Search for Planets like Earth around Late-M Dwarfs: Precise Radial Velocity Survey with IRD

PI: Bun'ei Sato (Tokyo Institute of Technology)
Co-PI: Nagayoshi Ohashi (NAOJ, Subaru)

E. Akiyama[1], W. Aoki[2], C. Beichman[3], T. Brandt[4], G. Cataldi[5], C. Clergeon[5], T. Currie[5], R. Dong[6], Y. Fujii[7,8], H. Fujiwara[5], A. Fukui[2], H. Genda[7,8], T. Groff[9], O. Guyon[5,10,11], D. Hall[31], H. Harakawa[2], J. Hashimoto[2,11], Y. Hayano[2], M. Hayashi[2], K. G. Hełminiak[12], T. Henning[13], T. Hirano[8], K. Hodapp[31], Y. Hori[2,11], Y. Ikeda[14], S. Inutsuka[24], H. T. Ishikawa[21], M. Ishizuka[15], H. Izumiura[2], S. Jacobson[31], M. Janson[17], N. Jovanovic [23], E. Kambe[2], H. Kawahara[15], T. Kodama[15], Y. Koizumi[8], E. Kokubo[2], M. Konishi[2,11], T. Kotani[2,11], T. Kudo[2], T. Kurokawa[2,11], N. Kusakabe[2,11], M. Kuzuhara[2,11], J. Kwon[16], C. Lee[5], J. Livingston[15], M. Machida[28], T. Matsuo[27], D. Mawet[23], M. McElwain[9], V. Meadows[29], E. Mieda[5], T. Mizuki[16], J. Morino[2], T. Nagata[20], T. Nakagawa[16], T. Nakajima[2,11], N. Narita[15], J. Nishikawa[2,11,21], S. Nishiyama[18], H. Nomura[8], M. Ogihara[2], D. Oh[25], M. Omiya[2,11], S. Oshino[2], T. Pyo[5], E. Serabyn[3], M. Sitko[19], H. Suto[2,11], R. Suzuki[2], Y. Takagi[5], H. Takami[2], T. Takarada[8], N. Takato[2], M. Tamura[2,11,15], Y. Tanaka[30], H. Terada[2], R. A. Torres[17], E. L. Turner[22], A. Ueda[2], T. Usuda[2], T. Uyama[15], S. Vievard[5], J. Wang[23], J. Wisniewski[26], and Y. Yang[21]

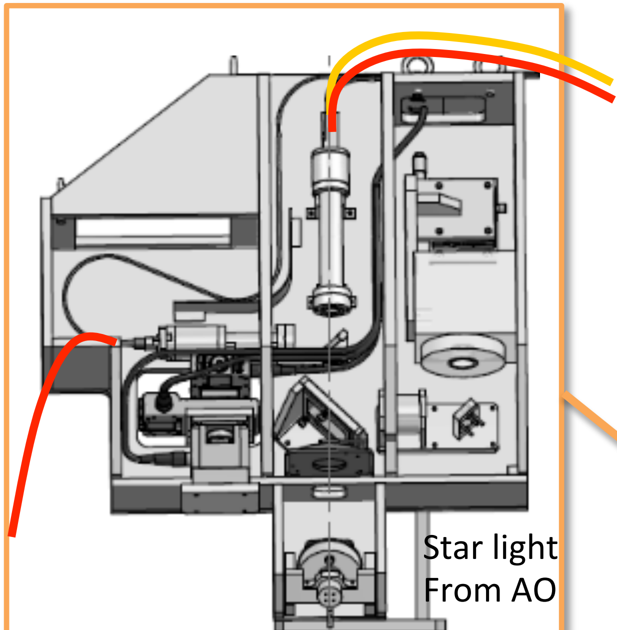
1. Hokkaido University; 2. NAOJ; 3. JPL/Caltech; 4. UC Santa Barbara; 5. Subaru Telescope; 6. University of Victoria; 7. ELSI; 8. Tokyo Institute of Technology; 9. NASA Goddard; 10. University of Arizona; 11. Astrobiology Center, NINS; 12. Nicolaus Copernicus Astronomical Center; 13. MPIA; 14. Photocoding; 15. University of Tokyo; 16. ISAS/JAXA; 17. Stockholm University; 18. Miyagi University of Education; 19. Space Science Institute; 20. Kyoto University; 21. SOKENDAI; 22. Princeton University; 23. Caltech; 24. Nagoya University; 25. National Meteorological Satellite Center; 26. University of Oklahoma; 27. Osaka University; 28. Kyushu University; 29. University of Washington; 30. TUAT; 31. University of Hawaii, IfA

Summary

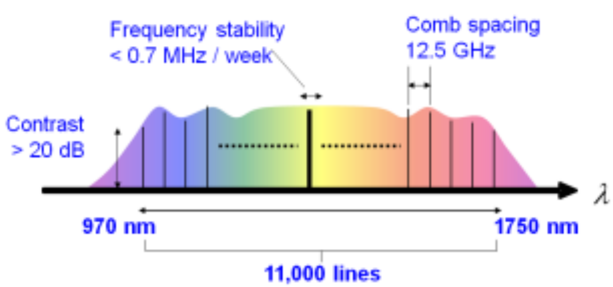
- InfraRed Doppler instrument (IRD)
  - A high-dispersion (R=70,000) near-infrared spectrograph for Subaru telescope
  - Currently RV precision of ~2 m/s is achievable for M dwarfs

- IRD-SSP
  - Aiming at detecting earth-mass (~1-3M_{earth}) planets in habitable zone around late-M dwarfs, and unveiling planet population in wide range of mass and orbit around late-M dwarfs
  - We expect to find ~60 planets in 60 sample stars by 5-year (175 nights; 35 nights/year) survey.
  - The first-two-year survey (19A-20B; 70 nights) is now officially approved.
  - Observations have been conducted almost every month since this February.
  - The first screening observation is now ongoing.

