The Galaxy NGC 1365

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One of the most beautiful barred galaxies in the sky is found in the southern hemisphere, in the Fornax cluster at a declination of −36°. The galaxy – NGC 1365 – with its diameter of 11 arc minutes and its prominent spiral structure stands out well among the cluster galaxies. Situated 1.2 degrees from the cluster centre and with a radial velocity of + 1,650 km s^{-1} – very close to the average radial velocity of the cluster – it is very probably a member. Among its closest neighbours we find the peculiar radio galaxy Fornax A and NGC 1386, which is the nearest type 2 Seyfert galaxy known.

NGC 1365 was one of the first galaxies to be photographed with the ESO 3.6 m telescope by Svend Laustsen and Hans Emil Schuster during the commissioning phase, and it was observed by one of us (P.O.L.) during the first visiting observers run with the 3.6 m telescope in October 1977. Two plates from this observing run are seen as Figs. 1 and 2.

As can be seen in the two-hour exposure the bar and spiral arms are prominent – the latter delineated by bright H II regions. There are strong absorption lanes along the bar and the spiral arms, as well as an intricate pattern of dust lanes and bright branches and twigs. In particular, there is a set of dark whisps across the bar extending from (or rather running into) the prominent absorptions on the front side of the bar.

If we estimate the distance of the Fornax cluster to 20 Mpc, the diameter of NGC 1365 as seen in Fig. 1 is 65 kpc and the total absolute magnitude −21.6, i.e. it is a true supergiant galaxy. Spectral data show that the NE side is approaching and the SW side receding. If the spiral arms are trailing, then the NW side is the near one. With its inclination of 55° to the plane of the sky and a position angle of the bar 35° from that of the minor axis the orientation of the galaxy is very well suited for dynamical studies.

