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CONCLUDING REMARKS

Judith J. Perry[1]

Presentation by Deborah Dultzin

"It is a privilege to introduce Prof. Judith Perry. I met her in 1985, in Bangalore, India. I was attending the first Quasar International meeting of my career. I hung a poster that contained my first observational results, and ran away immediately, God forbid anyone should ask me anything. In the evening I felt I had successfully survived the first day, and then Judith approached me:"Are you Deborah?" she asked "yes" I said, "from Mexico? "yes". And she went on: "OK, I have organized a poster session for Wednesday, and you'll be presenting posters 1 to 10, you'll have half an hour".

I could not believe my ears. I said "OK" like a zombie, actually I wanted to drop dead. I inmediately felt sick in my stomach, and got a migraine attack. I hated Judith with all my heart. Still, I set to work at once. I made an incredible effort, and I approached everyone whose poster I did not understand. Everyone was very patient to explain everything. I learned a lot, and my presentation came out very well. All the pundits present (and there were all of them) got to know my work and who I was, and this meant a turning point in my life, particularly since I had studied in the former Soviet Union and started my career in general relativity.

My hatred toward Judith turned first into gratitude, and then into love for a dear friend. Her first degree was in structural engineering, which I only recently learned, and she had a lifelong love and talent for architecture and design which informed her almost architectural models of galactic nuclei. The fact that she retired from astronomy a few years ago, and is now an architect, will, I'm sure give her somewhat of a "learned outsider" very special view of how the field has moved on in the last few years."

It was an honour and a privilege to have been invited to give the concluding remarks at this wonderful conference honouring my dear friend Deborah, particularly since I haven't been working in the AGN research for six years. A long standing bond between Deborah and me has been our sceptical and questioning attitude toward received wisdom as well as our determination to help women succeed in astronomy.

When I began to plan my remarks I quickly realised that my role would –of necessity– be less that of 'Grand Old Man' and more that of the 'Wicked Witch' – I hope to honour Deborah by being questioning and giving not so much a detailed summary and review of the meeting but a broad look at the issues facing AGN research now and how the work presented here fits into the quest for understanding.

When Meg opened this meeting she was asked what things had been like 30 odd years ago. Looking around this room, it appears that Vaha Petrosian and I are perhaps the oldest, or, if not, then the two here who started working in AGN research the longest ago: so it falls to me to answer that question. Both the subject itself and the position of women in the field have changed almost beyond recognition in the intervening years.

The study of quasi-stellar objects, or QSOs, started in 1969; I entered the field in 1971. There were almost no women in the field; Margaret Burbidge was both an intellectual and scientific leader and an inspiration to those very few women in the subject. Throughout the 70s and early 80s most meetings had no women speakers at all; at the meetings where I spoke I was the only woman speaker or, at most, one of two. For the meeting that Deborah just spoke about, the 1985 IAU session on QSOs in Bangalore, I had been invited to organise the session on spectral line studies. I deliberately set out to invite the best speakers in the field and of those, where possible, to choose women who were leaders in the field. I believe it was the first meeting at which the women speakers outnumbered the men. Bev Wills, Suzy Collin, Deborah and I spoke, as did Alex Filippenko and David Turnshek. A few years ago a male colleague who was at that meeting told me how very important it had

[1] Sohnius & Perry Ltd. & The University of Cambridge, Cambridge, UK (perry@sohnius-perry.co.uk; http://www.sohnius-perry.co.uk).

been to him and to his understanding of the sociology of science and of the position of women in astronomy. He reported that he had felt very uncomfortable in a session dominated by women, and understood for the first time what it must have been like for women to have been always in the minority. I must say however, that I always benefited from the strong support and encouragement of many of my male colleagues and have always loved working with those men. Vive la difference.

