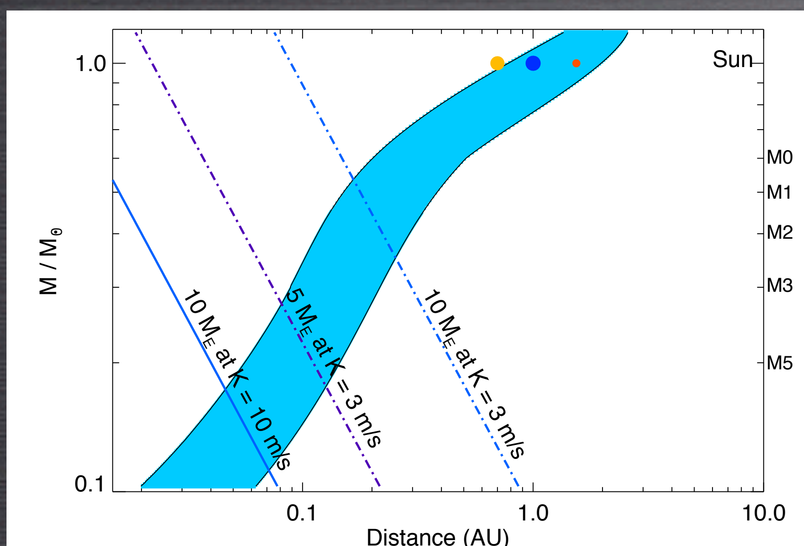
SIG #1: Towards A much Needed Consensus in the Exoplanet Community



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Key Science Questions

- Which of the nearest stars host Earth and super Earth planets in their HZs, and what is the architecture of these planetary systems? Which of them transit?
- What are the atmospheric compositions/signatures of Earth and super-Earth planets, Neptunes, and Jupiter analogues?
- What is the atmospheric composition/signatures of an Earth-size planet in HZs, and what are the bio-signatures? How common are planets with bio-signatures?

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Needs long term, high precision RV capability, preferably with a single instrument, to detect planets. RVs provide masses of transiting planets.

Mission	Target identification for mission science yield optimization	Follow-up validation & characterization of low mass transiting exoplanets	Exoplanet mass & orbit determination
Kepler		✓	✓
K2	✓	✓	✓
TESS	✓	✓	✓
JWST	✓	✓	✓
AFTA/probe Coronagraph or Starshade direct imaging	✓		✓
Future Flagship direct imaging	✓		✓

- Plavchan et at. SAG Draft Report, Table 1.

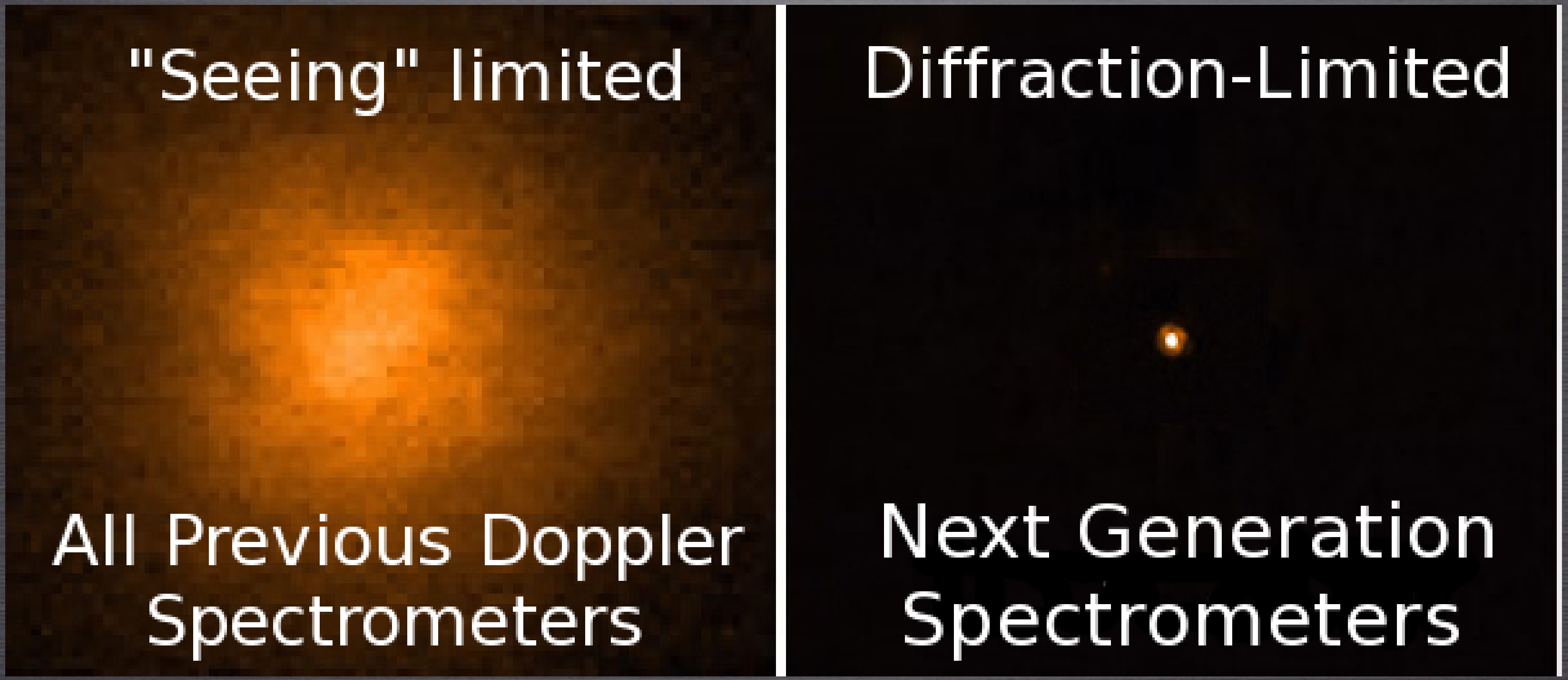
Table 1 | Non-exhaustive table of present (active) and future (approved) high-precision Doppler velocimeters

