Triggered star formation and the large-scale structure of the interstellar medium

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Introduction - Background

The large-scale structure of the interstellar medium (ISM) in the Galaxy can be significantly affected by violent events. Massive stars can affect the nearby ISM not only at late stages when they become supernovae but during more stable states by their strong stellar winds. These processes can create **large bubbles in galaxies**, built up by shock waves sweeping up gas and dust in thin shells.

In the surroundings of the Galactic midplane the shells provide a nest for the next generation of stars. Then high-mass stars, forming here, are the next sources of various shock waves. In the shells of the bubbles, dense cores are the first phases of star formation, traced by radio observations. Afterwards, intensive infrared radiation accompanies the life of young stellar objects; from the cloud core phase to debris discs around the evolved stars.

We performed an **all-sky survey of loop/arc-like intensity enhancements** in the diffuse far-infrared emission (Kiss Cs. et al. 2004, Könyves et al. 2007). Altogether we catalogued 462 of these features. This data forms the **Catalogue of Far-Infrared Loops in the Galaxy**.

Furthermore, we studied the properties of **LDN 1188 dark cloud** and the physical parameters of the star forming dense cores sitting within the cloud, based on infrared, submm and radio observations. LDN 1188 is located at a distance of ~910 pc in the wall of the **Cepheus Bubble** (Kun et al. 1987), named GIRL G102+06 in our catalogue.

