National Aeronautics and Space Administration

Postdoc Research

New Theory for the Origin of Debris Disks' Gas

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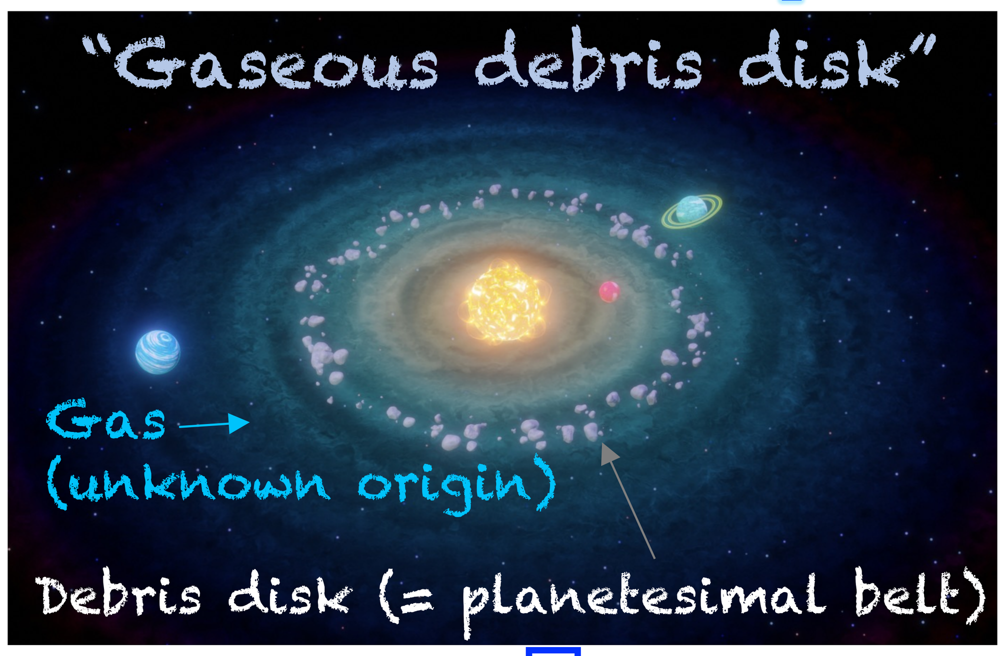
1. An intermediate object between a protoplanetary disk and a planetary system!?



- Debris disks are Kuiper belt analog and are thought to be devoid of gas, but gas has been detected in > 20 sources.
- These gaseous debris disks are key to understanding the evolution from a PPD to a planetary system.

	Protoplanetary disk (PPD)	Debris disk
Age	< 10 Myr old	**> 10 Myr old** ✓
Gas presence	**Yes** ✓	No
Dust mass	$M_d > 1\ M_\oplus$	$\boldsymbol{M_d < 1\ M_\oplus}$ ✓

2. What is the timescale of a PPD evolving into a planetary system?

Classical scenario

Gas-rich PPDs must evolve into gas-less planetary systems **within 10 Myr.**

New Observations

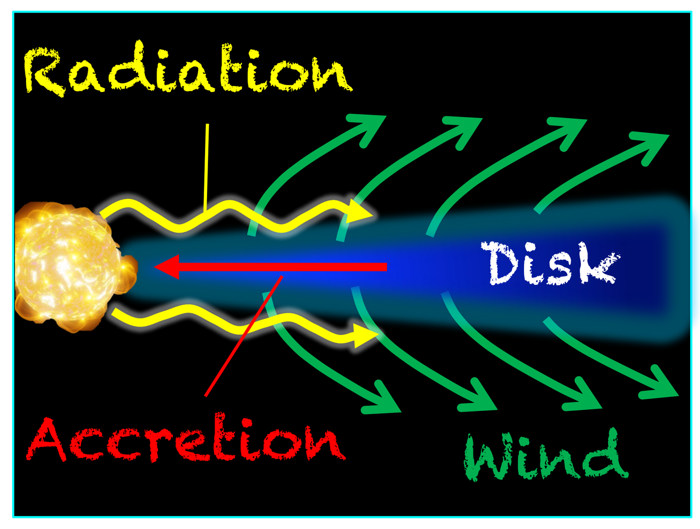
That seems not necessarily true. There are gaseous debris disks.

