East Asian Young Astronomers Meeting 2017
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ART HOTEL ISHIGAKIJIMA, Ishigaki city, Japan

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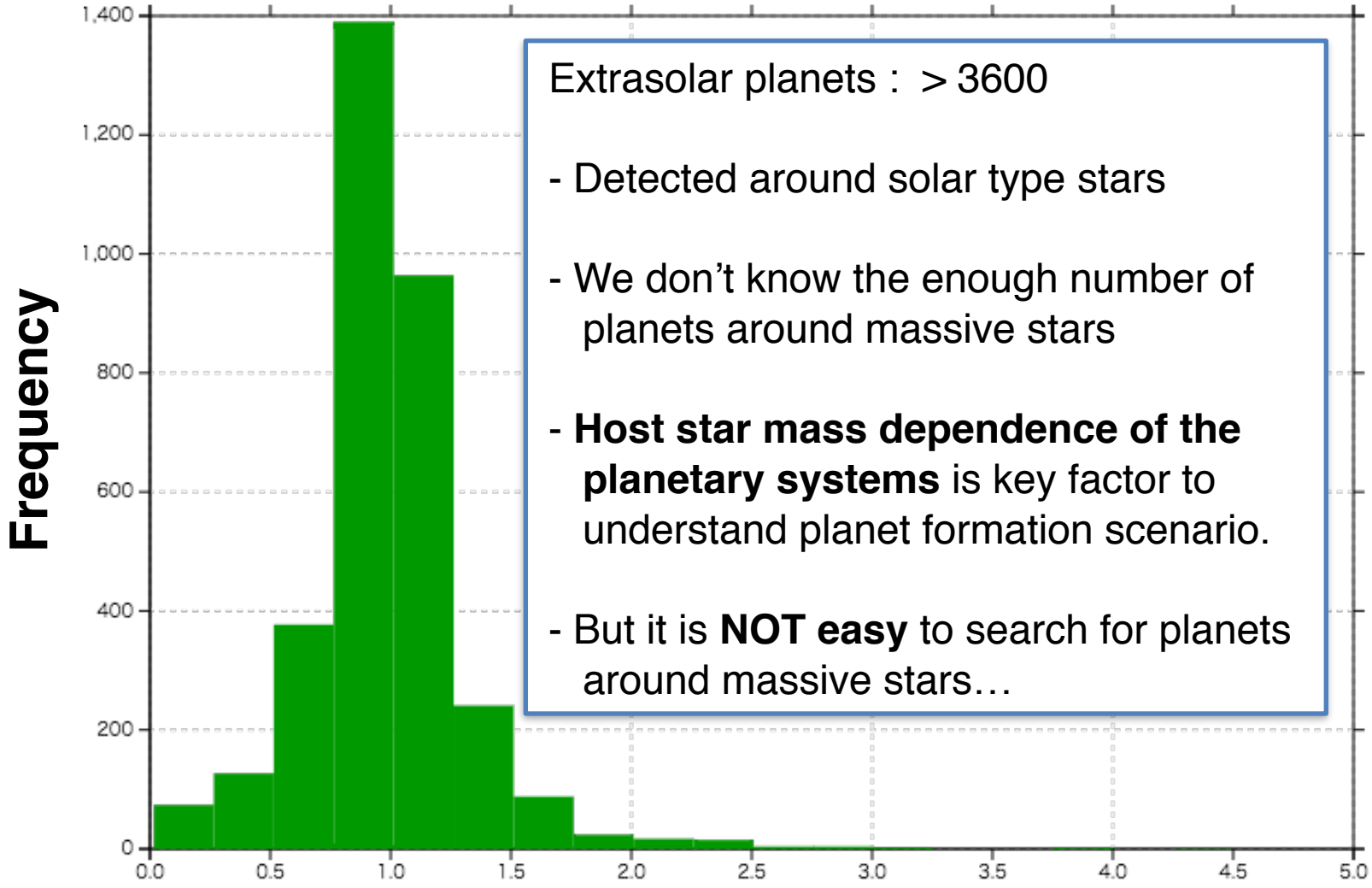
East-Asian collaboration to search for planets around giants

1. EAPS-Net (East-Asian Planet Search Network)
2. Summary of Korean-Japanese Planet Search
3. Current results and future of the Network
4. Summary

