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A simultaneous solution to the Hubble tension and observed bulk flow within 250 h^{-1} Mpc

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ABSTRACT

The Λ cold dark matter (ΛCDM) standard cosmological model is in severe tension with several cosmological observations. Foremost is the Hubble tension, which exceeds 5σ confidence. Galaxy number counts show the Keenan-Barger-Cowie (KBC) supervoid, a significant underdensity out to 300 Mpc that cannot be reconciled with ΛCDM cosmology. Haslbauer et al. previously showed that a high local Hubble constant arises naturally due to gravitationally driven outflows from the observed KBC supervoid. The main prediction of this model is that peculiar velocities are typically much larger than expected in the ΛCDM framework. This agrees with the recent discovery by Watkins et al. that galaxies in the CosmicFlows-4 catalogue have significantly faster bulk flows than expected in the ΛCDM model on scales of $100-250\,h^{-1}$ Mpc. The rising bulk flow curve is unexpected in standard cosmology, causing 4.8σ tension at $200\,h^{-1}$ Mpc. In this work, we determine what the semi-analytic void model of Haslbauer et al. predicts for the bulk flows on these scales. We find qualitative agreement with the observations, especially if our vantage point is chosen to match the observed bulk flow on a scale of $50\,h^{-1}$ Mpc. This represents a highly non-trivial success of a previously published model that was not constrained by bulk flow measurements, but which was shown to solve the Hubble tension and explain the KBC void consistently with the peculiar velocity of the Local Group. Our results suggest that several cosmological tensions can be simultaneously resolved if structure grows more efficiently than in the ΛCDM paradigm on scales of tens to hundreds of Mpc.

Предыстория

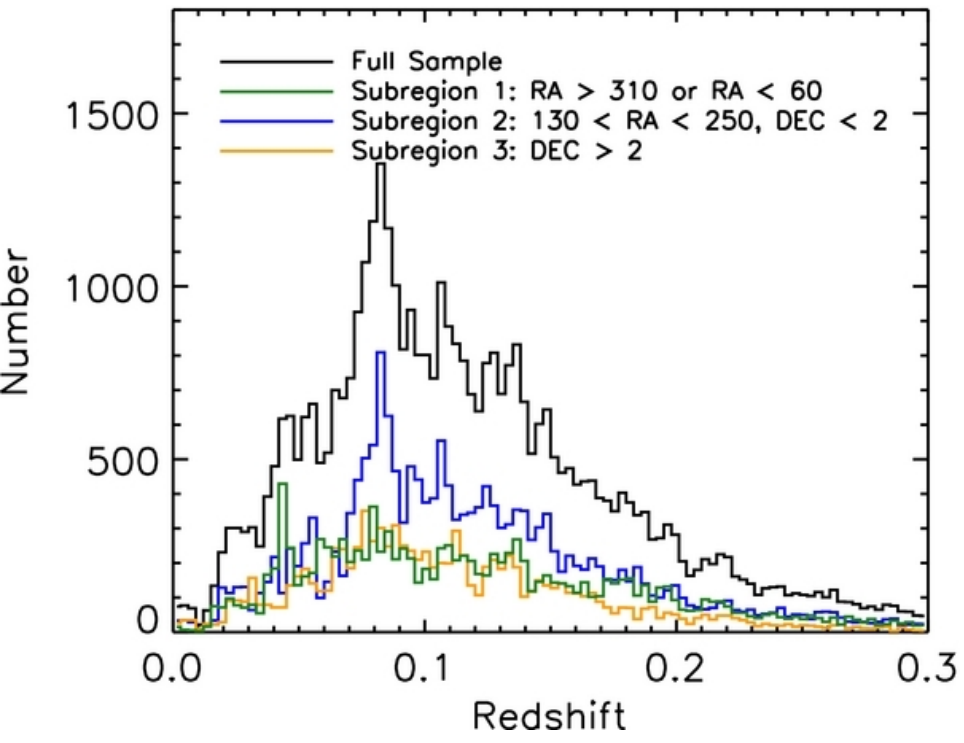
- Огромный местный войд, радиусом как минимум 300 Мпк: Keenan et al.(2013)

- не согласуется с предсказаниями LCDM

Модель аналогичного войда в рамках новой космологии (Haslbauer+ 2020):

