

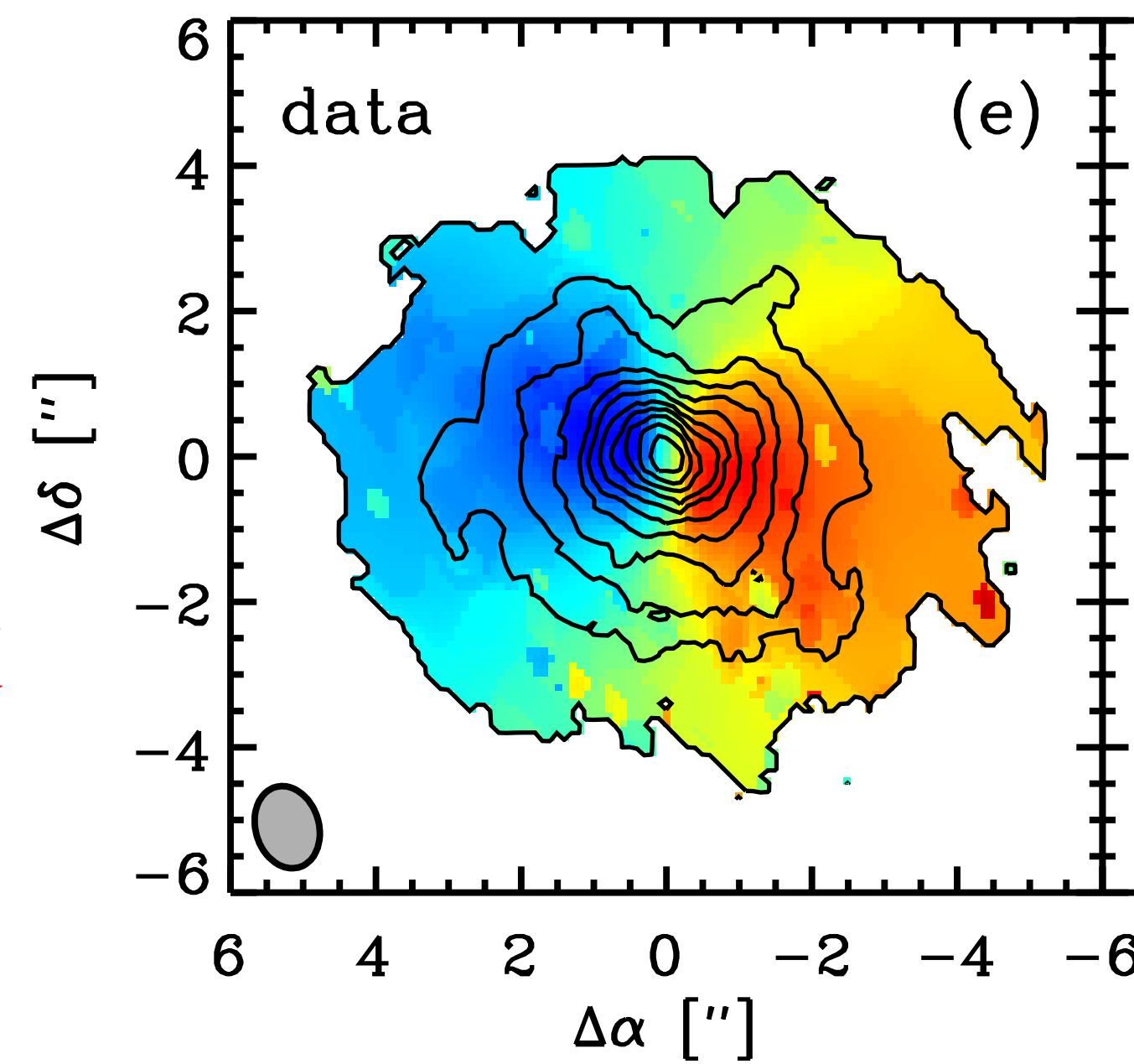
# Seeing Double: Multiwavelength Studies of the Remarkable $\beta$ Pic Moving Group Member V4046 Sgr

Joel H. Kastner & Valerie Rapson\* (*RIT Laboratory for Multiwavelength Astrophysics*) and a Cast of Dozens...

