A Statistical Comparison of the near-IR emission with the Hα emission from the HII regions of NGC 4321 and of NGC 4736.

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ABSTRACT

We report on our ongoing project "Statistical studies of HII regions in nearby galaxies". We measure the Hα luminosities, and the near IR luminosities in the 4 Spitzer passbands, of a complete sample of 78 and 74 isolated luminous HII regions in the grand design galaxy NGC 4321(M100) and NGC 4736 respectively. We find a strong, and expected positive correlation between the total IR luminosity and the Hα luminosity, but no significant correlation between the luminosity and the IR colour temperature of the regions, and draw a physical conclusion about the dust distribution within the HII regions.

DATA & SAMPLE

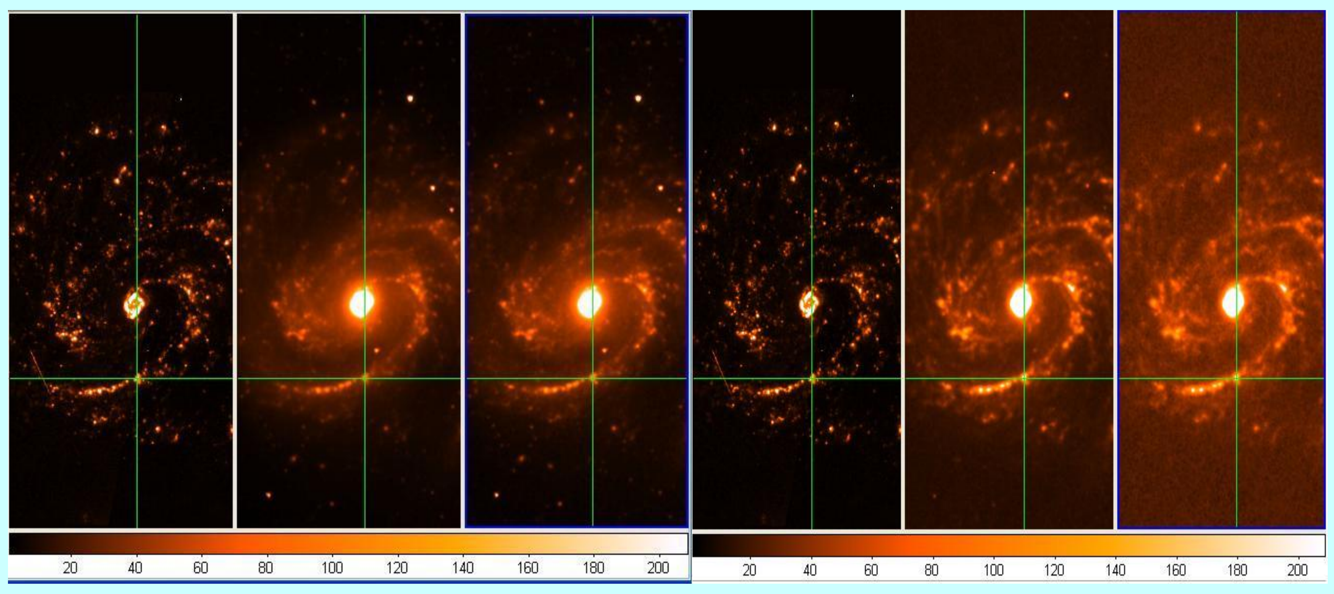


Figure 1a: Aligned images (M100). Panels from left to right. Left: Hα image (4.2m William Herschel Telescope, La Palma), Spitzer IRAC 3.6μm band, IRAC 4.5μm band; Right: Hα image IRAC 5.8μm band, IRAC 8μm band.

