The study of UGC11919: mass-to-light ratio, nuclear disk and stellar population

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Abstract: We performed HI and optical long-slit observations of a spiral galaxy UGC11919 to study its kinematics and stellar population. The previous studies gave basis to suspect that this galaxy possesses a peculiarly low mass-to-light ratio M/L of stellar population. The stellar mass-to-light ratio estimated for different evolutionary models using both the broad-band magnitudes and the detailed spectral data confirm this peculiarity if the disk inclination angle i≥30°, as it follows from the optical isophotes and agrees with the HI data cube. However, the HI data cube also admits the lower value of i=13°, where the peculiarity of M/L ratio disappears. The thickness of stellar disk corresponding to the measured velocity dispersion of stellar population also gives evidence of the low inclination. We conclude that the stellar population of this galaxy is not peculiar, however the flatness of optical isophotes is surprisingly large for the nearly face-on disk, evidencing that its stellar disk may be non-axisymmetric. The derived stellar kinematic profiles reveal a signature of kinematically decoupled nuclear disk in the galaxy. Using different evolution models we estimated stellar metallicity and the mean luminosity-weighted stellar age for the bulge, disk and nuclear disk of this galaxy. We show that the disk of UGC11919 is dynamically overheated independently of the adopted inclination angle - probably as the result of the gravitational interaction with companions noticeable in the HI line.

