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Astronomy: Classifying ourselves

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Astronomy

Classifying ourselves

from Virginia Trimble

DECIDING just how normal or average our star and Galaxy are is of practical as well as philosophical interest. The assumption that ours is a normal galaxy of a particular type is now being used in efforts[1] to pin down the extragalactic distance scale, the value of Hubbles's constant and the age of the Universe, all still uncertain by about a factor of two. And properties of other stars are frequently determined by comparison with those of the Sun. Thus, if spectral type, colour, temperature and luminosity of the Sun are not known accurately, our ideas about how the chemical composition of the Galaxy has evolved with time, about the mass–luminosity relationship and even about the distance to the Hyades (which feeds back into the extragalactic distance scale) will come out wrong[1-4]. Two recent papers[5,6] represent the latest round of squabbles over whether the Milky Way is an Sb or an Sc spiral and whether the Sun is unusually red or normal for its spectral type.

Hubble[7] and later workers[8,9] classified spiral galaxies into two sequences, with central bars present (SB) or absent (S or SA). Both sequences are ordered by the degree of prominence of the spiral arms, from Sa, with bright nuclei and inconspicuous tightly-wound arms, through Sb to Sc, with very conspicuous loosely-wound arms. Many other properties of galaxies correlate well with Hubble type, including the zero points of the relationships (between total luminosity and rotational velocity, or surface brightness, or other distance-independent parameters) used to calibrate the extragalactic distance scale. The difference in luminosity between Sb and Sc galaxies at a given value of some other parameter is typically about a magnitude, corresponding to a 60 per cent error in distance if you guess the wrong type. As a result, we can only calibrate these relationships using data from our Galaxy if we know its Hubble type and that it is normal for its type with some precision. Unfortunately, we cannot photograph the Milky Way from outside and compare arms and nucleus optically. Thus all classifications of our Galaxy are more or less indirect and correspondingly uncertain. The advent of radio astronomy greatly increased the number of indirect indicators available[10] and led Baade to decide that we live in an Sb galaxy[11]. Later determinations[5] have oscillated between Sb and Sc. The most detailed yielded the classification SAB(rs)bc[12], indicating intermediate status in all parameters, including existence of a ring, r.

If we accept this intermediate type, then our Galaxy is quite normal[1,12-14], having values of all the usual parameters intermediate among those of four other galaxies of similar types. A composite drawing of the four shows more than two spiral arms, not all of equal brightness. And Hubble's constant, H, must be near 100 km s^{-1} Mpc^{-1} or the coherent picture falls apart. This last conclusion disturbs many astronomers, as it requires either that the Universe be less than 10^{10} years old or that Einstein's infamous cosmological constant be non-zero.

But suppose we are really an Sc. Galaxies of that type are intrinsically fainter than Sb galaxies. Thus when other galaxies are matched to ours, the effect is to make them intrinsically brighter, hence further away. According to Paul Hodge[5], an equally coherent picture can then be assembled with H near 50 km s^{-1} Mpc^{-1}, at least for luminosity and type determinations based on the scale length of the ionized hydrogen distribution in galactic discs. Classifications as Sc not depending on the distance scale[15-17] then become arguments in favour of the lower value of H. It remains to be seen whether other distance-dependent indicators of Hubble type can also make the Milky Way look like a normal Sc with the larger distance scale. De Vaucouleurs (private communication) believes that this will not prove possible.

By contrast, the spectral type of our Sun cannot be debated. Modern systems of classification define G2V stars as those whose spectra are like the Sun's, at least at relatively low dispersion. During the 20 years from Kuiper[18] to Stebbins and Kron[19], there seems to have been general agreement that many other G2V stars indeed had absorption line spectra like the Sun's and were, on the average, the same colour, $(B-V) = 0.63$, and so at the same temperature.

Metal abundances for solar-type stars in the Hyades and other young clusters using these similarities turn out larger than solar by 20–50 per cent, implying that our Galaxy is becoming richer in heavy elements as generations of supernovae pour out synthesized nuclei. Most of us would like to believe all this.

Doubts began to gather only when modern photoelectric measurements of the solar colour[20-22] and indirect determinations, employing comparisons of spectral features with those of other stars[23], started yielding significantly redder colours of 0.65–0.69, typical of G5, but not G2, stars.

Hardop added to the difficulties by searching among the brighter stars for ones that would match the Sun in both broad-band energy distribution and detailed absorption line profiles[2,3,6,24-26]. Such solar analogues are rare[26] — fewer than a dozen out of several thousand stars searched — and nearly all are rather red, with $(B-V) = 0.65$–0.71. Most had been classified near G5, not G2; and three of the closest analogues are in the Hyades, implying that the Sun and these stars are rather similar in their abundances of the heavy elements.

What can have gone wrong? Chmielewski[27] has looked again at indirect measures of solar $(B-V)$, obtaining a best value of 0.633 ± 0.25. This would permit the conventional wisdom to persist. He questions the accuracy of the direct measurements, all of which require some intermediary to bring small amounts of sunlight into a telescope and photometer that can also look at stars. But the most detailed direct determination yet[28] persists in finding 0.686 ± 0.01, using three independent intermediaries.

