A cornerstone study of the jet/outflow connexion with ALMA and JWST

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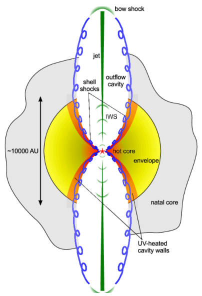
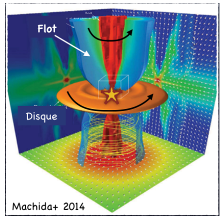
The origin and impact of protostellar molecular outflows

Star formation is accompanied by powerful bipolar ejections (see e.g. Frank et al. 2014 for a recent review). Slow molecular outflows are traditionnally interpreted as 'cavities' created by swept-up material, tracing the interaction between the inner jet and/or wide-angle winds with the infalling envelope or parent core. However, recent ALMA observations have revealed massive rotating molecular outflows originating from well inside the disk (e.g. Bjerkeli et al. 2016, Tabone et al. 2017, Louvet et al. 2018), suggesting that they could trace **matter directly ejected from the disk.** Such disk winds, if fully confirmed, **could solve the problem of angular momentum transport** in the low-ionization dead zones of disks where MRI turbulence is quenched (Bai et al. 2016, Bethune et al. 2017) and **strongly affect planet formation and migration** in the telluric zone (ee e.g. Kimmig et al. 2020).





ALMA observations of the DG Tau B CO outflow: a candidate disk wind

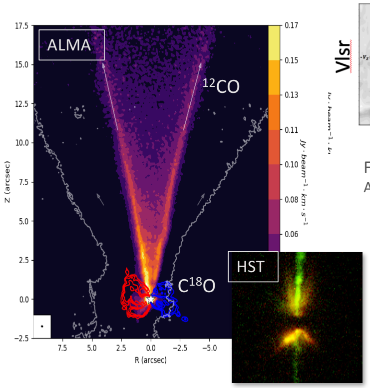


Figure 1: ALMA/HST observations of the DG Tau B CO molecular outflow and jet. Adapted From de Valon et al. (2020) and Stapelfeldt et al. (1997)

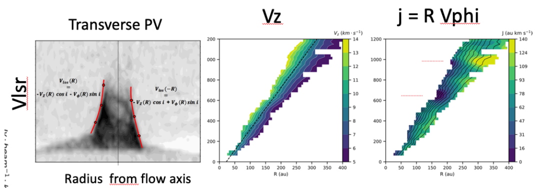


Figure 2: Reconstructed 3D kinematics of the DG Tau B CO conical outflow. Adapted from de Valon et al. (2022).

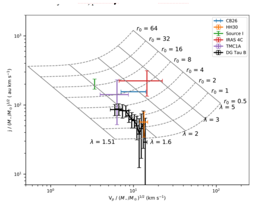


Figure 3: j versus Vp diagram for the candidate CO disk winds (symbols) versus expectations for steady and axisymmetric MHD disk winds (black curves).

DG Tau B is a class I protostar in the Taurus cloud known to drive a jet (see composite optical HST image). We have recently mapped its bipolar outflow in ^{12}CO with ALMA at 0.1'' angular resolution (de Valon et al. 2020, Fig. 1). The rotating disk is clearly detected in $C^{18}O$ (red/blue contours). The bright inner conical outflow shows a clear stratified velocity structure with faster material moving closer to the flow axis (see the transverse position velocity diagram in Fig. 2 left panel). Assuming axisymmetry, we reconstruct the 3D kinematics (Vz, j=RVphi) in the flow referential (Fig. 2, middle and right panels). The large CO mass flux () combined with the derived CO kinematics are compatible with expectations from a steady and axisymmetric MHD disk wind originating from disk anchoring radii in the range r_0=0.5-4 au (Fig. 3).
For more details see de Valon et al. (2020,2022).

JWST Cycle 1 program

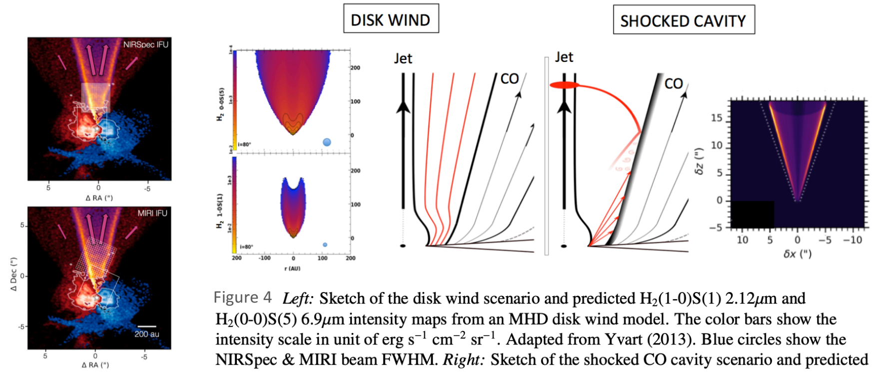


Figure 4 *Left:* Sketch of the disk wind scenario and predicted H_2(1-0)S(1) 2.12μm and H_2(0-0)S(5) 6.9μm intensity maps from an MHD disk wind model. The color bars show the intensity scale in unit of erg s^{-1} cm^{-2} sr^{-1}. Adapted from Yvart (2013). Blue circles show the NIRSpec & MIRI beam FWHM. *Right:* Sketch of the shocked CO cavity scenario and predicted emission map for H_2 lines located in a thin layer at the CO location. *By resolving the H_2 emission spatially, we will distinguish between these two scenarii.*

We have obtained a Cycle 1 JWST program to map with MIRI-MRS, NIRspec-IFU & NIRCAM the inner 5'' (=700 au) of the prototypical DG Tau B outflow in ro-vibrational and rotational H_2 and [Fe II], [S I] & [Ne II] emission lines. These observations will allow to map any wind component at temperatures intermediate between the hot (T=10^4 K) axial jet and the cold (T = a few 10 K) CO outflow, providing critical constraints on the disk wind versus swept-up cavity scenario. They will also provide for the first time a global view of the mass loss process in a young solar twin and critical insights into the importance of mass loss and magnetic field in proto-planetary disk evolution . **Stay Tuned !** 😃

References:

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