Doppler Planet Searches with Subaru/HDS

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1. Precise Radial Velocity Measurements
2. A Hot-Jupiter Search
3. Planets around Evolved Intermediate-Mass Stars

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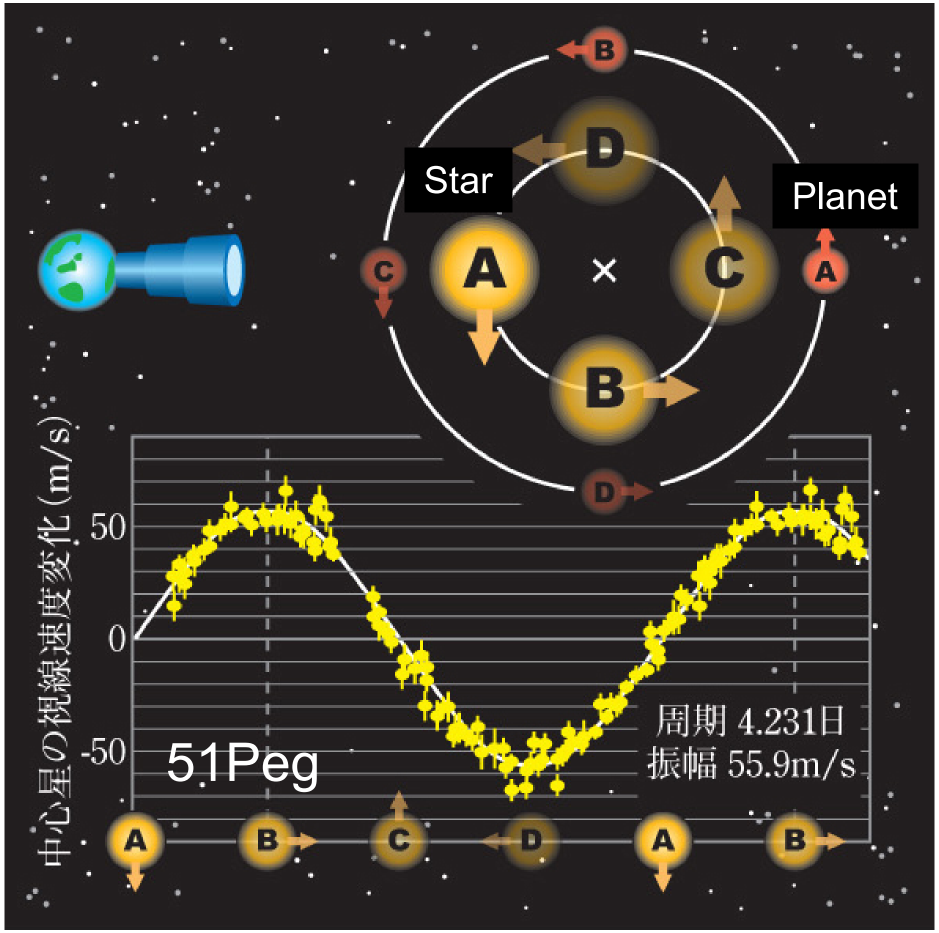
Planet Detection

- Wobble in stellar radial velocity due to gravitational pull of planets

$$K = \left(\frac{2\pi G}{P}\right)^{1/3} \frac{m_p \sin i}{(M_\star + m_p)^{2/3}} \frac{1}{\sqrt{1-e^2}}$$

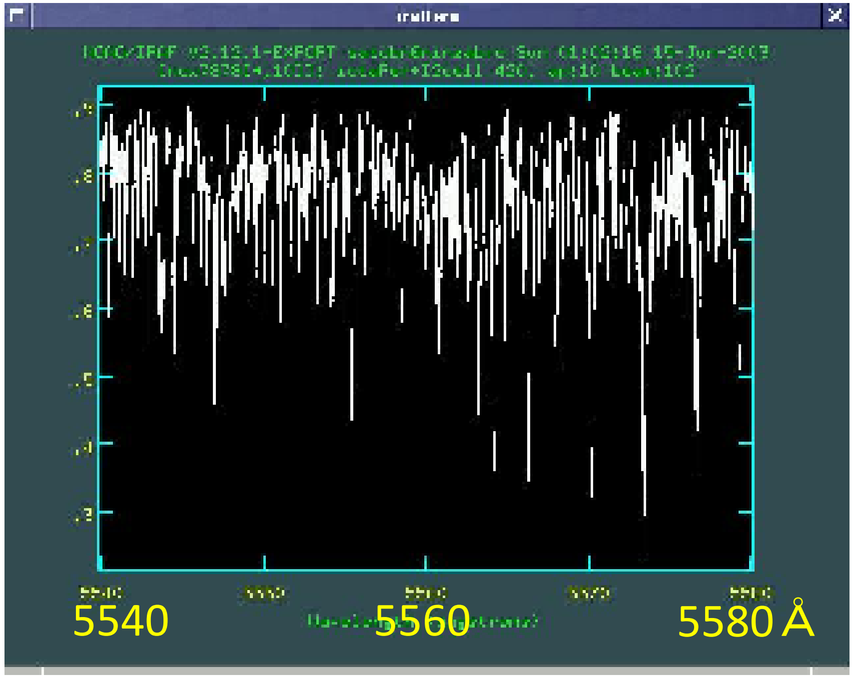
- Doppler shift in stellar light detected by spectroscopic observations

- K_{SUN} ~ 13 m/s (Jupiter)
  → $\Delta\lambda$~0.0002 Å (@5500 Å)



http://www.rikanenpyo.jp/kaisetsu/tenmon/tenmon_024.html

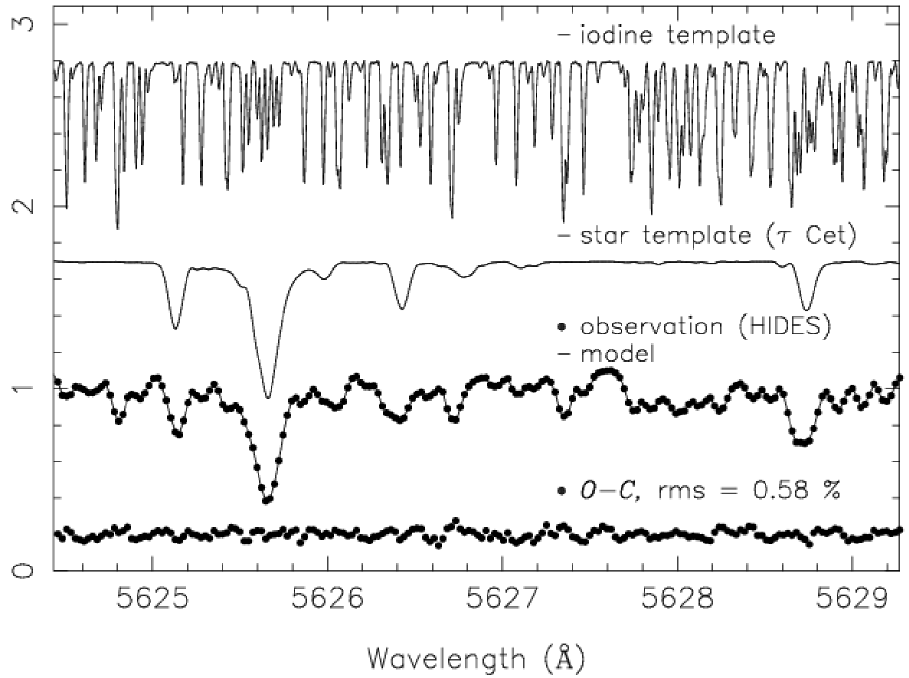
Iodine Absorption Cell



Modeling technique was first outlined by Butler et al. (1996)