AGN was not a term in use 30 odd years ago. We spoke of QSOs and quasars (the radio loud QSOs) not even sure how they related to each other. Seyferts were not then considered related objects, and were not discussed at the same meetings. The 70s were a magic, vibrant time – the community was small and the meetings turbulent and exciting, brimming with lots of heated argument: people literally shouted at each other, albeit with (mostly) good humour. All questions were open: The physical origin of the high redshifts was still controversial: were the redshifts cosmological, gravitational or intrinsic? Were the blue shifted absorption lines, discovered in some spectra shortly after the discovery of the first QSOs, due to foreground objects or were they intrinsic and measures of dramatic outflows of gas? What was the origin of the heavy elements seen in all QSO spectra? At that time, before the discovery of starbursts, the accepted picture of the evolution of the universe was that it was slow and orderly, and that the abundances of the elements were built up gradually as stellar populations and galaxies aged. Therefore the heavy elements observed in high redshift QSO or cosmologically young objects were disturbing and inexplicable. QSOs and quasars could not be resolved and it was not clear if, or how, they were related to galaxies. It was also a rather snobbish community who tended to scorn the stellar and interstellar community, seeing that science as boring and unexciting. Therefore the community didn't learn about interstellar winds, supernovae interactions with the ISM, and all the other physics which we now know is important in active galaxies.

The theoretical model, or paradigm, which was gradually assembled in the 80s was consolidated in the 90s. It is now accepted that AGN have nuclei with black holes surrounded by a dense stellar cluster, with an accretion disc around the black hole which is the source of the non-thermal continuum. Some objects have a dusty torus; some powerful radio emission. Interactions and secular instabilities play a role in triggering activity. It appears that no major or fundamental change in that canonical model has been required since the late 90s. Are we stuck? Or is the field now entering a new phase? The field is maturing – the early excitement of initial discovery and of new theoretical ideas is waning as it always does.

It is time to elucidate the details and build up very detailed physical models of real objects rather than continuing to build "average" observations putting too many objects into the same box and looking for 'universal' prototype AGN all of whose differences can be accounted for by angle of observation. It is the time to replace simple models with a deeper understanding of the complexities of the vast panoply of objects in this class. It would be all too easy to see the work now required as the 'boring' equivalent of the early detailed work of our stellar and interstellar medium colleagues who diligently built the models which now inform the models of the evolution of not only AGN but also of cosmology and of galaxies. (And I believe many cosmologists do feel that AGN are no longer exciting – a view clearly not shared by anyone here!) It is time to flesh AGN models out, and the wonderful observational results presented here should help do just that – but only if the results are analysed in detail and not squeezed into a box with too few parameters. For this detailed, high signal to noise observations of individual objects need to be made and a classification system developed equivalent to the classification of stars into the O, B system. Such a system will certainly need to be multi-dimensional.

Before going further I would like to make a plea for the importance of negative results – these are vital to establish what does and what does not work. I believe strongly that negative results must and should be published.

What were the highlights of this meeting as I see them?

I will come away from Mexico with a deep admiration for the new methods which have been devised in recent years to discover more and more objects and to study AGN with ever increasing precision and in ever more detail with ever more signal to noise.

At this meeting staggeringly impressive and superb observations were presented. What do I think, with the advantage of 6 years distance, were the major advances presented here and what are the remaining problems to be solved? The list is long:

- Beautiful, impressive new instruments.
- The discovery of new objects with HST deep fields and polarization studies which have begun to enable us to elucidate the richness of the variety of the AGN zoo.

• The detailed studies of local, low luminosity objects to extract the stellar contribution to the black hole environment. The imaging spectroscopy of the centres of nearby AGN which found starbursts within the central parsecs is, naturally, particularly exciting for me as it confirms our predictions from the early 80s.

• Detailed deep imaging, microlensing and polarization studies. Although limited to nearby objects the beautiful NLR studies which are beginning to map the inner regions of AGN and allow the separation of components will surely elucidate physical processes which are probably relevant at all redshifts.

• Line ratio studies whose complexities show that there must be several distinct contributing regions.

• The mapping of nuclear winds and the warm absorber (but are we seeing collimation?).

• The rich, detailed studies of SgrA which is yielding such important insight into the spectral continuum generation and putting limits on the contribution of inverse Compton and Synchrotron scattering and other processes. Similarly the detailed physical studies of OJ287 are exciting. Taken together these studies are beginning to address the question of the role of binary black holes and they certainly show that one parameter families do not work.

