poral behaviour (Fig. 7). First of all we note that the knot is indeed present in all frames. It thus appears quasi-stationary for more than six years, although the position appears to vary at the 0.1 arcsecond level. The de-reddened flux of the knot (Fig. 4) is measured to be 9 × 10^{-28} ergs s^{-1} cm^{-2} Hz^{-1} but variations of the flux by at least 50% are observed.

4. Discussion and Implications

For the pulsar itself we have added new information in the IR. Together with the optical-UV data in Sollerman et al. (2000) this significantly revises the observational basis for the pulsar emission mechanism. In fact, most of the theoretical efforts have been based on the old optical data from Oke (1969) and the IR continuation of Middleditch, Pennypacker & Burns (1983). Our new results call for a fresh look on the emission mechanism scenarios for young pulsars.

For the knot, we have shown that the structure is indeed quasi-stationary, and that the emission has a red spectrum. Few models are available for the knot. Lou (1998) presented a formation scenario in terms of MHD theory, while Shapakidze & Machabeli (1999) argue for a plasma mechanism. None of these scenarios predict a very red spectral distribution.

Another area where caution may be required is in the recent claims of weak and red off-pulse emission from the Crab pulsar in the visible (Golden, Shearer & Beskin 1999). It is clear that the knot close to the pulsar has to be seriously considered in these kinds of studies.

5. Future Plans

The Crab pulsar and its environment continue to be the prime astrophysical laboratory for the study of the pulsar emission mechanism and the spin-down powering of pulsar nebulae. Although much observational effort has been put into this object, a modern re-investigation is likely to clean up the many contradictory measurements. Optical imaging in good seeing would require only a few minutes with the VLT, and would directly determine the knot-subtracted spectral energy distribution. ISAAC in the LW range can in less than 3 hours clarify if the knot is significantly contributing to the emission at these frequencies, and would establish if the IR drop of the pulsar is real.

Most interesting is the possibility to monitor the very central parts of the pulsar environment with NAOS/CONICA. With a resolution superseding HST we will be able to monitor the structures close to the pulsar, with 2 pixels corresponding to merely 50 AU. This would provide an unique opportunity to study the structure and dynamics of the inner pulsar wind and its interaction with the surroundings.

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SOFI Discovers a Dust Enshrouded Supernova

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1. An IR Search for SN

Luminous Infrared Galaxies (LIRGs) are characterised by luminosities larger than 10^{11} $L_\odot$ mostly emitted in the far-IR spectral range. Since the discovery of a handful of these objects by Rieke & Low (1972), and afterward the extensive list produced by IRAS, the source of energy of the LIRGs phenomenon has been matter of debate. The radiation observed is mostly thermal emission by dust heated by some primary source. Dust extinction in LIRGs can exceed several magnitudes in the optical and this makes any optical study more difficult than in normal galaxies. Recent IR observations, mostly by ISO, allowed to shed new light on the problem and to identify the starburst (SB) activity as the main source of energy for most LIRGs (Genzel et al. 1998). However, the presence of obscured AGNs, which are elusive in the optical, has also been identified in a few cases raising again the issue on the relative contribution of active nuclei to the bolometric luminosity. Yet, if most of the lumi-

