Do we know the velocity field well enough to determine H_0 ?

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Abstract

In a provocative paper Turner and colleagues have questioned whether the classical approach to the extragalactic distance scale is capable of measuring a global value of H_0 in the presence of a velocity field which exhibits large scale flows. The results of their numerical experiments can be summed up in the following alarming illustration: "Even if the local expansion rate is known to be 80 ± 8 km/s/Mpc out to 30 h^{-1} Mpc in the North Galactic Cap, the 95% confidence limits on the true global value of H_0 is 50–128 km/sec/Mpc in a CDM model."

The Hubble Space Telescope Key Project to measure H_0 effects the calibration of secondary distance indicators whose effective range extends beyond the Coma cluster. At Coma the same *rms* difference has fallen from 45% to 3% in CDM according to Turner's model.

Empirical evidence that real velocity fields present no larger problem than these calculations suggest is provided by:
(1) an all-sky survey of Tully-Fisher distances to clusters of galaxies
(2) an all-sky survey of brightest cluster galaxies (Lauer & Postman)
(3) the type II supernova expanding photospheres data set.

We can hypothesize a 'bubble model' in which $\delta H/H_0 \sim 0.5$, that is, $H_0 = 75$ km/s/Mpc within the distance of the Coma cluster and $H_0 = 50$ outside that radius. The data appear to rule out a model with such a large difference between local and global H_0. Such a model is also heavily constrained by the isotropy of the cosmic microwave background on 1° scales. One hundred Mpc, which is approximately the radius of the volume enclosing Coma, corresponds to 1° (12′) on the surface of last scattering for $\Omega = 1$ (0.2). The requirement that $\delta H/H_0 \sim 0.5$ in a 'bubble model' of this type implies a three times larger density perturbation than is represented by the Great Attractor. A Great Attractor would evolve from $\Delta T/T = 1.7 \times 10^{-5}$ in an $\Omega = 1$ Universe. The measured $\Delta T/T < 1 \times 10^{-5}$ on 1.5° scales. A low density Universe would relax these constraints considerably.

1 Introduction

In the expanding universe,

$$H_0 = v/d$$

velocities (v) tend to be well determined and distances (d) are usually the main problem.

But velocity perturbations are actually frequent and significant. For spirals and ellipticals the largest velocity perturbation in the vicinity is the Great Attractor:

$$\delta v/v \sim (.1,\ .3) \quad at\ 4000\ km/sec$$

For clusters of galaxies,

$$\delta v/v \sim .05 \quad at\ 15000\ km/sec$$

(Lauer & Postman 1993). In CDM simulations with $\Omega = 1$ (Turner et al 1992),

$$\delta v/v \sim .25 \quad at\ 3000\ km/sec$$

There are two ways of answering the question posed in the title. One is to understand the local velocity fields; the other is to measure distances sufficiently far from us that the unknown quantities in the velocity field are negligible compared with the recession velocity.

2 The Velocity field

The Virgocentric flow field is now a classic (Peebles 1976, Schechter 1980). In its simplest form there is one parameter, the local value of the infall velocity. Noteable estimates include:

$$v_{infall} = 250 \pm 64 km/sec \quad (Aaronson\ et\ al\ 1982)$$

$$340 \pm 80 km/sec \quad (Tonry,\ Dressler,\ \&\ Luppino\ 1992)$$

$$240 \pm 40 km/sec \quad (Jerjen\ \&\ Tammann\ 1993)$$

New estimates within this range are by Staveley-Smith (this meeting) and Tonry (this meeting).

Reaching out a little further, the bilinear infall model adds a second mass concentration to the kinematic description. Han & Mould (1990,1992) have applied this formulation to two physical situations,

- Virgo plus the Great Attractor,
- Perseus-Pisces and the Great Attractor.

These formulations can be compared with simpler models involving bulk flows, such as,

- the early bulk flow model of the Seven Samurai (Dressler et al 1987)
- the 100 Mpc bulk flow of Mathewson and Ford (1994).

Taking the *rms* over all these models, Han & Mould (1992) find

$$v_{expansion} = 7120 \pm 125 \qquad at\ Coma$$

Non parametric models are in principle capable of a better description of the velocity field and have been discussed by Tully at this meeting.

