| r180480 U | | | | | | |
|---|---|---|---|---|---|---|
| Delta RA | Delta Dec | x | y | Magnitude | Magnitude Error | Classification |
| *Arcsec* | *Arcsec* | *Pixels* | *Pixels* | *Mag* | *Mag* | |
| 0.28 | 0.32 | 1452.9 | 2007.6 | 19.876 | 0.013 | Non-stellar |
| **r169604 g** | | | | | | |
| 0.11 | 0.28 | 1461.8 | 1964.3 | 19.439 | 0.003 | Non-stellar |
| **r160072 r** | | | | | | |
| 0.06 | 0.22 | 1516.0 | 1992.3 | 18.916 | 0.003 | Non-stellar |
| **r168795 i** | | | | | | |
| 0.23 | 0.08 | 1447.8 | 1960.8 | 18.237 | 0.003 | Non-stellar |
| **r168385 z** | | | | | | |
| 0.06 | 0.03 | 1458.9 | 1968.9 | 17.802 | 0.004 | Non-stellar |

| 2MASS XSC | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Delta RA | Delta Dec | x | y | J Magnitude | J Magnitude Error | H Magnitude | H Magnitude Error | K Magnitude | K Magnitude Error |
| *Arcsec* | *Arcsec* | *Pixels* | *Pixels* | *Mag* | *Mag* | *Mag* | *Mag* | *Mag* | *Mag* |
| 0.40 | 1.46 | 1446.0 | 1970.0 | 15.209 | 0.093 | 14.639 | 0.148 | 14.472 | 0.178 |

| SWIRE v1.0 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Delta RA | Delta Dec | x | y | flux_36 | flux_48 | flux_58 | flux_80 | flux_24 |
| *Arcsec* | *Arcsec* | *Pixels* | *Pixels* | | | | | |
| 0.45 | 0.22 | 1443.0 | 1967.0 | 571.520 | 376.350 | 254.830 | 1977.420 | 1855.340 |

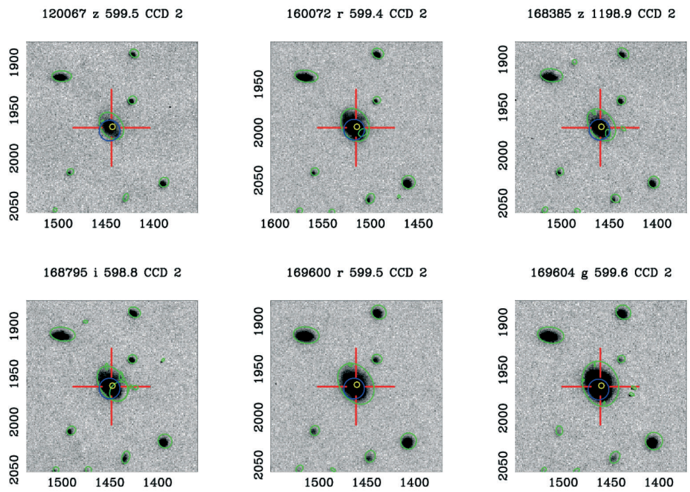


*Figure 6 (left). Example catalogue federation output for one source (display rearranged due to page size limits). Together with the WFS optical magnitudes, also the magnitudes from 2MASS are displayed as the properties from our user supplied catalogue. Figure 7 (right). Example cutouts in different wavebands returned from the DQC query around our selected source with object catalogues overlaid.*

federation with user supplied catalogues as well as image mosaicking and stacking. The INT WFS imaging data has also been used by external programmes. ¤