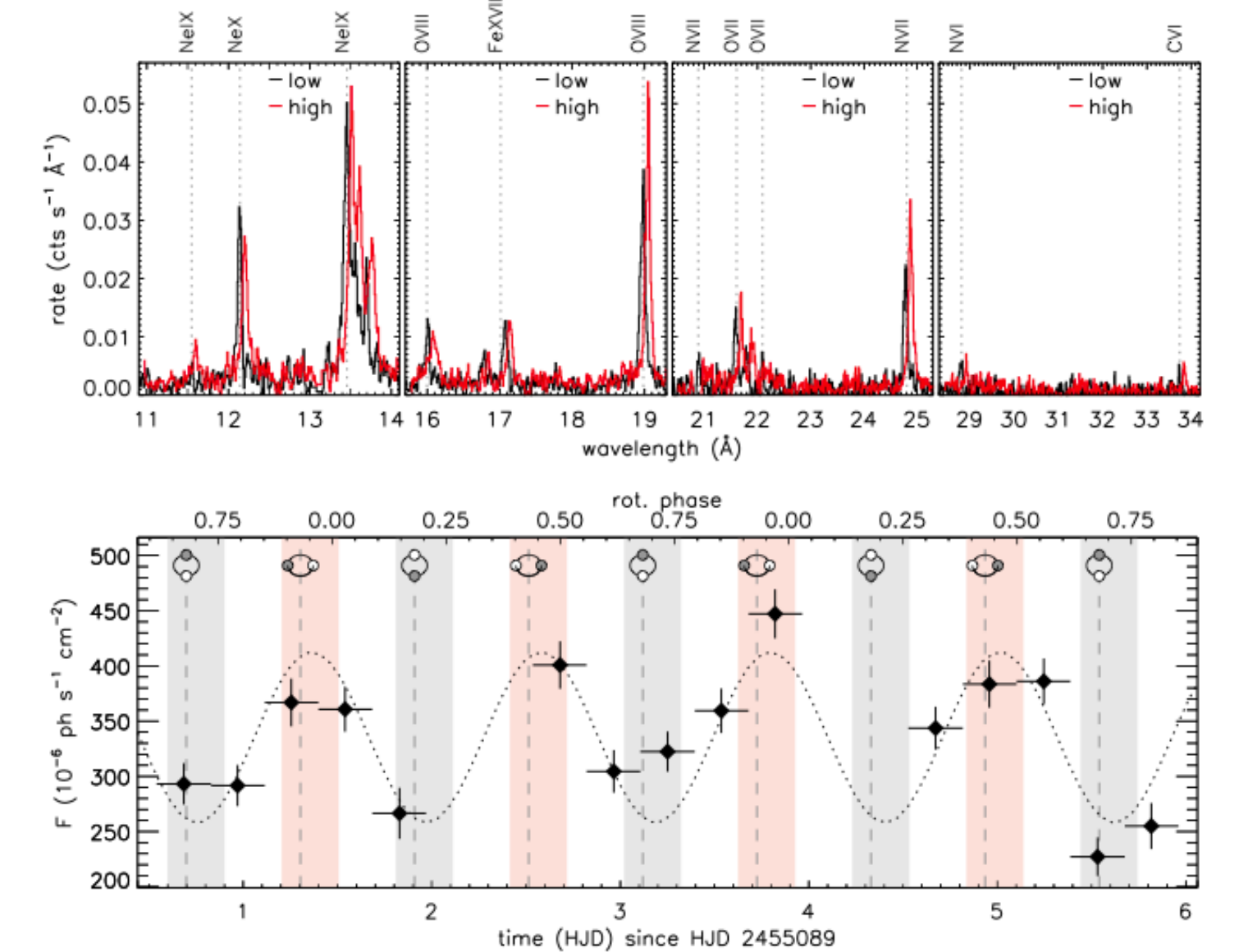
\*Defending PhD thesis (focused on these V4046 Sgr results) in May 2015

