HAWK-I IR SN SEARCH IN STARBURST GALAXIES

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A- Abstract

The high FIR luminosity of SB galaxies is a direct measure of their SFR and implies a high SN rate. This seems in contradiction with the fact that very few SNe have been discovered in SB galaxies. This is due to several factors, mainly extinction, low statistic or small depth of previous SN searches.

Early attempts of NIR searches (e.g Mannucci et al 2003, Mattila et al 2007), where extinction is strongly reduced, show no evidence of enhanced SN rate in SB. For this reason we started a new search to measure the SN rate using HAWKI@VLT. We found four cases with spectroscopic confirmation. This is fully consistent with the expected number of detectable events (5.2+/- 2.3), estimated on the basis of the ongoing SFR (from LFIR), the standard supernova scenarios and the detection limit of our IR search. The conclusion is that we do not confirm the evidence of a peculiar ratios LFIR/SFR/SN rate in SB galaxies.

B- The Galaxy sample

From the IRAS Revised Bright Galaxy Sample we selected a sample of 30 SB galaxies with z<0.07, FIR luminosity log(L_{FIR})>10.8 and visible at ESO in the semester from April to October. The FIR luminosity of galaxies of our sample is about 10 times the B luminosity (Fig.1, right).

Most of the galaxies in the sample are isolated but some are interacting or contain double nuclei.

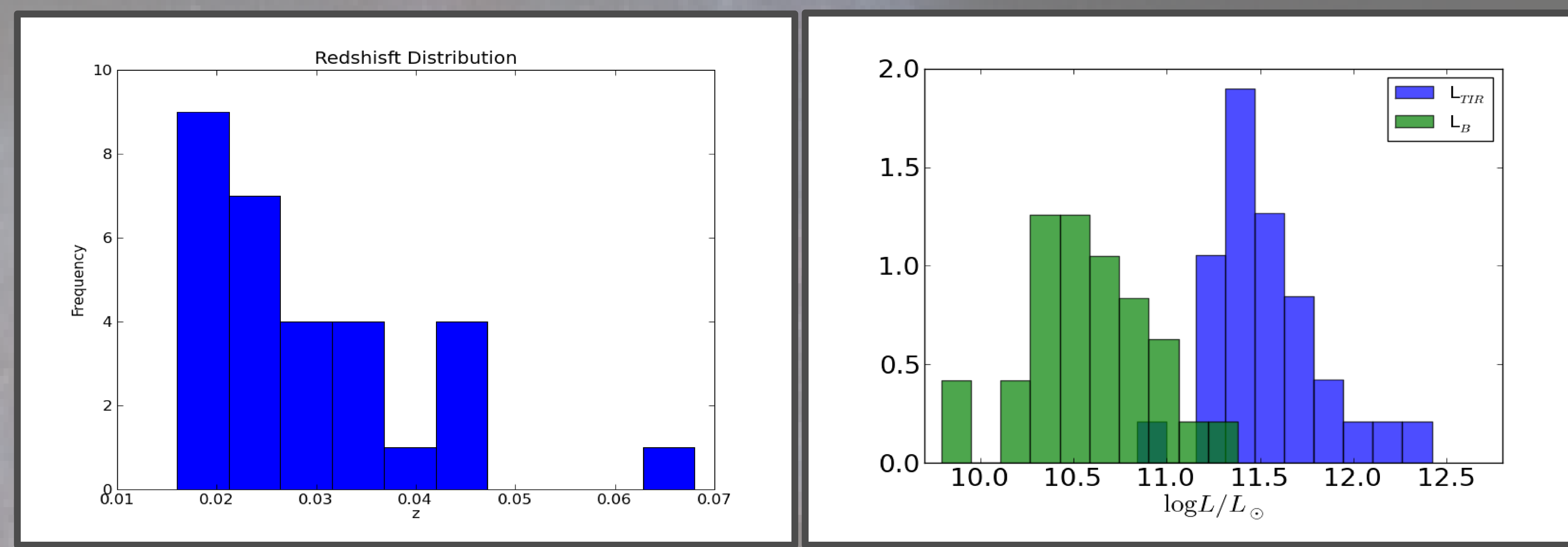

Fig.1: Redshift distribution (left) and comparison between B and FIR luminosity (right) of the galaxy sample

