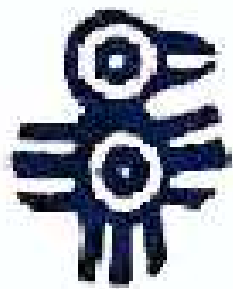


Speckle Interferometry of the Solar Neighborhood



Valeri Orlov

Instituto de Astronomía, UNAM

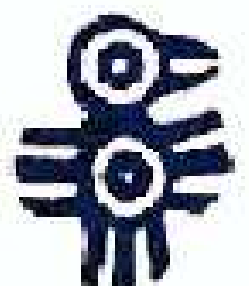
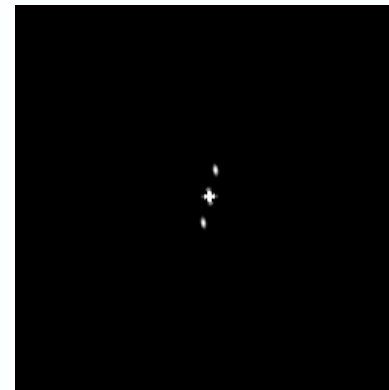
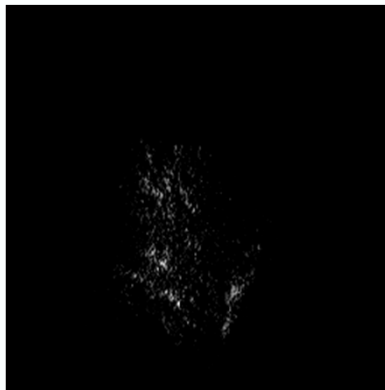
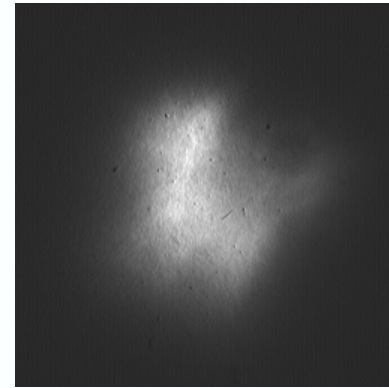




Angular Resolution



- Spatial Resolution is usually limited by atmospheric seeing. Good seeing is when resolution $< 1''$
- Telescope aberrations also affects on resolution.





Comparison SI y AO

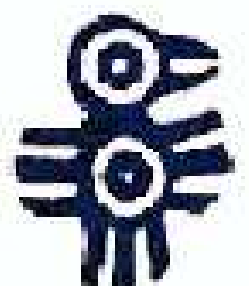


SI

- Simple;
- Diffraction limited (DL);
- Limit apparent magnitude 14-15;
- Post processing;
- Small field of view;
- Low cost.

AO

- Complicated;
- Not always DL;
- Limited by sky darkness only;
- Real time processing;
- Big field of view;
- Not working in UVB|;
- Very expensive.





Speckle Interferometry



Speckle Interferometry

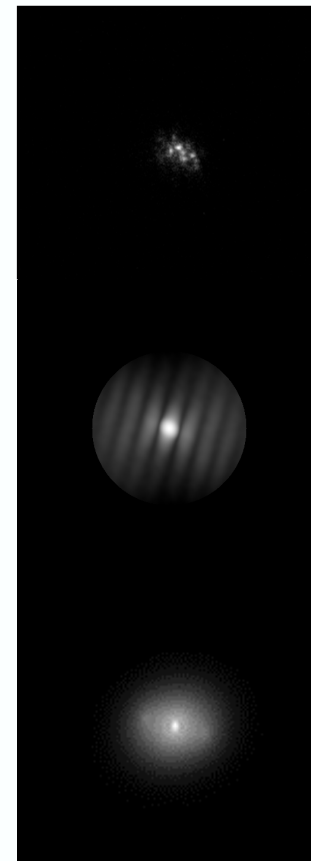
$$i_n(\mathbf{x}) = o(\mathbf{x}) \otimes p_n(\mathbf{x})$$

$$I_n(\mathbf{u}) = FFT\{i_n(\mathbf{x})\}$$

$$I_n(\mathbf{u}) = O(\mathbf{u}) \cdot P_n(\mathbf{u})$$

$$\langle |I_n(\mathbf{u})|^2 \rangle = |O(\mathbf{u})|^2 \cdot \langle |P_n(\mathbf{u})|^2 \rangle$$

$$|O(\mathbf{u})|^2 = \langle |I_n(\mathbf{u})|^2 \rangle / \langle |P_n(\mathbf{u})|^2 \rangle$$





Data Processing



- Preprocessing;
- Calculations of PSF and ACF;
- Calculations of Separation and PA:
 - First approximation from ACF .
 - Improved value from PSF using model:

$$\langle |I_n(\mathbf{u})|^2 \rangle = \langle |P_n(\mathbf{u})|^2 \rangle [A + B \cos(2\pi \mathbf{u} \cdot \mathbf{r})]$$

- Relative photometry

$$\Delta m = -2.5 \log(y)$$

$$y = \frac{A}{B} - \sqrt{\frac{A^2}{B^2} - 1}$$

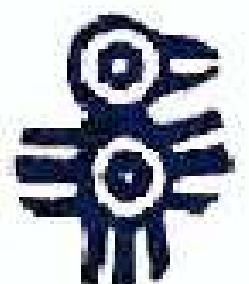
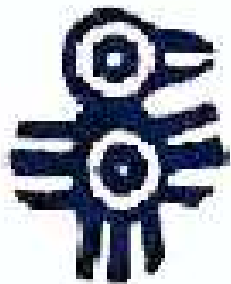
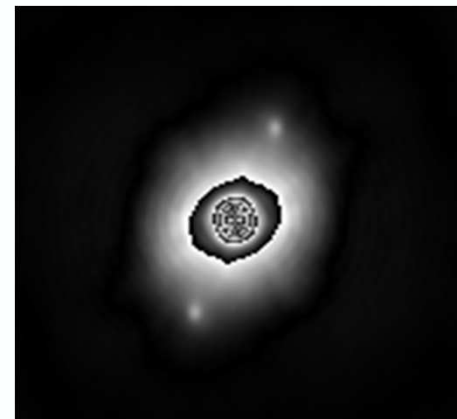
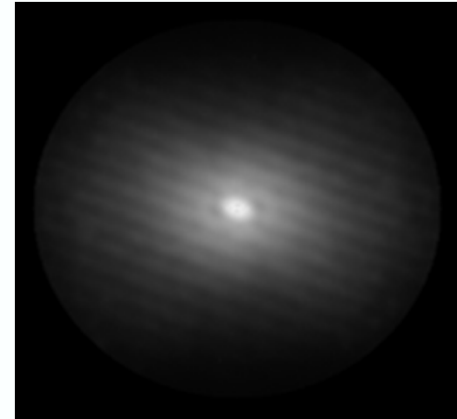