| Run Number | Centre RA | Centre Dec | Filter | Available | Download Images | Download Object catalogues | Stacking group | Mosaic group |
|---|---|---|---|---|---|---|---|---|
| 120067 | 16:04:26.60 | +54:50:00.01 | z | y | ☑ | ☑ | 1 | 1 |
| 168385 | 16:04:26.60 | +54:49:59.76 | z | y | ☑ | ☑ | 1 | 2 |
| 160072 | 16:04:26.60 | +54:49:59.96 | r | y | ☑ | ☑ | 2 | 3 |
| 169600 | 16:04:26.60 | +54:50:00.14 | r | y | ☑ | ☑ | 2 | 4 |
| 347495 | 16:04:26.60 | +54:50:00.09 | r | y | ☑ | ☑ | 2 | 5 |
| 168795 | 16:04:26.60 | +54:50:00.03 | i | y | ☑ | ☑ | 3 | 6 |
| 169604 | 16:04:26.60 | +54:49:59.94 | g | y | ☑ | ☑ | 4 | 7 |
| 219706 | 16:04:26.60 | +54:49:59.84 | g | y | ☑ | ☑ | 4 | 8 |
| 305239 | 16:04:26.60 | +54:50:00.06 | g | n | | | 4 | 9 |
| 305240 | 16:04:26.60 | +54:49:59.89 | g | n | | | 4 | 10 |
| 180480 | 16:04:26.60 | +54:50:00.01 | U | y | ☑ | ☑ | 5 | 11 |
| | | | | | All | All | | By Filter |

*Figure 8. Data retrieval form. We have selected to retrieve the catalogues from all the images as well as per band stacked images. Note that two of the images and catalogues are not available to the user because they are propietary.*

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# Direct Detection of Giant Exoplanets

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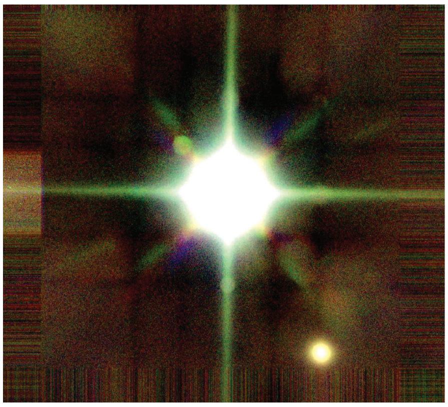
Since the discovery in 1995 of the first extrasolar planet candidate around a solar type star using the radial velocity method (Mayor & Queloz, 1995), to date (beginning of 2005), 135 candidate planets around main sequence stars have been discovered by the transit and the radial velocity (RV) methods. Their minimum masses are in the range 0.045 to 13 $M_{\rm Jup}$. The proximity of these planets to their host stars has prevented direct imaging and spectroscopy, making a precise characterisation of their physical structure and chemical composition difficult.

The least massive objects imaged and spectroscopically confirmed outside the Solar System are the so called isolated planetary-mass objects (IPMOs) discovered in the σ Orionis cluster (age ~3 Myr, distance ~350 pc), with masses in the range 3–13 $M_{\rm Jup}$ (Zapatero Osorio et al., 2000, 2002; Béjar et al., 2001). Very recently, Chauvin et al. (2004) have announced the discovery of a ~ 5 $M_{\rm Jup}$ object at a projected separation of 55 AU of a brown dwarf of the TW Hydrae association (age ~ 8 Myr, distance ~70 pc). This object awaits confirmation by proper motion studies and high signal to noise spectroscopy. Slightly



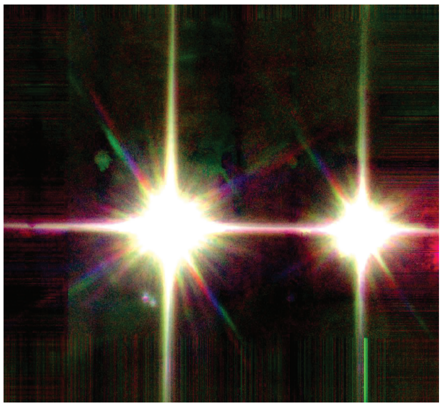


*Figure 1 (left). JHKs composite image of the G 196-3AB system. The images were taken with the NAOMI+INGRID Adaptive Optics system at the William Herschel Telescope. North is up and East is left. Size is 41 arcsec×41 arcsec. G 196-3A, an extremely young nearby M star, is in the centre of the field of view. G 196-3B, 13.5 arcsec to the SWS, is a late L spectral type brown dwarf that shares common proper motion with the A component. Estimated mass of G 196-3B is 25 $M_{Jup}$ or less. These images are sensitive to discover superjupiters at separations ≳50 AU to the central star.*

*Figure 2 (right). Same as previous figure, but for the V639 and V647 Herculis system. The double object at 6.5 arcsec SSE of the brightest star is a blue background object of unknown nature. It does not belong to the stellar system. The FWHM of the JHKs images is better than 0.2 arcsec.*

more massive is G 196-3B, a substellar companion of a young nearby M dwarf (Rebolo et al., 1998). Its mass could be significantly lower than 25 $M_{Jup}$ if the age of the system is confirmed to be much less than 100 Myr (McGovern et al., 2004).

