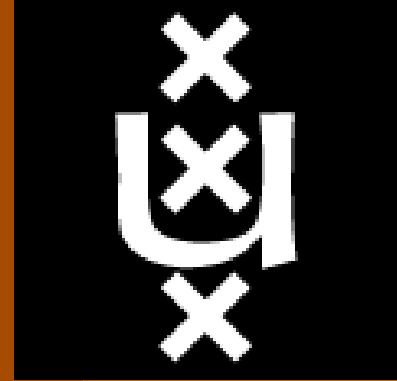


Milli-arcsec spatial resolution tomography of two proto-planetary disks.

Evidence for a rich inner disk carbon chemistry?



G. van der Plas^{1,2}, M.E. van den Ancker¹, B. Acke³, A. Carmona⁴, C. Dominik², D. Fedele⁵ and L.B.F.M. Waters²

[1] European Southern Observatory, Garching bei Munchen, Germany. [2] Astronomical institute “Anton Pannekoek”, Universiteit van Amsterdam, Amsterdam, The Netherlands. [3] Institute of Astronomy, KU Leuven, Leuven, Belgium. [4] ISDC data center for astrophysics, university of Geneva, Switzerland [5] Max-Planck-Institut fur Astronomie, Heidelberg, Germany

Introduction On this poster we present both spatially and spectrally resolved observations on the two Herbig stars **HD 97048** and **HD 100546**. Using a rich spectrum of fundamental Carbon Monoxide (CO) emission lines, we probe the physical properties of the circumstellar gas and model its kinematics. Furthermore, by using milli arcsecond precision spectro-astrometry, we constrain the physical size of the emitting regions in the disks.

Comparing these results with already available data reveals interesting questions about the inner-disk chemistry.

Methods We use high-spectral-resolution 4.6 - 5.1 μm spectra, taken with the CRILES on the VLT. These data contain a wealth of spatially and spectrally resolved fundamental CO emission (Figs 1,4), allowing us to use the following techniques:

Emission line (modelling)

Modelling the kinematics allows us to determine the inner, and to lesser extent the outer, radius of the emitting region.

Astrometry

This allows us to determine the spatial offset of the emission lines compared to the continuum (SPP) with milli arcsecond precision. The FWHM outside the emission lines translates directly to the size of the continuum emitting region.

Conclusion HD 97048 and HD 100546 Both lack detectable CO emission within 12 AU. This has been reported for more disks, e.g HD 141569, and is explained by a cleared out inner disk. HD 97048 and HD 100546 however, show abundant dust and gas well within these 12 AU. The absence of CO emission can therefore not be attributed to the paucity of matter in the inner disk. We suggest two possible explanations.

- The CO gas may be efficiently destroyed at radii smaller than 12 AU. A possible explanation is the higher temperature and density closer to the star, which may drive a rich chemistry in the disk, so that CO may be replaced by other species (e.g. Methane) as the dominant reservoir of carbon.

- Alternatively, radiative transfer effects could suppress the line emission from the innermost region.

Solving this problem may offer us a first glimpse of the molecular chemistry of the inner disk. Furthermore, using CRILES on nearby circumstellar disks allows for sub-AU resolution observations (This poster, Pontoppidan et al. 2008).

HD 97048 (Sp. type A0pshe) is a well-studied nearby Herbig star. Its disk is rich in dust and gas, some of the detections are listed below.

- 630 nm [OI] emission, tracing gas in the disk atmosphere, between 0.5 and 60 AU (Acke & van den Ancker, 2006)
- Mid-IR imaging with VISIR (Lagage et al. 2006, Figure 3)
- Nano-diamond features from within 15 AU (Habart et al. 2004)
- The S(1) pure rotational line of H₂ at 17.035 μm arising from the inner 35 AU of the disk (Martin-Zaidi et al. 2007)
- PAH emission up to 200-300 AU (van Boekel et al. 2004)

Below we show a close up of the spectrum of HD97048 in Fig 1, the average astrometric- and line profiles determined from the whole spectrum in Fig. 3, and the SED in Fig. 2

