Figure 8: *Mapping of the chemical inhomogeneities in the shell of the recurrent nova T Pyx. Colour coding as in Figure 7.*

of oxygen in the polar blobs is due to meridional circulation of white dwarf material at the onset of the outburst (Kippenhahn and Thomas 1978) than to differences in the ashes of nuclear burning.

The apparent abundance inhomogeneities can be mapped by combining pictures taken through interference filters isolating the radiation of [O III] and [N II] + Hα, respectively. In the colour plots, regions with relatively higher contributions of [O III] are blue, those with relatively higher contributions of [N II] + Hα are red (Figs. 7, 8).

Aside from their physical meaning, which must still be better substantiated, the colour plots help to determine the symmetry axes in nova shells. This was already shown for the northern nova GK Per (Duerbeck and Seitter 1987) which until then was considered irregular. The shell of RR Pic is shown in Figure 7. The colour method is particularly useful for shells which appear in nearly spherical projection, such as T Pyx (Fig. 8).

This ends our present report on nova shells. With a plethora of novae and nova remnants still awaiting their observational share, the field of stellar cataclysms appears to be as attractive as ever.

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Internal Dynamics of the Gum Nebula

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Introduction

Among the many large and spectacular objects of the southern sky, the Gum nebula with an angular diameter of 36 degrees in the sky is the object with the largest known apparent dimensions. Unlike the other large objects like the Large Magellanic Cloud (diameter $\simeq 8°$) and the Small Magellanic Cloud (diameter $\simeq 3°$) which clearly stand out as highly luminous regions in the night sky, the Gum nebula, however, is extremely faint and is not visible to the naked eye. The only way to see this nebula is to look at the photographs taken in emission lines like H_α λ 6563 Å and [NII] λ 6584 Å lines since the entire visible radiation from the nebula is confined to a few such emission lines. But the extent of the nebula is so large that it fills the conventional Schmidt photographs and can be detected only from a mosaic of Schmidt photographs. In fact, the nebula was first detected this way in 1953 by Colin S. Gum, who made a mosaic of several long exposure Schmidt plates of this region, each with an 11° field, taken in the H_α + [N II] lines. It is befitting that the nebula now bears the name of its discoverer, C.S. Gum, who was unfortunately killed in a skiing accident in Switzerland in 1960, at a relatively young age of 36.

The central region of the Gum nebula contains Zeta Puppis (O4f), the brightest O-type star in the sky, and Gamma Velorum (WC 8 + 09 I). From the ESO IIa-O and the SERC IIIa-J plates of the region of the Gum nebula, about 29 cometary globules (CGs) and 7 dark clouds have been identified (Hawarden and Brand, 1976, Sandqvist, 1976, Zealey, 1979, and Reipurth, 1983). Cometary globules are dark clouds which have dark, dense heads which are completely opaque to the background starlight, and faint, luminous tails through which background stars can be seen. The heads often have bright rims on the side that points towards the centre of the Gum nebula complex while the tails, in general, point away from this central region. To date, a total of about 38 CGs have been noted and catalogued of which 29 lie in the Gum nebula region. Several of these

CGS show signs of star formation. Reipurth (1983), Brand et al. (1983) and Pettersson (1987) have conclusively shown that CG 1 and CG 30 are sites of star formation. We have carried out a study of CGs and dark clouds in the Gum nebula using IRAS and other optical data (Srinivasan et al., 1987) where we find the dust to be concentrated and compressed on the side of the head that faces the central region of the Gum nebula complex. Our study also shows that there is evidence for the presence of point sources in the heads of a few CGs indicating that star formation is current in these globules. Hence from the morphology of the CGs in the IR it seems that the internal dynamics of the Gum nebula has played an important part in their formation and in triggering a series of star forming events in the heads of the CGs.

Previous Studies

Earlier work on the internal dynamics of the Gum nebula have clearly suggested the need for further work. There have been three attempts in this direction. They are listed below with the methods and essential results.

(1) The earliest attempt to study the internal dynamics of the Gum nebula was made by Hippelein and Weinberger (1975) where they used a photographic Fabry-Perot interferometer and detected no systematic expansion. Since their actual interferograms are not published, it is difficult to judge the errors and the reliability of the results. But the velocity resolution in this study seems rather poor and the results seem uncertain due to the many problems associated with the difficulty in correcting for the background using the old photographic techniques, particularly when the object is faint.

(2) More accurate measurements were carried out by Reynolds (1976) where he used a twin-etalon Fabry-Perot spectrometer and a photo-electric detector to obtain line profiles in H_α λ 6563 Å, [N II] λ 6584 Å and [O III] λ 5007 Å lines in 8 positions of the nebula. At a few positions, he detected expansion velocities as high as 20 km/s and less in a few other positions. The northern location of the telescope used in this study (the telescope used was the McMath telescope at KPNO) however forced the observations to be confined only to the northern parts of the nebula, leaving the southern regions of the nebula completely unexplored.

