existence of IPMOs? Is there any scenario that could explain qualitatively and quantitatively the observational features? Are IPMOs the result of direct collapse and fragmentation of clouds? These questions will also be addressed by the JOVIAN project using the first light instruments of the Gran Telescopio Canarias.

Members of the JOVIAN project at Instituto de Astrofísica de Canarias: R. Rebolo, E. Martín, V. J. S. Béjar, J. A. Caballero, G. Bihain and J. Licandro (also at ING); LAEFF/INTA: M. R. Zapatero Osorio and D. Barrado y Navascués; Universidad Politécnica de Cartagena: A. Díaz, A. Pérez and I. Villo; Max-Planck-Institut für Astronomie: C. Bailer-Jones and R. Mundt; Thüringer Landessternwarte Tautenburg: J. Eisloeffel.

More information on JOVIAN can be found at `http://www.iac.es/project/jovian/`. ¤

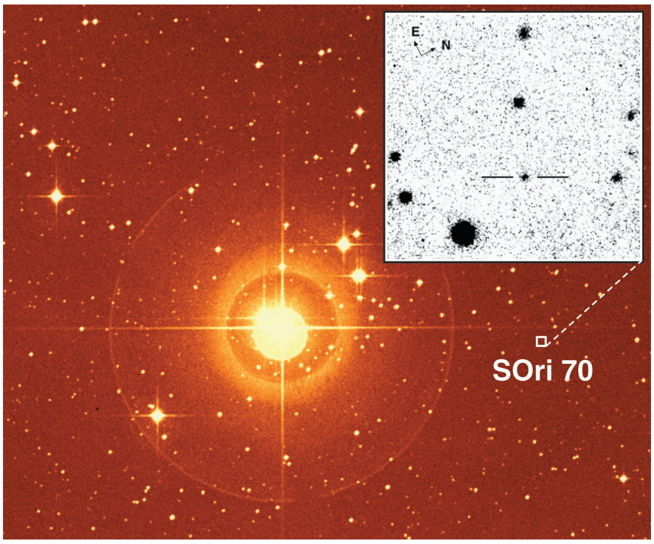

Figure 5. Near-infrared image of S Ori 70 (marked with two lines), overimposed onto a Digitised Sky Survey image centred in the multiple stellar system σ Orionis, that gives the name to the cluster. The mass of S Ori 70 is calculated to be in the range 2 to 8 Jupiter masses.

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LIRIS Observations of SN 2004ao

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The knowledge of the properties of supernovae (SNe) at optical wavelengths has experienced enormous progress in the current decade. In contrast, comparatively little is known about the SN behaviour in the near-infrared (NIR) window. Such a knowledge would give us relevant clues to key questions related to the nature of SN progenitors and to the interaction with SN environments. Hence, programs for NIR spectrophotometry of SNe of all supernova types are clearly useful, and the Long-Slit Intermediate Resolution Infrared Spectrograph (LIRIS) could be a good choice (see Acosta-Pulido et al., 2002, 2003, for more details on the instrument).

Currently, the most widely accepted scenario to explain the SN types Ib and Ic involves the core-collapse of a hydrogen-naked massive star. However, it is still a matter of debate whether these two SN types (Ib and Ic) constitute two completely separate classes of events, produced by different classes of progenitors or, on the contrary, both SN types correspond to variations within a more or less continuous sequence of core-collapse SNe (Matheson et al., 2001; Hamuy et al., 2002). It should be emphasised that the main distinguishing difference between the Type Ib and the Type Ic SNe is based on the strength of their optical HeI lines: these lines are clearly present in the SNe Ib optical spectra, whereas these lines appear weak, or even are absent in Type Ic SN optical spectra.

The He abundance in Type Ib/c SN atmospheres is critical for deciding between alternative progenitor models. It should be noted that the HeI λ10830 line is strong even in the case of weak HeI lines at optical wavelengths (Jeffery et al., 1991). Thus, this NIR HeI line is a more sensitive tracer of small amounts of He (Wheeler et al., 1993). In this sense, NIR spectra of SN types Ib and Ic could be a very useful tool to better establish the He abundances in these objects.

SN 2004ao, in UGC 10862, was discovered on March 7.54 (Singer & Li, 2004). The supernova lies close to the southern arm of its host galaxy. From an optical spectrum obtained on March 14.53 the supernova was classified as a Type Ib approximately one week after maximum (Matheson, Challis & Kirshner, 2004). SN 2004ao was fairly bright at the date of its discovery (V~15; Singer & Li, 2004), thus we decided that this target could be appropriate to get useful results with the scheduled LIRIS configuration without a high cost in observing time. Here we present the first NIR observations of Type Ib SN 2004ao, that we performed as a test of the LIRIS capabilities for SN spectrophotometry in the NIR window.

Results

On June 8.1 UT, (~three months after discovery), we used LIRIS on the WHT to obtain a 24-second exposure through the *J* filter of the SN 2004ao field and a *ZJ* spectrum (range 0.89–1.53 µm, $\Re$~700) of the supernova.

