What next in dynamical modelling?

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- We need dynamical and ‘cosmological models’
- Equilibrium assumption not always justified
- What data do we need?
- What is the best way to determine the gravitational potential?
- Some dynamical modelling issues
- Test problems for modelling?

We need dynamical models and 'cosmological' models

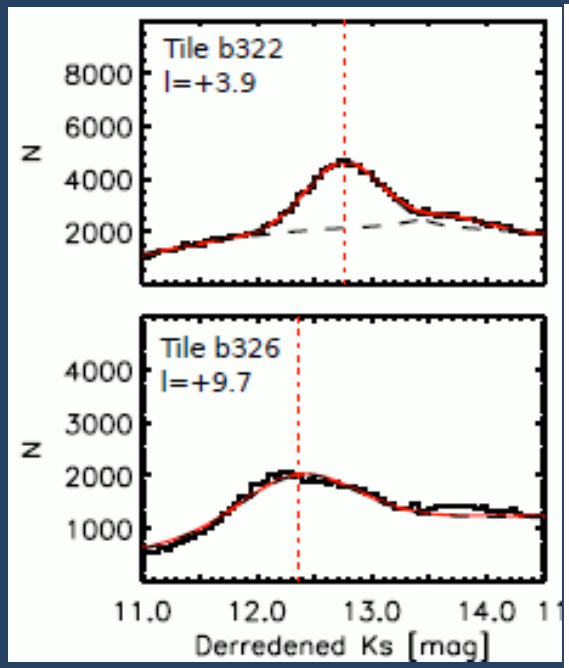
- Dynamical model: current dynamical state inferred from data
  - Set of tracers – selection function, incompleteness, systematics?
  - Modelling approach – modelling assumptions (e.g., dynamical equilibrium, gravitational potential, symmetry, anisotropy)?

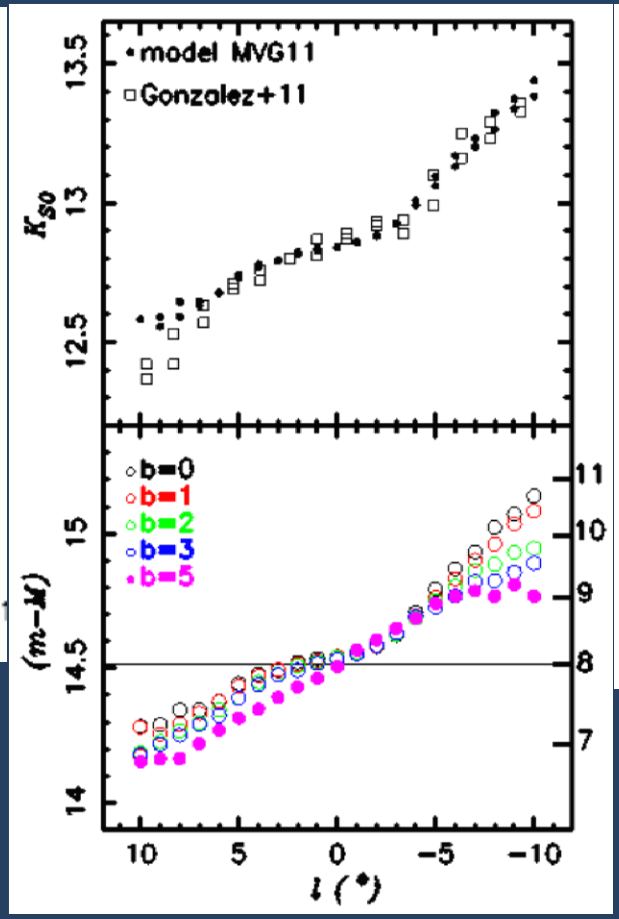
  E.g., mass distributions, orbit distributions