- **The set of HII regions of M100 and of NGC 4736, calibrated in Hα luminosity, and the image in Hα were obtained from Knapen (1998) and Knapen et al. (2004) respectively.**
- **Both the SINGS/IRAC images of M100 and NGC4736 were obtained from the SINGS Public Data Set Archive.**

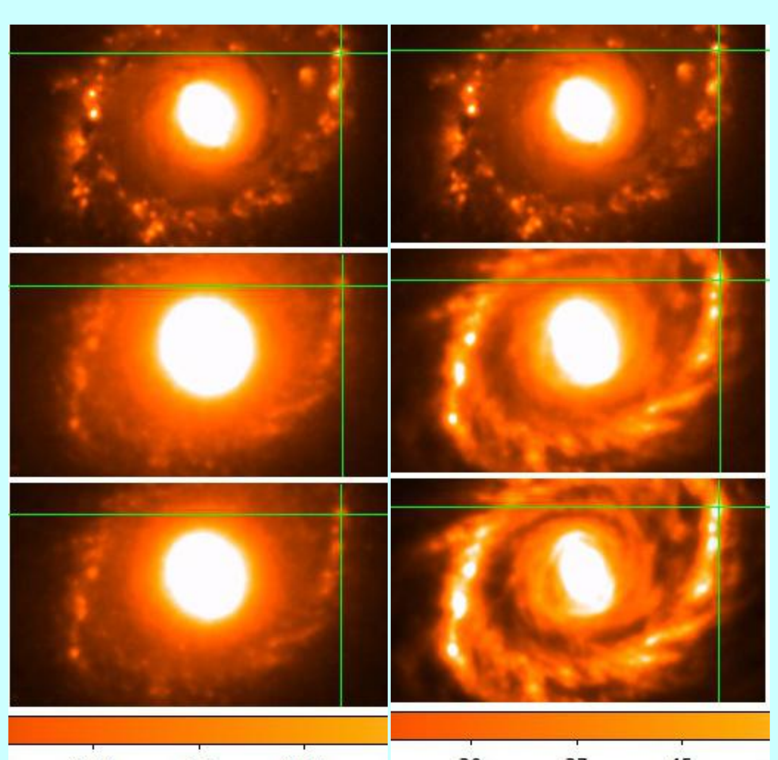
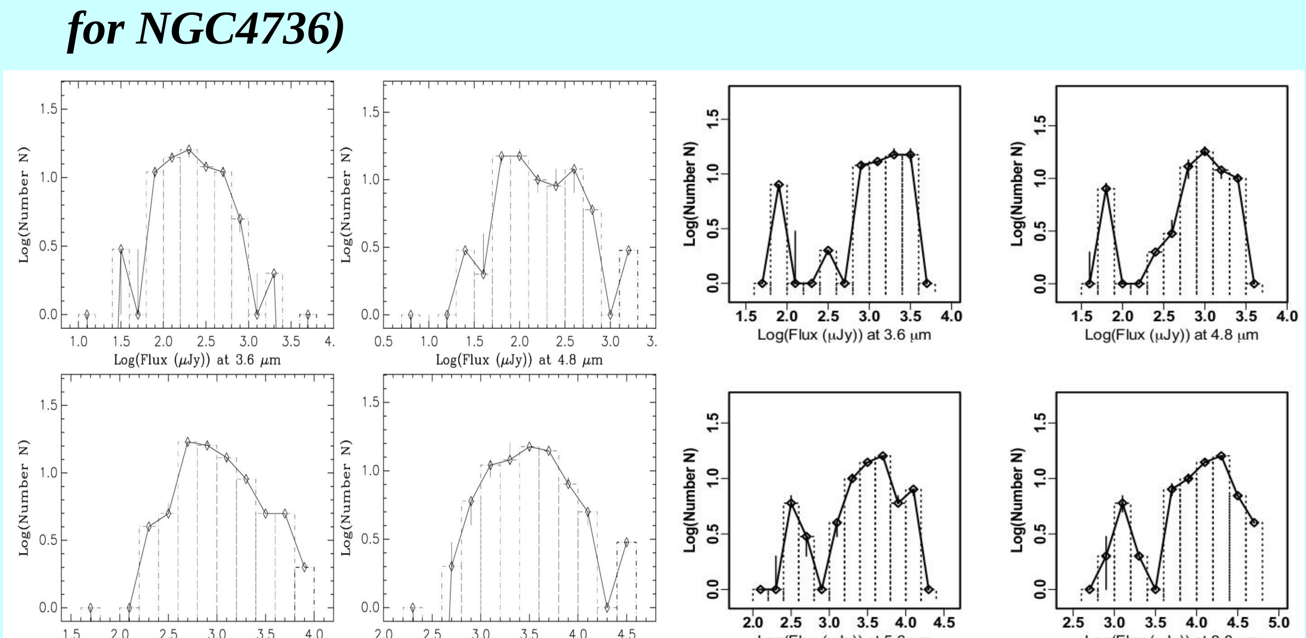


