The Transiting Exocomets of HD 172555

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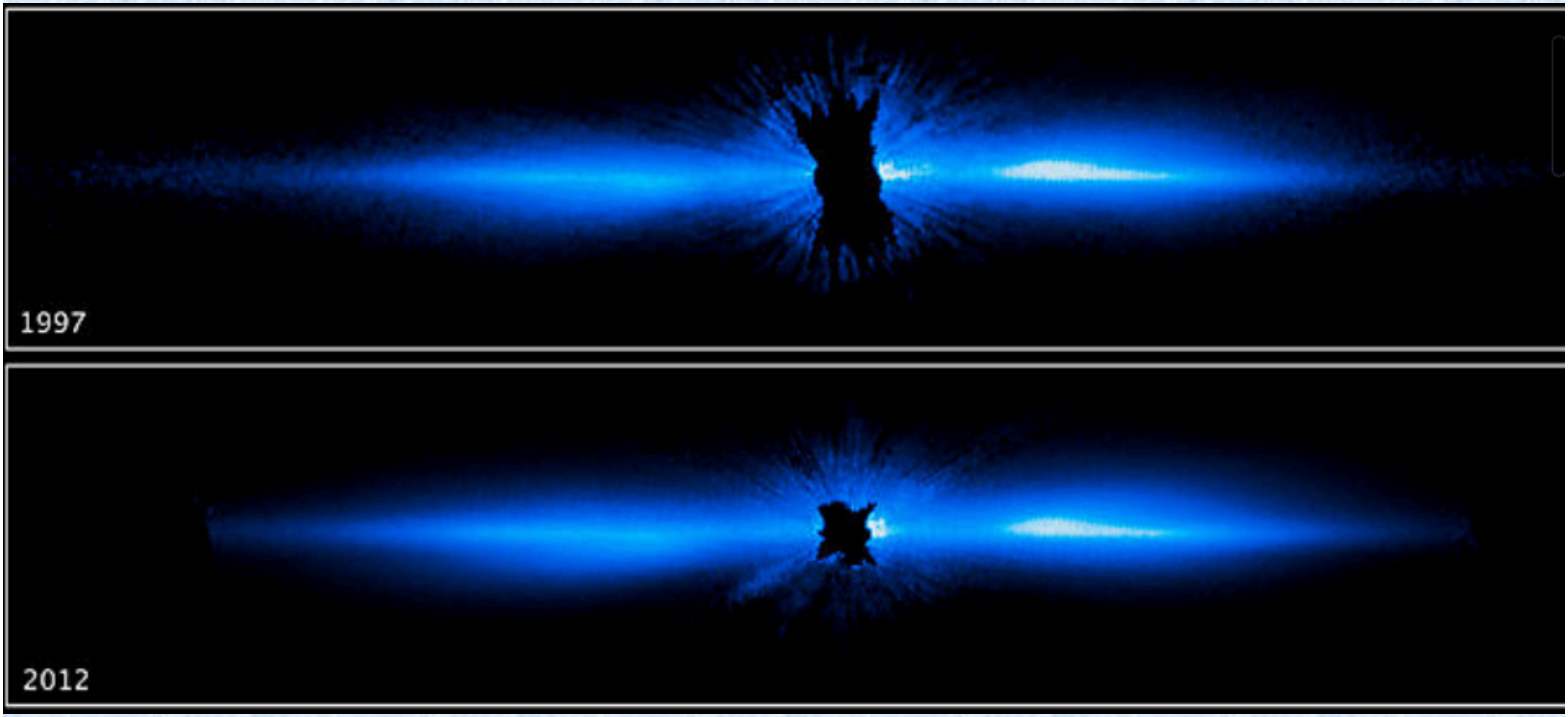
Talk Roadmap

- Quick review of β Pic – protypical transiting exocomet system with disk and planet
- HD 172555 - β Pic's evil twin and its transiting exocomets
- Implications for planet frequency and searches for additional systems

I. Background - β Pic

- A5V star (T_{eff}=8100 ± 200 K)
- Young moving group member (23 ± 3 Myr Mamajek & Bell 2014)
- 2 component disk – outer disk at ~120 AU, viewed edge-on (Dent et al. 2014), inner disk to ~40 AU inclined by 5° with respect to the outer disk (Golimowski et al. 2006)
- Gas: molecular, atomic and a range of ionization stages of abundant elements

