

WIDE-FIELD PLATE DATABASE AND PRESENT EXPLOITATION OF THE ARCHIVAL PLATES

KATYA TSVETKOVA

*Institute of Astronomy, Bulgarian Academy of Sciences, Tsarigradsko Shosse 72,
1784 Sofia, Bulgaria*

e-mail: katya@skyarchive.org; milcho@skyarchive.org

Abstract. The last development of the Wide-Field Plate Database (WFPDB) - unique source of information for archived astronomical wide-field photographic observations worldwide made with professional telescopes since the application of photography as a method for observations, is present. The WFPDB collects at the moment information for 531 000 photographic plates (or 24% of all existed and stored 2 200 000 wide-field plates in astronomical observatories and institutions all over the world). In order to enable future possible investigations on the base of the WFPDB a list of the used observational programmes is compiled. The main characteristics of these programmes is their long duration and as a result - the accumulation of large knowledge about the observed phenomena. A compiled list of astronomical tasks and results achievable through the access to digitized archival wide-field plates (composed light curves of interesting variable stars, search for long-term brightness variations, possible activity cycles and past eruptions of a pre-main sequence star, detection of new small solar system bodies, monitoring of known objects and improvement of their orbits, search for optical analogues of GRBs and photometric variability of quasars, present use of CdC plates, etc) is present.

1. INTRODUCTION

The archival photographic plates which accumulated large knowledge about observed astronomical objects are especially wanted in studies requiring look and estimation of the position and brightness back in time. Papers based on the archival plates appear frequently helping to solve the questions about object origin, way of evolution, trajectories. The essential first step to widely re-use of the plate archives stored in the astronomical observatories and institutions all over the world is a fast and easy on-line access to the information for the plate archive locations and contents, parameters and quick visualization of the needed astronomical plates. Such tool integrating the plate archives information from many different observatories, used telescopes for plate observations and scanning facilities for

plate digitization is now the WIDE-FIELD PLATE DATABASE (WFPDB, <http://www.skyarchive.org>).

Aiming to store the valuable scientific heritage and quickly to offer the opportunity to see back in time records of interesting astronomical phenomena the WFPDB is at present the unique source of information for existing more than 2 200 000 wide-field astronomical plates worldwide obtained with professional telescopes since the application of the photography for astronomical observations. The WFPDB is based and developed since 1991 in the Institute of Astronomy, Bulgarian Academy of Sciences and with mirror site in Astrophysical Institute Potsdam since 2007. The first version of the WFPDB (containing information for 323 000 plates) has been installed at Strasbourg (<http://vizier.u-strasbg.fr/cats/VI.htx>) since 1997. The enlarged regularly updated and developed version can be found since 2001 at Sofia Sky Archive Data Center (<http://skyarchive.org>) giving information of about 119 distributed plate archives and on-line access to their prepared computer-readable catalogues with about 531 000 plates with possibility for quick preview of some of needed plates made with low resolution in JPEG format file and complete plate image with high resolution in FITS file upon request.

2. WIDE-FIELD PLATE DATABASE STRUCTURE

The WFPDB consists of four integrated parts:

- Catalogue of Wide-Field Plate Archives (CWFPAs, actual version from April 2008) giving in table form the information about 440 archives stored in 125 observatories (Tsvetkova and Tsvetkov 2006);
- Catalogue of Wide-Field Plate Indexes (CWFPs, regularly updated), containing at the moment information for 530 923 plates from 119 archives available through web based search system developed in Sofia Sky Archive Data Center (the all-sky distribution of the plate centers is present in Fig. 1).
- Bank of digitized plate images (with volume of about 2TB) – previews for quick plate visualization and easy on-line access, and working scans for photometric and astrometric investigations with implementation of Wavelet transformation methods for compression;
- Links to on-line services and cross-correlation with existing astronomical catalogues, or with journals (e.g. plate images in the WFPDB and published papers in IBVS as scientific output of the usage of plates).

In Fig. 2 the preview image of BUC038 207777 plate digitized for quick plate visualization and for storage of observer's markers, is present. The 24x24cm plate (taken on October 2, 1972) with emulsion AGFA GEVAERT and 2 exposures each with duration 15 min is scanned with the UMAX Alpha Vista II flatbed scanner. The output file is in TIFF format. The plate preview is done with 600dpi resolution yielded to 51MB file volume. In the WFPDB we have at disposal also the plate scan done with 1200 dpi, which gives 207MB output file (so called "real scan"). This plate is one from the existing 19 BUC038 plates containing images of 4 minor planets (Tsvetkova and Popescu 2008), on the plate BUC038 207777 these are images of 116 Sirona, 1527 Malmquista, 93 Minerva and 436 Patricia.

