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# Magnetic field measurements for $\theta^1$ Ori C with the 6-meter telescope

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**Abstract.** The longitudinal magnetic field is measured for the star $\theta^1$ Ori C at eight points in its period using the CIV 5801 Å and 5812 Å absorption lines. The measurements were made on the 6-meter telescope using a circular polarization analyzer with an image slicer and in the back-and-forth mode. The maximum value was $+231 \pm 47$ G.

The star $\theta^1$ Ori C (HD 37022) is the brightest ($m_v = 5.1$) in the Trapezium of Orion. Its age is estimated at 200000 years (Howarth and Prinja 1989). It is on the ZAMS. This star is the main source of ionization of the Orion nebula. This is a multiple system. It consists of two hot components (O 5.5

Figure 1: Fragments of a Zeeman spectrum in the region of 5850Å.

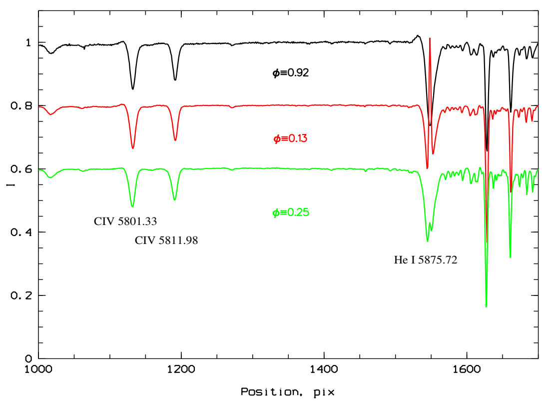


Figure 2: Fragments of spectra in three phases of rotation.

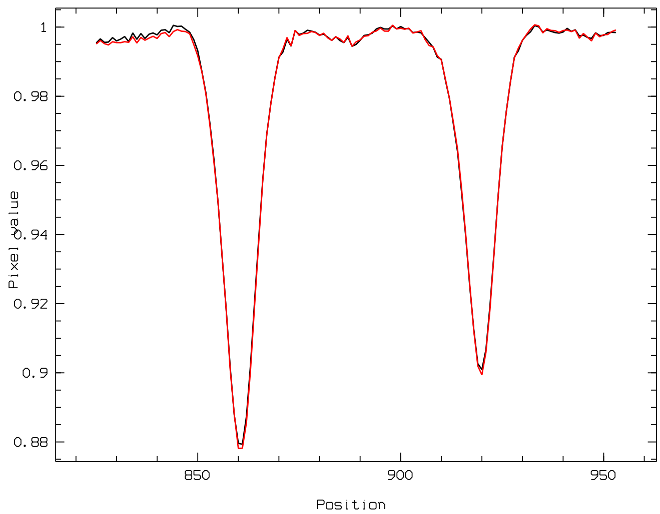


Figure 3: Fragments of extracted Zeeman spectra in the neighborhood of CIV $\lambda$5801 Å and $\lambda$5812 Å lines in phase 0.64.

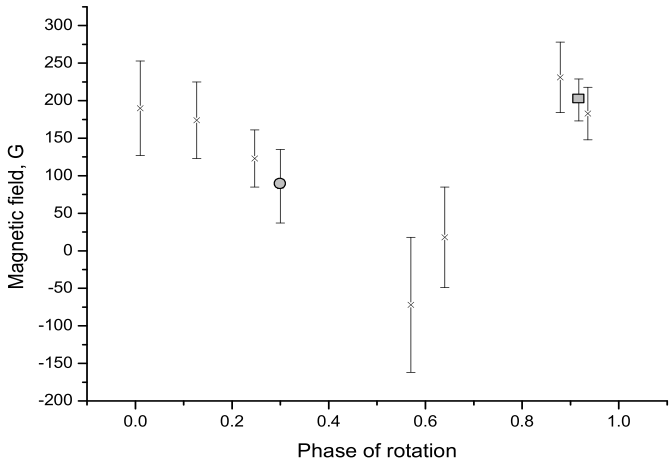


Figure 4: Variation in the magnetic field of $\theta^1$ Ori C with phase of rotation.

and O 9.5), K 7 component, and a cold object with temperature of 190 K (Vitrichenko 2004, Kraus, Balega et al. 2007). Parameters of hot components are: M = 34.0 $M_\odot$ and 15.5 $M_\odot$, $T_{eff}$ = 39900 K and 31900 K, the distance — 414±7 pc (Menten et al. 2007), the period of rotation — 15.426 days (Stahl et al. 1996). Chemical composition: He, C, O, Si, Fe, Ni, Zn — in deficit, Ne — in excess; N, P, S, Mn — at the solar abundance. A satellite at a distance of 0.033" has been reported (Weigelt et al. 1999). The minimum cycle time makes according to 8 years. Walborn, 1981 has found periodic variations of broad H-alpha emission line in the spectrum of $\theta^1$ Ori C, and detailed researches have revealed that many emission and photospheric absorption lines change with the same period, $15^d.426 \pm 0.002$. The strictly periodic change of lines allows one to believe that the case of a magnetic rotator is possible. The star shows a variability of brightness with an amplitude of $0^m.06$ (Kukarkin 1982). Gagne et al. (1997) have found that the X-ray flux from this star changes with a period of about 16 days. To explain this phenomenon, Babel and Montmerle (1997) have offered a model of an oblique rotator with a surface magnetic field Bs = 300 G. Since 1966 (see, for example, Kudryavtsev et al.