- Sophisticated spectral modeling

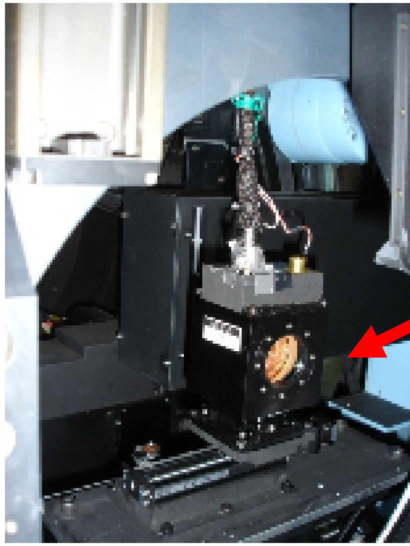
$$I(\lambda)=k[A(\lambda)S(\lambda+\Delta\lambda)]*IP$$



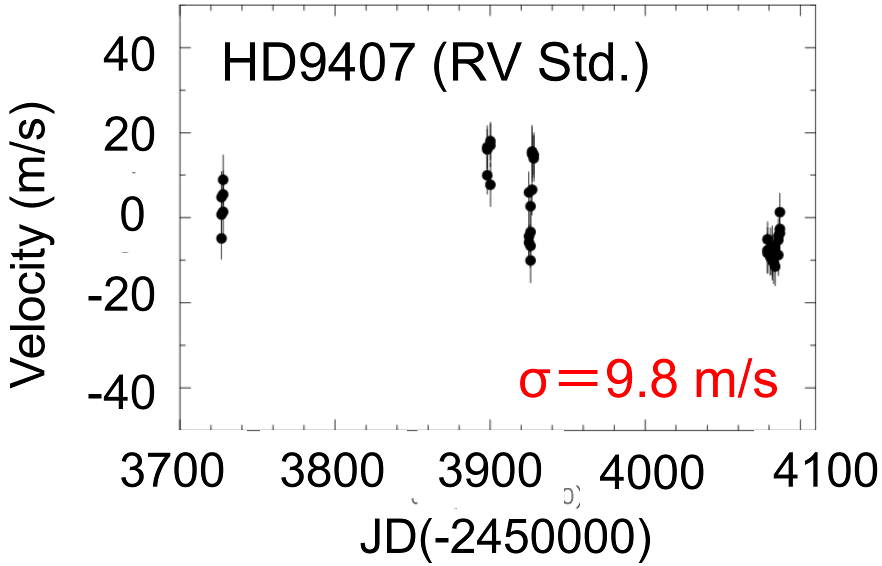
- Numerous deep and sharp iodine absorption lines in 5000-6000 Å
- Superpose wavelength reference onto a stellar spectrum

HDS Observation

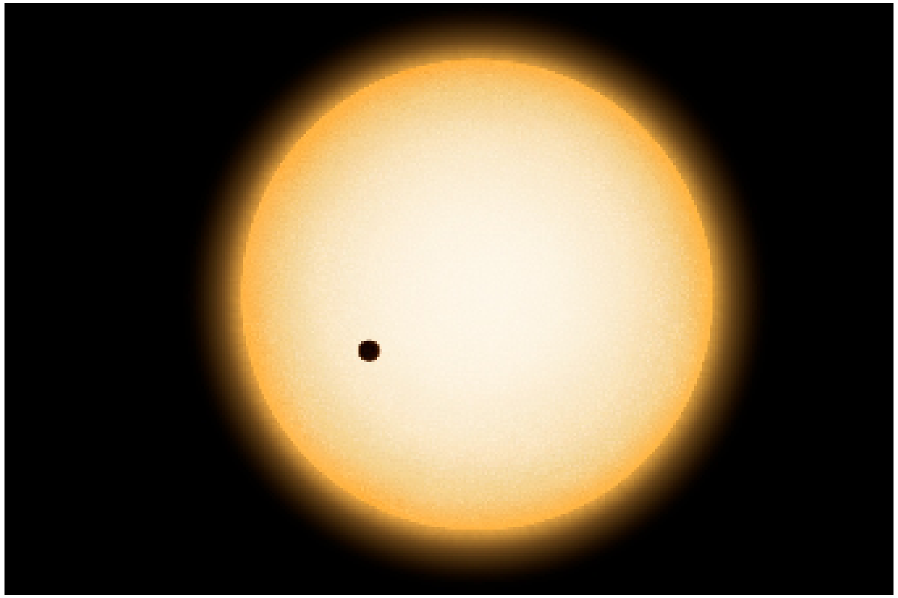
- StdI2a (4900--7600 Å) or StdI2b (3500--6100 Å)
- R=45,000 (0".8 slit)--100,000 (0".4 slit)
- SN~150 for V~8 with 80s exp.
- HDS cell was developed by Kambe et al. (2002)
- RV precision using Iodine Cell
  - ~4 m/s (within the same run)
  - 4--10 m/s (long-term)
  - Sato et al's code (2002)