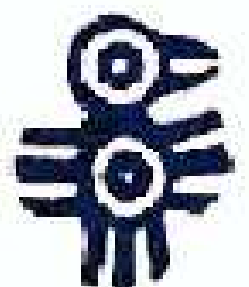
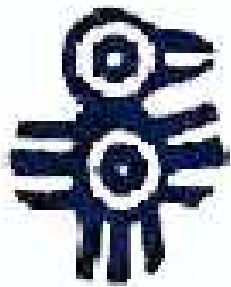
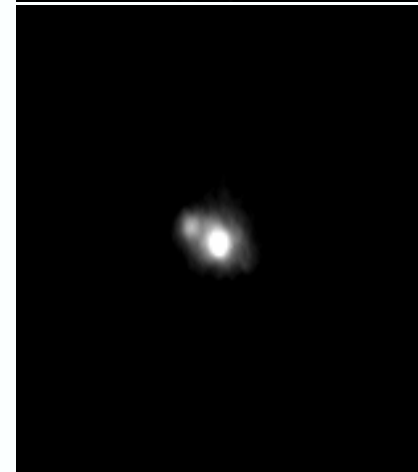
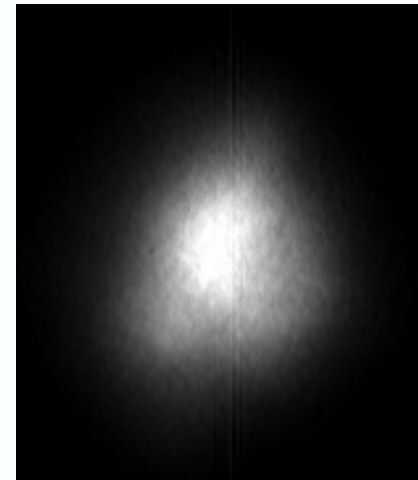


Image reconstruction



- Closure phase;
- Lucky imaging;
- Shift and Add :

Hip74643, Tel. 1.5m OAN-SPM
 $\rho \sim 0.4$ arcsec



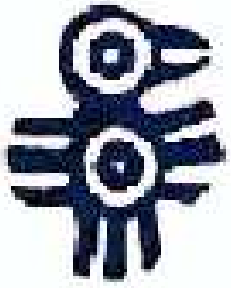


Speckle interferometry at telescopes OAN

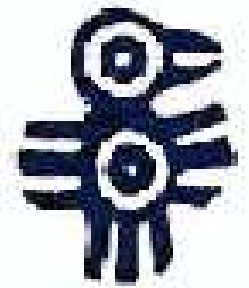


- Regular speckle interferometric measurements of double stars have been made with telescopes of the OAN since 2008.
- Observations were performed at telescopes of OAN-SPM and OAN-Tonantzintla.
- Different cameras were tested during these observations.
- Thousands measurements of double stars were performed.

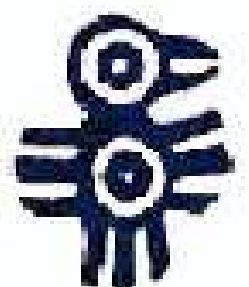




Telescopes OAN



- Site Tonantzintla, Puebla
 - It is located at 19° north latitude;
 - 1m telescope;
 - Long wet season;
 - Few clear nights;
 - Light pollution;
 - Suitable place for Speckle Interferometry.
 - Good place for teaching.





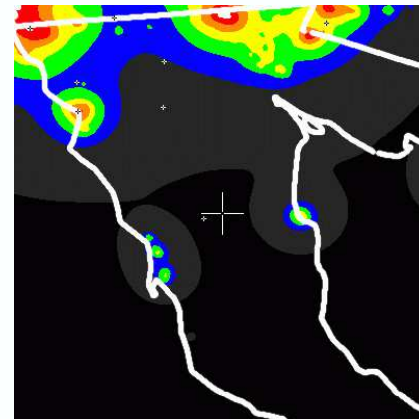
Telescopes OAN

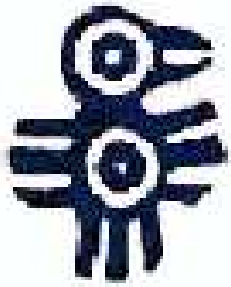


- **Site San Pedro Martir.**
 - It is located at 31° north latitude;
 - 2.1m, 1.5m, 0.84m telescopes;
 - It is located 2890 m above sea level;

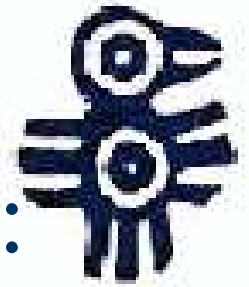
Site is characterized by

- Low humidity;
- Good seeing conditions;
- Good sky darkness;
- Exelent place for Speckle Interferometry.

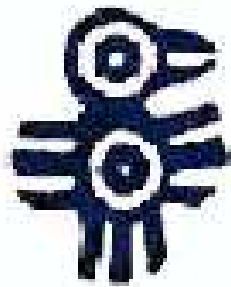
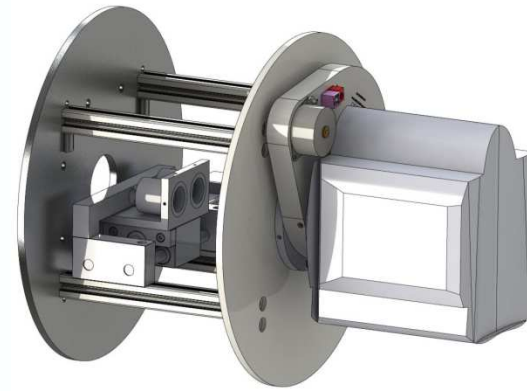


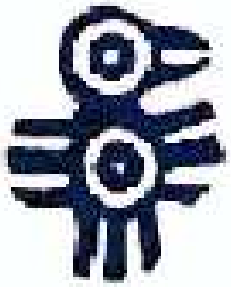


Speckle interferometer “Berkut”:



- Portable, weighing less than 10 kg.;
- Automatic change of optical lens.
One lens is finder, the second one is working lens.
- Automatic change of optical filters.
FLI color filter wheel:
 - UBVRI with EMCCD iXon885;
 - BVRI with EMCCD Luca S.



