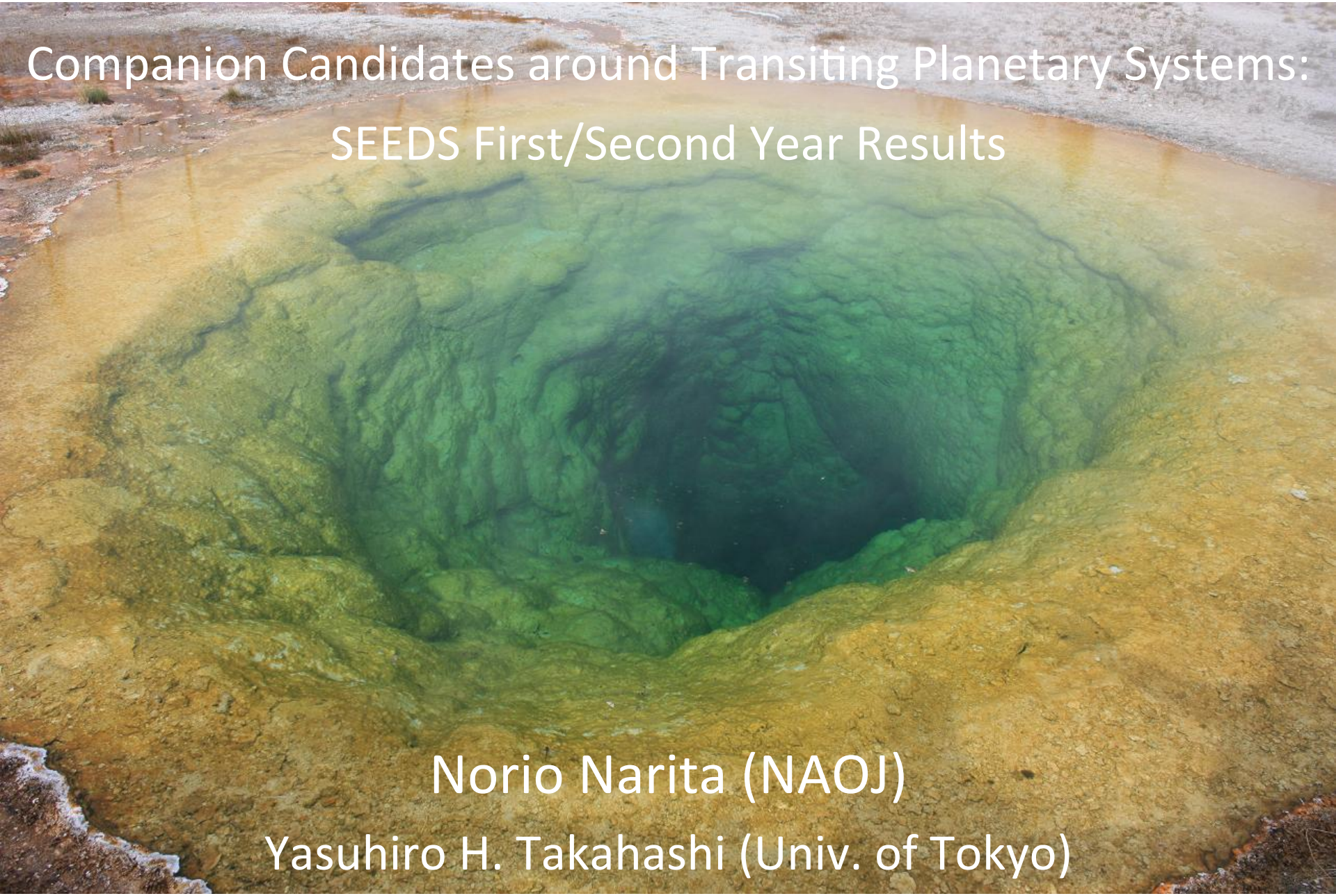


Companion Candidates around Transiting Planetary Systems: SEEDS First/Second Year Results

Norio Narita (NAOJ)
Yasuhiro H. Takahashi (Univ. of Tokyo)
and SEEDS/HiCIAO/AO188 teams

Outline

S E E D S

- Background and Motivation
  - How to constrain migration mechanisms via direct imaging
- Direct imaging of transiting planetary systems
  - Introduction of the SEEDS project and targets
- Early Results
  - 1st epoch summary of 10 systems
  - Cases for HAT-P-7 and HAT-P-11
- Conclusion and Summary

Various Migration Models

- consider gravitational interaction between
  - ✓ disk-planet (disk-planet interaction models)
    - e.g., Ida & Lin papers
  - ✓ planet-planet (planet-planet scattering models)
    - e.g., Chatterjee et al. 2008, Nagasawa et al. 2008
  - ✓ planet-binary companion (Kozai migration)
    - e.g., Wu & Murray 2003, Fabrycky & Tremaine 2007
- How can we discriminate those models by observations?

