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The structure of the barred galaxy NGC253: target of the VISTA and VST Science Verification extragalactic mini-survey

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Abstract. The Sculptor Galaxy NGC253 is a nearby barred Sc galaxy seen nearly edge-on and it has been the target of the Science Verification (SV) for the new ESO survey telescopes VST and VISTA: SV have been defined by teams of astronomers from ESO and the community, including the Italian National Institute for Astrophysics. On the behalf of the VISTA and VST SV Team, I will present in this paper the first results on the NGC253 structure by the new NIR VISTA and optical VST images. These data have emphasized the huge potentiality of the VISTA and VST telescopes to study the structure of galaxies with a detail and accuracy comparable to higher class telescopes, i.e. VLT and HST, with the advantage of the large Field of View (FoV): i) the high angular resolution let to detect and study the sub-structures towards the nuclear regions; ii) the large FoV let to "correlate" the inner features to the structure of the outer galaxy disk and to map the surface brightness and colors out to the very faint outskirts.

Key words. Galaxies: photometry - Astronomical data bases: Surveys

1. Introduction

Why a Science Verification (SV) - The SV for the new ESO survey telescopes VST and VISTA aims to test the expected potentialities of the telescope, camera and the software built ad hoc for the very elaborated data reduction. SV have been defined by teams of astronomers from ESO and the community, including the Italian National Institute for Astrophysics, in particular, were involved people that followed the built of telescope and the data reduction software.

Why NGC253 - NGC253 is a Southern[1], barred

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[1] RA(J2000)=00h:47m:33s; DEC(J2000)=-25d:17m:18s

edge-on spiral galaxy in the Sculptor group at a distance of 3.9 Mpc. As described in detail in Sec.1, it is a very complicated object: it was chosen as target for the SV because it is wide enough to fill much of the VISTA and VST field, so it is ideal to check possible reflections of the light and to test the background subtraction techniques; it is very dusty, so ideal for the NIR imaging to study the underlying structure of the disk; it seems to be very similar to our Galaxy and, finally, a wealth of data is available in the ESO archive (narrow band $H\alpha$, broad bands from ESO/MPI-2.2WFI, imaging and spectra of the nucleus from SINFONI at ESO/VLT).

SV science goals - The main scientific goals of the SV extragalactic mini-survey are: 1) detecting the Red Giant Brach stars in the faint outer halo, by using the deep exposures, and 2) study of the disk and bulge structure with shallow exposures. In this paper, I will focus on the last science case and I will show some of the major results derived by optical r band VST and NIR Ks band VISTA data.

1.1. Pre - VISTA-VST anatomy of NGC253

NGC253 is one of the best nearby example of nuclear starburst galaxy: even if its overall gas and star morphology is typical for a spiral galaxy, the several photometric and kinematical studies on this object have revealed that NGC253 has quite complicated structure. The deep image of Malin & Hadley (1997) reaching 28 mag arcsec^2 shows the presence of an extended asymmetrical stellar halo plus a Southern spur. The stellar disk is much more extended than the HI disk (Booomsma et al. 2005), contrary to what is typically observed in spiral galaxies. Furthermore, the HI distribution in NGC253 presents other two features: as the stellar disk, also the HI disk is asymmetric, appearing less extended on the NE side with respect to SW, and, on the same side, a plume is observed which is elongated perpendicular to the disk major axis and extending for about 12 kpc. These HI plume borders the Xray-halo emission (Pietsch et al. 2000) and the $H\alpha$ (Hoopes et al. 1996) on their northern side: given the spatial connection among the three components, a common origin for such feature has been proposed, which is suggested to be related to the central starburst or, alternatively, to a minor merger and gas a gas accretion event. Towards the nuclear regions, the $H\alpha$ rotation curve along the disk major axis is asymmetric inside 100 arcsec from the galaxy center and the steep velocity gradient for $R \leq 10$ arcsec on the NE side suggests the presence of a nuclear ring (Arnaboldi et al. 1995). Very recently, the presence of a nuclear torus-like structure of a comparable size has been detected by SINFONI data (photometry and 2D kinematics) in the Ks band (Muller-Sanchez et al. 2010). Taking into account that NGC253 is a nearby and very extended object, one limitation in all the previous data is the absence, in one shot, of high angular resolution data covering the entire galaxy extension, in order to study the fine substructure and to correlate them with the outer disk and halo: as I will discussed in detail in the next sections, this issue has been overcome thanks to the large FoV and high angular resolution the OmegaCam and VIRCAM camera at VST and VISTA telescopes, respectively.