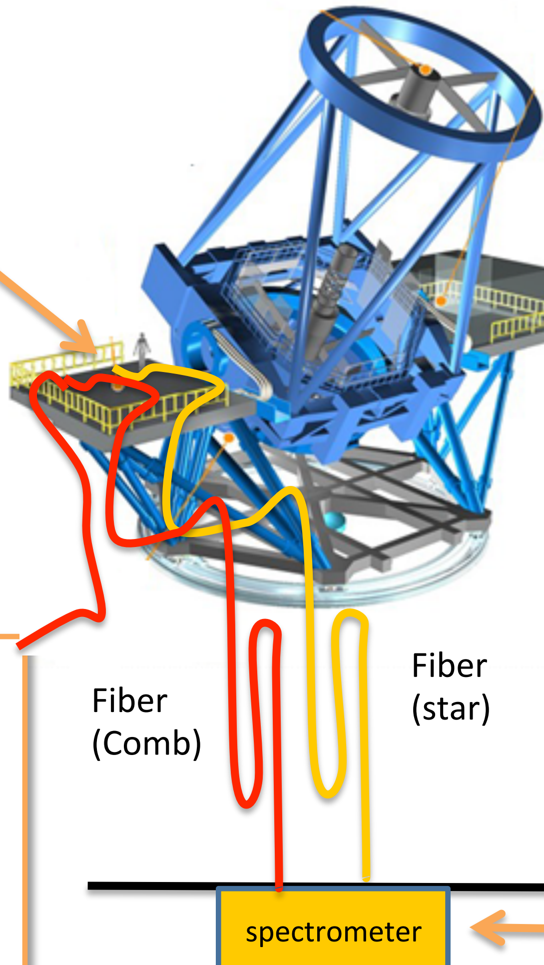
Overview of the IRD instrument



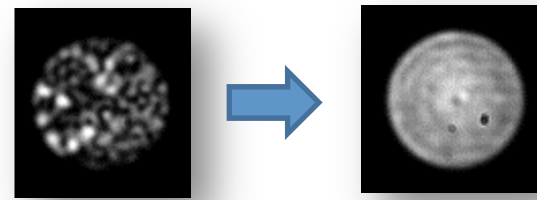
Fiber injection system
(AO bench)



Laser frequency comb
(IR Observing floor)



Coudé Room

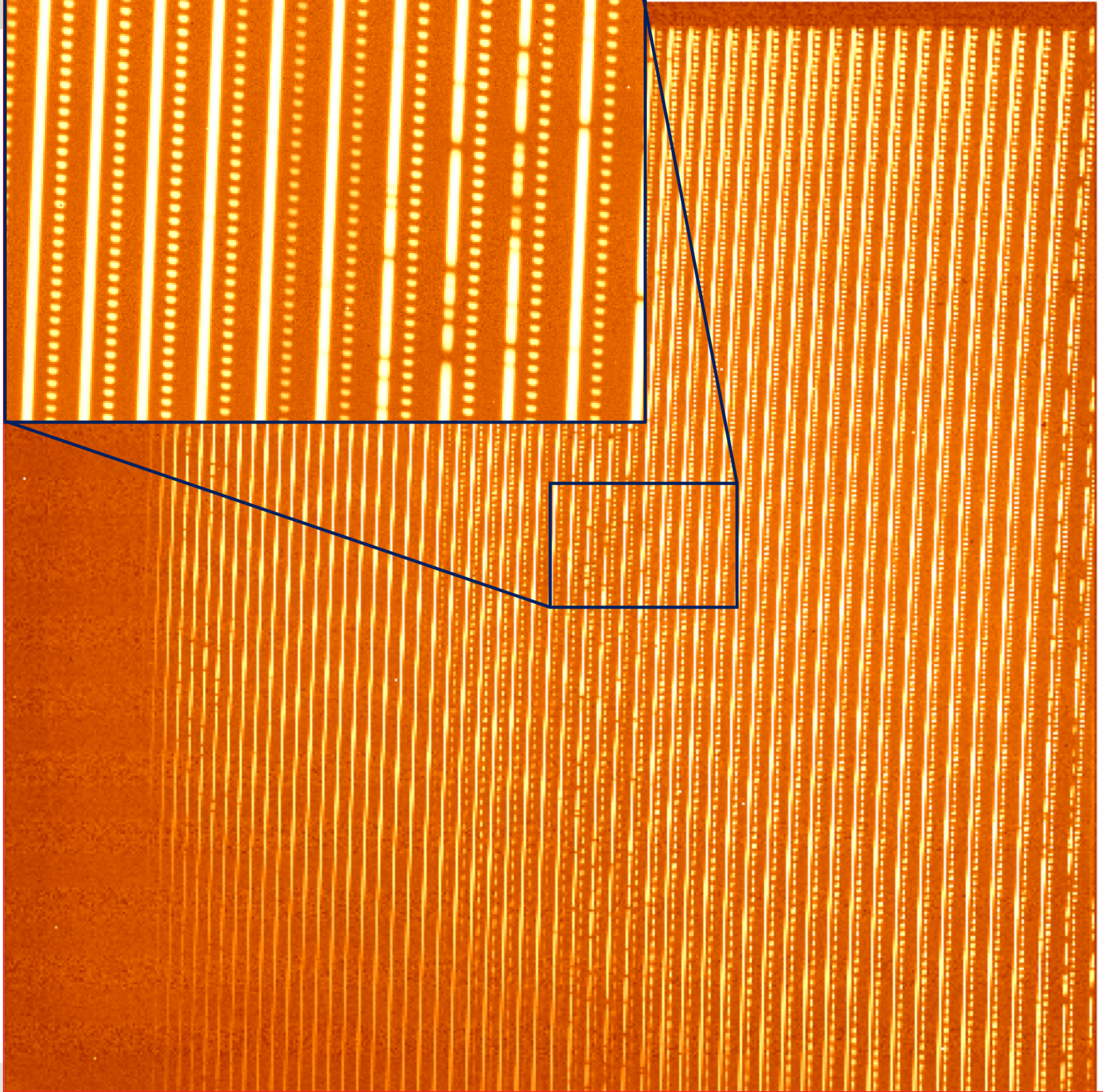


Mode scrambler

Resolution: R=70000
Wavelength: 0.97-1.75um
Cryo: 80K (detector), 180K (optics)

Spectrometer system
(Coudé room)

