A model independent method to measure peculiar velocity dispersion of galaxies

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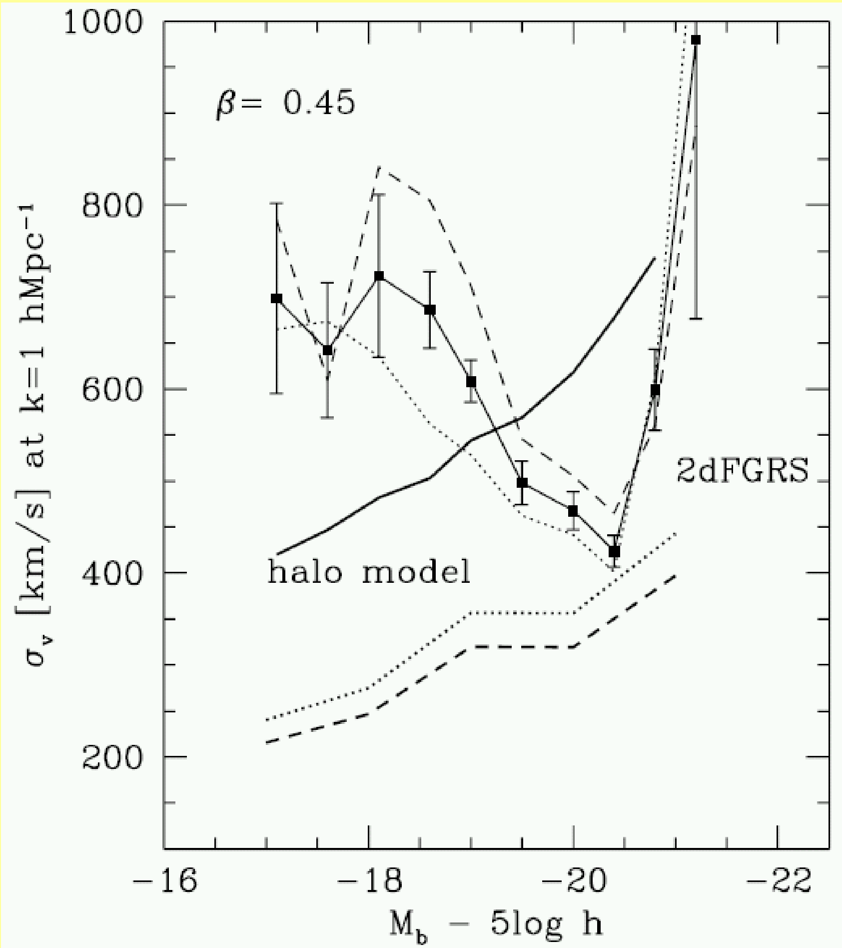
Introduction

- ✔ Position and velocity
- ✔ Redshift of cosmological object is contaminated by their peculiar velocity
- ✔ For most of the objects in cosmological distance, it is very difficult to resolve the contamination for each object.
  - Statistical measurement of velocity using redshift-distortion

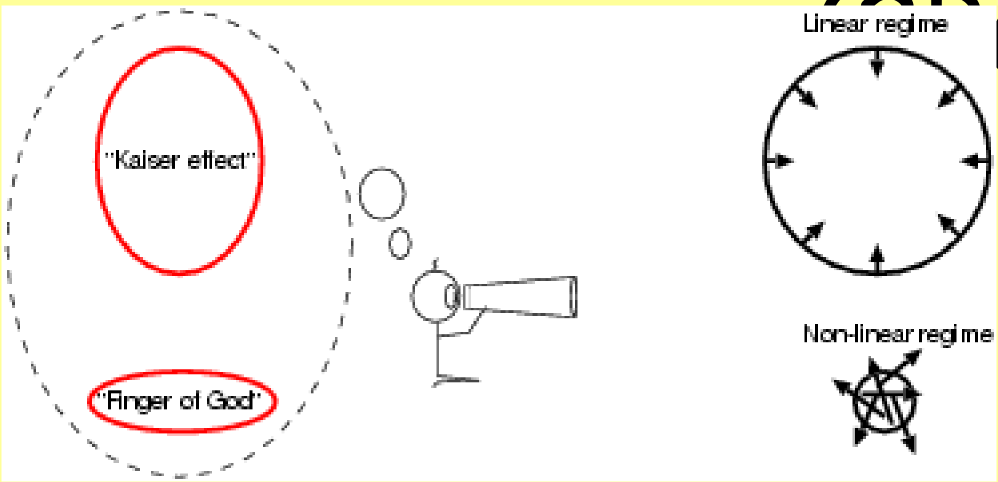
Jing & Börner 2004

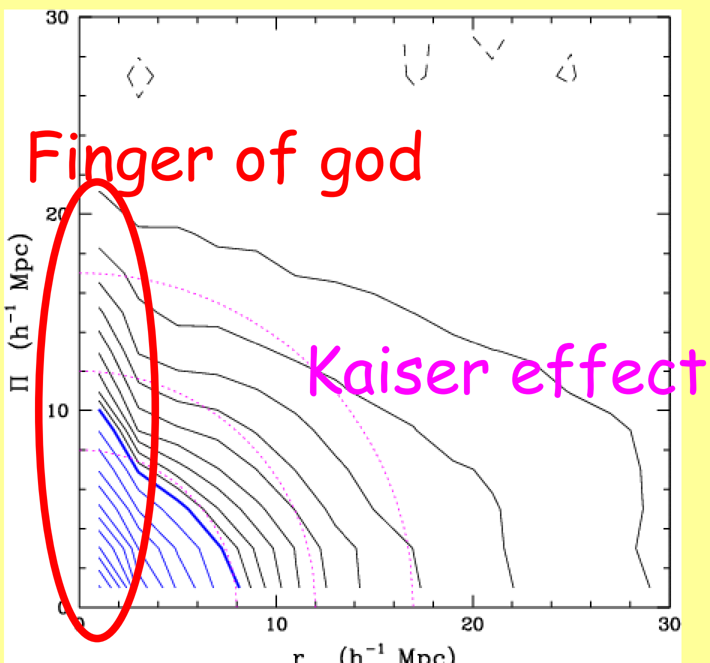


- ✔ found non-monotonic luminosity dependence of velocity dispersion.
  - – which conflicts with naïve expectation.
  - – Velocity grabs something that is not known only from the !

We would like to confirm this interesting result by an independent method.

