A NEW CLASS OF EXTRAORDINARY HI SHELL

Carl Heiles
Berkeley Astronomy Department
University of California

I consider an ordinary shell to be one which can be produced by ordinary means such as a supernova. Good examples are the HI shells associated with the prominent radio loops, discussed today by Prof. Weaver, and the large HI shell in Eridanus (Heiles, 1976). Figure 1 shows the shell which is associated with radio Loop I, made from a consolidation of data from Martha Cleary of Australia, Raul Colomb and Wolfgang Poppel of Argentina, and myself. It changes size with velocity in the manner expected for an expanding shell. The distance is only 100 pc or so. Similar shells should be easily resolvable in the galactic plane, even with a modest telescope, because differential galactic rotation eliminates the confusing effects of foreground and background gas.

I used the galactic plane survey of Weaver and Williams (1973) to make a large number of photographs equivalent to those of Figure 1. They reveal a wealth of structure, much of which is filamentary. In fact one has the impression that, if only the angular resolution were somewhat better, nearly all of the structure would be clearly resolved into filaments. Many filaments form circular arcs, some of which change size with velocity. The majority of these shells are of the ordinary class discussed above. But there is a small number, located mainly at large galactic radii, which are extraordinarily large in size and have swept up a huge amount of matter.

It is these shells, "supershells," which compose the new class of shell. An example is shown in Figure 2. This supershell has a galactic radius of 17 kpc, a distance of 13 kpc, a radius R of 800 pc, a kinetic energy of 4 x 10^{52} erg, and has swept up 2 x 10^{7} $M_{\odot}$ of gas while expanding through an average density of $n = 0.2$ cm^{-3}. If our supershells were produced by the sudden ejection of energy E_e, as would occur with a supernova, we have (Chevalier, 1974)

$$E_e = 5.3\ 10^{43}\ n_{cm^{-3}}^{1.12}\ R_{pc}^{3.12}\ V_{km/sec}^{1.4}\quad erg$$

