Proposal for the China-CONICYT Postdoc fellows

The impact of expanding HII regions on the surrounding molecular material

Abstract

HII regions are created when massive OB associations form in dense molecular clouds together with a large number of low mass stars and the hydrogen is ionized by the strong UV radiation. The expanding HII region, the high UV radiation field and turbulence compresses and sculpts the surrounding molecular cloud into a surrounding dense shell and smaller entities. This compression is likely to trigger further mostly low mass but even high mass star formation. We propose to study the small and large scale impact of the expanding HII region on the associated molecular material and the resulting triggered star formation. Selected HII regions from nearby well resolved regions (e.g the Rosette Nebula) to far away infrared bubbles detected in the Spitzer GLIMPSE survey will be observed in wavelengths from NIR to cm using available observing facilities in China and Chile including ALMA. In particular we want to study **1:** signs of interaction between the HII region and the ambient molecular cloud; **2:** the small scale structure of the shell, elephant trunks and globulettes and star/free floating planet formation in them; **3:** look for shocked molecular gas, signs of infall or outflows; **4:** determine the physical parameters of the molecular gas and dust (column density, density, mass, temperature, excitation, optical depth); **5:** identify YSOs and classify their type (Class 0, I or II); **6:** study the Core Formation Efficiency (CFE), Core Mass Function (CMF) to see possible effects due to the expanding HII region by comparing them to those of normal molecular cores.

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Description.

Despite more than half a century of intensive research of star formation it still remains one of the key issues of modern astronomy. Massive OB star clusters form in dense molecular clouds together with a large number of low mass stars. The HII regions are few and situated wide apart and combined with the short formation time and the high obscuration makes the likelihood of observing the actual high mass star formation process extremely small. In addition the turbulence produced by the expanding HII region and the strong UV radiation from stars modifies the natal parent cloud and the original structure can not be studied. However, the impact of the expanding HII region on the ambient molecular cloud is significant. The cloud is compressed into a dense shell around the HII region and individual globules, globulettes and elephant trunks are sculpted from it. Triggered star formation takes place in the shell and in the trunks and globules. Jupiter mass globulettes have been suggested as formation sites of free floating planets. The turbulent environment in and around the HII region differs significantly from that in quiescent massive molecular clouds and individual globules. The important question is if the Core Formation Efficiency and the Core Mass Function are the same in the two strongly different environments or if they are modified by the impact of the HII region.

The new NIR to FIR instruments and new ground based and space borne telescopes have revolutionised our view of dust clouds and regions previously obscured by high extinction. So called starless cores turn out to mostly have embedded newly formed stars. The nearest massive HII regions (e.g. Orion, Rosette and Carina) can be observed with high spatial resolution. The new large scale NIR to MIR surveys cover the whole Galactic plane. Spitzer GLIMPSE MIR survey provided us with unprecedented samples to examine the expansion of HII regions. Nearly 6000 infrared bubbles were found (Churchwell et al., 2005, 2007; Simposon et al., 2012).

It was recognized early that besides the elephant trunks protruding from the shells a number of smaller dark clouds were seen in silhouette against the bright background HI emission in optical images. Besides normal size globules there were a number of much smaller round or cometary like objects sometimes with bright rims facing the bright central stars (Thackeray 1950; Herbig 1974). Recently Gahm et al. 2007 (AJ, 133, 1795), concluded that the mass of these globulettes were subsolar and could therefore be forming sites of Jupiter mass free floating planets. The number of such objects is estimated to be larger than that of main sequence stars in the Milkyway (Sumi et al, 2011, Nature 473, 349). Follow up in submillimetre (Gahm et al. 2013) and NIR imaging (Mäkelä et al. 2014) and ALMA molecular line imaging (Haikala et al. 2017, in preparation) have confirmed the high density and subsolar mass of globulettes. Star formation takes place in the larger elephant trunks (Mäkelä et al. submitted) and the shell.

Follow - up studies of the infrared bubbles including statistics and observation were carried out. Thompson et al. (2012) found that young stellar objects were distributed toward the borders of bubbles. Associated gas was investigated with multiple lines. Excitation states and structures were revealed, showing the interaction of bubbles with surrounding gas (Deharveng et al., 2005,2008, Brand et al. 2011, Samal et al. 2014, Yuan et al. 2014, Liu et al. 2015). However, the physical processes still need to be examined. The characteristics and properties as well as evolution of the compressed gas and the formed YSOs are far from being known.

We propose to observe the impact of expanding HII regions on the surrounding molecular matter and related triggered star/planet formation in nearby and distant HII regions. Selected regions and individual objects in the nearby, well resolved HII regions are to be studied in great detail using NIR imaging, diffraction limited imaging, NIR and submm spectroscopy and in submm continuum. Typical infrared bubbles with complete and broken shells will be observed in a more global manner using submm to cm spectroscopy and in IR to submm continuum. The objects can be observed using arc-second resolution with ALMA. Combining the high spatial detailed results from the nearby HII regions with the more global view of the IR-bubbles allows to form a complete view of the impact of an expanding HII region on its ambient molecular cloud.

The project offers an interested Postdoc the possibility to investigate the structure and properties of expanding HII regions on two fronts using various observing methods from NIR to cm. The aim of the project is to form a detailed picture of the impact of expanding HII region and the related triggered star and free floating planet formation. The planned duration of the project is three years.

Recent publications related to the project.

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Mäkelä, M.M., L. K. **Haikala, L.K,** and Gahm, G., "Rosette Nebula globules: Seahorse giving birth to a star", A&A, submitted

Liu,Hong-Li; Miguel Figueira, Annie Zavagno, Tracey Hill, Nicola Schneider, Alexander Menshikov, Delphine Russeil, Frederique Motte, Jeremy Tige, Lise Deharveng, L.D. Anderson, Jin-zeng Li, **Yuefang Wu**, Jing-Hua Yuan, Maohai Huang, J. P. Bernard, and Alain Abergel,
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Liu, Hong-Li; **Wu, Yuefang**; Li, JinZeng; Yuan, Jing-Hua; Liu, Tie; Dong,Xiaoyi, "A Feedback-driven Bubble G24.136+00.436: A Possible Site of Triggered Star Formation", 2015, ApJ, 798, 30

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Wu, Yuefang; Liu, Tie; Qin, Sheng-Li
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Yuan, Jing-Hua; **Wu, Yuefang**; Li, Jin Zeng; Liu, Hongli
"Expanding Shell and Star Formation in the Infrared Dust Bubble N6", 2014, ApJ, 797, 40

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