Instrument/technique	Telescope/observatory	Start of operations	Band (μm)	Spectral resolution	Efficiency (%)	Precision (m s^{-1})
Hamilton[180]/self-calibration	Shane 3 m/Lick	1986	0.34–1.1	30,000–60,000	3–6	3
UCLES[181]/self-calibration	3.9-m AAT/AAO	1988	0.47–0.88	~100,000	NA	3–6
HIRES[12]/self-calibration	Keck I/Mauna Kea	1993	0.3–1.0	25,000–85,000	6	1–2
CORALIE[13]/sim. reference	EULER/ESO La Silla	1998	0.38–0.69	60,000	5	3–6
UVES[182]/self-calibration	UT2–VLT/ESO Paranal	1999	0.3–1.1	30,000–110,000	4–15	2–2.5
HRS[183]/self-calibration	HET/McDonald	2000	0.42–1.1	15,000–120,000	6–9	3–6
HDS[184]/self-calibration	Subaru/Mauna Kea	2001	0.3–1.0	90,000–160,000	6–13	5–6
HARPS[18]/sim. reference	3.6 m/ESO La Silla	2003	0.38–0.69	115,000	6	< 0.8
FEROS-II[185]/sim. reference	2.2 m/ESO La Silla	2003	0.36–0.92	48,000	20	10–15
MIKE[186]/self-calibration	Magellan II/Las Campanas	2003	0.32–1.00	65,000–83,000 and 22,000–28,000	20–40	5
SOPHIE[187]/sim. reference	1.93 m/OHP	2006	0.38–0.69	39,000 and 75,000	4 and 8	2
CRIRES[188]/self-calibration	UT1–VLT/ESO Paranal	2007	0.95–5.2	~100,000	15	5
PFS[189]/self-calibration	Magellan II/Las Campanas	2010	0.39–0.67	38,000–190,000	10	1
PARAS[190]/sim. reference	1.2 m/Mt. Abu	2010	0.37–0.86	63,000	NA	3–5
CAFE[191]/sim. reference	2.2 m/Calar Alto	2011	0.39–0.95	~67,000	25	20
CHIRON[192]/self-calibration	1.5 m/CTIO	2011	0.41–87	80,000	15	<1
HARPS-N[54]/sim. reference	TNG/ORM	2012	0.38–0.69	115,000	8	<1
LEVY[193]/self-calibration	APF/Lick	2013	0.37–0.97	114,000–150,000	10–15	<1
EXPERT-III[194]/NA	2-m AST/Fairborn	2013	0.39–0.9*	100,000*	NA	NA
GIANO[71]/self-calibration	TNG/ORM	2014	0.95–2.5	50,000	20	NA
SALT–HRS[195]/self-calibration	SALT/SAAO	2014	0.38–0.89*	16,000–67,000*	10–15*	3–4*
FIRST[194]/NA	2-m AST/Fairborn	2014	0.8–1.8*	60,000–72,000*	NA	NA
IRD[73]/sim. reference	Subaru/Mauna Kea	2014	0.98–1.75*	70,000*	NA	1*
NRES/NA	6 × 1-m/LCOGT	2015	0.39–0.86*	53,000*	NA	3*
MINERVA/self-calibration	4 × 1-m/Mt. Hopkins	2015	0.39–0.86*	NA (Kiwispec)*	NA	1*
CARMENES[72]/sim. reference	Zeiss 3.5-m/Calar Alto	2015	0.55–1.7*	82,000*	10–13*	1*
PEPSI[196]/sim. reference	LBT/Mt. Graham	NA	0.38–0.91*	120,000–320,000*	10*	NA
HPF[74]/sim. reference	HET/McDonald	NA	0.98–1.40*	50,000*	4*	1–3*
CRIRES+/self-calibration	VLT/ESO Paranal	2017	0.95–5.2*	~100,000*	15*	<5*
ESPRESSO[42]/sim. reference	All UTs–VLT/ESO Paranal	2017	0.38–0.78*	60,000–200,000*	6–11*	0.1*
SPIROU[76]/sim. reference	CFHT/Mauna Kea	2017	0.98–2.35*	70,000*	10*	1*
G-CLEF[43]/sim. reference	GMT/Las Campanas	2019	0.35–0.95*	120,000*	20*	0.1*