W. B. Burton (ed.), The Large-Scale Characteristics of the Galaxy, 301–305.

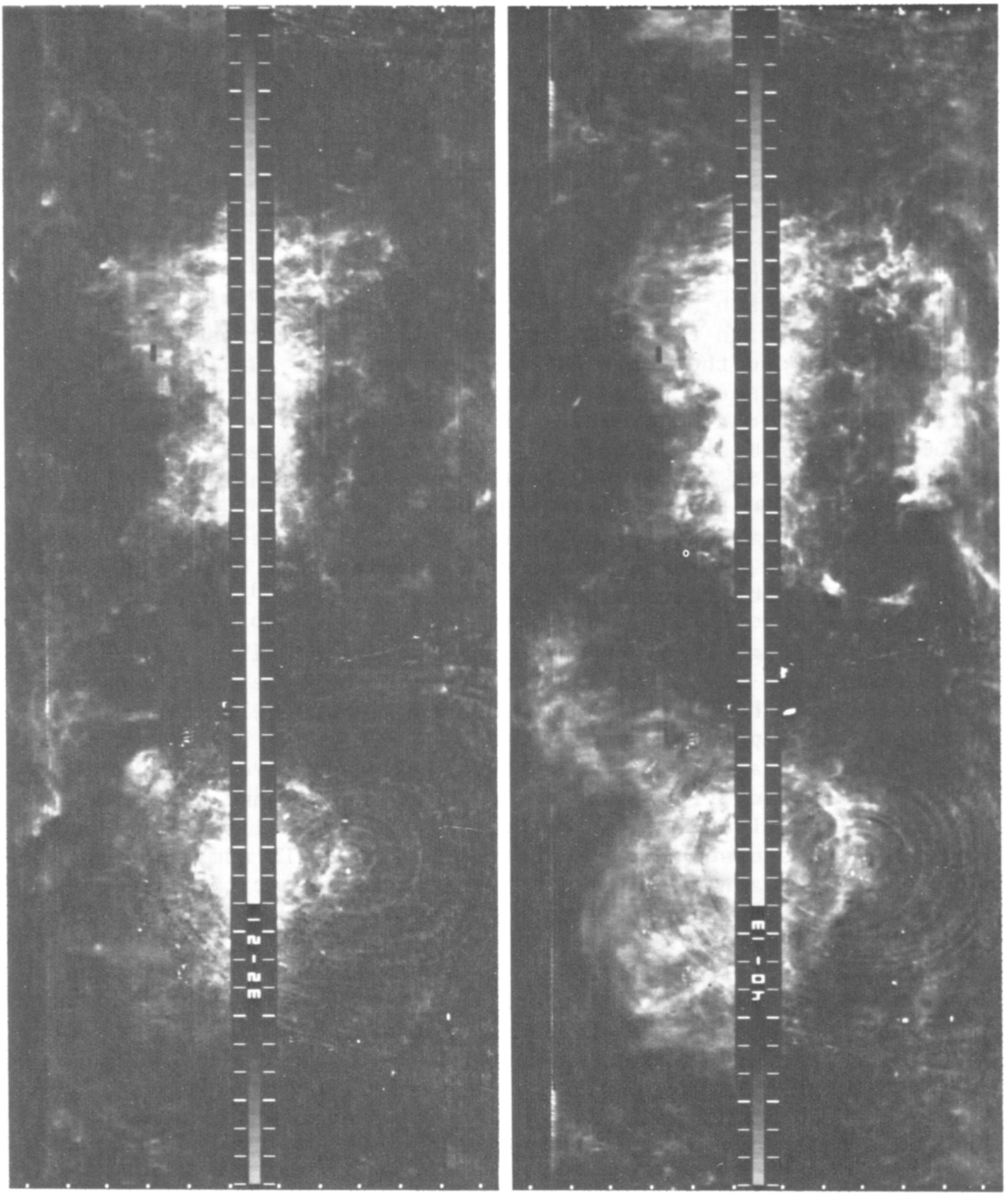

Fig. 1. Heiles

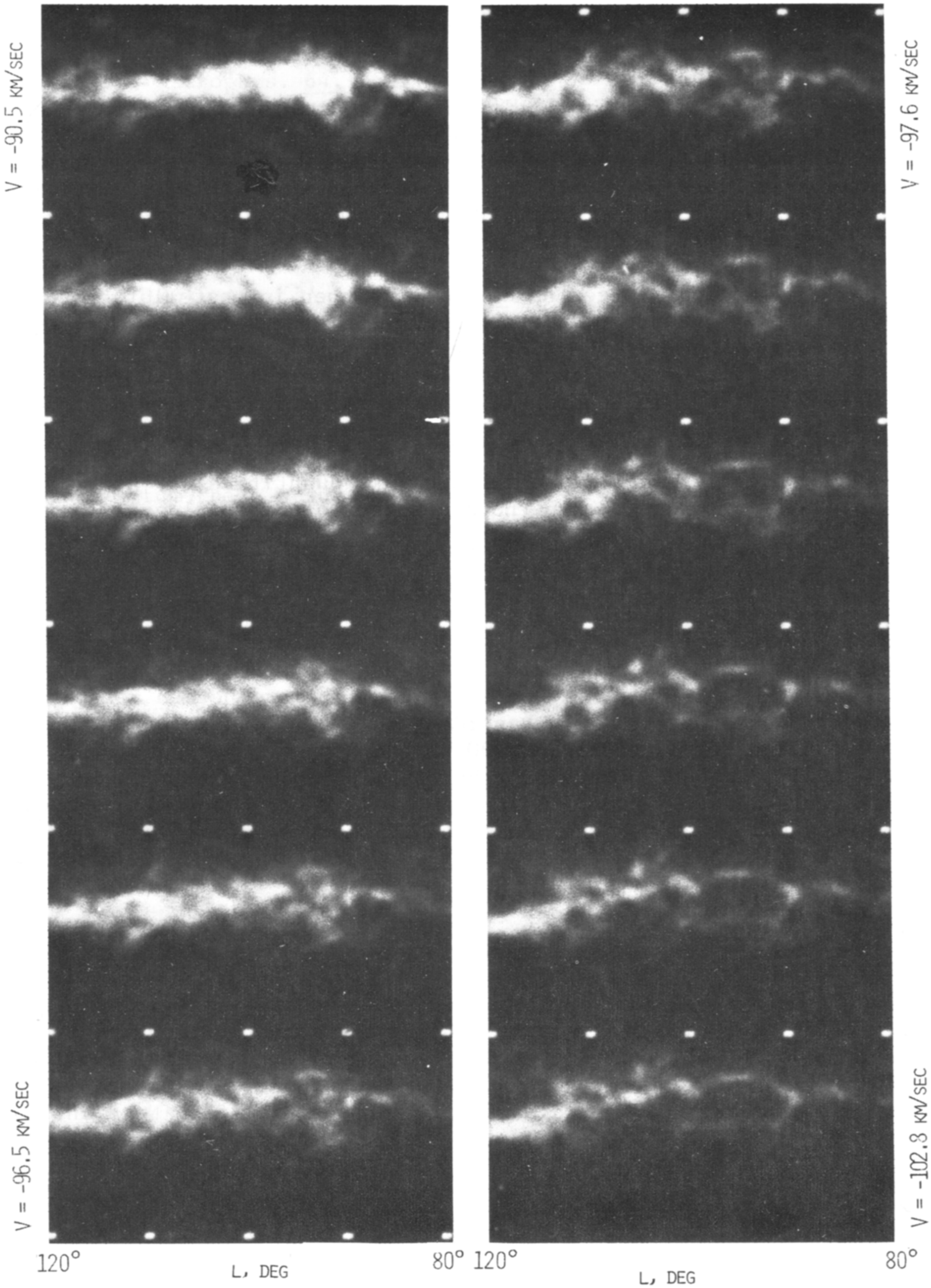
V = -90.5 KM/SEC
V = -96.5 KM/SEC
V = -97.6 KM/SEC
V = -102.3 KM/SEC
120°
L, DEG
80°
120°
L, DEG
80°

