A Systematic Survey for Nearby Young Stars
Eric L. N. Jensen, Rabi S. Whitaker, Swarthmore College
Beth A. Biller, CfA; Allyn Dullaghan, MIT
David W. Koerner, Nina R. Bonaventura, University of Pennsylvania

Survey Motivation and Design
Much of the study of low-mass star and planet formation relies on observations of stars (and associated disks) in the nearest regions of active star formation: Taurus-Auriga, Scorpius-Ophiuchus, and Chamaeleon, all located at distances of about 125–140 pc.

Extensive study of these regions has yielded a wealth of knowledge about stellar formation and evolution up to ages of ~10 million years (Myr). However, our knowledge about how low-mass stars and their disks evolve between the ages of nearby star-forming regions and the time they reach the zero-age main sequence (ZAMS) at ages of about 100 Myr is much less secure. This is the period during which stars lose their optically-thick circumstellar disks and are thought to become planetary.

To study disk evolution, we would like a nearby sample of these older pre–main-sequence stars (sometimes called “Post T Tauri Stars”) in order to be able to observe the disks with high spatial resolution and sensitivity to low flux levels. We do not know of many stars in the nearby star-forming regions with these ages, nor are there nearby open clusters with these ages (Figure 1).

Survey Results

- Luminosity a factor of at least 1.5 above the zero-age main sequence in the HR diagram.
- Spectral type (if known) of G5 or later.
- High fractional X-ray luminosity: LX/Lbol > 10^{-4}.
- Detection in both the Hipparcos Catalog and the ROSAT Bright Source Catalog.

Figure 2: Li equivalent widths (both from our observations and from the literature) for our sample stars (green dots), compared to those of stars in the 30–50 Myr old clusters IC 2391 and IC 2602 (blue dots, data from Randich et al. 2001). The blue line denotes the approximate empirical locus of the Li EW–Teff relation at the age of these clusters; data for the 100-Myr-old Pleiades show more dispersion but have a similar upper envelope. Roughly 25% of the stars in our sample (21 of 85 stars) lie on or above this line, indicating that they have ages of less than or equal to 50–100 Myr.

Some of the young stars selected by our criteria and shown at left are previously-known young systems such as HD 98800, PZ Tel, V343 Nor, and HD 155555. However, roughly half of the strong Li stars are new detections here. Some of these new detections associated with the Sco-Cen OB associations, while others are isolated from known star-forming regions.

Figure 6: a) Plot of flux density distributions from model debris disks around stars of different spectral types at the distance of nearby star-forming regions. The model disk is similar to the observed properties of debris disks around nearby A stars and incorporates 0.1 solar masses of 30 μm-sized dust grains in a Kepler Belt, while radiating 0.16 × 10^{-3} solar L_{bol} as a black body. Models are displayed as red bars for comparison. Note that IRAFS could only detect near-infrared disks around spectral type B or later. SIRTF will be able to detect such disks around G stars, which make up the bulk of the young stars detected here.

Further spectroscopic analysis
The spectra taken for this project typically have S/N > 100, spectral resolution of 0.14 Å, and spectral coverage from 5000–8000 Å. Thus, they contain a wealth of additional information about the stars observed, both the young stars discussed here and the older systems (many of which may be RS CVn binaries). We invite inquiries from anyone wishing to work with these spectra for further analysis.

Acknowledgments
We gratefully acknowledge the support of the National Science Foundation through grant AST-9966278, and Swarthmore College through a James Michener Fellowship.

Figure 5: Comparison of young (lower) and old (upper) spectra in the region of the Li 6707.8 Å line. Both stars show similar strengths in the Ca 6703 Å and Fe 6705, 6705, and 6710 Å lines, but the Li line in the older spectrum is clearly much stronger. As a rule of thumb, Li absorption comparable to or greater than the Ca absorption strength is a good indicator of youth.

Figure 3: This newly-discovered young K1 star lies at a distance of 45 pc. Its extremely high radial velocity (roughly 140 km/s; note that the 6707 Å line is shifted to 6711 Å) suggests that it is most likely a spectroscopic binary.

Frequency of disks

- Only 16% of the stars in our sample were detected by IRAFS. All but two of the detections were at 12 μm only, one was at 12 and 25, and one (HD 98800) was in all four bands.

