Status updates of IRD-SSP

Bun'ei Sato (Science Tokyo)

on behalf of the IRD-SSP team

Redefinition of science goals in 2022

- Minimum Success
  - Detection of >1 terrestrial planets (m sini = 1 -10 M_{Earth})
  - Limit on the distribution of giant planets (> a few 10 MEarth), located up to ~0.1 a.u. for >40 stars that can be compared to the result of gravitational microlensing planet.
  - Provide an upper limit on the frequency of HZ planets, >3 MEarth
- Full Success:
  - Discover at least one HZ planet with m sini = 1-10 M_{Earth}
  - Limit the distribution of short-period (orbital period < 10 days), planets >3 M_{Earth}
  - Limit the frequency of existence of low-mass planets (>3 MEarth), including HZ planets
- Extra Success:
  - Discovery of one or more HZ planets of about Earth mass (m sini= 1-3 M_{Earth})
  - Obtain frequency of existence for terrestrial planets (>1 MEarth), including Earth-mass HZ planets
  - Discover Earth-like planets that can be followed up (transit photometry) to understand the atmospheres and internal compositions (e.g. mass-radius relationship)

Observation progress in S25A&S25B

- A total of 175 nights allocated for S19A~S23B period
- 25.5 nights lost due to troubles (telescope, detector, COVID-19). The nights are compensated in S24A-S25A.
- 174.5 nights were used for IRD-SSP by October 2025.
- Remining 0.5 nights will be allocated in S26A

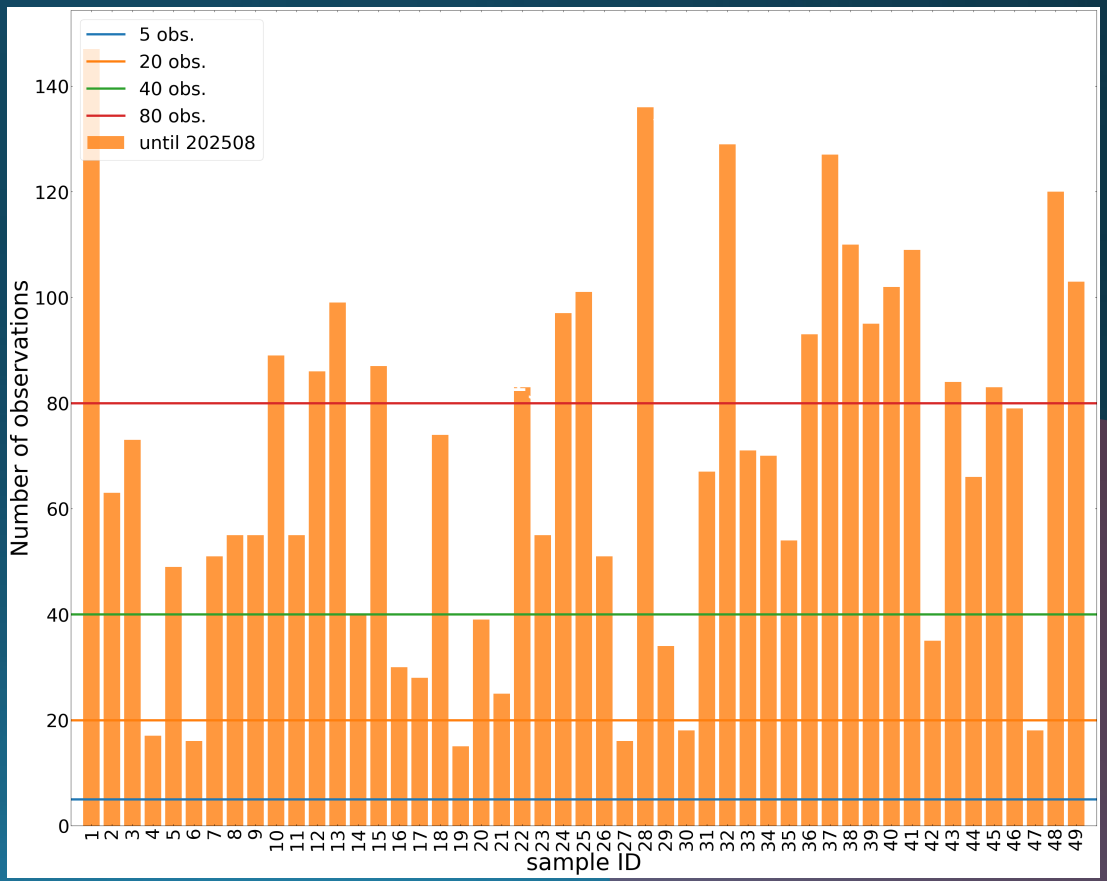
S25A	Allocated (nights)	Observed (nights)	Success rate (%)
February	1	0.5	52
March	1	0.2	20
April	0		
May	1.5	1.2	78
June	1	0.8	78
July	1.5	1.3	83
Total (S25A)	**6.0**	**3.9**	**65.2**

S25B	Allocated (nights)	Observed (nights)	Success rate (%)
August	0	0.05	# time exchange
September	0		
October	0.5	0.33	65
November	0		
December	0		
January	0		
Total (S25B)	**0.5**	**0.38**	**75.1**

Number of observations for each target

- Monitoring observations were carried out according to several criteria with levels of priority (screening, variability check, monitor, intensive follow-up).
- The numbers of observations for monitoring stars are shown on the right figure.
- The numbers of key stars are listed in the table below.

