# my research interests:

## at CERN :

MoEDAL– MAPP search for magnetic monopoles

## at Tufts :

Redshift and the shape of the Universe

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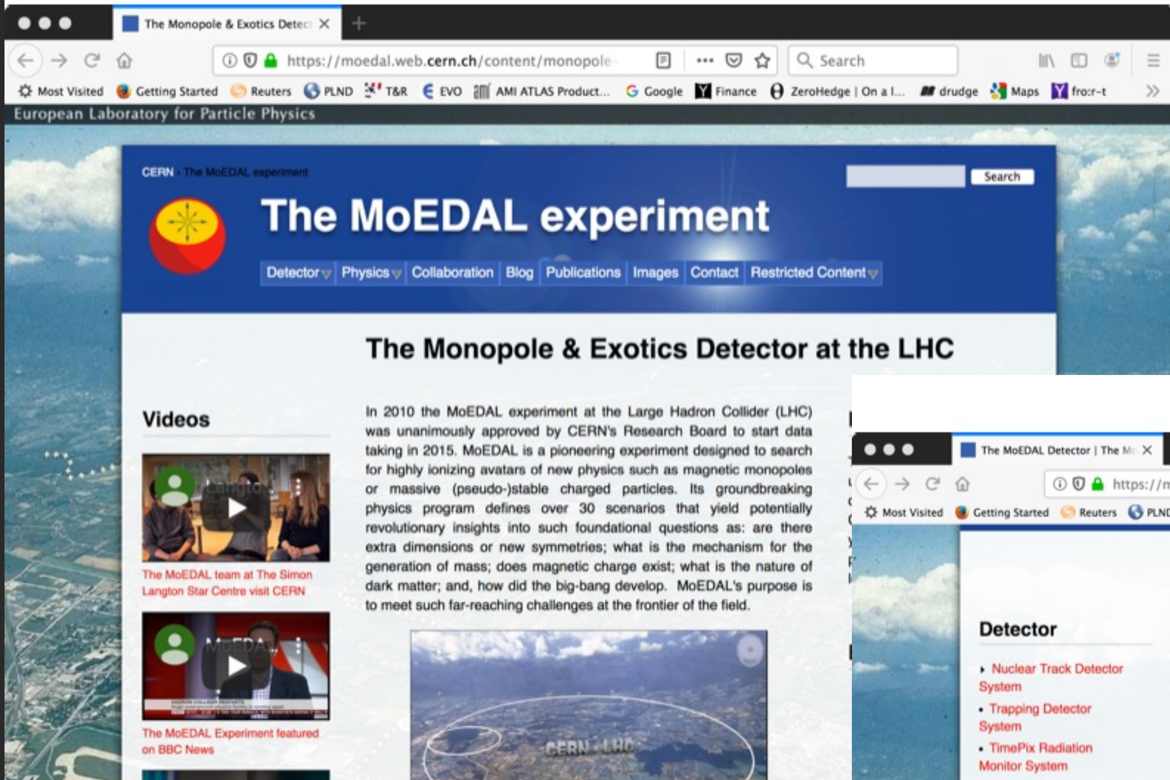
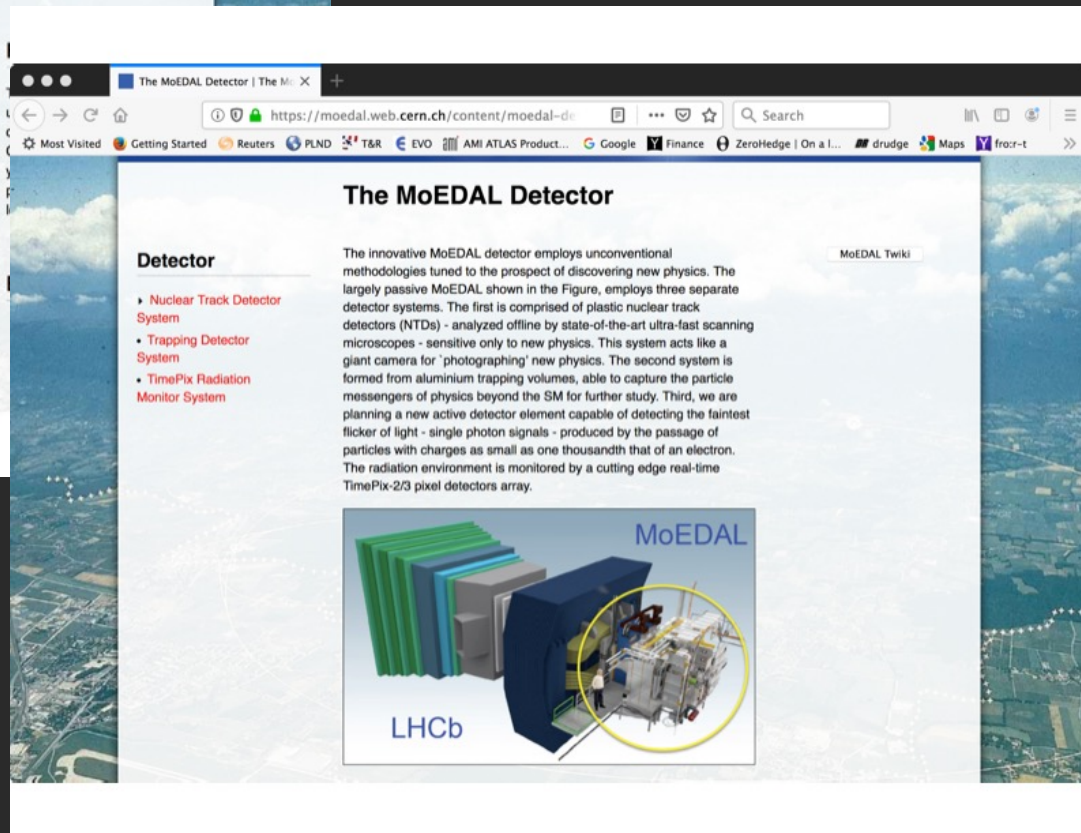
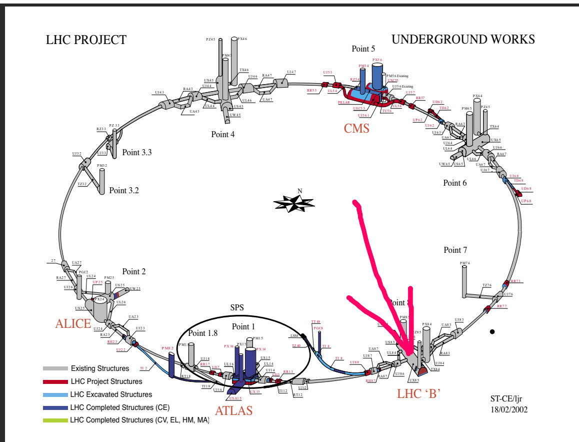
# MoEDAL-MAPP

