Dravins, D.: 1981, in M. H. Ulrich, K. Kjär (eds.) *ESO Conf. Scientific Importance of High Angular Resolution at Infrared and Optical Wavelengths,* p. 295.
Dravins, D.: 1982a, *Ann. Rev. Astron. Astrophys.* **20,** 61.
Dravins, D.: 1982b, in C. M. Humphries (ed.) *Instrumentation for Astronomy with Large Optical Telescopes,* p. 229.
Dravins, D., Lind, J.: 1983, to be published.
Dravins, D., Lindegren, L., Nordlund, Å.: 1981, *Astron. Astrophys.* **96,** 345.
Enard, D.: 1977, *The Messenger* No. 11, p. 22.
Enard, D.: 1979, *The Messenger* No. 17, p. 32.
Enard, D.: 1981, *The Messenger* No. 26, p. 22.
Gray, D. F.: 1980, *Astrophys. J.* **235,** 508.
Gray, D. F.: 1982, *Astrophys. J.* **255,** 200.
Gray, D. F.: 1983, *Publ. Astron. Soc. Pacific,* submitted.
Hanbury Brown, R.: 1974, *The Intensity Interferometer.*
Nordlund, Å.: 1978, in A. Reiz, T. Andersen (eds.) *Astronomical Papers Dedicated to Bengt Strömgren,* p. 95.
Nordlund, Å.: 1982, *Astron. Astrophys.* **107,** 1.

List of Preprints Published at ESO Scientific Group

February – May 1983

237. N. Panagia, E. G. Tanzi and M. Tarenghi: Infrared Observations of R 136, the Central Object of the 30 Doradus nebula. *Astrophysical Journal.* February 1983.
238. G. Chincarini: Redshifts and Large Scale Structures (Review). IAU Symposium No. 104, Crete 1982. February 1983.
239. I. Appenzeller, I. Jankovics and J. Krautter: Spectroscopy and Infrared Photometry of Southern T Tauri Stars. *Astronomy and Astrophysics Suppl.* February 1983.
240. P. A. Shaver et al.: PKS 0400–181: A Classical Radio Double from a Spiral Galaxy? *Monthly Notices of the Royal Astronomical Society.* April 1983.
241. B. E. Westerlund, M. Azzopardi, J. Breysacher and J. Lequeux: Discovery of a Wolf-Rayet Star in NGC 6822. *Astronomy and Astrophysics.* April 1983.
242. F. Pacini and M. Salvati: The Optical Luminosity of Very Fast Pulsars. *Astrophysical Journal.* April 1983.
243. S. D'Odorico, M. Rosa and E. J. Wampler: Search for Wolf-Rayet Features in the Spectra of Giant H II Regions: I. Observations in NGC 300, NGC 604, NGC 5457 and He2–10. *Astronomy and Astrophysics Suppl.* April 1983.
244. D. Gillet and J. P. J. Lafon: On Radiative Shocks in Atomic and Molecular Stellar Atmospheres. I. Dominant Physical Phenomena. *Astronomy and Astrophysics.* April 1983.
245. J. Danziger, R. D. Ekers, R. A. E. Fosbury, W. M. Goss and P. A. Shaver: PKS 0521–36, A BL Lac Object with an Optical and Radio Jet. (Talk given at the Turin Workshop on Astrophysical Jets, 7–8 Oct. 1982. D. Reidel Publ. Comp.) April 1983.
246. D. Baade: Can Shell Phases of Be Stars Be Predicted on the Basis of Rapid Spectroscopic Micro-Variability? *Astronomy and Astrophysics.* May 1983.
247. H. Pedersen, C. Motch, M. Tarenghi, J. Danziger, G. Pizzichini and W. H. G. Lewin: Optical Candidates for the 1978 November 19 Gamma-ray Burst Source. *Astrophysical Journal Letters.* May 1983.
248. C. G. Kotanyi and R. D. Ekers: A Westerbork Map of the Core of the Virgo Cluster. *Astronomy and Astrophysics.* May 1983.
249. L. Maraschi, E. G. Tanzi, M. Tarenghi and A. Treves: Quasi Simultaneous Ultraviolet and Optical Observations of PKS 2155–304 = H 2155–304. *Astronomy and Astrophysics.* May 1983.
250. W. K. Huchtmeier, O.-G. Richter, H.-D. Bohnenstengel and M. Hauschildt: A General Catalog of HI Observations of External Galaxies. May 1983.
251. D. Maccagni, L. Maraschi, E. G. Tanzi, M. Tarenghi and L. Chiappetti: X-ray and UV Observations of the BL Lacertae Object 3C 66A. *Astronomy and Astrophysics.* May 1983.
252. D. Gillet, E. Maurice and D. Baade: The Shock-Induced Variability of the Hα Emission Profile in Mira. *Astronomy and Astrophysics.* May 1983.