Diagnostics to discriminate migration models

small eccentricity and obliquity

disk-planet interaction

orbital eccentricity
by radial velocity

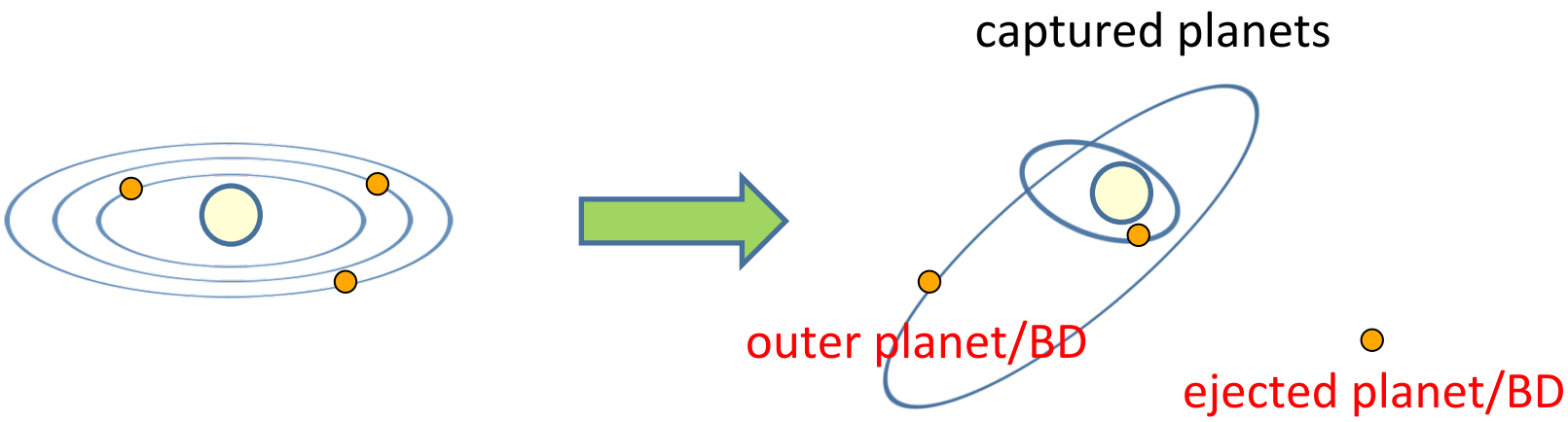
spin-orbit alignment angle
by the RM effect

