Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

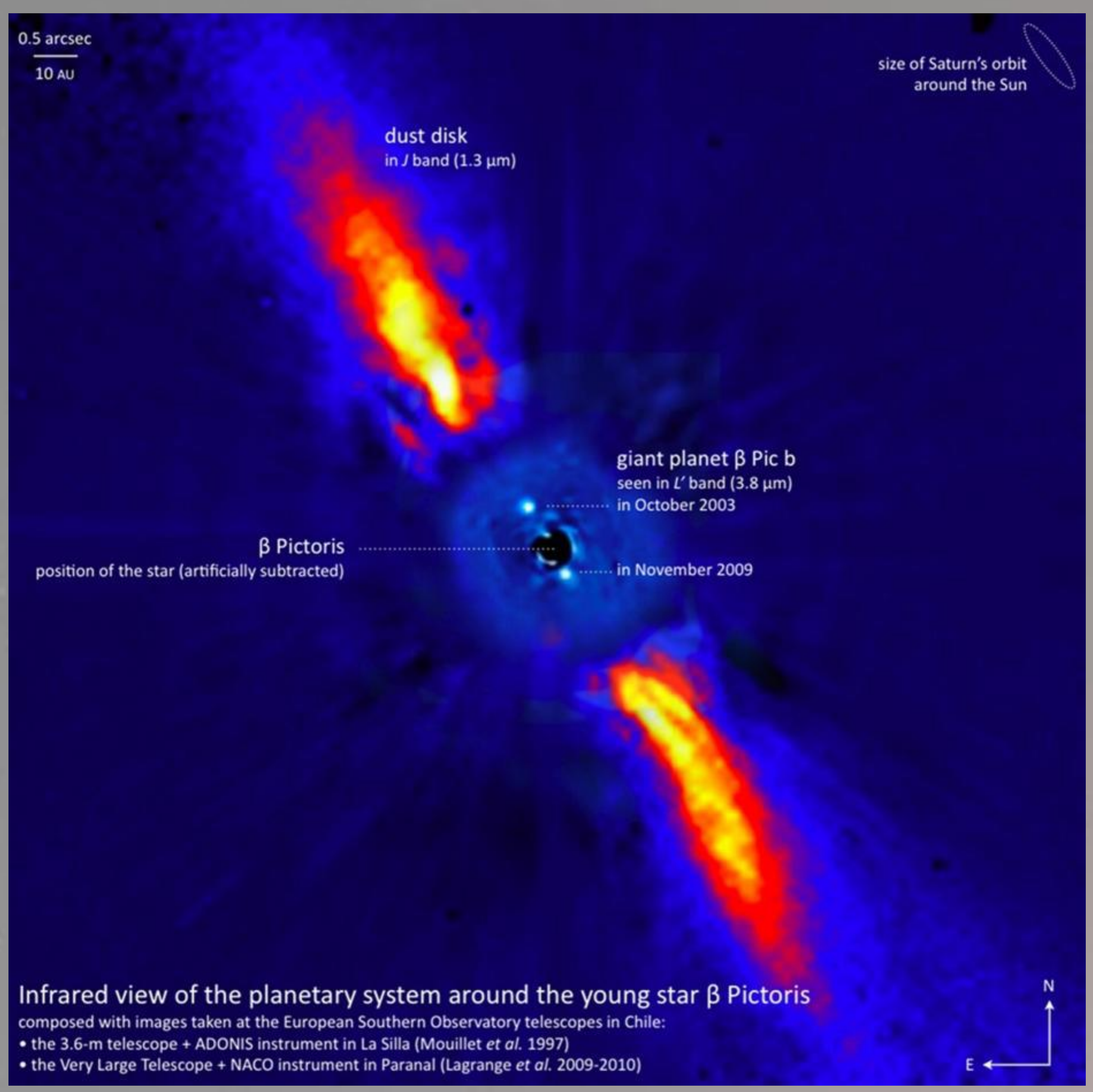
Beta Pictoris transit with PicSat

Lester David, Vincent Lapeyrere and Sylvestre Lacour

LESIA , Observatoire de Paris, CNRS, 5 place Jules Janssen, 92190 Meudon France

Contact: lester.david@obspm.fr

The objective of the PicSat space mission is to study the β Pic b transit forecasted in summer 2017. The idea of this demonstrator is to spatialize a 3U CubeSat using a 35mm effective aperture and a single pixel avalanche photodiode. To guarantee photometric precision and CubeSat stabilization, the Attitude Determination and Control System is loop controlled with a double-axis piezo-actuator. The piezo follows the maximum intensity of the signal in the focal plane to compensate the jitter of the pointing system. PicSat uses a single-mode fiber to guide the stellar light from the focal plane to the photodiode.