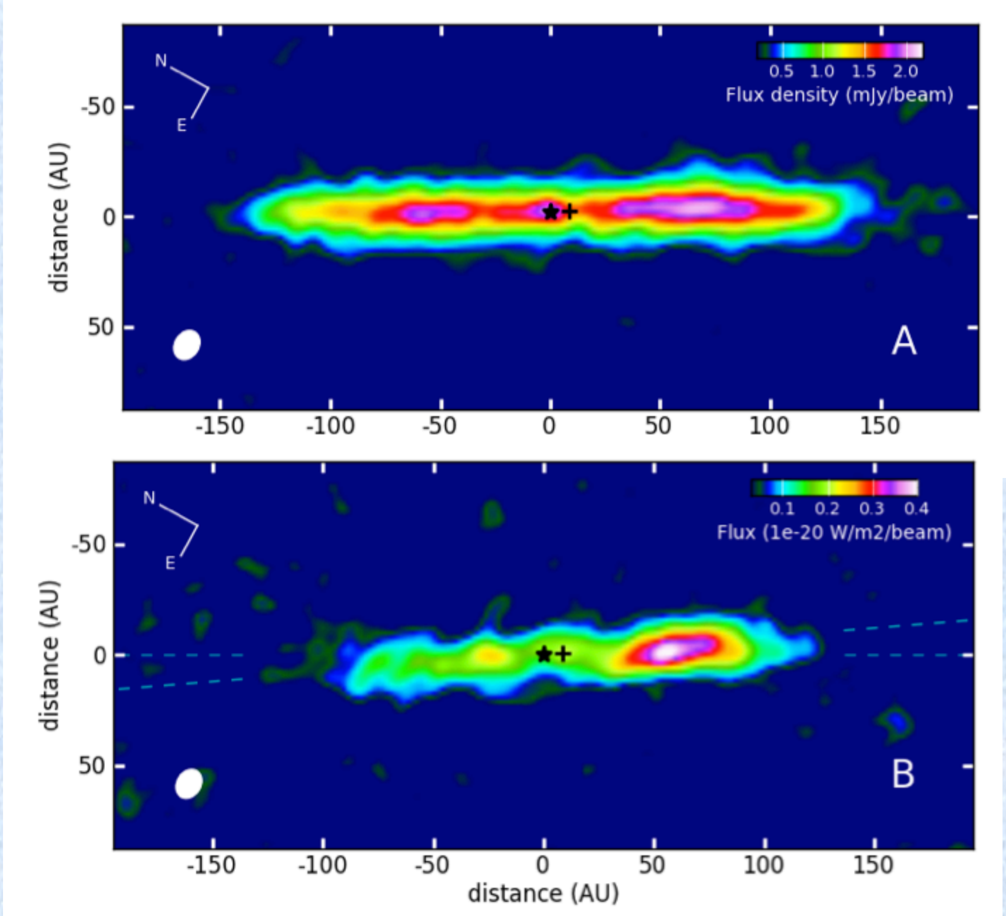
The Case of β Pic



- IR excess detected by IRAS
- edge-on debris disk first imaged by Smith & Terrile 1984
- no variability over 15 years Apai + 15
- inner disk inclination with respect to outer disk is 5° (Golimowski et al. 2006)

Edge-on Disk

- Constrain location of planetesimal belt from mm imagery
- Can locate or place upper limits on cold molecular gas
- CO asymmetrically distributed
- Pericenter offset seen with ALMA – indirect signature of planet(s)



Dent+15

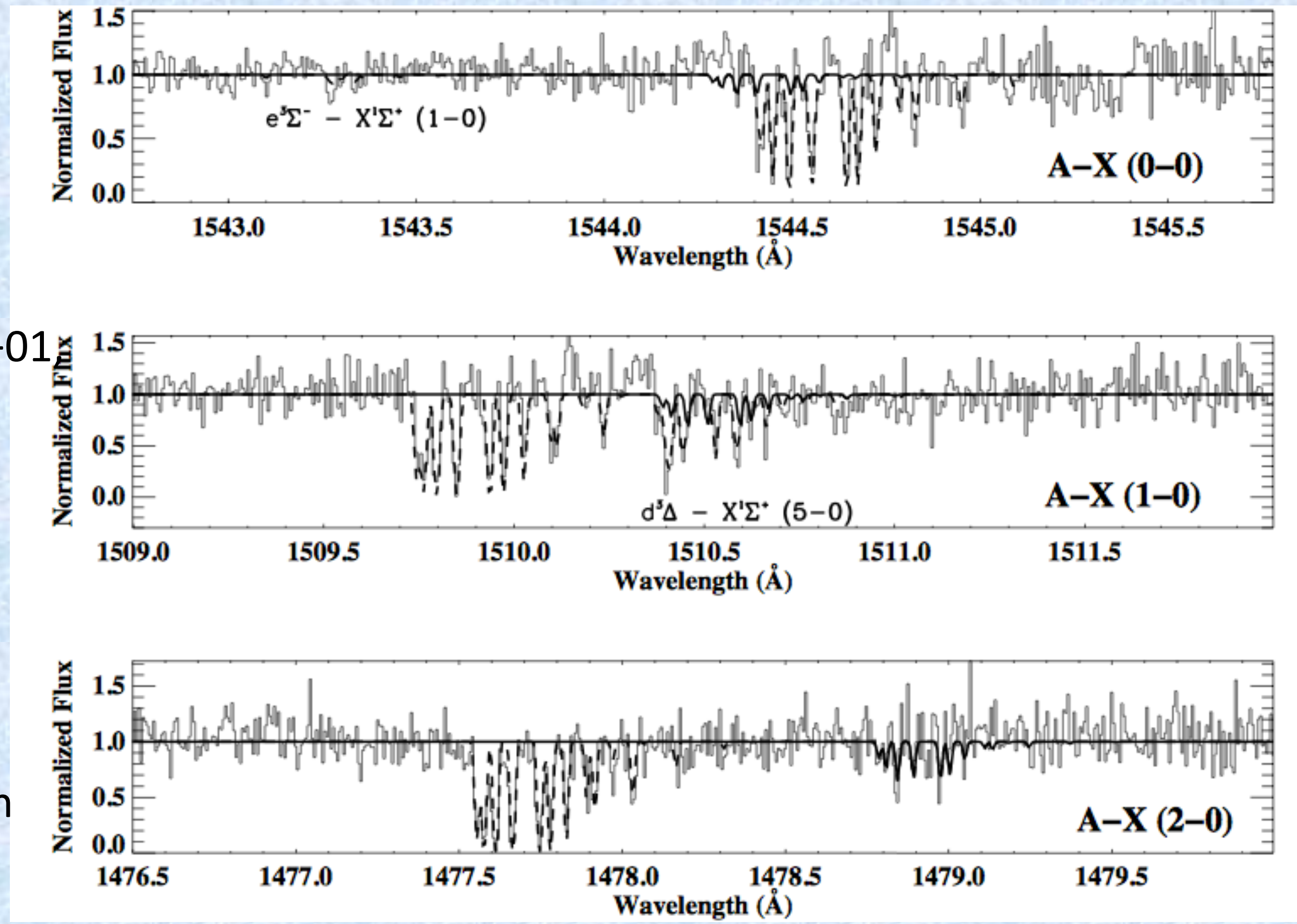
What we learn from Line of Sight UV Spectroscopy

