The Mechanisms Driving the Evolution and Dispersal of Protoplanetary Disks

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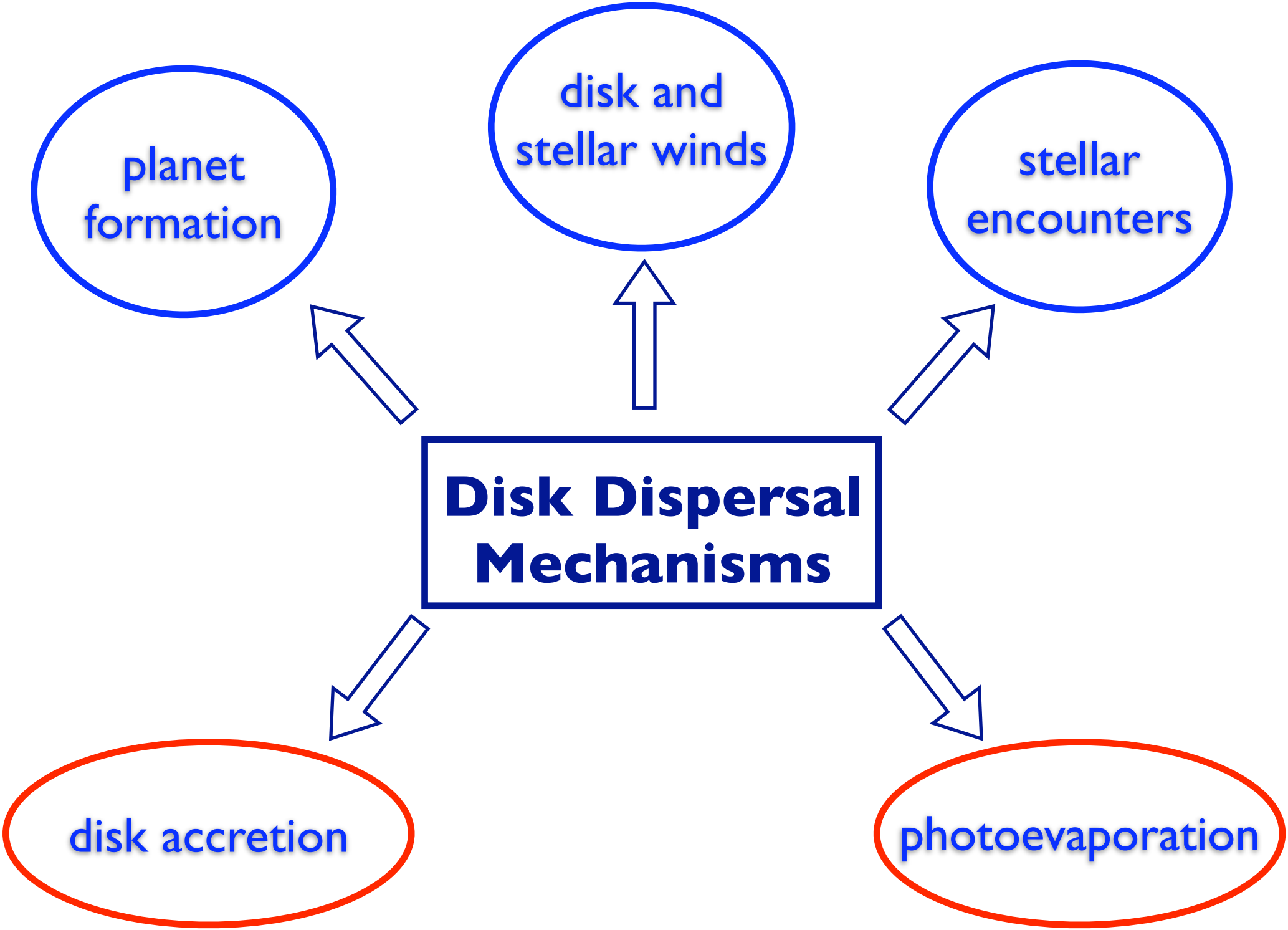
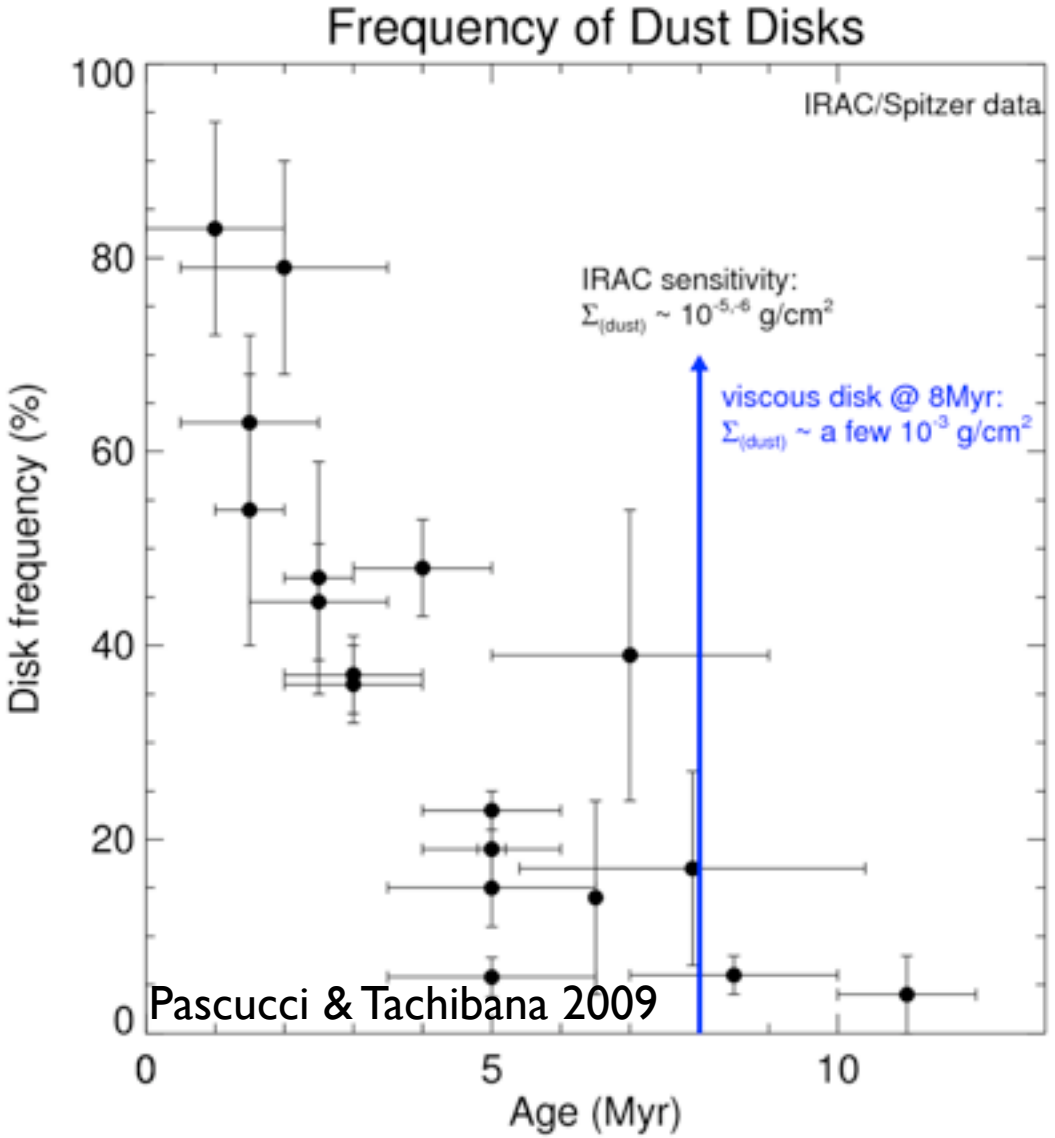
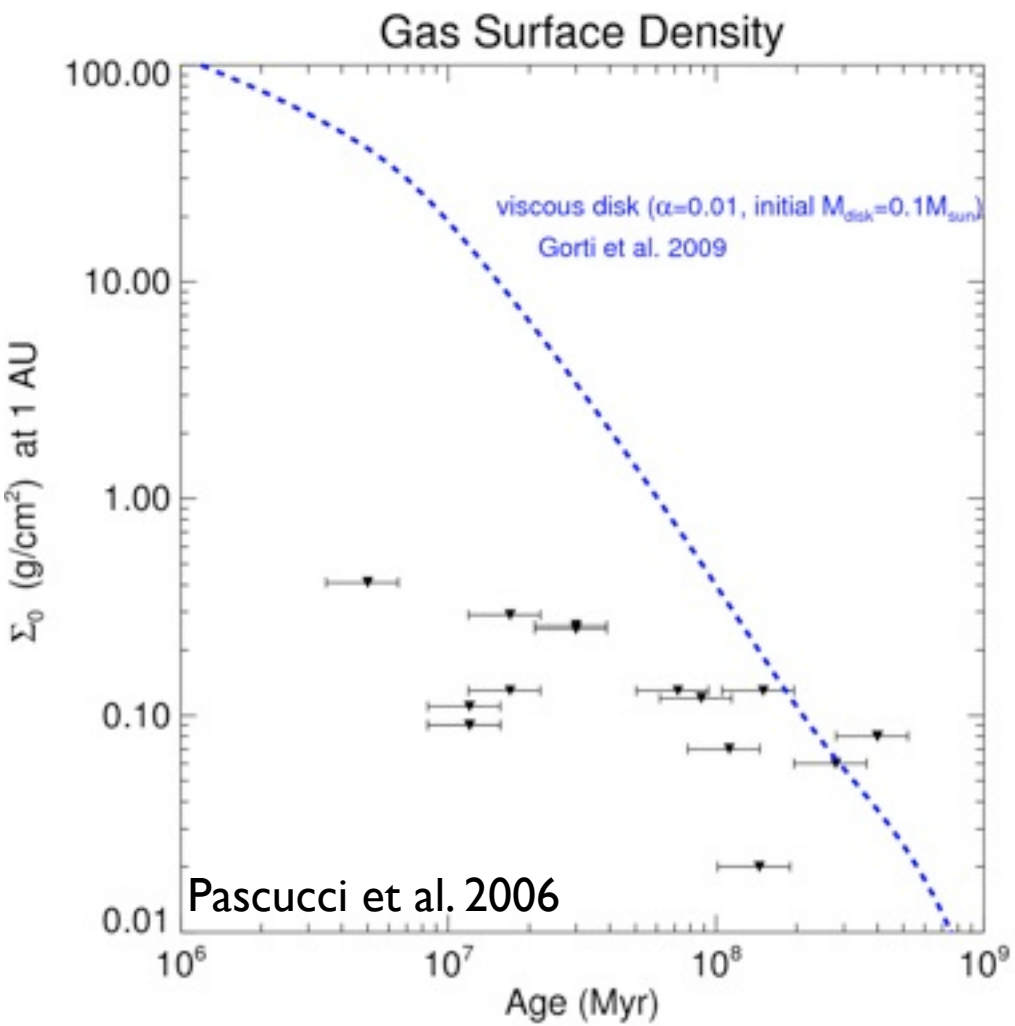
With thanks to : U. Gorti, D. Hollenbach, S. Edwards, R. D. Alexander, B. Ercolano, J. Owen