Infrared view of the planetary system around the young star β Pictoris
composed with images taken at the European Southern Observatory telescopes in Chile:
• the 3.6-m telescope + ADONIS instrument in La Silla (Mouillet et al. 1997)
• the Very Large Telescope + NACO instrument in Paranal (Lagrange et al. 2009-2010)

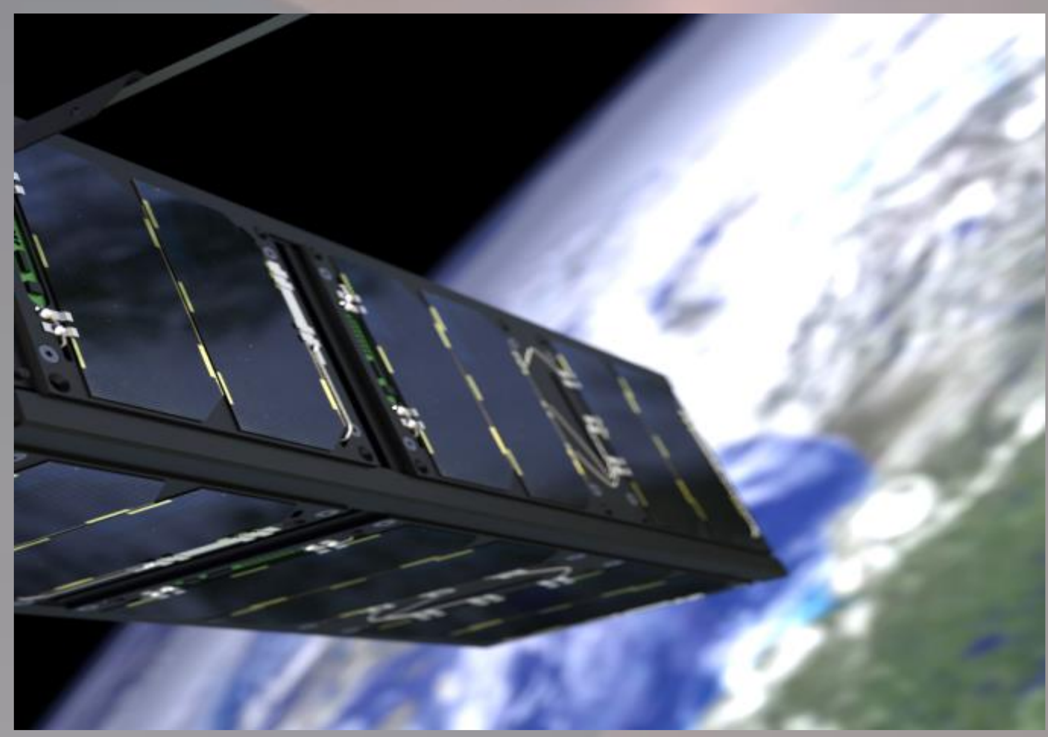
Beta Pictoris

β Pic is a 20 Myr old and 63 light-years away A5 star.

A large circumstellar disk is seen edge-on, in which an exoplanet, β Pic b was discovered in 2008 with VLT-NACO adaptive optics.