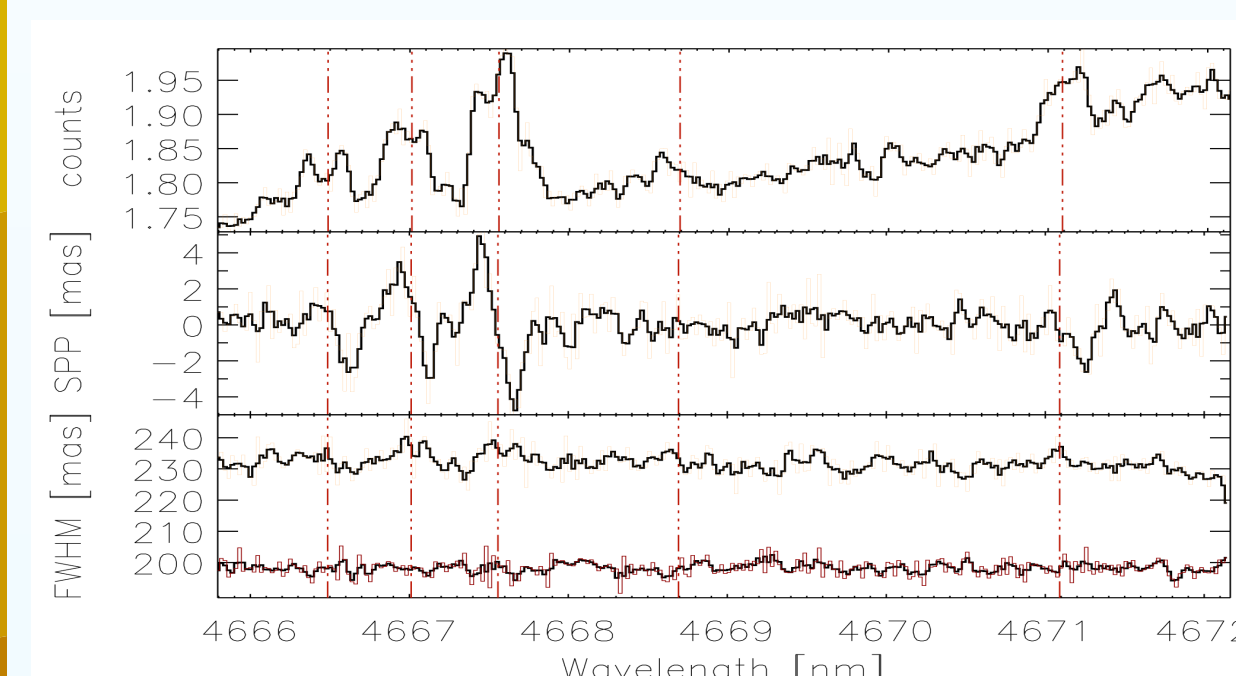


Figure 1. (top) Part of the spectrum of HD 97048, showing with vertical dotted lines resp. the 12CO v(4-3) R23, v(3-2) R14, v(2-1) R06, v(5-4) R33 and 13CO v(1-0) R12 emission lines. (middle) The SPP (astrometric signal). (bottom) The FWHM of HD 97048 (black line) and the telluric standard HIP 052419.