C- Search strategy

The SN search is performed in K band, where the extinction is strongly reduced compared to optical band, using HAWK-I@VLT. Given that the SN infrared light curves evolve relatively slowly, we do not need frequent visits: assuming an average of 3 visits per galaxy, per semester we planned for 100 visits per observing period. To reach a good S/N we estimated 25 mins per visit making a total request of 42h per period. Our search is well suited as a filler for the gaps in the scheduling of service observing and/or for non-optimal sky conditions, poor seeing or non-photometric conditions. Despite this lack of restrictions, little over 10% of images have seeing>1". The program has been allocated in three periods with The following completness: P83 100%, P85 70%, P87 70%. Spectroscopic confirmation of SN candidates was obtained with ISAAC@VLT (P83) and X-Shooter@VLT (P85/87) in ToO/GTO mode.

Data reduction is performed integrating EsoRex (the ESO Recipe Execution Tool) with custom programs. The search was performed on the difference betweene images taken at different epochs after image difference PSF match (ISIS).

D- SN sample

During the period 83 we have found 3 candidates but but none of them turned out to be a SN.

During the periods 85-87 we have found 6 SN candidates (5 CC SNe and 1 type Ia SN). The improved efficiency was be partly due to a better image quality which resulted from an improved dithering strategy. In two cases we obtained the discovery image (SN 2010hp, CBET2446 and 2011ee, CBET2773). For two other SNe the spectroscopic classification was obtained by other groups. Two candidates were two faint for spectroscpic observations and confirmation was based on analysis of multicolor photometry.

