A 'Halo' and a 'Blow-Out' in NGC 253

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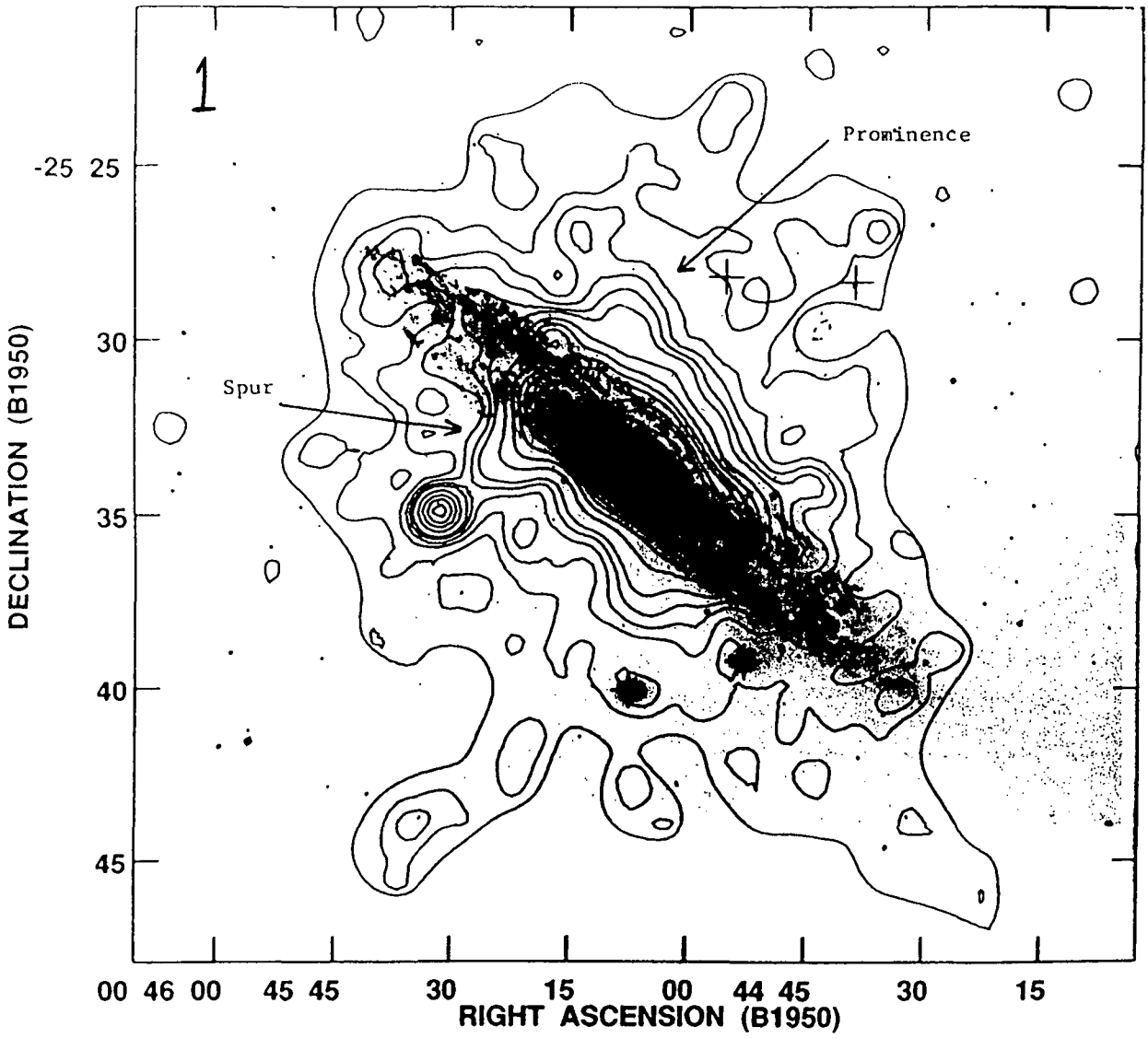
We present the discovery of a 'synchrotron halo' in NGC 253. NGC 253 is an inclined, dusty, barred Sc galaxy in the Sculptor Group. It is also one of the prototype nuclear starburst galaxies (Rieke *et al.* 1980, *Ap.J.*238, 24). VLA observations at 327 MHz and 1.4 GHz (Fig. 1) have revealed a synchrotron emitting 'halo' extending 9 kpc above and below the plane of NGC 253 (assuming a distance of 4 Mpc). The spectral index for the radio emission steepens from -0.7 in the disk to -1.0 in the halo. The fractional polarization at 1.4 GHz increases from $\leq$ 2% in the disk up to 20% in the halo, and the magnetic field vectors project parallel to the plane over most of the halo.