a dedicated experiment to look for magnetic monopoles produced in pp, pN or NN collisions at very high energies at the LHC:

so far all searches NEGATIVE



# geometry and topology of the Universe

- the Standard Cosmological Model $\Lambda CDM$ (SM)– the crucial starting point is an interpretation of the observed increase of redshift with the distance of far-away objects as a "Doppler-like" effect

- from this follows the idea of Big Bang and the expansion of the Universe, the Universe is flat and infinite, $M_o = R^1 \times R^3$ , or Minkowski "world"

- However, Irwing Ezra Segal (1918-1998) has shown in ~1970, that there is another possibility - the same axioms of global causal isotropy and homogeneity of space and time, which are satisfied by Minkowski spacetime $M_o$, are also satisfied by a $M = R^1 \times S^3$ Universe, which is finite, with its spatial part curved and closed, without boundary and compact

# geometry and topology of the Universe

- it is the geometry of the Einstein static Universe, which he abandoned when the interpretation of the increase of redshift with distance became universally accepted as evidence for expanding Universe.

- this spatially curved Universe M locally looks like $M_o$

- Segal has shown that in the $M=R^1 x S^3$ Universe the redshift appears simply a consequence of a distortion analogous to that in a stereographic projection from $S^2$ onto $R^2$, (when we make maps of Earth's surface)

- except, since we live in a 4-dimensional world with three spatial dimensions, the projection here is from $R^1 x S^3$ onto $R^1 x R^3$

# geometry and topology of the Universe

- Segal's model gives a verifiable prediction on the dependence of redshift z on propagation time t, or geodesic distance on $S^3$, if the Universe is $M=R^1 x\ S^3$

$$z = \ tan^2\left(\frac{t}{2R}\right)$$

- I've decided in 2017 to take a look at the newest data from catalogs available online to compare with predictions of Segal's cosmology and SM cosmology

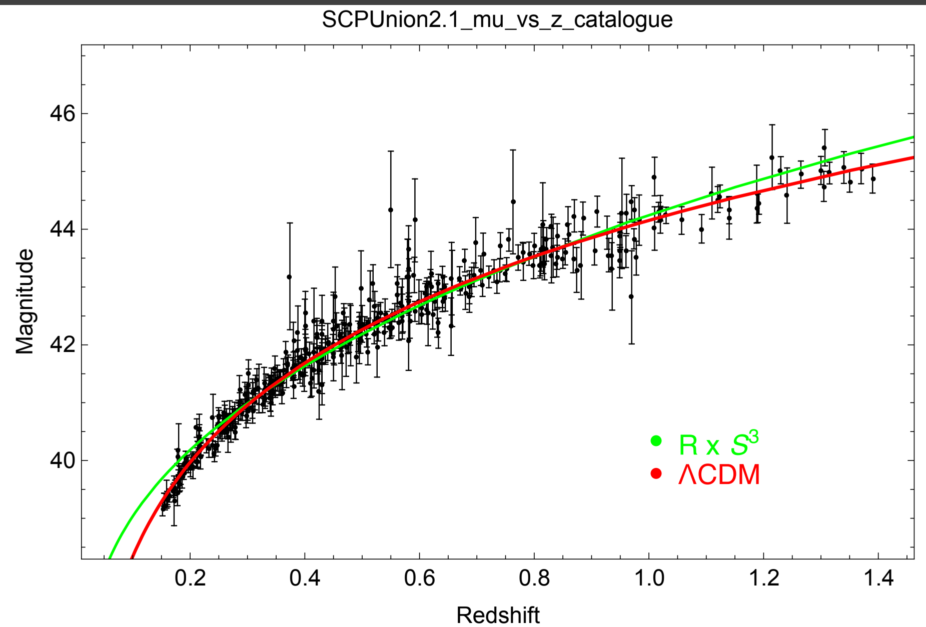
- it is not trivial, as for very far-away objects we can only use proxies for the distance (like luminosity), we cannot directly measure it – many caveats here!