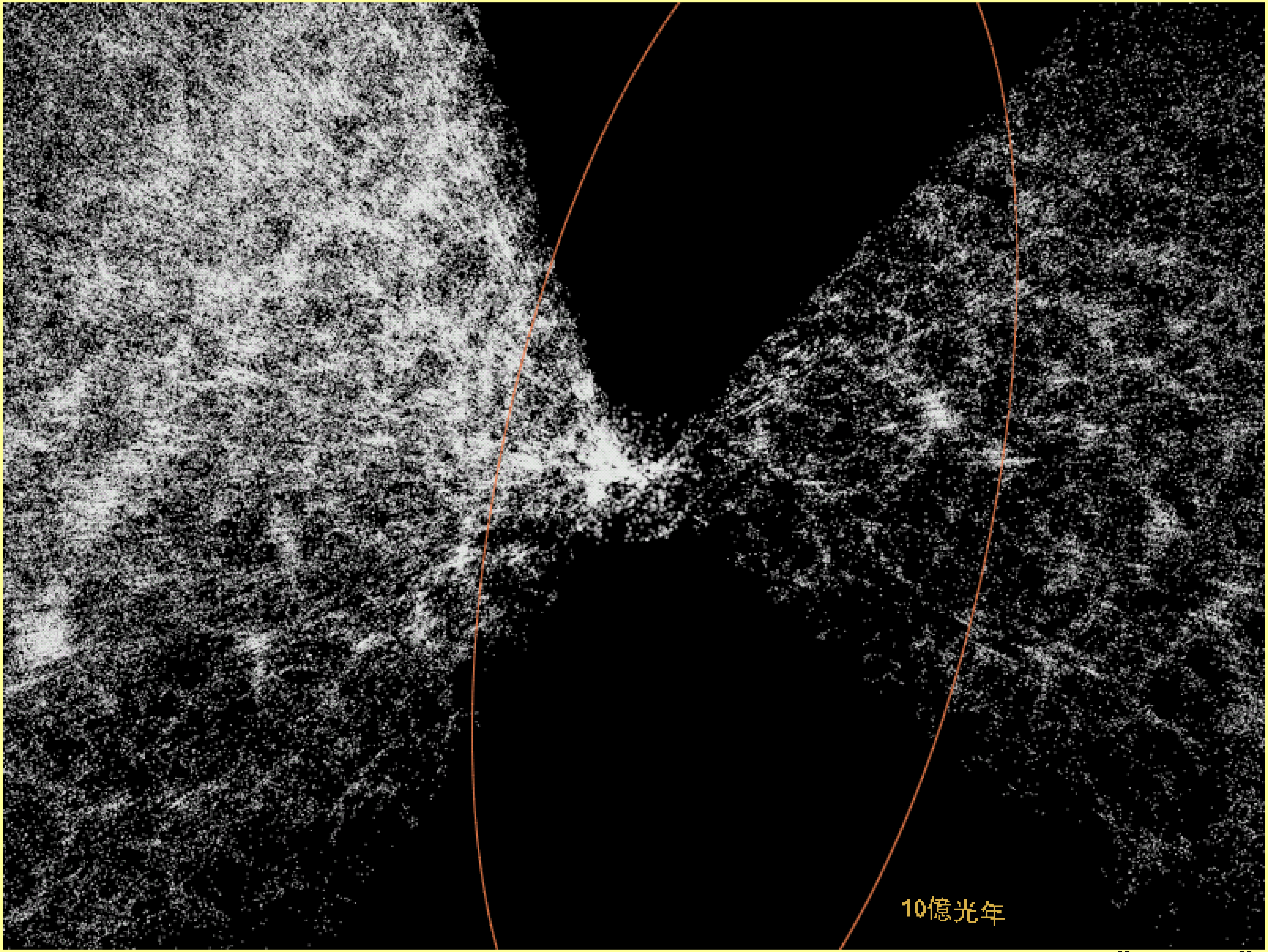
Redshift distortions on two-point correlation function (2PCF)





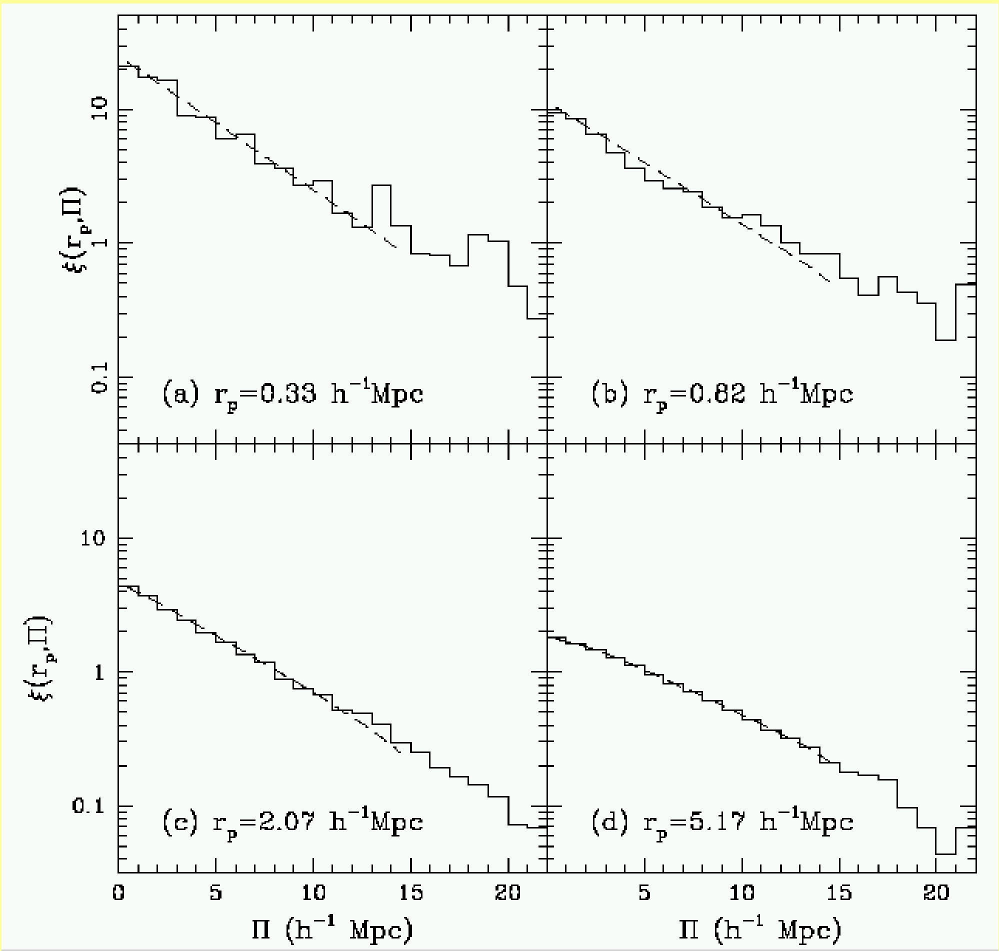
- ✔ Kaiser effect
  - Systematic infall
  - Linear description
- ✔ Finger-of-god effect
  - Random motion at scale of cluster of galaxies.
  - Nonlinear effect
  - Characteristic value is velocity dispersion
- ✔ Velocity will be an important cosmological and astrophysical tool.

Finger of god effect



NAOJ "Mitaka"

