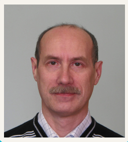
Magnetically Active Stars in Taurus-Auriga

K.N. Grankin
konstantin.grankin@rambler.ru
Crimean Astrophysical Observatory, Taras Shevchenko National University of Kyiv, Nauchny, Crimea, Ukraine



Introduction

Wichmann et al. (1996) identified 76 candidates for PMS stars toward the Taurus–Auriga star-forming region (Tau-Aur SFR). They found that about 60% of these stars could be regarded as good PMS, while the remaining stars probably belong to the ZAMS (Wichmann et al. 2000). Nevertheless, none of the objects from Wichmann's list was included in the list of recognized members of the Tau–Aur SFR published by Kenyon et al. (2008).

In this work, we use homogeneous long-term photometry and some published data for 28 well-known PMS stars from the Tau–Aur SFR and 60 candidates for PMS stars from Wichmann's list to determine their basic physical parameters and to improve the data on these magnetically active stars in the Tau–Aur SFR (Grankin, 2013a,b,c).

Photometric Observations

All broadband BV R observations for the stars from Wichmann's list were obtained with three telescopes at the Maidanak Astronomical Observatory. 60 stars down to about V = 14.4 are measured, with a photometric accuracy of ~ 0.02 mag achieved for stars brighter than about V = 12. More than 5000 BV R magnitudes were obtained for these objects in the period between 1994 and 2006. A detailed description of the observing and data reduction technique can be found in Grankin et al. (2008).

Rotation Periods

Using these photometric data, we have detected rotation periods for 20 stars from Wichmann's list and improved for 19 more objects. To increase our sample of magnetically active stars with known rotation periods, we used data for 22 well-known PMS stars from Grankin et al. (2008). Owing to such a combination, the sample of stars with known rotation periods toward the Tau–Aur SFR reached 61 objects.

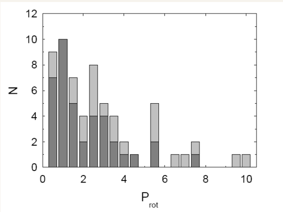


Figure 1: Distribution of the rotation periods for 39 stars from the Wichmann's list (darkly grey) and for 22 well-known PMS stars from Tau-Aur SFR (light grey).

Basic Physical Parameters

We have calculated accurate luminosities, radii, masses, and ages for 74 of the 88 sample stars and discussed principal sources of errors.

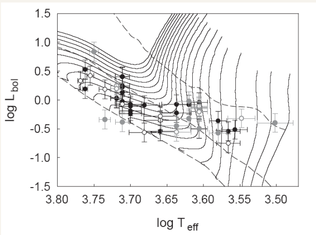


Figure 2: Hertzsprung–Russell diagram for the stars with reliable Prot and v sin i.

The stars from Wichmann's list were found to have masses in the range from 0.4 Msun to 2.2 Msun and ages from 1.5 to 40 Myr. About 33% of the stars from Wichmann's list have ages younger than 10 Myr.

The mean distance to 24 stars from Wichmann's list with reliable estimates of their radii is shown to be 143 ± 26pc. This is in excellent agreement with the adopted distance to the Tau–Aur SFR (140 pc).

Evolutionary Status

We analyzed a sample of 74 magnetically active stars toward the Tau–Aur SFR (24 well-known PMS stars + 50 candidates for PMS stars from Wichmann's list). Based on accurate data on their basic physical parameters and published data on their proper motions, X-ray luminosities, and equivalent widths of the Hα and Li lines, we refined the evolutionary status.

50 stars from this group belong to the Tau–Aur SFR with a high probability. Other 20 objects have a controversial evolutionary status and can belong to both the Tau–Aur SFR and the Gould Belt. The remaining 4 stars with ages of about 70-100 Myr were classified as ZAMS objects.

Rotation, Mass, and Ege

For 50 PMS stars with known rotation periods, we analyzed the relationship between their rotation, mass, and age.

The more massive stars of the sample rotate, on average, faster than the less massive ones (Fig 3).

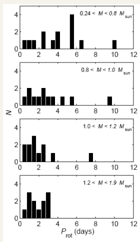


Figure 3:

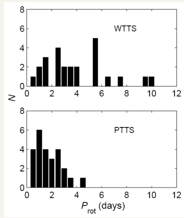


Figure 4: : The relatively old PMS stars (PTTS, t >10 Myr) rotate, on average, faster than the younger ones (WTTS, t <10 Myr).