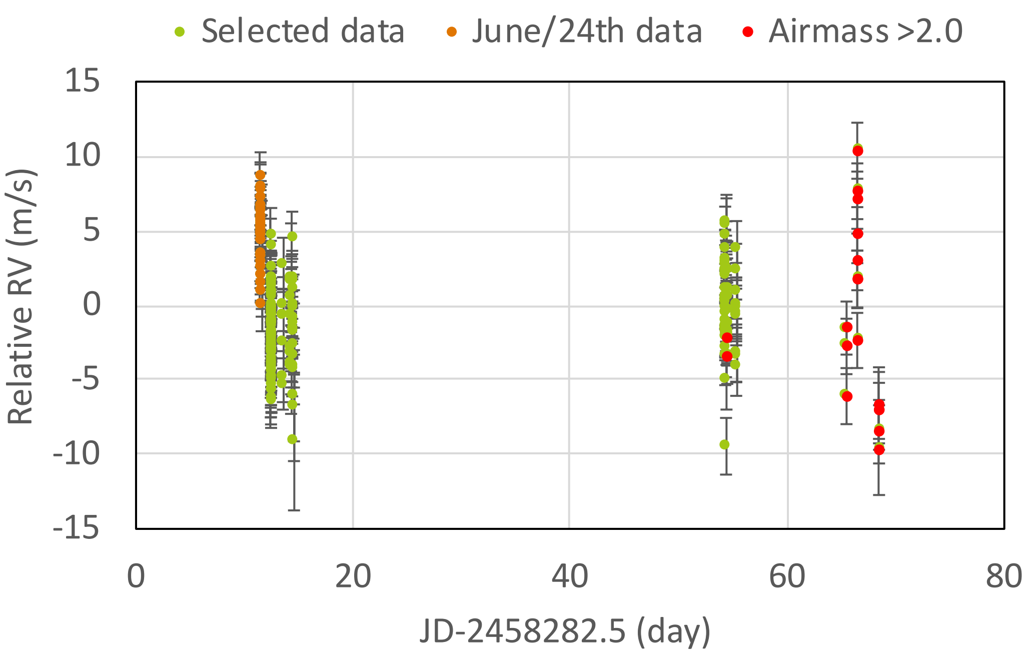
GJ 436
(M3V)

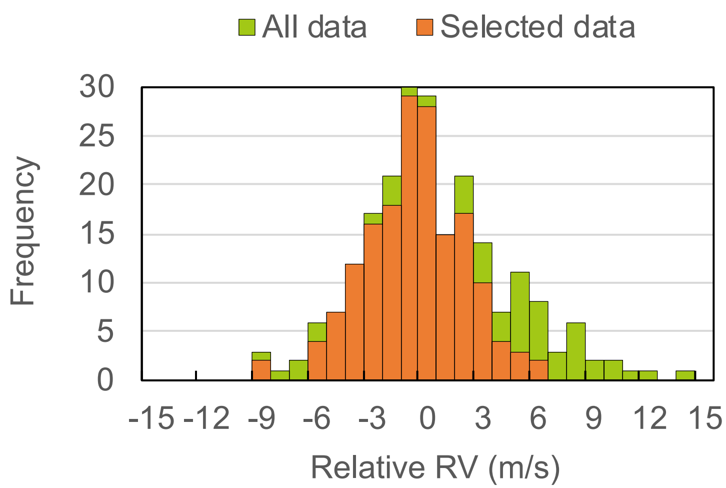


July, 2018

RV precision and stability

- Long-term monitoring of Barnard's star (GJ699; M4V)

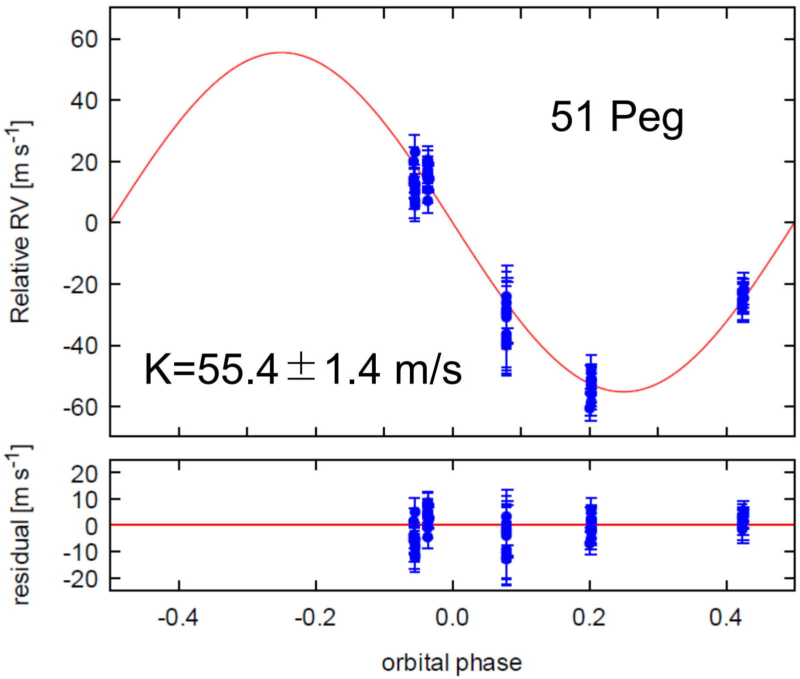


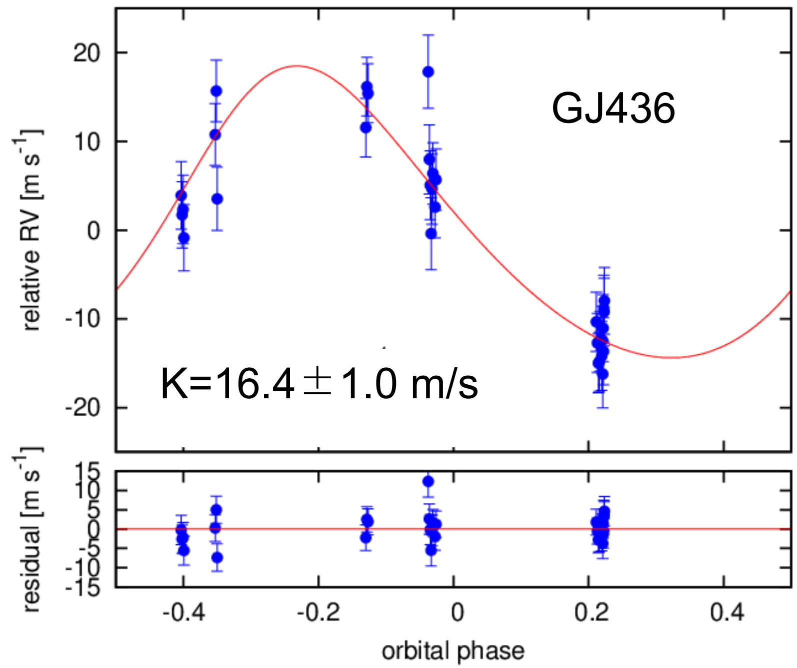


	Total error	Internal error	Instrument + activity error
All data	4.1 m/s	1.8 m/s	3.7 m/s
Selected data	2.7 m/s	1.8 m/s	2.0 m/s

