Feed and Grow.
Understanding and Measuring disk-to-star Accretion Rates

I. Mendigutía; *imendigutia@cab.inta-csic.es*
Centro de Astrobiología (CSIC-INTA)

Abstract

Understanding how young stars gain their masses through disk-to-star accretion is of paramount importance in astrophysics. In turn, mass accretion rate ($\dot{M}_{acc}$) estimates depend on the accretion paradigm assumed. For low-mass T Tauri (TT) stars with strong magnetic fields there is consensus that magnetospheric accretion (MA) is the driving mechanism, but the transfer of mass in massive young stellar objects (MYSOs) with weak/negligible magnetic fields probably occurs directly from the disk to the star through a hot boundary layer (BL). The intermediate-mass Herbig Ae/Be (HAeBe) stars bridge the gap between both previous regimes and are still optically visible during the pre-main sequence phase, thus constituting a unique opportunity to test a possible change of accretion mode from MA to BL. In a recent **review paper*** I have dealt with our estimates of accretion rates in HAeBes, critically discussing the different accretion paradigms. A brief summary of that work is provided here, showing that although mounting evidence supports that MA may extend to late-type HAes but not to early-type HBes, there is not yet a consensus on the validity of this scenario versus the BL one. Based on MA and BL shock modeling, it is argued that the ultraviolet (UV) regime could significantly contribute to discriminating between these competing scenarios.

"On the mass accretion rates of Herbig Ae/Be stars. Magnetospheric accretion or Boundary Layer?"
Mendigutía, I. ***2020, Galaxies, 8, 39.***
Invited Review Special Issue "Star Formation in the Ultraviolet" (Ed. J. Vink)

Context

Nowadays there is consensus that disk-to-star accretion in low-mass TT stars is driven by the stellar magnetic field according with the MA scenario (**Fig. 1**, top). Thus, their $\dot{M}_{acc}$ values are inferred from observations assuming such a paradigm, providing typical rates of ~ 10^{-8} $M_{\odot}$/yr for ~ $1M_{\odot}$ stars.

In contrast, HAeBes and MYSOs have comparatively weaker magnetic fields, for which it is not clear whether accretion may occur magnetospherically or directly from the disk to the star through a BL (mid- and bottom- panels of **Fig. 1**).

The same observations can lead to different $\dot{M}_{acc}$ estimates depending on the accretion scenario assumed, for which it is important to investigate the problem in depth. In turn, inferring correct values of $\dot{M}_{acc}$ is crucial for our understanding of stellar growth, protoplanetary disk dissipation, and planet formation, among others.

