Fig. 2 The backbone structure of normal Harvey *ras* protein complexed to GDP⁶. The structure is that of the amino-terminal 171 residues of 189-residue *ras* products, the protein p21. Residues 10–16 are near the phosphates, residue 30 is near the ribose ring and residues 116–120 and 145–147 form the guanine-base binding site. All the positions where oncogenic substitutions occur lie near the nucleotide-binding site. The epitope for the neutralizing antibody Y13-259, residues 63–73, is shown. The structure is very similar to the previously determined EF-Tu•GDP structure³.

G proteins, that determinants for G_i activation of adenylate cyclase are in the carboxy-terminal portion of the G_i protein. Although analogy with *ras* proteins could be misleading, it seems worthwhile examining regions in the carboxy-terminal domain of *ras* that might be potential sites for protein–protein interaction.

The deletion mutagenesis experiments of Willumsen *et al.*¹³ show that most hydrophilic regions outside the 32–40 region are not involved in *ras* transforming activity. The hydrophobic core itself, and the carboxy-terminal helix that appears to cover it in the GDP complex, remain to be explored. If the 32–40 region is itself not the site for interaction, this region could be involved in transmitting the GTP signal to the carboxy-terminal portion of the protein. When the crystal structure of the GTP complex of the *ras* protein becomes available, comparison of its structure with that of the GDP complex should reveal the exact location of the target binding site, the 'effector region'. □

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X-ray astronomy

Structure of a ring nebula

J.C. Raymond

THEORETICAL models predict that the interaction of a strong stellar wind with the gas surrounding a star produces a thin, dense shell of cool gas filled with very hot, low-density gas of the shock-heated stellar wind^{1,2}. A shell of this sort enclosing supernova 1987A has been inferred from the recent appearance of narrow nitrogen lines in the spectrum of the supernova³. N. Bochkarev reports on page 518 of this issue⁴ the measurement of X-ray emission from the hot interior of the ring nebula NGC 6888 that surrounds a Wolf–Rayet star. He finds that the temperature of the hot gas agrees with model predictions, but that the density does not.

As a massive star uses up its nuclear fuel, it can eject its outer layers to expose a hot core. Fusion has converted the hydrogen in such a star, called a Wolf–Rayet star, to helium. Either nitrogen (in a WN-type star) or carbon (WC-type) is abnormally abundant. The mass ejection which leads to the Wolf–Rayet-type behaviour can take the form of a high-velocity wind, mass transfer onto a binary companion or the ejection of a dense shell at low velocity.

A Wolf–Rayet star emits a very energetic wind, which sweeps the ambient interstellar gas and any stellar gas ejected earlier at low velocity into a thin, dense shell. Photoionization of this shell by the Wolf–Rayet star makes it visible as a ring nebula. NGC 6888 is one of the brightest and best-studied of the ring nebulae. The shell contains about five solar masses of gas expanding at 75 km s⁻¹ away from a WN star⁵. It is enriched in nitrogen and helium, and if one assumes that it is a mixture of normal interstellar gas and gas having the composition of the WN star, then it is composed of 90 per cent interstellar and 10 per cent stellar material⁶.

Theoretical models of such stellar wind bubbles have been widely used to interpret observations of ring nebulae and to model the structure of the interstellar medium. According to the models, the stellar wind expands freely until it encounters a nearly stationary shock front, which heats the gas to a temperature of about 10⁷ K. The pressure of this hot gas drives the dense shell into the surrounding gas.

Current models generally assume that thermal conduction of energy from the hot gas into the dense shell controls the interior temperature and that evaporation of material from the dense shell controls the interior density. Because the temperature and density determine the spectral shape and luminosity of the X-rays

emitted by the hot gas, X-ray observations should be an excellent test of the models⁷. One indication that such a test is needed is that the models predict the kinetic energy of the shell to be 20 per cent of the accumulated kinetic energy of the wind, but the observed kinetic energy of NGC 6888 is only 1 per cent of the estimated kinetic energy deposited by the stellar wind⁸.

Although the faintness of these nebulae makes X-ray observations difficult,

Image of NGC 6888 observed by ionized-nitrogen (N II) emission. The field size is 15 min × 13 min. Logarithmic intensity stretching enhances faint regions. Stars in the field have been suppressed. (Courtesy of J. Hester.)

Bochkarev⁴ uses data from the Einstein satellite to measure the X-ray brightness and spectrum of NGC 6888. The spectral shape is in excellent agreement with model predictions, confirming the role of thermal conduction in determining the interior temperature of the bubble. The X-ray luminosity is an order of magnitude lower than predicted, however, implying that the density of the interior is three or four times lower than expected. Bochkarev suggests that some of the hot gas leaks out of the nebular shell, either because the ambient medium has a porous structure or because of instabilities in the bubble itself^{8,9}. If that is the case, bubble models must be used with great caution. The basic model assumption of pressure balance seems to be violated. □

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