TURBULENCE VS WIND

15th – 19th, July @ Garching

Exclusively sponsored by:

UNIVERSITY OF LEICESTER

Challenges in differentiating viscous from wind-driven discs

Simin Tong[1], Richard Alexander[1] & Giovanni Rosotti[2]

[1] School of Physics and Astronomy, University of Leicester

[2] Dipartimento di Fisica, Università degli Studi di Milano

@simintong

st547@leicester.ac.uk

INTRODUCTION

Gas in the protoplanetary disc is required to lose angular momentum to accrete on to the central star. Conventionally, turbulence redistributes angular momentum in the inner disc to the outer disc[1]. Recently, magnetized winds have been proposed as an alternative way to extract angular momentum from the disc directly[2].

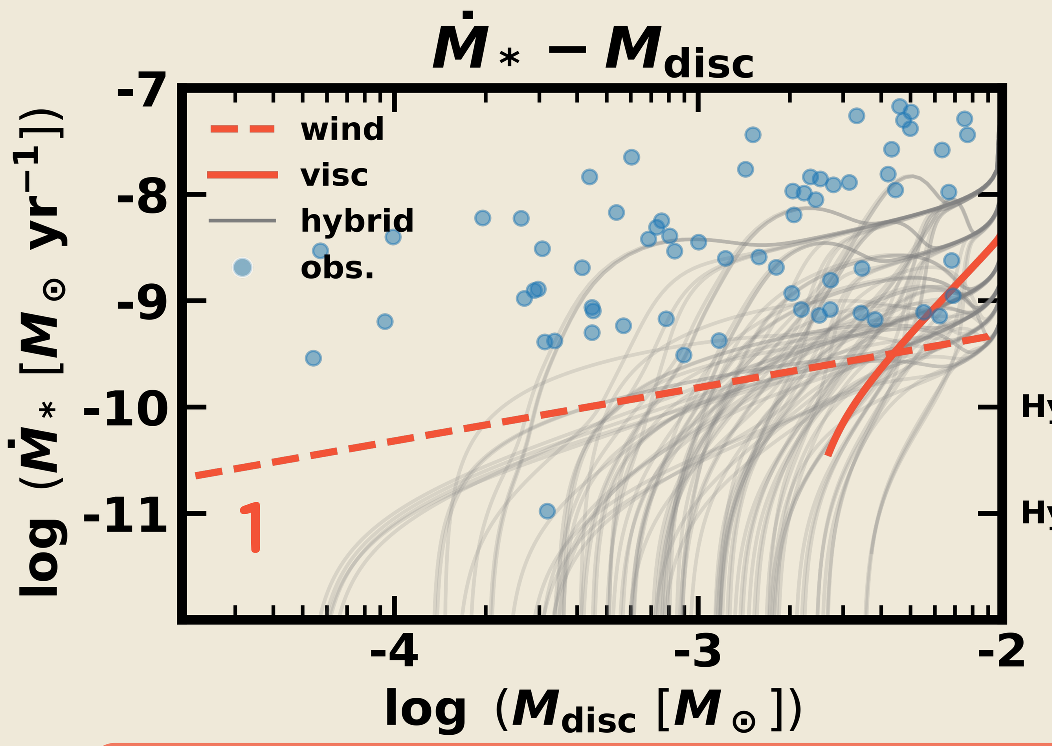
Demographic indicators, such as gas disc sizes[3] and stellar accretion rates[4], have been proposed as ways of distinguishing these two mechanisms. The former are expected to increase and decrease for the viscosity-dominated and wind-dominated discs, respectively. The latter should show different distributions.

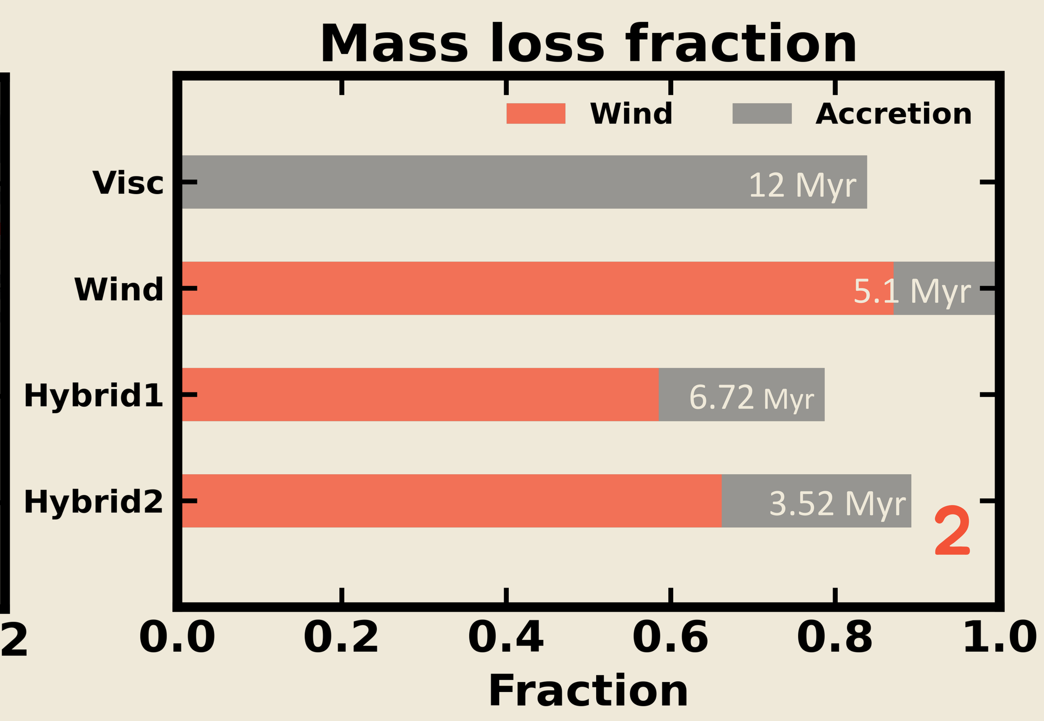
In this work, we run a suite of 1-D gas models to study **the evolution of protoplanetary discs simultaneously driven by viscosity[1] and winds[5] (hybrid discs)**. The efficiency of angular momentum removal by both mechanisms varies with radius. We characterise the disc evolution with several properties, including stellar accretion rates and gas disc radii. We further conduct **disc population syntheses** to examine the possibility of identifying the dominant mechanisms removing angular momentum by observations of disc sizes.