※SN~170

RV monitoring of planet-host stars





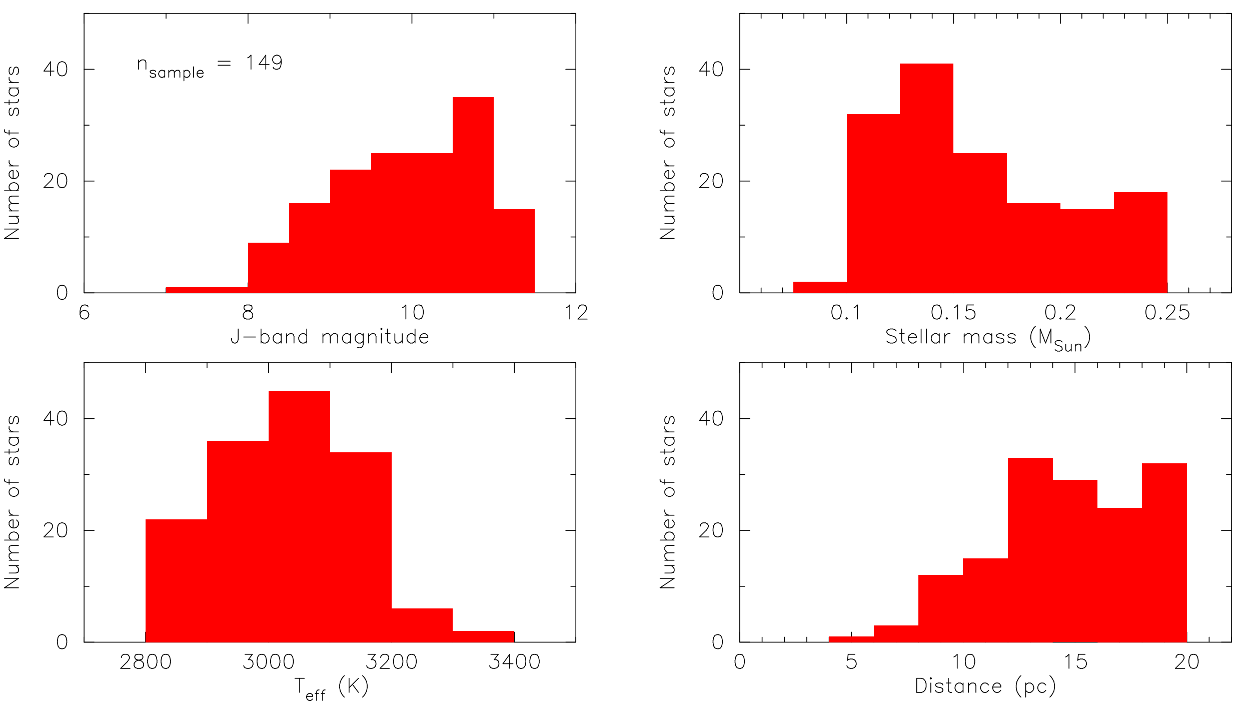
	51 Peg	GJ436
Spectral type	G2IV	M3V
Planet mass ($m_p$sin i)	0.466 M_{Jup}	21.36 M_{Earth}
Period	4.23	2.644
K (m/s)	55.4 ± 1.4 (IRD) 54.93 ± 0.18 (Birkby et al. 2017)	16.4 ± 1.0 (IRD) 17.38± 0.17 (Trifonov et al. 2018)

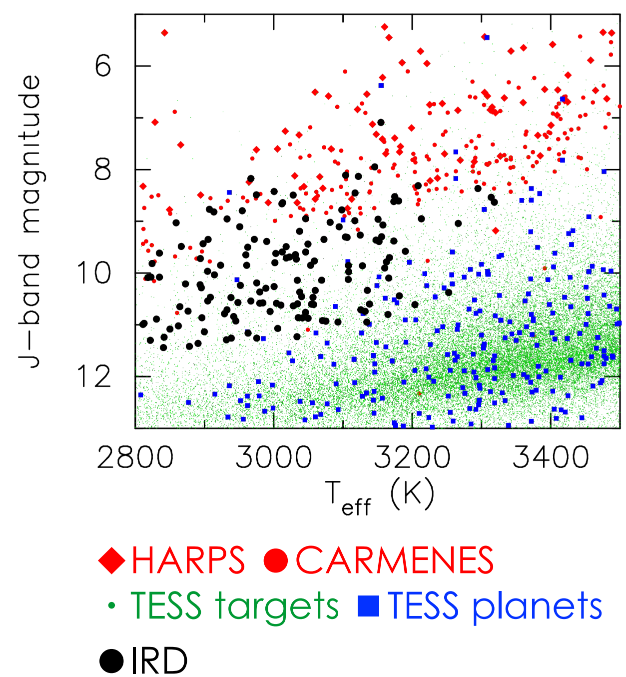
Purposes and goals of IRD-SSP

- Purposes
  - Detecting earth-mass (~1-3M_{Earth}) planets in habitable zone around nearby late-M dwarfs for future characterization
  - Understanding planet formation and evolution (e.g. orbital migration) across snow line by unveiling planet distribution in wide range of mass and orbit around late-M dwarfs
- Goals
  - Detecting a habitable-zone earth-mass planet around a late-M dwarf
  - Unveiling distribution of
    - earth-mass planets in P<100 d
    - super-earths in P<300 d
    - giant planets in P<1000 d across slow line