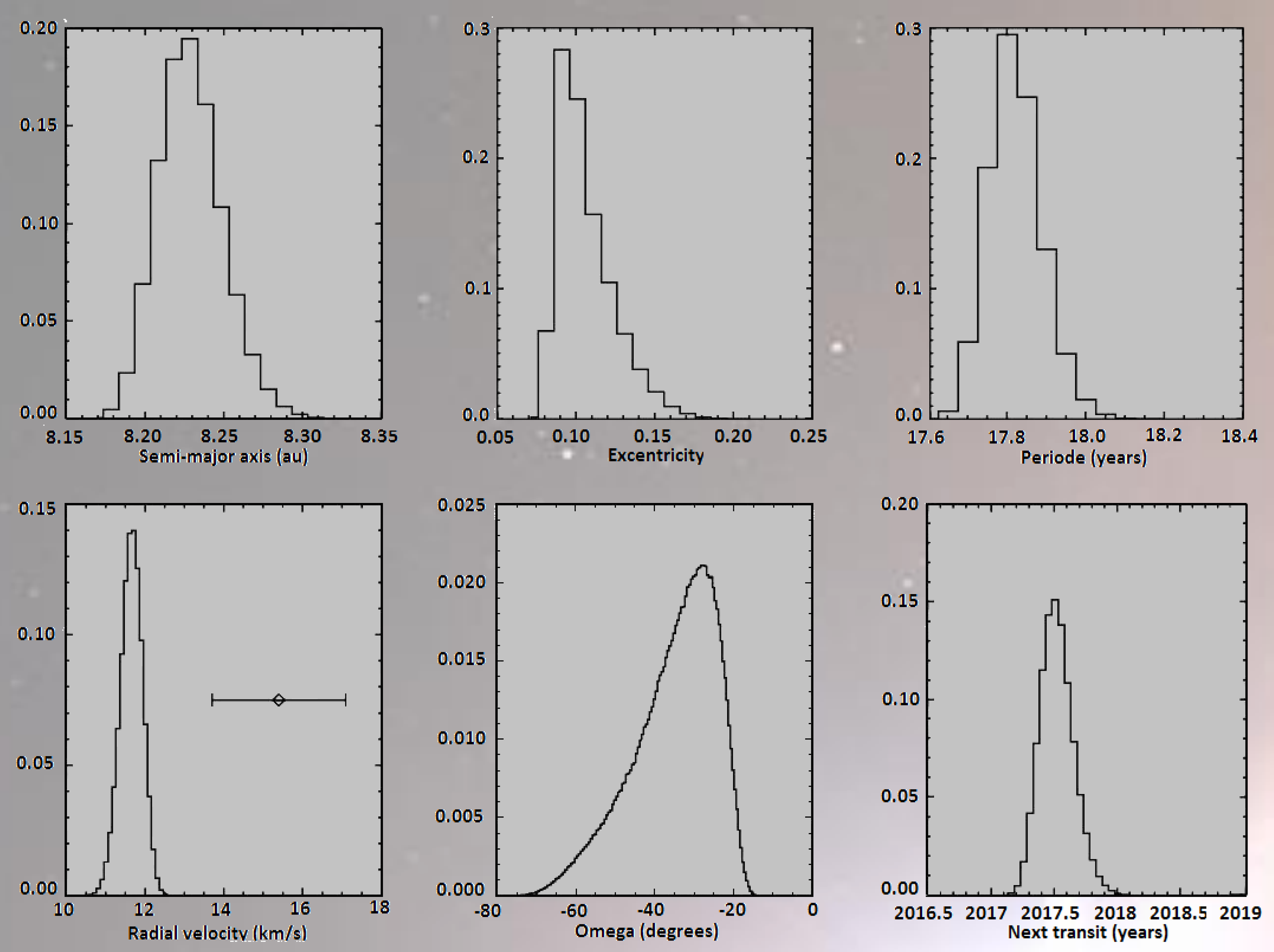
This planet -a Jupiter like gas giant- estimated mass is about 8-10 M_J and has a semi-major axis of 8 au.

CubeSat Standard



Developped in California and Stanford universities in 1999, CubeSat's objectives is to provide a standard for the design of small satellites, in order to reduce cost, development time and increase accessibility to space. For now, 340 CubeSat were launched.

Expected Transits

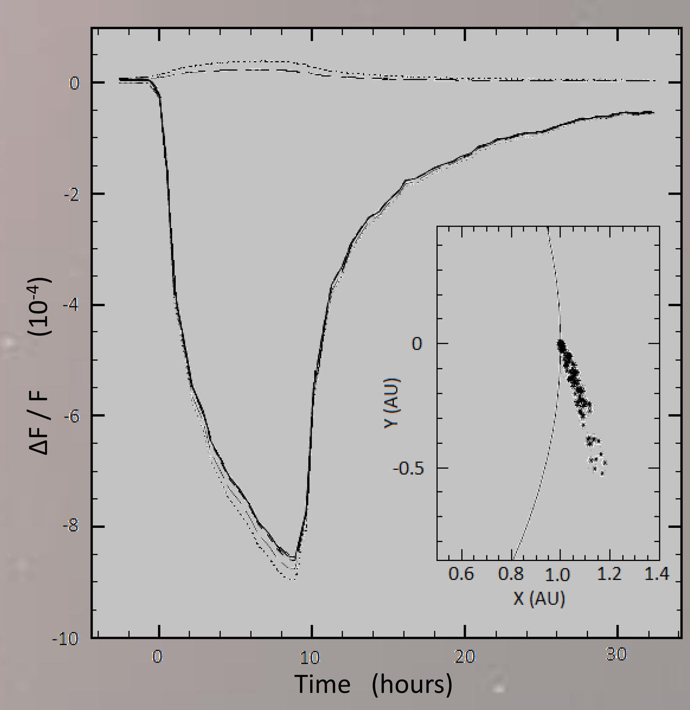


Probability distributions of orbital parameters

Orbital parameters of β Pic b considering the 1981 photometric event as a transit coupled with 2009-2013 observations, with a low eccentricity orbit (e ≈ 0.1, periode ≈ 18 yr)

