Comparison between the Maidanak Observatory observations and the reference azimuthal offsets in “star cluster - H II region” pairs in NGC 628 from the Hubble Space Telescope observations.

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In 1981, together with my colleague Mikhail Smirnov, I proposed and tested a then-new morphological method for determining the corotation radius in spiral galaxies, which confirmed the prediction of a spiral-shaped stationary shock wave there.

We first used this method in 1981 to study the spiral arms of the galaxy M33.

The distance to M33 is only 720 kpc, which allowed the observer to measure separately the coordinates of Hii-regions and OB associations in star-forming regions in this galaxy.

Fig.1 Triangulum Galaxy (NGC 598 -Messier 33), taken with amateur equipment.

This image was taken at Blackstrap provincial park Kanwar Singh, using a Celestron Edge HD 8" telescope with a Nikon D5200 camera.
https://en.wikipedia.org/wiki/Triangulum_Galaxy#/media/File:Triangulum_Galaxy_(Messier_33).jpg

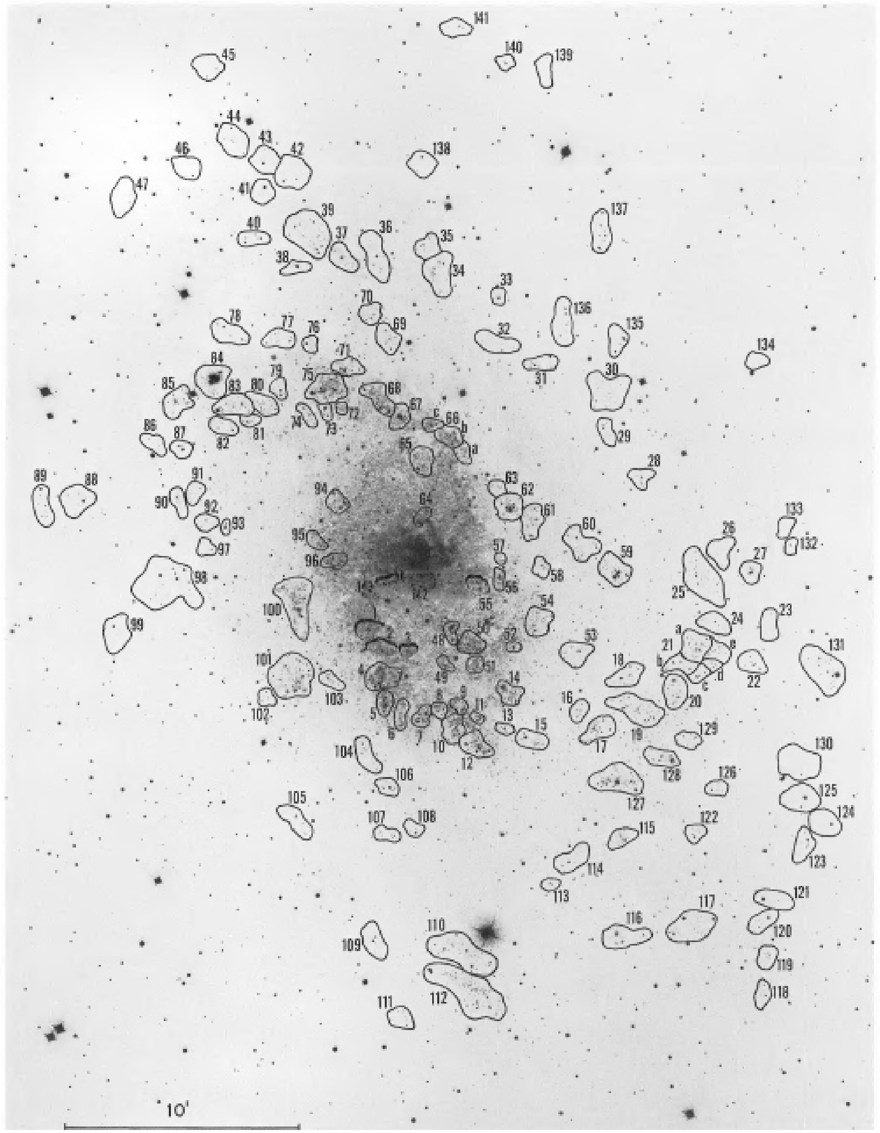


Fig.2 Map of OB associations in M33 taken from Humphreys and Sandage, 1980

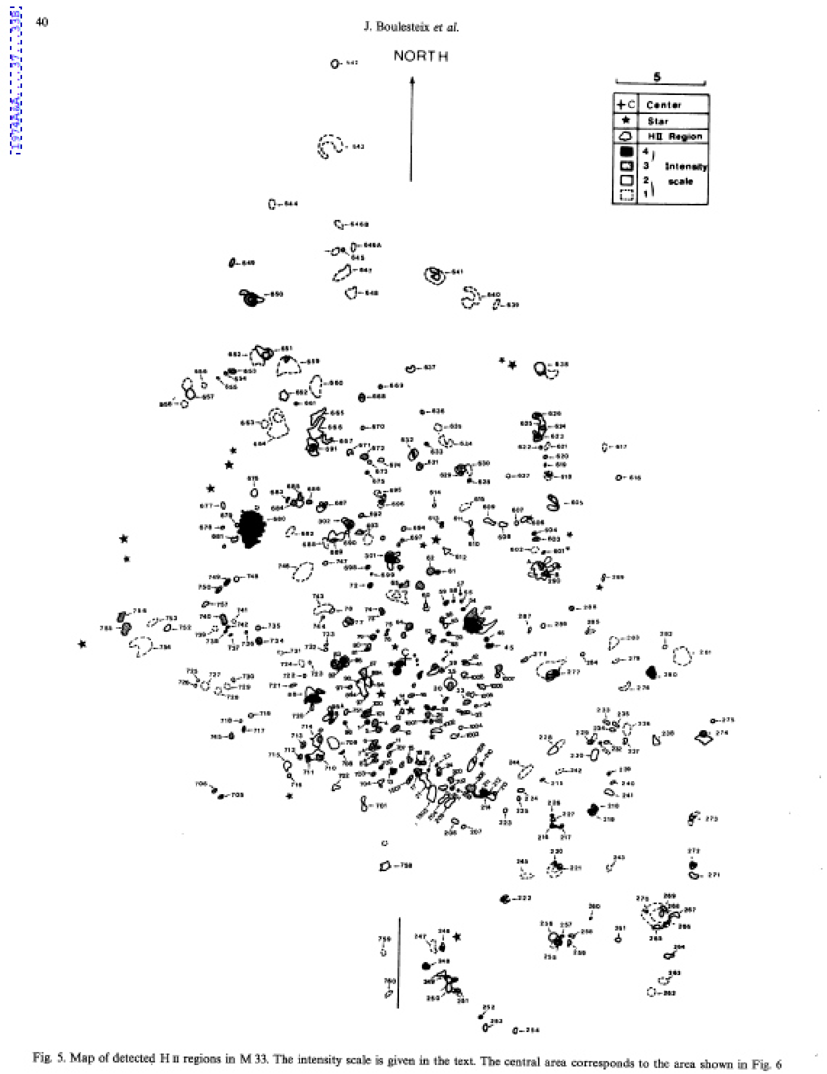


Fig.3 Map of Hii regions M33 taken from Bouleusteix at al., 1974.

Azimuthal offset between a subgroup of extremely young O stars and HII regions and a subgroup of older B stars without ionized gas in star-forming regions