Table 1: Magnetic field vs phase.

| +2450000.00 | Be, G | phase | sigma, G |
|---|---|---|---|
| 3339.27 | 190 | 0.01 | 63 |
| 3339.35 | 174 | 0.127 | 51 |
| 3279.50 | 123 | 0.247 | 38 |
| 2678.78 ** | 86 | 0.30 | 49 |
| 3747.29 | -72 | 0.57 | 90 |
| 3748.33 | 18 | 0.64 | 67 |
| 3366.38 | 231 | 0.879 | 47 |
| 2950.46 * | 201 | 0.917 | 28 |
| 3367.25 | 183 | 0.936 | 35 |

* – observations were made in a back-and-forth mode
** – Bagnulo et al. (2006)

2000), unsuccessful attempts to find magnetic field in this star have been undertaken. The difficulty of detection consists in the small number of spectral lines suitable for measurements. In 1999–2000 at the Anglo-Australian observatory Donati et al. (2002) have registered a magnetic field. They reported detection of a periodically changing longitudinal magnetic field of about 300 G with a period conterminous to the period of change of spectral lines. Estimations of the surface field gave a value of about 1 kG. The authors give the following parameters of the rotator: the inclination of the axis of the magnetic dipole to the axis of rotation of the star is $42° \pm 6$ and the angle of inclination of the axis of rotation of the star to the observer is about $45°$. Smith and Fullerton (2005) have revised the model of this star. While in last papers the attention is focused on a full structure ultra-violet CIV and NV resonant lines, they analyze blue and red wings of these lines. On the basis of this analysis of the behaviour of resonant spectral lines, a model of the star in which magnetic lines are broken off at some distance from the star is constructed. The component of the star wind shows absorption shifted towards the blue part of the spectrum. The geometry of the internal parts is more complex. Particles of the star wind move from poles along magnetic lines and collide at the magnetic equator. In collision emission occurs, and the particles fall on the star along magnetic lines. The high temperature of these falling condensates causes a red-shited emission.

Observations were made withn the Main Stellar Spectrograph of the 6-meter telescope with use of an analyzer of circular polarization and a double slicer (Chountonov 2004). One measurement was carried out in a back-and-forth mode (Chountonov et al. 2000). Instead of the Savart plate (an element from Iceland spar) usually used in the analyzer, a dichroic polarizer consisting of two glass prisms stuck together, to the diagonal side of which a multilayer dielectric covering is applied, is employed. The polarizer in contrast to the element of Icelandic spar does not cause dispersion at the slit of the spectrograph. The image slicers produce 7 slices 5 arcsec in height for each polarization, which increases the efficiency of measurements by a factor of 2–5. A diaphragm placed in front of the polarizer does not allow the Zeeman spectra to overlap. The magnetic field measurement data are listed in Table 1.

This star is beyond the range of magnetic chemically peculiar stars. The magnetic moment of such massive stars as $\theta^1$ Ori C is so great that such stars may appear to be predecessors of magnetars (single neutron stars with magnetic fields up to $10^{15}$ G).

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## References

Babel J. and Montmerle T., 1997, Astrophys. J., **485**, L29

Bagnulo S, Landstreet J. D., Mason E. et al., 2006, Astron. Astrophys., **450**, 777

Chountonov G.A., Murzin V.A., Ivashchenko N.G., Afanasieva I.V., 2000, in: Proc. of the Intern. Conf. "Magnetic fields of chemically peculiar and related stars", Yu.V. Glagolevskij and I.I. Romanyuk. (eds.), 249, Moscow

Chountonov G.A., 2004, in: Proc. of the Intern. Conf. "Magnetic stars", Yu.V. Glagolevskij, D.O. Kudryavtsev and I.I. Romanyuk. (eds.), 286, Nizhnij Arkhyz

Donati MJ-F., Babel J., T. J. Harries T. J. et al., 2002, Mon. Not. R. Astron. Soc., **333**, 55

Gagne M., Caillault J.-P., Stauffer J., and Linsky J. L., 1997, Astrophys. J., **478**, L87

Howarth I.D. and Prinja R.K., 1989, Astrophys. J. Suppl. Ser., **69**, 527

Kraus S., Balega Yu.Yu., Berger J.-P., et al., 2007, Astron. Astrophys., **466**, 649

Kudryavtsev D. O., Piskunov N.E., Romanyuk I.I., Chountonov G.A., and Shtol V.G., 2000, in: Proc. of the Intern. Conf. "Magnetic fields of chemically peculiar and related stars.", Yu.V. Glagolevskij and I.I. Romanyuk. (eds.), 64, Moscow

Kukarkin B.V. et al., 1982, New Catalog of Stars Suspected of Brightness Variations [in Russian], Nauka, Moscow

Menten K.M., Reid M.J., Forbrich J., Brunthalen A., 2007, Astron. Astrophys., in press

Smith M.A. and Fullerton A.W., 1994, Publ. Astr. Soc. Pacific, **117**, 13

Stahl O., Kaufer A., Rivinius Th. et al., 1996, Astron. Astrophys.,**312**, 539

Vitrichenko E.A., 2004, The Trapezium of Orion [in Russian], Nauka, Moscow, 304

Walborn N. R., 1981, Astrophys. J., **243**, L37

Weigelt G., Balega Yu., Preibisch T. et al., 1999, Astron. Astrophys., **347**, L15