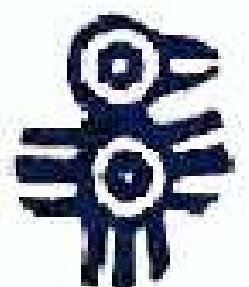
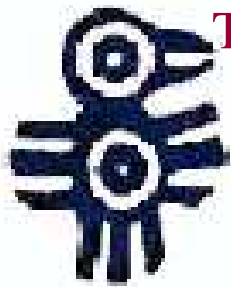


Project “Berkut”: Detectors



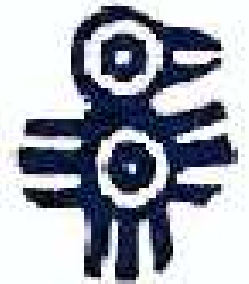
2013-...

- ANDOR iXon 885,
1002x1004, UBVR1,
200 measurements per night.
SPM 2.1m.
Up to 200 images/sec.
- ANDOR Luca S,
658 x 496 , BVR,
200 measurements per night.
Tonantzintla 1m





Resolution



SPM 2.1m telescope

ANDOR iXon 885

Seeing $> 0''.6$

Resolution with SI

- $\lambda_U / D = 0''.036$
- $\lambda_B / D = 0''.044$
- $\lambda_V / D = 0''.055$
- $\lambda_R / D = 0''.07$
- $\lambda_I / D = 0''.088$

Tonantzintla 1m telescope

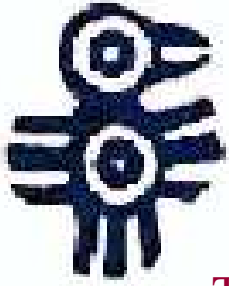
ANDOR Luca S

Seeing $> 2''.0$

Resolution with SI

- $\lambda_B / D = 0''.088$
- $\lambda_V / D = 0''.11,$
- $\lambda_R / D = 0''.14$
- $\lambda_I / D = 0''.176$

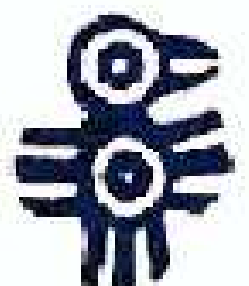
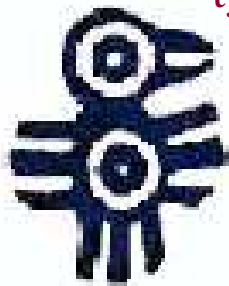


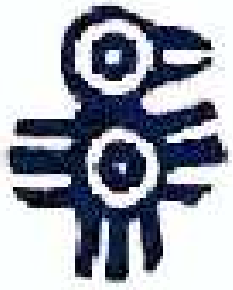


Tycho Catalogue

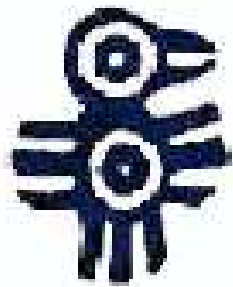
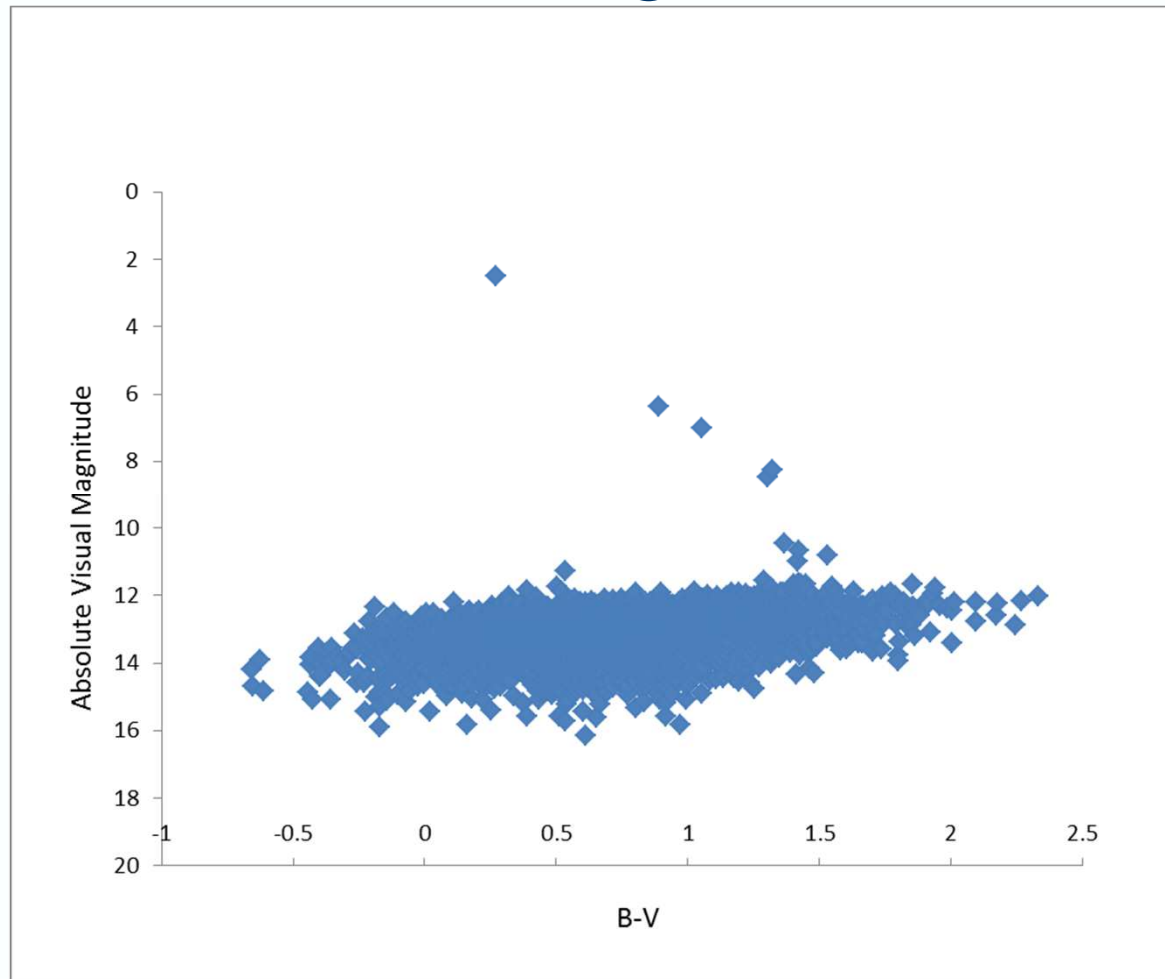