Number of observations	Number of stars
≥ 5	84
≥ 20	43
≥ 40	37
≥ 80	20



Publications

1. "A Super-Earth Orbiting Near the Inner Edge of the Habitable Zone around the M4.5-dwarf Ross 508", Harakawa et al. 2022, PASJ, 74, 904
2. "Elemental Abundances of nearby M Dwarfs Based on High-resolution Near-infrared Spectra Obtained by the Subaru/IRD Survey: Proof of Concept", Ishikawa et al. 2022, AJ, 163, 72
3. "An Earth-sized Planet around an M5 Dwarf Star at 22 pc", Hirano et al. 2023, AJ, 165, 131
4. "Direct Imaging Explorations for Companions around Mid-Late M Stars from the Subaru/IRD Strategic Program", Uyama et al. 2023, AJ, 165, 162
5. "Planetary companions orbiting the M dwarfs GJ 724 and GJ 3988: A CARMENES and IRD collaboration", Gorrini et al. 2023, A&A, 680, 28
6. "Gliese 12 b: A Temperate Earth-sized Planet at 12 pc Ideal for Atmospheric Transmission Spectroscopy", Kuzuhara et al. 2024, ApJ, 967, id.L21
7. "The CARMENES search for exoplanets around M dwarfs: Revisiting the GJ 317, GJ463, and GJ 3512 systems and two newly discovered planets orbiting GJ9773 and GJ 508.2", Morales et al. 2025, A&A, 700, id.A242
8. "Direct Imaging Explorations for Companions from the Subaru/IRD Strategic Program II; Discovery of a Brown-dwarf Companion around a Nearby Mid-M-dwarf LSPM J1446+4633", Uyama et al. 2025, AJ, 170, id.272

Several more papers are in preparation.

Collaboration with CARMENES

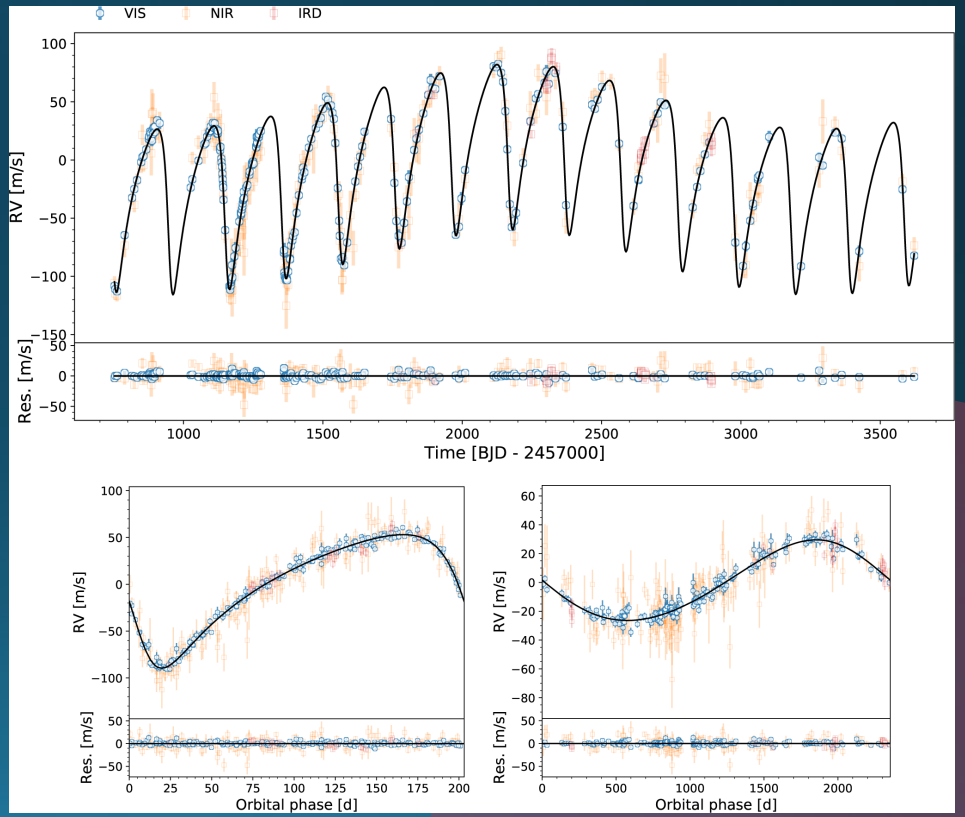
- New collaboration with the CARMENES team from 2022/09 to maximize science output of IRD-SSP
  - CARMENES project: visible & NIR RV survey of M-dwarfs started in 2016 (750-night exoplanet survey targeting ~300 M dwarfs)
  - Sharing a target list and RV data, coordinated observations, data reduction, activity analysis, etc.

