
IRD Planet-Search for Earth-like Planets around Late-M Dwarfs

B. Sato (Tokyo Tech.), IRD team

IRD Project

What is IRD?

- NIR high-dispersion spectrograph for exoplanet-searches by Doppler technique
- First light in 2016, survey start in 2017

Goal of IRD

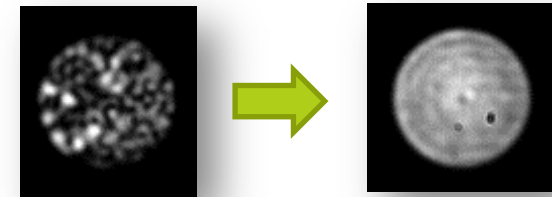
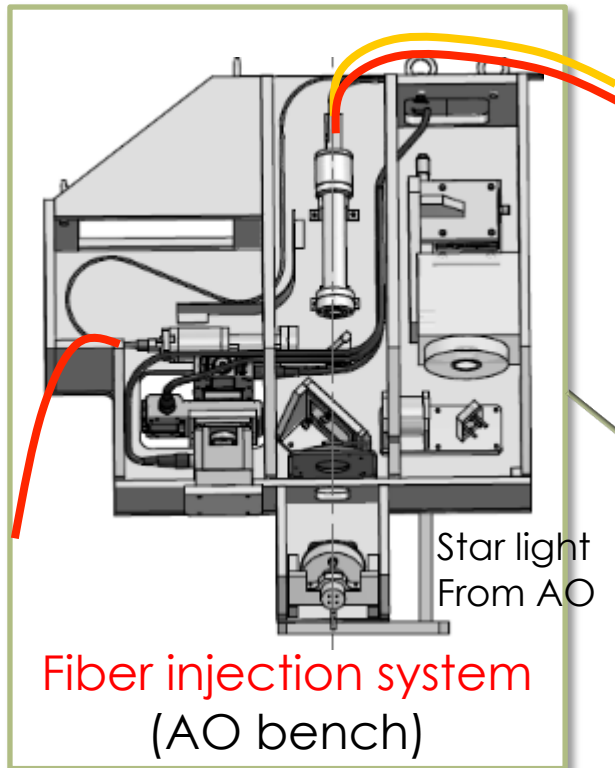
- Detect ~50 planets (including ~10 Earth-like planets in Habitable-Zone) around nearby M-type dwarfs
- Studies of M dwarfs, characterization of exoplanet's atmospheres, etc.

Uniqueness of IRD

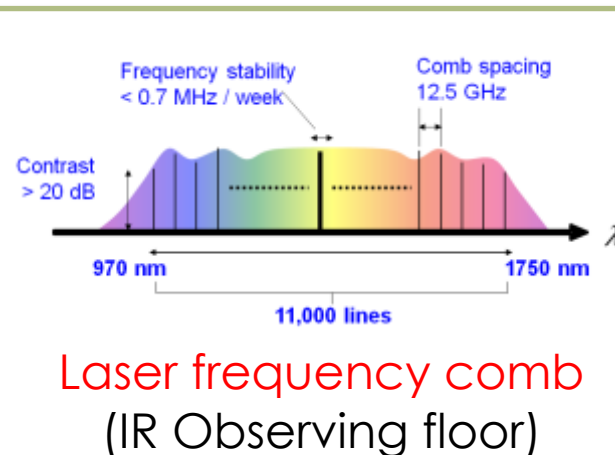
- Detect Earth-mass planets in HZ around **late-M dwarfs**
 - Only accessible with 8-10m class telescopes
- Wavelength resolution $R=70,000$ max
- Wide wavelength coverage (Y,J,H, 0.97-1.75 μ m)
- RV precision ~ 1 m/s



Overview of the IRD instrument



Resolution: $R=70000$
Wavelength: $0.97\text{-}1.75\mu\text{m}$
Cryo: 70K (detector),
200K (optics)



Fiber
(Comb)

Fiber
(star)

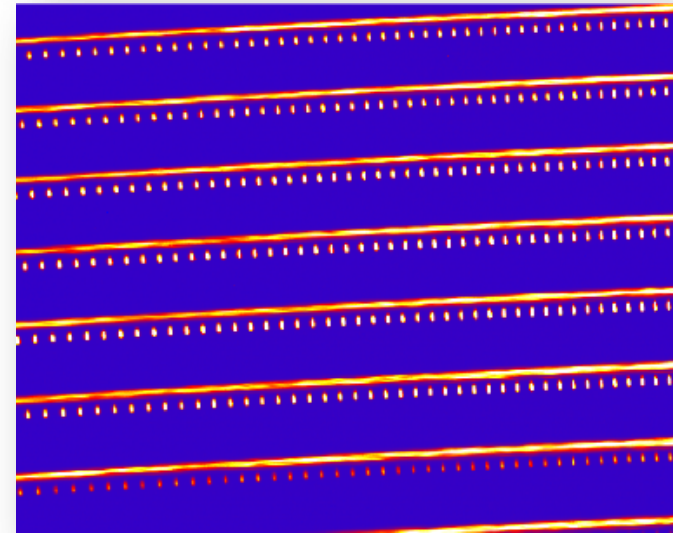
spectrometer

Coudé Room

This diagram shows the fiber connections for the spectrometer. Two fibers, labeled 'Fiber (Comb)' and 'Fiber (star)', are shown entering the spectrometer from the Coudé Room. The spectrometer is represented by a yellow box.