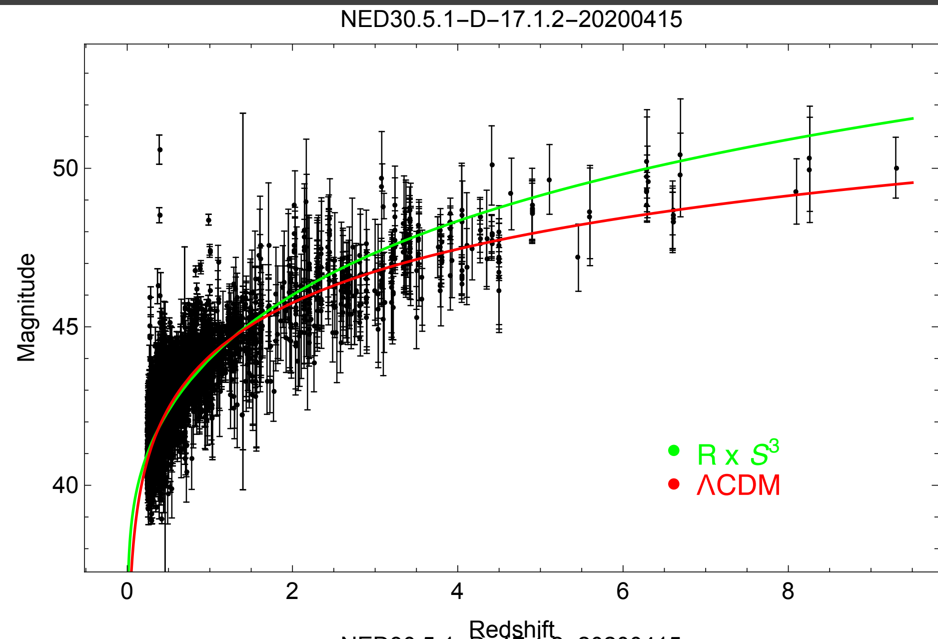
# geometry and topology of the Universe

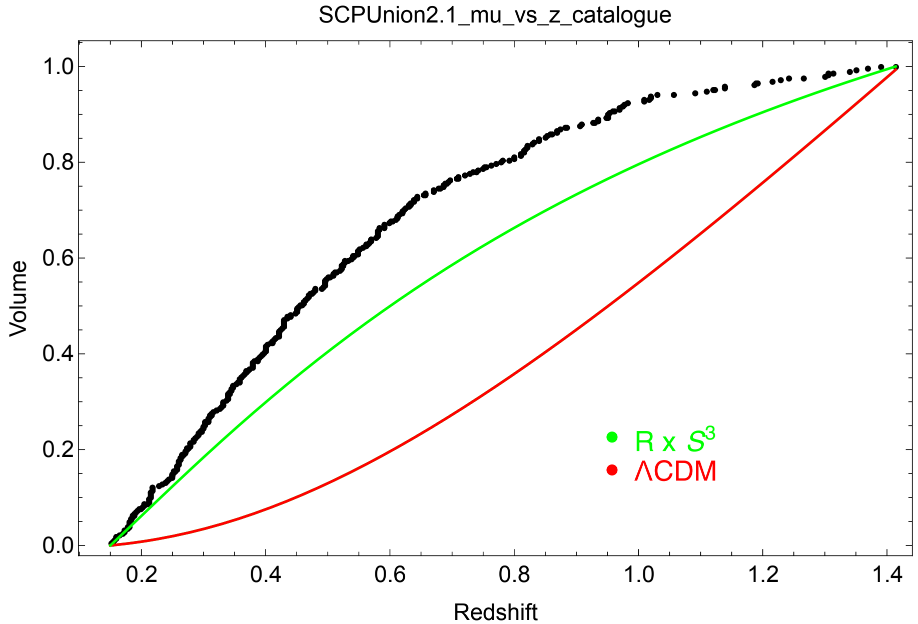
- surprisingly, Segal's theory cannot be falsified with the currently available data on m(z) – both SM and Segal's models give decent fits to the data and, while supernovae type 1a agree maybe a bit better with the SM, quasars agree better with Segal's – this is very preliminary, I'm still investigating this topic

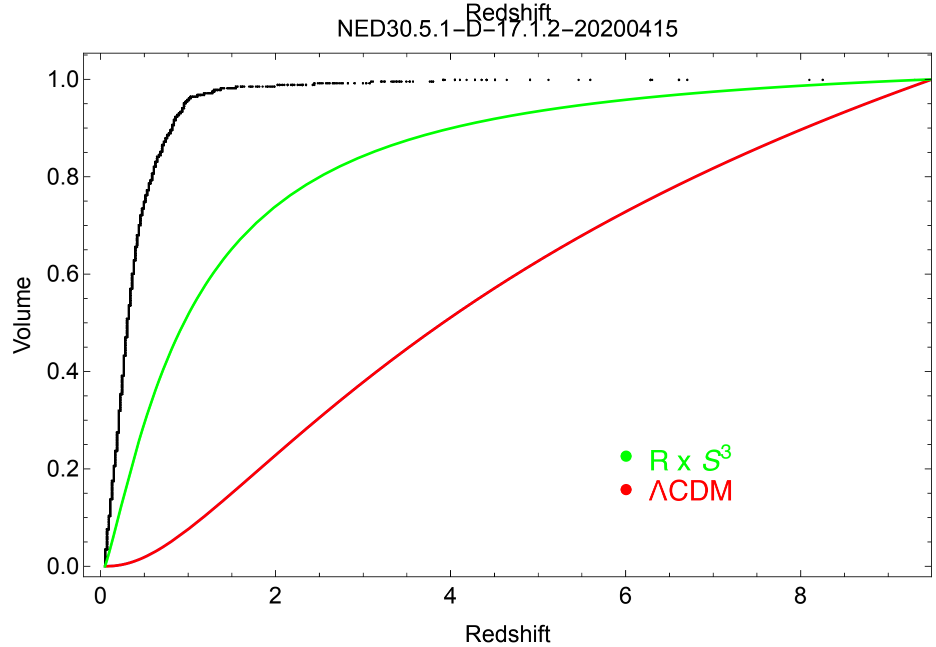
- another observable – "the number count", the number of given type of objects seen in a fixed cone versus redshift, N(<z), depends on the volume enclosed in this cone, and is thus sensitive to the geometry of space – it seems to be in better agreement with Segal's model than with the Standard Big Bang cosmology for several Deep Fields it – again, although in principle very simple, the comparison is not easy due to possible but unknown effects of absorption or evolution of galaxies in time (at very large redshifts there should be no galaxies in SM as they need time to form)

