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Deprojection of Planetary Nebulae

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Abstract. Useful information can be obtained by deprojection of the two-dimensional images of extended objects such as planetary nebulae or supernova remnants. Three-dimensional distributions (assumed to be axially symmetric) of emissivity, electron number density and temperature might be derived from the deprojected structures. As a test, we follow the iterative algorithm of Leahy & Volk (1994) to project the images of several PNe taken at different wavelengths. This method can also be applied to the images of supernova remnants and galaxy clusters.

1. Introduction

Planetary Nebulae have many different shapes. Their intriguing configurations might be explained in terms of the projection of axially symmetric ionization structures viewed at different look angles. Simple theoretical models have been found to be successful in fitting the observed morphologies (Aaquist and Kwok, 1996). The real structures of PNe as revealed by the deprojection method turn out to be far more complex (See Volk and Leahy, 1993). We have therefore built a program to investigate the deprojected three-dimensional structures of a large sample of PNe and eventually FLIERS, cometary knots and cometary globules in HII regions surrounding OB cluster.

The basic idea of deprojection is to derive the three-dimensional configuration of an object from the two-dimensional image (Fig.1). This is somewhat similar to tomography if it could be assumed that the structure of the object itself is axially symmetric. Mathematical treatments such as the Fourier Slice theorem have been used to deal with the deprojection of astrophysical objects. This is a very powerful technique with wide applications.

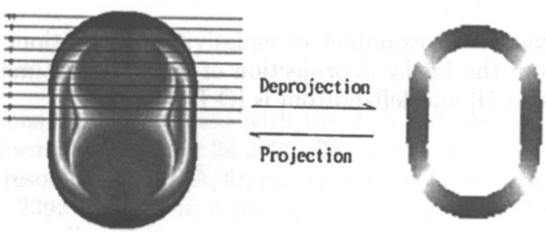

Figure 1. Projection and deprojection can derive the density or emissivity distribution.

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2. Matrix Method for Deprojection

The algorithm of the Leahy method is based on the iterative deconvolution technique given by Lucy (1974). The basic idea of matrix computation is derived from the integration of emissivity along the line of sight which can be written as (Leahy & Volk 1994)

$$I_j^k = 3D \sum_{i=3D1}^{N} K_{ji}\varepsilon_i^k \qquad (1)$$

Here, I_j is the intensity distribution on the sky plane from projected radius r_{j-1} to r_j. ε_i is a spherically symmetric emissivity distribution $\varepsilon(r)$. K_{ji} is the kernel matrix to transfer the coordinates from the spherical shell i to the sky plane j. The emissivity is then derived by using the inverse kernel Q_{ij} and iteration method

$$Q_{ij}^k = 3DK_{ji}\varepsilon_i^k / I_j^k \qquad (2)$$

$$\varepsilon_i^{k+1} = 3D\frac{\sum_{j=3D1}^{N} I_j^{obs} Q_{ij}^k}{\sum_{j=3D1}^{N} K_{ij}} \qquad (3)$$

As an example, the result for the line of IC 418 from WFPC2 (left of Fig.2) are shown in the right-bottom of Figure 2.

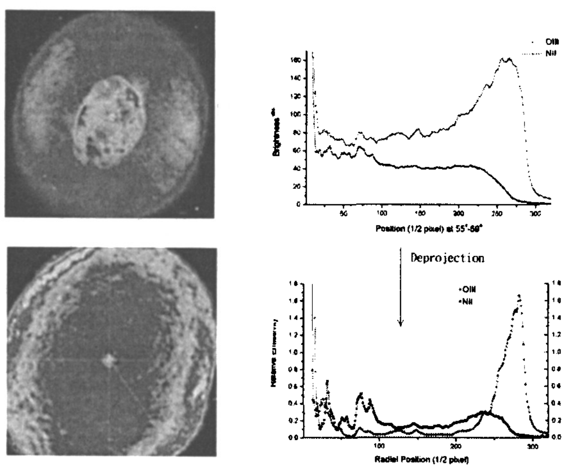

Figure 2. Numerical examples of emissivity distributions of [N II] and [O III] from the Leahy deprojection of the WFPC2 images of IC 418(left-top is [N II] and left-bottom is [O III]).

References

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