$$\Delta\varphi = (\varphi_{\rm OB} - \varphi_{\rm Hii})R\,({\rm pc})$$

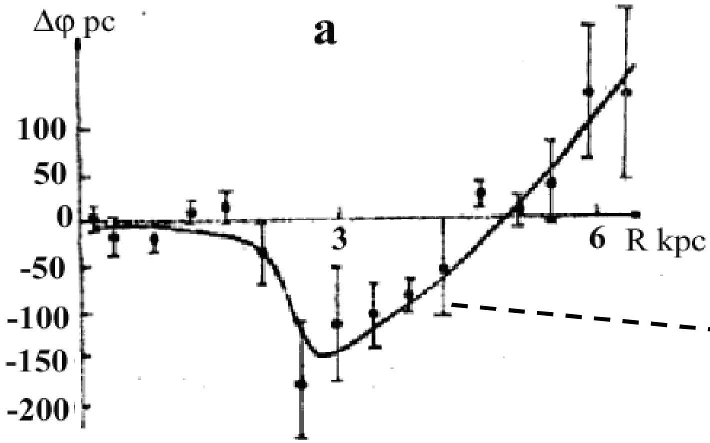
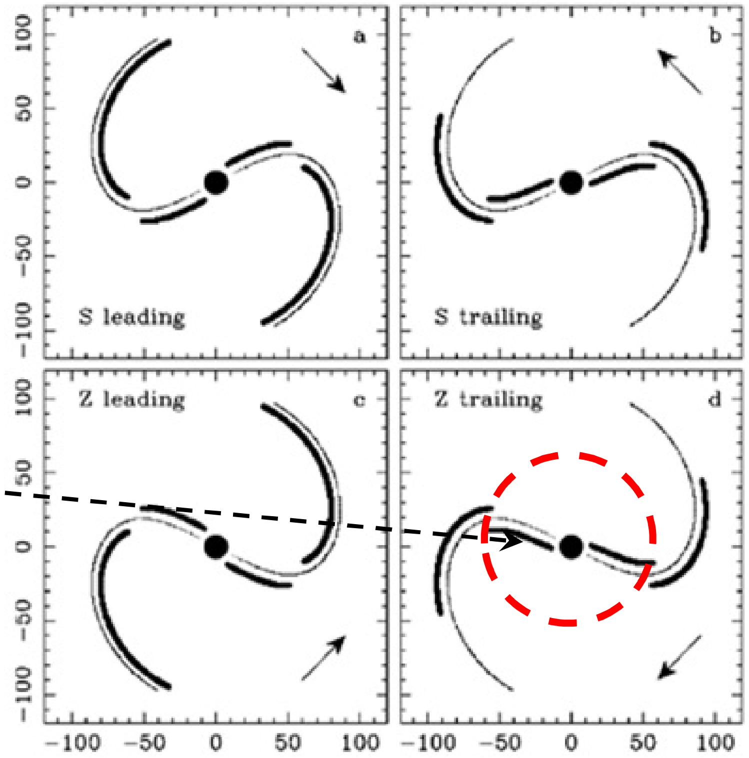


Fig. 4. Taken from Smitnov & Sakhibov (1981)

$$\Delta\varphi = 40\ {\rm pc} \quad \Leftrightarrow \quad \Delta\varphi \approx 20'' \quad \text{at } d = 0.72\ \text{Mpc}$$



Further such confirmations of the predictions of the spiral density wave theory in more distant spiral galaxies were limited by the sensitivity and resolution capabilities of the optical sensors.

Fig. 5. Taken from Puerari & Dottori (1997). Mutual location of the two-arm spiral pattern (thin line) and the stationary spiral shock wave in the interstellar gas (bold line).

The high sensitivity and resolution of modern detectors, combined with the excellent astro-climatic conditions at Maidanak Observatory, enabled us to apply our old ideas to new observational data

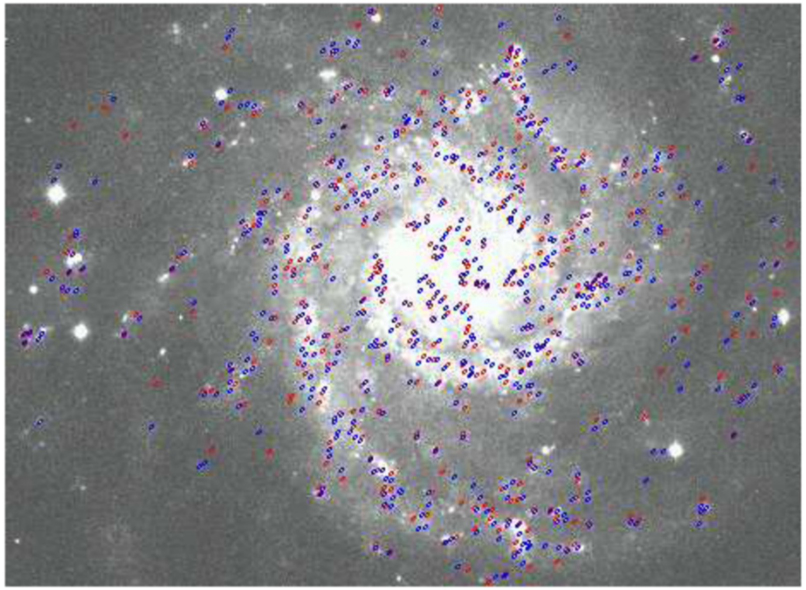


Fig. 6. Taken from Gusev&Shimanovskaya, 2019. B-image of NGC 628 and positions of selected star clusters (blue dots) and HII regions (red dots).

