Conference Impression

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Abstract. This paper gives a personal impression of the conference “Asymmetrical PNe II: From Origins to Microstructures”, flags some of the highlights, gathers together some facts and terminology, and indicates some promising future lines of work in this field.

1. Introduction

These conference proceedings are the condensed result of the 2nd meeting on Asymmetrical PNe, held at MIT during August of 1999. Being the last such meeting of this millennium, and a successor of the successful 1st asymmetrical meeting held at Oranim in Israel during August 1994, and published as Anns.Isr.Phys.Soc.,11 in 1995, it was especially good to see that the subject has made significant progress over the last lustrum. The main impact, as you can see immediately by just a quick skim through this volume, has come from the imaging done by the Hubble Space Telescope. The wealth of complex detail revealed by these unprecedented images has left the theorists reeling, the observers gasping, and both groups with plenty ground–based work ahead of them. A special highlight of the meeting was the free hand–out to participants of a CD with superb WFPC2 images by Hajian & Terzian! Note that references to papers in this volume are from here on indicated by an asterisk next to the authors name.

2. Overall impression

My overall impression from this meeting is that the observed morphologies of PNe are shown to be more and more complex, mainly due to the images from HST. The circle with a dot in the middle of 15 years ago is no more! The impact of the increased spatial resolution data available from the space observations is extraordinary! Archival research with HST data is now becoming a important tool for PNe research, especially in combination with ground–based high resolution spectroscopy. To date there are about 125 HST images of PNe available. Building on the basis created by the work of Josef Solf in the early eighties (e.g. Solf 1983, 1984), the spatial resolution and spectroscopic separation at the sub–pixel level of small features is now coming of age, and is teaching us a lot about the formation of PNe. All this detail, however, is clearly posing a problem for the theorists: the complexity is enormous and at present theory understandably
lags the observations.

Having said this, theory has also made progress; several models are getting better at producing the observed gross shapes of nebulae (Frank, García–Segura, Livio, Soker and others (*)), and attempts at explaining small scale structure (Dwarkadas(*)) are being made. The overall theoretical picture, however, is still quite elusive. Mass loading obviously plays an important role in some objects (e.g. globules in the Ring nebula (Dyson(*)), and perhaps also in NGC6369, and NGC6751 just from their complex morphology, and the theory for this phenomenon is well developed.

Point–symmetry has become very popular and it seems that there are hardly any asymmetrical PNe left that do not have some kind of point–symmetry. I recall that at the meeting in La Serena (Mass Loss on the AGB and Beyond) held in 1992, the concept was hardly known.

The use of movies to show time dependent behaviour of data is also on the increase with several presentations both of observational and theoretical material at the meeting, giving some interesting new ways of visualising data. The movie of M2–9’s inner nebula (Balick(*)) especially struck me, since it showed the nebula’s rotation, which would have got lost had the data been presented any other way. To “see” the ISM penetrating a PN (Villaver(*)) and thus creating an asymmetry was also spectacular. Internet access to this kind of movie is also an excellent way of showing the community what is happening.

3. Terminology

As a result of the increasing complexity of the observed morphologies, the terminology has recently also proliferated. Table 1 lists the terms I heard at this meeting to describe features in PNe. They range from the practical to the sublime, and even beyond...

| Jets       | Fliers     | Rings     | Cocoons    | Toroidal cocoons |
|------------|------------|-----------|------------|------------------|
| Disks      | Ansae      | Shells    | Trails     | Parallelograms   |
| Haloes     | Real haloes| Blobs     | Lobes      | Bullets          |
| Tori       | Structures | Knots     | Filaments  | Bubbles          |
| Forks      | Waists     | Hoops     | Loops      | Double Bubbles   |
| Tips       | Cylinders  | Envelopes | Funnels    | Tuning forks     |
| Stripes    | Dark lanes | Arcs      | Caps       | Capped bicones   |
| Tails      | Remnants   | Globules  | Cometary...| Nipples          |
| Rays       | Corkscrews | Rolls     | Ellipsoids | Smoking guns     |
| LIS        | Lattices   | Petals    | Slobs      |                  |
“Paradigm” is definitely in, the previously much over-used “scenario” is out; “Weather” (which you ignore...) is in; “Physics” (...which you don’t) is out. Other much used key words were: precession, point–symmetry, BRETS, episodic or periodic outflows, irregular, mass loading. Finally, a nice piece of nomenclature was reportedly found in the address of a famous Observatory, the “Navel Absorbatory”.