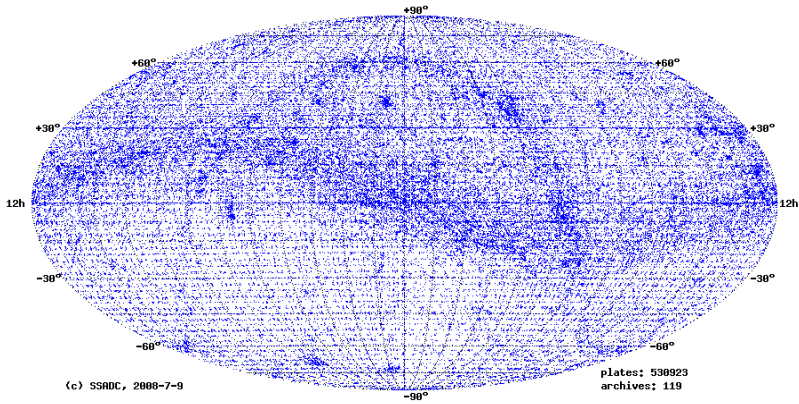


Figure 1: All-sky distribution of the plate centers.



Figure 2: Preview image of the digitized BUC038 207777 plate.

3. USED PROGRAMMES FOR PLATE OBSERVATIONS

From the analysis of the included into the WFPDB plate index catalogues a compiled list of long duration observational programmes in the frames of which the plates were obtained, is present here. This list includes:

- Observations of the major planets and their satellites;
- Small solar system bodies observations (search for new asteroids, astrometric observations of known asteroids and search for satellites of asteroids, photometric determination of the shape and the rotation of asteroids, discovery and past transits of comets);
- Photographic sky surveys;

- Selection of reference stars;
- Artificial satellites observations;
- Observations of stellar occultations;
- Discovery and patrol of variable stars (in the Milky Way and in external galaxies),
- Determination of parallaxes of stars,
- Determination of proper motions;
- Astrometric observations for the determination of orbits and parallaxes for binaries,
- Study of the Galaxy structure and kinematics from observations in selected areas (investigations of the emission nebulae and connected stars, spectral classification of the stars and determination of the stellar absorption in the direction of the emission nebulae);
- Search and monitoring of some interesting astronomical objects (AGNs, QSOs, novae and supernovae).

In Fig. 3 and Fig. 4 the distributions of the wide-field plates stored in the observatories of the two neighbouring countries of Serbia – Hungary (KON060 plate catalogue) and Romania (BUC038 and BUC016 plate catalogues) versus object type, as illustrations of the existing variety of observing programmes, are present.

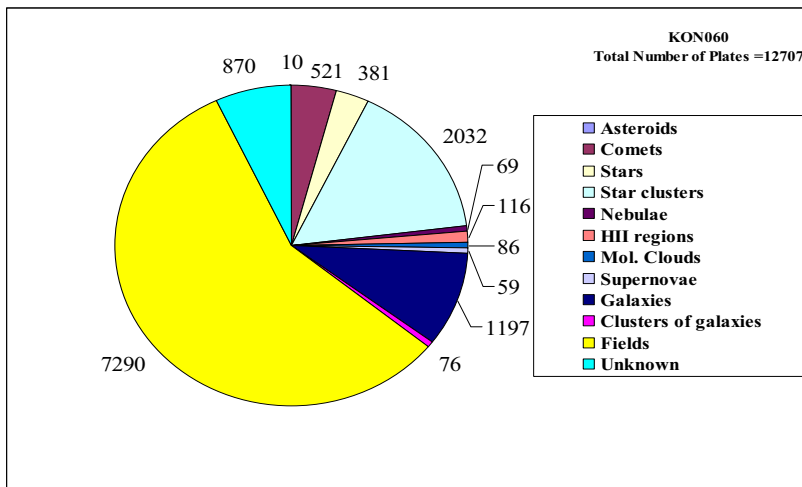


Figure 3: Distribution of the KONG060 plates versus object type.