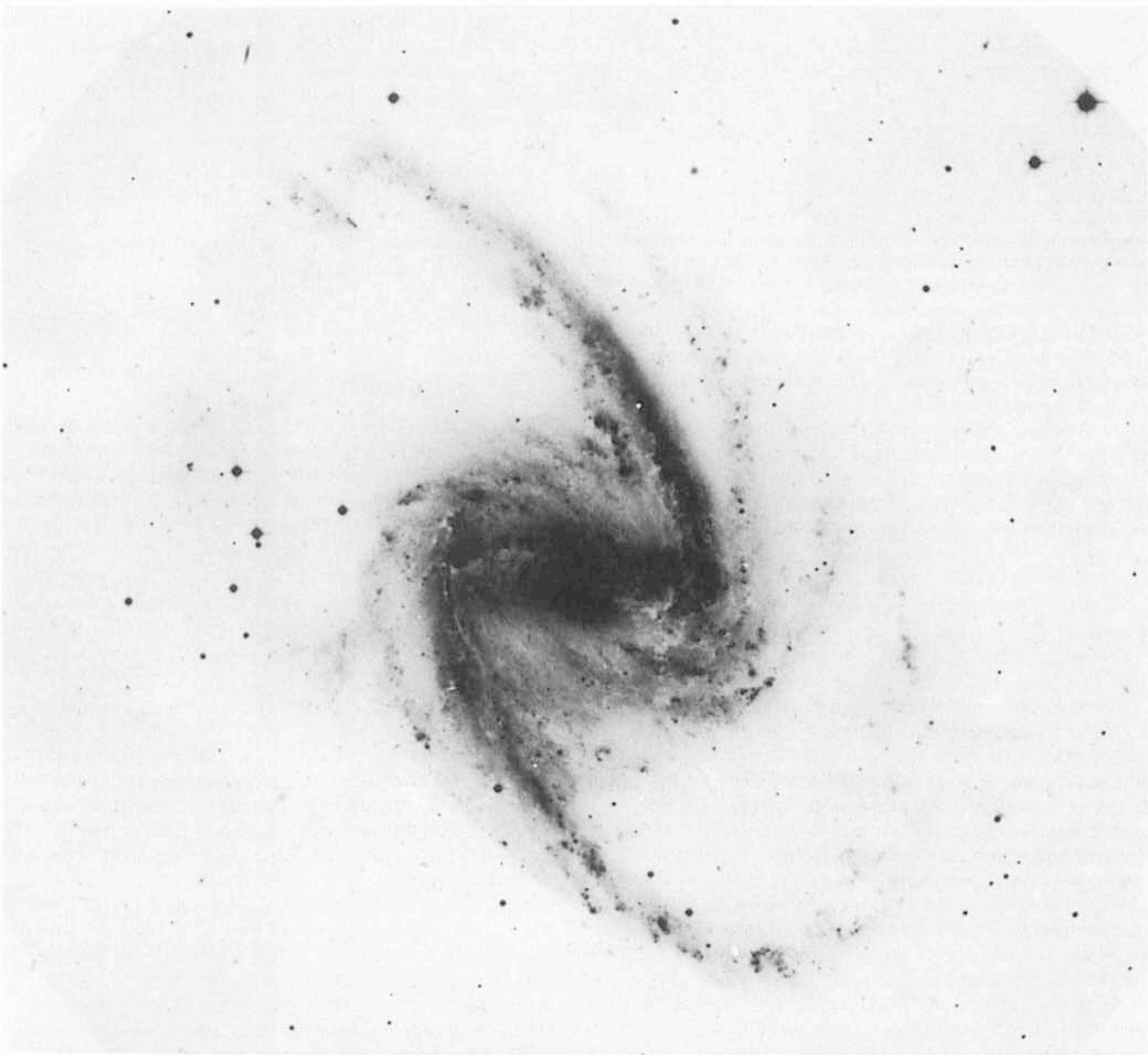

Fig. 1: *ESO 3.6 m photograph of NGC 1365 obtained in a two-hour exposure on a III a–J plate with GG 385 filter.*

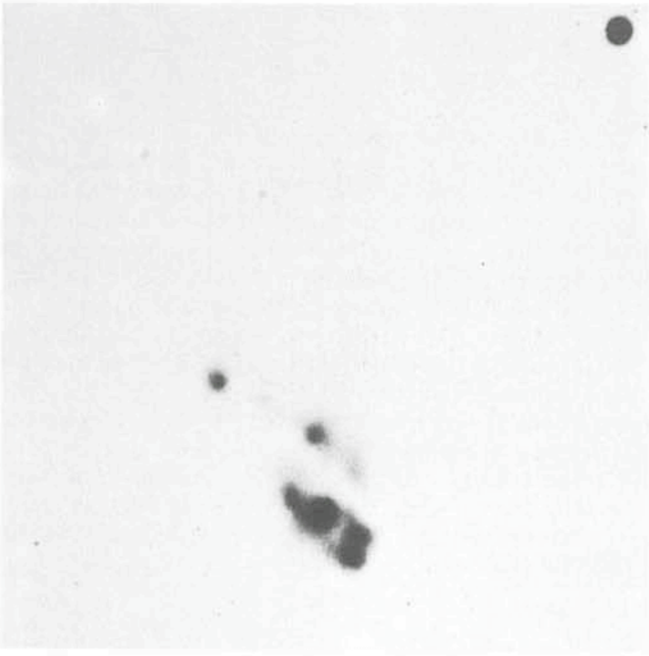

Fig. 2: *ESO 3.6 m photograph of the nucleus of NGC 1365 obtained in a one-hour exposure on a 127–04 plate with narrow-band Hα filter.*

Since the middle of the 1970s the dynamics of barred galaxies has been intensely studied from a theoretical point of view as it has been realized that the stability of bars made up of stars and their perturbing influence on gas flow are fundamental keys to the understanding of spiral structure in galaxies. Numerical n-body calculations have shown that stellar systems of sufficient angular momentum are highly apt to form bars that are very stable. Numerical gas flow calculations have shown how a bar potential can create large-scale shocks along the bar as well as a spiral structure in the region outside the bar. On the other hand, observational confirmation of the predicted kinematics has been rather scarce. This is due partly to the slow process by which an extragalactic object can be covered with slit spectra, the low angular resolution of radio telescopes and, in particular, the lack of neutral or ionized atomic hydrogen in the bar region. NGC 1365 was chosen for studies with the 3.6 m telescope, because of its ideal orientation for kinematic studies, its clean structure and richness of interstellar matter, and, not least, because early observations by the Burbidges at Mc Donald had shown that the strong emission line spectrum from the nuclear region might imply violent noncircular motions.

The nuclear region of NGC 1365 is penetrated by a strong dust lane and contains a number of so-called "hot spots" and H II regions, almost all situated along the nearer arm of a small nuclear spiral as seen in Fig. 2. The nucleus itself is much redder than the surrounding hot spots and shows a strong infrared excess. At least part of this redness is caused by the absorbing dust lane just touching the nucleus.

Already our first spectra of the nucleus showed that the Hα line in emission was suspiciously broad. In our discussions at ESO this aroused the immediate interest of Philippe Véron. IDS spectra secured by him and later by Danielle Alloin and P.O.L. showed that the Hα line contained a broad component with a full width at half maximum intensity of 1,700 km s^{-1}, while the forbidden lines remained unresolved at 4 Å resolution. This revealed the Seyfert 1 character of the nucleus (*Astron. Astrophys.* **87,** 245, 1980; **101,** 377, 1981).

