STSM 2016 RESEARCH PROJECT REPORT

Determining the nature of the ring-like infrared emission around the magnetar SGR 1900+14 with 3D dust radiative transfer

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Purpose of the STSM

The purpose of the STSM has been the determination of the nature of the mid–infrared emission ring detected on Spitzer MIPS 16 and 24μm data around the magnetar SGR 1900+14. This emission has been interpreted by Wachter et al. (2008, W08) as the infrared emission originating from dust surrounding a dust-free cavity. These authors argued that this cavity has been formed by the magnetar giant flare which was detected in August 1998. This interpretation has not been supported by a proper theoretical modelling of the dust distribution and the radiation sources powering the observed infrared emission. Our aim has been to perform such modelling with the aid of 3D dust radiative transfer numerical calculations.

Description of the work carried out during the STSM

We have performed several dust radiation transfer calculations assuming dust distributions and stellar positions which are compatible with the observed dust emission morphology and the projected positions of the stars. Specifically, we set up three different models for the dust distribution: 1) an "elliptical shell" model, where the dust is confined within a thin elliptical shell of constant density; 2) an "elliptical cavity" model, where the dust density is constant outside an ellipsoid delimiting the dust cavity; 3) an "elliptical wind" model, where the dust density increases from the magnetar until the border of the dust cavity and then decreases as the distance squared. The assumed dust density profiles are shown in Fig.1 as a function of the normalized radius R such that:

$$R^2 = \frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} \tag{1}$$

where a, b and c are the lengths of the three semi-axis of the "reference ellipsoid" with $R = 1$. To set the dust absorption and scattering parameters, we assumed a Milky Way dust model from Zubko et al. (2004). We assumed that the dust is only heated from two M supergiants, which are the brightest stars in the stellar cluster to which the magnetar allegedly belongs. The possible stellar positions in the 3D space defined in our models have been chosen such that the projected positions of the stars coincide with the observed ones. The stellar intrinsic luminosity spectra have been assumed to be blackbodies with total luminosities and effective temperature as found by Davies et al. (2009). The 3D dust radiation transfer calculations have been performed using the code DART-Ray (Natale et al. 2014, 2015). We explored a range of free parameters including the dust/gas density, the axis ratio b/a of the ellipsoidal dust structures and the distance of the stars from the magnetar.

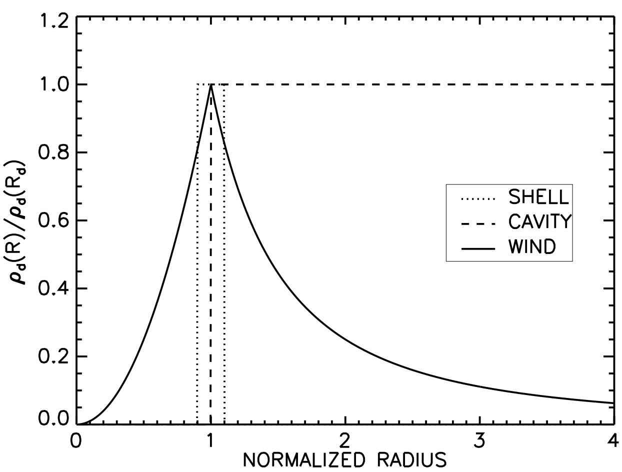

Figure 1: The three types of density profiles used to model the ring emission.

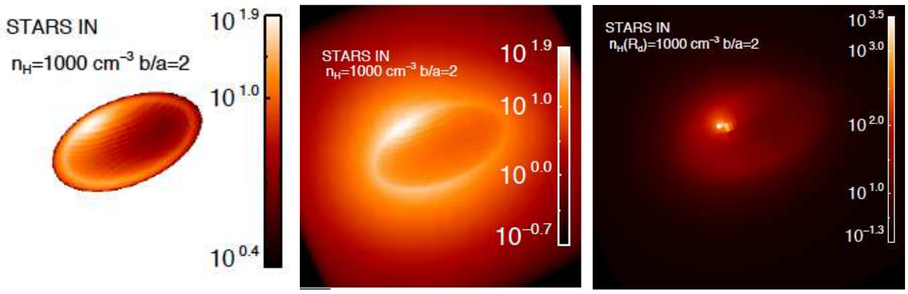

Figure 2: Simulated 16 μm maps for the elliptical shell model (left), the elliptical cavity model (centre) and the elliptical wind model (right). The ellipsoid axis ratio for these models is $b/a = 2$ and the gas density at the reference ellipsoid radius (R=1) is n_H=1000 cm^{-3}. The M supergiants stars illuminated the cavity are located within the dust cavity. The surface brightness indicated aside the colour bars are in units of MJy/sr.

Description of the main results obtained

For all types of dust geometries we assumed, we have found that the dust emission ring size and morphology can be recovered by assuming $b = c = 2.18$ pc, an ellipsoidal ratio $b/a = 2$ and, most importantly, by positioning the M supergiant stars inside the dust cavity. The integrated emission flux varies proportionally to the assumed dust/gas density. In Fig. 2, we show the 16 μm maps we derived assuming the above geometrical parameters and by assuming a gas density n_H=1000 cm^{-3} at R=1. The integrated ring fluxes we measured for all these models at both 16 and 24 μm are compatible with the fluxes measured by W08 on the Spitzer data within the error bars. These results show that several scenarios are in principle possible for the nature of the ring. The shell model could be compatible with the scenario of a dense supernovae remnant. The dust cavity model support the scenario, proposed by W08, that a cavity has been formed after the magnetar giant flare. In this case, our modelling suggests that this process happened within a high density environment, which is qualitatively compatible with the ISM expected for a young stellar cluster. Finally, the wind model, representing the case where the dust is distributed as in a stellar wind but depleted inside the cavity region, is also not excluded by our modelling. However, for this case, it is much harder to justify the high gas density required to fit the observed fluxes. We note that there are several possible reasons, of either artificial or physical origin, explaining why we found such a high density in our modelling of the ring. These will be discussed in the forthcoming paper on this work.

Foreseen publications/articles resulting from the STSM

We are planning to submit a paper describing the work performed during this STSM within the next two months.

Confirmation of the host institution of the successful execution of the STSM

To be sent separately.

References

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