Mass of planet host stars



Extrasolar planets : > 3600

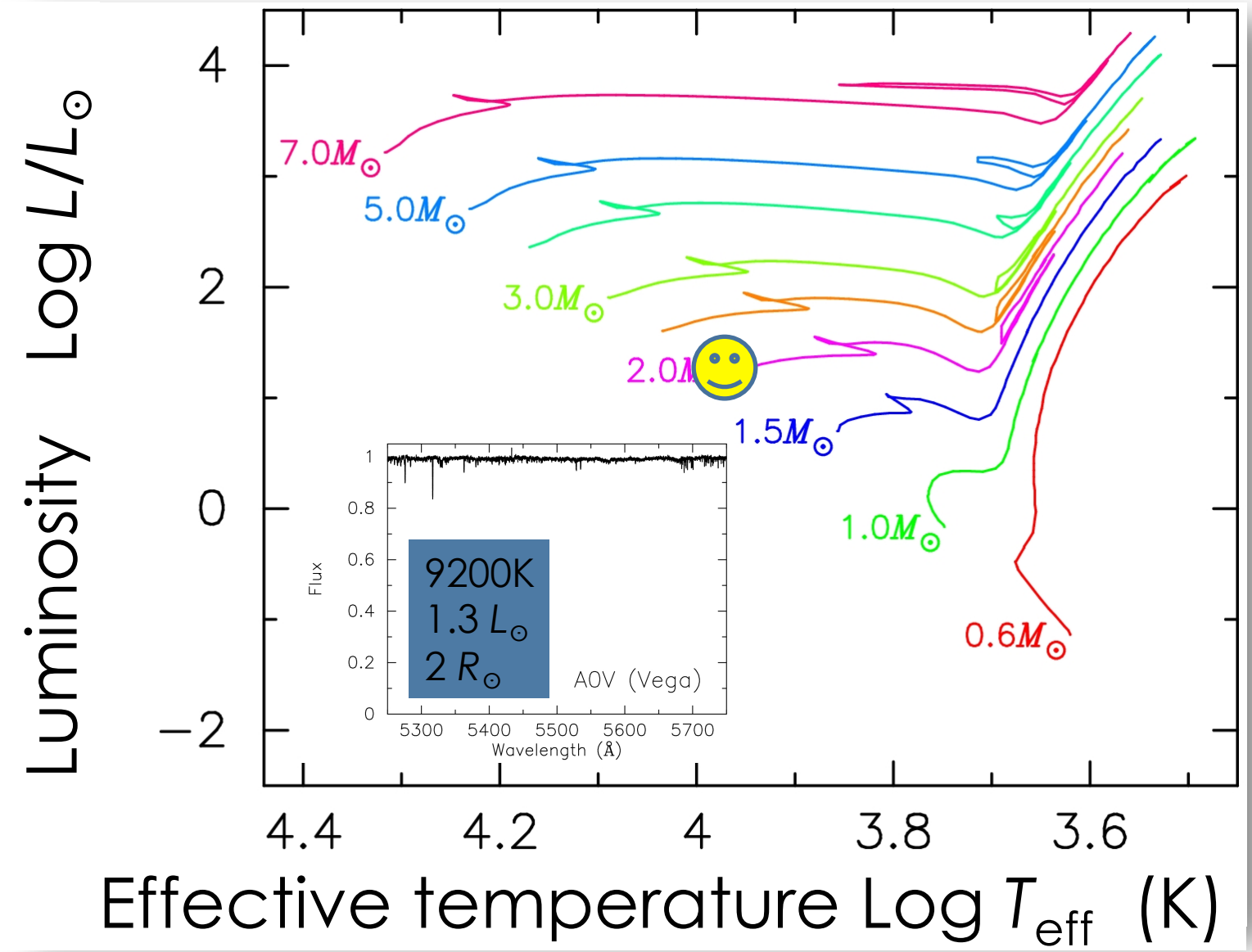
- Detected around solar type stars

- We don't know the enough number of planets around massive stars

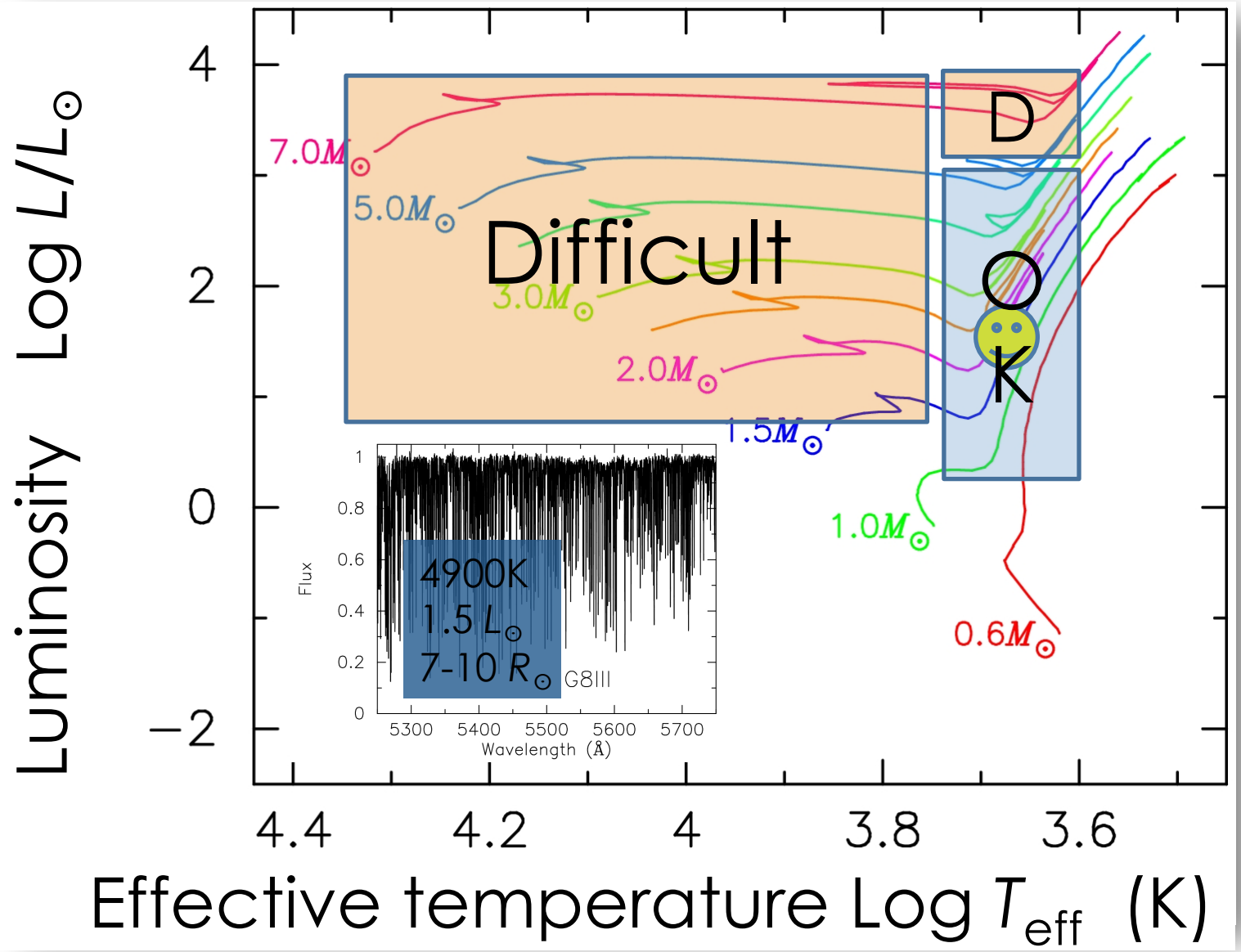
- **Host star mass dependence of the planetary systems** is key factor to understand planet formation scenario.

