European Observing Proposal

bouvier TBL-08B006

Spot evolution on the weak-line T Tauri star V410 Tau

Abstract

We have been monitoring the photometric variations of the young active T Tauri star V410 Tau for more than 20 years. Its light curve is periodic (P=1.8718d) and sinusoidal with an amplitude of up to 0.7mag in V, which indicates that the stellar surface of this rapidly-rotating young star is heavily covered with magnetic spots. For the first time in the last 20 years, the amplitude decreased in 2007 to a nearly vanishing level, which suggests a drastic reconfiguration of the spot coverage onto the star. We propose here to obtain a Zeeman-Doppler map of the stellar surface of V410 Tau, starting in 2008 and continuing over the next 5 years, in order to characterize and monitor the spectacular evolution of the surface magnetic field now taking place in this young star.

Science category : PNPS **Observing mode :** Service mode

Total requested nights: 6 nights

Telescope	Dark	First	Bright	Last	Instruments
TBL	2	2		2	Narval

Details, including preferred dates and periods to be avoided:

We ask for 6h/night over 13 consecutive nights (equivalent to 6 full winter nights). The preferred dates correspond to the maximum of visibility of the target, i.e., the dark or grey moon of November (from Nov.19 to Dec.7, 2008)

Contact Author

Title		***Institute***	Laboratoire d'Astrophysique de Grenoble
Name	jerome bouvier	***Department***	
Email	jbouvier@obs.ujf-grenoble.fr	***Address***	
Phone(first)	33(0)476514790	***Zipcode***	
Phone(second)		***City***	
Fax		***State***	
		Country	France

Pi

is the same as the contact author

Applicants

Name	Affiliation	Email	Country		Potential observer
jerome bouvier	Laboratoire d'Astrophysique de Grenoble	jbouvier@obs.ujf-grenoble.fr	France	Pi	Yes
dr jean-francois donati	observatoire midi-pyrenees (latt)	donati@ast.obs-mip.fr	france		Yes
Grankin Konstantin	Crimean Astrophysical Observatory	konstantin.grankin@rambler.ru	Ukraine		

Summary of observations

Number of targets	Telescope	Instrument	Exposure (mins.)
1 targets	TBL	Narval	40

Is this a long term proposal: Yes

We'd like to obtain a Zeeman-Doppler map of the surface of V410 Tau every year between 2008 and 2012 in order to monitor the long-term evolution of spot coverage and magnetic topology at the surface of this star.

No PhD Students involved

Linked proposal submitted to this TAC: No

Linked proposal submitted to other TACs: No

Science rationale:

Low-mass pre-main sequence stars (T Tauri stars) are amongst the most magnetically active objects in the solar neighborhood. Enhanced activity is betrayed by X-ray luminosities and non-thermal radio flares that exceed those of the quiet Sun by several orders of magnitude (e.g. Montmerle 1997). Cold dark spots are known to cover a large fraction on their stellar surface, up to several 10% of the photosphere (Bouvier & Bertout 1989). Whether the extreme activity of young stars results from strong fossil fields (Tayler 1987) or dynamo-generated fields (e.g. Bouvier 1990) is still under debate. Thanks to the advent of powerful spectro-polarimeters such as TBL/NARVAL and CFHT/ESPADONS, the magnetic field intensity and geometry of these young stars can now be studied with a new wealth of details.

Among young active stars, the weak emission-line T Tauri star V410 Tau is probably the most interesting and best studied. With a spectral type K4, lithium in absorption and a weak Hα emission (Herbig 1977; Cohen and Kuhi 1979; Holtzman, Herbst, and Booth 1986), it is also a source of highly variable, nonthermal, radio emission (Cohen, Bieging, and Schwartz 1982; Becker and White 1985), but exhibits no infrared excess (Rucinski 1985). V410 Tau is a fast rotating star ($v \sin i$ ~70 km/s; Hartmann et al. 1986) with a 1.87 day rotational period derived from its photometric variability (Rydgren & Vrba 1983; Vrba et al. 1988; Bouvier & Bertout 1989). The periodic light variations have an amplitude of 0.2-0.6 mag in the V-band, which is attributed to cold stellar spots that cover at least 45% of the stellar surface. This young rapidly-rotating star thus exhibits intense surface magnetic activity, also witnessed by its large X-ray luminosity (3.10^{30} erg/s, Stelzer et al. 2003) and strong flares in the U-band (Fernandez et al. 2004).