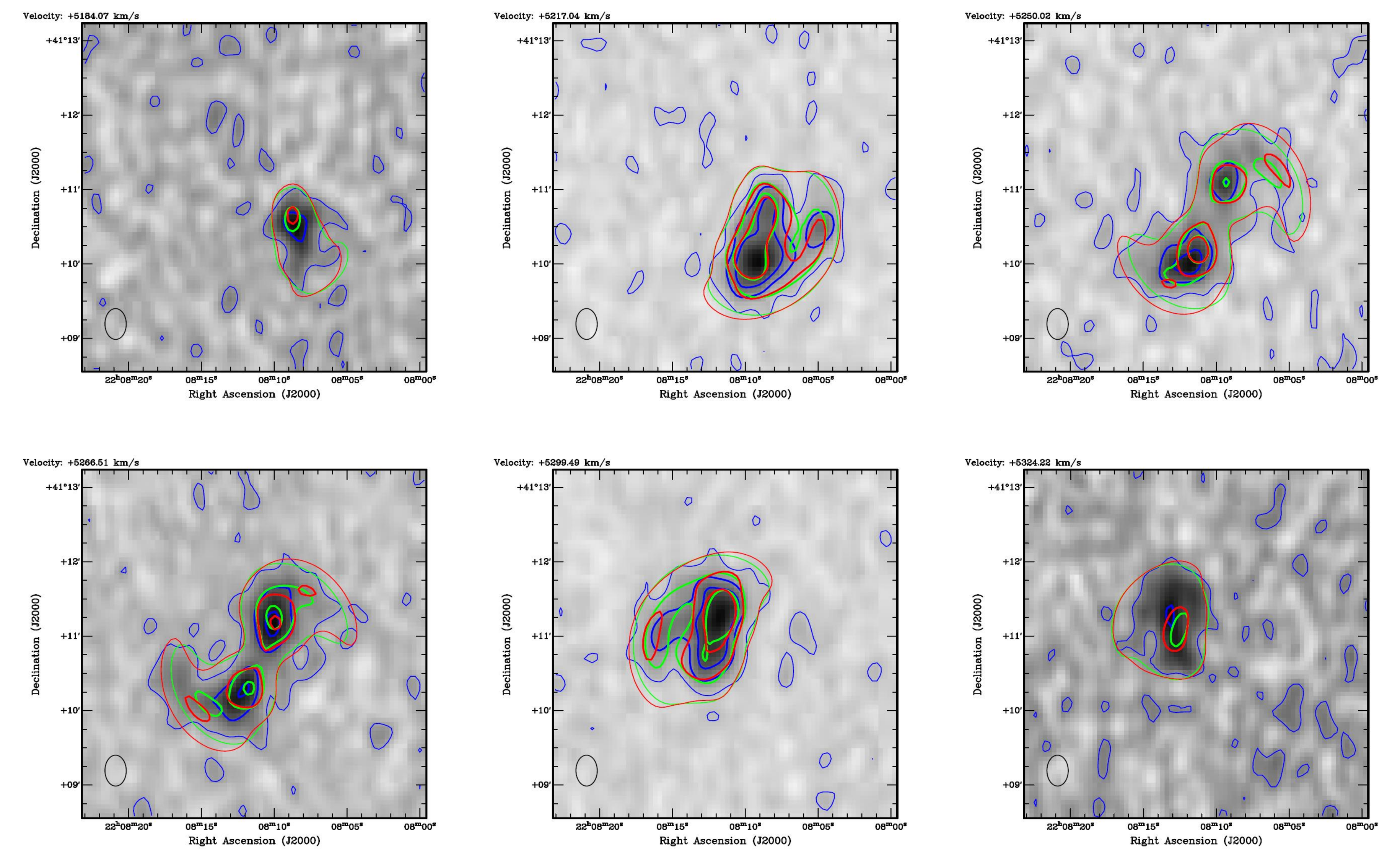

Fig. 2: Selected images of HI data cubes of UGC11919. Blue, red, and green contours represent the 0.75, 3, and 5 mJy/beam levels of the observed and model data cubes for i=30° and i=13°, respectively.
Both values of inclination angle are not in conflict with the HI data cube.

Observations and data reduction. We conducted HI observations of UGC11919 with the WSRT in September 2011. We modeled the HI data cube of UGC11919 using the TiRiFiC software (Józsa et al. 2007), allowing for a direct fit of modified tilted-ring models to the data cubes (for more details on data reduction see Saburova et al. 2013).

We also carried out the long-slit spectroscopic observations with the SCORPIO spectrograph (Afanasiev & Moiseev 2005) with the Russian 6-m BTA telescope in August 2013 for two position angles of slit $PA_{1,2}$=20, -52°. The parameters of internal kinematics and stellar population of galaxy were obtained by fitting high-resolution PEGASE.HR (Le Borgne et al. 2004) simple stellar population models with the NBURSTS full spectral fitting technique (Chilingarian 2007).

