A Systematic Survey for Nearby Young Stars

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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.

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 1–10 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 be forming planets.

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).

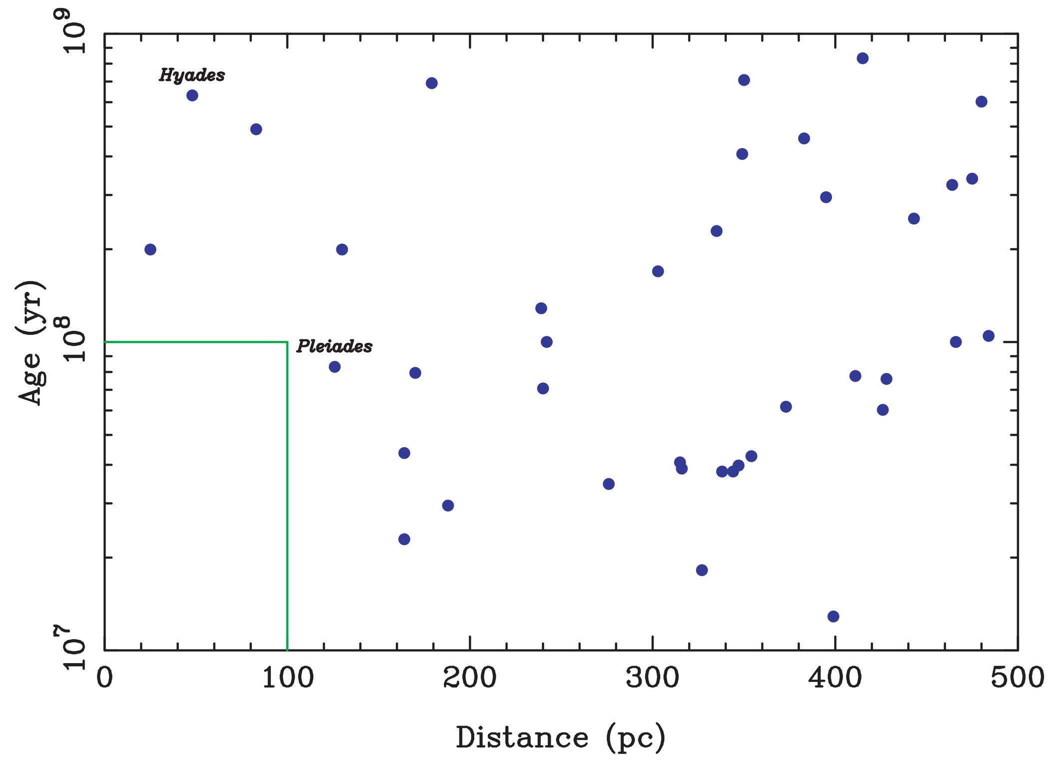

Figure 1: Open clusters within 500 pc. The green box shows the approximate parameter space covered by our survey; there are no open clusters that are both as near and as young as the stars discussed here. Thus, these stars provide a unique opportunity to study disk evolution.

Motivated by recent discoveries of nearby (< 100 pc), young (10–100 Myr) stars such as those in the TW Hya, η Cha, Horologium, and Tucana associations, we have undertaken a survey of the southern sky to look for additional nearby, young stars. A particular aim of our sample selection is to avoid criteria (such as infrared excess or Hα emission) that are strongly influenced by the presence of circumstellar material. This allows us to construct a sample that is selected in a way that is unbiased toward the presence or absence of disks, thus allowing us to study disk evolution in the 10–100 Myr age range.

Sample selection

- Detection in both the Hipparcos Catalog and the ROSAT Bright Source Catalog.
- High fractional X-ray luminosity: $L_X/L_{bol} > 10^{-4}$.
- 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.

Position above the main sequence selects both pre–main-sequence stars and giants. The addition of high X-ray luminosity eliminates most giants, but retains some active binaries, such as RS CVn and W UMa systems. Thus, we need an additional criterion of youth. We use the presence of a strong Li I λ = 6707.8 Å line, since Li depletes rapidly in late-type stars with large convection zones.