Sample

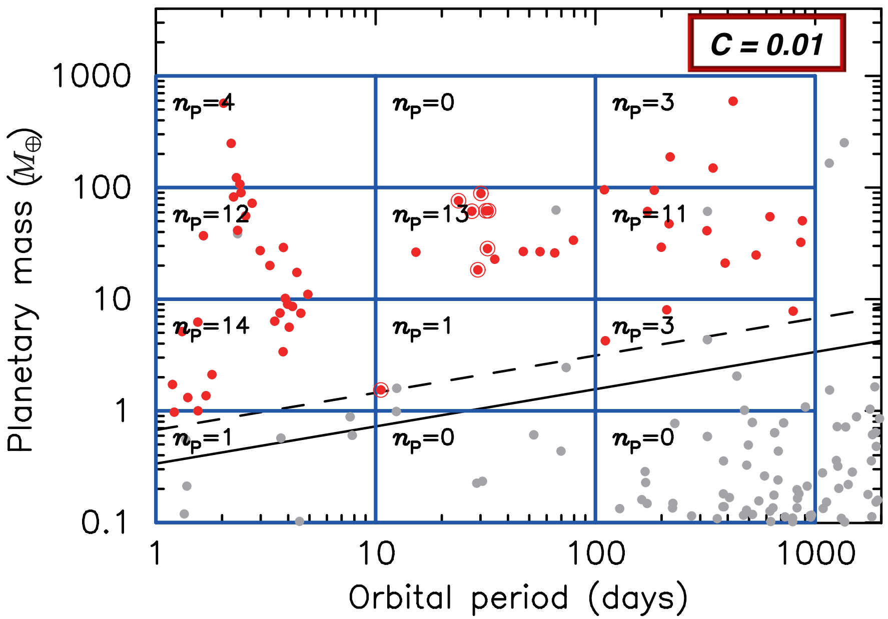
- D<25pc, M=0.08-0.25$_{\odot}$, J<11.5, no Ha emission
  ➔ 150 stars were selected by low-resolution spectroscopy
- Double-line spectroscopic binaries and rapid rotators will be screened out by initial observations with IRD
- Best 60 stars will be selected for IRD survey



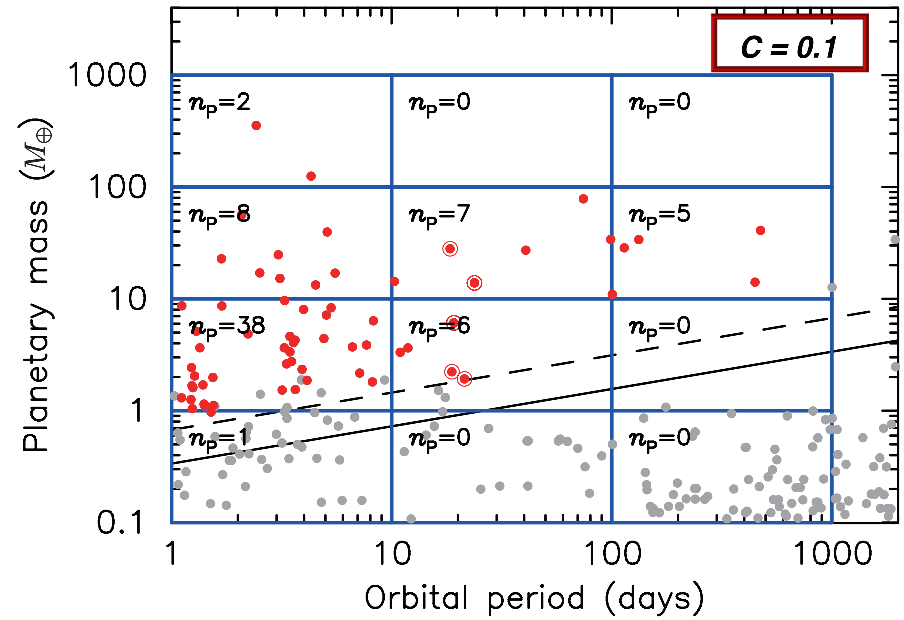


Simulation

Slow migration (Type-I)



Fast migration (Type-I)



- We expect to find ~60 planets in 60 stars by 175-nights observations.
- The number of the expected planets depend on adopted theoretical models of planet formation and evolution.

Summary of February – July 2019

- Allocated nights
  - 2/18(2nd), 19(2nd), 20(2nd), 21(2nd), 22(2nd), 23(2nd), 24(2nd)
  - 3/21(2nd), 22(2nd), 23(2nd)
  - 4/17(full), 18(2nd)
  - 5/18(1), 19(2), 20(2), 22(f), 24(1), 25(1), 26(1)
  - 6/15(f), 16(1st), 17(1st), 18(2nd), 19(2nd), 20(2nd), 21(2nd), 26(2nd)
  - 7/11(1st), 14(2nd)
- Cumulative allocated nights
  - 16.5 nights from S19A
- Rough success rate
  - ~77% (12.7/16.5nights)

Current progress of observation

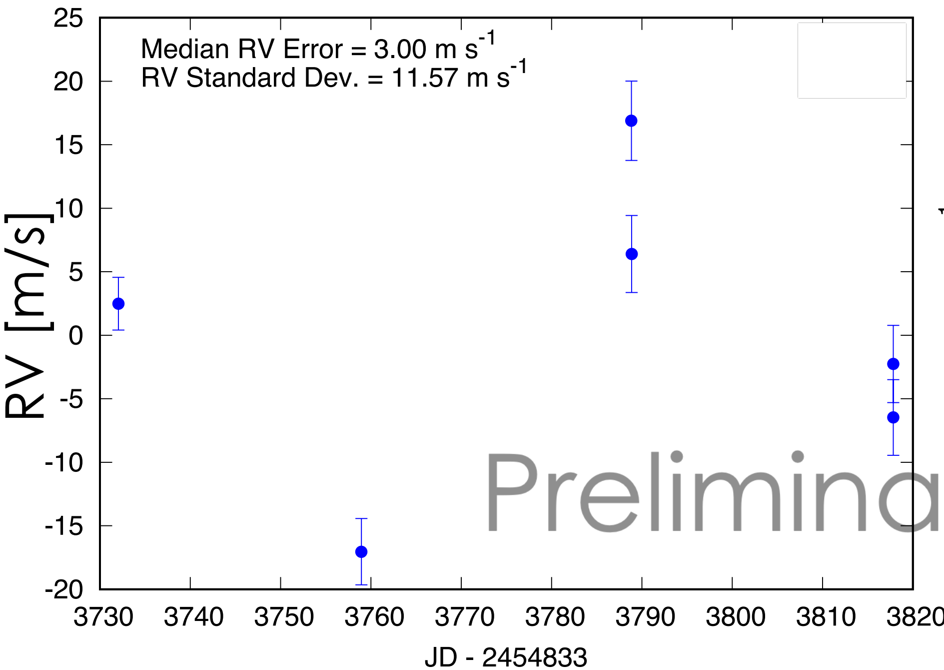
	observed stars
stars observed once	28
stars observed twice	16
stars observed 3 times	16
stars observe >3 times	11