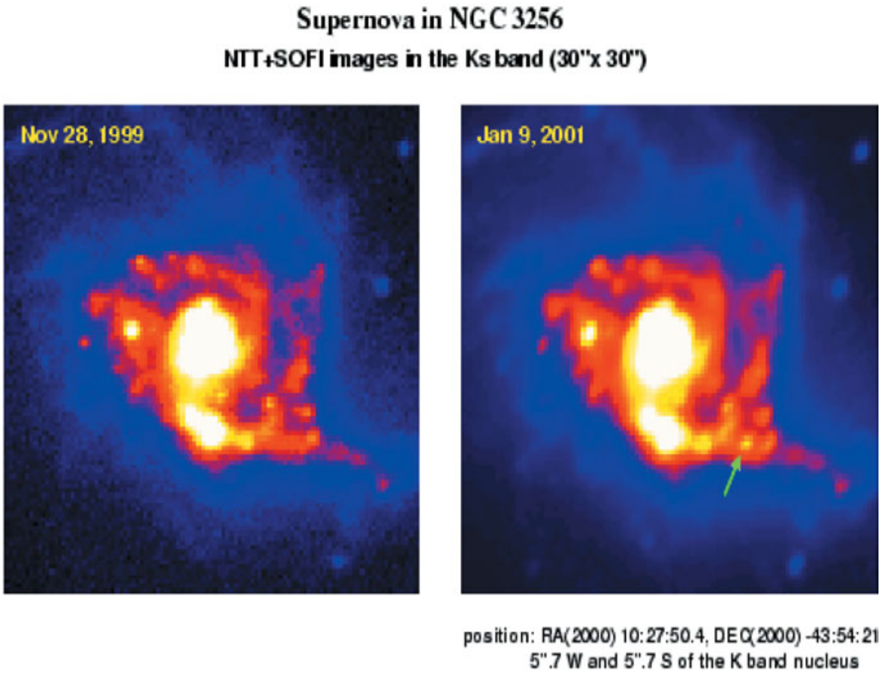

Figure 1: SN2001db is detected in the Ks image of NGC 3256 observed on January 9, 2001 with SOFI (right) when compared with an archival image (left).

nosity is powered by star formation, the SN rate should consequently be higher than in normal galaxies. Therefore measuring the SN rate in LIRGs is an indirect way to measure the star-formation rate.

Optical searches for SNe in standard starburst galaxies however failed in detecting the expected enhanced SN rate. This is most likely due to the large amount of extinction affecting these galaxies. A way around the problem is to observe in the near-IR where the dust optical depth is a factor of 10 lower than in the visible. The first attempts in this direction, however, have not been very promising (van Buren & Norman 1989, van Buren et al. 1994). LIRGs are an optimal sample for this kind of observations; in fact their huge luminosity requires star-formation rates up to a few 100 $M_\odot$ yr^{-1} and, consequently, a supernova rate up to a few SNe per year.

We started a monitoring campaign in the K (2.1μm) near-IR band of a sample of 35 LIRGs aimed at detecting obscured SNe. The survey started in late 1999 (not continuously) and carried on with the ESO NTT, the TNG (Galileo National Telescope) and the Kuiper/Steward Telescopes.

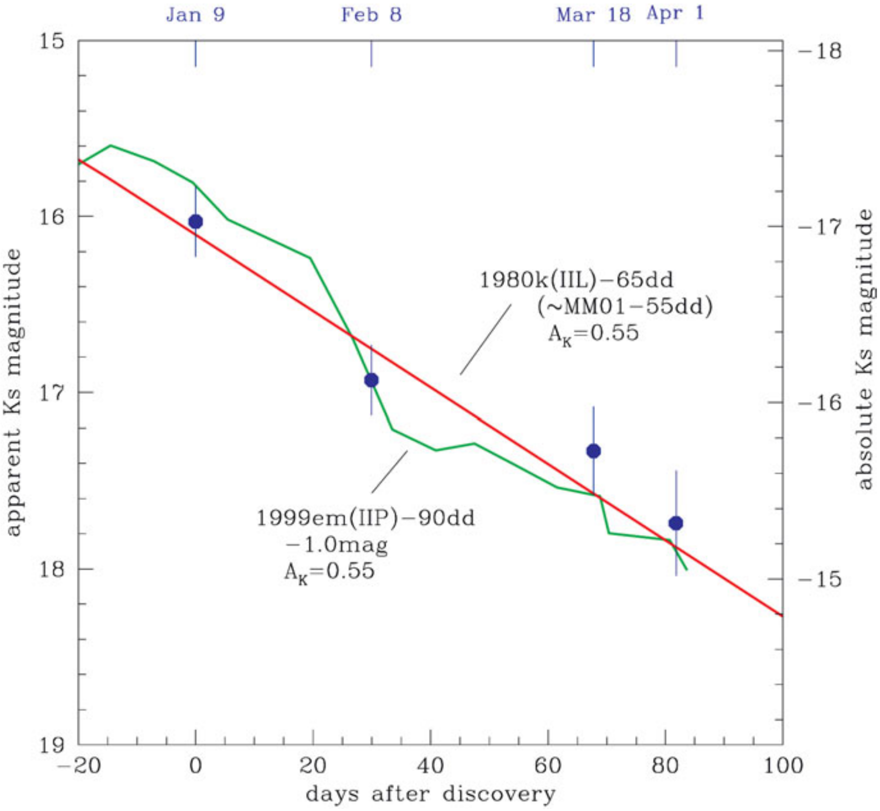

Figure 2: Ks light-curve of SN2001db (blue points) compared with template curves from the literature.

