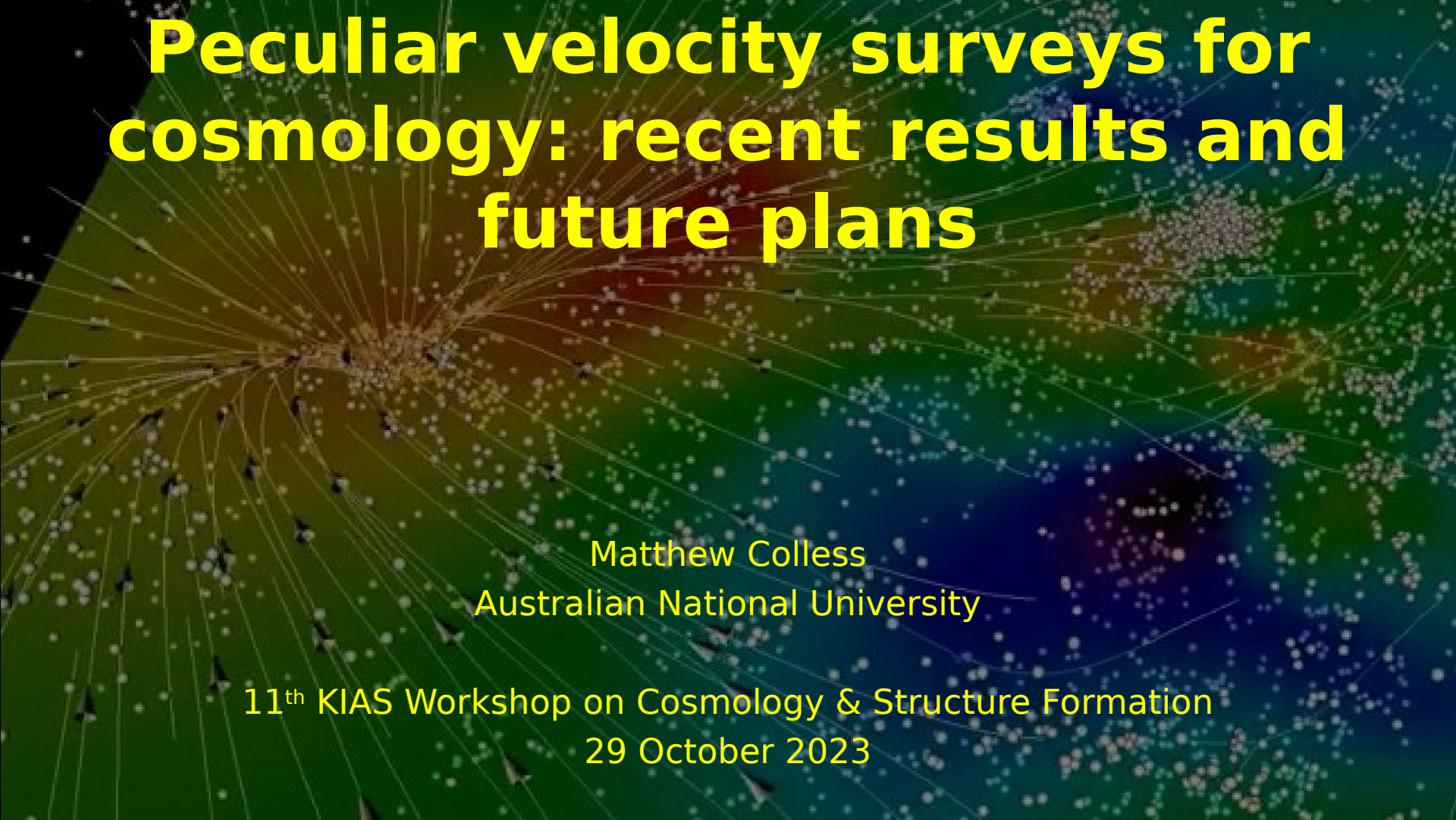
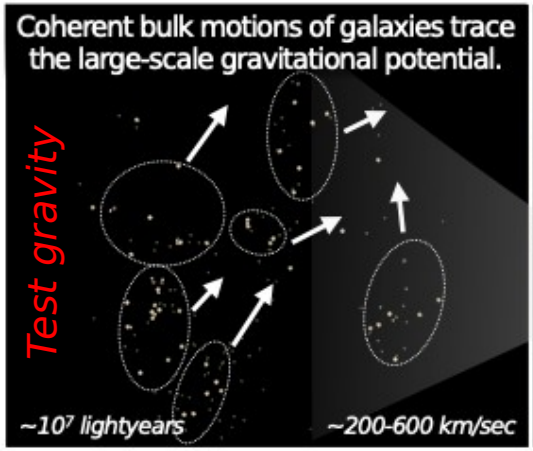
Peculiar velocity surveys for cosmology: recent results and future plans



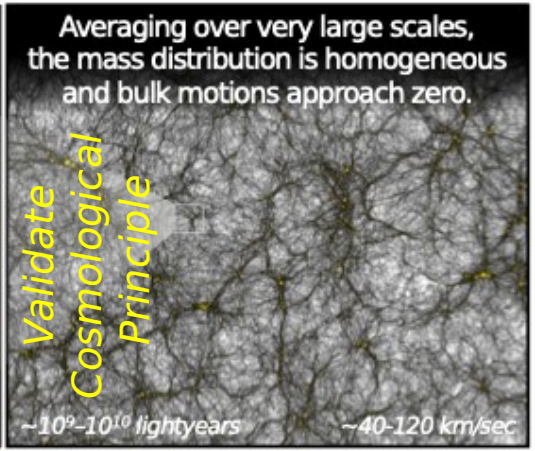
Matthew Colless
Australian National University

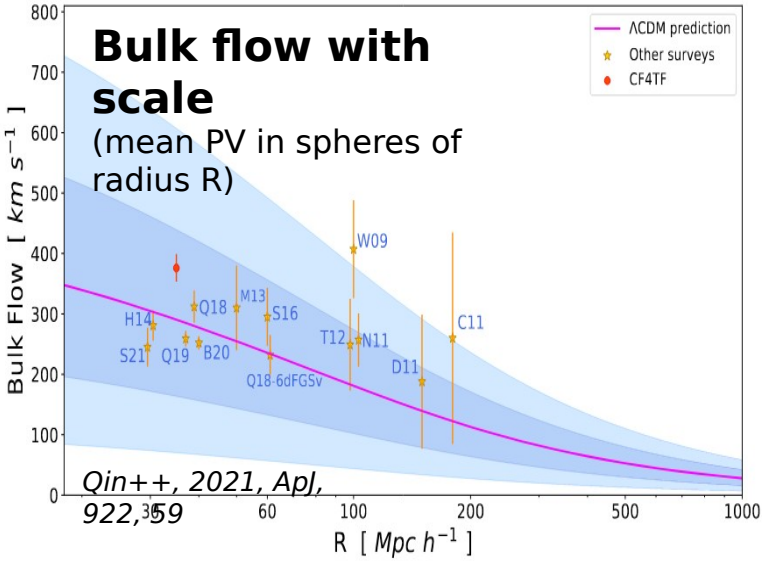
11th KIAS Workshop on Cosmology & Structure Formation
29 October 2023