carmenes carmenes

GJ3512 b,c: two jovian planets around a Mid-M dwarf, discovered with CARMENES+IRD data

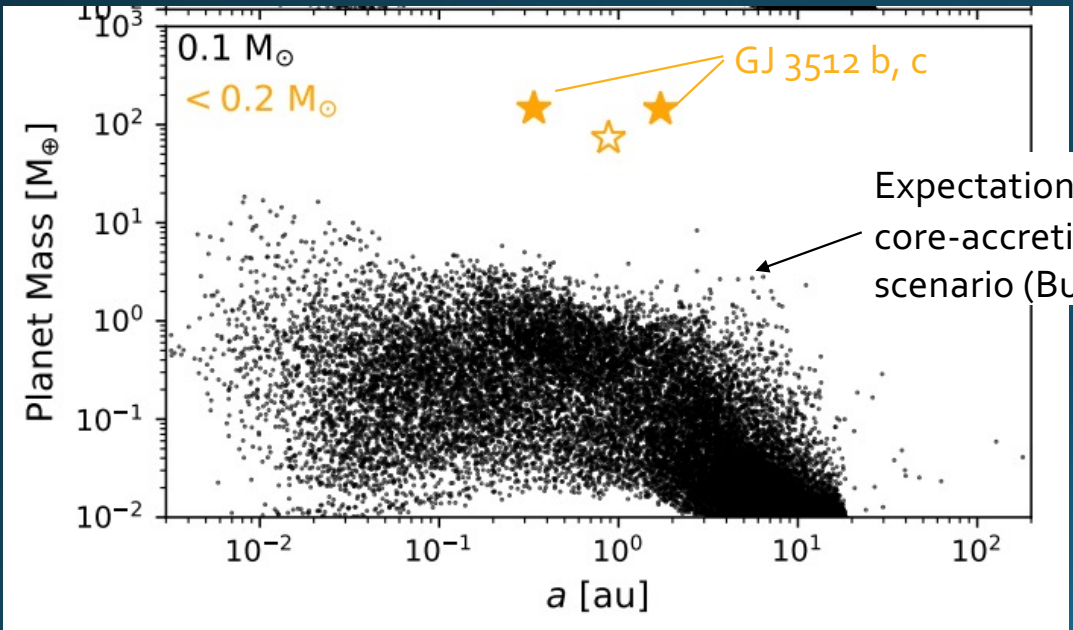
Star	GJ 3512
Karmn	J08413+594
Spectral type	M 5.5 V
α (J2000)	08:41:20.13
δ (J2000)	+59:29:50.44
pmα (mas a^{-1})	−260.276±0.023
pmδ (mas a^{-1})	−1279.562±0.026
π (mas)	105.294±0.031
d (pc)	9.4973±0.0028
M ($M_\odot$)	0.123±0.009
R ($R_\odot$)	0.139±0.005
$T_{\rm eff}$ (K)	3141±38
[Fe/H] (dex)	−0.07±0.16
$v \sin i$ (km s^{-1})	<2
pEWHα (Å)	−1.339±0.013[c]
$P_{\rm rot}$ (d)	83

Planet	Parameter	GJ 3512
	P_b (d)	$203.109^{+0.035}_{-0.034}$
	$\mathrm{BJD}_{0,b}$ (+2450000)	$7739.51^{+0.22}_{-0.20}$
	K_b (m s^{-1})	$71.28^{+0.32}_{-0.31}$
	P_c (d)	2354^{+36}_{-30}
	$\mathrm{BJD}_{0,c}$ (+2450000)	7339^{+32}_{-37}
	K_c (m s^{-1})	$28.02^{+0.36}_{-0.34}$
	e_b	$0.4279^{+0.0036}_{-0.0035}$
	ω_b (deg)	$126.80^{+0.62}_{-0.64}$
	$a_{2,b}$ (au)	$0.3376^{+0.0082}_{-0.0084}$
	$m_b \sin i_b$ ($M_{\rm Jup}$)	0.461±0.023
	e_c	0.089±0.012
	ω_c (deg)	50±10
	$a_{2,c}$ (au)	$1.731^{+0.043}_{-0.046}$
	$m_c \sin i_c$ ($M_{\rm Jup}$)	0.453±0.023