Iodine Cell
in front of the
slit of HDS

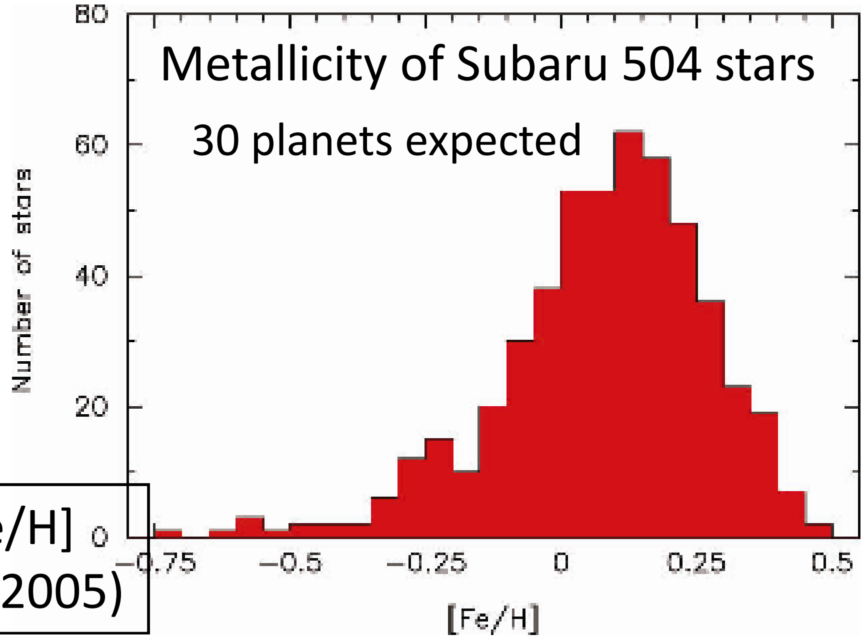


A Hot-Jupiter Search: N2K Consortium



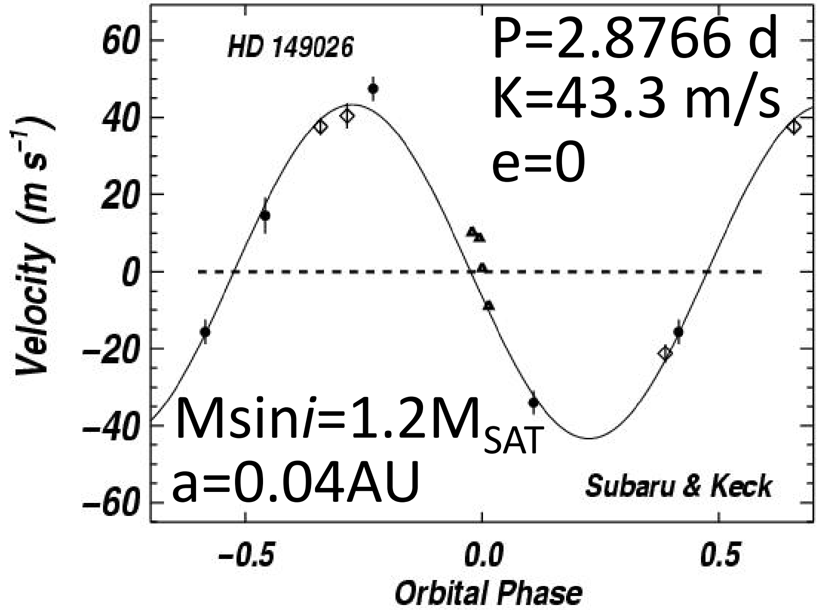
- 2000 solar-like metal-rich stars
- Since 2004
- Main targets are hot-Jupiters, but long-term observations enable us to detect various planets

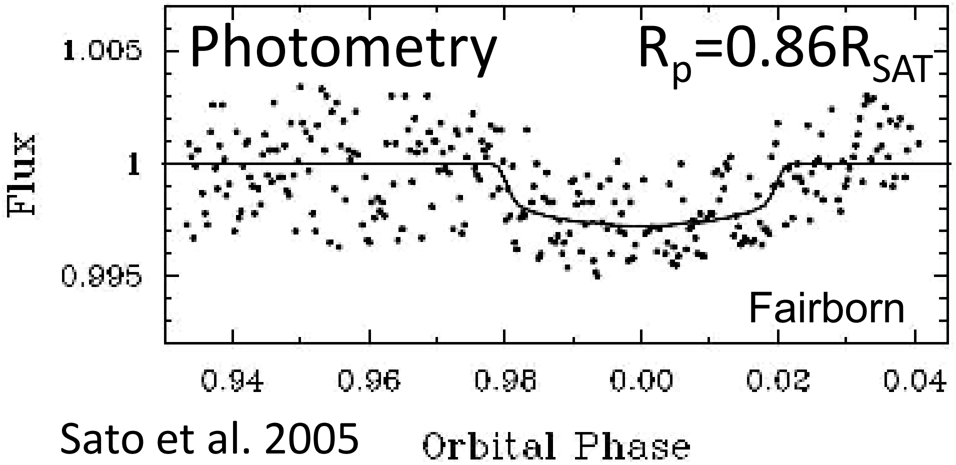
Collaboration with;
S. Ida, H. Harakawa, Y. Hori (Titech),
M. Omiya (Tokai U.), D. Fischer (SFSU) et al.



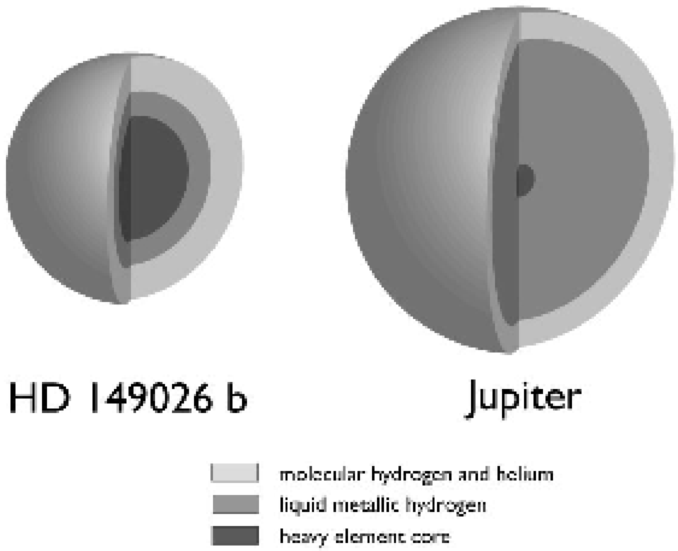
P_{pl}=0.03x10^2[Fe/H]
(Fischer&Valenti 2005)