Cosmology from peculiar velocities

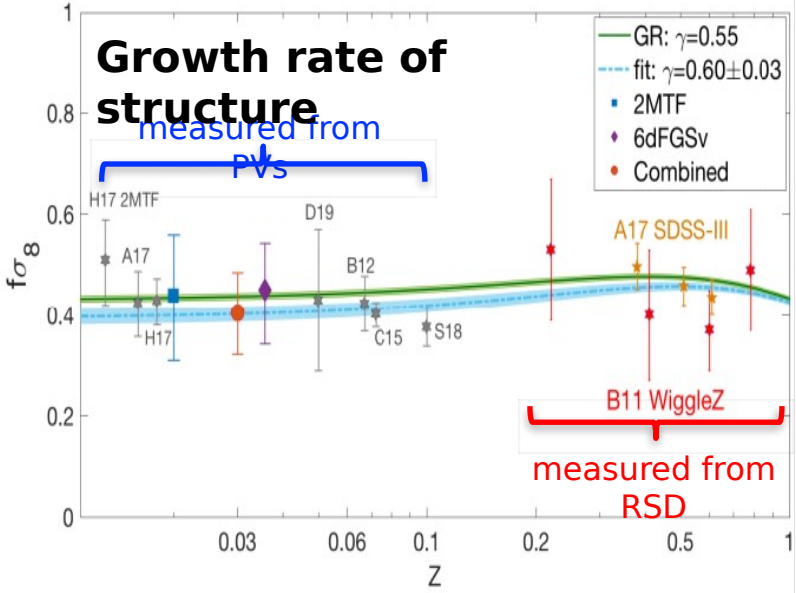








Qin++, 2021, ApJ, 922,59



Fundamental Plane peculiar velocities from the 6dFGS, SDSS and LAMOST surveys

MNRAS **497,** 1275–1293 (2020)
Advance Access publication 2020 July 11

doi:10.1093/mnras/staa2032

Joint analysis of 6dFGS and SDSS peculiar velocities for the growth rate of cosmic structure and tests of gravity

Khaled Said [1,2★] Matthew Colless [1★] Christina Magoulas,[3] John R. Lucey [4] and Michael J. Hudson[5,6,7]

MNRAS **515,** 953–976 (2022)
Advance Access publication 2022 June 20

https://doi.org/10.1093/mnras/stac1681

The Sloan Digital Sky Survey peculiar velocity catalogue

Cullan Howlett [1★] Khaled Said [1] John R. Lucey [2] Matthew Colless [3] Fei Qin,[4]
Yan Lai,[1] R. Brent Tully[5] and Tamara M. Davis [1]

[in prep.]

Bulk flow from 6dFGS, SDSS, and LAMOST all-sky peculiar velocities

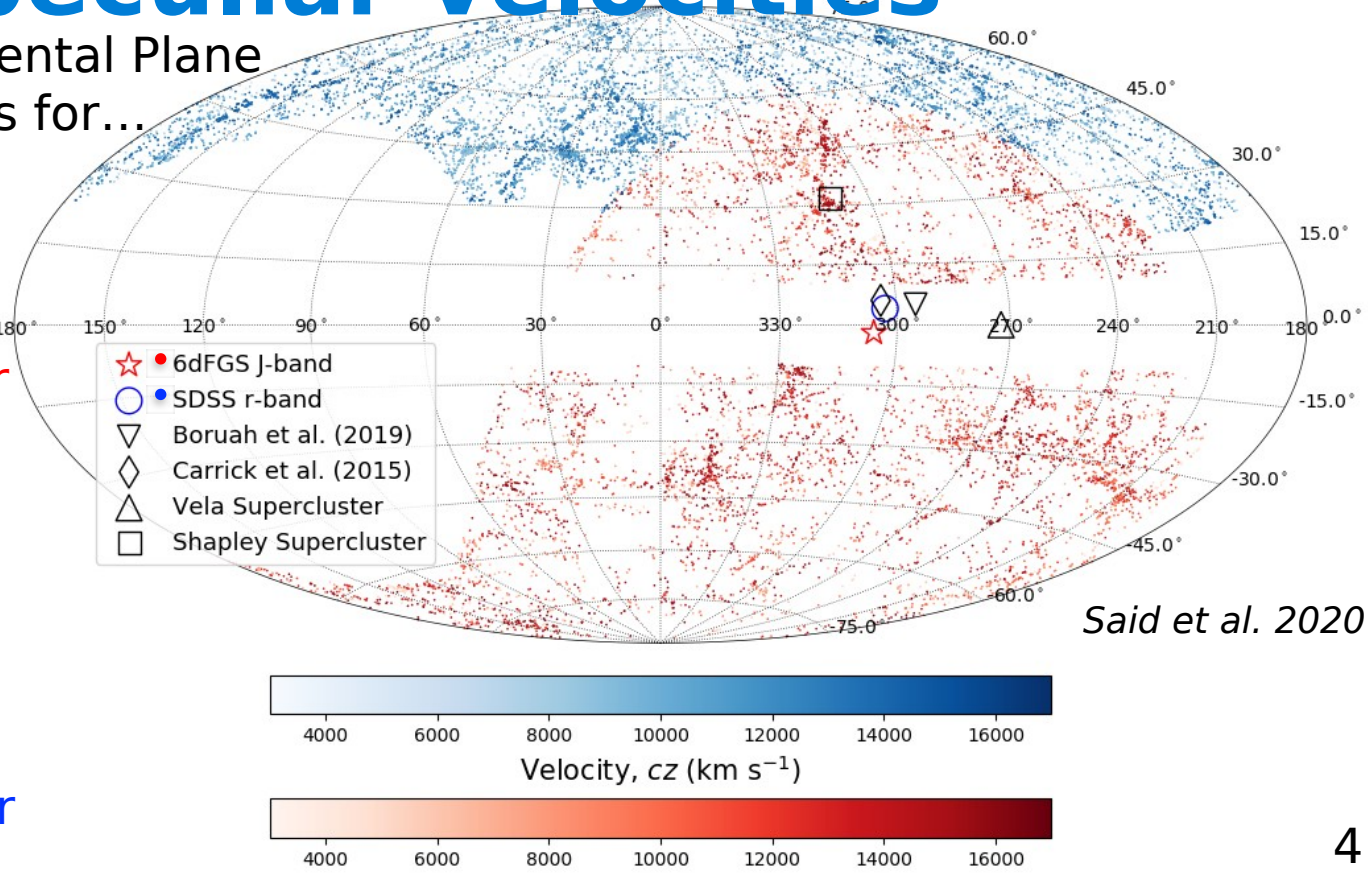
Rafif Rabbani[1★], Matthew Colless, Khaled Said, John R. Lucey, and Cullan Howlett