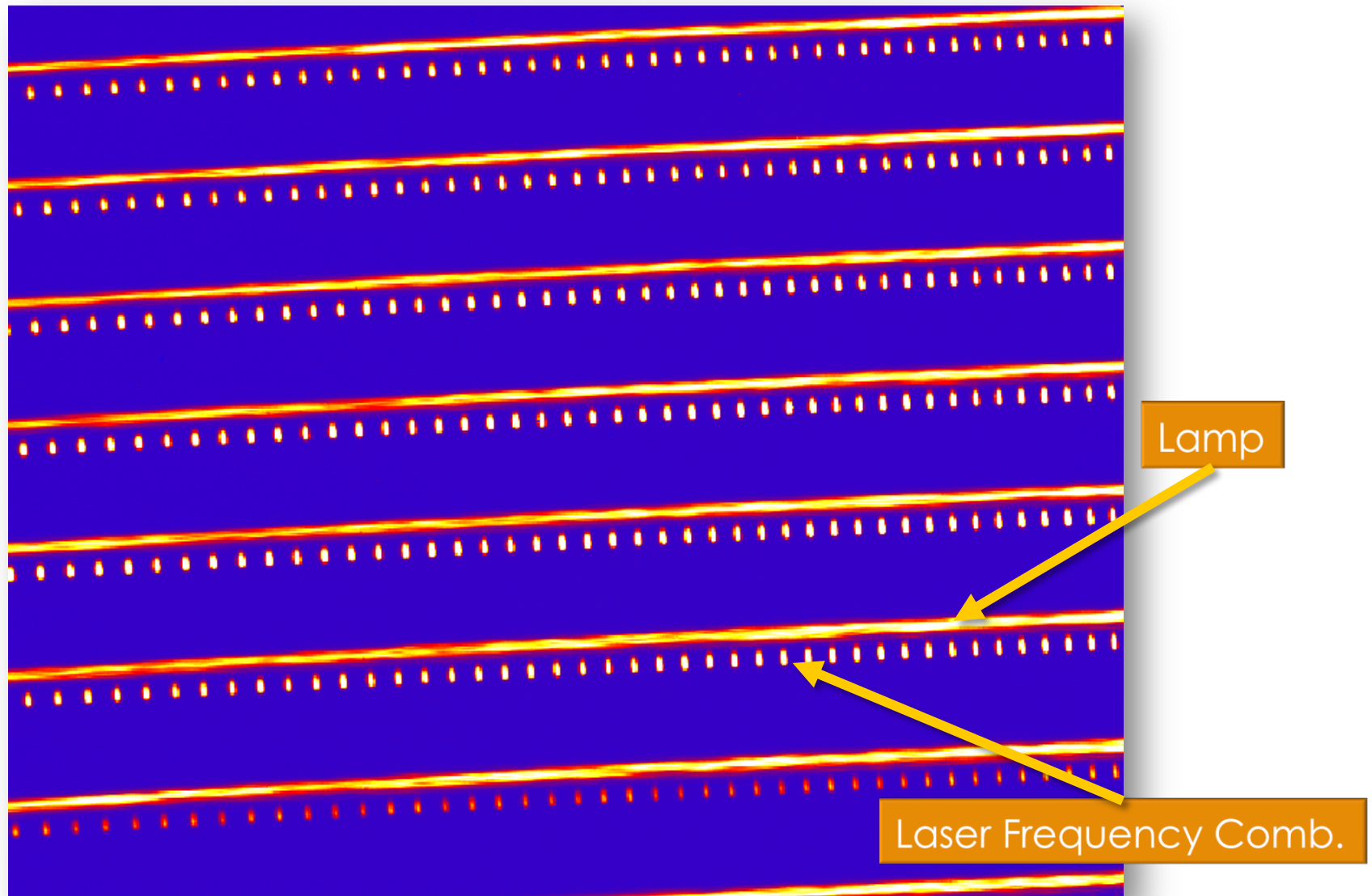
Current Status of IRD

- ~Dec. 2015 : Test at Mitaka, NAOJ (done)
 - Same configuration except for detector (2xH2RG)
- Jan. 2016 : shipping to UH (done)
- Late Feb. 2016 : assemble and test at UH
- Late Apr. 2016 : install at summit
- ~mid Jun. 2016 : stability test at summit
- Jul. 2016 : First light

