Disc Photoevaporation and Dispersal

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Introduction

Disc evolution is an important area of study as it provides important constraints on theories of both star and planet formation. For low-mass, T Tauri-type stars, disc lifetimes are observed to be in the range 10^6-10^7 years (eg. Haisch et al. 2001). However disc dispersal timescales - the time taken to evolve from a disc-bearing to a disc-less state - are observed to be 1-2 orders of magnitude shorter than the lifetimes (eg. Armitage et al. 1999; Duvert et al. 2000). Most models of disc evolution predict dispersal timescales comparable to disc lifetimes, and the observed two-timescale behaviour is difficult to reproduce. Further, this two-timescale behaviour is most clearly observed in low-mass star-forming regions (such as Taurus-Auriga or Chamaeleon) implying that the mechanism responsible is intrinsic to individual sources, rather than an environmental effect.

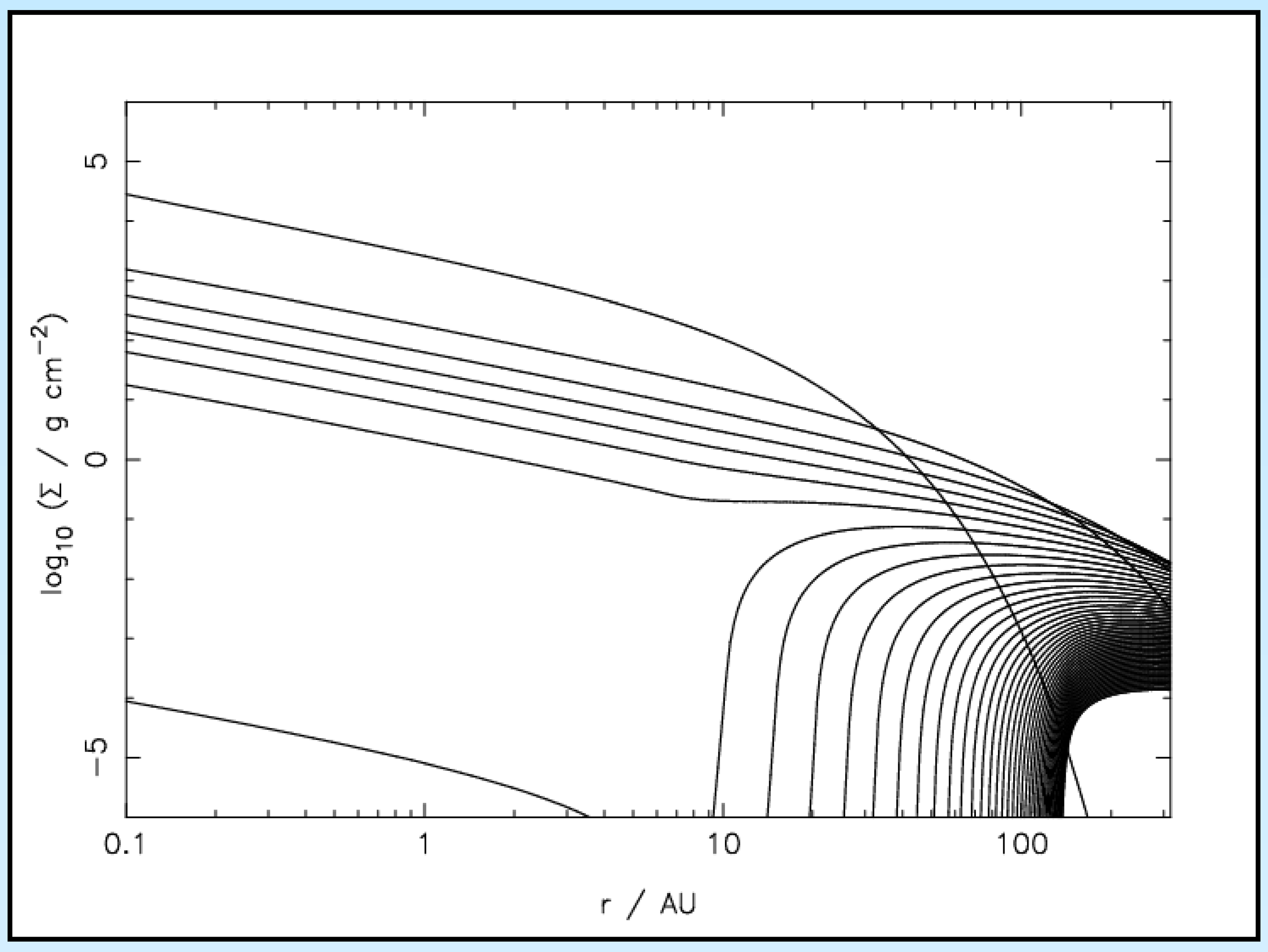

Figure 1: Snapshots of the disc surface density distribution from a combined photoevaporation/viscous evolution model, with snapshots plotted every 2×10^6yr Once the accretion rate falls to a level comparable to the disc wind the inner disc is rapidly cleared, satisfying the two-timescale constraint. (Figure adapted from Clarke et al. 2001.)

Disc Photoevaporation

Disc photoevaporation models provide a possible solution. In these models, ionizing photons from the central source create a hot, ionized layer on the surface of the disc. Outside some critical radius (~5AU for a $1M_\odot$ star), the thermal energy of the ionized material is sufficient to allow it to escape, resulting in a flow of material off the disc: a photoevaporative disc wind. For an ionizing flux of 10^{41} photon/s the mass-loss rate is $\sim10^{-10}M_\odot$/yr (Hollenbach et al. 1994). When disc photoevaporation is coupled to viscous evolution, the behaviour at early times if unaffected by the wind, as the mass loss rate is much less than the accretion rate through the disc. However at late times the accretion rate through the disc falls to a level comparable to the wind mass-loss rate. At this point the inner disc cannot be resupplied and drains rapidly on a viscous timescale, satisfying the two-timescale constraint (Clarke et al. 2001; see Fig.1 above). Adopting a spread of model parameters (initial accretion rate, viscosity etc.) provides a good match to observed data for both lifetimes and dispersal times (Armitage et al. 2003).