Combining 6dFGS & SDSS peculiar velocities

Measure Fundamental Plane peculiar velocities for…

6dFGS: 7030 galaxies with $z<0.055$ selected in the J band over ~17,000 deg² in the southern hemisphere

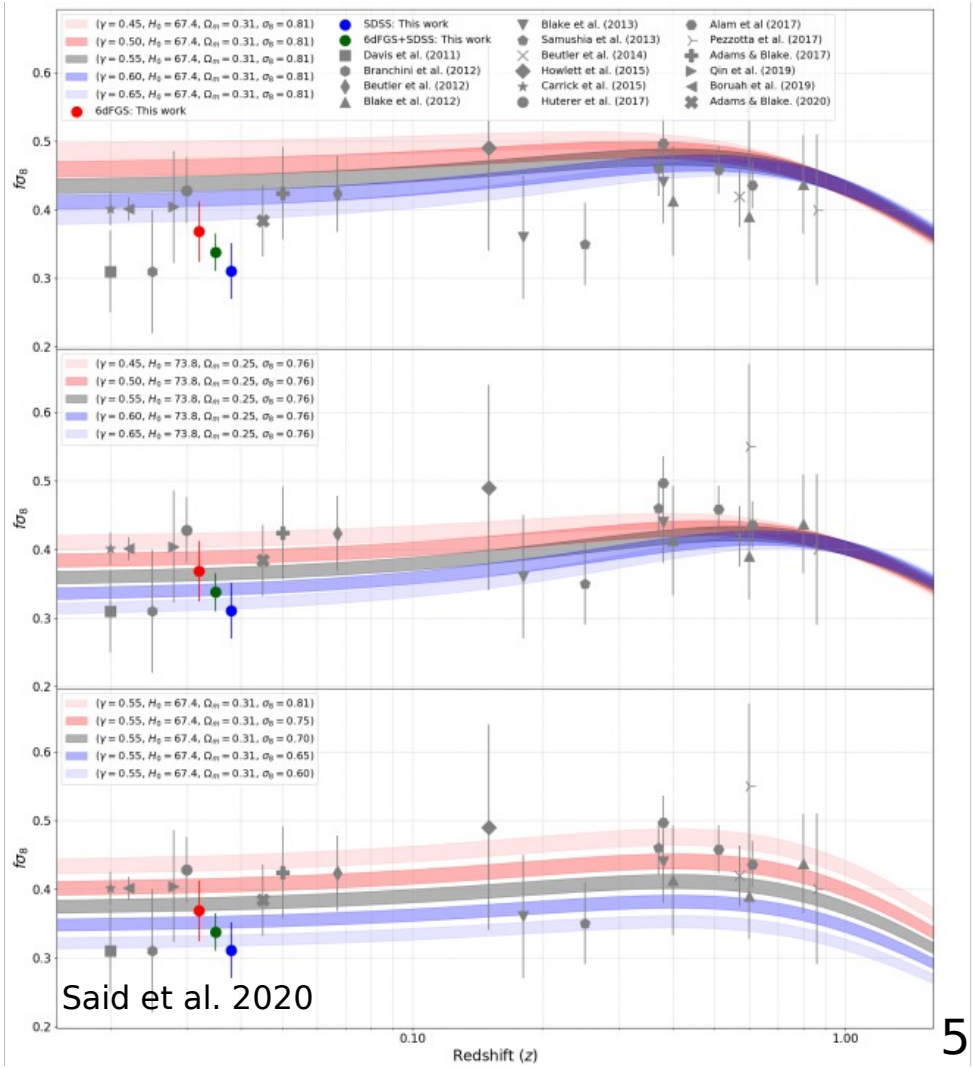
SDSS: 8864 galaxies with $z<0.055$ selected in the r band over ~10,000 deg² in



Said et al. 2020

Growth rate evolution

- Use peculiar velocities for ~16,000 galaxies from 6dFGS and SDSS to fit a model velocity field derived from the 2M++ redshift survey
- Recover $f\sigma_8$, the product of the growth rate and the RMS density fluctuation in 8 h^{-1} Mpc spheres
- Growth rate evolution depends on σ_8 , Ω_m , H_0 and γ (the growth index depending

