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The ejection-accretion connection in young stars: Testing MHD disk winds

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Abstract. Jets are ubiquitous in young accreting stars at all evolutionary stages, from deeply embedded protostars aged less than 0.1Myr to optically revealed 10Myr old T Tauri stars. The similar jet collimation at all ages is shown to require an effective magnetic collimation within the inner disk regions (inside 20 AU). This fact, and the high ejection to accretion ratio $\simeq 10\%$, appear to favor the presence of MHD disk winds. Ejection out to > 0.1 AU could explain the velocity drop and rotation signatures across the jets, and their dust and molecular content.

Keywords. accretion disks, MHD, stars: pre–main-sequence, ISM: jets and outflows

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The sub-arcsecond resolution achieved in recent years from the ground and in space has revealed unprecedented details on the inner regions of young stellar jets. The improved jet mass-fluxes confirm the correlation between ejection and accretion rates found by Hartigan *et al.* (1995), but with a higher ratio $\simeq 10\%$ if accretion shock models are adopted (Cabrit 2007). A similar ratio is obtained in protostars (Antoniucci *et al.* 2008, Lee *et al.* 2008). Collimating such a high mass-flux on observed scales seems only achievable with MHD disk winds:

1. The jet collimation issue and MHD disk winds

The high-velocity gas in T Tauri stars appears collimated into a narrow cone of about 20 AU in diameter at 50 AU from the source (Ray *et al.* 2007); the same jet widths are seen in the youngest protostars, arguing against collimation by the infalling envelope (Cabrit *et al.* 2007). The pressure of the disk atmosphere, including photo-evaporation, is also insufficient (Cabrit 2007). Therefore, *magnetic* jet collimation seems required.

Three different MHD ejection sites may contribute to jets, probably at the same time: stellar winds, magnetospheric winds, and disk winds (Ferreira *et al.* 2006). However, winds from the stellar surface meet strong problems in both ejecting and collimating such a high mass-flux (Cranmer 2009, Bogovalov & Tsinganos 2001). A higher mass-flux may be achieved in a sporadic "reconnexion wind" along the current sheet in the distorted stellar magnetosphere or a slower inner disk wind† (Zanni 2009, Romanova *et al.* 2009). However the ejection occurs at a 45° angle, therefore a confining disk field would still be required, of strength $\simeq$ 20mG $\sqrt{\dot{M}_{\rm acc}/10^{-7}M_{\odot}{\rm yr}^{-1}}$ at a radius of 20 AU (Cabrit

† Both differ from the "X-wind" proposed by Shu *et al.* 1995 in that they are not locked at corotation, and are mostly powered by magnetic torsion, and/or reconnexion of initially closed field-lines (see also de Gouveia Dal Pino *et al.*, this volume)

2007). Such a field could be passively advected in (Shu *et al.* 2007) or provided by a centrifugal MHD disk wind launched from the inner few AUs; the strong B_ϕ component of the latter is particularly efficient at confining inner winds (Meliani *et al.* 2006, Fendt 2009, Matsakos *et al.* 2009) and predicted jet widths agree with observations (Garcia *et al.* 2001, Ray *et al.* 2007).

2. Other suggestive indications of MHD disk winds

Subarcsecond studies of atomic T Tauri jets also reveal a drop in velocity away from the jet axis, and possible rotation signatures, that could be explained by MHD disk winds (Pesenti *et al.* 2004, Ray *et al.* 2007). The rotation values impose a maximum launch radius of 0.1–3 AU, and a moderate magnetic lever arm $\lambda \leqslant 13$ yielding jet speeds < 400 km/s and an ejection to accretion ratio $\simeq 4\%$–13% in the observed range, if the MHD wind dominates the angular momentum extraction from the disk (Ferreira *et al.* 2006). However, T Tauri jet rotation signatures are still tentative due to possible contamination by shock asymmetries (e.g. Soker 2005). MHD disk winds also seem promising to explain the presence of dust and molecules in/around atomic jets (Podio *et al.* 2006, Panoglou *et al.* 2009)†. The zone of MHD wind launching would be limited by the available B-field, or by X-ray ionization of the disk surface. Infrared interferometry and ALMA observations will be decisive to further constrain the disk wind extent in young stars.

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† Note that the small launch radii < 0.1 AU inferred in molecular jets with SMA (Lee *et al.* 2008) are very uncertain since the jet widths are unresolved, and rotation signatures are strongly suppressed in this case (Pesenti *et al.* 2004). ALMA will be crucial to settle this issue