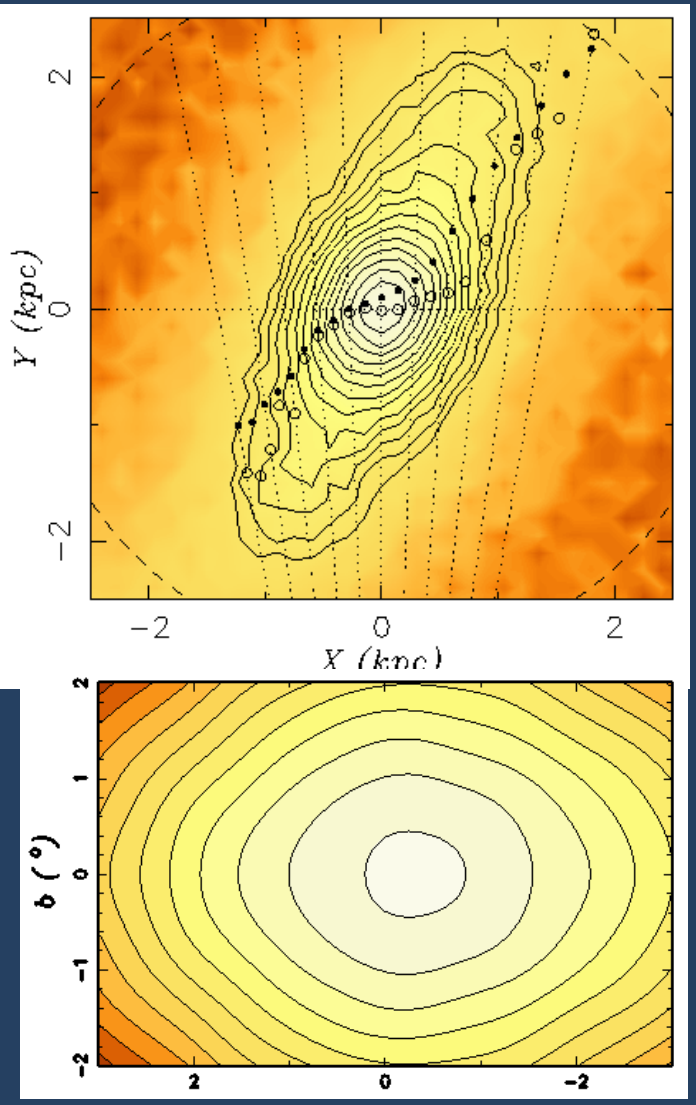
- 'Cosmological' model: predicting observational outcome of typical evolutionary histories
  - Forward evolution from priori assumptions – how well are initial conditions known, how variable?
  - Physical processes along the way – gas dynamics, star formation, cooling-heating-feedback, .. ?

  E.g., ETGs in cosmological simulations, evolving spiral disks, tidally stirred dwarf galaxies