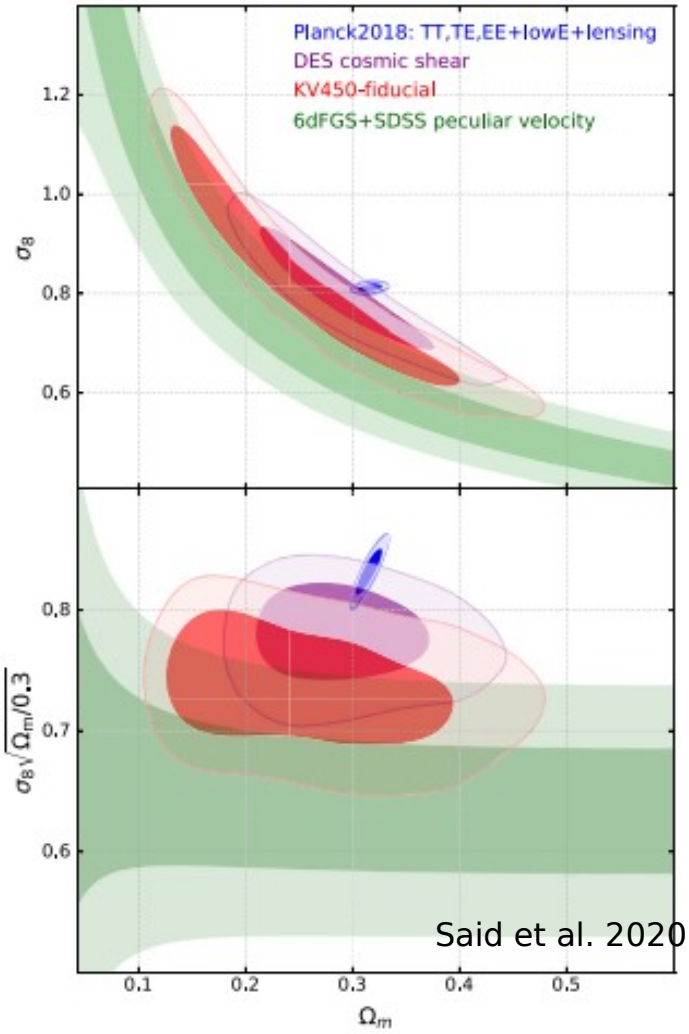


Ω_m & σ_8 constraints

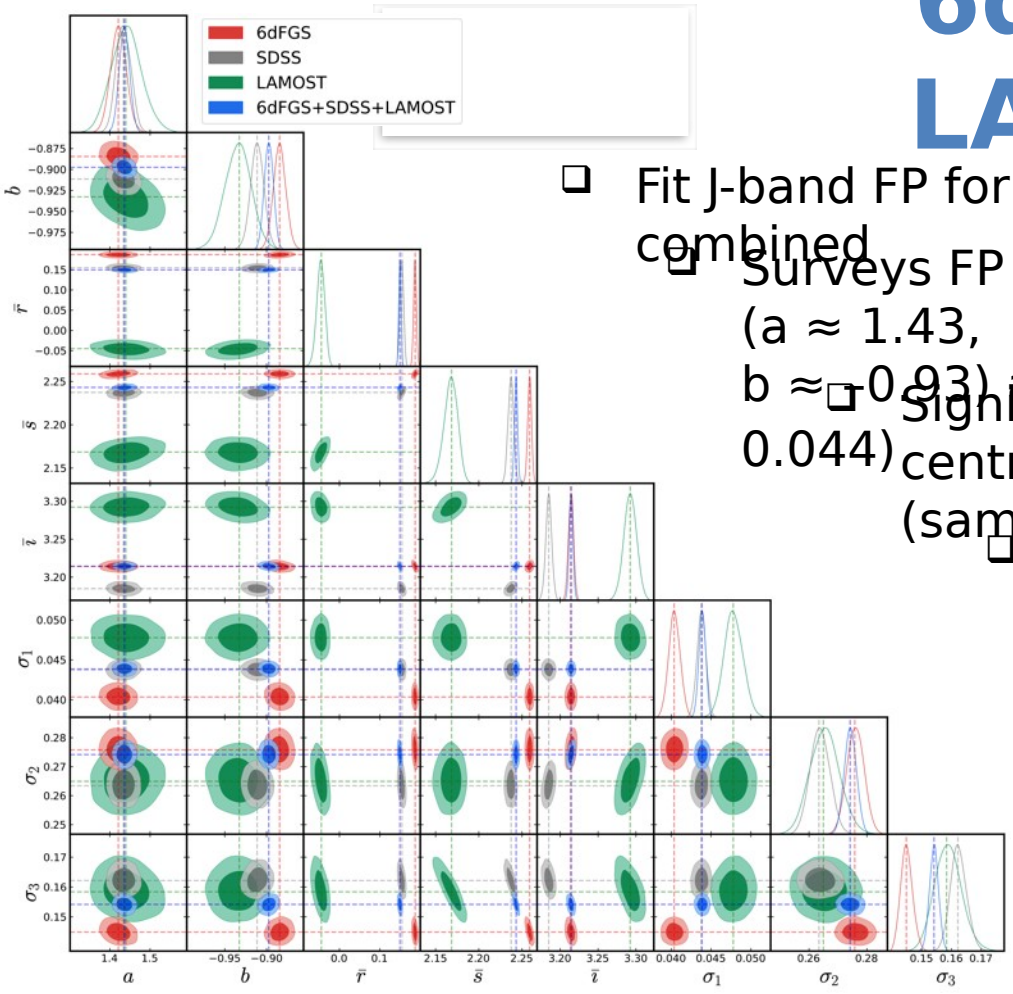
Fits to the 6dFGS+SDSS PVs prefer...

- fluctuation amplitude *or*
- Hubble constant km/s/Mpc *or*
- growth index *or*
- some combination of these

These results are consistent with other indicators of tension between high-*z* (i.e. CMB) and low-*z* measures of H_0 and σ_8



6dFGS, SDSS & LAMOST FP fits



- Fit J-band FP for surveys, both separately and combined
  - Surveys FP fits have very similar slopes (a ≈ 1.43, b ≈ −0.93) and intrinsic J scatters ($\tilde{\sigma}_1$ ≈ 0.044)
  - Significant variations in (r, s, i) centroids, esp. for LAMOST (sample selection?)
    - *Intrinsic* distance error ≈ 19%, so *total* distance error ≈ 24% if observational errors in velocity dispersions ≈ 10%
      - 'All-sky' sample of >20,000 galaxies with z<0.05 having uniformly-derived FP

Tully-Fisher peculiar velocities from Cosmicflows4 and the WALLABY survey

MNRAS **531,** 84–109 (2024)
Advance Access publication 2024 April 27
https://doi.org/10.1093/mnras/stae1122

Large-scale motions and growth rate from forward-modelling Tully–Fisher peculiar velocities

Paula Boubel,[1]★ Matthew Colless [1], Khaled Said [2] and Lister Staveley-Smith [3]

MNRAS **533,** 1550–1559 (2024)
Advance Access publication 2024 August 8
https://doi.org/10.1093/mnras/stae1925

An improved Tully–Fisher estimate of H_0

Paula Boubel,[1]★ Matthew Colless [1], Khaled Said [2] and Lister Staveley-Smith [3]

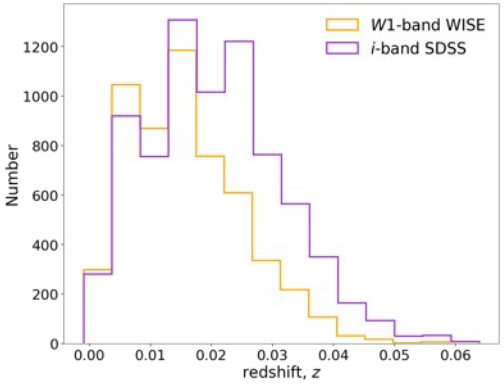
[in prep.]