## The JOVIAN Project

The aim of the JOVIAN project (Jupiter-like Objects in the Visible and in the Infrared: their Astrophysical Nature; P. I.: R. Rebolo) is to achieve the direct detection and characterisation of objects down to the mass of Jupiter, and help, through selected observations, to shed light on the formation of massive planets.

In the last six years we have followed two major strategies for direct detection of such objects: wide field imaging searches for 1 to ~13 $M_{Jup}$ objects in several very young open clusters; and high spatial-resolution imaging, with Adaptive Optics (AO) or the Hubble Space Telescope (HST), of young nearby late-type stars in the solar neighbourhood (age 600–30 Myr, distance <50 pc). In both strategies, youth is a key parameter given the large overluminosity of ultra-low mass objects during the contraction phase. We summarise below some of the results achieved in the ongoing JOVIAN project.

## IPMOs in the σ Orionis Cluster

The σ Orionis cluster has revealed as a paradigmatic place for understanding the formation of stellar and substellar objects. Following our first discoveries of massive brown dwarfs (50–30 $M_{Jup}$) in the120 Myr-old Pleiades cluster (Rebolo et al., 1995, 1996), we decided to investigate in a much younger cluster the formation of less massive objects down to the deuterium burning limit. The region around the multiple stellar system σ Orionis was selected because of its proximity, youth and low extinction. We have conducted *RIZ* surveys with the IAC-80 telescope (Observatorio del Teide) and the Wide Field Camera at the Isaac Newton Telescope (Observatorio del Roque de los Muchachos). From these surveys we covered the whole brown dwarf domain. Most of the one hundred brown dwarf candidates discovered were confirmed as bona fide cluster members, by follow-up near-infrared photometry and optical spectroscopy. Many of them have been confirmed using the ISIS spectrograph at the William Herschel Telescope or LRIS at Keck Observatory.

From these studies we have characterised the complete spectral sequence of the cluster in the brown dwarf domain from spectral type M6 to L1.5 (roughly 75 $M_{Jup}$ to 13 $M_{Jup}$). We have found that the substellar mass spectrum increases toward lower masses and can be represented by a power-law, $dN/dM \sim M^{-0.8\pm0.4}$ (Béjar et al., 2001). Our results indicate that brown dwarfs are very common in the cluster and suggest that a similar behaviour of the mass spectrum is possible at lower masses.

In order to detect fainter and less massive objects, we have performed and planned to conduct deeper surveys in the optical (*I* band, using the Wide Field Camera) and in the near-infrared (*JHKs* bands,with ISAAC/VLT, INGRID– LIRIS/WHT, Omega-2000/3.5m Calar Alto). From the new processed data we have identified about 15 new cluster member candidates with masses in the planetary domain. Our faintest candidate, S Ori 70, resulted from a *JH*-band mini-survey performed with INGRID at the WHT. Near-infrared low-resolution spectroscopy obtained at the Keck Observatory led us to derive a T6 spectral type and a mass in the range 2 to 8 $M_{Jup}$.

## Substellar Companions of Stars

In order to detect faint cool companions of young nearby stars, we have used the NICMOS instrument with the coronograph at the HST and AO systems attached at 4 m-class telescopes: Alfa+Omega-Cass at the 3.5-m Calar Alto, AdOpt@TNG+NICS at Telescopio Nazionale Galileo and, especially, NAOMI+INGRID at the WHT. The data taken by our group allow to resolve faint objects down to separations of ~1 arcsec of relatively bright stars. This separation in a stellar system at 10 pc corresponds to ~10 AU. The sensitivity to planetary-mass companions improves when the spatial resolution is higher (i.e. nearby stars) and the contrast is lower (i.e.

primaries are low-mass stars and planets are intrinsically brighter due to youth).