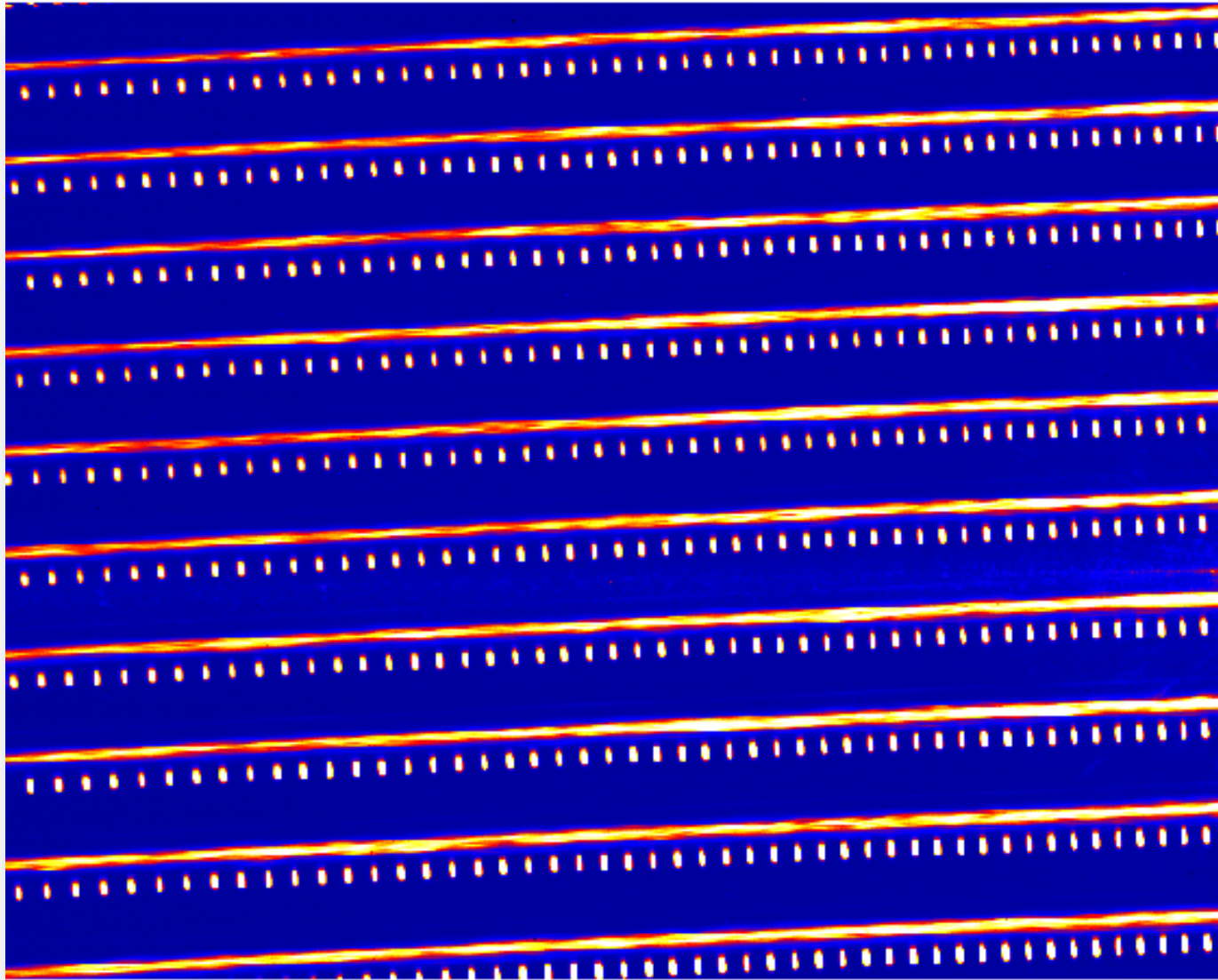


H-band (1550nm) spectrum

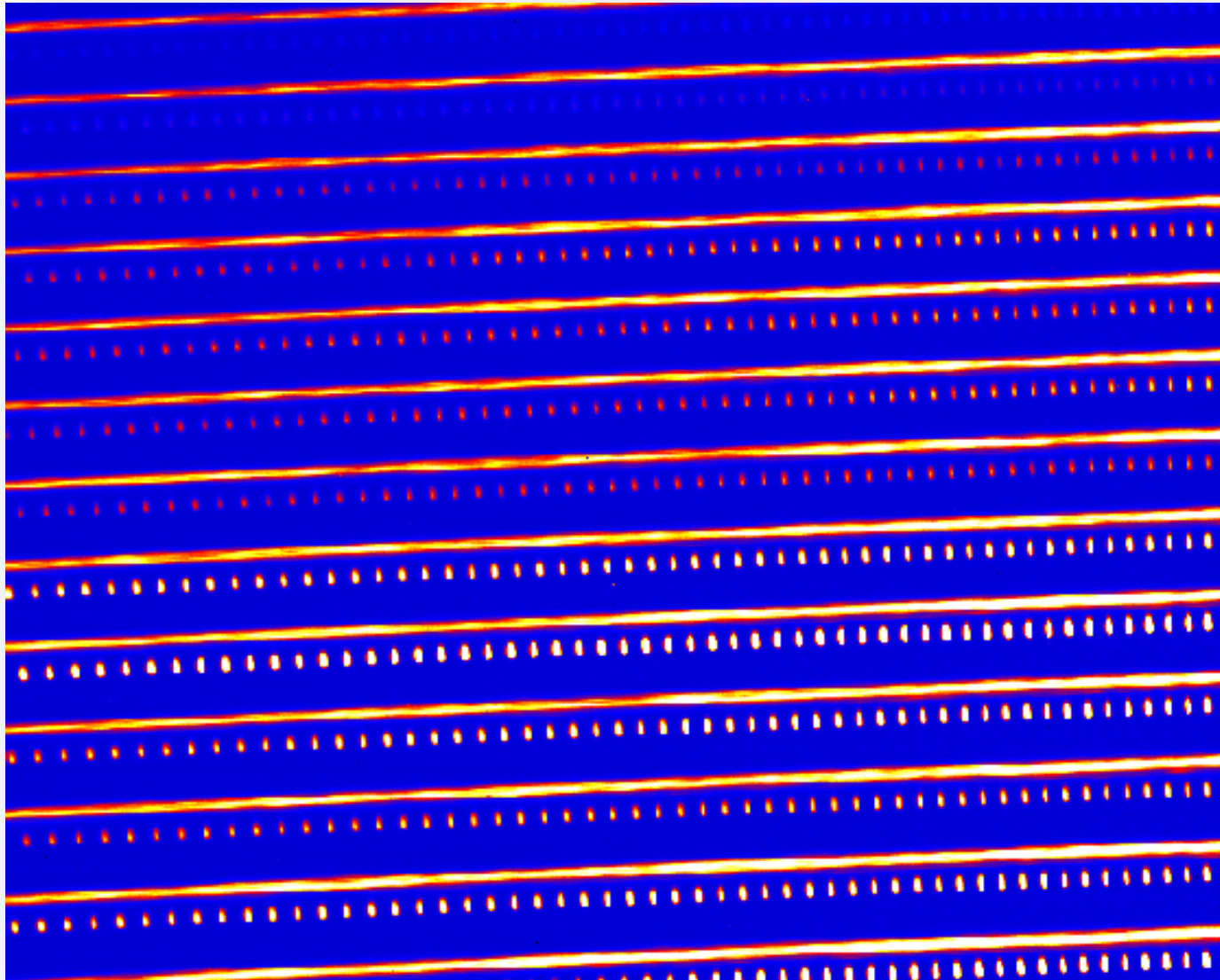
H-band (around 1550nm)



