Rational debate leading to progress??

Natural philosophy

leading to

Experimental philosophy

"the astronomers" mosaic
Pompeii

Caveat emptor: good large data sets exist. But.
“Saving the appearances” and “race for discovery” are not the way to get optimal science from data.
Science verification means what it says.

Perhaps to move
 His laughter at their quaint opinions wide
 Hereafter, when they come to model heaven
And calculate the stars: how they will wield
The mighty frame: how build, unbuild, contrive
To save appearances.

Milton *Paradise Lost*
(this written after visiting Galileo)

Surveys – in a Gaia context

ESA's premier astrophysics mission of the decade

AstroNet Science Strategy → top priority

Gaia science is transformational – the first 3-D galaxy

- What complementary data are essential?

2-D	3-D	5-D	6-D	12+ D
position	parallax	proper motions	spectrum	Astrophysical parameters
Ultra-precision, over years	distance	Transverse velocities	Radial velocity + chemistry	Ages, histories, astrophysics

Stellar orbits, star formation history, origin of the elements, Galaxy assembly,....
Dark Matter, Cosmological initial conditions, fundamental physics, solar system(s)

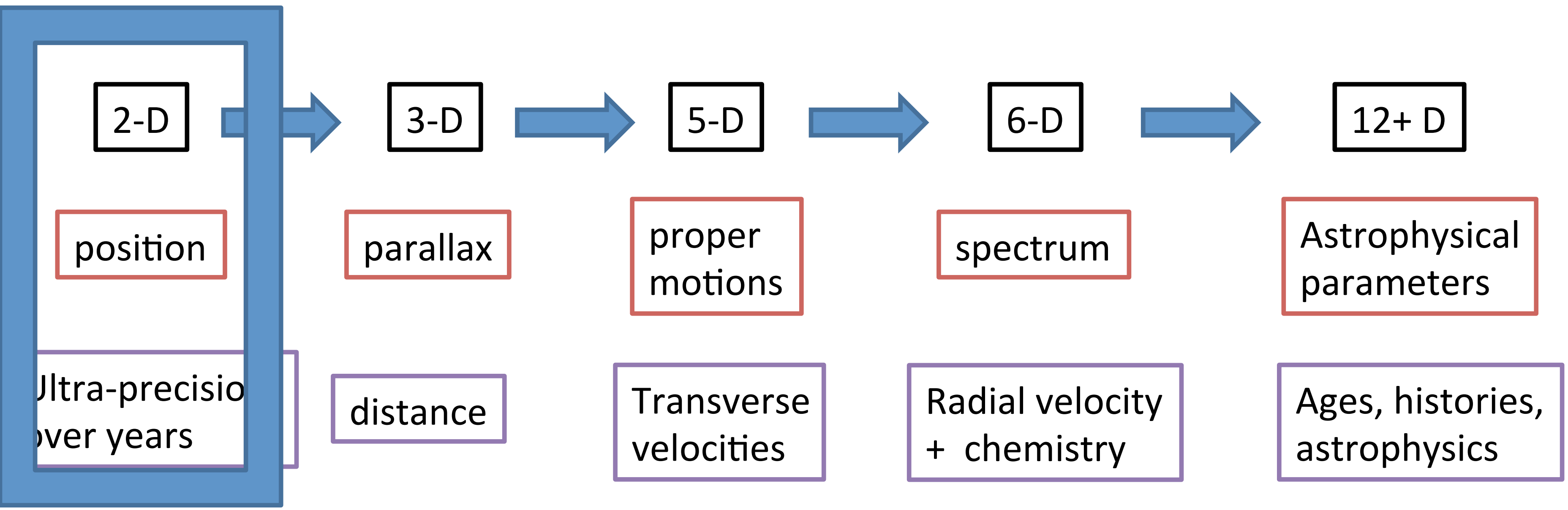
my view of Gaia

ESA's premier astrophysics mission of the decade

AstroNet Science Strategy➔ top priority

Gaia needs multi-colour optical+IR photometric surveys

➔ variability, complexity, extinction, non-stars!!!

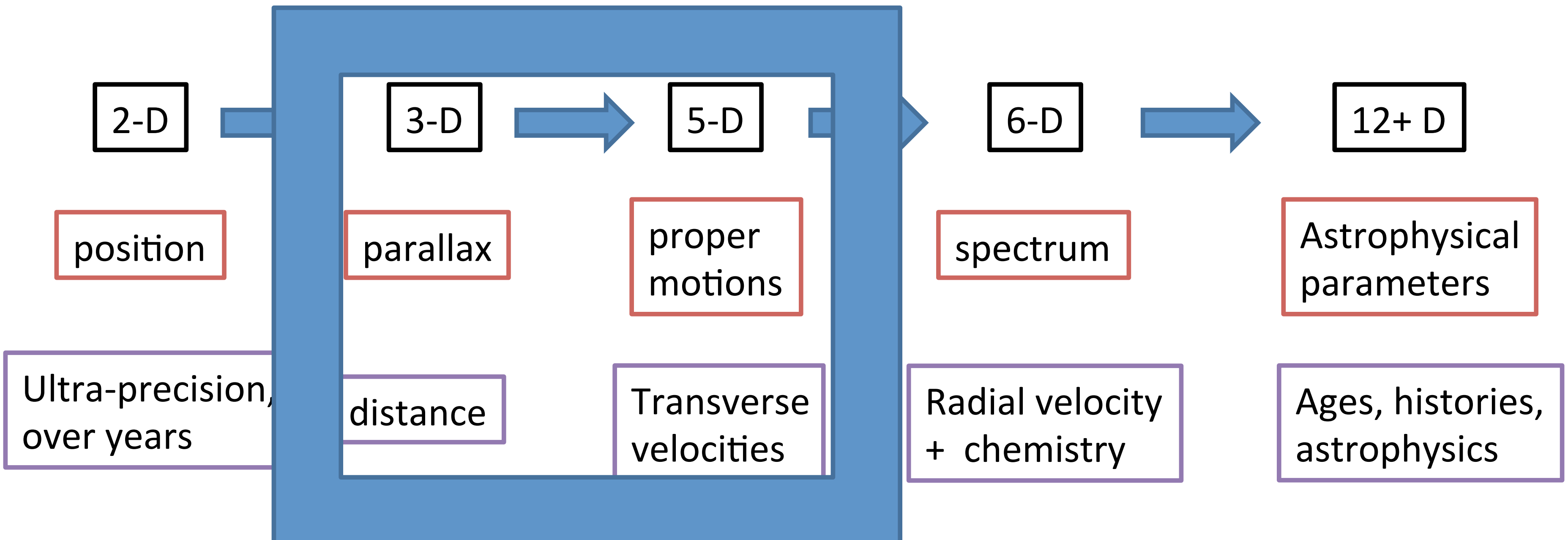


Stellar orbits, star formation history, origin of the elements, Galaxy assembly,....
Dark Matter, Cosmological initial conditions, fundamental physics, solar system(s)

my view of Gaia

ESA's premier astrophysics mission of the decade
AstroNet Science Strategy ➔ top priority

Gaia science is transformational – the first 3-D galaxy
<u>precision distances and motions for 1 billion stars</u>