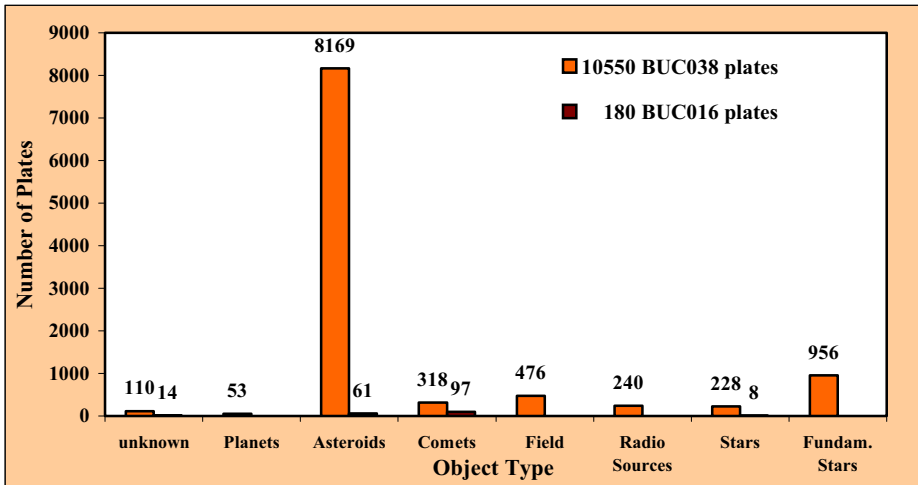


Figure 4: Plate number distribution of BUC038 and BUC016 plates versus object type.

4. PRESENT EXPLOITATION OF THE ARCHIVAL PLATES

It is known fact that almost half of all investigated stars are variable stars with different variability by type and by time/amplitude scale: from irregular variations, or cyclic ones with period from some days to some years, to stars which brighten and fade slowly over decades with small amplitudes or stars which undergo critical evolution stage. According to the Combined General Catalogue of Variable Stars (Samus et al. 2004) their number is more than 76 000 (among them 38 600 have designation) with rate of increasing of 1500 more every year (Samus 2008, private communication). Expanding the period of observations with archival observations in order to construct their light curves can be essentially for solving question of their origin. The larger statistical basis thanks to involving archival plates enable better classification of the variability type or discovery of new types of extremely slow variability. The plate digitization makes possible automatic search for brightness increase, which yielded in discovery of 50% more flare stars in the Orion region in comparison with the usual plate checking (Winterberg et al. 1995).

Having at disposal information for the distributed plate archives, the contents of their prepared plate catalogues and tool for searching observational data for certain object, spatial plate distribution on the sky region, temporal coverage, used observing method and special techniques, purpose of the plates (it is a part of sky survey or sky patrol), magnitude limit of the plates, plate quality, etc., and on the other hand the digitized images of the needed plates with photometric and astrometric accuracy making them practically identical with the originals, one can begin with astronomical research.

Here we present a compiled list of astronomical tasks and results achievable through the access to digitized archival plates from at least two plate archives stored in different astronomical observatories or institutions.

4.1. Composed light curves of different variable stars for as long as is possible time period

As an example of use of archival plates can be quoted the work of Johnson et al. (2005) who composed the BVRI light curves of KH 15D (T Tau type star) from observations covering period from 1954 to 1997. Photographic plates in the region of the stellar cluster NGC 2264, in which the star resides have been found to be at disposal in Asiago, Kiso, Kitt Peak, Mount Wilson, Palomar, Tautenburg, and Rozhen observatories and from the observed evolution of the system's light curve can conclude that the reason for the observed eclipses is that KH 15D is being occulted by an inclined, precessing, circumbinary ring.

4.2. Search for long-term brightness variations

In young solar-type stars: 1030 archival plates were used by Froehlich et al. (2002) for searching for activity cycle in the young solar analogue EK Dra - a slow decline of about 0.08m over 35 years was detected.

In RS CVn binary stars: Recently Froehlich et al. (2006) on the basis of archival plates investigated the active long-period RS CVn binary HK Lac with internal accuracy of 0.07m and thus proved the feasibility of such approach to increase the time coverage considerably, using plate archives.