• The detailed observations of blazars in outburst which appear to show that the internal shocks with the same energy input have different outputs implying that the environment plays a very significant role in the behaviour and that further study of such individual shocks may become a useful diagnostic tool for the study of the circum-nuclear atmosphere of the black hole.

• The variability studies and the relations that are emerging from the Sloane surveys which show that variability is correlated with the black hole mass.

– Are the larger amplitude variations seen in objects with more massive black holes due to inherent variability in the feeding mechanisms due to stellar cluster dynamics or is it an inherent instability of the accretion disc itself?
– How does this fit with the suggestion that the mass of the black hole is proportional to the age of the object and that massive objects are 'dying'?
– The non-periodic nature of the variations indicates that whatever processes are involved must be highly stochastic.
– Larger black holes have larger accretion radii and thus their gravitational influence extends further, and has a greater effect on the surrounding cluster and the nuclear atmosphere.

• The comparison studies of the morphology and characteristics of the host galaxies of AGN are again pointing to systematic differences in the hosts of radio loud and radio quiet objects. Thus one of the earliest ideas about these objects appears to be rising from the dead.

• Finally, I love the idea of diamonds in AGN!

Personally, in a perhaps prejudiced view, I thought that amongst the most important results in this meeting were the amazingly beautiful resolved pictures of the central regions of AGN which Thaisa Storchi-Bergmann presented. Such detailed views of the central regions were totally impossible to hope for when we were developing our ideas about the structure of the nuclear regions in the 80s and when we postulated that there must be young dense nuclear stellar clusters which, in consort with the supermassive central black hole explained the phenomenology of AGN. We relied solely on the power of physics and on deduction, but couldn't prove that we were right. I remember being attacked when I first suggested that such clusters existed (when I first proposed that there were supernovae near the black hole, starbursts were not yet a recognised phenomena, and the hypothesis that high supernovae rates could occur near the black hole was treated as heretical.) So it is a particular personal pleasure to see Thaisa's results.

Although the observations have shown that in many nearby and low luminosity objects there is a nuclear stellar cluster which is often a starburst, such SB signatures in high luminosity and distant AGN may still be below detection limits with respect to the continuum. It is also possible that SBs are in late evolutionary stages in these high luminosity objects and therefore that signatures of young SBs in such objects have not yet been seen. This is certainly frustrating, and we await the development of new instruments and data analysis to see if the results presented at this meeting can be extended to the more massive, more luminous objects.

I feel that the absence of magnetic field measurements and inclusion of magnetic effects in the interpretation of the data is perhaps the single most glaring omission in AGN research. What is their contribution to the phenomenon we observe? Magnetic fields are known to be important in the ISM and to play a very important role in many stars and winds so shouldn't we expect that it would be even more likely that they are important in the high energy environments of AGN? Surely they are not only important in the very limited region near the black hole and possibly in the inner regions of the accretion disc where the non-thermal continuum is generated.

The variability studies point toward one of the most important conclusions I would draw from the wealth of data presented here: They make it clear that our direct observations are of very complex 'Weather' – the complex hydrodynamics of an atmosphere driven by underlying physical processes we can not yet observe directly. The observed behaviour is far too complex to be controlled only by differences in the properties of the central black holes – black holes simply have far too few properties; they are actually rather simple creatures.

On all scales the observations indicate that the stellar distributions are smooth; yet the gas is fragmented and filamentary and the gaseous phenomenon is varied. This should not be surprising if the gas giving rise to the spectral signatures is an interstellar medium subjected to shocks and disturbances as the stars move through it at high orbital velocities and if random supernovae go off in the circum-black-hole region. In such an environment smooth flows or winds are not to be expected, and should not be assumed to be present when the spectra are analysed.

The physical variables which clearly are required to build a true comprehensive model include, at minimum, the following:

- the mass and angular momentum of the black hole,
- the mass, age, star formation rate and dynamics of the nuclear stellar cluster,
- the viscosity of the disc, the abundances and the mass accretion rate in the disc,
- the strength and topology of the magnetic fields of the disc and those in the interstellar medium, and
- the interaction history of the host galaxy and the resulting secular evolution.