reviews by e.g. Hollenbach et al. 2000, Dullemond et al. 2007

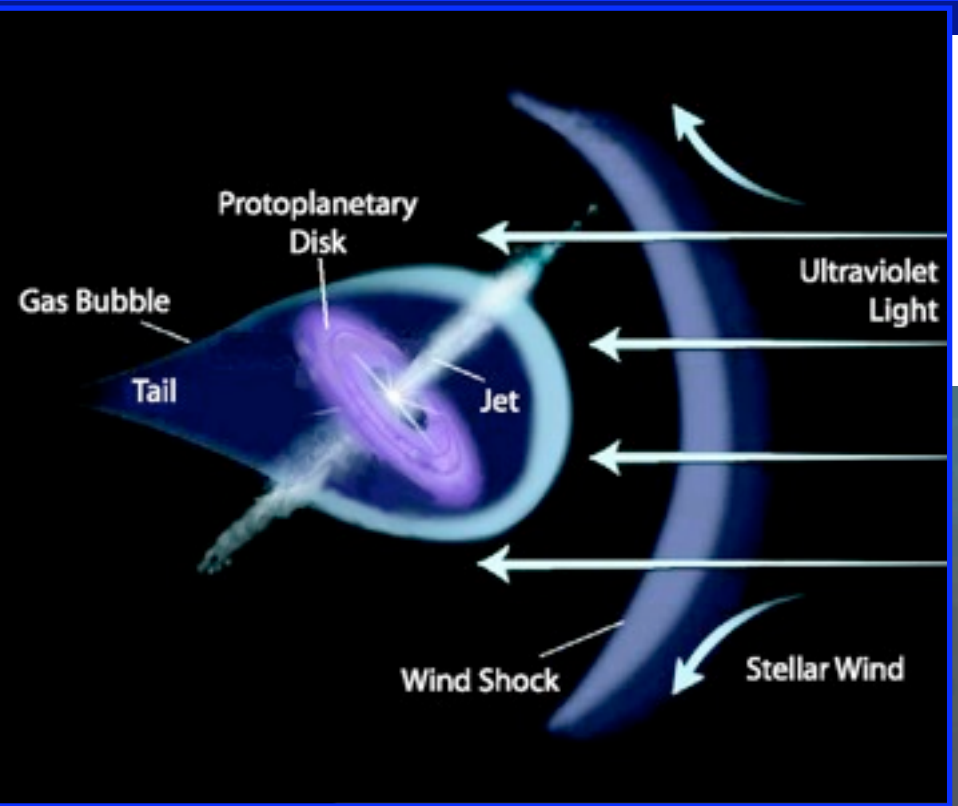
Viscous Evolution alone cannot explain the observed disk lifetimes





data from: Hartmann et al. 2005, Megeath et al. 2005, Lada et al. 2006, Silverstone et al. 2006, Sicilia-Aguilar et al. 2006, Hernández et al. 2006, 2007...

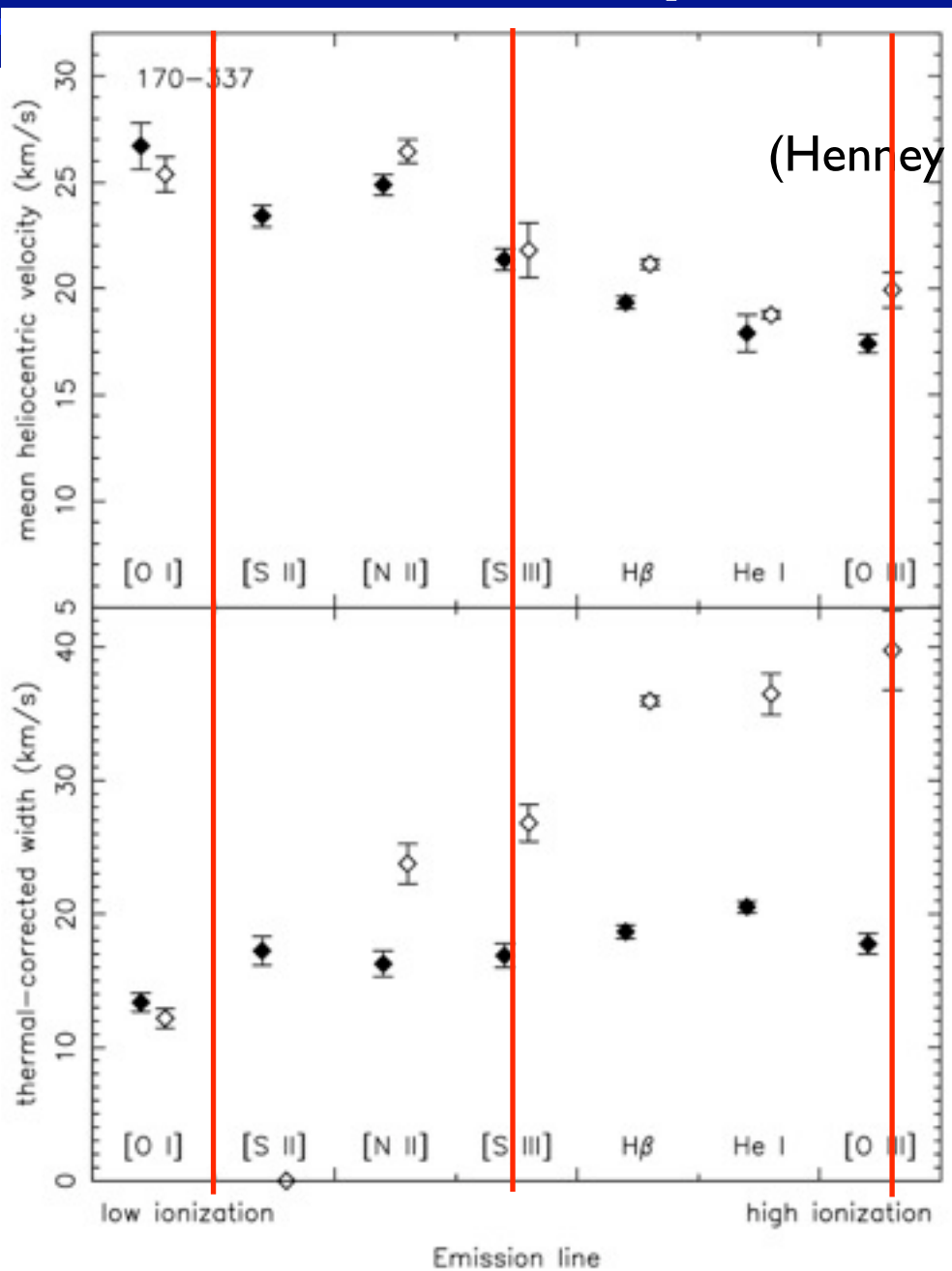
Evidence for Photoevaporation driven by Massive Stars (I)