# Supernovae Cosmology Project and NED
# N(<z) not meaningful here, here they don't come from a fixed cone deep fields

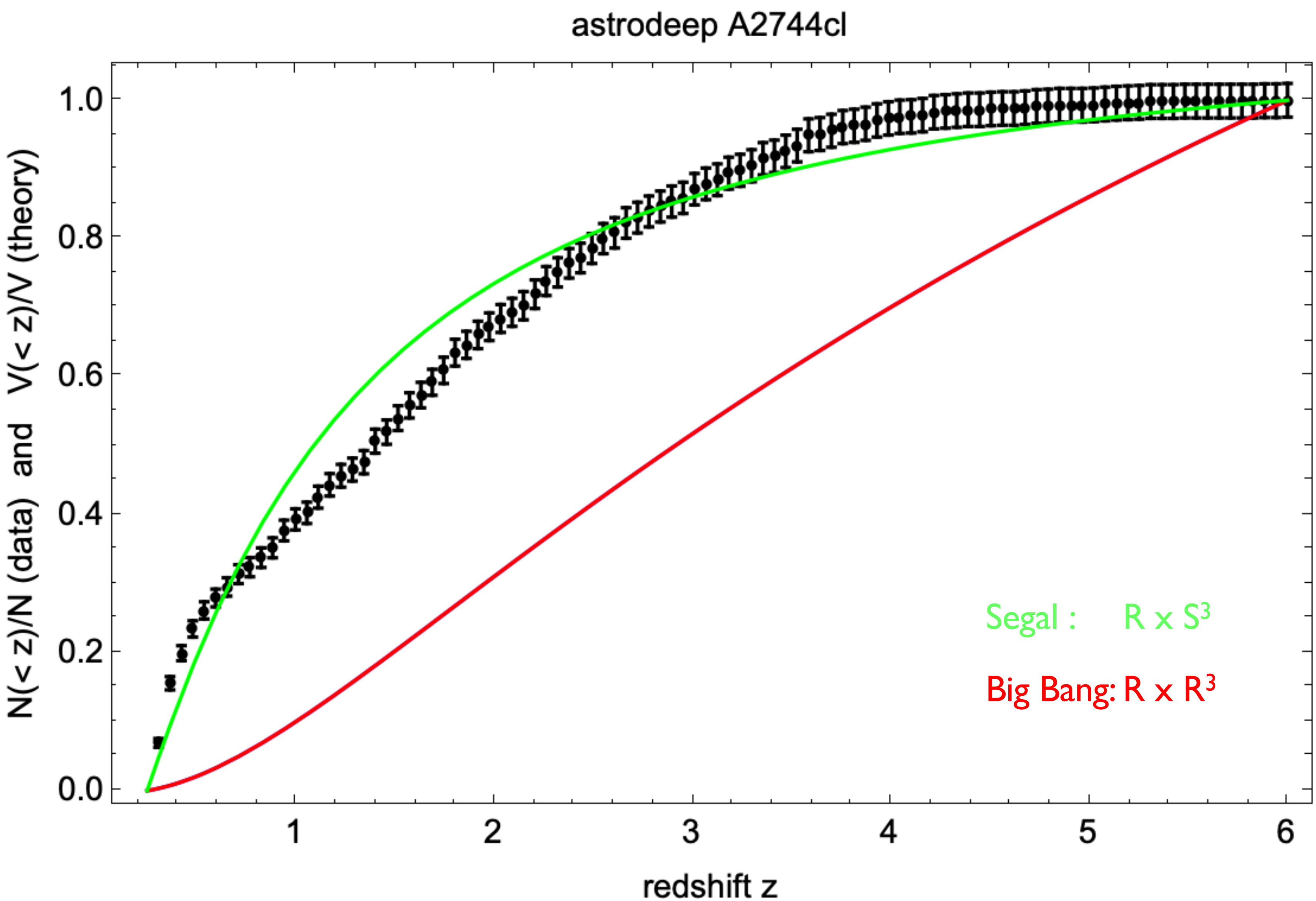