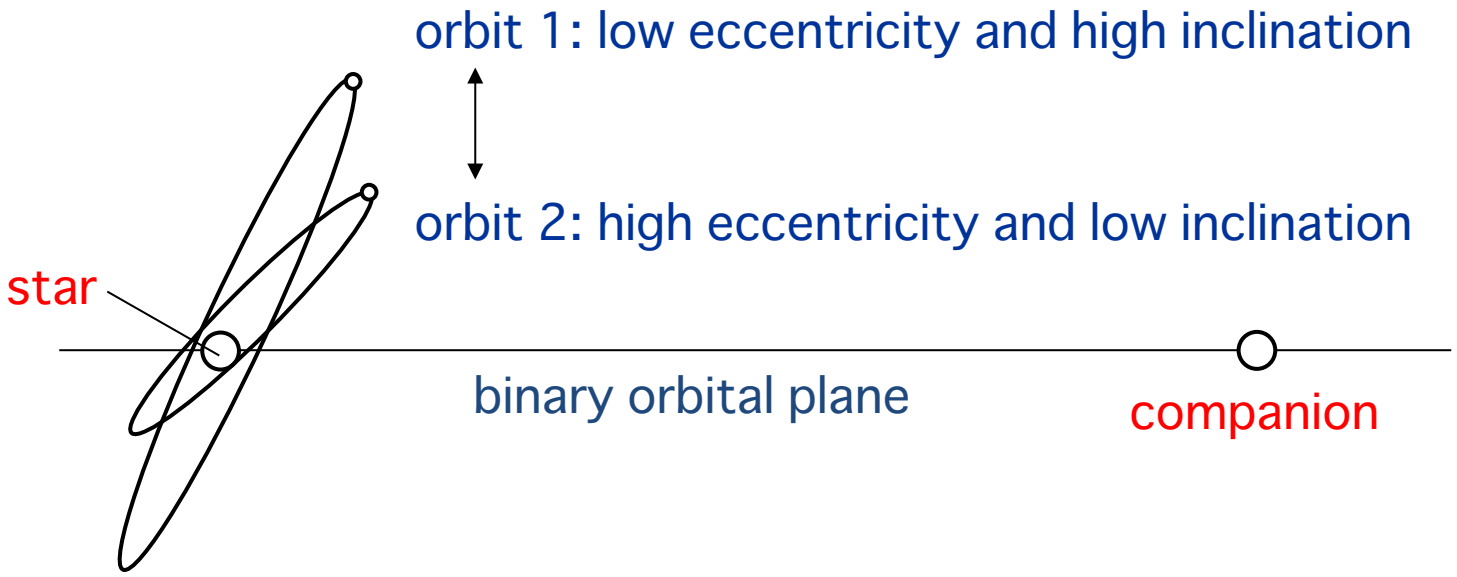
large eccentricity or obliquity

planet-planet scattering

Kozai migration

Two Models Need Outer Massive Body





Can we discriminate two models?

- Planet-Planet scattering

Additional information from direct imaging!

- Kozai migration

Search for outer massive bodies is important to constrain migration mechanisms for each system

SEEDS Project

- SEEDS: Strategic Exploration of Exoplanets and Disks with Subaru
- First "Subaru Strategic Observations" PI: Motohide Tamura
- Using Subaru's new instruments: HiCIAO & AO188
- total 120 nights over 5 years (10 semesters) with Subaru

✓ Direct imaging and census of giant planets and brown dwarfs around solar-type stars in the outer regions (a few - 40 AU)

✓ Exploring proto-planetary disks and debris disks for origin of their diversity and evolution at the same radial regions

S E E D S

SEEDS-RV Sub-category

- Members: N. Narita, Y. Takahashi, B. Sato, R. Suzuki
- Targets: Known planetary systems such as,
  - ✓ Very famous systems
  - ✓ long-term RV trend systems
  - ✓ Giant systems
  - ✓ Eccentric planetary systems
  - ✓ Transiting planetary systems (including eccentric/tilted systems)
- 25+ systems observed
  - ✓ including 10+ transiting planetary systems (1st epoch)
  - ✓ some follow-up targets were observed (2nd epoch)

First/Second Year Targets

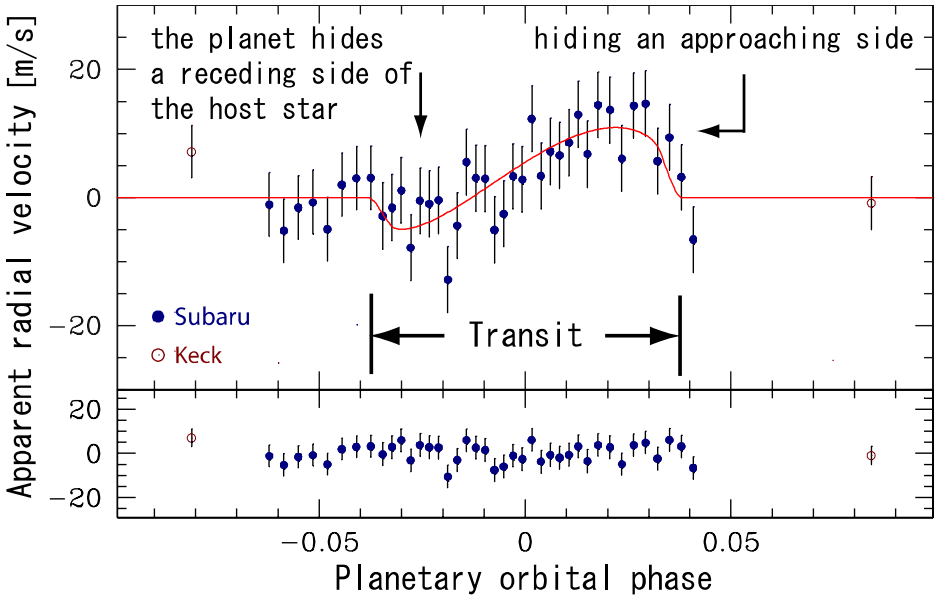
- We focused on tilted and eccentric transiting planetary systems
  - ✓ HAT-P-7
  - ✓ HAT-P-11
  - ✓ other 8 systems (sorry, still anonymous)
- Here I present a summary of early results and 2 cases with 2nd epoch observations

