Course: ABUNDANCE DETERMINATIONS IN HII REGIONS AND PLANETARY NEBULAE

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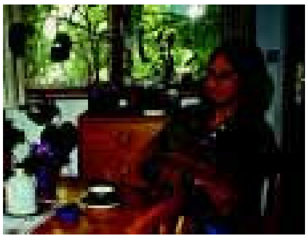
NEW COSMIC TOOLS



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It was the astronomer W. Huggins who, in 1864, discovered that true nebulae could be distinguished from those made from star clusters by studying their spectra. Nowadays, when we talk of nebulae we refer to clouds of gas. Emission nebulae shine with their own light; reflection nebulae reflect light from neighbouring bright sources, and absorption nebulae appear dark against a bright background. Both planetary nebulae and HII regions (diffuse nebulae) belong to the first of these groups and are the main focus of the investigations of Professor Grazyna Stasinska, from the Paris-Meudon Observatory. An expert in ionized nebulae (both planetary nebulae and HII regions), Stasinska works on the use of these singular objects as tools for obtaining a better understanding of the chemical composition of galaxies and stellar evolution.

The existence of dust is often ignored in many studies of ionized nebulae. To what extent does this hinder our current understanding of these objects?

"It is true that dust is often ignored in studies of ionized nebulae, although its potential role has been known for decades. I think the reason is that the effects of dust are secondary in many problems. For example, dust is believed to alter only slightly the ionization structure of nebulae. Since the physics of dust grains is far less known and far more complicated than the physics of free atoms, it is felt that introducing dust would tremendously complicate the studies without bringing definite answers. One should be very cautious, however, when using as diagnostics such nebular properties that are strongly affected by the presence of dust. For example, the determination of the luminosity of ionizing sources using nebular lines as indicators can be seriously flawed in presence of dust grains. Another, perhaps less well-known consequence of dust, is that the intensities of resonance lines are greatly affected by dust absorption, since resonance scattering multiplies the photon path lengths by enormous factors. Therefore, resonance lines cannot be used in a straightforward manner to derive abundances of chemical species in ionized nebulae."

The existence or otherwise of local fluctuations in the electron temperature of ionized nebulae is nowadays under discussion. Should they turn out to exist, how would they affect our current knowledge of the chemical composition of ionized gas? Do you think these temperature fluctuations really do exist?

"Indeed, 'temperature fluctuations', following the terminology introduced by Manuel Peimbert in 1967, are one of the major unsolved problems in nebular astrophysics. Peimbert showed that, if the nebular temperature is not uniform, the various temperature indicators should indicate different values of the temperature. And indeed, this is what is observed. The problem is that the observations seem to indicate much larger temperature variations than can be understood. However, these indications are mainly indirect ones.

Such temperature variations, if they exist, bias our determination of the chemical composition of ionized matter. In view of this, two main attitudes have been adopted. Some astrophysicists simply ignore these temperature variations, mainly because no physical explanation is available, which leads them to suspect that observational evidence is wrong. Others try to estimate them from the observations and apply a mathematical procedure based on the assumption that these variations are small-scale temperature fluctuations, which is not necessary the case. The errors in the abundance determinations due to temperature variations may amount to a factor two and more in some cases.

Among the various causes advocated for ‘temperature fluctuations’, the favourite one is additional heating by shock waves. My opinion is that, although shocks are known to exist and may be a valid explanation in some cases, they cannot provide a general solution to the problem. Shock fronts have very small dimensions with respect to the extension of photoionized nebulae, and in most cases the known supplies of mechanical energy are far below what is needed to explain the observations.

It is a funny coincidence that you are asking this question precisely now. A few months ago, I would have said that, frankly, I do not have an answer, although I have dedicated a lot of thought to this problem. But I have just submitted a paper with Ryszard Szczerba showing that the presence of small dust grains in nebulae with filamentary or knotty structures could easily produce the right amount of “temperature fluctuations”, by boosting the electron temperature in the diffuse regions through photoelectric emission of dust grains. High spatial resolution mapping of nebulae in relevant emission lines will be able to test this hypothesis.

Still, even if such an explanation proves to hold, there is a long way towards a secure determination of abundances to within better than a factor 2, because the dust content and the dust properties are so ill determined.

But let me not be too pessimistic: there are so many questions in Astronomy that greatly benefit from a knowledge of the chemical composition even with a factor 2 uncertainty.”

An important part of our knowledge concerning ionized nebulae depends on the accuracy of photoionization models, on which you are an expert. What aspects of these models should be improved in the near future?

“Actually, photoionization models are used to answer questions such as: what is the nature of the ionizing source? What is the chemical composition of the ionized nebula? The answers depend on the “external” ingredients of the models (for example the energy distribution of the ionizing radiation or the atomic data) and we have to know what answers are robust with respect to uncertainties or incompleteness in these ingredients. But the answer may also depend on how well the geometry of the model represents the true geometry of the objects under study. 3-D models are now feasible. The question is how to constrain a model with observational data. If some kind of symmetry is expected, like in planetary nebulae, combining line intensity and velocity field maps may help. But one first has to check whether the sophistication of the model really improves the validity of the answer. In the case of objects with more complex geometry, one should perhaps try to find a physical thread, related to the supposed dynamical evolution of the object. What makes the thing difficult is that both large scale and small scale phenomena may play a role. We really must first ask what questions we want to solve, and then try to find appropriate tools. In this respect, perhaps we should go and see how complex problems are being solved in other areas of science.”

PROFILE

GRAZYNA STASINSKA was born in France in 1948. She studied at the Orsay University where she graduated in 1969. She specialized in Astrophysics in the Institut d’Astrophysique de Paris. She moved to Meudon Observatory in 1971. After a two-year stay in Brazil in 1974-1975, she came back to Meudon Observatory, where she spent the remaining of her career.
She became a doctor of the Paris 7 University in 1978, with a thesis on photoionization models of nebulae. After several years of teaching at University, she has been appointed at the Centre National de la Recherche Scientifique in 1979.
She collaborates with researchers from many countries, including France, Poland, Mexico, Spain, Brazil and the USA with whom she always communicates in their native language, and is a frequent guest of the Nicolau Copernicus Astronomical Center in Torun (Poland) and of the Instituto de Astronomia of the UNAM in Mexico. She is an expert on ionized nebulae and has worked mainly on planetary nebulae, HII regions and emission line galaxies including active galaxies.
She has published over 60 papers in Astronomy & Astrophysics. One of her main interests is to use the nebulae as tools for astronomy, for example as probes of the chemical composition of galaxies or as indicators of stellar evolution.
She has been involved in the discovery of the most oxygen-poor planetary nebula known so far, whose oxygen abundance is less than one hundredth that of the Sun. She is a member of the Organizing Committee of the Division VI (Interstellar Matter) of the International Astronomical Union.
She has organized various international meetings and is presently responsible of a series of Euroconferences of the evolution of galaxies sponsored by the European Commission.