# Astrodeep/A2744cl_26012016 (Abell)



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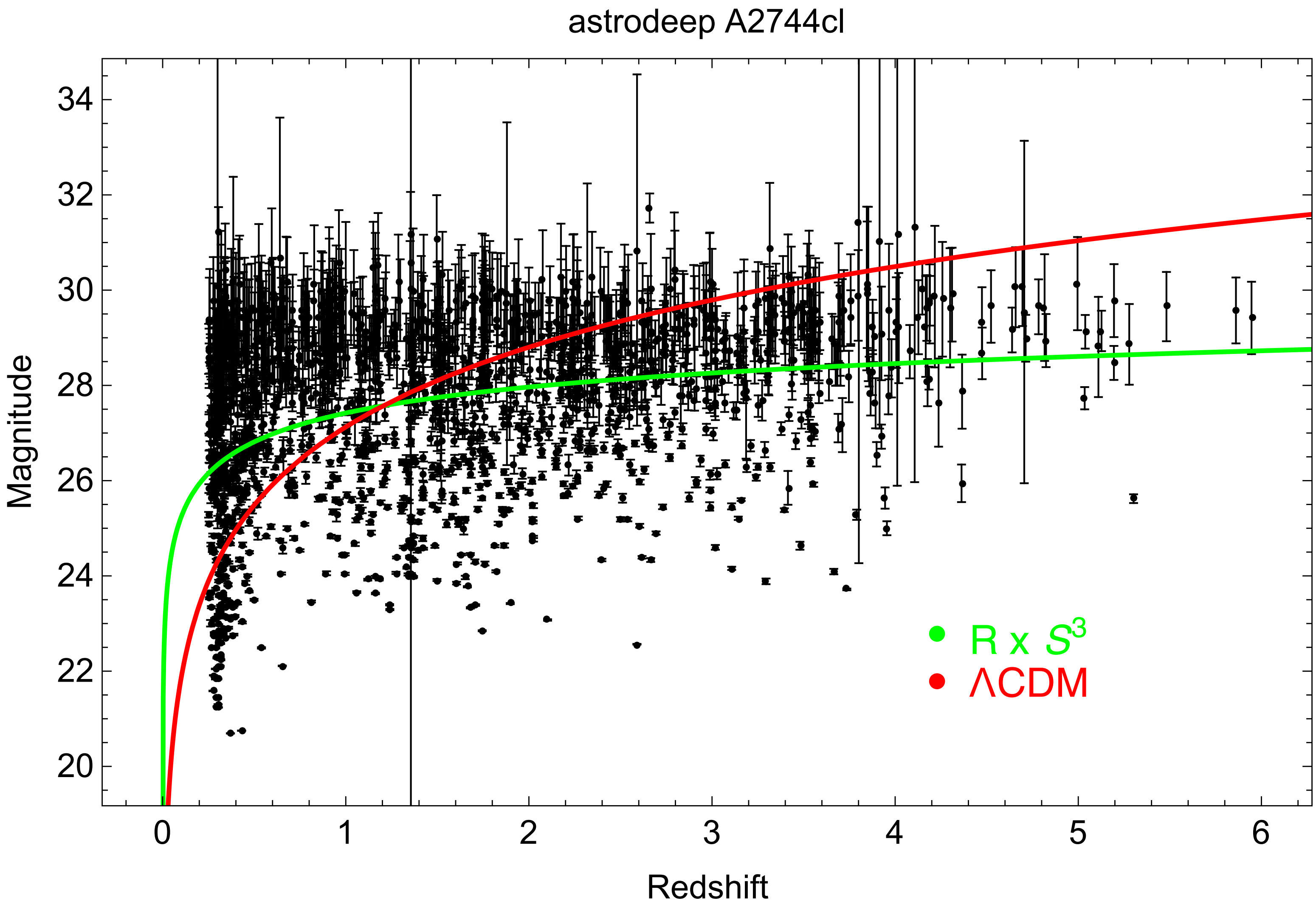


