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SPECKLE INTERFEROMETRY OF THE SOLAR NEIGHBORHOOD

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RESUMEN

Presentamos un nuevo estudio de interferometría de motas en estrellas con paralajes mayores a 200 milisegundos de arco, del Catálogo Principal Tycho. De acuerdo a este catálogo, hay más de 5000 objetos que cumplen este criterio. Telescopios relativamente pequeños pueden ser usados efectivamente con este propósito ya que pueden alcanzar la resolución límite de Rayleigh $R = 1.22\lambda/D$. Por ejemplo, la resolución de un telescopio de 2 m en la banda V es de $0.055''$. Para una distancia de 5 parsecs esto corresponde a 0.275 unidades astronómicas. En julio 2014 comenzamos las observaciones de las estrellas con mayores paralajes del Catálogo Principal Tycho.

ABSTRACT

We present a new observational speckle interferometric study of stars with parallaxes larger than 200 milliarcsecond (mas) from the Tycho Main Catalogue. According to this catalogue, there are more than 5000 objects meeting this criterion. Relatively small telescopes can be effectively used for this purpose since they can reach the Rayleigh resolution limit $R = 1.22\lambda/D$. For instance, the resolution of a 2m telescope in the V band is $0.055''$. For 5 pc that corresponds to 0.275 au. In July 2014 we began speckle observations of stars with large parallaxes from the Tycho Main Catalogue.

Key Words: binaries: visual — stars: fundamental parameters — techniques: high angular resolution — techniques: interferometric — techniques: speckle

1. INTRODUCTION

The Tycho Main Catalogue (TMC) is the astronomical database, which provides astrometry and two-color photometry for stars brighter than V =11.5 mag (Hog et al. 1997). Despite the fact that the precision of the data in the catalogue is lower than provided in other catalogues, the TMC is very useful for the selection of objects for observational programs. It is especially helpful for the study of the solar neighborhood. The nearby stars, due to their proximity, provide the only sample that allows us to study intrinsically faint stars in detail. However, it is very difficult to get a complete list of the nearby stars. For example, the Research Consortium on Nearby Stars (http://www.recons.org/) reports only about 87 stellar objects within 5 parsecs while the TMC provides more than 5000 objects with parallaxes larger than 200 mas. The purpose of our observational project is the speckle interferometry of 3242 stars from TMC which have parallaxes larger than 200 milliarcsec.

2. TYCHO MAIN CATALOGUE

The Tycho Main Catalogue (TMC) is one extension of the Hipparcos mission. The TMC contains over one million entries of position, parallax, and proper motion with a median astrometric precision of seven mas for $V < 9$ mag, and 25 mas at $V = 10 - 11$ mag. The parallaxes have systematic errors below about one milliarcsec and a typical accuracy of 25 milliarcsec so that four sigma is 100 mas. The TMC contains over forty-five thousand objects with parallaxes larger than 100 mas but only 20% of them are marked as stars with a doubtful parallax. On the other hand, a non-Hipparcos star with a Tycho parallax $> 40+4\sigma$ mas will in only very few cases be a real nearby star since nearly all nearby stars with parallaxes greater than 40 mas are Hipparcos stars (ESA 1997). There is some controversy. The TMC provides two-color photometry and parallaxes for all stars so that we can construct Hertzsprung-Russell (HR) diagrams. Let's construct HR diagram for stars with large parallaxes from TMC. Figure 1 shows the HR diagram for 5288 objects with parallaxes larger than 200 mas. As one can see, only a few stars are on the main sequence, whereas most of the objects are located below it. These objects require a more detailed study. If these stars are not dwarfs, their parallaxes in TMC are erroneous. In addition, we have to admit that forty percent of these stars are variable.

We suspect that many of stars with erroneous parallaxes are binaries with a semi-major axis close to the value of the parallax and with relatively short

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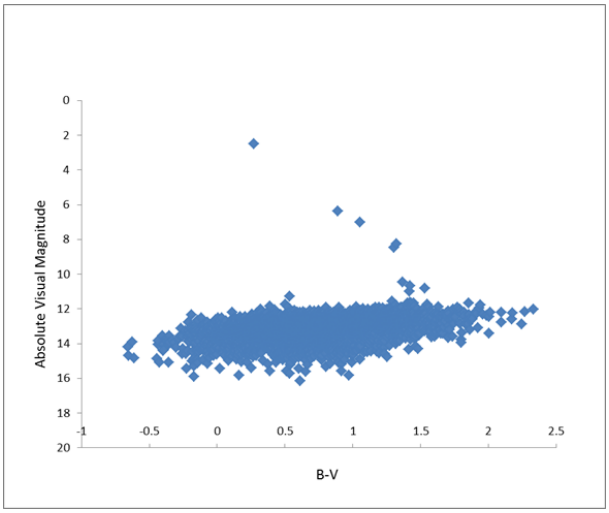

Fig. 1. HR diagram of stars from TMC with parallaxes larger than 200 mas.

periods. Therefore, stars with large parallaxes from TMC are good objects for speckle interferometric observations.