Galactic bar-bulge: understanding star count data





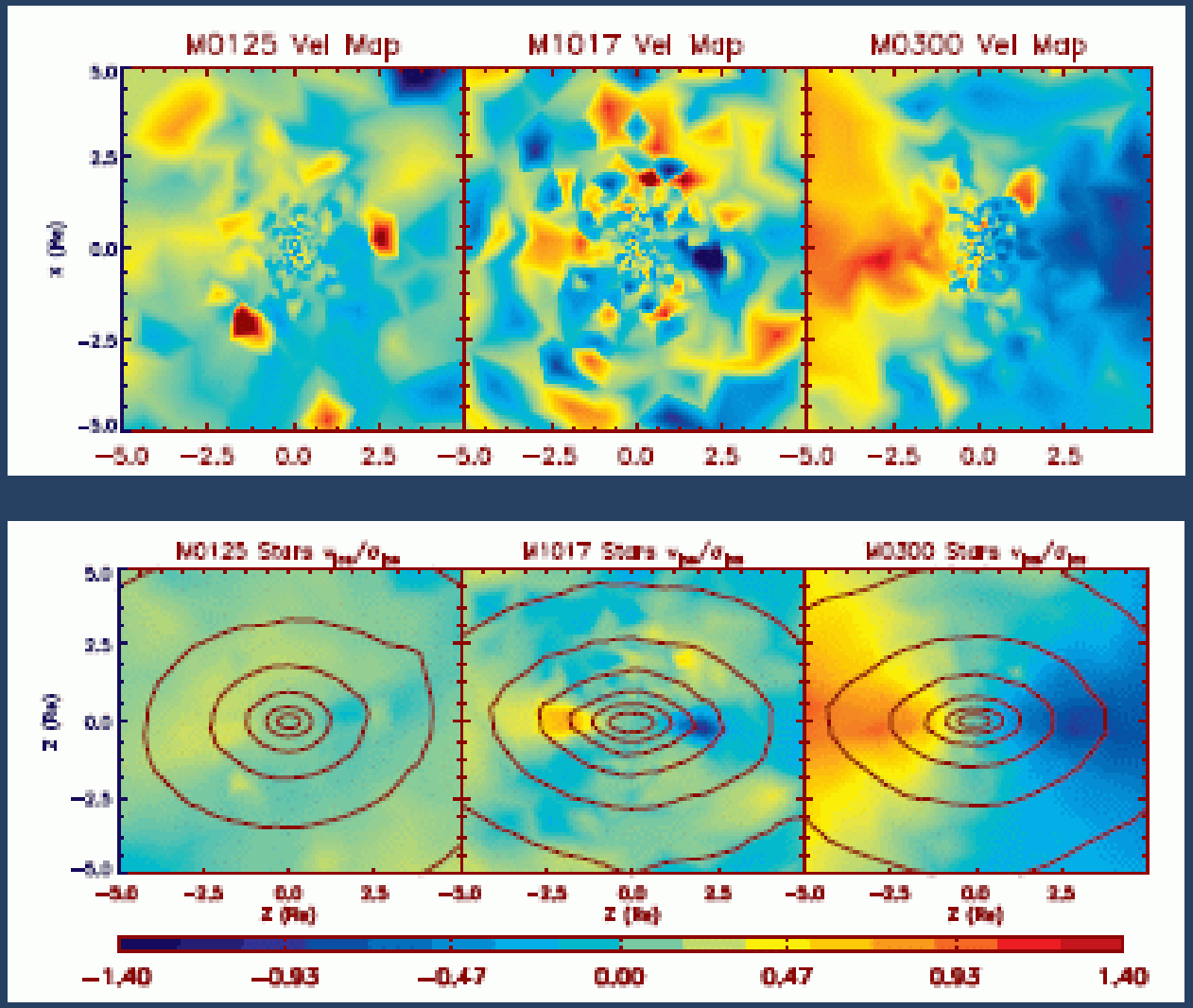


Slope in RC longitude profiles from VVV and asymmetry in 2MASS starcounts

Can be quantitatively/qualitatively explained with a boxy bulge formed in a bar unstable disk simulation. No need for classical bulge and separate nuclear bar. Good starting point for further analysis, e.g., dynamics, stellar population results from BRAVA & ARGOS, APOGEE.

OG+Martinez-Valpuesta'12

ETGs from cosmological (re)simulations: Is the assumption of dynamical equilibrium justified?



… for ETG halos possibly not …

← Polar grid-based velocity fields for 3 ETGs from cosmo-resim's: satellites, particle noise (Oser+'10; Wu+'12)