But how could PPDs survive for > 10 Myr??? It contradicts the PPD-dispersal theory.

This study

Well, previous models did not consider the stellar and disk evolution effects, which **underestimated the timescale.**

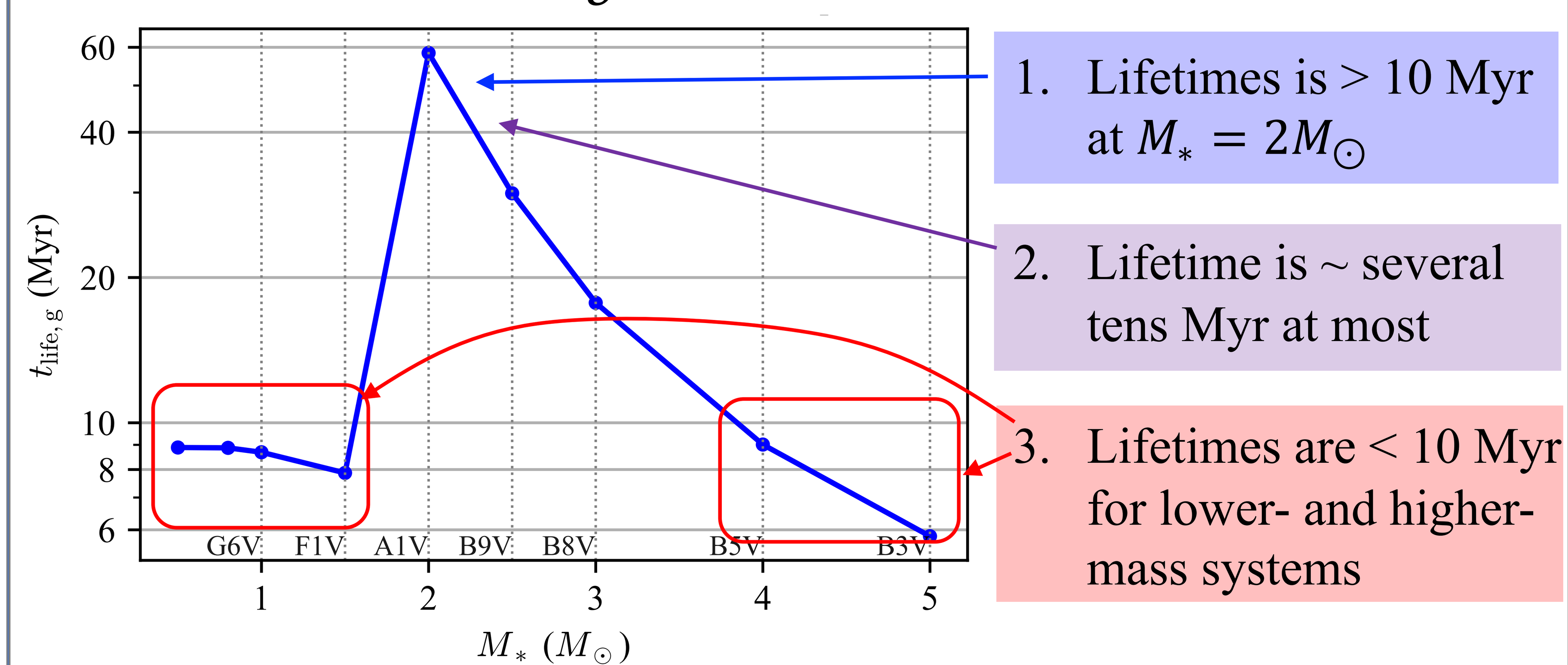
3. Our PPD dispersal model explains the observations of gaseous debris disks well.



