since most of the information about the nature and the origin of comets lies in the central region – the nucleus and its immediate environment – which are usually too small to be observed from the ground. In the case of Comet IRAS, a spatial resolution of about 10–20 km could be reached at the time of closest approach.

Comet IRAS was observed with three instruments at La Silla: IDS spectra were obtained at the 3.6 m telescope, and image-tube spectra (fig. 1) with the 1.52 m telescope; CCD pictures were recorded at the 1.54 m Danish telescope. These data are now under reduction.

Since the spectra were recorded at several points of the comet, in the inner coma and outside, we hope to derive information upon the abundances of radicals as a function of their distance to the nucleus, which is important for the understanding of the dissociation processes which lead from the parent molecules (ejected from the nucleus) to the daughter molecules and the radicals observed in a larger scale. This would be especially interesting for Comet IRAS where the parent molecules H_2O and NH_3 have been detected at radio wavelengths. The CCD pictures (fig. 2), with a scale of about 0.5 arcsec per pixel, might be able to confirm the visual observations reported by S. Larson (IAU Circular No. 3811) which suggest the existence of a 12 km cocoon surrounding the nucleus, and the radar observations of Campbell et al. (IAU Circular No. 3811) also suggesting the presence of a "skirt" around the nucleus.

Recent Results of IR Speckle Interferometry at ESO

C. Perrier, ESO

Our speckle system was implemented in late 1979 on the 3.6 m telescope. Although at that time every component was in a preliminary state, we could record results useful enough to prove the feasibility of such a high spatial resolution instrument. The astrophysically usable results came later in 1981 together with sensitivity gain of the IR photometer (Perrier, 1981, *The Messenger* No. 25, p. 26). Since then we have entered a period of studies of specific astrophysical targets, some of which will be reported in this article.

In the meantime, the pioneering work done by Sibille, Chelli and Léna (1979, *Astronomy and Astrophysics* **79,** 315) triggered the development of similar instruments at the Anglo-Australian, K.P.N.O., IR Facility and Canada-France-Hawaii telescopes. This recent interest in IR speckle instruments is related to the lack of high angular resolution of objects suffering a high extinction. Especially concerned are those discovered in the systematic search for compact IR objects which is currently being carried out in molecular clouds (like the Orion complex), but also some exotic objects whose mass loss (e.g. η Car, IRC+10216) or activity (NGC 1068) is better studied in the near infrared where the inner regions become visible. These instruments are also well suited for the search of IR companions as shown by the spectacular discovery of the one of T Tau (Dyck et al., 1982, *Astrophysical Journal* **255,** L103).

The trend to expand the access to such facilities cannot go without developing more reliable observational procedures and more powerful reduction techniques. Part of them have already been exposed by Mariotti et al. (1983, *Astronomy and Astrophysics* **120,** 237) and a thorough review has been done by Bates (1982, *Physics Reports,* **90,** 203). We shall give here some indications of these advances besides the presentation of the results.

Some Instrument Related Remarks

Let us in short see what the speckle observing procedure looks like. A description of the system was published in the *Messenger* No. 25 but it has evolved now to a more sophisticated one and will do so until an optimized version, physically separated from the photometric facilities, comes into use one year from now. Thus no updated documentation exists.

The standard speckle procedure gives on-line access to the visibility or 1-D Fourier Transform (FT) modulus of the intensity distribution (see e.g. Léna, 1981 in "ESO Conference on Scientific Importance of High Angular Resolution"). The observation must be repeated several times to ascertain sufficiently low statistical errors. When the reference source is only a few degrees away from the object it is now possible to alternate very frequently allowing a sequence "Ref.-Source" to last less than 5 minutes. A series of sequences is computer-controlled, so no time is lost by manual pointing. In this way the seeing variations are minimized.

Some objects allow a non-standard procedure: if they are close enough (a few arcsec) they permit a "source switching" very similar to the photometric beam switching. The 3.6 m telescope can perform this accurately enough every 10 seconds for any scanning direction and offset vector. This procedure is most useful for objects otherwise too faint for an accurate guiding. The reference star serves for this and of course for the mean transfer function measurement. This fast switching mode also provides adequate conditions for the image reconstruction of extended sources.