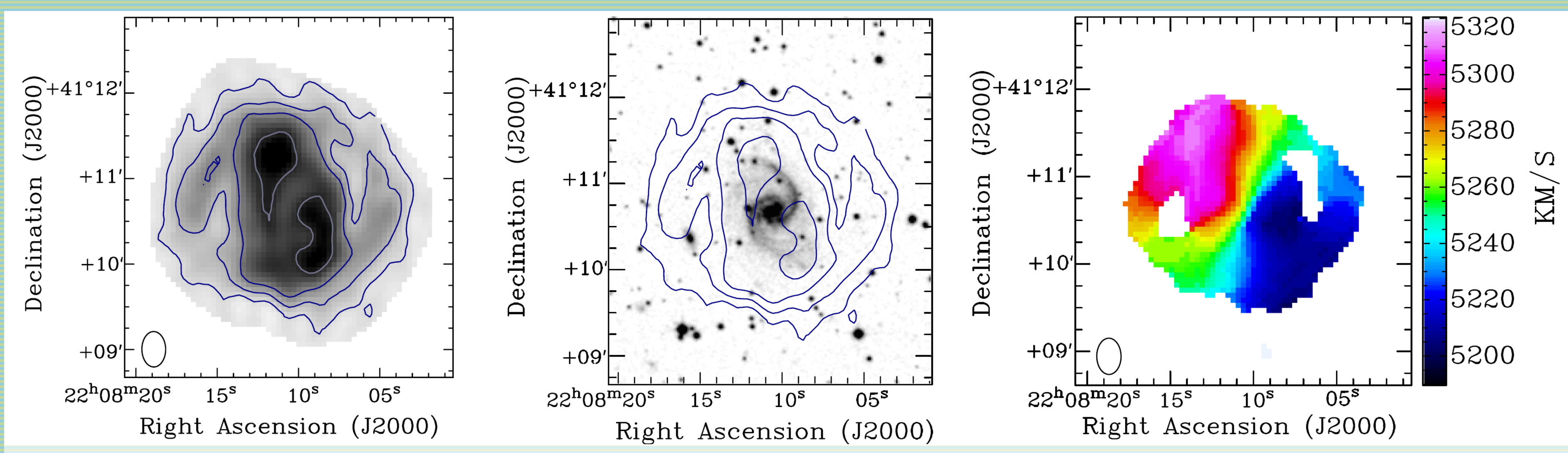

Fig. 1: HI total intensity map and R-band optical image of UGC11919 with overplotted HI total intensity contours: 5.4, 20, 35, 80 x 10^{19} atoms cm^{-2} (left and middle panels respectively) and the first moment map of UGC11919 (right panel).

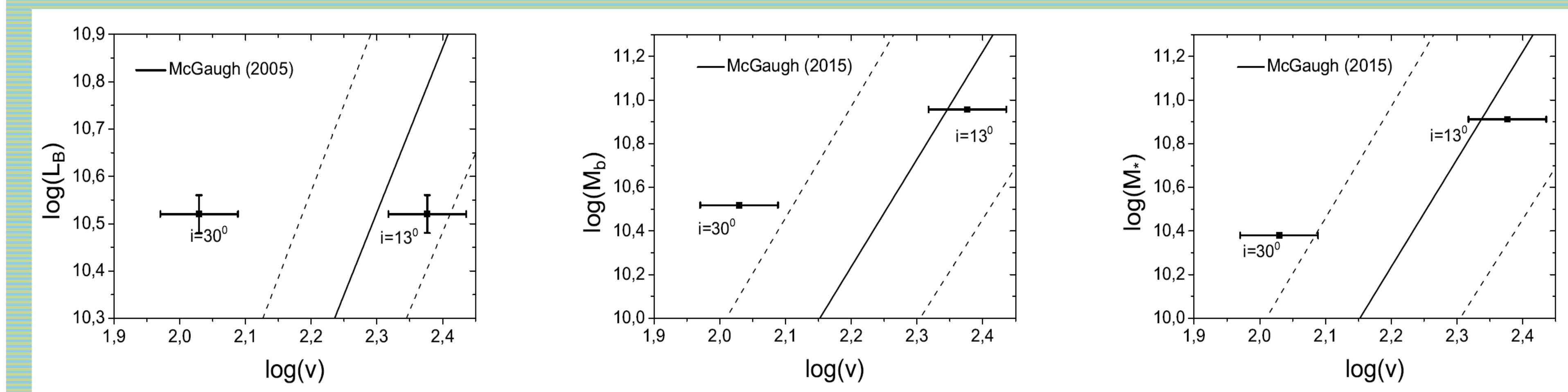

Fig. 3: The position of UGC11919 for two values of inclination angle on the Tully-Fisher diagrams. Left: the 'classical' ($\log(L_B)$ versus $\log(v)$) Tully-Fisher relation, the lines correspond to the relation found by McGaugh (2005) and its uncertainty. Central and right hand panels show baryonic ($\log(M_b)$ versus $\log(v)$) and stellar ($\log(M_*)$ versus $\log(v)$) Tully-Fisher relations respectively, the lines denote the sequences found by McGaugh, Schombert (2015) and their uncertainties. **The low inclination i=13° is in a good agreement with the position of the galaxy at the Tully-Fisher diagrams.**

