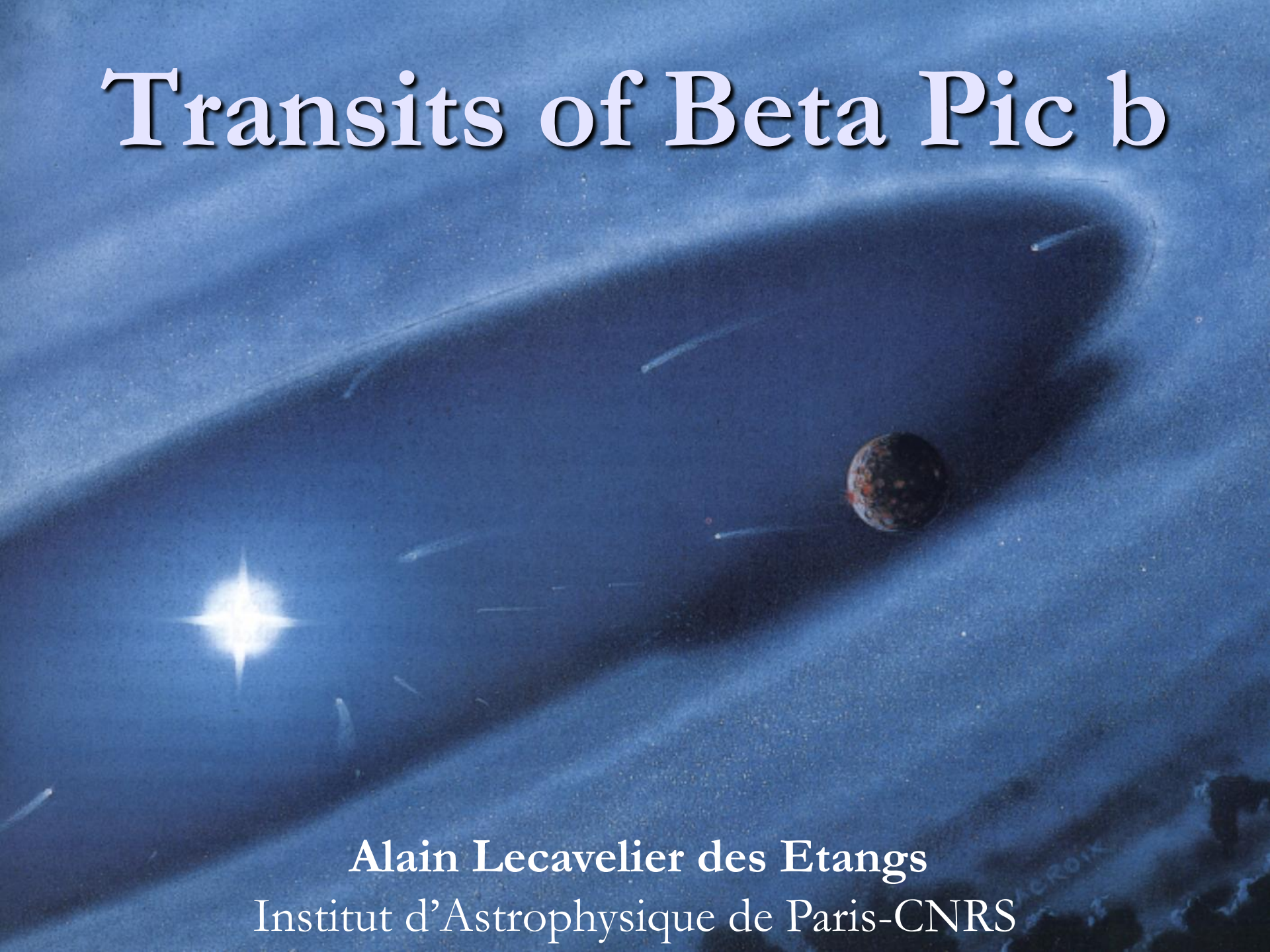
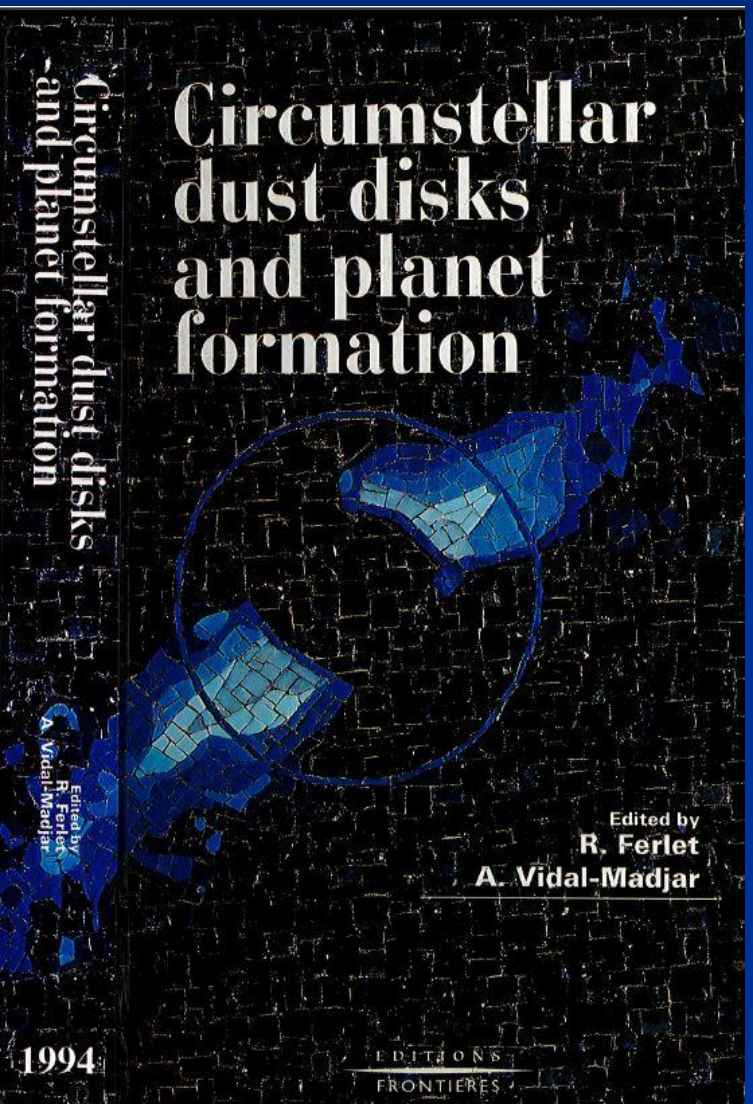
Transits of Beta Pic b



Alain Lecavelier des Etangs
Institut d'Astrophysique de Paris-CNRS

Circumstellar dust disk and planet formation conference (1994)



FOREWORD

During a full week, Paris was at the center of all circumstellar disks

The subject chosen for the tenth anniversary of the annual meetings[1] of the Institut d'Astrophysique de Paris of the Centre National de la Recherche Scientifique (CNRS), LES DISQUES DE POUSSIERES CIRCUMSTELLAIRES ET LA FORMATION DES PLANETES – "CIRCUMSTELLAR DUST DISKS AND PLANET FORMATION" was and still remains at the forefront of astronomical research.

A large number of teams in the world are involved in the study of disks around very young stars as well as around main sequence stars, and this field of research is in rapid expansion. Since 1984 when the dusty disk around the star β Pictoris was imaged for the first time, many detailed multi-wavelengths spectroscopic observations including those by the Hubble Space Telescope, have led to a detailed characterization of this disk, in which kilometer size small bodies have been indirectly detected. Recent photometric observations, of what is already thought to be the prototype of a planetary system in formation, or even already formed, suggest the presence of at least a giant planet which has already condensed. It seems now possible to be able to directly test some predictions of dynamical models of planet formation for the first time.