As stated before, our technique is well suited for the study of a wealth of objects, even with its present limiting magnitudes – e.g. L≃5 at 3σ with a one-hour sequence and a 2-arcsec seeing – still 2 to 2.5 magnitudes below their optimum values. We have focused our work on objects showing an intense IR excess and the 10 μm silicate feature, indicator of circumstellar dust grains. They have large dust envelopes usually due to high mass loss rates. Often these are so large that the shell

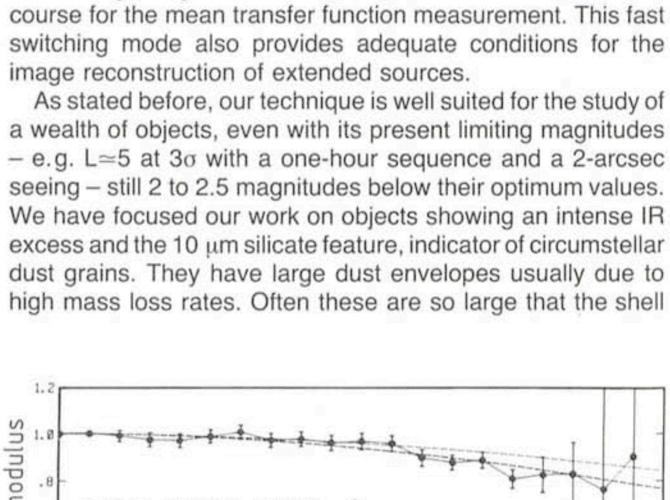

Fig. 1: *Visibility of NGC 2024 #2 fitted with theoretical filled-disk spectra of diameters 0.12 and 0.15 arcsecond λ = 4.64 μm. Position angle = 90°. The error bar is the standard deviation from the mean for several independent observations.*

gets thick enough to almost completely absorb the visual light from the star and re-emit this energy at the temperature of the shells.

We first consider two pre-main-sequence or early-type objects which fall into this class of IR emitters.

Young Objects in the Orion Molecular Cloud

(a) The Source NGC 2024 # 2

The role of this embedded object in the second complex source of the region is still not clear. In particular it could be a highly reddened star exciting the nearby bright H II region, or a star with an envelope in a compact H II region. Near infrared spectra by Thompson et al. (1981, *Astrophysical Journal* **249,** 622) give a B_γ line flux consistent with an underlying B 0.5 ZAMS star. Speckle observations of this object were made at 4.6 μm in April 1982 and give direct support to Thompson's view by substantiating a complete model of #2 (Jiang, Perrier and Léna, submitted to *Astronomy and Astrophysics).*

In this case the usual Labeyrie method is used where the observed power spectra are co-added and corrected from the mean atmospheric + telescope transfer function. For a size close to or below the diffraction limit of the telescope, there is not much to learn from a true image and thus we do not need the phase information (of the complex FT). It is sufficient to check for a possible object asymmetry by scanning at perpendicular directions as we did: we obtain an equivalent filled disk diameter d_{fd} = 0.12 arcsec (fig. 1).

The filled disk assumption is not compatible with the photometric data whatever the extinction is, except for abnormally high values. But using a model of an optically thin dust envelope (Allen et al., 1981, *Monthly Notices of the Royal Astronomical Society* **196,** 797) defined by an inner boundary r_{in}, a density law αr^{-2} and a temperature law $\propto r^{-2/5.5}$ one finds an inner radius of 0.03 arcsec and can account well for the observed spectrum and derive other parameters: an interstellar extinction of 21.5 m, a shell inner temperature of 1,160 K. With the B_γ line flux, one finds a B 0.5–0.2 type for the central ZAMS star. The properties of the shell can then be defined: it is formed by the stellar wind which drives a mass loss of 1.5 10^{-6} $M_\odot$.yr^{-1}, responsible in turn for the compactness of the H II region; most of the condensed phase is made of graphite grains. From the comparison of luminosities involved one deduces that the cloud causing the extinction must be well detached from the object and is mainly heated by some other sources.

