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Research Note

A bright emission region in the new nearby dwarf irregular galaxy Cassiopeia 1

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Abstract. In recent years several dwarf galaxies belonging to the highly obscured Maffei–IC 342 group have been discovered. Due to its shape, colour and the presence of a few possible H II regions, one of these objects (ℓ = 129°.6, b = +7°.1) was suspected to be a dwarf irregular galaxy, named Cas 1. We have obtained optical spectra of the brightest H II candidate in Cas 1. By using the H_α/H_β emission line ratio we could, for the first time, determine a rather reliable foreground extinction of A_V = 2.5 mag and thus cannot support Tikhonov's (1996) view that Cas 1 is a member of the Local Group. For [O III](5007 Å)/H_β we obtained a ratio of 2.6, much higher than typical ratios for (galactic) H II regions. The nature of the emitting nebula is unclear: a supernova remnant seems to be implausible (there is an IRAS counterpart), but we might deal with an H II region, possibly excited by a WR star.

Key words: galaxies: individual Cas 1 – galaxies: irregular – galaxies: ISM – galaxies: dwarf

1. Introduction

In the last decade many thousands of galaxies could be optically identified in the plane of the Milky Way. Among them, a handful has turned out to be nearby systems, within a distance of a few Mpc, like Dwingeloo 1 = Cas 2 (Kraan-Korteweg et al. 1994, Huchtmeier et al. 1995), two likely late-type galaxies found by McCall & Buta (1995) and several other objects, most of them probably belonging to the Maffei - IC 342 group of galaxies, at a distance of about 3 Mpc.

The object under discussion in this article, suspected first to be a nearby ($\lesssim$ 5 Mpc) strongly reddened dwarf irregular galaxy by Weinberger (1995), was resolved into stars by Lercher et al. (1996). The first sound proof for its nature and proximity was, however, given by Huchtmeier et al. (1995) who observed it in H I and named it Cas 1. One of the arguments of Weinberger (1995) for proposing this object as a dwarf irregular galaxy was the presence of a few H II region candidates; only one of these regions has a brightness high enough so that a useful optical spectrum with a two meter telescope appeared to be feasible. With the observations of this candidate we intended to perform the first optical study of a non-stellar source in this galaxy.

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2. Observations and reductions

All observations were carried out at the observatory of the University of Padova (Cima Ekar, Asiago, Italy).

For the spectroscopic observations in January 1997 we used the Boller & Chivens spectrograph attached to the 1.83 m telescope with a grating of 300 lines/mm. The dispersion was 169 Å/mm corresponding to 3.9 Å/pixel. The spectral resolution is $\approx$10 Å and the usable spectral range 4750 – 6850 Å. The detector used was a TH 7882 CCD chip with 580 $\times$ 388 pixels (23 μm), UV-coated. As slit width we chose 250μm and placed the slit in east-west direction. Altogether three exposures (two on January 11, one on January 13) of 3 600 s each were obtained, reduced and added with the software package IRAF. Absolute calibration was done using Hiltner 600 as standard star and for the wavelength calibration we used a FeAr laboratory lamp.

A 900 s direct image in H_α (bandwidth 45 Å) was taken in February 1995 by use of a TK512M CCD chip (512 $\times$ 512, 27 μm). Data reduction was carried out with MIDAS.

3. Results and discussion

3.1. Direct image

In Fig. 1, we show a reproduction of our CCD H_α image of Cas 1; the emission nebula candidate under discussion is marked by arrows. This candidate is about 0′.5 to the west with regard to the center of the galaxy and its position (2000) is α = 02^{h}06^{m}01^s.11, δ = +69°00′00″.9 with an accuracy of $\pm$3″. It coincides with the weak IRAS point source 02019+6845 (only