• CO absorption at system velocity Roberge + 2000

•N(H_2)≤1E18 cm^{-2} Lecavelier des Etangs +01, CO/H_2>6E-4

•low optical depth + radiation field of star – lifetime is <200 years

• gas not primordial, must be sequestered in planetesimals

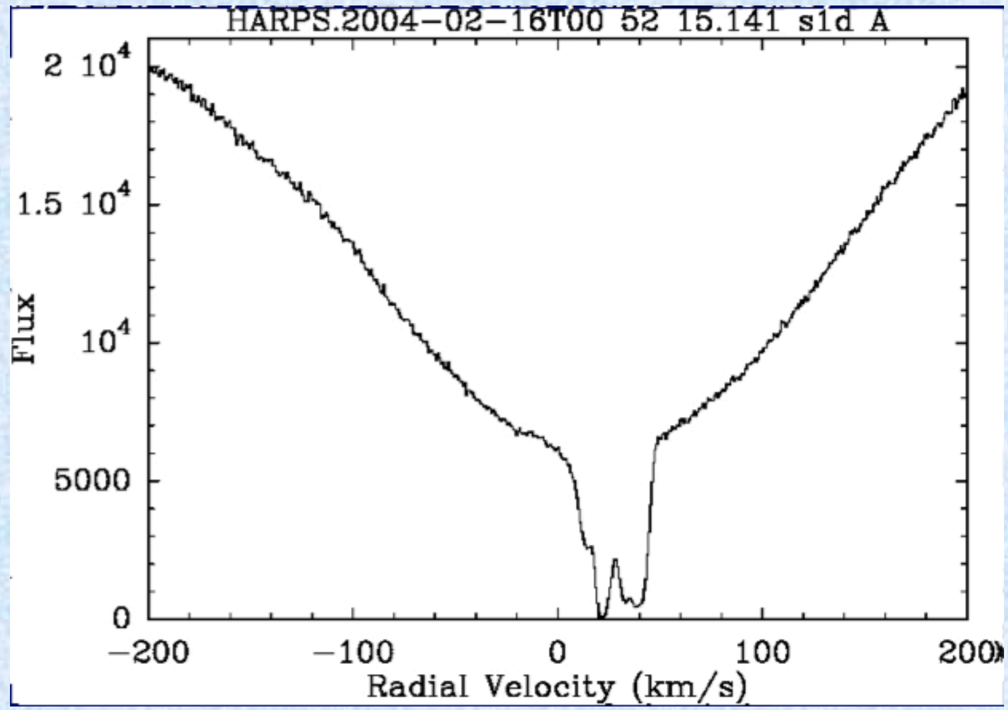


Roberge + 2000

Atomic and Ionic Gas in the β Pic System

• A-shell star – features superposed on rotationally broadened photospheric spectrum - Slettebak 1975 in Ca II and Na I

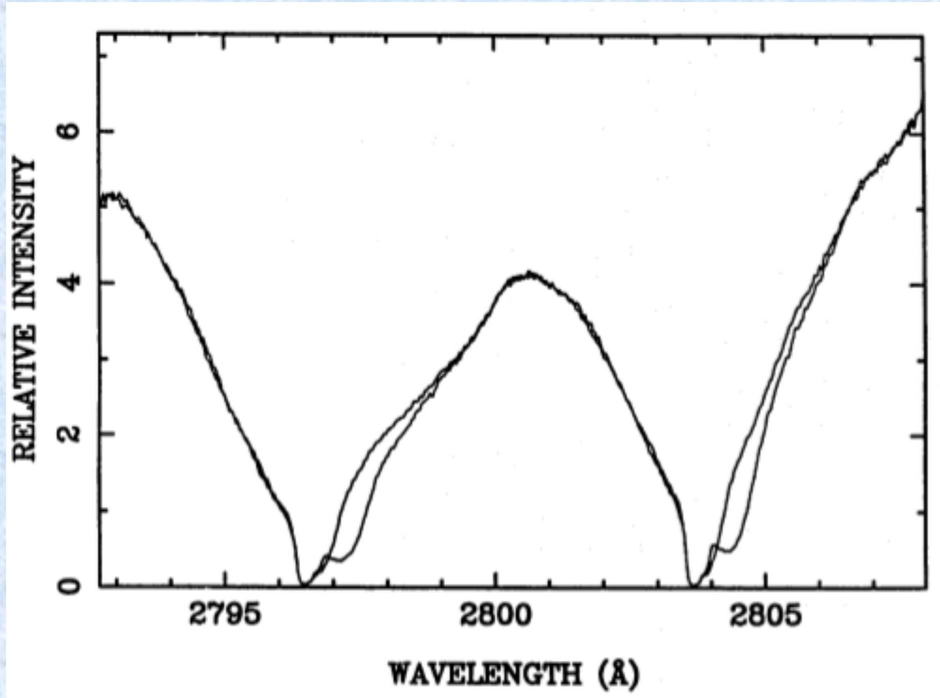
• same transitions used to probe ISM, so natural to go to UV where high oscillator-strength transitions of first few ionization stages of cosmically abundant elements are located

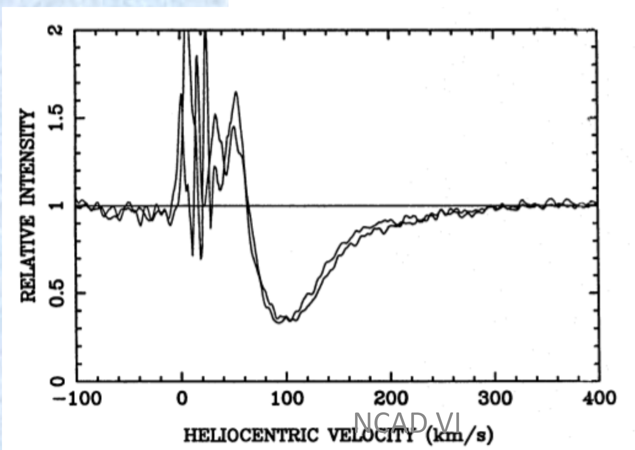


Beust 14

High Velocity Gas

- typically redshifted, although blue-shifted events are known - Crawford + 98
- Higher the velocity, the faster the variablity
- absorption optically thick, but does not fully cover the stellar disk Lagrange + 1988
- 30 years of data