(b) IRc2 in the KL Nebula

In the core of the Orion nebula, the infrared sources clustered in the Kleinmann-Low (KL) nebula have very large extinction. The energetic balance, polarimetric and radio observations have made it clear, although recently (Downes et al., 1981, *Astrophysical Journal* **244,** 869), that one of them, IRc2, a secondary source close to the more prominent well known Becklin-Neugebauer (BN) object, was the very reddened energy source powering the whole cloud. In order to observe this relatively faint source one can take advantage of the proximity of BN (at 9 arcsec), known to be quasi point-like at 5 μm, not only for guiding but as a deconvolution key. This means that a scan gives the point spread function of the telescope and the seeing degraded image of the object simultaneously. Thus a deconvolution may be performed leading to the true 1-D image which would otherwise be inaccessible at M for the 3-magnitude object IRc2.

We recorded some 8,000 scans in November 1982 at a position angle (PA) of 142°, the exact direction of the BN-IRc2

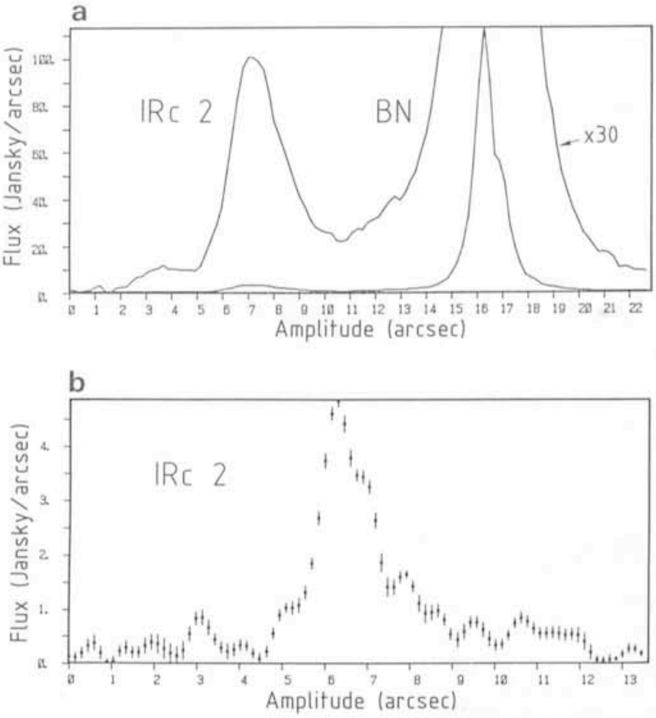

Fig. 2a: *Average of scans obtained at 4.64 μm on IRc2 at different scales. IRc2 is on the left, BN on the right. The bridge linking the sources is due to instrumental diffusion and cancels out with a proper calibration.*

b: *Final 1-D image after deconvolution. The resolution is 0.5 arcsecond. The error bars represent the standard deviation from the mean for 20 independent results. The calibration refers to the integrated flux along the slit and relies on the measured magnitude of BN. Note the feature at 3 arcsec whose width (0.5 arcsec) equals the resolution: it remains unresolved and could have something to do with the activity of the central source.*

line. IRc2 shows up in the left half of the average given in fig. 2a. The signal to noise has been greatly improved since it was 0.5 for individual scans. In the reduction, we selected the best images, recentred them with respect to the maximum of BN and built 20 independent blocks by averaging 400 scans. A simple deconvolution by the BN profile produced the image of fig. 2b giving the calibrated object profile. All the interpretation relies on this high resolution photometry and is exposed in Chelli, Perrier, Léna (1983, submitted to *Astrophysical Journal* lett.).

First, the source is well resolved with a size of 1.4 arcseconds. A dereddened temperature of 360°K and a 3.6–12.5 μm (excluding the silicate absorption) optical depth of 5.2 lead to A_v = 170 mag. Thus the luminosity derived from the size is 8.10^4 $L_\odot$, a large fraction of the cloud luminosity (Genzel and Downes, 1982, *Regions of recent star formation,* Reidel ed.). This directly confirms IRc2 in its role of primary source of the cloud. Second, the profile exhibits some features like a shoulder in the central core. We can interpret this central component as a double source with an intensity ratio of 2. This figure agrees very well with the radio observation consequences. They show evidence of a gas velocity structure consistent with a "doughnut"-like source and a high velocity outflow along its axis (Wright and Plambeck, 1982, preprint). Moreover, the positions of the SiO masers, well structured in a double lobe emission, coincide with IRc2 (Wright and Plambeck, 1983, preprint). We can derive the inclination of the axis with respect to the sky plane and explain the difference in IR intensities with the local extinction given by the model. The radio and IR observations converge now toward a scheme where IRc2 is a highly active component of the complex. To improve further the knowledge of its structure, new observations in other directions and wavelengths are planned.

