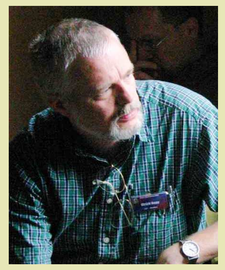
The Dwarf Galaxy Crisis of Cosmology Continues

Dr. Regina E. Schulte-Ladbeck & Dr. Ulrich Hopp



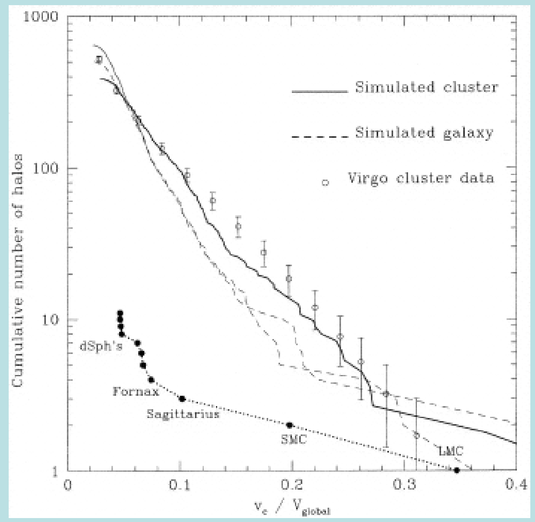
Contact us at hopp@usm.uni-muenchen.de and rsl@pitt.edu

BACKGROUND

The Problem:

In 1999, Klypin *et al*. and Moore *et al*. noticed that numerical simulations of galaxy formation predict CDM subhalo counts that are an order of magnitude in excess of the numbers of observed dwarf satellites surrounding the Milky Way Galaxy.

Density of dark matter within a galaxy halo of mass 2×10^{12} solar masses.



Cumulative numbers of halos as a function of their circular velocities in MWG simulations (dashed curves), compared to known observed dwarfs as compiled by Mateo (1998).

Proposed Solutions:

1. **There is something wrong with CDM galaxy formation.** Simulations cannot be reconciled with observations.
2. **The CDM hierarchical paradigm is correct, but not all of the astrophysics of galaxy formation is as yet correctly included in simulations.** This will eventually reduce the numbers of predicted satellites and reconcile simulations and observations.
3. **The CDM hierarchical paradigm is correct, but most dwarf galaxy satellites of the MWG have been missed observationally.** This will eventually increase the numbers of observed satellites and reconcile simulations and observations.

Klypin, A., Kravtsov, A.V., Valenzuela, O., Prada, F., 1999, ApJ, 522, 82

Moore, B., Ghigna, S., Governato, F., Lake, G., Quinn, T., Stadel, J., Tozzi, P., 1999, ApJ, 524, L19

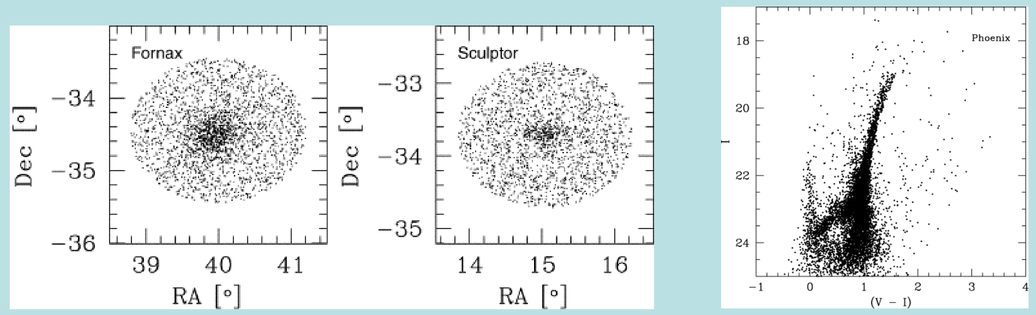
Mateo, M., 1998, ARA&A, 36, 435

OUR WORK

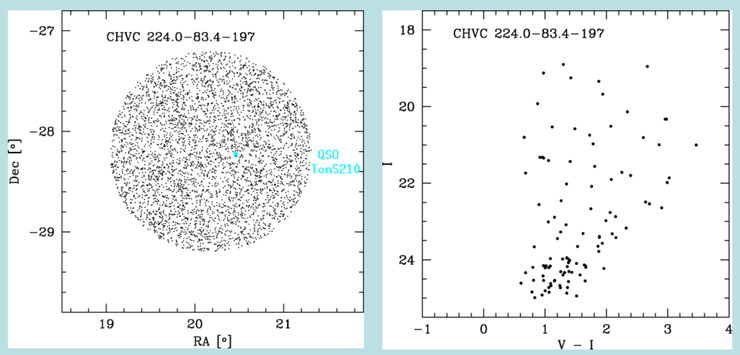
Testing Proposed Solution #3 with Targeted Observations of Compact High-Velocity Clouds

Blitz *et al*. (1999) proposed that abundant high-velocity clouds (HVC) observed in the Local Group may be the observational counterparts of the CDM halos unaccounted for by known dwarf galaxies.