A Transiting Planet: HD 149026 b





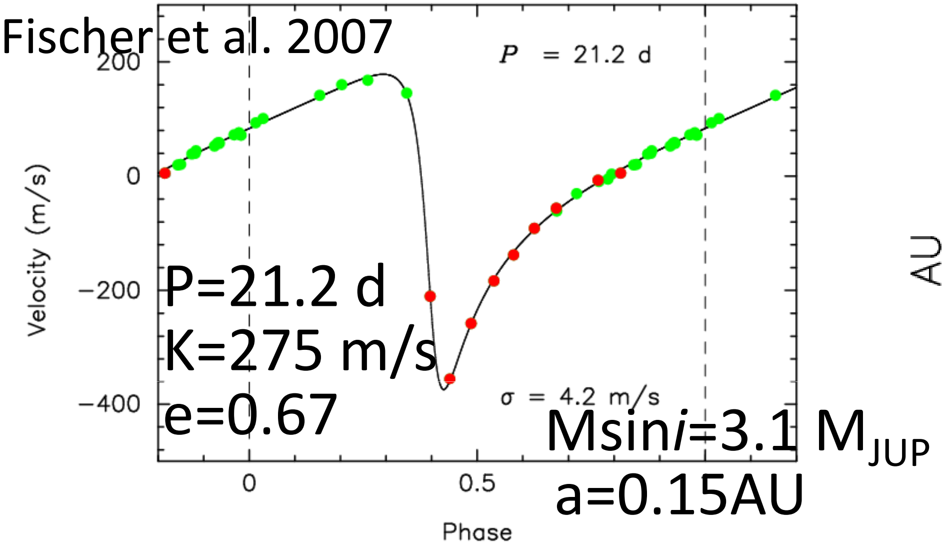
Sato et al. 2005

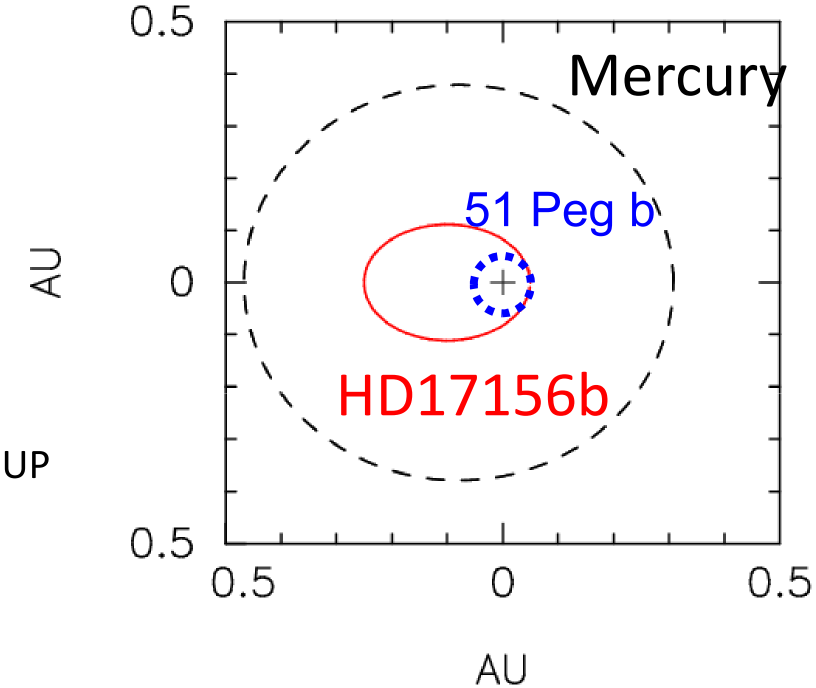


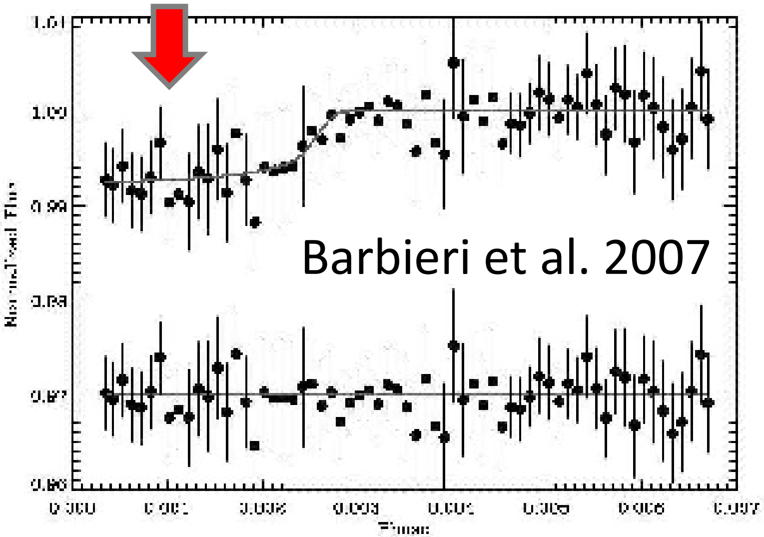
- Mean density $\rho=1.7\rho_{SAT}$
  High metal content
  ➔ 70 M_E core

Support formation via core-accretion

A Transiting Planet: HD 17156 b







- Large eccentricity despite the short period (q=a(1-e)=0.05AU)
- Formation via "Jumping Jupiters" scenario or existence of outer planets/companions?

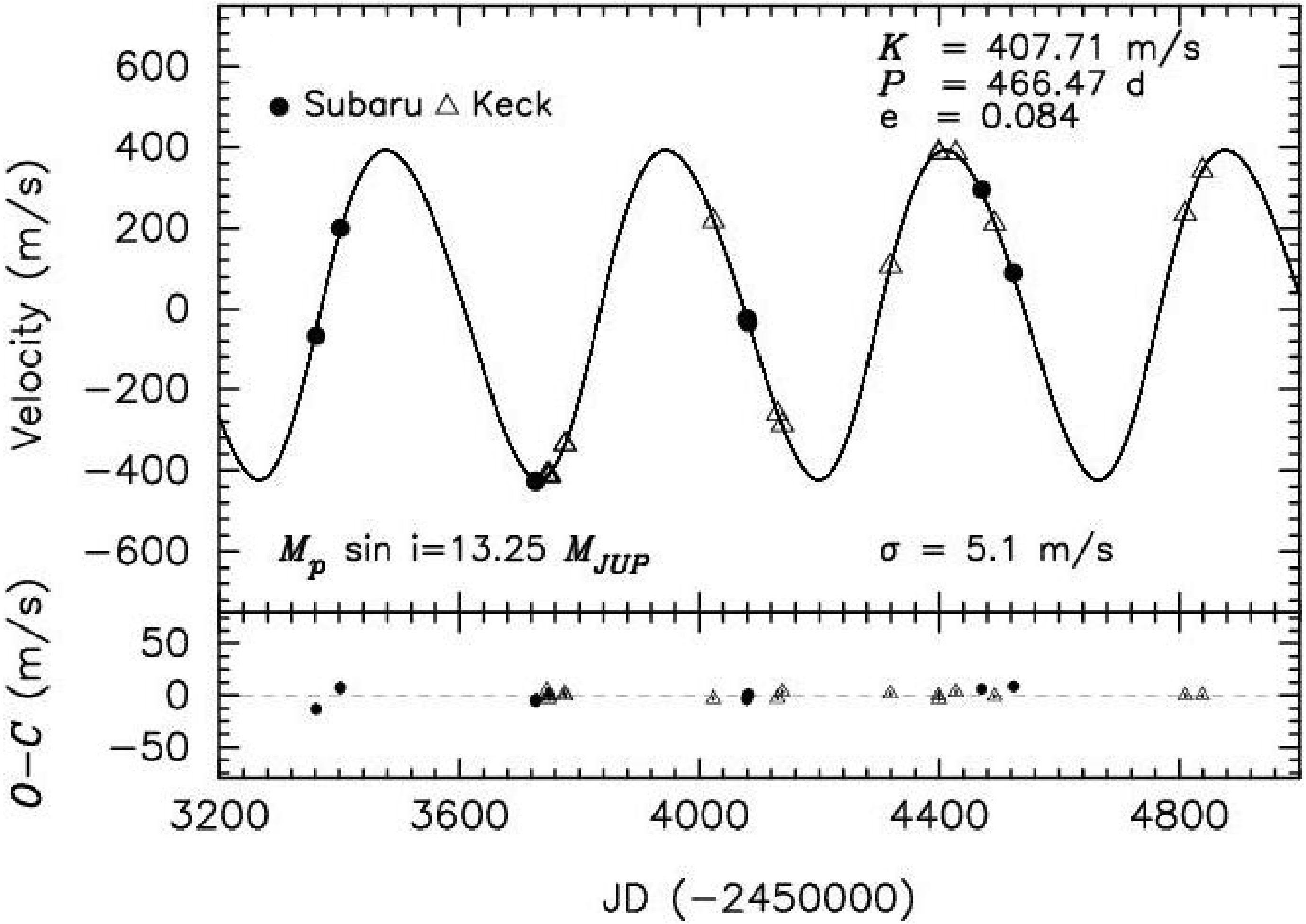
A $13M_{JUP}$ Companion in a 1.3yr Nearly-Circular Orbit