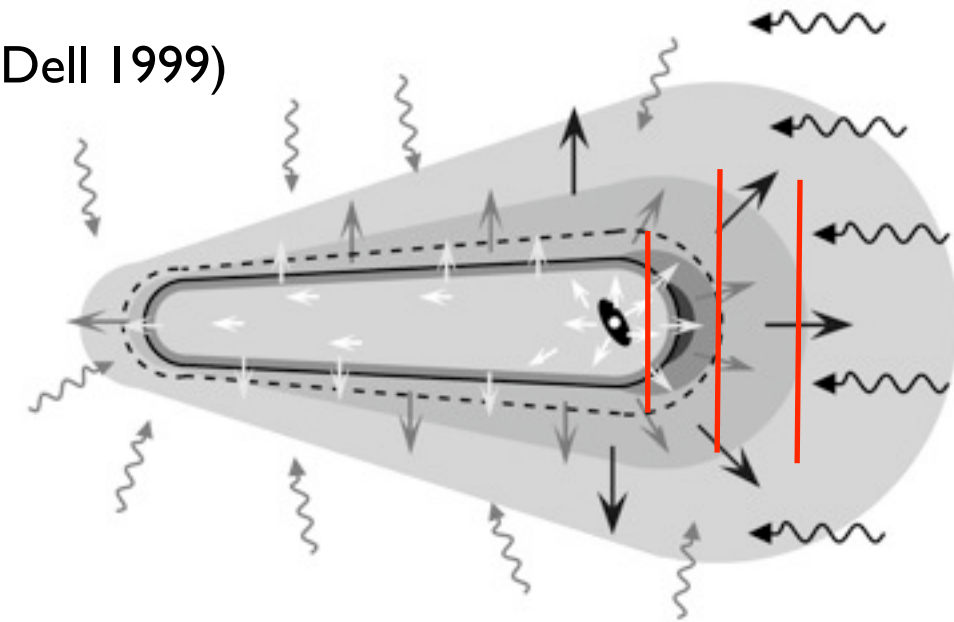
Hubble Space Telescope images of Proplyds

Credit: O' Dell, NASA/ESA

Evidence for Photoevaporation driven by Massive Stars (II)



(Henney & O'Dell 1999)



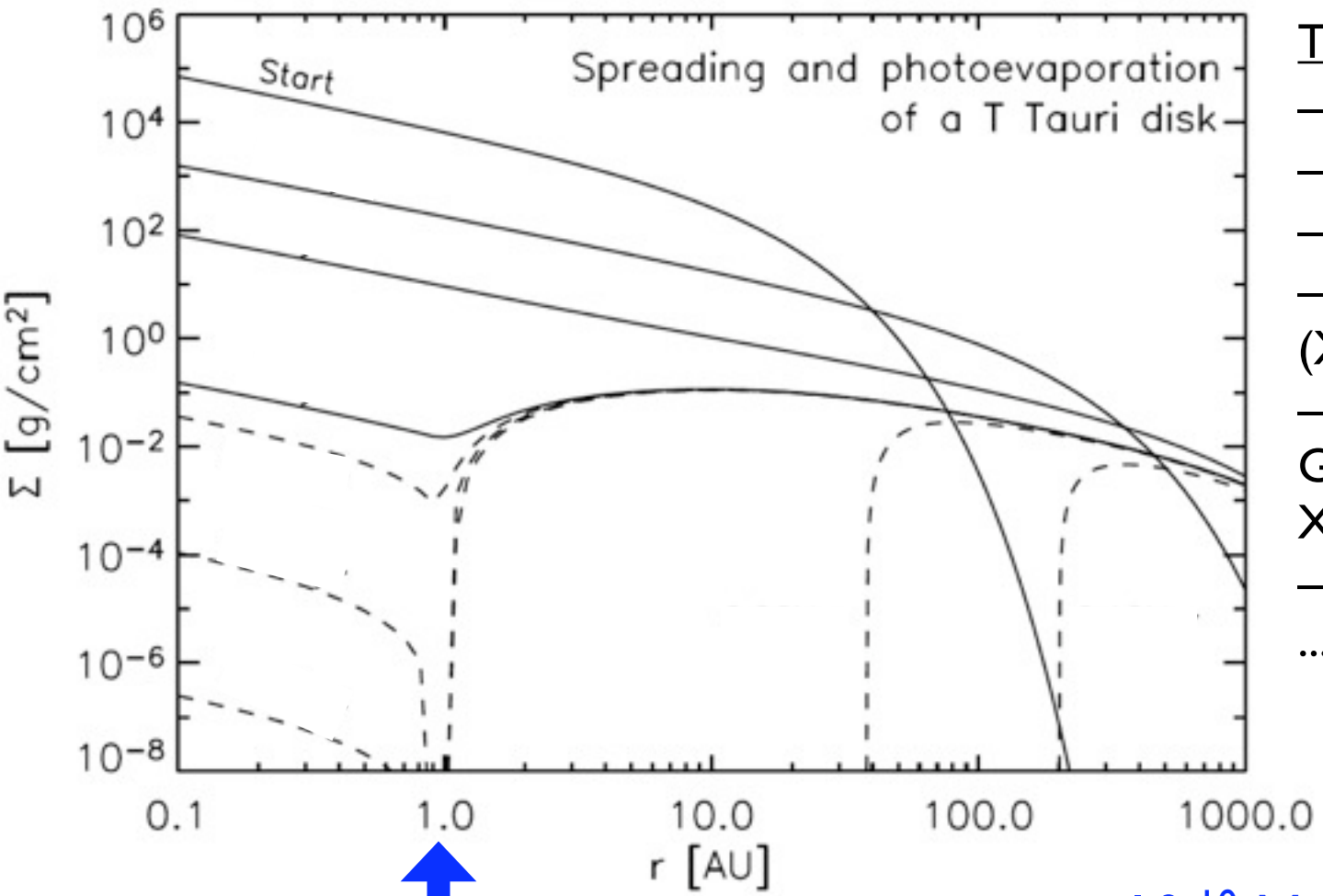
mass loss rates ~ 10^{-7} Msol/yr

(see also Bally et al. 1998, O'Dell 1998, 2001..., Johnston et al. 1998, Hollenbach et al. 2000 Rigliaco et al. 2009...)

Photoevaporation driven by the Central Star

Theory: formation of an inner hole and disk lifetimes

Fig. from Dullemond et al. 2007 (models from Alexander et al.)



Theory papers:(selection)

– Clarke et al. 2001 (EUV)
– Font et al. 2004 (EUV)
– Alexander et al. 2006a,b (EUV)
– Ercolano et al. 2008, 2009 (Xrays)
– Gorti & Hollenbach 2009, Gorti et al. 2009 (EUV, FUV, Xrays)
– Owen et al. 2009 (Xrays,EUV)
.....