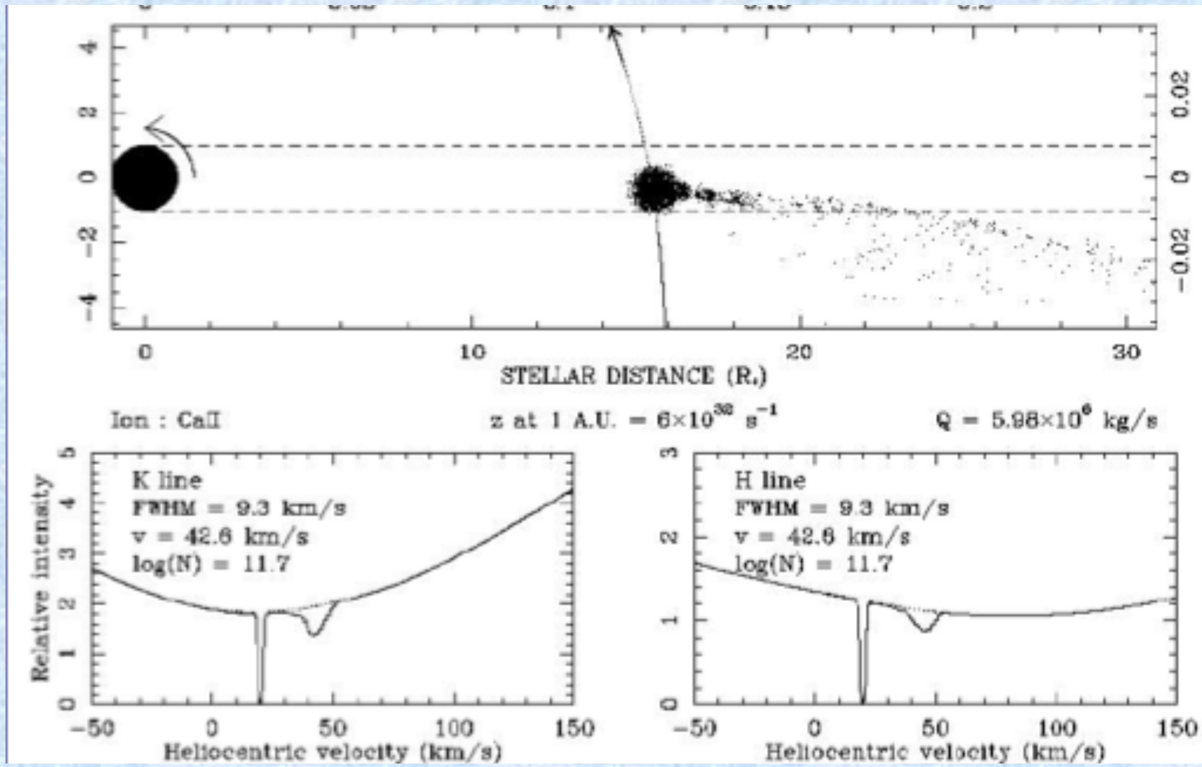


Vidal-Madjar 1994

Simulations

- assume we are tracking ions in coma of evaporating body –Beust & collaborators (1990, 1995, 1998, 2014)

- periastron varies from event to event
- event duration indicates r<0.5 AU
- longitude of periastron not random
- need high eccentricities
- long duration events => fragmentation
- Same mechanism as for Sun-grazing comets
- Mean Motion Resonances – favored mechanism
- implies Jovian mass planet, eccentricity ~0.05 required

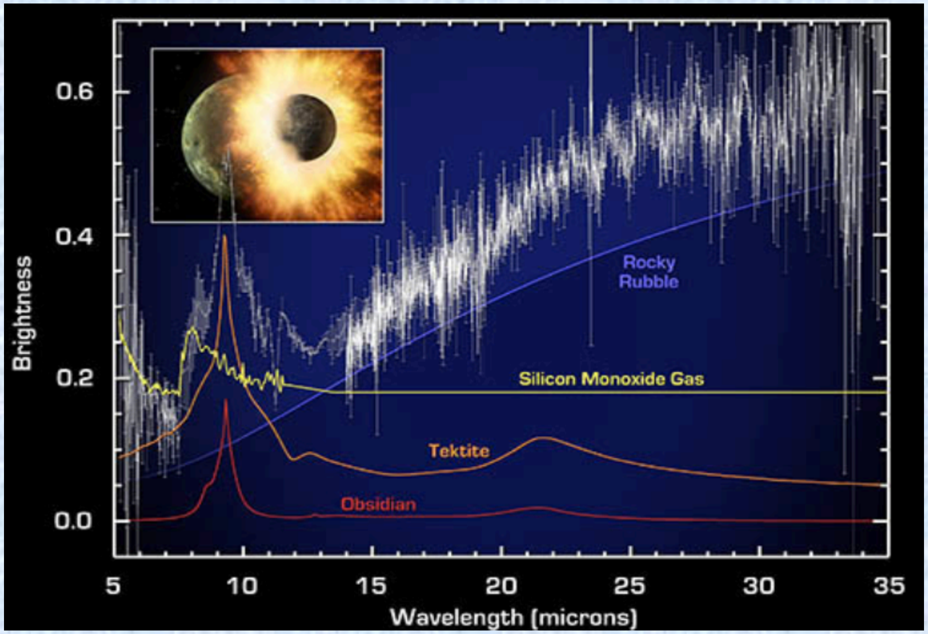


Link to β Pic b?