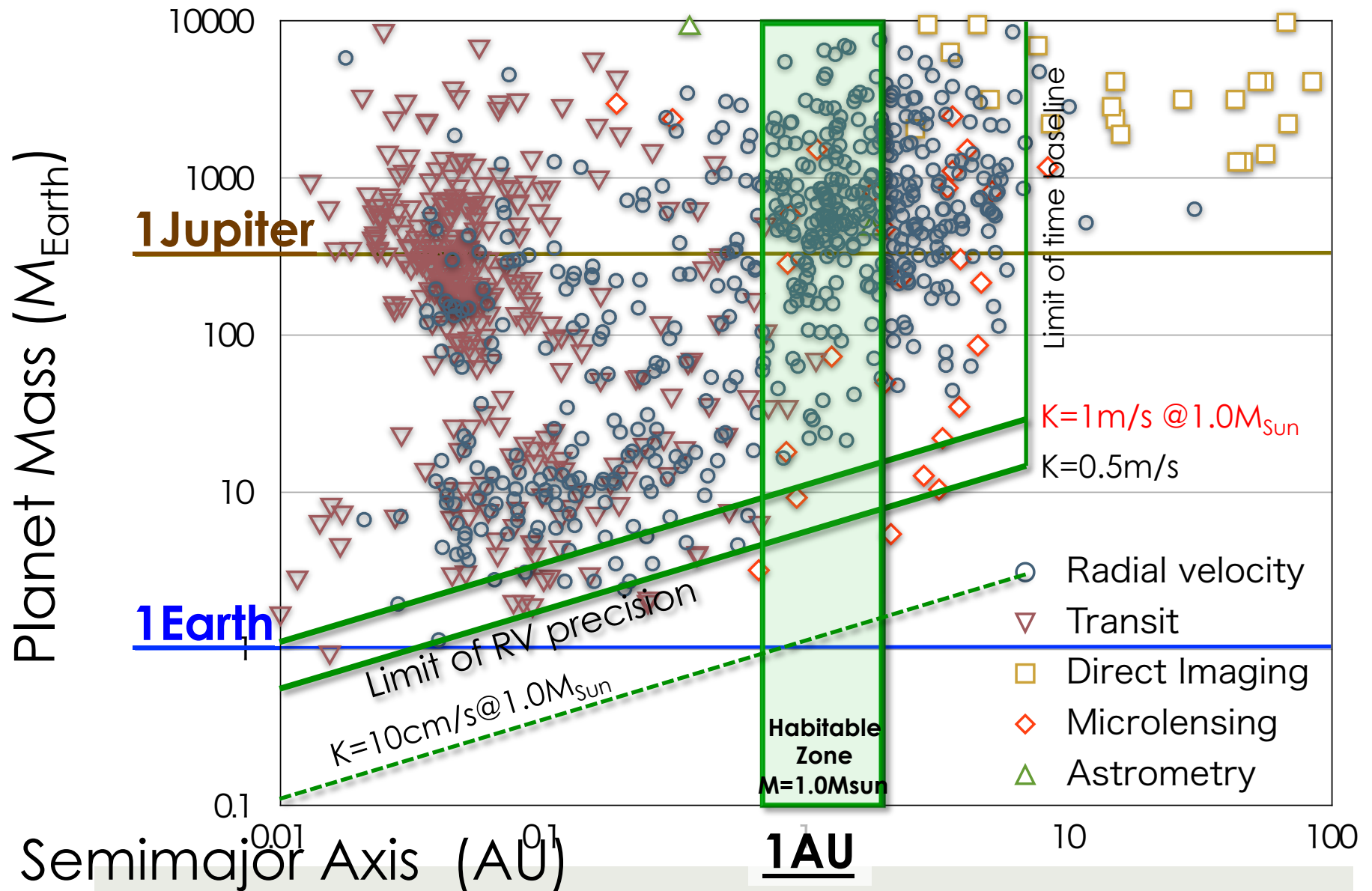
J-band (around 1310nm)