Optical & NIR RV Instrumentation: Pepe, Nature 2014

Really need northern hemisphere instruments being developed to push <1m/s

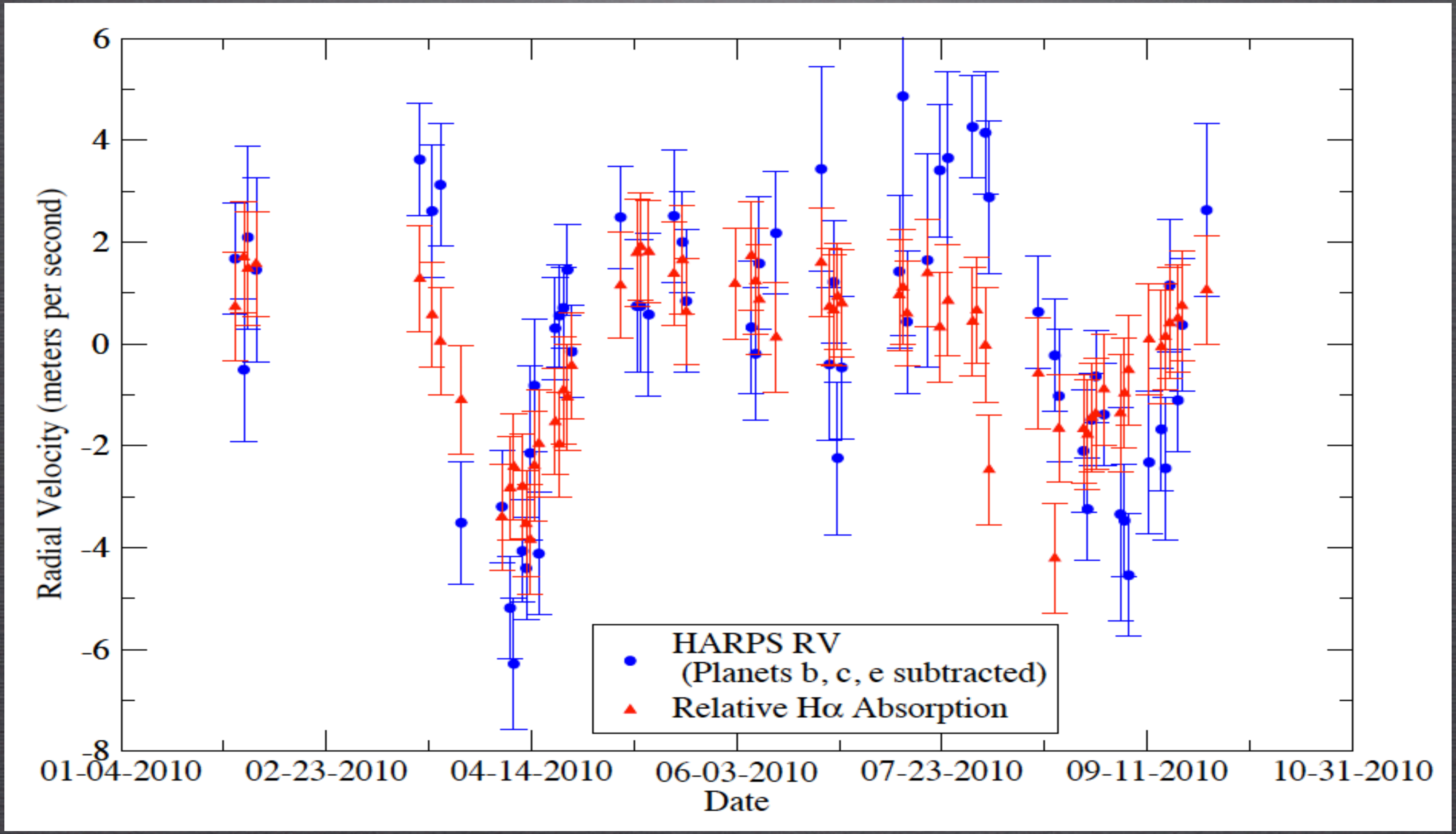
AO FED Spectrographs



Potential for more efficient, compact spectrographs coupled to large telescopes with AO with single mode fibers.