Although the IRAS satellite discovered infrared excesses, interpreted as due to dust envelopes, in many nearby stars, the case of β Pictoris remains unique. In fact, disks around main sequence stars are far less luminous than those observed for most of the T-Tauri stars, especially if they are not seen edge-on from the Earth. The differences between these systems resulting either from planetary accretion or from ejection of matter, can in fact provide constraints or processes of planet formation.

The Paris Conference therefore dealt with finding possible links between differents types of disks, and studying their evolution toward planetary systems, as well as putting forward the implications for processes of planetary growth. A a matter of fact, one of the major issues in these studies is to understand the formation of our own Solar System. That is why another original point of the IAP Meeting was to define possible analogies between the β Pictoris system and our own, in order to more precisely constrain the wonderful story, which led to the still unique exemple of the solar planets.

As many as eighty seven attendees from the whole world (Australia, Canada, USA, India, Japan, Eastern countries and EEC countries) met in Paris from the 4th to the 8th of July 1994 to confront their views. This was undoubtedly an opportunity to realize the need for pluridisciplinary links between theoreticians and observers, and, what is more unusual, between specialists from the "stellar" community and that of the "Solar System". The discovery of planets around β Pictoris and /or elsewhere will be one of the challenges in the next decade. If a consensus was easily reached about the excitement involved in such an adventure, on the contrary the participants did not agree on the date on which this discovery will occur!

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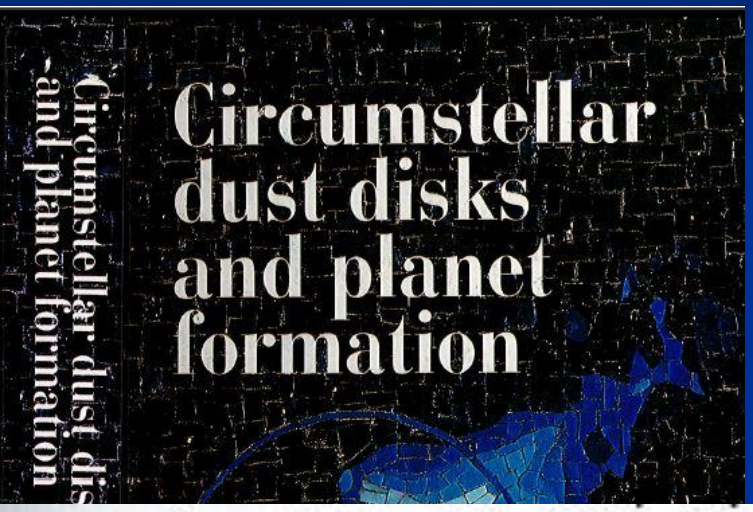

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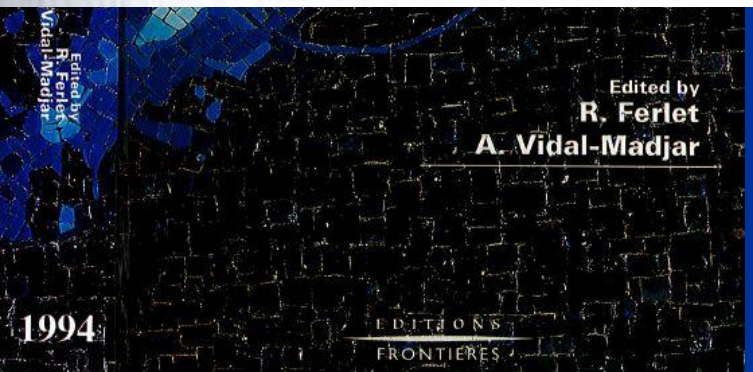

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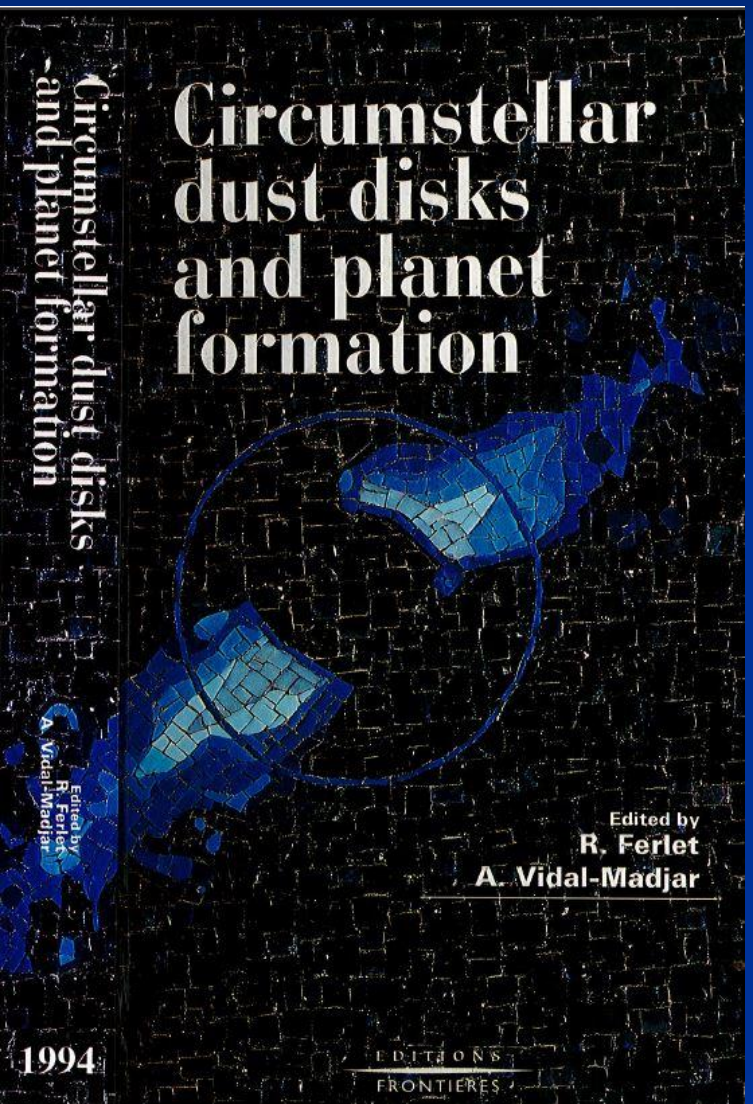

