Triggered Star Formation in a Turbulent ISM
Proceedings IAU Symposium No. 237, 2006
B. G. Elmegreen & J. Palouš, eds.

doi:10.1017/S1743921307001329

The enigmatic loop III and the Local Galactic Structure

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Abstract. The aim of the present study, based on literature data, is to find signatures of the giant radio continuum structure Loop III on the nearby interstellar medium, and search for molecular cloud and star formation, possibly triggered by its expansion. The preliminary results are as follows: (1) The 3D map of the Local Bubble, published by Lallement *et al.* (2003) suggests that Loop III is probably more distant than the early models had indicated. (2) The molecular clouds at high galactic latitudes in the 2nd Galactic quadrant are probably associated with the neutral/molecular wall of Loop III. (3) Star formation in Lynds 1333 and Lynds 1082 (GF 9) might have been triggered by the expansion of Loop III. (4) The supernova(e), whose explosion produced Loop III, might have been located in the SU Cas association.

Keywords. ISM: bubbles, ISM: structure, (ISM:) supernova remnants, ISM: individual: Loop III

1. Introduction

The giant galactic radio continuum loops, thought to be nearby, old remnants of single or multiple supernovae, were first studied by Berkhuijsen (1971) and Spoelstra (1972). The basic properties of Loop III, revealed by these early radio continuum surveys, are as follows: *Galactic coordinates of the centre:* $l \approx 125^{\circ}, b \approx +15.6^{\circ}$; *Angular diameter:* 65°; *Estimated distance to the centre:* 150 pc; *Radius:* 85 pc; *Estimated age:* about 10^6 yrs.

Due to its huge angular diameter Loop III affects most of the lines of sight toward the positive latitude part of the second Galactic quadrant. Nevertheless, it has been clearly identified only as a radio continuum source due to the complexity of the interstellar medium over its surface. Loop III is expected to have profound effects on the structure of the local interstellar matter, and possibly on the recent star formation in our Galactic neighbourhood. Nevertheless, only a few data are available on such effects. In particular, Verschuur (1993) pointed out that Loop III has modified the distribution of the high velocity gas at its high-latitude boundaries, demonstrating that the high-velocity hydrogen clouds are local objects.

The aim of the present study, based on literature data, is to find further signatures of Loop III on the nearby interstellar medium, identify interstellar atomic and molecular clouds connected with it, and search for star formation possibly triggered by its expansion.

2. Signatures of Loop III in the distribution of local ISM

Loop III and the Local Bubble. The distance of 150 pc, obtained by Spoelstra (1972), is based on van der Laan's (1962) theory of expanding supernova remnants. In the light of more recent theories of supernova shells (e. g. Asvarov 2006) this value is rather uncertain. If the centre of Loop III were at 150 pc from the Sun, its near wall should be as close as about 65 pc to us, thus a region of its interaction with the Local

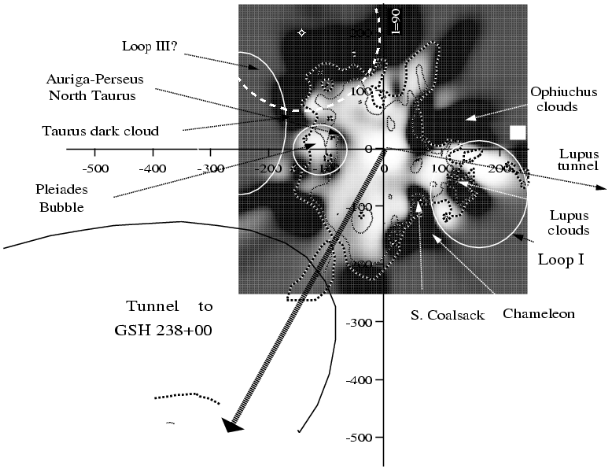

Figure 1. Cross-section of the Local Bubble in the Galactic plane and the outlines of its bordering structures, adopted from Lallement *et al.* (2003). Two hypothetical positions of Loop III are plotted: Solid line: position assumed by Lallement *et al.* (2003); dashed circle: with centre position and angular diameter derived by Spoelstra (1972), and assuming D = 250 pc.