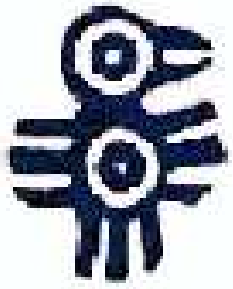
- The Tycho catalogue is the biggest astronomical database which provides both astrometry and two-color photometry for stars brighter than $V = 11.5$ mag.
- The Tycho catalogue contains over one million entries.
- Double stars with separations larger than 2 arcsec and with moderate magnitude difference are usually resolved.
- The parallaxes have the systematic errors below about one mas and typical accuracy 25 mas
- More than 45000 objects have parallaxes higher than 100 mas.
- More than 5000 objects have parallaxes higher than 200 mas
- For the stars within 5pc more than 40% of them shown variability.
- Only 20% of them are marked as stars with a doubtful parallax.



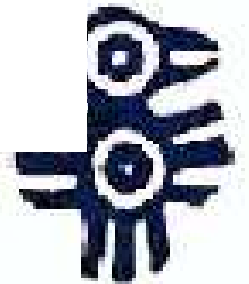
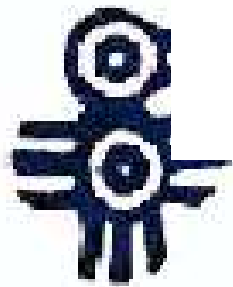
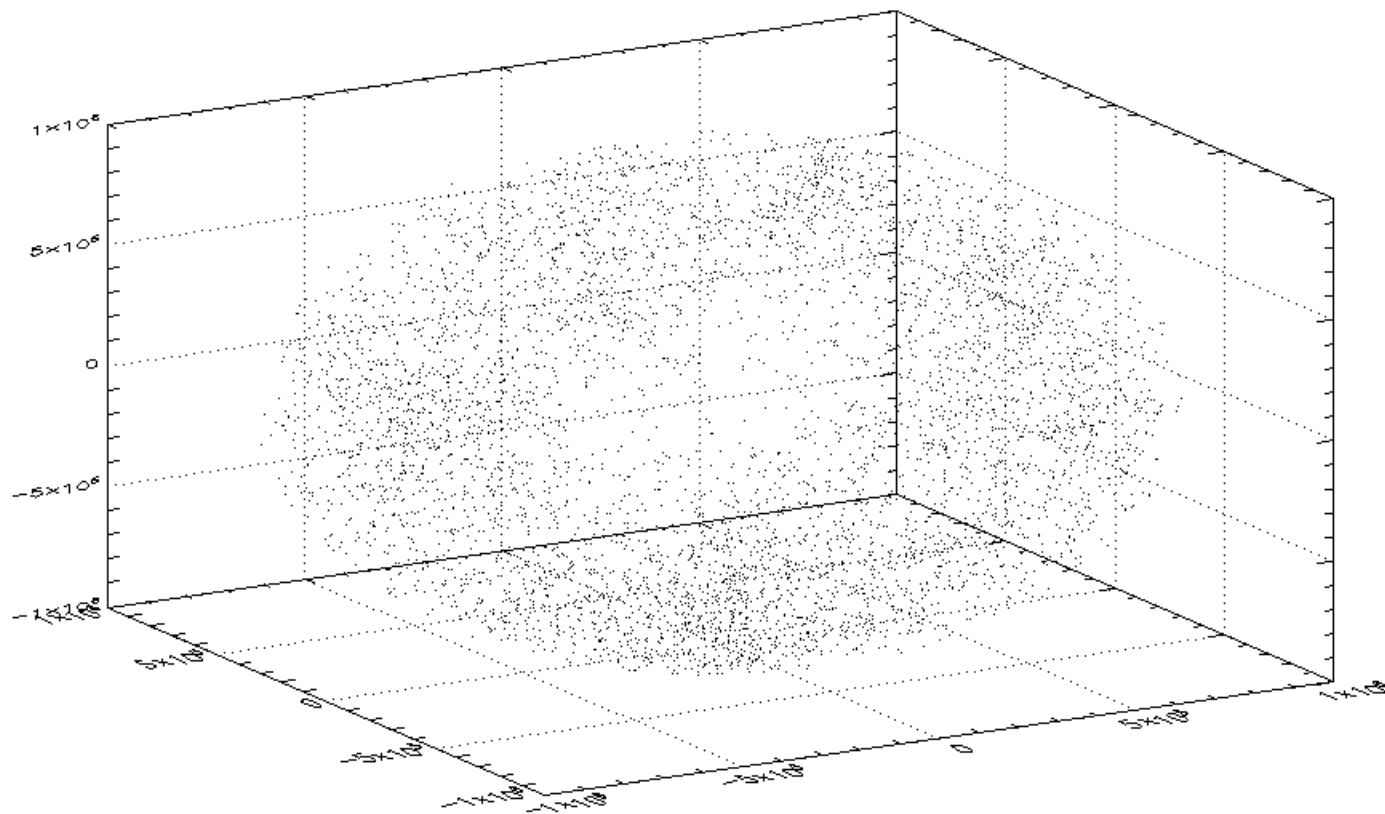