Morales et al. 2025

GJ3512 b, c challenges the core-accretion scenario



Morales et al. 2025

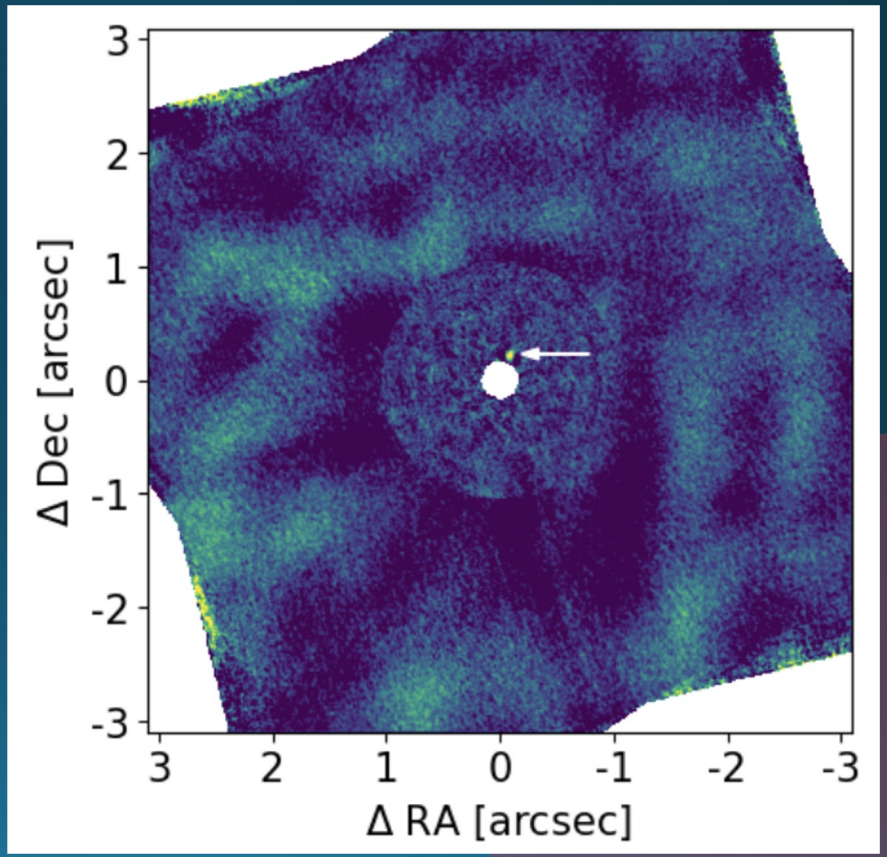
GJ 3512 b,c are too massive to explain them with the framework of core-accretion scenario

↓

Gravitational instability?

Direct imaging explorations for companions around Mid-Late M stars

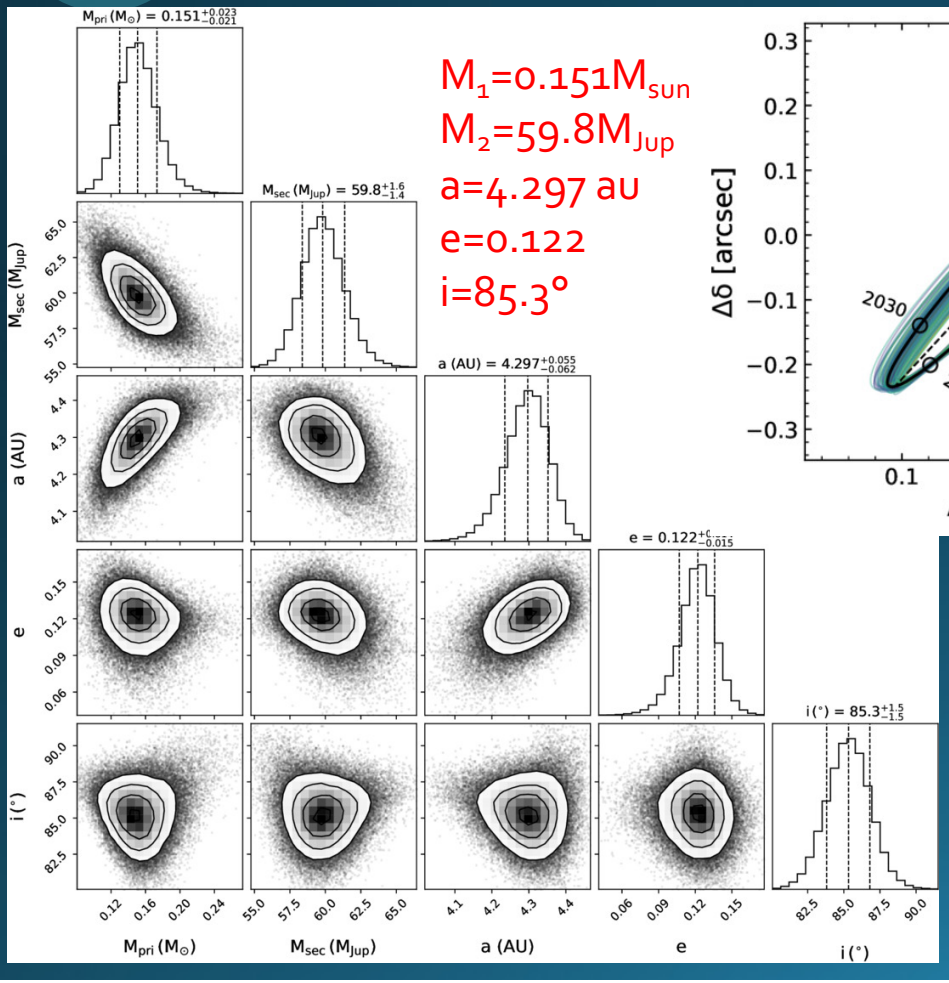
- Binarity study of IRD-SSP sample by Keck/NIRC2 and IRD/FIM
- "Deprioritized" IRD-SSP targets that have signatures of long-term RV trends and/or large RUWE values from the Gaia catalog suggesting unresolved systems
- Detected 7, including 4 new, companions at projected separations between ~ 2 – 20 au from the target stars (Uyama+ 2023)
- Detected more companions including a brown dwarf from 2023-2024 campaign (right fig.)



