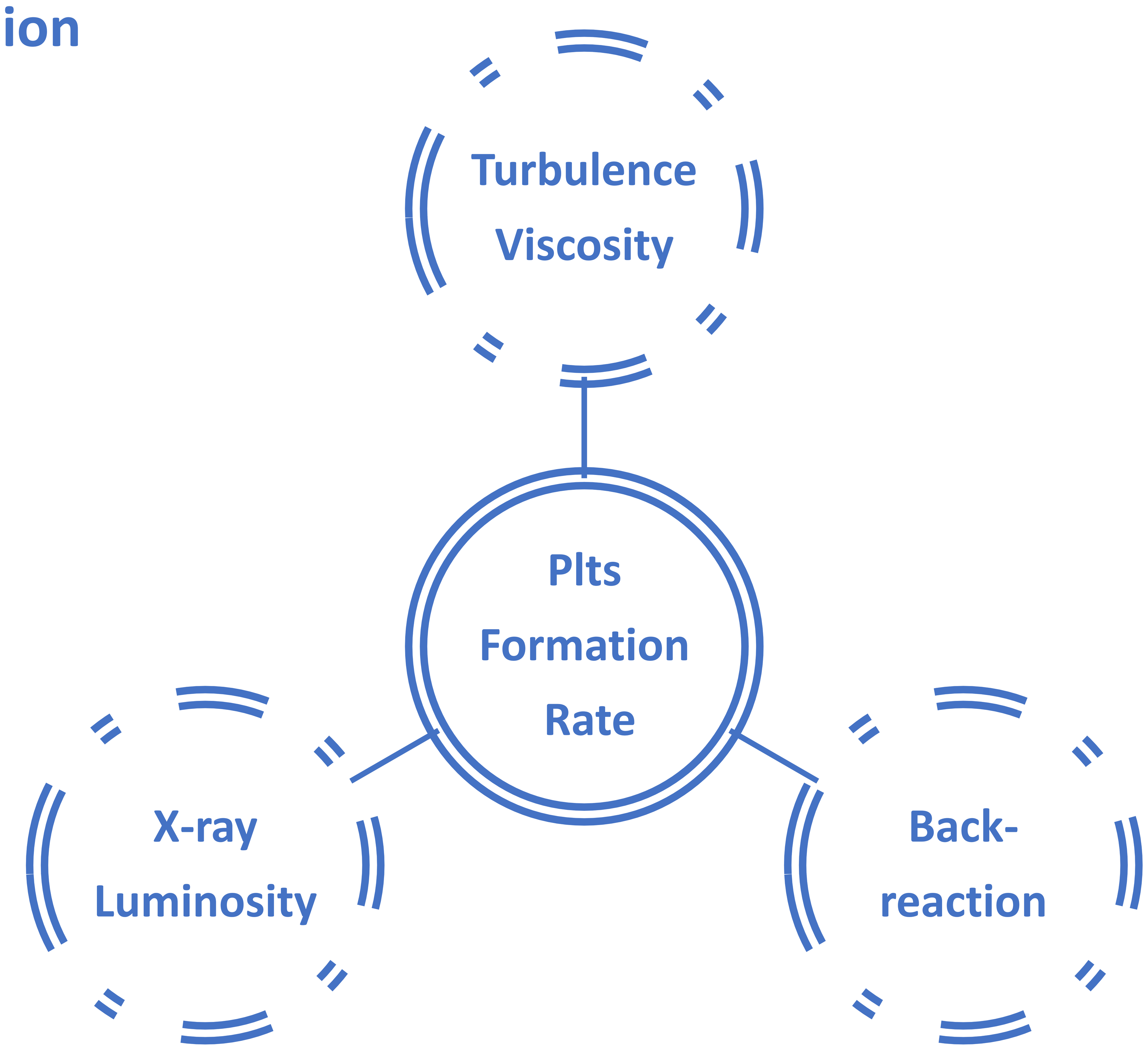


- After ~130,000 years, the effective metallicity of solid around the inner and outer boundaries of gap reaches the critical value and the solid convert into planetesimals. As photoevaporation proceeds, the gap expands, allowing planetesimals to form widely in the range of about 2~20 AU.

Discussion



- Full-disc formula of internal X-ray photoevaporation with different L_X
- The activity of the star affects the X-ray luminosity, and as L_X increases, gap opens earlier, leaving more dust and pebbles in the disc and facilitating planetesimals to form.



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