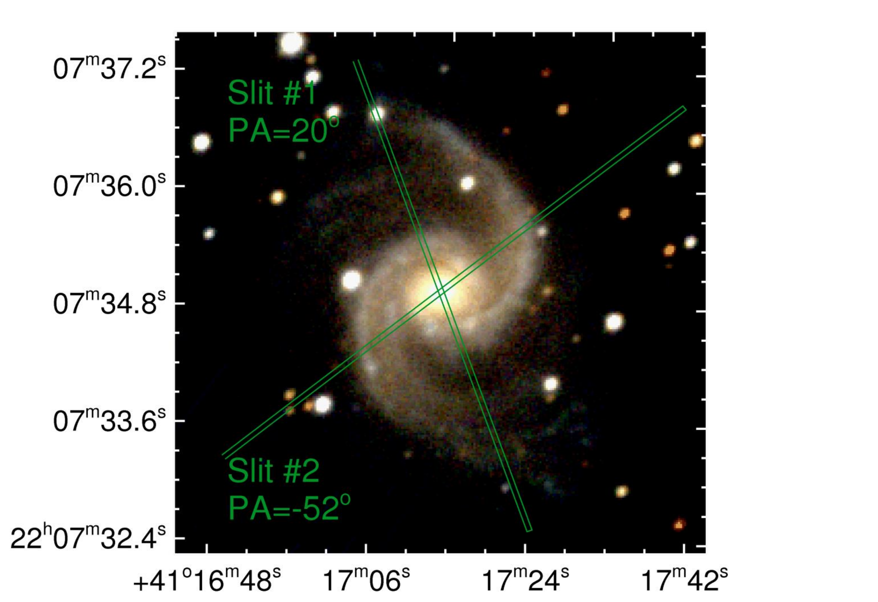

Fig. 4: Composite gri- image of UGC11919 from SDSS with the overplotted positions of the slits.