## V4046 Sagittarii: "fast facts"

- $\beta$  Pic Moving Group member**
  - Age 12-21 Myr (Torres et al 2008; Binks & Jeffies 2014)
  - Distance  $\sim 73$  pc (Torres et al 2008)
- Hierarchical quadruple system** (Kastner et al. 2011)
  - V4046 Sgr AB: 2.4-day binary w/ sp. types K5+K7
  - V4046 Sgr C[D]: M-type binary located  $\sim 12$  kAU from AB
- V4046 Sgr AB is still actively accreting** (Guenther et al. 2006; Curran et al. 2011) **from a massive circumbinary molecular disk**
  - CO radius  $\sim 350$  AU, inclination  $33.5^\circ$  (Rodriguez et al. 2010)
  - $\sim 0.1 M_\odot$  of  $H_2$  (Rosenfeld et al. 2013) orbiting a binary with component masses  $0.90+0.85 M_\odot$  (Rosenfeld et al. 2012)
  - Submm-bright dust ring w/ outer radius  $\sim 50$  AU and inner ("hole") radius  $\sim 30$  AU (Rosenfeld et al. 2013)



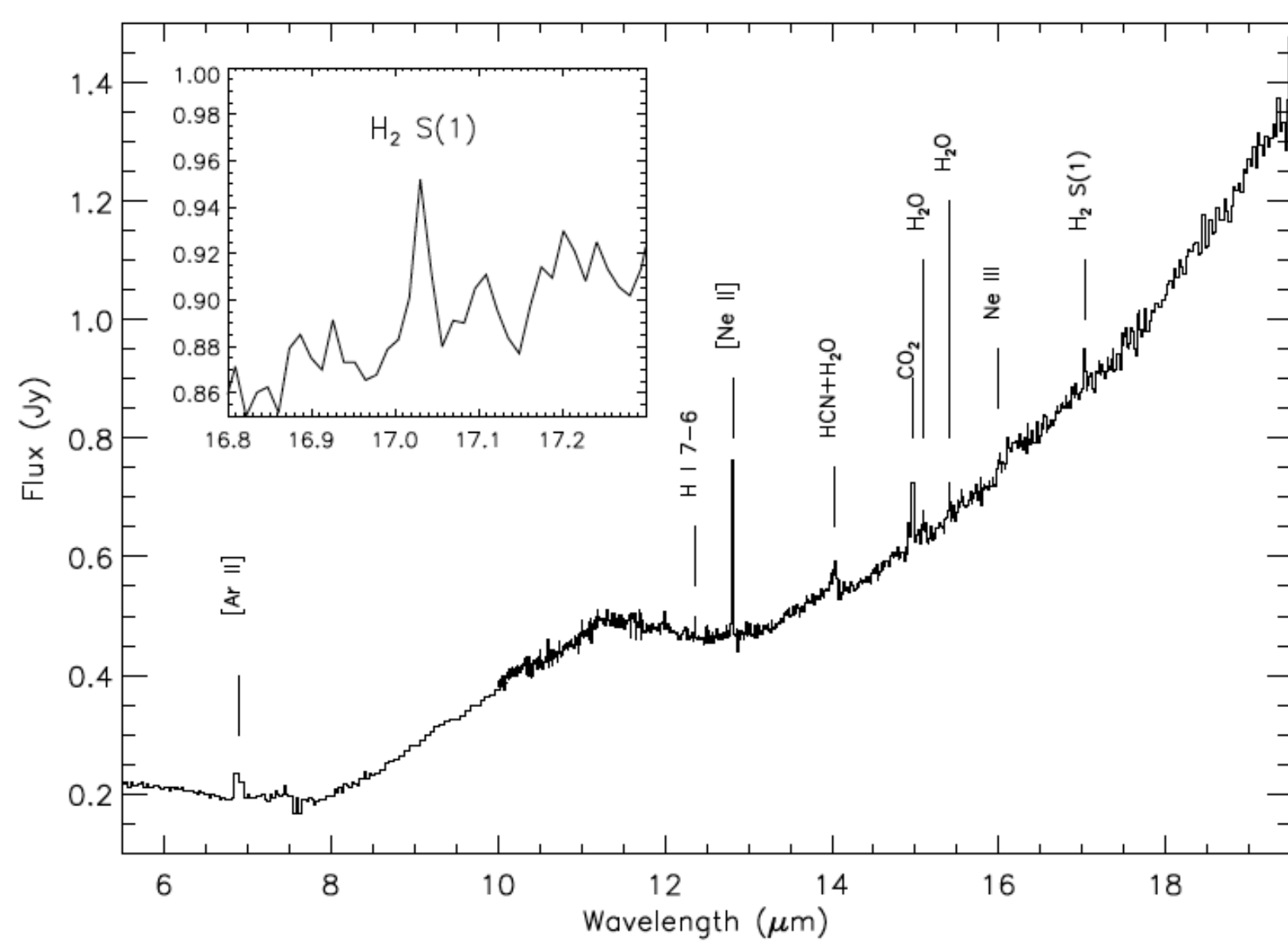
Circumbinary disk of V4046 Sgr as mapped in CO. Colors illustrate mean gas velocity. (From Rosenfeld et al. 2013)