It is clear that astronomers are also influenced by "fashions" or "trends". Please start a trend and use the word “polarigenic” (coined by yours truly about 15 yrs ago), as in "polarigenic mechanism" for something that produces polarisation.

4. Observational appearance of bipolar and point–symmetric PNe.

Figure 1 shows the possible appearances of bipolar and point–symmetric nebulae as projected onto the plane of the sky. Under certain circumstances blue and red shifted components can be located on the same side of the object, even though this is, at first sight, counter intuitive. For objects with a precession cone cut by the line of sight or plane of the sky this is observed (e.g. IC4634) and such objects are point–symmetric. M2–9 is a bipolar that shows plane symmetry in it’s inner nebula, and point–symmetry in it’s outer lobes which are also both red shifted since they are reflecting light from the central object. So far this is unique among PNe. Nebulae are put into the following classes:

Bipolars: NO (near, or not too far from plane of sky), EO (nearly end–on), RR (both lobes red shifted)
Point–symmetricals: P1 ( $0 \leq i \leq 0.5\phi$ ), P2 ( $0.5\phi \leq i \leq 90-0.5\phi$ ), P3 ( $90-0.5\phi \geq i \leq 90$ ), where $\phi$ the precession cone opening angle, and $i$ is the inclination angle to the plane of the sky of the nebula.

5. Future work

Some lines of research are promising and should be continued in the near future. Here I mention a few, based on what I heard and saw at the meeting, that I find of particular potential interest.

5.1. Binaries versus single stars

The whole issue of what kind of mechanism drives the production of the most asymmetrical and physically different class of PNe, the bipolar nebulae (Corradi & Schwarz, 1995), depends critically on finding the binary central stars. There is strong circumstantial evidence for the presence of binaries in several bipolars, but it has so far been very difficult to obtain direct determinations of the numbers of bipolars and other PNe that contain binary central stars. A promising method is that of radial velocity determinations, especially in the infra–red, where obscuration is less of a problem. Bond (*) has done pioneering imaging work with HST, which is rightly being continued.
Figure 1. The possible appearances of bipolar and point–symmetric nebulae are shown. The inclinations are assumed and result in these appearances. The ease of discovery of bipolar nebulae depends on their inclination: near the plane of the sky they present a bipolar aspect which makes (typically) imaging discovery easier. The opening angle for precession cones is taken to be smaller than 40°, and α is the projected cone angle. For P2 nebulae, the precession cone is not cut by the plane of the sky or the line of sight, and this type does not show blue and red shifted components on the same side of the central object. Note that type EO can also have B and R shifts on the same side of the object, and that the radial velocity difference refers to the projected blue and red lobe velocities.
From the theorist’s point of view the single versus binary star model for bipolar nebulae is split into two parts: the making of a bipolar nebula starting with an asymmetrical density distribution, and the mechanism to produce that initial density distribution in the first place. To make a bipolar nebula with some outflow in an asymmetrical density distribution, is relatively easy and many models can do this. Particularly successful are the models of García–Segura (*), a two wind interaction combined with magnetic field and near break–up rotation, and the work by Frank et al. (*) based originally on work by Icke (1988) using the Kompaneets theory. The nebulae with the highest aspect ratios, such as M2–9, pose more of a problem as the required density gradient and other parameters become un–physically high. Here the binaries form a more natural system to generate a strong pole to equator density gradient, and their accretion disks can blow disk winds that are highly collimated and fast, explaining the high observed velocities, the strong collimation, and the large wings of the observed hydrogen line profiles. Excretion disks, as proposed by Morris (1987), can shape the slow wind from the primary star into two lobes, through which the fast wind then blows out HH–like objects as in He2-104. In single stars there is no identified mechanism to produce the necessary high underlying density gradient that shapes the wind, and a particular combination of strong magnetic fields, rotation, and equatorial mass loss has to be invoked to give asymmetrical nebulae at all. My overall impression is that binaries are needed for the most extreme bipolars and perhaps for all bipolars. Point–symmetry is most easily explained by precession; again something that occurs naturally in binaries. Also the combination in M2–9 of both point– and plane symmetry is difficult to explain without a binary central object, as is the presence of [OIII] lines and a low luminosity central object. I think that an object like He3–1475 (see the HST image on the CD handed out at the meeting) cannot be explained by any single star model! We must go and find those binaries!