3. SPECKLE INTERFEROMETRY AT TELESCOPES OF OBSERVATORIO ASTRONOMICO NACIONAL

Speckle interferometry is the main method for accurate astrometric measurements of binary and multiple stars. We chose this technique because it is simple and less expensive than other high-resolution methods. One of the advantages of speckle interferometry is the fact that it provides diffraction-limited resolution in the visible range, as opposed to adaptive optics. Speckle interferometry reaches a diffraction-limited resolution by means of the analysis of many short exposure images (Figure 2).

The result of classical speckle interferometry is an autocorrelation function free from atmospheric distortion (Figure 3 left). Sometimes in order to eliminate the 180 degree ambiguity one can use any technique of image reconstruction (Figure 3 right).

We started regular speckle interferometric measurements of binary stars in 2008 (Orlov et al. 2009, 2010, 2011, 2012, 2014). In the beginning, this project was observational practice for UNAM students at telescopes of the OAN. However, we now have a scientific instrument "Berkut" (Figure 4). Due to limitations imposed by the geographical location and design of telescopes, we are not able to observe some parts of the sky. As a rule, we choose objects within declinations from -20 to 65 degrees.

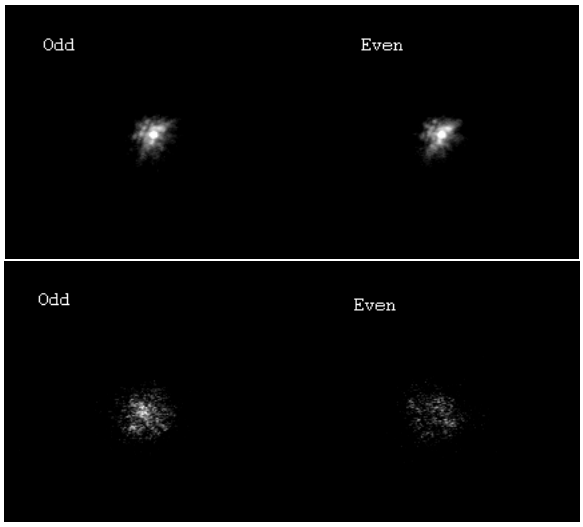

Fig. 2. Short-exposure images. The upper consecutive images were obtained under good atmospheric conditions. The bottom consecutive images were obtained under poor atmospheric conditions.

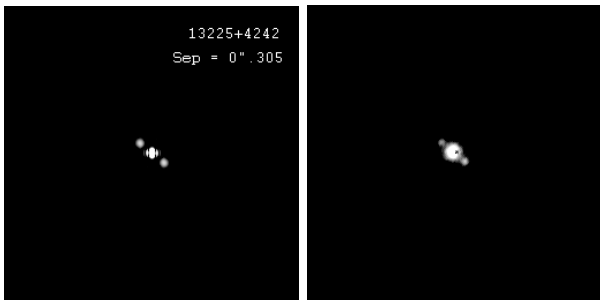

Fig. 3. Reconstructed ACF of the binary star COU 1581. Separation = $0.305''$ (Left). Result of a self-calibrating shift-and-add technique for the same binary star (Right). The window is $6.3'' * 6.3''$.

The 2.1-m telescope allows us to reach very attractive resolutions:

$$\begin{aligned} \lambda/D_U &= 0''.036, \\ \lambda/D_B &= 0''.044, \\ \lambda/D_V &= 0''.055, \\ \lambda/D_R &= 0''.07, \\ \lambda/D_I &= 0''.088. \end{aligned}$$

These resolutions are at least 10 times higher than direct images.