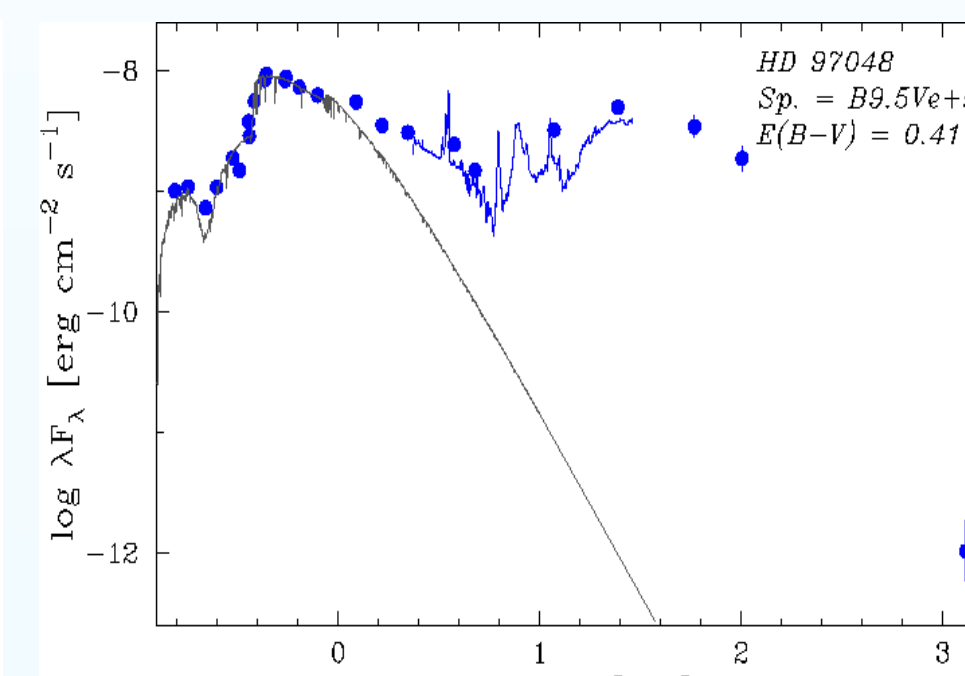


Figure 2. The SED of HD 97048 showing photometric data points, the ISO-SWS spectrum and a reddened Kurucz model of the stellar atmosphere.