V410 Tau is indeed an ideal candidate for a continued study of magnetic activity in cool stars : it is relatively bright, well situated for observation from the northern hemisphere and has exhibited the largest amplitude of variability among all known spotted variables (including RS CVn and BY Dra stars). The study of long-term photometric variations is of considerable interest as one expects the light-curve to evolve over the years as the spots change size, shape, temperature, and/or location at the stellar surface. It would also be very interesting to find evidence for long-term cyclic patterns that could be related to dynamo cycles.

The first systematic UBVR observations for this star began in 1986 at the Maidanak Observatory. Over nearly 20 years (1986-2004, see Fig.1), V410 Tau has exhibited smooth periodic light variations (P=1.8718 days) resulting from cool spotted regions on its surface (see Grankin et al. 2008). Model calculations (Grankin 1999) show that, (1) the spot temperature is lower than the photospheric temperature by at least by 1450 K, and (2) spotted regions cover from 29 to 42% of the visible stellar hemisphere at maximum light and from 61 to 67% at minimum light. Small variations in the maximum brightness level, in the amplitude and the shape of the light curve over the period 1986-2004 suggest limited spot evolution over the years.

However, drastic changes started to occur in the light curve of V410 Tau from 2005 on. This is shown on Figure 1, where the V-band light curve is shown over the past 27 years (!). While the photometric variations were quite smooth, sinusoidal and repeatable over the time period 1986-2004, the amplitude suddenly started to decrease quite significantly in 2005, reaching a minimum in 2007 (oct.07- jan.08). It is quite noticeable that a similar episode occurred nearly 27 yr ago over the period 1981-1985. This ~27 yr evolution possibly reflects a long term activity cycle similar to the 11 yr cycle occuring in the Sun.

We speculate that the phase at which the light curve reaches a minimum and the 5 following years of recovery trace a crucial period of the activity cycle. What happens to the spot configuration and to the underlying magnetic field distribution during these 5 years of perturbations should therefore give us hints on how dynamo processes are operating in PMS stars, something on which very few constraints have been obtained so far. At least 2 possible interpretations can be put forward to explain the sudden decrease in amplitude of variability : either large monolithic spots have drifted exactly to the stellar poles, or many small spots are now nearly evenly distributed over the stellar surface. These 2 possible, nearly axisymmetric, configurations would produce little modulation of the light curve, as observed in 2007.

In order to decide between these alternatives, we need to obtain a Doppler map of the stellar surface, or even better, a Doppler-Zeeman map. We will then be able to capture how the cool polar spots and equatorial regions develop and extend with time, how much toroidal and poloidal fields the magnetic topology contains at each stage of the evolution process, and how much the surface of V410 Tau is sheared by differential rotation, a crucial ingredient for the dynamo process. The first Doppler images of V410 Tau were published by Joncour et al. (1994) and Strassmeier et al. (1994), and were confirmed by Hatzes (1995) and Rice & Strassmeier (1996). All of them showed a large cool spot that extends over one of the stellar poles and smaller cool features located at low latitudes. These images were all obtained at an epoch when the star showed a large amplitude of variability.

Today, the amplitude of variability has reached its deepest mimimum in the last 27 years of observations. Obtaining a Zeeman-Doppler image of the stellar surface at this very peculiar and presumably short-lasting state of spot evolution is therefore a unique opportunity to i) understand the origin of the light-curve amplitude variations, ii) put definite constraints on the evolution of cold magnetic spots at the surface of rapidly-rotating late-type stars, and iii) investigate the physics and evolution of magnetic field topologies at the surface of young active stars.