Most of these detections are of stars found not to be young, and all but two of them are consistent with photoevaporative emission. The exceptions are HD 98800, a well-known young quadruple system in the TW Hya Association, and HIP 100117. HIP 100117 has a relatively weak Li line (52 mÅ at T_{eff} = 5300 K), so we do not regard it as a young star. Thus, only one of our young star candidates has evidence for circumstellar material.

Disks like those found around most 1 Myr-old T Tauri stars are rare among the 10–100 Myr-old stars in our sample. However, IRAFS was not sensitive enough to detect debris disks (like those around HR 8799 and Vega) if they surround late-type stars.

Analysis and Future Work

Limitations of the survey

Completeness:
- The Hipparcos catalog is complete only to V=7.3–9.0, depending on galactic latitude. Since our selection procedure relies on Hipparcos, there may be many fainter young stars (especially K and M stars) not included in these observations. The FAME satellite will provide parallaxes and proper motions for a much larger sample of stars, allowing this type of survey to be pursued in a more complete sample.

In the meantime, however, the detections reported here may be “signposts” that are the brighter members of possible undiscovered associations of young stars. We are currently searching the Tycho-2 catalog (which includes proper motions of much fainter stars than Hipparcos) and radial-velocity catalogs from the literature to look for fainter stars that have the same space motions as the young stars detected here.

IRAS sensitivity to disks:
- While IRAS could detect disks that have high opacity due to small dust grains, it did not have sufficient sensitivity to detect disks once the gas is dispersed and the grains start to coagulate into larger particles (“debris” disks). Figure 4. Thus, our conclusion regarding disk frequency only applies to small-grain T-Tauri-type disks.

Figure 4: Survey Results at a glance:
- ~ 25% of 85 Hipparcos/ROSAT late-type stars surveyed are younger than ~100 Myr.
- Only one shows evidence of circumstellar material at levels detectable by IRAS.
- SIRTF follow-up planned to constrain disk evolution in the 10–100 Myr planet-building epoch.

Swarthmore Astronomy

Li equivalent widths for candidates compared to 30–50 Myr-old clusters

Sample selection

- Determined in both the Hipparcos Catalog and the ROSAT Bright Source Catalog.
- High fractional X-ray luminosity: LX/Lbol > 10^{-4}.
- Spectral type (if known) of G5 or later.
- Luminosity a factor of at least 1.5 above the zero-age main sequence in the HR diagram.

Acknowledgments
We gratefully acknowledge the support of the National Science Foundation through grant AST-9966278, and Swarthmore College through a James Michener Fellowship.

Swarthmore Astronomy

Further spectroscopic analysis
The spectra taken for this project typically have S/N > 100, spectral resolution of 0.14 Å, and spectral coverage from 5000–8000 Å. Thus, they contain a wealth of additional information about the stars observed, both the young stars discussed here and the older systems (many of which may be RS CVn binaries). We invite inquiries from anyone wishing to work with these spectra for further analysis.

Acknowledgments
We gratefully acknowledge the support of the National Science Foundation through grant AST-9966278, and Swarthmore College through a James Michener Fellowship.

Swarthmore Astronomy

Further spectroscopic analysis
The spectra taken for this project typically have S/N > 100, spectral resolution of 0.14 Å, and spectral coverage from 5000–8000 Å. Thus, they contain a wealth of additional information about the stars observed, both the young stars discussed here and the older systems (many of which may be RS CVn binaries). We invite inquiries from anyone wishing to work with these spectra for further analysis.

Acknowledgments
We gratefully acknowledge the support of the National Science Foundation through grant AST-9966278, and Swarthmore College through a James Michener Fellowship.

Swarthmore Astronomy

Further spectroscopic analysis
The spectra taken for this project typically have S/N > 100, spectral resolution of 0.14 Å, and spectral coverage from 5000–8000 Å. Thus, they contain a wealth of additional information about the stars observed, both the young stars discussed here and the older systems (many of which may be RS CVn binaries). We invite inquiries from anyone wishing to work with these spectra for further analysis.

Acknowledgments
We gratefully acknowledge the support of the National Science Foundation through grant AST-9966278, and Swarthmore College through a James Michener Fellowship.