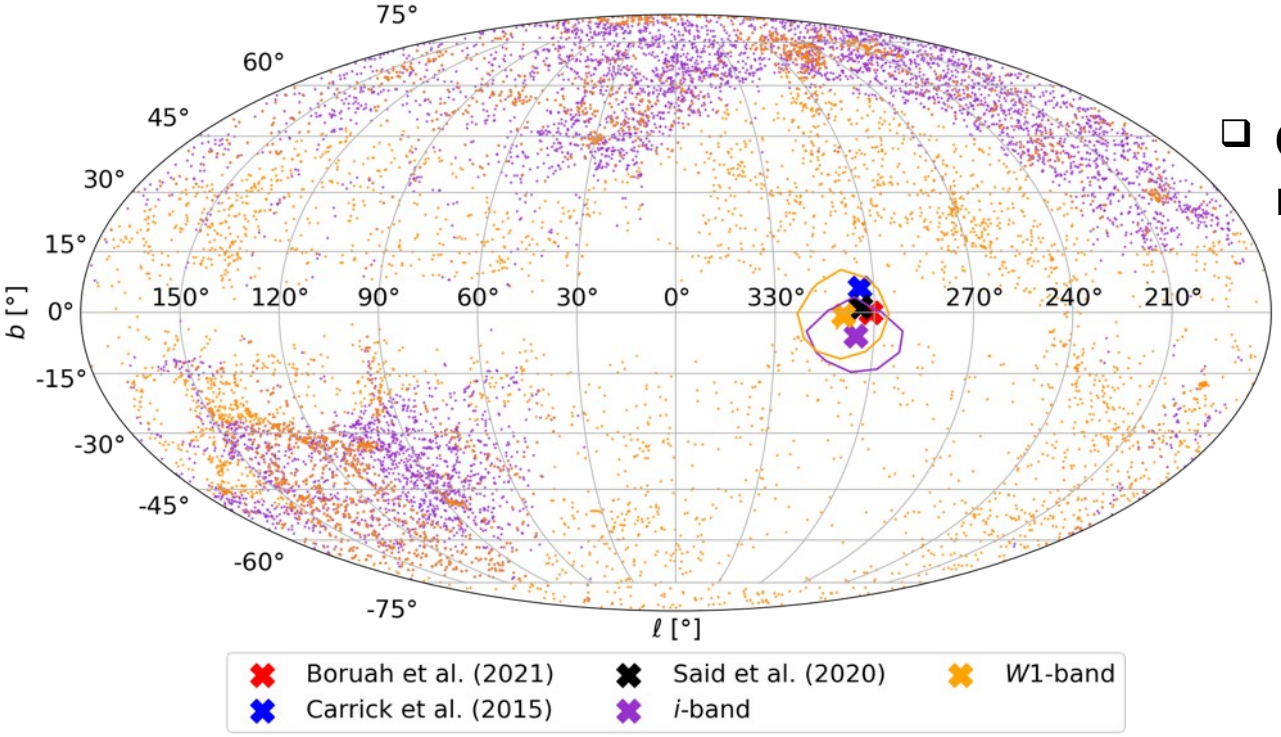
Direction-dependent H_0 from the Tully-Fisher relation

Paula Boubel[1]★, Matthew Colless[1], Khaled Said[2] and Lister Staveley-Smith[3]

CF4 Tully-Fisher peculiar velocities

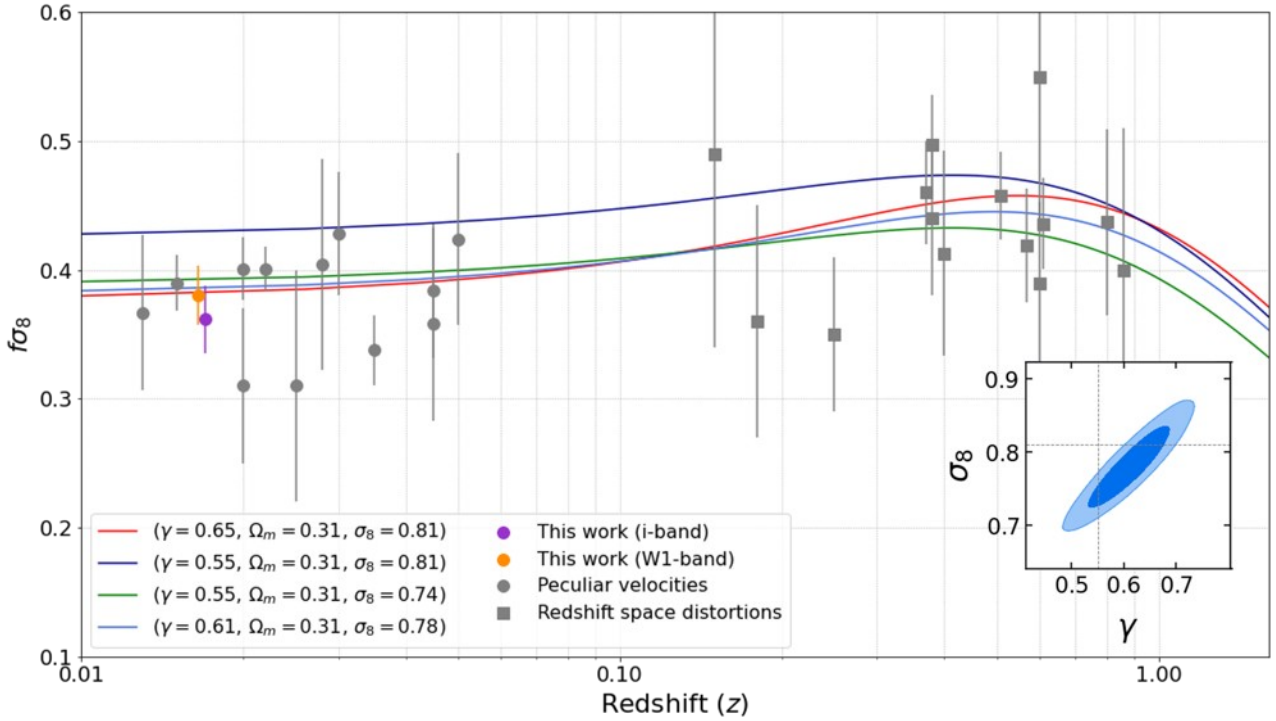
- Re-analysing the ALFALFA HI Tully-Fisher data from the Cosmicflows-4 data collation





- CF4 uses a two-step method:
  1. calibrate TFR on clusters
  2. derive PVs for all galaxies
- New one-step method: fit the TFR and PVs simultaneously, using a velocity field model derived from