Figure from Crepp 2014, *Science* Perspective

Stellar Activity Masquerading as Planets in the HZ



Gliese 581 d: Robertson et al. *Science, 2014*

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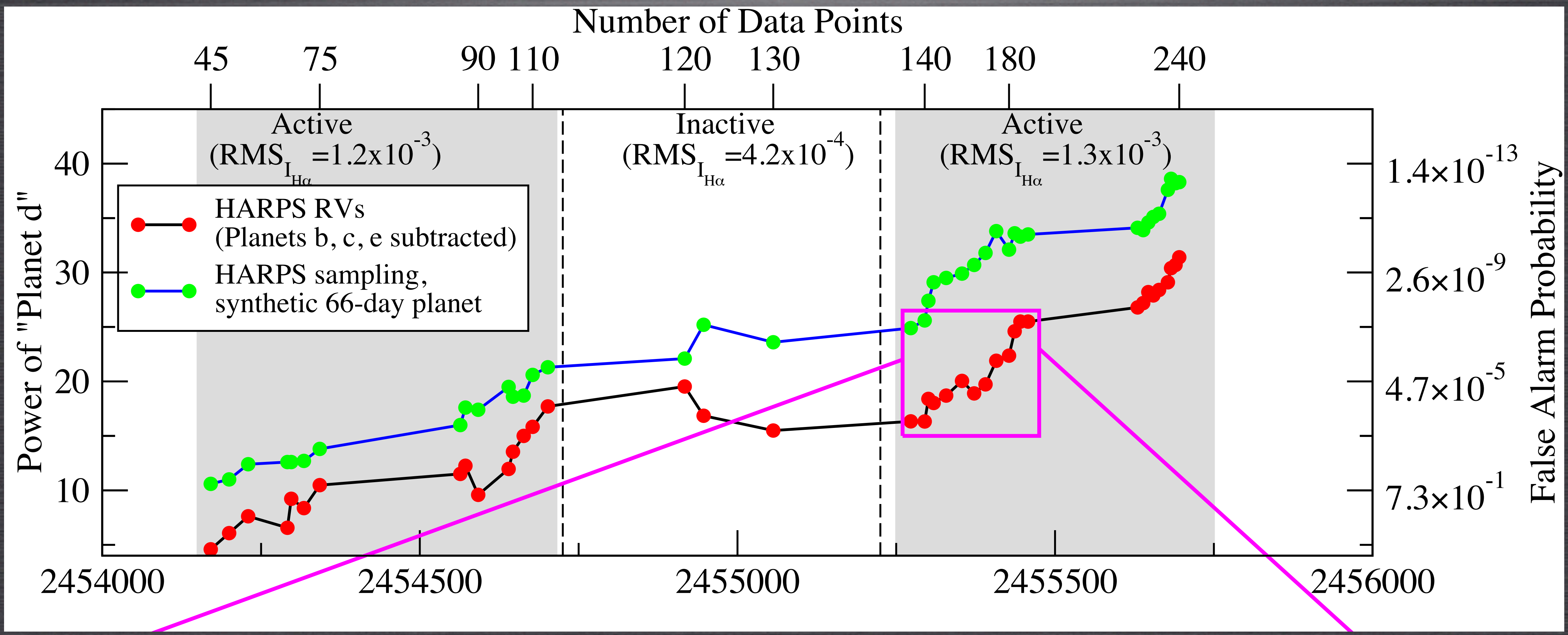