In active red dwarf stars: A search for slow and low amplitude brightness variations in 40 K and M dwarf stars was made by Bondar' (1995) using plates from Moscow University, Sonneberg and Odessa observatories with time coverage of more than 100 years. In 23 investigated stars brightness changes of 0.3m up to 1.0m with characteristic times from 3 to 60 years were discovered, obviously due to change of the stellar activity for decades. Existence of flare cycles in late dwarf stars was in the ground of the project suggested by R. Gershberg (Crimean Observatory) to use patrol plates in stellar aggregates. By this request 87 plates from the archives in Asiago, Heidelberg, Kiso, Rozhen Siding Spring and Tautenburg Observatories for the stars PZ Mon and V577 Mon have been found.

In the Pleiades red dwarf stars: The Pleiades are good and accessible sample for studying of long-term brightness variations in the red dwarf stars (the most of the red dwarf stars are flare stars). The total number of the known Pleiades flare stars according to the Flare Stars Database (Tsvetkova et al. 1995) is 547, having in view that for some stars published as flare stars better observations are needed to confirm their membership to the flare star class of variables according to Tsvetkova and Tsvetkov (1989). The statistical evaluation of the total number of all flare stars in the Pleiades (registered and not registered up to now) is about 1000. Precise coordinates of the known Pleiades flare stars were determined as a

necessary step to the further work of automated search for long-term brightness variations. Searching the WFPDB for the Pleiades plates more than 3100 plates obtained in the period 1885 – 1998 were found in the observatories in Asiago (Italy), Sonneberg (Germany), Harvard (USA), Kyiv (Ukraine), Moscow (Russia), Rozhen (Bulgaria), Konkoly (Hungary), Byurakan (Armenia), Potsdam (Germany), Edinburgh (UK), Bamberg (Germany). Some of them are already digitized and added to the developed Pleiades Plate Data Base (Borisova et al. 2003; Tsvetkov et al. 2005). It gives the opportunity to obtain almost continuous photometric data set for the red dwarf stars in the cluster.

4.3. Search for past eruptions of a pre-main sequence star

A result from searching for past eruptions of the pre-main sequence star on archival plates can be found in Aspin et al. (2006). The estimated B magnitudes of V1647 Ori, illuminating McNeil's nebula, and B limiting magnitudes of the plates from different observatories taken in the period October 1965 – February 1968 helped to make clear the question about the observed brightness and duration of the outburst, which took place in 1966 - 1967. The comparison with the recent outburst in 2003 – 2006 allows considering this star as FU Orionis type star.

4.4. Observations of small solar system bodies

For many of the wide-field plates the primary aim of the observations were small solar system bodies. That is why now the old photographic plates are in demand for searching of asteroids, Potentially Hazardous Asteroids (PHAs), Near Earth Objects (NEOs), Trans-Neptunian objects (TNOs) and comets in order to improve their orbits, to detect new objects and to monitor known fainter objects. Among 949 PHAs (the minor planets with the greatest potential for close approaches to the Earth) according to the List of Minor Planet Center (MPC, <http://cfa-www.harvard.edu/iau/lists/Dangerous.html>) in the WFPDB a search for pre-discovery observations of the potentially hazardous NEA 1997 XF11 according to the given MPC ephemerides (<http://cfa-www.harvard.edu/iau/mpc.html>) for favorable opportunities for recording the asteroid in 1950, 1957, 1964 1971 1976, 1983 and 1990, was made. The found 27 plates satisfied the demands for coordinates, time and telescope parameters.

For the TNO 28978 Ixion (2001 KX 76) the earliest pre-discovery images were found on plates from 1982, for 90482 Orcus (2004 DW) - from 1951. Today from known 1078 TNOs only 12% have well determined orbits.

4.5. Search for optical analogues of Gamma Ray Bursts

One possibility for identification of the optical counterparts of Gamma Ray Bursts (GRBs), although restricted on non-obvious assumption that the events are recurrent, is the use of archival observations made with different instruments all over the world in the field of known GRBs. The archival searches are of great value due to their ability to provide very large fractions of monitoring time with reason-