We are studying more than fifty stellar systems closer than 50 pc, with spectral types later than solar and with features indicative of youth (high lithium abundance, X-ray and/or UV emission, membership to young proper motion associations, etc.). The ages of the stellar systems range between 30 and 600 Myr. Forty of them have been completely analysed, comparing first and second astrometric epochs and performing photometry when possible. Although the data would allow us to discover objects with masses down to 3–10 $M_{\rm Jup}$ in several of the systems, we have not detected any previously unknown substellar companion at distances between ~30 and ~1000 AU of the primaries. We have only detected two, possibly three, stellar companions in very close orbits and a previously known L-type dwarf secondary. From our study, the frequency of substellar companions at intermediate and large separations of the primary stars is <4%.

This apparently disappointing result is of great interest, since together with work performed by other authors, allows to conclude that only ~1% of the solar-like stars have massive planetary companions and brown dwarfs at intermediate and large distances (e.g. McCarthy & Zuckerman, 2004). This figure must be compared with the 7.3±1.5% of the solar-like stars that have exoplanet candidates discovered at small separations with the RV method.

## Future Prospects

The ultimate goal of the JOVIAN project is to set observational constraints on the scenarios of formation of giant planets with masses from 1 to ~13 $M_{\rm Jup}$ (jupiters and superjupiters). These objects appear to be quite abundant, as they exist at close distances of relatively old solar-like stars, but also free floating in very young open clusters. Is the lack of massive giant planets at intermediate and large distances related to the

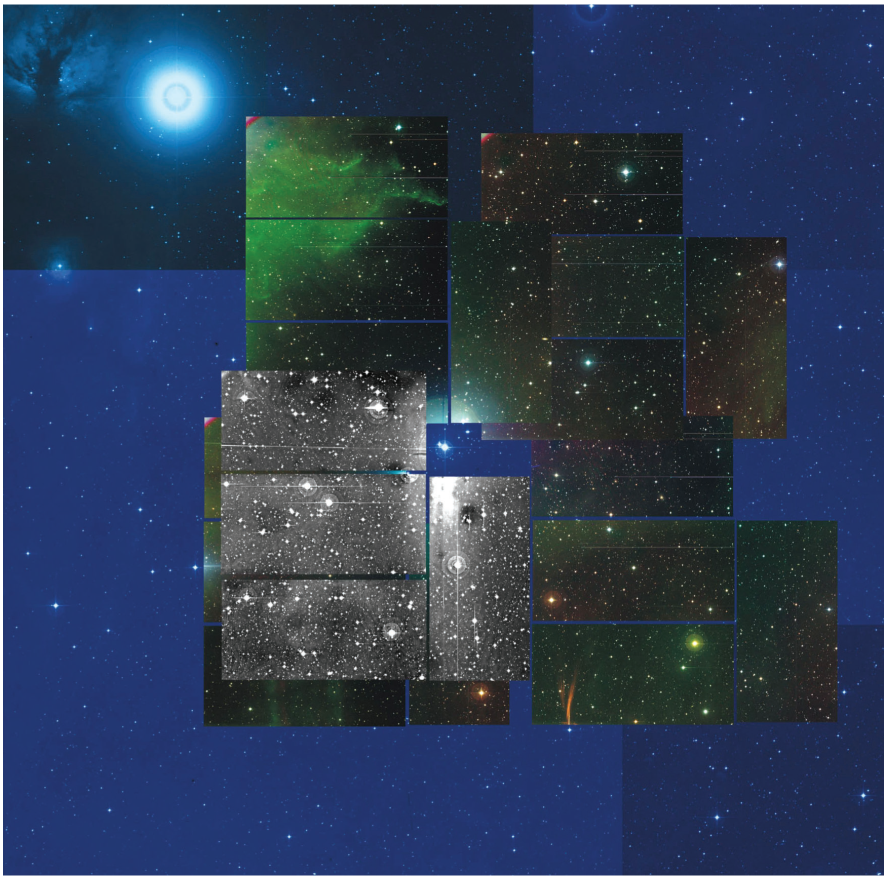


*Figure 3. The σ Orionis region and the WFC surveys. The bright star to the up left corner (North East) is Alnitak, one of the stars of the Orion Belt. Blue background: I-band image from Digitised Sky Survey. Coloured intermediate level: WFC survey in VRI-bands (note the emission in R band (or Hα) of the nebula associated to Alnitak and the Horsehead Nebula). Grey foreground: very deep I-band WFC survey ($I_{lim}$ about 24.5).*