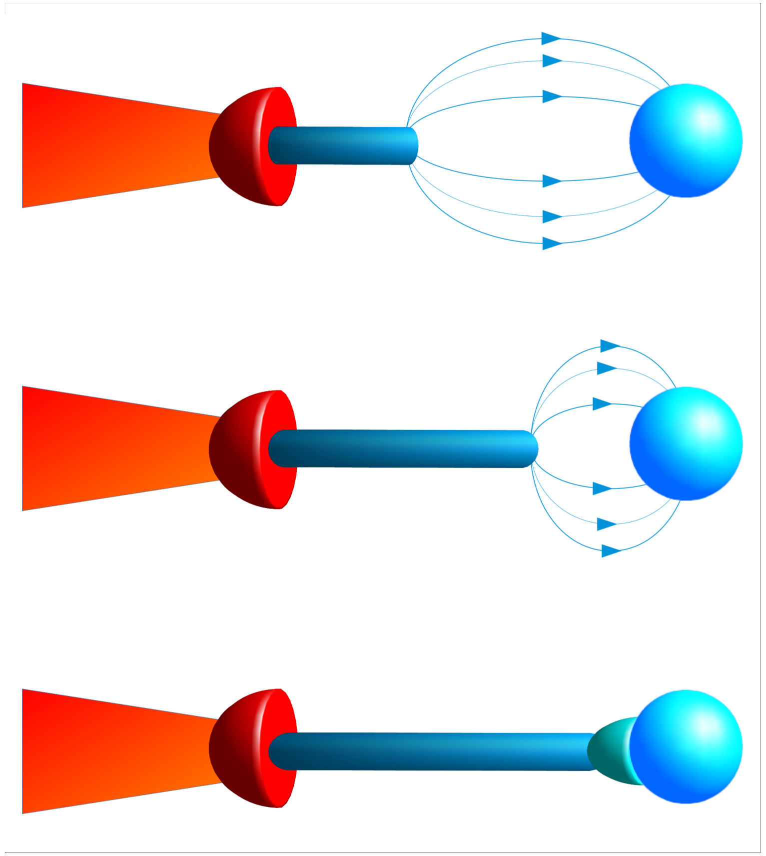

Fig. 1*: Edge-on accreting disk where the dust (red) is further from the star than the gas (blue). Gas is channelled through the stellar magnetic field lines according to MA (top and middle panels, corresponding to decreasing magnetic strengths and sizes of the magnetosphere), and directly onto the star through a BL (indicated in cyan at the bottom panel) in the absence of a strong enough magnetic field*

Outline of the review paper

- *Sect. 1:* ***Introduction***, where the general problem of obtaining accretion rates across the full range of stellar masses is described.

- *Sect. 2:* ***A Brief Historical Perspective***, where a chronological overview about how accretion has been understood and measured first for TTs (Sect. 2.1) and then for HAeBes (Sect. 2.2) is included.

- Sect. 3: ***Is Magnetospheric Accretion Plausible for HAeBe stars?***, where the viability of MA in HAeBes is discussed, mainly focused on the required and the observed magnetic fields.

- *Sect. 4:* ***Magnetospheric Accretion Measurements of HAeBe Stars***, where the different ways to measure accretion rates and the corresponding accuracies based on MA are described.

- *Sect. 5:* ***Boundary Layer Measurements of HAeBe Stars***, *w*here the few available accretion rate estimates based on the BL scenario are discussed in comparison with the MA measurements.

- *Sect. 6:* ***The Ultraviolet Link***, *w*here it is argued that the UV regime may be critical to test the validity of both competing scenarios.

- Sect. 7: ***Concluding Remarks***, *w*here the final conclusions and future research lines are summarized.

Main take-home results

MA-based methods to derive $\dot{M}_{acc}$ from observations (**Fig. 2**) work for most HAeBes (with exceptions for early-type HBes), providing reasonable values of ~ 10^{-7} $M_{\odot}$/yr for ~ 2-3$M_{\odot}$ stars. Indeed, most independent works support that MA is valid at least for late-type HAeBes, and their current magnetic field measurements/detection limits are still compatible with that scenario. For the HBes, BL-based methods provide accretion rates larger than MA from the same observational data (**Fig. 3**).

