Accretion can be estimated from all spectral lines: HD 100546 as a test case

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1. THE EMPIRICAL CORRELATIONS

Measuring accretion in young stars surrounded by disks is crucial to understand their evolution. Correlations between the accretion luminosity ($L_{\text{acc}}$) and the luminosity of spectroscopic emission lines ($L_{\text{line}}$) were first found for T Tauri stars around two decades ago [1]. Since then, those have been improved including larger samples of stars and spectral transitions spanning from the near-UV to the near-IR. Recently, we have extended the correlations to the Herbig Ae/Be regime [2], [3], [4]. Two examples are given for the H$\alpha$ (Fig. left) and Br$\gamma$ (Fig. right) lines (T Tauri stars in red and Herbig Ae/Be stars in gray [5]). The $L_{\text{acc}}$-$L_{\text{line}}$ correlations are useful to quickly derive accretion rates over wide samples of stars by measuring the luminosity of a given emission line. However, what is the origin of the correlations?

2. COULD THE CORRELATIONS RESULT FROM MAGNETOSPHERIC ACCRETION?

It is widely accepted that material from the inner disk of T Tauri stars and many Herbig Ae/Be stars fall on to the central object through magnetoacoustic accretion (MA). In this view, ionised gas in the inner disk is funneled through the stellar magnetic field lines at a few stellar radii, free falling until it shocks at the stellar surface (Fig. left, from [5]). MA is able to reproduce emission line profiles shown by young stars. An example is given in Fig. right [2], where we reproduced (dashed line) the observed H$\alpha$ profile of the Herbig Ae/Be BF Ori (solid line). According with MA, the bulk of the emission lines is generated in the magnetosphere. Under this background, it is tempting to assume that the $L_{\text{acc}}$-$L_{\text{line}}$ correlations result from a physical connection between the spectral lines and accretion.

3. OBSERVATIONAL TEST: RESOLVING HD 100546 WITH AMBER SPECTRO-INTERFEROMETRY

HD 100546 is a young star (- 7 Myr, [6]) with a complex circumstellar environment showing evidence of ongoing planet formation. A protoplanet is located in the outer disk at $\sim$ 50 au [7], and a planet candidate could be located at $\sim$ 12 au, in the gap that separates the outer region and the inner dust disk. These properties, along with its brightness and close distance (100 pc), make HD 100546 the perfect laboratory not only to test planet formation theories but also our knowledge of accretion in young stars. Our AMBER/VLTI results (Fig. in red) in terms of Br$\gamma$ line fluxes, visibilities, and differential phases (Fig. left) are consistent with a line emitting region inside the dust inner rim ($\sim$ 0.25 au, dashed line in Fig. right) with a Keplerian, disk-like structure rotating counter-clockwise, and probably flared ($\sim$ 25\degree). The amount of gas detected needs to be replenished on time-scales of a few months to years, perhaps by planet-induced flows from the outer to the inner disc as has been reported for similar systems [8]. In addition, the Br$\gamma$ emission indicates that HD 100546 is still accreting at $\sim 10^{-9} M_{\odot}/yr$ (see also [9]). However, despite the location of HD 100546 in the $L_{\text{acc}}$-$L_{\text{line}}$ correlations is perfectly consistent with the rest of the stars, the bulk of the emission does not come from the magnetosphere (not-dashed line in the zoom-in of Fig. right), as assumed in MA.

4. REVISITING THEORY: THE ORIGIN OF THE EMPIRICAL CORRELATIONS

Young stars -from brown dwarfs to massive Herbig Ae/Be stars- show a correlation between $L_{\text{acc}}$ and the stellar luminosity ($L_{l\star}$) (Fig. left). We have recently shown [10] that all near-UV/optical/infrared (IR) $L_{\text{acc}}$-$L_{\text{line}}$ correlations result from the fact that $L_{\text{acc}}$ and $L_{l\star}$ correlate. Observational and synthetic data using artificial lines (Fig. Right) illustrate that the shape of the $L_{\text{acc}}$-$L_{\text{line}}$ correlations is determined by the $L_{\text{acc}}$-$L_{l\star}$ correlation shown by the sample under analysis. Because PMS stars show the $L_{\text{acc}}$-$L_{l\star}$ correlation implies that $L_{\text{acc}}$ also correlates with the luminosity of all spectral lines. Therefore, the $L_{\text{acc}}$-$L_{\text{line}}$ correlations alone do not prove any physical connection between the spectral lines and accretion. When looking for correlations with possible physical meaning, $L_{\text{acc}}$-$L_{l\star}$ and $L_{\text{acc}}$-$L_{\text{line}}$ should be used instead of $L_{\text{acc}}$ and $L_{\text{line}}$.

References:

[10] Mendigutía et al. 2015, 452, 2837