ionized flow caused by interaction with a low velocity wind, perhaps arising in the expanding ionized gas rather than in the stellar wind itself. Clearly the ionization mechanism in the vicinity of these globules and their tails need to be explored more closely and NGC 7293 provides an excellent site.

Where do the globules come from? Perhaps they represent clumpy ejecta from the progenitor asymptotic giant branch (AGB) star ejecta during a phase of mass loss or are formed through instabilities when the hot fast wind from the central star collides with the slow higher density red giant wind. Dyson et al. [12] have suggested that the knots could be remnants of SiO maser spots which were formed in the atmosphere of the AGB star and have survived ejection and photoionization. CO emission has been detected from some of the globules even though the beam is larger than the globules themselves [13]. The CO linewidths are small suggesting molecular gas at ~25 K. Further observations at high spatial resolution in the optical and millimetre will enable the parameters of the globules, such as the gas and dust content, to be determined and their formation and evolution to be more thoroughly investigated. So far no other planetary nebulae with similar small-scale structures have been observed but there is no reason to think that the Helix is atypical and such structures probably exist in all planetary nebulae. Until more are found the Helix will continue to be an ideal laboratory for the study of these ionized-neutral/dusty interfaces.

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OTHER ASTRONOMICAL NEWS

Detection of Faint Extended Structures by Multiresolution Wavelet Analysis

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1. Introduction

The wavelet transform, in common with other image transforms such as the Fourier or the Haar transforms, can be used to produce insightful perspectives on image data. Some particular attributes of the wavelet transform will be discussed in the next section, which seem to make it very appropriate for astronomical image data. Two illustrative examples will be used, where the original images do not provide much indication of underlying faint extended structure. The wavelet transform can effectively uncover such faint structure. It is a new mathematical tool which ought to be kept in mind when exploring and analysing image data.

2. Multiresolution Analysis with the Wavelet Transform

We will briefly motivate the use of wavelets by making reference to (i) the property of multiresolution usually associated with the wavelet transform; and (ii) the perspective of the wavelet transform as a discrete convolution filter.

It has been known for a long time that multiresolution approaches to images allow an image to be interpreted as a sum of details which appear at different resolutions. Furthermore, each scale of resolution may pick up different types of structure in the image. For example, a coarse resolution may pick up gross structure, and finer resolutions allow progressive insights into faint and textured structures.

Consider the convolution of an image with a Gaussian. The effect is to smooth the image. Now consider that Gaussian to have a scale parameter, a function of the standard deviation (e.g. $1s$, $2s$, $3s$, ..., where s is the standard deviation). By varying the scale parameter, a sequence of Gaussian-filtered images is arrived at. These provide a sequence of resolution scales. The Gaussian function is not a wavelet; for the latter certain properties are required, such as translation invariance, and a "scaling property" – a dilation invariance property – which relates the filtered images at two successive scales. The wavelet used in this article is isotropic, which is unlike some other wavelets used to enhance alignments or to develop useful strategies for image compression. An isotropic wavelet appears to be a good choice for the investigation of astronomical objects.

The natural incorporation of a suite of resolution scales in the wavelet transform has been beneficially used in different application fields. Such multiresolution analysis is particularly appropriate for astronomical data since the structures we want to recognize have very different scales. A priori we cannot know the size of a local neighbourhood where contrast should be enhanced, i.e. we cannot define in advance an optimal resolution level for analysing an image. The wavelet transform implicitly caters for a more sophisticated astronomical image model than the simple "background plus objects" image model. The latter, implicitly, is very widely used: object detection packages estimate the local background, and then define protrusions from this as objects; or in image restoration, a two-channel algorithm regularizes the background differently from non-background objects. In practice, astronomical images often encapsulate more complex, superimposed objects and/or structures than is allowed for by the traditional image model.

Let us take image restoration as an example. There are different ways of enforcing, e.g., the smoothness of the background, or of planetary objects, by adapting the widely-used Richardson-Lucy (RL) method. A good alternative is de-noising through shrinking noisy wavelet coefficients. The latter define the wavelet-transformed image. Furthermore wavelet coefficients are obtained which define the transformed image at varying levels of resolution. The original image may be reconstructed from the series of wavelet-transformed images. A noise-removal strategy is based on the wavelet coefficients being clipped in value if they are considered to be associated with noise. Such an approach has been pursued by various authors. This strategy was investigated by Starck and Murtagh (1993) with the conclusion that such de-noising, in the framework of RL restoration, leads to significantly improved detection of faint objects. This de-noised RL image restoration method, used in the preparation of some of the images discussed below, is available in the MIDAS image processing system (version N093).