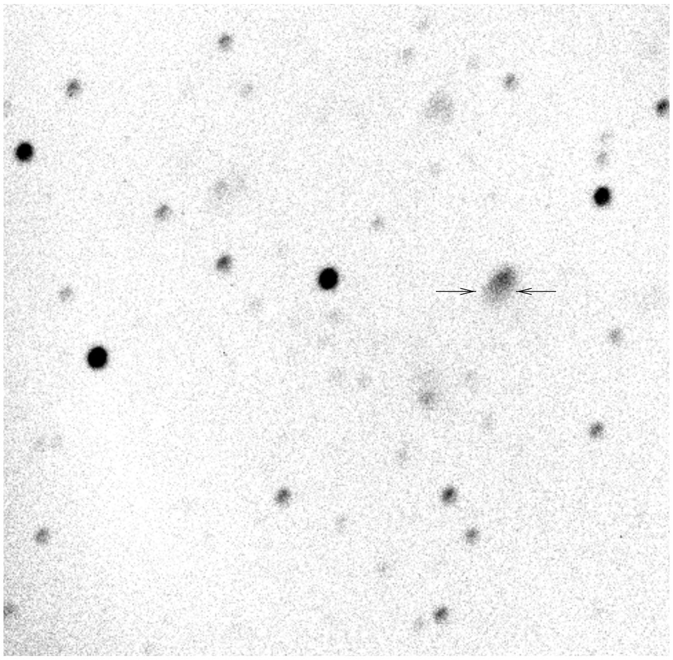

Fig. 1. A reproduction (about 2′.2 × 2′.2) of a 900 sec H_α CCD frame of Cas 1. The galaxy is not visible here, but the H II region candidate can be seen and is marked by arrows. North is at top, East to the left.

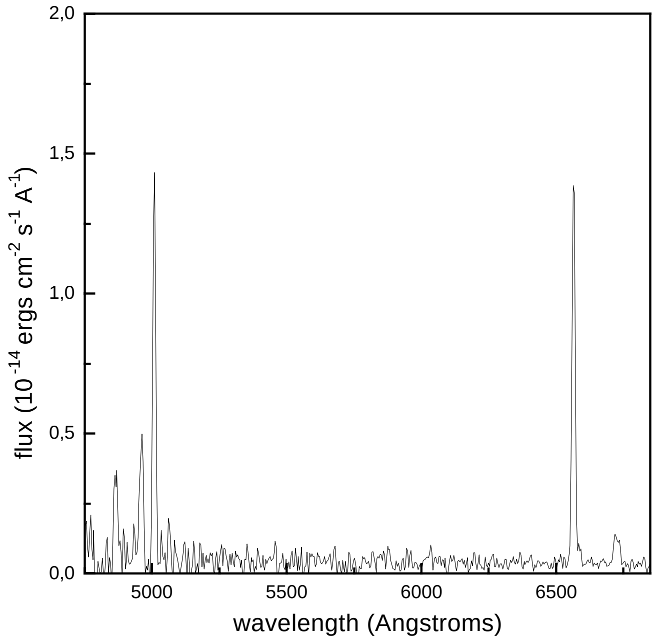

Fig. 2. The optical spectrum (extinction-corrected) of the brightest emission nebula in Cas 1, representing a sum of three spectra with a total exposure time of 3 hours.

detected at 60μm with a flux of 1.49 Jy). There is no other IRAS source within the boundaries of Cas 1.

3.2. Optical spectrum

In order to improve the signal to noise ratio, we added the three spectra that were obtained from the emission nebula candidate, leading to a spectrum with an exposure time of three hours in total. The candidate indeed is an emission-line object, showing H_α, H_β, [OIII] 4959 and 5007 Å, [SII] 6717 and 6731 Å, and [NII] 6583 Å. By taking into account the extinction along the line-of-sight derived from the H_α/H_β ratio (A_V = 2.5 mag), the absolute line fluxes (in erg cm^{-2} s^{-1} Å^{-1}) were found to be 1.90 10^{-13}, 6.72 10^{-14}, 7.94 10^{-14}, 1.75 10^{-13}, 1.80 10^{-15}, and 1.45 10^{-15}, respectively; no value is given for the [NII] line due to its blend with H_α. The spectrum is displayed in Fig. 2.