Stellar orbits, star formation history, origin of the elements, Galaxy assembly,....
Dark Matter, Cosmological initial conditions, fundamental physics, solar system(s)

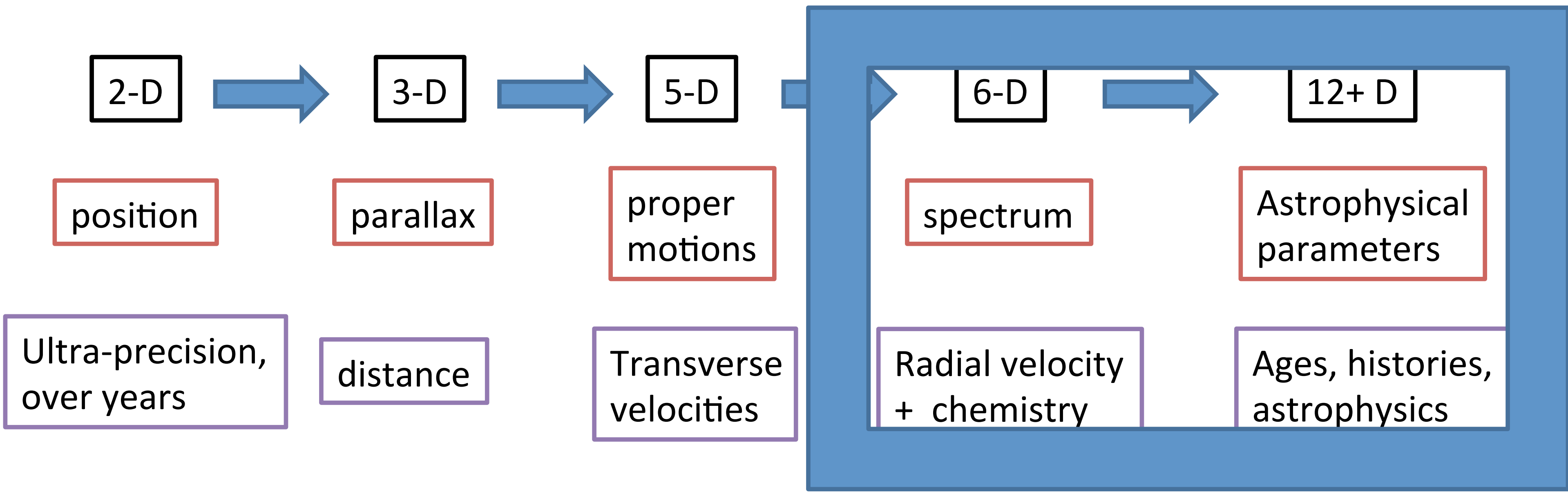
my view of Gaia

ESA's premier astrophysics mission of the decade

AstroNet Science Strategy➔ top priority

Gaia science needs spectra – lo-res RVs + [M/H]

<u>Hi-res ➔ full astrophysical analyses</u>



Stellar orbits, star formation history, origin of the elements, Galaxy assembly,....
Dark Matter, Cosmological initial conditions, fundamental physics, solar system(s)

The value of extra information:

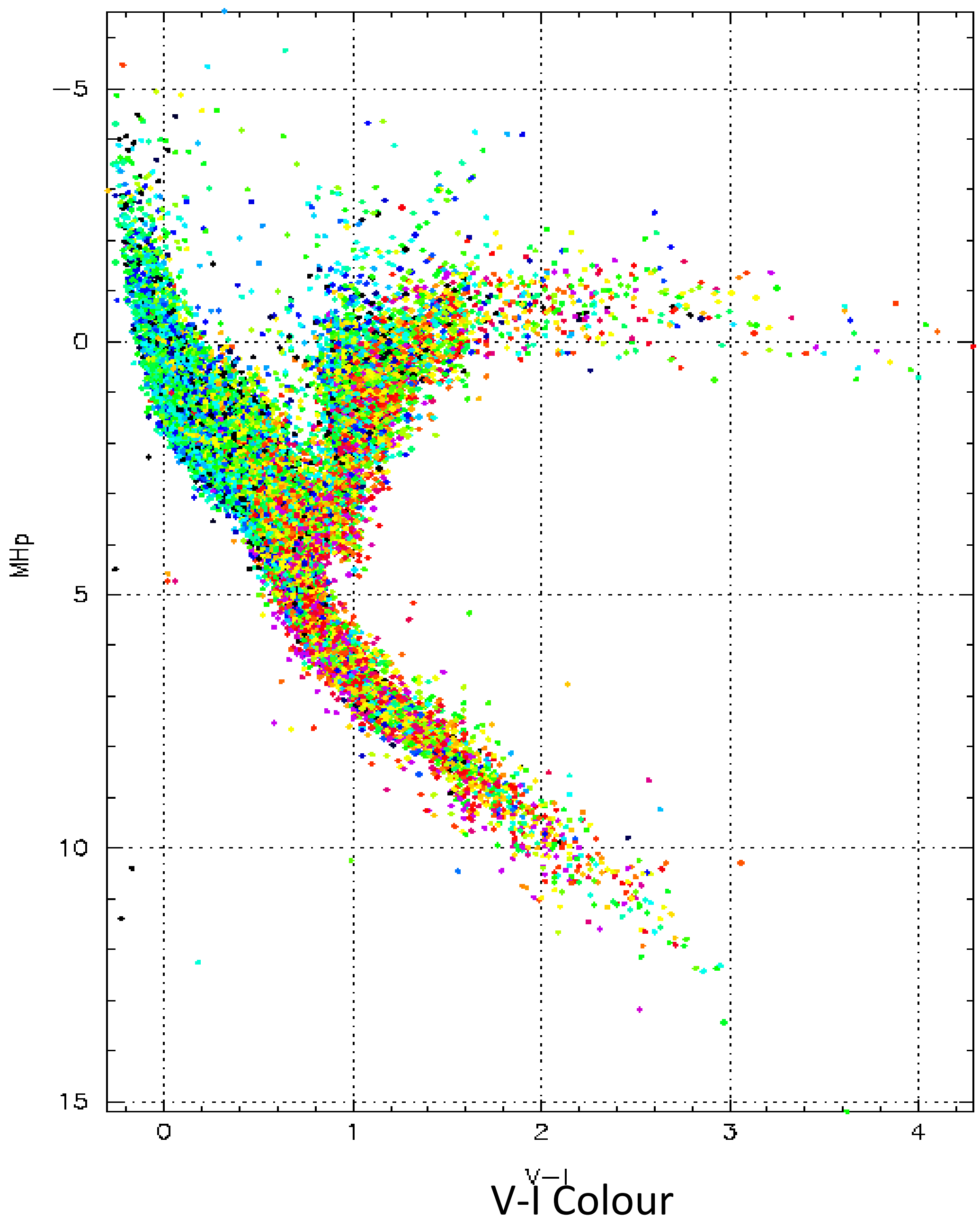
This is the Hipparcos HRD

Colour code is proper motion:
Blue=small, red=large.