- But it is **NOT easy** to search for planets around massive stars…

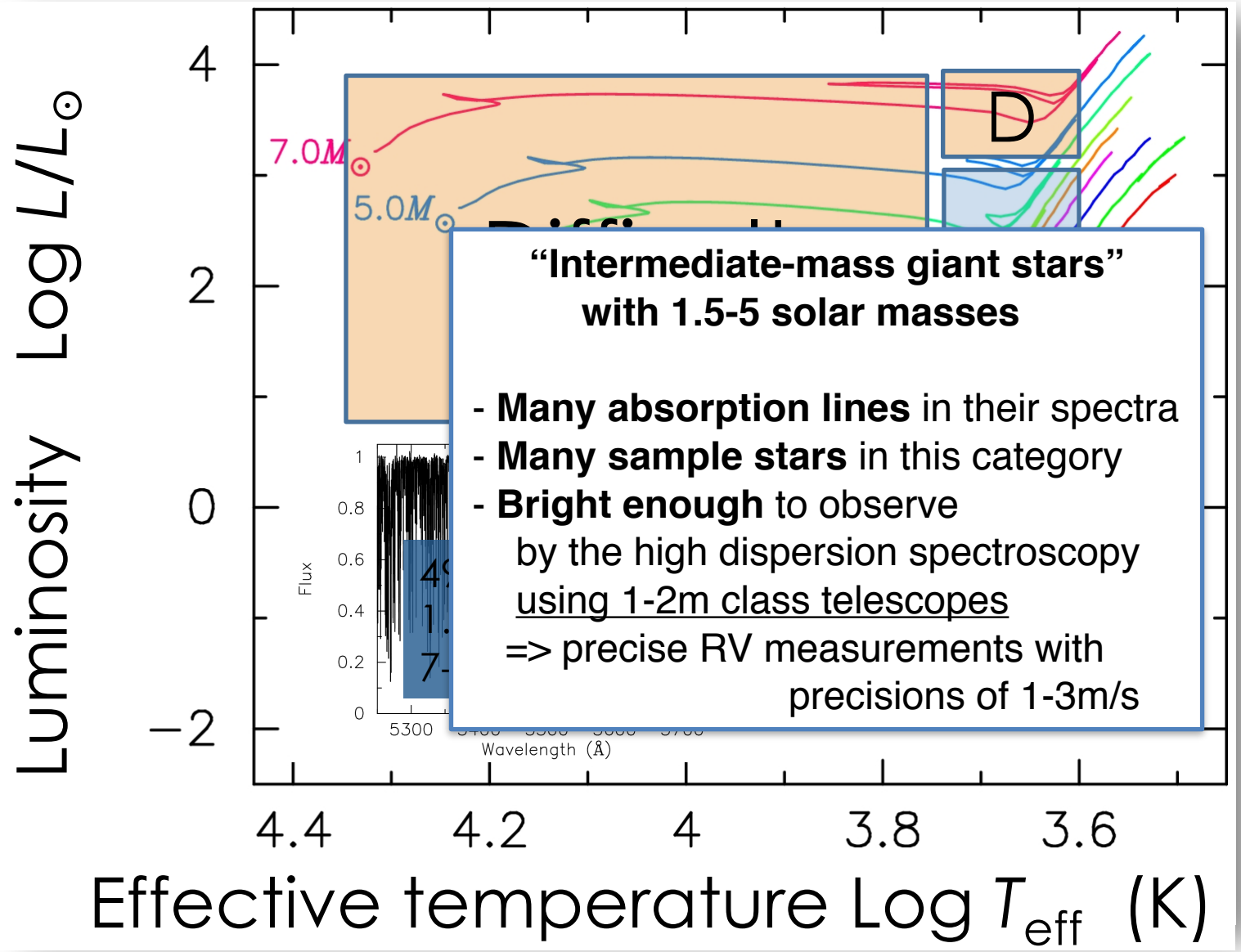
Dwarfs or Giants ?



Dwarfs or Giants ?



Dwarfs or Giants ?



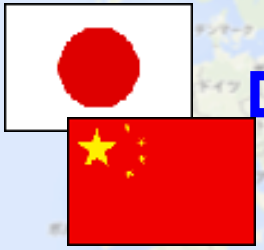
Why East-Asian collaboration ?

- The East-Asian Planet search Network, EAPS-Net
  - precise RV monitoring to search for planets around MANY giant stars
  - Using the 2m-class telescopes in East-Asia
  - Sample stars of the planet search : >700 in total
  - Need to observe many times and long term monitoring
- Planet search program in the collaboration between researchers in Korea and Japan
  - To search for planets around intermediate-mass giant stars with masses of 1.5-5 solar masses
  - Using BOAO 180cm and OAO 188cm telescopes for precise RV measurements
  - Target : 190 late-G - Early K type giants (V=6.2-6.5) fainter than Okayama planet search program

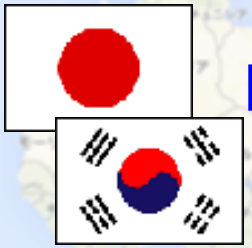
Goal: ***To understand the planetary systems and their formation scenario around intermediate-mass giants***

East-Asian Planet Search Network
EAPS-Net

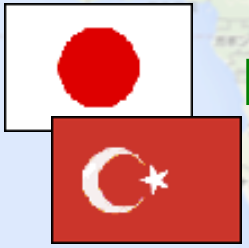
- **Okayama planet search program**
  - Okayama Astrophysical Observatory, OAO, Japan
  - 300GK giants (V<6), ~2-4m/s



- **Chinese-Japanese planet search**
  - Xinglong Station & OAO
  - 100GK giants (V~6), ~8m/s



- **Korean-Japanese planet search**
  - Bohyunsan Optical Astronomy Observatory & OAO
  - 190GK giants (V<6.5), ~7m/s



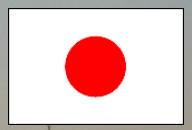
- **Turkish-Japanese collaboration**
  - TÜBITAK - Turkish National Observatory & OAO
  - 50GK giants (V~6.5), ~10m/s

- **EAPS-Net with the Subaru telescope**

Bohyunsan Optical Astronomy Observatory (BOAO)

1.8m telescope + BOES (with Iodine cell)
BOES: BOhyunsan Echelle spectrograph
Resolution: R=λ/Δλ~50,000
Wavelength range: 3800~9000Å
Fine day ratio: ~30 % (2005/1-2016/6)
Precision: ~8 m/s (S/N~150photons/pix@5,500Å
Number of Sample: 80 stars + α

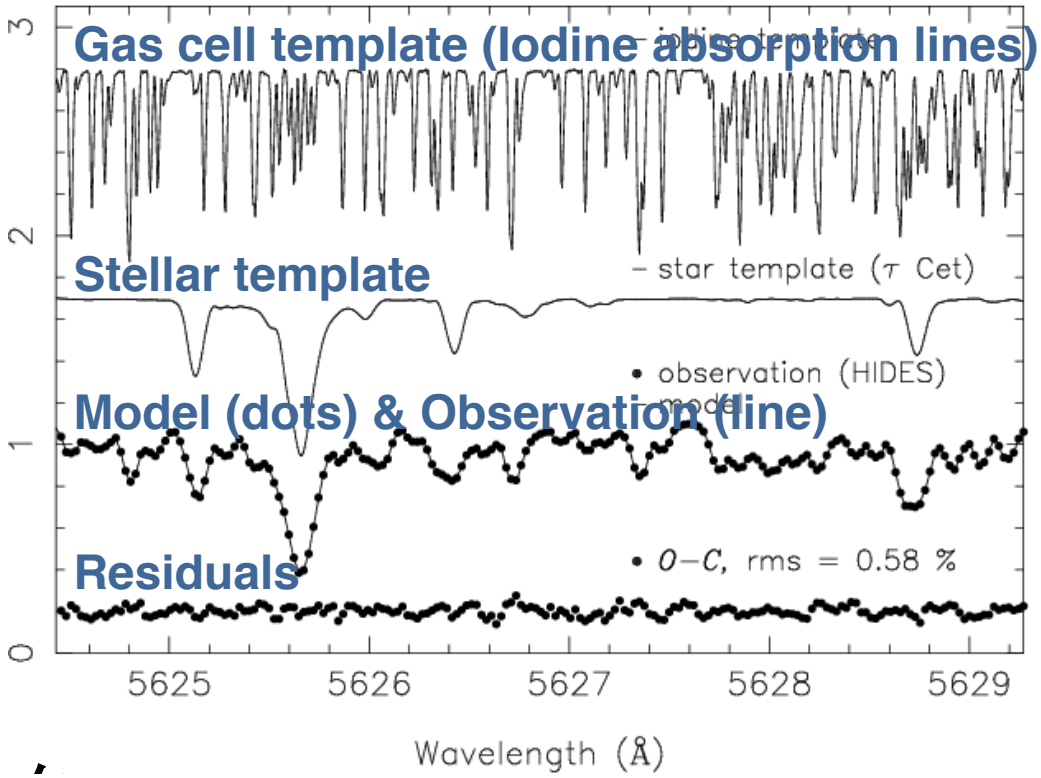
1.88m telescope + HIDES (with Iodine cell)
HIDES: High Dispersion Echelle Sepctrograph
Resolution: R=λ/Δλ~65,000
Wavelength range: 3850~7500Å
Fine day ratio: ~50 % (2005/1-2016/6)
Precision: ~5 m/s (S/N~150photons/pix@5,500Å
Number of Sample: 110 stars + β