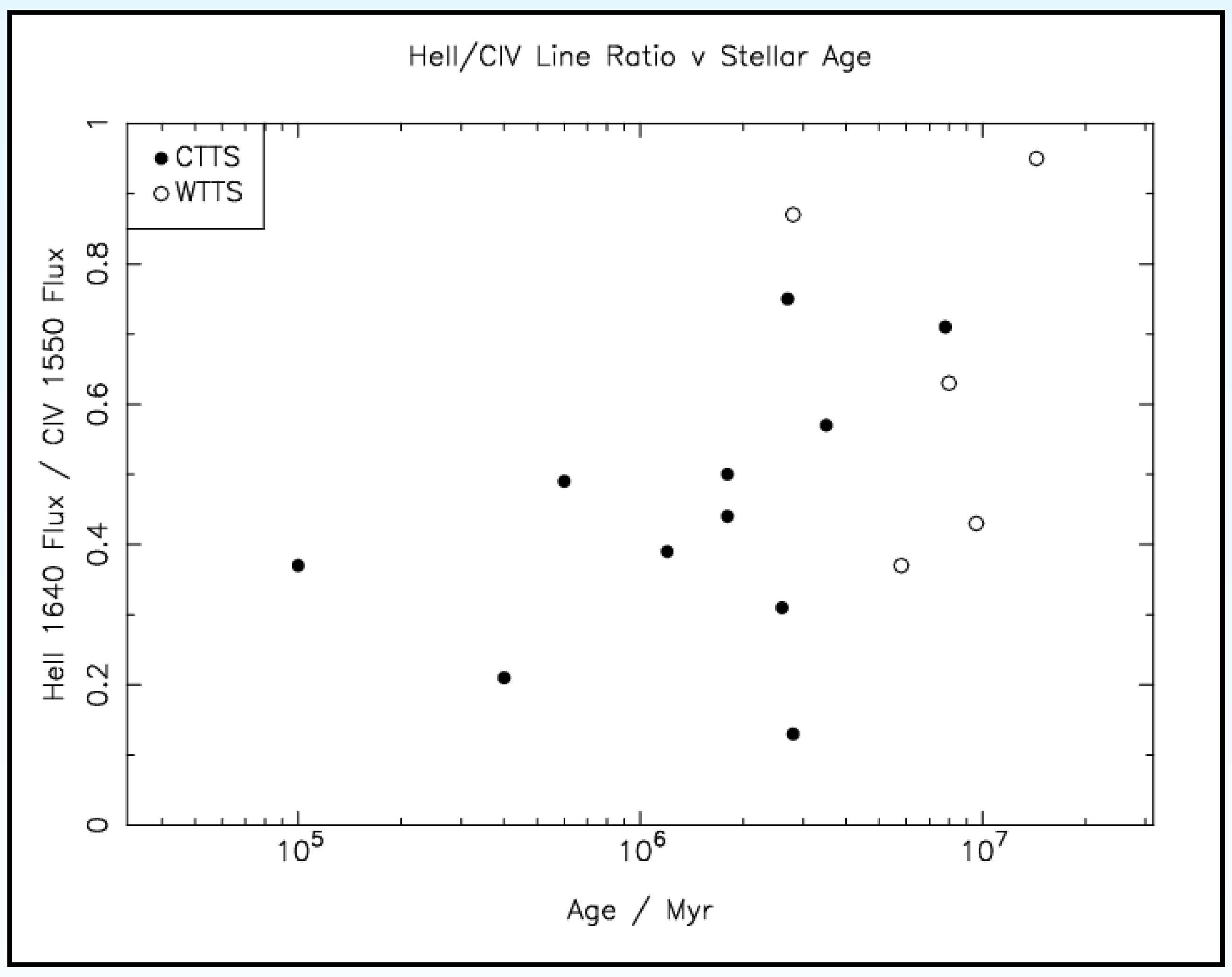

Figure 2: Observed HeII:CIV line ratio plotted against stellar age (ages from Palla & Stahler 2002). The line ratio shows no evidence for decline with time against any evolutionary indicators, implying that the ionizing flux produced does not decrease as the objects evolve. (Figure from Alexander et al. 2005.)

Driving Photoevaporation

A key requirement of the photoevaporation model is that the central star produce a strong ionizing flux, of order 10^{41} photon/s. We have previously considered both the accretion shock and coronal X-rays as potential sources of ionizing photons, but have found that neither can drive the required wind (Alexander et al. 2004a, 2004b). Here we turn our attention to the chromospheres of T Tauri stars (Alexander et al. 2005).

In order to estimate the ionizing flux emitted by the chromosphere we have first made use of an emission measure (EM) analysis. We model the chromosphere as an optically thin plasma, using EMs taken from the literature (Brooks & Costa 2003). Using these data and the **CHIANTI** spectral synthesis code we have estimated ionizing fluxes for 5 T Tauri stars to be in the range **~10^{41}-10^{43} photon/s** (see Table 1). These values are somewhat uncertain, due to reddening uncertainties, but are ample to drive the photoevaporation model.

Star	Photon flux in waveband ($\times10^{42}s^{-1}$)			A_V
	700-912Å	912-1100Å	912-2000Å	
BP Tau	**0.68**	1.5	6.6	0.5
RY Tau	**2.1**	2.3	14	0.55
RU Lup	**2.3**	2.6	16	0.4