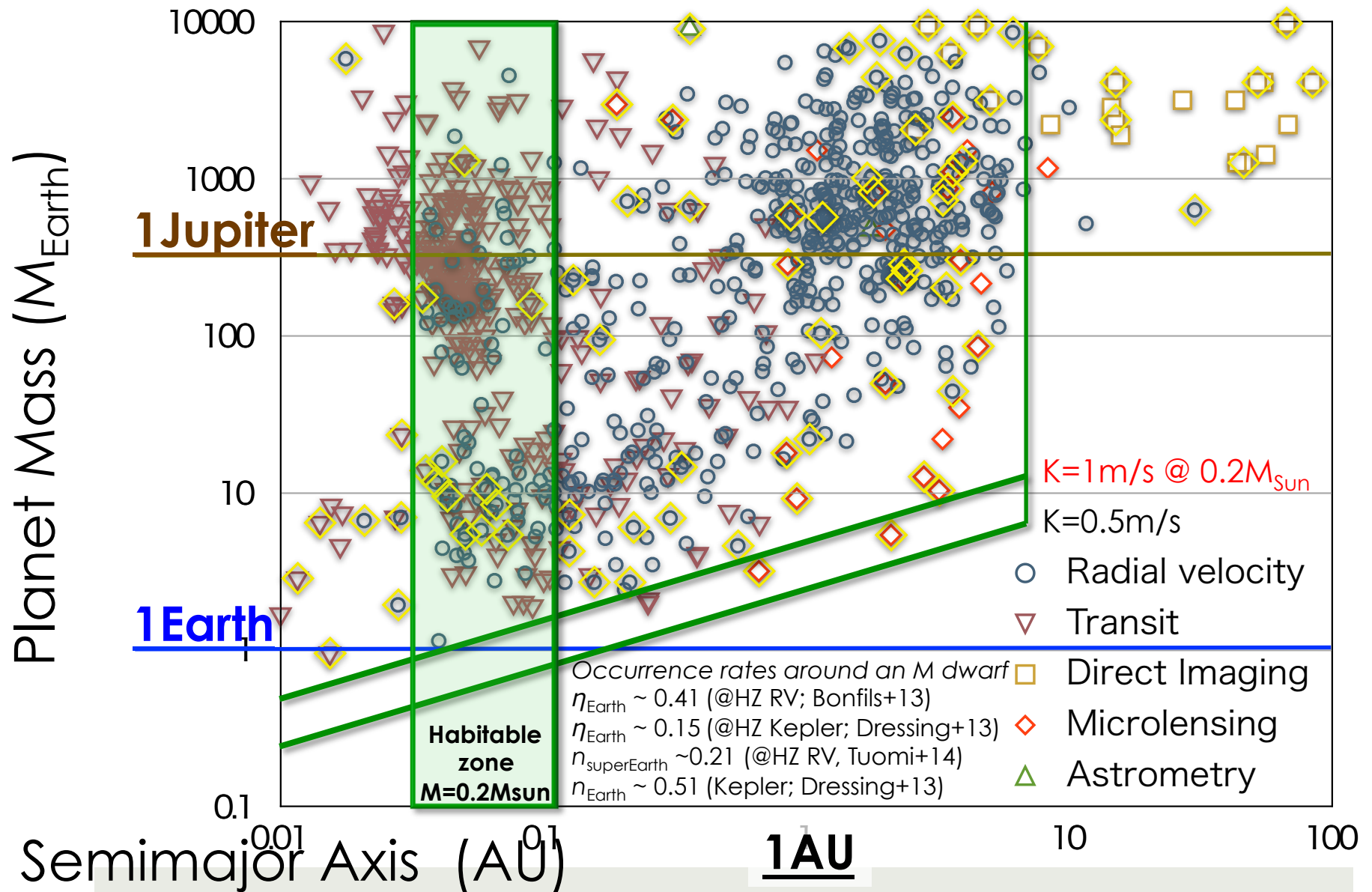
Y-band (around 1060nm)



Limit of Planet Detection: Solar-mass Stars

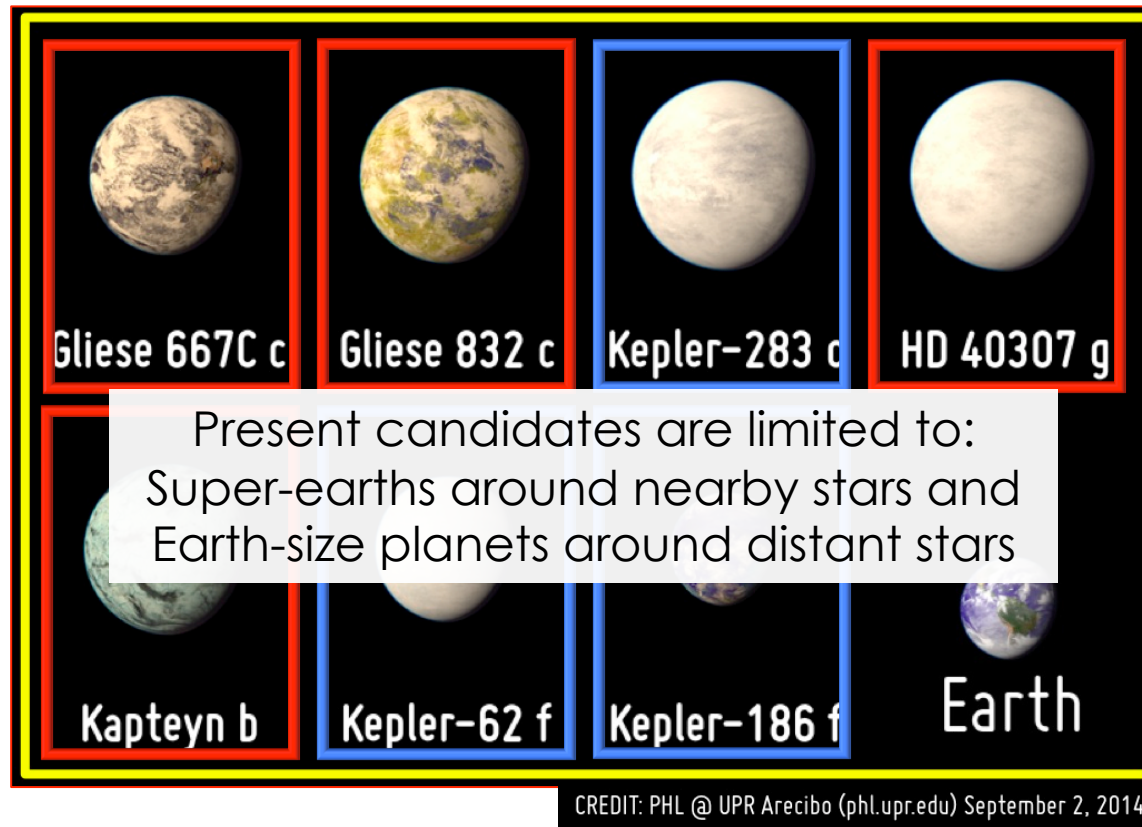


Limit of Planet Detection: Late-M Stars



Earth-like Planet Candidates in HZ

0.1-10 Earth Masses or 0.5-2.0 Earth Radii in conservative Habitable zone



- Planets around nearby late-type stars (red)
 - Around Early MK dwarfs
 - Large planet-mass
 - $M_{\text{planet}} \sin i > 3.8 M_{\text{Earth}}$
- Kepler planet candidates (blue)
 - Faint central stars
 - Follow-up studies are difficult
 - No planets confirmed by Doppler technique
 - Mass is unknown

- No planets with earth-mass, size, and surface temperature have been found around nearby stars so far
- Earth-like planets in HZ are still small in number for statistics