# geometry and topology of the Universe

- there is another important observational fact:  our Universe is filled with the omnidirectional cosmic microwave radiation (CMB) with black body spectrum corresponding to temperature of about T=2.7 K

- in the standard $\Lambda$CDM model, CMB is explained as the light that was originally emitted from  "the surface of last scattering" about 380,000 years after the Big Bang, now at redshift of z~1100

- in February 2022, following Segal's original idea that CMB appears unavoidably as the residual light when considering solutions to Maxwell equations travelling over multiple turns around the spatially closed $R^1 \times S^3$ Universe, I was able to show that the observed value of the CMB temperature T=2.7 K *can indeed be naturally explained*

# geometry and topology of the Universe

- it also seems that it is possible to explain the observed structure in the power spectrum of CMB fluctuations as being due to hierarchy of the large-scale structures in the Universe - galaxy clusters, superclusters, voids et cetera

- last year, we were able to show that the first peak in CMB power spectrum at l~200 can indeed be reproduced in this way

- I've been working on this topic with undergraduate students - Max Kaye and Nathan Burwig, both were Tufts Summer Scholars, and both wrote their Senior Theses in 2021 and 2023, respectively.

# main features in CMB power spectrum (from Nathan's Senior Thesis and my notebooks)

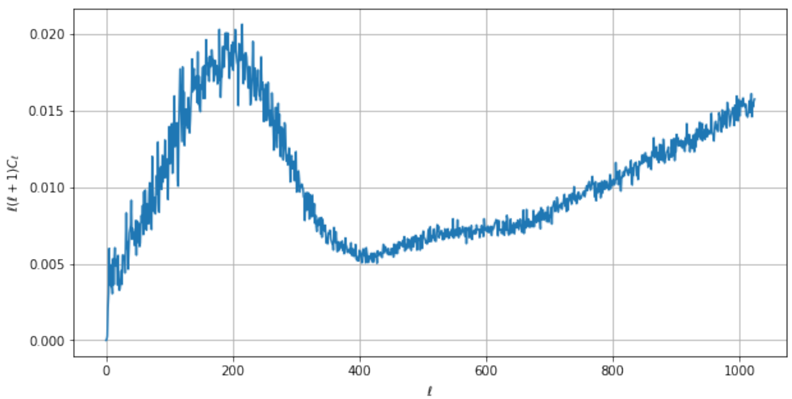
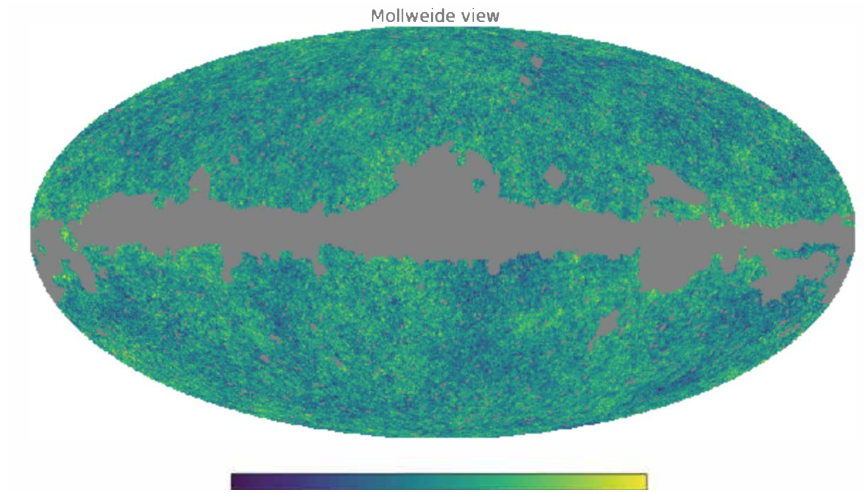



Figure 4: The CMB power spectrum produced in healpy directly from the WMAP data. Notably, the Planck data is not used in this thesis as its resolution is quite high and comparing to a resolution that high would require significantly more computation time in the simulations where that resolution is generally not required for first order approximations.