First/Second Year Results

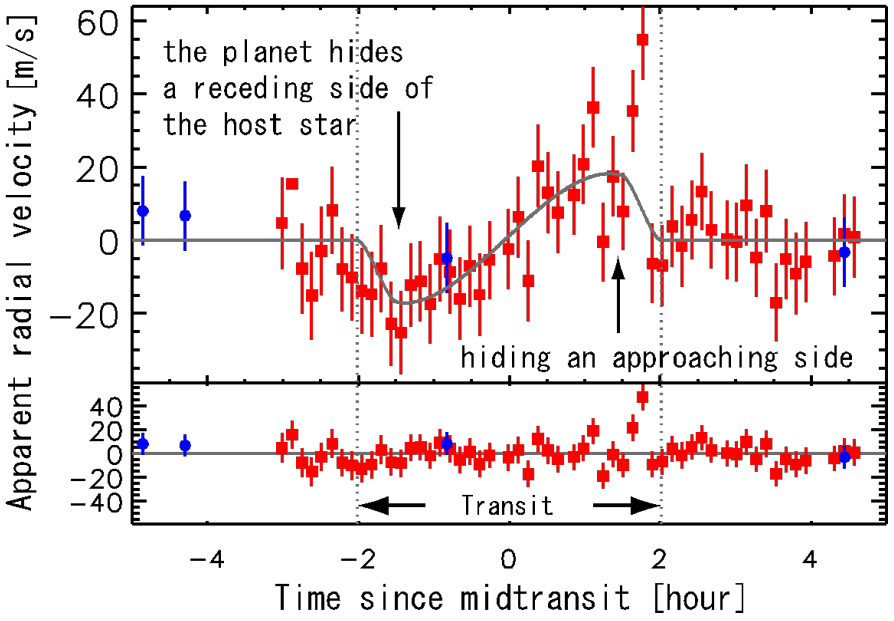
- 9 out of 10 systems have companion candidates
  - ✓ high frequency of detecting candidate companions
  - ✓ Caution: this is only 1 epoch -> follow-up needed
- Message to transit/secondary eclipse observers
  - ✓ Be careful about contamination of candidate companions, even they are not real binary companions
  - ✓ sometimes they may affect your results
- 2nd epoch observations are ongoing
  - ✓ e.g., HAT-P-7 and HAT-P-11

First Application: HAT-P-7

◆ not eccentric, but retrograde (NN+ 2009, Winn et al. 2009)



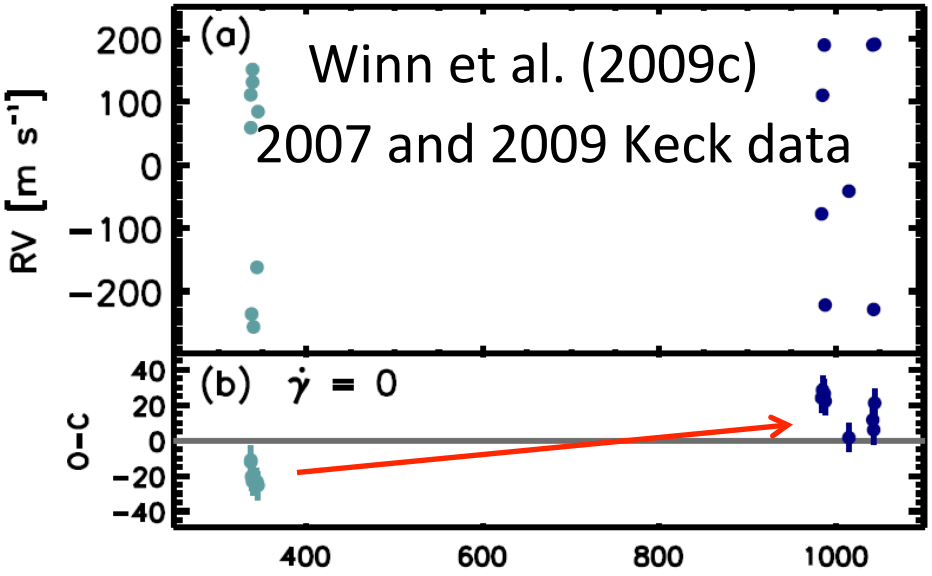
NN et al. (2009)

