The 6dFGS Peculiar Velocity Field, Part 2

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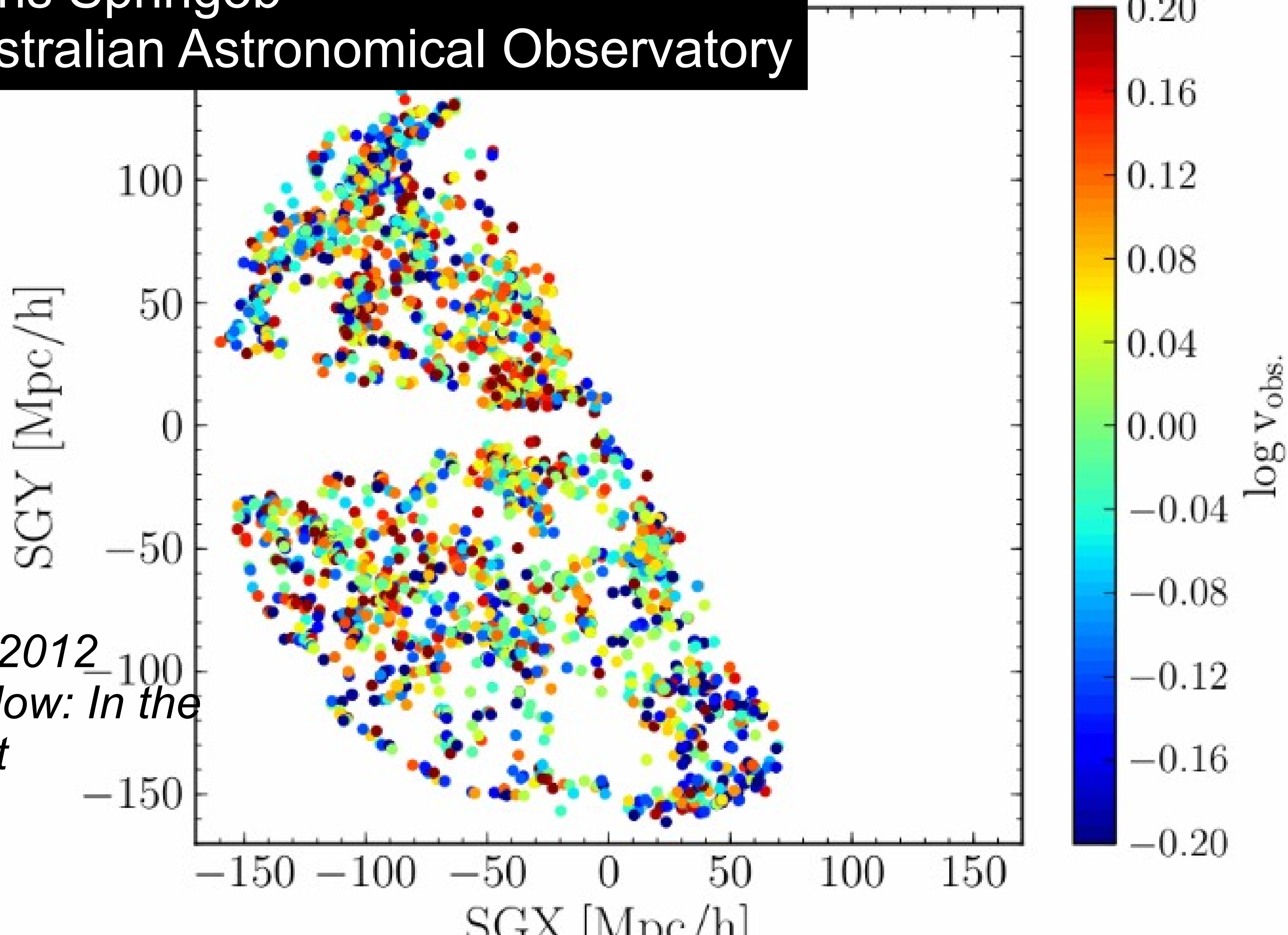


February 2012
Cosmic Flow: In the Rainforest

Bayesian Method for deriving peculiar velocities

- Within the Bayesian framework, we have two choices:

1) Compute a Bayesian probability distribution for the peculiar velocities for each individual galaxy, then analyze these derived velocity probability distributions

2) Do a Bayesian analysis of the observational dataset as a whole, without computing individual peculiar velocities.

1) Bayesian probability distribution for deriving peculiar velocities of individual galaxies

We use a Bayesian approach to measure peculiar velocity probability distributions rather than a single peculiar velocity measurement with error bar.

That is, we want to calculate the posterior probability that a galaxy has peculiar velocity, v_i, given observable data from Bayes Theorem:

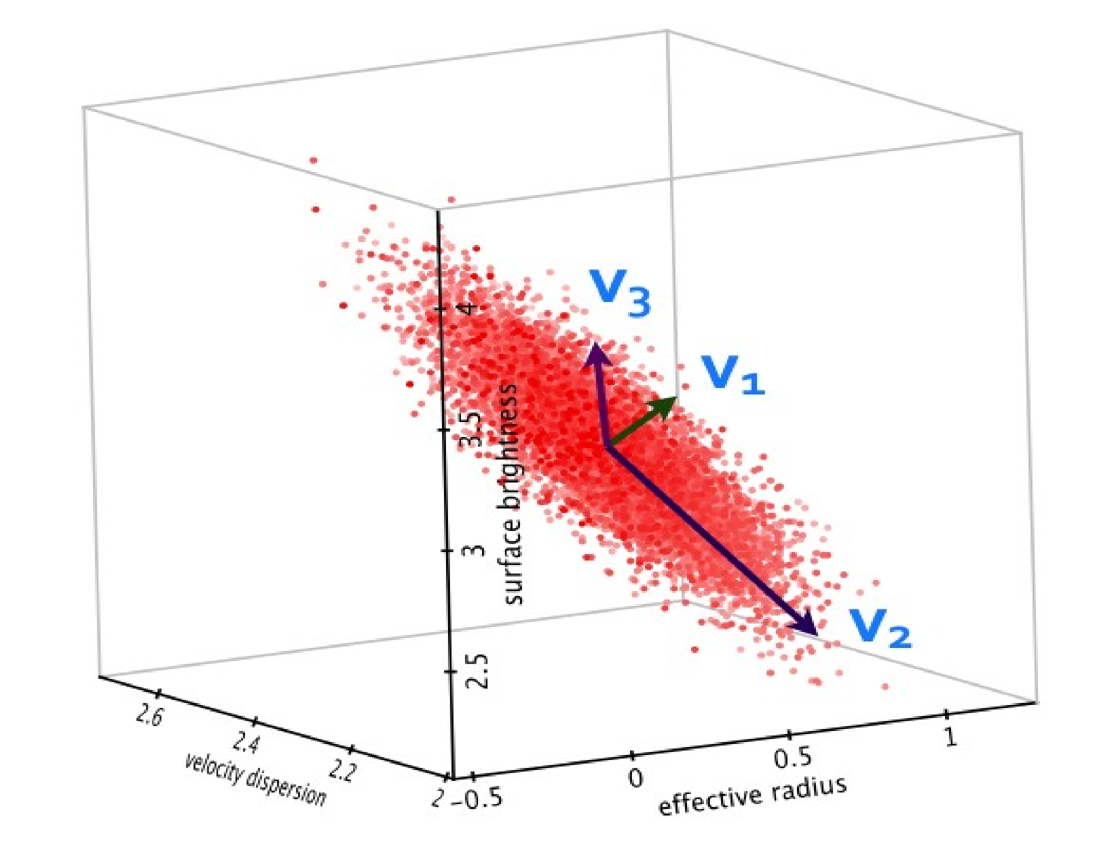
Likelihood of observing galaxy with v_i

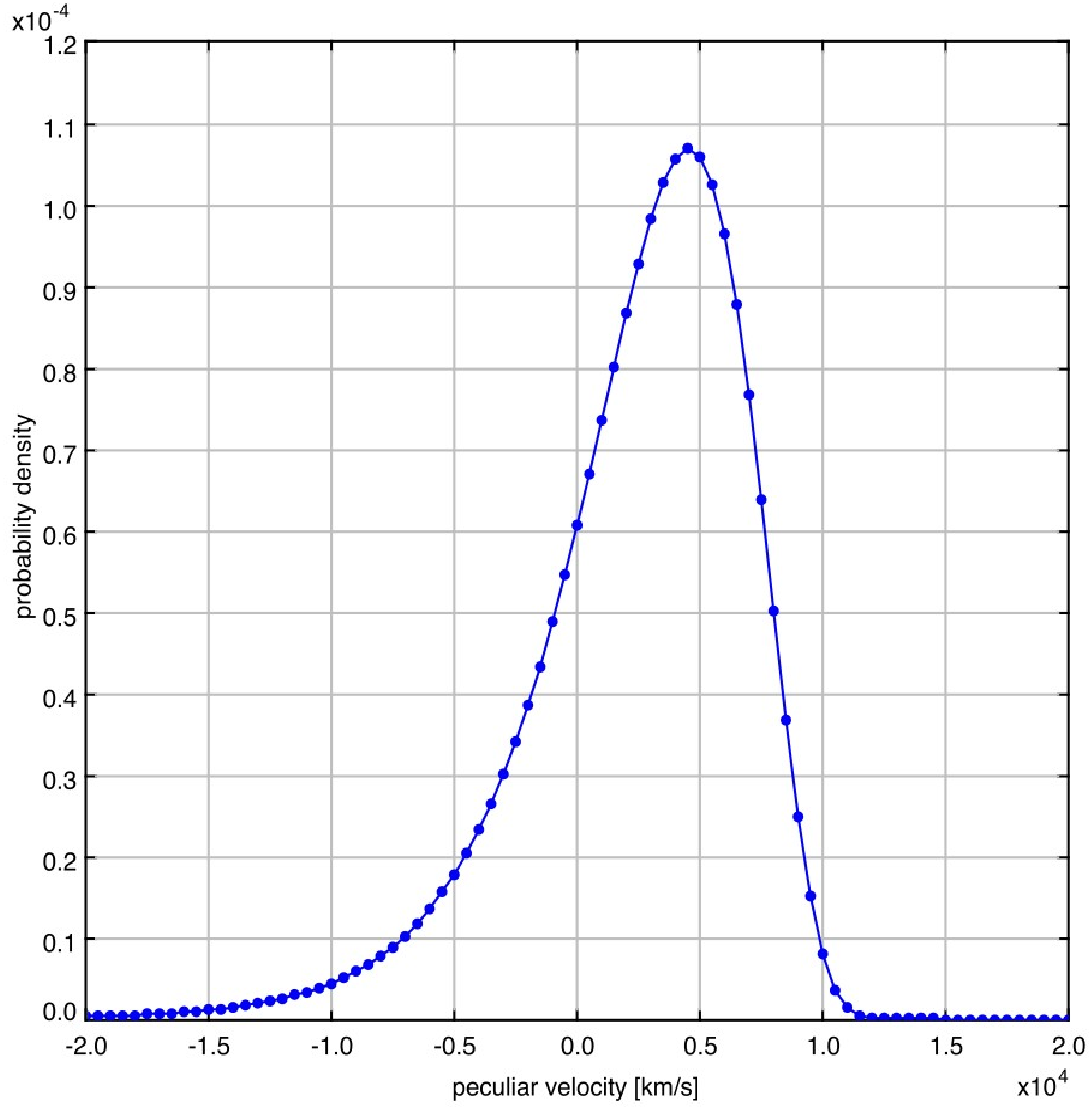
$$P(v_i|r_{ang}, s, i, z) = \frac{P(r_{ang}, s, i, z|v_i)P(v_i)}{P(r_{ang}, s, i, z)}$$