Distances to Planetary Nebulae

R. Gathier, Kapteyn Astronomical Institute, Groningen, The Netherlands

When astronomers want to determine the properties of an object in the universe, they need a reliable distance to that object. Consequently there always has been much effort to find methods for distance determination. In the case of planetary nebulae, distances are very difficult to determine. Several methods have been tried but individual distances in general are still uncertain by a factor of two to three, sometimes even more. We have used an in principle powerful method, the "extinction method" to derive accurate distances for about 10 planetary nebulae.

The Importance of Accurate Distances

Planetary nebulae are believed to represent a late stage in the evolution of the many stars in the Galaxy with intermediate masses. During the planetary nebula phase, the star loses mass that becomes visible as a gaseous nebula which surrounds the central star.

Without an accurate distance to a planetary nebula important parameters such as nebular radius, nebular mass, luminosity and radius of the central star remain unknown. It is important to know the nebular mass, for example, because it determines the amount of gas that is returned to the interstellar medium by the planetary nebula phenomenon. This mass return has a large influence on the evolution of the entire Galaxy.

We also need accurate distances to many planetaries in order to determine their distribution in the Galaxy. This distribution can then be compared with distributions of other kinds of stars in order to try to determine which stars pass through the planetary nebula phase and which do not. Especially a comparison with the galactic distribution of white dwarfs and red giants is very interesting since it is believed that the planetary nebula phase lies between the red giant phase and the white dwarfs. Once the distance to a planetary nebula is known, the luminosity of the central star can be determined. The effective temperature of the central star can usually be derived so that the star can then be placed in a luminosity–temperature diagram. Many positions of central stars in such a diagram define in fact how temperature and luminosity evolve with time. This enables astronomers to check theoretical calculations of the evolution of stars with different masses.

Reasons Why Standard Methods Cannot be Applied

The reason that most planetary nebulae have unknown distances is that standard methods for distance determination are usually not applicable. All nebulae are much too far for distance measurements by means of trigonometric methods. With our knowledge about normal stars it is usually possible to determine their intrinsic luminosities by means of spectroscopy or photometry. The intrinsic luminosity, combined with the observed magnitude leads to the distance. This method cannot be used for the central stars of planetary nebulae. They differ strongly from normal stars; their intrinsic luminosities are as yet unknown, that is why we need accurate distances! Another problem is that planetary nebulae are usually not found in stellar groups for which distance determinations are possible. There are only a few nebulae for which one of the standard methods of distance determination is applicable. Some central stars have a normal companion star for which a distance can be determined. One planetary has been found in a globular cluster, M15, and also nebulae near the galactic centre and in extragalactic systems have known distances.

Specific Methods

For planetary nebulae one has to use specific methods that are only applicable to individual cases. One method makes use of the expansion of the nebulae. This method compares the observed angular expansion rate of the nebula with the radial expansion velocity of the gas as deduced from the splitting of emission lines. Another method is based on the fact that usually the total amount of extinction by interstellar dust to a planetary nebula can be derived. If it is also possible to determine the relation between interstellar extinction and distance along the line of sight to the planetary nebula, the distance to the nebula follows from this relation. We have applied this "extinction method" to 13 nebulae.

The "Extinction Method"

The total extinction to a planetary nebula can be derived in several ways. One method is to investigate the ultraviolet spectrum of the central star. Interstellar extinction causes a characteristic absorption near 2200 Å. From the strength of this absorption the extinction can be found. The extinction can also be measured from a comparison of the observed ratio of the strengths of certain nebular emission lines (such as He II 1640 Å/4690 Å) with the theoretically expected ratio. Very often the extinction is derived from the *observed* ratio of radio to H_β flux density, compared with the *expected* ratio.

The relation between interstellar extinction and distance in the direction to the planetary nebula can be determined from spectroscopy or photometry of stars in that direction. Especially hot (early type) stars are used, since their theoretical energy distributions are well known and they are usually visible up to large distances. Spectroscopy or photometry gives the observed energy distribution of the star. This tells us how the stellar light is affected by absorption of interstellar dust particles. This absorption causes the colour of the star to become somewhat redder. From the amount of this "reddening", the total interstellar extinction to the star can be derived. A careful comparison of the theoretical and observed energy distribution gives the intrinsic luminosity of the star. Combined with the observed magnitude this leads to the distance of the star.

