Cosmic flows and Hubble constant with GW and Megamasers

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Action Dark Energy, Théorie, Octobre 2020

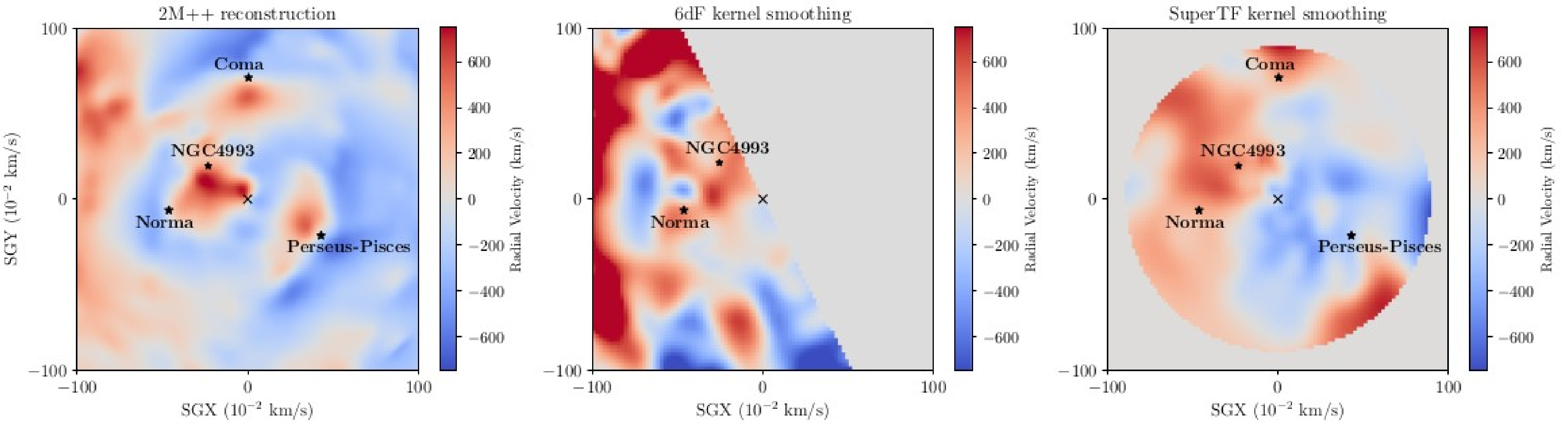
Aquila consortium (https://aquila-consortium.org)

Some velocity reconstruction techniques

- Derive from tracer density (luminosity or mass)
  - 2M++ linear (Carrick et al. 2015, S. Boruah et al. 2020)
  - BORG-PM (Jasche & Lavaux 2019, Mukherjee et al. 2020)

- Interpolate from velocity derived from distance data
  - 6dF (Springob et al. 2014, Nicolau et al. 2020)
  - Simplified idea of POTENT method of 1990s

Velocity field in the Supergalactic plane



Derive vs interpolate

$$\vec{v}(\vec{r}) = \frac{H_0 f}{b} \vec{\nabla} \Delta^{-1} \delta_{\mathrm{g}}$$