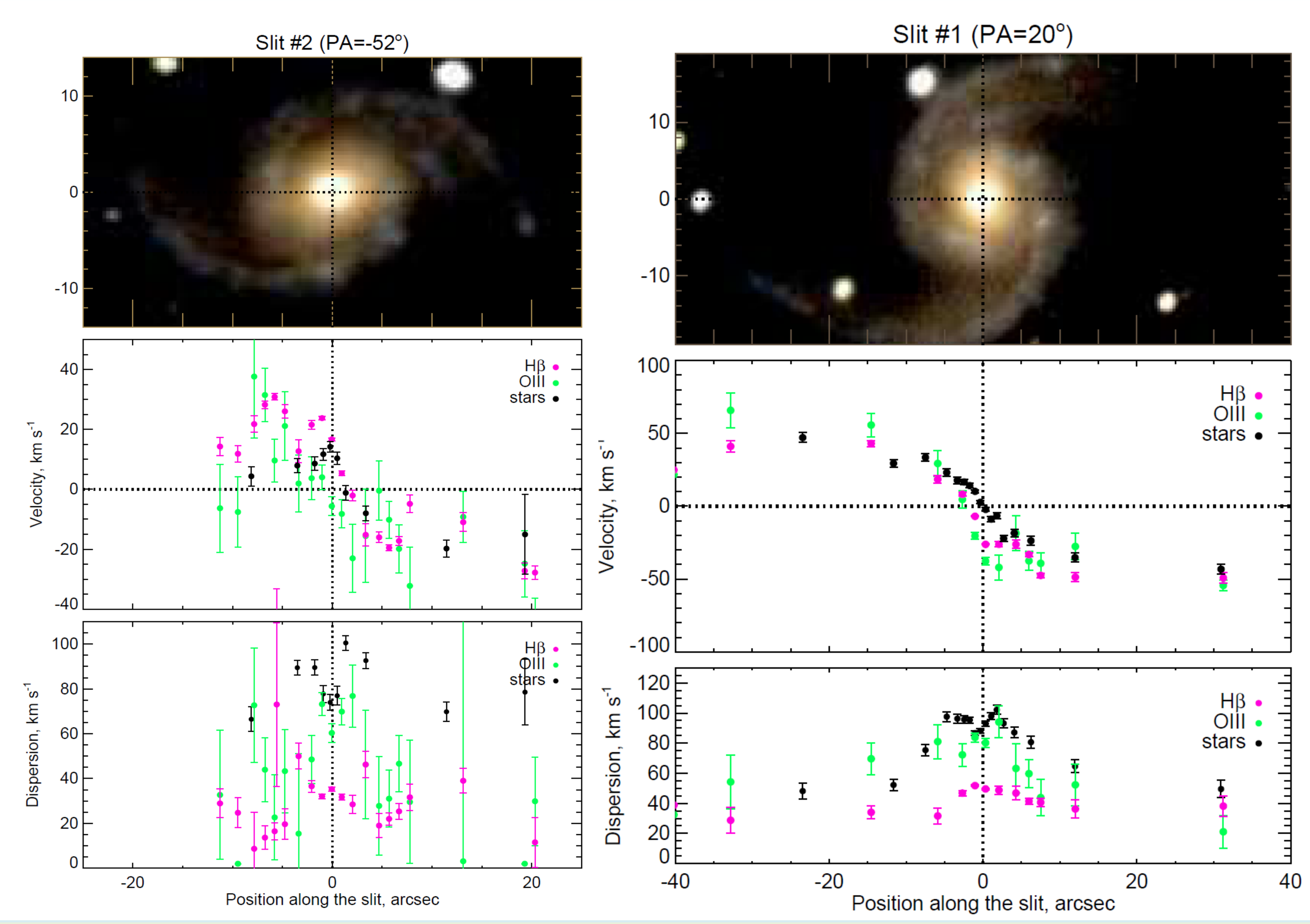

Fig. 5: The kinematical profiles of the motion of stars and ionized gas obtained from the long-slit spectra at PA=-52° (left) , 20° (right). **The central depression of stellar velocity dispersion indicates the presence of nuclear disk.**

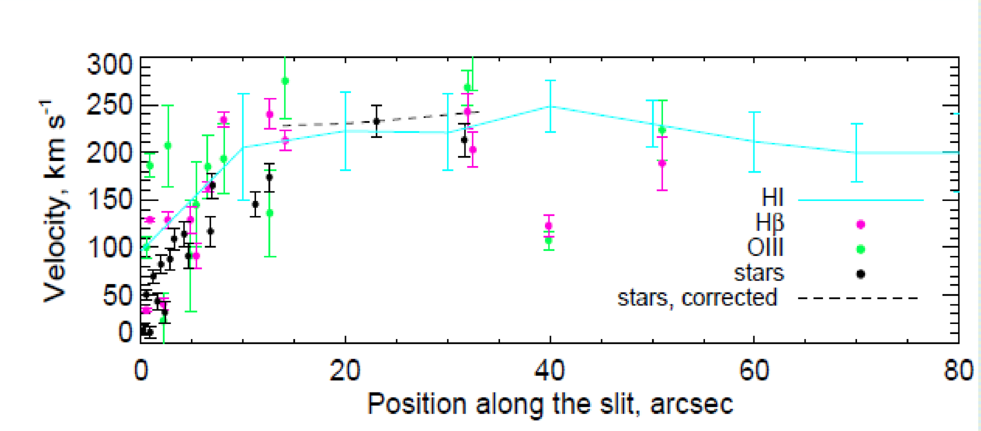

Fig. 6: The rotation curve of UGC11919 assuming i=13 °. Dashed black line demonstrates the rotation velocity of stars corrected for the asymmetric drift.