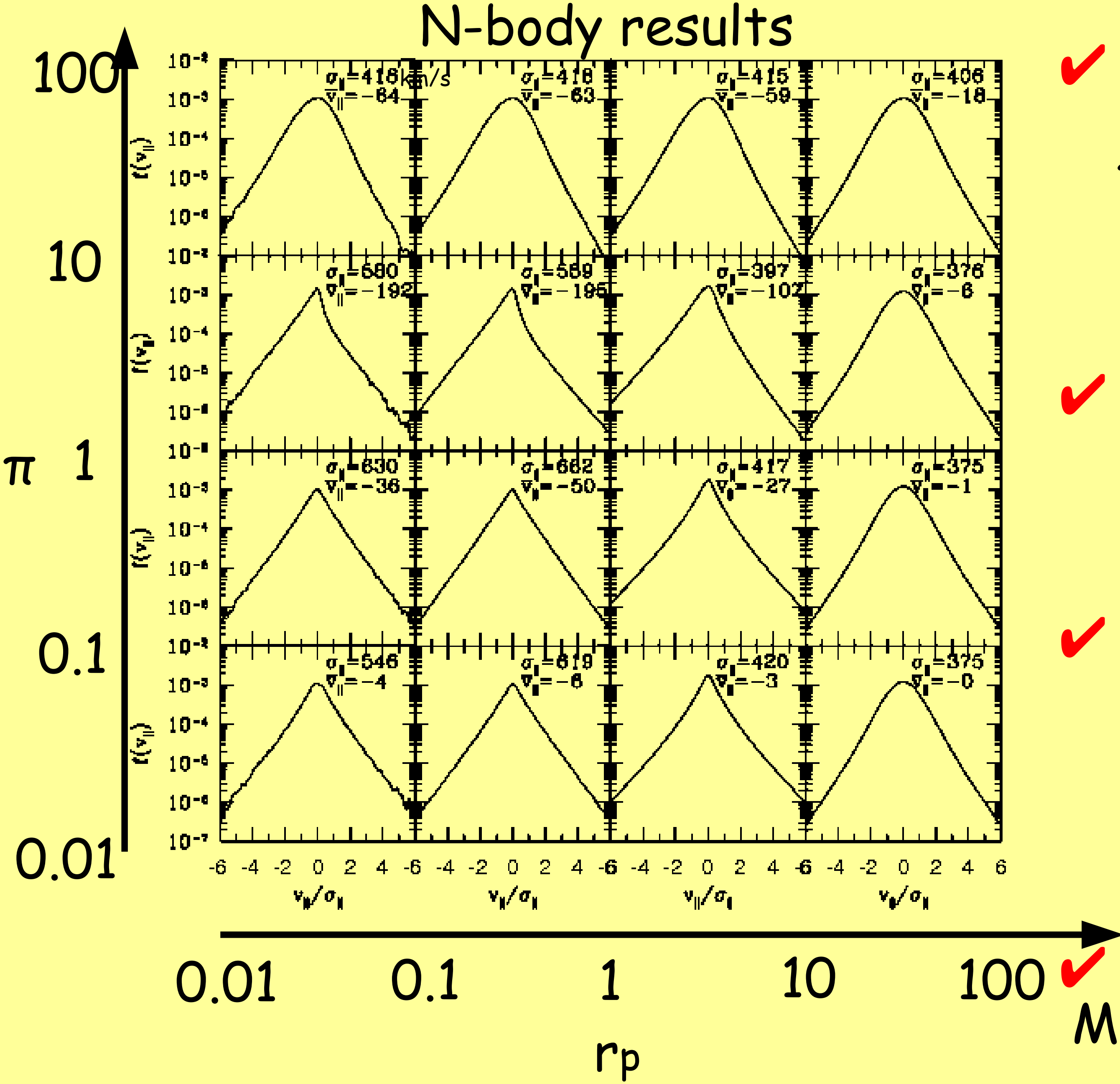
Traditional method to measure velocity dispersion



Zehavi et al. 2002

- ✔ assumes some function for the velocity distribution.
  - – ex. exponential
- ✔ fits 2PCF and obtains velocity dispersion as a fitting parameter.

Complex feature of f(v)



- Shape of $f(v_{||}, r_p, \pi)$ is actually complex.
- Small scale
  - exponential
- Large scale
  - Gaussian core + exponential tail
- We cannot use particular form

An old and new method

$$1+\xi_s(r_p,\pi) = \int dv_{12} f(v_{12};r_p)[1+\xi(\sqrt{r_p^2+(\pi-v_{12}/H_0)^2})]$$

$$\xi_s(r_p,\pi) = \int dv_{12} \tilde{f}(v_{12};r_p)\xi_K(r_p,\pi-v_{12}/H_0)$$

2PCF which includes only Kaiser effect

$$\int d\pi\pi^2\xi_s(r_p,\pi) = \int d\pi\pi^2 \int dv_{12}\tilde{f}(v_{12};r_p)\xi_K(r_p,\pi-v_{12}/H_0)$$

$$= \int dy \int dv_{12}\tilde{f}(v_{12};r_p)(y+v_{12}/H_0)^2\xi_K(r_p,y)$$

$$y \equiv \pi - v_{12}/H_0$$

$$= \int d\pi \int dv_{12}\tilde{f}(v_{12};r_p)(\pi+v_{12}/H_0)^2\xi_K(r_p,\pi)$$

$$= \int d\pi \int dv_{12}\tilde{f}(v_{12};r_p)(\pi^2+v_{12}^2/H_0^2)\xi_K(r_p,\pi)$$

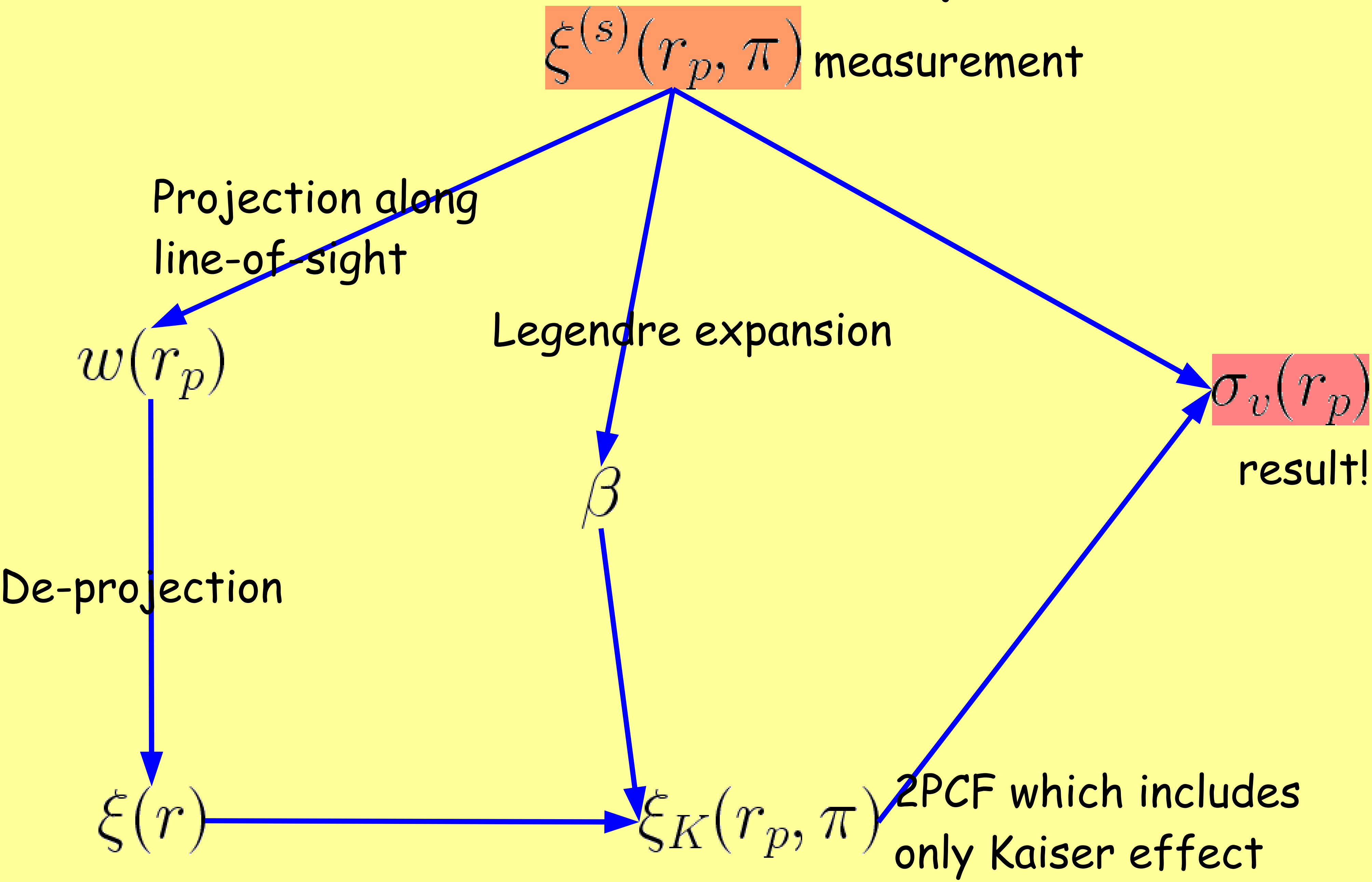
$$\tilde{f}(v_{12}) = \tilde{f}(-v_{12})$$

$$= \int d\pi\pi^2\xi_K(r_p,\pi) + \int d\pi\xi_K(r_p,\pi)\frac{1}{H_0^2}\int dv_{12}^2 v_{12}^2\tilde{f}(v_{12};r_p)$$