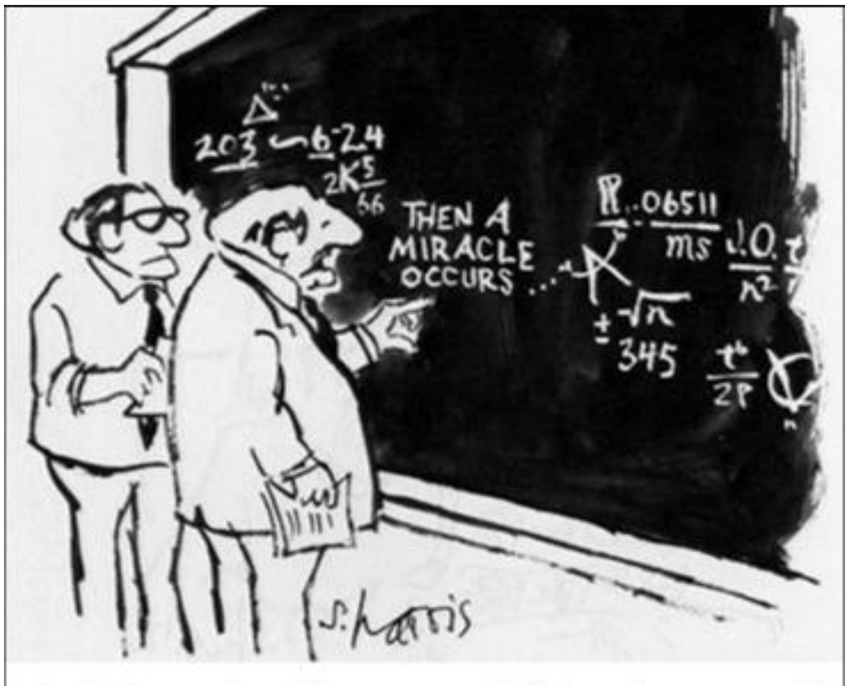
The Galactic age-velocity relation is immediately obvious.

Gaia-ESO will add elemental abundances and precise radial velocity

With 2-3-4 families of elements, (and sub-giant ages with Gaia) this increases dimensionality and adds statistical weight.

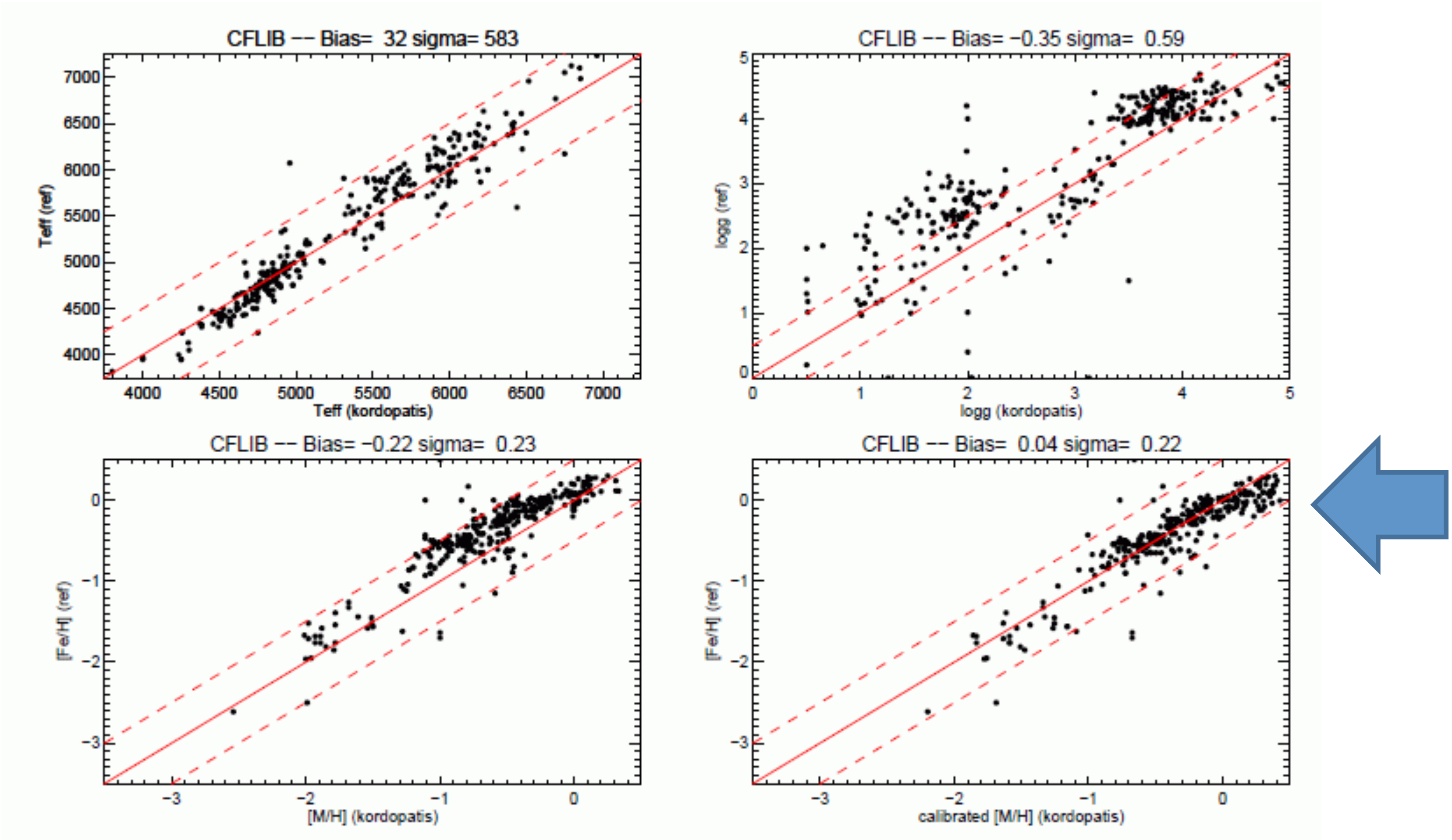


A survey is not a black box.
All data need sanity-checking: discovering the new is important, but the new is usually wrong