Consultation on the date of the first exoplanet observation

→ **Some answers were "November 1981" !! ?**

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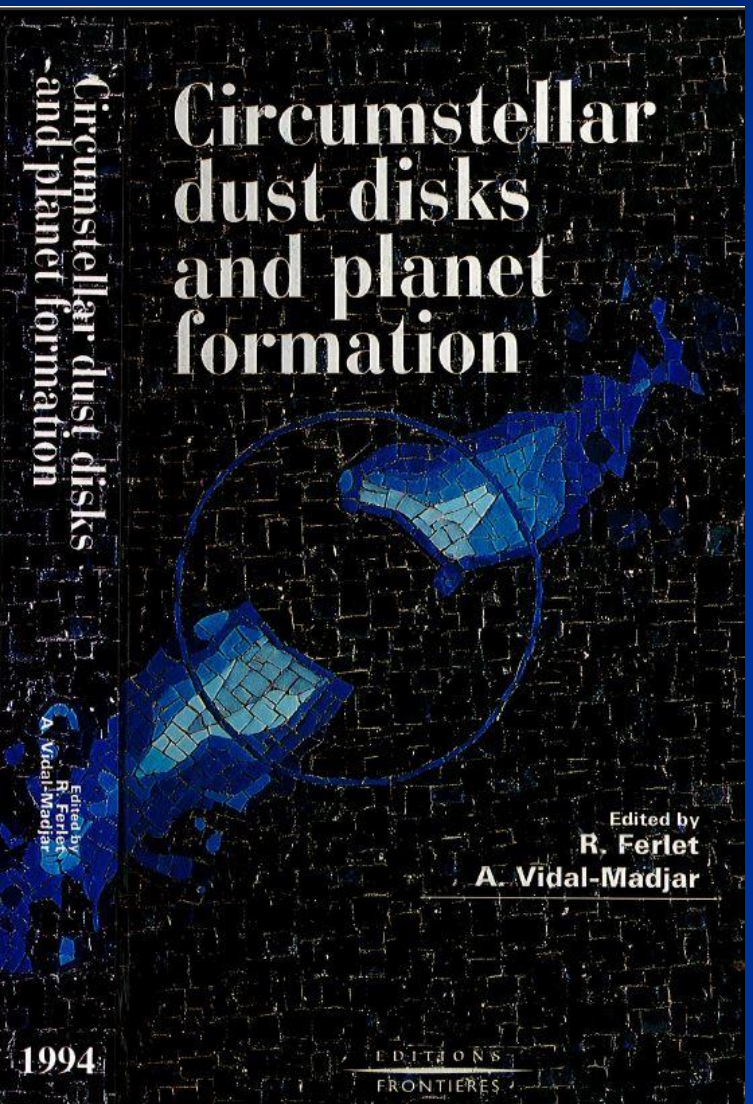


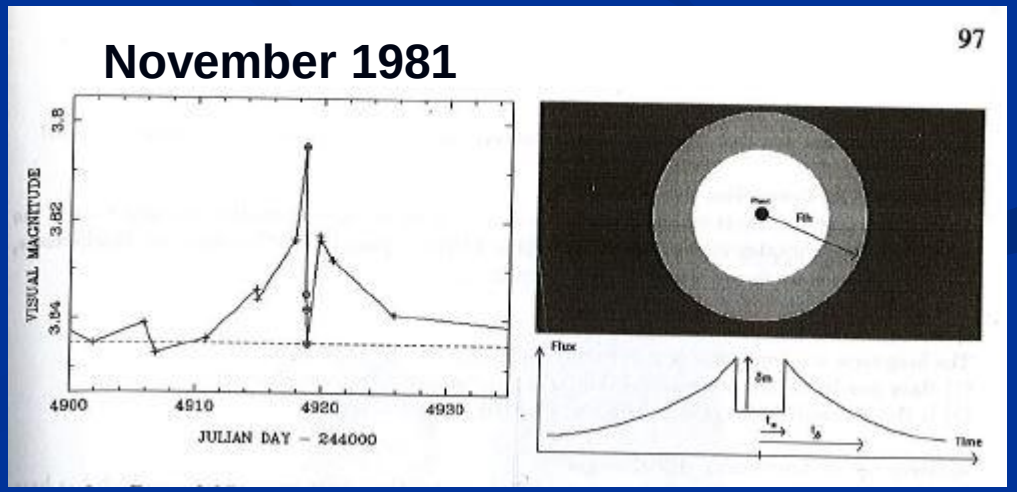
Consultation on the date of the first exoplanet observation

→ Some answers were "November 1981" !! ?

→ Presentation of Beta Pic light variations:

- Long term (years)
- Short term (days and hours in Nov 1981)

➔ interpretation in term of planet's transit



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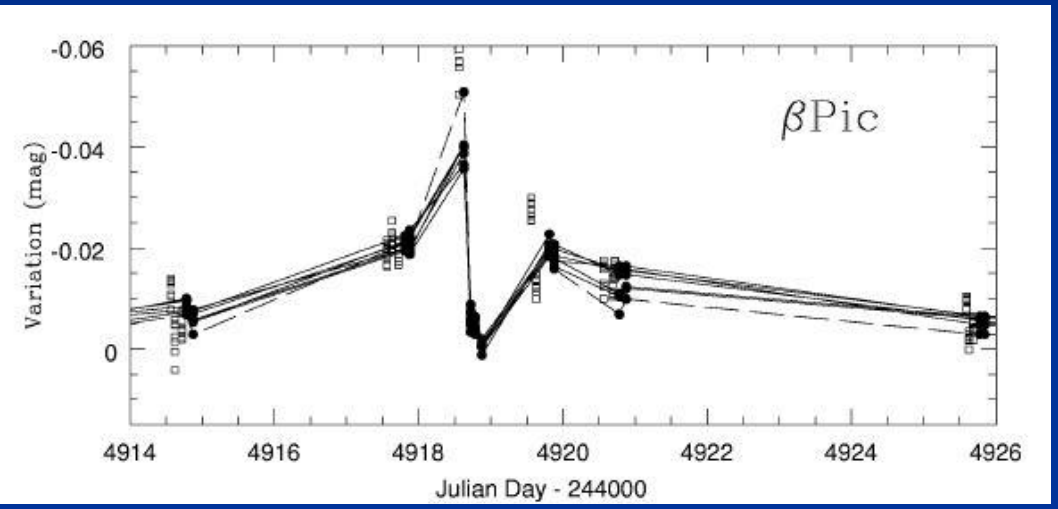
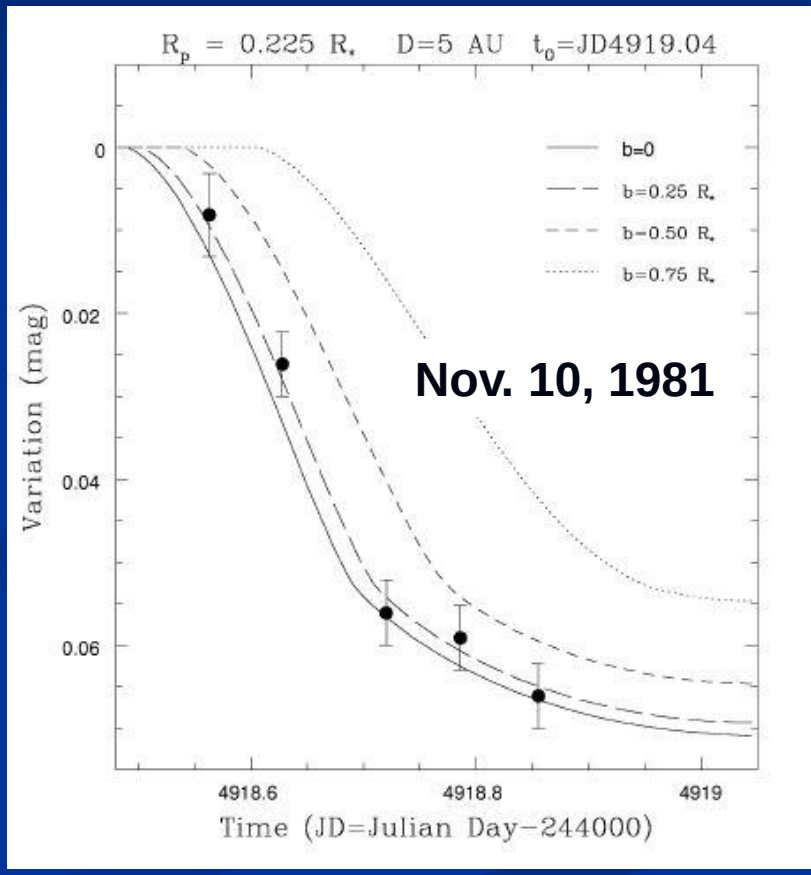


Photometric variations on days time scale related to a hole of obscuring dust around the planet



Photometric variations on hours time scale related to the transit of a planet (with limb-darkening !)