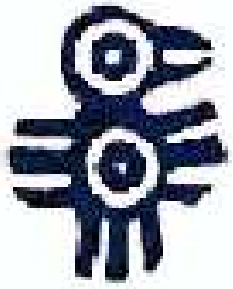
HR diagram of stars within 5 pc of solar neighborhood



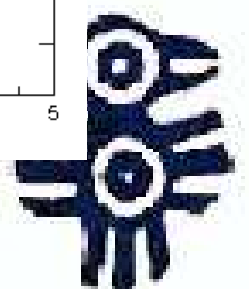
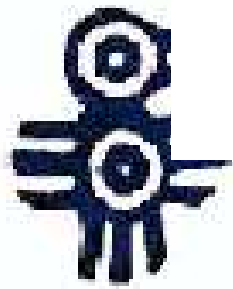
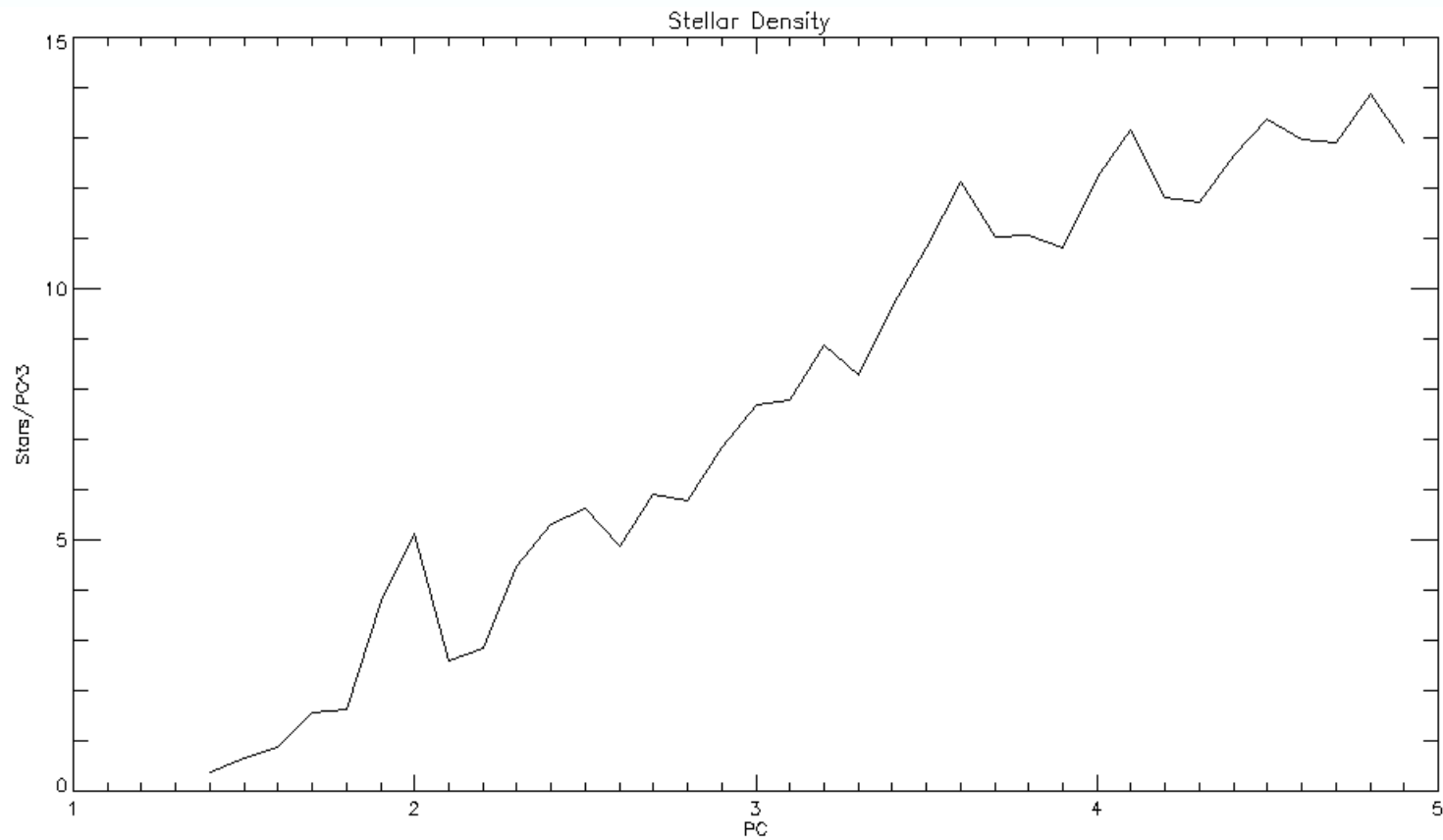


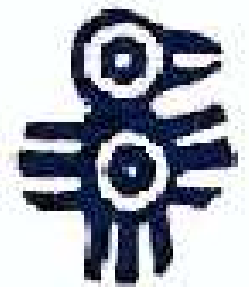
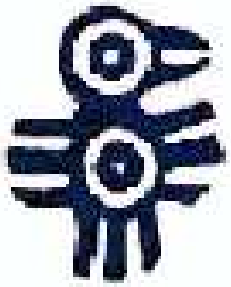
Stellar populations