Beginning in 2014, we started using the EMCCD iXon 885 DU from Andor Technology, which is a low-noise, high-sensitivity EMCCD camera. It is cooled thermoelectrically to $-95°C$ which provides excellent elimination of EM-amplified dark current noise,

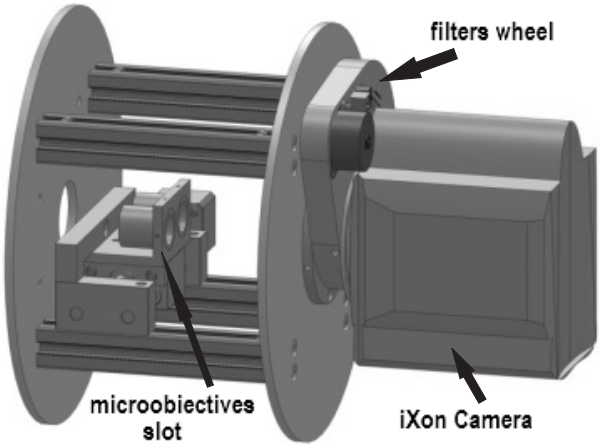

Fig. 4. Astronomical instrument "Berkut".

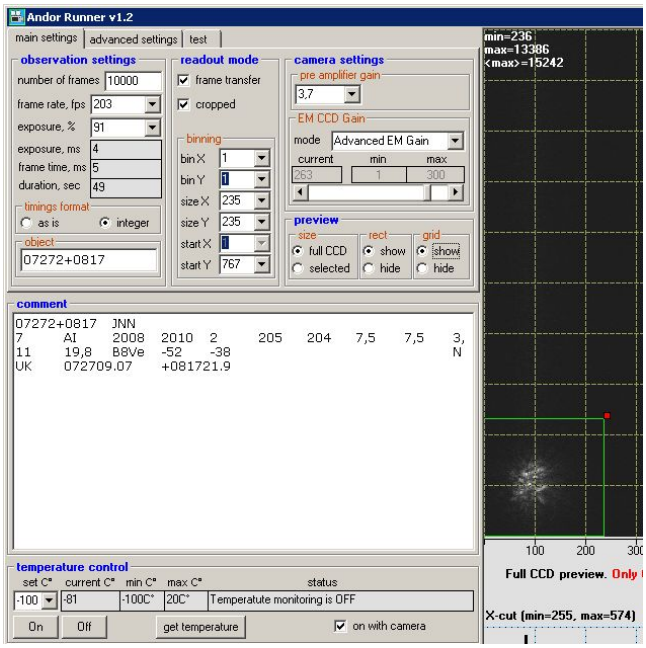

Fig. 5. AndorRunner: the program to control the iXon CCD camera during observations.

even for the short time exposures. This fast frame-rate detector has $1004x1002$ pixels of 8μm and more than 40% quantum efficiency in the range of 400-800 nm.

In order to simplify the camera usage in astronomical observations a program named AndorRunner was developed (Figure 5). AndorRunner is designed in such a way that it allows one to interactively control all settings and options of the camera during observations. In addition, to simplify the data reduction it records all of the camera parameters and user-defined comments inside each data file.

4. OBSERVATIONS

The aim of this program was determine if "Berkut" is the appropriate instrument for our observational program. The program includes all objects from the TMC with parallaxes larger than 200 mas. However, due to limitations imposed by the design of the telescope, we had to cut the list down to 3,242 objects. In July 2014 we observed more than 250 stars at the 2.1m telescope under moderate atmospheric conditions (seeing and transparency). All stars were observed through three filters: V(540/90 nm), R(640/130 nm) and I(800/160 nm). For each star, the typical observing procedure involved the accumulation of three sets of 400 frames, each of which consisted of a two-dimensional 500x500 array of 16-bit numbers. After the calibration, we determined that the pixel scale was equal to $0.017''/px$. After pre-processing the data, we found a very high percent (about 10%) to be new double stars, i.e. more than 25 with separations less than $5''$. Most of them are likely binaries.

5. CONCLUSION

Objects from the TMC with parallaxes larger than 100 mas are the most controversial part of that catalogue. We find that many of them are binaries. Observations with "Berkut" show that it is an appropriate instrument for speckle interferometric observations of these stars. This instrument enables of to resolve double stars with separations greater than 55 mas and with the magnitude differences between the binary components of $\Delta m < 5$.

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REFERENCES

ESA 1997, The Hipparcos and Tycho Catalogues, ESA SP-1200

Hog, E. et al. 1997, A&A, 323, L57

Orlov, V. G. et al. 2009, RMxAA, 45, 155

Orlov, V. G., Voitsekhovich, V. V., Rivera, J. L., Guerrero, C. A., & Ortiz, F. 2010, RMxAA, 46, 245

Orlov, V. G. et al. 2011, RMxAA, 47, 211

Orlov, V. G., Voitsekhovich, V.V., & Guerrero, C.A. 2012, RMxAA, 48, 177

Orlov, V. G., Guerrero, C. A., & Voitsekhovich, V. V. 2014, RMxAA, 50, 151