GW Ori	**13**	9.4	56	0.8
CV Cha	**78**	71	440	1.7

Table 1: Derived ionizing fluxes from EM analysis of 5 T Tauri stars. The fluxes obtained from our models in two other UV wavebands are included for comparison. (Table from Alexander et al. 2005.) The resultant values are sufficient to power the disc photoevaporation model.

However, the model also requires that the ionizing flux persist to late times in the disc evolution. We note that the synthetic spectra from our plasma model reproduce the observed lines well (1200-1900Å), with the exception of the HeII 1640Å line.

- We contend that the HeII 1640Å line is radiatively excited, and as such should provide a diagnostic of the ionizing flux emitted by the central source.
- We also note that the CIV 1550Å line traces the total power radiated by T Tauri chromospheres (Brooks & Costa 2003).
- Thus we propose that the HeII:CIV line ratio should provide a normalised, reddening-independent diagnostic of the behaviour of the ionizing flux.

Using data from the *IUE* final archive (Valenti et al. 2000) we have studied the behaviour of this line ratio against a number of evolutionary indicators (stellar age, accretion rate, Hα strength etc.; see Fig.2 below left, Fig.3 below). We find no evidence for any decline with evolution, and conclude that the chromospheric ionizing flux is sufficient to power disc photoevaporation. However more observations, particularly of weak-lined T Tauri stars, would still be beneficial to this problem.