Could spectral classification methods have unexpected bugs[3,29]? Hardorp has noted that the solar spectrum used as a standard is often that of sunlight reflected from Uranus or Neptune. Processes in the planetary atmospheres can partially fill in absorption lines, making the spectrum mimic that of a hotter star. Thus, when these artificially weakened lines are used as a standard, stars that really are like the Sun are classified as cooler, near G5. Once this is allowed for, then several of the solar-analogue stars end up as G2–3 (ref. 6), and $(B-V) = 0.67 \pm 0.01$ becomes normal for the type.

But since the Sun and its analogues in the Hyades then match in line profiles, detailed energy distributions and broad-band colours, they must have the same temperatures and the same compositions. If the galactic metal abundance has not changed in nearly 5,000 million years, then either supernovae have stopped expelling heavy elements (which sounds unlikely but is remarkably hard to disprove[30]) or the products must be diluted by gas from

1. de Vaucouleurs, G. *Astrophys J.* **268**, 451, 468 (1983).
2. Hardorp, J. *Astr. Astrophys.* **88**, 334 (1980).
3. Hardorp, J. *Astr. Astrophys.* **91**, 221 (1980).
4. Barry, D. L., Cromwell, R. H. & Schoolman, S. A. *Astrophys. J.* **222**, 1032 (1978).
5. Hodge, P. W. *Publ. Astr. Soc. Pac.* **95**, 721 (1983).
6. Hardorp, J. & Tomkin, J. *Astr. Astrophys.* **127**, 277 (1983).
7. Hubble, E. *Astrophys. J.* **64**, 321 (1926).
8. Sandage, A. R. *Hubble Atlas of Galaxies* (Carnegie Institution, Washington, 1961).
9. de Vacouleurs, G. *Handb. Phys.* **53**, 275 (1959).
10. Baade, W. & Mayall, N. U. *1st (Paris) Symp. on Cosmical Gas Dynamics*, 165 (Central Air Documents Office, Daytona, 1949).
11. Baade, W. *Publ. Univ. Mich. Obs.* **10**, 16 (1950).
12. de Vaucouleurs, G. & Pence, W. *Astr. J.* **83**, 1163 (1983).
13. de Vaucouleurs, G. *IAU Symp.* **20**, 88, 195 (1984).
14. de Vaucouleurs, G. *IAU Symp.* **38**, 18 (1970).
15. Arp, H.C. *Astrophys. J.* **139**, 1047 (1964); **141**, 43 (1965).
16. Becker, W. *Zs. f. Ap.* **58**, 202 (1964).
17. Georgelin, Y. P. & Georgelin, Y. M. *Astr. Astrophys.* **49**, 57 (1976).
18. Kuiper, G. *Astrophys. J.* **88**, 432 (1938).
19. Stebbins, J. & Kron G. E. *Astrophys. J.* **126**, 266 (1958).
20. Gallouët, L. *C.r. Séanc. Soc. Biol.* **256**, 4593 (1963).
21. Gallouët, L. *Annls Astrophys.* **27**, 423 (1964).
22. Emmons, R. R. *et al. Astr. J.* **72**, (1967).
23. van den Bergh, S. & Sackmann, I. J. *Astr. J.* **70**, 353 (1965).
24. Hardorp, J. *Astr. Astrophys.* **63**, 363 (1978).
25. Hardorp, J. *Astr. Astrophys.* **96**, 123 (1981).
26. Hardorp, J. *Astr. Astrophys.* **105**, 120 (1982).
27. Chmielewski, Y. *Astr. Astrophys.* **93**, 334 (1981).
28. Tüg, H. & Schmidt-Kaler, T. *Astr. Astrophys.* **105**, 400 (1982).
29. Branch, D., Lambert, D. L. & Tomkin, J. *Astrophys. J.* **241**, 183 (1980).
30. Trimble, V. 1983. *Rev. mod. Phys.* **55**, 511 (1983).
31. Armour, R. *The Classic Reclassified*, 27 (McGraw-Hill, New York, 1960).

regions where no massive stars have formed (less unlikely, but also hard to prove).

In summary, to conclude that the Milky Way is a normal Sbc galaxy and that the Sun is a normal G2V star, while philosophically satisfactory, leads to unexpected difficulties in understanding the scale of the Universe and the evolution of our Galaxy. This discussion may remind some readers of the revolutionary hypothesis advanced by Richard Armour[31] that *Julius Caesar* was written neither at the end of Shakespeare's first period nor at the beginning of his second period (an ancient topic of controversy) but, rather, between two periods. If so, the blame attaches entirely to the present writer and not to those working on problems of stellar and galactic classification. □

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Astronomy

Latin-American gathering

from W.H. McCrea

The latest in a series of regional meetings on astronomy, the third Reunion Regional Latinoamericana de Astronomia, in Buenos Aires, 28 November–3 December 1983, was yet another illustration of the value of these conferences, held under the general auspices of the International Astronomical Union. The meeting was attended by about 200 astronomers from at least six Latin-American countries as well as several invited speakers from North America and Europe. Although the general objective of the organizers is to hold regional conferences in this series at intervals of two years, the next meeting is to be late this year in Brazil.