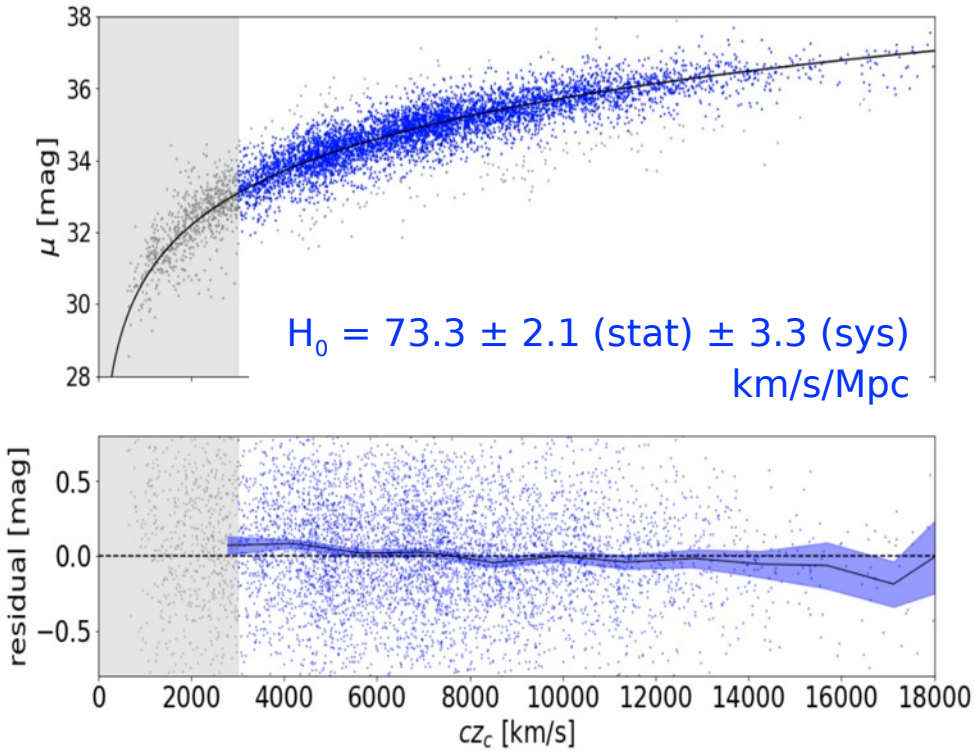
Growth rate measurements



$z_{\rm eff}$	$f\sigma_8$	Reference
0.013	0.367±0.06	Lilow & Nusser (2021)
0.015	0.39±0.022	Stahl et al. (2021)
0.017	0.39±0.02	This work
0.017	0.37±0.03	This work
0.02	0.31±0.06	Davis et al. (2011)
0.02	0.401±0.024	Carrick et al. (2015)
0.022	0.401±0.017	Boruah et al. (2021)
0.025	0.31±0.09	Branchini et al. (2012)
0.028	0.404±0.082	Qin et al. (2019)
0.03	0.428±0.048	Huterer et al. (2017)
0.035	0.338±0.027	Said et al. (2020)
0.045	0.384±0.052	Adams & Blake (2020)
0.045	0.358±0.075	Turner et al. (2023)
0.05	0.424±0.067	Adams & Blake (2017)
0.067	0.423±0.055	Beutler et al. (2012)
0.15	0.49±0.15	Howlett et al. (2016)
0.18	0.36±0.09	Blake et al. (2013)
0.25	0.35±0.06	Samushia et al. (2012)
0.37	0.46±0.04	Samushia et al. (2012)
0.38	0.497±0.039	Alam et al. (2017)
0.4	0.413±0.08	Blake et al. (2012)
0.51	0.458±0.035	Alam et al. (2017)
0.57	0.419±0.044	Beutler et al. (2014)
0.6	0.55±0.12	Pezzotta et al. (2017)
0.61	0.436±0.034	Alam et al. (2017)
0.8	0.437±0.072	Blake et al. (2012)
0.86	0.4±0.11	Pezzotta et al. (2017)

Improved Tully-Fisher H_0 estimate

- We fit a peculiar velocity model jointly with the TF relation and calibrate using galaxies with absolute distance estimates to obtain
  a fully self-consistent H_0 estimate
- *For Cosmicflows-4, the uncertainties from fitting the TF relation are only 0.2 km/s/Mpc*
- Available absolute distance calibrators yield $H_0 = 73.3 \pm 2.1$ (stat) $\pm$ 3.5 (sys) km/s/Mpc
- The *statistical* uncertainty is dominated by the small number of absolute distance estimates
- The large *systematic* uncertainty is due to inconsistencies in the various



WALLABY and 4HS *z*+*v* surveys



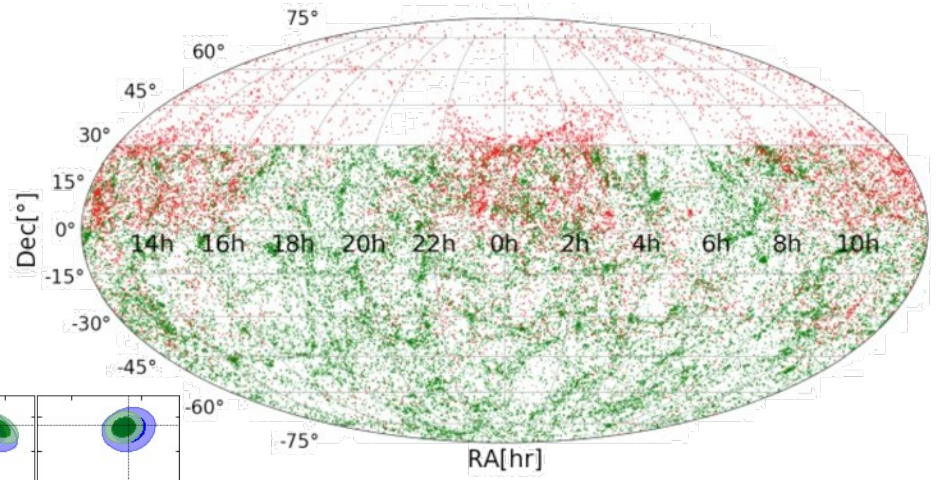
Australian SKA Pathfinder(ASKAP) radio array at Murchison Observatory