- Host Star

  Mass: $0.79M_{\odot}$

- Planet

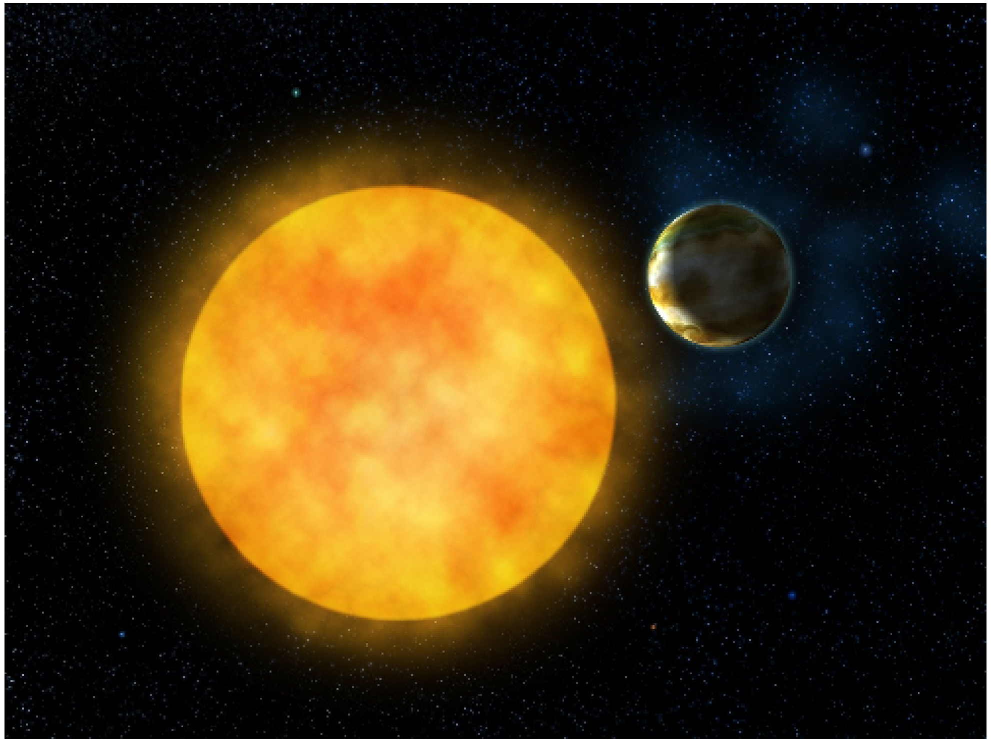
  $M\sin i$=$13M_{JUP}$
  a=1.1 AU
  e=0.08



Sato et al. submitted to ApJ

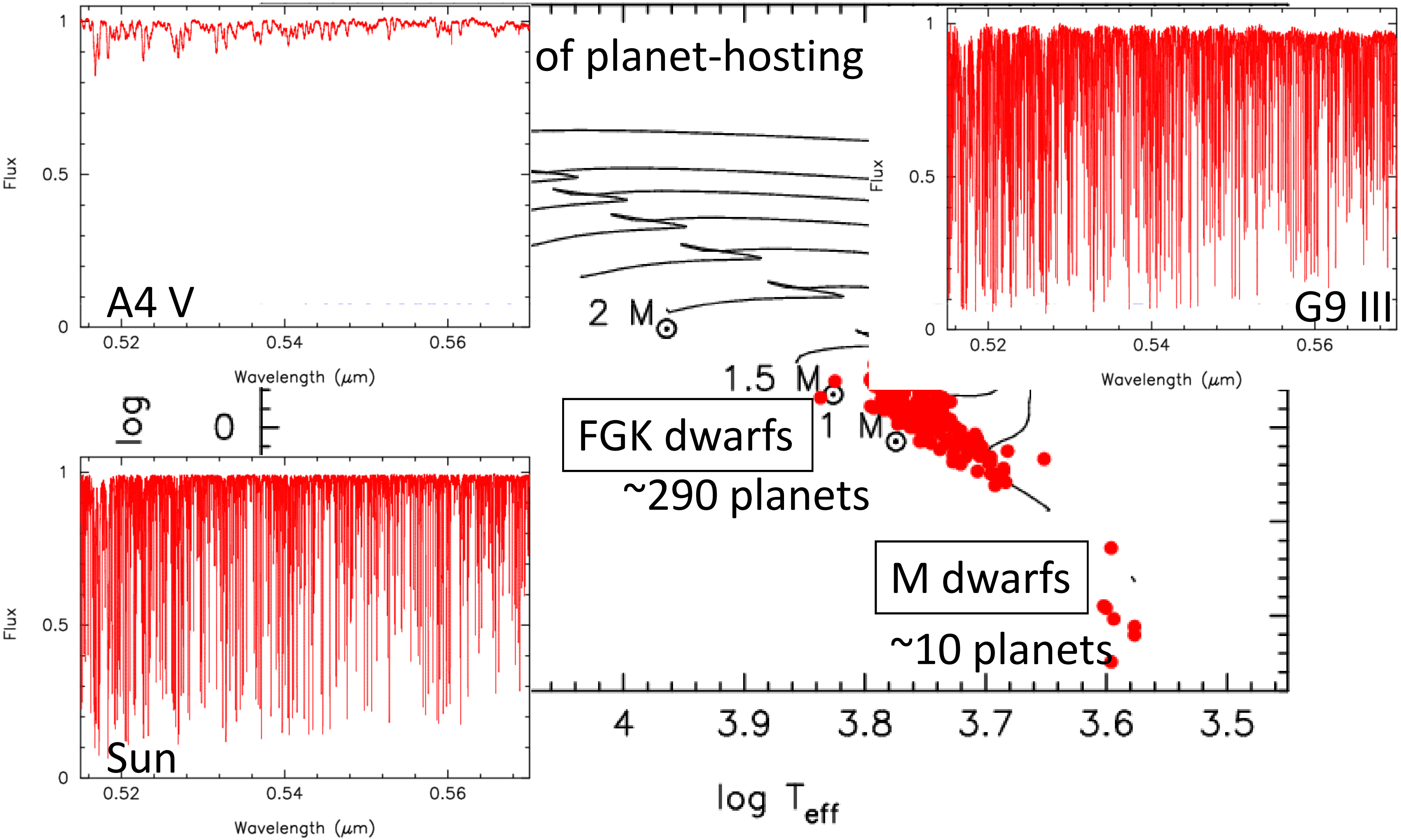
Searching for Planets around Evolved Intermediate-Mass Stars