Prior - uniform? Gaussian?

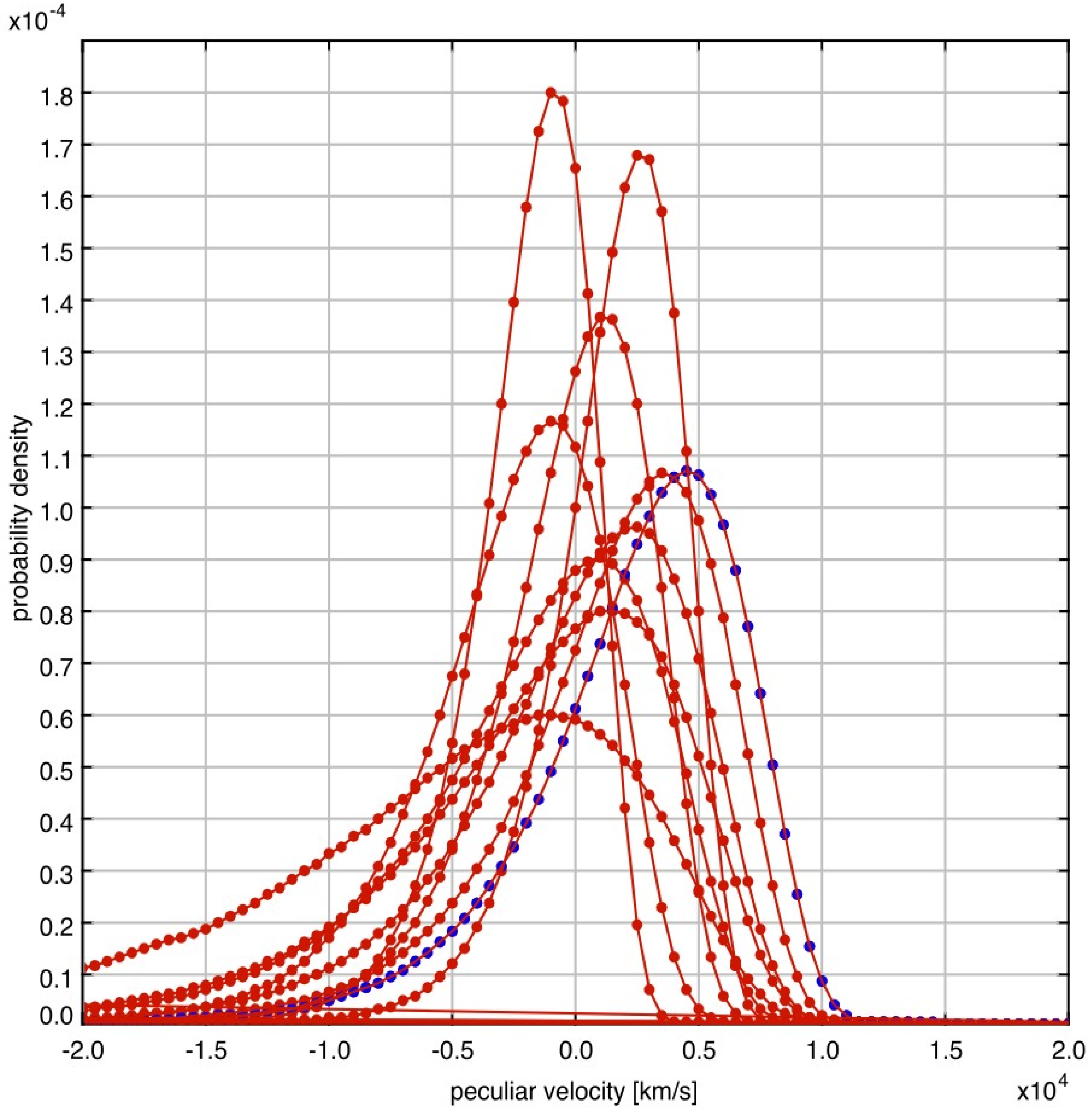
How do we do this?

- Specify FP template relation - 3D Gaussian FP model
- For each galaxy, loop through all possible co-moving distances
- At each distance, calculate the likelihood of the galaxy being at that distance, given its presumed position in FP space
- Multiply that likelihood by the prior and normalize to calculate the posterior probability of possible distances/peculiar velocities for each galaxy
- Apply appropriate weighting to account for galaxies that are too faint to be observed in our sample





Right: The peculiar velocity probability distribution for a typical galaxy, in linear units.