This nucleus is surrounded by a rapidly spinning narrow line disk with a radius of about 7" corresponding to 700 pc as is clearly displayed by the inclined emission lines. The position angels of the maxima and minima of the velocity gradients coincide closely with the position angle of the line of nodes as given from faint outer isophotes of the two-hour exposure in Fig. 1. There is of course no need for the plane of the nuclear disk to have the same orientation as that of the outer edge, but we can state that the velocity gradients of the nuclear disk as given by the Hα and [N II] lines give no reason to assume anything but circular rotation of this disk with an angular velocity of 280 km $s^{-1}kpc^{-1}$, or about ten times the angular velocity of the sun around the galactic centre. This gives a mass for the nucleus of the order of 10^9 solar masses.

The velocity field outside the nuclear region has been measured from our slit spectra with the Boller & Chivens spectrograph on the ESO 3.6 m telescope equipped with image tube or with the Image-Photon-Counting System of Boksenberg, from image-tube slit spectra obtained by Charles Peterson with the 4 m telescope at Cerro Tololo, from TAURUS observations on the ESO 3.6 m and from 21 cm observations by J.M. van der Hulst with the VLA. All these velocity measurements are now in some stage of reduction. All of these observations have strong signals in the spiral arms, but all suffer from the weakness of the emission lines in the bar. Only the IPCS spectra contain absorption lines to give information about the stellar motions. A preliminary rotation curve based on Charles Peterson's and our spectra is shown in Fig. 3. The pattern of systematic deviations from this curve are studied and will be combined with photometry and numerical calculations carried out in Collaboration with Preben Grosbøl and E. Athanassoula.

As is well known from the observations of M51 by Mathewson, van der Kruit and Brouw, large-scale galactic shocks may reveal themselves by enhanced non-thermal continuum radio emission. Inspired by these beautiful results, we set out to observe NGC 1365 with the Very Large Array (VLA) in New Mexico. The resolution with this radio synthesis interferometer would be of the order of arcseconds and our hope was to detect enhanced continuum radio emission from the strong dust lanes along the bar and spiral arms, where the existence of galactic shocks could be expected.

The observations with the VLA were carried out at 6 and 20 cm wavelength in November 1979 (*Astron. Astrophys.* **110,** 336, 1982). At that time the VLA was not fully finished—in particular the northern arm was very short, which resulted in a rather elongated beam shape for this southern object. As a matter of fact NGC 1365 lies rather close to the southern limit

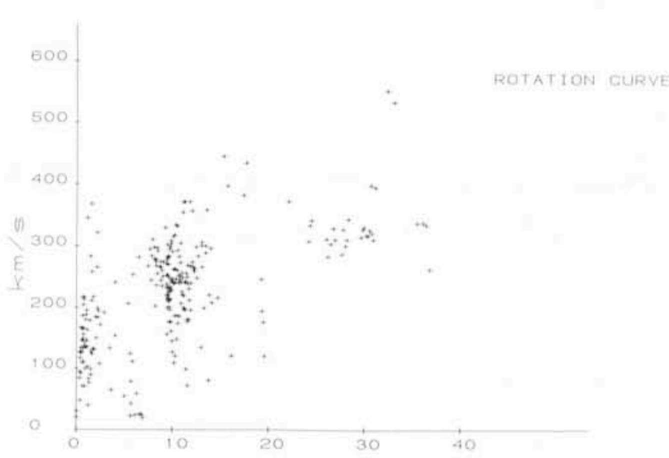

Fig. 3: *Preliminary rotation curve of NGC 1365 derived from ESO 3.6 m Boller & Chivens spectra and spectra obtained by Charles Peterson with the 4 m telescope on Cerro Tololo.*

for observations with the VLA and the integration time was maximized at 6 hours for each wavelength region.

As it turned out, however, there was no trace of a radio emission from the bar and the spiral arms, but the nuclear region again proved to be rather interesting. The highest resolution was reached at 6 cm, and Fig. 4 shows our 6 cm radio map superposed on the optical Hα picture of the nuclear region. As can be seen, the radio structure is resolved into a number of components, some of which are still unresolved at arcsecond resolution. These discreet sources have intensities of 1–8 mJy. The total flux from the nuclear region is 190 and 450 mJy at 6 and 20 cm respectively. This gives an average spectral index of –0.72 which indicates non-thermal radiation and is a normal value for Seyfert galaxies. Observations with the Einstein satellite by T. Maccacaro, G.C. Perola and M. Elvis show that the soft X-ray luminosity is $1.6 \cdot 10^{41}$ erg s^{-1} (0.2–3.5 keV).