The coordinates of star clusters and Hii regions, obtained by measuring B and (Hα+[Nii]) images taken with the **1.5 m telescope of the Maidanak Observatory** in Uzbekistan in 2002-2006.

Offset Δ**S** $\approx$ 40 pc $\Rightarrow$ Δ**S** $\approx$1.5“

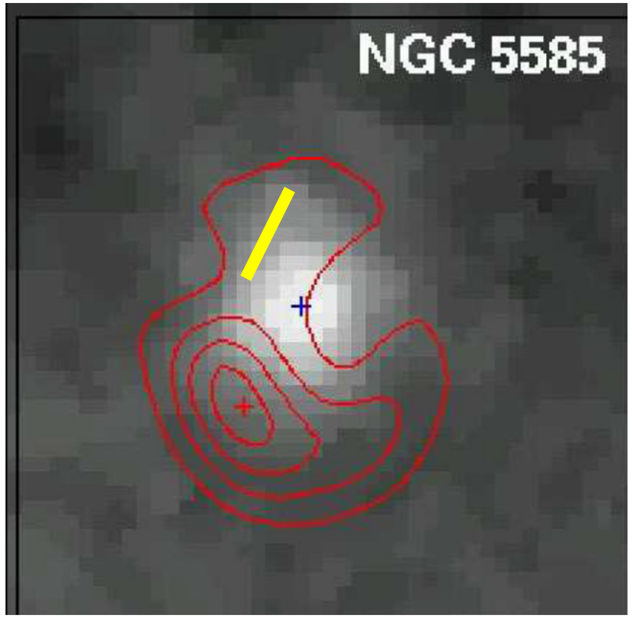


Fig. 7. Taken from Gusev&Shimanovskaya, 2019. *B* image of a selected star cluster in NGC 5585 with superimposed isophotes of the Hα line intensity. The centre of the star cluster is marked with a blue cross and the HII region with a red cross. The angular size of the image is 11.7 × 11.7 arcsec^2, which corresponds to a linear size of 320 pc
(d=5.6 Mpc)