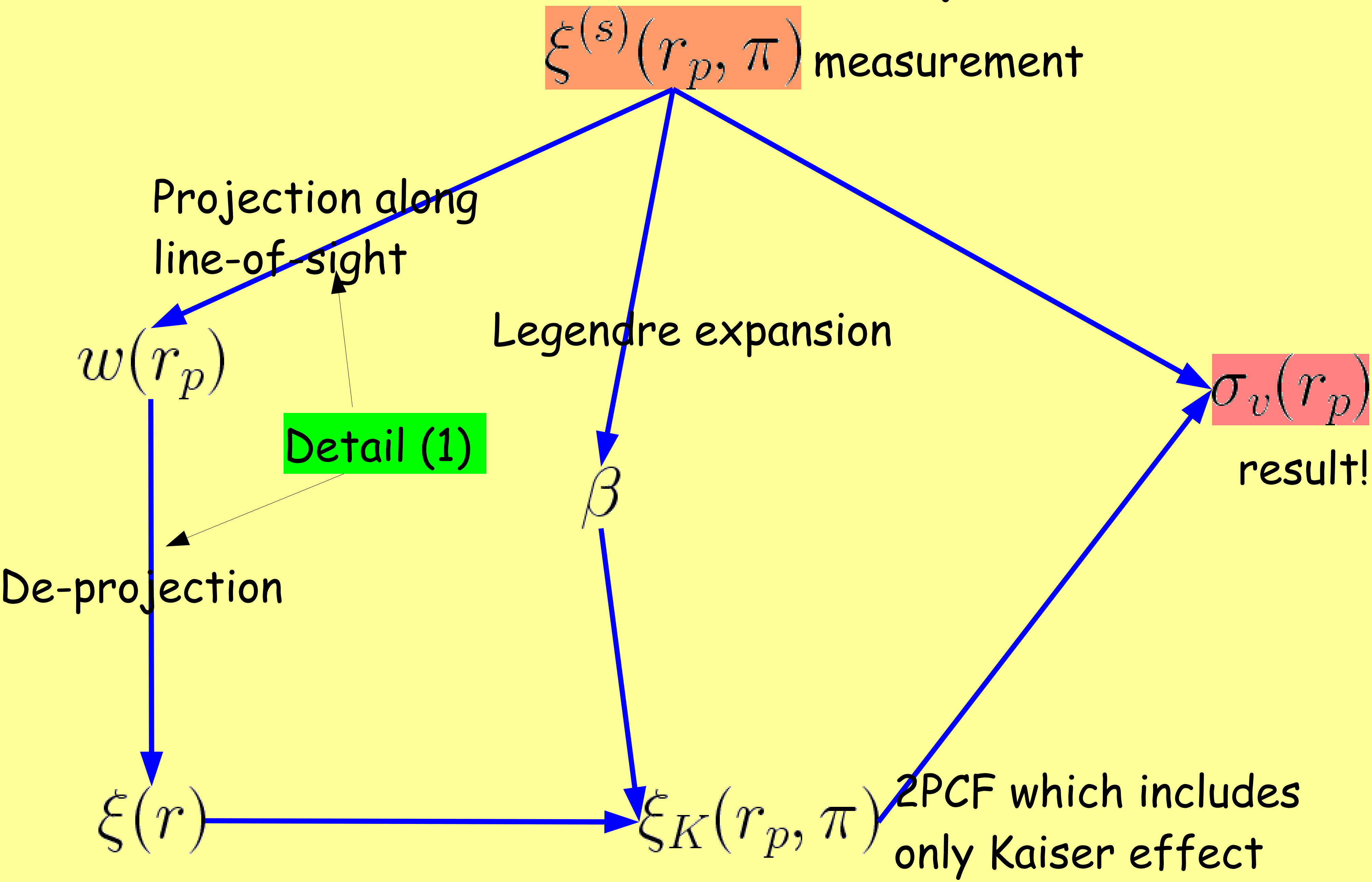
$$\sigma_{12}^2(r_p) = \frac{H_0^2\int d\pi\pi^2[\xi_s(r_p,\pi)-\xi_K(r_p,\pi)]}{\int d\pi\xi_K(r_p,\pi)}$$

Velocity dispersion!

Flow chart of analysis



Flow chart of analysis



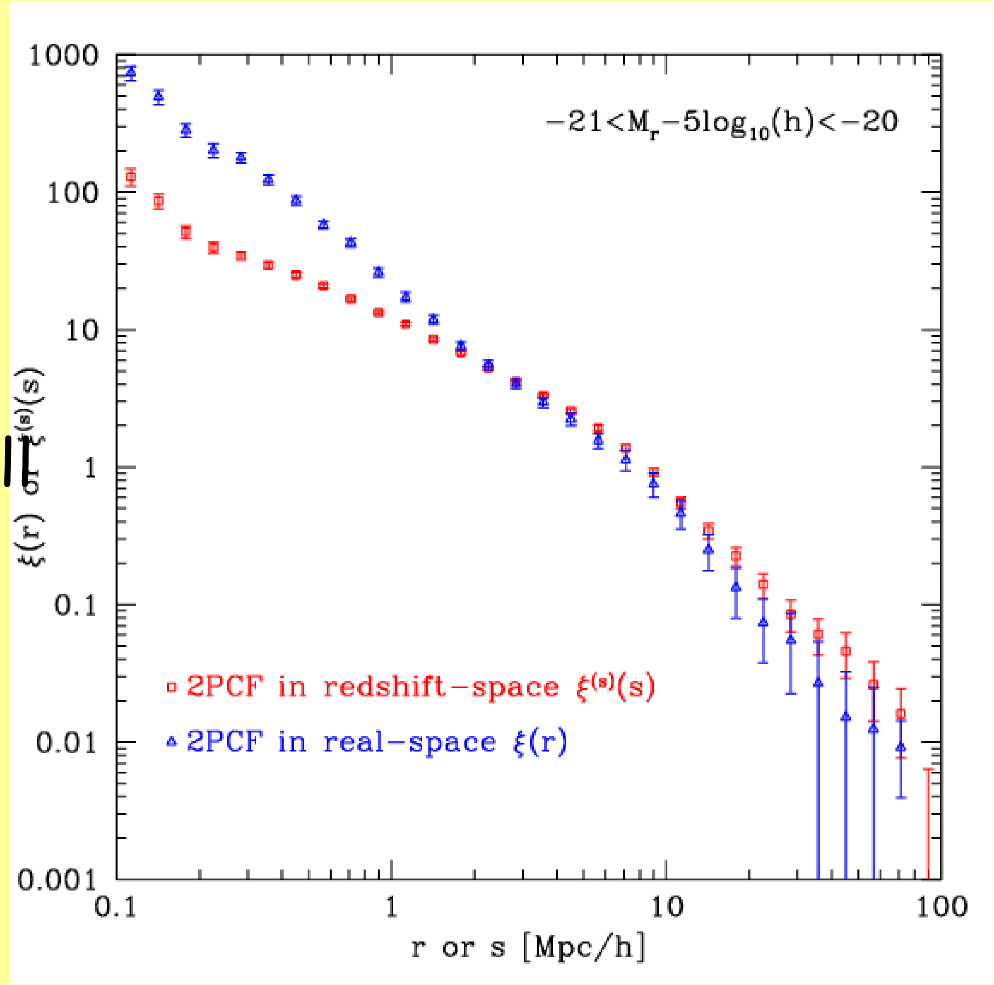
Detail of Procedure (1)