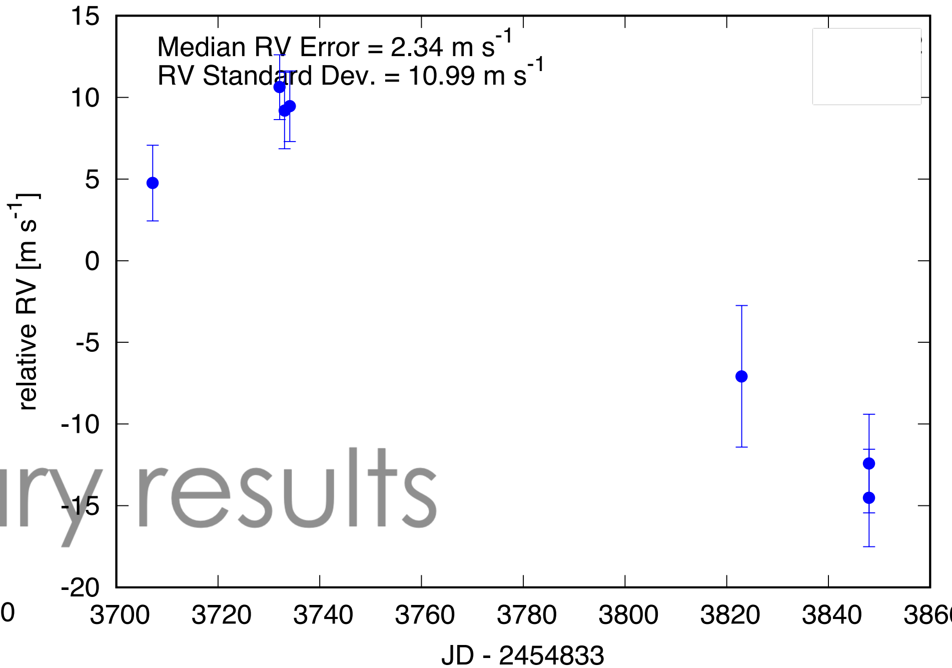
Numbers of Allocated nights and results in S19A

Month	Feb.	March	April
Allocated	3.5 nights	1.5 nights	1.5 nights
Observed	0.5 nights	~1.5 nights	~1.5 nights
Month	**May**	**June**	**July**
Allocated	4 nights	4.5 nights	1 nights
Observed	3.7 nights	~4 nights	1.5 nights

IRD Screening: Planet candidates?

