SACY - A SEARCH FOR ASSOCIATIONS CONTAINING YOUNG STARS *

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Abstract  The scientific goal of the SACY (Search for Associations Containing Young-stars) was to identify possible associations of stars younger than the Pleiades Association among optical counterparts of the ROSAT X-ray bright sources. High-resolution spectra for possible optical counterparts later than G0 belonging to HIPPARCOS and/or TYCHO-2 catalogs were obtained in order to assess both the youth and the spatial motion of each target. More than 1000 ROSAT sources were observed, covering a large area in the Southern Hemisphere. The newly identified young stars present a patchy distribution in UVW and XYZ, revealing the existence of huge nearby young associations. Here we present the associations identified in this survey.

Introduction  
In 1989, de la Reza et al. searched for isolated T Tau stars (TTS) and found a group of TTS around TW Hya. This was the beginning of the Pico dos Dias survey (PDS). The PDS was a search for young stars using

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the IRAS Point Source Catalog as the main selector (Gregorio-Hetem et al., 1992; Torres et al., 1995; Torres, 1998). X-ray sources from the ROSAT All-Sky Survey (RASS) gave a new tool to find new young associations (Neuhäuser 1997). With some of these sources, Torres et al. (2000) found evidences for a young nearby association: they called it Horologium Association (HorA). Almost simultaneously, Zuckerman & Webb (2000) found another one, very similar and adjacent in the sky, which they called Tucana Association (TucA). In order to examine the physical relation between both of them, and to search for other ones, we started the SACY project (de la Reza et al. 2001; Torres et al. 2001; Quast et al. 2001).

1. Observations

For SACY we selected all bright RASS sources that could be associated with TYCHO-2 or HIPPARCOS stars with \((B-V) > 0.6\), excluding well known RS CVn, W UMa, giants, etc from SIMBAD. We restricted our sample to stars later than G0 because we use the Li I \(6707\) Å equivalent width as an age indicator.

We obtained high resolution spectra for the selected candidates with the FEROS échelle spectrograph (Kaufer et al. 1999) (resolution of 50000; spectral coverage of 5000 Å) of the 1.52 m ESO telescope at La Silla or with the coudé spectrograph (resolution of 9000; spectral coverage of 450 Å, centered at 6500 Å) of the 1.60 m telescope of the Observatório do Pico dos Dias. For some stars we obtained radial velocities with CORALIE at the Swiss Euler Telescope at ESO (Queloz et al. 2000). We derived spectral classifications, radial velocities and equivalent widths of Li I \(6707\) Å lines. In particular, the Li I line is important since it can provide a crude age estimate (Jeffries 1995) for late type stars. If the Li I line equivalent width is larger than the highest values for stars stars belonging to the Local Association (Neuhäuser 1997), the star is flagged as young. This is shown in Figure 1. In Figure 2 we plot, in a polar projection, the complete sample observed.

1.1 Statistics

There are 9574 RASS bright sources in the Southern Hemisphere, 2071 of them having counterparts with \((B-V) > 0.6\) in TYCHO-2. We observed 1096 sources. We also used published information for 99 others, most of them without interest for our search and the young ones taken mainly from Covino et al. (1997). This defines the area in Figure 2, within which the SACY is complete to about 90% . Unfortunately the southern area without observations is in the core of the Sco-Cen
Association. We classified 201 stars as giants and 966 as dwarfs, 421 of them being younger than the Pleiades, 174 having the Pleiades age and 371 older than it.

2. The Young Associations

Kinematical motions (UVW) have been found for the stars measured by HIPPARCOS. According to our age classification, we find some striking concentrations in the young star UVW space that are not in the same loci of the Pleiades age ones. Older stars lack these concentrations. This can be easily demonstrated with the mpeg-movies on the CD anex.

There are four main concentrations in UVW space for young stars that probably define distinct associations. In fact, two could be identified as previously known associations: the Tuc-HorA – that we call GAYA (Great Austral Young Association) for its huge size – and the $\beta$ Pic association. Kinematically and spatially near GAYA there is another group of stars, but even more widespread and distant. The other association (AnA) is less characterized.
Most of our young stars have no HIPPARCOS parallaxes, and we applied the following kinematical analysis to find possible associations: Each point in UVW space is taken as a convergence point and we calculate for it the parallaxes of all stars such as to minimize the moduli of the space velocity vectors relative to this point (but, of course, preserving the parallaxes of HIPPARCOS stars). Then we calculate the density of stars in the velocity space around each point of a grid in UVW. Around some points there are density concentrations much larger than the background.
fluctuation, revealing possible associations. All the main concentrations are also constricted in space, albeit some of them cover large areas.