able detection limits. We looked for not only positional but temporal coincidence too. One of the main problem of past archival searches was the large size of investigated GRBs error boxes. The situation was improved after the Interplanetary Network (IPN). The new error boxes are with areas of order of a few square arcmin. Having at disposal a list of 38 GRBs with comparatively correct and precisely determined coordinates (about 10 arcmin) we made a search in 48 wide-field plate archives of 8 observatories – Asiago, Bucharest, Heidelberg, Kiso, Rozhen, Siding Spring, Sonneberg and Tautenburg. The archives contain information for 301 256 plates with total effective observing time of more than 205 000 hours. We found 220 488 plates preserving information about the fields with possible GRBs optical analogues according to positional coincidence. 99% of the plates had been obtained with comparatively small aperture instruments (< 50 cm). Most of them were from the Sonneberg Observatory. The limiting magnitudes of these small instruments are about 13.5 – 14.5 mag (pg) and in these cases only the plates obtained in the moment of the GRB event are of interest. After temporal/positional coincidence search for GRB analogues we found only 92 plates received 3 days before and 7 days after the GRB alert registered. All these plates were from the Sonneberg photographic patrol survey. Among 92 plates there are some plates, which deserve a special interest because the temporal coincidence is very good.

4.6. Search for photometric variability of quasars

In the light curve of 3C273 constructed from the archival observations from the Harvard plate collection over the period 1887 – 1980 Angione and Smith (1985) found a periodicity in the light curve in the period 1928 - 1954. Whether this periodicity is real or not, and whether it existed prior to 1928 could not be concluded because not enough data. The systematic Harvard patrol ended in the early 1950s, creating a critical gap before the beginning of photoelectric measures of 3C 273. Considering the confirmation or the rejection of the 16-year period very important in the WFPDB 2906 additional photographic plates from 34 archives in the WFPDB have been found.

4.7. Supernovae search in digitized archives

A Supernova search in the galaxy cluster Abel 426 (Perseus) was made by Meusinger et al. (1999). They have used 173 plates taken for Supernova patrol from the archives of Asiago, Cote d'Azur, Palomar, Konkoly and Tautenburg, and selected with the help of WFPDB. Such systematic Supernovae search in digitized archives requires limiting magnitudes of at least 16m.

4.8. Present use of Carte du Ciel plates

The Carte du Ciel (CdC) project is the very first photographic all-sky survey, started in 1887 and accomplished with the efforts of 20 observatories covered the sky with 22 000 plates obtained up to 1940. Practically the number of the CdC plates is bigger, because only the best plates were taken for the CdC project pur-

pose. The CdC plates are considered as good material - with respect of age and sky coverage, suitable for discoveries of variable stars with long period (50 to 100 years), as well as for quick brightness changes (because the triple exposures on the plate). The digitization of CdC plates with flatbed scanners provide accuracy better than 0."2 (Vicente et al. 2008).

For proper motion determinations: In 2006, a positional catalogue of 344781 stars from the Bordeaux Carte du Ciel zone ($+11^0 - +18^0$) was published by Rapaport et al. (2006), as part of the programme of proper motion measurements from the Bordeaux Observatory (the so-called CdC2000 Bordeaux Carte du Ciel catalogue) with standard errors of about 0.10 to 0.12 arcsec on the positions and of 0.6 mag on the photographic magnitudes. This catalogue relies on the 512 Carte du Ciel plates archived at the Bordeaux Observatory and digitized with the Cambridge Automatic Measuring Machine (APM). The complete PM2000 Bordeaux Proper Motion Catalogue of 2670974 stars down to 15.4m is presented in Ducourant et al. (2006). Depending on the magnitude, the positional precision at the mean epoch ranges from 50 to 70 mas while the precision of the proper motions varies from 1.5 mas/yr to 6 mas/yr.

For the determination of proper motions of the stellar clusters: The deep CdC plates taken for the CdC sky atlas have also been considered as well suited for the determination of proper motions of the stellar clusters by Geffert et al (1996). The digitized Paris CdC plates were used to determine the proper motions of 2,220 stars in the field of the open cluster NGC 1647 with an astrometric accuracy, which ranges from 100 to 200 mas.

For discoveries of quick brightness changes: The potential of the CdC plates for discoveries of quick brightness changes (time scales up to 20 minutes and flare amplitudes larger than 0.5 mag) in stars with brightness in the photographic range 10 – 14 was investigated by Fresneau et al. (2001).

For investigations of the differential rotation in the galactic plane up to 500 pc from the Sun: A set of 650 CdC astrographic plates of the former Sydney Observatory were used in investigations of the differential rotation in the galactic plane by Fresneau et al. (2003, 2005).

