# Crossing the Snow Line: Mapping Ice Photo-desorption products in the Disks of Herbig Stars

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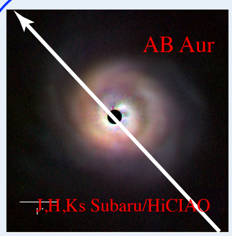
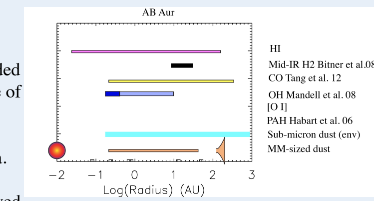
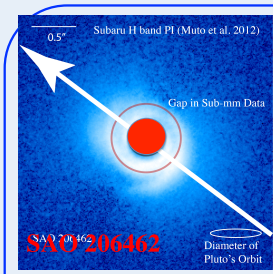
ABSTRACT: Water is a key constituent of protoplanetary disks. In our Solar System, small, icy grains are thought to have boosted the disk solid surface density, setting the stage for icy planetesimal formation and ultimately the growth of gas giant planets, while water vapor warms the disk, facilitating chemistry. Survival of water, in either phase, is sensitive to the UV radiation field. Intermediate-mass PMS stars, the Herbig stars, straddle the temperature range where icy grains can survive at r<10 AU to systems where ice is photo-desorbed at the disk surface to beyond 100 AU. While water vapor has proven elusive in these disks, we present preliminary findings on the spatial distribution of water dissociation products, combining new HST/COS and STIS data with data in the literature for 5 Herbig stars. In the next phase of this study we will model the disks following Oka et al. (2012).

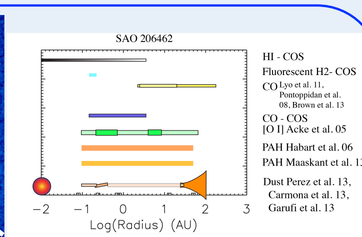



The dust disk of AB Aur is a gapped ring with an inner disk and large envelope (Tang et al. 2012), which is also seen in the NIR at J,H,Ks polarized intensity (Hashimoto et al. 2011). This system differs from our other program stars in having an envelope which may be optically thick in the FUV.

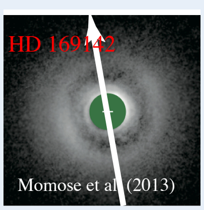


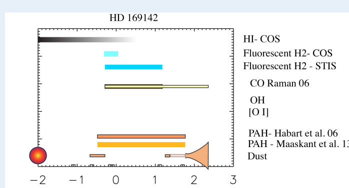

Only HI Ly $\alpha$ is spatially extended in the STIS FUV spectral image of AB Aur from Feb. 2013. We do not detect the 1202.25 Å transition of $H_2$ in the STIS data. PAH and [O I] emission are detected, but not spatially resolved, suggesting that these species come primarily from the inner disk. OH emission appears to come from the surface of the inner disk, possibly indicating release from a UV-shadowed region. The inner and outer disks should be icy.

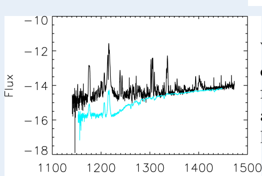



Fluorescent $H_2$ emission is present (France et al. 2012) and originates at r<1 AU, interior to the inner dust disk. The FUV emission is unresolved in STIS long-slit data from mid-July 2013. The outer disk is likely to be icy.

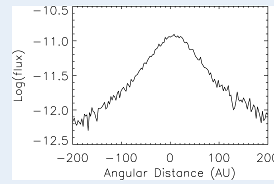


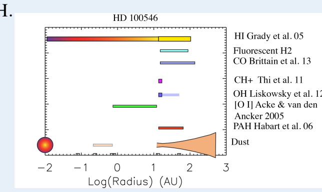

When compared with a scaled GHRS spectrum of Altair, the COS spectrum of HD 169142 from March 2013 shows excess FUV emission at $\lambda$< 1300 Å, as well as emission in $H_2$ and lines typical of actively accreting Herbig stars.

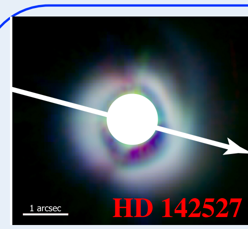
To date, HD 169142 is the earliest spectral type Herbig Ae star where fluorescent $H_2$ emission is seen in COS G130M spectra. In contrast to SAO 206462, fluorescent $H_2$ emission is strong, and originates between 0.2 and 1.2 AU. Ly $\alpha$ is unresolved. This star is accreting at an extremely low rate, and has an excess relative to Altair of only 20x near Ly alpha. $H_2$, however is extended to at least the wall at 20 AU seen at H (Quanz et al. 2013).

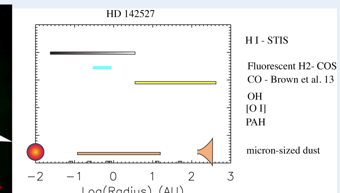




HD 100546 has spatially extended HI Ly$\alpha$ with a break at or near the inner edge of the outer disk.

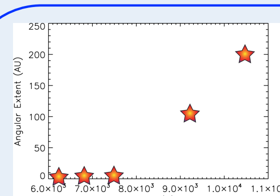
HD 100546 also has spatially extended emission in $H_2$, OH, [O I], CO, and PAH. [O I] is seen within the gap, while OH is concentrated at the inner edge of the outer disk. $H_2$ and CO have spatial distributions consistent with primordial gas in the outer disk. The available data indicate that we have detected water ice photo-desorption at the inner edge of the outer disk and the primordial gas disk at larger radii.



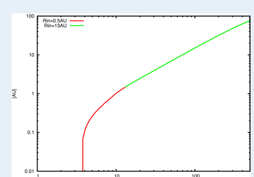




The STIS spectral image of HD 142527 is consistent with an unresolved source (r<7.5 AU) in both the lines and continuum. The spectral resolution of the fluorescent $H_2$ emission is consistent with an inner radius for molecular gas of <1 AU. Previous studies have shown that the inner edge of the outer disk and outer disk surface are conspicuous in water ice (Honda et al. 2009; Oka et al. 2012). We conclude that source of the gas features is in the inner regions of the inner disk component, with the outer disk lying well beyond the water snow line.




The radial extent of the Ly $\alpha$ emission is correlated with stellar $T_{eff}$.



**Model calculation for HD 100546, following Oka et al. (2012)**: While the snow line would reach the disk midplane at 4 AU, absent the gap, it is at the dust disk surface for r>13 AU. the inner edge of the outer disk is directly irradiated, and ice photodesorption produces the OH emission and break in the H I emission. at the location of the planet candidate noted by Quanz et al. (2013), the disk is icy and can still produce gas or ice giant planets.

This work, in part, is based on observations made with the NASA/ESA *Hubble Space Telescope*, obtained at the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555. New observations presented here were obtained under HST-GO-13032. We also have made use of data obtained using the Subaru Telescope as part of *The Strategic Exploration of Exoplanets and Disks with Subaru*. Grady is also supported under NSF AST 1008440 and through the Origins of Solar Systems program on NNG13PB64P. JPW is supported NSF AST 100314.