(3) Reynolds' results were contradicted by Wallerstein et al. (1980) where they studied optical and UV interstellar absorption line spectra of about 70 stars in the direction of the Gum nebula and concluded that the nebula undergoes no systematic expansion. Their analysis, however, involves the assumption that the Gum nebula is the cause of the observed absorption features, although it is not clear whether some other component of the ISM in the line of sight could also be the cause of these features.

Thus the need for further systematic observations to resolve the issue was clear and we have undertaken a study where high resolution ($R \cong 40{,}000$) line profiles could be obtained at many points uniformly distributed throughout the nebula.

Observations

The ESO 1.4-m telescope, which is equipped with a Coudé Echelle Spectrograph, a short camera and a CCD detector, is well suited to study such large and faint nebulae. Since the nebula is extremely large, high spatial resolution is not necessary and hence the short camera can be used advantageously to increase the field of view thereby increasing the light-gathering power of the spectrometer. Use of the CCD provides an extra advantage since it is possible, at the data reduction stage, to rebin the spectra in the direction perpendicular to the dispersion up to about 50 to 100 pixels thereby increasing the S/N by a large factor.

Observations were made in February and May 1987, in the H_α λ 6563 Å, [N II] λ 6584 Å and [O III] λ 5007 Å lines at 14 positions well distributed in the nebula, with a resolution of $R \cong 40{,}000$. Care was taken to include southern regions which were not included in the study of Reynolds. Three of our positions coincide with those of Reynolds and were taken for the sake of comparison. Figure 1 shows a photograph of the Gum nebula, with the approximate positions of Reynolds and our observation positions superposed on it. Typical exposure time for all the three lines was 1 hour. The data were reduced using MIDAS (Munich Image Data Analysis System) at ESO, Garching.

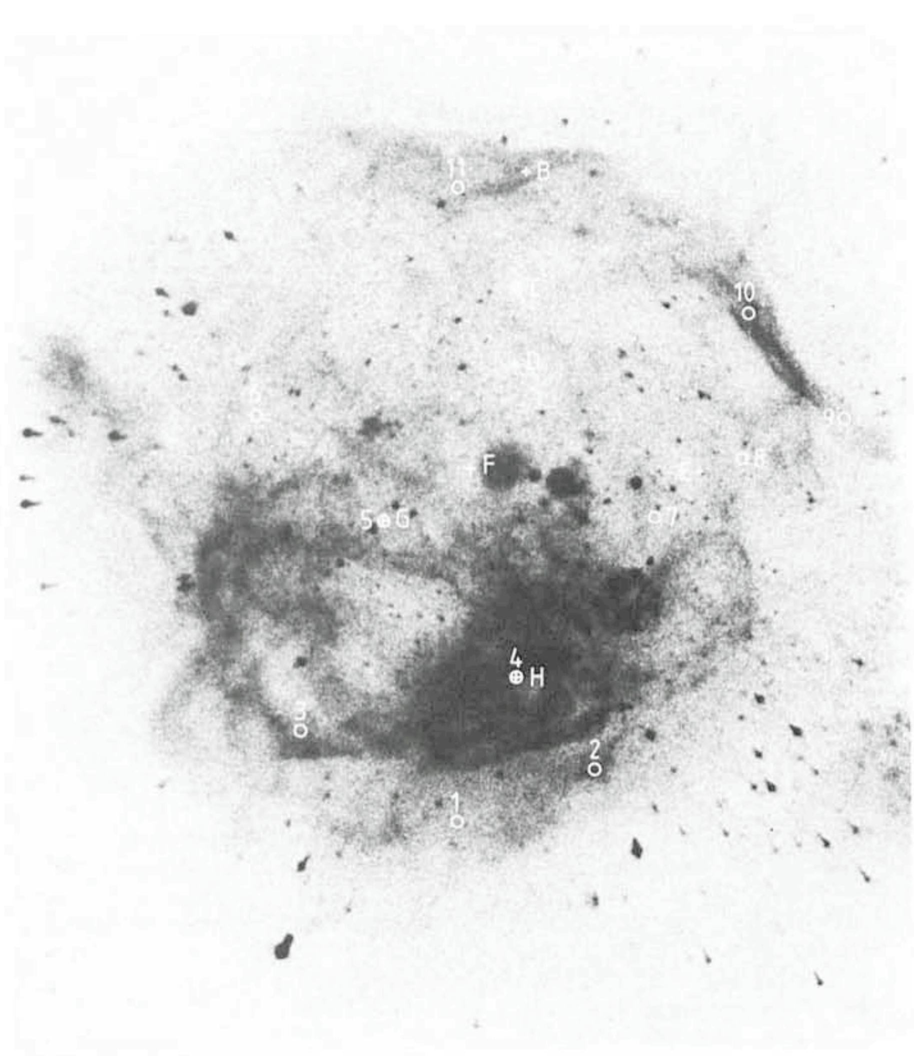

Figure 1: *This photograph of the Gum nebula was obtained by J.P. Sivan and has been reproduced from the ESO book "Exploring the Southern Sky", by S. Laustsen, C. Madsen and R.M. West. Superposed on the photograph are the approximate positions at which our observations are taken (indicated by O) and those of Reynolds (indicated by +).*