← Time-smoothed v/σ fields and iso-SB contours

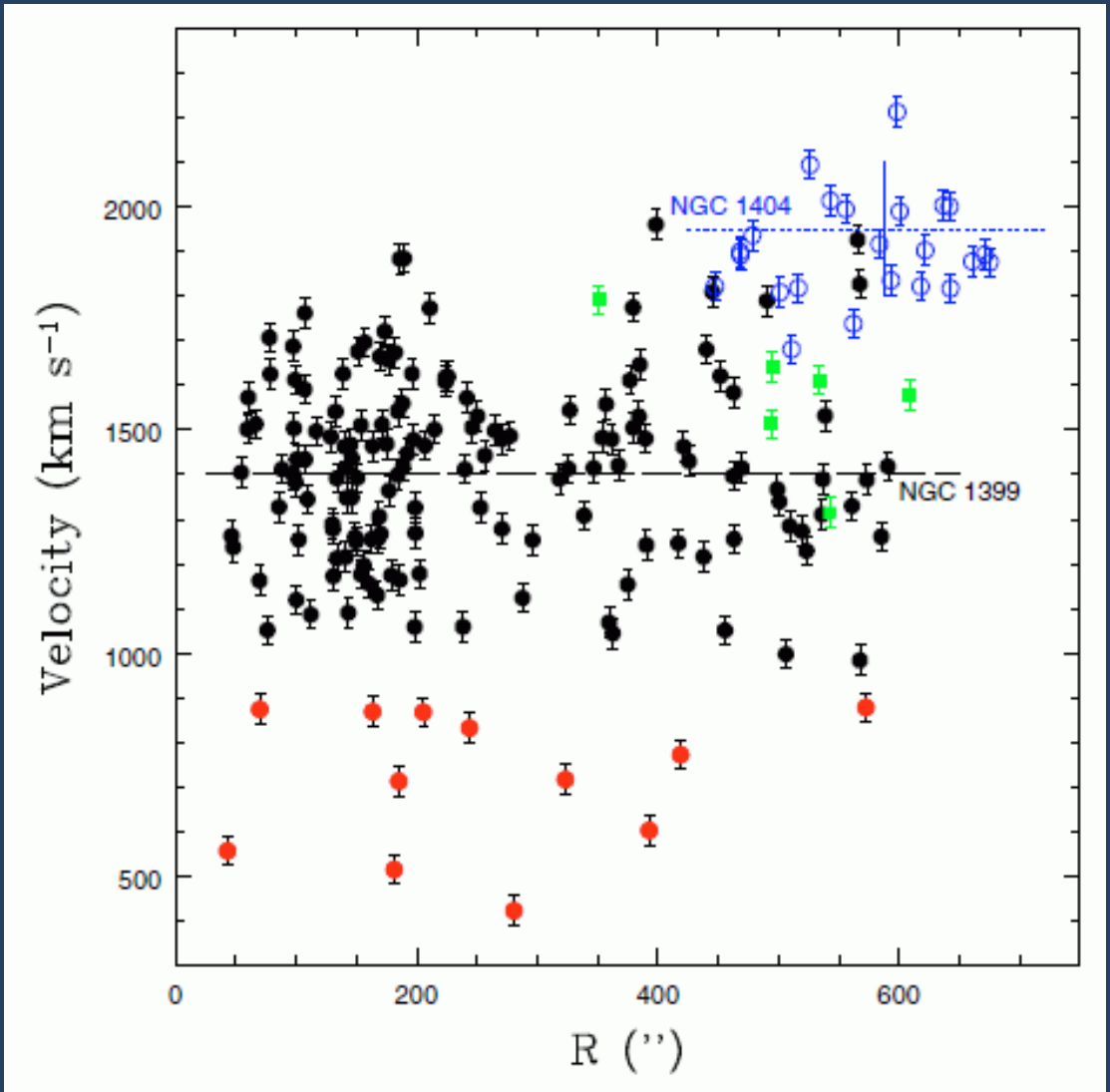
PNe around NGC 1399

Phase-space plot R-v_{los} shows three components:

- **NGC 1399**
- **NGC 1404**
- **Low-velocity outliers, at ~750±250 km/s**

McNeil et al. 2010

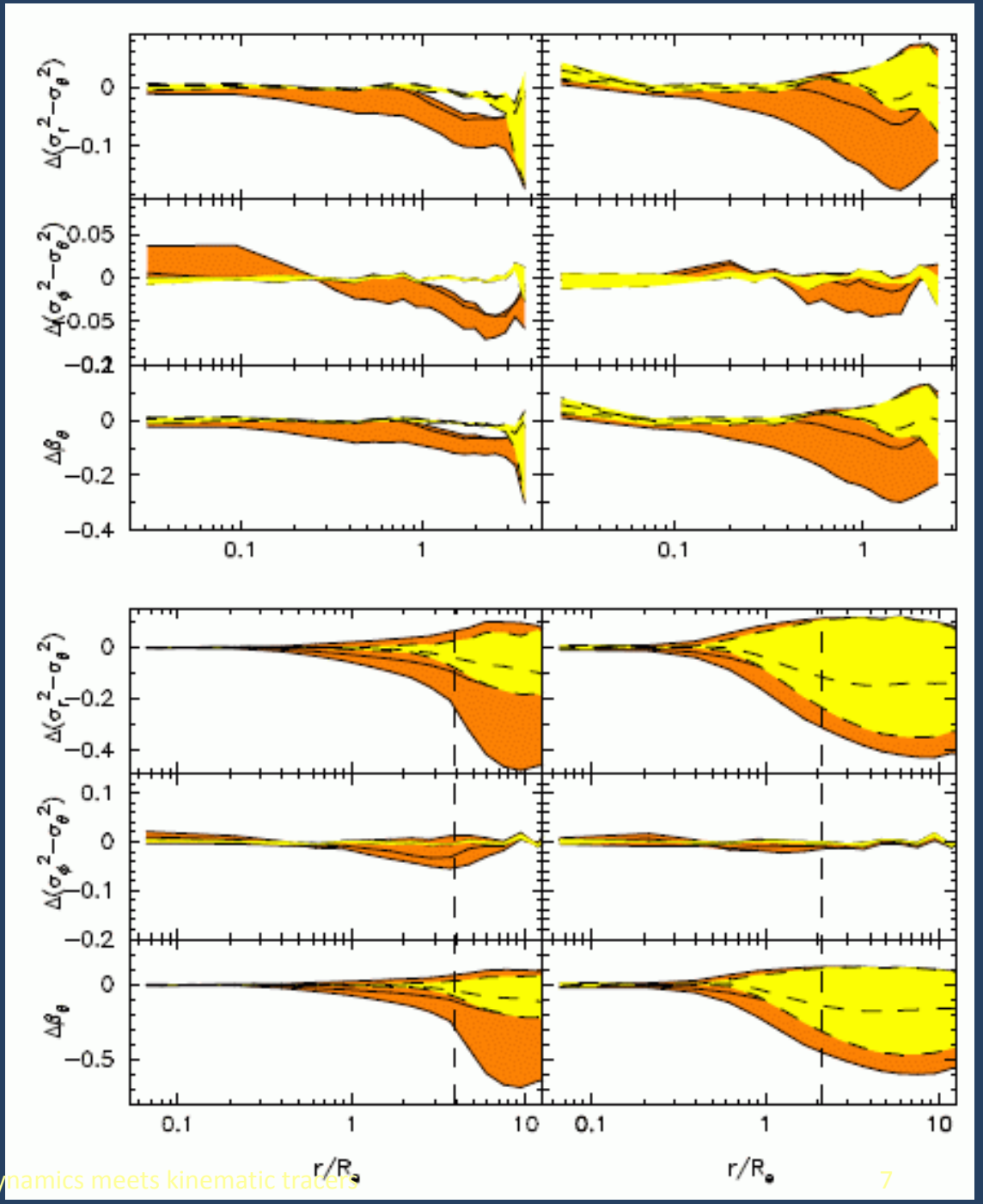
A fraction of large ellipticals have a second galaxy within a 10-20' field.