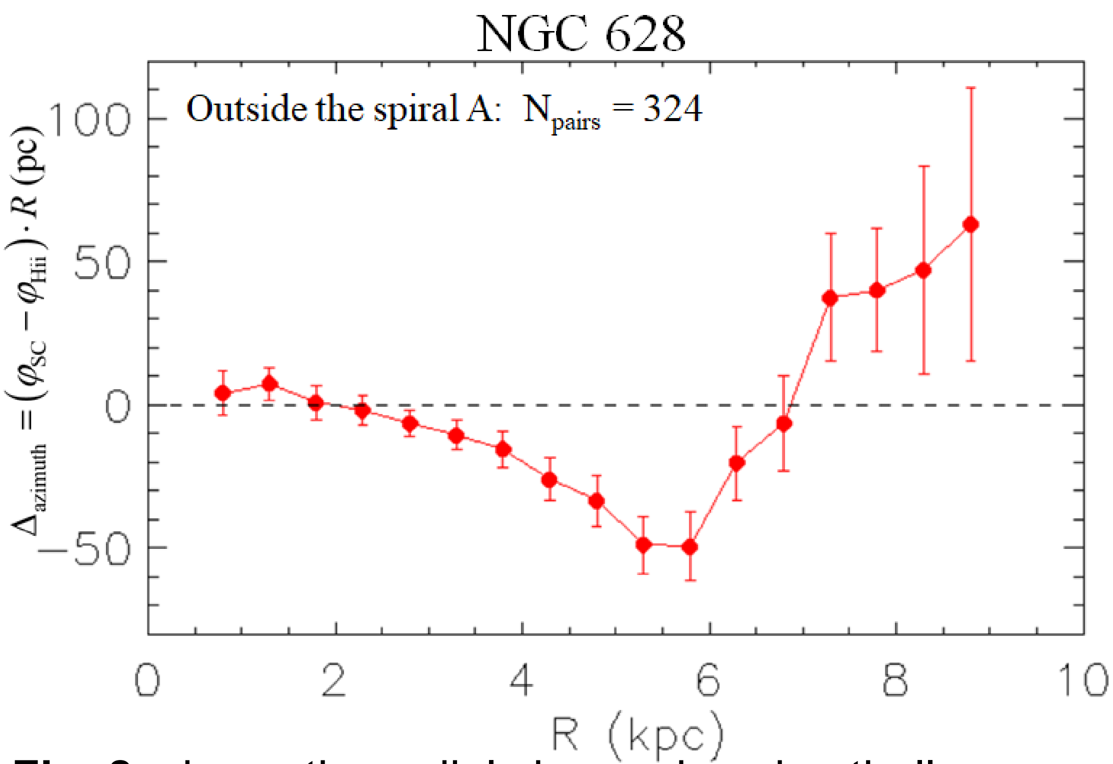


Fig. 8. shows the radial change in azimuthally averaged offset calculated for 324 SC–HiiR pairs

$\Delta_{azimuth} < 0$ => Hii-regions are closer to the **inner edge** of the arm