$$v_r(\vec{r}) = \vec{v}(\vec{r}) \cdot \hat{r}$$

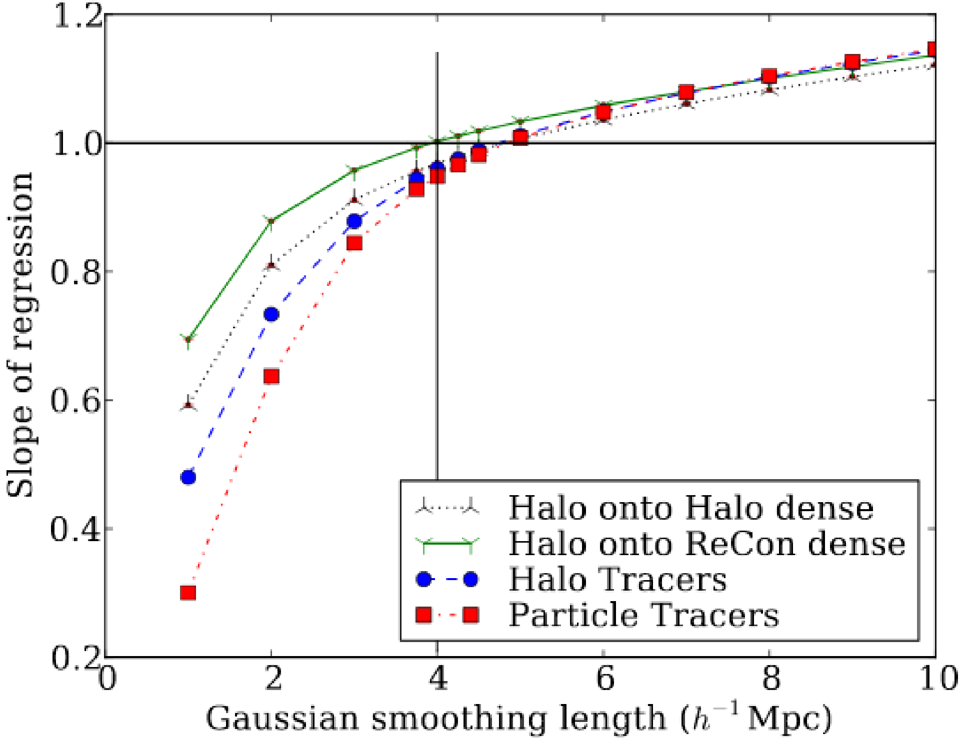
Estimated from 2M++

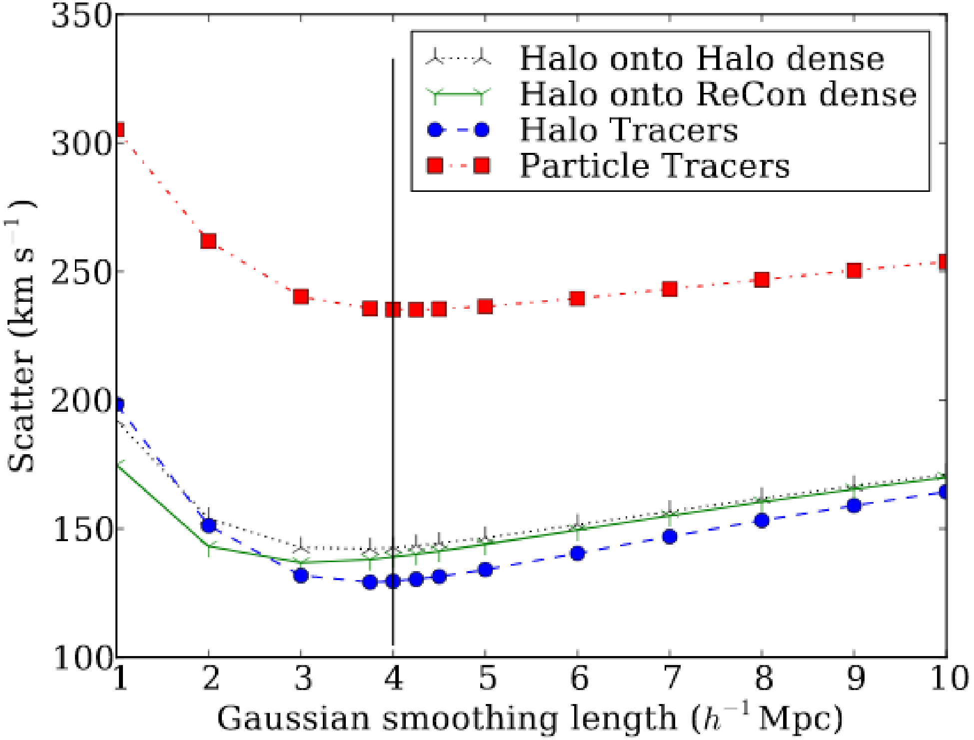
$$v_r(\vec{r}) \propto \sum_{g \in \mathrm{gal}} v_r^{\mathrm{tracer}}(\vec{y}_i) \cos\theta_i \mathrm{e}^{-\Delta r_i^2/(2\sigma_i^2)} \sigma_i^{-3}$$

$$\Delta r_i = |\vec{r} - \vec{y}_i| \qquad \cos\theta_i = \vec{r}.\vec{y}_i/|\vec{r}||\vec{y}_i|$$