Technical:

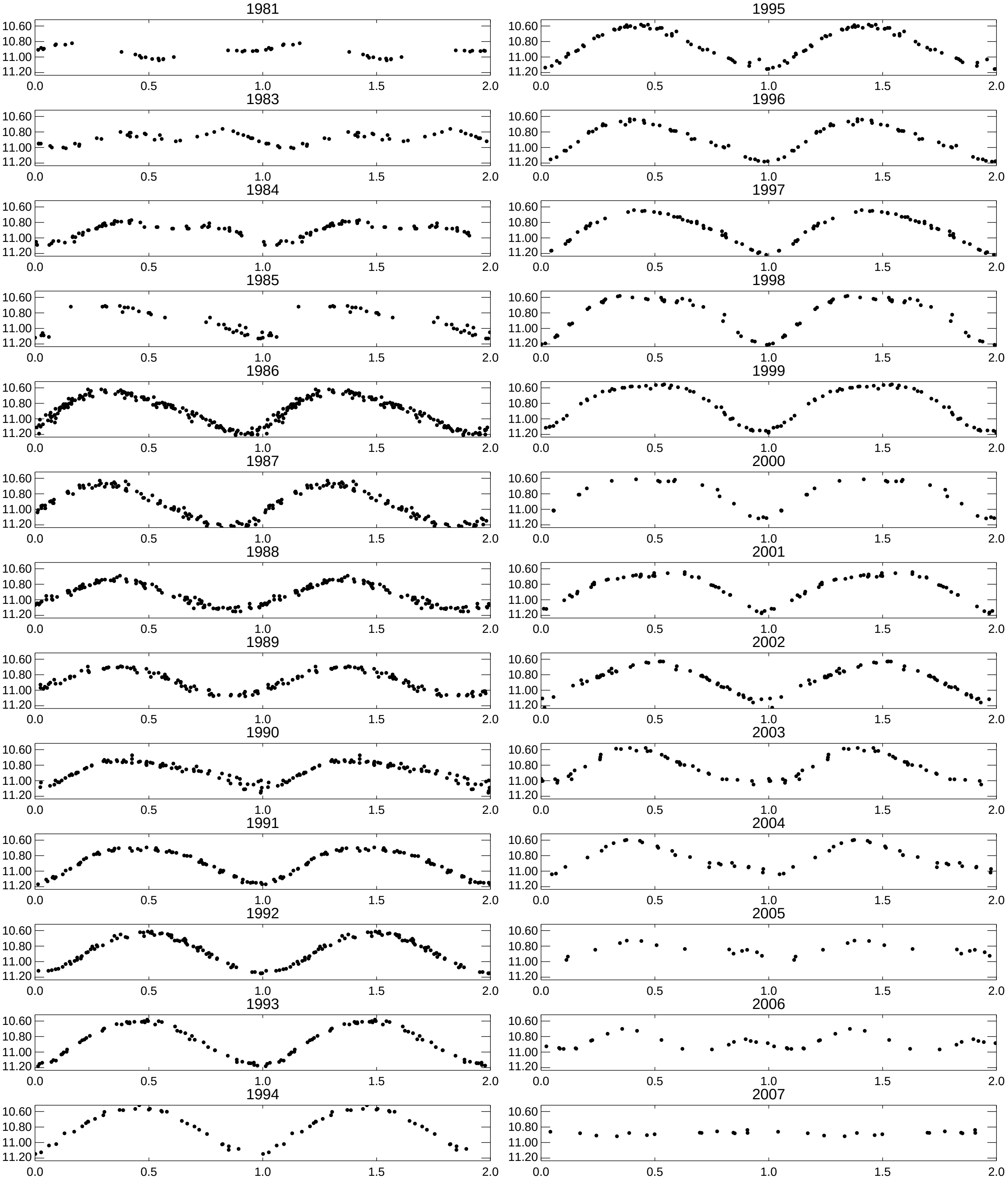
In order to be able to reconstruct a Zeeman-Doppler map of the surface of V410 Tau, we have to obtain high S/N NARVAL spectra of the target in the polarized mode with an even sampling of the rotational phase (P=1.87d). For V410 Tau (Sp.T=K4, V=11), NARVAL yields a peak SN of about 150 per 2.6km/s velocity bin in Stokes V spectra for a 4x600s exposure polarisation sequence. Using least-square deconvolution (LSD), we will extract the polarisation information through 9,000 lines simultaneously, thus improving the SN ratio in the V spectra by a factor of 40 with respect to the peak SN in individual spectra. This will provide V signatures with a noise level as low as 1.7e-4, i.e., enough to detect the magnetic signatures that we expect from active stars like V410 Tau, and to monitor their rotational modulation.