Understanding properties of planets as a function of stellar mass, evolutionary stage, etc.



(c) Okayama Astrophysical Observatory

Why Giants?



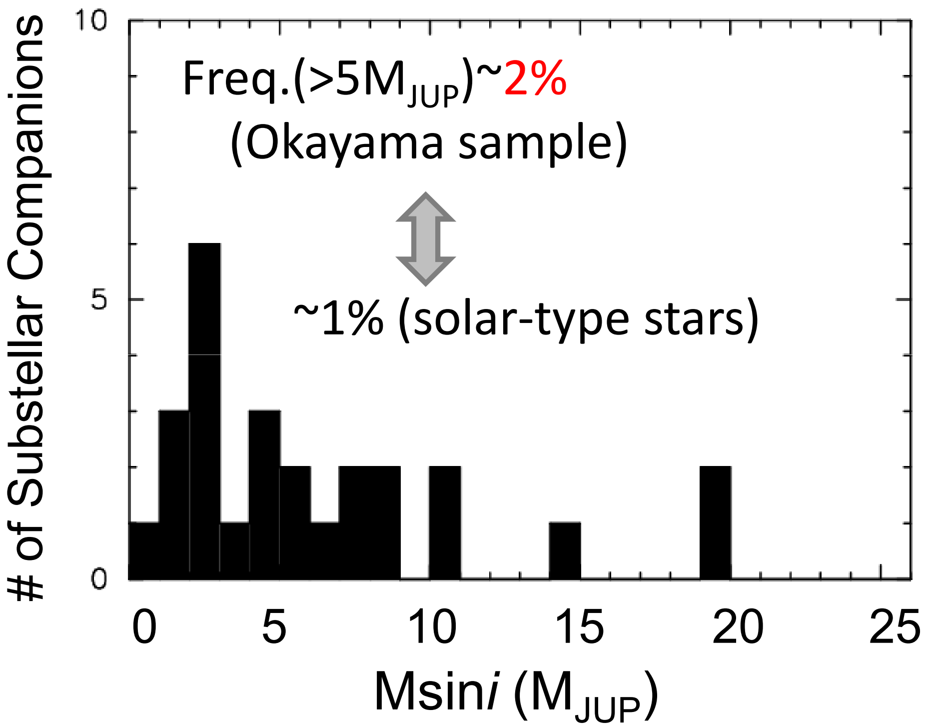
of planet-hosting
A4 V
G9 III
Sun
Flux
Wavelength (μm)
2 M⊙
1.5 M⊙
1 M⊙
FGK dwarfs
~290 planets
M dwarfs
~10 planets
log
log T_eff
4
3.9
3.8
3.7
3.6
3.5

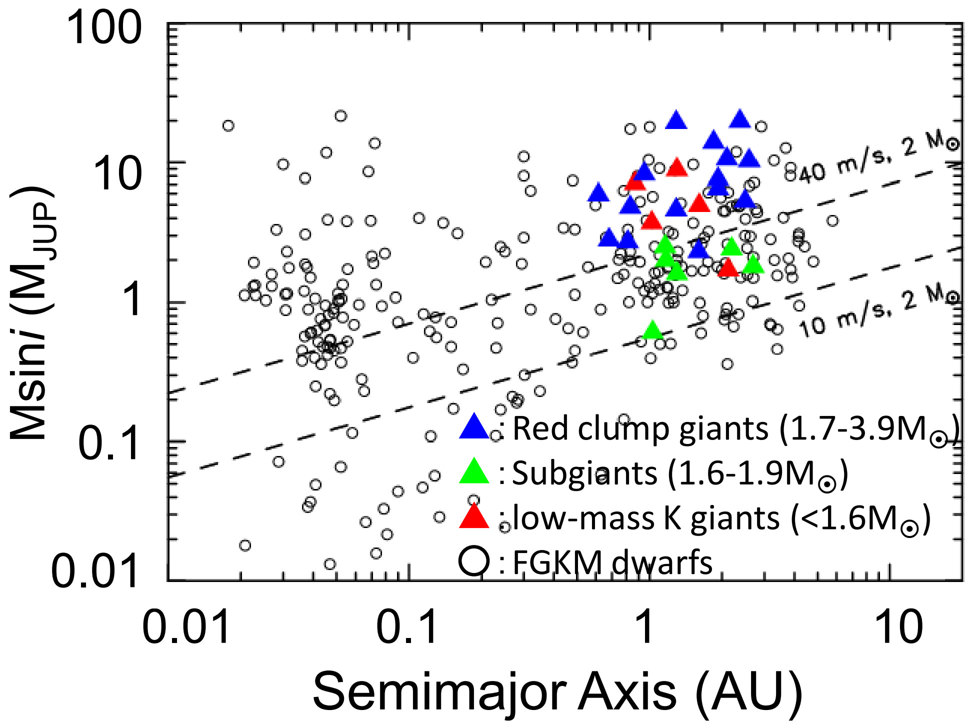
East-Asian Planet Search Network

- Okayama 1.88m tel., Japan
  - 300 GK giants (V<6), since 2001
  - 10 planets and 1 brown dwarf
- Xinglong 2.16m tel., China
  - 100 GK giants (V~6), since 2005
  - (1 planet and 1 brown dwarf)
- Bohyunsan 1.8m tel., Korea
  - 140 GK giants (V<6.5), since 2005
  - 1 brown dwarf
- Subaru 8.2m tel., Japan
  - >200 GK giants (6.5<V<7), since 2006
  - Several candidates
- TUBITAK 1.5m tel., Turkey
  - 50 GK giants (V~6.5), since 2008