Figure 1b: Aligned images (NGC4736). Panels from left to right. Left: Hα image (JKT , La Palma Palma), Spitzer IRAC 3.6μm band, IRAC 4.5μm band; Right: Hα image IRAC 5.8μm band, IRAC 8μm band.

Figure 2 (below) : Histograms of the IRAC fluxes for the HII regions in the four IRAC bands (Left for M100; Right for NGC4736)



CONSTANT TEMP. AND DUST MODELS

It is very interesting to note that there is no correction between L(Hα)) *and* $T_{col(IRAC)}$*. The mechanism(s) that might lead to this near-invariance of the temperatures we measure could be the following possible three scenarios or the combination of any of them.*

(A) dust destruction model: *The dust is ablated away in the inner zones of the HII regions, close to the OB stars, in such a manner that the more luminous the star cluster, the greater the range of this grain destruction. In consequence, the emitting grains turn out to have around the same temperature for all the regions, because the dust which emits has its inner limit at a greater radial distance from the cluster, the higher the luminosity.*

(B) stellar-wind model: *The dust in the ISM surrounding an ionising star cluster is swept out beyond a radial distance from the cluster, which depends on the cluster luminosity. In any HII region the dust emission would then come from a thick shell whose inner radius is larger, the higher the stellar luminosity.*

IRAC COLOUR TEMPERATURE

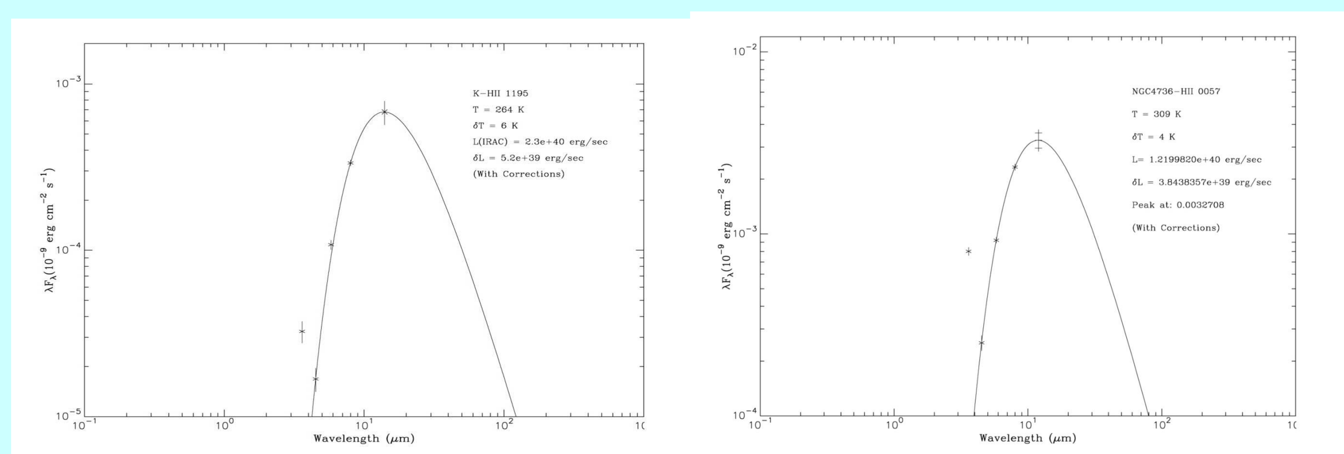


Figure 3 (above): The IRAC fluxes of a sample of HII regions (figures from left (M100) to right (NGC4736) for the four bands, with a best blackbody fit to the three longer wavelength bands. The point at the maximum of the curve is not an observed flux, but the estimated peak flux with its error bar. The 3.6 μm excess is attributable to PAH emission.