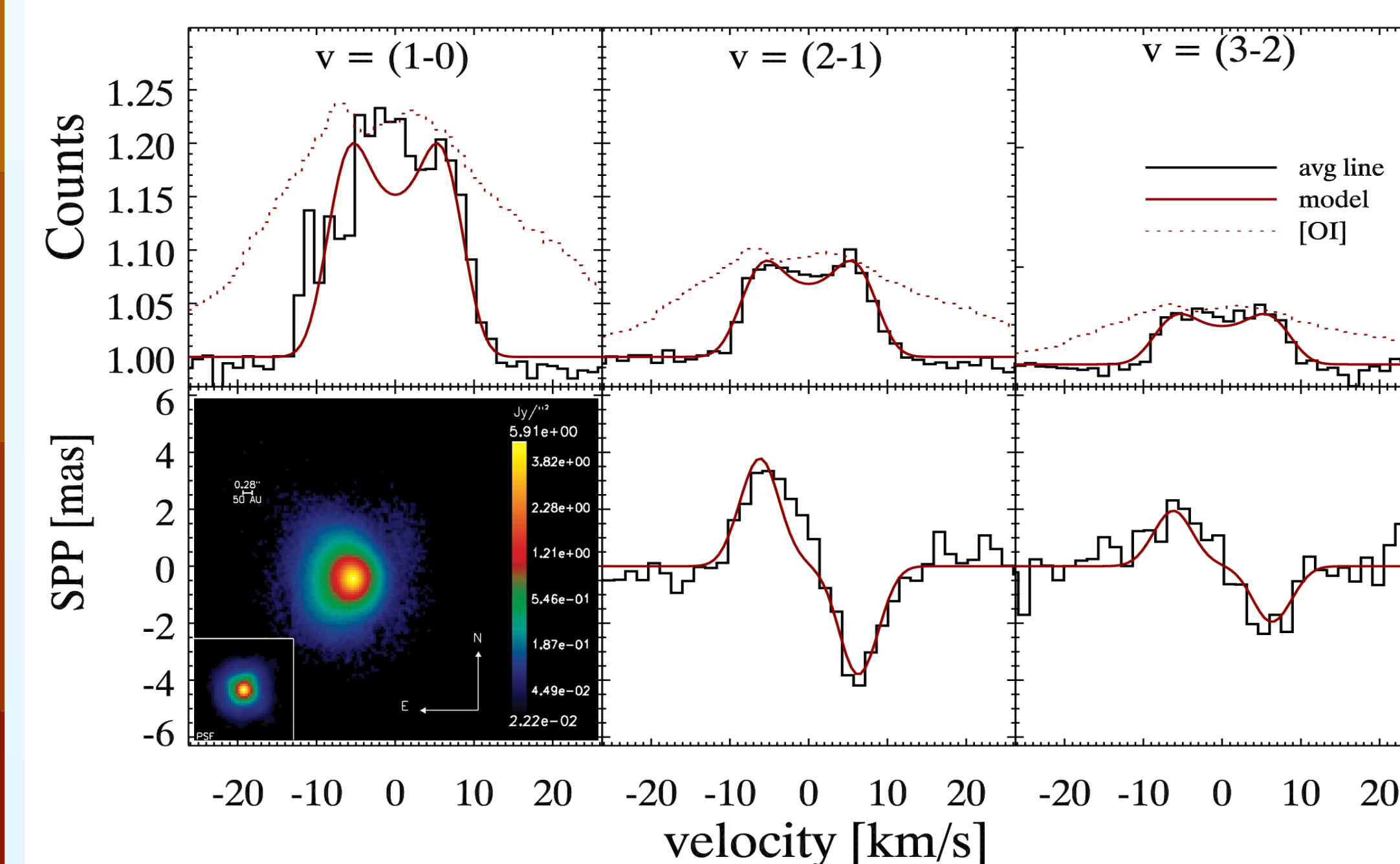


Figure 3. (top) Average CO line profiles of the $v = 1-0$ to $v = 3-2$ vibrational transitions, with the [OI] line profile over plotted with red dots, and a kinematic fit with an inner and outer radius of 12 and 45 AU with the solid red line. (bottom) in panel 2 and 3 the average astrometric profiles of the $v = 2-1$ and $v = 3-2$ vibrational transitions. The red line is an over plotted model for the astrometric signal assuming the same parameter as used by the kinematic fit. (bottom left) VISIR false-color image of the emission from the PAH emission from the circumstellar material surrounding HD 97048 (Lagage et al. (2006))

- Acke, B & van den Ancker, M.E. 2006, A&A 449,267
- Bouwman, J., de Koter, A, Dominik, C. & Waters, L.B.F.M. 2003, A&A 401, 577
- Geers, V.c., van Dishoeck, E.F., Visser, R., Pontoppidan, K.M., Augereau, J.C., Habart, E., & Lagrange, A.M. 2007, A&A 476,279
- Grady, C.A., et al 2001, AJ 122,3396
- Habart, E., Testi, L., Natta, A., & Carillet, M. 2004, ApJ, 614, L129
- Lagage, P.O., et al. 2006, Science, 314, 621
- Martin-Zaidi, C., Lagage, P.O., Pantin, E., & Habart, E. 2007, ApJ, 666, L117
- Pontoppidan, K.M., Blake, G.A., van Dishoeck, E.F., Smette, A., Ireland, M.J., & Brown, J. 2008, ApJ, 684, 1323
- van Boekel, R., Waters, L.B.F.M., Dominik, C., Dullemond, C.P., Thielens, A.G.G., & de Koter, A. 2004, A&A, 418, 177

Table 1. Spatial information for the *averaged* vibrational transitions shown in Figs 3 and 6, and the radii used to model the kinematics.

HD 97048	cont.	v(2-1)	v(3-2)	v(4-3)	$R_{\text{in,out}}^{\text{model}}$
SPP [AU]	0	$18.2^{+0.9}$	$22.1^{+2.7}$	-	12
FWHM [AU] ^a	$21.2^{+1.6}$	$\geq 23.8^{+1.1}$	$\geq 23.0^{+1.1}$	-	45
HD 100546					
SPP [AU]	0	$10.0^{+0.5}$	$8.7^{+0.5}$	$9^{+1.5}$	15
FWHM [AU]	$10.0^{+0.9}$	$\geq 13.7^{+0.6}$	$\geq 13.1^{+0.6}$	$\geq 11.5^{+0.7}$	40

^a Note that this FWHM is a function of continuum + line emission, but that the SPP has been corrected for the continuum dilution, and thus is a function of the line emission.

HD 100546 (Sp. type B9Vne) is also a well studied Herbig star. Its disk contains lots of dust and gas, shows rich large-scale structure and has a gap between 5-10 AU. Other inferred properties are:

- 630 nm [OI] emission, tracing gas in the disk atmosphere, between 0.5 and 60 AU (Acke & van den Ancker, 2006)
- A gap - or inner wall – at 10 AU from modelling the SED (Bouwman et al. 2003)
- PAH emission from within 12 AU (Geers et al. 2007)

Below we show a close-up of the spectrum of HD 100546 in Fig. 4, the average astrometric- and line profiles determined from the whole spectrum in Fig. 6, and the SED in Fig. 5.