Two scenarios

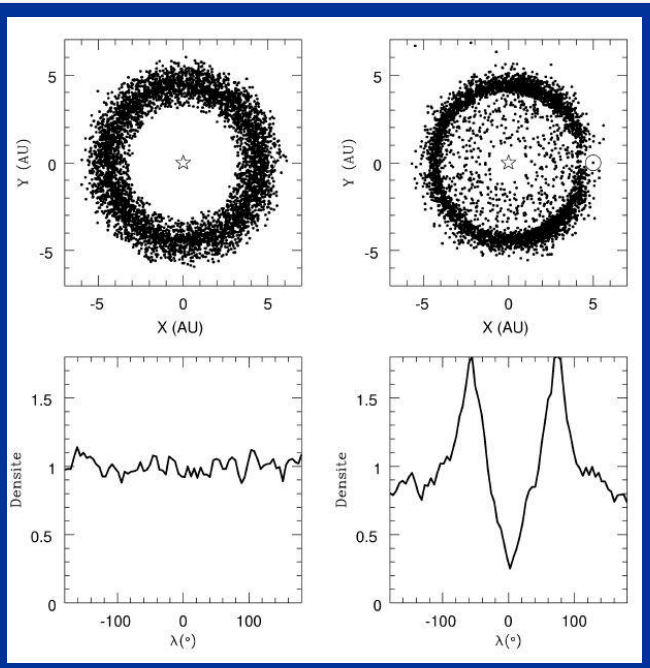
(Lecavelier et al. 1997; Lamers et al. 1997)

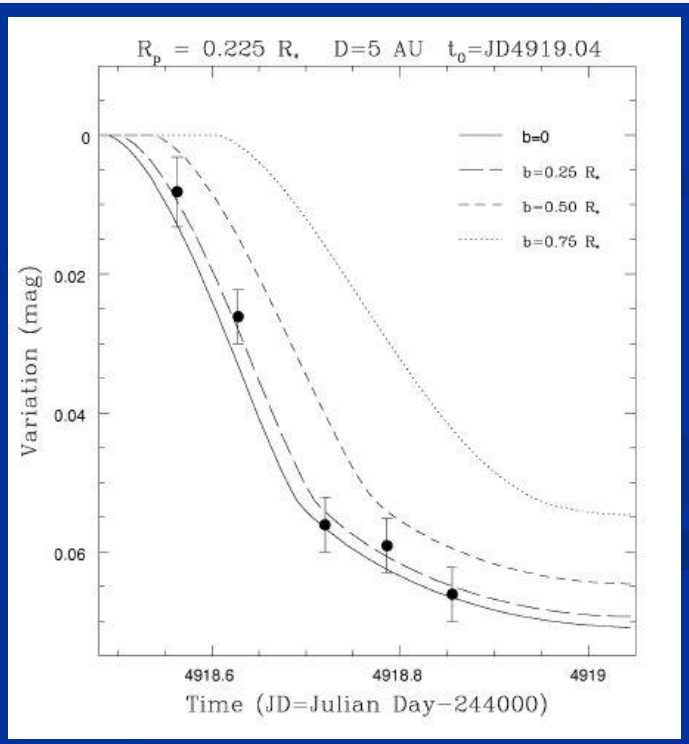
I. Transit of a planet

β Pictoris light variations

I. The planetary hypothesis

A. Lecavelier des Etangs[1,2], A. Vidal-Madjar[1], G. Burki[3], H.J.G.L.M. Lamers[4], R. Ferlet[1], C. Nitschelm[1], and F. Sèvre[1]





Dust in 1:1 resonance

(see dust ALMA image by Dent et al. !!)

Two scenarios

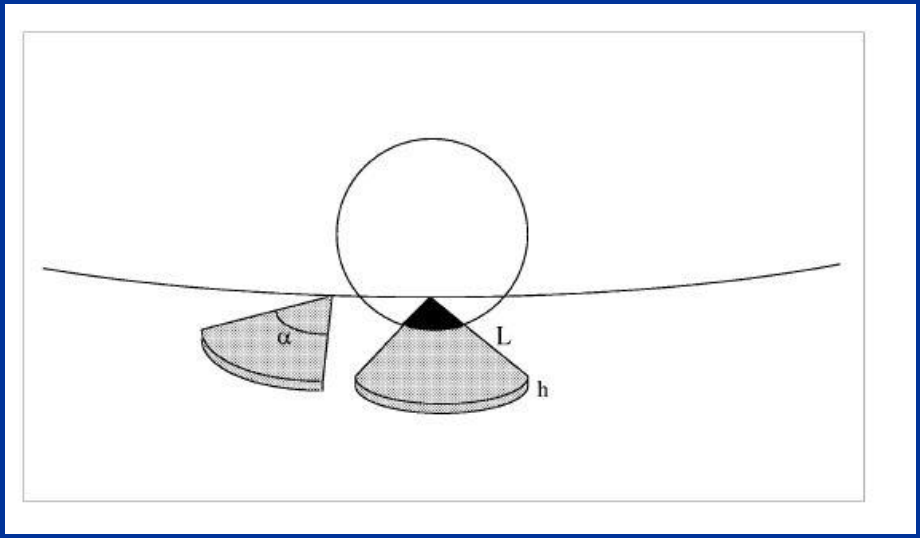
(Lecavelier et al. 1997; Lamers et al. 1997)

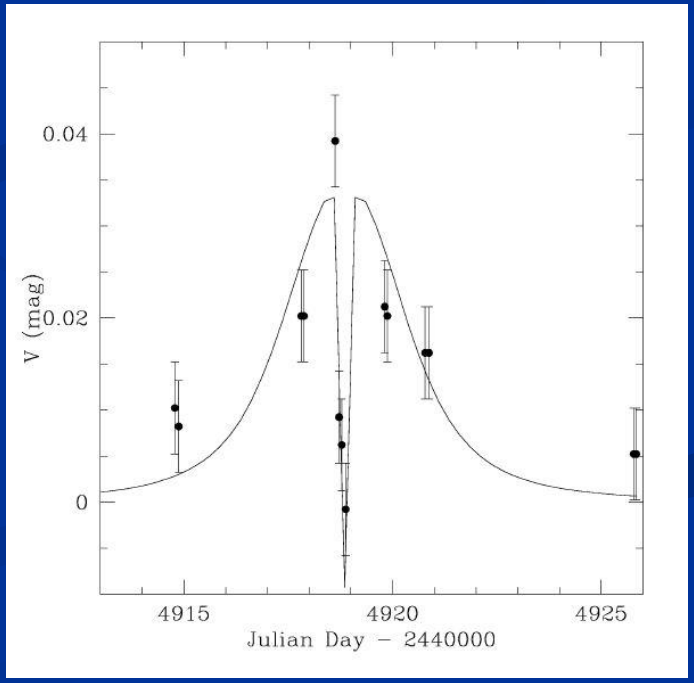
II. Transit of a comet

β Pictoris light variations

II. Scattering by a dust cloud

H.J.G.L.M. Lamers[1,2], A. Lecavelier des Etangs[3,4], and A. Vidal-Madjar[3]