Estimated from 6dF & SuperTF distances

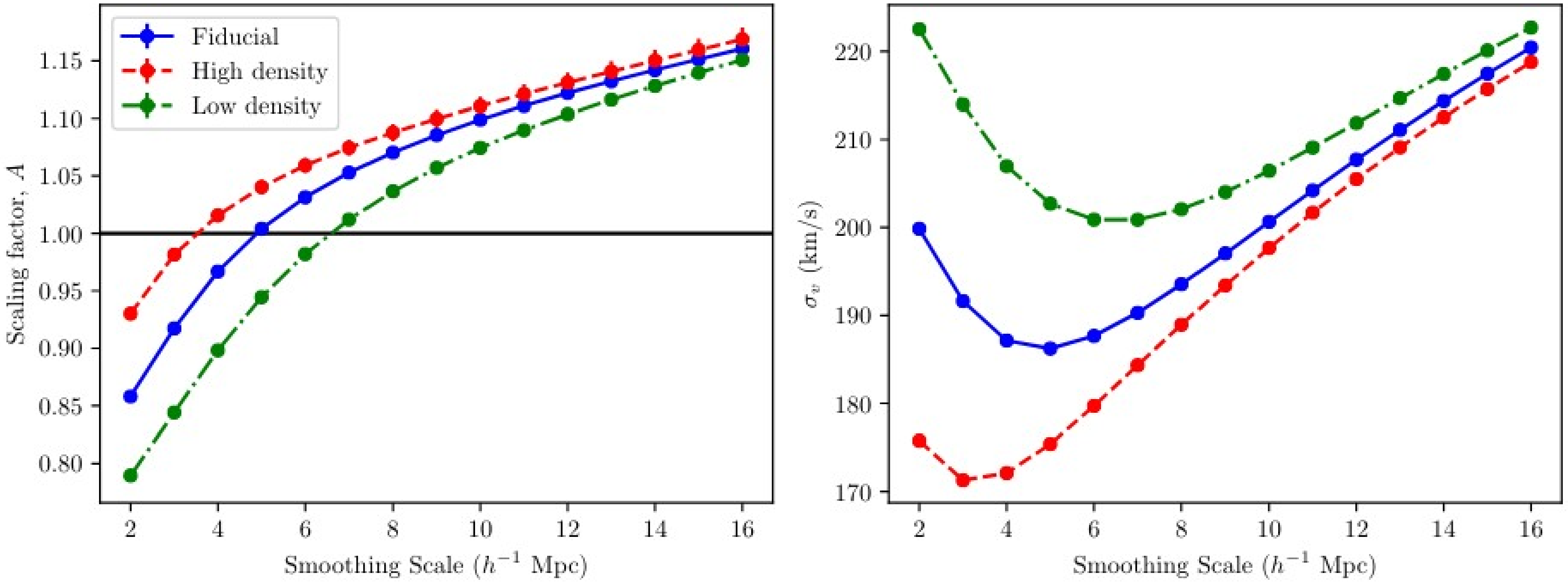
Optimal smoothing / corrections: 2M++





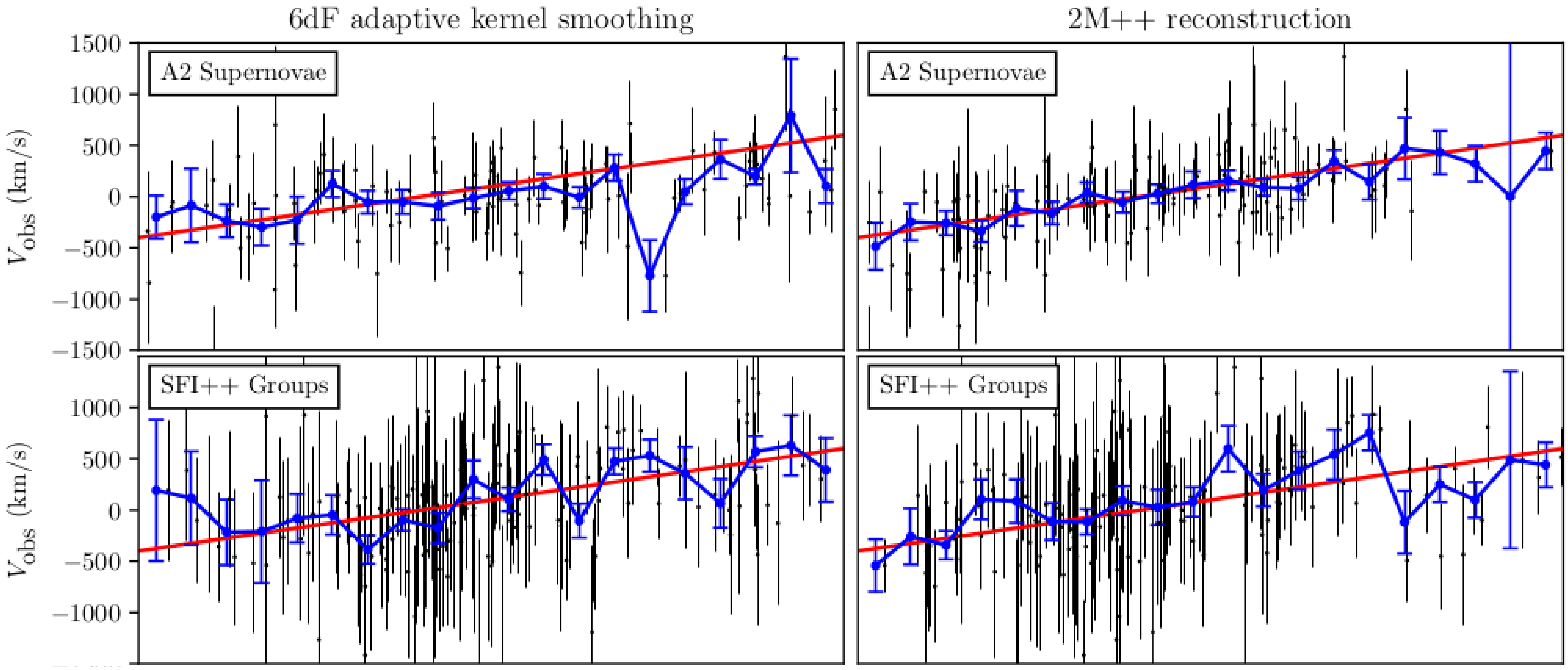
Test on VELMASS halo mock catalog

Optimal smoothing / corrections: 6dFv/TF



Test on VELMASS halo mock catalog

Direct, visual, comparison



Bayesian evidence for respective V models

Evidence for 2M++ velocity field w.r.t interpolated velocities (>0 => favor 2M++)

Test set	Redshift selection	$\ln\left(\frac{\mathcal{P}_{2M++}}{\mathcal{P}_{6dF}}\right)$	$\ln\left(\frac{\mathcal{P}_{2M++}}{\mathcal{P}^{\rm scaled}_{6dF}}\right)$	$\ln\left(\frac{\mathcal{P}_{2M++}}{\mathcal{P}_{\rm SuperTF}}\right)$	$\ln\left(\frac{\mathcal{P}_{2M++}}{\mathcal{P}^{\rm scaled}_{\rm SuperTF}}\right)$	$N_{\rm tracers}$