CONCLUSION

Comparison between discs driven by a single mechanism and hybrid discs shows that the latter behave mainly like viscous discs in terms of stellar accretion rates (Fig. 1) and disc expansion, and like wind-driven discs in terms of cumulative mass loss and lifetimes (Fig. 2).

Winds originating from a radius larger than the disc inner edge may only drive local accretion where winds dominate. The fact that viscosity drives the observed stellar accretion rate places obstacles in differentiating between these two mechanisms by the distribution of stellar accretion rates.



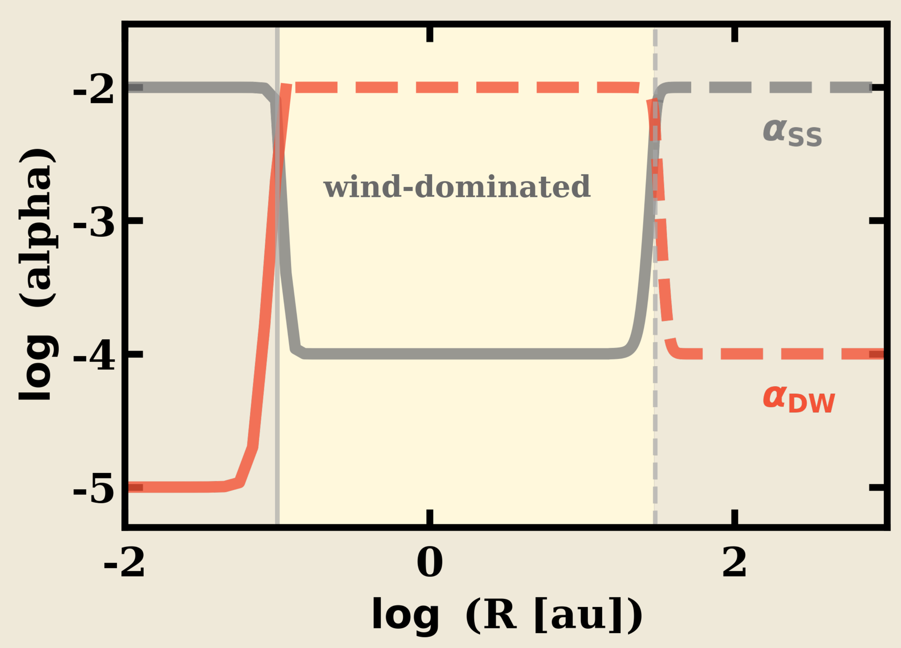


In population syntheses, the disc size change over time becomes flat unless observed at very high sensitivity. This indicates that identifying the dominant mechanism of angular momentum transport in the outer disc from measuring disc sizes can be more challenging than previously thought.

Stellar accretion rates and gas disc sizes are good indicators for the *local* angular momentum transport. Other observable diagnostics should be considered jointly to determine the *global* mechanism transporting angular momentum .

METHODS

We incorporate **a wind component**, including an advection term and a mass extraction term, into the viscous evolution model[5]. The efficiency of removing angular momentum by winds is parametrised by $\alpha_{\rm DW}$[5], equivalent to $\alpha_{\rm SS}$ in the viscous model[1]. A simple internal photoevaporation model[6] is also adopted to facilitate disc dispersal. The wind is predicted to be weaker in the inner and outer discs while more efficient in the region sandwiched between them[7]. Turbulence, which has a stricter requirement on the degree of ionisation, behaves in the opposite way[7]. Therefore, we build **a three-zone model[8,9] considering different values for $\alpha_{\rm SS}$ and $\alpha_{\rm DW}$ in each zone**, respectively, and naively assume viscosity and winds share the same transition radius between zones.



