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POWERING THE SUPERWIND IN NGC 253

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NGC 253 AS A NUCLEAR STARBURST GALAXY

NGC 253 is a prototypical moderate nuclear starburst galaxy. It is a barred SBc spiral galaxy at a distance of approximately 3 Mpc and can be studied on scales down to 15 pc in the optical and near IR.

It is a bright IRAS source with a flux of 1000 Jy at 60 μm (Rice et al. 1988) and a FIR luminosity of 3×10^{10} $L_\odot$ (Telesco and Harper 1979, Rice et al. 1988). It has a strong Brγ emission line, a signature of ongoing massive star formation (Rieke, Lebofsky, and Walker 1988), and deep CO absorption bands, indicative of the dominance of red supergiants in the near IR. It contains a population of compact radio sources, similar to those seen in M82 (Turner and Ho 1985, Antonucci and Ulvestad 1988, Ulvestad and Antonucci 1991). Optical spectra show that the nucleus is heavily reddened, with a Balmer decrement of approximately 30.

NGC 253 possesses a 'superwind,' seen both in X-ray emission (Fabbiano 1988) and in optical line emission (McCarthy, Heckman, and van Breugel 1987). Nuclear ejection was first suggested by Demoulin and Burbidge (1970) to explain the kinematics of the nuclear region.

NEAR IR OBSERVATIONS

We have obtained J, H, and K images of the entire galaxy at 1.3 arcsec/pixel (18 pc/pixel) using SQIID on the KPNO 1.3m. We have constructed a mosaic of 180 s exposures which traces the galaxy over much of its optical extent. The data were shifted, rotated, magnified, and calibrated following normal practice.

The PtSi detectors in SQIID have a low quantum efficiency (of order 5%) and excellent stability, linearity, and cosmetic quality. To check the quality of the calibration, we compared our images to single-channel measurements (de Vaucouleurs and Longo 1988) in apertures with diameters ranging from 10 arcsec to 100 arcsec and found excellent agreement to around 10%.

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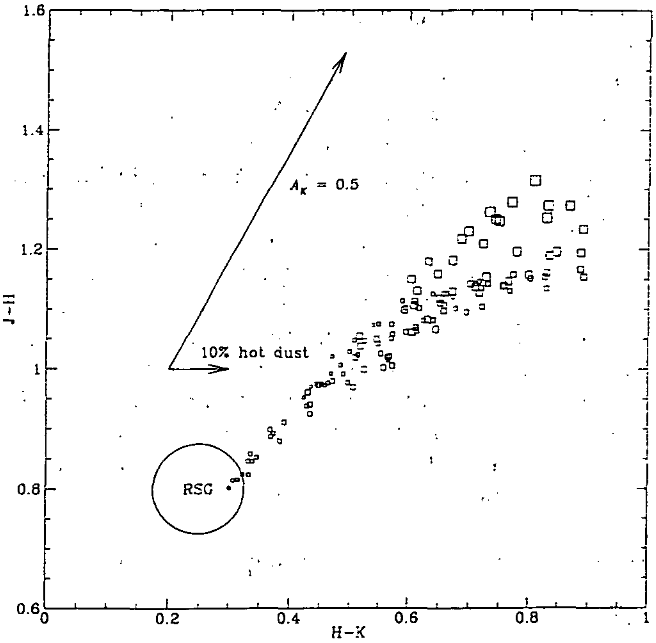
Rieke, Lebofsky, and Walker (1988) published images of the nucleus with a pixel size of 1.2 arcsec. They report that the nucleus was significantly bluer than the circumnuclear region (of order 0.5 mag in $H-K$); we find no trace of this in our data, nor in data taken in October 1991 with SQIID in its current configuration, nor in the data of Forbes et al. (1992). It is possible that seeing or focus effects could blur our colors or that Rieke, Lebofsky, and Walker caught a transitory event, such as a supernova.

We have constructed the $J-H$ and $H-K$ colors for each pixel in our image. We show the color-color diagram for all of the pixels in a region 14 x 14 arcsec centered on the nucleus. The area of the symbol is proportional the the K flux in that pixel. The points clearly form a locus leading from $J-H \approx 0.8$ and $H-K \approx 0.25$ up to much redder colors in the nucleus. We have indicated the standard Milky Way extinction law by an arrow which corresponds to $A_K \approx 0.5$ or $A_V \approx 4.5$. In agreement with Scoville et al. (1985), we interpret the near IR color-color diagram of the nucleus to be due to a dust-shrouded population of red supergiants plus a contribution at K from hot (1000 K) dust.