A2-South	$cz < 3000$ km/s	2.21	2.70	2.41	2.88	16
	$cz < 4500$ km/s	2.33	3.86	5.07	5.89	32
	$cz < 6000$ km/s	5.21	6.05	8.85	10.21	53
	$cz < 9000$ km/s	9.19	10.58	15.56	17.80	79
A2-low-z	$cz < 3000$ km/s	—	—	11.38	11.95	49
	$cz < 4500$ km/s	—	—	20.76	21.89	92
	$cz < 6000$ km/s	—	—	49.82	52.86	168
	$cz < 9000$ km/s	—	—	85.92	92.90	310
2MTF	$cz < 3000$ km/s	24.6	24.4	—	—	108
	$cz < 4500$ km/s	39.00	36.28	—	—	247
	$cz < 6000$ km/s	55.65	53.06	—	—	379
	$cz < 9000$ km/s	69.49	69.01	—	—	483
SFI++ Groups	$cz < 3000$ km/s	12.08	11.88	—	—	61
	$cz < 4500$ km/s	9.35	9.29	—	—	100
	$cz < 6000$ km/s	18.89	17.87	—	—	165
	$cz < 9000$ km/s	18.78	17.78	—	—	170
SFI++ Field	$cz < 3000$ km/s	9.94	9.01	—	—	63
	$cz < 4500$ km/s	5.72	5.24	—	—	153
	$cz < 6000$ km/s	13.52	11.70	—	—	388
	$cz < 9000$ km/s	53.66	44.29	—	—	736