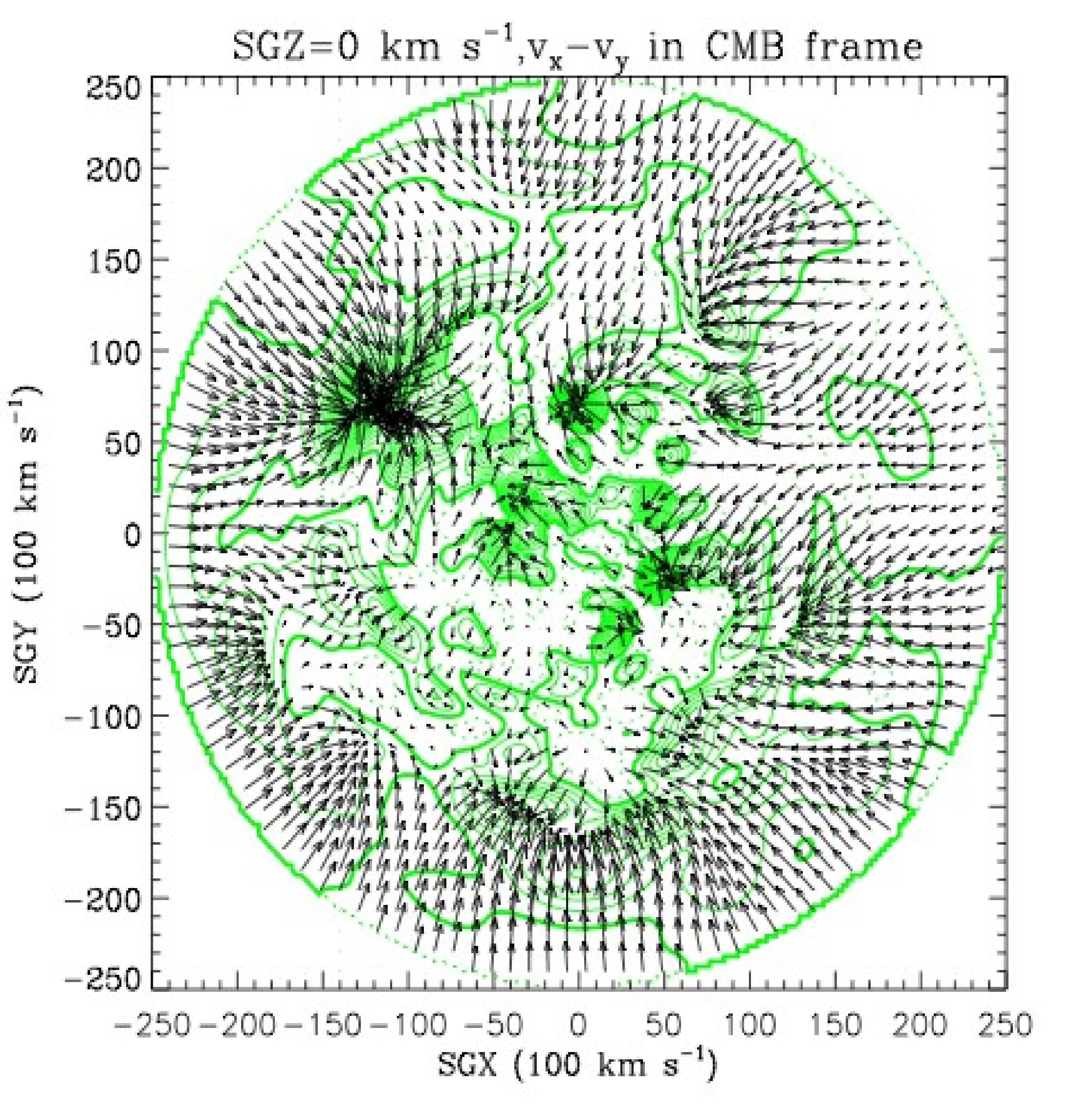
Right: The peculiar velocity probability distribution for 10 typical galaxies, in linear units.

The 2MRS velocity field

As described by Erdogdu et al. (2006), take the 2MRS redshift space distribution of galaxies, and reconstruct the predicted peculiar velocity field, assuming galaxy distribution traces matter distribution, and