Integration of 2D-2PCF along los removes redshift distortion

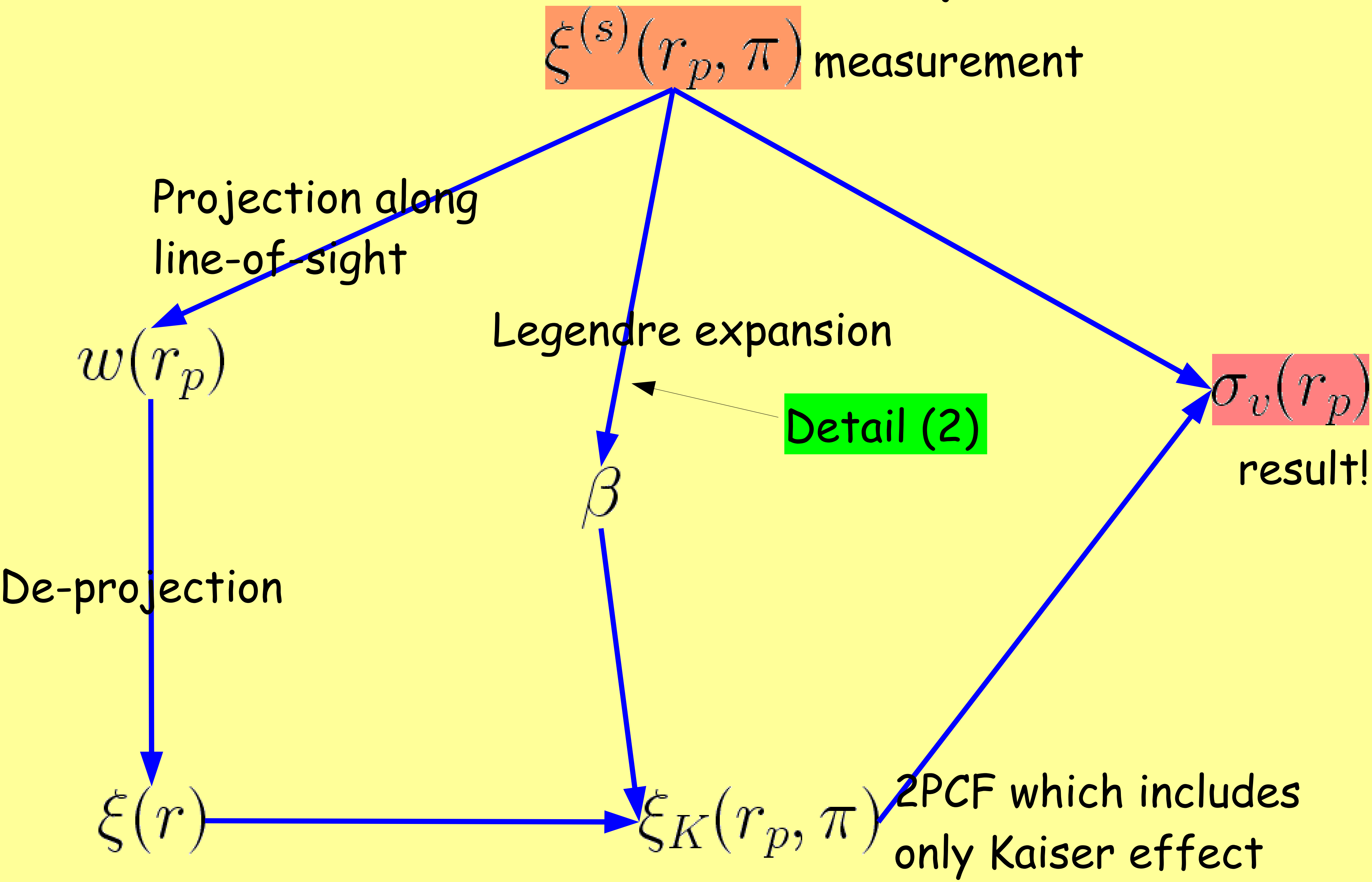
$$w(r_p) = \int_{-\infty}^{\infty} d\pi \xi^{(s)}(r_p, \pi)$$

Assuming isotropy of the 2PCF in real-space, it is recovered by Abell integral.

$$\xi(r) = -\frac{1}{\pi}\int_r^{\infty} \frac{dw(r_p)}{dr_p}(r_p^2 - r^2)^{-1/2} dr_p$$



Flow chart of analysis

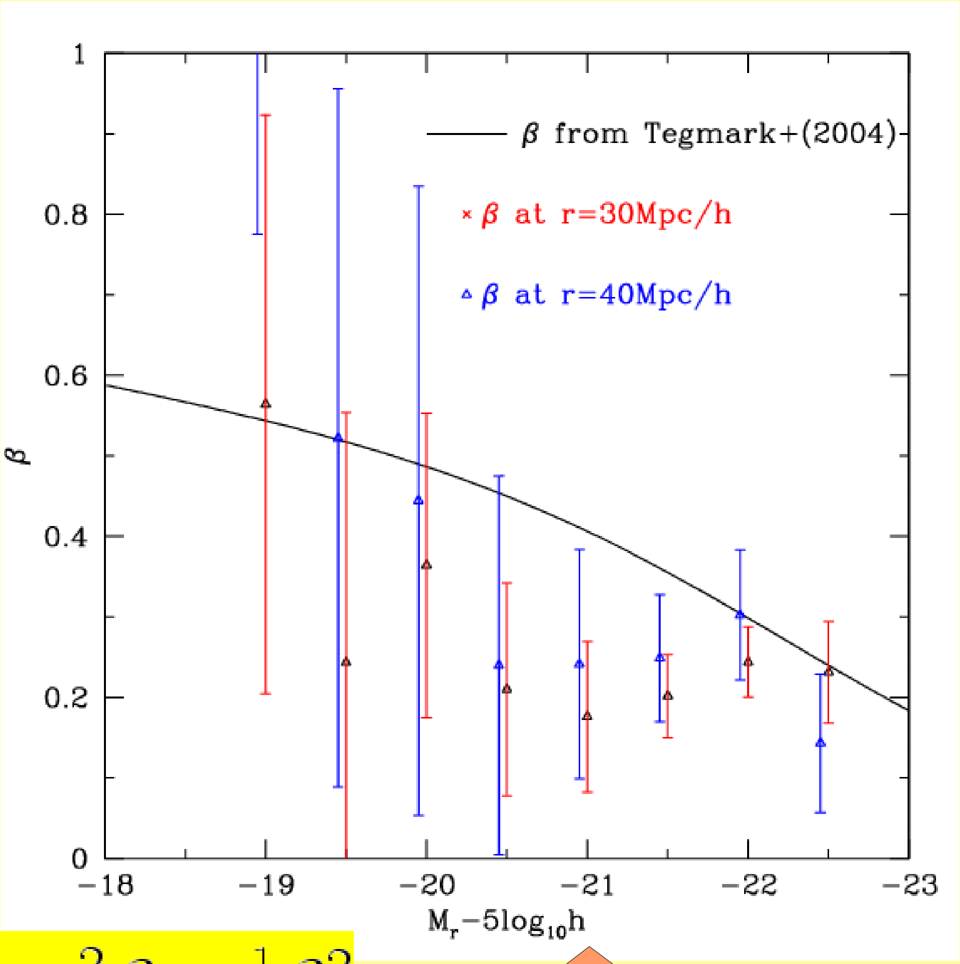


Detail of Procedure (2)

Legendre expansion of $\xi^{(s)}(r_p, \pi)$

$$\xi^{(s)}(r_p, \pi) = \sum_l \xi_l(s)\mathcal{P}_l(\mu)$$

$$\xi_l^{(s)}(x) = \frac{2l+1}{2}\int_{-1}^{1} \xi^{(s)}(r_p, \pi)\mathcal{P}_l(\mu)d\mu$$