5.2. PNe–ISM interactions

There were several papers on the interactions of PNe with the ISM (Knill–Degani; theory, Kerber; observations, Villaver; modeling, with movie(*)). This is clearly a very interesting asymmetry producing mechanism, especially affecting the outer parts of the PNe, and in some cases even resulting in stars being outside their own nebula. The ratio of density between a typical PN and the ISM is about 50 in the Galactic plane and 300 in the halo. Under certain circumstances the ISM can penetrate the PN, giving spectacular interactions, as shown in the presented movie.

5.3. Morphology in the HR diagramme

The morphologies derived from HST images of a sample of PNe taken and to be taken in the Magellanic Clouds, can yield important relationships between morphology and the central star evolutionary stage. This work was started by using Galactic PNe, extracting statistical information about a sample of which narrow band images had been taken, and making a morphological classification of the nebulae. The result was a plot of their central stars in the HR diagram as a function of morphological class, yielding some intriguing correlations, especially for the bipolars (Stanghellini et al.1993). The large uncertainty in the individual
distances to the PNe in this sample make this result only statistically interesting. By going to the Clouds, the distance uncertainty is gone and much better results can be obtained, again using HST. Stanghellini is undertaking this important work.

5.4. Polarimetry

Polarimetry was meagrely represented at this conference, as at most meetings that do not specifically deal with the subject. Only one out of 55 talks and 2 out of 38 posters contained some item about polarimetry. Since polarimetry often can provide a missing and vital piece of information, this is a plea for all observers to use and be more aware of polarimetry. The fact that the title of this meeting contains the word “asymmetrical” should already make people think about polarimetry, as it is uniquely suitable to detect asymmetries.

Two examples of the importance of polarimetry are: Trammell et al. (1994) found that 77% of 31 AGB objects are intrinsically polarised, while Johnson and Jones (1991) found 74% of their sample to be polarised. There clearly is a high fraction of AGB stars with asymmetries. If there are no features in the polarisation spectrum, there has to be a global asymmetry in the object, and probably dust scattering; if there are spectral features, local asymmetries such as convection cells or other atmospheric features must be present. The whole critical question of the onset of asymmetry during late stellar evolution, whereby essentially spherical stars produce PNe of which many are asymmetrical, can be uniquely studied with polarimetry. The mechanism of dust scattering in the faint loops in M2-9 (Schwarz et al. 1997) was a supposition until the loops were found to be 60% polarised at right angles to the plane formed by the source, scatterer and observer. Such high degree of polarisation is not only easy to observe it also firms up the proposed dust scattering mechanism to a certainty. This then allowed the distance to M2–9 to be determined accurately from it’s expansion parallax. Polarimetry provided the key piece of information that allowed the physical parameters of this object to be found.

Continued and increased work using polarisation measurements on PNe and AGB stars–such as that in the press (ApJ) by Weintraub, Kastner (who showed the data at this meeting), Sahai, & Hines, who used NICMOS to image AFGL2688–will surely yield important results!

In summary, this was a meeting clearly dominated by the observers using HST imagery making theorist’s lives difficult. The old Chinese curse “May you live in interesting times!” is applicable here, and times will become even more interesting in the near future. Thanks for inviting me, Joel and Noam, and see you at the next asymmetrical meeting!

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