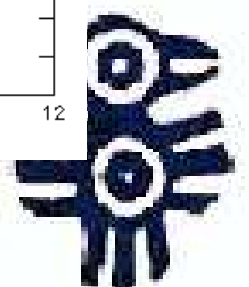
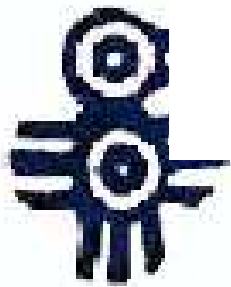
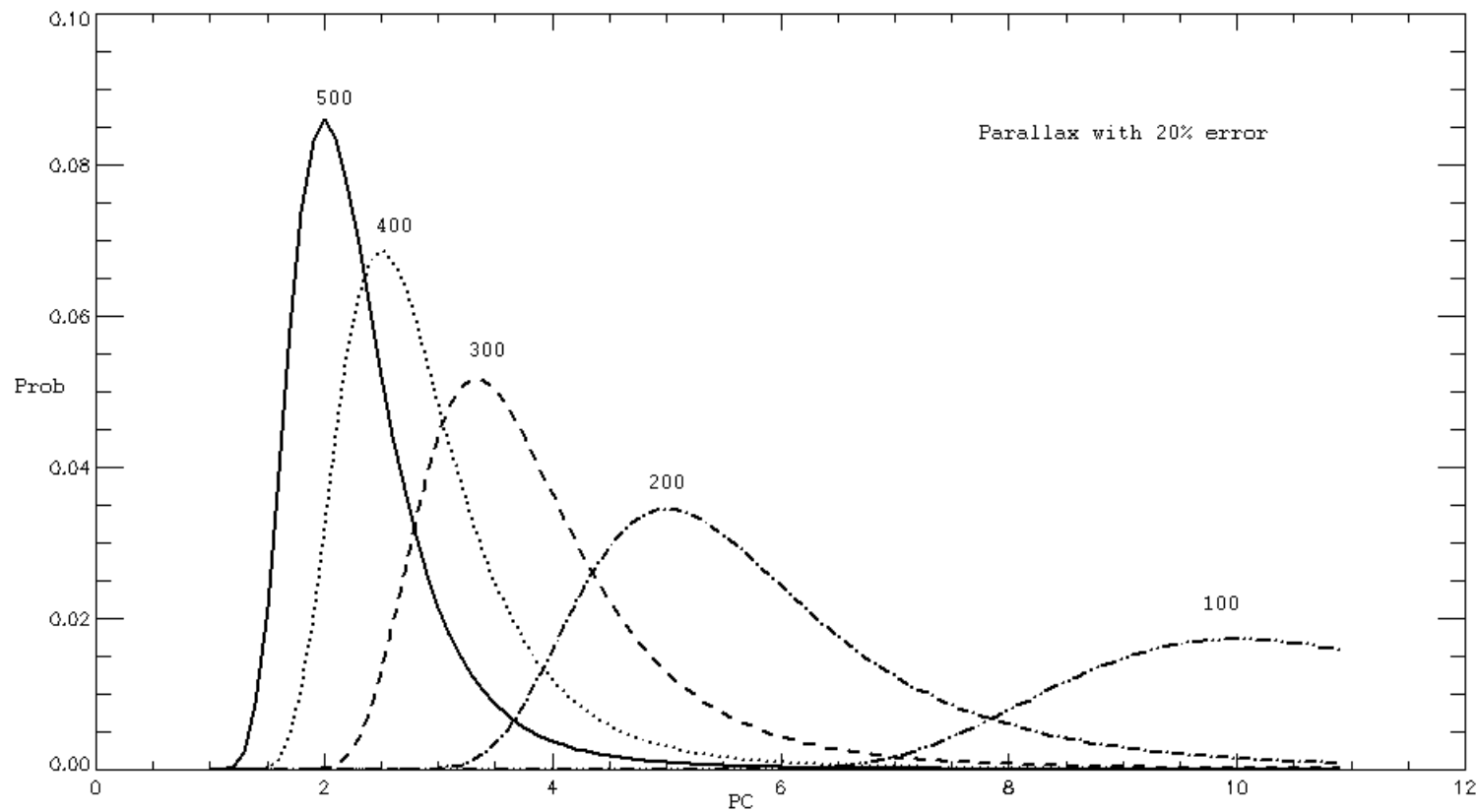


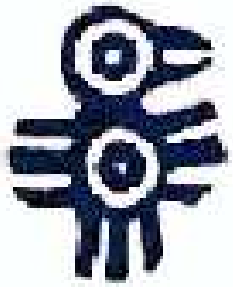
Stellar Density



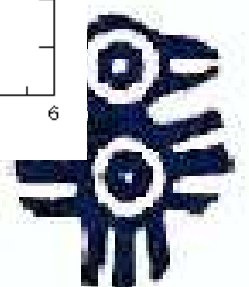
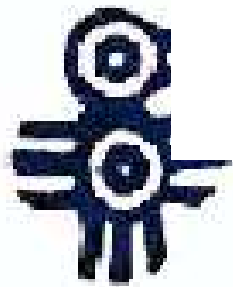
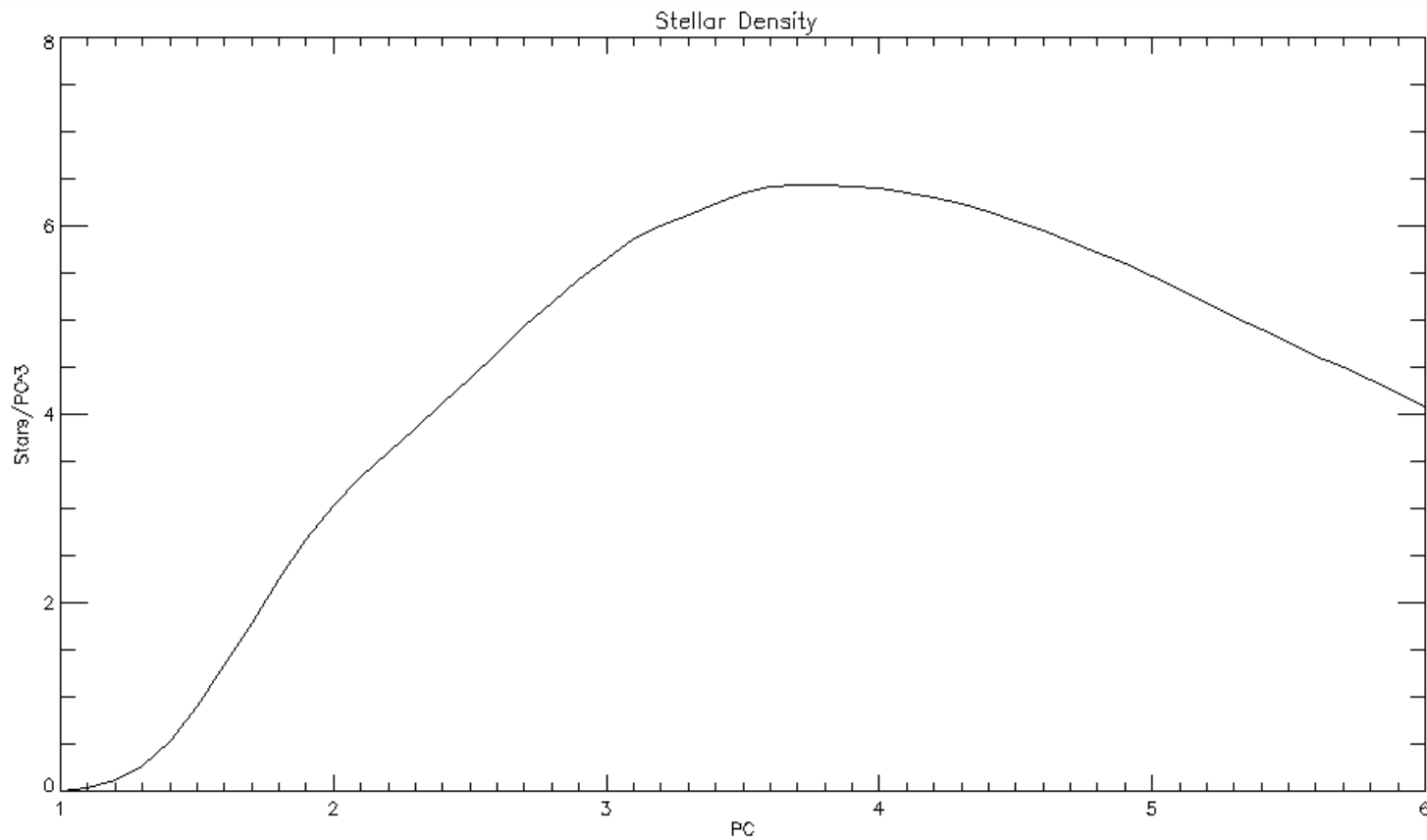


