Newly-discovered young, nearby stars

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Results:

- Isolated 10-30 Myr-old stars at 50 pc, *b* = –80∞
- Young stars found outside canonical boundaries of Sco OB2 and Chamaeleon.

For decades, astronomers have been studying the early stages of stellar evolution by observing large associations, such as Taurus-Auriga and Sco-Cen, that are known to be active star formation regions. In recent years, however, a number of young stars have been detected in isolated parts of the field, and at distances of only 50–100 pc (e.g., Gregorio-Hetem et al. 1992; Mamajek et al. 1999; Zuckerman & Webb 2000). These discoveries are interesting not only because we do not yet have a clear picture of star formation outside of large molecular clouds, but also because such stars are excellent candidates for studying disk evolution and planet formation. In contrast to stars in large associations, most of which lie at distances of 140 parsecs or more, these stars are near enough that we may be able to observe their circumstellar material in great detail.

With this long-term goal in mind, we have undertaken a survey of the Southern sky to search for nearby pre–main-sequence stars. In the first phase of this project, we selected a number of observation targets based on the following criteria indicating potential youth: detection in both the Hipparcos Catalog and the ROSAT Bright Source Catalog; spectral type of G5 or later; and high fractional x-ray luminosity. Subsequent observations and measurements of lithium equivalent widths allowed us to determine which of these stars are actually young. Because lithium is destroyed as low-mass stars age (see Figure 4), it is an excellent indicator of youth. Low-mass stars with significant lithium abundances are likely to be less than 50 Myr old (see Figure 1). We detected 25 young stars in this previous survey, referred to below as Phase I.

Because stars tend to form in groups, there may be additional young stars in the same regions of space as the young stars found in Phase I. Here we report on the first observing run of Phase II of our survey, in which we looked for additional young stars near the Phase I targets.

We searched the Tycho-2 catalog, which is complete to fainter magnitudes than the Hipparcos catalog is, within a ten-degree-radius field around each previously-detected pre–main-sequence star to find targets that not only meet all the previous selection criteria but that also have proper motions similar to those we know to be young. By doing this, we hoped to eliminate projection effects and select only those stars that are at similar distances to the stars we detected in Phase I. Stars in both phases of the survey were observed with the echelle spectrograph on the 4-meter Blanco telescope at CTIO on August 4–5, 2003.

Three young stars found in the first phase of our survey formed the basis for this initial Phase II run, in three different parts of the sky. HIP 86672 is projected outside the boundaries of the Upper Sco and Upper Centaurus-Lupus subgroups of the Sco-Cen OB association; HIP 70351 about 7∞ northwest of the Chamaeleon II cloud; and HIP 5191 is not near any known star-forming regions (see Table 1). We discuss each of these regions in turn. We find 19 of 33 stars in our new observations to be young (Figure 1).

Table 1. Young stars from Phase I observations

HIP	Other name	RA, Dec (J2000)	Gal. coords	V	log (L_X/L_{bol})	Spec. type	Dist. (pc)	Li EW (mÅ)	Notes
5191	HD 6569	01 06 26.09 −14 17 46.3	138.°9, −76.°7	9.5	−3.8	K1V	49	140	Isolated
70351	HD 125485	14 23 39.19 −72 48 29.1	309.°7, −11.°2	9.2	−4.0	G3/G5V	90	170	Near Chamaeleon
86672	HD 160682	17 42 30.36 −28 44 55.2	359.°8, + 0.°7	9.0	−3.6	G3/G5V	72	240	Near Upper Sco