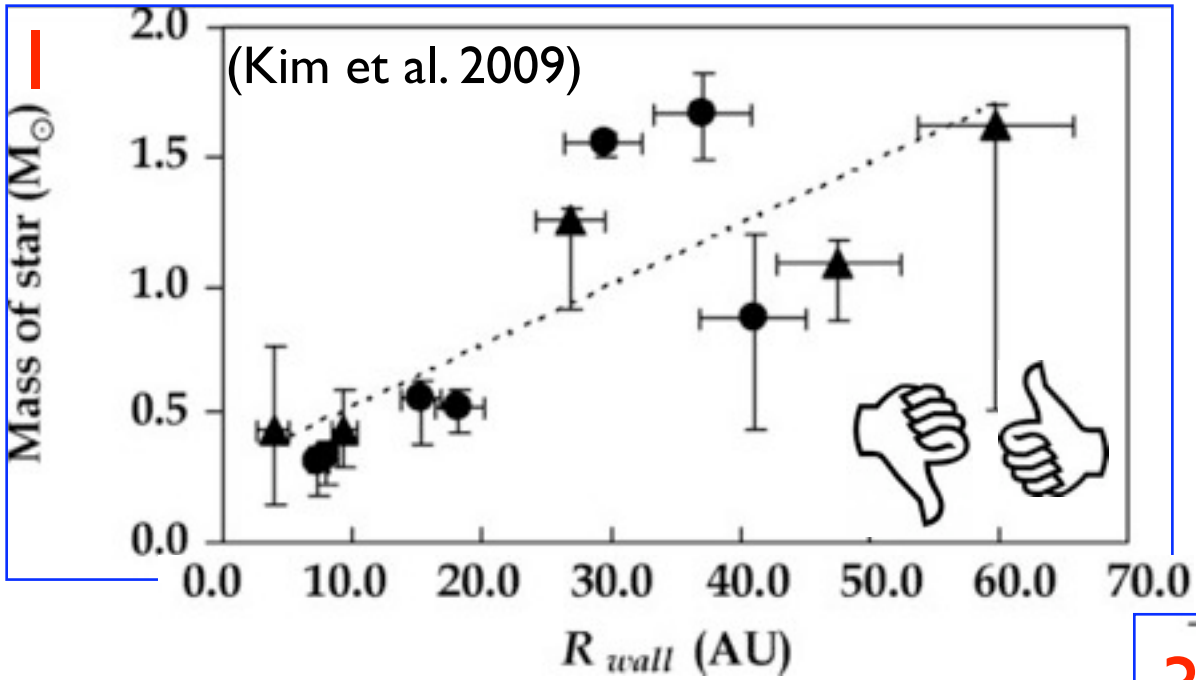
typical mass loss rates

~ 10^{-10} Msol/yr EUV

~ 10^{-8} Msol/yr Xrays/FUV

Observational tests based on dust disk properties

1



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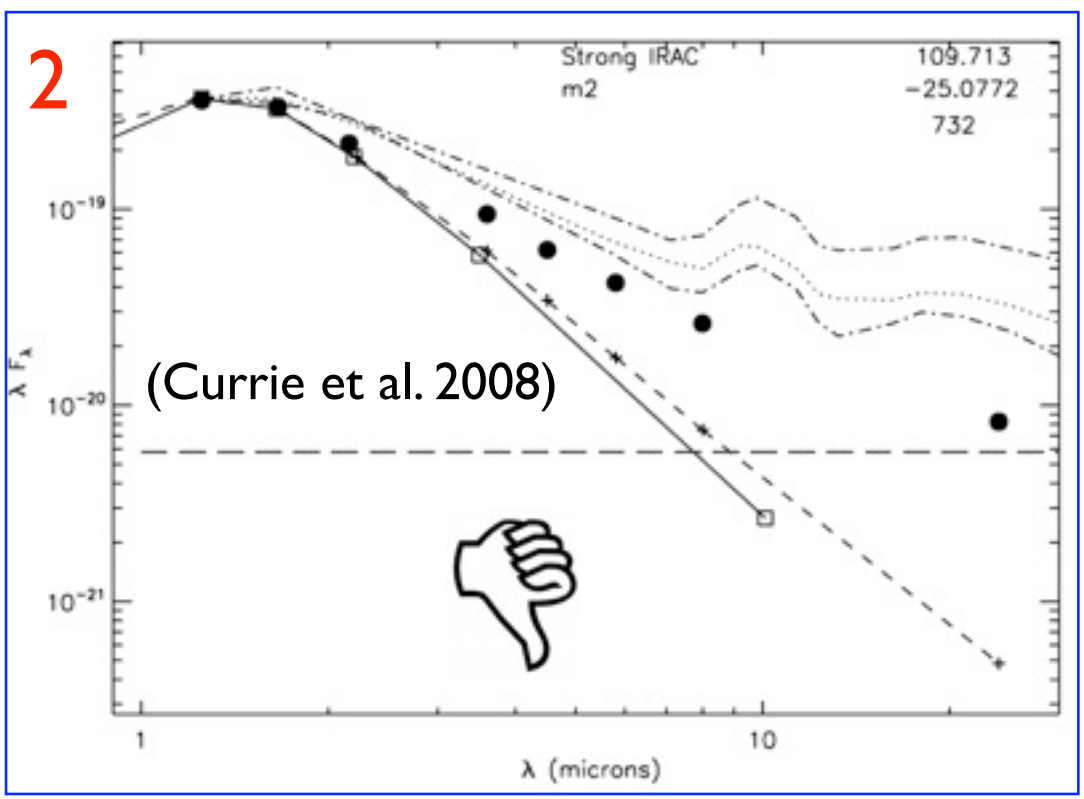