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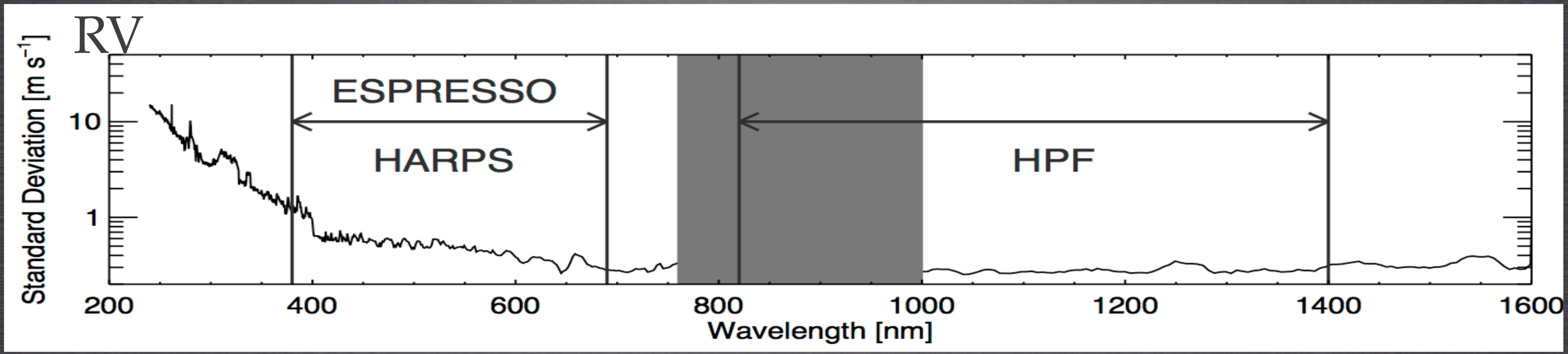
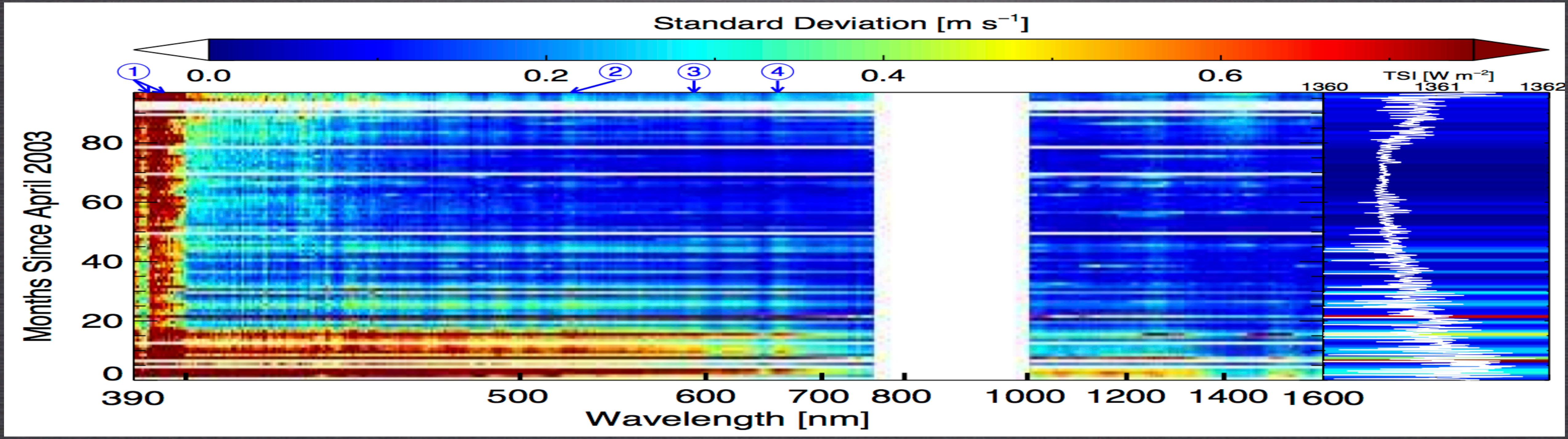
Solar Activity: Lower in the NIR





Stellar activity induced noise is lower in the NIR than the optical. RV variability for Sun estimated using SOURCE SIM solar spectral irradiance data and the FF' technique (Marchwinski et al. 2015)

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NN-EXPLORE WIYN Spectrograph is an excellent move in the right direction (though on an extremely aggressive time schedule).