Visibilities of other interesting young objects have been measured and deserve some more insight, for instance RCW 57/IRS 1 which shows a faint core in a very extended structure.

Evolved Objects

(a) The Active Object η Car

η Car is quite exceptional in many aspects like its brightness (M (4.6 μm) $\simeq -3.4$, this makes it one of the strongest near IR sources; its distance is 2.8 kpc), or the clumpy aspect of the fast outward-moving cloud of surrounding material. Some violent event is known to have occurred in the mid-nineteenth century. We probably see now the result of it through the long-term decrease in brightness due to dust formation. The nature of the central object is still a disputed question. Yet its very high luminosity ($\sim 10^7 L_\odot$) suggests that it is in a rapid evolutionary stage, an idea consistent with the behaviour of high mass post-main-sequence objects (Davidson et al., 1982, *Astrophysical Journal* **254,** L47). In any case a multi-component system, preferably with ejected condensations, is not excluded. Therefore the spatial information may bring decisive clues to these problems. In the infrared the best spatial resolution was attained by Hyland et al. (1979, *Astrophysical Journal* **233,** 145) who discovered a secondary inner component at 1.1" from the centre at 3.6 μm. We therefore had good reasons to observe this source, lowering the resolution to 0.1 arcsec or so.

It turned out that η Car was a complex source at K (2.2 μm) and M at the sub-arcsec scale. In order to extract the available astrophysical information from our data, we had to go further than simple visibility computation. With this aim, we used a technique of image reconstruction relying on algorithms not yet applied to real IR data (Chelli, Perrier, Biraud, 1983, *Astronomy and Astrophysics* **117,** 199). Its main features in addition to normal speckle processing are:

(i) to select the diffraction-limited images (in the 1-D sense) which happen to be frequent at 4.6 μm under very good seeing conditions as shown by Fried (1978, *J.O.S.A.* **68,** 1551).

(ii) to compute the FT phase of the image, usually not recorded because of noise, by means of the so-called Knox and Thompson algorithm (1974, *Astrophysical Journal* **193,** L45).

(iii) to restore the image by inversion of the FT in the "maximum entropy" sense (well known in radio applications); this provides the smoothest image compatible with the data and their noise. The solution is an image where no a priori information has been arbitrarily added.

Two examples are given in fig. 3. The scanning direction is 150° with respect to north for both wavelengths. The central peak is resolved in both cases according to the spatial frequency-limited resolution. The secondary component, well defined at K, is merged into the central peak foot by the degraded resolution but could also have a higher colour temperature than the central core envelope. The bump in the M image corresponds to low temperature material which produces the envelope seen in all directions at 4.6 μm.

The 1-D images cannot provide a clear idea of the overall structure. The next step consists in restoring the 2-D image by using simultaneously the information obtained for all directions which covers conveniently enough the spatial frequency plane. Preliminary results do confirm the very clumpy structure inferred from the past activity of η Car. We intend to analyse the

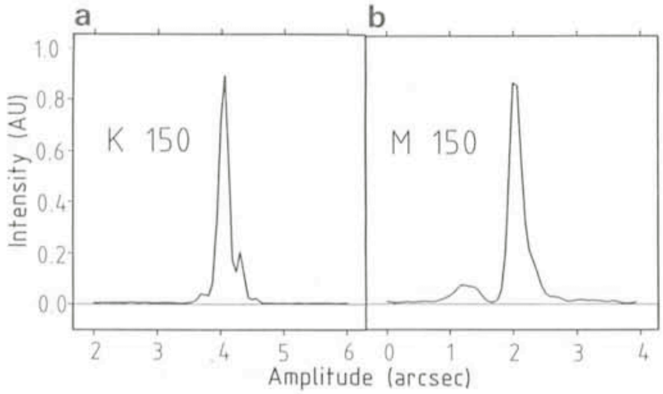

Fig. 3: *1-D images of η Car at PA = 150° represented with arbitrary intensity units. a – λ = 2.2 μm. Resolution is 0.15 arcsecond (see text). b – λ = 4.64 μm. Resolution is 0.20 arcsecond.*

recent models hypothesis in the light of the final map. But it is already obvious that the present models rely on photometric data which are too biased by the significant departure from the simple-minded geometry assumed. Moreover the complex structure probably contains two or three secondary components with various colour temperatures.