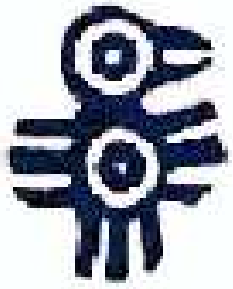
Probability



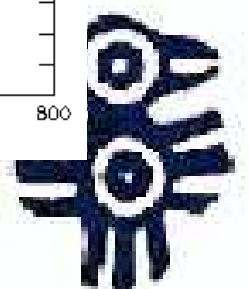
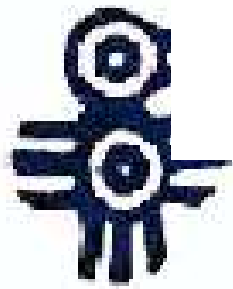
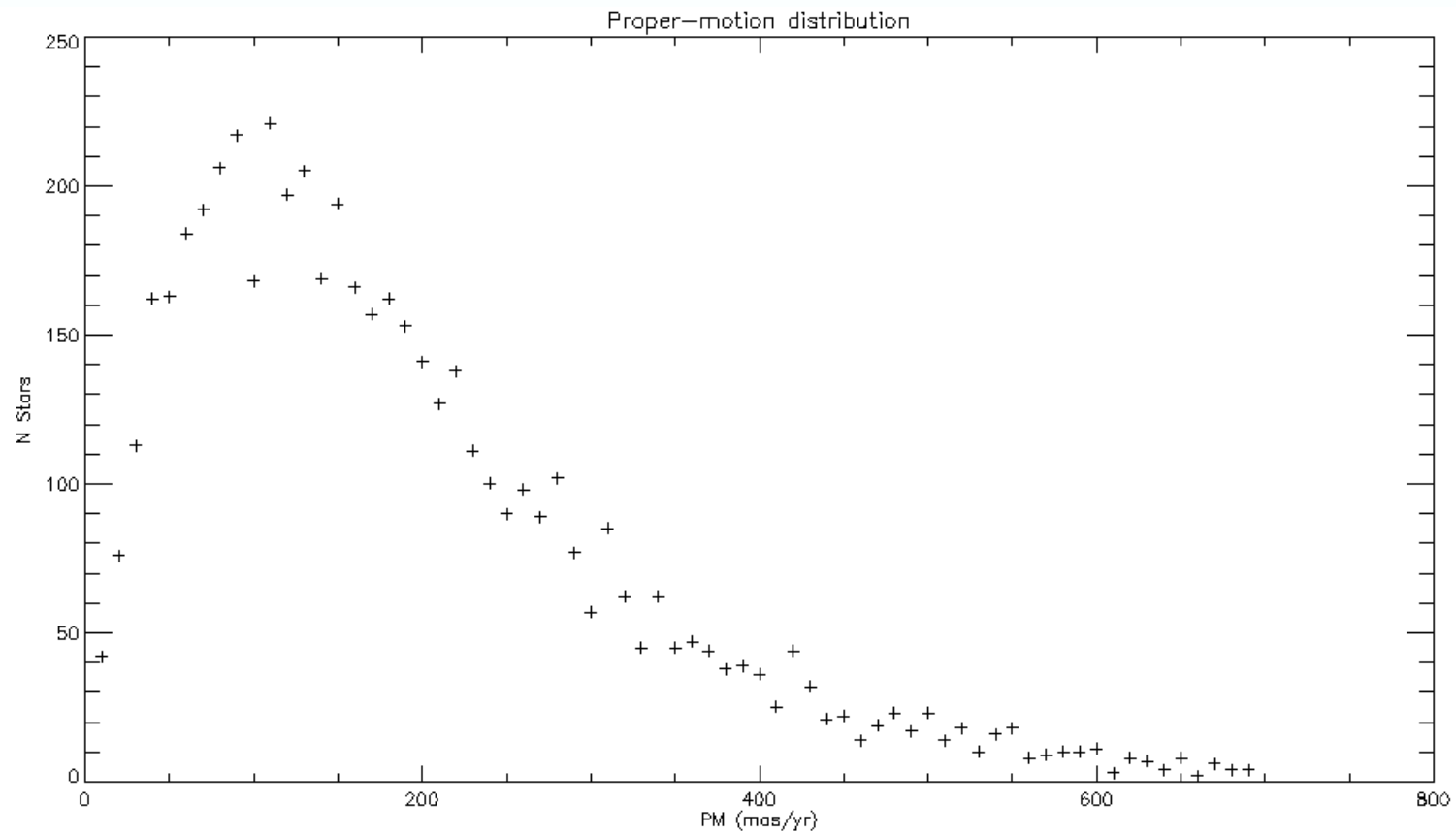