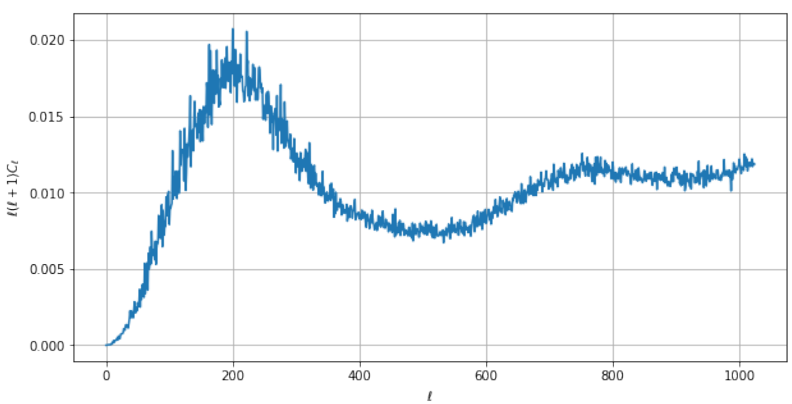
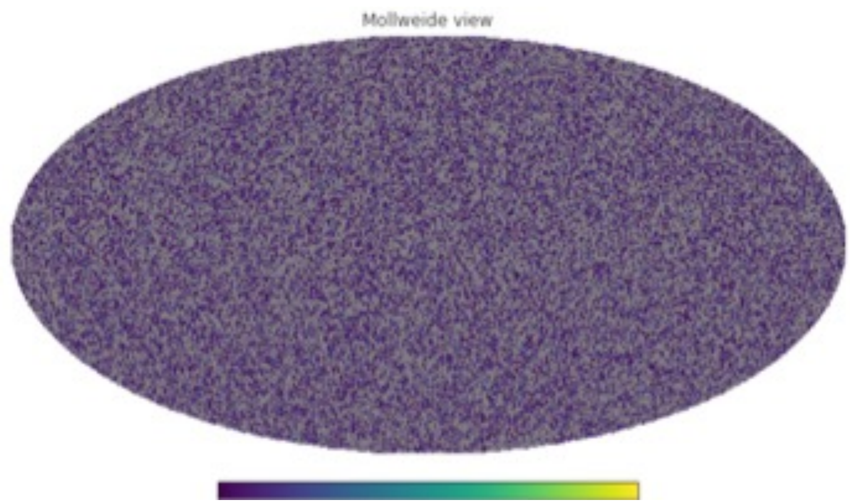




Figure 5: The CMB power spectrum produced in healpy directly from the Mathematica output utilizing cubic packing. We note the spectrum is characteristically varied, and notably starts from zero, likely due to there being no constraint on how close exactly the packed superclusters are allowed to be to some origin point (the celestial sphere).



# geometry and topology of the Universe

- interestingly, in a recent paper in Nature, based on JWST data, Labbe et al: "*A population of red candidate massive galaxies ~600 Myr after the Big Bang*", an observation of galaxies of uncharacteristically large mass, given their high redshifts, was reported

- according to the current ideas about evolution of galaxies in the expanding Universe, such objects are not really expected so early after the Big Bang. Their presence is, of course, naturally explained in a static $R^1 \times S^3$ Universe

- Our Universe actually may be not expanding, it could be finite, with its spatial part closed, without boundary and compact: Segal-Einstein Universe $M=R^1 \times S^3$

# geometry and topology of the Universe

- I will further explore the topology and geometry of the Universe. The first step is to reanalyze the updated redshift catalogues and Deep Fields data. I'll will also try to find new observables that could differentiate between $R^1 \times R^3$ versus $R^1 \times S^3$ geometries.

- rather than to study independently the magnitudes and the number of observed galaxies as a function of redshift, m(z) and N(< z), it would be preferable to perform a *simultaneous fit* to those observables; possibly the new data from the James Webb Space Telescope (JWST), the new Deep Field catalogues may allow such analyses; also, JWST data could provide more information about absorption, which obviously complicates the m(z) and N(<z) observations

- the most important topic is energy conservation and creation of matter in a static Universe, black hole -> white-hole recycling is an interesting possibility