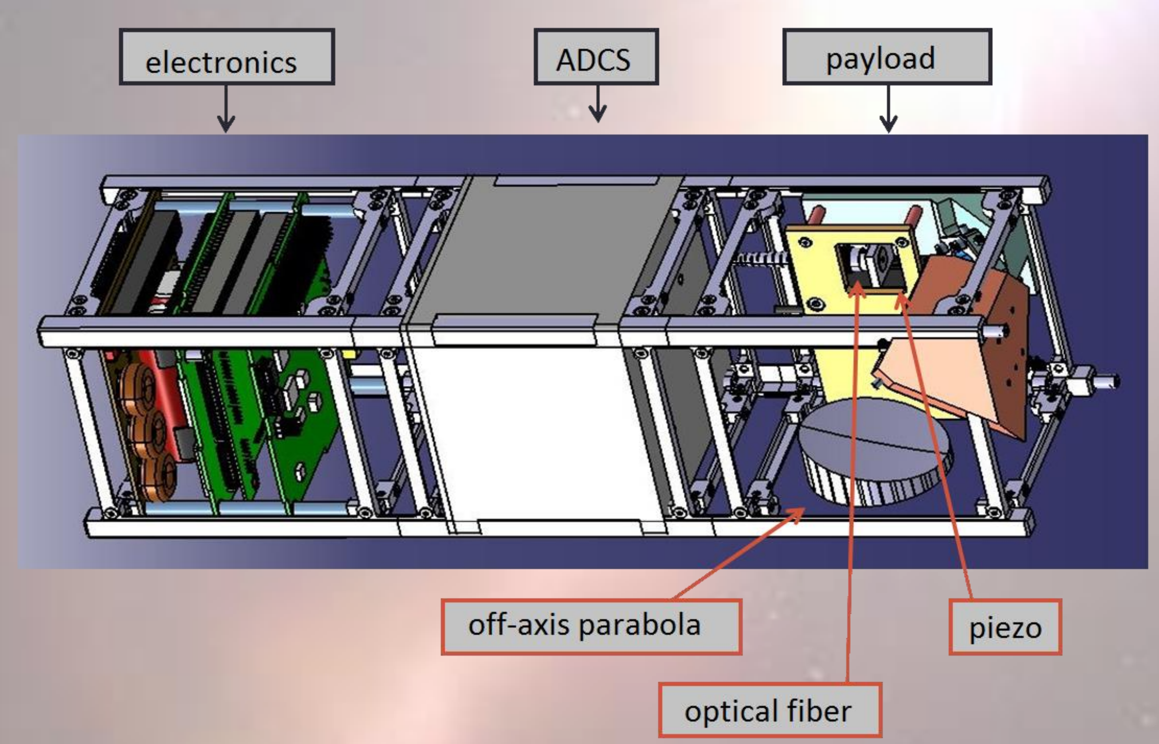
Next transit maximum probability is mid 2017.

In case of a high eccentricity (e ≈ 0.3, periode ≈ 36 yr) the next transit will be in winter-spring 2018.



Simulation of photometric varations during cometary occultation. The insert is a view from the top when the comet is crossing the line of sight (Y = 0) at the periastron.