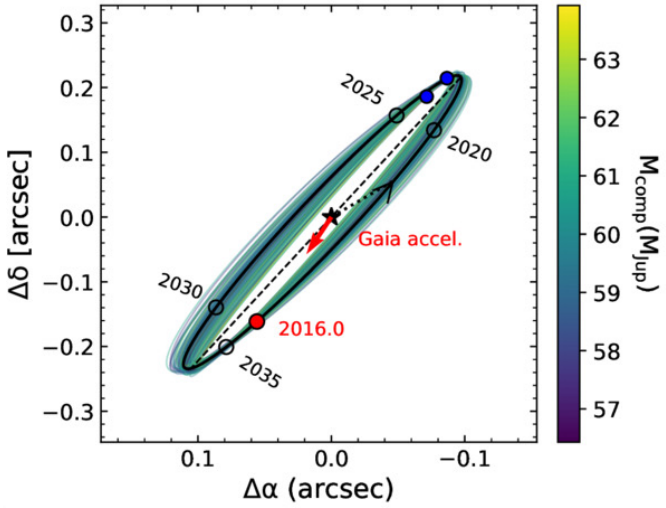
LSPM J1446+4633 (w/ Keck/NIRC2) Uyama et al. 2025

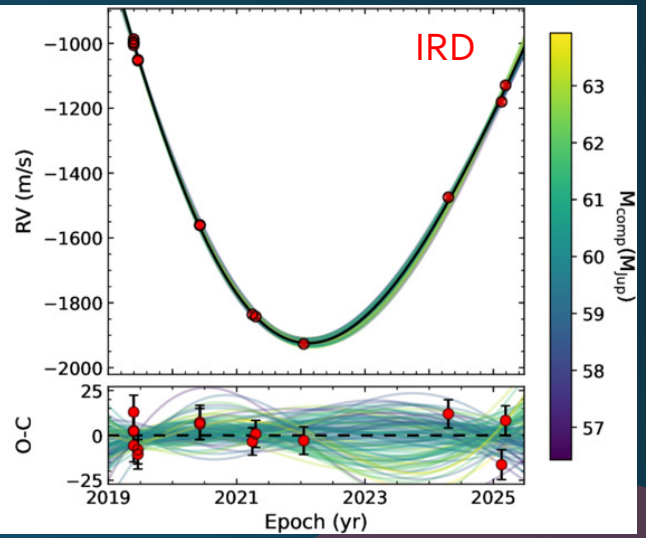
A BD (late-T-dwarf) companion around a Nearby (~17 pc) Mid-M-dwarf LSPM J1446+4633

Uyama et al. 2025



M_1=0.151M_{sun}
M_2=59.8M_{Jup}
a=4.297 au
e=0.122
i=85.3°



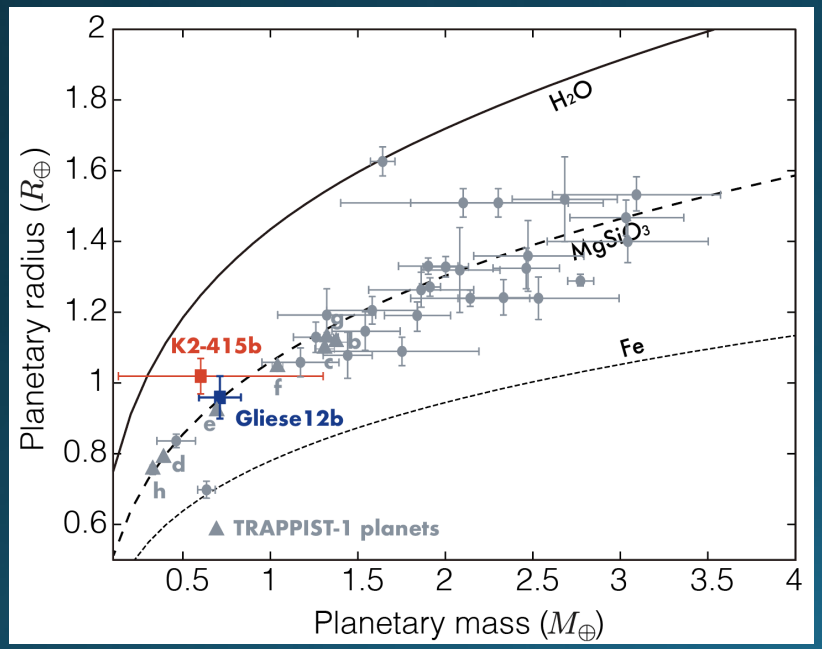


- Orbit determined by RV (IRD) + DI (NIRC2) + Gaia Acceleration
- Showing a ~30% variability in L'-band flux
  - Clouds, temperature variability, hot spot, aurorae?