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References

- Angione, R. J., Smith, H. J.: 1985, *Astron. J.*, **90**, 2474.
 Aspin, C., Barbieri, C., Boschi, F., Di Mille, F., Rampazzi, F., Reipurth, B., Tsvetkov, M.: 2006, *Astron. J.*, **132**, 1298.
 Bondar', N.: 1995, *AAP Suppl. Ser.*, **111**, 259.

- Borisova, A. P., Tsvetkov, M. K., Tsvetkova, K. P., Hambly, N., Kalaglarsky, D. G., Richter, G. M., Boehm, P., Kelemen, J., Fresneau, A., Argyle, R. W.: 2003, *Astronomical and Astrophysical Transactions*, **22**, 487.
- Ducourant, C., Le Champion, J. F., Rapaport, M., Camargo, J. I. B., Soubiran, C., Perie, J. P., Teixeira, R., Daigne, G., Triaud, A., Requieme, Y., Fresneau, A., Colin J.: 2006, *Astron. Astrophys.*, **448**, 1235.
- Fresneau, A., Argyle, R., Marino, G., Messina, S.: 2001, *Astron. J.*, **121**, 517.
- Fresneau, A., Vaughan, A. E., Argyle, R. W.: 2003, *Astron. J.*, **125**, 1519.
- Fresneau, A., Vaughan, A. E., Argyle, R. W.: 2005, *Astron. J.*, **130**, 2701.
- Froehlich, H.-E., Kroll, P., Strassmeier, K.G.: 2006, *AAp*, **454**, 295.
- Froehlich, H.-E., Tschaepe, R., Ruediger, G., Strassmeier, K.G.: 2002, *AAp*, **391**, 659.
- Geffert, M., Bonnefond, P., Maintz, G., Guilbert, J., 1996, *Astron. Astrophys. Suppl. Series*, **118**, 277
- Johnson, J., Winn, J., Rampazzi, F., Barbieri, C. Mito, H., Tarusawa, K., Tsvetkov, M., Borisova, A., Meusinger, H.: 2005, *Astron. J.*, **129**, 1978.
- Meusinger, H., Brunzendorf, J., Pollas, C., Szécsényi-Nagy, G., Turatto, M.: 1999, in *Acta Historica Astronomiae*, 6, *Treasure-hunting in astronomical plate archives*, 138.
- Rapaport, M., Ducourant, C., Le Champion, J. F., Fresneau, A., Argyle, R. W., Soubiran, C., Teixeira, R., Camargo, J. I. B., Colin, J., Daigne, G., Perie, J. P., Requieme, Y.: 2006, *AAp*, **449**, 435:
- Samus, N. N., Durlevich, O. V. et al.: 2004, Combined General Catalogue of Variable Stars <http://cdsarc.u-strasbg.fr/viz-bin/Cat?II/250>.
- Tsvetkov, M., Tsvetkova, K., Borisova, A., Kalaglarsky, D., Barbieri, C., Rampazzi, F., Kroll, P., Sergeeva, T., Sergeev, A., Min, k D., Doane, A., Samus, N.: 2005, in *Kinematika i Fizika Nebesnykh Tel*, Suppl, **5**, 567-569.
- Tsvetkova, K., Popescu, P.: 2008, *AIP Conference Proceedings* (in press).
- Tsvetkova, K. P., Tsvetkov, M. K.: 1989, *IBVS*, No. 3366, 1989.
- Tsvetkova, K. P., Tsvetkov, M. K., Stavrev, K. Y.: 1995, in *Lecture Notes in Physic*, **454**, 121, Eds. J. Greiner, H. W. Duerbeck and R. E. Gershberg, Springer Verlag.
- Tsvetkova, K., Tsvetkov, M.: 2006, Catalogue of Wide-Field Plate Archives: Version 5.0, in *Virtual Observatory, Plate Content Digitization, Archive Mining, Image Sequence Processing*, Eds. M. Tsvetkov, V. Golev, F. Murtagh, R. Molina, Heron Press Science Series, Sofia, ISBN-10: 954-580-190-5, p. 45-53.
- Vicente, B., Abad, C., Garzon, F.: 2008, *Astron. Astrophys.*, manuscript no. 6843 c ESO 2008.
- Winterberg, J., Nolte, M., Seitter, W., Duerbeck, H.M., Tsvetkov, M. K., Tsvetkova, K. P.: 1995, in *Lecture Notes in Physics*, **454**, 119.