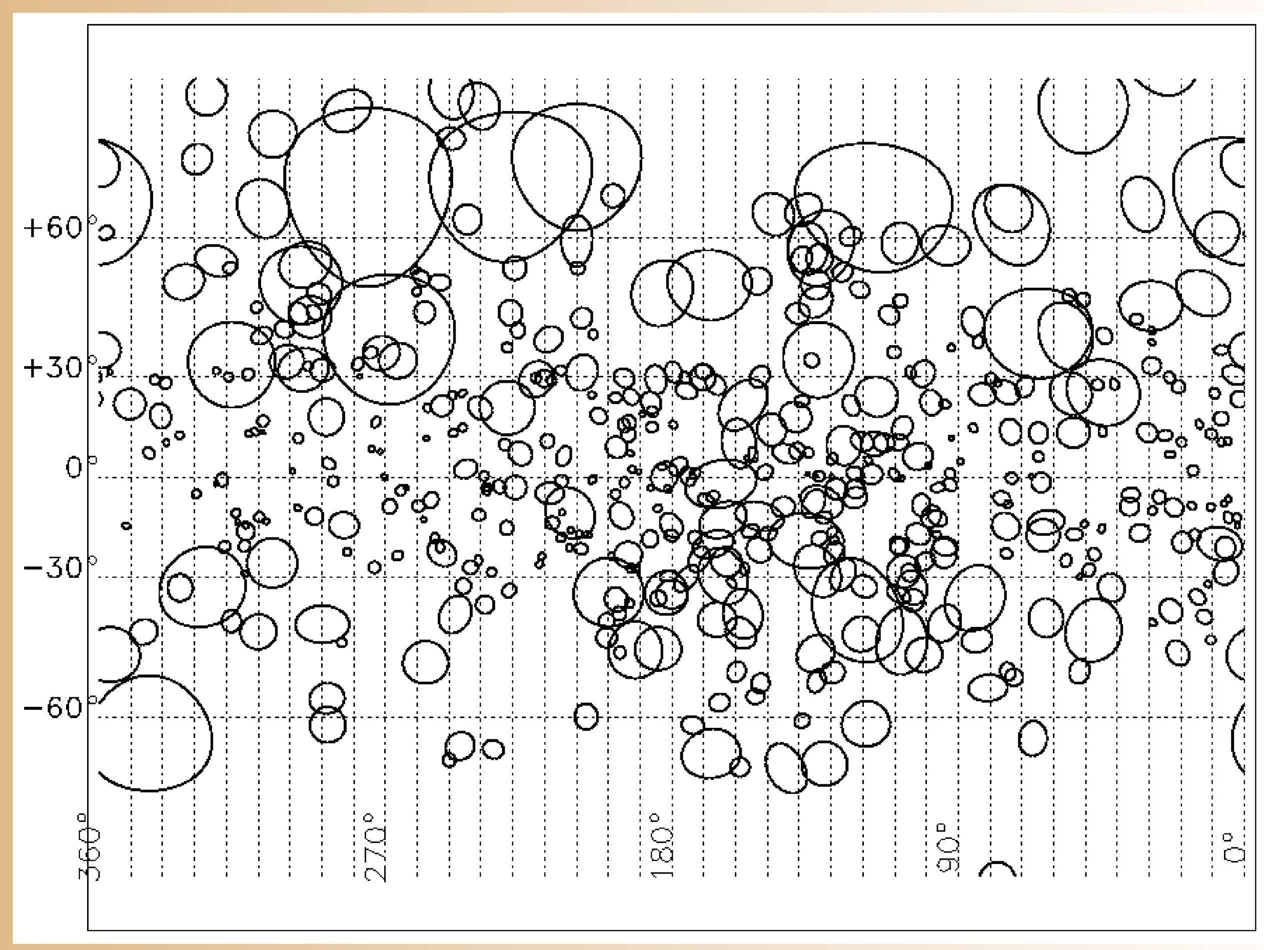
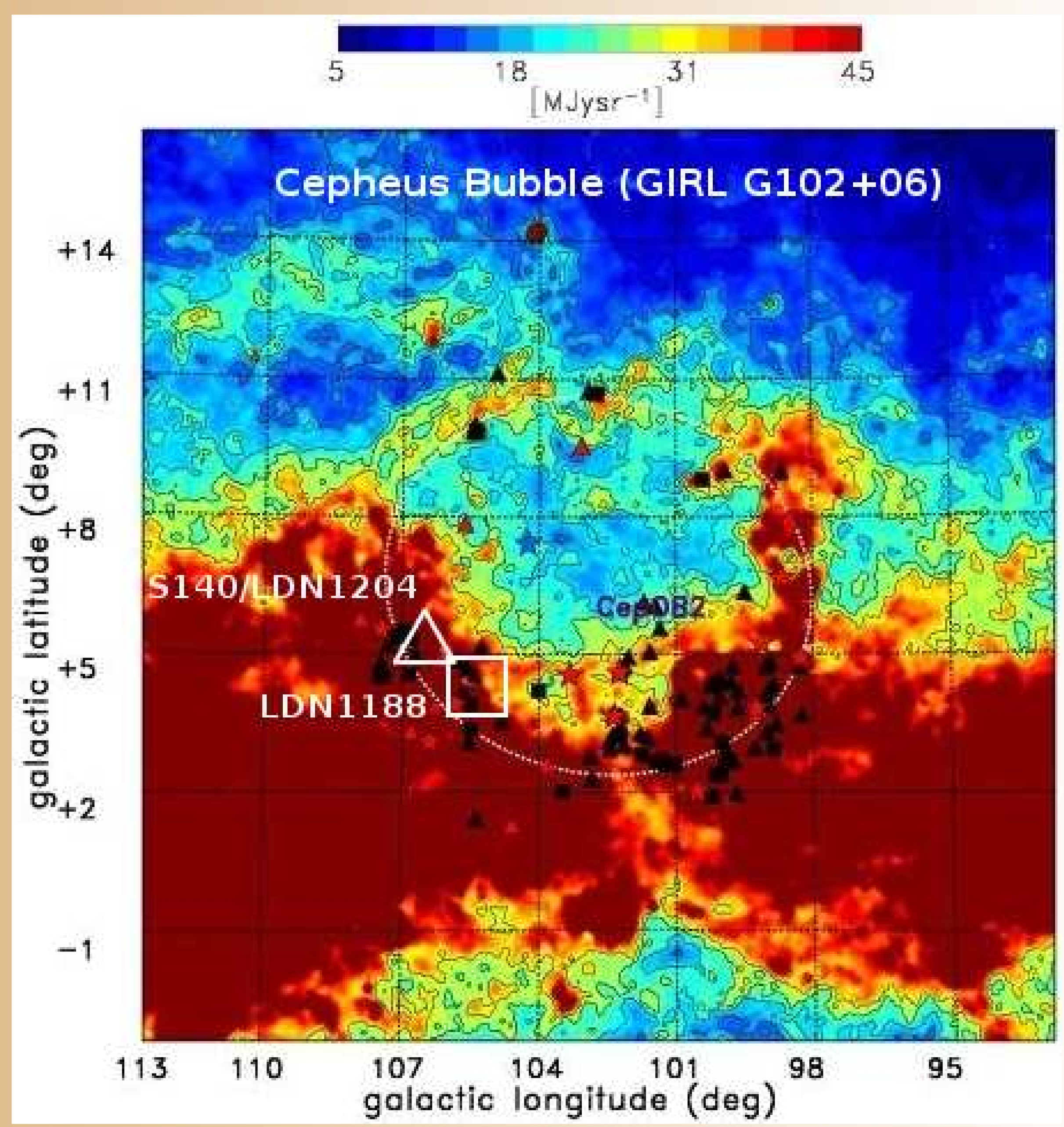


Fig. 1: Distribution of GIRLs in the sky (Mercator projection), represented by the fitted ellipses. Note that Mercator projection causes a size distorsion at polar regions.