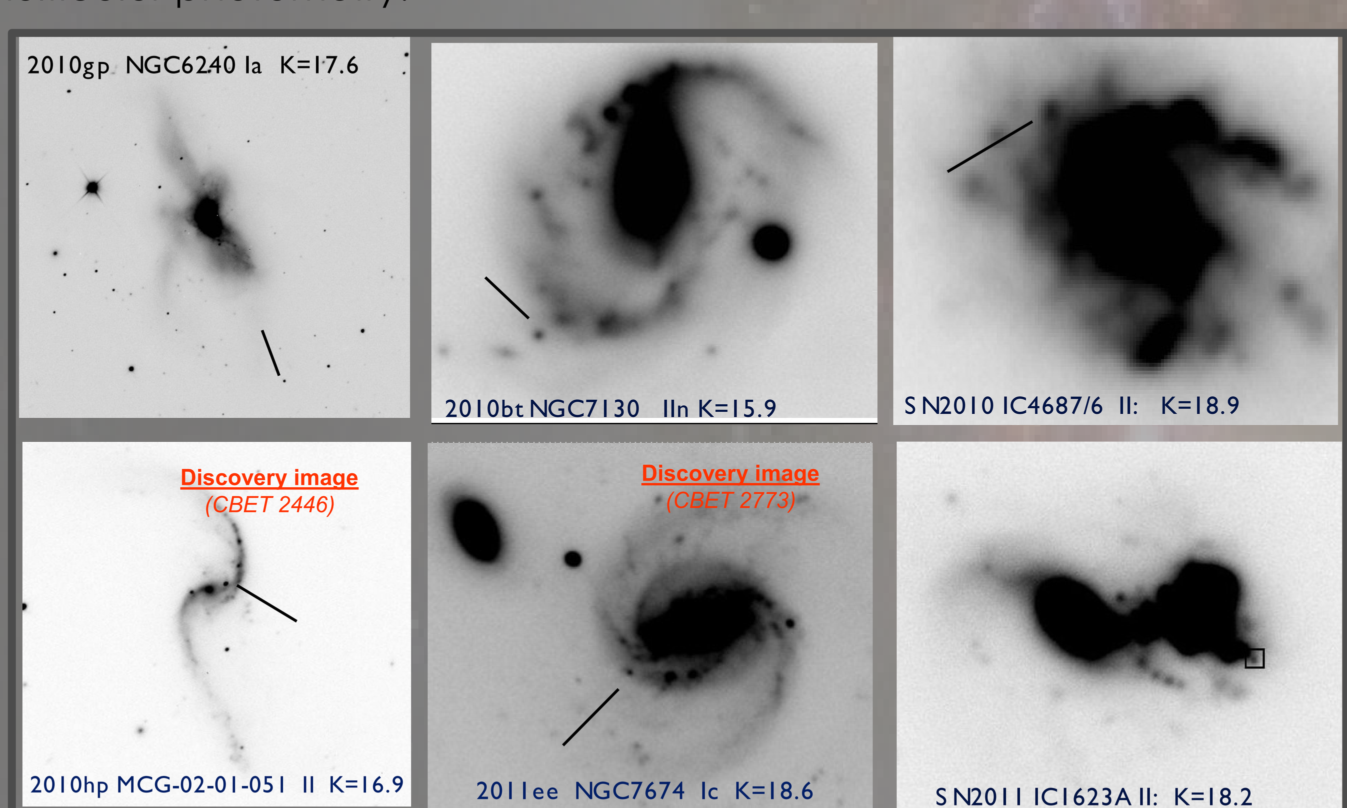

Fig.2: SNe discovered in our search.

E- Detection efficiency

Estimating the SN rate requires accurate estimate of the detection efficiency of the search. The magnitude limit of the SN detection For each of the difference image has been estimated through artificial star experiments. This was found to depend on the quality of the subtracted images (mainly on seeing) together with the detailed technique used to extract the signal (SNe candidates) from the background (cosmic rays, bad subtractions, etc). In addition, there is a strong dependence on position inside the host galaxy. The artificial star experiment proceeded as follows. For every epoch simulated supernovae were added to the search images as stellar sources with the appropriate point-spread-function. The subtracted images were processed with the same pipeline used for the supernova search. This allows us to measure detection efficiencies as a function of supernovae magnitude and supernova position inside the galaxy for all individual pbserving epochs.

As seen in Fig. 4 the detection efficiency strongly depends on seeing, in particular in the enuclear region, where the magnitude limit is lower.