The function of the meetings is twofold: to give the communities of astronomers in the countries of Latin America a sense of belonging to a larger community; and to provide Latin-American astronomers, sometimes hindered by geography and problems of foreign exchange from attending the periodic general assemblies of their union, a sense of belonging to the international community.

In the past decade, Latin-American astronomy has been stimulated by the interest of astronomers from elsewhere who go to Chile to work in the new optical observatories in the Southern Hemisphere, as well as by a number of interesting bilateral collaborations with North American and European astronomers such as that between the Max Planck Institute for Radioastronomy (Bonn) and the Instituto Argentino de Radioastronomia on long-baseline observations.

On this occasion, Jorge Sahade (Argentina), a former vice-president of the union, was chairman of the scientific committee, which included Manuel Peimbert (Mexico), a vice-president of the union, and Victor Blanco (Chile), recently director of Cerro Tololo Inter-American Observatory.

The meeting showed that Latin America as a whole is active in most fields of astronomical research with current interest, both observational and theoretical. Clearly, this community has benefited from some access to the large internationally controlled telescopes in Chile and to some spaceborne facilities, the International Ultraviolet Explorer satellite for example. Many of the papers presented included co-authors from other parts of the world, but it seemed a pity that only a few of the astronomers from outside who make their observations in Chile were actually present in Buenos Aires.

In Argentina itself, astronomy has strong traditions in stellar astrophysics and in the studies of galaxies and galactic systems, centred particularly on the Córdoba and La Plata Observatories, as well as the radioastronomy institute. The observatories of Córdoba, La Plata and San Juan are to share in the use of a new 2.15-m optical reflector, the erection of which is nearing completion at El Leoncito in the approaches to the Andes. The dates of the conference had been chosen as near as practicable to the centenary of the founding of the La Plata Observatory in November 1883; some of the proceedings were designed to honour this occasion. Incidentally, this observatory has always included a strong geophysical section. □

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Shock waves from a bullet

Some of the earliest photographs of the shock waves generated by a speeding bullet were taken in the laboratory of Ernst Mach at the German University of Prague in the winter of 1888. In 1884 Mach had tried to record such waves, using the schlieren technique and target pistols, but had failed because the muzzle velocity was subsonic.

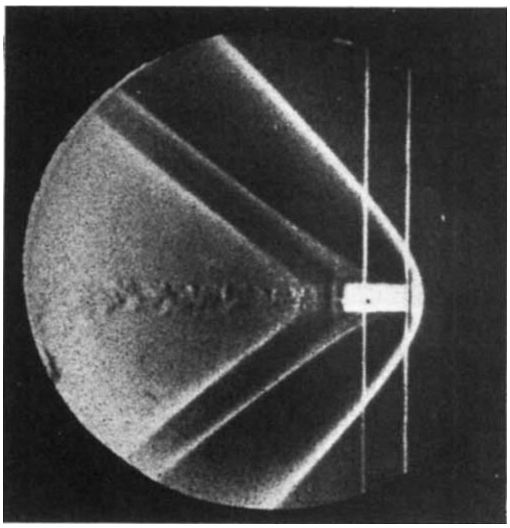
At his behest, P. Salcher and S. Riegler at the Royal Imperial Naval Academy, in what is now Rijeka, Yugoslavia, experimented with larger projectiles and higher velocities and obtained successful photographs in 1886. In the same year, working with his son Ludwig on the artillery range at Meppen, Mach found that at any velocity v_P of the projectile greater than the speed of sound v_S in the medium, trailing shock waves formed a constant angle α with respect to the direction of motion regardless of the projectile's size, whence the equation: $\sin \alpha = v_S/v_P$.

When the Machs returned to the Physical Institute of the University of Prague, they gradually improved their apparatus in which a test bullet is illuminated by the brief spark discharge from a Leyden jar. In the photograph shown here, the bullet is a blunt cylinder of brass, 23 mm long and travelling at a speed of 520 m s^{-1}. The vertical white lines are copper wires, 0.5 mm thick, connected to opposite terminals. The bullet shorts the circuit. The original photograph, taken on Schleussner's extra-sensitive dry plates with an exposure of about 2 μs, measures only 1 cm across.

The hyperboloidal leading wave looks merely hyperbolic in cross-section because the three-dimensional shell is too thin to reflect much light except when seen edge-on. Similarly, the trailing waves, which always point at a more rakish angle than the leading wave, are really cones seen in cross-section.

The Machs' experiments, and those by C.V. Boys the following decade, had repercussions beyond experimental physics. The fact that sharper bullets yield fewer eddies and lower drag, for example, was of considerable significance for artillerists. Mach was quite aware of the military implications and once commented sardonically, "To shoot in the shortest time possible as many holes as possible in one another's bodies is the most important affair of modern life".

Jon Darius



One of the photographs in an exhibition 'Beyond Vision' at the Science Museum, London from 19 April. A book of the same title will be published in April by Oxford University Press. The photograph is reproduced by courtesy of the Ernst-Mach-Institut, Freiburg, FRG.