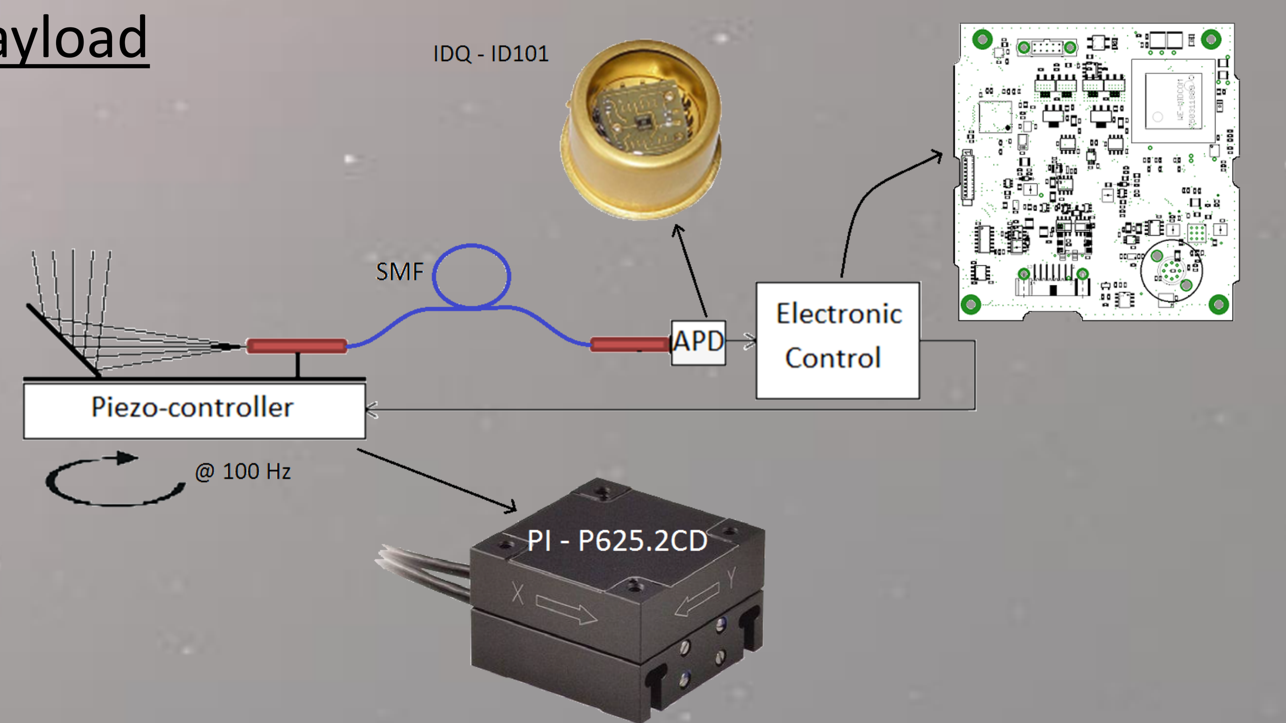
Light curve presents the very specific "rounded triangular" shape. Production rate at 1 AU is 2.10^6 $kg.s^{-1}$



The satellite is based on a 3 units CubeSat platform (10x10x34cm) with 1U for electronics, 1U for ADCS and 1U for our payload. A prototype of the payload is currently being tested in Meudon, electronics components and ADCS are off-the-shelf systems.

The telescope is a 50mm F/2.7 parabola (and 2 reflecting mirrors) coupled with a single mode fiber carrying the light to an Avalanche PhotoDiode.

Payload



The payload will track the star by moving the fiber head in the focal plane. The Single Mode Fiber (SMF) is mounted on a 2 axes piezo stage that modulates the position around the star with a 100Hz frequency.

The photometric error budget gives a total error of 168 ppm/hour considering a 35mm diaphragm, a total transmission of 20%, a quantum efficiency of 30% for a Vmagnitude = 3.86 star.

	Assumption	Error	Error (ppm/hour)
Photon noise	8.10^4 e/s	$1/\sqrt{N_{photon}}$	60
Readout noise	0	0	0
Dark current	10^3 e/s	$\sqrt{N_{current}/N_{photon}}$	0.01
Scattered light	150 e/s	N_{moon}/N_{photon}	77
Thermal stability	0.01°C	0.4% per °C	40
Voltage stability	100µV	20% per volt	20
Pointing stability	5% @ 100Hz	$\Delta Inj \times \sqrt{t \times 100Hz}$	83
		Total error	168

References : Lecavelier Des Etangs et al. (1997, A&A, 328, 311L)
Lecavelier Des Etangs, Vidal-Madjar & Ferlet (1999, A&A, 343, 916L)
Lecavelier Des Etangs & Vidal-Madjar (2009, A&A, 497, 557L)
Lagrange et al. (2009, A&A, 493L, 21L)
Kiefer et al. (2014, Nature, 514, 462K)
Apai et al. (2015, ApJ, 800, 136A)

PicSat

http://www.lesia.obspm.fr/PICSAT.html

Contact: lester.david@obspm.fr

31st International Colloquium of the Institut d'Astrophysique de Paris

Background: Artist view of β Pictoris. Credits: ESO L. Calçada/N. Risinger