2. Observations and data reduction

Both the *VLT Survey Telescope (VST)* and the *Visible and Infrared Survey Telescope for Astronomy (VISTA)* are located at Cerro Paranal, in Chile. VST is a 2.6 meter telescope, it is equipped with the wide field camera OmegaCAM, made of 32 CCD, which covers a 1×1 deg^2 FoV, in the optical wavelength range from 0.3 to 1.0 micron (Capaccioli & Schipani 2011). The mean pixel scale is 0.21 arcsec/pixel.

VISTA is a 4 meter telescope and the wide field near-infrared camera VIRCAM consists of 16 2048×2048 arrays, which covers a 1.29×1.02 deg^2 FoV, in the wavelength range from 0.85 to 2.4 micron. The mean pixel scale is 0.34 arcsec/pixel. Even if the VISTA mirror is larger than that of VST, the number of pixels covered by the VST camera (i.e. 256 Mpixels) is one order of magnitude larger than that of VISTA camera (i.e. 65 Mpixels): this is due to

the large gaps between each VIRCAM array of 0.90 and 0.425 of a detector along the x and y axes respectively (Emerson et al. 2004). One VIRCAM exposure, named *pawprint*, is made of a 16 non-contiguous images, of $FOV = 0.6$ deg^2 with gaps, the contiguous area of 1.65 deg^2, the *tile*, is obtained by combining a minimum of 6 appropriately off-setted pawprints. The further complication moving to longer wavelengths is given by the bright (particularly in the H and Ks bands) and highly variable sky with the increasing exposure time: to overcome this problem, the observation strategy is to obtain a series (NDIT) of short exposures (DIT) on the target, that will be add together, and on an adjacent empty sky field. For NGC253, the total exposure time of the Ks band images is 72 sec ($NDIT \times DIT = 12 \times 6$ sec); the VST r band images are integrated for 1.03 hrs.
Data reduction have been performed by using the dedicated pipelines, developed specifically for the reduction of the OMEGACam and VIRCAM data: the VST-Tube (Grado et al. 2012) and CASU (Irwin et al. 2004) respectively for the VST and VISTA observations. Both pipelines are modular and allows different processing recipes to be applied for different observing strategies: they provides the fully calibrated and stacked images from the raw data.

3. Results

The new VST and VISTA observations have revealed that the morphology of NGC253 changes dramatically from optical to near-infrared wavelengths: the galaxy structure in the visible resembles that of an Sc spiral, the disk is very dusty and star formation regions dominates the spiral arms (Fig.1, left panel); several dust filaments are evident on the NW side, which seems to be elongated perpendicular to the disk major axis. The most prominent features of NGC253 in the NIR (see Fig.1, right panel) are *i)* the bright nucleus with a diameter of $\sim$ 1 kpc; *ii)* the central prominent bar that cross the nucleus, which ends with very bright ansae; *iii)* the spiral arms which starts at the bar edges' and dominates the outer disk till about 700 arcsec ($\sim$ 10 kpc); *iv)* an inner ring-like structure, detected for the first time, located in the main disk between the bar and the outer spiral arms, with a radius of $\sim$ 180 arcsec ($\sim$ 2.8 kpc).
Zooming in the nuclear regions of NGC253, the Ks image (Fig.1, top-right panel) reveals the presence of a torus-like structure of about 30 arcsec diameter ($\sim$ 0.4 kpc). It is characterized by very bright knots on the East side. Such feature was already detected by Muller-Sánchez et al. (2010) in the Ks data obtained with SIFONI at VLT and its morphology and extension is consistent with that derived by the Ks VISTA image. The perturbation by dust is high enough to obscure all these structure in the optical images of NGC253: so, the bar, the ring and the nuclear torus cannot be detected in VST r band image.
The surface brightness profiles along the disk major axis is much more extended in the optical VST r image than in the Ks VISTA image, reaching $\sim$ 20.1 kpc and $\sim$ 10.8 kpc respectively; the limiting magnitudes in the r band is $\mu \sim 26$ mag/arcsec^2 and in the Ks band is $\mu \sim 20$ mag/arcsec^2.
The dust distribution and the star forming regions are well mapped by the r-Ks color map and profiles: overall, dust is associated to the spiral arms and to the inner ring; the redder regions, i.e. $r - Ks \sim 4$, are the NW arm, the edges of the bar, along the EW direction and the nuclear regions (see Fig.2). Close to the galaxy center the main feature is a "hole", which is bluer than the adjacent regions.