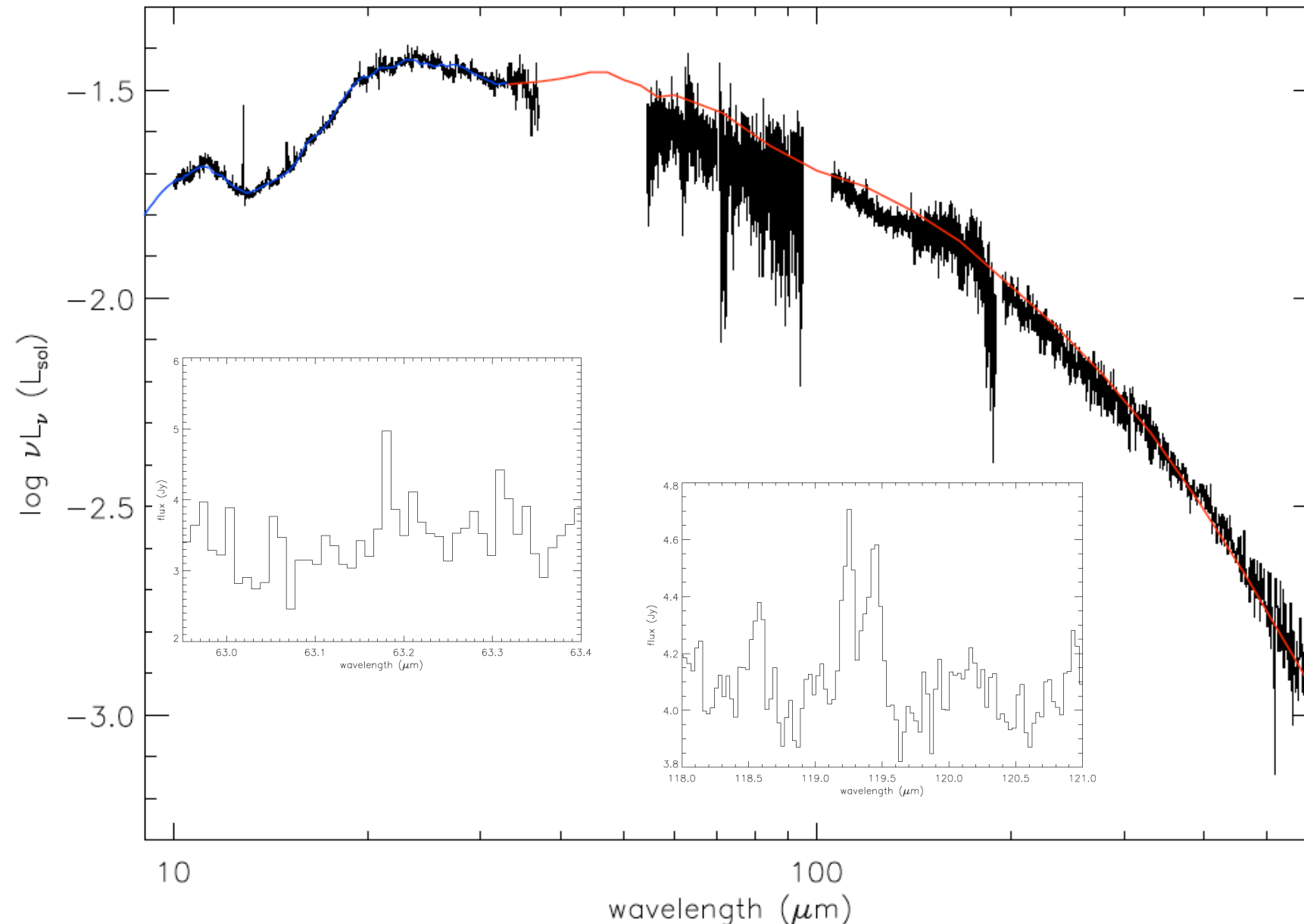
Top: XMM/RGS X-ray spectra extracted during low (black) and high (red) states of V4046 Sgr AB; spectra are shifted in wavelength, for clarity. Bottom: apparent rotational modulation of soft X-ray lines attributable to accretion shocks. (From Argiroffi et al. 2012)

