An update on MAROON-X

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Plus many collaborators and users

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MAROON-X

Primary Science Driver: EPRV measurements of Earth-sized exoplanets, particularly around M dwarfs.

Specifications: A highly-stabilized, fiber-fed spectrograph covering 500 – 920 nm at R 85,000 with simultaneous calibration, and a sky fiber.

Status: Commissioned in 2019, in regular operations since May 2020, and offered to the community.

Performance: 30 cm/s precision and reach to late M dwarfs as faint as m_V=19.

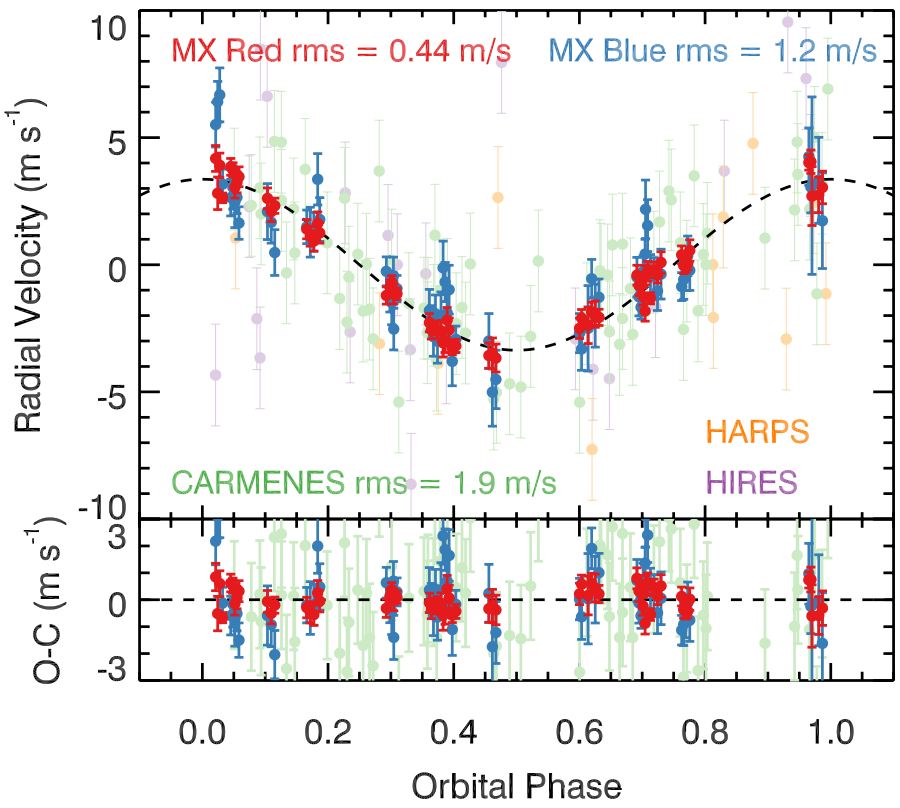
More Info: Seifahrt+ 2016, 2018, 2020, 2022 SPIE

Extreme Precision Radial Velocity instrument at Gemini-N

You should know about MAROON-X

- **MAROON-X is a Gemini "Transition Instrument"**, operations is like a Visitor Instrument but the Observatory is committed to taking ownership
- **MAROON-X is not on the telescope all the time**, ~150 nights per year in six blocks of 1 – 5 weeks each
- **MAROON-X time on the telescope is driven partially by demand**, **~**600 hours of Band 1-2 time allocated over the past year
- **Gemini is open access (through the US system) and queue scheduled, has Fast Turnaround and Bad Weather programs**
- **We currently perform all data reduction and can provide radial velocities from a template-matching code (SERVAL)**
- **The MAROON-X team is very small and we welcome new users and collaborators**

MAROON-X performance



Data taken in May 2020 yield a precise mass measurement of Gl 486 b

$K = 3.4 \pm 0.1$ m s^{-1}
$M_p = 2.8 \pm 0.12\ M_{earth}$ ($\sigma < 5\%$)