Bubble (LB) could be identified at such a distance. A detailed 3D map of the LB was published by Lallement *et al.* (2003). Their Fig. 9, displaying the cross section of this map in the Galactic plane, demonstrates that the extension of LB is larger than 100 pc toward the 2nd quadrant, suggesting a larger distance for Loop III. The authors also plotted an assumed position of Loop III at larger distance and closer to the Galactic anticentre than indicated by the radio continuum observations. If we accept the position and angular diameter of Loop III, determined by these observations, and assume that the boundary of LB, found by Lallement *et al.* (2003), is defined by its intersection with Loop III in the second quadrant, we obtain 250 pc for the probable distance to the centre and about 140 pc for its radius. Figure 1 shows this hypothetical Loop III, overplotted on Lallement *et al.* 's (2003) Fig. 9 as a dashed circle.

HI and molecular clouds associated with Loop III. Nearby interstellar structures, projected within Loop III, are displayed in the left panel of Fig. 2. The distribution of the neutral hydrogen, $\int T_B dv \sin|b|$, obtained from the Leiden–Dwingeloo survey data base (Hartmann & Burton 1997), is displayed for the radial velocity interval of $-8\,\mathrm{km\,s^{-1}} < v_{\mathrm{LSR}} < 8\,\mathrm{km\,s^{-1}}$. Positions of the most prominent molecular clouds/complexes and the probable members of the SU Cas association (see below), are also indicated.

Large-scale CO maps by Dame, Hartmann & Thaddeus (2001), Heithausen & Thaddeus (1990), and Heithausen *et al.* (1993) show that molecular gas can be found over the whole area of Loop III. Table 1 lists the Galactic positions and distances of these molecular clouds/complexes, and the literature sources of their distances. The most prominent molecular structure projected within the boundary of Loop III is the Cepheus flare. Recently Olano, Meschin & Niemela (2006) established that the interstellar gas in the Cepheus flare is distributed over the surface of an expanding shell (Cepheus flare shell, CFS), centred on $l \sim 124^{\circ}$, $b \sim +17^{\circ}$ and at a distance of 300 pc, and having a radius of about 50 pc. According to Olano, Meschin & Niemela (2006), all these quantities are rather uncertain estimates. As most of the molecular clouds in the Cepheus flare region are found at 200 and 300 pc (Kun 1998), the true distance to the centre of this shell may well be about 250 pc, suggesting that Loop III and CFS are nearly concentric and possibly identical.

Another prominent molecular complex, the Polaris flare, is located at a distance of ~ 110 pc, and thus probably is associated with the near boundary of Loop III. At the highest Galactic latitude segment the North Celestial Pole Loop (Meyerdierks, Heithausen &