- Planet reported from direct imaging (Lagrange + 2010)
- Need refined orbit for the planet to test key prediction, eccentric orbit
- Other A to early F star members of βPic Moving Group more distant – require smaller IWA imaging observations for direct planet detection, but 2 known planets in this moving group - β Pic and 51 Eri (Macintosh + 2014)

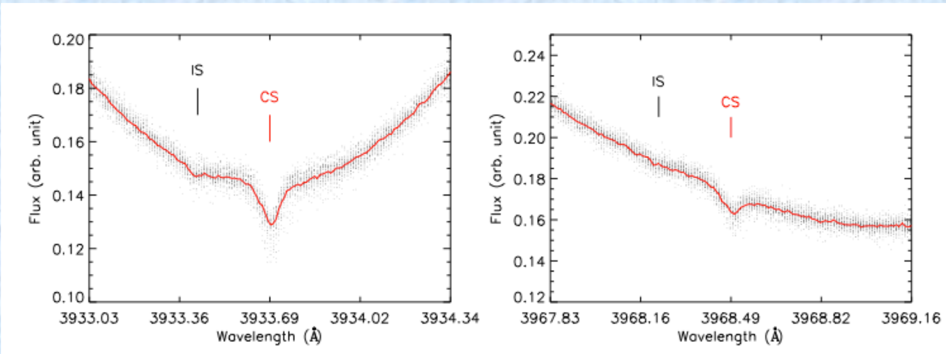
II. HD 172555 – β Pic's Evil Twin

- A6V, T_{eff}=7800±200 K d=29.2 pc (Riviere-Marichalar + 2012), BPMG
- Star is co-moving with CD -64° 1208 (K5Ve, Feigelson +06)
- [O I] (Riviere-Marichalar+12)
- silica and SiO (Lisse et al. 2009, but see Wilson + 2016), suggestive of a hypervelocity impact
- Small disk (Smith +12) to ~24 au, inferred inclination i~75°



Lisse + 09

HD 172555 - Ca II

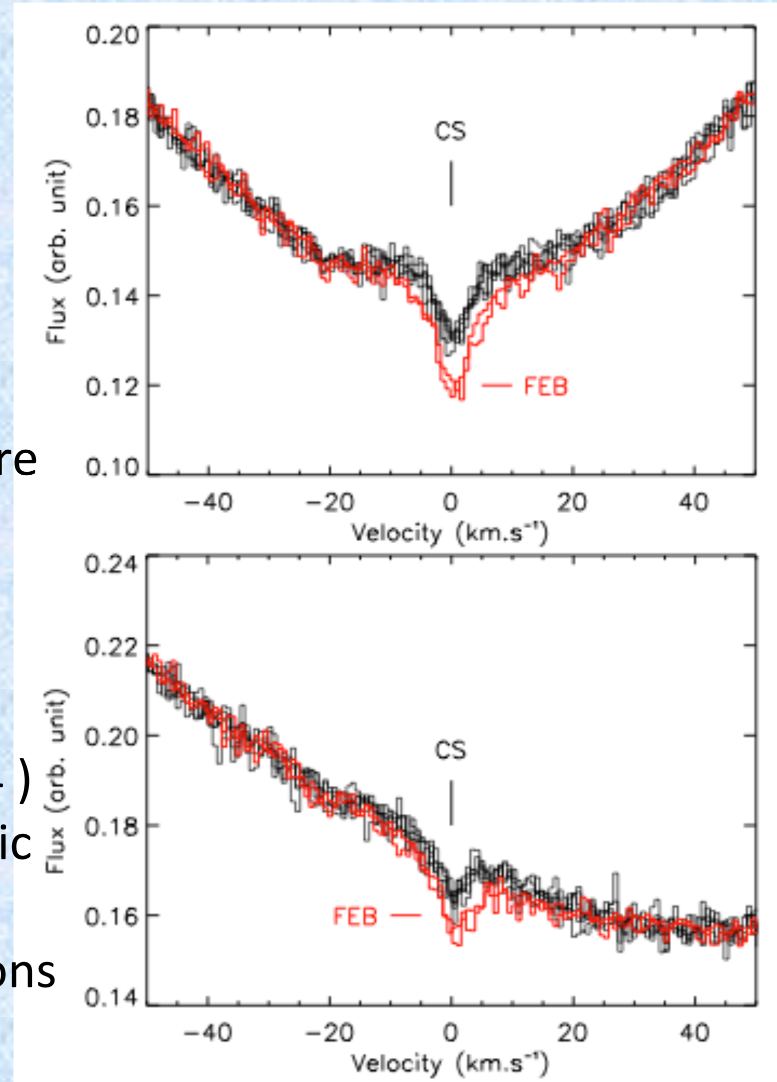


•CS absorption well separated from IS feature

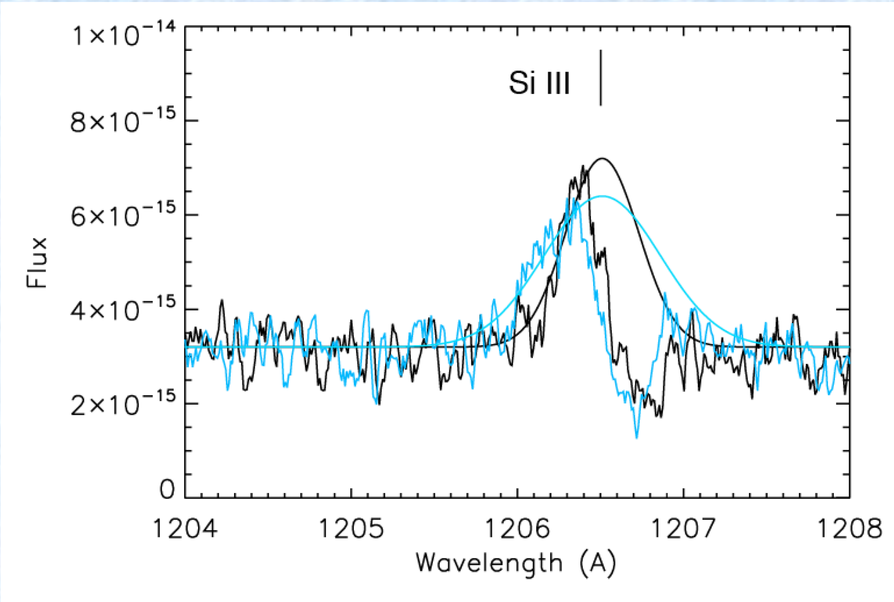
• Variable low velocity gas seen in Ca II;
no stable gas

