Facilities — SMARTS Consortium and 0.9m Telescope

The PI, Henry, helped found the SMARTS (Small and Moderate Astronomy Research Telescope System) Consortium in February 2003, and has since played an integral part in operating the 0.9m, 1.0m, 1.3m, and 1.5m telescopes at CTIO. In 2017, the PI took over as Principal Scientist of SMARTS. The 0.9m is the facility that provides most of the data for the proposed work, and it would unfortunately close without the PI's long-term program. The PI has managed operations of the 0.9m since 2003, including formulating the overall plan for the facility, scheduling and supporting observations carried out by users, and making upgrades, e.g., a new Telescope Control System in 2005 and a new CCD Control System in 2016. The PI also handles all financial considerations, including budgeting, recruiting users, and working with scientific, engineering, and administrative staff in La Serena and Tucson. Membership in SMARTS is a GSU Astronomy program priority, and through 2020, the PI has secured $1.8M in funding to support the SMARTS effort, split between grant sources and GSU. *As has been the case for past RECONS work supported by NSF, there is no funding requested in this proposal for GSU's SMARTS telescope time.*

To carry out the program outlined in this proposal, we observe ∼80 nights/year at the 0.9m. Started in 1999, this is the longest-running combined astrometry/photometry effort in the southern hemisphere, spanning 1663 nights at the 0.9m as of November 2020, during which we have amassed a dataset of more than 135,000 images. Via this proposal, the 0.9m will be used to obtain (a) astrometric orbits for Vrijmoet's thesis, (b) long-term variability due to starspot cycles for Couperus' and Kar's theses, (c) mid-term variability due to rotation for Couperus' and Kar's theses, and (d) optical characterization photometry for all three efforts. To carry out the science, there are now 733 targets on the observing list.

The 0.9m and its optical Tek 2Kx2K camera (401 mas pixels, field 16′.8 on a side) have proven to be an excellent combination that provides parallaxes with a median error of 1.4 mas (best cases 0.5 mas) for white, red, and brown dwarfs as faint as $VRI = 20$. Proper motions are measured with a median error of 0.7 mas/yr for stars observed at least 3 years (best cases 0.1 mas/yr). We have published high quality parallaxes and proper motions for 813 objects using the 0.9m, of which 372 were the first parallaxes for objects within 25 pc of the Sun.

The 0.9m is also a reliable photometric workhorse, as we have made more than 5000 successful sets of VRI observations of stars and brown dwarfs. Photometry is routinely obtained to $VRI = 18$ with errors of ±0.03 mag and to $VRI = 20$ with errors of ±0.06 mag. Relative photometry used for variability measurements can be obtained to 7 mmag for routine, in-focus observations, and to 2 mmag for defocused observations during which more signal is accumulated.

The PI has worked with a series of 8 postdocs and graduate students as SMARTS Fellows at GSU. In addition to carrying out their own science programs, these Fellows have learned details of observatory operations such as trouble-shooting new computer and detector systems, documentation development, assisting other astronomers with their observing programs, and stretching the science capabilities of the 0.9m.

Facilities — Other Observatories/Databases

SOAR 4.1m — We have a high-resolution speckle imaging program underway using HRCam+SAM at the SOAR 4.1m, in collaboration with Andrei Tokovinin at CTIO. Tokovinin built the SOAR Adaptive-Optics Module (SAM), a laser-assisted adaptive optics system used for speckle work, and remains the Instrument Scientist. Graduate student Vrimjoet has been

awarded long-term status for the SOAR speckle program through semester 2022A.

CTIO/SMARTS 1.5m — The PI has managed operations of the CTIO/SMARTS 1.5m since reopening the facility in 2017. We are using the CHIRON high-resolution spectrograph at the 1.5m to observe 1265 K dwarfs to measure their metallicities and characterize their activity levels, and targeting roughly half of those for radial velocities to reveal companions down to Jovian planet masses. We use CHIRON to measure the activity levels for some red dwarfs in the SURVEY, TWINS, and exoplanet samples observed at the 0.9m.

ASAS/ASAS-SN — The All Sky Automated Survey (ASAS, started 1997) is a photometric monitoring survey of the entire sky, targeting ∼10 million stars brighter than magnitude 14 in the V and I filters. Although of lower precision (∼50 mmag) than our data (∼7 mmag), these data can be used to augment the long-term cycles determined at the 0.9m. We can also used data from a related survey, ASAS-SN (SN for Supernovae, started 2015) that reaches to magnitude 18 in g and V with precision ∼20 mmag.

Chandra — For a few systems, time has been awarded to use *Chandra* to secure x-ray data. These data are being used by Couperus to complement the ground-based discoveries.

Gaia — Data Release 2 from *Gaia* was made available in April 2018 and all members of the RECONS group are steeped in using *Gaia* data. Early Data Release 3 is scheduled for December 2020 and Data Release 3 in 2022. All three graduate students working on the red dwarf projects described in this proposal are using *Gaia* results.

MEarth — The MEarth team began monitoring several hundred nearby red dwarfs in the southern sky starting in 2014 from a site on Cerro Tololo just down the hill from the 0.9m. Many of the nearest red dwarfs are included in our 0.9m and the MEarth programs, and datasets can be used for graduate students Couperus' and Kar's variability efforts (but do not have sufficient astrometric accuracy for Vrijmoet's work). A former RECONS graduate student, Jennifer Winters, is a postdoc member of the MEarth team and we are already working with her and PIs David Charbonneau and Jonathan Irwin on related red dwarf studies.

TESS — Members of the RECONS group (Couperus and Jao in particular) are already using *TESS* data. Couperus' and Kar's efforts will use *TESS* data where available, although many of the red dwarf targets are corrupted by other sources in the large *TESS* pixels.

Facilities — Georgia State University Resources

The RECONS group at GSU has been one of the largest groups in the Department of Physics & Astronomy for many years, and currently hosts one Research Scientist (Jao) and five graduate students (Couperus, James, Kar, Paredes, and Vrijmoet). The research proposed here is the focus of the Ph.D. work of Couperus, Kar, and Vrijmoet.

Since the inception of SMARTS in 2003, 16 undergraduates, 44 graduate students, 14 postdocs, and 25 senior researchers (including 7 GSU Astronomy faculty) have used data via the GSU SMARTS effort. We have an excellent working relationship with the staff at CTIO, and as a department have sent 43 students and faculty to observe at CTIO as part of SMARTS since 2003. (list at http://www.astro.gsu.edu/∼thenry/SMARTS/smarts.gsubeneficiaries.htm)

Researchers working in the RECONS group on the science proposed here have office space and desktop computers in the GSU Department of Physics & Astronomy, as well as portable laptops that are used to work off site, including at the telescopes. The department provides network level support in a Linux environment with IRAF, IDL, and Python computing.