$\Delta_{azimuth} > 0$ => Hii-regions are closer to the **outer edge** of the arm

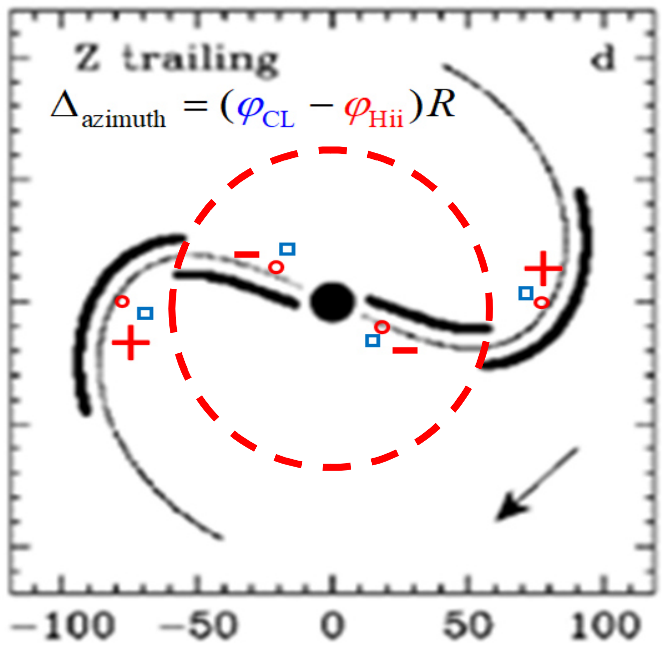
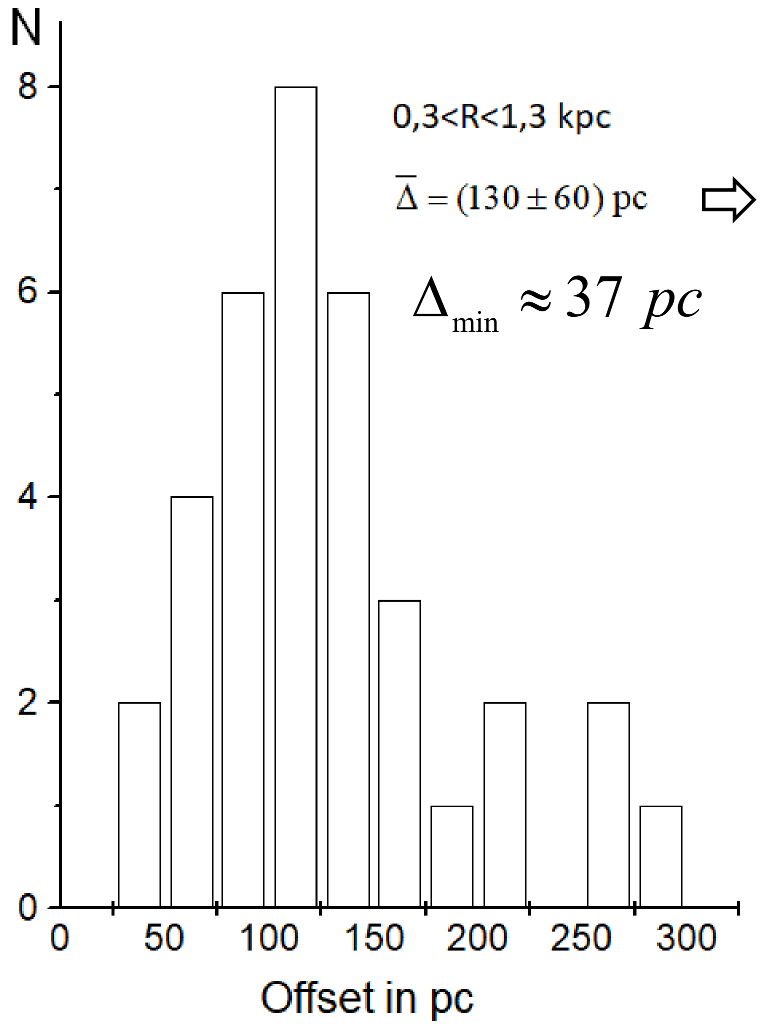