East-Asian Planet Search Network (EAPSNET)

Properties of Planets around Evolved Intermediate-mass Stars



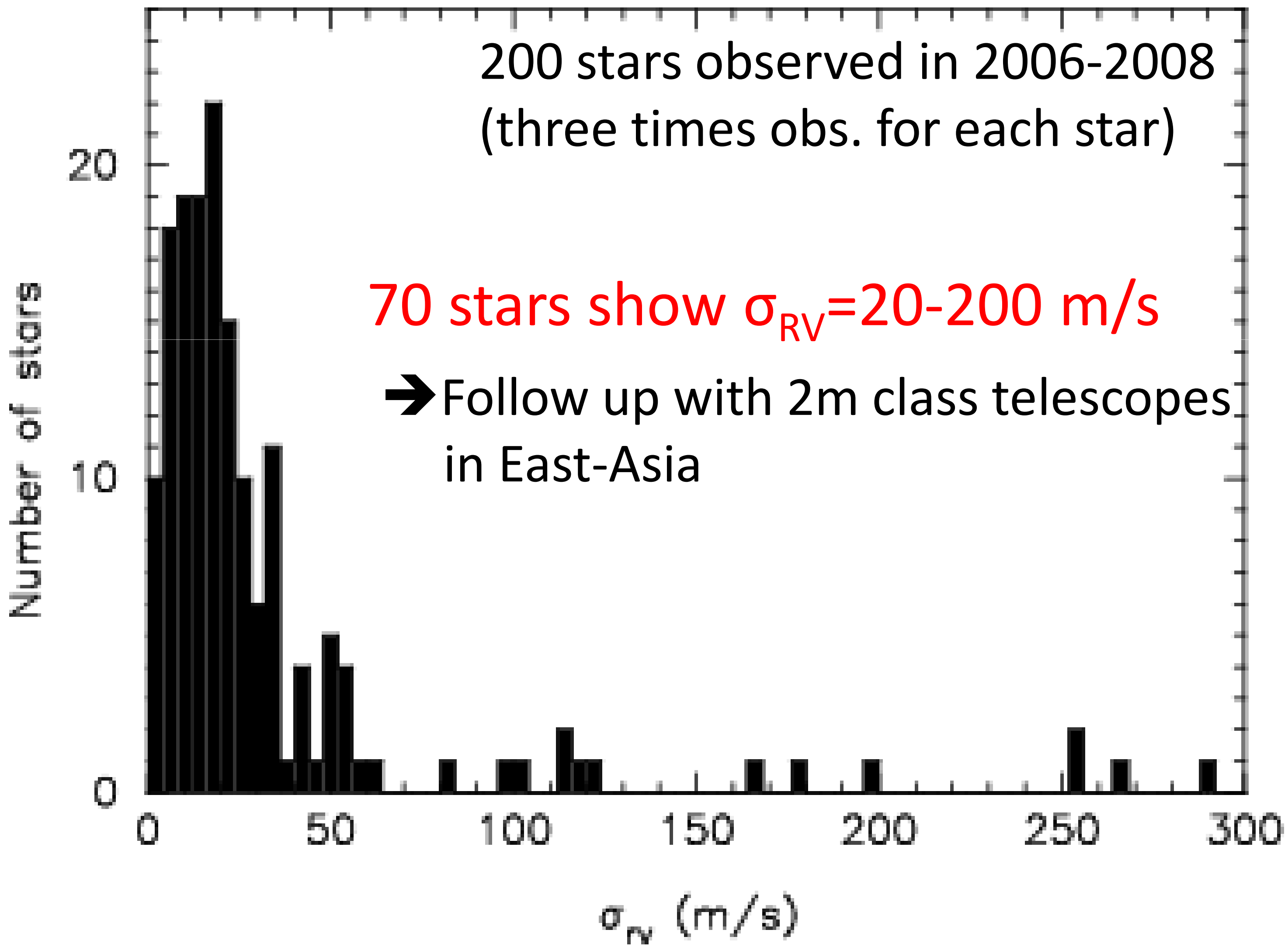


Higher frequency of massive planets

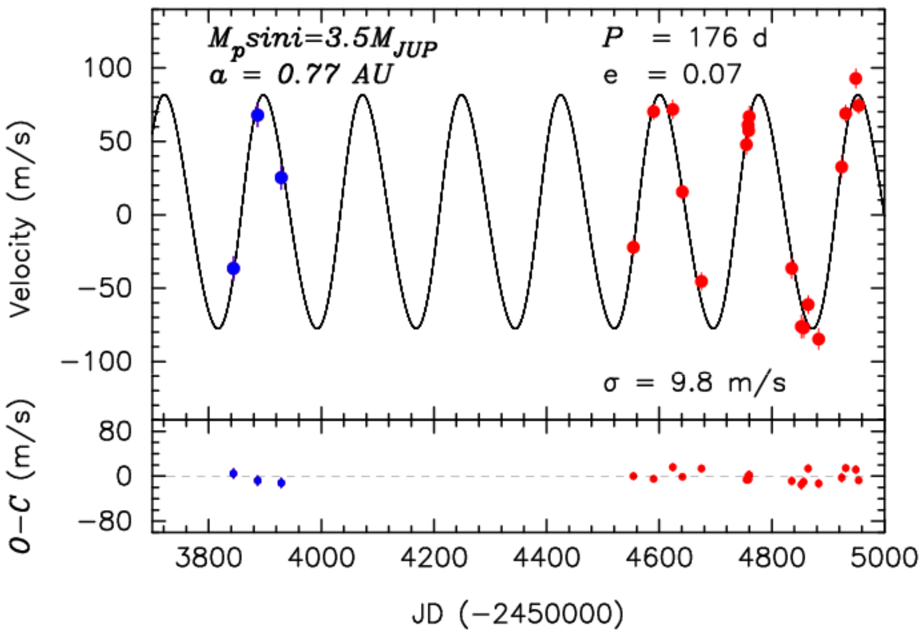
Paucity of inner planets

Properties of planets around intermediate-mass stars may be different from those around solar-type stars