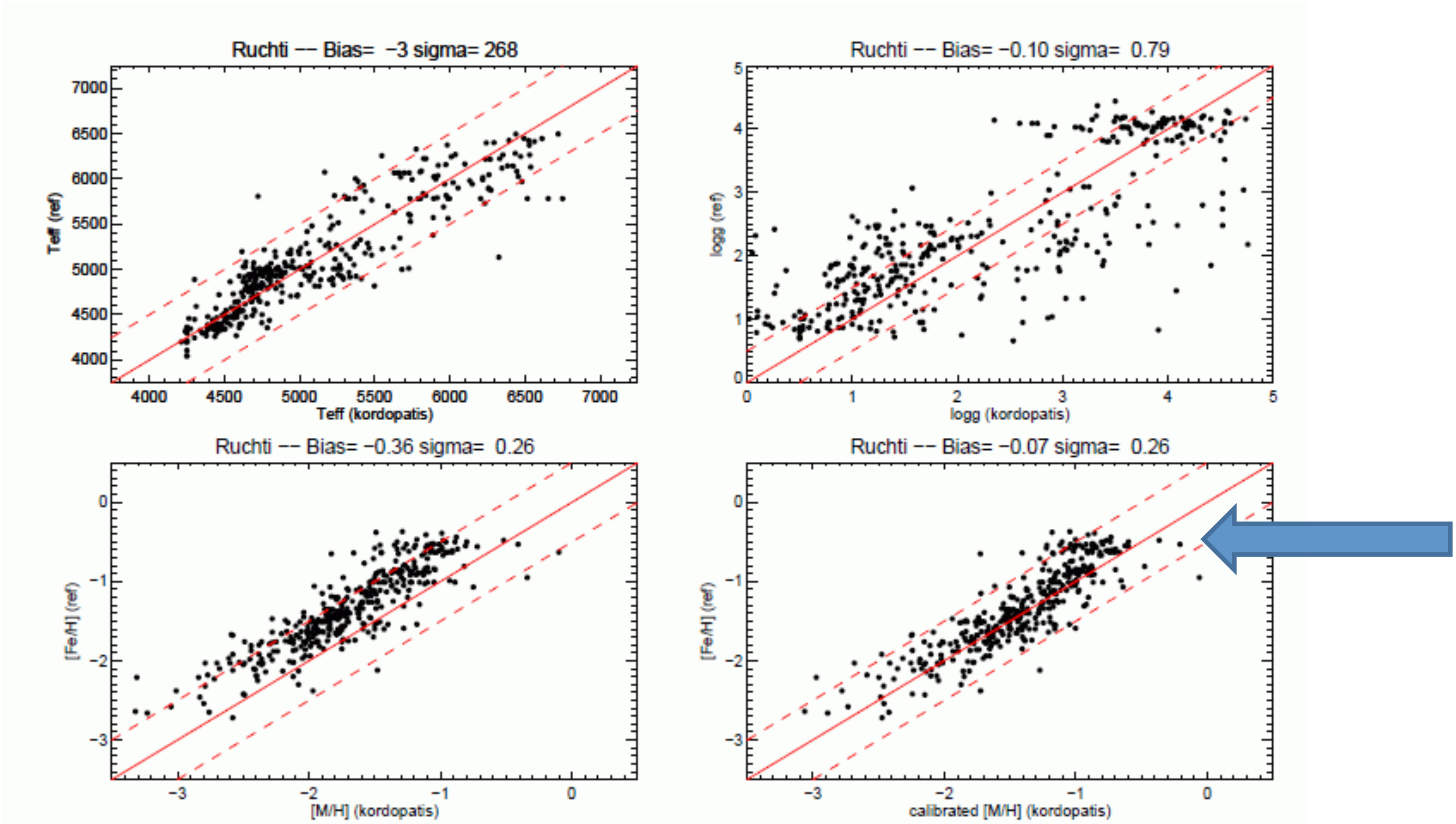
"I think you should be more explicit here in step two."

all data need calibration
a RAVE example



Empirical calibration – works well ONLY if “standards” cover parameter space

all data need calibration
a RAVE example



here the systematics in the dwarfs are probably in the literature data

- Here's my explanation of the [Mg/Fe] difference between the 2010 paper
- and the current (2012) value, beginning with an extract from the table
- ____
-
- ___ All lines Blue & Red ________Only lines redder than 4800A___
- (see Tab 2 ApJ, 711, 350)
- log(eps) s.e. Nlines log(eps) s.e. Nlines Delta log(eps)
- ____
-

	All lines Blue & Red: log(eps)	s.e.	Nlines	Only lines redder than 4800A: log(eps)	s.e.	Nlines	Delta log(eps)
Mg I	4.34	0.10	8	4.20	0.02	3	0.14
Fe I	3.79	0.02	81	3.84	0.03	35	-0.05

- ____
- The relevant data by our publication year are:

Year	2010	2012
logeps(Mg)	4.34	4.20
logeps(Fe)	3.79	3.84
logeps(Mg)sun	7.53*	7.60#
logeps(Fe)sun	7.45*	7.50#

- * = Asplund (2005); # = Asplund (2009)
- ____
- Then
- [Mg/Fe] = (logeps(Mg)-logeps(Mg)sun) - (logeps(Fe)-logeps(Fe)sun)
- In 2010 we have
- [Mg/Fe] = (4.34-7.53) - (3.79-7.45) = 0.47
- and in 2012
- [Mg/Fe] = (4.20-7.60) - (3.84-7.50) = 0.26

All data must be calibrated –
that means systematics, and changes,
which need careful consideration
This from Venn etal ApJ in press

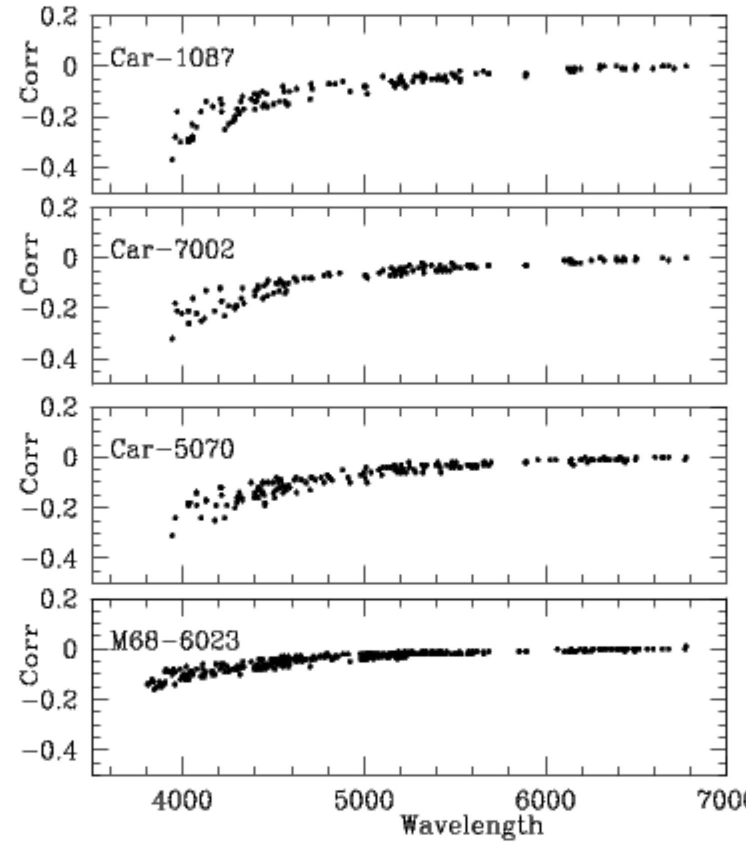


Fig. 5.— A comparson of the line abundance *corrections* from MOOG-SCAT for one of the M68 standard star and the three most metal-poor stars in Carina. The y-label "Corr" = MOOG-SCAT − MOOG.

Metallicity calibration involves the Solar value – changing!!! And data selection: hi/lo SNR
Systematic errors rarely known or quoted, but can be relatively large.

New results are rarely the only relevant information – treating the LHS as the only data wastes a valuable reliable prior

Sample size vs precision trade

But note the "signal" is barely resolved – implies care with SNR, sample cuts, ...