(b) Very Long Period Variable Stars

We now consider some late-type objects surrounded by very thick circumstellar shells and completely obscured in the visible, with a variability with a period of years. These intense IR emitters were detected by sky surveys or IR counterpart searches of OH masers with which they are associated (Engels 1981, *The Messenger* **24,** 24). The double-peaked radio spectrum shows that the shell is expanding radially.

A prototype of these objects is OH/IR 26.5+0.6, a Mira variable with a 1,630-day period and mean magnitudes K=8.9, L=1.9 and M=0.0. Its amplitude at L is 2.4 mag, the mean K-L colour temperature of the shell is 380 K with an amplitude of 80 K. The bolometric luminosity of this star varies over 2 mag about a mean of –7.0 mag (adopting a distance of 2.2 kpc). An equivalent black body, of temperature 380 K, would have linear diameters of $9.2\ 10^{15}$ and $5.6\ 10^{15}$ cm respectively at maximum and minimum light. These values correspond to angular diameters of 0.28 and 0.16 arcsec very well suited to IR speckle interferometry. Yet, as the temperature is decreasing radially outwards, one expects that the angular diameters increase with wavelengths. So the above diameters are only mean values. As most of the energy is emitted beyond 5 μm, angular diameters measured at shorter wavelengths should be smaller than those computed for a black-body.

Visibilities of this object have been obtained at several epochs covering a period of two years. Fig. 4 shows two results at M obtained about one year apart in the east-west direction. In fig. 4a, a diameter $d_{fd} = 0.14 \pm 0.02$ arcsec was computed at phase 0.67 (June 1981); in fig. 4b, $d_{fd} = 0.17 \pm 0.02$ arcsec at a phase close to maximum. Actually we started to monitor this source regularly to get the size as a function of magnitude directly. These sizes and their variation with the energy input from the star are crucial parameters of the model calculations applied to the shell which require the knowledge of the inner and outer radii to start any spectrum synthesis (Butchart and Whittet, 1983, *Monthly Notices of the Royal Astronomical Society* **202,** 971).

Another characteristic of these objects relates to the possibility of probing the shell geometry with radio interferometry. OH

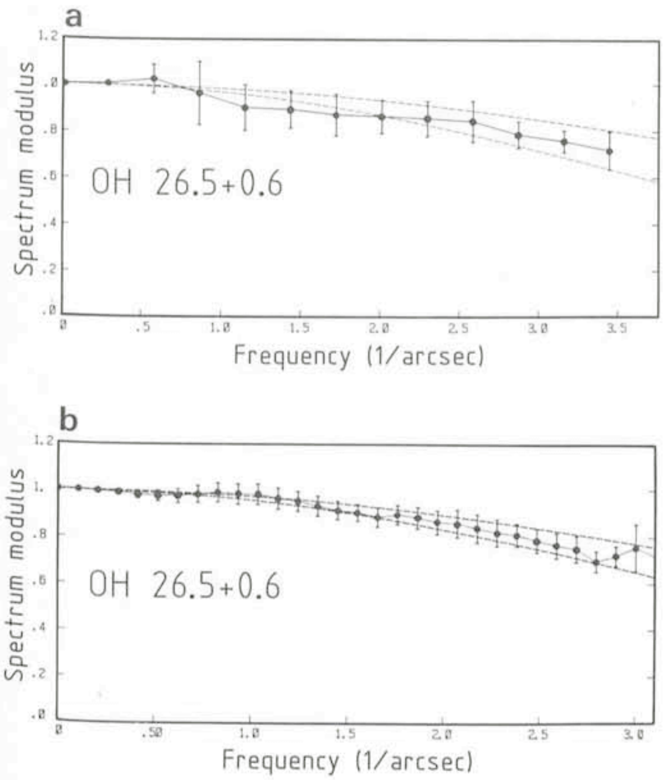

Fig. 4: *Visibilities of OH/IR 26.5+0.6 at 4.64 μm. The scanning direction is east-west.*
a – *June 1981, the large errors at ~ 0.8 arcsec⁻¹ come from seeing effects.*
b – *April 1982 (near maximum light). The improved step in frequency comes from a wider scan amplitude. Note also the smaller range of errors due to improved performance.*