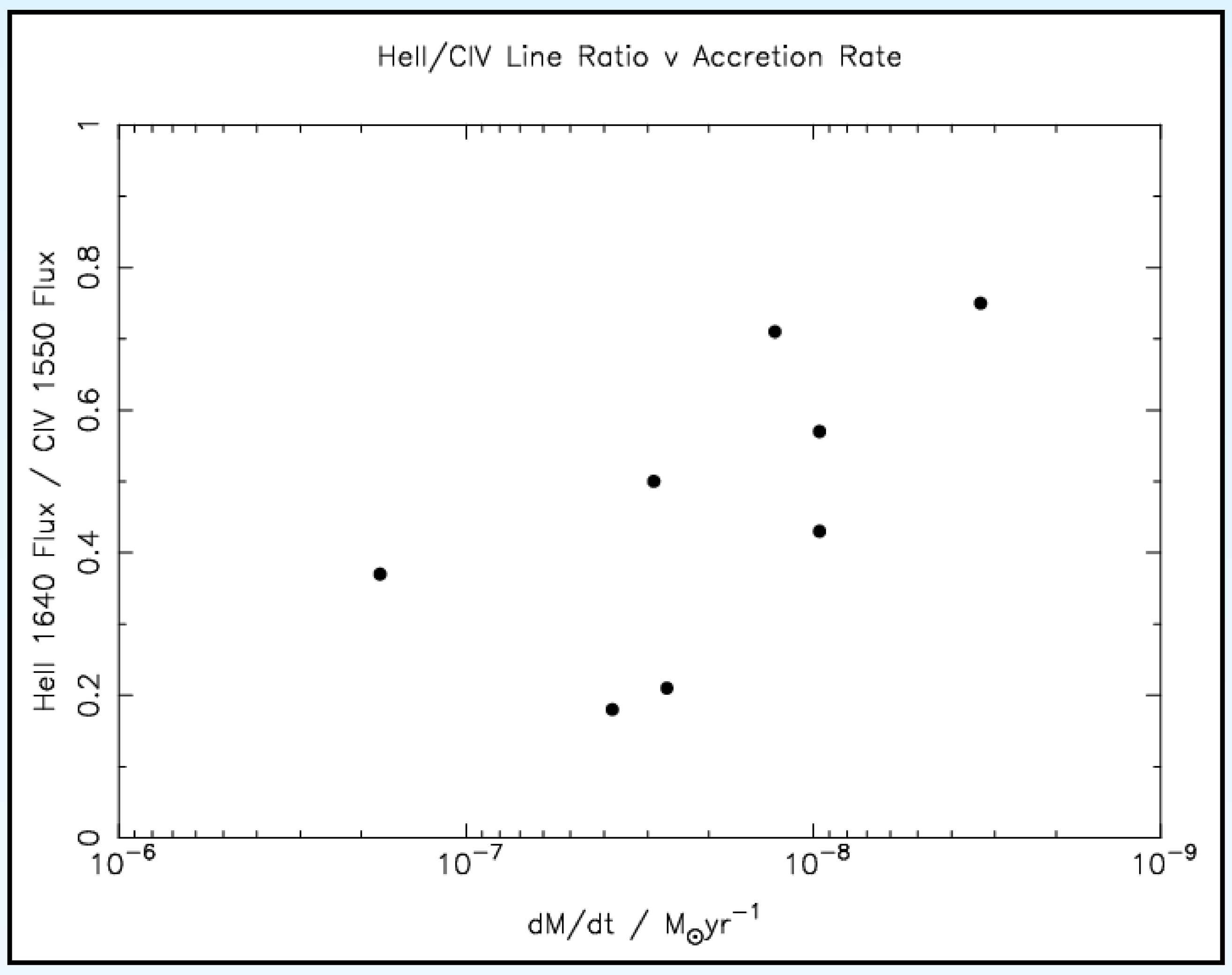

Figure 3: As Fig.2, but with the line ratio now plotted against accretion rate (accretion rates from Gullbring et al 1998, plotted so that objects "evolve" to the right). Again, there is no evidence for any decline in the ionizing flux with evolution. (Figure from Alexander et al. 2005.)

Summary

Photoevaporation of discs, when combined with viscous evolution, can explain the rapid inner disc clearing observed in T Tauri stars. We have shown that the stellar chromosphere can provide the ionizing flux required to drive such models. We are now incorporating this result into disc evolution models.

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