The intriguing question is now of course the nature of the radio sources and the optical hot spots, their interrelation and the origin of their energy output. As can be seen from Fig. 4, there is no clearcut correspondence between radio sources and optical hot spots, and the Seyfert nucleus itself is no strong source of radio radiation. Could activity in a Seyfert nuclear engine generate these compact sources far apart? But, at least as far as the Hα and [N II] emission is concerned, there seems to be no clear evidence for violent outflow or drastically noncircular motion. Or could the radio sources be supernova remnants? The radio luminosity of each of the compact sources is of the order of 100 times Cas A and their energy content can be modeled as if coming from 100 supernova remnants that would have to be confined to a volume of less than 50 × 200 pc. Steady-state calculations then show that about one supernova per year should occur in the nuclear region. So far, one supernova has been reported in 1957 to appear in one of the spiral arms. In the nuclear region a supernova would be more difficult to detect. As an alternative, one could imagine each compact source to be a radio supernova of the type detected in M 100, that reached a radio luminosity at 6 cm of 180 times Cas A. Their life time, however, is only of the order of years and would cause a noticeable change of the radio emission over a short time. Our repeated 6 cm VLA observations in September 1982, although with lower resolution, give no evidence for such a variation.

To support the supernova rate mentioned each of the radio sources would have to be associated with about 10^5 O and B stars. This number of hot stars may not be inconsistent with the Hβ flux from the hot spots that may be places for recent bursts of star formation. However, the luminosity function could not be a standard one, as the mass in low luminosity stars required would spoil the regular velocity field of the nuclear disk. Also the lack of clear association between concentrations of supernova remnants and hot stars needs an explanation.

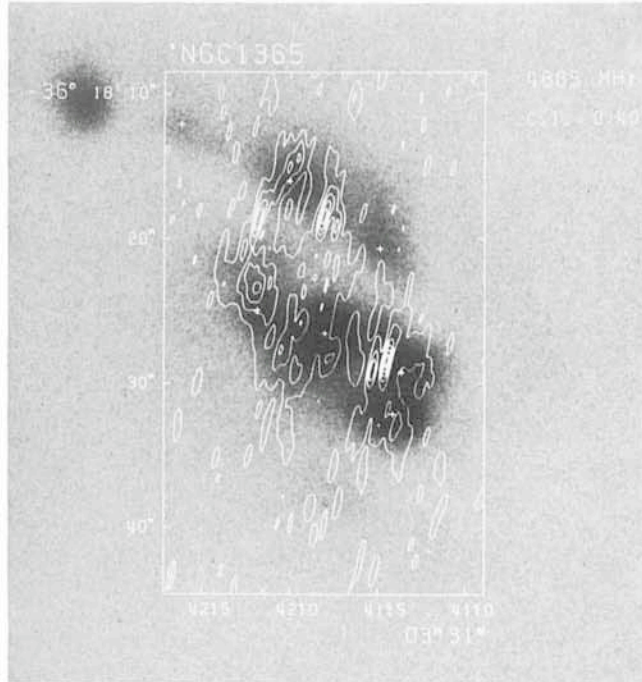

Fig. 4: *The VLA 6 cm map superposed on the Hα picture of Fig. 2.*

In the midst of this puzzling situation a very important observation has appeared to add to the confusion, but not improbably to ultimately give the clue to what is going on. M.M. Phillips, A.J. Turtle, M.G. Edmunds and B.E.J. Pagel show in a recent preprint that extended regions of high-excitation gas around the nucleus reveal a velocity field considerably more complicated than the rotating disk inferred above from the Hα and [N II] lines. As a matter of fact, the [O III] line at λ 5007 Å over this region is split up into several components with different velocities and velocity gradients. For some positions of their slit the [O III] line is actually inclined in opposite sense to that of the hydrogen lines. It seems that our IPCS observations show a peculiar behaviour also for the Ne III λ 3869 line. This may imply outflow of high-excitation matter from the nucleus in directions out of the plane of the disk. It could very possibly indicate a connection between the activity in the nucleus and the radio sources and hot spots in its surrounding.

Active Chromosphere in the Carbon Star TW Horologium

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Introduction

Herzberg (1948) was the first to suggest the existence of a corona-like nebulosity surrounding cool stars from strong Fe II emission lines he observed in the spectral region λλ 3150–3300 in the two supergiants α Herculis (M5 II) and α Scorpii (M1 Ib). Fifteen years later, Bidelman and Pyper (1963) suggested that these Fe II emission lines would be present in practically all giants of sufficiently late type. Then, Boesgaard and Boesgaard (1976) showed that this emission is nearly universal in M-type stars and thus appears to be a natural occurrence in stars with low temperature. At present, these emission lines are recognized as an undisputed chromospheric indicator. Chromospheres have been detected in late-type (F-M) stars, in particular for M giants through their bright UV emission lines (the Fe II lines besides the Mg II h and k lines), and most notably Linsky (1980) has pointed out that a wider spectral range of stars than was thought previously may possess chromospheres.