A benchmark system to improve our understanding for cool dwarfs

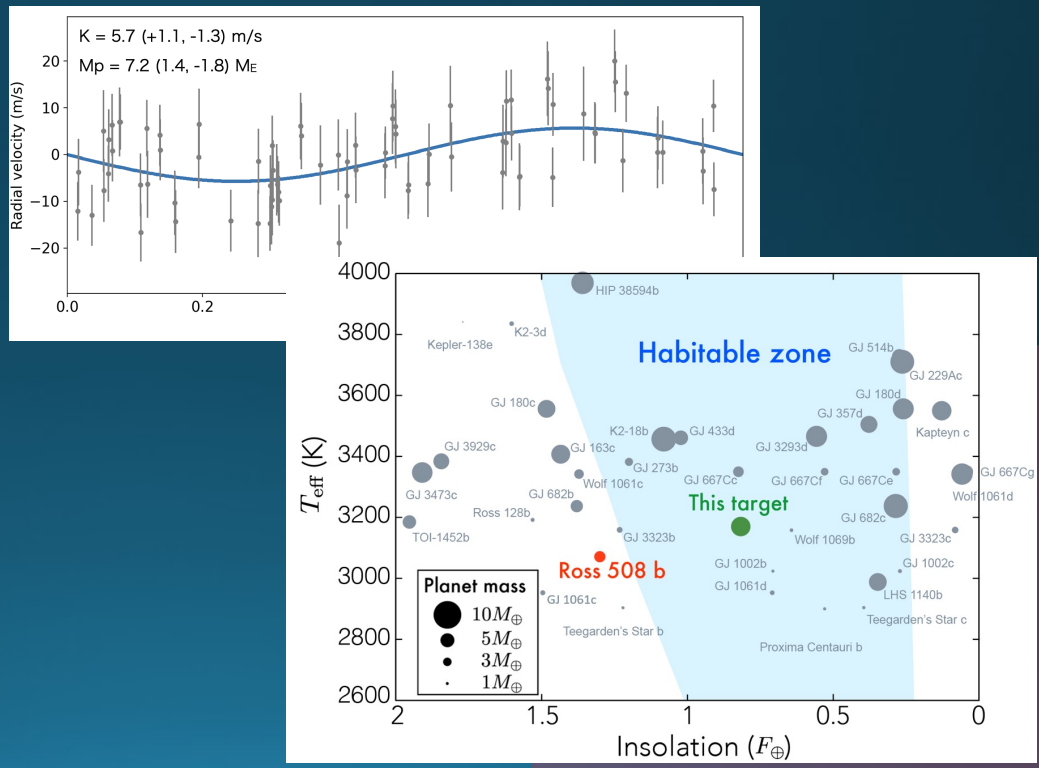
Follow-up observations for IRD-SSP planets and planet candidates

- Improving mass and eccentricity estimates for Earth-sized planets, GJ12b and K2-415b



w/ Subaru/IRD, Gemini/MAROON-X led by Kuzuhara (S25A & S25B accepted, S26A proposed)

- Confirming a super-Earth candidate in the HZ

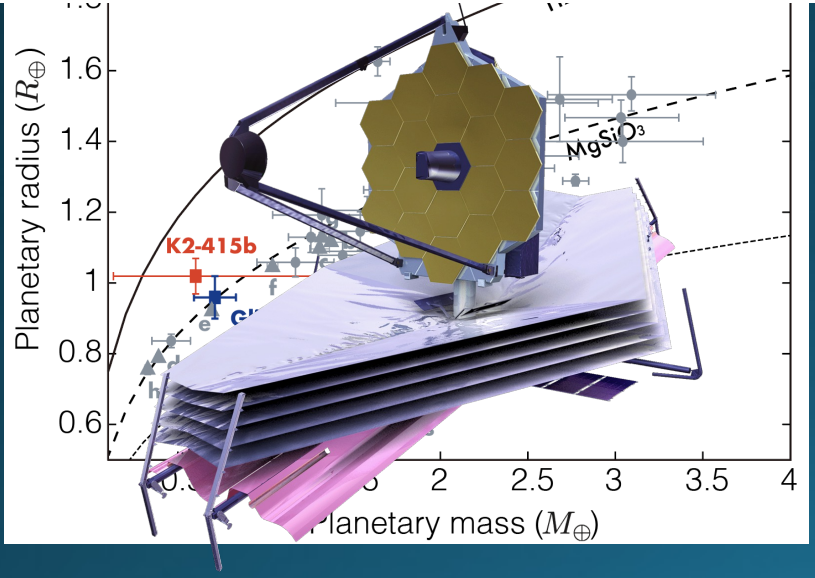


w/ Gemini/MAROON-X led by Kotani (S26A proposed)