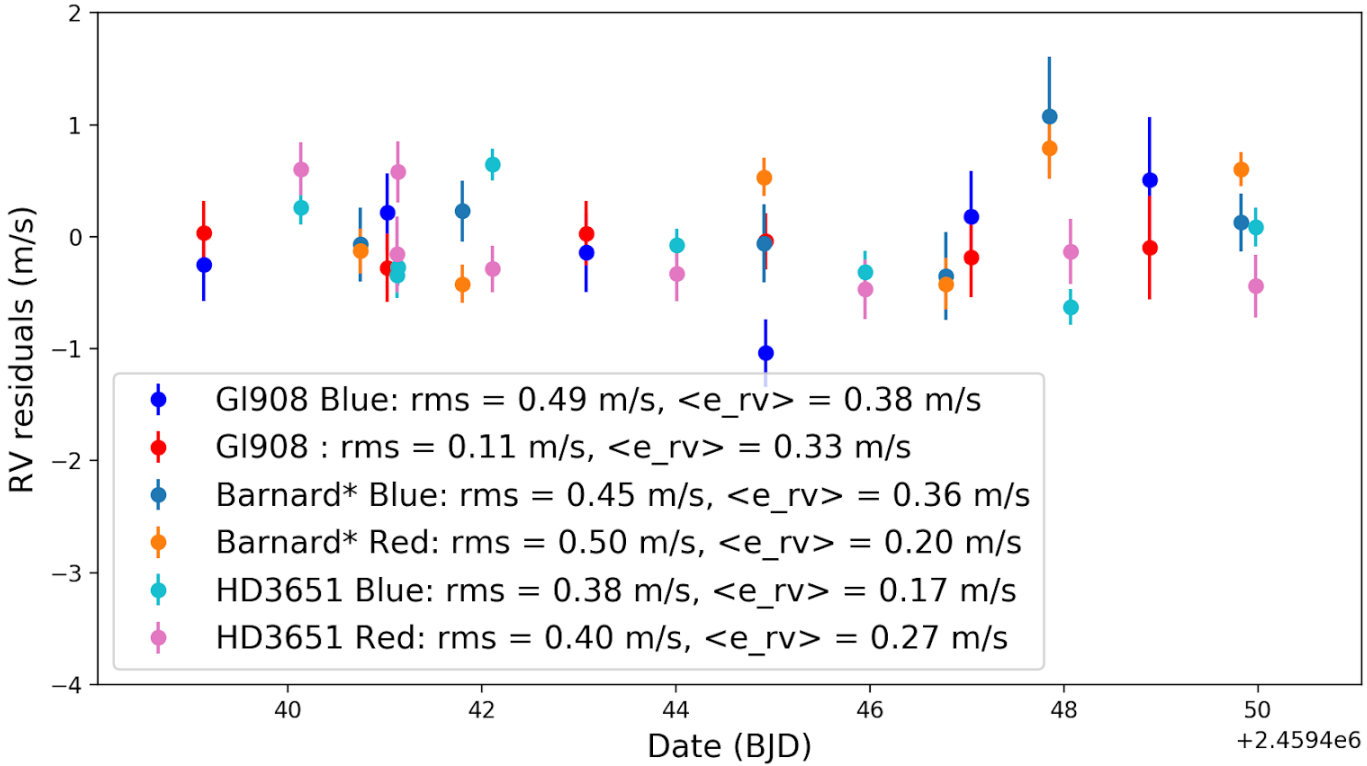
No detrending!