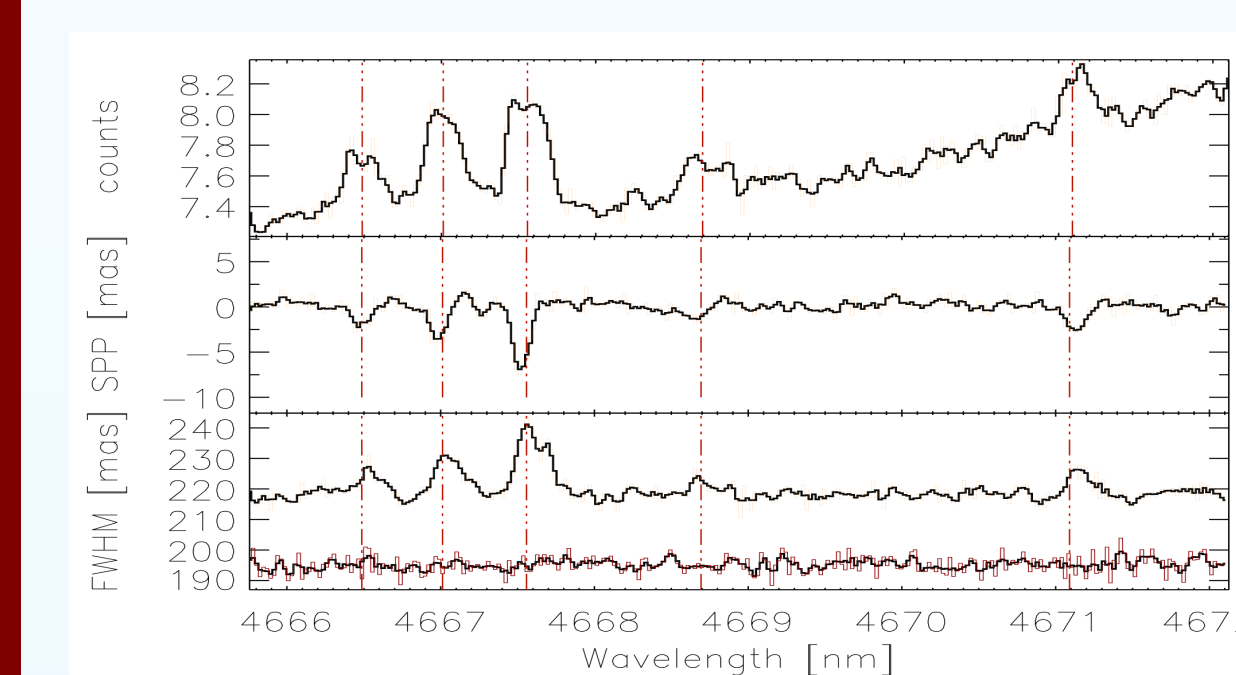


Figure 4. Same as Fig. 1 for HD 100546.