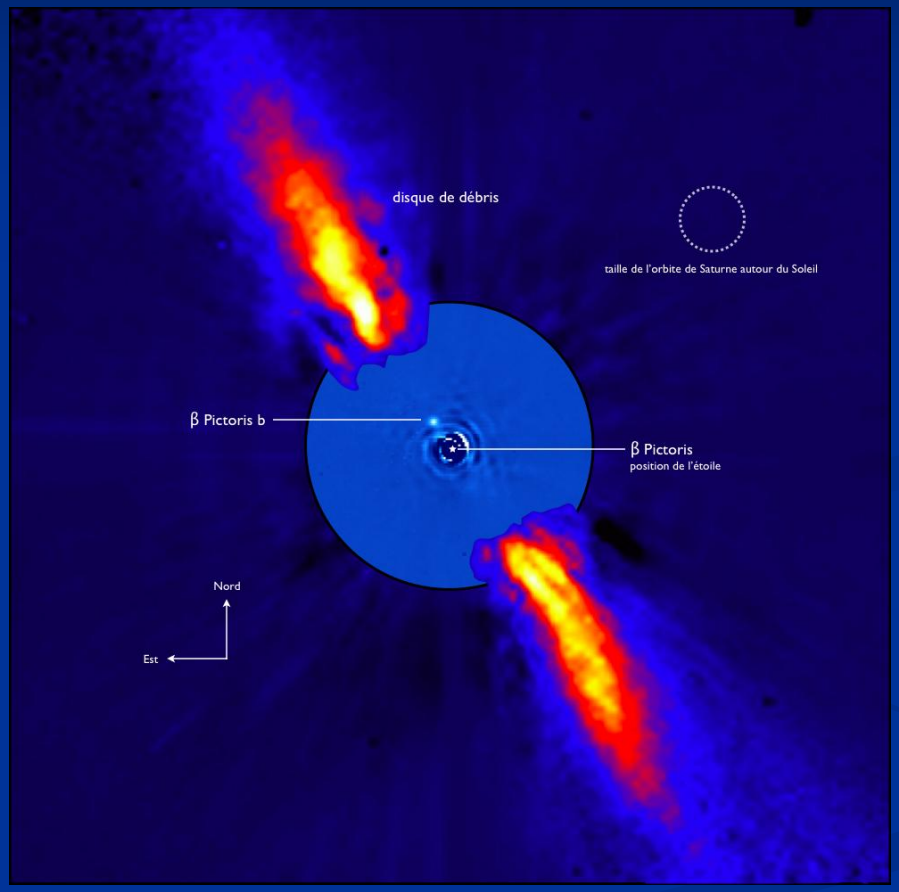




Forward scattering by a (huge) dust cloud

Image of Beta Pic b in 2003

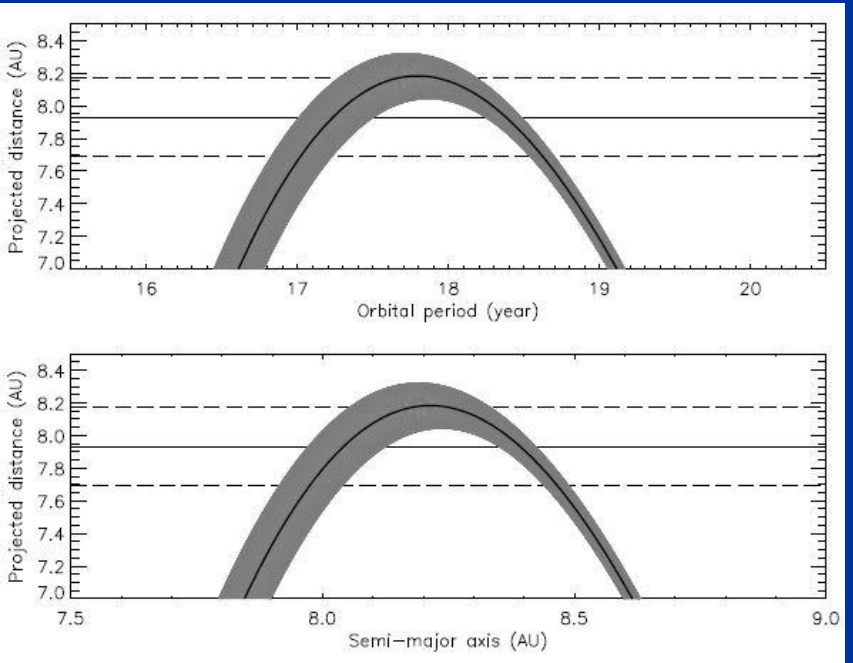
(Lagrange et al. 2009)

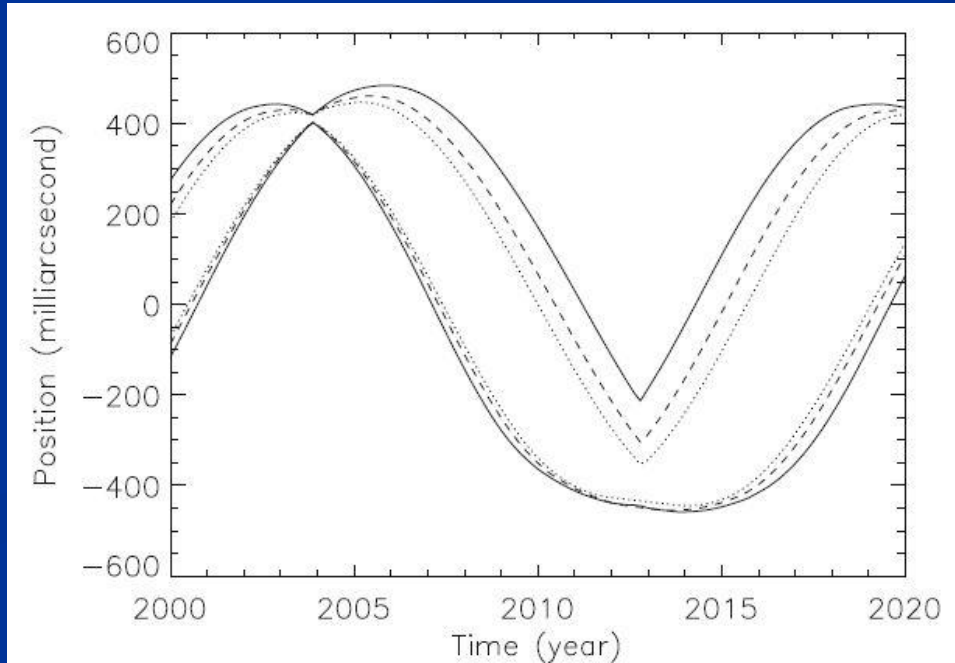


Could it be the transiting planet of 1981 ??