2. First Success with SOFI – SN2001db

A southern sample of galaxies was observed with SOFI at the NTT during period 66. A total of 6 nights, about one month apart from each other, were allocated. Images were obtained in the Ks filter using a total integration time on source of about 30 minutes per object. The data were reduced using the ESO Eclipse package and then compared with each other and with archival images.

The LIRG NGC 3256 was observed for the first time on January 9, 2001, and subsequently on February 8, March 18 and April 1. SN2001db was detected on the first image, after comparison with the following ones, at coordinates R.A.(J2000) = 10^{h}27^{m}50^s.4, Dec.(J2000) = –43 54′ 21″, 5″.7 to the West and 5″.7 to the South of the Ks nucleus. The Ks magnitude of the SN in the image of January is 16.03. In Figure 1 we show the archival SOFI image of NGC3256 (left) and the first image obtained in 2001 (right) where SN2001db has been detected.

In Figure 2 the infrared light-curve of SN2001db is compared with those of SN1980k and SN1999em taken as representative of type IIL and type IIP, respectively (data from Dwek 1983, Barbon et al. 1982, Hamuy et al. 2001). The light-curve has been extinguished by an A_K = 0.55 (see next section). The infrared observations can be roughly fit both with the light-curve of SN1980k offset by 65 days, and with the light-curve of the SN1999em offset by 90 days and 1.0 mag. The average K-band light-curve for type II SNe obtained by Mattila & Meikle (2001) is nearly identical to the SN1980k light-curve in Figure 2, but offset by 55 days. We estimate that the V-band magnitude of the SN was most likely fainter than 20 at its maximum and, therefore, it would have been missed by most of the optical SN search programmes.

After this discovery we immediately applied for Director Discretionary Time to spectroscopically confirm our finding at the VLT. An optical spectrum was obtained on May 16, 2001, with FORS1 at the ESO VLT-UT1 using grism GRIS_300V and 1″ slit yielding a spectral resolution of 500. The total integration time was 15 minutes. Most of the

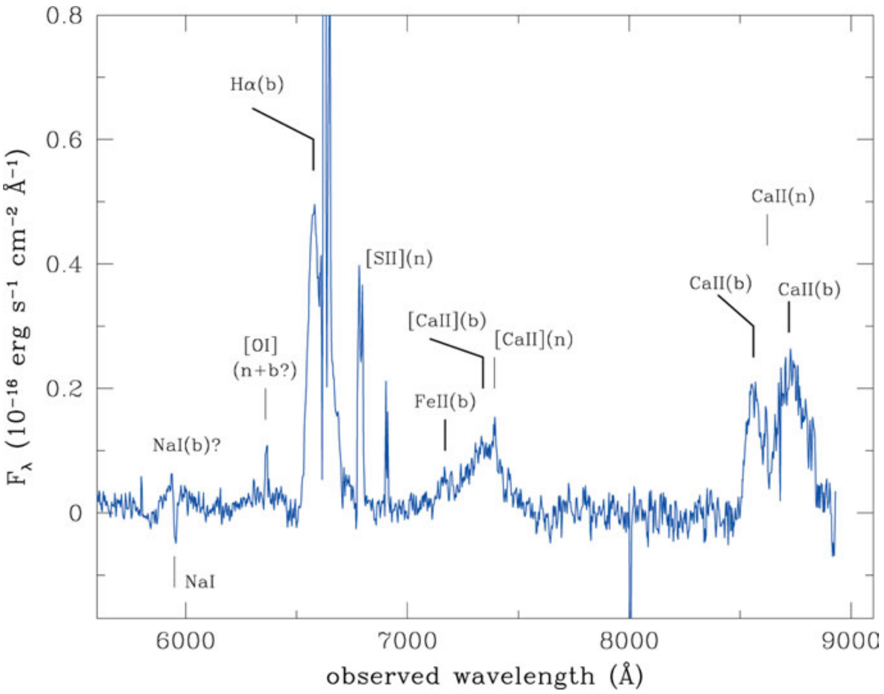

Figure 3: Optical spectrum of SN2001db observed with FORS1.