Fig. 5d. Mutual location (case Z-trailing) of the two-arm spiral pattern (thin line) and the stationary spiral shock wave in the interstellar gas (bold line).



$\bar{\Delta} = (130 \pm 60)\ \text{pc} \Rightarrow (3.7 \pm 1.7)''$

$\Delta_{\min} \approx 37\ pc \Rightarrow \approx 1.05''$ ➡ Angular resolution provided by MAO is $\approx 1''$

Fig. 9. shows the distribution diagram of the azimuthal offset absolute value in the first annuli

Here we should note, that HST data have major advantages for studying local properties of stellar populations in nearby galaxies,
and
our study would be stronger if we can demonstrate that our HII region-cluster pairings remain valid when observed with the much higher angular resolution provided by HST

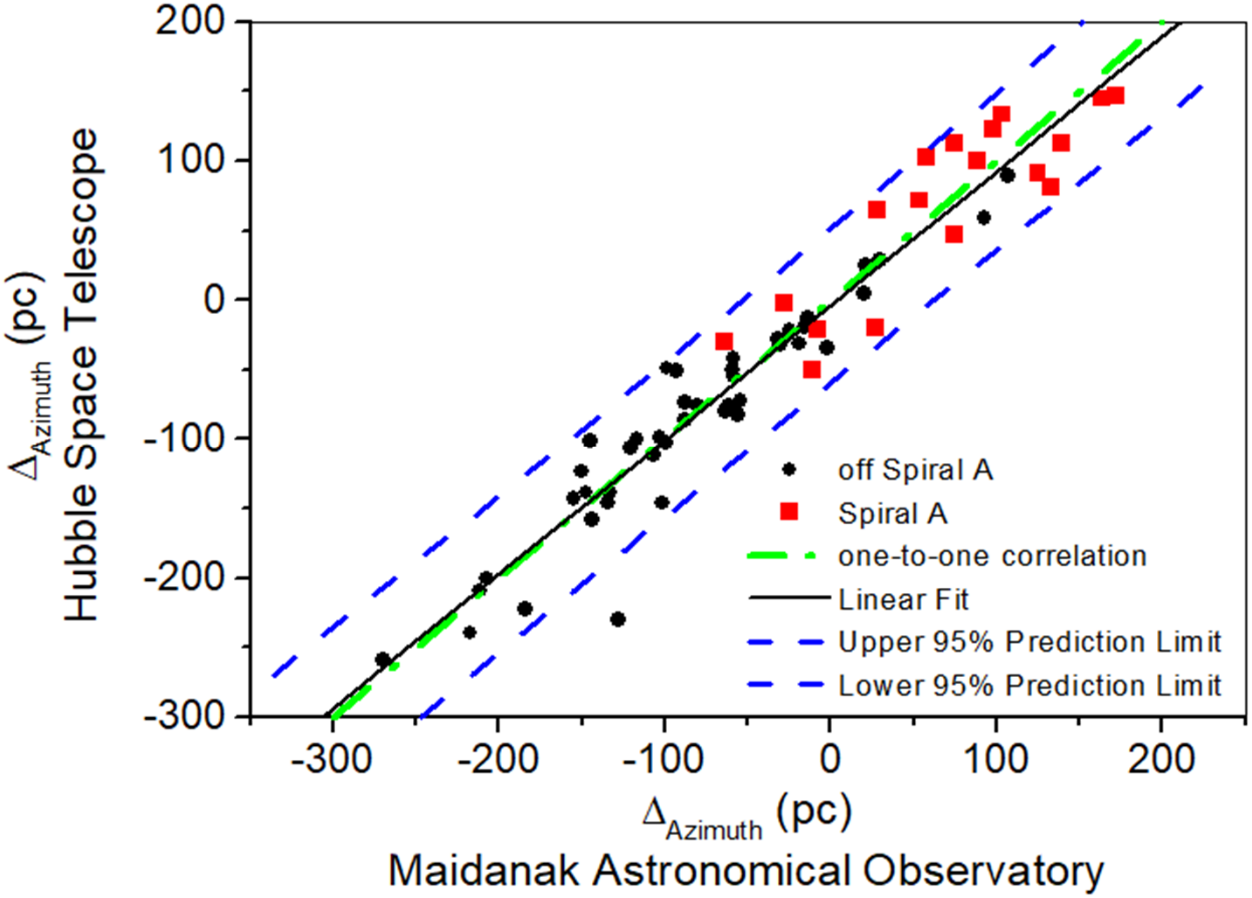


Fig.10 shows that our HII region-cluster pairings **remain valid** when observed with the much higher angular resolution provided by HST.

We have identified our HII regions with the HII regions observed with SITELLE (new imaging Fourier transform spectrograph) on the CFHT Rousseau-Nepton et al.(2018} and our stellar clusters with clusters extracted from the Legacy ExtraGalactic UV Survey with HST (LEGUS) star cluster catalogue Adamo et al.(2017).

Fig. 10. Comparison between our (MAO) and the reference azimuthal offsets in SC--HiiR pairs in NGC 628 from the HST observations.