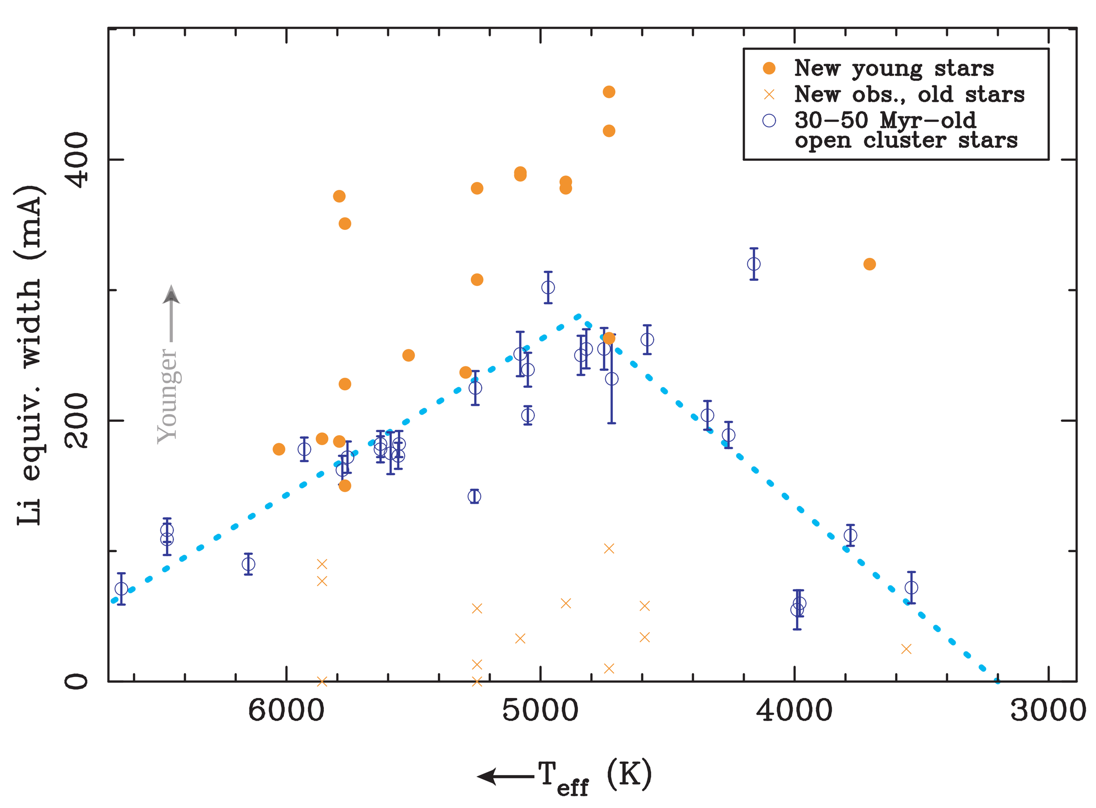

Figure 1. Li equivalent widths for stars from our new observations (orange symbols), compared to those of stars in the 30–50 Myr old clusters IC 2391 and IC 2602 (blue circles, data from Randich et al. 2001). The blue line denotes the approximate empirical locus of the Li EW–T_{eff} relation at the age of these clusters; data for the 100-Myr-old Pleiades show more dispersion but have a similar upper envelope. The stars plotted as filled orange circles lie on or above the locus of the cluster stars, and thus are likely to be 30-50 Myr old or younger. Some stars in our observations do not show strong Li (orange X's) and are presumably older; these stars are not discussed further here.

Stars near Upper Sco

As noted at left, we searched for stars within a 10∞radius of HIP 86672. While HIP 86672 lies at a distance of only 72 pc, compared with 140–145 pc for Upper Sco (US) and Upper Centaurus-Lupus (UCL) (de Zeeuw et al. 1999), and the new stars found are projected 5∞-10∞beyond the canonical boundaries of US and UCL, we believe they are members of (or at least related to) these subgroups of Sco OB2 rather than composing a distinct group of their own around HIP 86672. If we plot these stars on the HR diagram (blue symbols in Figure 5 at right) assuming a distance of 72 pc, many of them fall below the main sequence, indicating that the assumed distance is too small. When we use a distance of 145 pc (which is what is shown in Figure 5), the stars' ages (with one exception) are found to be 10–30 Myr, consistent with their observed Li equivalent widths (Figure 1).

In addition, when we use this distance to calculate galactic space velocities U, V, and W for our newly-observed stars, we find that they are roughly consistent with the average space velocities for US and UCL. This evidence, combined with similarities in measured radial velocities (see Figure 3), makes a strong case for these stars' membership in Upper Sco or Upper Centaurus-Lupus, at distances between 100 and 145 pc. The ages of these stars are more consistent with UCL (mean age of 22 +/– 1 Myr using the same evolutionary tracks, Mamajek et al. 2002) than with US (mean age 5 Myr, de Geus et al. 1989, Walter et al. 1994).