The change in the angular momentum of the sample stars within the first 40 Myr of their evolution has been investigated. An active star-protoplanetary disk interaction is shown to occur on a time scale from 0.7 to 10 Myr.

Chromospheric Activity

Most of the stars from our sample are chromospherically active objects. The maximum activity level increases rapidly for K7–M4 stars.

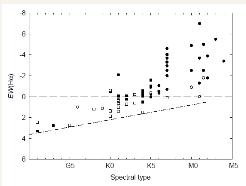


Figure 5: The dash–dotted line indicates the upper limit of EW(Hα) for nonactive field stars. The dashed line corresponds to zero for EW(Hα). The black and white symbols denote the objects with a reliable and unreliable evolutionary status, respectively. The objects classified as WTTS (with ages <10 Myr) and PTTS (with ages >10 Myr) are marked by the circles and squares, respectively.

X-Ray Activity

All stars are shown to be in the regime of a saturated dynamo, where the X-ray luminosity reaches its maximum and does not depend on the Rossby number (R_0=P_{rot}/τ_c).

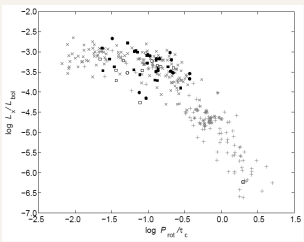


Figure 6: L_X/L_{bol} versus Rossby number. The crosses are stars from the Pleiades, IC 2391, and IC 2602 open clusters; the asterisks are Hyades stars; the pluses are MS dwarfs from Pizzolato et al. (2003). The position of the Sun at the maximum of the activity cycle is also marked. The designations of PMS objects are the same as those in Fig. 5.

Photospheric Activity

We analyzed the photospheric activity of PMS stars based on original long-term photometric observations. The maximum photometric variability amplitude was found, on average, to decrease with increasing age of the sample objects and to increase with increasing equivalent width of the Hα emission line and the lithium absorption line.

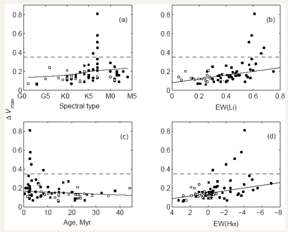


Figure 7: Maximum photometric variability amplitude versus spectral type (a), Li line equivalent width (b), age (c), and Hα equivalent width (d). The designations of PMS objects are the same as those in Fig. 5.

Li Evolution

We found a statistically significant correlation between the lithium line equivalent width and the age of solar-mass (in the range from 0.7 to 1.2M) PMS stars. The older the age, the smaller the Li line equivalent width.

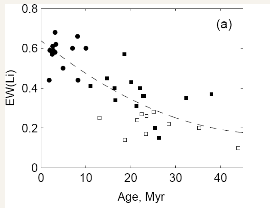


Figure 8: EW(Li) versus age. The designations of objects are the same as those in Fig. 5.

Long-Term Photometric Behaviors

Significant differences between the long-term photometric behaviors of very active well-known PMS stars and stars from the Wichmann's list have been found.

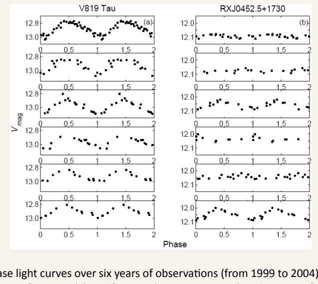


Figure 9: Phase light curves over six years of observations (from 1999 to 2004) for V819 Tau with an age of 3.3 Myr (a) and for W62 (RXJ0452.5+1730) with an age of 22 Myr (b).

Most active PMS stars exhibit the maximum photometric variability reaching 0.4 – 0.8 mag and the stability of the phase light curve over several observing seasons (Fig 9a). The remaining sample stars exhibit small photometric variability amplitudes (< 0.15 mag), with a periodicity being observed not in each observing season (Fig 9b). This result can be an indirect confirmation of the evolution of the magnetic field in pre-main-sequence stars from predominantly dipole and axisymmetric to multipole and nonaxisymmetric.

Acknowledgment

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