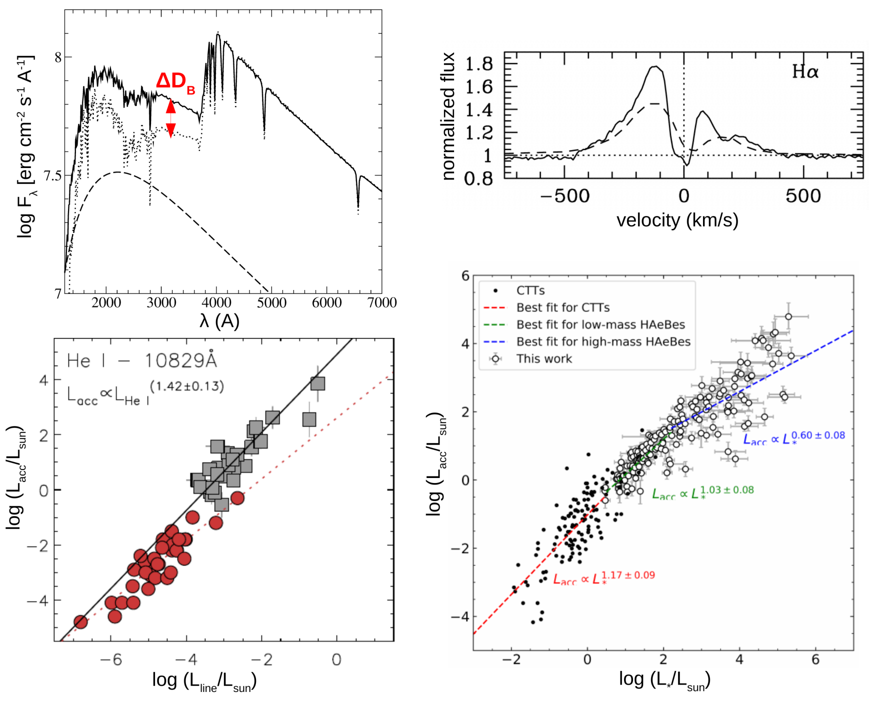

__Fig. 2__: The different methods to estimate accretion rates based on MA: modeling of the near-UV excess (top left), spectral line modeling (top right), empirical correlations with emission lines (bottom left), and the empirical correlation with the stellar luminosity (bottom right).

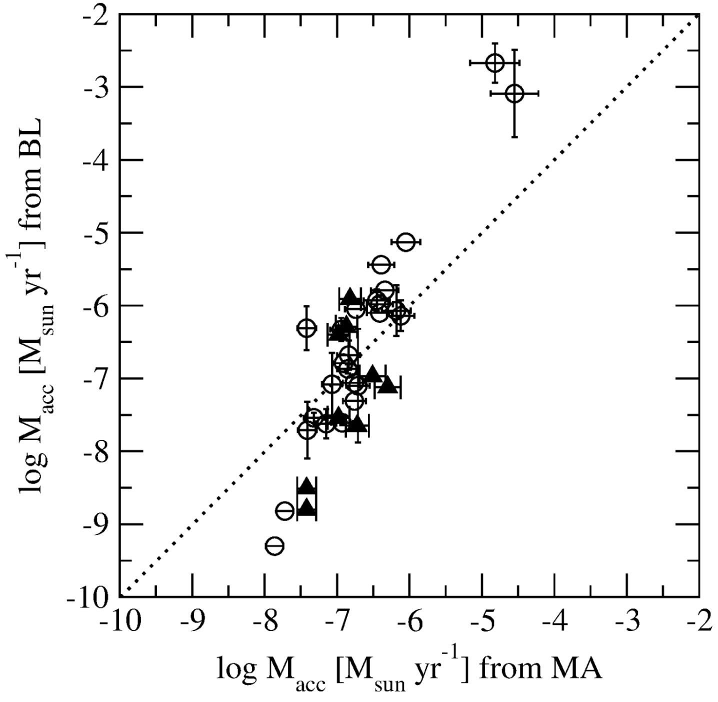

__Fig. 3__: Comparison between accretion rates estimated from MA and BL for the same sample of HAeBes and observational data. Equal values are represented with the dashed line.

Main take-home results

The near- and mid-UV flux excesses (3500–3700 Å and 2000–2250 Å) predicted by MA and BL shock modeling are generally different (**Fig. 4**). Thus, the use of simultaneous data at these wavelengths can serve to disentangle between both accretion paradigms.

Still, BL shock modeling depends on several free parameters that need to be constrained. Moreover, the BL paradigm is comparatively much less developed than MA, for which further observational and theoretical research on the former scenario is necessary.