Fig. 2. Heiles

where V is the expansion velocity. For the shell in Figure 2, E_e = 3 x 10^{53} erg. We define supershells as having $E_e > 3 \times 10^{52}$ erg; the largest value for our sample is 6 x 10^{53} erg.

HI supershells have probably been observed in other galaxies. Hindman (1967) discovered three in the SMC. Several large holes in the HI distribution of M101 appear very prominently in the beautiful photograph of Allen et al (1978). Westerlund and Mathewson (1967) discovered a large ring of HI, bright blue stars, HII regions, and supernovae remnants in the LMC.

A shell will no longer be discernable when interstellar clouds, or other shells, penetrate the shell and fill the volume. For cloud velocities of 10 km/sec the time scale for this process is R/10 million years, about 10^8 years for the supershell in Figure 2. If the galaxy contains 10 supershells, their formation rate is of order 10^{-7} yr^{-1}.

The production agent must release vast quantities of energy into the interstellar medium. Supernova searches of external galaxies should be well-suited for discovering the production agent. They have been in progress for about 40 years; during this time interval about 250,000 galaxies would have had to be searched to accumulate a reasonable probability of seeing such an infrequent event. The Palomar Supernova Search encompasses only 3003 galaxies (Sargent et al, 1974), and searches by other groups increase this number by a modest amount. Thus it is extremely unlikely that the production agent has ever been seen. One possible candidate is type III supernovae, which have expansion velocities of 12,000 km/sec and have very optically thick shells, probably containing hundreds of solar masses (Zwicky, 1964). Unfortunately type III supernovae have not been well-studied, since only two have ever been observed (Sargent et al, 1974).

Figure 1. HI at -21 and -13 km s^{-1} in upper and lower photographs, respectively. For each photograph, ℓ=0° at the righthand edge, increasing through 360° to 60° at the left; latitude increases from -65° at the bottom to +65° at the top, with HI between -10° and +10° omitted; fiducial marks for both coordinates are given every 10°. Note the shell located at 270° < ℓ < 350°, b < -10°, and its change of size with velocity.

Figure 2. 12 photographs showing HI at 12 velocities separated by 1.1 km s^{-1}, ranging from -90.5 at the upper left to -102.8 at the bottom right. Each of the 12 pictures covers the range b = -10° to +10°. Note the supershell centered near ℓ=95°, b=+4°, and its change of size with velocity.

REFERENCES

Allen, R.J., van der Hulst, J.M., Goss, W.M., and Huchmeier, W.: 1978, Astron. Astrophys. 64, 359.
Chevalier, R.A.: 1974, Astrophys. J. 188, 501.
Heiles, C.: 1976, Astrophys. J. 208, L137.
Hindman, J.V.: 1967, Aust. J. Phys. 20, 147.
Sargent, W.L.W., Searle, L., and Kowal, C.T.: 1974, in Supernovae and Supernovae Remnants, ed. by C.B. Cosmovici, p. 33.
Weaver, H.F., and Williams, D.R.W.: 1973, Astron. Astrophys. Suppl. 8, 1.
Zwicky, F.: 1964, Ann. d' Astrophys. 27, 300.

DISCUSSION

Rubin: Some years ago at one of these symposia, Paul Wild pointed out large circular rings ($\sim$ few kpc) in galaxies. Can you form "spiral" structure" from these structures?

Heiles: One might think that large explosions would punch holes in the HI distribution, destroying spiral structure. On the other hand, they might enhance the spiral pattern by providing density contrasts whose shapes would be drawn out into a spiral pattern by differential rotation.