Searching for Earth-like Planets in HZ around Late-M dwarfs with Subaru/IRD

Detecting Earth-like planets in HZ around **solar-type stars** is difficult with current technique



Targeting Late-M dwarfs ($0.1-0.3 M_{\text{Sun}}$)

- M-type dwarfs are large in number in solar neighborhood
- Earth-mass planets in HZ are detectable
 - Large reflex motion of central stars ($K_1 \sim 0.5-2$ m/s), short period (< 40 d)
- IRD/Subaru is of advantage to targeting late-M dwarfs
 - Early-M dwarfs are accessible by existing optical-Doppler and new IR-Doppler instruments with 3m-class telescopes

Uniqueness of IRD/Subaru Planet Search

1. Detecting Earth-mass planets in HZ around nearby late-M dwarfs
2. Statistical studies of earth-like planets around M dwarfs

Survey Plan

- Targets ~100 stars
- Start : 2017~
 - Other teams also start surveys around the same time
- Observations
 - nights : ~170 (SSP)
 - period : 5 years
- Scheduling
 - 0.5 night × 7 times/month × 9~10 runs/year (170 nights)
- Expected results :
 - Earth-mass planets :
 - Earths and super-earths in HZ :

Estimated by obs.
simulation and
population synthesis

example schedule for October 2014

Sun	Mon	Tue	Wed	Thu	Fri	Sat
			Oct 01	Oct 02	Oct 03	Oct 04
			Eng HSC	Eng MOIRCS Obs MOIRCS	S14B-029 Takami HICIAO+AO188	
Oct 05	Oct 06	Oct 07	Oct 08 ○	Oct 09	Oct 10	Oct 11
S14B-029 Takami HICIAO+AO188	StrObs HICIAO+AO188		S12B IRD	StrObs S12B IRD	S12B IRD	S12B IRD
Oct 12	Oct 13	Oct 14	Oct 15 ●	Oct 16	Oct 17	Oct 18
S14B-153	Telescope	S12B IRD	S14B-141 Maeda HDS	S14B-066 Ferraro HDS	S14B-066 Ferraro HDS	S14B-066 Ferraro HDS
S12B IRD	S12B IRD	Service HDS	S14B-136 Hashimoto HDS	S14B-136 Hashimoto HDS	S14B-126 Kawakita HDS	S14B-126 Kawakita HDS
Oct 19	Oct 20	Oct 21	Oct 22	Oct 23 ●	Oct 24	Oct 25
S14B-12 Kawahara HDS	S14B-158		S14B-130	S14B-070		
Oct 26	Oct 27	Oct 28	Oct 29	Oct 30 ●	Oct 31	
Service FOCAS	S14B-013 Tadaki MOIRCS	Service MOIRCS	S14B-032 Minowa IRCS+AO188			
Eng Telescope		Eng MOIRCS				

0.5 night × 7 times

>50 planets

~28 planets

~10 planets

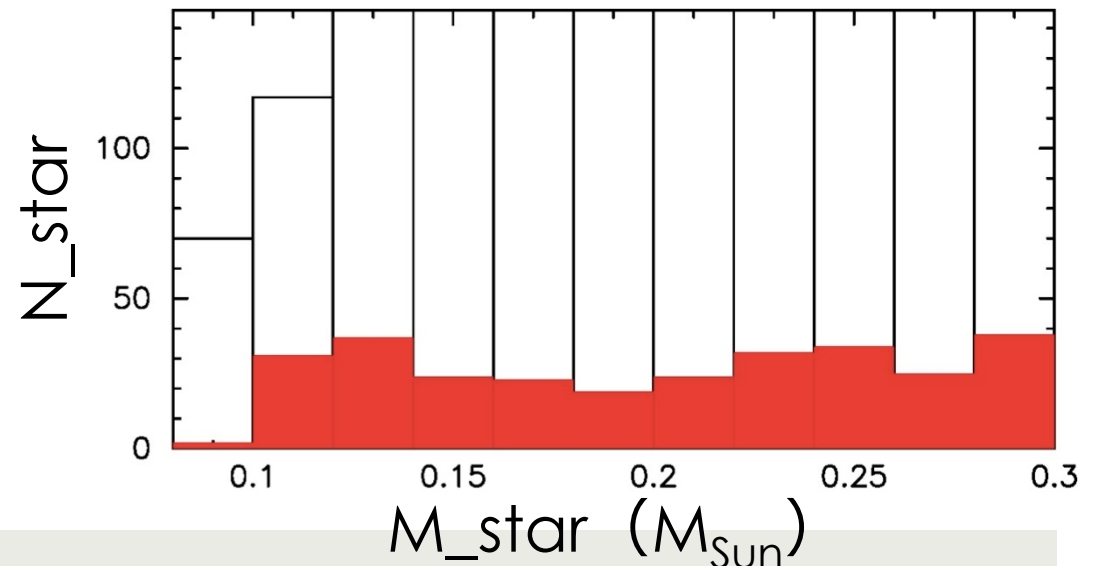
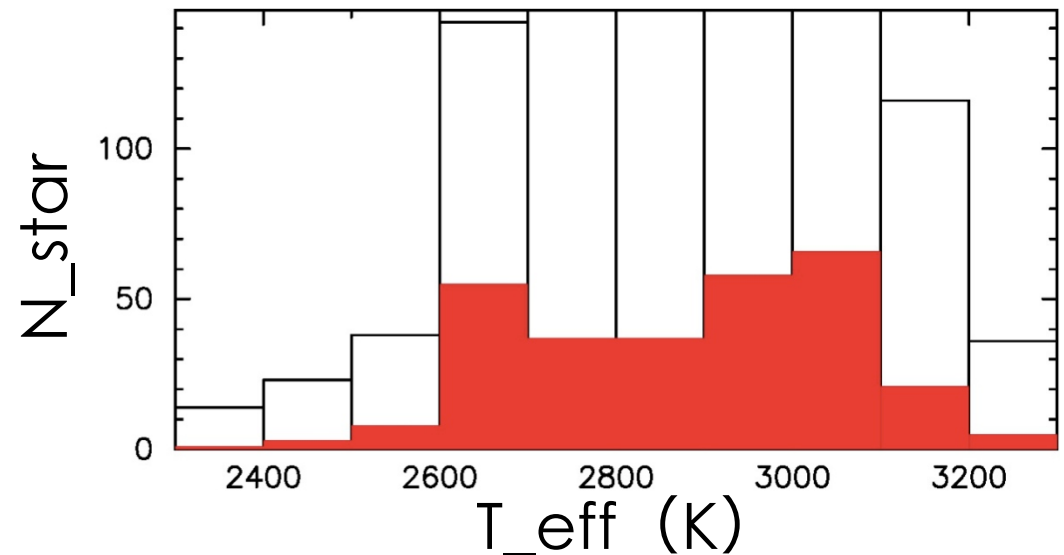
Survey Sample of Late-M dwarfs

