An All Sky Extrasolar Planet Survey (ASEPS) at the SDSS 2.5m Telescope. Jian Ge, Julian van Eyken, Suvrath Mahadevan, Curtis Dewitt, Roger Cohen, Scott Fleming, Pengcheng Guo, Andrew van den Heuvel, Stephen Kane & Stan Dermott (Department of Astronomy, The University of Florida, contact: jge@astro.ufl.edu), Rich Kron (The University of Chicago), Michael Strauss & James Gunn (Princeton University), Sara Seager (Carnegie institution of Washington), & Donald Schneider (Penn State)

Introduction

The All Sky Extrasolar Planet Survey (ASEPS) idea is to use the Sloan 2.5-m wide field telescope to undertake a large-scale visible and near-IR band Doppler survey of ~ 1 million relatively bright stars (generally V < 13) for extrasolar planets between 2008-2020. The survey will increase the number of known planetary systems by at least two orders of magnitude, providing a powerful statistical base for understanding different kinds of planetary systems. For instance, the sample of planets will provide a new and deeper understanding of extrasolar planet formation and migration, and determine the frequency and properties of planets as a function of the mass and metallicity of the central star.

The project has the sensitivity to detect Jupiter-mass planets at Jupiter-like distances from the parent star. The near-infrared survey conducted may lead to discoveries of terrestrial-like planets in the habitable zones (a few days orbital period) around low mass stars (~0.1 solar mass). The project will identify candidates for short-period systems that would be followed up elsewhere, and the survey will itself determine radial velocity curves for numerous long-period (several years) systems. This survey will also provide complementary work for future space planetary mission programs such as Kepler, SIM and TPF by understanding planetary system characteristics and frequency among stars with a large range in mass (~ 0.4 to 5 solar mass), providing a observation target list, determining planet size and mass through planet transit detection, and providing a number of transiting planets around bright stars for space observations of atmospheric compositions.

Prototype Instrumentation

The multi-object Doppler survey instrument is based on the dispersed fixed-delay interferometer design [1][2]. This new generation Doppler instrument, now under construction, is called the W.M. Keck Exoplanet Tracker (or Keck ET). A single-object prototype version of an ET instrument was developed by Ge’s team over 2000-2001 and tested on the sky at the KPNO 2.1m telescope in 2002 [1][3]. The scientific version of the ET instrument was commissioned at KPNO in November 2003. A Doppler precision of 3.6 m/s has been achieved with a bright RV stable star, 36 UMa. We were able to recover part of the Doppler curve for a planet-bearing star, 55 Cnc (V = 5.95), with a Doppler precision of 11 m/s. We were also able to uncover a RV curve of a binary star system with a V = 10.4 primary. The instrument was stable to 16 m/s over the six nights measured from the 36 UMa data.

Summary of Multiple Object ET Feasibility Results

In March and April 2005, Observations were obtained at the Sloan telescope with a prototype multiple-object Doppler instruments. The prototype produced 20 stellar spectra simultaneously, 10 of them with good stellar fringes for precision RV measurements and the remainders with very low contrast fringes due to the misalignment of part of the ET interferometer. Figure 2 shows the multiple object fringe spectra. 10 m/s was achieved with a RV stable star, 36 UMa (V = 4.8). We were able to recover part of the Doppler curve for a planet-bearing star, 55 Cnc (V = 5.95), with a Doppler precision of 11 m/s. We were also able to uncover a RV curve of a binary star system with a V = 10.4 primary. The instrument was stable to 16 m/s over the six nights measured from the 36 UMa data.

Figure 1. A possible planet detected by the ET instrument.

Figure 2. (left) the first light fringe data taken with the SDSS prototype multiple object ET on the night of March 21. Two stellar spectra were missing due to broken fibers. The brightest data represents a V = 8 star, the faintest one represents a V = 11 star. (right): Enlarged fringe spectra of the left side data. Fringes can be clearly seen in every spectrum.
Based on the single-object version ET performance at the 2.1m and the preliminary results at the Sloan telescope, we expect the full scale multiple object Doppler survey instruments at the Sloan telescope to be capable of monitoring solar type stars as faint as \( V = 13 \) with a Doppler precision better than 30 m/s (Table 1). This precision will allow detection of more than 80% of about 150 known extrasolar planets detected with the traditional cross-dispersed echelle instruments since 1995.

### ASEPS Summary

Each of northern accessible sky areas will be visited at least 5 times (possibly 10-20 times) during the first four years of the survey to identify detectable planet candidates with short (\(< 1 \text{ day}\)) to intermediate orbital periods (\(< 1 \text{ year}\)). These candidates will be monitored by Doppler instruments at other telescopes to acquire the complete radial velocity curves of these planets. All of the stars showing long term radial velocity variations as possible planet candidates in each Sloan field will be further monitored over the next 8 years with the Sloan telescope to uncover the complete phase of the Doppler radial velocity curves of those planets.

### Schedule and Total Survey Cost

The survey will have three phases.

- **Phase I**: the feasibility study with a prototype multiple object ET, 2004-2005, completed in March and April 2005, one planet confirmed, 20 object capability demonstrated
  - Phase II, pilot program for 20,000 stars during the bright time, 2006-2008, expect to discover \(~ 500\) planets
  - Phase III, All sky extrasolar planet survey, observe 1,000,000 stars, 2008-2020, expect to detect \(~ 30,000\) planets

Our current estimate for the overall project budget is about \$50M. The Phase I (feasibility and demonstration, 2004-2005) has cost about \$0.5M. The Phase II (the pilot program, 2005-2008) will cost about \$3M and the Phase III (the full scale project, 2008-2020) will require at least \$45M.

### Parallel SDSS Spectroscopic Surveys

Beyond 2008, there is a possibility to extend the current Sloan Spectroscopic Survey in parallel with ASEPS. Current Sloan focal plane fiber cartridge design allows simultaneous plugging of at least 1000 fibers. The ASEPS instrumentation can handle only \(~ 400\) fibers; the remained (up to 640 fibers) can be directed to the SDSS spectrographs. Therefore, some of the SDSS targets can be spectroscopically observed while the bright stars within the same field are monitored for planets. It is quite possible to reach good S/N for \( V \approx 20-21\) targets spectroscopically (perhaps 22 for emission line objects) with co-addition of all of the spectra of the SDSS targets taken over at least 5 epochs with Sloan. In April 2005, we have successfully demonstrated the piggy-back observations of 640 Kepler field stars with \( V = 12-14\) using the SDSS spectrographs while monitoring bright Kepler field stars (\( V = 8-11\)) for Doppler observations with a prototype multiple object ET instrument (see Mahadevan et al. in these proceedings).

### Acknowledgements

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### References:


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**Table 1. Radial Velocity Sensitivity (one hour)**

<table>
<thead>
<tr>
<th>( V ) magnitude</th>
<th>KPNO 2.1m (^1)</th>
<th>Sloan 2.5 m (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>5.7 m/s</td>
<td>2.8 m/s</td>
</tr>
<tr>
<td>9</td>
<td>9.0 m/s</td>
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<td>10</td>
<td>14.3 m/s</td>
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<td>11</td>
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<td>12</td>
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</tr>
<tr>
<td>13</td>
<td>56.3 m/s</td>
<td>28.0 m/s</td>
</tr>
</tbody>
</table>

\(^1\)/2 spectrograph, 4k CCD, 600 Å coverage.  
\(^2\)/1.2 spectrograph, 8k CCD, 2000 Å coverage.