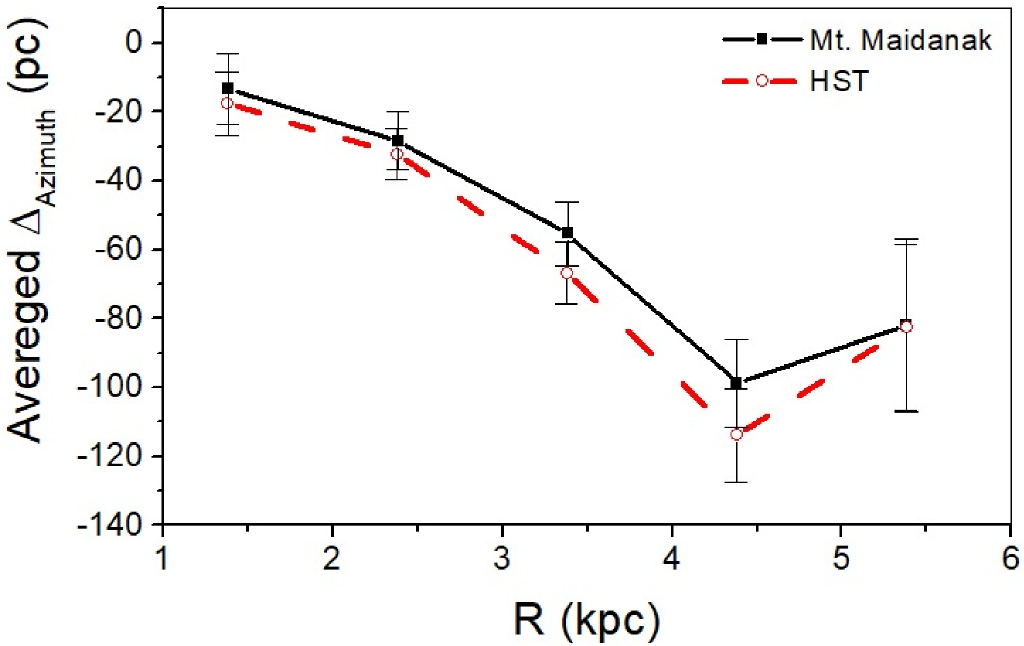
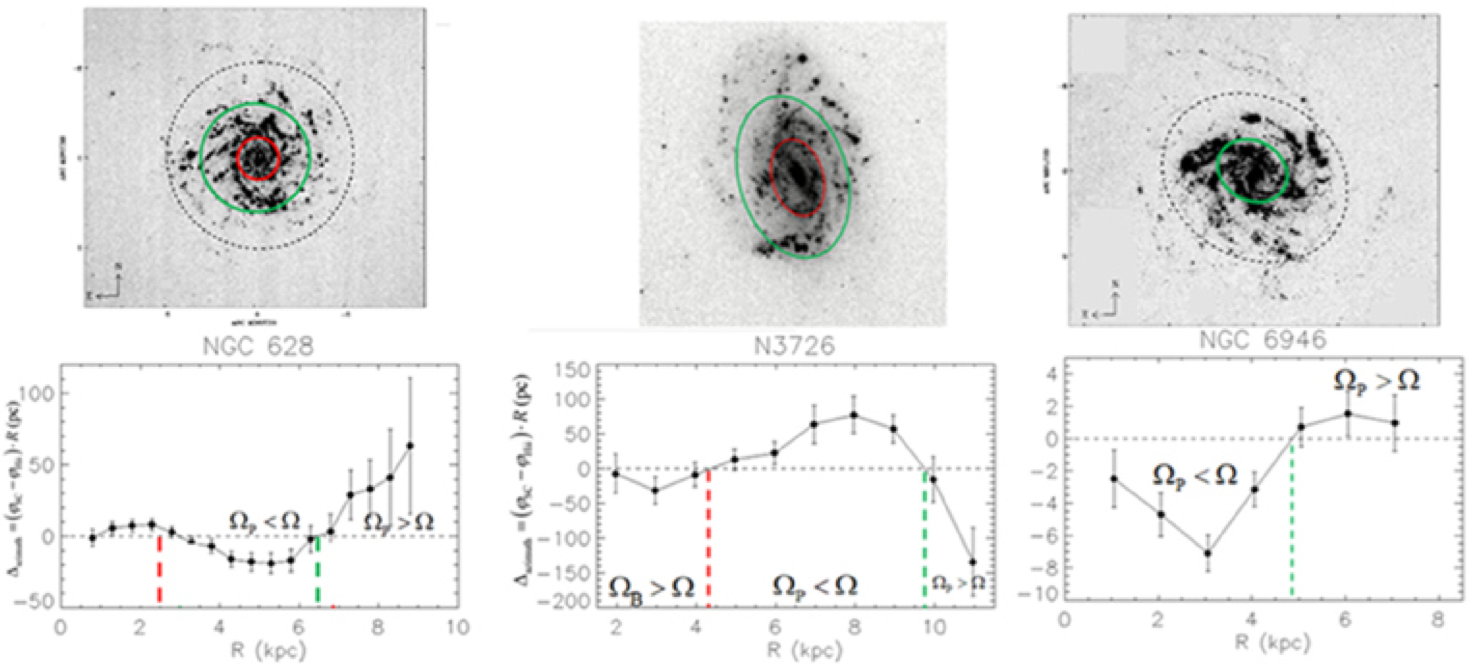


Fig. 11. Comparison between the radial change of the azimuthally averaged offset in the annulus calculated for 62 reference SC-HiiR-pairs observed by HST (red dashed line) and the radial change calculated for 62 pairs from our sample (black solid line) identified with HST objects.

The fact that the selected pairs from the highly accurate SITELLE and LEGUS catalogues are **not accidental** is confirmed by Fig. 11, which demonstrates a good agreement, within the error intervals, between the radial variation of the averaged azimuthal offset in the thin annulus derived from HST data and the radial variation derived from our ground-based imaging data.

Using high-quality data from the Maidanak Observatory we have successfully applied our method, which requires angular resolution of about 1 arcsec to study nearby galaxies, to NGC 628, NGC 3726 and NGC 6946 removed at distances of 7 Mpc, 14 Mpc , 6 Mpc, respectively.



The results presented in Fig.12 show that the data obtained at the Maidanak Observatory have a consistently high angular resolution and can be compared with the highly accurate data from the space telescope.

Fig. 12. „Azimuthal propagation of star formation in nearby spiral galaxies: NGC 628, NGC 3726 and NGC 6946" by F. Sakhibov, A.S. Gusev and C. Hemmerich, 2021, MNRAS, 508,912.

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