- Select late-M dwarfs with **small rotational velocity** and **low stellar activity** from available catalogs
- Candidates : **~250 stars**
 - J~7-11.5 mag (for J>10)
 - Mass~0.1-0.3M_{Sun}
 - V-J>5.5
 - Excluding
 - visual binaries
 - flare stars
 - BY-Dra type and other variable stars
 - X-ray, UV, Ha-luminous stars

Screening observations
(on-going with OAO/KOOLS)

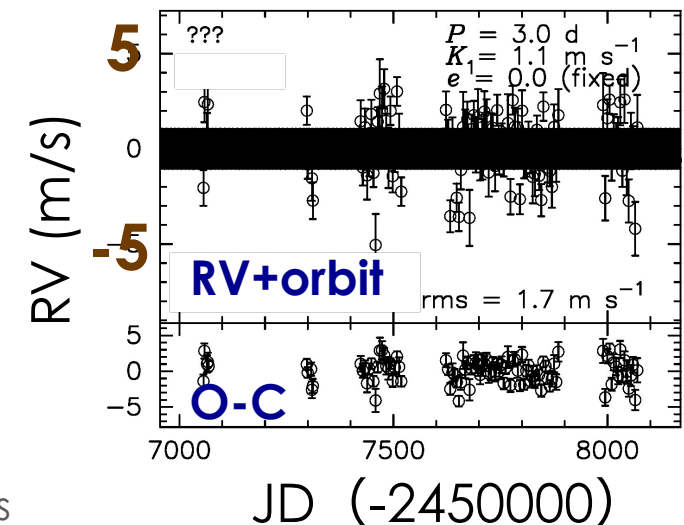
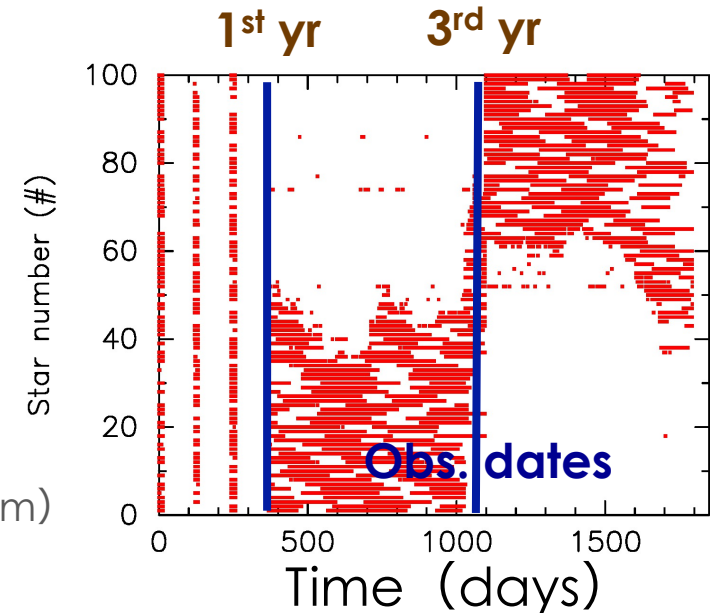
↓ by Activity, Vsinij, Binarity, etc.