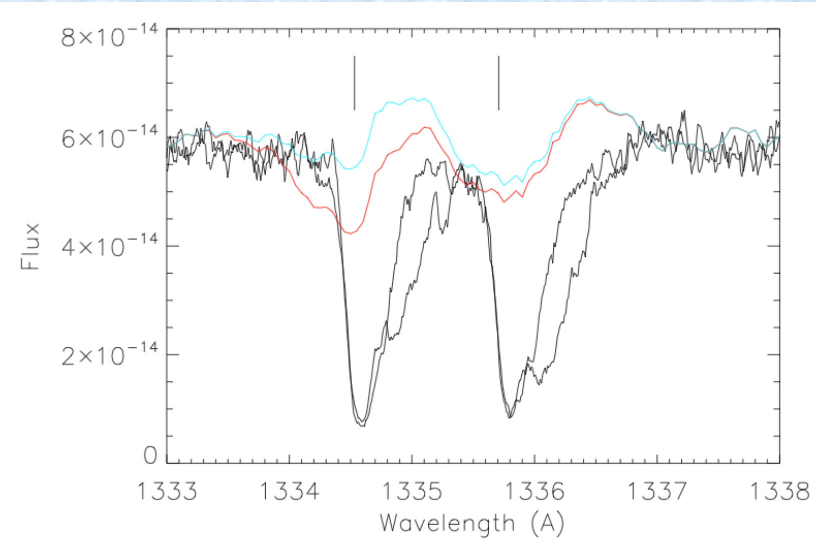
• 4 episodes seen in HARPS data (Kiefer +14)
suggests that FEB presence is at best sporadic

• no Ca II at the epoch of our HST observations

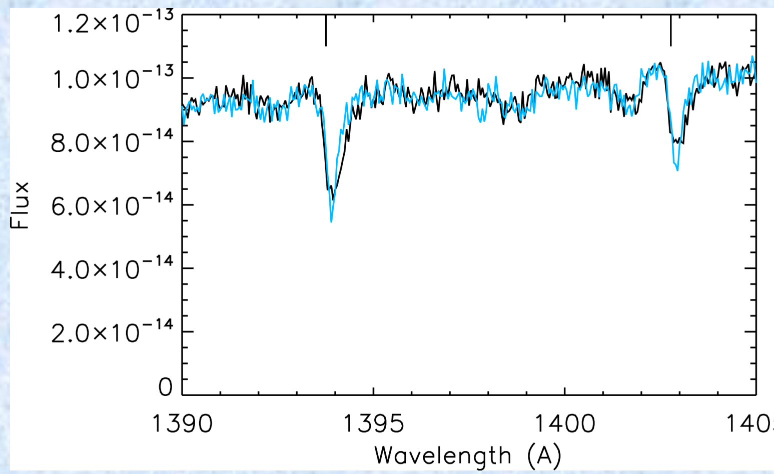


Transiting Exocomets – HST April 2015

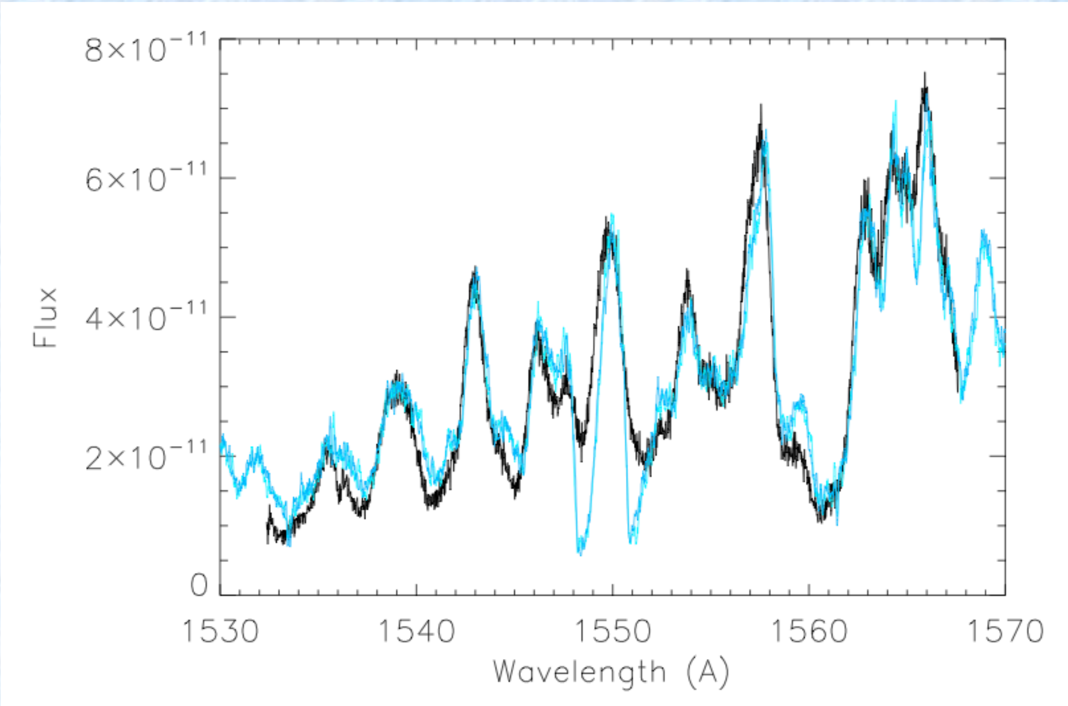




C II COS ~6 days separation FEBs in both datasets $-v_{max}= +160 \pm 10$ km s^{-1}
Excess signal compared to α Cep
• C II, Si III, and C III 1176 and red wing Lyα – chromospheric emission – star is active – amplitude and velocity <β Pic data from 2014