Prediction using the 2003 position
(Lecavelier des Etangs & Vidal-Madjar 2009)

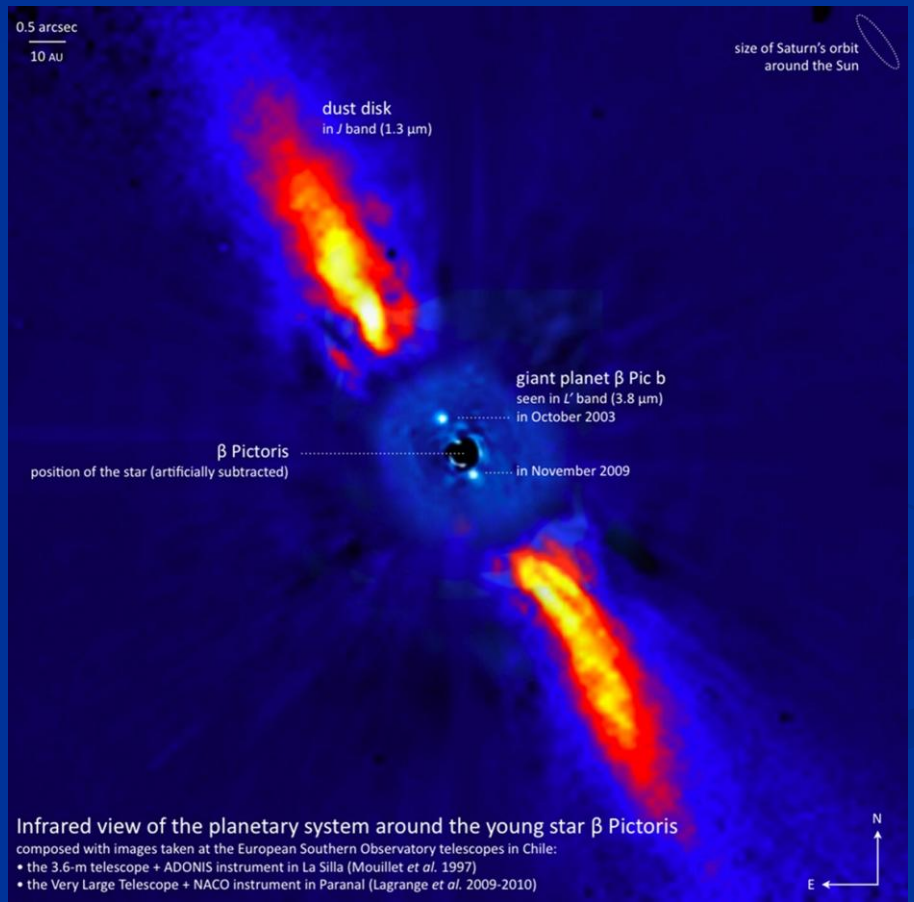
- If this is the same planet::
  - → orbital period is 17-19 years
  - → observed closed to quadrature in 2003
  - → Next quadrature (in the other side) predicted in 2012-2015





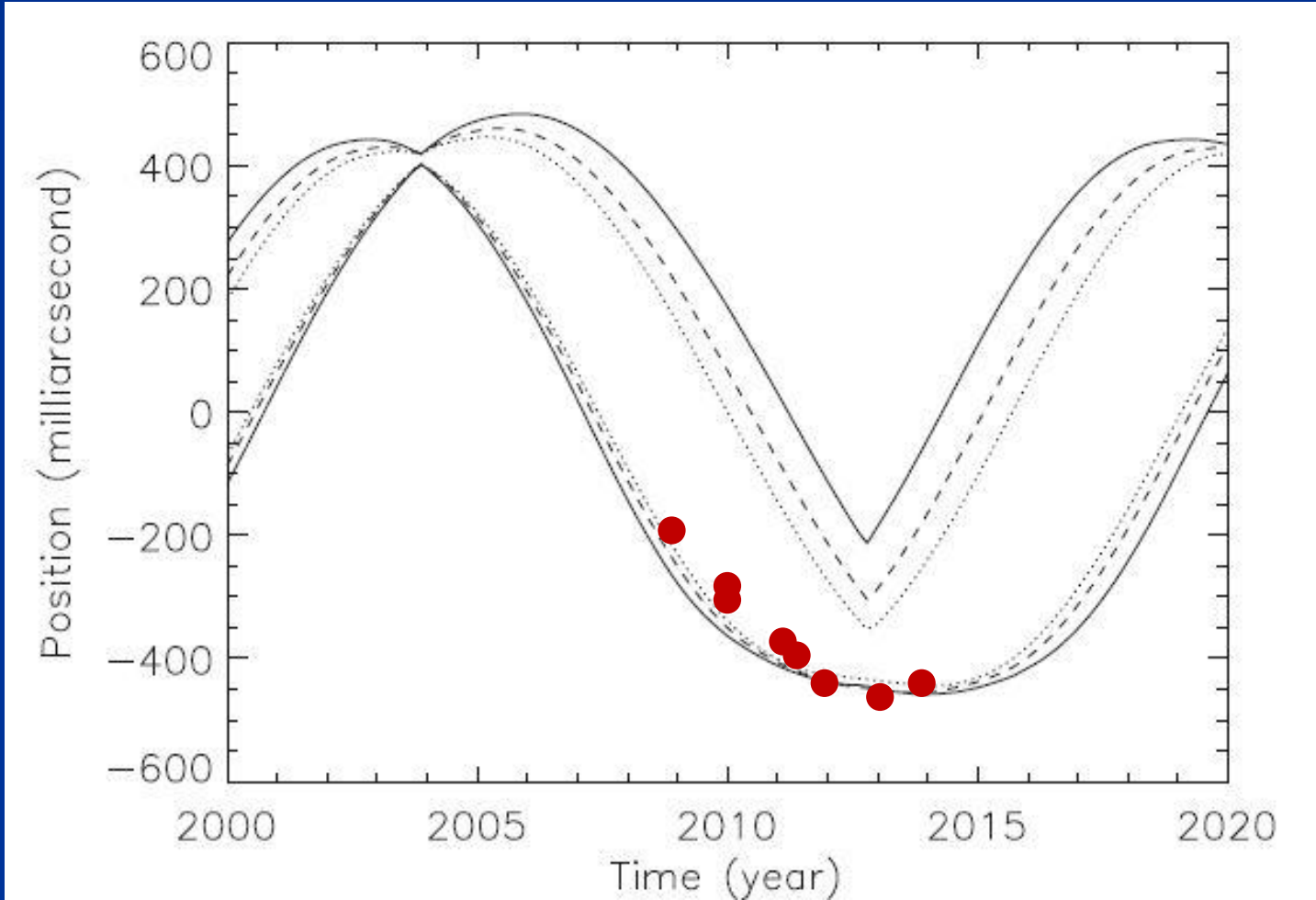
Observations of November 2009
(Lagrange et al. 2010)

- In 2009, the planet appears in the other side in agreement with the predictions.



Observations of Nov 2009 - Dec 2013

- The planet position is in agreement with the predictions.