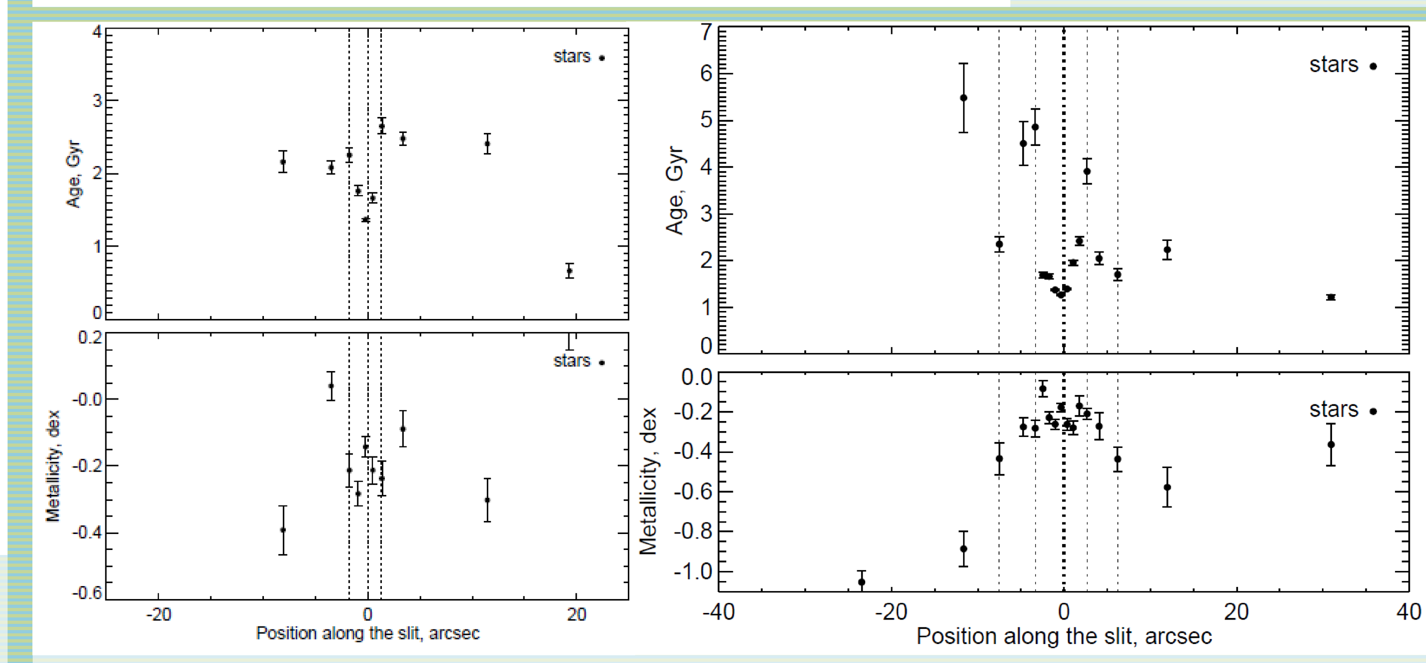

Fig. 7: Stellar population age and metallicity radial profiles along the PA=-52° (left) , 20° (right).