- Moderately large (σ~12m/s) RV variations



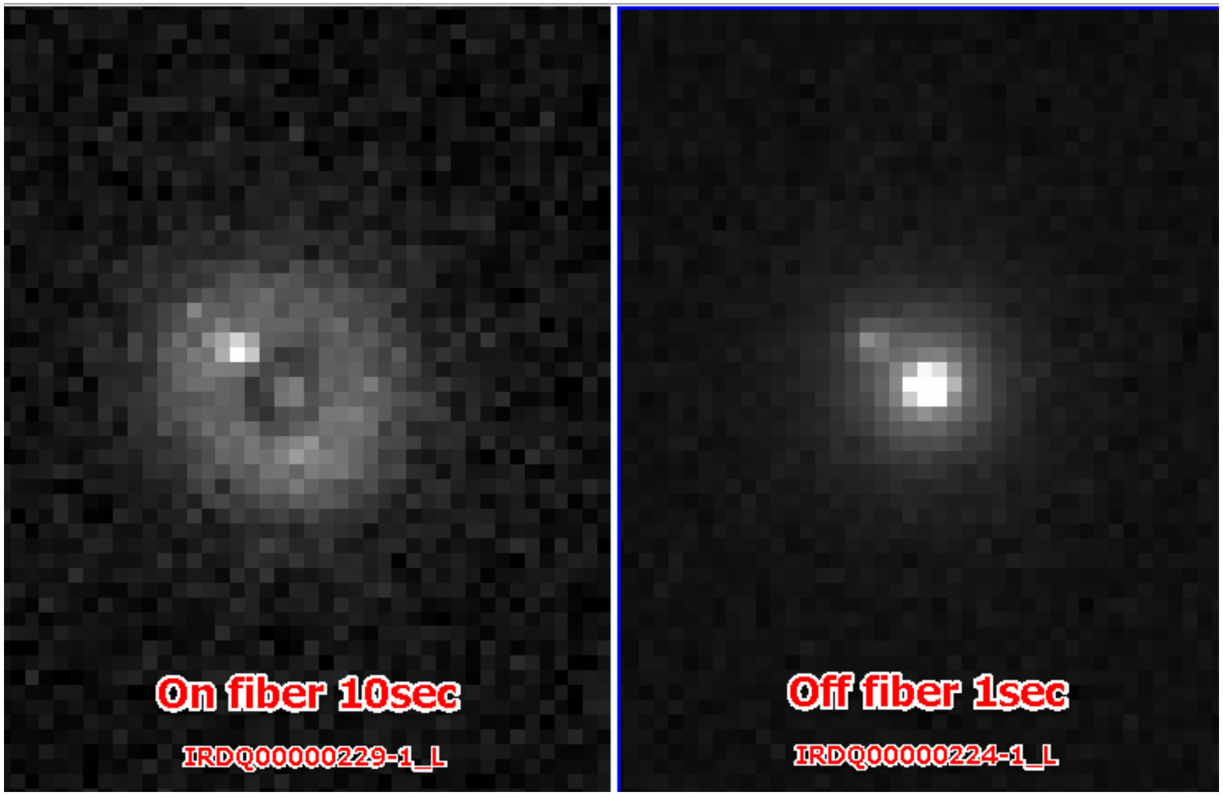


Preliminary results

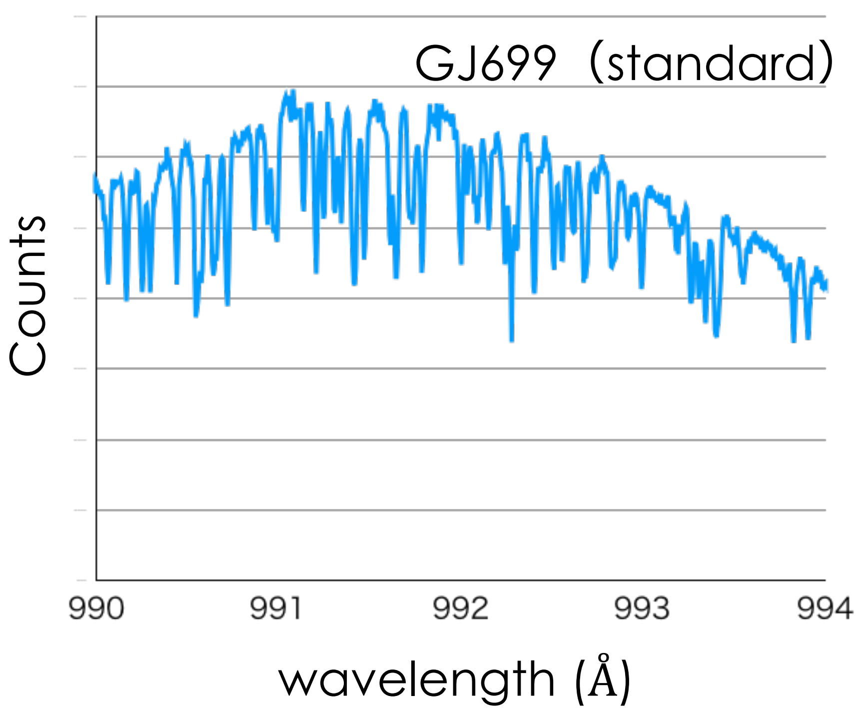
JD -2454833

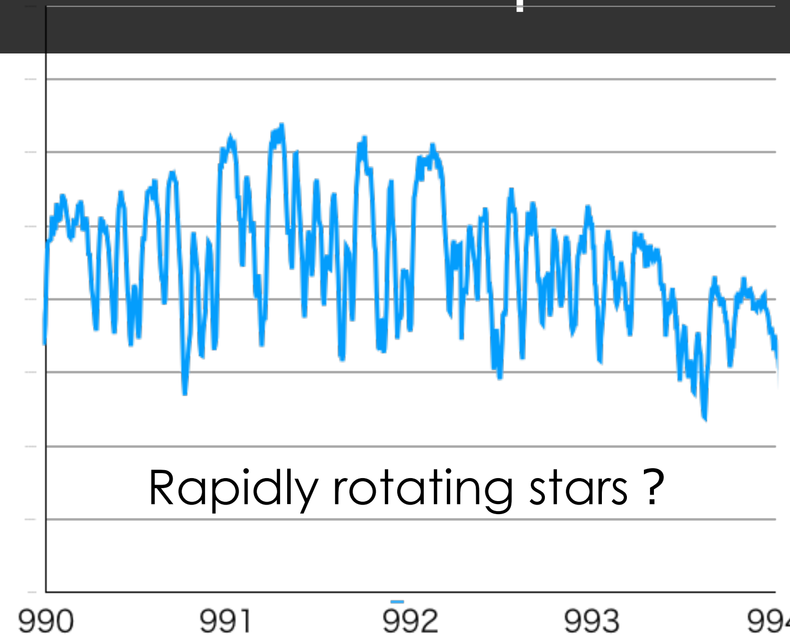
IRD Screening: AO images

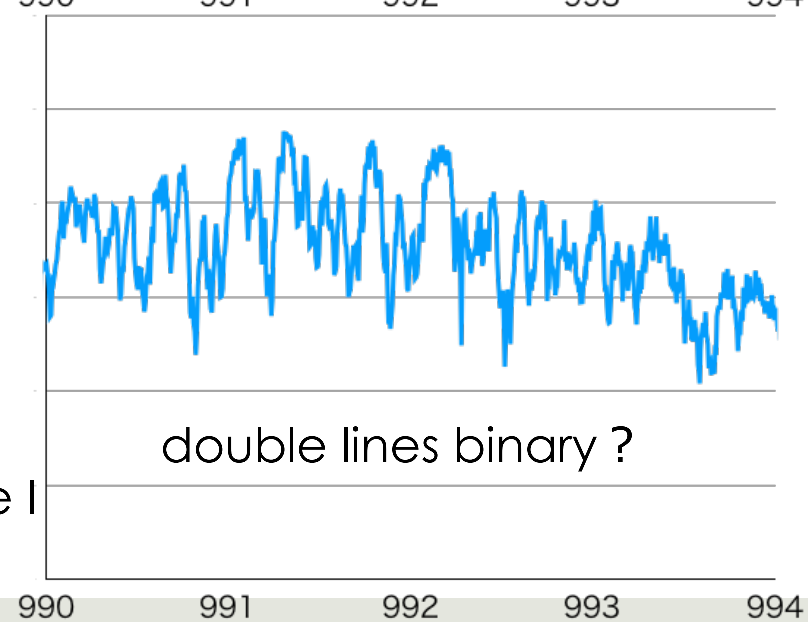
- To check existence of visual companions in the images of IRD-FIM
- e.g. A companion with contrast ratio 1:7 = M4 : M7
  - Angular separation = 0.2“, distance 17.7pc → 3.5AU (P~13.5yr)