THE ASTROPHYSICAL JOURNAL, 738:187 (17pp), 2011 September 10

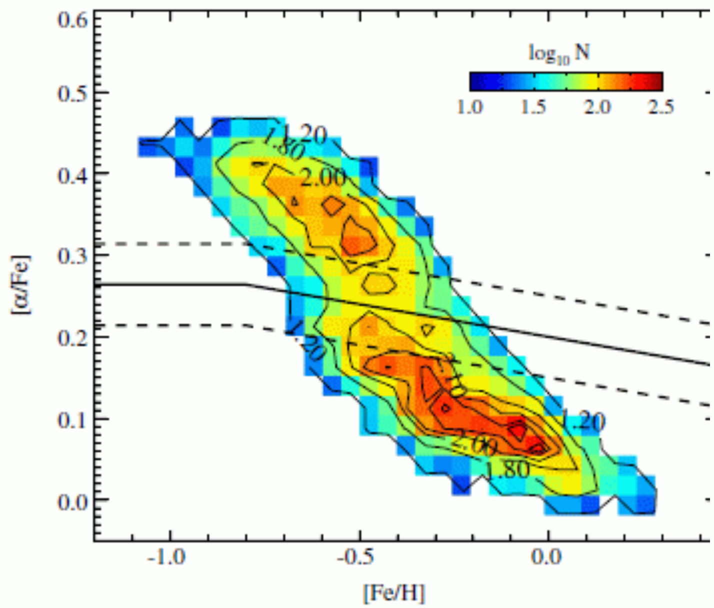


Figure 2. Distribution of logarithmic number densities, in the [α/Fe] vs. [Fe/I
plane, overplotted with equidensity contours. Each bin is 0.025 dex in [α/F
by 0.05 dex in [Fe/H] and is occupied by a minimum of 20 stars. The medi
occupancy is 70 stars. The solid line is the fiducial for division into like
thin- and thick-disk populations; the dashed lines located ±0.05 dex in [α/F
on either side of the solid line indicate the adopted dividing points for the hig
[α/Fe] (upper-dashed) and low-[α/Fe] (lower-dashed) stars in our sample.

Nearby stars – V 2913

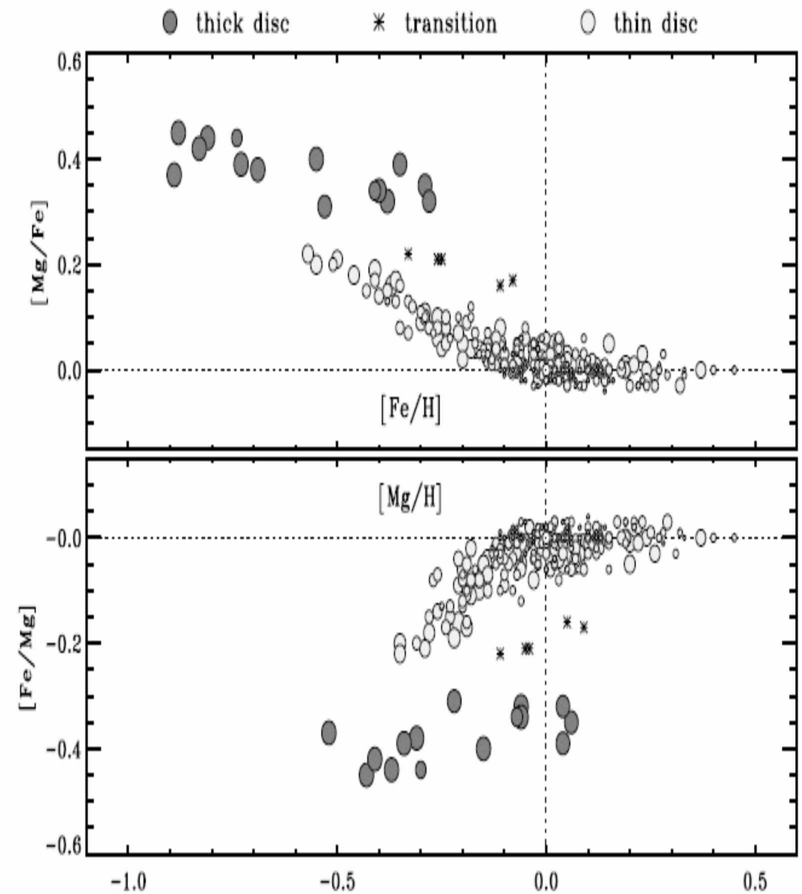
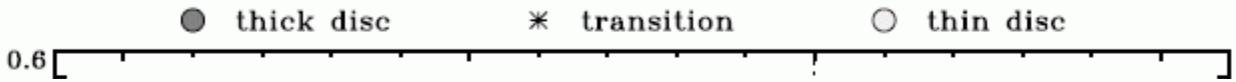


Figure 15. The local, volume-complete perspective on the magnesium and iron abundances of 271 F-, G- and K-type stars. Upper panel: [Mg/Fe] versus [Fe/H]; lower panel: the same data, but with the α-chain element magnesium as reference. Circle diameters are in proportion to the stellar age estimates. This chemical map portrays the imprint of a huge star formation gap that subdivides the extremely old ($\tau \geq 12$ Gyr) thick-disc stars in a fairly flat abundance distribution from the much younger and well-displaced thin-disc stars ($\tau \leq 8$ Gyr) in a curved string-of-pearl-like distribution. Only five objects dubbed as transition stars display intermediate characteristics.



