Recommendations for NASA/NSF Investment in Precise Radial Velocity Hardware and Facilities

William Cochran, Dawn Gelino, Sara Heap, John Johnson, David Latham
On behalf of the Precision Radial Velocity Community

Penn State University and the NASA Exoplanet Science Institute recently hosted a workshop on precision radial velocity (PRV) for the detection and characterization of exoplanets. The workshop was attended by more than 100 researchers from around the world (http://exoplanets.astro.psu.edu/workshop/program.html) and coincided with the release of the ASTRO2010 Decadal report that laid great emphasis on the importance of radial velocity measurements. The US PRV community, many of whom attended this conference, have prepared this series of recommendations for new PRV instrumentation and observing opportunities that will maintain US competitiveness and leadership in a field identified as critical by the ASTRO2010 decadal report.

National Research Council 2010 Decadal Survey Report

One of the top three scientific objectives of the National Research Council's 2010 Decadal Survey of Astronomy and Astrophysics is "New Worlds: Seeking Nearby, Habitable Planets." The report describes a "New Worlds Technology Development Program" in which "NASA and NSF should support an aggressive program of ground-based high-precision radial velocity surveys of nearby stars to identify potential candidates." Two sets of quotes from the report are particularly relevant:

> *"…The first task on the ground is to improve the precision radial velocity method by which the majority of the close to 500 known exoplanets have been discovered…Using existing large ground-based or new dedicated mid-size ground-based telescopes equipped with a new generation of high-resolution spectrometers in the optical and near-infrared, a velocity goal of 10 to 20 centimeters per second is realistic…The role of target-finding for future direct-detection missions … can be done at least partially by pushing ground-based radial-velocity capabilities to a challenging but achievable precision below 10 centimeters per second." (p. 7-8)*

> *"…Improve radial velocity measurements on existing ground–based telescopes to discover planets within a few times the mass of Earth as potential targets for future space–based direct–detection missions." (p. 7-10)* This is listed as a "Mid-Scale Project" in the $12 million to $40 million range. The report also suggests, *"It will be important to make strategic investments in new ground-based capabilities during the coming decade. One important component will be the aggressive development of ground-based high precision radial-velocity surveys of nearby stars at optical and near-infrared wavelengths (including efforts to determine the effect of stellar activity on these measurements). These surveys will need new spectrometers and significant time allocation on 8-10m class telescopes." (p. D-2)*

Context of The Decadal Survey Recommendations

The US must develop facilities that provide data of high precision, accuracy and long term stability, at faint magnitudes, and with sufficient observing time for PRV measurements, in order to respond to the decadal survey's recommendations. We note that the *European Southern Observatory (ESO)* is developing ESPRESSO for the VLT and CODEX for the ELT, which will provide important new capabilities to European astronomers. Without appropriate investments in instruments and telescope time, the US will lose competitiveness in this critical field. To achieve the most challenging goals, e.g. to detect planets in the habitable zones of solar type stars, will require some technology development to achieve the highest levels of precision. In other cases, only funding for the construction of well-understood spectrographic instruments and access to appropriate telescopes is required.

Kepler will continue to be a pioneer in the field of super-Earth and Earth-sized exoplanets making PRV data on faint targets an absolute necessity to validate the Kepler results and to provide primary physical characterization of the transiting systems. JWST will also need supporting PRV data to validate targets and characterize planets for spectroscopic follow-up observations. Supporting PRV data will also be essential to validate and characterize planets discovered in future, space-based, whole-sky transiting planet surveys.

NASA and NSF currently support a large number of observatories that could benefit current and future PRV work (Keck, IRTF, NOAO, Gemini). Both a new generation of optical and/or near-infrared spectrometers, and significant amounts of telescope time are essential to meet the objectives of the decadal survey. Private institutions may be interested in partnering with NASA and NSF to help achieve the decadal survey objectives.