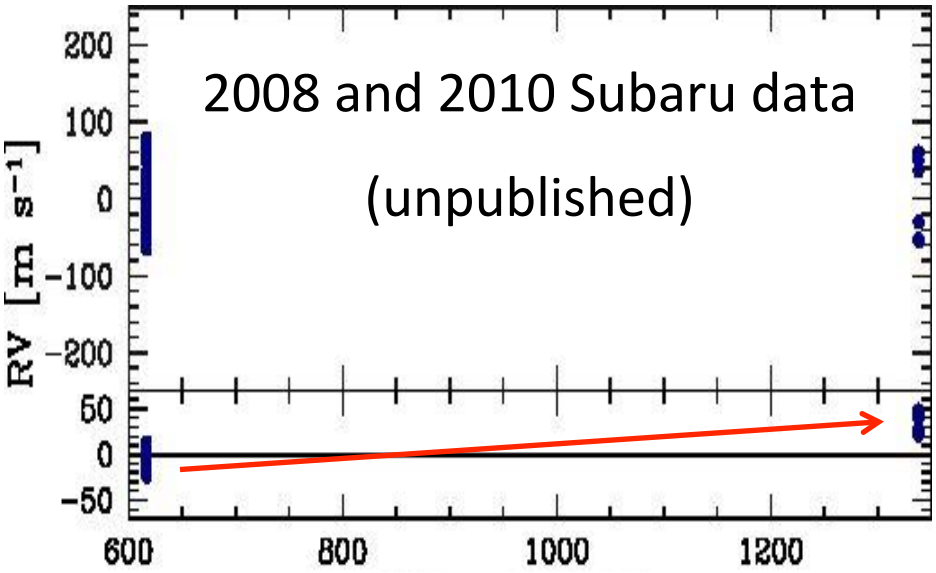


Winn et al. (2009)

very interesting target for direct imaging observation

Possible additional planet ‘HAT-P-7c’