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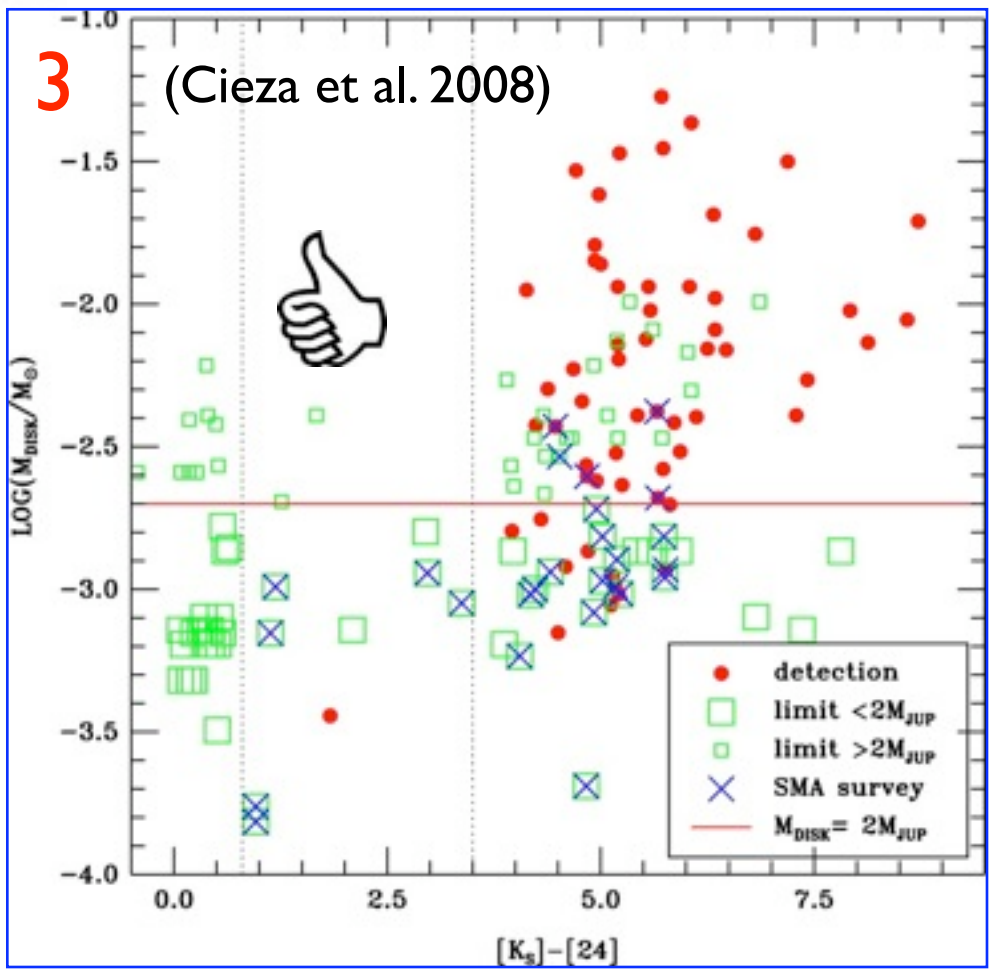
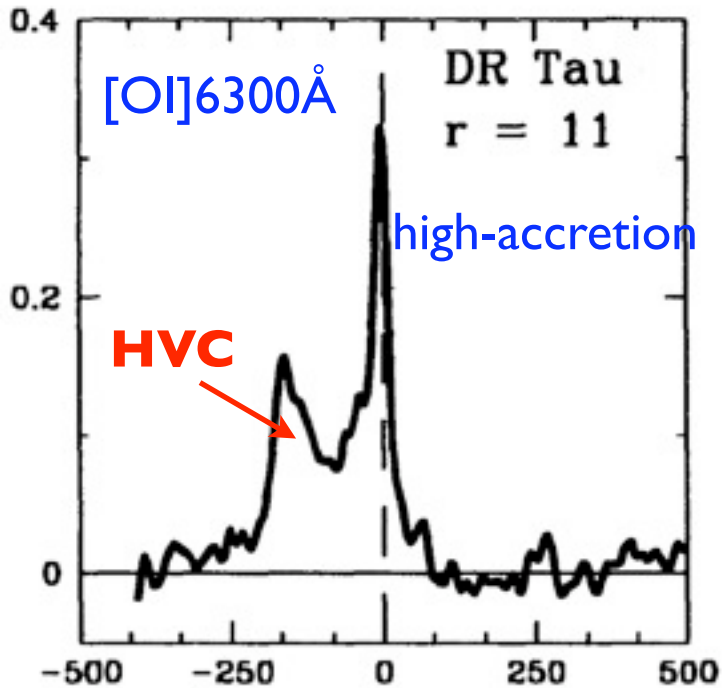
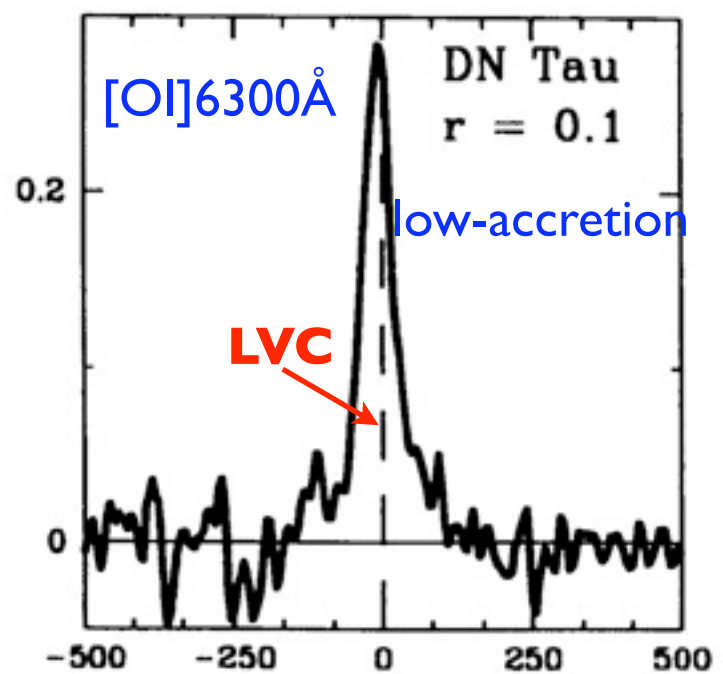
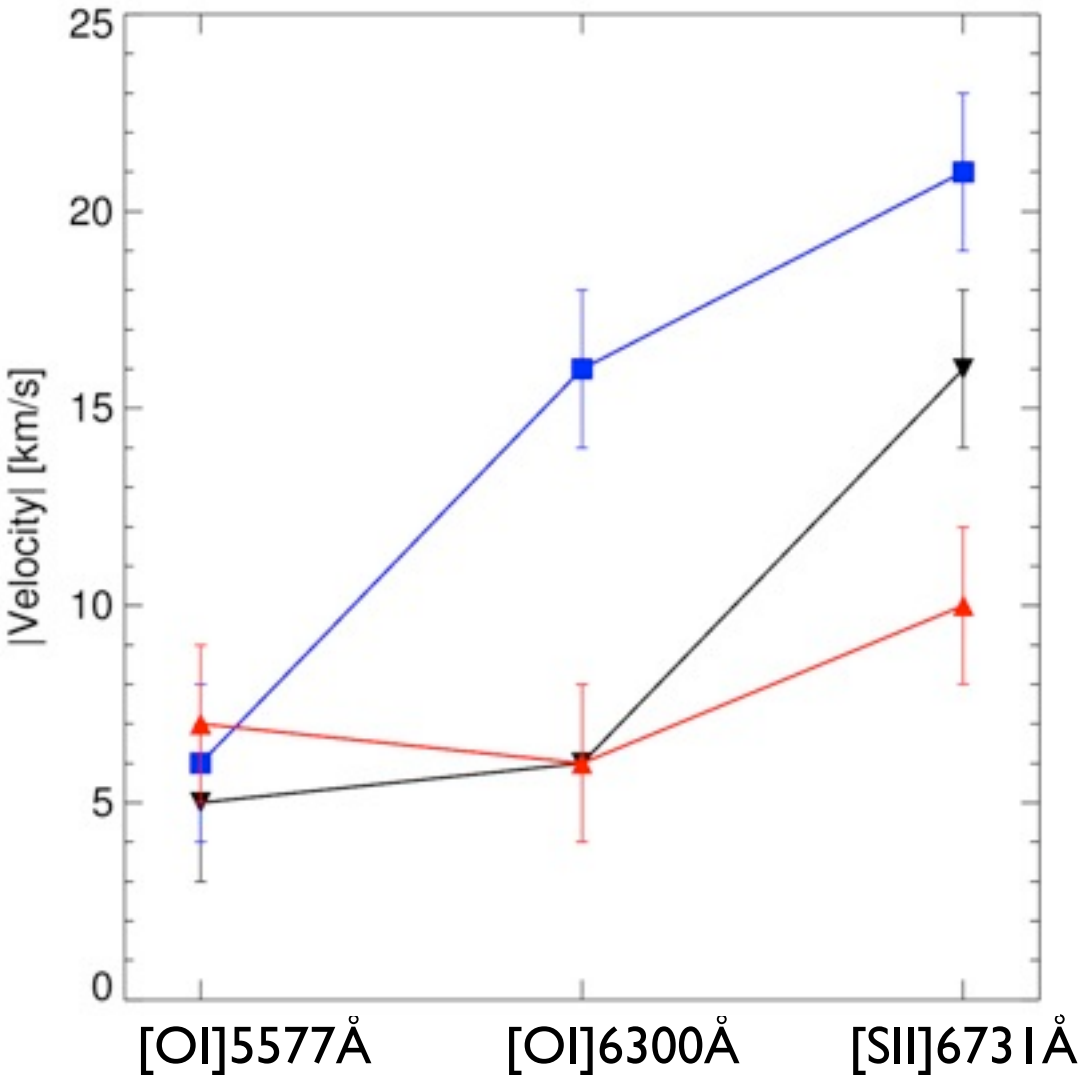