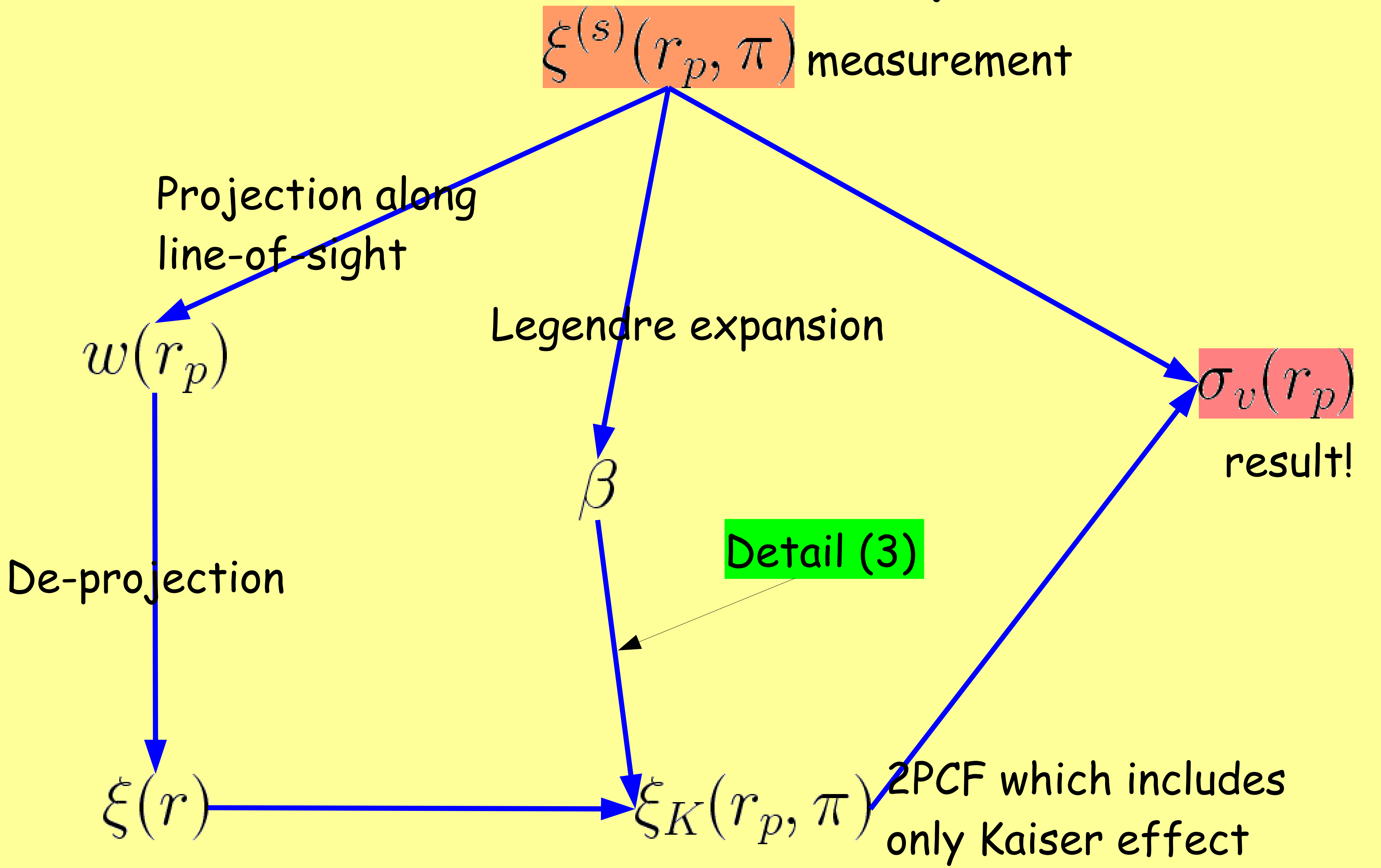


Distortion parameter β

$$\beta \equiv \frac{1}{b}\left|\frac{d\ln D(z)}{d\ln a}\right|_0 \sim \frac{\Omega_m^{0.6}}{b}$$

$$\frac{\xi_0^{(s)}(x) - \frac{3}{x^3}\int_0^x \xi_0^{(s)}(s)s^2ds}{\xi_2^{(s)}(x)} = \frac{1+\frac{2}{3}\beta+\frac{1}{5}\beta^2}{\frac{4}{3}\beta+\frac{4}{7}\beta^2}$$

Flow chart of analysis



Detail of Procedure (3)

Using measured β and recovered real-space 2PCF, we can construct redshift-space 2PCF only with Kaiser effect.

$$\xi_K(r_p,\pi) = \xi_0^{(s)}(x)\mathcal{P}_0(\mu)+\xi_2^{(s)}(x)\mathcal{P}_2(\mu)+\xi_4^{(s)}(x)\mathcal{P}_4(\mu)$$

$$\xi_0^{(s)}(x) = \left(1+\frac{2}{3}\beta+\frac{1}{5}\beta^2\right)\xi(x)$$

$$\xi_2^{(s)}(x) = \left(\frac{4}{3}\beta+\frac{4}{7}\beta^2\right)\{\xi(x)-\bar{\xi}(x)\}$$

$$\xi_4^{(s)}(x) = \frac{8}{35}\beta^2\left\{\xi(x)+\frac{5}{2}\bar{\xi}(x)-\frac{7}{2}\bar{\bar{\xi}}(x)\right\}$$

$$\bar{\xi}(x) = \frac{3}{x^3}\int_0^x \xi(r)r^2dr$$

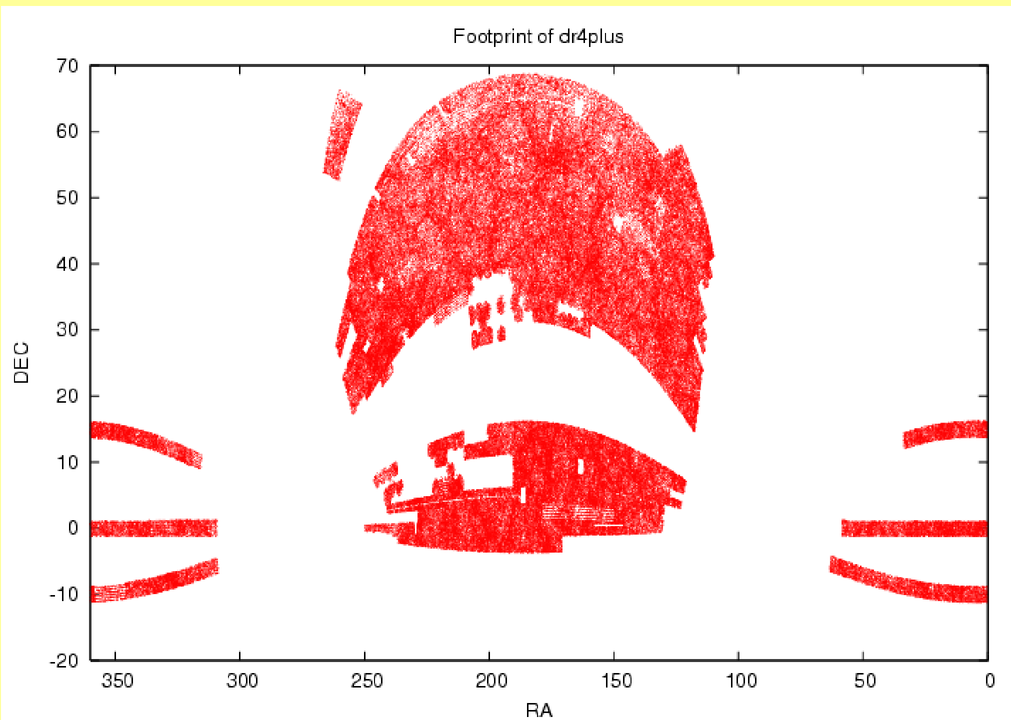
$$\bar{\bar{\xi}}(x) = \frac{5}{x^5}\int_0^x \xi(r)r^4dr$$