HJD - 2454000

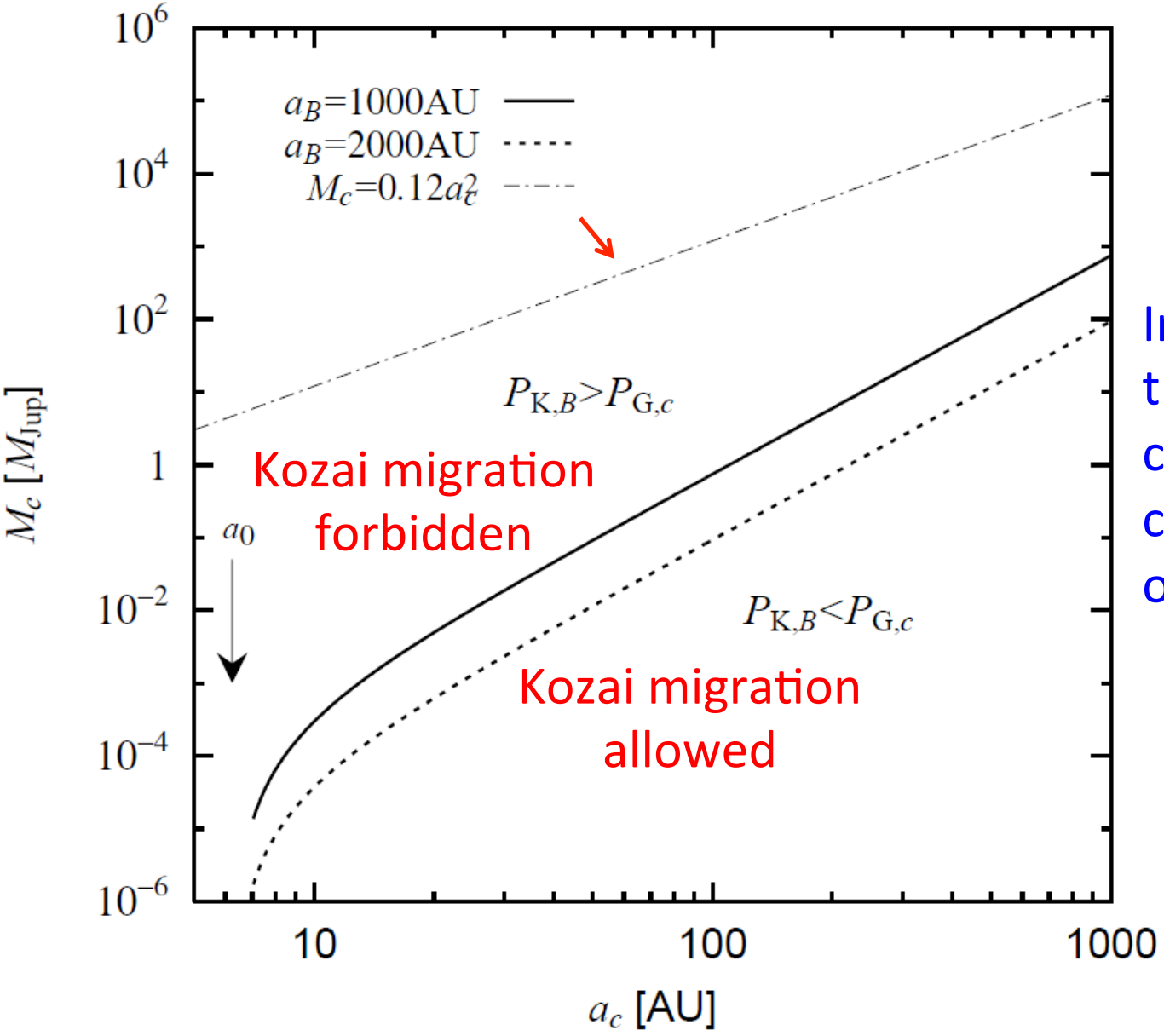
Long-term RV trend ~20 m/s/yr is ongoing from 2007 to 2010

constraint on the mass and semi-major axis of ‘c’

$$\frac{M_c \sin i_c}{a_c}^2 \sim (0.121 \pm 0.014)\, M_{Jup}\, \mathrm{AU}^{-2}$$

(Winn et al. 2009)

Additional Body Restricts Kozai migration



In the presence of 'c' the Kozai migration caused by the companion cannot occur in this system

Summary for the HAT-P-7 case

- We detected two binary candidates and one is confirmed as a CPM companion
- BUT the Kozai migration was excluded in the presence of the additional body
- planet-planet scattering appears plausible

Summary for the HAT-P-11 case

- We detected several companion candidates in 1st epoch
- 2nd epoch follow-up suggests they are not a real companion
- planet-planet scattering appears plausible

Conclusions

- Direct imaging for known planetary systems is important
  - ✓ Presence of binary companions are sometimes overlooked
  - ✓ We can constrain migration mechanism for each system
- We found high frequency of detecting candidate companions
  - ✓ Caution: this is only 1 epoch
  - ✓ Further follow-up observations are important
- Be careful for contamination of companion candidates
  - ✓ Depth of transit/secondary eclipse may be affected, even they are not real companions

If you are a Subaru referee…

Subaru Telescope
National Astronomical Observatory of Japan

Semester	S12A
Proposal ID	S12A0110N
Received	09/13/2011

Application Form for Telescope Time

1. Title of Proposal

Confirmations of the binary nature of known planetary systems

2. Principal Investigator

Name: Takahashi Yasuhiro
Institute: Univ. of Tokyo
Mailing Address: 2-21-1 Osawa, Mitaka, Tokyo, JAPAN
E-mail Address: yasuhiro.takahashi@nao.ac.jp Phone: +81-422-34-3528

3. Scientific Category

☐ Solar System	☐ Normal Stars	★ Extrasolar Planets	☐ Star and Planet Formation
☐ Compact Objects and SNe	☐ Milky Way	☐ Local Group	☐ ISM
☐ Nearby Galaxies	☐ AGN and QSO Activity	☐ QSO Abs. Lines and IGM	☐ Clusters of Galaxies
☐ Large-Scale Structure	☐ Gravitational Lenses	☐ High-z Galaxies	☐ Cosmological Parameters
☐ Miscellaneous			

Please keep in mind!