1. Need high precision <~0.5m/s
2. Needs **time (lots of it)** and very regular access for ~10+years
3. Needs coherent RV streams (ie. without breaks) as much as possible
4. Need higher resolution and/or larger wavelength coverage for activity discrimination

By 2020

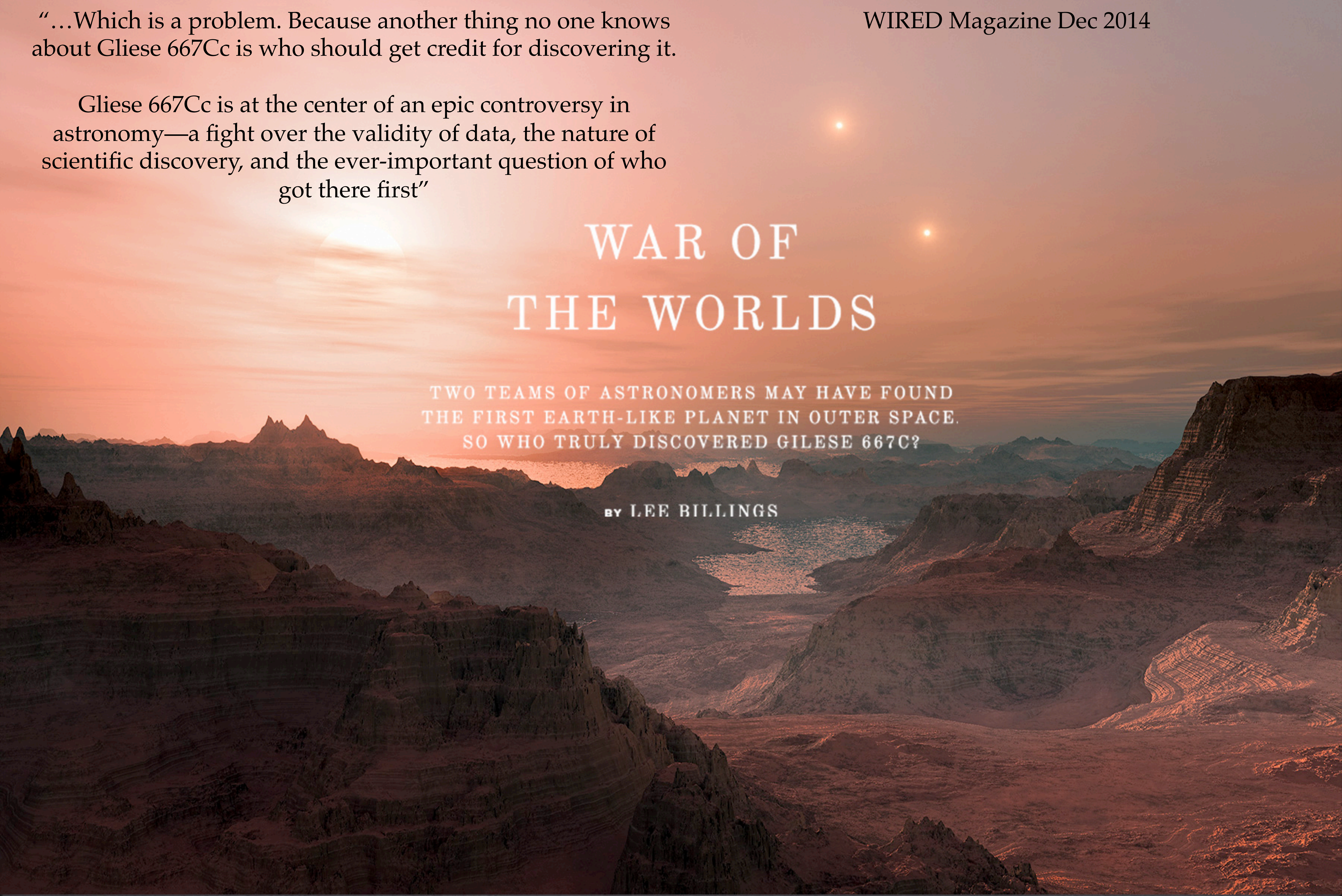
NEED TO FIND OUT THIS DECADE WHETHER WE CAN GET TO 10-30 cm/s

NEED TO FIND T^3 PLANET HOSTING M DWARFS FOR JWST FOLLOWUP

"…Which is a problem. Because another thing no one knows about Gliese 667Cc is who should get credit for discovering it.

Gliese 667Cc is at the center of an epic controversy in astronomy—a fight over the validity of data, the nature of scientific discovery, and the ever-important question of who got there first"

WIRED Magazine Dec 2014



NEED TO DO THIS WITHOUT THE COMMUNITY BEING PERCEIVED TO BE INSULAR, FRACTIOUS OR DIVISIVE.

