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

• 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

- Captured planets
- Outer planet/BD
- Ejected planet/BD

Orbit 1: Low eccentricity and high inclination
Orbit 2: High eccentricity and low inclination

Binary orbital plane

Star

Companion
Can we discriminate two models?

• Planet-Planet scattering

• 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
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)

very interesting target for direct imaging observation
Possible additional planet ‘HAT-P-7c’

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

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

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

(Winn et al. 2009)
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...

Please keep in mind!