## Infrared and Radio Spectroscopic Surveys of the Circumbinary Disk Orbiting V4046 Sgr AB

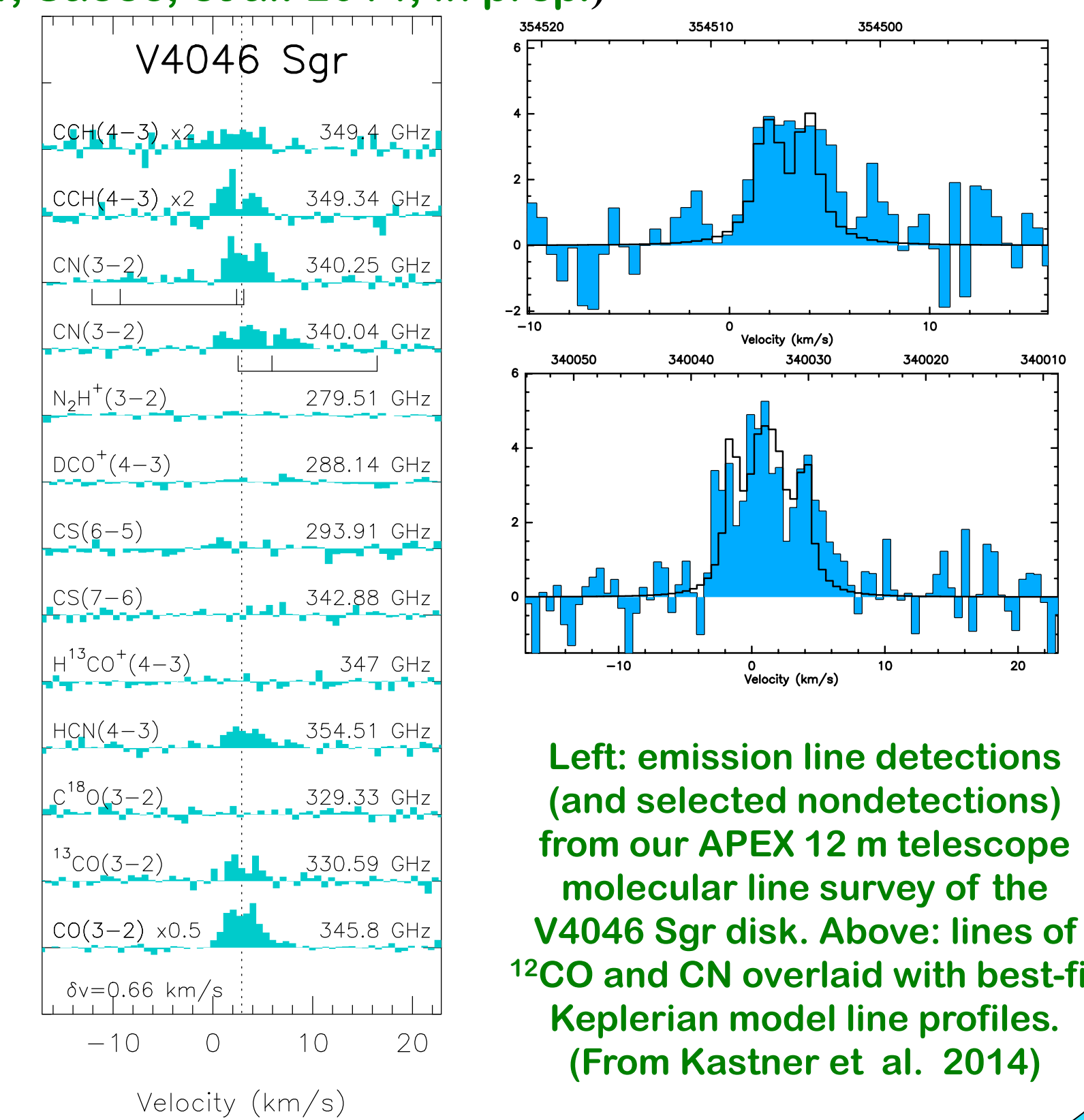
(Kastner, Hily-Blant, Rodriguez, et al. 2014, ApJ, in press (astro-ph/1408.5918); Rapson, Kastner, Sacco, et al. 2014, in prep.)



Spitzer IRS (SH) spectrum of V4046 Sgr, with the most prominent emission lines indicated. The inset shows emission from the 17 micron pure rotational line of  $H_2$ . (From Rapson et al. 2014)