Thus, with spectroscopy or photometry of a "normal", preferably early-type star, it is possible to derive both its extinction and its distance. With extinctions and distances of many individual stars in a certain direction on the sky we can try to determine the relation between extinction and distance for that direction.

Our Approach

We selected a number of planetary nebulae for which extinctions could be determined with the methods described above. The ultraviolet spectra that we used to derive the extinction were obtained with the IUE satellite.

We have used photometry of stars along the line of sight to a planetary nebula to determine the extinction–distance relation. Because the interstellar material is distributed very irregularly throughout the Galaxy, extinction–distance relations can differ strongly for different directions. In order to determine a reliable relation it is therefore necessary to use stars that are as close as possible to the line of sight to a planetary nebula. This means that mainly planetaries near the galactic plane can be studied, where the density of stars is high enough so that many measurable stars are found within a small field around the nebula. Besides, extinction–distance relations for directions outside the galactic plane can only be determined for the first few hundred parsecs, since the interstellar dust is very concentrated to the galactic plane.

In total we selected 13 planetary nebulae near the galactic plane, with well-known extinctions. To determine the extinction–distance relations for the directions to these nebulae we used the Walraven VBLUW photometer with the Dutch 91 cm telescope at La Silla (J. Lub, *The Messenger* **19**, 1, 1979). The observations were done during January 1981 and February – April 1982. The VBLUW photometer is very well suited for our purposes. The light of a star is measured in 5 different wavelength bands, from the visual (V-band) to the near ultraviolet (W-band). This means that the energy distributions of early-type stars (temperatures > 9,000 K) can be observed over a wide wavelength range. As mentioned earlier the intrinsic energy distributions are well known for these early-type stars and are therefore very suitable for determining extinction–distance relations. Moreover, these stars can be seen over large distances in the galaxy. Another advantage of the photometer is that light is measured simultaneously in the five different wavelength bands. With this instrument it is therefore possible to measure many stars in a short time.

Construction of Extinction–Distance Diagrams

I will try to explain now in more detail how we can derive from the photometry of an individual star its distance and extinction. With the five wavelength bands, four independent so-called colour indices can be constructed (e.g. [V-B], [B-U], [B-L] and [U-W]). The observed VBLUW colours of an early-type star, compared with the intrinsic colours, give the amount of reddening of the star, usually expressed as the colour-excess E_{B-V}.

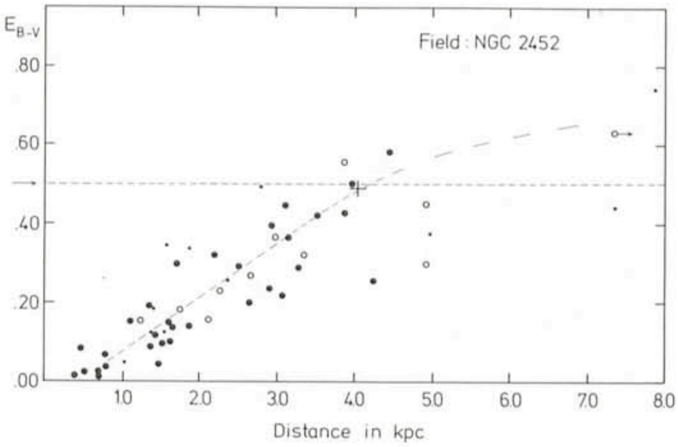

Fig. 1: *Diagram of reddening E_{B-V} as a function of distance for stars within a field of 0.5 degree around the planetary nebula NGC 2452. The different symbols indicate the accuracy of individual points. Small dots have large uncertainties, open circles are better determined and filled circles are the most accurate measurements. The cross at 4 kpc represents the young open cluster NGC 2453. The reddening to NGC 2452 is indicated by the horizontal dotted line.*

This quantity leads to the total amount of extinction. The observed brightness of the star can then be corrected for the extinction. Now we have to find the intrinsic luminosity of the star. The energy distribution of an early-type star is mainly determined by its temperature T and pressure p at the surface of the star. It is possible to make certain combinations of VBLUW colour indices that are insensitive to reddening. These are called reddening-free indices. The observed reddening-free indices can be compared with indices, calculated with theoretical spectra, as a function of T and p, of early-type stars (we used models by Kurucz). From this comparison we then find T and p of the star (for an application of this method to cool stars, see J. W. Pel, *The Messenger* **29**, 1, 1982). Now we use calculations of stellar evolution (for example by P. M. Hejlesen, *Astron. Astrophys. Suppl. Ser.* **39**, 347, 1980). These calculations give for a star with given mass its T, p and luminosity L as a function of time. We have determined T and p, so L follows. Since we now have the intrinsic luminosity of the star together with the observed brightness, corrected for extinction, the distance can be calculated.