Reddy and Fuhrmann studies in excellent agreement – and with very many more

Reddy etal sample
Metal-rich thick disk still an unknown

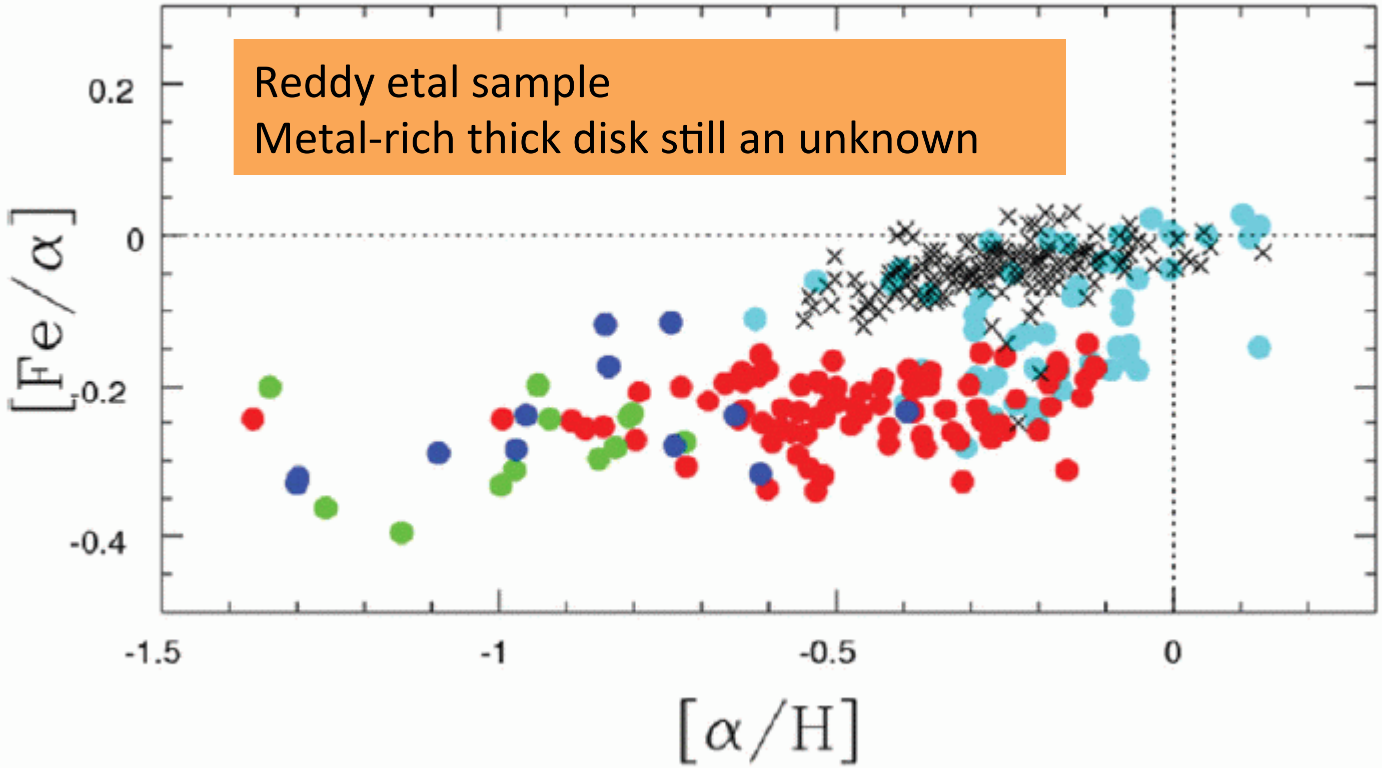


Figure 2. Abundances ratio [Fe/α] versus [α/H] for samples of the thick disk, the thin disk and the halo stars. Colour and symbol coding are same as those for in the Figure 1.

Fuhrmann MNRAS 414 2893 (2011)

Consecutive Segue analyses – the data are converging to some “calibration”

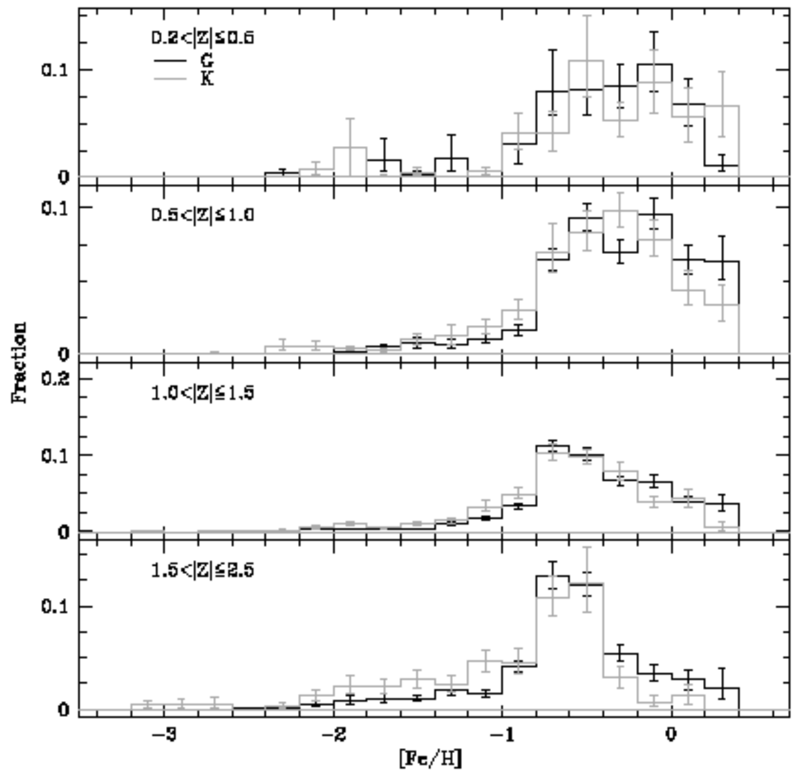


Fig. 16.— The volume-complete weighted MDF for the G (black) and K (gray) dwarfs at a range of $|Z|$, where $|Z|$ is the current distance from the plane in kpc. The uncertainty in each bin was determined from our bootstrap analysis over 500 iterations. These distributions are listed in Table 7 and 8.

There are large numbers of super-solar abundance stars here, even far from the Plane...

Is this consistent with local kinematics?

1112.2214
Schlesinger etal

Kinematics can be dodgy, too

The Astrophysical Journal, 747:101 (13pp), 2012 March 10 Moni Bidin, Carraro, & Méndez

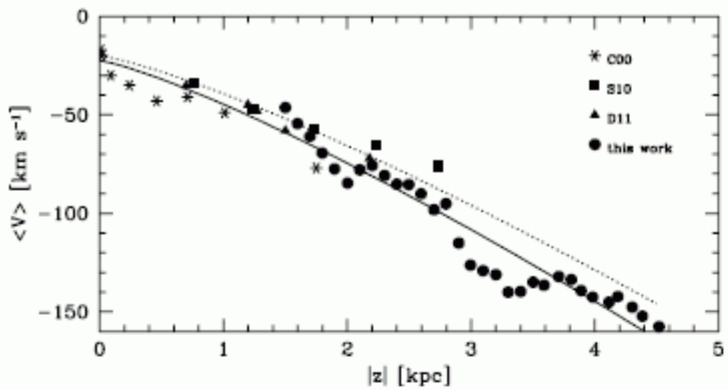


Figure 5. Rotational velocity of thick disk stars as a function of distance from the plane. Full dots: our work; asterisks: Chiba & Beers (2000, C00); squares: Spagna et al. (2010, S10); triangles: Casetti-Dinescu et al. (2011, D11). The dotted curve indicates the power-law solution proposed by Bond et al. (2010); the thick curve is the analogous relation obtained from the fit of the plotted data points.

(2010), because they do not distinguish between different disk components, thus finding steeper gradients as a result of the mix of thin and thick disk stars. Caution must also be taken when comparing the results obtained in different ranges of $|Z|$, because the underlying trend of the dispersions is not necessarily linear and the gradient can assume different values. For example, the models of Girard et al. (2006) indicate that the vertical profile should be progressively flatter at increasing $|Z|$.