Red + blue residuals bin down to **30 cm s^{-1}** over 30 minutes

Planet consistent with an Earth-like core mass fraction to high precision

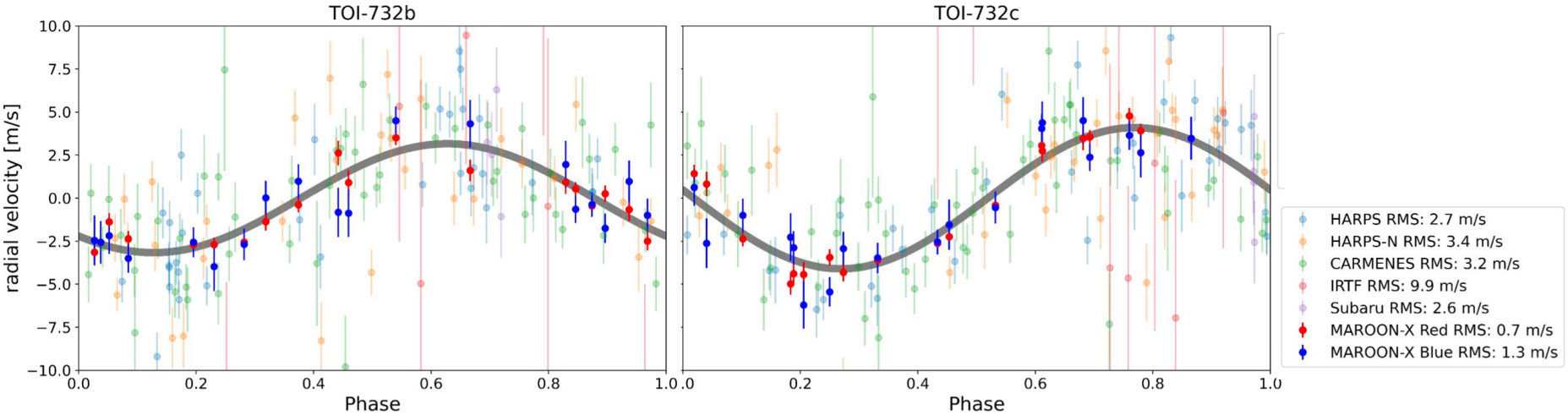
Trifonov+ 2021, Science
Caballero+ 2022, A&A

Short-term performance is excellent



Radial velocity follow up of transiting planets

- **All *TESS* M dwarfs within 30 pc and observable from Mauna Kea**
- Requirement: relative mass errors to at least 10%, goal is 5%
- Objectives: statistical constraints on the mass-radius relationship and mass function for M dwarf planets; detection of additional planets; enabling JWST atmospheric characterization



Brady+ in prep

Short-term performance is excellent

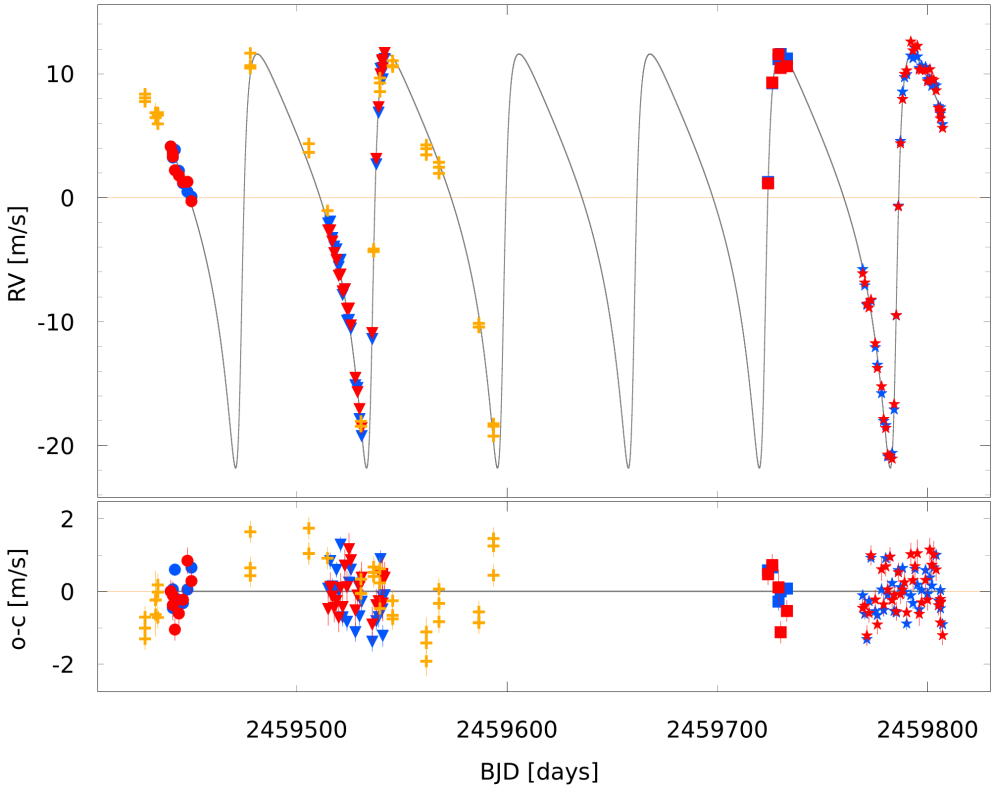
MAROON-X calibration strategy tying together etalon, ThAr and Iodine.