Approach

- PPDs disperse via **accretion** and **winds** driven by stellar radiation and magnetohydrodynamics effects.
- We **model this disk dispersal process** incorporating stellar evolution to derive disk gas lifetimes.

Results: Disk gas lifetime VS stellar mass



Gaseous debris disks are often found around A-type ($2M_\odot$) stars with ages of < 50 Myr and rarely detected around lower- and higher-mass stars.

Our model shows remarkable consistency with observations.

Conclusions

- The disk lifetimes can be longer (> 10 Myr) than previously thought for A stars. This is because their radiation weakens substantially during the disk evolution, leading to smaller winds' mass loss.
- Observations are explained if gas in debris disks is a PPD remnant.

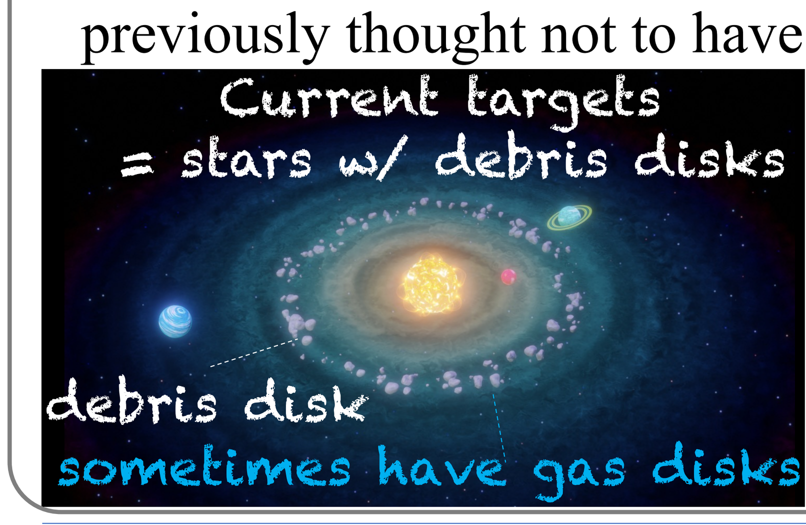
4. What do our results imply? - Updates to the classical theory, prediction of the phantoms, link to planet occurrence.

Classical scenario

So, you have essentially updated me?

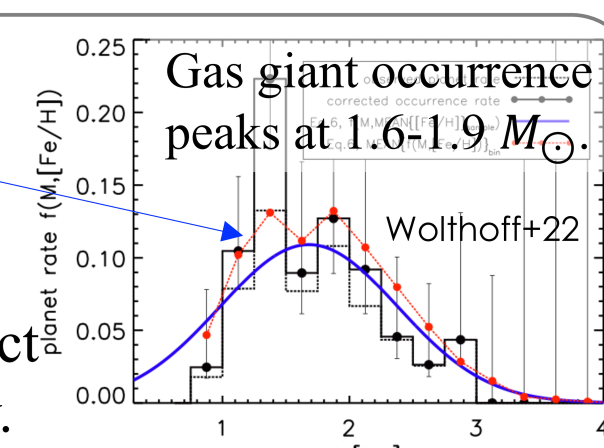
Yes, **the timescale of a PPD evolving into a (proto)planetary system** depends on the host star's mass and can be **longer than 10 Myr.**

① Prediction: There may be A-type stars that have gas disks but were previously thought not to have dust or gas disks = **Phantom disks**



② The long disk lifetime helps gas giants form more frequently??

③ The presence of gas suppresses the orbital instability of planets → Suppressing giant impact events = Affecting moon formation, habitability.



Useful for understanding disk evolution/origins of planets and for target selection to explore disk/planet/habitable world.

Future Work:

- Modeling the co-evolution of dust and gas in PPDs, constructing a global view and timeline of PPD evolution.
- What is the impact of forming planets? (e.g., gravity, viscosity)
- Searching for phantom disks with ALMA (I'm a member of the ARKS team, an ALMA large program.)

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Nakatani et al. submitted to the Astrophysical Journal Letters
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