Nearly one-third of the young stars in our sample are spectroscopic binaries or triple-star systems (see Figure 2). This may be partly due to our use of x-ray brightness as a selection criterion, since short-period binaries are more likely to be rapid rotators, producing stronger x-ray emission.

It appears from our observations that the distribution of pre–main-sequence stars around Sco OB2 may extend beyond the canonical boundaries defined by previous observations.

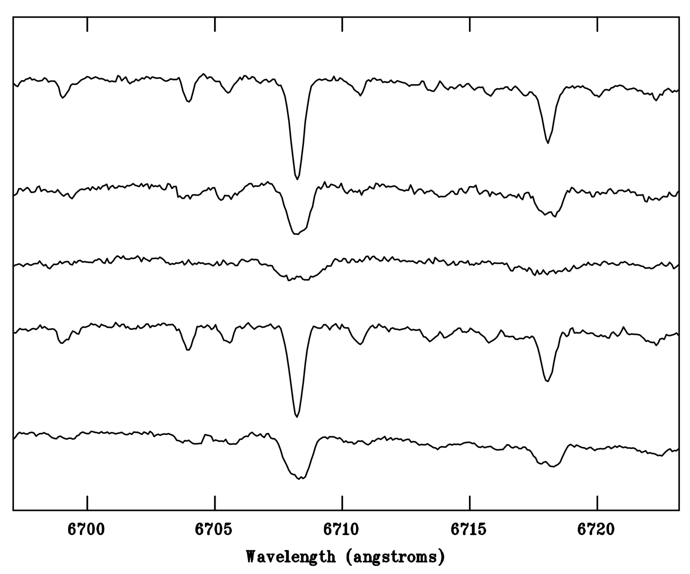

Figure 2. Spectra in the region of the Li 6708 Å line from five young stars near Upper Sco. Note that three of the five are double-lined binaries as well as being rapid rotators. A star in a binary system is more likely to have a high rotational velocity and a correspondingly large x-ray luminosity than an equivalent star that is not part of a binary system. Thus our selection of stars based on strong x-ray emission may explain why we found so many double- and triple-lined binaries (6 out of 19 young stars).

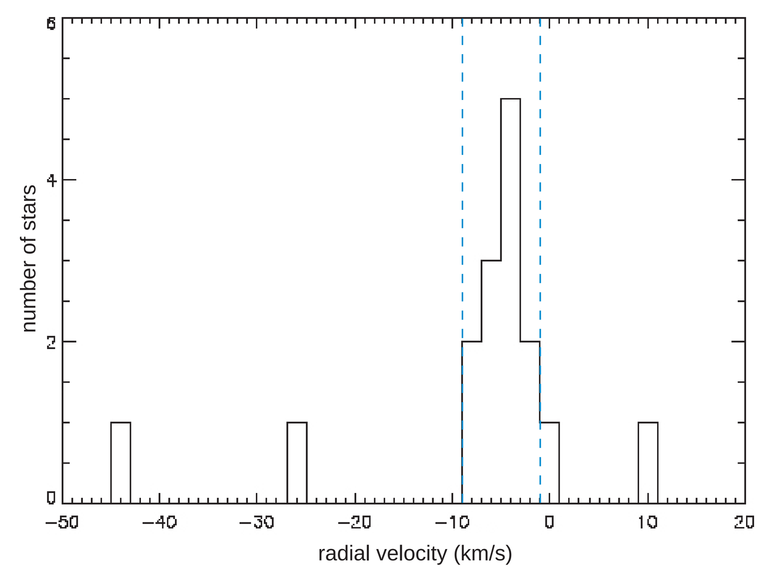

Figure 3. Histogram of radial velocities for newly-observed stars near Upper Sco (bin size = 2 km/s). Stars in Upper Sco have radial velocities ranging from –1 to –9 km/s (Walter et al. 1994), peaked at –5 km/s. Of all the stars that we observed in this region, all but three have measured radial velocities within this range, indicated by the blue lines. The star with v_{radial} = –43 km/s is not young; other outliers are stars in double-lined binary systems. For double-lined binaries, the average of the component velocities from our observations is plotted, but the true center-of-mass velocity is unknown.