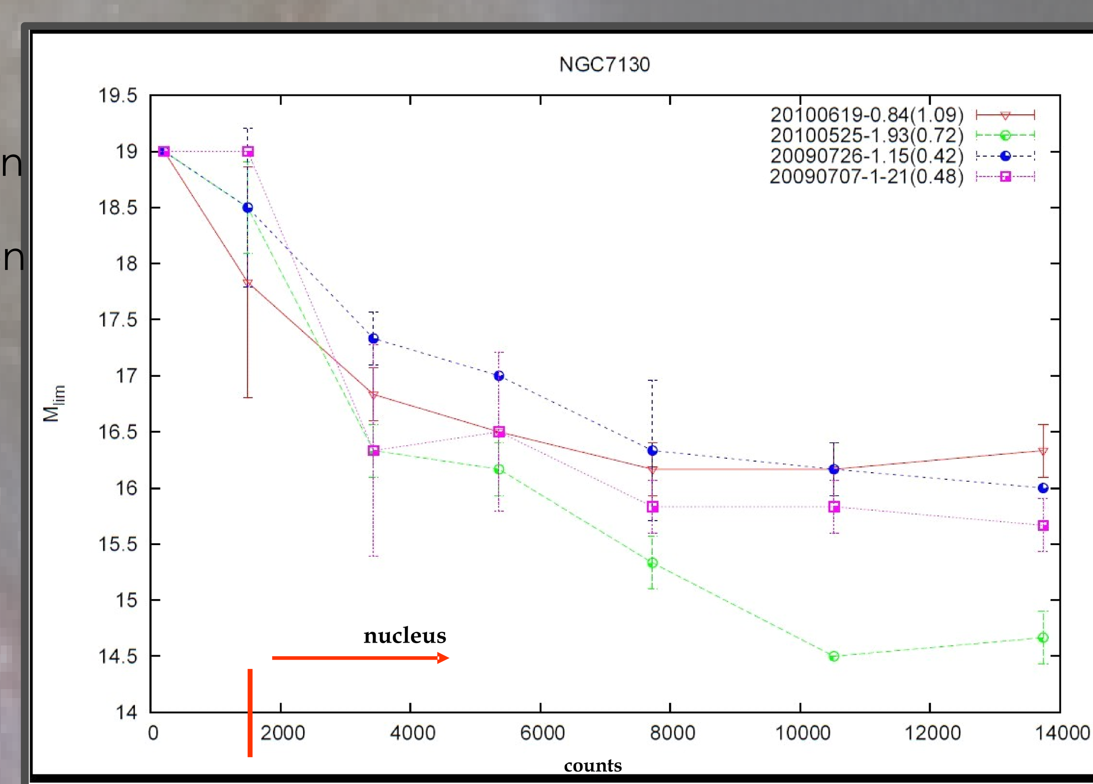

Fig.4: Plot of Mag. Limit vs counts. The magnitude limit for epochs with worst seeing is lower in particular in the nuclear region.

F- Estimate of the SN rate

Through MonteCarlo simulations we estimated the expected SN rate, based on specific assumptions, in order to obtain a comparison with the observed rate.

The main inputs in these simulations are:

- log of observations, the sample galaxy catalog and the limiting magnitude of the search for each observation
- the SFR based on L_{FIR}, the latter from IRAS fluxes (Dale et al. 2001)
- the number of SNe expected from a given star formation episode. For core collapse SNe this is determined only by the adopted mass range of the progenitors (8-50 $M_\odot$). For type Ia we need to consider the realization factor, that is the fraction of events in the proper mass range which occurs in suitable close binary systems.
- extinction is assumed to scale with SFR. This is scaled starting form a maximum extinction value in the nucleus that, for the reference case, is assumed A_V (*max*) = 30 mag (cf. Arp 220, Shioya et al, 2001)
- the adopted star formation spatial distribution inside the parent galaxies, assumed to be distribuited as to L_K : $SFR \propto L_K^{\alpha}$, where a is 1.0, 1.25, 1.5, 2.0 for single galaxies, pairs, close pairs or mergers.

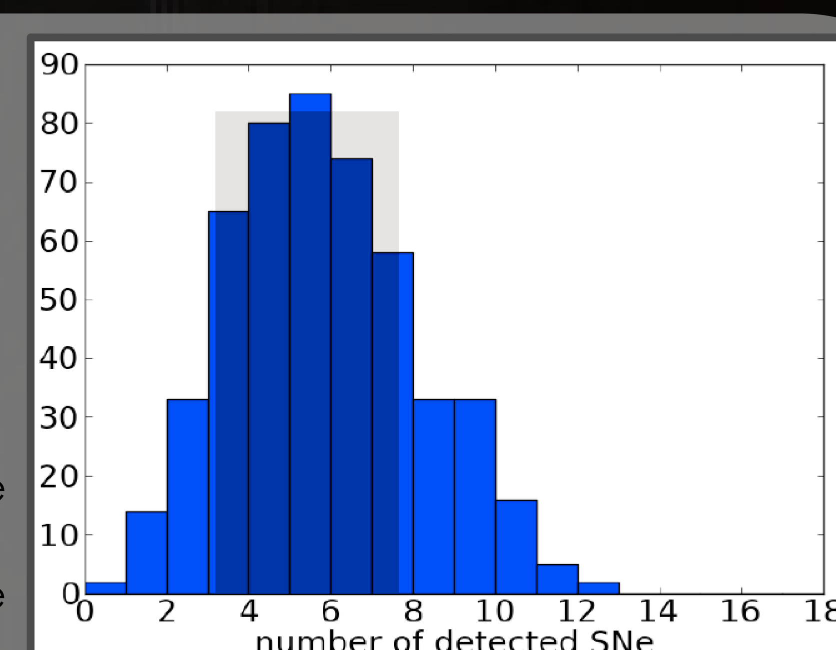

Fig. 5: Histogram of the number of detected SNe. In grey, we evidence the area of the histogram within ±1σ from the average.