Tracing the outflowing gas with optical lines



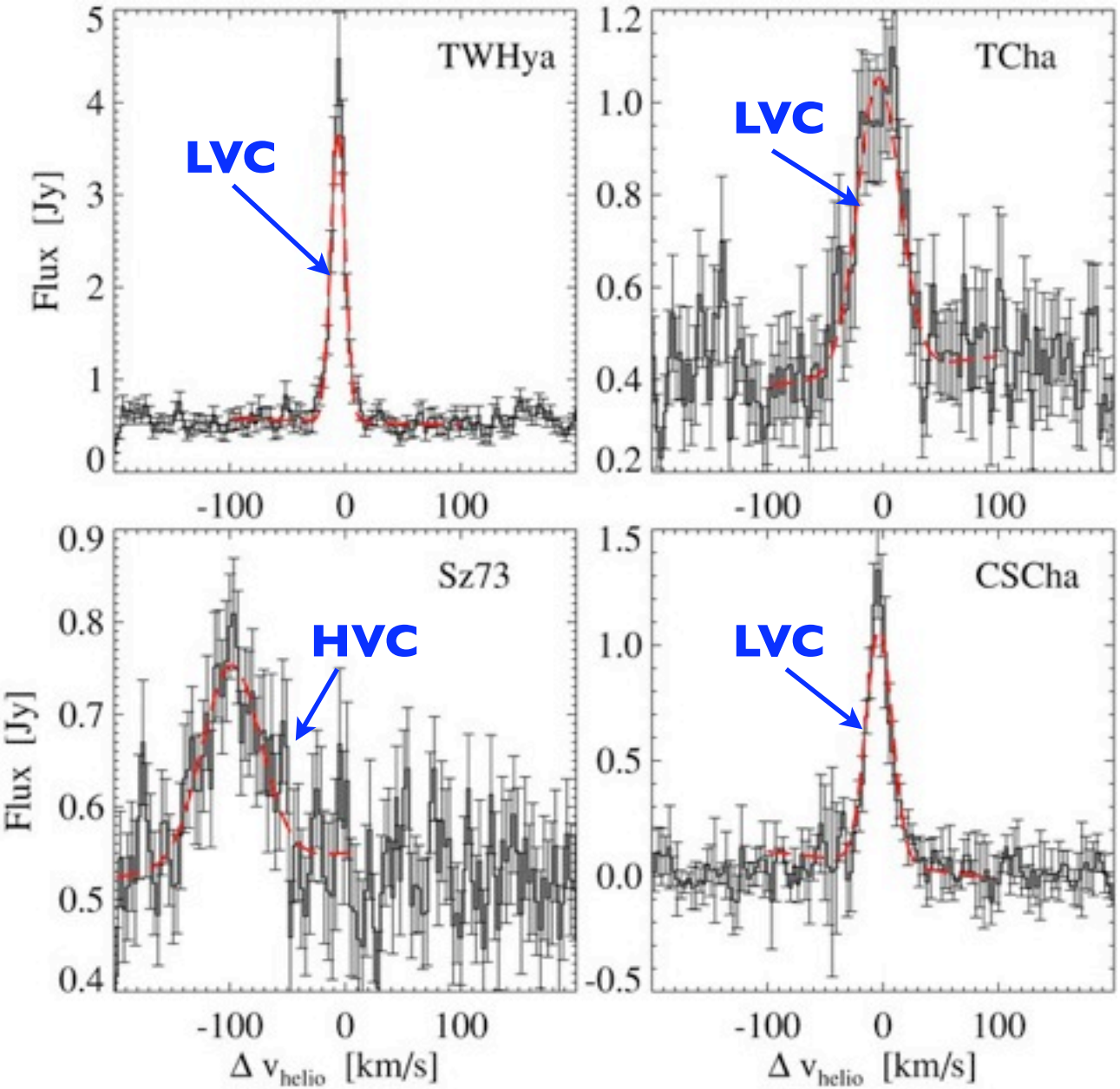


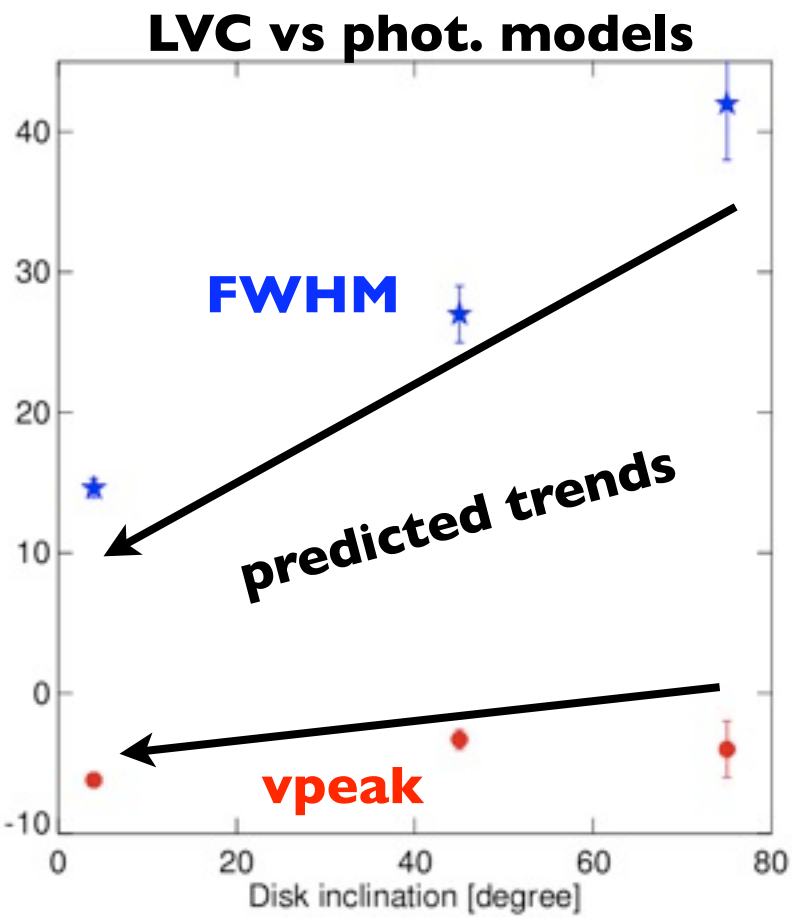
from Hartigan, Edwards & Ghandour 1995



critical density

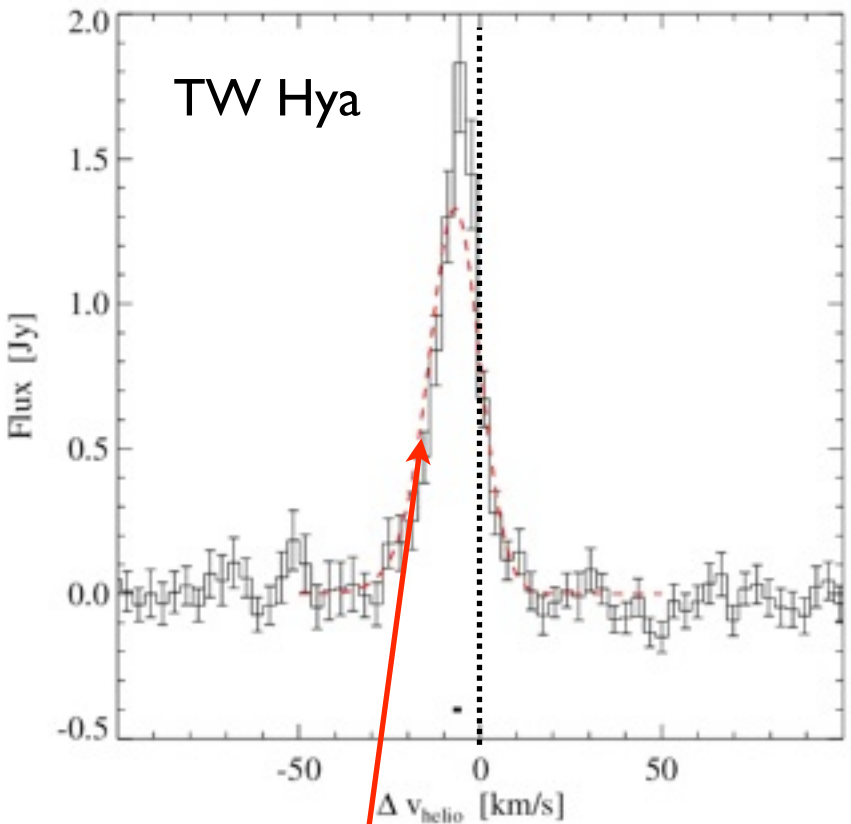
Evidence for central star-driven photoevaporation – [NeII] emission



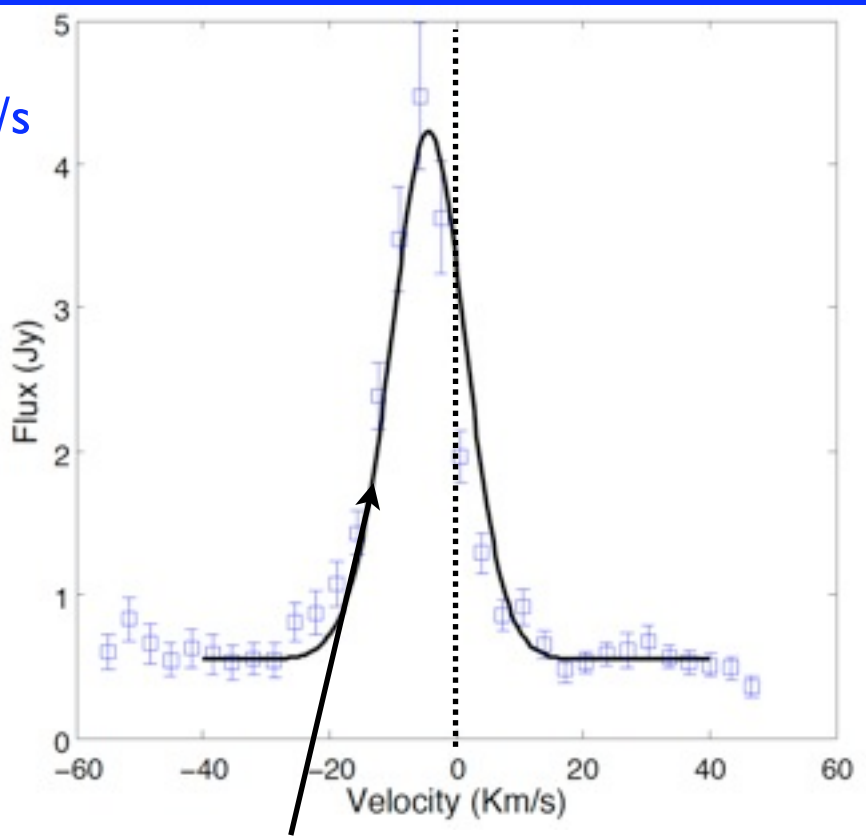


from Pascucci & Sterzik 2009

Photoevaporation rates – the case of TW Hya



blueshift of -6km/s



EUV-driven wind (Alexander 2008)