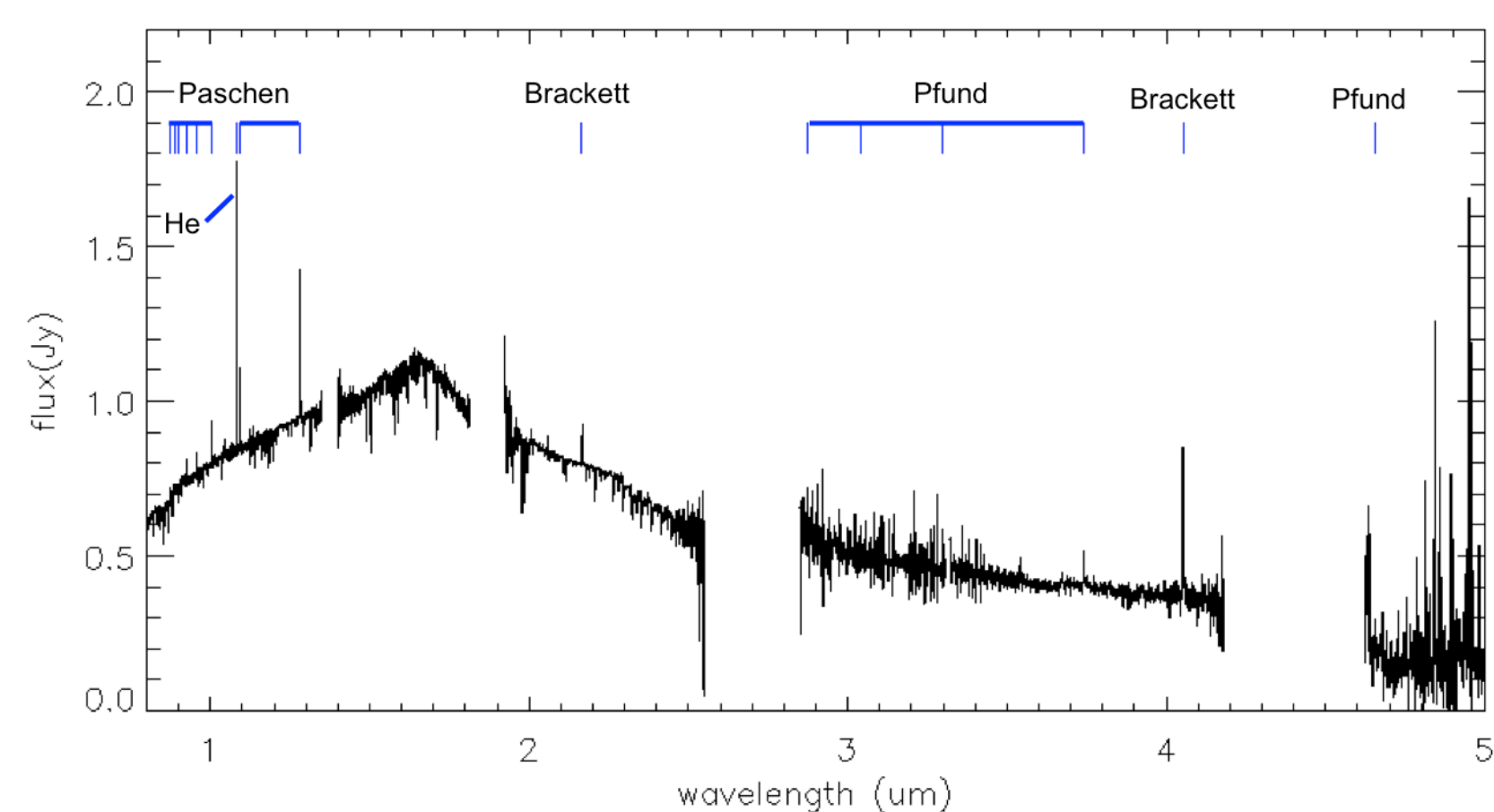
Merged Spitzer IRS and Herschel PACS+SPIRE spectrum of V4046 Sgr, overlaid with a composite dust disk model that was fit separately to the Spitzer & Herschel spectral regimes. The insets show emission in the 63.2 and 119.3 micron lines of [O I] and OH, respectively. (From Rapson et al. 2014)



Left: emission line detections (and selected nondetections) from our APEX 12 m telescope molecular line survey of the V4046 Sgr disk. Above: lines of  $^{12}CO$  and CN overlaid with best-fit Keplerian model line profiles. (From Kastner et al. 2014)