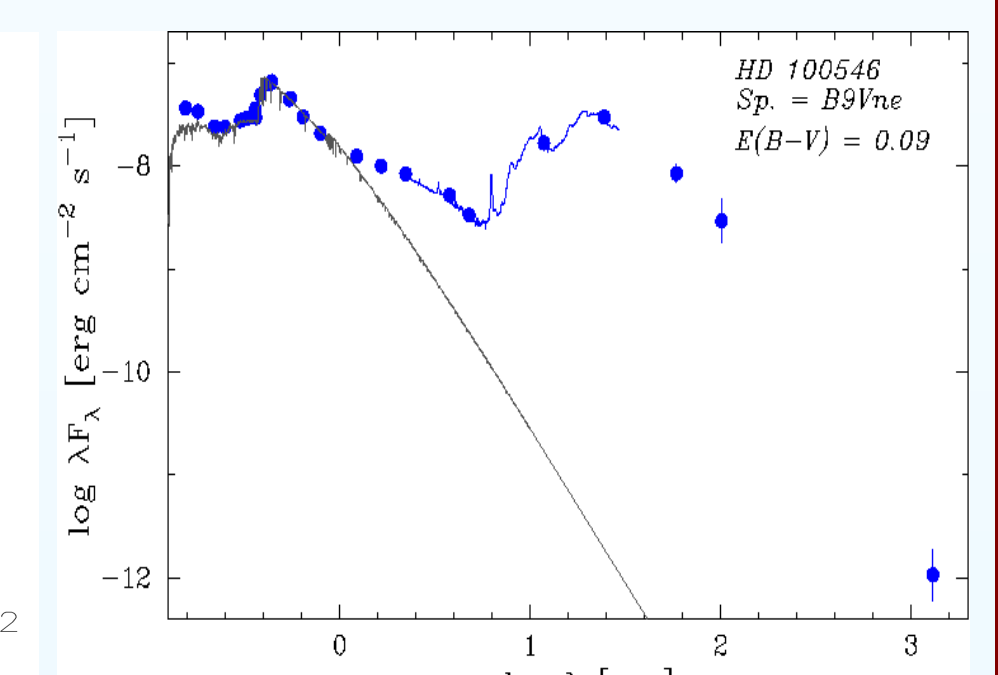


Figure 5. Same as Fig. 2 for HD 100546

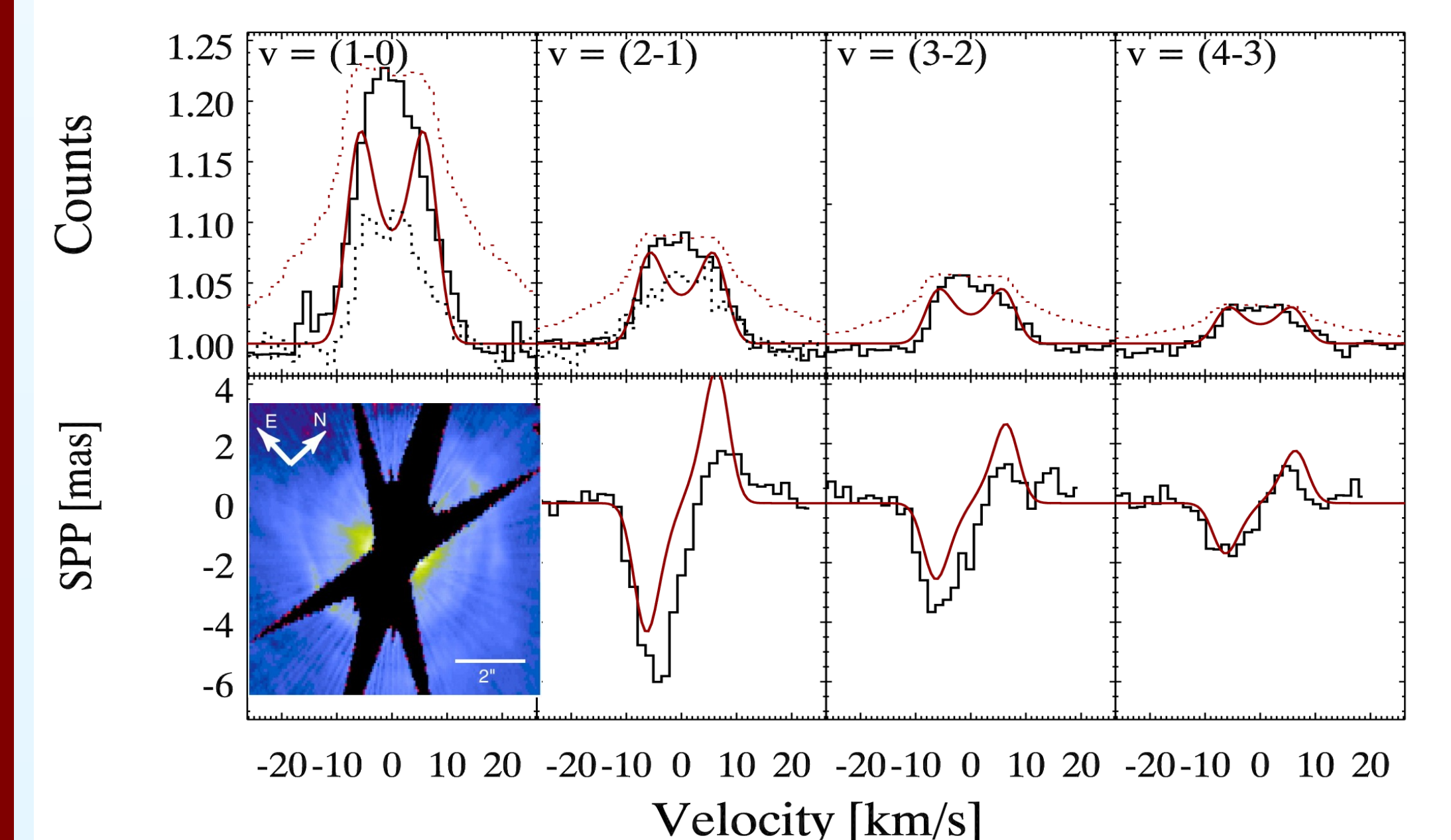


Figure 6. Same as Fig. 3 for HD 100546, with the exception that the image at the (bottom left) is a false color deprojected image from STIS showing rich structure. (Grady et al. 2001).