Okayama Astronomical Observatory (OAO)

Precision RV measurements

- Calibration: Iodine cell
  - Observed with an Iodine cell
  - Kambe+02, Kim+07
- Analysis: Modeling technique
  - Model the observed spectra from templates
  - Fit the model spectra to the observed spectra
    - Sato+02, 12
  - Calculate a RV for each segment with ~3Å
- Precision of RVs
  - OAO >3 m/s
  - BOAO >8 m/s (Omiya+09)



$$I_{\rm obs}(\lambda) = k[T_{I2}(\lambda) I_s(\lambda + \Delta\lambda)] * {\rm PSF},$$

Marcy & Butler 1992, Valenti et al. 1995
Butler et al. 1996, Sato et al. 2002

Strategy of the planet search

1. Observe the RVs and spectra of each original sample
   - To screen planet candidates with large RV variations
   - Sample: 80 stars (BOAO), 110 stars (OAO)
   - Determine stellar properties
     - mass, radius, abundance, chromospheric activity etc.

2. Follow-up the planetary candidates by both observatories
   - To determine the orbital parameters of planets quickly
   - To check false positive of the planetary signals

3. Monitor the long time RVs of the samples

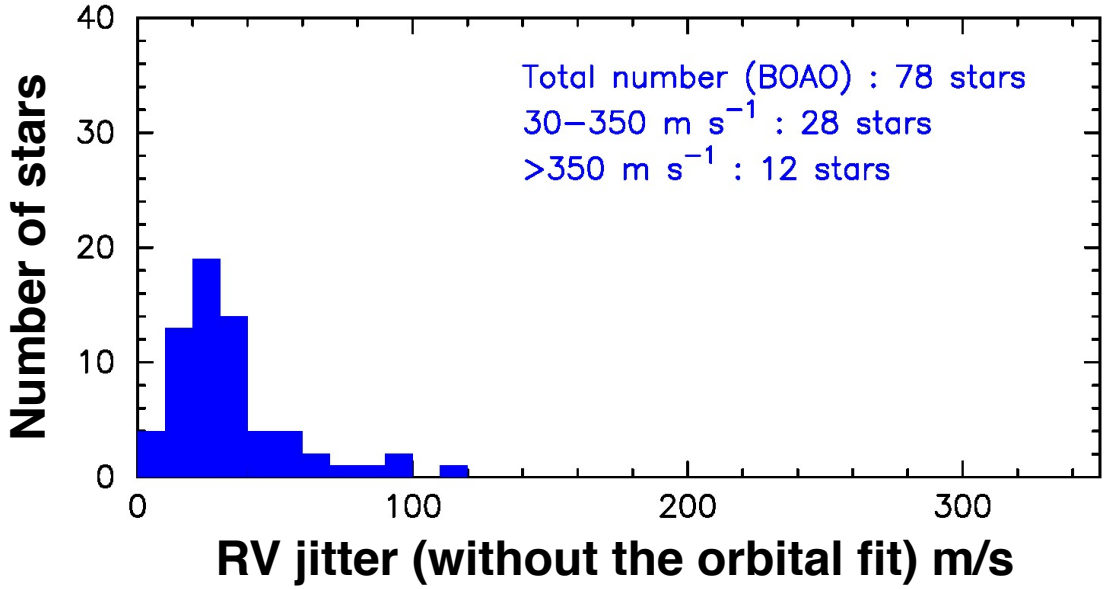
RV jitter and planet candidates

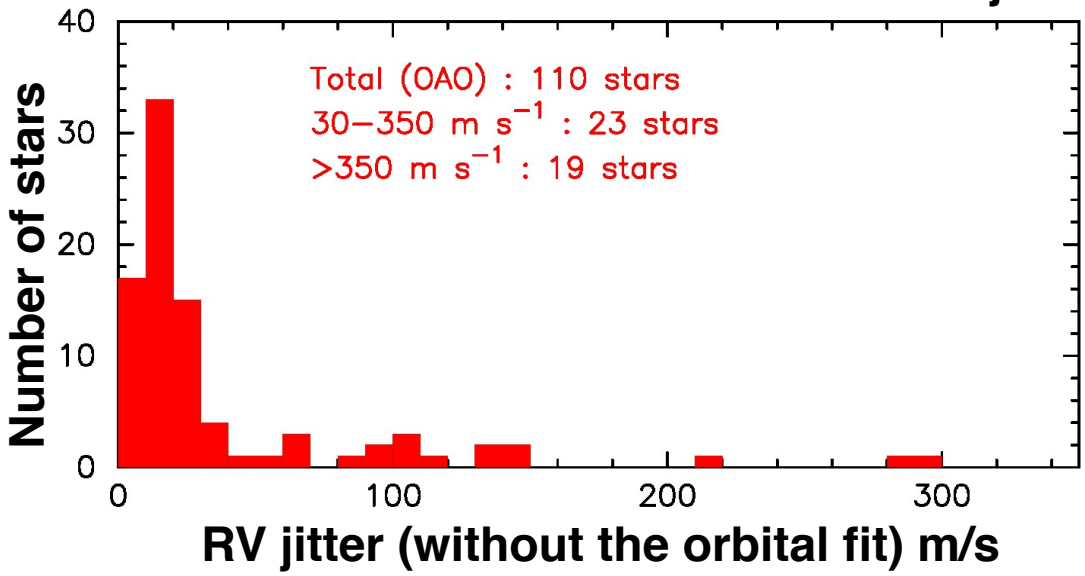
RV variations of BOAO sample

Typical jitter: 10-30 m/s

Planet candidates: 28 stars

Binary candidates: 12 stars





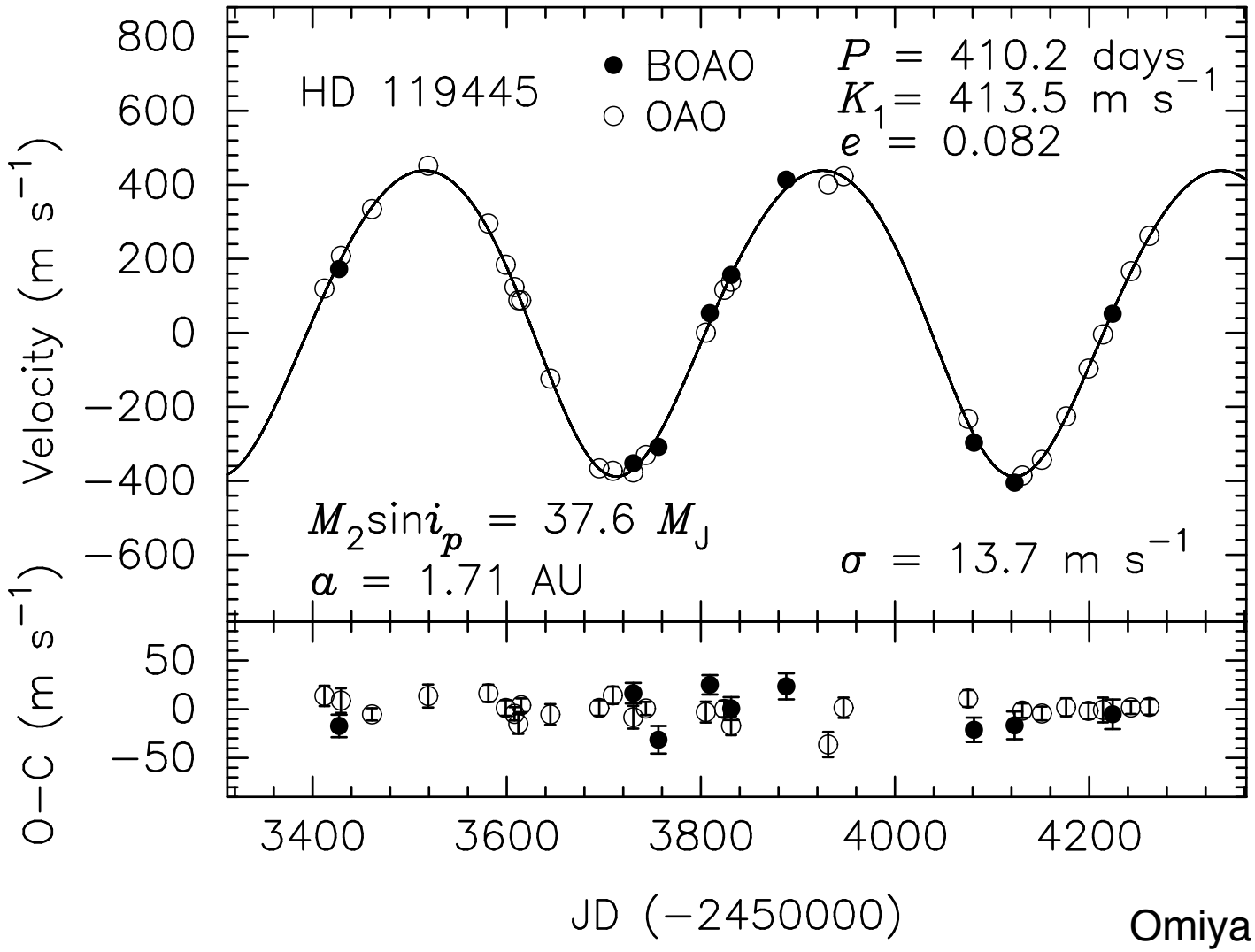
RV variations of OAO sample

Typical jitter: 10-20 m/s