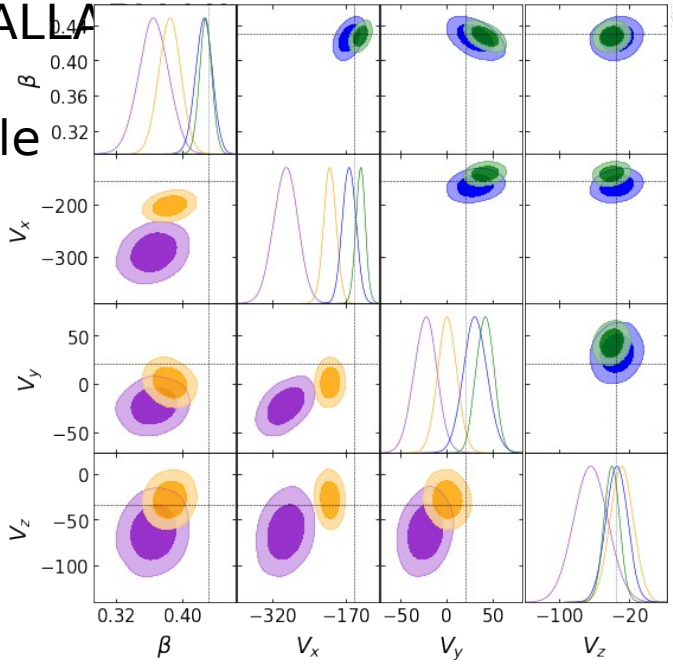


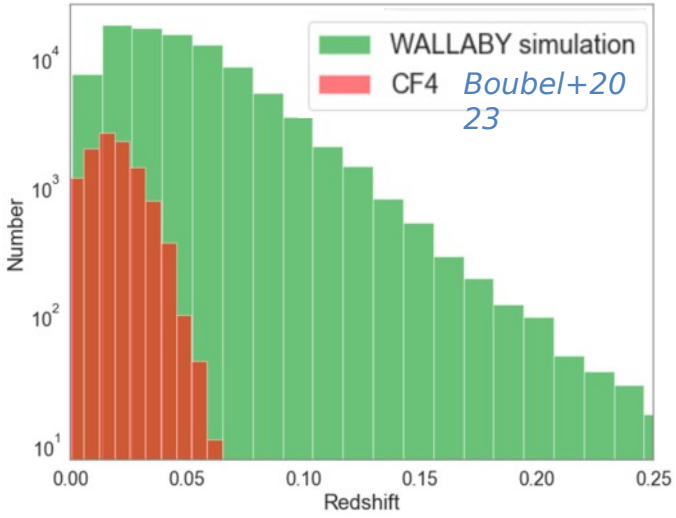
VISTA 4-metre telescope at Paranal Observatory with 4MOST

WALLABY *z+v*-survey

- WALLABY will measure HI Tully-Fisher peculiar velocities for ~50,000 galaxies (i.e. ~10% of WALLABY detections will have suitable inclinations and sufficient S/N)
- Comparison with Cosmicflows-4 PVs shows precision gains from the ~10x greater size size of