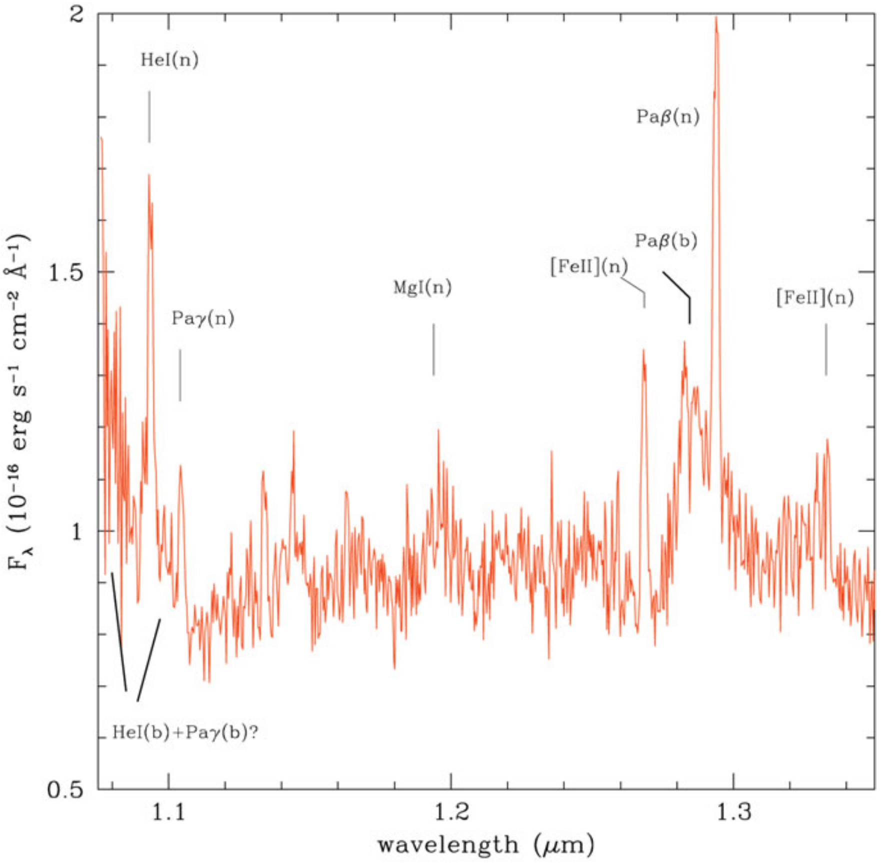

Figure 4: Near-Infrared spectrum of SN2001db observed with ISAAC.

emission lines detected are due to H II regions or SN remnants (see next paragraph) while the continuum is due to the background emission of the galaxy, however, the spectrum shows a clear broad component of Hα which is a clear signature of a type II SN. Hα has an asymmetric profile with a peak blueshifted by about 2000 km/s with respect to the parent galaxy. The FWHM is ~ 5000 km/s. Broad emissions at 7324Å and 8542Å–8662Å due to Ca II respectively are detected. In Figure 3 we show the optical spectrum subtracted of the underlying background. At the same redshift of the peak of the broad Hα we detect a Fe II 7155Å line. Finally the spectrum shows indications for two broad emission features at 5893Å (Na I) and 6300Å ([O I]).

A near-IR spectrum was obtained in the J band with ISAAC at the ESO VLT-UT1 on April 21, 2001 with a slit of 1 arcsec and the low resolution grating set at the 4th order, yielding a spectral resolution of 500. The total integration time was 45 minutes. The spectrum is shown in Figure 4. The broad component of Paγ is more prominent with respect to Hα and the profiles are almost identical. There are indications of a broad component of Paγ and He I 1.0083μm as well. It is worth noting that the strong [Fe II] emission relative to Pap (narrow) indicates that the underlying emission is not simply due to H II regions, but must be contributed significantly by SN remnants. No conclusive results on the SN sub-type (IIL vs. IIP) can be driven from the spectroscopic data.