The linear fit of the trends with $|Z|$ yields

$$\sigma_U(Z) = (82.9 \pm 3.2) + (6.3 \pm 1.1) \cdot (|Z| - 2.5)\,\mathrm{km\,s^{-1}}, \quad (3)$$

$$\sigma_V(Z) = (62.2 \pm 3.1) + (4.1 \pm 1.0) \cdot (|Z| - 2.5)\,\mathrm{km\,s^{-1}}, \quad (4)$$

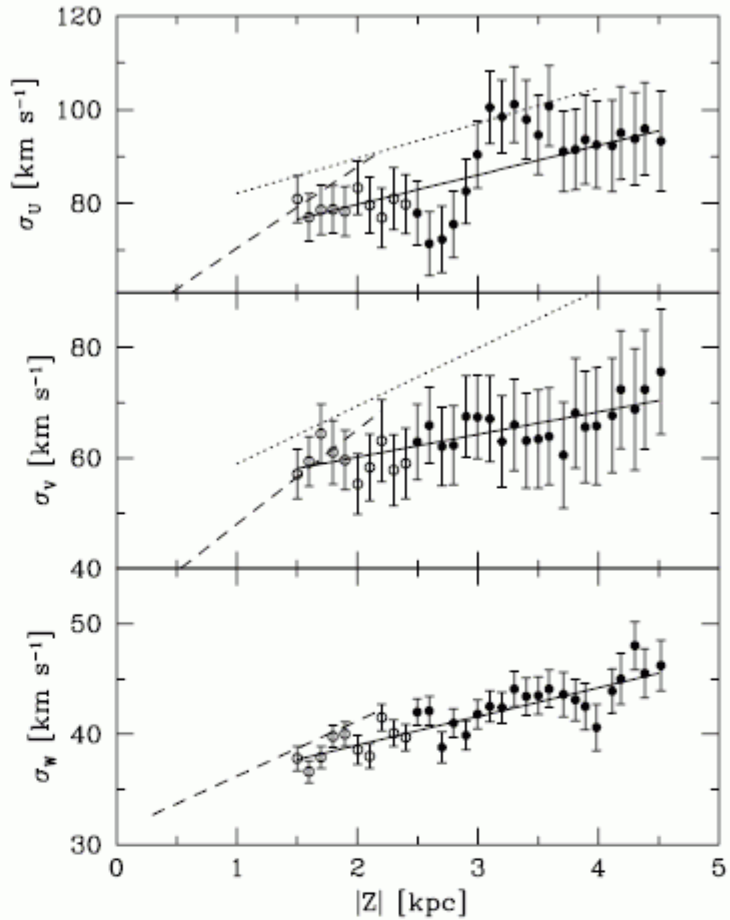


Figure 6. Velocity dispersion as a function of distance from the plane (from top to bottom: radial, rotational, and vertical velocity dispersion). The thick curve indicates the linear fit of the data given in Equations (3)–(5). The empty dots and dashed and dotted lines are as in Figure 4.

Inconsistent results require thought

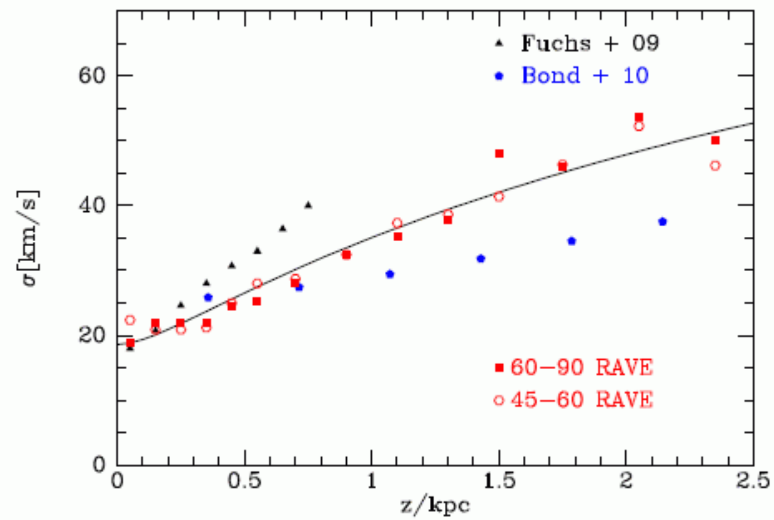


Figure 2. The variaton of σ_z with distance from the Galactic plane. The triangles a filled circles show conflicting determinations from the SDSS survey. The full curve the model of [2]. The red squares and circles show the values subsequently determin from the RAVE survey by [8].

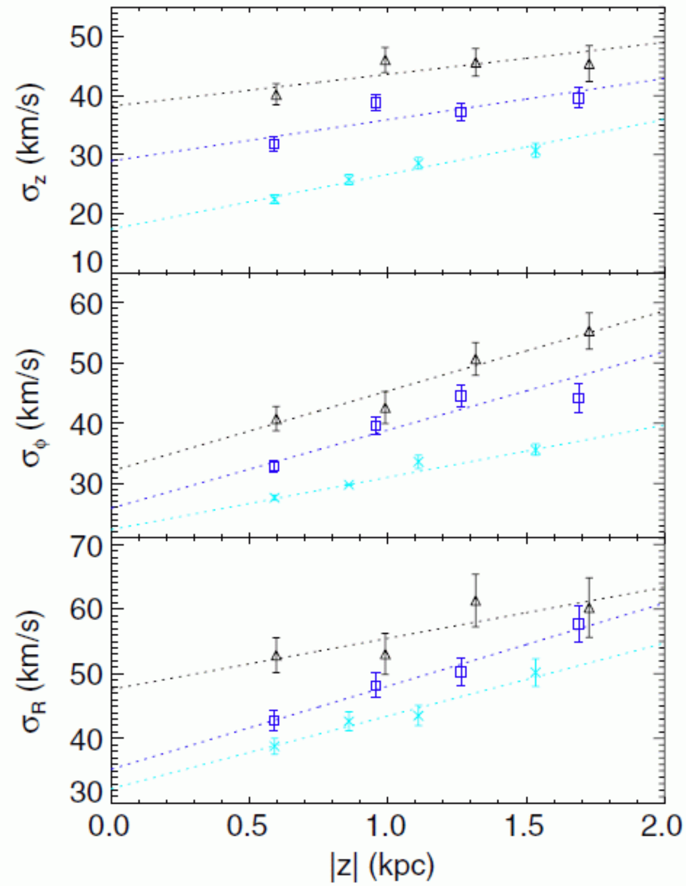
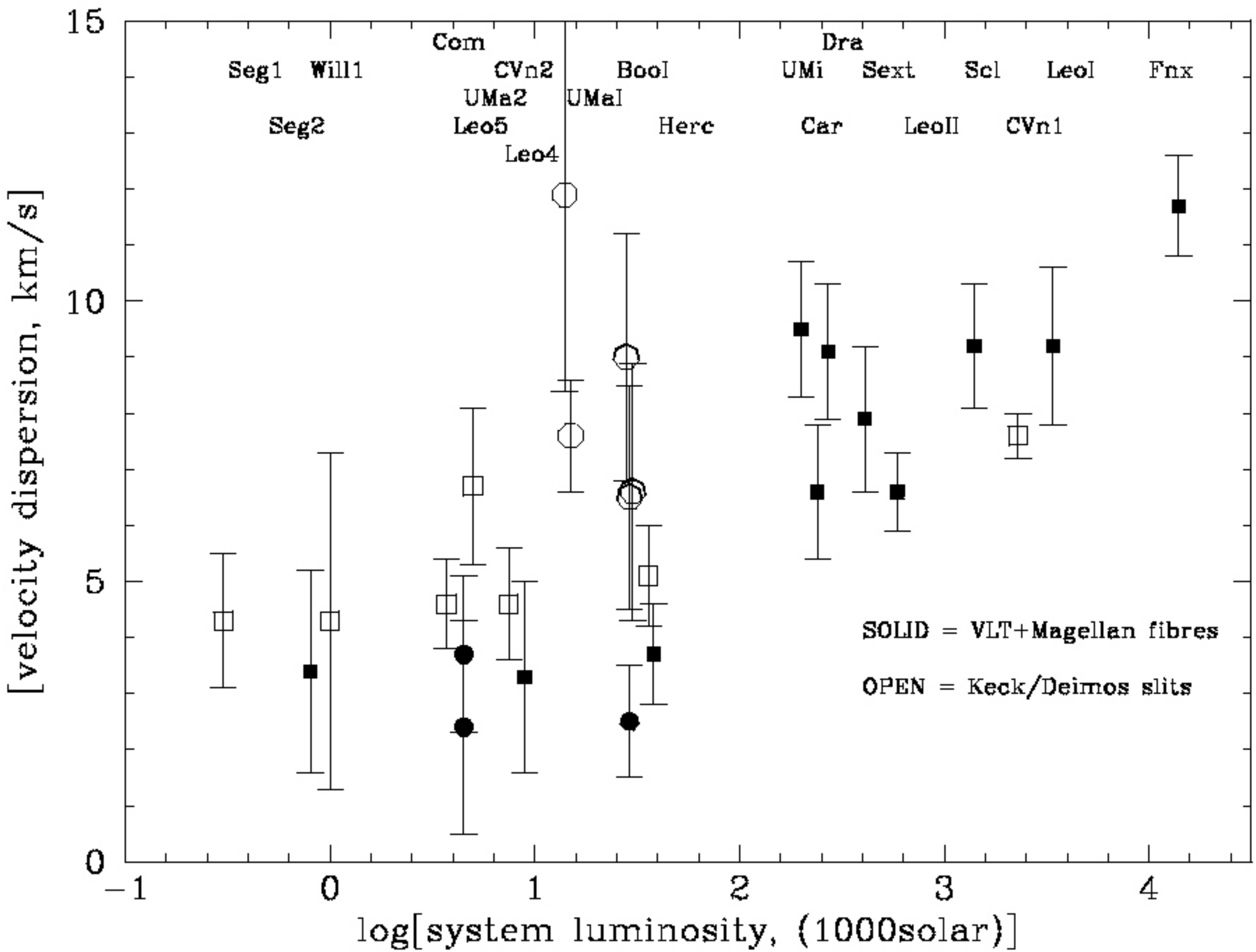