Selected results of the 'GIRL' catalogue

Physical and statistical investigations of the all-sky GIRL (Galactic InfraRed Loop) database provide a great opportunity to **study the large-scale structure of the ISM in the Galactic neighbourhood of the Sun**.

- In the **size distribution** of the shells a trend can be seen that the same amount of energy injection of an event creates larger shells further from the Galactic plane. Furthermore, **color indices** of the loop walls show that most of the loops have a far-infrared colour similar to that of the Galactic cirrus with an average value of $\Delta I_{60}/\Delta I_{100} = 0.25 \pm 0.12$ (Lagache et al. 1998), while shells sitting in the Galactic midplane seem to be "warmer".
- The **celestial distribution** of the identified loops is rather complex. Loop structures are associated with large-scale molecular material; in some cases with molecular complexes. **Galactic longitude distribution** of the GIRLs partly reflect the spiral structure of the Galaxy. However, their **Galactic latitude distribution** clearly suggests that there is an efficient process that can generate loop-like features at high Galactic latitudes.
- To a subsample of 73 loops we were able to derive distances using the distances of **associated objects** (e.g., dark clouds, supernova remnants, OB-associations, HII regions). We used this sample to characterize the large-scale distribution of the ISM in the vicinity of the Solar System.
- The **hot gas volume filling factor** f of a galaxy is an important parameter in characterizing the structure and life cycle of the interstellar medium. It can be hardly constrained observationally to our Galaxy. From far-infrared observations we determined estimates for the hot gas volume filling factor of the inner ($f_{\rm in}$) and outer ($f_{\rm out}$) Galactic environment of the Solar System. The obtained $f_{\rm in}$ value is of the order of ~20%, as predicted by Ferriére (1998) and Gazol-Patiño & Passot (1999). On the other hand, the $f_{\rm out}$ value is very similar to $f_{\rm HI} \approx 5\%$ found by Ehlerová and Palouš (2005) through an automated identification of HI shells in the 2nd Galactic quadrant.



Sequentially triggered star formation in the Cepheus Bubble

Evolution of the Cepheus Bubble

This region provides a nice example of interaction between massive stars and the interstellar medium, specifically, the process of propagating star formation by sequential triggering.

- After Simonson (1968), Kun et al. (1987) also confirmed the **rich and diverse history of the Cepheus Bubble region** around the Cep OB2 association.
- Patel et al. (1998) has detected triple wave of star formation in the region. The existence of runaway stars suggests that their massive binary companion could have exploded as supernovae somewhere in the central region of the Bubble, which was fed by more of such single supernova events.
- A bubble around Cep OB2 originated from a compressed shell of gas that was blown out by the combined effects of stellar winds and photoionization from OB stars of the first generation, some 13–18 Myrs ago (shown in **Fig. 2a**).
- These O and B stars start to blow stellar wind bubbles after their birth into the remaining shell of the bubble (**Fig. 2c**). The dynamical timescale of these expanding subsystems is 1–3 Myr, which is roughly consistent with the age of Cep OB2.
- Around O-type stars, in the wall of smaller bubbles, IRAS point sources were associated with dusty globules which represent the **third generation of stars currently forming** in the region of the Cepheus Bubble. In **Fig. 2d** IRAS point sources represent the low- and medium-mass star formation in the compressed clouds.