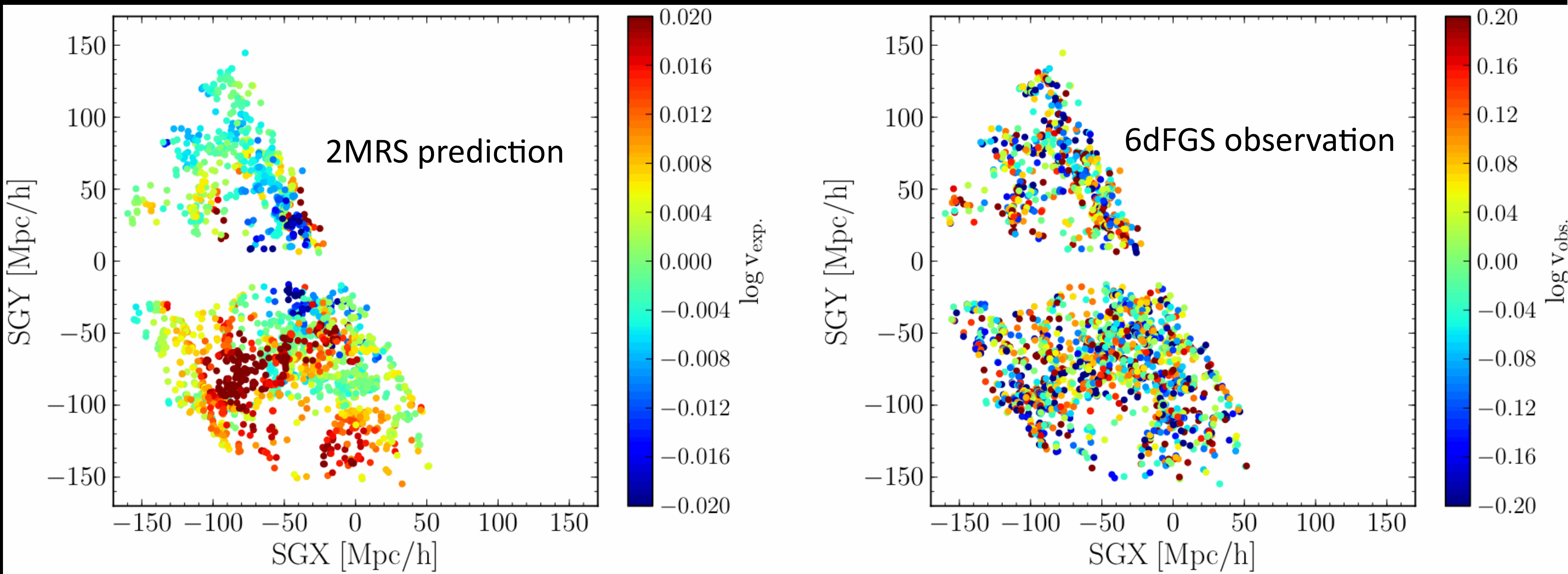
$$b=\delta_{gal}/\delta_{mass}$$

Right: The reconstructed peculiar velocity field for 2MRS (11.75 mag. limit sample.).



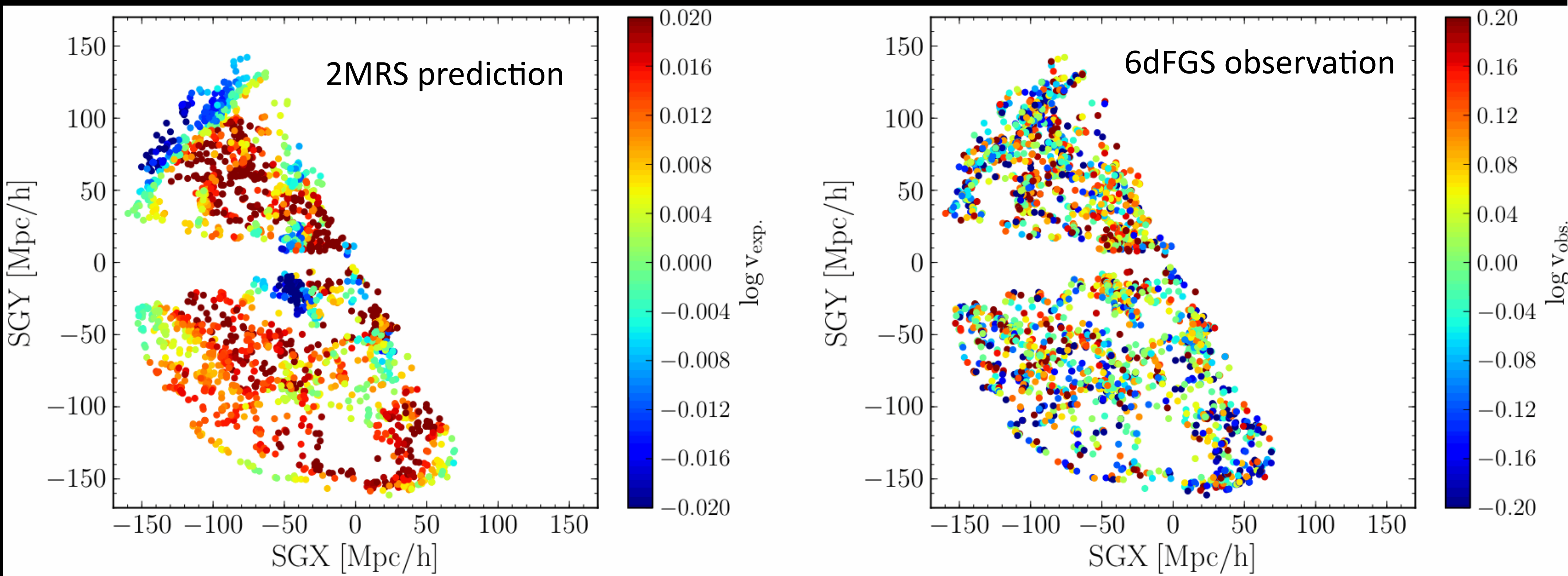
Individual peculiar velocity maps through slices of SGZ