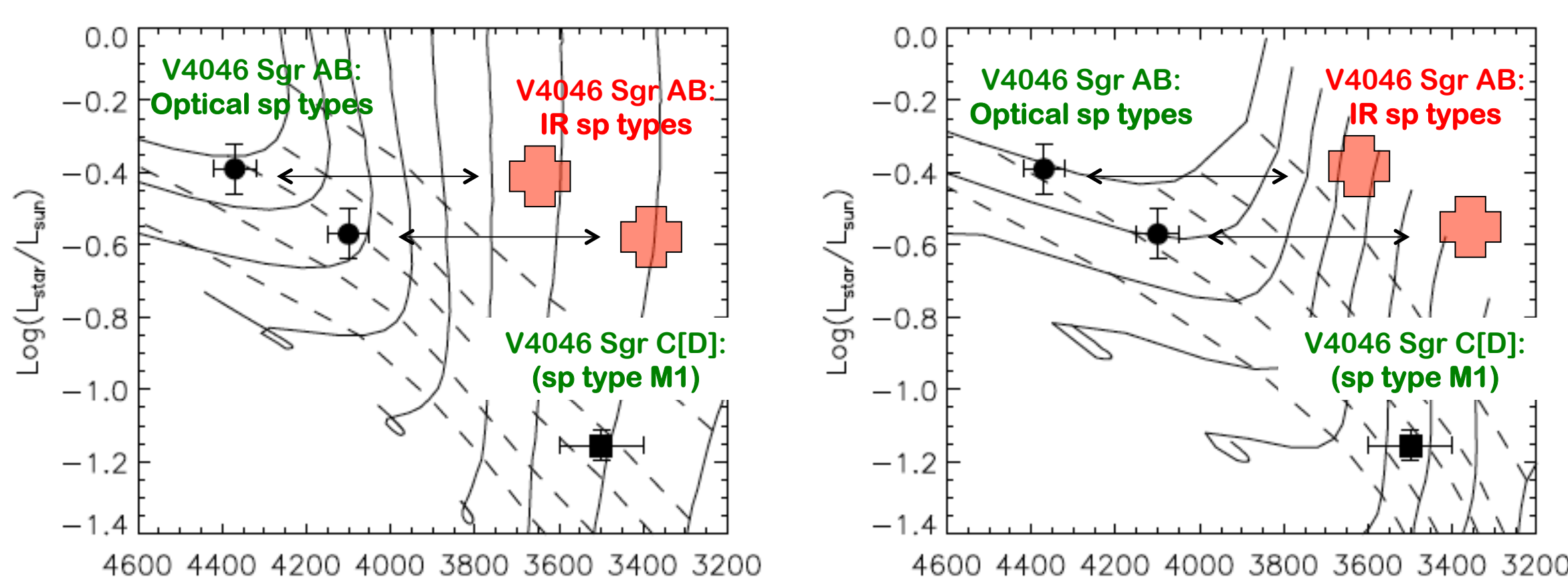
## IRTF/SpEx spectroscopy of V4046 Sgr AB

(Kastner, Rapson, Sargent et al. 2014, in Proceedings of Cool Stars 18)



IRTF/SPEX spectrum of V4046 Sgr AB, with H and He emission lines labeled.

The composite near-IR spectral type for V4046 Sgr AB is significantly later than the (K5+K7) composite type previously determined from optical spectroscopy, but the optically-determined spectral types are in better agreement with V4046 Sgr AB's well-established dynamical masses and age. These results demonstrate that one must exercise caution in using near-infrared spectroscopy to infer the photospheric temperatures and, hence, the ages and masses of pre-MS stars via placement on pre-MS evolutionary tracks (see, e.g., analysis of the IRTF/SpEx spectrum of TW Hya by Vacca & Sandell 2011).



V4046 Sgr AB and C[D] vs. pre-MS evolutionary tracks. Masses (solid lines) run from 0.2 to 1.0  $M_\odot$ , and the isochrones (dashed lines) are for ages 5, 10, 15, 25, and 40 Myr. The positions of V4046 Sgr AB inferred from IRTF/SPEX data are overlaid as red crosses.

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## "Early Science" with Gemini Planet Imager: Polarimetric/coronagraphic imaging of a dust ring system within the "submm hole" in V4046 Sgr AB's inner disk

(Rapson, Kastner, Andrews, et al. 2014, in prep.)



We report the discovery of a dust ring system in the inner  $\sim 30$  AU of the disk orbiting the young binary system V4046 Sgr AB. This ring system is seen in scattered starlight via near-infrared polarimetric/coronagraphic imaging with the new Gemini Planet Imager. The dimensions of the scattered-light ring system provide evidence for dust size segregation (i.e., large-grain "filtration") processes that are likely associated with a young, massive planet with an orbital semimajor axis in the range 4-12 AU, thereby placing essential constraints on theories describing the formation of giant planets.

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