C IV

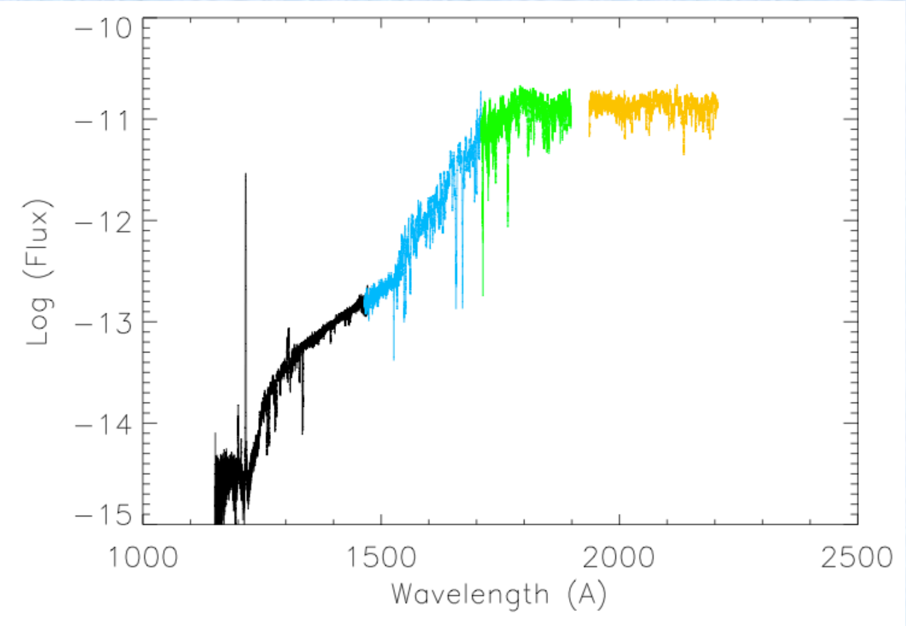


- C II, C III not the only carbon ions seen.

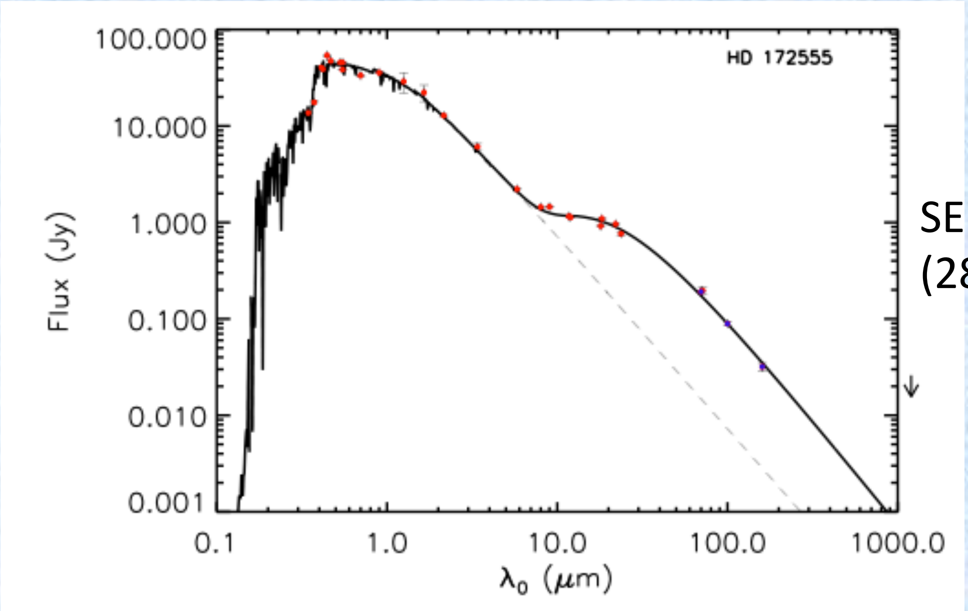
Comparison with Altair – not perfect but good enough to show excess absorption in C IV

Current Limits to Analysis

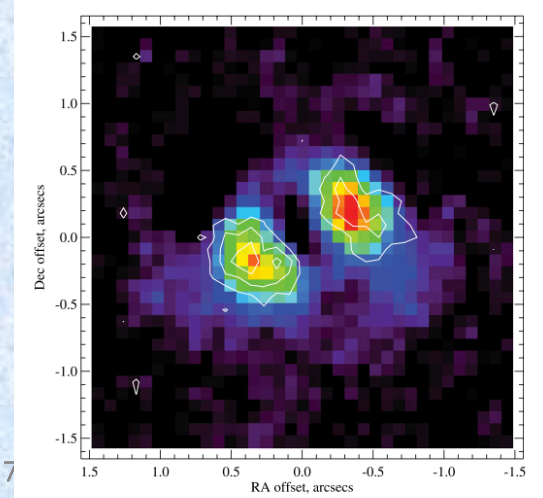
- comparison data sparse and essential at λ<1600 Å
- Large dynamic range of data makes high S/N spectra challenging
- Stellar activity