RV Variations of HDS Targets

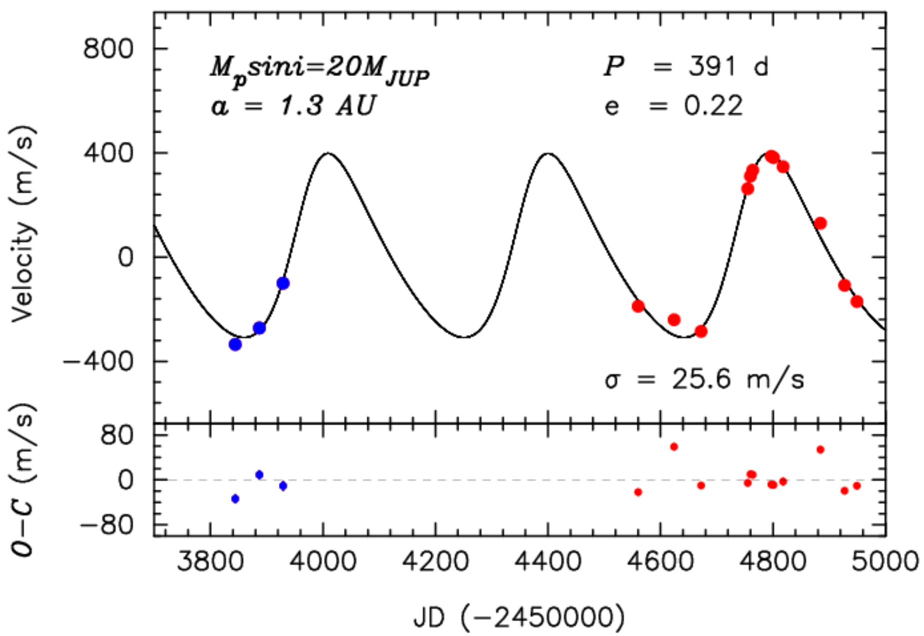


New Planets around Giants



Msini=3.5M$_{JUP}$
a=0.77AU

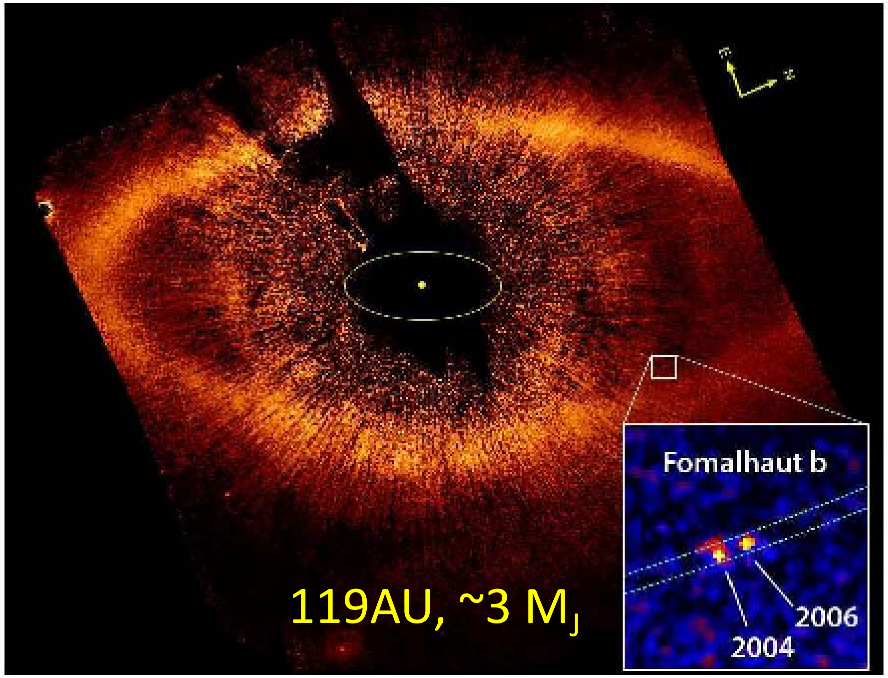
Blue: Subaru
Red: Okayama



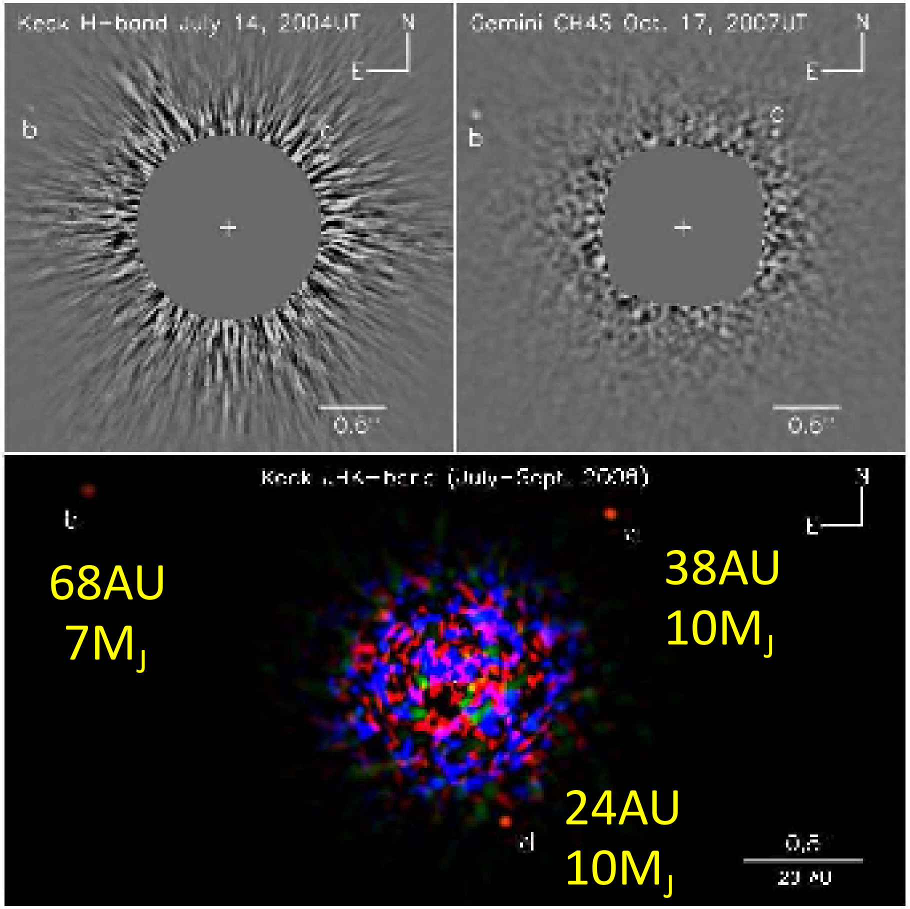
Msini=20M$_{JUP}$
a=1.3AU

Imaging Planets around A-type Dwarfs

Fomalhaut (A3V) Kalas et al. 2008



HR8799 (A5V) Marois et al. 2008



The discoveries strongly encourage RV planet searches around intermediate-mass stars !

Summary

- A hot-Jupiter search with Subaru/HDS
  - A few planets including 2 transiting planets have been discovered around solar-type stars at Subaru
  - A total of about 30 planets are expected from the Subaru sample
- A search for planets around evolved intermediate-mass stars with Subaru/HDS
  - 70 out of 200 Subaru targets showed large RV variations and they are (will be) under follow-up observations using 2m class telescopes
  - The Subaru survey will significantly improve statistics of planets around intermediate-mass giants
- To improve RV precision of HDS is a big issue