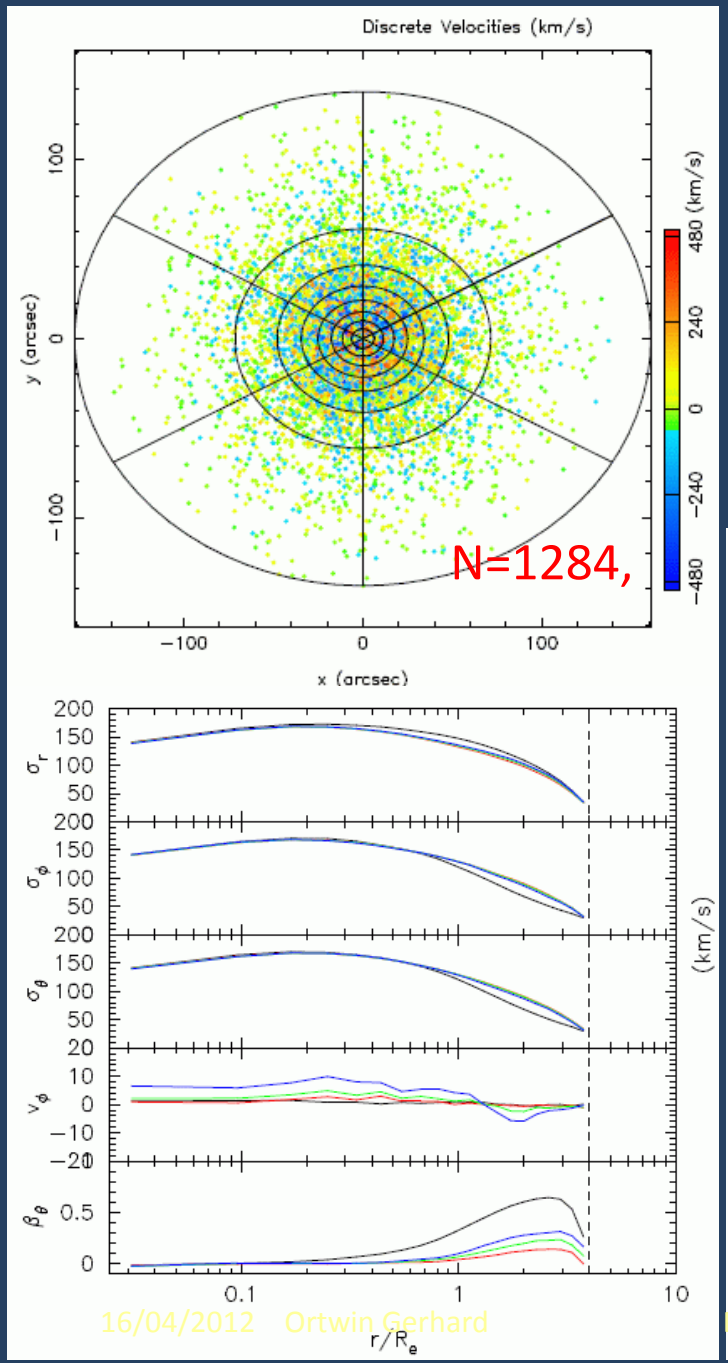
Effects of incomplete data

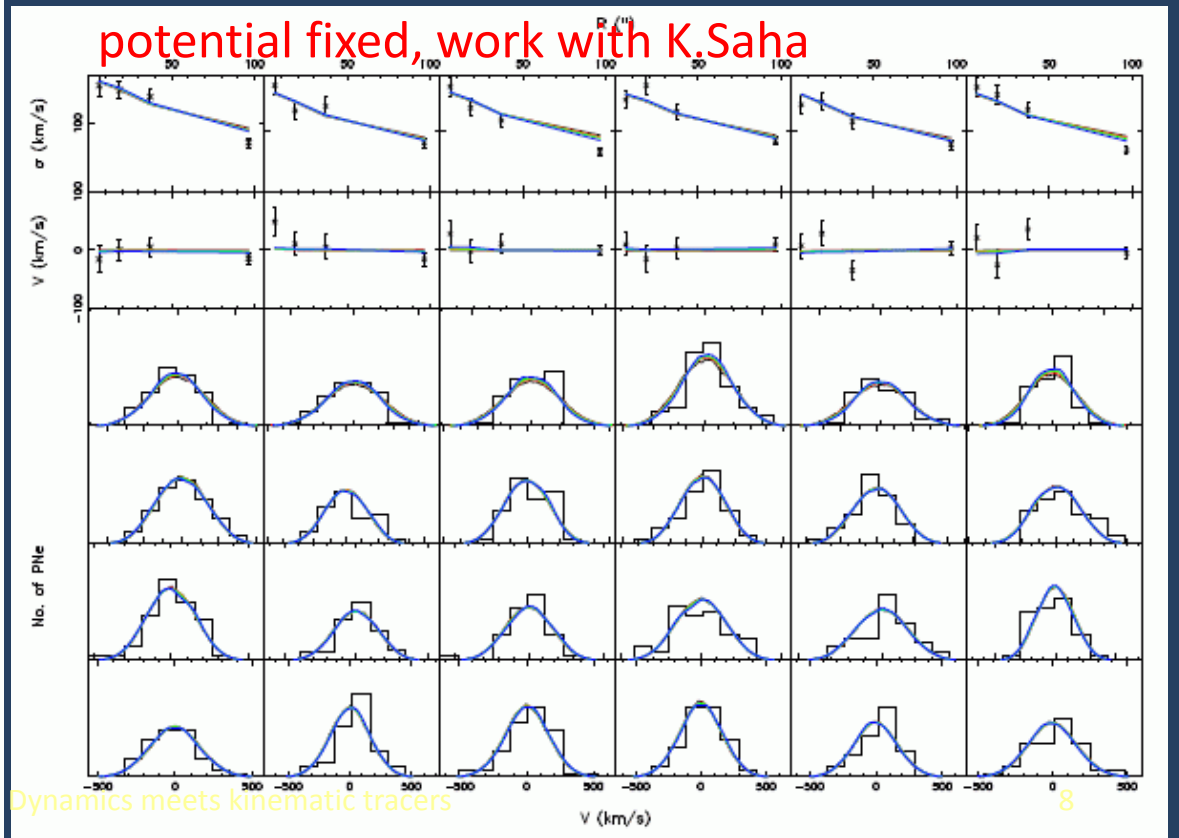
With spatially limited realistic data, uncertainties seen down to 1/3 limiting radius of the data