Hα LUMINOSITY V. IR COLOUR TEMPERATURE

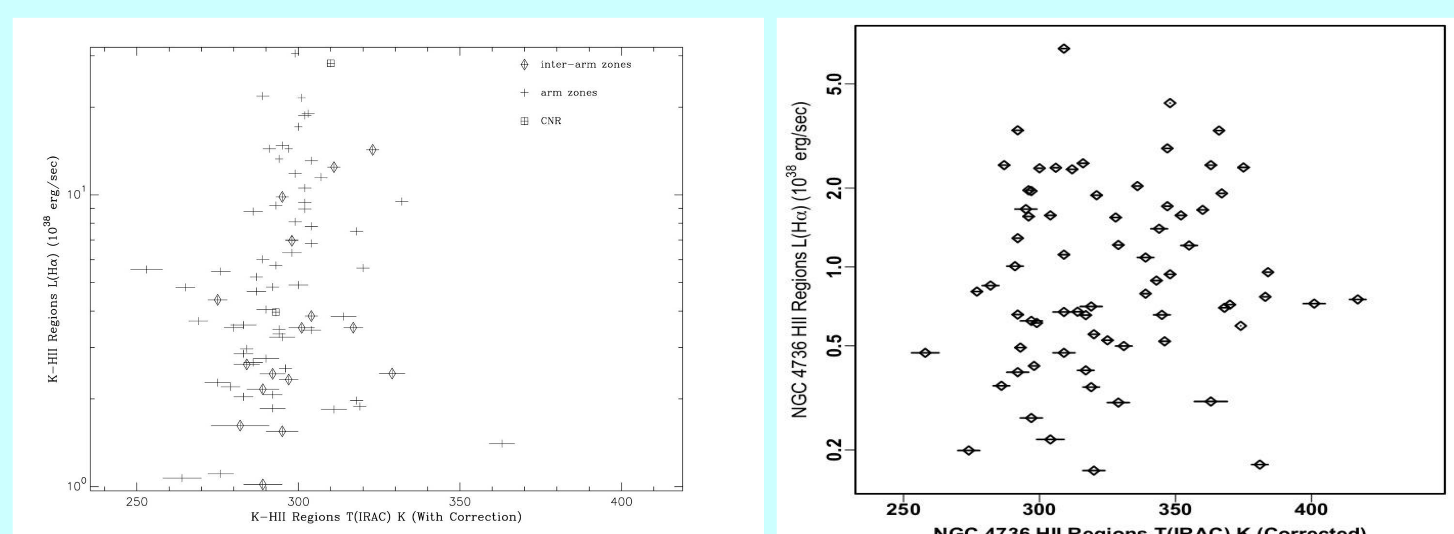


Figure 4 (above) : Interesting phenomena of colour temperature. Left: Colour temperatures against L(Hα) for the HII regions in M100 Right: Colour temperatures against L(Hα) for the HII regions in NGC4736.

•We can see that there is no correlation between the two variables and that the position of the an HII region.

•Figure 4 (Left figure for M100) also shows that there is no correction between the two variables. Their positions in the arms, in the interarm zone or in the circumuclear region (CNR) do not cause any systematic effect.