Based on the analisys of 500 MonteCarlo simulation we estimated, on average, the discovery of 5.4±2.3 SNe in our search, of which 5.2±2.3 core collapse and 0.2±0.2Ia. The expected number compares very well with the observed number. Indeed we found that the expected number of SNe is ≤ 6 in 55% of the experiments (fig.5). Even if we conservatively consider only the SNe with spectroscopic classification (4) chance of occurrence is significant (22%). As a consistency check we verified that also the expected K magnitude distribution and the predicted extinction distribution compares very well with observations (fig. 6).

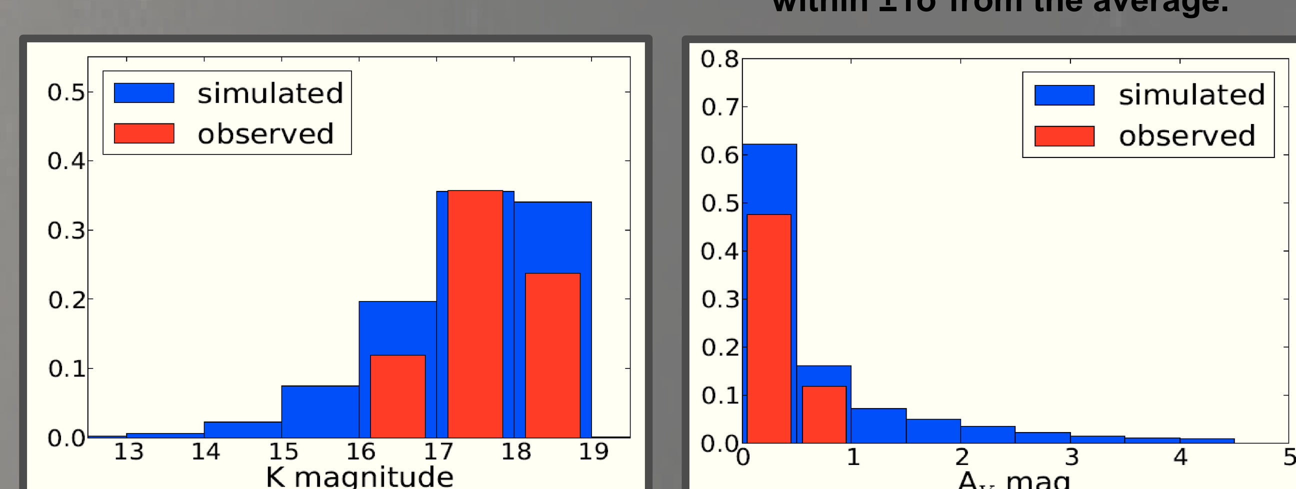

Fig. 6: Comparison between expected and observed K magnitude distribution (*left*) and extinction distribution (*right*).

G- Conclusions

The *main* result of our analysis is that the number of observed SNe is *consistent* with the expectations, *not* confirming results of previous infrared SN search that detected a number of events much smaller than expected. The comparison of predicted and observed K magnitude extinction distribution shows that even in our K-band search we expected to find mainly low extinction events. The emphasis of our approach was on the *accurate estimate of the detection efficiency* as a function of the SN position in the host galaxy and the determination of the *size* and *distribution* of the star formation for each galaxy of our sample.

To understand how a different choice of the tests parameters can influence the expected rate, we varied each of them and compute the rate repeating the MonteCarlo simulation.

Based on the different simulation tests, we also conclude that about 60% of the events remain hidden in the nuclear regions due to a combination of high extinction and reduced detection efficiency, the latter having greater influence on the value of the expected rate. This confirms that it is crucial to obtain the best possible estimate of the magnitude limit in particular in the nuclear region where the magnitude limit is lower.

We also tested the choice of different IMF and variable core collapse progenitor mass range. It turned out that the IMF shape has *little* effect on the predicted SNR. Varying the upper or the lower limit of the range we confirmed that the rate is *quite insensitive to the upper mass limit* for M>50$M_\odot$ while most important is instead the *great dependence* on the lower cut off mass, the productivity decreasing by a factor of ≈ 0.7 if M_{CCJ} goes from 8 to 10 $M_\odot$ for a Salpeter IMF.

References

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