Observations made in 1983 and 1984 were compared to observations taken in 1991 and 1992. Moffett, Goss and Reynolds reprocessed the earlier VLA data using the same computer software on both data sets to ensure they had the same resolution.

The earlier image was then digitally subtracted from the later one to reveal the amount of expansion. To arrive at the amount of expansion over the eight-year interval, the team digitally enlarged the earlier image by given constants and subtracted it again, repeating this process until they reached an amount of enlargement that made the earlier image the same size as the later one.

By this process they have a model for the shell which indicates it is expanding at the rate of 0.049 % per year, or at about 2,140 miles per second. In addition they found evidence indicating that the shell is not expanding at a uniform rate in all directions. By measuring the expansion rate in both the optical and radio spectrum, different components of the expansion are revealed.

Not all supernovae have regular shell-like remnants. Indeed, two of the most spectacular supernova remnants the Crab Nebula and 3C58 have irregular shapes whose expansion is thought to be driven by a central pulsar.

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NGC 6164/5 and NGC 5189

Two extraordinary bipolar nebulae

By Zac Pujic

In interpreting the Michigan-Mount Wilson Southern $H\alpha$ Survey, Karl Henize tentatively classified NGC 6164/5 as a planetary nebula in a 1959 letter to The Astronomical Journal. However Henize conceded that this was only a morphological and not an evolutionary classification of the object.

Since then, astronomers have shown that it formed from the young central star, HD 148937, an O6.5pf type star, rather than from an old one as normal planetary nebulae do. The "O" indicates that it is at the hot end of the spectral sequence while the "p" indicates that certain properties of its spectrum appeared peculiar to astronomers who first characterised it.

The star is at the centre of a hierarchy of nebulosity, the innermost of which is given the NGC numbers 6164 and 6165 and is about 4,230 light-years away. NGC 6164 is also designated PK336-0.1 and together with 6165 forms a reverse S-shaped complex 6 x 3 arcminutes (8 x 4 light years) in size whose major axis is oriented northwest-southeast. Fainter nebulosity (shown by arrows in the photograph) which extends some 15 arcminutes (18 light years) from the central star is too faint to be visually observed even in telescopes as large as 1.9-m in aperture and is older than the bright central knots of nebulosity. Lastly, a large bubble of nebulosity about 58 arcminutes (71 light years) in radius also roughly centred on HD 148937 is so faint that only recently was it fully characterised. All of these nebulae are presumed to have been generated by HD 148937 which suggests this star influences the interstellar medium in a bubble almost 150 light years across.

NGC 6164/5 is thought to have formed by mass-loss from the extremely young zero-age main sequence central star which is less than 350,000 years of age and is the brightest member of a triple star system.

Although these astronomically high figures of thousands of years seems enormous, they pale into insignificance when compared to, say, the period of rotation of the Milky Way (250 million years) and so these objects may seem rare because they are short-lived.

Although the fainter bubbles of nebulosities 15 and 58 arcminutes in radius about the star were formed from a steady stellar wind, the two NGC nebulae seem to have been generated from a more explosive ejection event about 5,000 years ago by an as-yet unknown mechanism. Such a structure should be short-lived, implying that the condensations are recent ejecta. Spectroscopic evidence has shown that the two NGC objects are composed of high-density gas—their red colour due mainly to emission of atomic hydrogen, $H\alpha$ light. The diffuse nebulae closer to the star are of a hotter, more tenuous gas and emit strongly in the light of OIII (ionised oxygen emission). The green-blue colour from OIII combines with that of the $H\alpha$ to produce a pink colour visible in these 'bridges' connecting the NGC objects and the central star. Clearly, this curious object is neither a planetary nebula nor a Wolf-Rayet bubble nebula.

Despite being superbly photographed by David Malin using the 3.9-m Anglo-Australian Telescope at the Anglo-Australian Observatory, this object will prove to be challenging in telescopes of less than 30-cm aperture. Observing from the dark skies of Mt Barney, Queensland, I could see both nebulae as very faint crescents with averted vision using a 32-cm f/5.75 Newtonian, 9-mm Nagler eyepiece and Lumicon OIII filter. Even so, the nebulosity was elusive and observers with less acute vision failed to see any nebulosity. A 42-cm f/4.5 Newtonian with the same eyepiece/filter combination showed the two nebulae more clearly, but it was only with a 51-cm Newtonian that I could see the object with ease, at which point the nebulosity showed uneven light distribution.