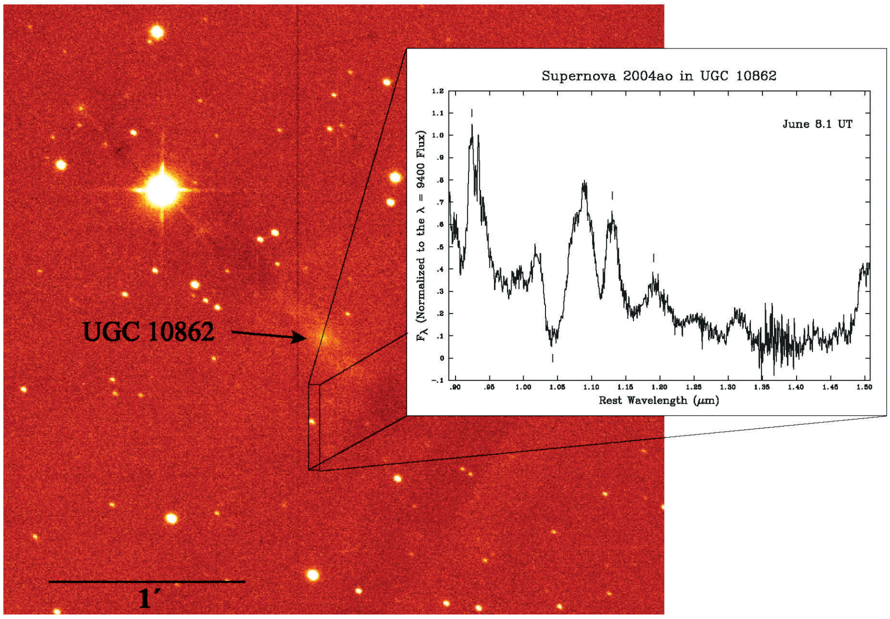

Figure 1. J-band image (left) and NIR spectrum (right) of SN 2004ao, obtained on 8 June, 2004 (t~+90 days) with LIRIS on the WHT. The nucleus of the host galaxy UGC 10862 is visible to the northwest of the supernova. The slit position has been marked with a box enclosing the supernova. North is to the top and East is to the left. On the spectrum, the main features referred in the text have been marked with a vertical line.

SN 2004ao is quite a bright supernova. The object was clearly detected in the *J*-band image (Figure 1) at the date of the run, three months after its discovery. A magnitude of *J*~16.6 was derived from differential photometry using three field stars. A plot of the SN 2004ao spectrum (1200s exposure) is also displayed in Figure 1. The spectrum shows a set of broad emission bands superimposed on a quite flat continuum, indicating that the SN was close to reaching the nebular phase at the date of our observation. Special attention should be paid to the P-Cygni feature, with the absorption at ~1.043 µm, as well as to the emission bands at λλ~0.924, 1.130 and 1.191 µm (all these wavelengths are referred to the host-galaxy rest frame, which corresponds to z=0.0056).

Currently, few NIR spectra of core-collapse SNe are found in the literature. In particular, this fact is more evident for Type Ib SNe at phases older than ~one month after maximum (that would be useful for comparison with our spectrum of SN 2004ao). Thus, as a first step of our study, we have compared the LIRIS SN 2004ao spectrum with the available spectra of core-collapse SNe acquired at nearly similar SN ages. We found that the features detected in our spectrum were also found in the spectra of the peculiar Type Ic SN 1998bw at phase ~+50 days (Patat et al., 2001). In addition, all these features were also detected in the spectra of the Type IIn SN 1998S at phases ~+60 and ~+110 days (Fassia et al., 2001) as well as in those of the Type II SN 1987A at phase ~+110 days (Meikle et al., 1989). In all of these NIR spectra, the He I λ 1.083 µm is identified as the main contributor to the P-Cygni feature, whereas the three emission bands at λλ~0.924, 1.130 and 1.191 µm are attributed, respectively, to O I λ 0.926, O I λ 1.129 + S I λ 1.131 + Na I λ 1.138 and Mg I λ 1.183 + Si II λ 1.205 µm. From the absorption minimum of the He I line, we derived an expansion velocity of ~11,000 km s^{-1} for the ejecta of SN 2004ao. Note that this value is similar to the velocity values derived in other "normal" Type Ib/c SNe (e.g., SN 1990W) from their NIR HeI lines (Wheeler et al., 1994), significantly lower than the velocity derived in "peculiar" hyper-energetic core-collapse SNe (eg., v~13,000–18,000 km s^{-1} in SN 1998bw; Patat et al. 2001). From the spectral data, we suggest that this supernova probably was a "normal" (i.e., non hyper-energetic) Type Ib SN, despite it being a fairly bright object.

The SN 2004ao data recorded in this observing test show the feasibility to undertake programmes of spectrophotometric follow-up of SNe in the NIR window with LIRIS.

We thank all of the LIRIS Team for the acquisition of SN 2004ao spectrum and images during guaranteed time. ¤

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