REFERENCE FRAMES AND THE EXTRAGALACTIC DISTANCE SCALE

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SUMMARY. It is suggested that proper motions will continue to play a key role in fixing the extragalactic distance scale and that uncertainties in the present reference frame are of significance for distance scale problems.

One objective of this meeting is to assess the demands that astronomy and astrophysics place on the fundamental reference frame and how practical it will be to fulfil these demands. This paper briefly considers problems related to the extragalactic distance scale.

It is often said that the Hubble constant H_0 is uncertain by a factor of two and one might deduce from this that uncertainties in the reference frame can hardly affect H_0 significantly. Such a conclusion would be misleading. We need to ask where we may reasonably expect to get with the distance scale problem during the next few years, and the demands that such progress will make on the reference frame.

In fact there are reasons to be quite optimistic about the distance scale problem. Work on the Magellanic Clouds shows that BVI photometry allows Cepheids to be dereddened and fitted to a Period-Luminosity-Colour relation with a standard deviation of 0.1 magnitudes or somewhat better (cf. Caldwell & Coulson 1985). Although Cepheids have long been recognized as major tools in the distance scale problem, it has been technically very difficult to obtain accurate photometry in galaxies more distant than the Magellanic Clouds. This situation has radically changed with the introduction of CCDs. It should now be possible to carry out BVI work on Cepheids in galaxies out to ~4 Mpc. If we could measure ~25 Cepheids per galaxy (a not impossible task), we might expect to get relative distances of galaxies to an accuracy of 1-2%. It is true that abundance differences from galaxy to galaxy may need to be allowed for, but in principle this can be done by spectroscopic observations of HII regions or from the BVI Cepheid photometry itself or from infrared photometry of Cepheids.

Distances of this order of accuracy would obviously lead to a great advance in comparative studies of stellar populations in different galaxies and in many other areas. The Tully-Fisher relation (perhaps

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in its infrared form) could be calibrated with high accuracy and when applied to a number of clusters of galaxies might give H_0 to 2-3% (cf. Aaronson 1983).

To keep the accuracy of the absolute distances of galaxies comparable with that of their relative distances then obviously requires a calibration of the Cepheid zero point to ~1% in distance.

The current Cepheid zero point depends on the Hyades (or Pleiades) distance. Can we expect the Hyades distance to be determined with the necessary accuracy in the near future? Hipparcos will measure quasi-absolute parallaxes with an uncertainty of ~0.002 arcsecs (Hög 1978). This is ~9% uncertainty per Hyades member measured. Thus ~100 Hyades star must be measured to bring the uncertainty down to the 1% level. This seems an impractically large number. Errors of ~0.001 arcsecs have been quoted for Space Telescope parallaxes (Jefferys 1978), but these are relative and uncertainties of ~0.001 arcsecs may well be associated with the conversion to absolute parallaxes. So again we may need an unrealistic number of Hyades parallaxes to get the errors low enough.

The above may well be an unduly pessimistic assessment (and others have given more optimistic figures) but it suggests that we should not rule out the use of improved proper motions in deriving the Hyades distance. In recent times the distance of the Hyades as derived from the convergence point method has increased by ~18% (0.4 mag). This change has been primarily due to the use of new proper motions (cf. Hanson 1975). The differences between the old and new proper motions are mainly due to a different representation of the reference frame in the region of the Hyades. Space Telescope proper motions will be relative ones. Hipparcos will not have this complication. Nevertheless it has been estimated that the uncertainly between FK5 and Hipparcos will be ~0.2 arcsecs/100 years (Roser 1983). This could lead to a systematic error in the Hyades distance of ~2% due to this cause alone. Evidently it would be important to reduce this uncertainly.

I have taken the Hyades in order to stress that even in this case the uncertainty in the reference frame is by no means negligible for distance scale problems. Another example would be the Sco-Cen association. Some years ago high hopes were held out for the use of Sco-Cen as a basis calibrator of absolute magnitudes. However various difficulties have been found (cf. Balona & Feast 1975), amongst these are the fact that the FK4 proper motions of Sco-Cen members are ~20% bigger than N30 ones (Jones 1970). This appears to be a reference frame problem.

We shall not be content with the extragalactic distance scale unless we have some distance indicators other than Cepheids which can at least be used as a check in the nearer galaxies. Perhaps the most promising indicators are RR Lyrae variables and Mira variables. The latter have recently been found to show an excellent period-luminosity relation in the infrared (Glass & Lloyd Evans 1981, Feast 1984, Glass & Reid 1985). At present we can calibrate the luminosities of both these classes of objects either from statistical parallaxes or from their membership in globular clusters.

For the RR Lyraes a typical proper motion is 0.03 arcsecs/year. Even in the most favourable case i.e. for Hipparcos, when we have a rigidly connected frame all over the sky there is an uncertainty in the correction to an inertial system of ±.002 arcsecs. That is, there could be a 6% uncertainty in distance from secular parallax arising from this cause alone. For Miras where a typical proper motion is ~0.01 arcsecs/year, the uncertainty is ~20%. Evidently even if proper motions of very high accuracy can be obtained for these objects relative to some known frame, these requirements place a great strain on the accuracy required for the conversion to the fundamental system.

The calibration via globular clusters looks promising - and of course the distances of globular clusters are vital for many other problems including estimates of a lower limit to the age of the universe and a limit to q_0.

CCDs should allow us to obtain accurate main sequences for a good many globulars. The globular cluster distance scale currently depends on the parallaxes of 7 subdwarfs (cf. Carney 1979). This situation is obviously unsatisfactory both because of the small number of stars and because a large Lutz-Kelker statistical correction (0.2 mag - 10% in distance) has to be applied to them.

It has been pointed out (Beckwith et al. 1985) that out to 200 pc there are ~1000 subdwarfs for which the space telescope can obtain parallaxes to ~10%. This would obviously be of great value. However a 10% accuracy involves a significant statistical correction and such a correction depends very sensitively on the errors of measurement (a correction of 0.10 mag for 9% errors, 0.25 mag for 14% errors).

To keep the statistical corrections small one needs to have 5% accuracy and this would limit the distances of the subdwarfs to within ~50 pc. This would restrict the number of stars and may cause problems if one wants to divide the sample according to abundance. In this case too, therefore, one might want at least to supplement the results by statistical parallaxes and here again the systematic uncertainties of the correction of proper motions to a fundamental reference frame may be a limiting factor.

In conclusion therefore, it seems possible that even in the era of space astrometry, proper motions will continue to play a key role in fixing the extragalactic distance scale, and in that case uncertainties in the fundamental frame may well soon constitute a major uncertainty in the distance scale out to at least 4 Mpc and perhaps beyond.

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