26.5+0.6 appears to have a fairly complex gas shell structure at the arcsecond scale with an internal component elongated east-west like a disk seen edge-on as proposed by Baud (1981, *Astrophysical Journal* **250,** L79). Thus it is of prime importance to confirm the expected asymmetry of the emitting dust structure whose kinematics can no longer be interpreted as a simple spherical expansion. Our study aims now to obtain the size in at least two scanning directions.

In our programme, some other OH masers are included, but they belong to both types, depending on which – the main (Type I) or the satellite (Type II; like OH 26.5 + 0.6) – emission line is actually dominant. OH 308.9+0.1, observed in June 1981, is very small at H (d_{fd} < 0.1 arcsec) and has IR characteristics which, in addition to its type I OH maser spectrum, relate it to protostellar objects (Epchtein et al., 1981, *Astronomy and Astrophysics* **97,** 1). Thus the classification "OH/IR" covers very dissimilar mechanisms.

Conclusion

Other types of source were present in our programme. Much is still to be reduced or interpreted but worth mentioning are the observations of the Seyfert galaxy NGC 1068 in four directions in filter L. The visibility at a PA of 45° gives the highest size with an equivalent d_{fd} of 0.40 arcsec whereas other PA yield 0.20–0.25 arcsec. This actually corresponds to the direction of the radio-jet (Pedlar et al., 1983 *Monthly Notices of the Royal Astronomical Society* **202,** 647). This result clearly illustrates the widely spread application field of IR speckle interferometry.

We anticipate to use soon a more efficient instrument which should make it possible to extend the list of accessible objects as well as to provide visibilities of bright objects with smaller statistical errors. This progress comes at a time when released IRAS data may offer new interesting sources and the CERGA long base line two-telescope interferometer may complement speckle results with a higher resolution.

The work presented here was done in collaboration with A. Chelli and P. Léna who promoted it and are largely involved in all the aspects. D. Engels and R. Foy are participating in the evolved object programme. Most of the computer work was supported by ESO La Silla and Munich. I wish to thank M. Maugis and J. Roucher (La Silla) for their permanent and essential support.

A Bright and Extreme W UMa-type Binary: ε Cr A

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The W UMa Systems, a Mystery of Stellar Evolution

The light curves of close (eclipsing) binaries are not flat between eclipse intervals, due to proximity effects (tidal distortion, light reflection on facing hemispheres). The separation of the two components is so small in W UMa systems that continuous variations are observed in the light curves. Minima are nearly equal (see fig. 1) which means similar colours and effective temperatures for both components (spectral types A to K). They are also spectroscopic binaries. Individual masses and radii of the components can be derived in the most favourable cases. Apparently, they prove to be dwarf stars not too far from the main sequence.

Further advances in the analysis reveal astonishing features. The luminosity ratio between components is roughly proportional to the mass ratio, instead of the fourth power of the mass ratio as usual for dwarfs (for instance, the luminosity ratio is nearly 2 : 1 for a 2 : 1 mass ratio instead of 16 : 1). As a consequence, the spectra of secondaries (less massive stars) can be observed and the amplitudes of light curves do not exceed one magnitude. Recent modeling of light curves on computers shows that the surfaces of the elongated components are actually in contact. As a basic feature, recent theories include the transfer of energy from the primary to the secondary, through a common envelope which could explain the anomalous luminosity ratio. We would be observing rotating "dumb-bell configurations". This interpretation is however confronted with considerable difficulties when the internal structure of the components is investigated and no satisfactory model is yet available.

The contact systems of periods less than one day outnumber other binaries by a factor of (at least) ten. This is an additional difficulty since computations suggest that such configurations should represent a short-lived phase of stellar evolution. Fast evolution is also indicated by period variations (see section 4) but the subject is a matter of controversy. Finally, we have to