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- What are the atmospheric compositions/signatures of Earth and super-Earth planets, Neptunes, and Jupiter analogues?

For the M Dwarfs, a transiting Super-Earth planet *can* be characterized by JWST and possibly by future large optical telescopes on the ground.

WFIRST Coronagraph for gas giants

A Probe class OIR mission for spectroscopy of transiting planets discovered by K2 and TESS (possible MIDEX call ~2017) or post-PLATO

Comparative Exo-planetology is important in understanding what factors affect planets and what to look for.

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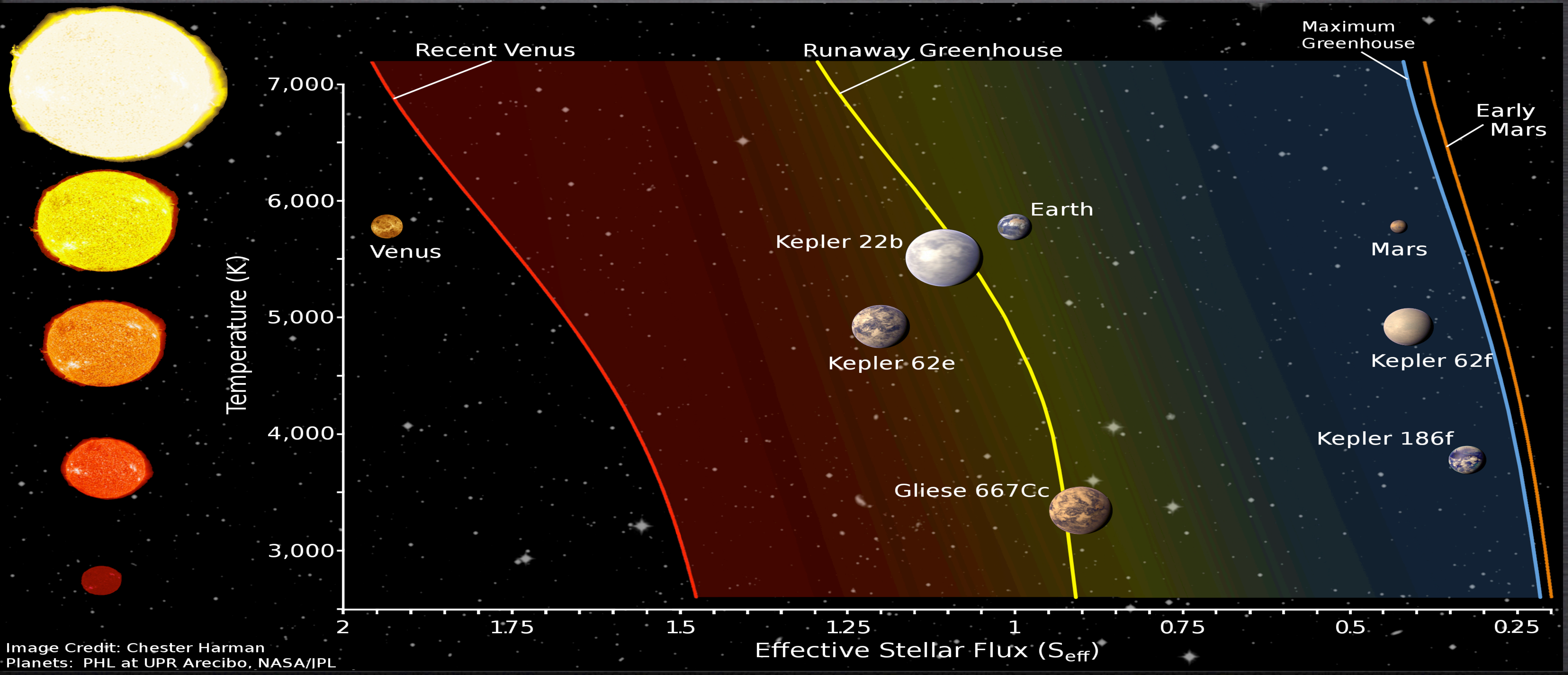
20202 Decadal, 2030s launch: Habitable Exoplanet Imaging Mission – **needs strong community support!**



HZs & BiosignatureS

While a lot of progress is being made in understanding Habitable Zones, and atmospheric characterization and search for "biomarkers” in low-mass planets this is fundamentally now a data-starved field and we really need (prospect of) spectra and data to drive significant progress in many of these avenues.

- Models need to couple climate with photochemistry and geology which then needs to be tied to a spectral code to generate spectra.
- For HZ boundaries beginning to go to 3D models (clouds, spatial temperature differences, tidal locking..), but need more independent groups.