Stars near Chamaeleon

Observations with ROSAT and optical follow-up revealed the presence of a substantial population of pre–main-sequence stars in the Chamaeleon region that are not associated with molecular gas (e.g., Feigelson et al. 1993, Alcalá et al. 1997). Our Phase I observations revealed an additional young star, HIP 70351, about 7∞northwest of the Cha II cloud and outside the region surveyed in previous work. Our new follow-up observations in a 10∞ radius field around HIP 70351 found one additional young star, TYC 9034 968 1, which is projected even farther from the Cha dark clouds. Assuming that TYC 9034 968 1 lies at the same distance as HIP 70351, 90 pc, we find the two stars to be coeval with an age of roughly 30 Myr (red symbols in Figure 5).

In addition, our proper-motion and x-ray selection criteria were met by TYC 9426 682 1, found by Covino et al. (1997) to have a Li equivalent width of 195 mÅ, consistent with being a similar age as the other two stars, though it is projected much closer to the molecular cloud.

We also note that Frink et al. (1998) argue for the existence of a group of stars near Chamaeleon with distinct kinematics (their subgroup 2) and a distance of about 90 pc, similar to the stars found in this work.

High-latitude isolated young stars

Perhaps the most interesting discovery in our Phase II survey to date is finding young stars at high Galactic latitude, far from any known region of star formation. HIP 5191 lies at 50 pc, and its Li line is somewhat weaker than some of the other stars in our survey, suggesting that it may be older than 30–50 Myr (Figure 1). Searching for x-ray bright stars projected near it, however, we found the M1 star TYC 5853 1318 1. This star has an extremely strong Li line, suggesting a young age. Figure 4 shows a comparison between TYC 5853 1318 1, GJ 846 (an older main-sequence star), and GJ 803 (AU Mic), a co-moving companion of **b** Pictoris. Note the extremely strong Li line in TYC 5853 1318 1, and the weaker but still present Li line in GJ 803. GJ 803 has been suggested to be part of an association with **b** Pic that has an age of 12–20 Myr (Zuckerman et al. 2001). The much stronger Li line in TYC 5853 1318 1 suggests that it is even younger than GJ 803. Assuming that it lies at the same distance as HIP 5191 (50 pc), its position on the HR diagram gives an age of 10 Myr (Figure 5).

The Galactic space motion of TYC 5853 1318 1, (*U*,*V*,*W*) = (–7.8, –14.5, –7.3) km/s assuming a distance of 50 pc, is similar to that of the **b** Pic group suggested by Zuckerman et al. (2001). However, it is fairly different from that of HIP 5191, (*U*,*V*,*W*) = (–9.1, –30.6, –10.8) km/s. Thus, despite lying near each other in the sky, these stars may not be part of a common group.

We found one other Li-rich star in this region, TYC 5850 274 1, but its kinematics are quite different from those of the other two stars, especially in *W*, with (*U*,*V*,*W*) = (–2.8, –3.0, 9.8) km/s. In addition, its position on the HR diagram (Figure 5, green triangle below the main sequence) indicates that it lies at a significantly greater distance than the 50 pc assumed here.

Thus, these high-latitude young stars do not appear to have a common origin.