Observations of Nov 2009 - Dec 2013

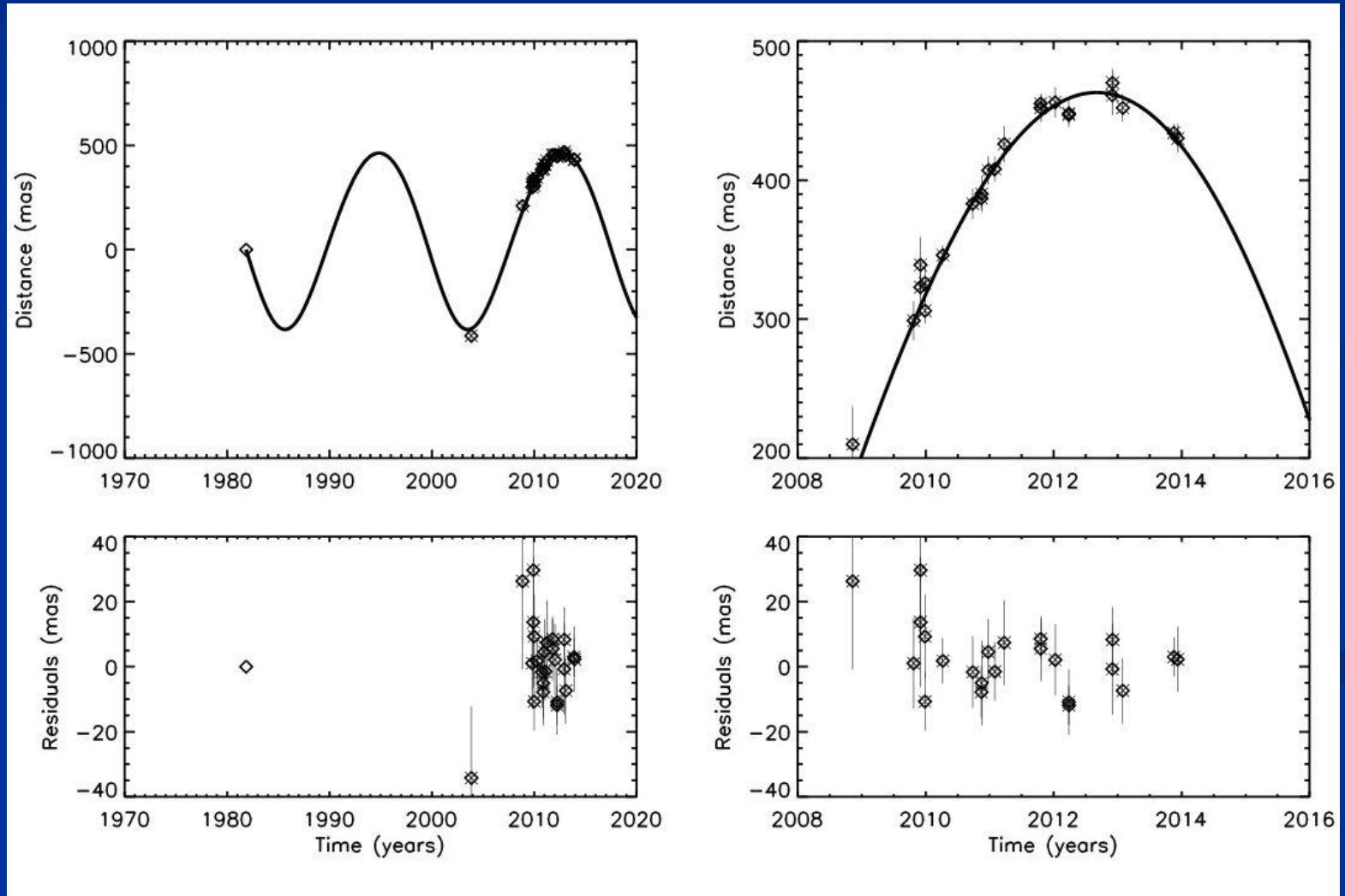
- What are the new constraints on the planet and the transit ?

  MCMC statistics (fit to 24 astrometric position measurements)

  ➔ two families of orbits : e~0.1 and e~0.3

Observations of Nov 2009 - Dec 2013

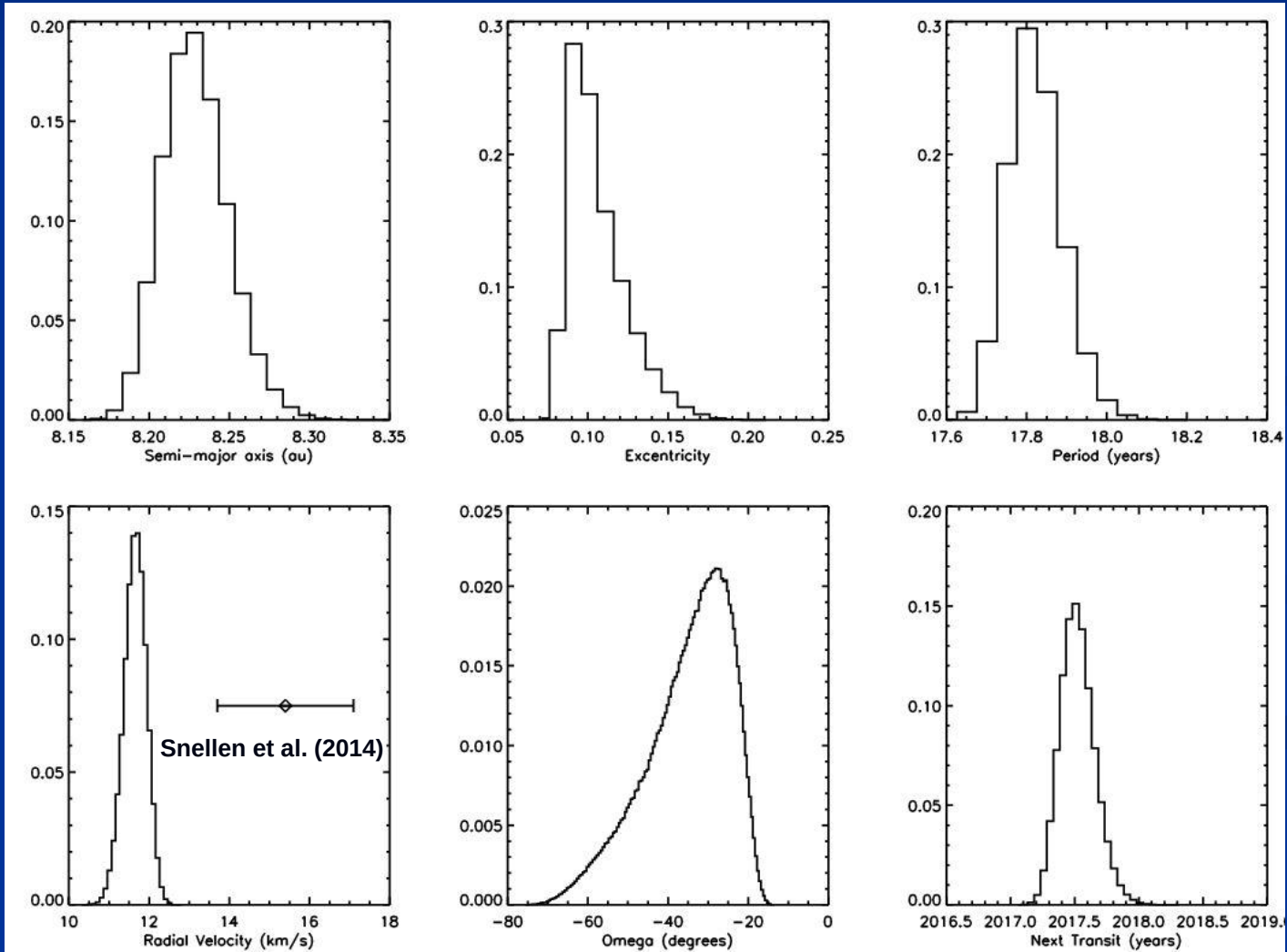
Low eccentricity orbit (e~0.1, Period~18 years)