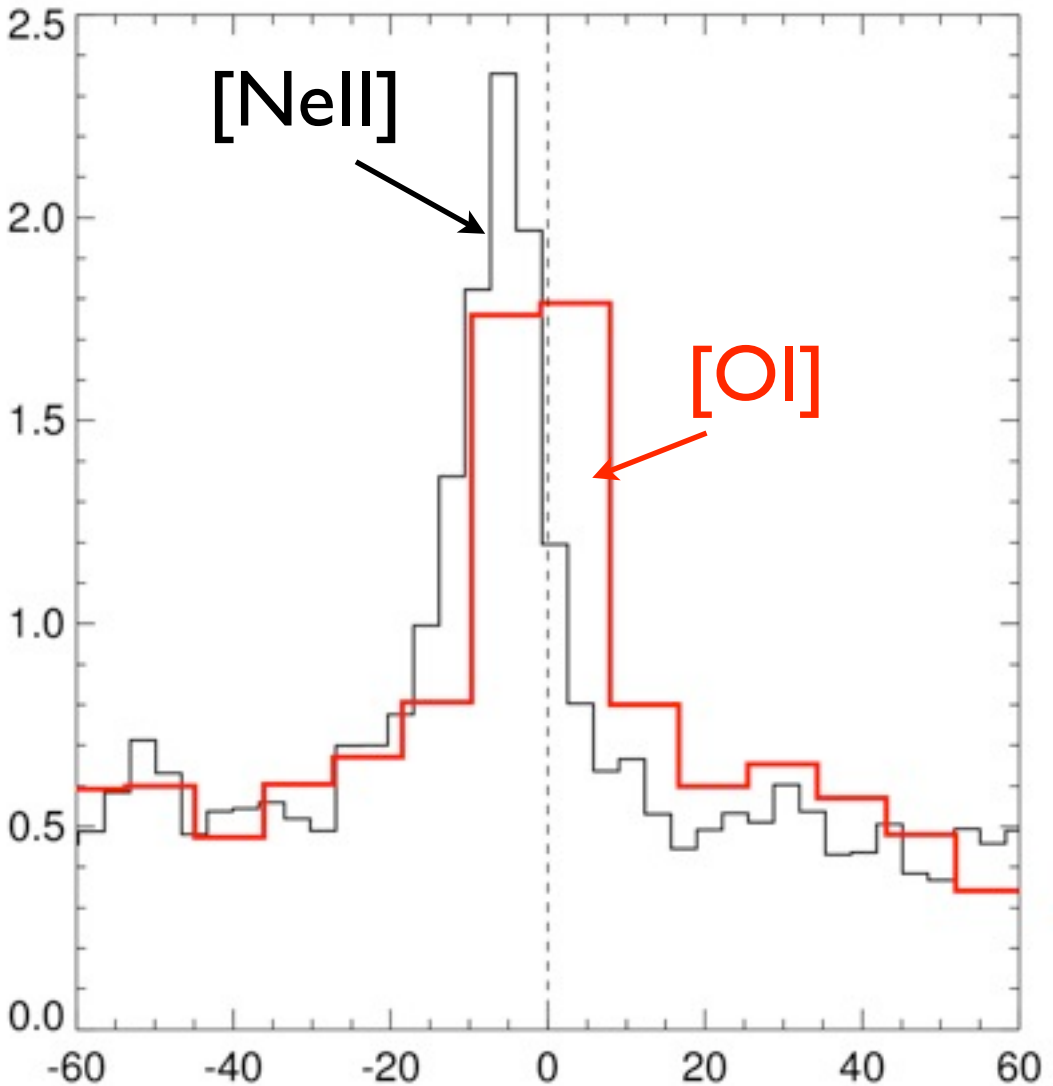
EUV/Xrays-driven wind
(Ercolano et al. in prep.)

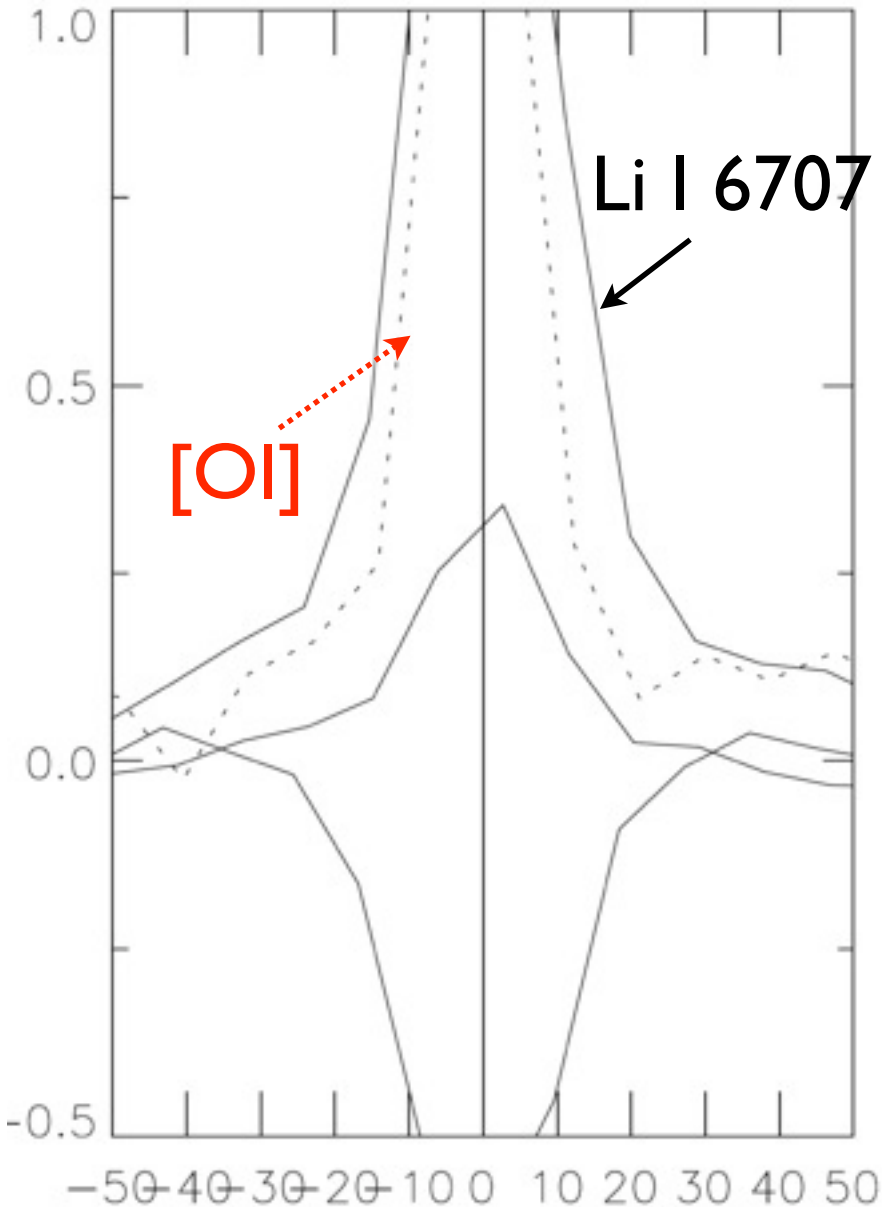
mass loss rate ~ 10^{-10} Msol/yr
(Pascucci & Sterzik 2009)

mass loss rate ~ 10^{-8} Msol/yr

disk lifetime
150 Myr vs 2 Myr

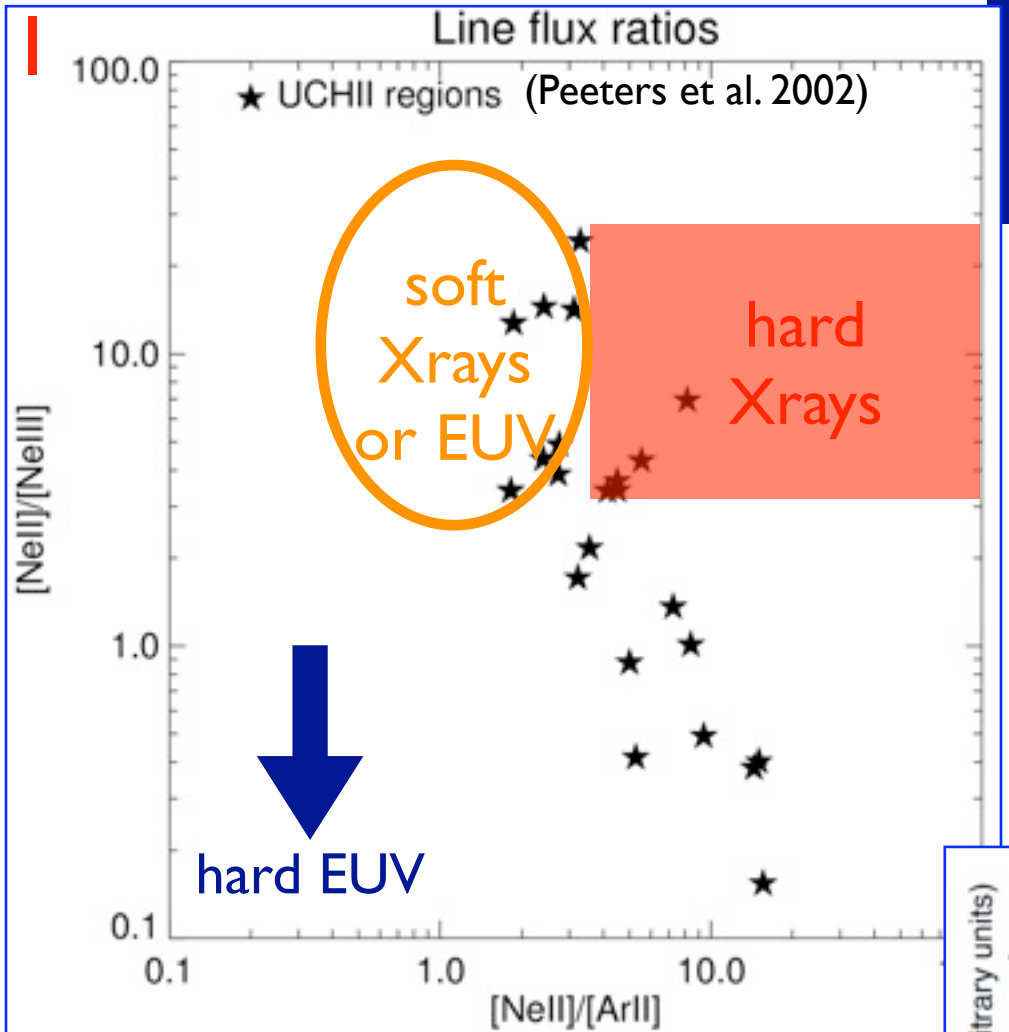
TWHya – Photoevaporating gas in the [OI]6300Å (?)