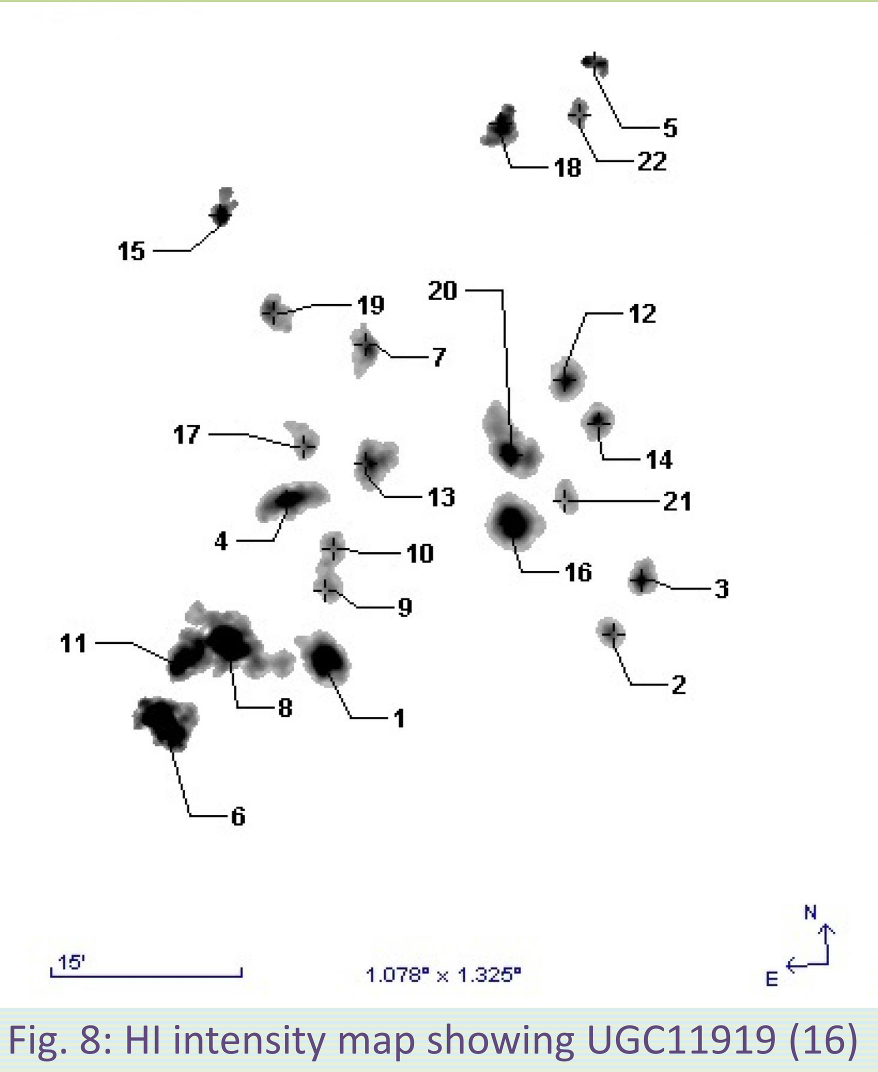

Fig. 8: HI intensity map showing UGC11919 (16) possessing two companions - objects 20 and 21.

The measurement of stellar velocity dispersion at one disk radial scalelength r_d ≈21 arcsec ≈7.5 kpc allows to find:
1. Equilibrium scale height for stellar disk: $Z_0=c_z^2/\pi G\sigma(r_d)$, where c_z is the vertical component of stellar velocity dispersion, σ is the disk surface density. For i=13° and for i=30° Z_0/r_d=0.2 and Z_0/r_d=0.7 respectively. **The case of i=30° and peculiarly low M/L corresponds to the unrealistically high disk thickness.**

2. The disk surface density corresponding to its marginal gravitational stability: $\sigma(r)=c_r(r)æ(r)/Q_T(r)3.36G$, where æ(r) is epicyclic frequency, $c_r(r)$ is radial stellar velocity dispersion, $Q_T(r)$ ~1.2-3 is Toomre parameter appears to be higher than it follows from the dynamical modelling of the rotation curve for both values of inclination. **It evidences that the disk is dynamically overheated.**

Conclusions.
The analysis of long-slit data gives the mass-to-light ratios of stellar population that are several times higher than it follows from the dynamic modeling of the rotation curve if the disk inclination angle corresponds to the photometrically defined values i>30°. However the HI data cube is also compatible with the inclination i = 13°, which may eliminate the contradiction between the dynamical and photometrical estimations of disk mass. In addition, the stellar velocity dispersion at the radial scalelength r_d better agrees with the "heavy" disk (i = 13°) . The lower inclination also is in a good agreement with the position of the galaxy at the Tully-Fisher diagrams. It allows to conclude that the disk inclination of UGC11919 is significantly lower than it follows from the photometry which may evidence the internal ellipticity of the isophotes in this nearly face-on galaxy..

Spectral slices of UGC11919 allow to propose that the galaxy possesses a nuclear disk, where the stellar velocity dispersion is lower than in the bulge. We obtained the mean age (4.2, 2.6 and 2.3 Gyr) and metallicity [Z/H] (-0.4, -0.5 and -0.3 dex) for the bulge, disk and nuclear disk of UGC11919 correspondingly.

We found that the main disk of the galaxy is dynamically overheated – may be as the result of gravitation interaction with the companions some of which are observed in HI line only.

References:
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