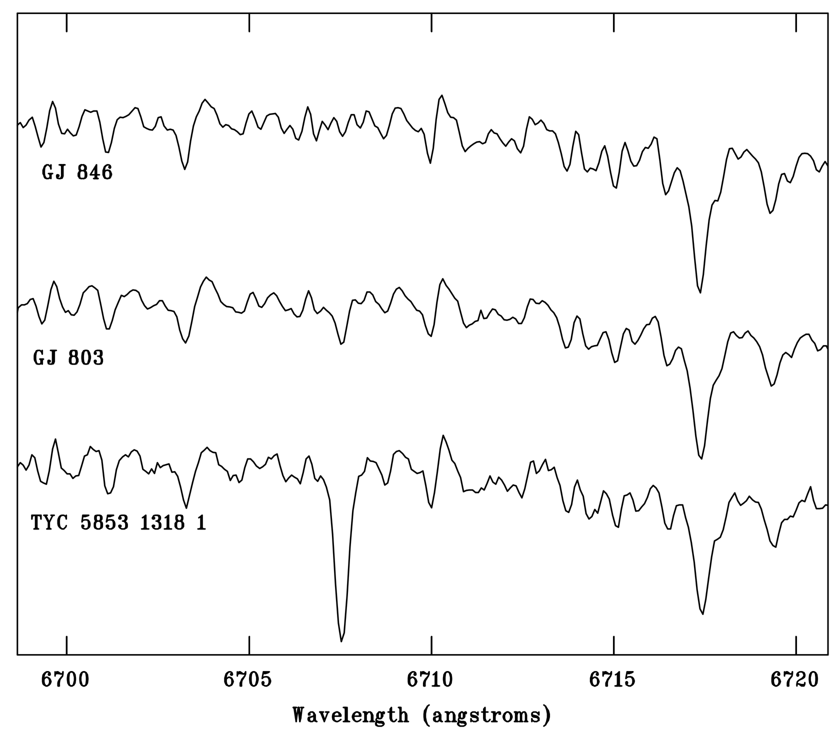

Figure 4. Spectra in the region of the Li 6708 Å feature for three early M stars. The spectra all have S/N > 100, so every feature seen here is real. Note that GJ 803 (a co-moving companion of **b** Pic) does have a detected Li line, though it is much weaker than that of TYC 5853 1318 1, a newly-discovered young star at a Galactic latitude of *b* = –85∞

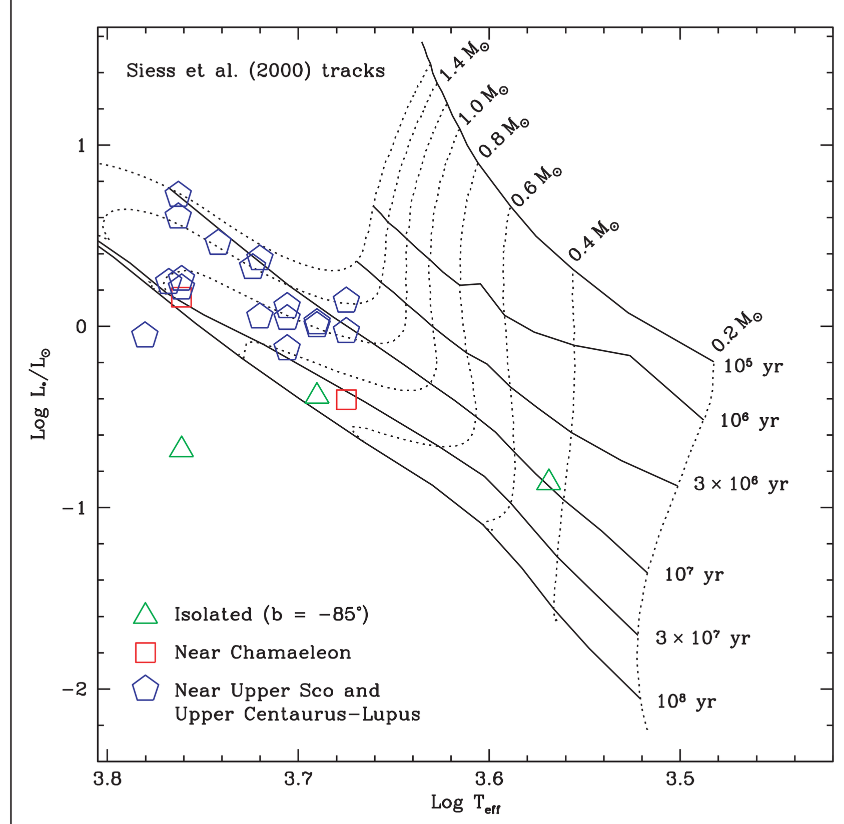

Figure 5. HR diagram of the young stars detected in this work, using the pre–main-sequence evolutionary track of Siess et al. (2001). Distances for many of these stars are unknown, so we have assumed 145 pc for the stars near Sco OB 2 (blue symbols), 90 pc for the stars near Chamaeleon (red symbols), and 50 pc for the stars at high Galactic latitude (green symbols). For a few stars these distances are clearly incorrect, but for a majority they yield ages of 10–30 Myr, consistent with their strong x-ray emission and Li absorption. We are pursuing parallax observations of TYC 5853 1318 1 and TYC 5850 274 1 (two of the high-latitude young stars) to determine their distances.

Acknowledgments

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