To obtain a complete map of the surface brightness (spots) and of the magnetic topology of V410 Tau, as well as to estimate surface differential rotation, we need to observe the star for 3h twice per night (i.e., on each side of the visibility window, giving access to 11% of the rotational cycle) and to repeat this sequence over 13 consecutive nights (giving access to phases 0.00-0.11 on n1, 0.53-0.64 on n2, 0.07-0.18 on n3, 0.60-0.71 on n4, 0.14-0.25 on n5, 0.67-0.78 on n6, 0.21-0.32 on n7, 0.74-0.85 on n8, 0.27-0.38 on n9, 0.81-0.92 on n10, 0.34-0.45 on n11, 0.88-0.99 on n12 and 0.41-0.52 on n13). We therefore ask for about 6 complete winter nights (14h/night) spread on 13 consecutive nights (at a rate of 6h/night) in semester 08B.

As shown by the long-term evolution of V410 Tau's light-curve (Fig.1), the recovery from the deep photometric amplitude minimum that occurred in 2007 is likely to take several years (see the 1981-1985 light curves). We therefore plan to repeat these observations over the 4 following years (2008-2012) to trace the long-term evolution of the spot configuration and magnetic topology at the stellar surface. Photometric monitoring will be pursued simultaneously on this time frame by K. Grankin in order to relate NARVAL results to the evolution of photometric light curves.

References:

Becker, R.H., and White R.L. (1985). ApJ Lett. 297, L649.
Bouvier, J. (1990). AJ, 99, 946
Bouvier, J., and Bertout, C. (1989). A&A 211, 99.
Cohen, M., and Kuhi, L.V. (1979). ApJ Suppl. 41, 743.
Cohen,M., Bieging, J.H., and Schwartz, P.R. (1982). ApJ 253, 707.
Fernandez, M., Stelzer, B., Henden, A., Grankin, K.N., et al. (2004). A&A 427, 263.
Grankin, K.N. (1999). Astron. Lett., 25, 611.
Grankin, K.N., Bouvier, J., Herbst, W., and Melnikov, S.Yu. (2008). A&A 479, 827.
Hartmann, L., Hewett, R., Stahler, S., and Mathieu, R. (1986). ApJ 309, 275.
Hatzes, A.P. (1995). ApJ 451, 784.
Herbig, G.H. (1977). ApJ 174, 401.
Holtzman, J.A., Herbst, W., and Booth, J.F. (1986). AJ 92, 1387.
Joncour, I., Bertout, C., and Menard, F. (1994). A&A 285, L25.
Montmerle, T. (1997). Memorie della Societa Astronomica Italiana, 68, 1017
Rice, J.B., and Strassmeier, K.G. (1996). A&A 316, 164.
Rucinski, S.M. (1985). AJ 90, 2321.
Rydgren, A.E., and Vrba, F.J. (1983). ApJ 267, 191.
Stelzer, B., Fernandez, M., Costa,V.M., Gameiro, J.F., Grankin, K. et al. (2003). A&A 411, 517.
Strassmeier, K.G., Welty, A.D., and Rice, J.B. (1994). A&A 285, L17.
Tayler, R. J. 1987, MNRAS, 227, 553
Vrba, F.J., Herbst, W., nd Booth, J.F. (1988). AJ 96, 1032.


1981
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
10.60
10.80
11.00
11.20
0.0
0.5
1.0
1.5
2.0

Justify the nights

The rotational period of V410 Tau is 1.8718 days (Grankin et al. 2008). We need to evenly sample the rotational phase of the object in order to be able to reconstruct the surface Zeeman-Doppler map from NARVAL spectra. An even (no gaps) and complete phase coverage can be obtained by observing the object 6h/night over 13 consecutive nights. We thus ask for this amount of time, in either dark or grey moon.

Relevant previous Allocations: No

No additional remarks

Observation details

Telescope: TBL

Narval Instrument details

Observing mode: POL3 (polarimetry R=65000)

Required scheduling constraints

The period of the target is 1.8718d. We aim at obtaining an even and complete phase coverage in order to be able to reconstruct the Zeeman-Doppler map of the stellar surface. This constraint can be met by observing the target 6h/night over 13 consecutive nights.

Dark or grey time requested, as full moon is close to the target.

No preferred scheduling constraints

Field	RA	Dec	Epoch	Exposure (min.)	Moon	Seeing	Water	S/N	Magnitude	Comments
V410 Tau	04:18:31.11	+28:27:16.1	J2000	40	first quarter	>0.9	don't care	150	11	Period=1.87d