4. Summary

The nearby starburst barred Sc galaxy NGC253 has been the target of the extragalactic mini-survey SV for the new ESO survey telescopes VST and VISTA: on the behalf of the VISTA and VST SV Team, in this paper are presented the first results on the NGC253 structure by the new NIR VISTA and optical VST images. Results by these new data have tested the value of the VISTA and VST telescopes to study the structure of galaxies with a detail and accuracy comparable to higher class telescopes, i.e. VLT and HST, with the advantage of the large field of view

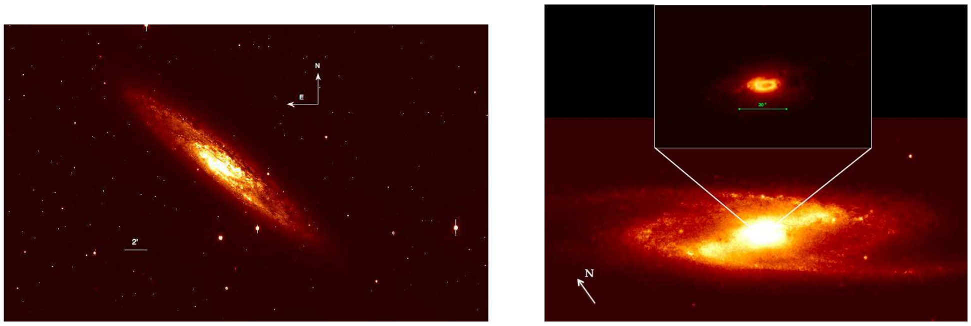

Fig. 1. NGC253. Left panel - VST r band image. Right panel - VISTA Ks band image; top panel: zoom in the nuclear regions.

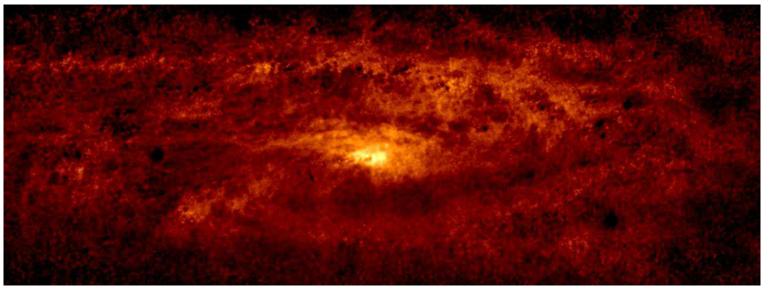

Fig. 2. r-Ks color map of NGC253; orientation is the same as in Fig.1 right panel.

(FoV): i) the high angular resolution let to detect and study the sub-structures towards the nuclear regions; ii) the large FoV let to ”correlate” the inner features to the structure of the outer galaxy disk and to map the surface brightness and colors out to the very faint outskirts. In detail, given the minimum perturbation due to the dust absorption, the NIR photometry shows that NGC253 has very complex structure and reveals the coexistence of, at least, 4 components: nuclear torus, inner ring, bar, outer disk. In particular, the new VISTA Ks data let to a very accurate estimate of the bar intrinsic length (l_b = 151.5″ ∼ 2.3 kpc) and of the corotation radius (R_{cor} ∼ 2.5 kpc): a detailed study of the bar and disk structure, by using the NIR VISTA data, will be presented in a forthcoming paper (Iodice et al. in preparation).

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