Planet candidates: 23 stars

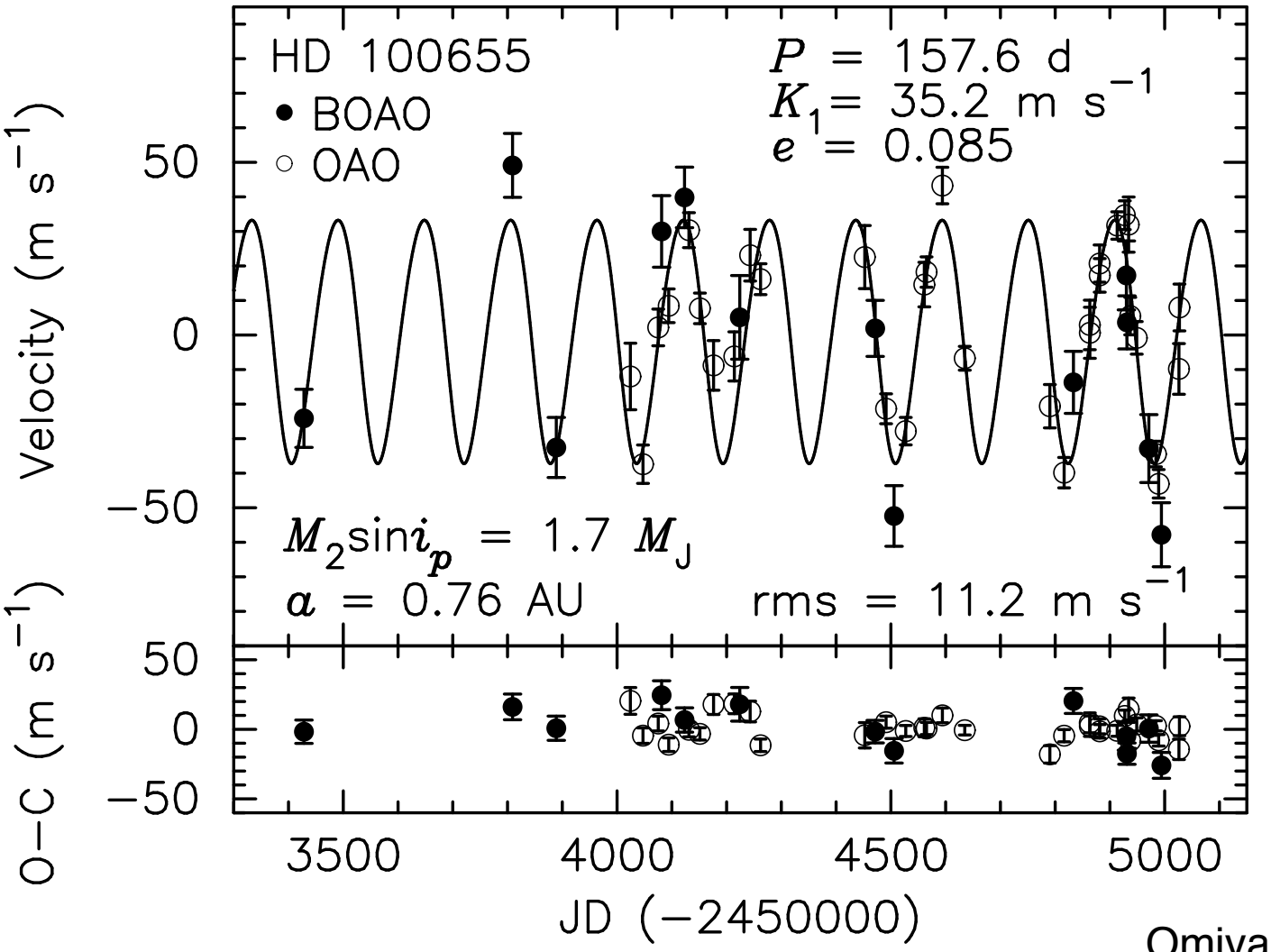
Binary candidates: 19 stars

A substellar companion



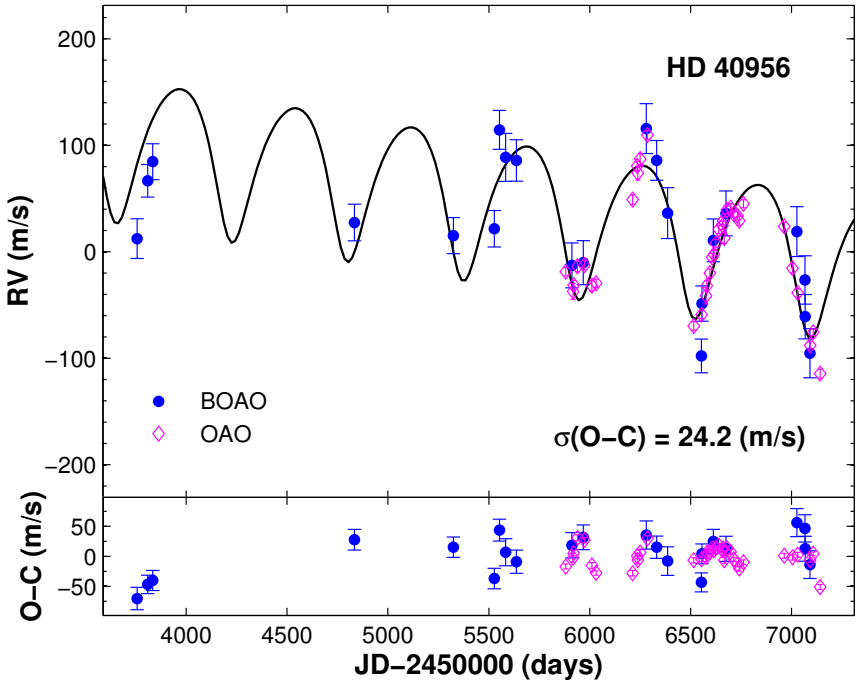
Omiya et al. 2009

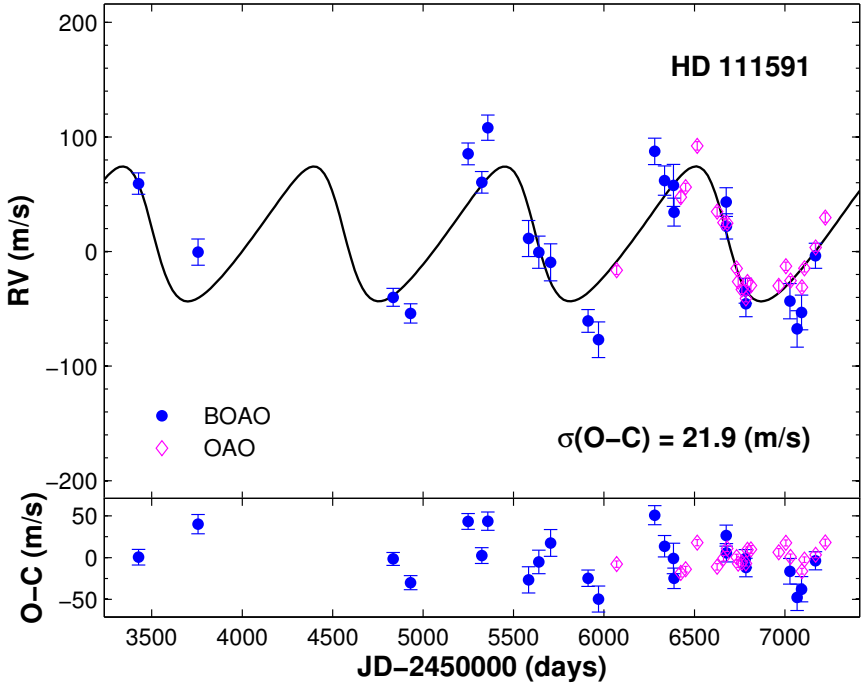
A planetary companion



Omiya et al. 2009

Planetary companions



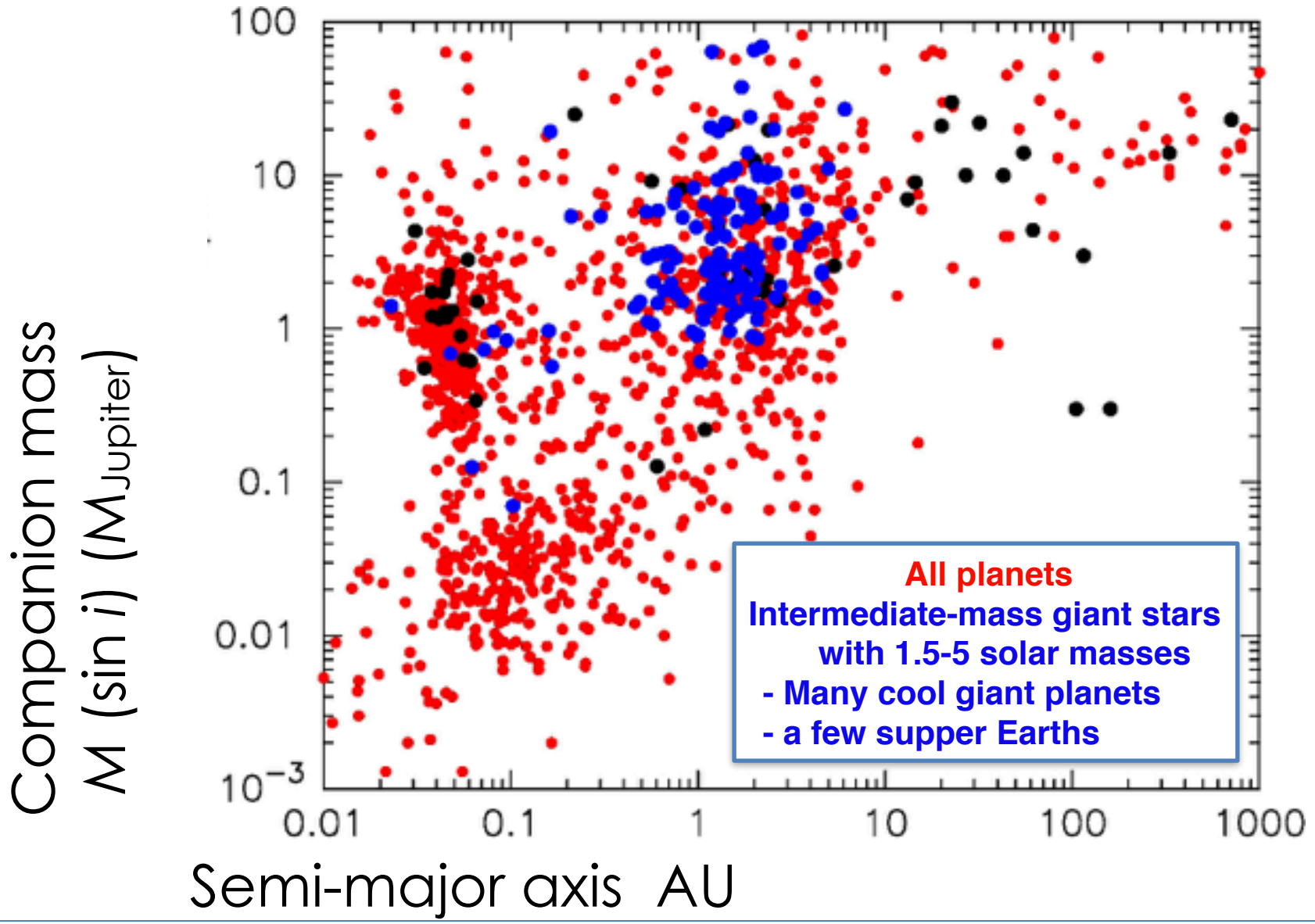


Parameter	HD 40956 b	HD 111591 b
P (days)	578.6 ± 3.3	1056.4 ± 14.3
K (m s^{-1})	68 ± 2	59 ± 3
$T_{periastron}$ (JD)	2455341.88 ± 11.07	2455602.40 ± 30.85
e	0.24 ± 0.05	0.26 ± 0.10
ω (deg)	338.62 ± 7.74	78.72 ± 11.94
$m \sin i$ (M_J)	2.7 ± 0.6	4.4 ± 0.4
a (AU)	1.4 ± 0.1	2.5 ± 0.1
Slope (m $s^{-1} \cdot yr^{-1}$)	-13 × 10^{-2}	–
N_{obs}	54	44