3 The Large Velocity Approach to H_0

With the Cepheid distance to Virgo (Freedman et al 1994) a new calibration of the Tully-Fisher relation is available (Mould et al 1995) which allows us to carry distance measurements to 100 Mpc.

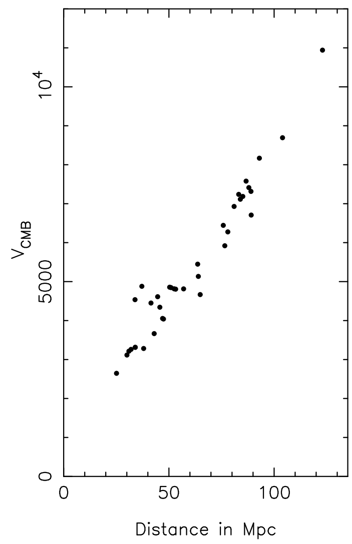

Figure 1: *The velocities of clusters of galaxies in the frame in which the microwave dipole anisotropy vanishes are plotted against the Tully-Fisher distances of these clusters.*

Similarly, we can plot the recession velocities of type Ia supernovae from the sample of Tammann & Sandage (1993). We assume that SNeIa are simple standard candles whose apparent visualmagnitude at Virgo is 12.13 ± 0.14 mag.

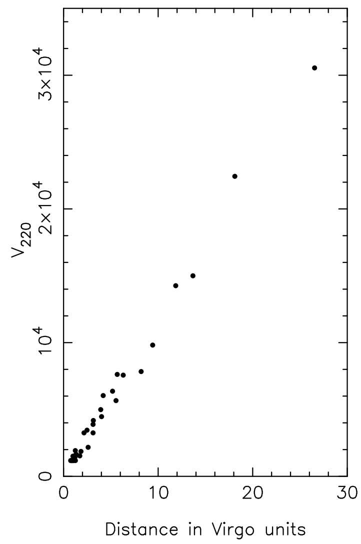

Figure 2: *The Hubble flow as seen in the distances of type Ia supernovae. Recession velocities have been corrected for a Virgocentric flow model with an amplitude of 220 km/sec locally.*

The $(D_n,\ \sigma)$ relation provides a second extension of the Population II distance scale to large distances. We show the distances of all the groups tabulated by Faber et al (1985) with more than five members observed. This will be carried out further by the EFAR collaboration.

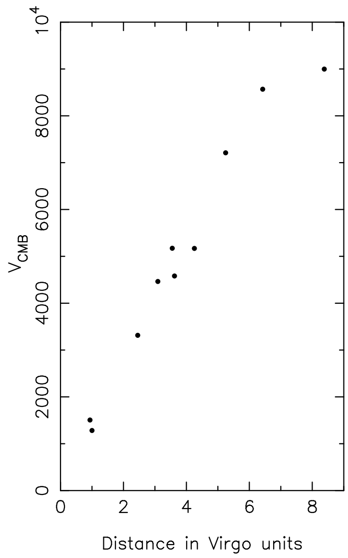

Figure 3: *All groups of galaxies studied by the Seven Samurai with more than 5 observed members are shown in a plot of recession velocity versus distance.*

The work of Schmidt et al. (1994) now extends to 14,000 km/sec. Cepheid calibrations of host galaxy distances will provide the empirical test of distances from the Expanding Photospheres Method.