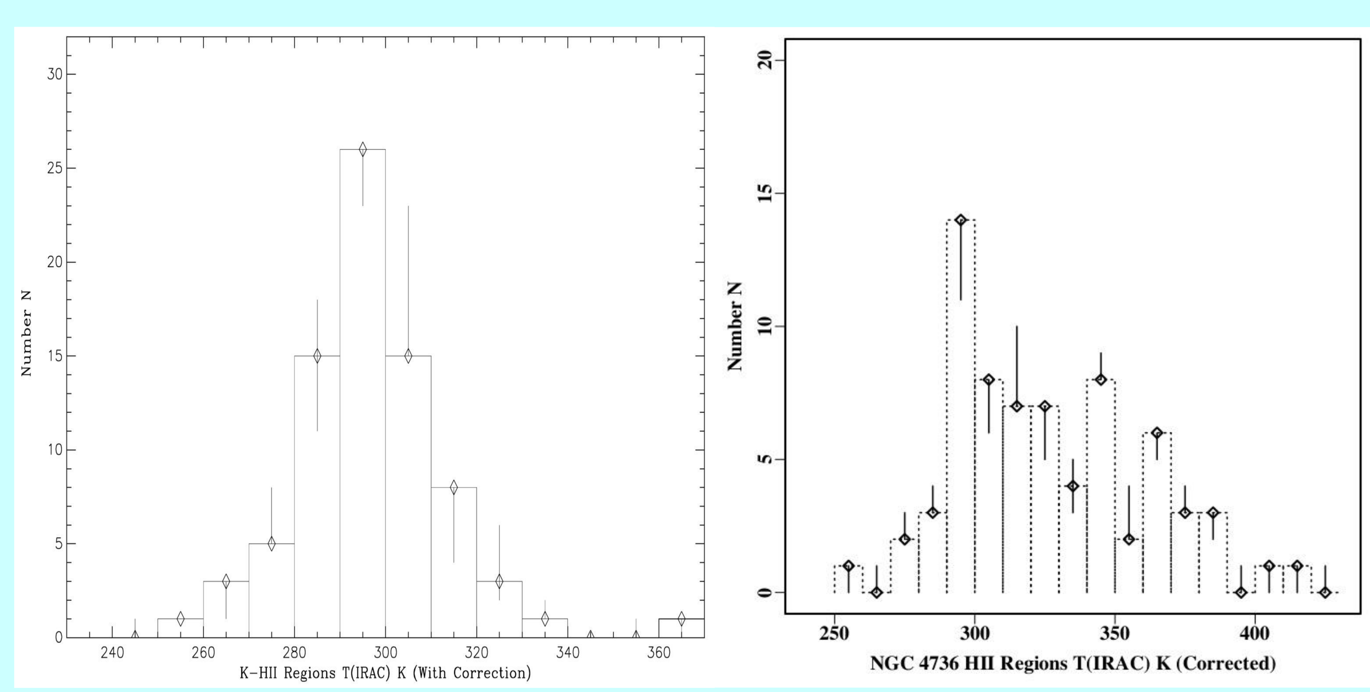


Figure 5 (above): Histogram of the colour temperatures for 78 HII regions in M100 (Left) and 76 regions in NGC 4736 (Right) measured respectively.

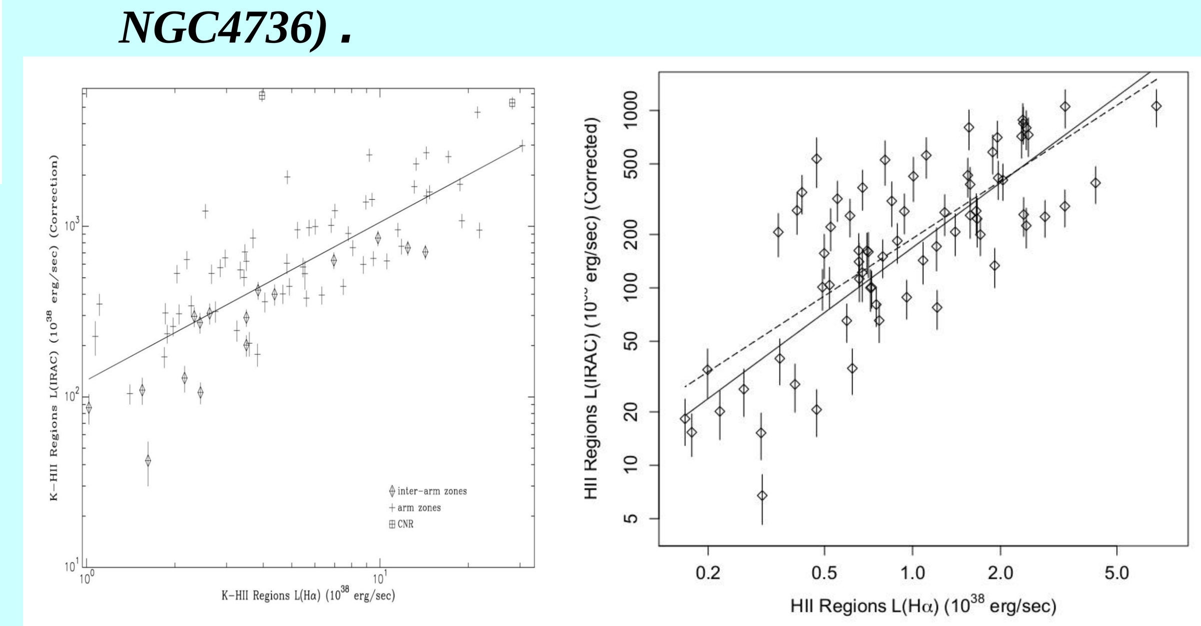
• We can see that the mode value is just over 300K, with a range from 265K to ~400 K, surprisingly restricted, given the wide range of luminosities of the regions.