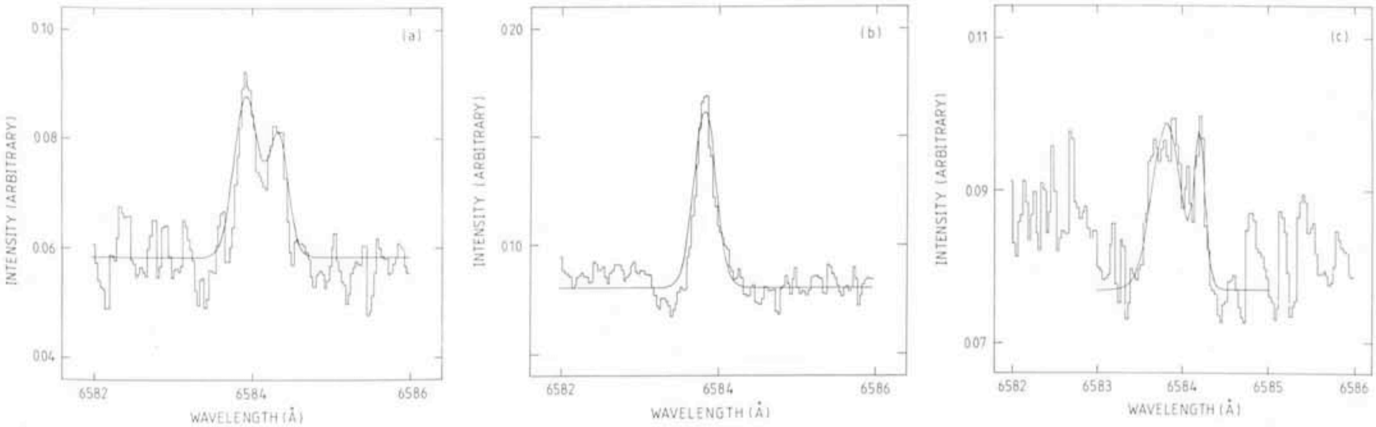

Figure 2: *(a, b, c): The observed [N II] λ 6584 Å profiles (histograms) obtained at positions 2, 1 and 4 respectively using the ESO 1.4-m CAT + Coudé Echelle Spectrograph + CCD, along with the Gaussian best fits (smooth curves). Position 4 corresponds to position H of Reynolds.*

Results

Though the detailed analysis and modelling are in progress, some results can be stated here which are the following:

(1) To derive the true expansion velocity of the nebula, we have applied the geometric correction factors to the observed line of sight velocities and our observations are more consistent with an expansion velocity of Vexp = 10 km/s for the Gum nebula as obtained from the splitting of the [N II] line profiles. Figure 2 shows the [N II] line profiles obtained at positions 1, 2 and 4.

(2) We failed to detect [O III] emission in any of the 14 positions observed, in contradiction with the observations of Chanot and Sivan (1983) (who made spectrophotometric observations of the Gum nebula) and in agreement with the observations of Reynolds. In order to confirm our non-detection, we repeated exposures in the region near Gamma Velorum (position 4) where the [O III] emission was reported by Chanot and Sivan to be high. We failed to detect [O III] at this region in spite of integrating exposures of totally 2 hours and 20 minutes, which shows that the object is a low-excitation nebula.

(3) None of the H_α profiles showed any splitting. This is however not surprising because of the large thermal width of the H_α line (the expected FWHM of the H_α line is about 22 km/s at 10,000 K). The non splitting of the H_α line profiles shows the expansion velocity to be less than 10 km/s which is consistent with the results obtained from the [N II] profiles.

A comparison of our observations and results with those of the previous studies is shown in Table 1.

A physical model for the Gum nebula taking into account the observed geometry and the velocity structure is underway. We also plan to obtain high resolution spectra at many more positions in the nebula in different ionization lines for further study of the internal dynamics and the ionization structure of the nebula.

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TABLE 1.