The Precise Radial Velocity Community Response
To the NRC 2010 Decadal Report

In view of the numerous, exciting targets identified by *Kepler*, and the pre-publication report of the NRC 2010 Decadal panel (ASTRO2010), we recommend that NASA and NSF collaborate and coordinate their activities to achieve the near- and long-term goals outlined in the ASTRO2010 report. By taking the steps below, the US community will maximize the scientific return from *Kepler* and future space missions, and carry out the radial velocity surveys needed to achieve ASTRO2010's goal of discovering and characterizing habitable exoplanets around the nearest, brightest stars:

1. *Initiate an open, competitive program to develop advanced precise radial velocity (PRV) spectrographs for existing U.S.-affiliated observatories both in the optical to achieve the 10 cm/s goal set by the Decadal report, and in the near-infrared to provide initial PRV capabilities of 1-10 m/s[1];*

2. *Augment the existing program of PRV observations of Kepler candidates by obtaining observing time at existing facilities having the requisite instrumentation;*

3. *Support upgrades of existing spectrographs and the building of new PRV spectrographs (~1 m/s) on NASA-, NSF-, or privately-funded telescopes. These instruments would provide the cadence, precision, and wide sky coverage needed for surveys to find rocky planets orbiting nearby stars. Some of these upgrades or new instruments using existing technology could proceed on a rapid enough timescale to be valuable for Kepler follow-up;*

4. *Accelerate the development of PRV spectrographs by explicitly encouraging instrumentation and/or technology fellowships in this area;*

5. *NSF, NASA, and other government agencies should collaborate to develop the requisite wavelength calibration capabilities to reach the ASTRO2010 goals in both the optical and near-infrared;*

6. *Develop a comprehensive calibration and archiving plan to ensure data obtained via these initiatives are available to the astronomical community in a timely fashion.*

[1] We are encouraged to note that in the August 2010 "NOAO Currents" newsletter, Gemini announced, *"…its intention to build a new high-resolution optical spectrograph, a development that is, in part, an outcome of the ALTAIR committee report. Gemini is soliciting science and instrument white papers from the community…"* and *"…is also investigating new, lower-cost operations models for the post-2012 era."*

The following members of the Precise Radial Velocity Community support this document:

Guillem Anglada, Carnegie Institution of Washington
Charles Beichman, NASA Exoplanet Science Institute
James Beletic, Teledyne Imaging Sensors
Chad Bender, Pennsylvania State University
Tim Brown, LCOGT
Joseph Catanzarite, Jet Propulsion Laboratory
David Ciardi, NASA Exoplanet Science Institute
William Cochran, McDonald Observatory, University of Texas
Jeff Crane, Observatories of the Carnegie Institution of Washington
Justin Crepp, California Institute of Technology
Scott Diddams, National Institute of Standards and Technology
Michael Endl, McDonald Observatory, University of Texas
Debra Fischer, Yale University
Eric Ford, University of Florida
Gabor Furesz, Smithsonian Astrophysical Observatory
Jian Ge, University of Florida
Dawn Gelino, NASA Exoplanet Science Institute
Ronald Gilliland, Space Telescope Science Institute
Elizabeth Gomez, Pennsylvania State University
Sara Heap, NASA's Goddard Space Flight Center
Andrew Howard, University of California, Berkeley
John Johnson, California Institute of Technology
Stephen Kane, NASA Exoplanet Science Institute
David Latham, Harvard-Smithsonian Center for Astrophysics
Jack Lissauer, NASA Ames Research Facility
Phillip MacQueen, McDonald Observatory
Robert Mathieu, University of Wisconsin-Madison
Geoff Marcy, University of California, Berkeley
Suvrath Mahadevan, Pennsylvania State University
Steve Osterman, University of Colorado
Peter Plavchan, NASA Exoplanet Science Institute
Lisa Prato, Lowell Observatory
John Rayner, NASA Infrared Telescope Facility
Evgenya Shkolnik, Carnegie Institution of Washington
Steinn Sigurdsson, Pennsylvania State University
Andrew Szentgyorgyi, Harvard-Smithsonian Center for Astrophysics
Angelle Tanner, Georgia State University
Andrei Tokovinin, Cerro Tololo Inter-American Observatory, NOAO
Alan Tokunaga, NASA Infrared Telescope Facility
Guillermo Torres, Harvard-Smithsonian Center for Astrophysics

Larry Ramsey, Pennsylvania State University
Stephen Redman, Pennsylvania State University
Jeff Valenti, Space Telescope Science Institute
Julian van Eyken, NASA Exoplanet Science Institute
Kaspar von Braun, NASA Exoplanet Science Institute
Richard Wade, Pennsylvania State University
Sharon X. Wang, Pennsylvania State University
William Welsh, San Diego State University
Aleksander Wolszczan, Pennsylvania State University
Jason Wright, Pennsylvania State University