In Tables 1 & 2 we present the properties of the young associations detected in this way. In Table 1 we give the mean kinematical values and the mean parallax. For some known associations we use bonafide members not observed in the SACY to help in their definition. Their numbers are indicated in the last column in Table 1. In Table 2 we give the mean XYZ, the age, and the distance ($\rho_{\text{max}}$) of the most distant member with respect to the calculated center of the association, giving
an idea of its size. The method gives no unique solution for some stars, but in almost all cases we can infer a “best membership”.

2.1 Comments about the associations

2.1.1 GAYA1. We are calling GAYA (Torres et al. 2001) two nearby concentrations on the UVW space, separated mainly in W velocities. Both seem adjacent in the real space. GAYA1 is somewhat older and is one of the more well defined of the associations in SACY and the previous HorA and TucA are within it. Some of the proposed members of TucA are outside of the velocity definition (mainly the eastern ones). Of their 16 proposed members 8 have parallaxes in HIPPARCOS. The spread in distance is small and this does not seem an artifact either of the SACY or our analysis as its derived center is at only 45 pc. We tested 14 of its proposed members for spectroscopic binarity without any positive detection. GAYA1 seems deficient in binaries.

2.1.2 GAYA2. GAYA2 is much less well defined, although it shows a clear concentration using HIPPARCOS stars, but reinforced by members of Lower Cru-Cen (LCC). Actually, the UVW are very near the LCC ones and it is adjacent in space. Nevertheless GAYA2 seems older than LCC and closer to us.

2.1.3 TWA. The TW Hya association is not very well defined in SACY since only two members have trigonometric parallaxes. Torres et al. (2003) present a list of proposed members, but many of them lack information for a complete kinematical analysis. Anyway, we try to use all possible data. The convergence method has problems as TWA is near in velocity and space of $\epsilon$ ChaA and LCC. We applied it limiting the possible spatial volume but including any star position in Torres et al. list. Nevertheless our solution excludes many stars in their list. We proposed as bonafide kinematical members: TWA 1, 2, 3, 4, 7, 8, 12 plus a new member, CD-39 7538.

2.1.4 $\epsilon$ ChaA. This association is defined by Mamajek, Lawson & Feigelson (2000). We propose new members, enlarging it. There is ambiguity for about half of the proposed members between $\epsilon$ ChaA and LCC, but the solutions show a consistent separation in UVW space. The distance found by us indicates it is in front of the Cha complex.

2.1.5 LCC. This association has UVW near those of $\epsilon$ ChaA and GAYA2 and the age seems between both. The LCC found in SACY is very similar to that found by Sartori et al. (2003) for early-type stars.
2.1.6 US. The Upper Sco (US) has UVW near those of LCC and YSSA. US can easily be separated from LCC in real space, but many stars may be assigned both to US and YSSA. Since we have almost no observations in Upper Cen-Lupus we can not say if they would be separated in SACY.

2.1.7 YSSA. This is a group of young stars, spread from $\rho$ Oph to R Cra, with very similar properties, that we are now calling the Young Sco-Sgr Association. The western border engulfs the stars mentioned in Quast et al. (2001) and Neuhäuser et al. (2000). The split in space distribution can be explained by the incompleteness in the RASS coverage. Anyway, the convergence process gives some superposition with US association. The distance is near the assumed one for the R CrA cloud.

2.1.8 $\beta$ PicA. As described by Zuckerman et al. (2001) this association is very close to the Sun. We propose new members, some of them as far as 80 pc, but the distribution in space seems very consistent. Among the new proposed members is V4046 Sgr, a notorious object, classified before as an isolated SB classical TTS (de la Reza et al., 1986; Quast, 1998; Quast et al. 2000). WW PsA and TX PsA could be members (Song et al. 2002), but their parallaxes should be 49.5 mas, closer than HIPPARCOS ones, about $2\sigma$ of the HIPPARCOS errors.

2.1.9 OctA. This is a very homogeneous small group of almost aligned stars (all young G stars) near the South Celestial Pole. Since this region belongs to a completely surveyed area of the SACY, new members have to be found by other means.

2.1.10 ArgusA. Although not very well defined, it has a special position in UVW. Since many stars are in Car, Vel and Pup we tentatively propose to call it as Argus A.

2.1.11 AnA. Like ArgusA, the main reason to claim for this possible association are the very special UVW. The majority of the proposed members have parallaxes and, therefore, this is one of the concentrations in the HIPPARCOS sample.

GAYA1, GAYA2, LCC, US and YSSA form a decreasing sequence in age, going from west to east, and they seem to form a kind of continuum in UVW space. All the associations but the last three in the tables can represent local aspects of a global star forming process. More details of these associations can be seen in the poster of Quast et al. in the enclosed CD.
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