Also visible with a 51-cm telescope the two very faint bridges of nebulosity which appear to connect NGC 6164 and 6165 to the central star making the complex look like the reverse S in the photograph. Using a Lumicon OIII or UHC filter is necessary if observers try to view this object with a small telescope since its visual magnitude is probably around 13. A Lumicon Deep-Sky filter helps little. HD 148937 is of visual magnitude 6.8 and so is easily visible in any telescope. NGC 6164/5 is located in Norma at RA: 16h 34m, DEC -48° 06' (2000).

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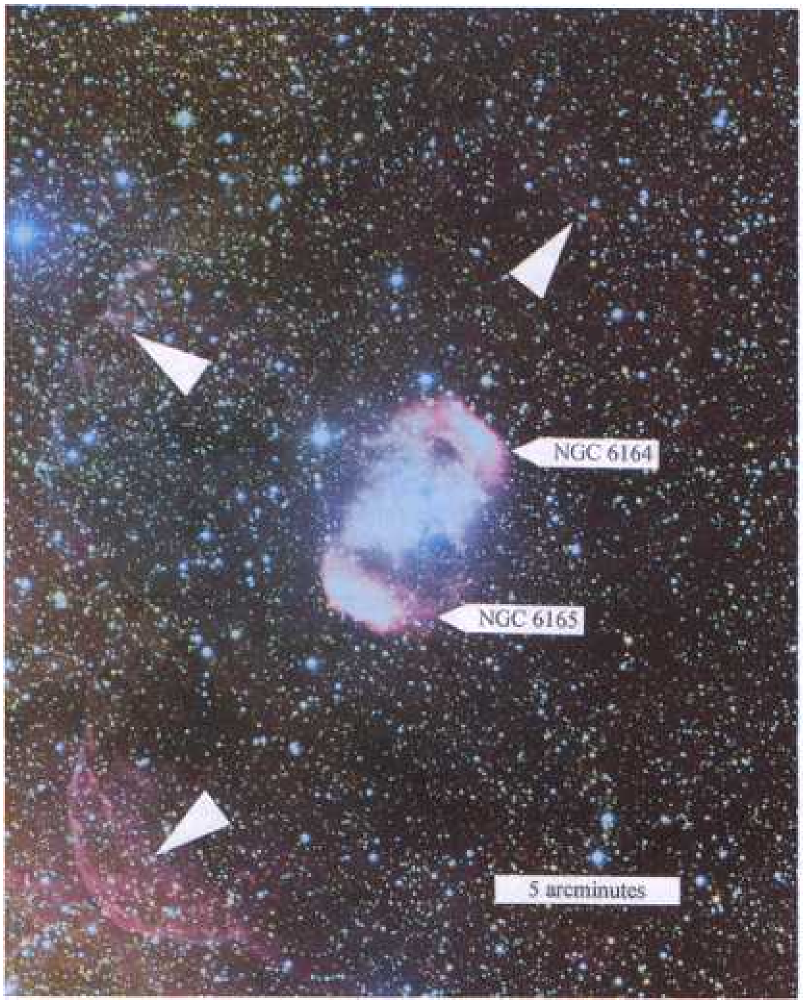

NGC 6164–5. Photograph by David Malin with the Anglo-Australian Telescope.
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Fig.3: Photo by Claude Voarino. Lagoon Nebula in Sagittarius. 12-inch Schmidt-Cassegrain telescope with focal reducer (1500mm EFL - ie F/5); 55 mins exposure on Konica 3200 colour film.

Fig.4: Photo by Luke Dodd. Zeta Orionis and the Horsehead Nebula. 12cm Astrophysics STAR ED refractor with tele-compressor: 60 minutes at F/5.6, on hypered Fuji 400. Guided with ST-4.

At magnitude 10.3, NGC 5189 is easier to observe. It is a highly fragmented planetary nebula whose high surface brightness makes it easy to observe in telescopes as small as 6-cm. In a 32-cm Newtonian, the view is that of a bar of light surrounded by numerous tufts and curlicues of nebulosity up to 20 arcseconds in diameter. Although the central star is of magnitude 14.0, it is difficult to see. In fact, the whole structure resembles a barred spiral galaxy, complete with central bar, curving spiral arms and a few faint stars immersed in its light!

Telescopes with apertures of 42 to 51-cm at high magnification with an OIII filter will reveal an object so convoluted, detailed and bright that it is difficult to understand why photographs of this object have not been taken by astrophotographers more often. It is about 1.7 x 2.5 arcminutes in size, and the major axis has a northwest-southeast elongation. Best views are obtained using moderate to high magnifications in conjunction with an OIII filter.