• Figure 5 (Right for NGC4736) barely shows the skewed shape toward the right side. However, Figure 5 (Left for M100) only shows there may be a interesting tail towards to right side. It raises an issue in general regarding the decision for *outliers or "undiscovered" cases.*

(C)tiny stochastically heated grain model:
We may be observing stochastically heated nano-sized dust grains so that their "temperatures" are independent of the illuminating field. The heating mechanism for small grains is stochastic heating, in which a grain is heated by absorption of a single photon. This form of heating implies that the temperatures of the grains do not respond in the same way as they would if they were in thermodynamic equilibrium, so that their mean temperature does not depend on the luminosities of the stars supplying the photons, and depends only slightly on the temperatures of those stars.

Hα vs. IR LUMINOSITY

Figure 6 (below): The integrated IR luminosities of the HII regions (Left for M100,; Right for NGC 4736) plotted against their Hα luminosities. We use statistical fluctuation weight for the linear fitting (solid line). We also show a dashed line (by using uniform weighting) in the figure (Left for NGC4736) .



▪We can see a strong correlation. Figure 6 (Left for M100) also shows that the correlation does not depend on whether a region is in an arm or in the interarm zone.
▪The slope of the graph is unity within the measurement errors, i.e., L(IRAC) vs. L(Hα) (with a measured offset in the relation).
▪Either of these luminosities could be used as a proxy for the other when estimating star formation rates.

REFERENCES

Bradley, T., Knapen, J.H., Beckman, J.E., Folkes, S.L., 2006, A&A, Letters, 459, L13
Chan, S.J., Beckman, J.E.: 2013: A&A, 553, A54
Draine, B.T. & Li, A., 2007, ApJ, 657, 810
Kennicutt, R.C., Jr., Edgar, B.K., Hodge, P.W., 1989, ApJ. 337, 761
Knapen, J.H., 1998, MNRAS, 297, 255 (SIMBAD online catalogue, J/MNRAS/287/255/catalog)
Knapen, J.H., Stedman, S., Bramich, D.M., Folkes, S.L, Bradley, T.R., 2004, A&A, 426, 1135

SUMMARY

- ***The origin of the emission in the 3.6 μm and in the other IRAC bands is different. We suggest that the 3.6 μm excess is mainly due to the PAH C-H stretching feature (PAHs with N_c < 50 carbon atoms. (see Fig. 6 in Draine & Li 2007).***
- ***By using a chi-squared fitting technique, we estimate IRAC 3-band colour temperatures from around 250 K up to around 400 K.***
- ***There is a strong correlation between the L(Hα) and L(IRAC) of the selected HII regions (see Figure 6). We propose that this strong correlation be used for studying star formation rate issues. Calibrating this relation and combining the IRAC luminosity with the mid-IR luminosity should allow a practical derivation of the star formation rates without direct recourse to Hα observations.***
- ***It is notable that the IRAC 3-band colour temperature shows no significant dependence on the HII region luminosity. Three main possible scenarios have been proposed : dust destruction model, stellar-wind model and tiny stochastically heated grains model.***