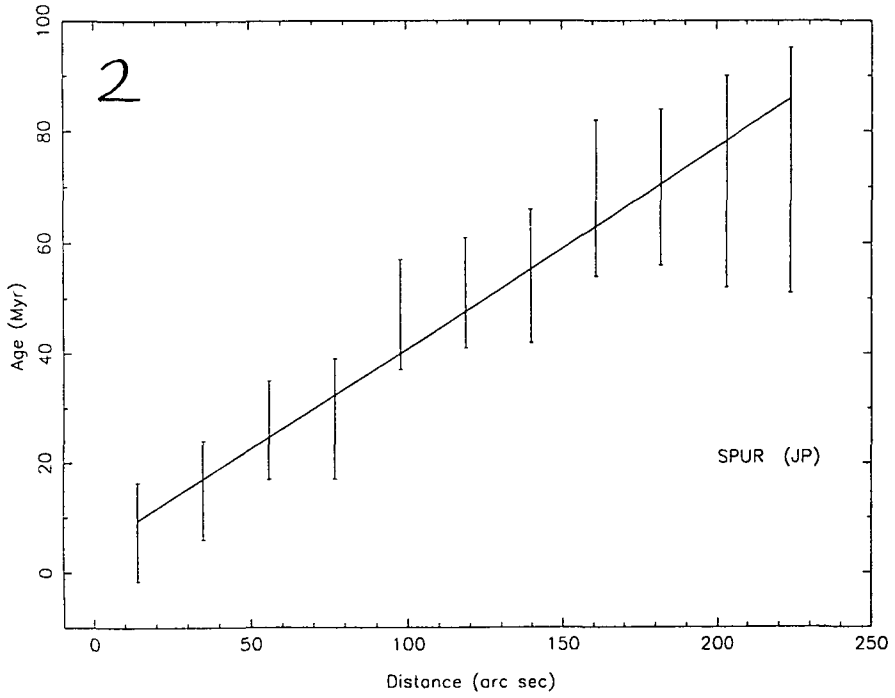
The radio continuum images reveal structures in the disk-halo interface which suggest interaction between the disk and halo. The most striking feature is a 'spur' originating at the northeast end of the bar and extending 5 kpc perpendicular to the disk. The spectral index gradient along the spur implies outflow along the feature, with a velocity $\geq$ 53 km sec^{-1} (Fig. 2). Shearing outflow along the spur is also suggested by the magnetic field vectors, which project parallel to its length. Spectral line observations of neutral and ionized hydrogen show excessive 'activity' at the northeast end of the bar (*i.e.* at the base of the spur), with departures from circular motions $\geq$ 30 km sec^{-1} (Puche *et al.* 1991, *A.J.*, 101, 456, Pence 1981, *Ap.J.* 247, 473). And radio continuum and Hα imaging show very active star formation in this region (Fig. 1 and Waller *et al.* 1988, *A.J.* 95, 1057).

Overall, observations suggest that there is outflow from the disk into the halo of NGC 253 along the spur, and that this outflow is driven by the active star formation at the north-east end of the bar. The total kinetic energy in the outflow is $\geq 2\text{x}10^{52} \times (\text{n}_e/10^{-3}\ \text{cm}^{-3})$ ergs, or roughly the energy output of 20 supernovae. The non-thermal radio continuum luminosity from the base of the spur is $\geq$ 30 times that of Cas A.

Figure 1: An optical image of NGC 253 reproduced from the Hubble atlas of galaxies (Sandage and Tammann 1987). The contours are of total intensity from NGC 253 at 0.33 GHz with a resolution of 60″. Contour levels are: -3, 3, 6, 9, 12, 15, 24, 36, 48, 60, 100, 400, 1600, and 3200 mJy/beam. The outer-most contour is for an image convolved to 120″ resolution. The level for this contour is 24 mJy/beam.

Figure 2: The maximum radiative lifetimes for the relativistic electrons as a function of distance from the plane of NGC 253 along the spur. Spectral ages were derived from data at 0.33 and 1.4 GHz, assuming energy losses through synchrotron and inverse Compton radiation (Van der Laan and Perola 1969, *A.A.*, 3, 468, Carilli *et al.* 1991, *Ap.J.*, 383, 554). The slope implies an outflow velocity of 53 $\pm$ 18 km sec^{-1}.


1
Prominence
Spur
-25 25
30
35
40
45
DECLINATION (B1950)
00 46 00
45 45
30
15
00
44 45
30
15
RIGHT ASCENSION (B1950)


2
Age (Myr)
0
20
40
60
80
100
0
50
100
150
200
250
Distance (arc sec)
SPUR (JP)