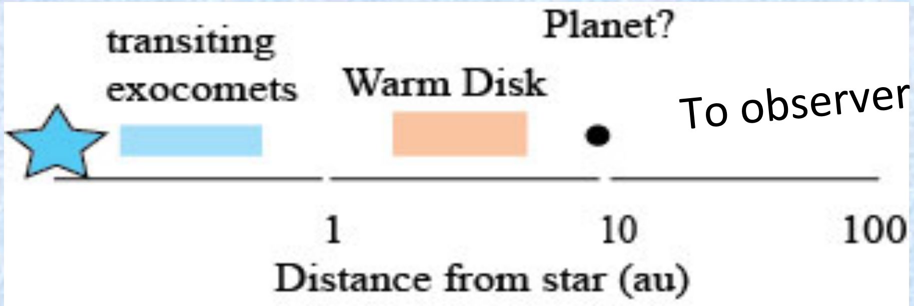
System Architecture



SED warm belt
(280 K) at r≥4 au, Riviere-Marichalar +12



Smith + 12



To observer =>

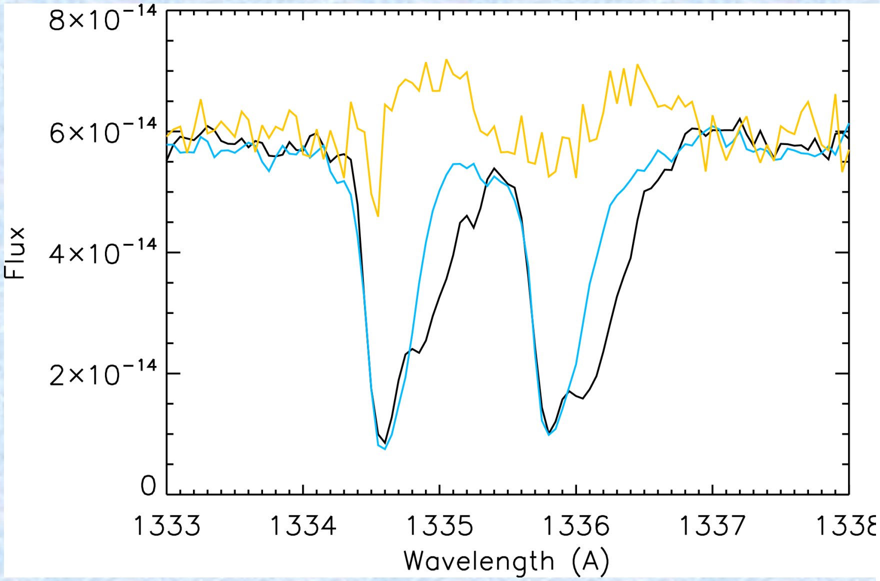
III. What Have We Learned?

- Transiting exocomets unexpectedly common in βPMG (at least 40% of A stars), also seen in 49 Cet (Roberge + 2014; Miles + 2016) and potentially other young systems
- Infall features at epoch when Ca II data suggest should not be seen – possibly more than one family of parent bodies?
- Most conspicuous in carbon ions – similar to β Pic and 49 Cet
- Direct imaging limits to planet mass 2-3 M_{jup} at r>0.5”(14.5 AU), 4 M_{jup} at 0.4” (11.68 AU), smaller separations unexplored (Quanz + 2011)
- If have a common origin in high-eccentricity bodies perturbed into star-grazing orbits by Jovian-mass planets, may have a novel technique for finding exoplanets.

Potential Jovian-mass planet frequency in βPMG A stars:

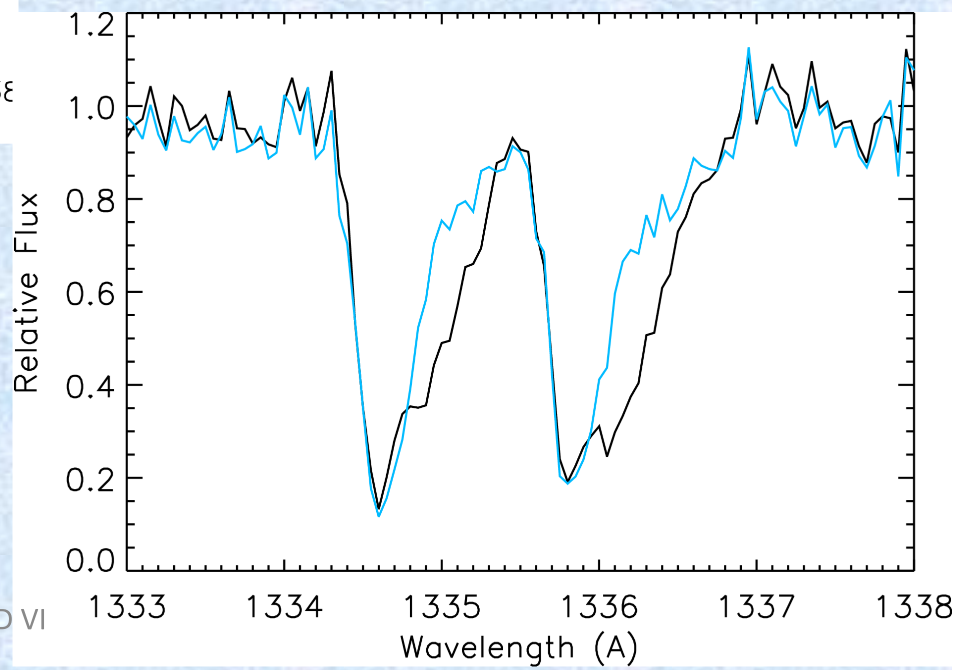
- 2 systems with transiting exocomets known, - data for a third in October…
- Planet frequency for A- early F stars – 25% from direct imaging
- Implication is that Jovian-mass bodies are common, and for the βPMG most probable location(s) are r~8-20 AU – gap in exoplanet searches

C II –optically thick



- adopt α Cep for photospheric spectrum, since Simon, Landsman, & Gilliland 1994 find no net C II emission, and add optically thin CII emission components to make continuum on blue edge of profile flat

- S/N largely dominated by noise in α Cep data ±5% - C II is optically thick and we measure covering factors up to 70%



Follow-on

- Acquisition of additional COS data, suggest single grating setting paralleling obs. of β Pic. – full orbit time-tag observation at or near opposition to minimize geocoronal emission
- Comparison object ι Boo match in Sp.T., color, V magnitude – needed for C IV region; would help with COS region
- Acquisition of comparison object spectra with FEB target observations may open up observations of very late A/early F stars and allow exploration of activity as a function of stellar rotation.