Bayesian evidence for respective V models

Test data set !=
Tracer dataset

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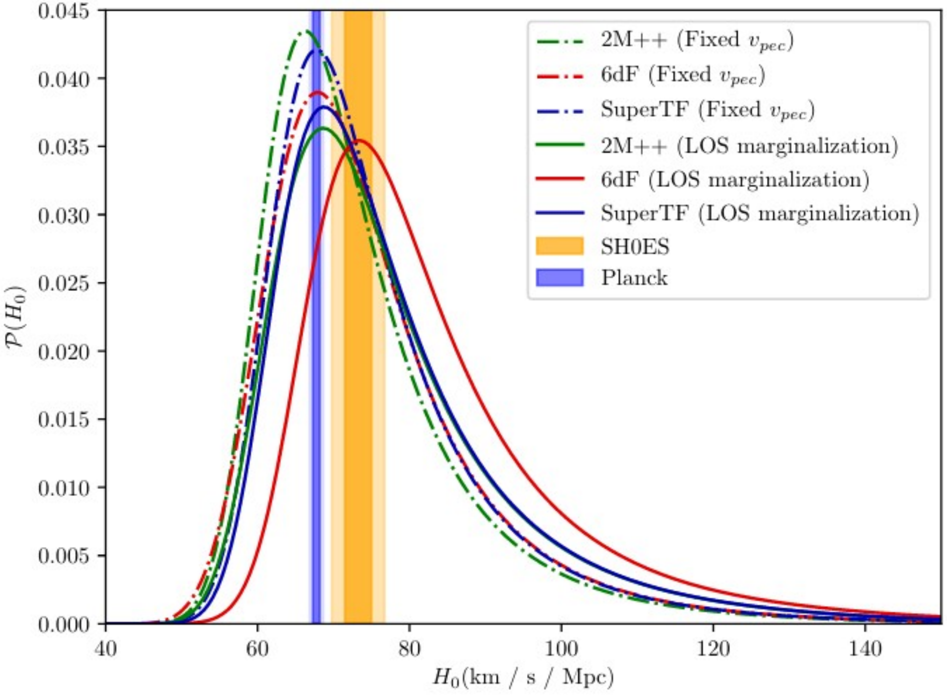
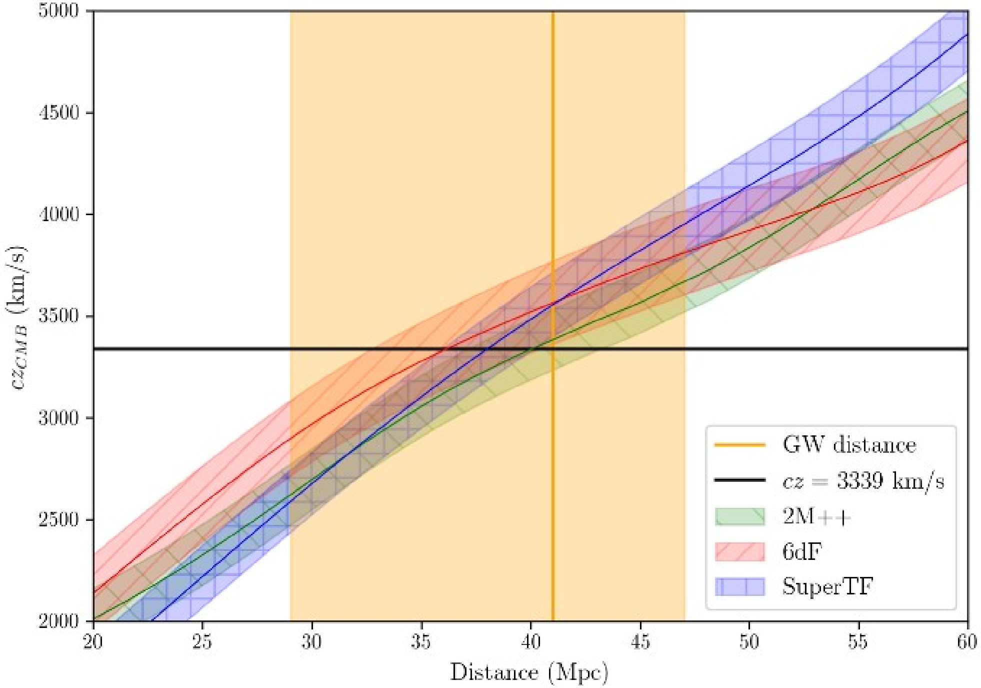
Application to H_0 for GW@NGC 4993