The above criteria yield a sample of 96 stars in the southern half of the sky. Of these stars, 35 had Li measurements in the literature. We observed an additional 50 of these stars with a spectral resolution of 0.14 Å at the CTIO 1.5-m and 4-m telescopes in August 2000 and April and November 2001. We report results here for this sample of 85 stars.

Survey Results

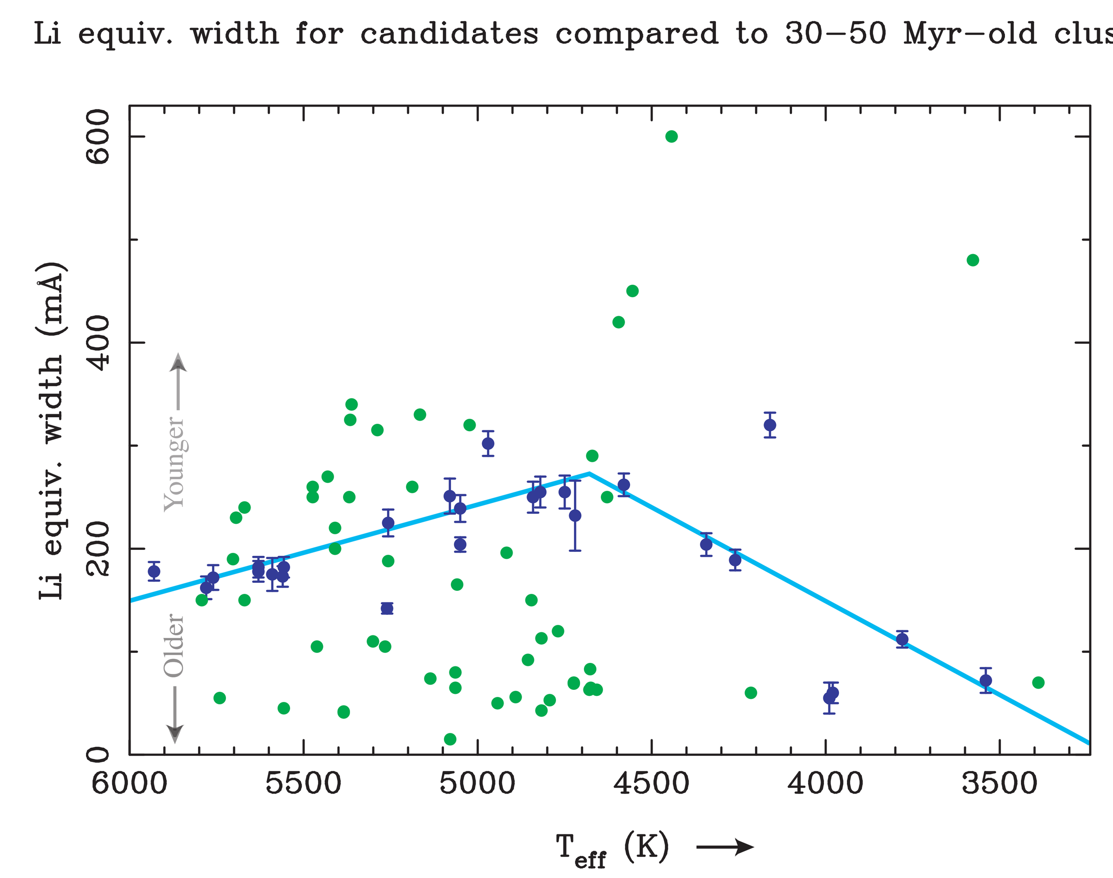

Figure 2: Li equivalent widths (both from our observations and from the literature) for our sample stars (green dots), compared to those of stars in the 30–50 Myr old clusters IC 2391 and IC 2602 (blue dots, data from Randich et al. 2001). The blue line denotes the approximate empirical locus of the Li EW–T_{eff} 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 are associated with the Sco-Cen OB associations, while others are isolated from known star-forming regions.