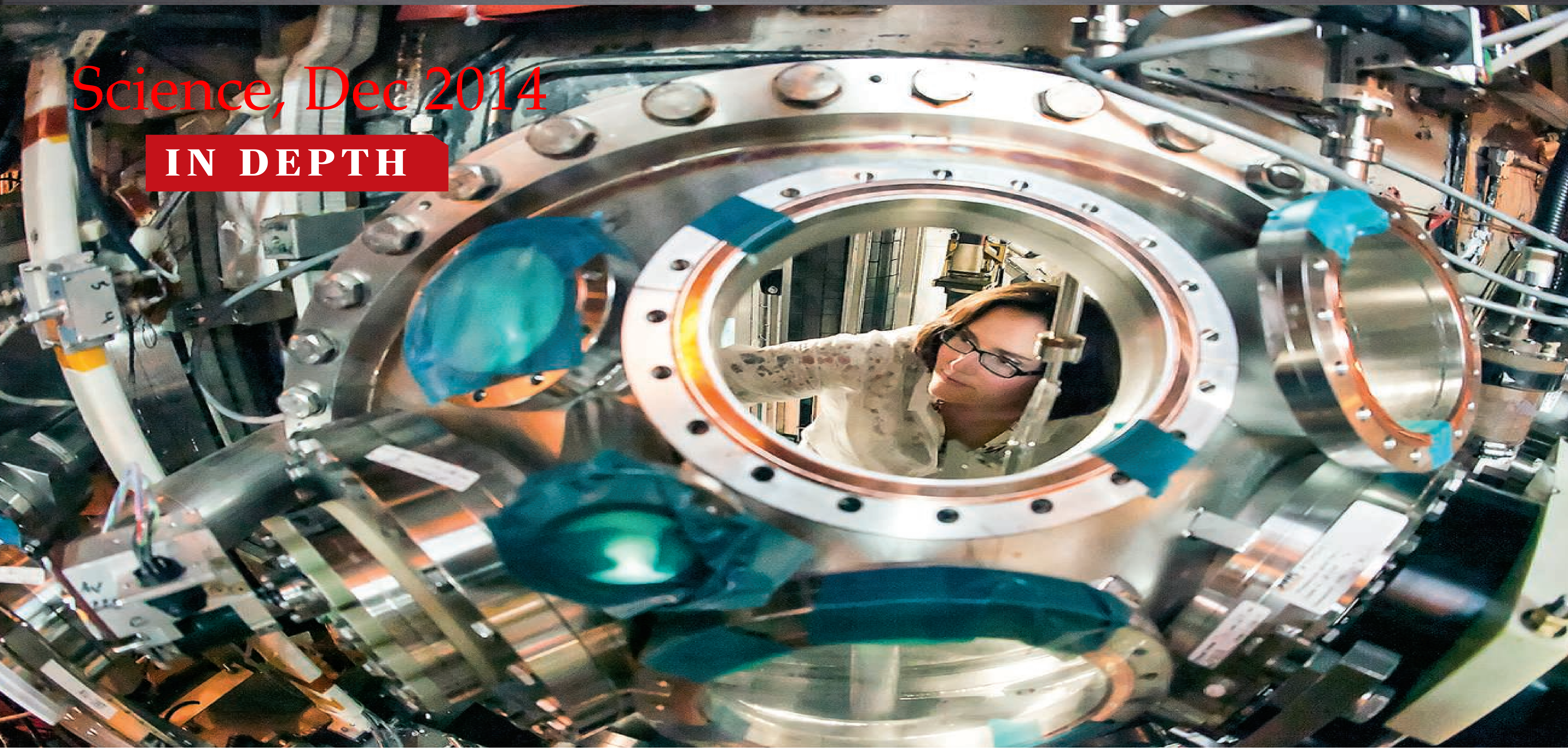
Need Sustained Investment in Theory to built and compare independent models. Currently funded by NAIs and individual PI grants. Probably needs more strategic long term investment

Top Level Summary of Informal Discussions

The Exoplanet Community would like to chart a path to the detection and characterization of Earth-mass planets in their HZs, with the goal of both and obtaining a spectrum of such a planet and correctly interpreting this signature.

Successfully navigating this path requires investment in theory, observations, observational resources, and cutting edge instrumentation on the ground and in space (and developing , keeping, and expanding the talented human resources to make this possible)

Community. Consensus.



ENERGY RESEARCH

U.S. fusion effort melts down

Scientific community battles with its federal office