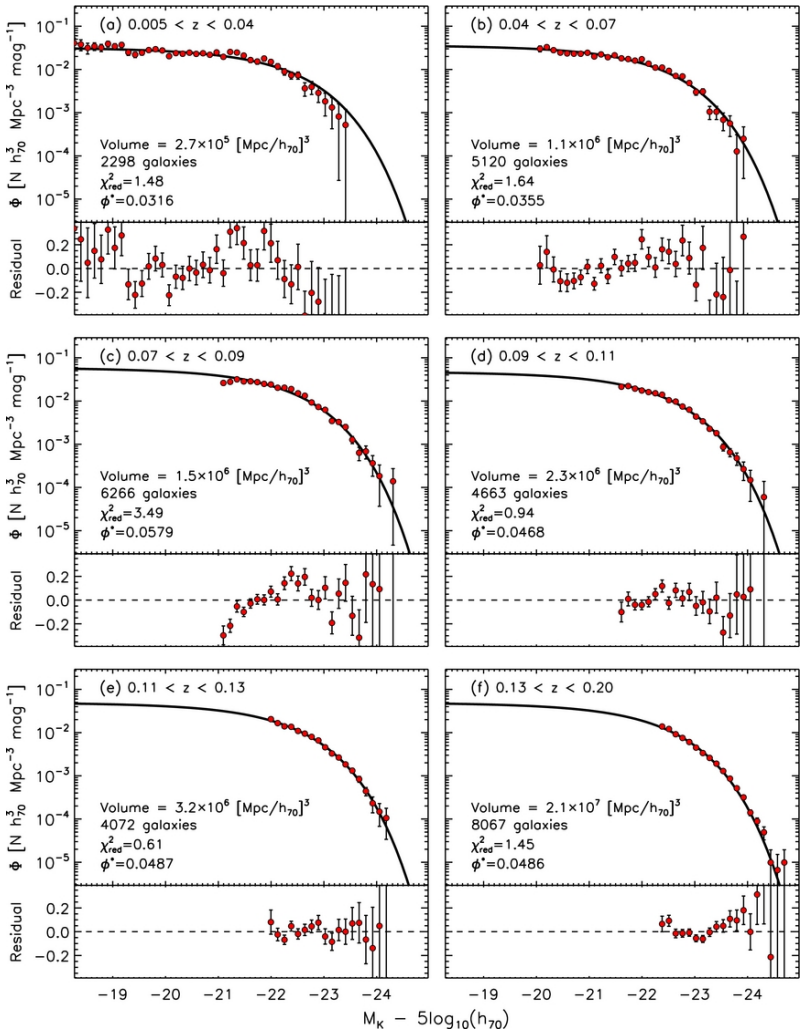
MOND+нейтринная горячая материя

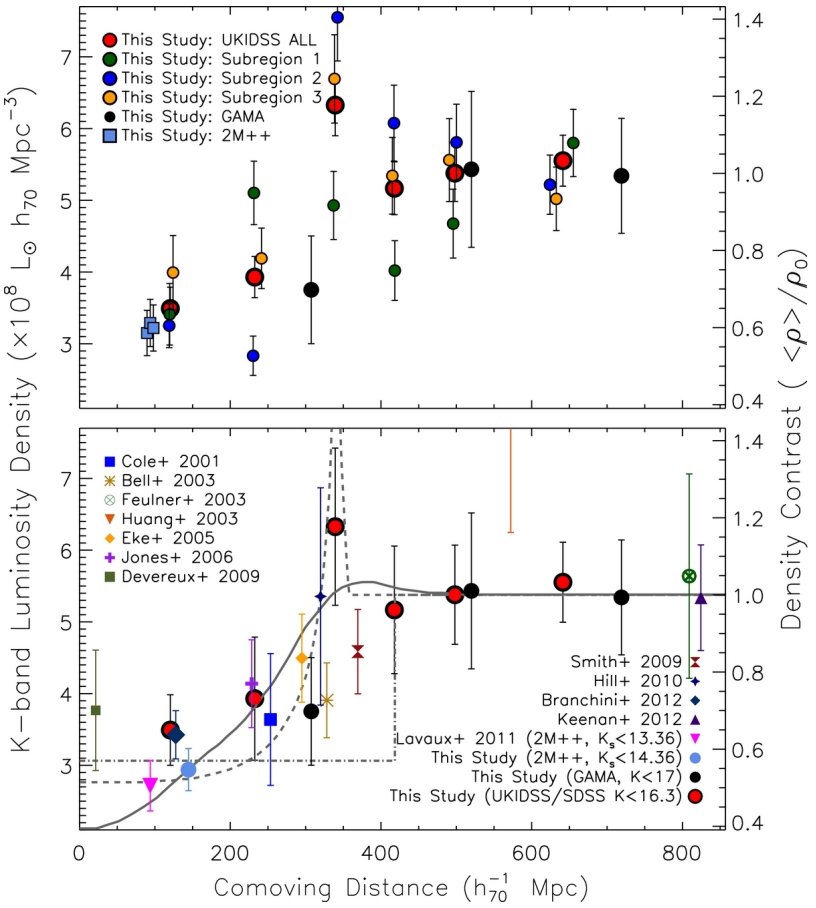
Keenan+(2013)