SGZ > +20 Mpc/h

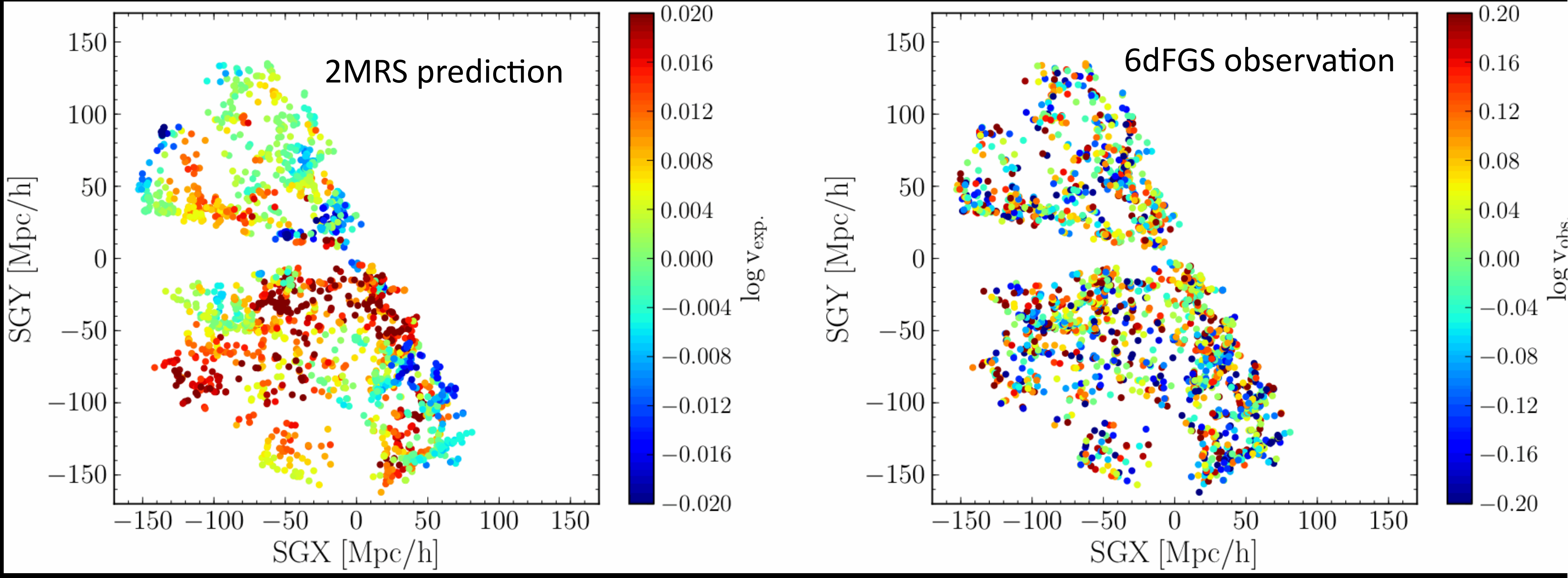


Above: SGX vs. SGY distribution of galaxies in 6dFGS...but only for galaxies with SGZ>20 Mpc/h. The points are color-coded by peculiar velocity in log units, where the real distance is (left) taken from the 2MRS velocity field's prediction, and (right) the expectation value of the distance from the 6dFGS distance probability distribution for that galaxy.

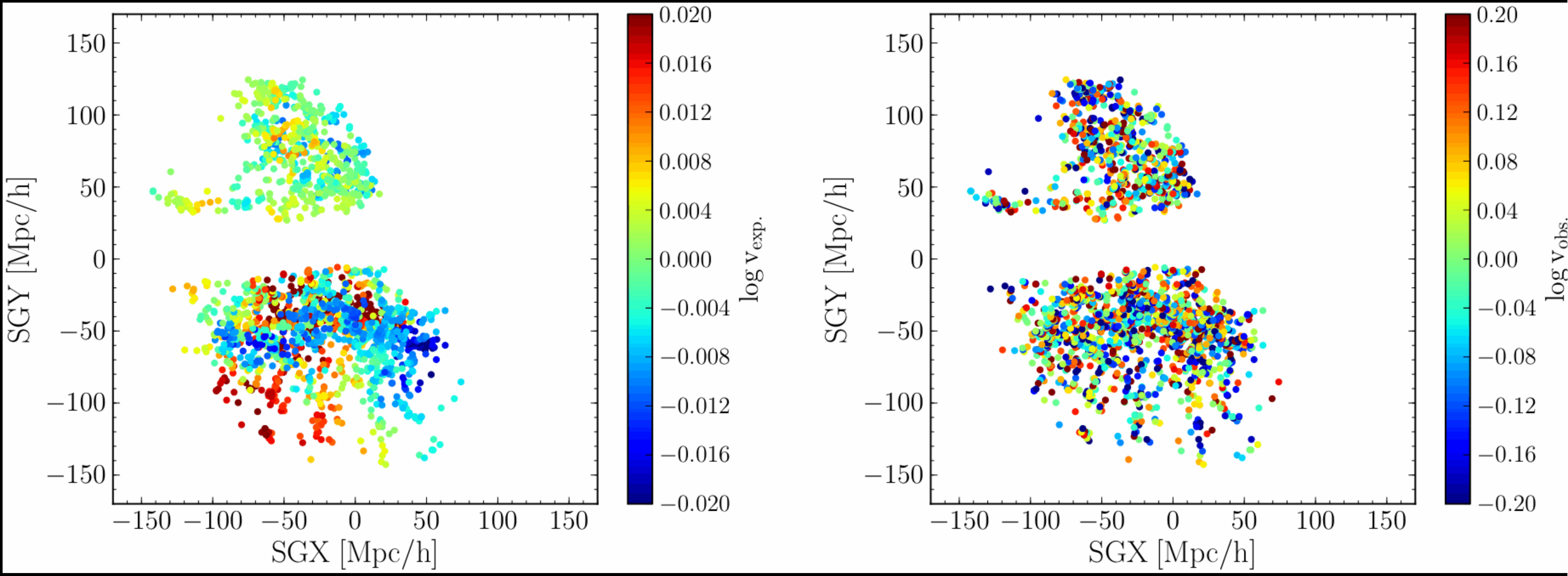
-20 < SGZ < +20 Mpc/h



-70 < SGZ < -20 Mpc/h



SGZ < -70 Mpc/h



Can then use peculiar velocity probability distributions of individual galaxies for cosmological analysis