Morganti + OG ‘12

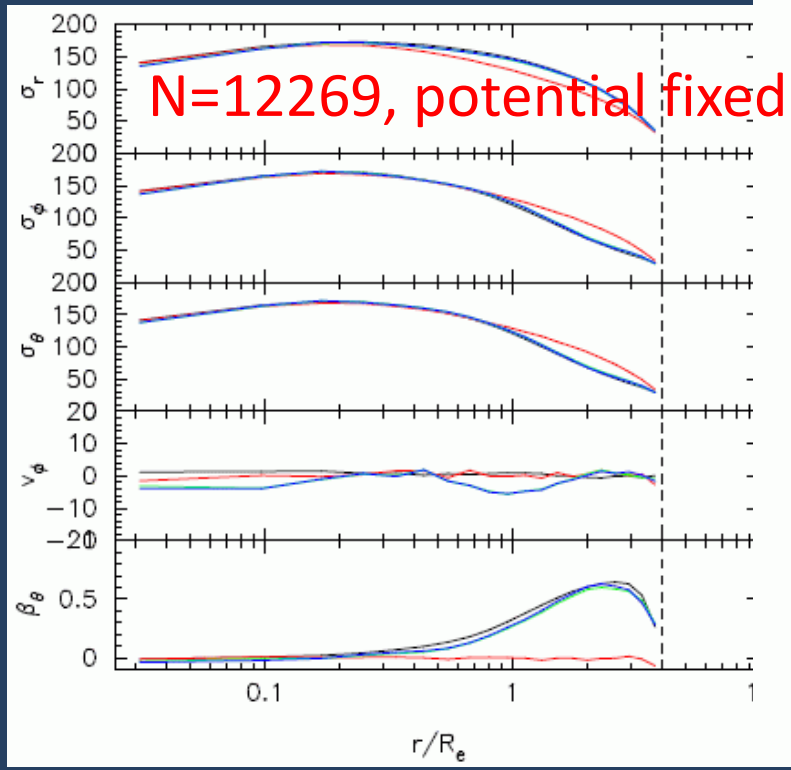


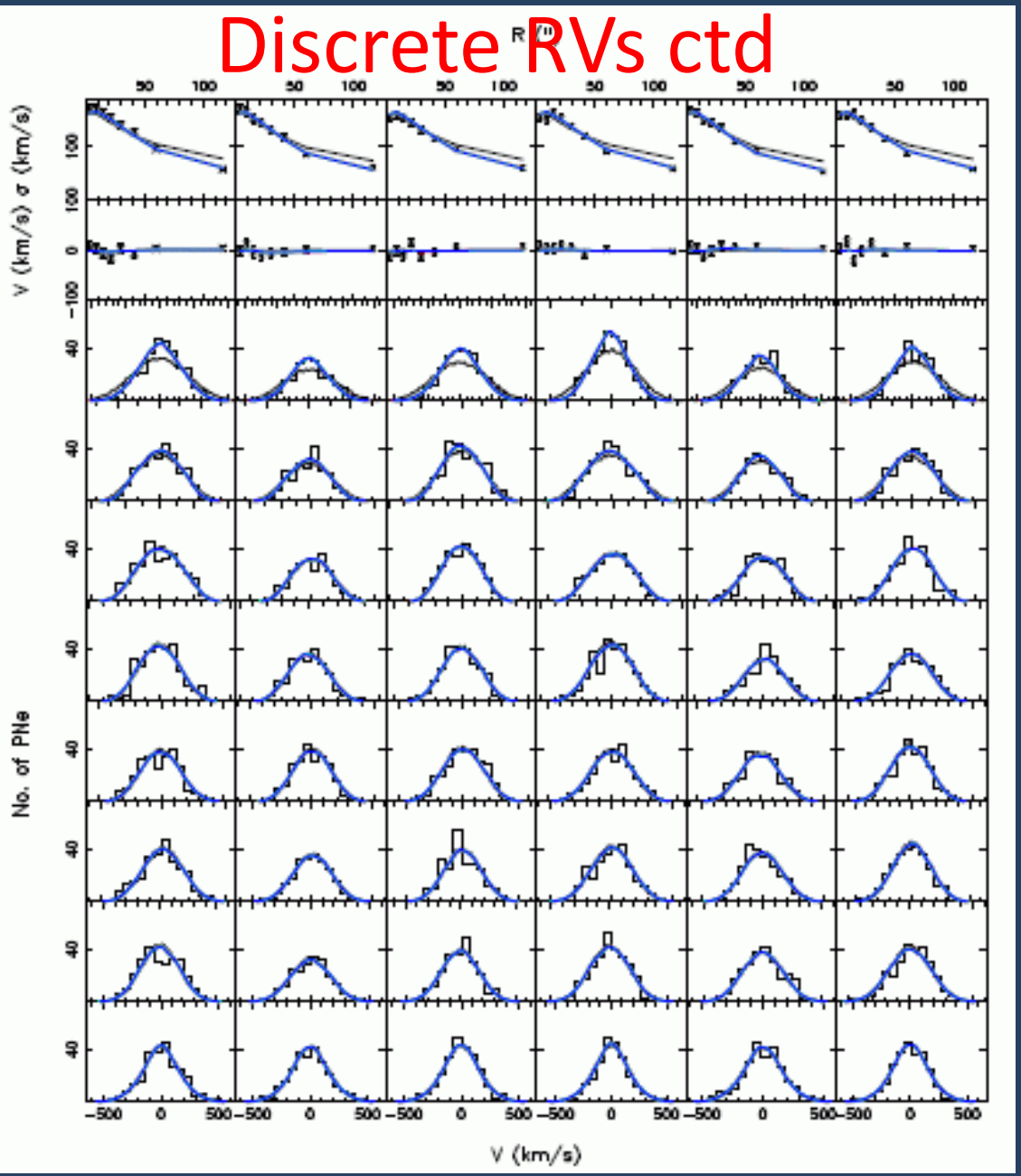
Simple test: recovering DF of a radially anisotropic Hernquist sphere from discrete RVs





Discrete RVs ctd





What is the best way to determine the gravitational potential?

- MW: Observing orbits – potential differences from phase-space measurements
- Modelling streams
- Virial arguments – masses (differences) for separate dSph populations
- Black hole masses - $\Delta\chi^2$ analysis – best when SIS resolved
- DM mass distributions from detailed kinematic data – or alternatives [cold gas rarely available, X-rays sometimes but have their own problems, lensing only for some galaxies]

Some dynamical modelling issues

- The newest data are the most interesting and the least well understood; need help from the observers
  - Incompleteness, selection functions, systematic errors, how to objectively recognize outliers?
  - 'Data self-calibration' ?
- When the obsvl constraints are limited, is a simple model enough? Yes, but beware biases.
- Model-data comparison: how to prevent outliers from ruining the likelihood?
- What is a practical way to marginalize over all possible DFs specified by 10^6 particles or 10^4 orbits?
- Wouldn't it be nice to marginalize over intrinsic shapes?

Should we set up series of test problems for comparing different modelling approaches?

- Simple equilibrium models first
  - Easy to generate pseudo data with NMAGIC models
  - Can do series of increasing complexity (spherical -> triaxial, w/wo DM or BH)

  Good to know the true answer. Real galaxy tests afterwards?
- Non-equilibrium models from simulations
  - Cosmological ETG models
  - Evolving disks
  - Tidally stirred dwarf galaxies
- We want to know that it all works but need to be efficient in finding out

Summary

- Dynamical models and ‘cosmological’ models both important
- What are the implications of assuming dynamical equilibrium when it is not strictly true?
- How much data do we need – this can be predicted!
- What is the best way to determine the gravitational potential of the Milky Way? Of dSphs? Of ETGs? New ideas always needed!
- What should be given in the observational papers to make it easier to understand systematics in the data? What information was missing in past papers?
- Simple models for limited data but beware biases
- How to include systematics and outliers in robust model-data comparison?
- How to marginalize over ALL DFs, shapes, … ?
- Test problems for different modelling approaches?