- Выборка из ~30000 галактик до z~0.3
- С инфракрасной фотометрией и красными смещениями из разных обзоров
- Функции светимости на 2 мкм в бинах по z

Keenan+(2013)


(a) 0.005 < z < 0.04
Volume = 2.7×10^5 [Mpc/h70]^3
2298 galaxies
χ²red=1.48
φ*=0.0316
(b) 0.04 < z < 0.07
Volume = 1.1×10^6 [Mpc/h70]^3
5120 galaxies
χ²red=1.64
φ*=0.0355
(c) 0.07 < z < 0.09
Volume = 1.5×10^6 [Mpc/h70]^3
6266 galaxies
χ²red=3.49
φ*=0.0579
(d) 0.09 < z < 0.11
Volume = 2.3×10^6 [Mpc/h70]^3
4663 galaxies
χ²red=0.94
φ*=0.0468
(e) 0.11 < z < 0.13
Volume = 3.2×10^6 [Mpc/h70]^3
4072 galaxies
χ²red=0.61
φ*=0.0487
(f) 0.13 < z < 0.20
Volume = 2.1×10^7 [Mpc/h70]^3
8067 galaxies
χ²red=1.45
φ*=0.0486
Φ [N h70^3 Mpc^-3 mag^-1]
Residual
M_K − 5log10(h70)


This Study: UKIDSS ALL
This Study: Subregion 1
This Study: Subregion 2
This Study: Subregion 3
This Study: GAMA
This Study: 2M++
Cole+ 2001
Bell+ 2003
Feulner+ 2003
Huang+ 2003
Eke+ 2005
Jones+ 2006
Devereux+ 2009
Smith+ 2009
Hill+ 2010
Branchini+ 2012
Keenan+ 2012
Lavaux+ 2011 (2M++, Ks<13.36)
This Study (2M++, Ks<14.36)
This Study (GAMA, K<17)
This Study (UKIDSS/SDSS K<16.3)
K−band Luminosity Density (×10^8 L⊙ h70 Mpc^-3)
Density Contrast (<ρ>/ρ0)
Comoving Distance (h70^-1 Mpc)

Задачи данной работы:

- Посмотреть поле пекулярных скоростей модели войда из Haslbauer +(2020)…
- И сравнить эти модельные предсказания с наблюдаемыми данными Cosmicflow-4 по крупномасштабным потокам галактик в ближней Вселенной, опубликованным только в 2023 году.