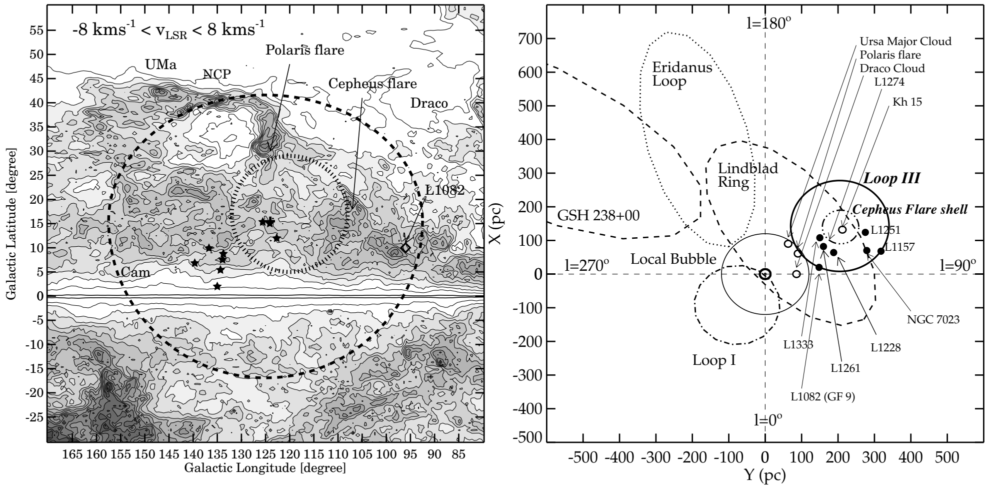

Figure 2. Left: Distribution of the neutral hydrogen over the surface of Loop III in the radial velocity interval $-8\,\mathrm{km\,s^{-1}} < v_{\mathrm{LSR}} < 8\,\mathrm{km\,s^{-1}}$. The position of the centre and boundary are indicated by the cross and dashed line, respectively. Dotted circle indicates the Cepheus flare shell, star symbols show the members of the SU Cas association and other late B–early A type stars located at a distance of about 250 pc. Positions of some molecular clouds are also indicated. Right: Distribution of nearby HI shells, projected onto the Galactic plane. Star forming clouds projected within Loop III are marked by black circles, and non star forming clouds by open circles.

Reif 1991) closely follows the boundary of Loop III. The Camelopardalis clouds are located at the high-longitude, low-latitude boundary of Loop III. According to Zdanavičius *et al.* (1996) absorbing matter can be found between 100 and 300 pc in this direction, demonstrating that the line of sight is parallel to the wall of Loop III.

Star formation possibly triggered by Loop III. In the right panel of Fig. 2 the distribution of the nearby HI shells projected on the Galactic plane, adopted from Heiles (1998), is plotted and supplemented by the position of Loop III and the Cepheus flare shell. The distribution of the molecular clouds of the region is shown as well. Most star forming (possibly older) molecular clouds can be found inside Loop III, whereas the non-star forming (younger) ones are located close to its present surface, suggesting that star formation had been initiated by the expansion of the shell. The trigger by Loop III is conspicuous in the case of L 1333 (see Kun *et al.* 2006). Another candidate is the L 1082 (GF 9, Schneider & Elmegreen 1979), located close to the boundary of Loop III in both projections, in which very early stages of star formation can be observed (Wiesemeyer, Güsten & Wright 1997).

Possible origin of Loop III. The stars plotted in the left panel of Fig. 2 are late B–early A type members of the SU Cas association (Turner & Evans 1984) and a few other stars similar in spectral type, proper motion and distance modulus to the association members. The supernova(e), whose explosion(s) produced Loop III, might have been high-mass member(s) of this association.

3. Conclusion

The preliminary results presented in this paper suggest that careful studies of the available data on the spatial and velocity distribution of the interstellar structures may reveal several connections which combine them into a coherent structure.

Table 1. Molecular cloud distances in the 2nd Galactic quadrant

Cloud	l (°)	b (°)	D (pc)	Reference
Draco	90	38	86	(1)
Lynds 1082 (GF 9)	97	+10	100–150	(2)
Cepheus flare	100–120	10–20	200 and 300	(3), (4), (5)
Polaris flare	118–126	20–30	$105 < D < 125$	(6)
Lynds 1274	118.1	+8.8	200 ± 30	(7)
Khavtassi 15	122.7	+9.6	250 ± 25	(8)
Ursa Major	141.8	+35.9	$100 < D < 120$	(9)
Camelopardalis clouds	140–150	0–10	100–300	(10)
Lynds 1333	127	15	180 ± 30	(11)

References: (1) Lallement *et al.* (2003); (2) Wiesemeyer, Güsten & Wright(1997); (3) Straižys *et al.* (1992); (4) Kun (1998); (5) Olano, Meschin & Niemela (2006); (6) Zagury, Boulanger & Banchet (1999); (7) Nikolić *et al.* (2001); (8) Kiss, Tóth, Sato *et al.* (2000); (9) Penprase (1993); (10) Zdanavičius *et al.* (1996); (11) Obayashi, Kun, Sato *et al.* (1998)

Acknowledgements

This research was supported by the Hungarian OTKA grant T 049082.

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https://doi.org/10.1017/S1743921307001329 Published online by Cambridge University Press

Discussion

Mac Low: 1. Has this loop been detected in more recent surveys, such as the sensitive Wisconsin H-α mapper survey, or more recent continuum surveys? 2. Might Loop III actually be a superposition of unrelated objects in a low resolution survey?

Boulanger: (answered for M. Kun) Loop III is well detected as a coherent structure in emission and polarization in the 23 GHz synchrotron maps provided by the Cosmic Microwave Background Probe WMAP (Page *et al.* 2006). HI gas at $V_{LSR} < -20$ km s^{-1} is seen over the sky area interior to the synchrotron loop.

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