Results when fitting the orbit with NEID and MAROON-X data:

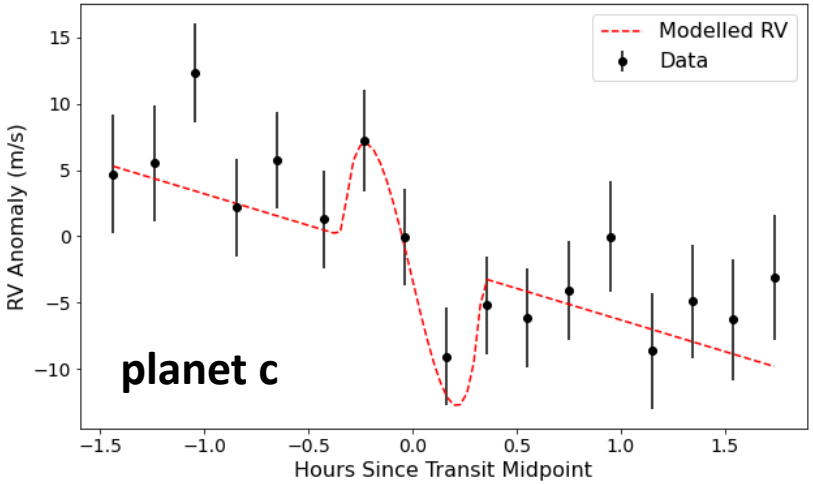
NEID (2021):	0.86 m/s
MAROON-X blue (2021):	0.63 m/s
MAROON-X blue (2022):	0.56 m/s
MAROON-X red (2021):	0.38 m/s
MAROON-X red (2022):	0.64 m/s

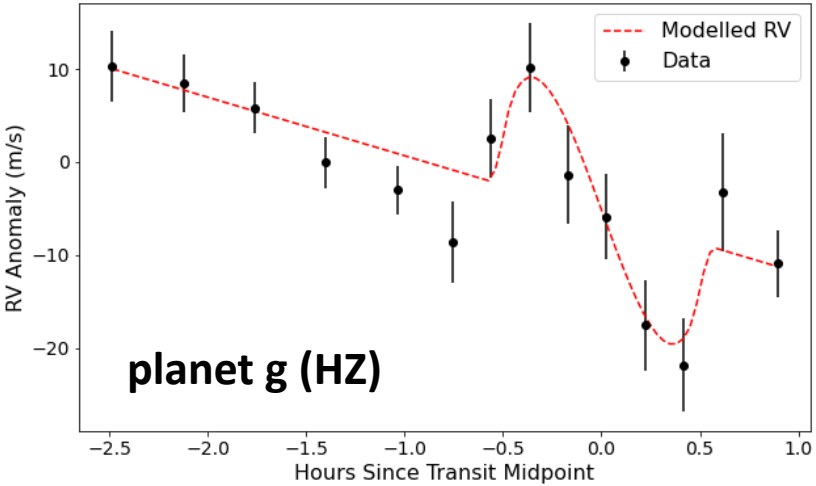
Run-to-run offset uncertainty of ~0.5-1.0 m/s will persist until the installation of a Laser Frequency Comb

HD 3651 (K1V)



Spin-orbit alignment of the TRAPPIST-1 planets





Brady+ ApJ accepted

- Preliminary results constrain $\lambda = 0° \pm 10°$
- Challenging observations due to the m_V =18.8 mag host star, short (~1 hour) transit durations, and 5-10 m/s signal
- Red arm data only, no signal in the blue arm

Atmospheric characterization at high resolution

KELT-9b (Kasper+ 2021)