In this article we wish to see what insights the wavelet transform, at some appropriate resolution level, can offer in terms of uncovering faint extended structures and physical processes. Differing structures, which are not at all apparent in the given image, may become salient at other resolution scales. We select a range of *differences* of resolution levels of the image, – which are sensitive to faint structures, and which are produced and output in the new MIDAS wavelet package. Thus, what may be referred to as a "level 1" image is the difference between the original image and the first wavelet-transformed image; the "level 2" image is the difference between the first and the second wavelet-transformed images; etc. Similar objectives have also been pursued using another wavelet-based approach, the H-transform. The latter is available in MIDAS as a command FILTER/ADAPTIV.

3. Cometary Coma Analysis

The abilities of the wavelet transform to provide insight on cometary comas was tested with images of the periodic comet P/Swift-Tuttle. The data were collected with the 1.2-m telescope at the Calar Alto Observatory in Spain in October and November 1992 and were kindly provided by Dr. K. Birkle of the Max-Planck-Institut für Astronomie, Heidelberg.

Figure 1 shows the cometary coma of P/Swift-Tuttle observed through the CN molecule filter of the IHW filter set. The isophote pattern is asymmetric with respect to the nucleus (= central brightness peak) and highly irregular which usually indicates the presence of jets in the coma. Figure 2 gives the level 4 wavelet transform result for the CN image. Three jets can clearly be identified. It is also easily possible to determine the geometry, the curvature and the approximate position angles of the jets at the nucleus from the wavelet image.

Compared to other methods for the coma structure enhancement (see Larson and Sekanina, 1984; A'Hearn et al., 1986; Schulz, 1990; Boehnhardt and Kohoutek, 1992) the wavelet analysis can be applied in a very convenient and straightforward way to cometary coma images. Most importantly, it does not depend on the accurate determination of the nucleus position as a reference point for angular or radial shifts (method of Larson and Sekanina, and of Schulz) or for the alignment of the images analysed (all other methods). Therefore, the interpretation of the wavelet analysed coma structures should not suffer from the presence of image processing artifacts or "diseases" (artificial structures, modified geometry, "blindness" as regards ring structures) as do each of the previous methods.

In summary, the wavelet analysis of cometary images promises to become a very useful tool for the enhancement of faint coma and tail structures. The identification of jets, fans, shells and brightness excess areas, and the derivation of their characteristics from such images can be used for the determination of important properties of cometary nuclei (rotation motion and axis, nucleography of activity centres) from ground-based observations.

4. Physical Processes around Elliptical Galaxies

The HST PC (Planetary Camera) image of elliptical galaxy NGC 4261, and the NTT SUSI image of the same object, as described in Zeilinger et al. (1993), were used. The objective was to uncov-

