Near-infrared photometry and radio continuum study of the massive star-forming regions IRAS 21413+5442 and IRAS 21407+5441

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ABSTRACT
IRAS 21413+5442 and IRAS 21407+5441 are two massive star-forming regions of high luminosity, likely associated with each other. Near-infrared (NIR) photometry on these two IRAS sources was performed at United Kingdom Infrared Telescope (UKIRT) using the UFTI under excellent seeing conditions yielding an angular resolution of ∼0.5 arcsec. Our results reveal details of stellar content to a completeness limit (90 per cent) of $J = 18.5, H = 18.0$ and $K = 17.5$ mag in the two regions. In IRAS 21413+5442, we identify a late O-type star, having large $H - K$ colour, to be near the centre of the CO jets observed by earlier authors. The UKIRT images reveal in IRAS 21407+5441, a faint but clear compact H II region around a central high- and intermediate-mass star cluster. We have detected a number of sources with large $H - K$ colour which are not detected in $J$ band. We also present the GMRT radio continuum map at 1.28 GHz covering the entire region surrounding the two star-forming clouds. The radio continuum fluxes are used to estimate the properties of H II regions which seem to support our NIR photometric results. Based on our radio continuum map and the archival Midcourse Space Experiment (MSX) 8.2-μm image, we show that the two IRAS sources likely belong to the same parent molecular cloud and conjecture that a high-mass star of large IR colours, present in between the two sources, might have triggered star formation in this region. However, one cannot rule out the alternative possibility that Star A could be a nearby foreground star.

Key words: stars: formation – dust, extinction – H II regions – infrared: stars – radio continuum: general.

1 INTRODUCTION
Appearance of a compact H II (CHII) or an ultra-compact H II (UCHII) region embedded in a molecular cloud signifies the formation of a massive star of spectral type earlier than ∼B3 (Shepherd & Churchwell 1996; Churchwell 2002). During this phase, the massive star is believed to be close to its zero-age main sequence (ZAMS), although pre-main-sequence (PMS) manifestations such as outflows have been detected in some cases (e.g. Weintraub & Kastner 1996; Beuther et al. 2002; Kumar, Keto & Clerkin 2006). Massive star formation occurs always in clusters. Further, the environment around the massive stars gets affected by their strong winds and energetic radiation. It is therefore important to study such CHII/UCHII regions in order to find out possible evolutionary stage of stellar content in their vicinity. Near-infrared (NIR) photometry was shown to be very useful for this purpose (e.g. Lada 1985). Supplementary radio continuum measurements can provide important physical parameters concerning the object under certain assumptions (e.g. Scheffler & Elsasser 1988, and references therein). In this paper, we describe a study in NIR and radio continuum in and around two IRAS sources that are believed to be massive star-forming regions by virtue of the presence of CHII/UCHII.

IRAS 21413+5442 (Object 1) is one of the highly luminous, massive young stellar objects (YSOs) in our Galaxy and is situated at an estimated distance of 7.4 kpc (Wouterloot & Brand 1989; Yang et al. 2002). This source is identified with the presence of a UCHII region, called IRAS 21413+5442S, about 20 arcsec south of a CHII region, called IRAS 21413+5442N (Miralles, Rodriguez & Scalise 1994). The far-IR luminosity from IRAS fluxes at 12, 25 and 60 μm was estimated to be $3.2 \times 10^5 L_\odot$ (Campbell, Persson & Matthews 1989). The CO surveys of Shepherd & Churchwell (1996) have classified this source as a massive star-forming region