rms (m s^{-1})	21.1	21.9

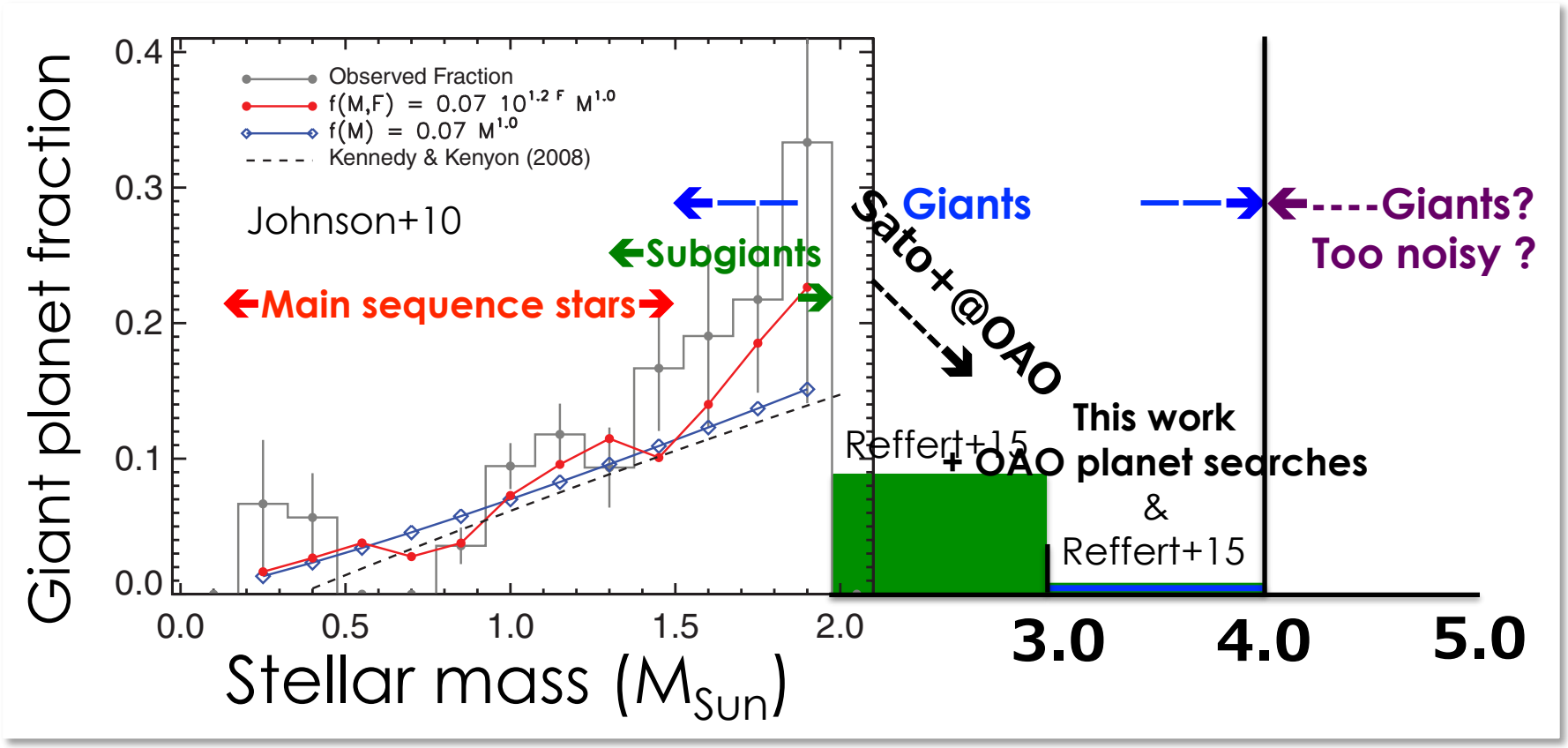
Parameter	HD 40956	HD 111591
Spectral type	K0	K0 III
m_v (mag)	6.584 ± 0.001	6.594 ± 0.001
B-V (mag)	1.011 ± 0.006	1.002 ± 0.002
d (pc)	117.97 ± 7.08	108.12 ± 5.51
RV (km s^{-1})	− 15.80 ± 0.25	5.67 ± 0.17
π (mas)	8.44 ± 0.51	9.22 ± 0.47
$T_{\rm eff}$ (K)	4869 ± 28	4884 ± 30
[Fe/H]	0.14 ± 0.05	0.07 ± 0.04
log g (cgs)	3.02 ± 0.09	3.10 ± 0.10
$v_{\rm micro}$ (km s^{-1})	1.20 ± 0.10	1.23 ± 0.11
Age (Gyr)	1.35 ± 0.18	1.41 ± 0.14
$R_\star$ ($R_\odot$)	8.56 ± 0.33	8.03 ± 0.49
$M_\star$ ($M_\odot$)	2.00 ± 0.08	1.94 ± 0.07
$L_\star$ ($L_\odot$)	46.17	38.07
$v_{\rm rot} \sin i$ (km s^{-1})	2.7	3.1
$P_{\rm rot}$ / sin i (days)	158.9	130.5