Follow-up observations for IRD-SSP planets and planet candidates

- Improving mass and eccentricity estimates

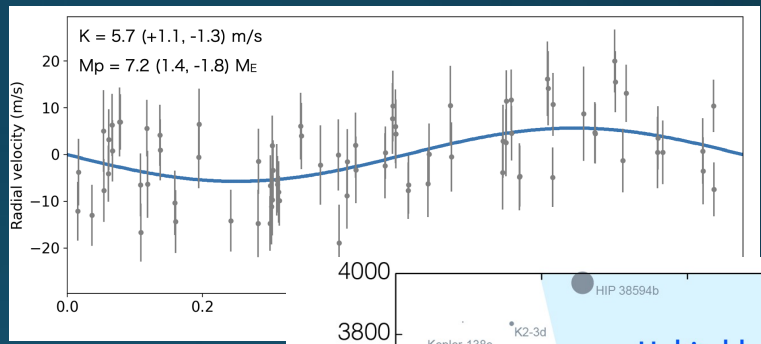
Good JWST targets for atmosphere spectroscopy

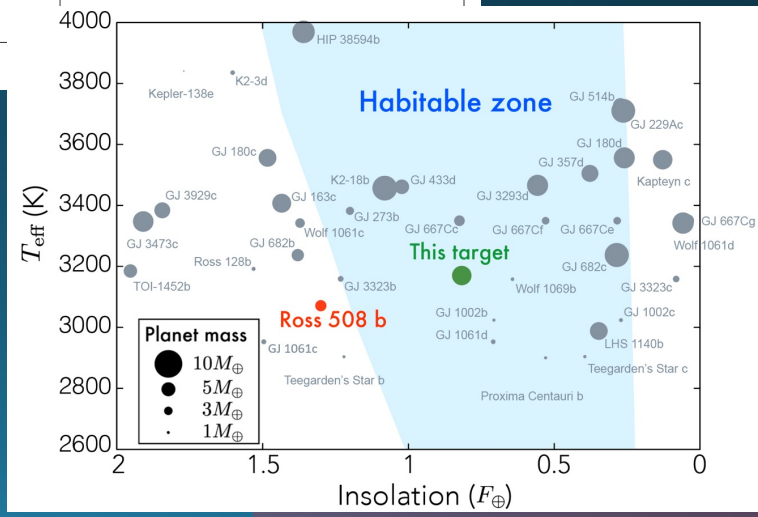


JWST image credit: NASA

w/ Subaru/IRD, Gemini/MAROON-X led by Kuzuhara (S25A & S25B accepted, S26A proposed)

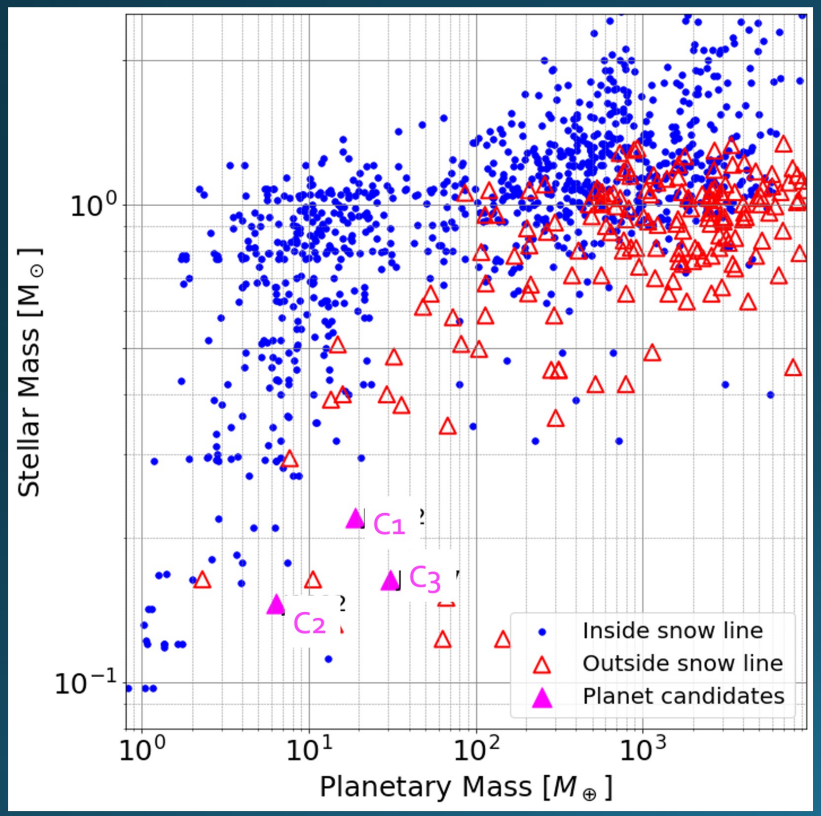
- Confirming a super-Earth candidate in the HZ