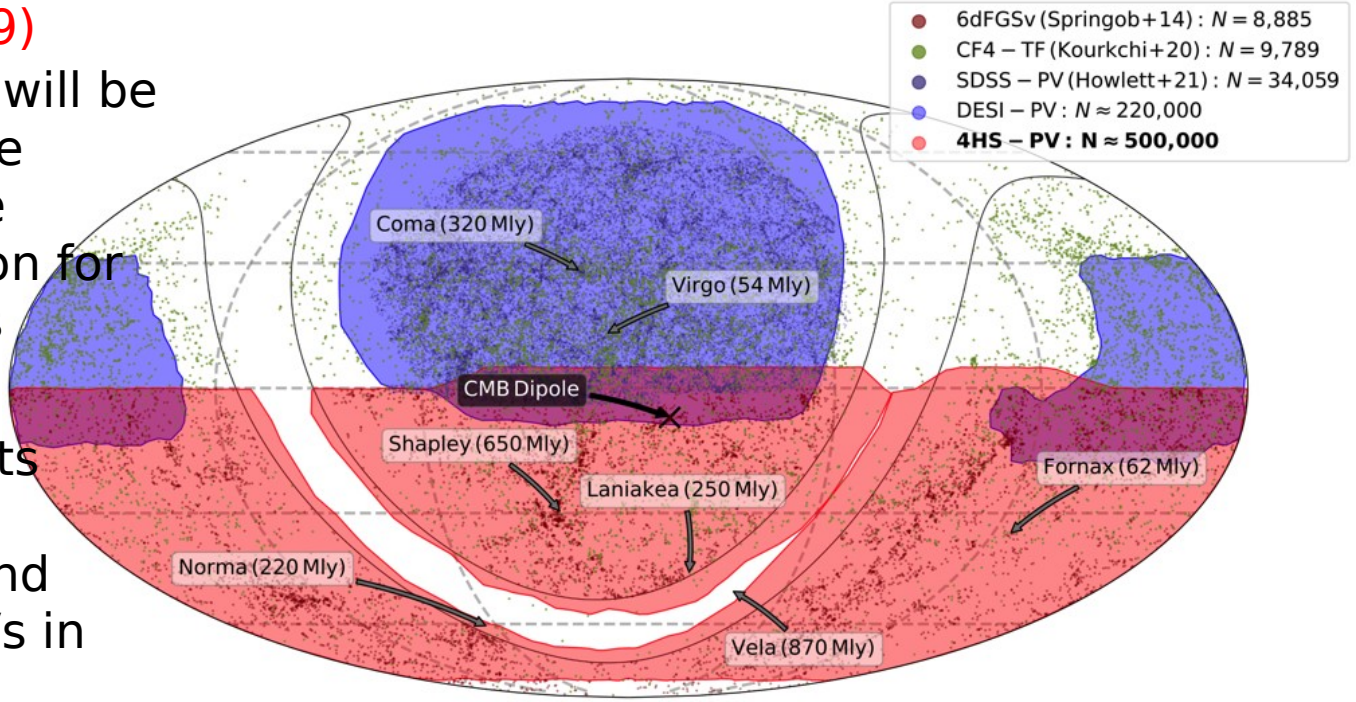




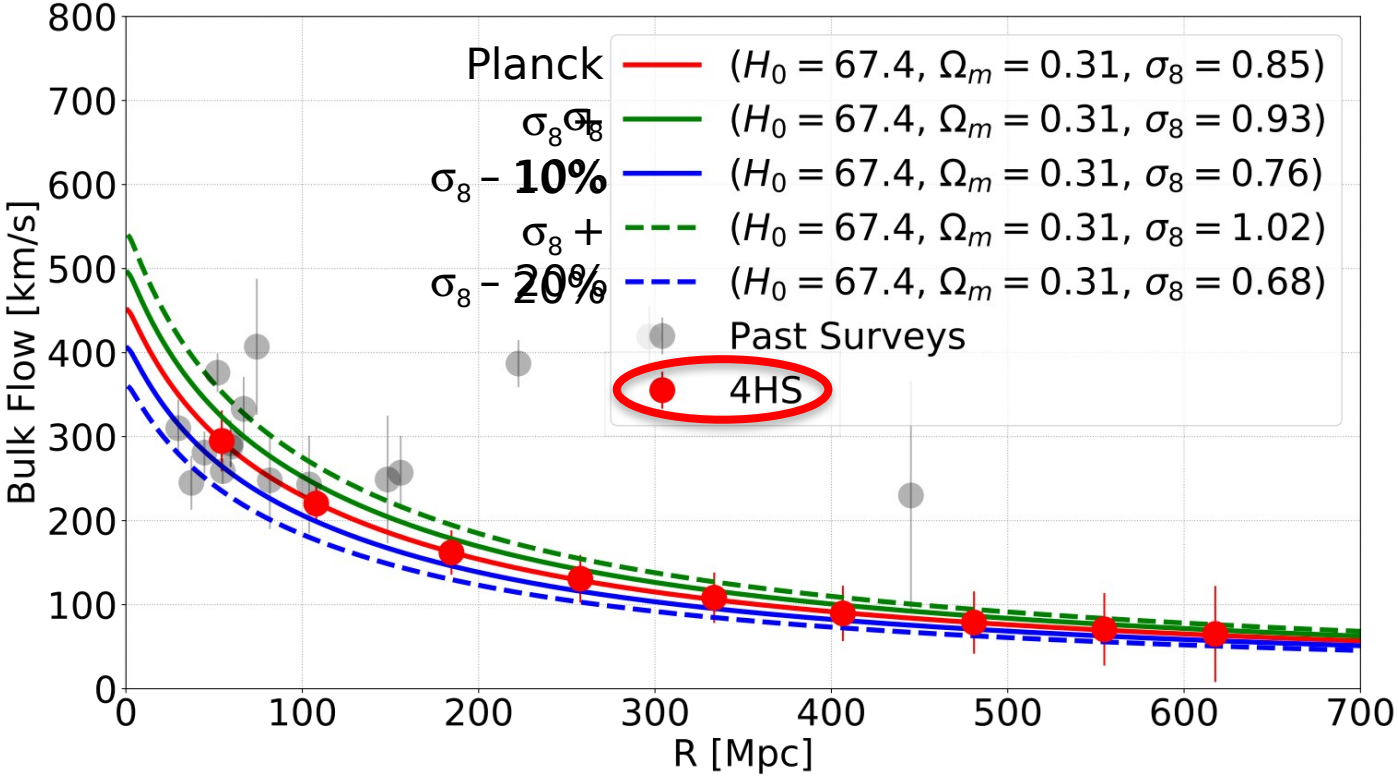


4HS-PV: the 4HS peculiar velocity survey

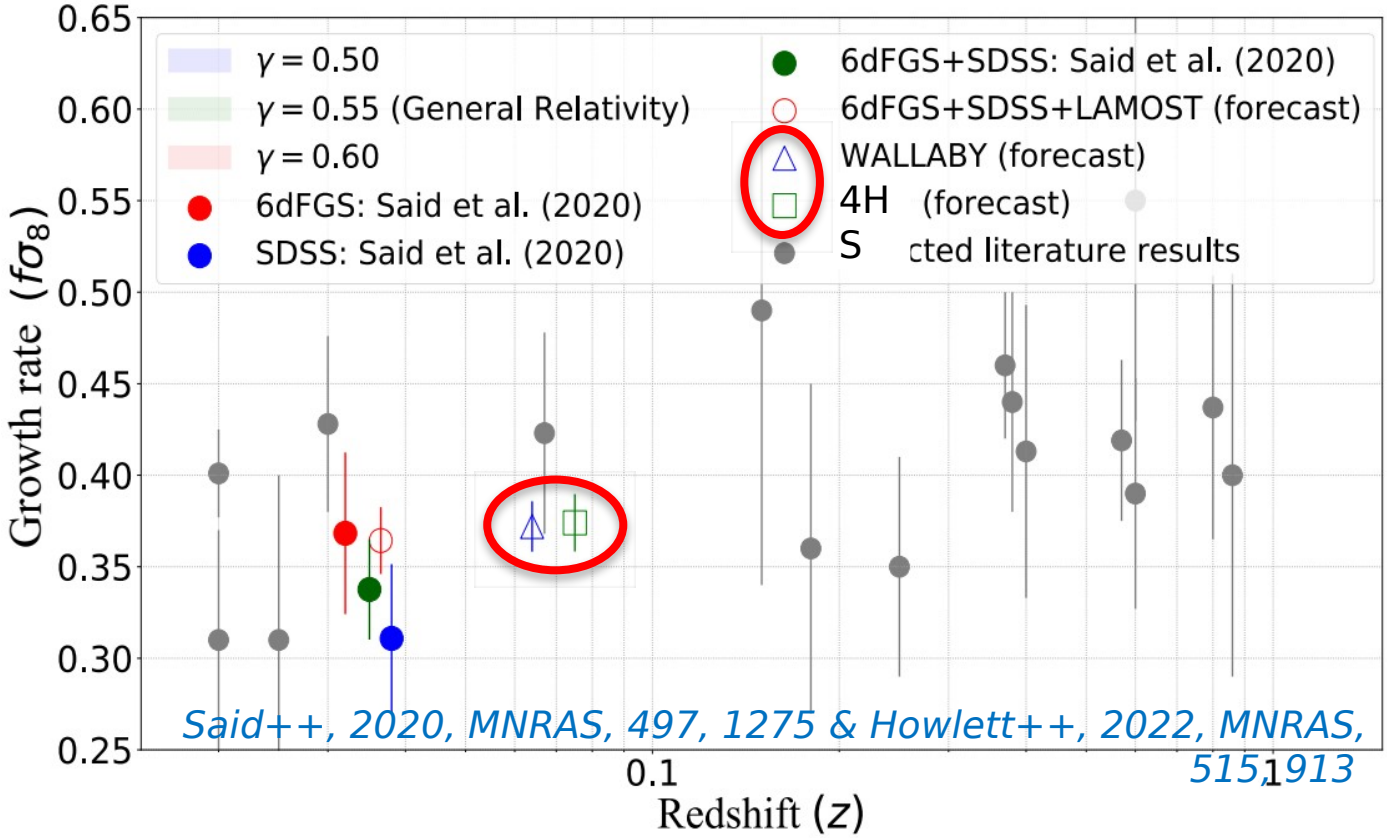
- 4MOST Hemisphere Survey (4HS-PV) will measure peculiar velocities for ~500,000 galaxies at z<0.12 over 20,000 deg^2 in the south over 5 years (2024-2029)
- Distances and PVs will be measured using the Fundamental Plane with ~25% precision for early-type galaxies
- 4HS-PV (FP PVs in south) complements DESI-BGS/DESI-PV (FP PVs in north) and WALLABY (HI-TF PVs in south)



Bulk flows as a function of scale



Growth rate from WALLABY + 4HS



Said++, 2020, MNRAS, 497, 1275 & Howlett++, 2022, MNRAS, 515, 1913

Forecast constraints on growth rate

- WALLABY (HI TF survey) and 4HS-PV (optical FP survey) will measure >500,000 peculiar velocities in the nearby sc
- Peculiar velocities are very subject to systematic errors, so *independent* measurements using *different* methods on *disjoint* samples in the *same* volume provide critical checks on the reliability of the derived velocity field
- Combining peculiar velocities with redshift-space distortions, the DESI, WALLABY and 4HS surveys will provide 5-10% precision on the growth rate ($f\sigma_8$) in four Δz=0.05 bins to z=0.2