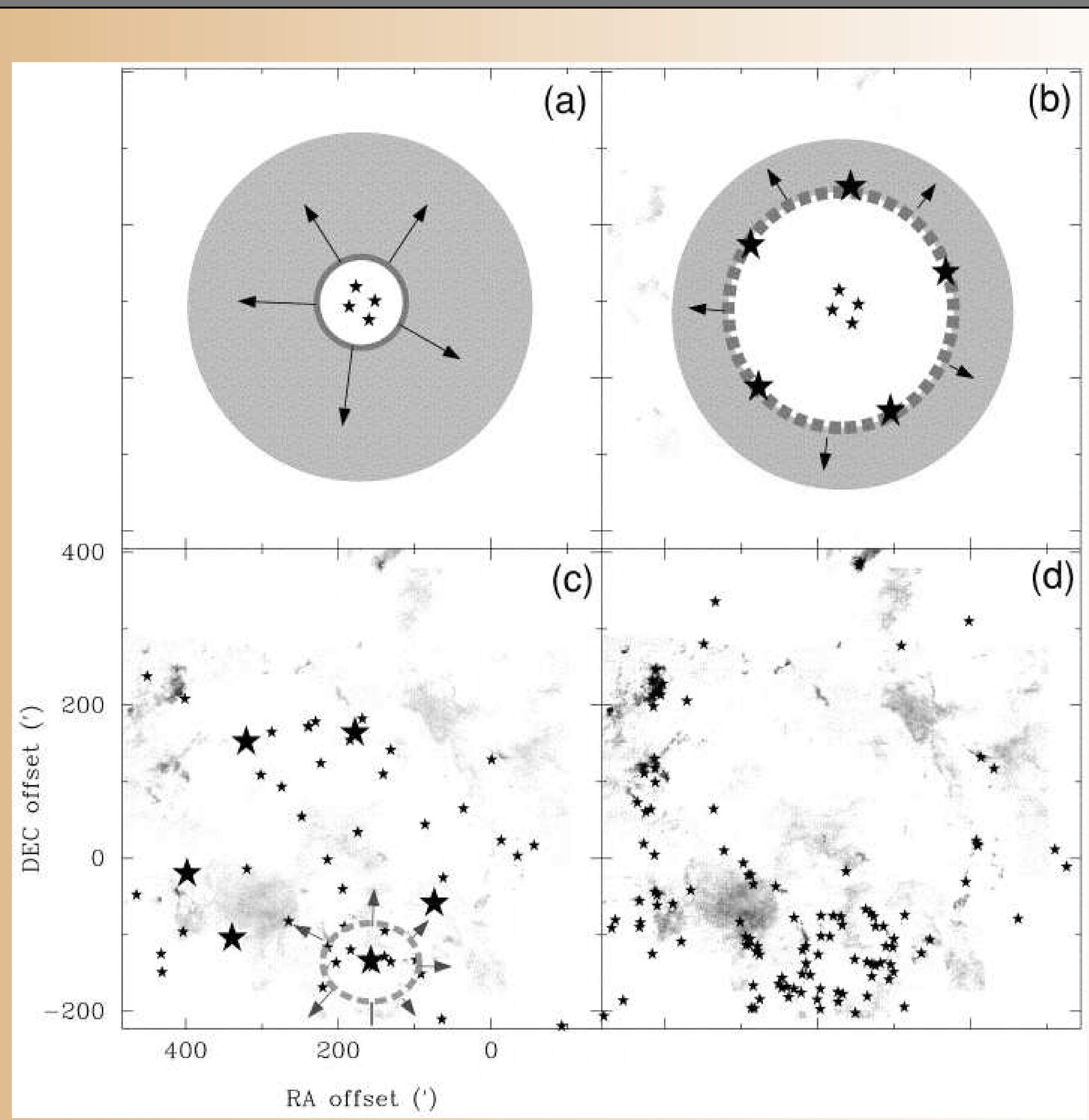


Fig. 2: Sequentially triggered star formation in the region of the Cepheus Bubble. Fig. 8 of Patel et al. 1998.

LDN 1188 dark cloud complex

LDN 1188 is a medium-sized dark cloud complex at $l \approx 105.^\circ6$, $b \approx +4.^\circ2$, in the neighbourhood of the well known S 140/LDN 1204 star forming region. Both are at the periphery of the giant ring around Cep OB2 association. The Cepheus Bubble is marked as GIRL G102+06 in our far-infrared all-sky survey, therefore, LDN 1188 is a good candidate to investigate triggered star formation.

- Ábrahám et al. (1995) identified 6 ^{13}CO clumps in the complex, and derived their physical porperties. They detected 15 H_α emission line objects and 6 IRAS point sources; many of these are closely associated with the ^{13}CO clumps. The adopted distance of the LDN 1188 is ~910 pc, and the total molecular mass of the complex was estimated to be ~1800 $M_\odot$.
- Investigation of the infrared spectral energy distribtion of the sources IRS 4, 5 and 6 was presented in Könyves et al. (2004) on acrminute scales, allowed by the spatial resolution of IRAS and ISOPHOT. Two sources (IRS 4 and IRS 6) were qualified as **Class I type protostars** based on the definition by Lada (1987).
- From further analysis and from the infrared, submm and radio observations, we can see that **different stages of star formation exist parallelly in the LDN 1188 molecular cloud**, from the ammonia cores to the evolved young stars with protoplanetary discs.

References

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