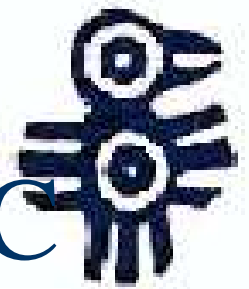
Corrected Stellar Density



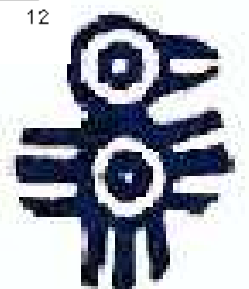
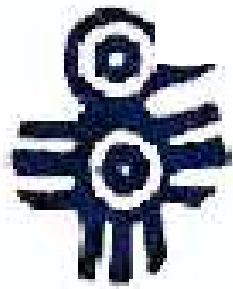
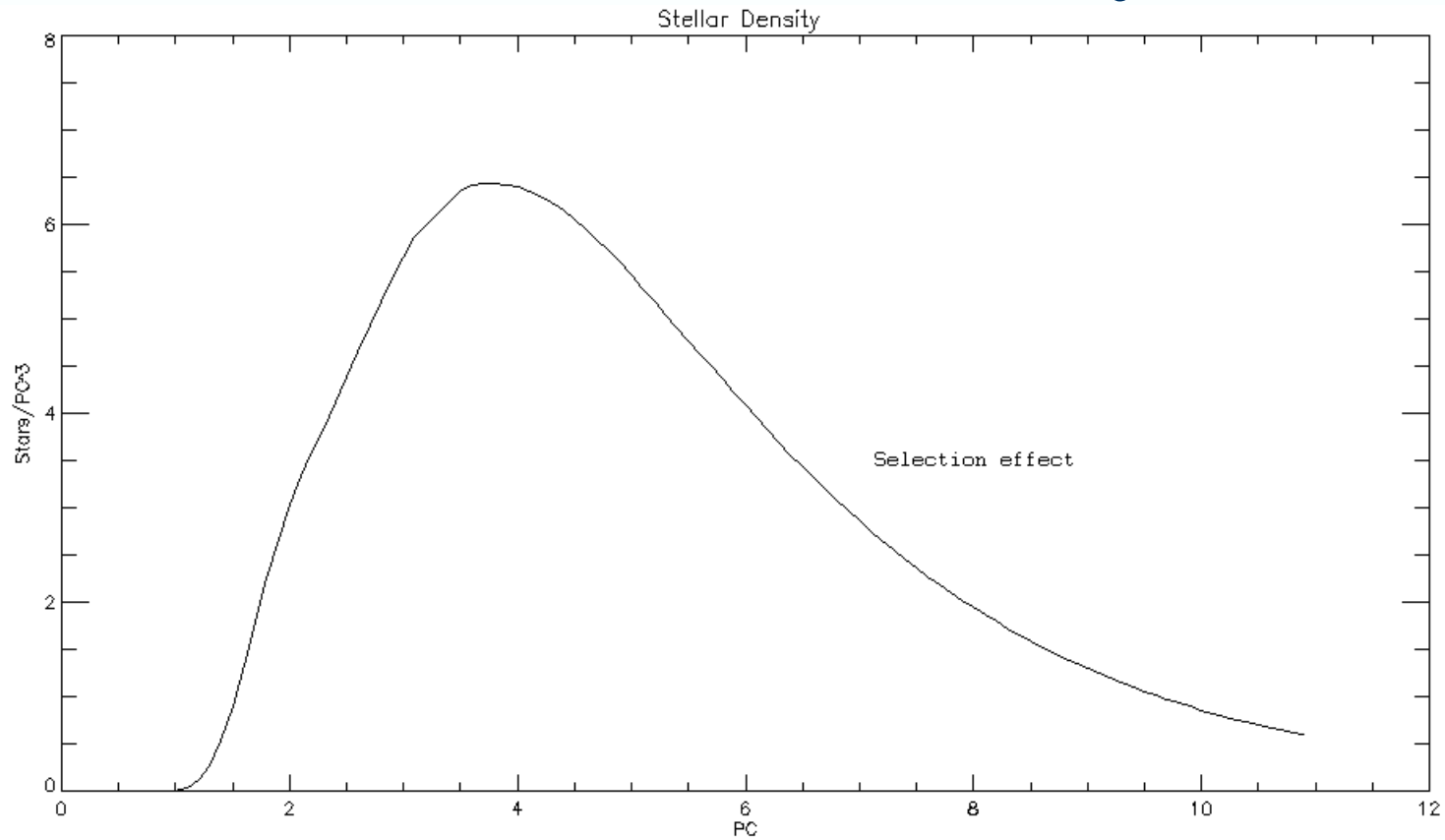


Proper-motion distribution





Corrected Stellar Density 10PC

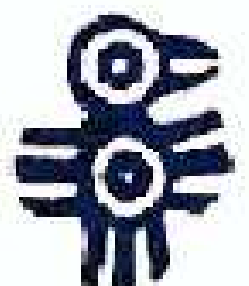


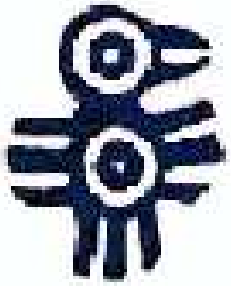


Conclusion



- The solar neighborhood within 10pc is this most controversial part of Tycho catalogue.
- The sample of stars within 5pc are least affected by a selection effect.
- Most of the stars from the 5pc area have not been studied by other instruments.
- Relatively small telescopes can be effectively used for this purpose because allow to reach the Rayleigh resolution limit $R = 1.22\lambda/D$.
- In July 2014 we start speckle observations in three colors at the OAN-SPM 2.1m telescope .
- With OAN telescopes we able to observe objects with declinations from -20 to 65 degrees.
- The resolution of 2m telescope in V band is 0.055". For 5 pc it corresponds to 0.275 au.
- The complete list of objects for observation includes 3240 entries.





Acknowledgements



The speckle interferometry program at the OAN telescopes is supported by the Direccion General de Asuntos del Personal Academico (UNAM, Mexico) under the projects IN102514 .

