Dark Galaxies and Lost Baryons
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Dark Galaxies: How about this one?

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Abstract. We report on the (serendipitous) detection and analysis of an extremely massive H I cloud without an obvious stellar counterpart nearby the relatively isolated giant spiral galaxy NGC 1030 and present first results of this dark galaxy candidate.

Keywords. Galaxies: kinematics and dynamics, galaxies: ISM, galaxies: interactions, galaxies: structure, galaxies: individual: NGC 1030

1. Observations and analysis

We use independent H I observations of NGC 1030 and its surroundings obtained with the VLA (8h C-array) and the WSRT (8h maxi-short configuration). Figure 1 (left panel) shows an H I total intensity map based on the VLA data overlaid on a DSS image. NGC 1030 is relatively isolated: we detect H I in two known galaxies at projected distances of 154 kpc and 357 kpc, and additionally a cloud to the NE of NGC 1030 with an H I mass of $2.7 \pm 0.6 \cdot 10^9$ $\mathrm{M}_\odot$ that lacks a stellar counterpart in the DSS (Fig. 1, left panel). While a gaseous bridge between this object and the galaxy is evident from both data sets (Fig. 1, right panel), the gas cloud, the bridge, and the galaxy are morphologically and kinematically separated (Fig. 1, middle panel; note the turn in the direction of the velocity gradient from stream to cloud). Hence, the cloud can be identified as an individual system. The data reveal a rotational signature in the H I cloud with the direction of rotation orientated roughly perpendicularly w.r.t. the stream (Fig. 1, middle panel).

The quality of the VLA data allows a fit of a kinematical tilted-ring model for both NGC 1030 (aka UGC 2153; Fig. 6 in Struve *et al.* 2007) and the cloud using our software TiRiFiC (Józsa *et al.* 2007). For the cloud we achieve good fits for a wide range of inclinations i, and with that a wide acceptable range of rotational amplitudes.

A lower limit to the dynamical mass is the total neutral gas mass of the object ($3.6 \pm 0.8 \cdot 10^9$ $\mathrm{M}_\odot$, including helium). Hence, models with an inclination above 30°, which result in an unphysical dynamical mass, can be discarded. Still in very good agreement with the data is the much higher estimate of the maximal dynamical mass of $1.3 \cdot 10^{10}$ $\mathrm{M}_\odot$ that we derive by fixing the inclination at 20°. Models with an inclination $< 15°$ can be discarded, because they show an unphysically strong falloff of the rotation curve. All our models (except for very low inclinations $< 15°$) indicate a rising or at least flat rotation curve at our last modelled radius ($v_{\mathrm{rot}}(r_{\mathrm{max}}) \approx 24$ km s^{-1} for $i = 30°$, $r_{\mathrm{max}} = 30'' \simeq 17.5$ kpc), meaning that we do not trace the complete mass of the object. Our measured internal

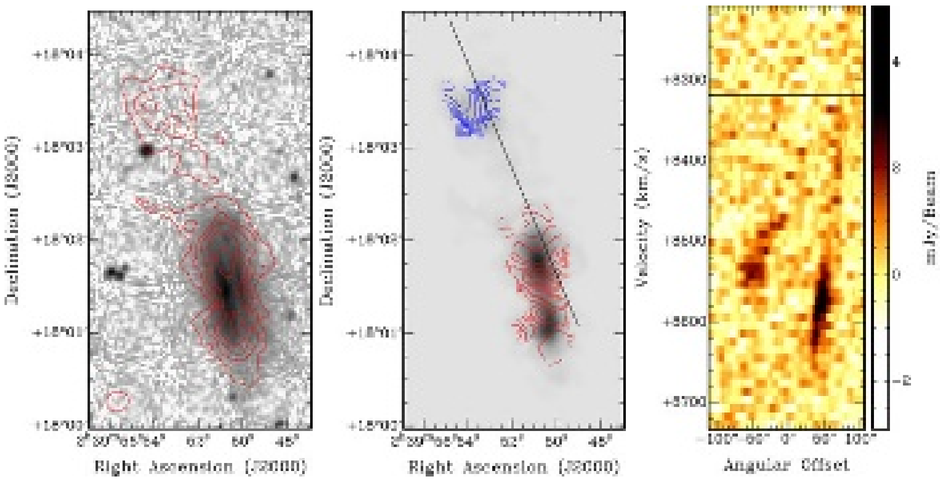

Figure 1. Left: Optical image (DSS2) of NGC 1030 overlaid with H I column density contours: the presence of a massive gas cloud to the NE of NGC 1030 becomes evident. The ellipse denotes the observational beam. Contour levels: 1, 3, 6, 12, 24 $\cdot\ 10^{20}$ atoms cm^{-2}. Middle: H I total intensity image overlaid with velocity contours. Contour levels for NGC 1030: $v_{\rm sys} = 8318 \pm 30$, 60, 90, 120, 150, 180, 210, 240, 270, 300 km s^{-1}. Contour levels for cloud: $v_{\rm sys} = 8535 \pm 2$, 4, 6, 8, 10, 12 km s^{-1}. Right: PV diagram along the line shown in the middle figure (left: cloud; right galaxy). Both are connected by a gaseous bridge. Horizontal line: systemic velocity of NGC 1030.

dispersion of 13.5 ± 2.0 km s^{-1} is significantly lower than the rotational amplitude, indicating a stabilised, dynamically cold disk.

2. Interpretation, discussion, and summary

We found a rotating gas cloud with a mass of $3.6 \cdot 10^{9}$ M$_{\odot}$ (accounting also for the helium mass), involved in an interaction process with the spiral galaxy NGC 1030. No optical counterpart is seen in the DSS. Is this assembly a dark cloud which has failed to build stars? And if so, is Dark Matter needed to stabilise it? Currently, we are not able to answer either question. The successful kinematic modelling of the gas cloud and, with that, the measures of rotation amplitude and internal dispersion hint towards a rotationally stabilised disk with an inclination between 15°and 30°. The lower limit to the dynamical mass is given by the cloud's gas mass. An upper limit to the dynamical mass of about $1.3 \cdot 10^{10}$ M$_{\odot}$ inside a radius of 17.5 kpc would require quite some amount of Dark Matter or undetected luminous matter. But even assuming this upper limit, we cannot exclude a purely baryonic nature of the object, taking into account an estimated upper limit for an undetected luminosity of about $7.5 \cdot 10^{9}$ L$_{\odot}$ in the DSS (blue). Without further constraints from deep optical observations, we require a small amount of Dark Matter ($< 10\%$) to be consistent with our mass estimates. However, the large H I mass of the object, compared to the H I mass of the seemingly unperturbed NGC 1030 (9.5 ± 1.0 M$_{\odot}$) makes a purely tidal origin of the cloud questionable (cf. Bournaud and Duc 2006). Future investigations will shed more light on the nature of this remarkable object.

References

Bournaud, F. & Duc, P.-A. 2006, A&A 456, 481
Józsa, G., Kenn, F., Klein, U., Oosterloo, T. 2007, A&A 468, 731
Struve, C., Józsa, G., Kenn, F., Klein, U., Pizella, A. & Salucci, P. 2007, NewAR 51, 120