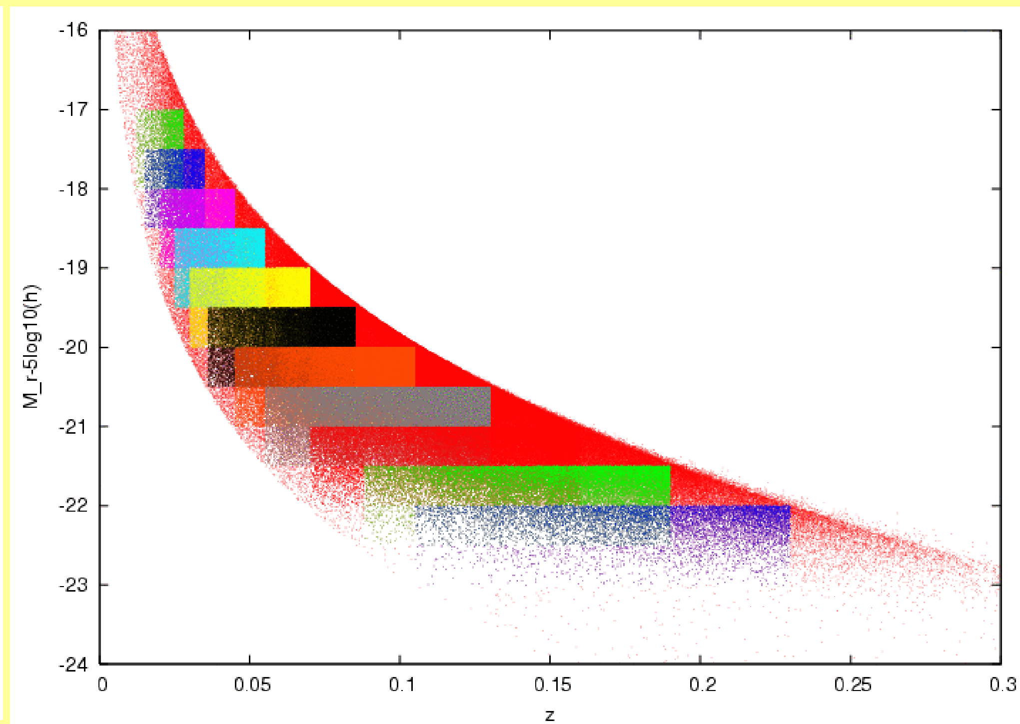
And finally

$$\sigma_v^2(r_p) = \frac{H^2\int d\pi\pi^2[\xi^{(s)}(r_p,\pi)-\xi_K(r_p,\pi)]}{\int \pi\xi^{(s)}(r_p,\pi)}$$

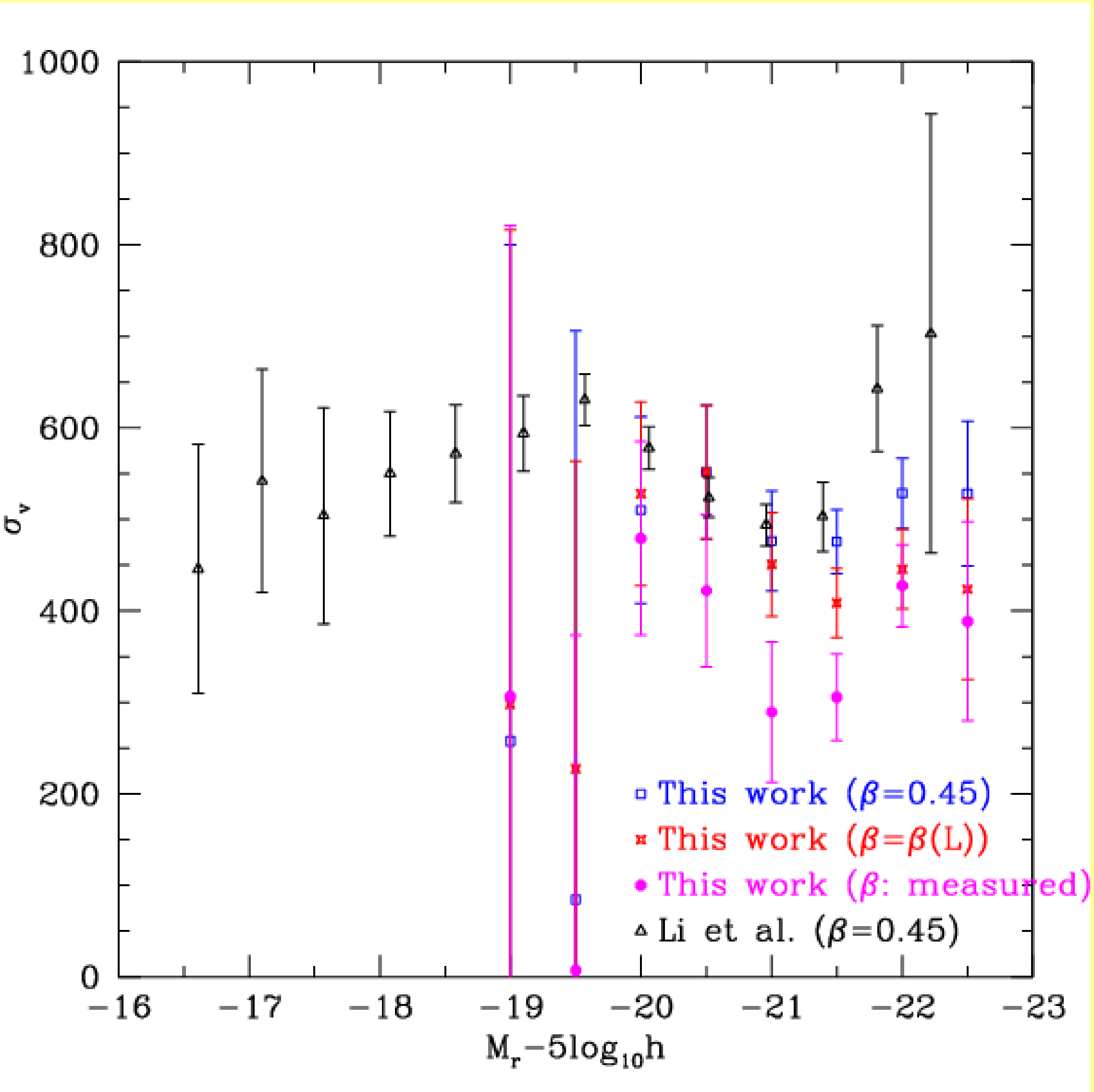
SDSS Data

- NYU Value-Added Galaxy Catalog
  - http://astro.physics.nyu.edu/blanton/vagc
  - Construct volume-limited sample from "dr4plus" (~ 5700 sq.deg)





Result and Summary



- ✔ Similar luminosity dependence found by Jing & Börner (and Li+ 2005).
- ✔ Measurement of β is a source of bias....
  - – Different ways to measure β show bias on measurement of