- Jeremy's talk describes how we use this to measure β $(=\Omega_m^{0.55}/b)$ and the three components of bulk flow

2) Bayesian analysis of observational dataset as a whole, without computing peculiar velocities of individual galaxies

Fitting the value of β

- Fix the Fundamental Plane parameters using Christina's fit
- Transform the 2MRS velocity field from real space to redshift space
- Look up the 2MRS-predicted peculiar velocity for each galaxy in the sample, given its z-space position
- Iterate over every possible value of β, β_i, computing the corresponding distance to each galaxy for that β_i

$$(1+z_{\mathrm{Hubble},i})=(1+z_{\mathrm{obs}}) / (1+z_{\mathrm{peculiar},i}) \quad \text{with}$$

$$z_{\mathrm{peculiar},i} = (\beta_i / \beta_{\mathrm{2MRS\text{-}input}})\, z_{\mathrm{peculiar,2MRS\text{-}input}}$$

- Calculate the physical radius of the galaxy according to its assumed distance, and recalculate the likelihood. Then, the maximum likelihood value of β is the one that maximizes the sum of the log likelihoods from each of the N galaxies

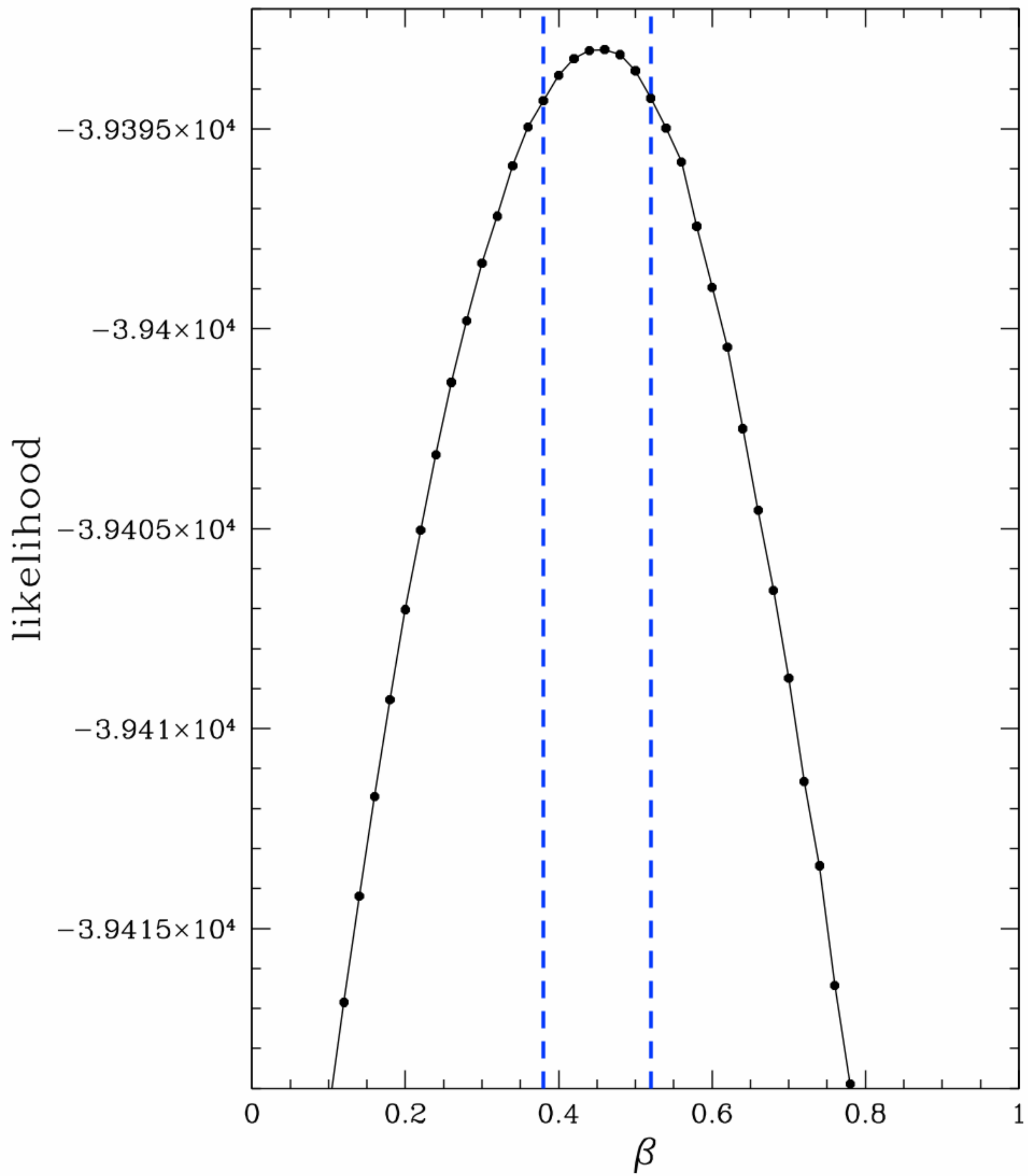
$$\ln(L(\beta_i)) = \Sigma_{j=1,N} \ln(P(x_j))$$ where x=(r,s,i) position in FP space

- As with Method 1, can generalize this approach to also fit for the three components of the bulk flow. Simply adjust the model velocity to include a bulk flow component

Maximum likelihood fit of β

Right: likelihood vs. β for 6dFGS peculiar velocity sample, using comparison to 2MRS velocty field. In this case, we find

β = 0.45+/-0.07, (but don't believe this number, it's just proof-of-concept for now).