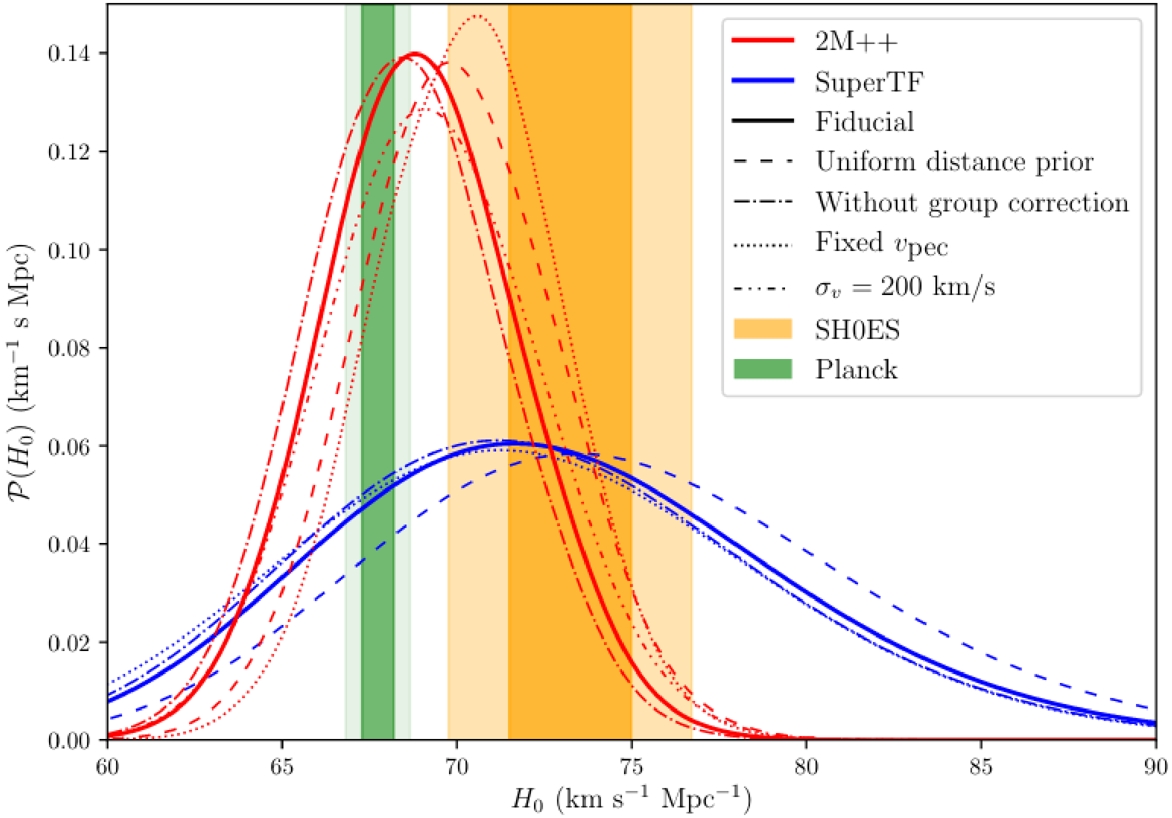




Hubble measurement

Velocity along the Line of sight

Application H_0 with Megamasers



Important differences:
- Marginalized likelihood
- Volumetric prior
- Group corrected redshift
- Check on two σ_v

Impact of each ~0.5 to 1 km/s/Mpc

Summary

- 2M++ reconstructed velocity field much better than adaptive interpolation
- Interpolation has to include multiplicative correction as well
- Hubble constant in better agreement **with** distance marginalization
- Check your **distance prior** of course.