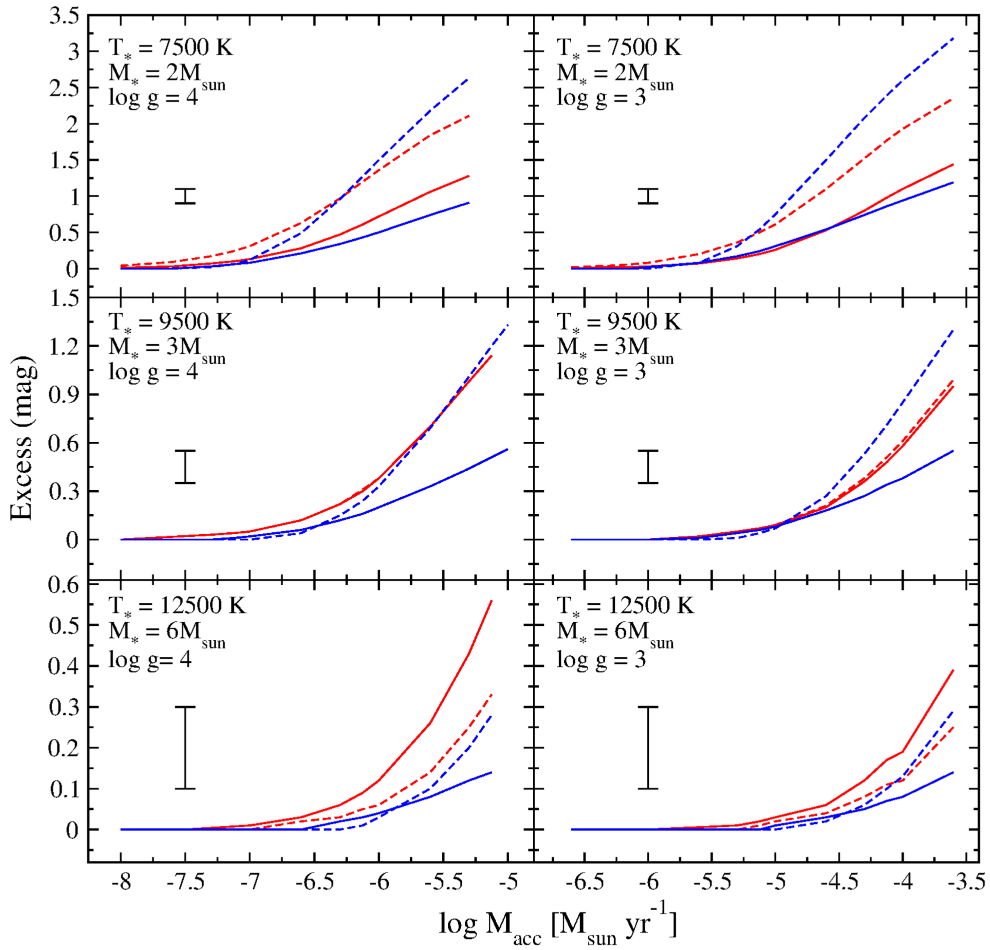

***Fig. 4**: Excess predicted from MA (red) and BL (blue) as a function of $\dot{M}_{acc}$. The solid and dashed lines refer to the near- and mid-UV, respectively. The panels show models for a late-type HAe star (top), an early-type HAe star (middle), and a mid-type HBe star (bottom). Maximum observational errorbars are shown.*

Conclusions and Future

- MA reproduces the observations of most HAeBes and is compatible with current magnetic field detections, although further improvement of magnetic field detection limits is needed.

- Still, there is not yet a consensus on the physical mechanism driving disk-to-star accretion in HAeBes, specially for the HBes, that need an alternative mechanism (MA is not capable of reproducing the near-UV excesses for > 25% of such sources).

- However, the competing BL scenario is comparatively less developed than MA, and further observational and theoretical development of this paradigm is needed (Marcos-Arenal et al. in prep).

- The UV region of the spectrum could be crucial to disentangle between models, given that simple shock modeling shows that the excesses predicted differ depending on the accretion paradigm assumed.

- Alternatively, the observed UV excesses in HBes may not be explained mainly in terms of accreting material shocking onto the star (as for HAes and TTs) but perhaps in terms of photoevaporative outflows shocking onto the disks (Guzmán-Díaz et al. in prep).

More details in the online version of the review paper:

https://www.mdpi.com/2075-4434/8/2/39