Studies	Telescope and instrument	Field of view	Resolution (km/s)	No. of positions	Line studied	Results
Hippelein and Weinberger (1975)	16-cm telescope (Gamsberg, S. Africa) + photographic F.P. interferometer	3°.5	19–28	2000	Hα (em.)	no expansion
Reynolds (1976)	60-cm McMath telescope (USA) + twin-etalon F.P. spectrometer	5'.7	12	8 (northern regions)	Hα [N II] [O III] (em.)	Vexp = 20 km/s
Wallerstein et al. (1980)	1.5-m CTIO (Chile) + Coudé spectrograph and Copernicus satellite results	not relevant	> 12 for (Ca II) and > 25 for (Na I)	70	Ca II Na I (abs.)	no expansion
Present study (1987)	1.4-m ESO (Chile) + Coudé Echelle Spectrograph + CCD	1' X 1''.6	7.5	14 (including southern regions)	Hα [N II] [O III] (em.)	Vexp = 10 km/s

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V 605 Aquilae – a Star and a Nebula with No Hydrogen

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Three planetary nebulae are known with hydrogen-poor central nebulosities and WR-type central stars: A 30, A 78 and A 58. While the former have been discussed extensively in the literature, the latter remained spectroscopically unknown until 1983. Its story, however, begins much earlier.

In 1920 Max Wolf found a $10^{m}_{\cdot}4$ star on photographic plates taken in 1919. The object had been invisible before 1917; it disappeared in 1923. In 1921, Lundmark took spectra of the suspected nova. These had no resemblance with spectra of any of the known evolutionary states of novae, they looked like those of carbon stars. Decades later, the region around the star, now designated V 605 Aql, was inspected. Abell (1966) found a faint old planetary nebula and entered it as number 58 into his catalogue, Herbig (1971) noticed a very faint starlike object near the centre of A 58 and suggested that this was the remnant star of V 605 Aql.

Our own story of V 605 Aql and A 58 starts in 1983, when I joined H. Duerbeck in his spectral survey of faint old novae with the Calar Alto 2.2-m telescope. The central star of A 58 was not visible on the telescope monitor. However, we had just recorded another unseen old nova, V Per, because it had appeared somewhere along the long slit with which the unwidened spectrum was taken. Thus, the long slit was placed across the planetary nebula in various positions. When it lay exactly across the centre, as deduced from the pattern of spectra from neighbouring stars, a central point-like emission spectrum appeared in addition to the emission lines of the extended planetary nebula. The central nebulosity showed no hydrogen, only strong [O III] and moderately strong [N II] lines, slightly blueshifted with respect to the planetary emission lines (Seitter 1985a).

An EFOSC spectrum taken for us with the ESO 3.6-m telescope by P. Angebault in 1986 shows the spectra of *three* objects: lines of the planetary nebula and the central nebula and stellar emission lines superimposed on a weak continuum of red magnitude 22.3 (Seitter 1987).

Follow-up observations were obtained on July 1/2, 1987, again with the EFOSC at the ESO 3.6-m telescope. A slit width of 1″ was chosen in order to clearly separate the [N II] 658.4, 654.8 nm lines at a dispersion of 23 nm/mm. The mean spectra obtained in the blue and red/near infrared regions are shown in Figures 1 to 4. In all spectra, contributions from the night sky and the planetary nebula are removed. The subtraction of the latter rests on the assumption that the strengths of the nebular lines towards the northern part of the PN do not differ from those superimposed on the central nebula. This seems to be justified from the appearance of the hydrogen lines in the two-dimensional spectra, where no differences are noticed between the two regions (see Figs. 2 and 3 in Seitter 1985b).

The result is striking as seen in Figure 4: no trace of Hα is found between the nitrogen lines. The central nebula of A 58, which also appears to be the remnant nebula of the nova-like outburst of the central star V 605 Aql in 1917, is the foremost candidate for a nebula entirely free of hydrogen.

The central star of the two nebulae exhibits a strong C IV 580.6 blend, besides marginal lines of He II 468.6, O V and O VI. The broad C IV feature with a FWHM of 2,300 km/s and a total width of 4,400 km/s suggests that this star is of WR type, as are the central stars in A 30 and A 78. An additional similarity of the three objects is the presence of cool dust. Extended dust shells of 140 K were derived for both A 30 and A 78 (Cohen and Barlow 1974) while the IRAS data indicate a point source of 170 K for A 58.

The central object of A 58 is interesting not only because of its extreme properties but also because the outburst was observed photometrically and spectroscopically. This puts severe constraints on any theory trying to explain the observed phenomena.

Following earlier suggestions (e.g. Iben et al. 1981 for A 30 and A 78, and Pottasch 1985 for A 58) the central stars of all three PNs are candidates for post helium shell flash evolution. The central nebulae in A 30 and A 78 have kinematic ages of a few thousand years. If the central stars reached their observed positions in the H-R diagram during the same time interval, one finds fair agreement with evolutionary computations. V 605 Aql, on the other hand, has reached a magnitude comparable to its pre-outburst brightness after less than 70 years.

Because the temperature determination is difficult for a star which displays just one well-defined line, the bolometric