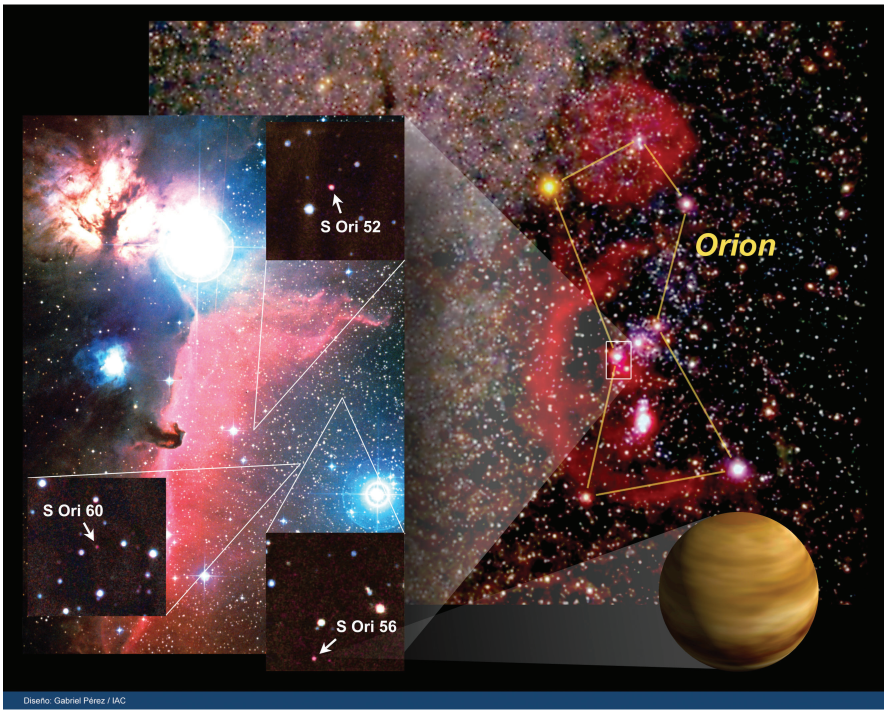



*Figure 4. Pictorical view of several isolated planetary-mass objects (IPMOs) in the σ Orionis cluster (Zapatero Osorio et al., 2000).*

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/`. ¤

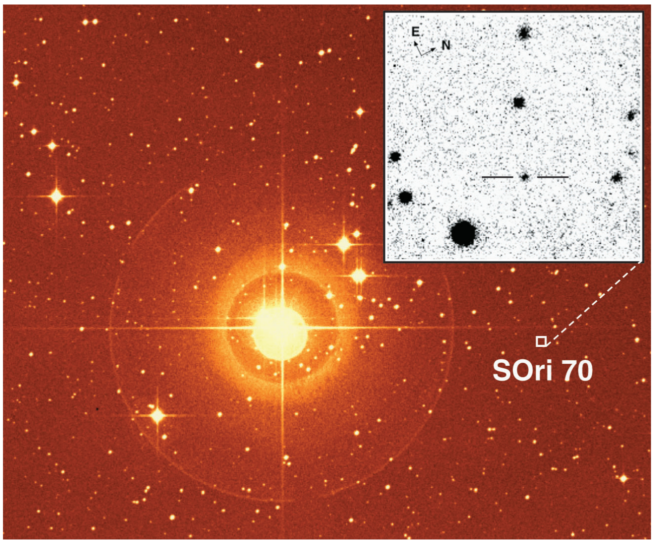



*Figure 5. Near-infrared image of S Ori 70 (marked with two lines), overimposed onto a Digitised Sky Survey image centred in the multiple stellar system σ Orionis, that gives the name to the cluster. The mass of S Ori 70 is calculated to be in the range 2 to 8 Jupiter masses.*

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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