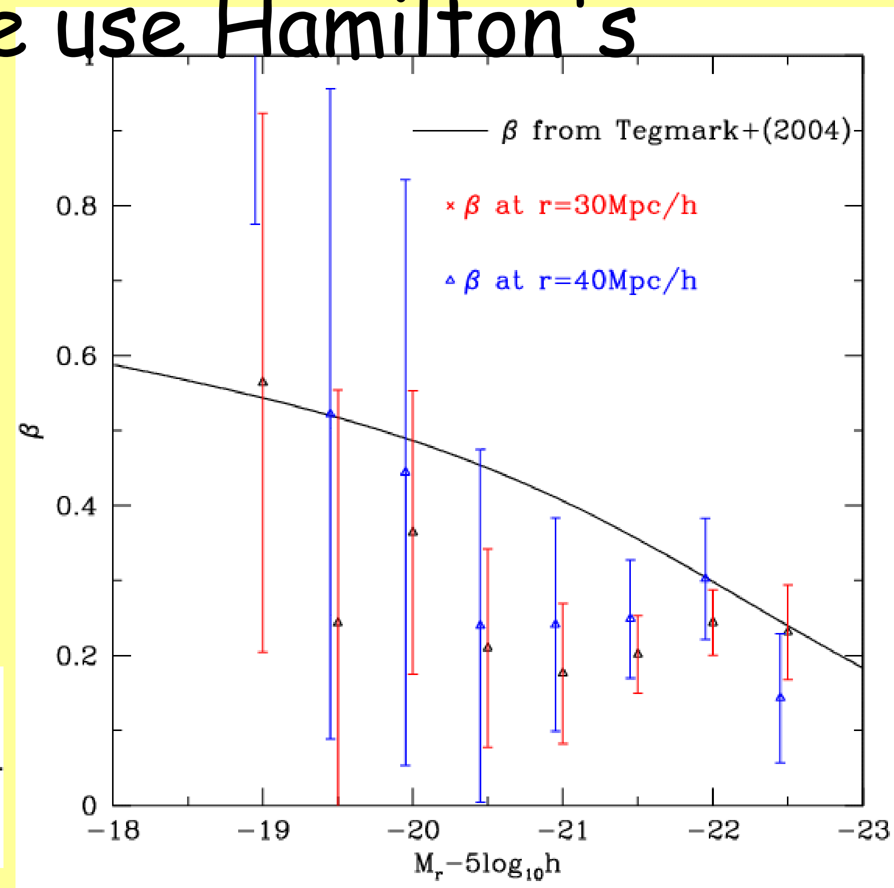
Toward a better way to measure β

- ✔ In the previous plot, we use Hamilton's method (1992)
  - – expands 2PCF with Legendre polynomials

$$\xi_l^{(s)}(x) = \frac{2l+1}{2}\int_{-1}^{1} \xi^{(s)}(r_p,\pi)\mathcal{P}_l(\mu)d\mu$$

$$\frac{\xi_0^{(s)}(x) - \frac{3}{x^3}\int_0^x \xi_0^{(s)}(s)s^2 ds}{\xi_2^{(s)}(x)} = \frac{1+\frac{2}{3}\beta+\frac{1}{5}\beta^2}{\frac{4}{3}\beta+\frac{4}{7}\beta^2}$$

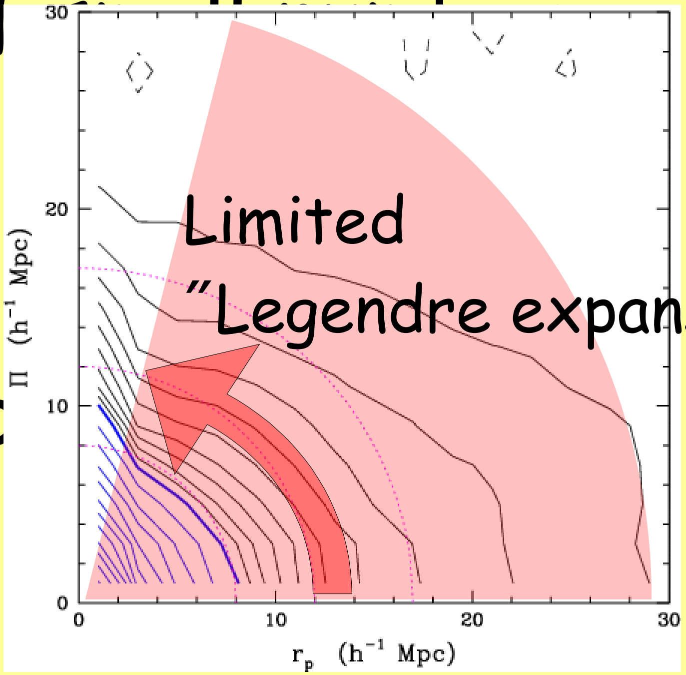
such as



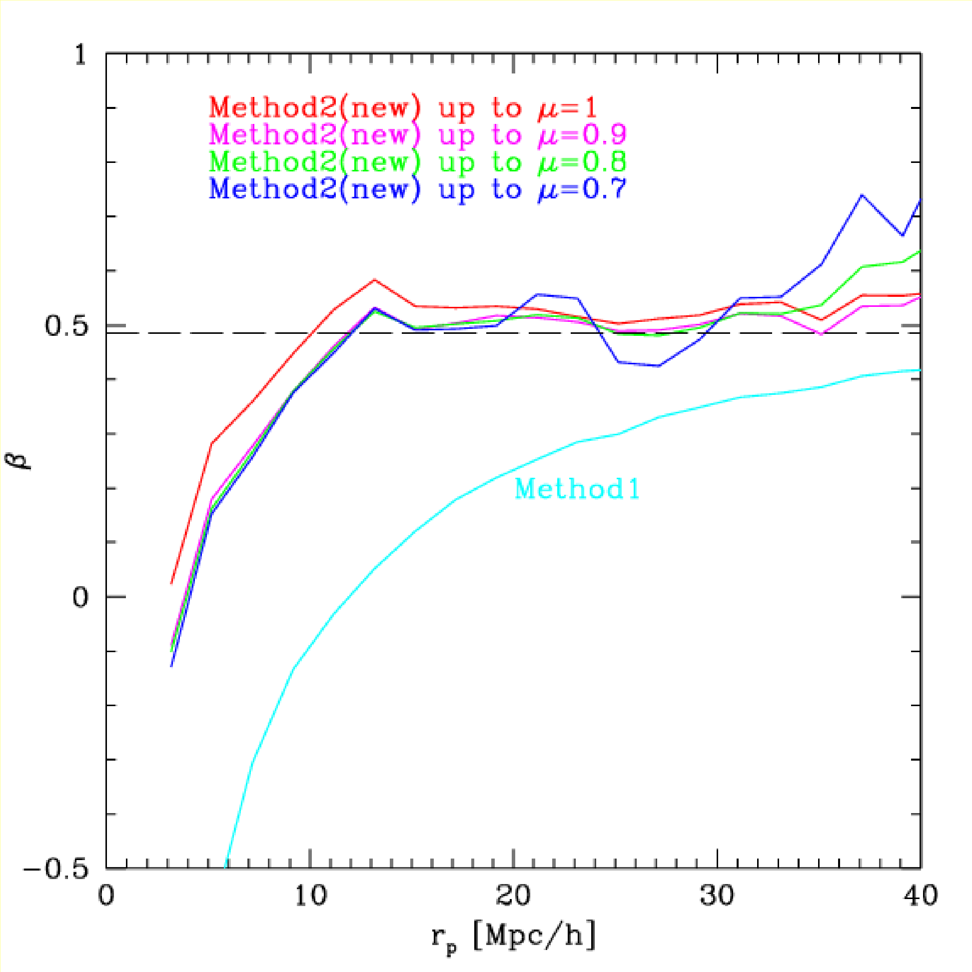
A better way to measure β?

- Measurement of 2PCF along the line-of-sight (r_p~0) tends to be noisy due to higher-order correlations.
- It is noisy also because of
  of modes.
- Finger-o -god effect is
  prominent along the line-o

"Legendre expansion" up to some limited angle.



Performance of the new method



Demonstration by N-body

- Faster conversion is achieved than Hamilton's method (Method1).
- Expansion up to μ=0.9 is enough to remove the contamination from finger-of-god effect effectively.
- Further investigation is needed to control systematics!!

And more for improvement

- ✔ Effect of fiber-collision of the SDSS spectrograph
  - Due to the mechanical limitation of the spectrograph, galaxies within 55" cannot be observed simultaneously (~0.1Mpc@z=0.1)
  - Over 20 % effect on $\xi(s)$ and $w(r_p)$
- ✔ Larger sample, SDSS DR7
  - Twice data
- ✔ Error estimation?