Photographs of NGC 5189 have revealed the presence of numerous pairs of ansae around the central O VI type star (designated HD 117622). These are the tufts of light visible in telescopes. The pairs of ansae however are not located in a single plane, suggesting that precessional torque from an unseen binary companion may have precessed the rotation of the central star over the period of time during which these ansae where ejected by the star. Consequently, the clouds of gas, ejected at speeds up to 25 km/sec by the central star, have enveloped it in a swarm of about 11 small nebulae. Furthermore, the whole system is enveloped in two faint lobes of nebulosity which may have arisen from a strong stellar wind. Its distance of about 800 light years from Earth means these clouds extend about a quarter of a light year from the progenitor star.

NGC 5189 is also called ARO 515, Gum 47, IC 4274, RCW 76, PK 307-3.1 or ESO 096-16 and is located in Musca at RA 13h 33.52m, DEC -65° 58.6' (2000). Were it located closer to the Magellanic Clouds, it probably would receive less attention, but its presence in a constellation otherwise devoid of bright nebulae makes this stunning and classy little object a must to see.

Due to the small size of these bipolar nebulae, they are suitable candidates for CCD-imaging by amateurs. I have not seen any photographs of either nebula published by an amateur astrophotographer and I challenge the readers to produce photographs of these beautiful sights for **Southern Sky**.

Introduction To Astrophotography

Part 4 Star Clusters, Nebulae and Galaxies

by Claude Voarino

Photography of 'extended' celestial objects, such as star clusters, nebulae and galaxies is referred to as 'deep-sky' photography, and it is possibly the most fascinating branch of astrophotography.

Extended objects appear large enough so that their images cover an appreciable film area. On the other hand, 'point-source' objects such as stars make a tiny image on film, the size of which is nearly independent of lens diameter (aperture) or focal length.

When dealing with an extended celestial object, the size of the image on film is proportional to the focal length. Its photographic brightness and the exposure duration are proportional to the focal ratio (F-ratio) of the optical system in use. The F-ratio, **for a given focal length**, depends on the aperture of the optics.

Because, in general, deep-sky objects appear rather dim, the F-ratio of the optics used to photograph them is of primary importance. The image from an F/4 telescope is 4 times brighter (photographically, but not visually) than the image from an F/8 system. Therefore, a picture of an extended object taken at F/4 requires an exposure time 1/4 as long as a picture taken at F/8. Likewise, a lens or mirror of, for example, 6-inch diameter will collect and transmit 4 times more light than one of 3-inch diameter. From what has been said above, it is apparent that, as far as deep-sky photography is concerned, large aperture telescopes and small focal ratios are a very good combination.

Because of their apparent dimness, photography of star clusters, nebulae and galaxies requires exposures of from 5-10 minutes to 2 hours or more. Therefore, of course, this type of photographic work calls for an equatorially-mounted and electrically-driven telescope, a drive corrector, some sort of guiding system and fast and/or hypersensitized film. As with planetary photography, accurate polar alignment is also necessary. Furthermore, in order to set the telescope to chosen values of Right Ascension and Declination, reasonably accurate setting circles are needed.

Image scales

The angular size of deep-sky objects varies considerably. For example, the Sombrero Galaxy (NGC 4594) has an angular diameter of 4.1 minutes (minor axis) and 8.9 minutes (major axis). The angular diameter of the Rosette Nebula (NGC 2237-9) is 60 minutes (minor axis) and 80 minutes (major axis). The Large Magellanic Cloud has an angular diameter of 550 minutes (minor axis) and 650 minutes (major axis).

Such a great difference in angular diameter means that a variety of focal lengths must be used in order to obtain images of the proper size on film. For example, at the prime focus of a telescope of 3000 mm focal length, the major axis of the image of the Sombrero Galaxy is a mere 7.8mm long. On the other hand, in order to record the whole of the Large Magellanic Cloud on a 35mm film frame, a focal length of no more than about 180mm is required.

Cameras using larger film sizes than the usual 35mm cameras can be used to give a photograph of a larger area of sky for a given focal length of lens or telescope. Amateurs have often used 120 roll-film cameras, in 6 x6 cm or 6 x 7cm formats, to cover larger fields on a single photograph, when suitable optics (camera lens or telescope) were available.

Alternatively, the use of a larger format allows the SAME area coverage with a LONGER focal length, giving a better scale to the image on the film.

Narrow or Wide

There are two main types of deep-sky photography: 'wide-angle' and 'narrow-field'. Wide-angle photographs of deep sky objects can be taken with equatorially-mounted cameras and lenses, astrographs and Schmidt cameras.

Alternatively, these picture-taking devices can be mounted in piggy-back fashion on a telescope that has a suitable equatorial mount and clock drive. In this case, the telescope is used for guiding, but its optical system is not involved in the actual picture taking.