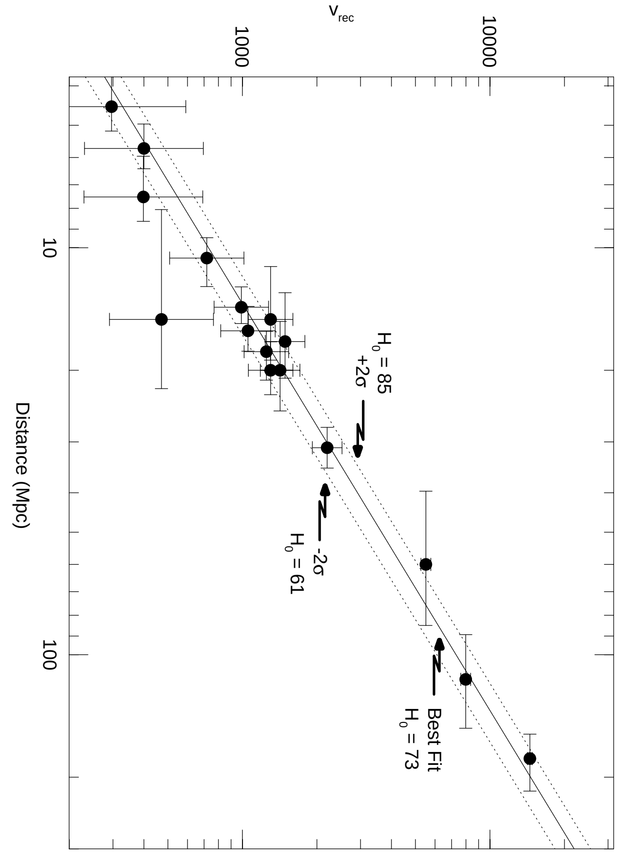

Figure 4: *The Hubble flow as seen in EPM distances (Schmidt et al 1994).*

By means of these techniques measurements of H_0 can be freed from the effects of velocity perturbations on the largest scales.

4 The Bubble Model

Without strong a priori constraints on the density structure of the Universe we cannot exclude the possibility that the local value of the expansion rate is different from the global rate. Constraints exist from the velocity field and from the isotropy of the microwave background radiation, however. For the sake of definiteness we can hypothesize a bubble model in which the expansion rate is 75 km/sec/Mpc locally but 50 km/sec/Mpc outside the radius of Coma.

Figure 5 shows two of the largest scale velocity field constraints on this model. The data offer no support for $\Delta H/H = 0.5$ at or around the velocity of Coma.

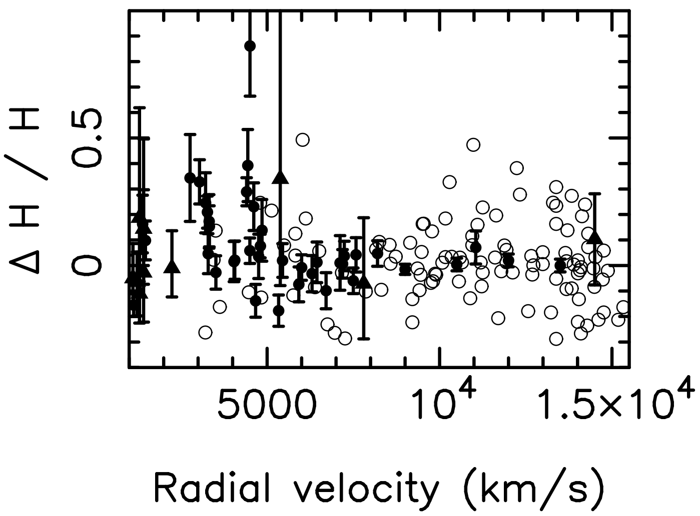

Figure 5: *Deviations from a uniform Hubble flow. Solid circles: clusters of galaxies with Tully-Fisher distances. Solid triangles: EPM data of Schmidt et al. (1994). Open symbols: brightest cluster members from Lauer & Postman (1994). There is no evidence that a different value of the Hubble Constant pertains inside and outside the distance of the Coma cluster at v_{CMB} = 7200 km/sec.*

We might also expect perturbations of this size to make a strong imprint on the microwave background radiation, as Silk has pointed out at this meeting. A velocity perturbation of $\Delta H/H \sim 0.5$ is three times the velocity perturbation seen in the vicinity of the Great Attractor. It follows that in such a bubble

$$\frac{\Delta\rho}{\rho} = 3 \, \frac{\Delta\rho}{\rho_{GA}}$$

But this value of $\frac{\Delta\rho}{\rho_{GA}}$ implies

$$\frac{\Delta T}{T} = 2 \times 10^{-5}$$

according to Bertschinger, Gorski & Dekel (1990), if $\Omega = 1$. Under that condition the anisotropy would be detected on $1°$ scales. For $\Omega = 0.1$ the anisotropy would appear on $12'$ scales. Currently detection has been achieved at this level and on these scales in both the Python and OVRO experiments (Dragovan 1995, Myers 1995). But anisotropies as large as the bubble model imply 3σ abnormalities. The bubble we are hypothesizing would therefore be an extremely rare place for us to find ourselves in, unless the Universe is open (Fullana et al. 1994).

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5 References

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