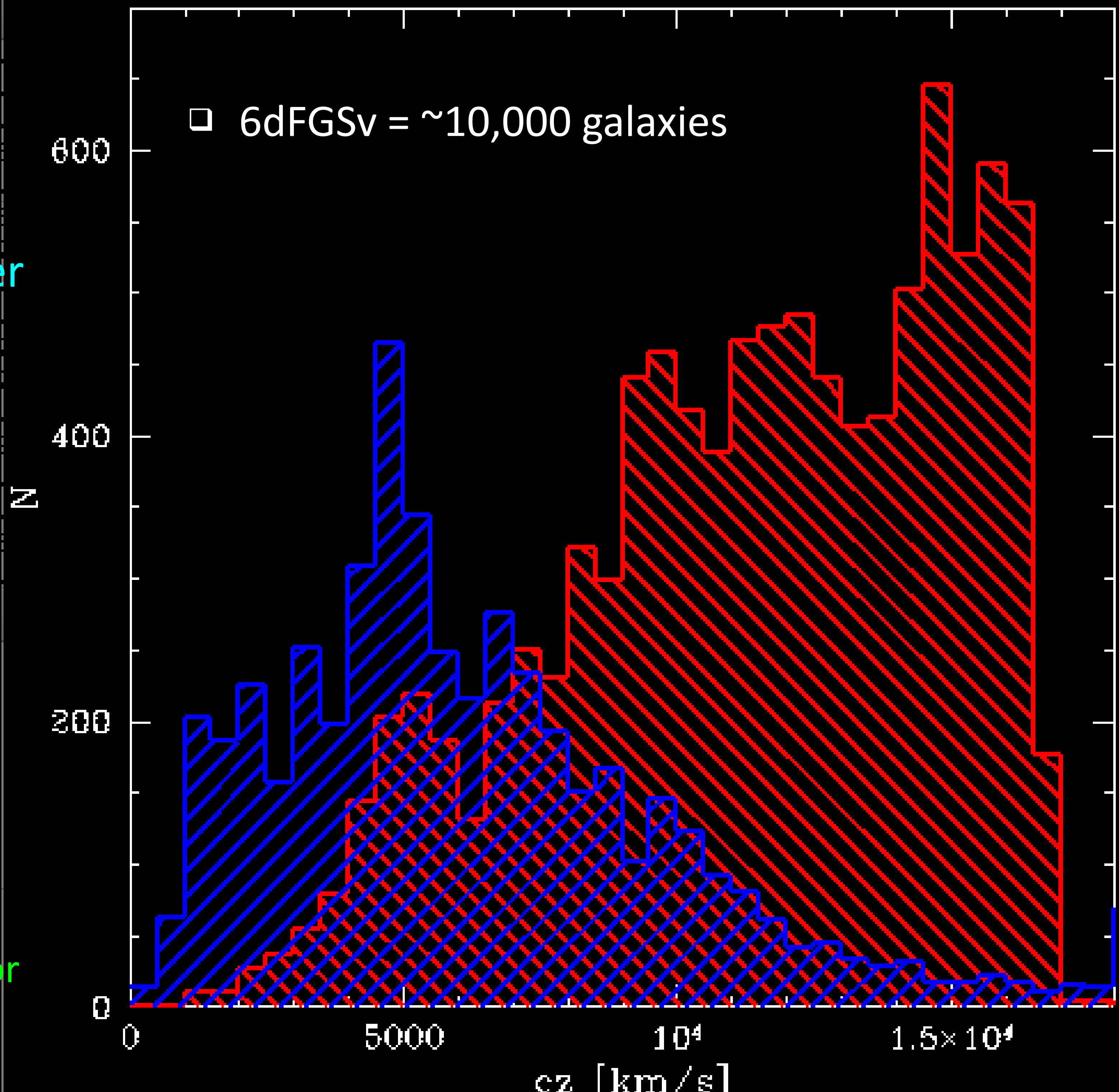


Conclusions

- We have Bayesian peculiar velocity probability distributions for each of the ~10,000 galaxies in the 6dFGS FP sample.
- Have compared to predicted velocity field from 2MRS, <u>and find agreement</u>, though still working to nail down the actual value of β
  - Will also expand method to measure the bulk flow vector

Extra slides

6dFGS goes deeper than the previous large FP or TF surveys.



Redshift histogram for SFI++ (blue) and 6dFGS (red).

Future plans (should probably be in Jeremy's talk instead)

- More detailed cosmographic description
- Parameter estimation:
  - Fit for additional parameters, using the current maximum likelihood approach
  - Multipole analysis, a la Watkins, Feldman, & Hudson (2009)
  - Peculiar velocity power spectrum, a la Burkey & Taylor (2004)
- Parameters include bulk flow, shear, power spectrum shape parameter Γ, correlation coefficient between luminous and dark matter r_g, etc....