Jeong et al. 2017

Planetary systems around giants



Occurrence rate of planetary companions

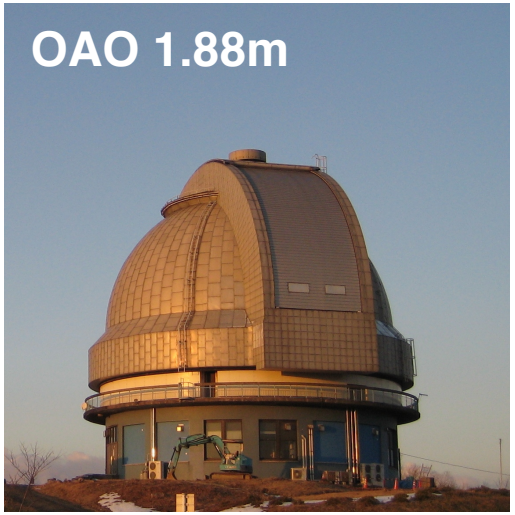


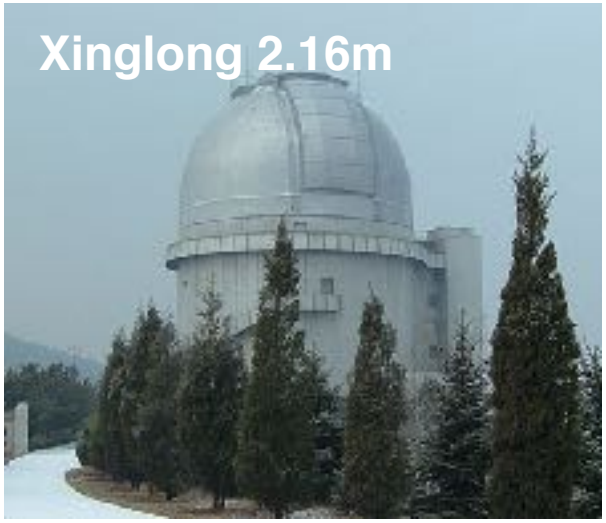
Occurrence rates of giant planets with semimajor axis of <3AU decrease with increasing stellar mass in >2.0M_{Sun} stars.
Our result is consistent with results of Reffert et al. 2015.
Long period planets may be fruitful around massive stars.
NOTICE: less massive giant planets with < 3$M_{Jupiter}$ cannot be detected around massive stars.

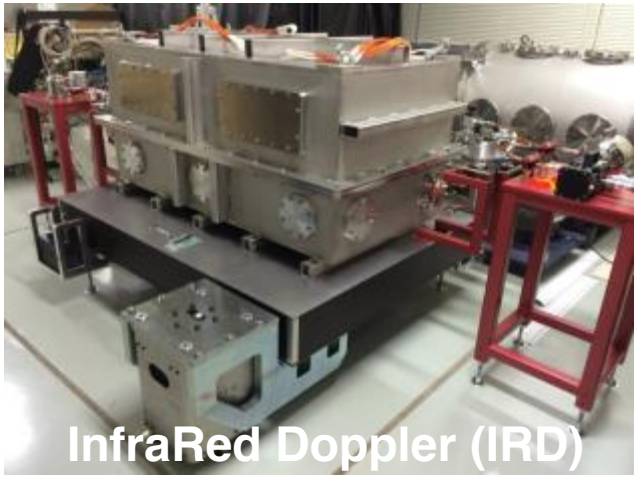
Collaboration in East-Asia

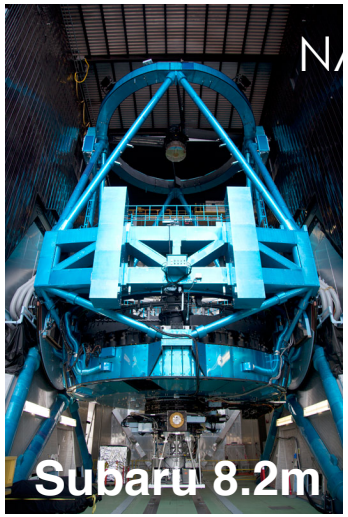
- East Asian Planet Search Network
  - Annual meeting in Japan, China, Korea
  - precise RV surveys in this network
  - To increase a number of sample stars in the surveys (planet search programs)
- Future collaboration using planet hutting machines in East-Asia
  - Planet searches at 2m class telescope at OAO, BOAO, Xinglong observatories
  - New searches with HDS, IRD at the Subaru telescope
  - Plan to construct a new high dispersion spectrograph for the new 3.8m telescope at the Okayama observatory

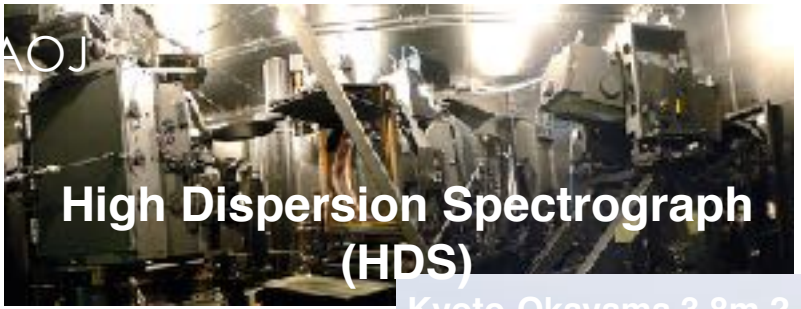
Telescopes and planet hutting machines in Our Network











Summary of my talk

- East-Asian Planet search Network (EAPS-Net)
  - Monitor RVs of ~700 GK-type giants in Japan, Korea, and China for 10 years
  - published many planets, candidates and some substellar companions
  - Recently two Jovian-mass planets (Jeong+17)
  - Continue our collaboration with a new strategy and new instruments
- Properties of the planetary companions around intermediate-mass giant stars
  - Many cool giant planets
  - Frequency of planets around high mass stars is low?

It is different from planetary systems around solar type stars?

THANKS