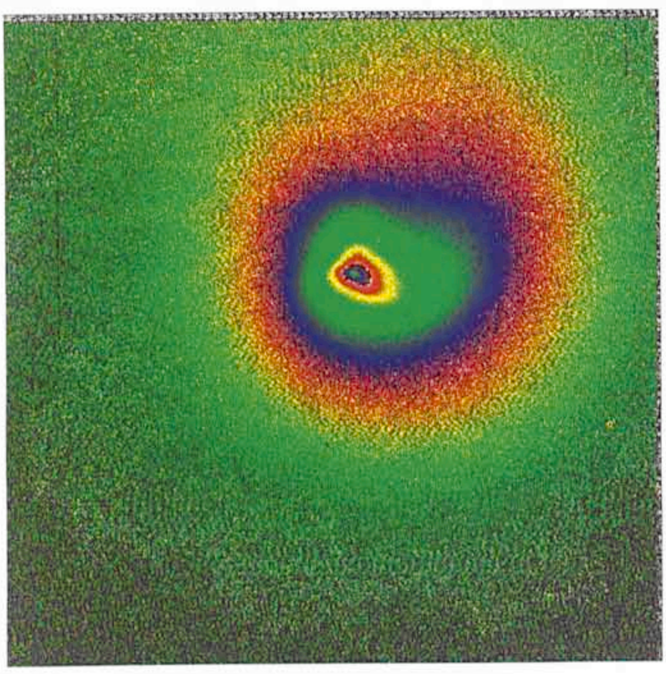

Figure 1: *Comet P/Swift-Tuttle, October-November 1992.*

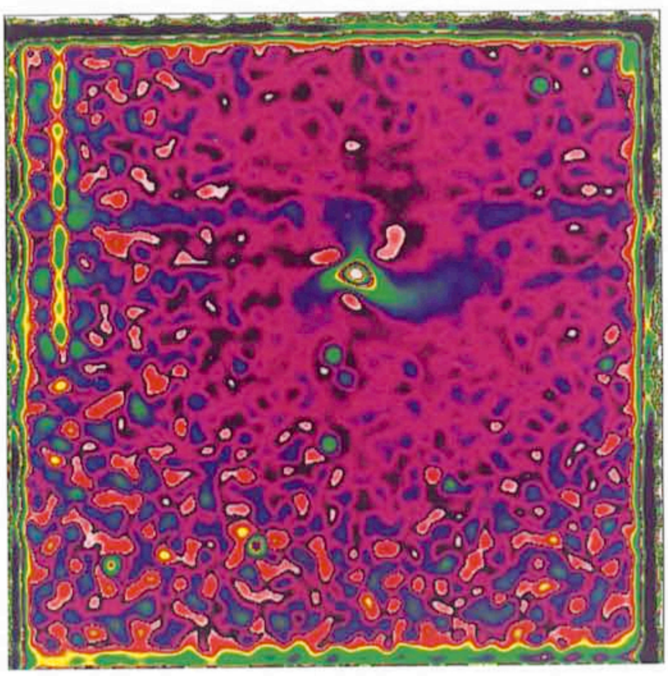

Figure 2: *Wavelet transform of Figure 1 image, enhancing coma.*

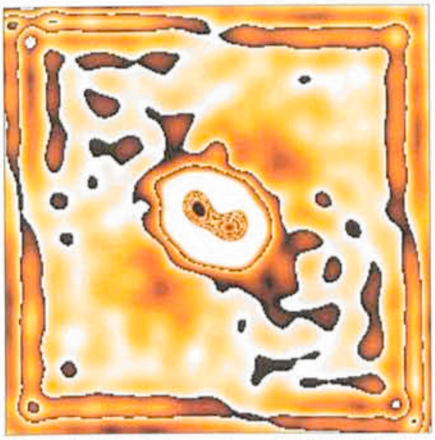

Figure 3: *Wavelet transform of the SUSI image of NGC 4261.*

Figure 4: *Wavelet transform of the PC image of NGC 4261 (level 4).*

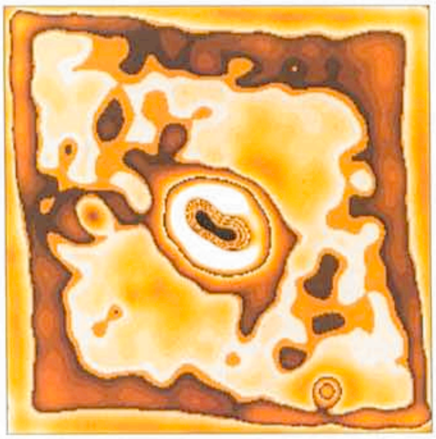

Figure 5: *Wavelet transform of the PC image of NGC 4261 (level 3).*

er the morphological characteristics of infalling matter in the central region of the galaxy. The original images provided no direct clues. Availability of a pair of images from different instruments with very different resolutions and signal levels affords a very good framework for validating the faint structures uncovered by the wavelet transform, as will be seen. (See also p. 28 of this issue.)

To lessen the impact of different effects due to image borders and image resolution, the SUSI image was rebinned to the scale of, and rotated to be aligned with, the PC image. Both images are shown in Zeilinger et al. (1993). The SUSI image was sharpened, and the PC image was restored, using 40 iterations of the de-noising RL method referenced in Section 1 above.

Figure 3 shows a wavelet transform image (level 4) of the de-noised and sharpened SUSI image. Figures 4 and 5 show two wavelet transform images (levels 3 and 4) of the de-noised and restored PC image. A rather severe intensity transfer function has been used to emphasize the faint features external to, and closely adjacent to, the central dust lane of the galaxy. In the ground-based and level 3 space-born images one notices a clear protrusion to the right-hand side (which is far less pronounced in the level 4 PC image). Similarly, much of the detail in the upper left-hand side is common to these images. These features may be interpreted in terms of a warp related to the central disk. Emphasized features in the background, and towards the image borders, are artifacts which are of course uninteresting.

5. Conclusion

The wavelet transform provides a powerful exploratory tool for the analysis of faint features associated with processes which are superimposed and/or not easily distinguished. It is undemanding in terms of image pre-preparation or modelling. If faint and complex features are present, then it offers an excellent way of heuristically demarcating them.

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StarGates and StarWords

AN ON-LINE YELLOW PAGES DIRECTORY FOR ASTRONOMY

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1. General

Two new databases have been made available at ESO under Starcat (Pirenne et al., 1993). They are products of the Star*s Family encompassing databases, data sets, dictionaries, directories, mailing labels, and so on, compiled by the second author (see Heck, 1991c). They offer a comprehensive *yellow pages* service of astronomical institutions world-wide as well as a lookup database of acronyms and abbreviations used in astronomy and related sciences.

2. StarGates

StarGates is an on-line database of astronomy, space sciences, and related organizations in the world. It offers essentially the information listed in directories on paper published previously under the acronyms IDAAS (Heck, 1989a), IDPAI (Heck, 1989b) and ASpScROW (Heck, 1991 a&b), and currently available under the homogenized name of *StarGuides* (Heck, 1993 a&b). *StarGates* has however the advantage of being permanently updated. To date, more than 6,000 entries from about 100 countries are accessible.

Besides astronomy and space sciences, related fields, such as aeronautics, aeronomy, astronautics, atmo-