This picture relies on large distances to HVCs, which cannot be derived from HI observations, but could be determined from stellar photometry if HVCs contained a stellar population.



2MASS position plots and VLT color-magnitude diagram (CMD) of three *known* MWG satellites.



CHVC 224.0-83.4-197 intercepts the line of sight to the QSO Ton S210; its HI column produces Lyman series absorption in the QSO's spectrum; an upper limit on its O/H is lower than the O/H in the MWG's interstellar medium.

2MASS and VLT data for one of ten CHVCs in our program. There is no concentration of stars indicative of a dwarf galaxy. The CMD is consistent with Galactic foreground. The other data sets are qualitatively similar. For a quantitative discussion of the detection limits, see Hopp *et al*. (2003).

Our Null Result:

We do not detect stellar populations intrinsic to the CHVCs. There is a 50% chance of getting a null result in ten trials if fewer than 7% of all CHVCs (41 of 582) contain stars. Therefore, HVCs are a very unlikely source to provide the missing dwarf galaxies of the Local Group predicted by numerical simulations.

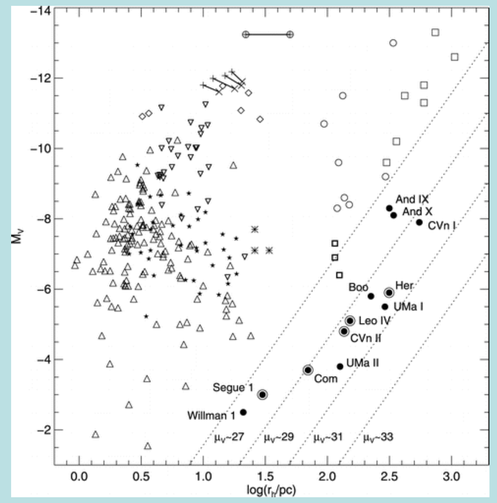
Blitz, L., Spergel, D.N., Teuben, P.J., Hartman, D., Burton, W.B., 1999, ApJ, 514, 818

Hopp, U., Schulte-Ladbeck, R.E., Kerp, J., 2003, MNRAS, 339, 33
Hopp, U., Schulte-Ladbeck, R.E., Kerp, J., 2007, MNRAS, 374, 1164

OTHER WORK

Testing Proposed Solution #3 with SDSS Data

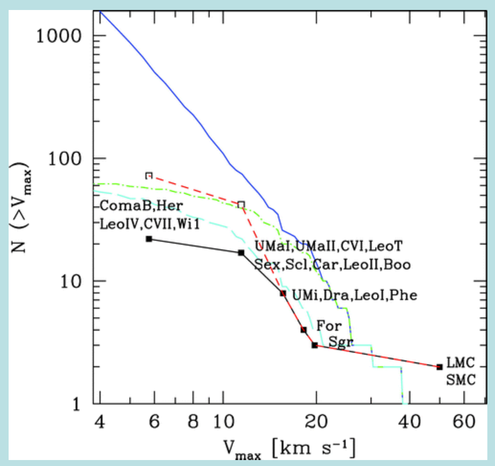
A total of 10 new MWG satellites have been discovered as stellar overdensities in SDSS data (e.g. Belokurov *et al*. 2007).



Location of globular clusters, ultra-compact and Virgo dwarfs, and of Local Group dwarfs (dSphs), in the plane of absolute magnitude vs. half-light radius. The filled circles denote MWG satellites found in SDSS data.

Testing Proposed Solution #2 with New Simulations

In the high-resolution, Via Lactea simulations of Madau *et al*. (2008), there are now two orders of magnitude more CDM subhalos than there are known dwarf satellites of the MWG.



Cumulative number of Via Lactea subhalos (solid blue curve). The dashed red line shows the expected abundance of luminous MWG satellites after correcting for the sky coverage of the SDSS.

In addition, another problem has been emerging: the simulations and the observations yield different radial distributions of the MWG satellites.

Belokurov, V., Zucker, D.B., Evans, N.W., Klenya, J.T., & 30 co-authors, 2007, ApJ, 654, 897

Madau, P., Diemand, J., Kuhlen, M., 2008, ApJ, 679, 1260