John Hartnett replies

Courtesy of NASA

I have looked at the two references cited in *Sky and Telescope* (S&T).[1,2] The whole analysis of the evidence, from which they concluded the existence of invisible dark-matter dwarf galaxies around other galaxies, depends on assumptions about gravitational lensing of quasars.

Firstly, there is a lot of evidence that quasars are not so distant as the establishment claims. In the case of the first S&T reference,[1] the quasar is allegedly 10 billion light-years and the lensing galaxy 3 billion light-years distant. Halton Arp, Geoffrey Burbidge and others have published many excellent papers challenging this paradigm. If they are correct then the lensing may not be occurring at all, instead the multiple images may, in fact, be separate quasars near a parent galaxy. If so, how can one apply a computer model to simulate the galaxies gravitational field with the wrong assumptions?

It seems they desperately want to find the dwarf galaxies in question so any little perturbation in some simulation will make it so. But let us be sure the model is correctly applied. In this case, I think not. Even so, they have a solution and it means that the dwarf galaxies comprise only dark-matter, which they can't see with any form of light (or electromagnetic radiation). How convenient! They need normal dwarf galaxies but invisible ones will do.

Secondly, looking at the figures in the second S&T article,[2] it is claimed these are five images of the same background quasar. If the quasar is at such a greater distance than the foreground galaxy, why does at least one of the images indicate that the quasar is connected (by filaments) to the parent galaxy? They look more like evidence that Arp has in his book for quasars physically connected to but ejected from the parent galaxy.[3]

I don't think the problem is any more solved than the big bang is solved by the latest data from the Wilkinson Microwave Anisotropy Probe (WMAP). In that case, they claimed with big fanfare all is revealed, but only after carefully filling their model with dozens of parameters. They assume the model to prove the model. Smoke and mirrors, it is all in the initial assumptions.

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Gravitational lensing over MOND?

Readers of Bill Worraker's perspectives article 'MOND over dark matter?'[1] should know about recent gravitational lensing work.[2] Apparently analysis of X-ray data should have taken into account thermodynamic disequilibrium in the radiating clouds inside their respective galaxies and clusters of galaxies. Where the galaxy or cluster shows evidence of thermal equilibrium, X-ray data and lensing data analyses agreed on its mass. On the other hand, where disequilibrium should be expected from observational data, they tended to disagree, usually by a factor of 2 to 4. I am of the tentative opinion that MOND is now not worthwhile.

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The Delta 2 rocket carrying Rosat into orbit.

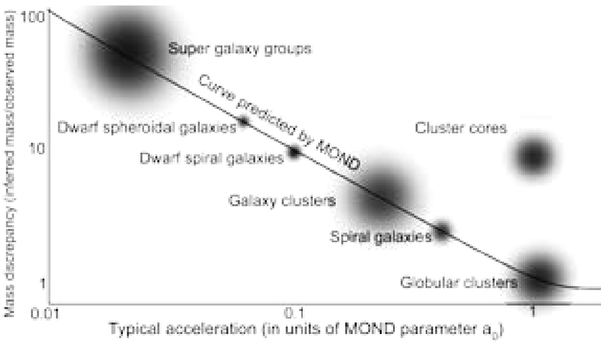
Bill Worraker Replies:

Courtesy of NASA

Dr Campbell's letter refers to a preprint of a paper by S.W. Allen which was published in peer-reviewed form in 1998.[1] Allen reports on masses within galaxy clusters inferred from (i) measurements of the X-ray emission profiles of hot intracluster gas observed with instruments on the ASCA and ROSAT satellites, and (ii) literature-based gravitational lensing studies. His results, in line with several similar investigations,[2,3] imply the presence of more mass in the cores of large clusters of galaxies than can be accounted for by the observable gas and stars *even if a MOND analysis is used.* Allen himself does not comment on MOND.

Note first that MOND is not ruled out by Allen's results. If a MOND analysis implied *less* mass than was directly observable we would consider it definitely falsified, but there are no such cases on record. The real issue, however, is that MOND was initially developed to explain the mass discrepancy problem for spiral galaxies without invoking 'dark matter',[4] yet in the case of these cluster cores it appears to require at least some additional mass. According to Sanders[2] and Sanders and McGaugh[3] the virial discrepancy (the ratio of inferred mass to observable mass) is typically reduced from a factor of 4 in a Newtonian analysis to a factor of 2 in a MOND analysis.

In a recent popular article on MOND, Milgrom[5] plots mass discrepancy against typical acceleration (see illustration above) for a series of galactic systems spanning 2–3 orders of magnitude in



Mass discrepancy versus typical acceleration for various galactic systems (after Milgrom).[5]

size. In all cases except cluster cores, MOND correctly predicts the trend and magnitude of the discrepancy. This could mean that MOND is revealing something very important about physics on the scale of galaxies and beyond. It could also mean that the cores of rich galaxy clusters are unique amongst galactic-scale systems; perhaps, as Sanders[2] predicts, they contain hitherto-undetected baryonic 'ordinary' matter.

Strong gravitational lensing, which may produce multiple and sometimes highly distorted images of background objects, is generally associated with these selfsame cluster cores.[6] My original article[4] notes that gravitational lensing is a general relativistic (GR) phenomenon which MOND cannot address. Therefore without a GR form of MOND one cannot fairly assess its predictions for cluster cores. This seems a good reason for developing the theory further rather than abandoning it as Campbell suggests.

We should remember that MOND provides a unified explanation—in some cases a prediction—of several phenomena about which the essentially *ad hoc* 'dark matter' hypothesis has nothing to say. Examples include the correlation (noted above) between mass discrepancy and typical acceleration for most galactic systems, the universal Tully–Fisher relationship between galaxy mass and rotation speed, the existence of an upper limit on the mean surface brightness of spiral galaxies, and so on.[3] Furthermore, beyond the gravitational effects, which it was originally invoked to explain, there is still no evidence that non-baryonic dark matter actually exists!

Consider the comments of Anthony Aguirre, the lead author of two critical studies of MOND:[7,8]
'Those who are most sympathetic to Milgrom's hypothesis should continue the search for a fundamental theory of MOND, without which the idea will never draw the majority of physicists away from the standard paradigm. For others, I think that it is productive to study, test and use MOND as a convenient rule of thumb whether or not one accepts a modification of Newtonian dynamics.'[9]

Given the above, including the positive suggestions of a knowledgeable leading critic of MOND, I cannot agree with Campbell's conclusion. I submit that there is considerable scientific value in developing and employing MOND as an aid to understanding the dynamics of galaxy-scale systems; it may be useful in cosmology too.

All of the foregoing discussion, both by proponents and critics of MOND, presupposes that the results of gravitational lensing studies are beyond question. However Arp[10] has suggested several reasons why, at least in some cases, a lensing interpretation of astronomical images may not be correct. The redshift of the (supposedly) lensed object is always higher than that of the lensing object, and 'dark matter' is practically always invoked in lensing models. Thus gravitational lensing is an integral part of today's mainstream cosmology and in many cases is needed to preserve the belief that extragalactic redshifts must always be cosmological in origin. There can often be serious difficulties in fitting credible lensing models to the data, as is clear from standard texts on the subject.[11]

I suggest, therefore, that gravitational lensing could prove to be a fruitful field of investigation for creationist researchers. Although the Word of God is totally reliable, the same cannot be said of the Word of Man, however confidently pronounced.

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