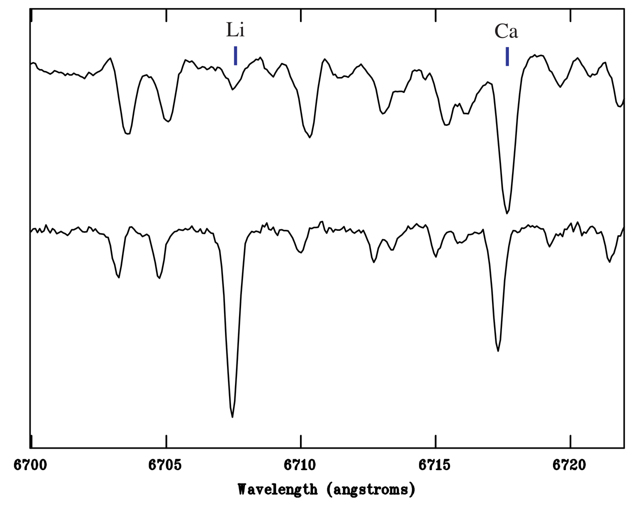

Figure 3a. Comparison of young (lower) and old (upper) spectra in the region of the Li 6707.8 line. Both stars show similar strengths in the Ca 6716 and Fe 6703, 6705, and 6710 lines, but the Li line in the lower spectrum is clearly much stronger. As a rule of thumb, Li absorption comparable to or greater than the Ca absorption strength is a good indicator of youth.

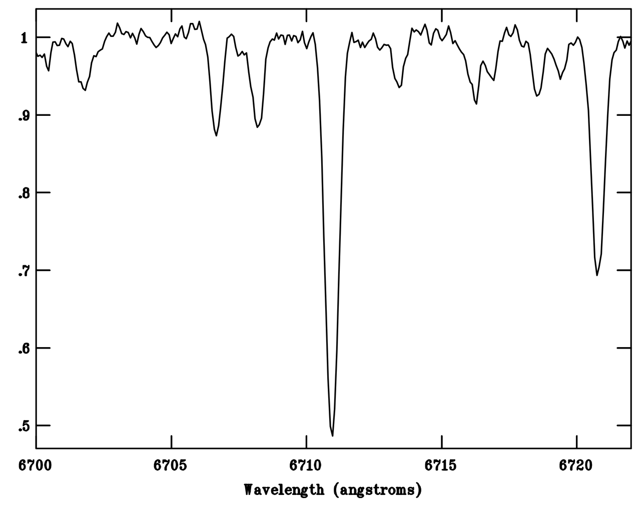

Figure 3b. This newly-discovered young K1 star lies at a distance of 85 pc. Its extremely high radial velocity (roughly 140 km/s; note that the 6707.8 Å line is shifted to 6711 Å) suggests that is most likely a spectroscopic binary.

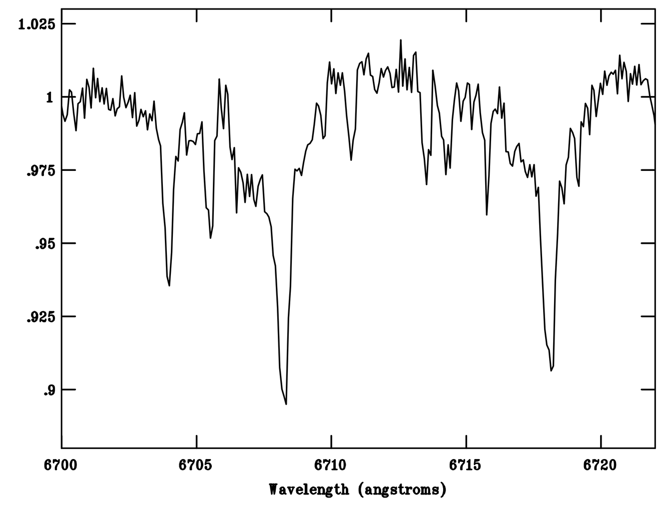

Figure 3c. This young G5 system was found to be a 0.5" binary by Hipparcos. The spectrum appears to contain both narrow-lined and broad-lined Li and Ca absorption features, suggesting that the two components of the binary have very different projected rotational velocities *v* sin *i*.