ESTIMATING THE SUPERNOVA RATE

We have obtained the 'dereddened' H magnitude within a radius of 10 arcsec (180 pc) of the nucleus by correcting each pixel for reddening, assuming an intrinsic $J-H$ color of 0.8 for red supergiants. The 'dereddened' H magnitude within 10 arcsec is 7.28, compared the the observed H magnitude of 7.78. (Corrections for extinction are complex, but we consider our correction to be conservative.)

The luminosity of the red supergiants in the nucleus corresponds to about 2% of the bolometric luminosity of NGC 253. The luminosity of massive stars remains roughly constant during their lifetime and they spend a few percent of their life as red supergiants. Assuming a typical red supergiant absolute magnitude at H of -11.0 and a distance of 3 Mpc, the H magnitude of the nucleus corresponds to 4400 red supergiants within 180 pc of the nucleus.

A typical lifetime of a massive star in the red supergiant phase is approximately 10^5 yr, and if we assume continuity over this lifetime we derive a supernova rate of 0.04 yr^{-1} in a 180 pc radius aperture. This is somewhat lower than the rate of 0.1 yr^{-1} to 0.25 yr^{-1} in a 300 pc radius aperture derived from VLA observations of compact sources by Antonucci and Ulvestad (1988). Although our apertures differ in size, our results are directly comparable as most of the compact sources are in the central 10 arcsec. Possible systematic differences between our results may be due to confusion with H II regions and the possibility that the evolution of supernovae in dense environments is not straightforward.

POWERING THE SUPERWIND

From Einstein X-ray observations, Fabbiano (1988) estimates that the temperature and mass of the superwind are of order 10^7 K and about 2×10^7 $M_\odot$. The extent of the wind is at least 4.5 kpc. The wind is highly over-pressurized and is likely to be flowing out at close to the sound speed. This is confirmed by the presence of 300 $km\,s^{-1}$ bulk velocities at the base of the wind seen in long-slit echelle spectra obtained with the CTIO 4m. With these properties, the superwind is being supplied with hot gas on a timescale comparable to the sound crossing time of 10^7 yr. Mass is being supplied to the superwind at a rate of 1.5 $M_\odot\,yr^{-1}$. Energy is flowing into the wind at a rate of about 2×10^{41} $erg\,s^{-1}$ or 6×10^7 $L_\odot$. This corresponds to about 15% of the energy released by supernovae.

This figure should not be over-interpreted. The extinction correction used to derive the supernova rate ignores complications from nebular lines and patchy extinction which will leads us to believe that the true supernova rate wil be somewhat higher than our estimate. Also, the physical properties of the superwind, especially its temperature, are uncertain.

Nevertheless, we can draw two conclusions. It seems inevitable that energy is being efficiently transferred from supernovae in the nucleus into the base of the superwind. The high supernova rate in the nuclear region must lead to an ISM with a global structure vastly different to the ISM in quiescent disks.

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REFERENCES

Antonucci, R.J., and Ulvestad, J.S. 1988, ApJ 330, L97.
Demoulin, M.-H., and Burbidge, E.M. 1970, ApJ 159, 799.
Fabbiano, G. 1988, ApJ 330, 672.
Forbes et al. 1992., MNRAS 254, 509.
McCarthy, P.J., Heckman, T.M., and van Breugel, W. 1987, AJ 93, 264.
Scoville, N.Z., et al. 1985, ApJ 289, 129.
Rice, W., et al. 1988, ApJS 68, 91.
Rieke, G.H., Lebofsky, M.J., and Walker, C.E. 1988, ApJ 325, 679.
Telesco, C.M., and Harper, D.A. 1980, ApJ 235, 392.
Turner, J.L., Ho, P.T.P. 1985, ApJ 299, L77.
Ulvestad., J.S., and Antonucci, R.J. 1991, AJ 102, 875.
de Vaucouleurs, A., and Longo, G. 1988, Catalogue of Visual and IR Photometry of Galaxies (University of Texas: Austin).