Clearly with this many physical variables, whose independence of, or dependence on, each other is not yet clear, we need a minimum of as many independent observational data as there are independent physical variables. Thus I do not believe that relying on two dimensional diagnostic diagrams will ever serve to establish the details of the physical situation and the work to establish multidimensional diagnostics reported by Deborah and her collaborators points the way to the future. Line spectra reveals what is happening in the gaseous interstellar medium of the nucleus and in the atmosphere of the accretion disc.

This is directly equivalent to someone observing the weather on earth without being able to see the earth itself or to measure its spin, orbit, surface topology, or to observe the moon and its orbit. What does the study of the weather on earth teach us about what we may expect in our study of AGN? Consider how essentially simple the earth-sun-moon system is, and how complex and variable the weather is. Granted that the earth itself has far more physical parameters than a black hole, yet as a system the earth-sun-moon is far simpler than that of the black hole-stellar cluster-host galaxy. If one constructed average spectra we would be averaging over all the varied storms, winds, and tranquil weather at the poles, the equator, over the oceans and over the complex and varied land masses. What would we learn? We know that global warming is one of the most important issues facing the world at the moment and that some of the most skilled scientists, aided by detailed, direct measurements cannot yet be sure what is driving it and how it will develop. We have perhaps the best Weather Service in the world in Britain, yet even ours, with its vast computer resources, its expert meteorologists and its direct observations cannot predict the weather with certainty, although, on average, they do get it right more often than not.

With the limited spectral coverage and all the other limitations faced in AGN research, is it then surprising that it is so difficult to explain, in detail, the data we have – particularly when we discuss average spectra? Although such average spectra yielded fantastic and ground breaking insights into the photoionization processes and helped establish the broad picture which is now the accepted paradigm, I don't believe that they will be useful in the construction of detailed models of individual objects so that we can understand the AGN zoo and its many different populations. Furthermore, we may have to accept that we may never be able to explain all the complexities of the spectral observations in detail, any more than we can predict the weather precisely.

I am concerned that we are working the orientation effect far too hard and thereby ignoring many basic physical processes which may scale with black hole mass or depend on the properties of the stellar cluster or the galaxy structure. Surely black hole spin and the magnetic field play a significant role which is largely unexplored to date. The origin of the dusty torus is not understood. If it is an extension of the accretion disc it is certainly not a 'tube'. Flares disturb the simplistic ideas of uniform flows. Again, to use an analogy from the weather on earth, fractal studies famously show that a butterfly in the Amazon can trigger storms in the northern hemisphere.

So in summary, I was excited and delighted by the wonderful observations and thrilled by the high resolution data which is casting so much light into areas that we dark and unresolved for so many years. I am worried, however, by the attempts to shove such complex and varied data into simple boxes. I believe the field is on the threshold of, hopefully, a new era which will see the development of detailed, complex models of this most fascinating subject.

To conclude I would like to say what a great pleasure it was for me to attend this conference. When I was invited by Pepa and Erika I was delighted that her colleagues in Mexico and throughout the world had decided to honour Deborah for all the wonderful contributions she had made to astronomy, to the position of women within astronomy and to the development of extragalactic research in Mexico. I thoroughly enjoyed the reunion with colleagues I haven't seen in years, and was delighted to be able to catch up with a field I had worked in for almost 30 years and loved. The new observations are wonderful beyond our wildest hopes in the 70s and have revealed a marvellous and complex picture and are now beginning to illuminate the models we developed, albeit rather primitively, in the 80s and 90s. I look forward to seeing some wonderful new results from all the young astronomers here who will carry the field forward in this 21st century. It is a particular pleasure that because there are now many women there can be a joyful interaction between scientists of both genders which is creative and unintimidating for everyone. The atmosphere of this meeting is unlike anything that would have been possible when Deborah and Meg and I started out.

May Deborah continue her excellent work, and take great pleasure from this meeting and encouragement for the next decade of her life. A very big thank you to Erika and to her local and scientific organising committees and to Pepa who wrote inviting me and encouraging me to return however briefly, with great pleasure, to AGN research, before returning to architecture.

Thank you!