Select best **~100 stars**

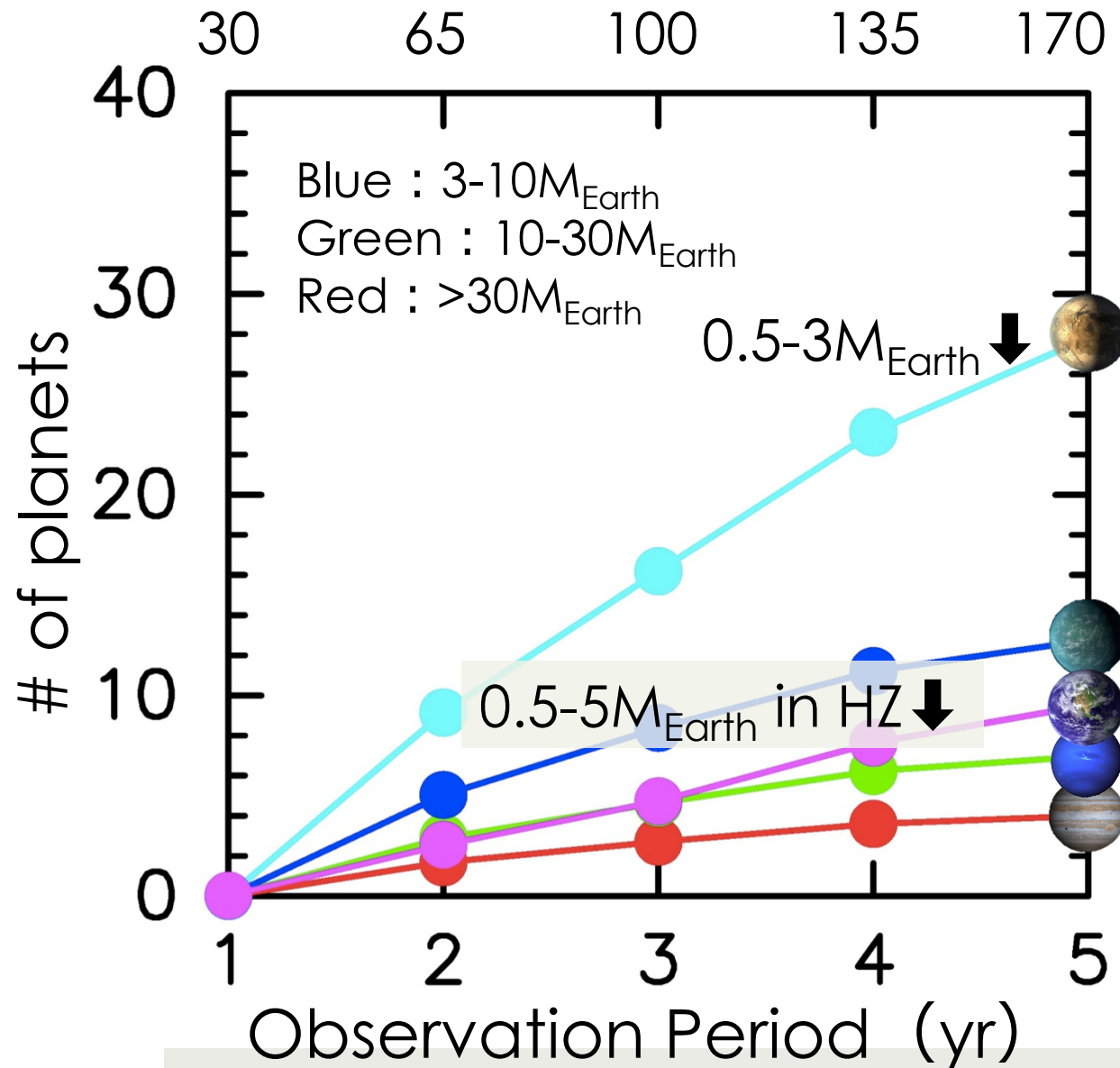


Survey Simulation

- Observing targets : ~100 late-M dwarfs
 - Selected from Lepine et al. (2005) following criteria
 - No X/UV/Ha, M4V-M9V etc.
 - RV jitter : ~1 m/s
 - cf. Barnes et al. (2011): 0.06-0.27 m/s
 - Rotational velocity : $v_{\text{sin}i} \sim 1\text{-}3 \text{ km/s}$
 - RV measurement error : ~1 m/s
- Observing time : SSP ~170 nights
 - Queue-mode : 5-6h/night (70 nights/yr at maximum)
 - Normal-mode : 1-night unit
- Observing conditions
 - 1st yr: 10 nights x 3 (Normal-mode)
 - 2nd-5th yr: every 5 days (Queue-mode)
 - $N_{\text{obs}} \sim 100$ for each star
 - Setting integration time to achieve SN~200
 - Dead-time (including AO pointing) = 360 sec
 - Frequency of clear night = 70%
- Estimating the number of planet detections
 - Based on theoretical population synthesis of planets



Expected Planet Detection



Expected detection

Jupiter-mass	: 4
Neptune-mass	: 7
Super-Earth	: 13
Earth-mass	: 28

Conditions

nights : 170
 sample : 100 stars
 Obs. : 50 or 80 times
 RV error : $\sim 1\text{m/s}$
 jitter : $\sigma \sim 1\text{m/s}$
 Theoretical model :
 standard
 overhead : 8 min.

Members (individual institute, 2014/4/1-, ~50 people)

- ★ **NAOJ**: Kotani, T., Nishikawa, J., Kurokawa, T., Suto, H., Kusakabe, Kudo, T., N., Aoki, W., Usuda, T., Morino, J., T., Narita, N., Kokubo, E., Hayano, Y., Izumiura, H., Kambe, E., Hori, Y., Fukui, A., Guyon, O., Hayashi, M., Suzuki, R., Oshino, S., Takami, H., Takato, N., Terada, H., C. Helmniak, Harakawa, H., Tamura, M.
- ★ **GUAS**: Baba, H., Oh, D., (Suenaga, T.)
- ★ **Tokyo**: Ikoma, M., Kawahara, H., Kwon, J., Uyama, T., (Takahashi, Y.)
- ★ **TAUT**: Kashiwagi, Y. Okuyama
- ★ **Hawaii**: Hodapp, K., Jacobson, S., Hall, D.
- ★ **Photocoding**: Ikeda, Y.
- ★ **TITECH**: Sato, B., Omiya, M., Ida, S., Genda, H., Hirano, T., Kuzuhara, M., Fujii, Y., Ohnuki, Y., (Tachinami, C.)
- ★ **Miyagi**: Nishiyama, S.
- ★ **Kyoto**: Matsuo, T., Nagata, T.
- ★ **Nagoya**: Ogihara, M.
- ★ **Tokai**: Hidai, M.
- ★ **Kyusyu**: Machida, M.
- ★ **Okulahoma**: Hashimoto, J.
- ★ **And many other contractors**
- ★ *Call for new science (and engineering) members to be announced.*

Summary

▣ Searching for Earth-like planets in HZ

- ▣ Targeting late-M dwarfs with IRD/Subaru
- ▣ Survey start in 2017, 34 nights x 5 years (170 nights, SSP)

▣ Expected results from IRD/Subaru survey

- ▣ ~10 Earth-like planets in HZ
 - ▣ Frequency of habitable planets
 - ▣ Provide targets for future direct imaging with TMT
- ▣ ~50 Earths, super-earths, gaseous planets
 - ▣ Statistical studies of planets around low-mass stars