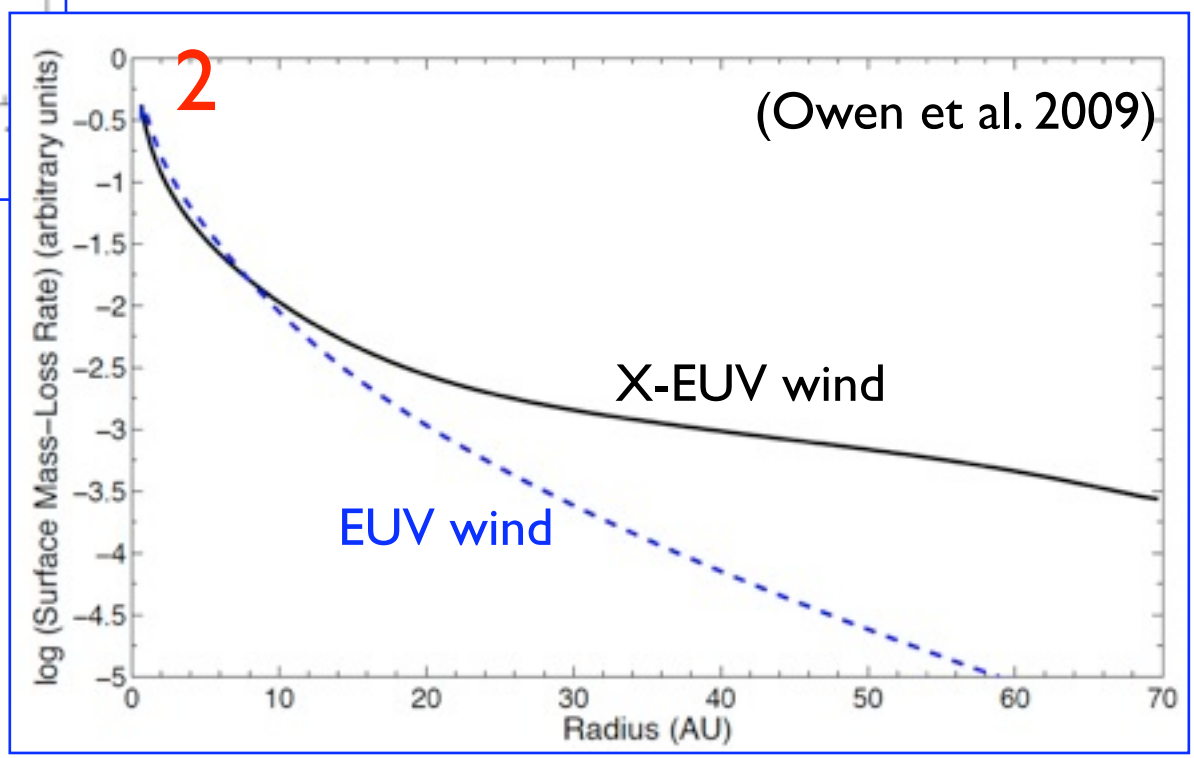


courtesy of S. Edwards

X-rays vs EUV: tests

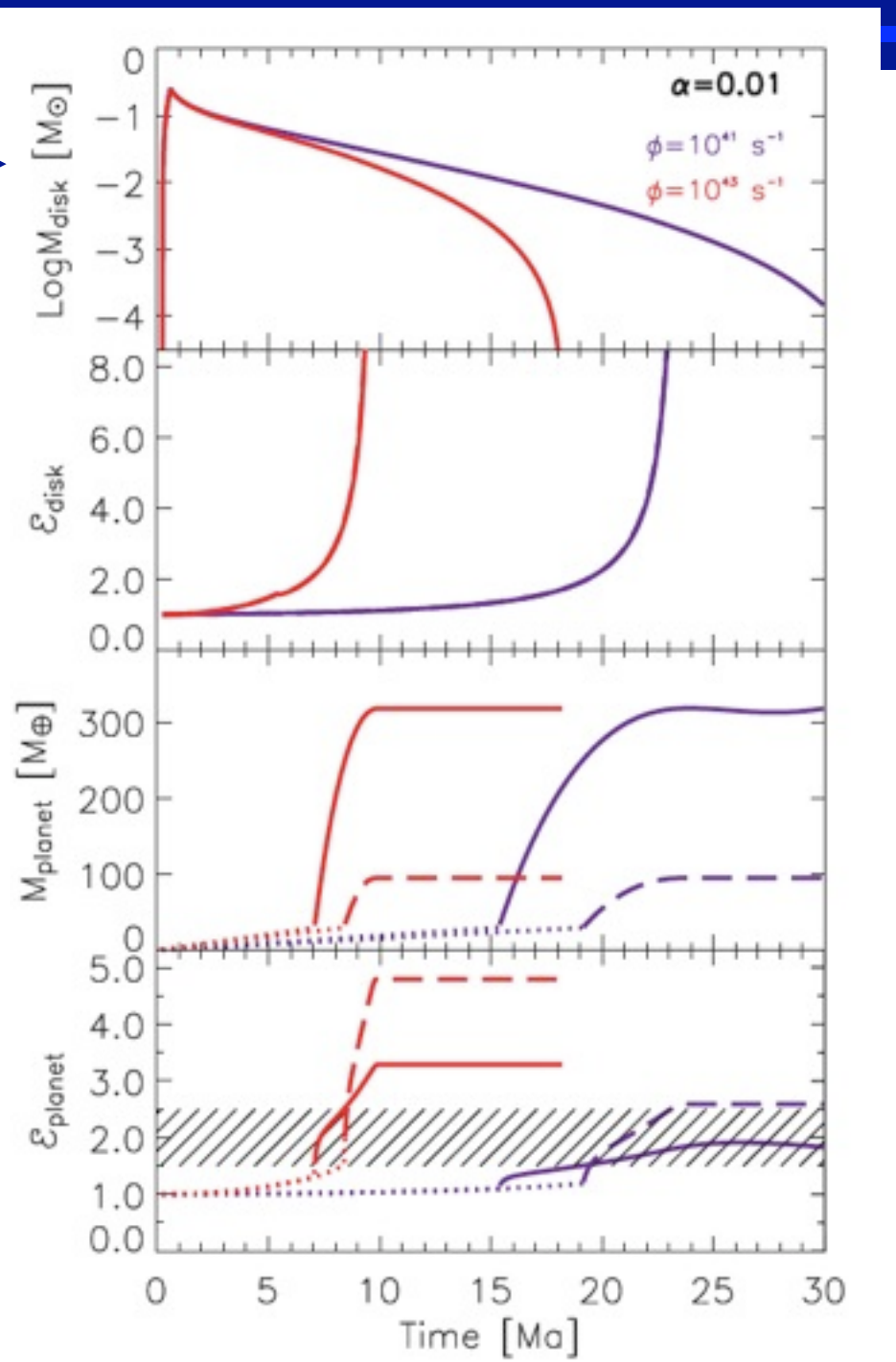


(Hollenbach & Gorti 2009)



Imprints of Photoevaporation

Model of a photoevaporating protosolar nebula (Guillot & Hueso 2006)



This model can explain

WHY the atmosphere of Jupiter is enriched in the noble gases Ar, Kr, and Xe in comparison to the solar composition (Mahaffy et al. 2000)

Take–away messages

- viscous evolution alone cannot explain the observed disk lifetime

- the dust disk properties provide only limited information on the efficiency of photoevaporation

- [OI]6300Å and [NeII] 12.81μm emission lines trace photoevaporating gas in some (evolved) disks

- the simultaneous modeling of multiple gas lines is needed to constrain photoevaporation rates