Observations of Nov 2009 - Dec 2013

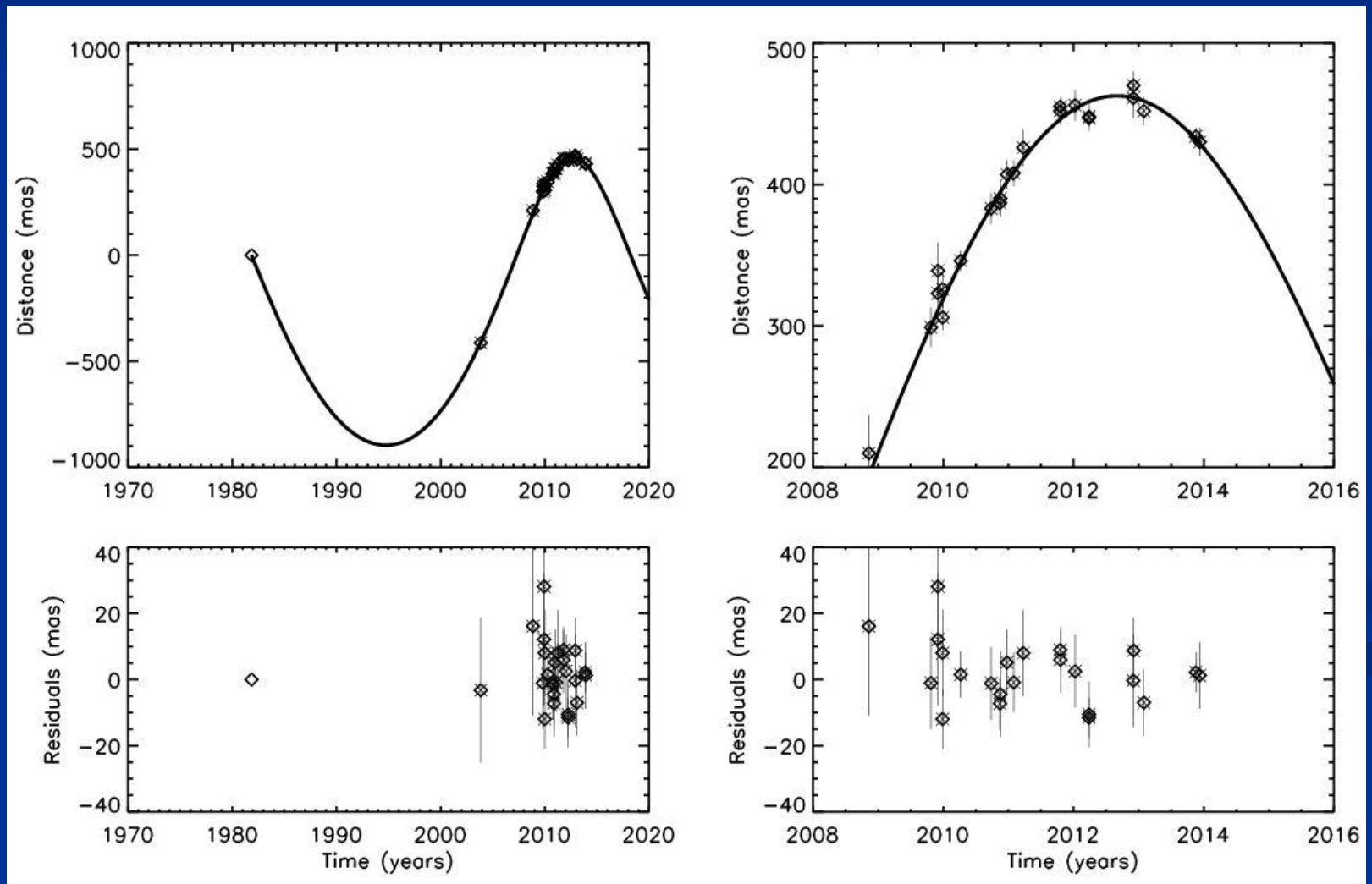
Low eccentricity orbit (e~0.1, Period~18 years)

Next transit in mid-2017



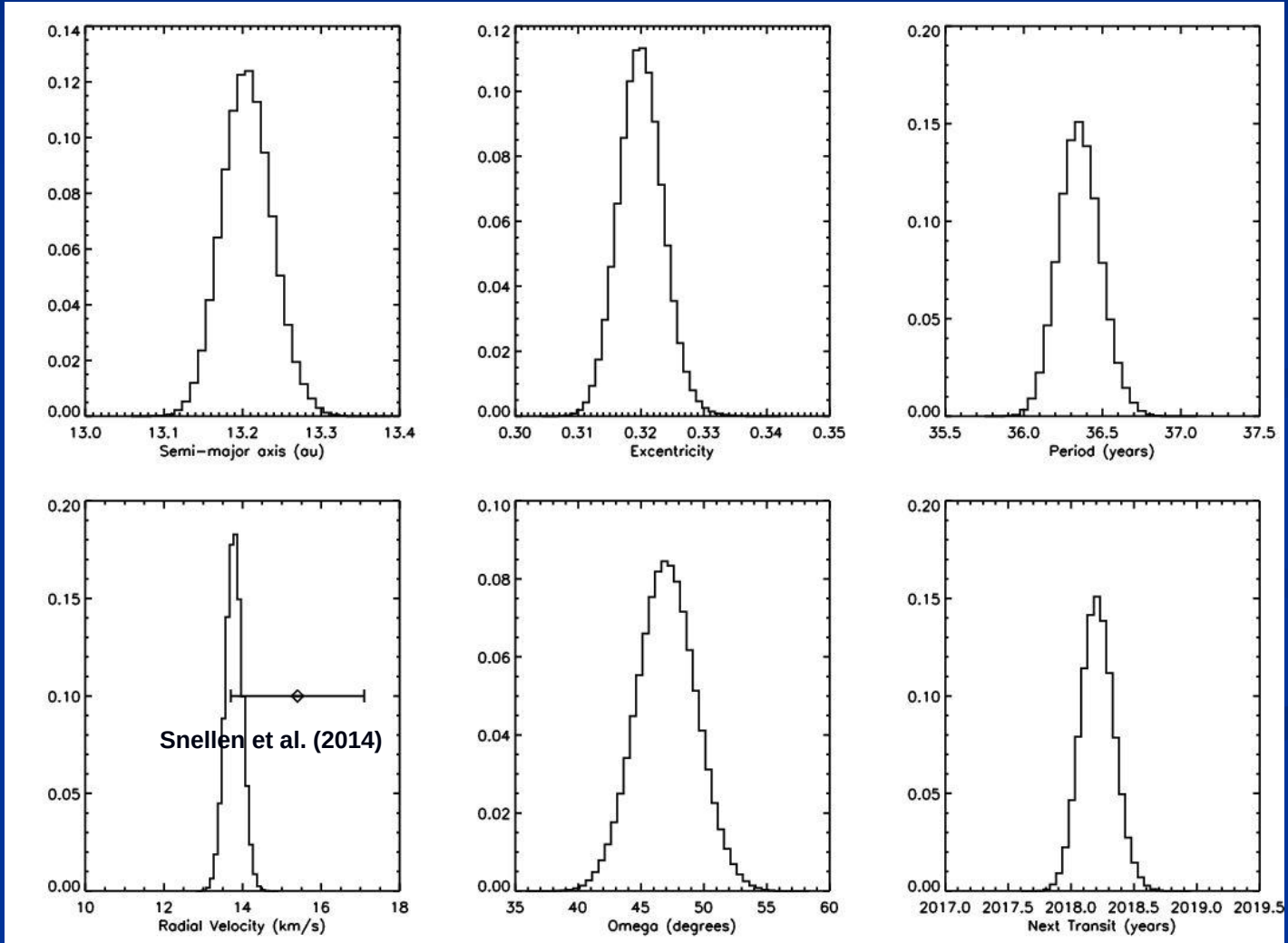
Observations of Nov 2009 - Dec 2013

Higher eccentricity orbit (e~0.3, Period~36 years)



Observations of Nov 2009 - Dec 2013

Higher eccentricity orbit (e~0.3, Period~36 years)
Next transit in 2018



Conclusion

Beta Pic b can be a transiting planet !!

Transit of a young planet in front of a 3.8 magnitude star !

Transit observations have been proven to be extremely powerful to scan the planet environment and atmosphere::

→ Rings, Satellites, etc.

***Rendez-vous* in 2017**