Frequency of young stars

Figure 2 shows the results of the Li observations. Roughly 1/4 of the stars in our sample have Li equivalent widths that are greater than or comparable to those of stars in the 30–50 Myr-old clusters IC 2602 and IC 2391. The figure does not show points for a number of stars that had no apparent Li line

Frequency of disks

Only 16 of the stars in our sample were detected by IRAS. 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 photospheric 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, IRAS was not sensitive enough to detect debris disks (like those around β Pic and Vega) if they surround late-type stars (Figure 4). We plan follow-up observations with SIRTF to place much better constraints on the level of circumstellar material among stars of these ages.

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.

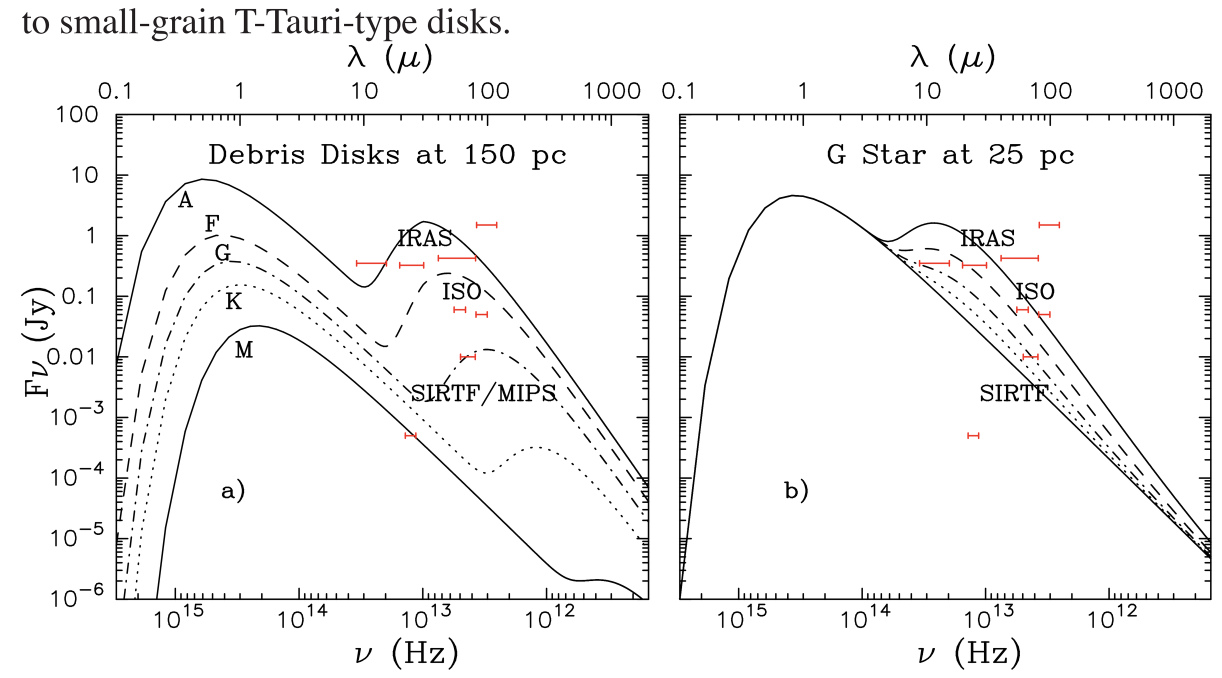

Figure 4: a) Plot of flux density distributions from model debris disks around stars of different spectral types at the distance of nearby star-forming regions. The model disk is similar to the observed properties of debris disks around nearby A stars and incorporates 0.1 lunar masses of 30 µm-sized dust grains in a Kuiper Belt zone extending 30 to 60 AU. IRAS, ISO, and SIRTF sensitivities are displayed as red bars for comparison. ***Note that IRAS could only detect such disks around stars of spectral type A or hotter. SIRTF will be able to detect such disks around G stars, which make up the bulk of the young star detections reported here.***

b) Plot of flux density distributions from zodiacal dust disks around a sun-like star at a distance of 25 pc. As in the solar system, dust is confined to a ring between 3 and 5 AU, with masses that span a range from 10^{-5} (dotted line) to 5×10^{-4} (upper solid line) lunar masses. SIRTF will be capable of detecting dust at 100 times the level of that in our own solar system.

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 CVns). We invite inquiries from anyone wishing to work with these spectra for further analysis.

Acknowledgments

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