3.3. The nature of the nebula

In all probability the emission nebula is not a projection of a galactic object onto Cas 1; one argument is that we deduce a velocity of $v_{\rm hel} = 93 \pm 90$ km s^{-1} from our spectra. This can be compared to $v_{\rm hel} = 35 \pm 2$ km s^{-1} determined in H I (Huchtmeier et al. 1995). A much stronger argument is the extinction along the line-of-sight of A_V = 2.5 mag; this means that a galactic source at these galactic coordinates ($\ell \approx 130^\circ, b \approx 7^\circ$) would hardly suffer from an interstellar extinction this high, except being quite distant. A third argument is the very low probability that a galactic emission nebula is projected onto a galaxy with a diameter of less than 2′. Thus, we can safely assume that our emission nebula indeed belongs to the dwarf irregular galaxy Cas 1.

As to the distance of the nebula, both the angular vicinity to the Maffei–IC 342 group of galaxies (≈ 3 Mpc) and the low radial velocity speak in favour of a membership of Cas 1 to this group, but Tikhonov (1996), from an analysis of the colour-magnitude diagram for stars of Cas 1 concluded that A_V = 4.0 mag and that the galaxy is a member of the Local Group. Quite recently, Karachentsev et al. (1997) estimated A_B = 5.5 mag based on CCD aperture photometry of Cas 1 and a proposed distance of 1.7 Mpc. Our method of determining the extinction is much more reliable as those of Tikhonov or Karachentsev et al.; we will thus retain our distance estimate of 3 Mpc. At this distance, the nebula which shows signs of being double or bipolar and has an angular size of 4″ × 7″, would have a linear size of 58 × 102 pc.

A discussion of the nature of the nebula must include the [O III] (5007 Å)/H_β ratio of 2.6 and the faintness of the [SII] lines. Judging from the level of excitation alone, the nebula could be a planetary nebula, a supernova remnant, a (highly excited) H II region, or, in principle, a nebula of low metallicity surrounding a supersoft X-ray source.

Although the morphology would fit, a planetary nebula can be ruled out with certainty since these objects are of small linear (and consequently angular) size.

Among supernova remnants (SNRs) we encounter various shapes and excitation conditions. However, SNRs of several dozens of pc in diameter do not show such high optical surface brightnesses like the nebula, and the coincidence with an IRAS source of 1.49 Jy at 60 μm, probably stemming from dust emission is unexpected for SNRs; in addition, the absence of [O I] (6300 Å) emission and the faintness of the sulphur lines might be taken as a further counter-argument.

If the emission nebula is an H II region, then - in the light of its morphology - it could in fact consist of two (separated, superposed, or connected?) nebulae. They might represent more or less ideal Stromgren spheres with a radius of about 30 pc each. Under galactic conditions, assuming negligible dust content and a gas density of 1 cm^{-3}, one single O9V star per nebula would then be sufficient to maintain such a sphere.

According to Wilcots (1994) who has investigated classical H II regions in the Magellanic Clouds, there is a tendency for these regions to have higher electron temperatures than their galactic counterparts. However, it seems that the ionizing sources of classical H II regions in the Clouds are not systematically hotter or more luminous than the ionizing sources of classical H II regions in the Galaxy, but that the reason for the higher temperature is the low metallicity.

Wilcots (1994) defined the excitation as η = [O III] (4959 + 5007)/H_β. For the H II regions in the Large Magellanic Cloud he found an average value of η = 2.3 and including the (few) regions of the Small Magellanic Cloud, the average was 2.8. In our case, we get η = 3.8, which is much higher than average, but not exceptional; a Wolf-Rayet star as exciting source could probably fit.

Shortly, both the morphology, linear size, electron density, and the excitation (although being very high) are in accordance with our nebula being a (perhaps double) H II region. However, we are puzzled over the fact that this region is bright in the I_c image of Lercher et al. (1996) too: the I_c band extends from about 7250 - 8750 Å and we are not aware of any emission line(s) that should be intense enough to be responsible for the I-brightness. Unfortunately, this image was not calibrated and we are unable to quantify the data. Perhaps we deal with a broad continuum emission band superposed on a significant amount of scattered light similar to the one in the Bubble Nebula, where this band peaks around 7800 Å (Sivan & Perrin 1993).

It would be rewarding to observe this nebula in much more detail.

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