An illustration of the model is shown above. We fix $\alpha_{\rm SS} = 10^{-2}$ and $\alpha_{\rm DW} = 10^{-5}$ in the innermost region (0.01--0.1 au), and $\alpha_{\rm SS} = 10^{-4}$ in the wind-dominated region. We leave other parameters, denoted by the dashed lines, (as well as the characteristic radius, which is not shown here,) as free parameters to explore in this study.

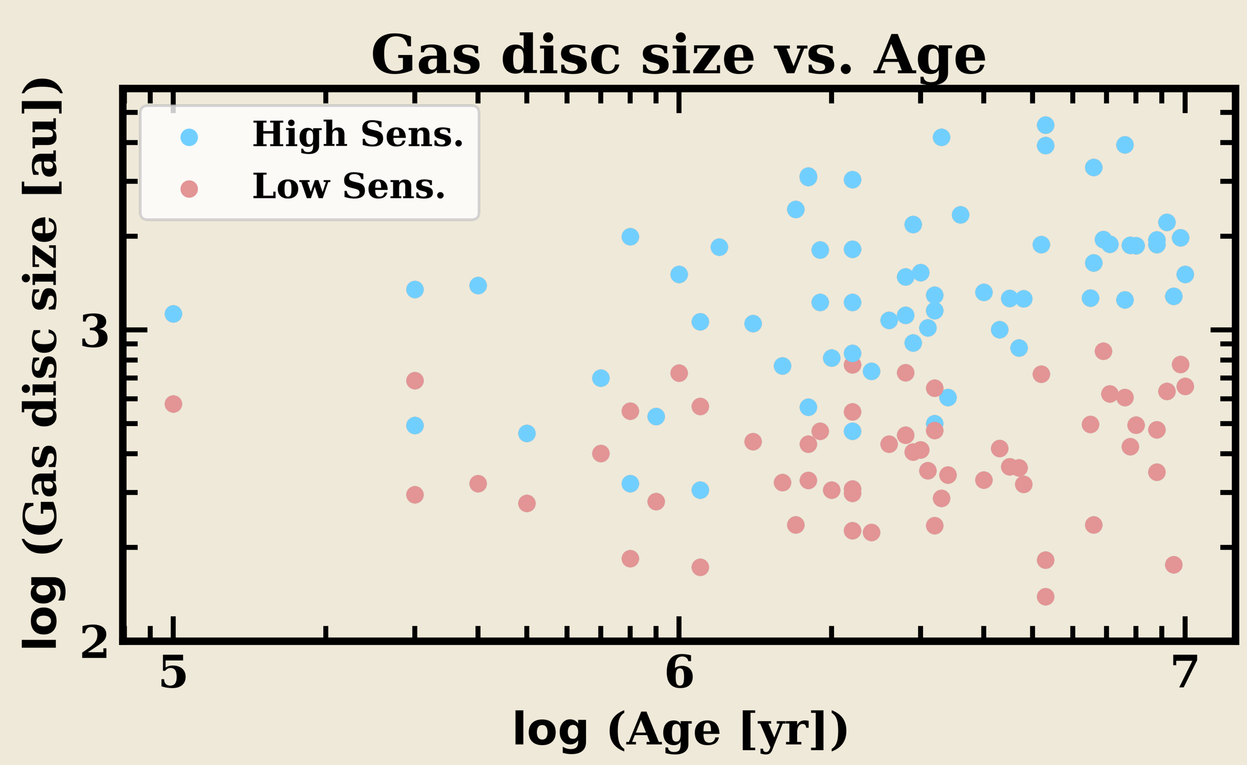
The combinations of these free parameters give rise to 90+ models. We evolve these discs till they are fully depleted or reach the time limitation (12 Myr), which is shorter.

We expand the diversity of hybrid disc properties **to a population level** to mimic various discs in disc demographics. For the first population, we assume:

- disc mass: binary uniform distribution 0.01 & 0.05 $M_\odot$
- characteristic radius: exponential distribution 20—200 au
- wind dominated region / characteristic radius: uniform distribution 10--120%
- $\alpha_{\rm DW} = 10^{-3}$ in the wind-dominated region, and $\alpha_{\rm SS} = 10^{-3}$, $\alpha_{\rm DW} = 10^{-4}$ in the radii beyond it.

For the second population: we additionally assume logarithmically uniform distributions for the three α-parameters fixed above.

We randomly draw 100 discs from each population at different ages and measure their sizes by two surface density thresholds (10^{-2} and 10^{-4} g cm^{-2}) to mimic lower- and higher- sensitivity observations.



Until we **move to the high sensitivity observation**, can we **see the disc sizes slightly increase with time**, aligning with the model assumed in this study. However, this high sensitivity is close to **the physical limit where 12CO is photo-dissociated.**

References: [1] Lynden-Bell&Pringle 1974, [2] Bai&Stone 2013 [3] Najita&Bergin 2018, [4] Alexander et al. 2023, [5] Tabone et al. 2022, [6] Alexander 2012, [7] Bai 2013, [8] Morishima 2012, [9] Gárate et al. 2021