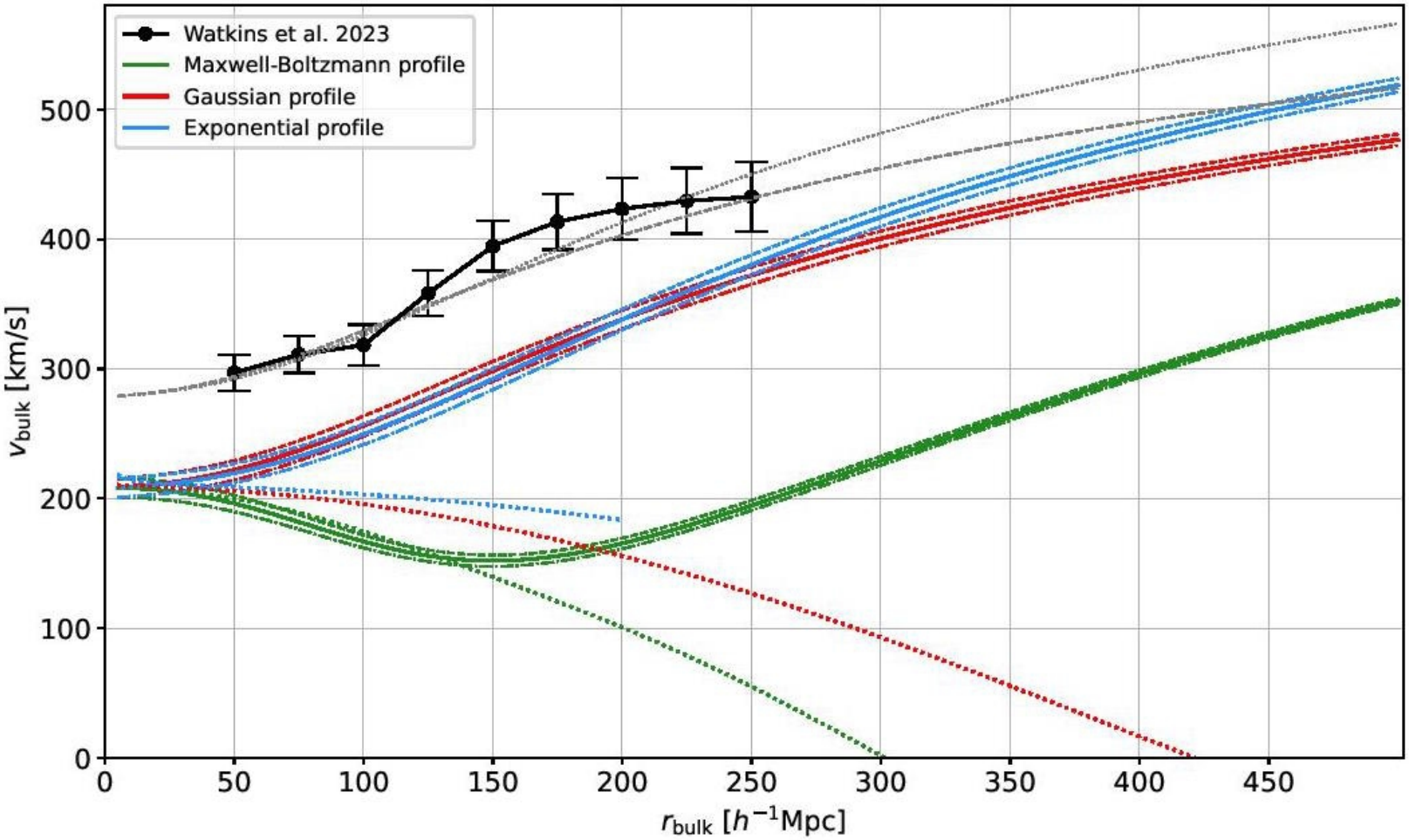


Figure 1. Bulk flows in spheres of different radii around an observer with a suitable CMB-frame velocity for the Maxwell-Boltzmann, Gaussian, and Exponential density profiles (green, red, and blue curves, respectively). The solid black points with uncertainties show the observed bulk flows (bottom right panel of figure 7 in Watkins et al. 2023). The two innermost data points use the same method and survey data but were not published in that study, so these were provided in a private communication by its lead author. At $r_{\rm bulk} = 0$, the simulated curves begin at $v_{\rm LG}/3$ because the observed bulk flows use only the line of sight velocities, which are treated as vectors that are then combined (see below Equation 5). The solid curves represent the bulk flows as seen by the inner observer if $v_{\rm LG} = 627\,{\rm km\,s^{-1}}$. The dashed curves (typically above each solid curve) are the bulk flows for $v_{\rm LG} = 627 + 22\,{\rm km\,s^{-1}}$. The dashed-dotted curves (typically below each solid curve) are the bulk flows for $v_{\rm LG} = 627 - 22\,{\rm km\,s^{-1}}$. These additional curves help to show the impact of the uncertainty in $v_{\rm LG}$, which slightly shifts our vantage point in the context of each model and can thus affect the predicted bulk flow. The grey dashed (dotted) curve shows the bulk flow curve for the Gaussian (Exponential) density profile if $v_{\rm LG} = 840\,{\rm km\,s^{-1}}$, which shifts the inner vantage point by 29.8 (38.0) Mpc towards the void centre. The coloured thin dotted curves represent the outer observers for all density profiles. These all assume the observed $v_{\rm LG}$ and use the same colour as the corresponding results for the inner observer.

Выводы:

- Если супервойд реален, это объясняет высокое значение постоянной Хаббла в локальной Вселенной: галактики просто разлетаются в направлении от центра войда за счет грав. притяжения стенок
- Но чтобы сделать войд радиусом 300 Мпк, надо отказаться от LCDM (где вероятность существования такого войда 10^{-4})
- А тогда решатся и другие нестыковки: массивные скопления на больших z, диполь в распределении квазаров и тд