3. Extinction

Extinction can be measured by using different methods. The ratio between the narrow components of Hα and Hβ is 12.0 which, for a Galactic extinction curve, gives an equivalent screen extinction A_V = 4.2 mag, or higher if assuming a mixed case. The Na I interstellar absorption doublet at ~ 5890Å has an equivalent width of 5.87Å that according to the relations of Barbon et al. (1990) implies an equivalent screen extinction $A_V \geq 3.0$–4.9 mag. To use the ratio of the broad components of Paβ and Hα to directly constrain the reddening of the SN requires the assumption that during the 25 days elapsed between the infrared and the optical spectrum the line flux has not changed significantly (e.g. Danziger et al. 1991). If this is true the observed ratio between the broad components is 1.73 which implies an extinction of A_V = 6.7 mag. for the case B theoretical ratio. There are, however, indications that a ratio higher than case B is more appropriate in SNe (Fassia et al. 2000, Xu et al. 1992) this would give A_V = 5.3 mag. In the case of variation of the emission line flux between the two observations, conservative estimates give a lower limit on the extinction of $A_V > 4.6$ mag. We assume $A_V \approx 5.6$ mag, with an uncertainty of about 1 mag.

SNe discovered in the optical are much less extinguished. In the compilations given by Schmidt et al. (1994) and by Mattila & Meikle (2001) the optical extinction is generally lower than $A_V <$ 1.5 mag, as shown in Figure 5 where the distribution of extinction for optically discovered SNe is reported. If these compilations are representative, then the extinction inferred for the IR SN2001db is probably the highest among the SNe so far discovered.

4. The IR SN Rate

So far, our programme has detected 4 SNe: two of them were detected also in the optical (SN1999gd and SN 2000gb); another SN (1999gw) was discovered at the TNG, but we could not obtain a spectroscopic identification; the fourth one is SN2001db discussed in this paper. The number of SN events found can be compared with the expected detection rate in the LIRGs of our sample. Assuming the conversion from blue luminosity to SN rate (all types) given in Cappellaro et al. (1999), i.e. SNr $\simeq 10^{-12}$ $(L_B/L_\odot)$ yr^{-1}, we would have expected to detect ~ 0.5 SNe. Since we have detected 4 SNe, we roughly infer a SN rate about an order of magnitude higher than estimated by the conversion inferred by optical surveys. This is quite different from the number of SNe expected from the far-IR luminosity. If most of the far-IR luminosity is due to star formation and we

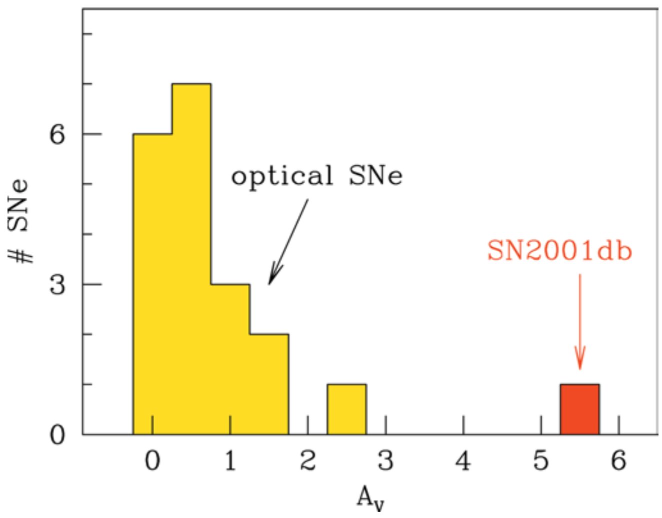

Figure 5: Distribution of the extinction for optically discovered SNe.

adopt the conversion from L_{FIR} to the SN rate given in Mattila & Meikle (2001), i.e. SNr $\simeq 2.7 \times 10^{-12}$ (LFIR/$L_{\odot}$) yr^{-1}, we find that our survey has missed about 80% of the expected SNe. This can be explained if most of the SNe are so embedded in dust that they are significantly obscured even in the near-IR or, alternatively, obscured AGNs may contribute substantially (~ 80%) to the far-IR luminosity of these galaxies. Finally, there is growing evidence that most of the starburst activity is located in the nuclear region (Soifer et al. 2001). If most SNe occur in the nucleus (i.e. within the central 2″), then our limited angular resolution would have prevented us to disentangle them from the peaked nuclear surface brightness of the host galaxies.

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A Deep Look at an Active Galaxy

The image below shows the peculiar edge-on spiral galaxy NGC 3628. It is situated in the constellation Leo and forms a famous triplet of galaxies together with M65 and M66, also known as the Leo Triplet. Its distance is 35 million light-years/11 Mpc.

NGC 3628 is interesting in several respects: although classified as a spiral