Fig. 1 shows the results for stars along the line of sight to the planetary nebula NGC 2452. Only stars within 0.5 degree from the nebula are included. Many late-type foreground stars are not shown in the figure. The symbols used indicate the accuracy: thick dots are the better determined points (in terms of T and p). Individual distances have on average estimated accuracies of ~ 30 %, while individual reddenings are accurate to ~ $0\overset{m}{.}03$ in E_{B-V}. Most of the scatter in this diagram is believed to be caused by multiple stars and an irregular reddening distribution across the field. The cross at 4.0 kpc with E_{B-V} = 0.49 represents the young open cluster NGC 2453, only $8\overset{'}{.}5$ away from NGC 2452. The circle with arrow at 7.3 kpc represents a lower limit to the distance of a very distant B2 supergiant. NGC 2452 has a reddening of $E_{B-V} = 0\overset{m}{.}50 \pm 0\overset{m}{.}05$. It is determined from the observed He II 1640 Å/4690 Å ratio and from the ratio of the radio to H_β flux density. From the relation in Fig. 1 we find a distance to NGC 2452 of ~ 4.1 kpc with an estimated accuracy of 25–30 %. Previous distance estimates by several authors range from ~ 1.5 to ~ 3.0 kpc, but with larger uncertainties.

This example shows that the "extinction method" is very powerful in deriving distances to planetary nebulae. Similar diagrams as Fig. 1 will be available soon for 12 other nebulae.

Large Scale Structure of the Universe, Cosmology and Fundamental Physics

As announced in the *Messenger* No. 30, this first ESO/CERN symposium will be held from 21 to 25 November 1983 at CERN in Geneva.

PROGRAMME

Introductory Lecture (D. W. SCIAMA, Oxford University and ISAS, Trieste).

Electroweak Unification and its Experimental Status (P. Darriulat, CERN, Geneva).

Unified Field Theories (P. FAYET, Ecole Normale Supérieure, Paris).

Experimental Tests of Unified Field Theories: Proton Decay and n-n̄ Oscillations (E. FIORINI, University of Milan); **Monopoles** (G. GIACOMELLI, University of Bologna).

Dynamical Parameters of the Universe (A. SANDAGE, Mount Wilson and Las Campanas Observatories, Pasadena, CA).

Radiation in the Universe (D. T. WILKINSON, Princeton University, NJ).

Galaxies (S. M. FABER, University of California, Santa Cruz).

Clusters, Superclusters and their Distribution (J. H. OORT, University of Leiden).

Formation of Galaxies and Structures (Ya. B. ZELDOVICH*, Institute of Applied Mathematics, Moscow).

Neutrinos (R. L. MÖSSBAUER, Technical University, Munich).

Early Nucleosynthesis (J. AUDOUZE, Institute of Astrophysics – CNRS, Paris).

Observational Evidence for the Evolution of the Universe (L. WOLTJER, ESO, Garching bei München).

Unified Field Theories and the Early Universe (A. D. LINDE*, Lebedev Physical Institute, Moscow).

Quantum Gravity (S. W. HAWKING, University of Cambridge).

Closing Lectures (J. ELLIS, Stanford University, CA, and CERN, Geneva); M. J. REES, University of Cambridge).

The following scientists will act as chairmen and discussion leaders of the various sessions: N. CABIBBO (University of Rome), G. COCCONI (CERN), A. D. DOLGOV* (Institute of Theoretical and Experimental Physics, Moscow), M. S. LONGAIR (Royal Observatory Edinburgh), A. SALAM (Imperial College and ICTP), E. E. SALPETER (Cornell University), D. N. SCHRAMM (Chicago University), J. SILK (IAP, Paris, and University of California, Berkeley), N. STRAUMANN (University of Zurich), H. VAN DER LAAN (University of Leiden).

* Participation has not yet been confirmed.

The aim of the symposium is to establish the status of our knowledge on the subject and to provide a forum for discussions among people from different disciplines. To this end about equal time will be dedicated to the formal lectures and to the general discussions on each topic. The audience will be mainly composed of about equal numbers of astrophysicists and particle physicists and will be limited to approximately 150 participants.
The participation in the symposium is by invitation only. People who are definitely interested in participating in the symposium should write to the chairmen of the Organizing Committee at the addresses below prior to 31st July 1983.

Prof. G. Setti
ESO
Karl-Schwarzschild-Str. 2
D-8046 Garching b. München
F. R. G.

Prof. L. van Hove
CERN
TH Division
CH-1211 Genève 23
Switzerland