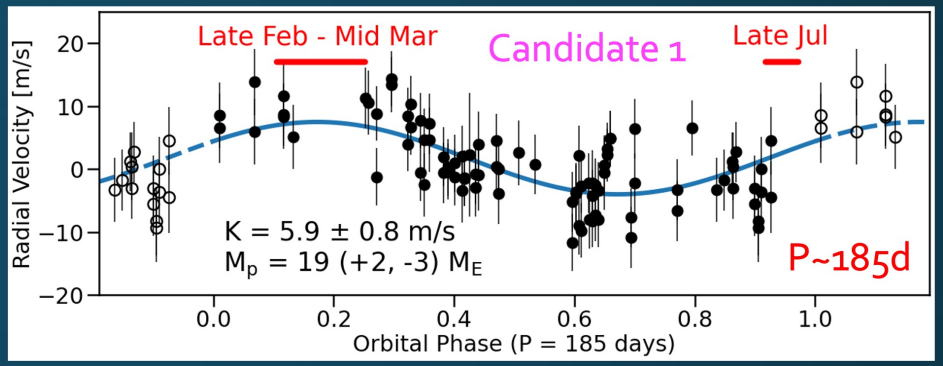


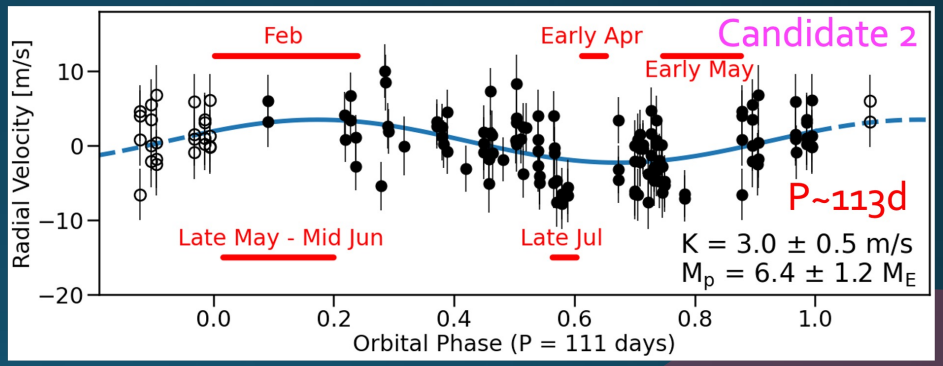
w/ Gemini/MAROON-X led by Kotani (S26A proposed)

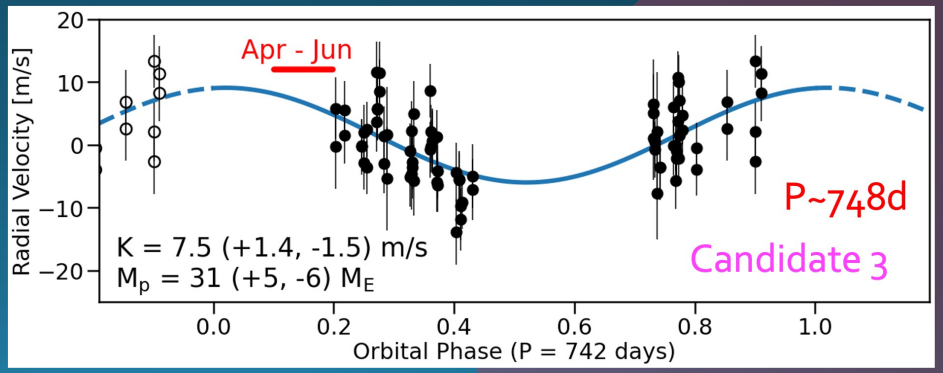
- Confirming planet candidates beyond snow lines, giant-planet forming regions, around lowest-mass M dwarfs



w/ Subaru/IRD led by Takarada (S26A proposed)







Papers in planning

- Magnetic activity of M dwarfs (activity indicator, line-profile analysis etc.)
- Binary study (orbital motion, dynamical mass, etc.) using FIM and RV data
- Atmospheric parameters and abundance analysis for IRD-SSP targets
- Development of calibration method for telluric lines using rapidly rotating stars taken with IRD
- Input catalog (target parameters, stellar activity, Hα intensity etc.)
- Spectral library (N1R spectra of IRD-SSP targets)
- RV data release paper (DR1, DR2)
- Follow-up works on known planet-host stars
- Statistical analysis (occurrence rate, distribution of planets etc.) for IRD-SSP targets
- .....

Thank you for your attention!