IRD Screening: Spectral shape

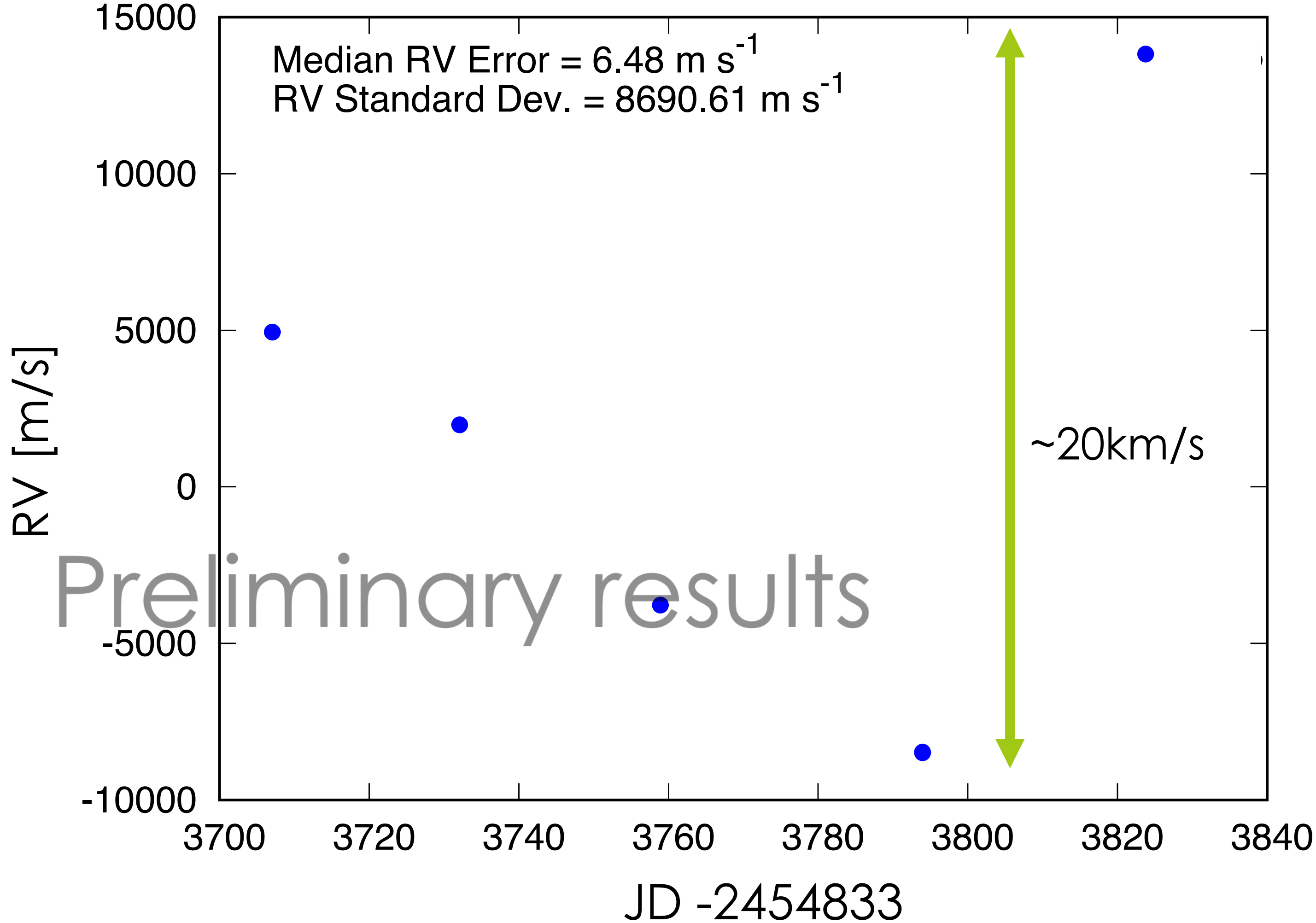






From HR spectra we also check
- Activity indicators (line shape, Pachen, He I
- Metallicity

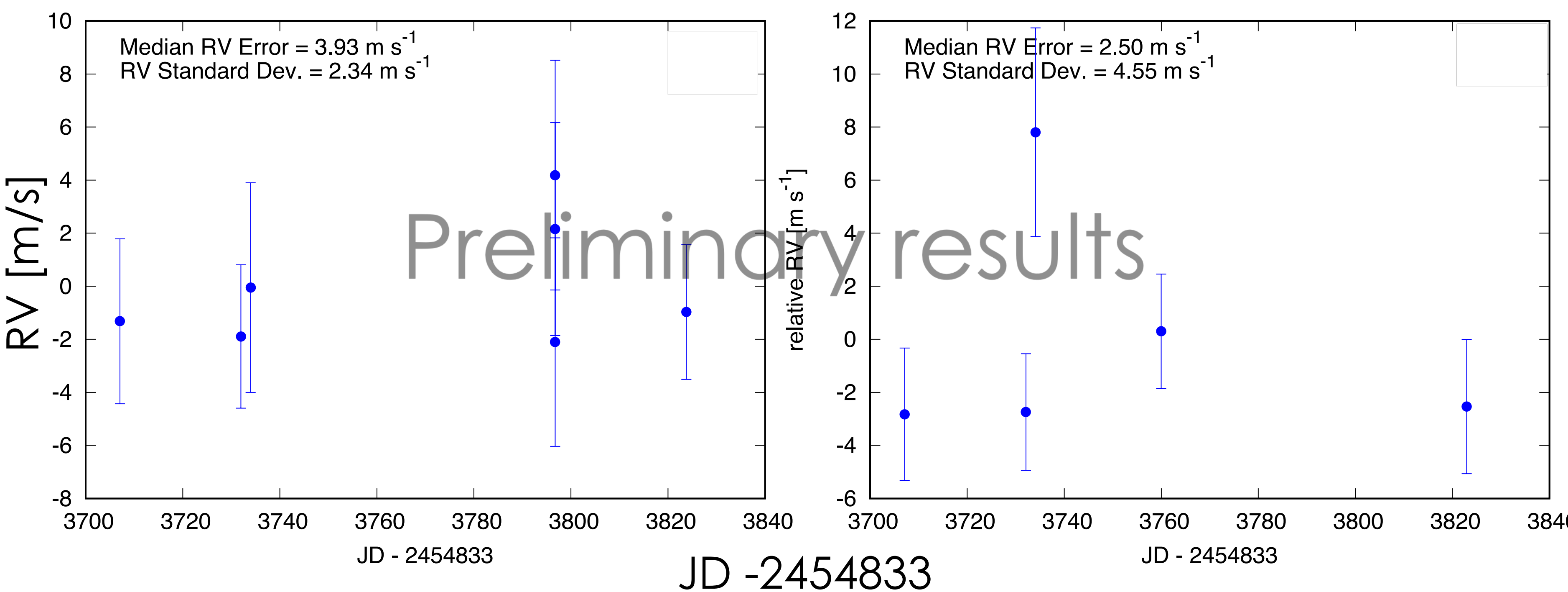
IRD Screening: Spectroscopic binary



IRD Screening: Target candidates

- NOT visual binary
- NOT spectroscopic binary
- Rotation is slow
- Small RV jitter

→ Long term RV monitor to search for planets



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