β Pictoris b
a proxy for planet formation studies

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Signposts of exoplanets -- October 2011
Aumann et al. (1984): Vega

Aumann (1985): IR excesses
Vega, α PsA, ε Eri, β Pic

Small, short lived grains => replenishment from larger bodies
**Gaps, belt-like structures (thermal IR)**

**Origin of the clumps:**
- on-going destruction of a large body?

See also *Okamoto et al (2003):* Subaru 10 μm spect

*Wahhaj et al (2002)*

*Telesco et al (2005)*
Inner (< 200 AU) disk shape


Planet on a 5° inclined orbit, + disk of planetesimals (15-150AU)

Mouillet et al. (1997)
Augereau et al. (2001)
Modeling the warp

Mouillet et al. (1997)

\[
\log \left( \frac{R_w}{10 \text{AU}} \right) = 0.29 \log \left( \frac{M}{M_\odot} \right) - \frac{\left( \frac{D}{10 \text{AU}} \right)^2 t}{t_{\text{unit}}} - 0.2.
\]
Late 80’s: Falling Evaporating Bodies on β Pictoris
=> indirect evidence for planet?

Vidal-Madjar, Lagrange, Roberge Beust, Morbidelli, etc

a~10 AU; 0.05<e<0.1
FEB in 4:1 or possibly 3:1 resonance
Total mass evaporated: a few Earth masses
B Pic light variations
(Nov. 10, 1981)

Planet around $\beta$ Pictoris

VLT/NaCo

Nov 2003

VLT/NaCo

Fall 2009

N

E

400mas

300mas
Planet around β Pictoris

ΔL′ = 7.8 +/- 0.2 mag
Sep = 298 +/- 16 mas
PA~ 210.6 +/- 3.6°

Lagrange et al (2010)

Teff ~1500K; M ~9MJup (Lyon’s group models)
Quanz et al (2010)

Currie et al (2011)

Bonnefoy et al (2011)

\[ \text{Teff} = 1600 \pm 200 \text{K} \]
Orbit of $\beta$ Pic b

Special care for calibrators (FoV orientation)

Chauvin et al (2011a)
Orbit of β Pic b

Chauvin et al (2011a); see also Currie et al (2011)
Mass estimates from imaging: model-dependent and uncertain!

Need for dynamical masses
Close planets needed!!

Fortney et al (2008)
See also Spiegel & Burrows (2011)
Mass of $\beta$ Pic b

for $a = 9$ (resp. 10, 12) AU, $M < 12$ (resp. 16, 25) MJup

Lagrange et al (2011a)
Planet and warp

A massive GP at ~10AU explains also:
- the FEBs
- the photometric event

should be located in the warped disk
(but see also T Currie’s talk)
Where is $\beta$ Pic b?

larger FoV Ks, data
detailed error budget
total error = 0.14° (internal error) (up to 0.35°)
β Pic b projected position is not in the main disk
β Pic b de-projected position is not in the main disk
Open questions & future prospects
(biased: observer’s point of view)

Orbit of β Pic b

Link between β Pic b and the disk: XAO imaging; HST; Alma; JWST

Characterization (log g; Teff; composition): NaCo & XAO spectro

Other planets?: AO, RV, VLTI, JWST

Disk: secondary or warped? Other origins for the β Pic warp?

Formation process: CA (possible) or GI (can GI produce massive EGP at 10 AU ?) => observe other planets in resolved disks
3.6m/Harps  Lagrange et al (2011a)