Figure 2. Dispersions σ_R, σ_z, and σ_ϕ as functions of z and metallicity. The triangles, squares and crosses correspond to metallicity ranges $-1.5 \leqslant$ [Fe/H] $\leqslant -0.8$, $-0.8 \leqslant$ [Fe/H] $\leqslant -0.5$, and $-0.5 \leqslant$ [Fe/H] $\leqslant 0.5$, respectively.


Seg1
Will1
Seg2
Com
CVn2
UMa2
Leo5
Leo4
UMaI
BooI
Herc
Dra
UMi
Car
Sext
LeoII
Scl
CVn1
LeoI
Fnx
SOLID = VLT+Magellan fibres
OPEN = Keck/Deimos slits
[velocity dispersion, km/s]
log[system luminosity, (1000solar)]
0
5
10
15
−1
0
1
2
3
4

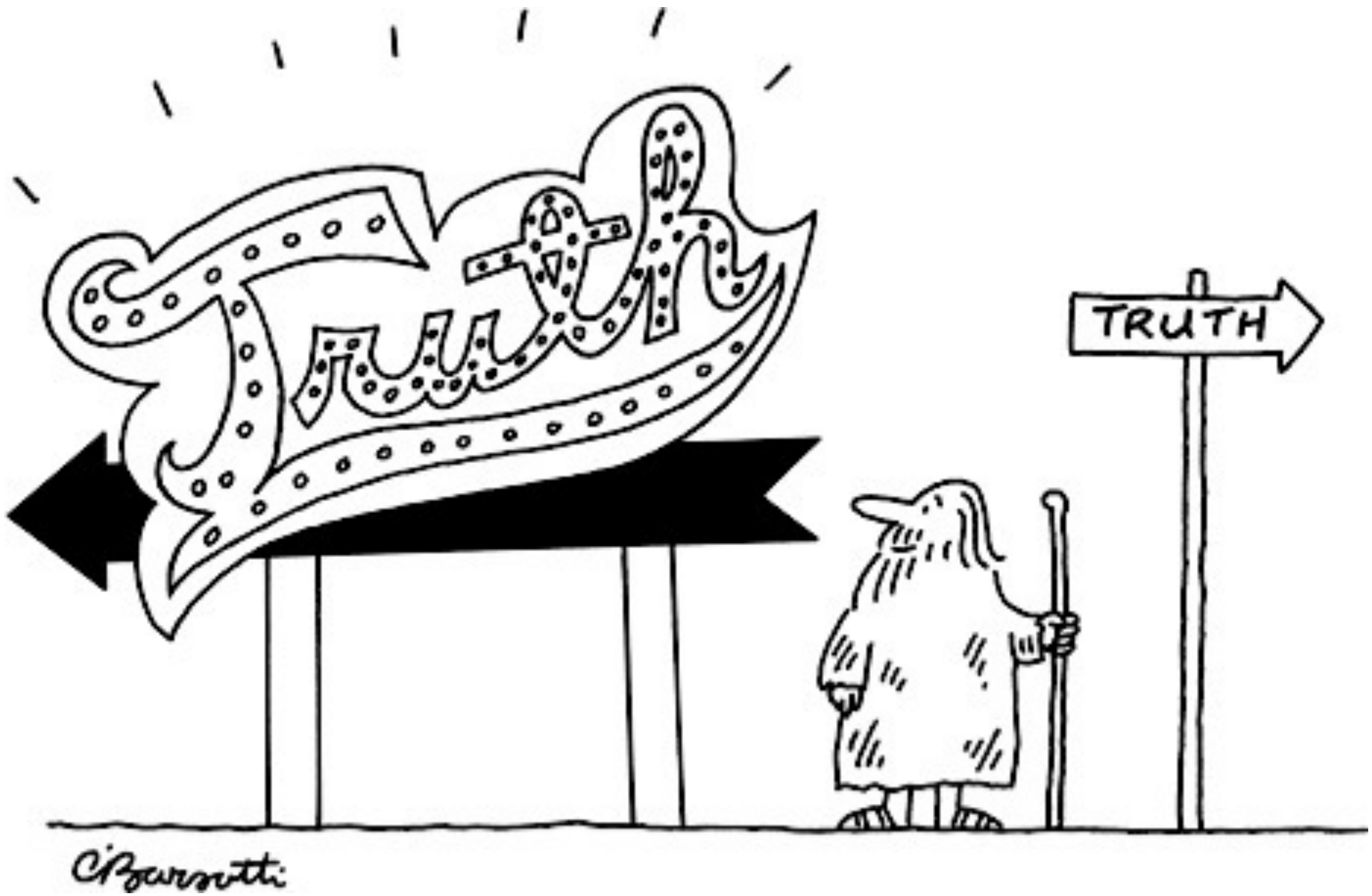
Imperfect data!!

- Next you'll be telling me our political leaders are imperfect!!

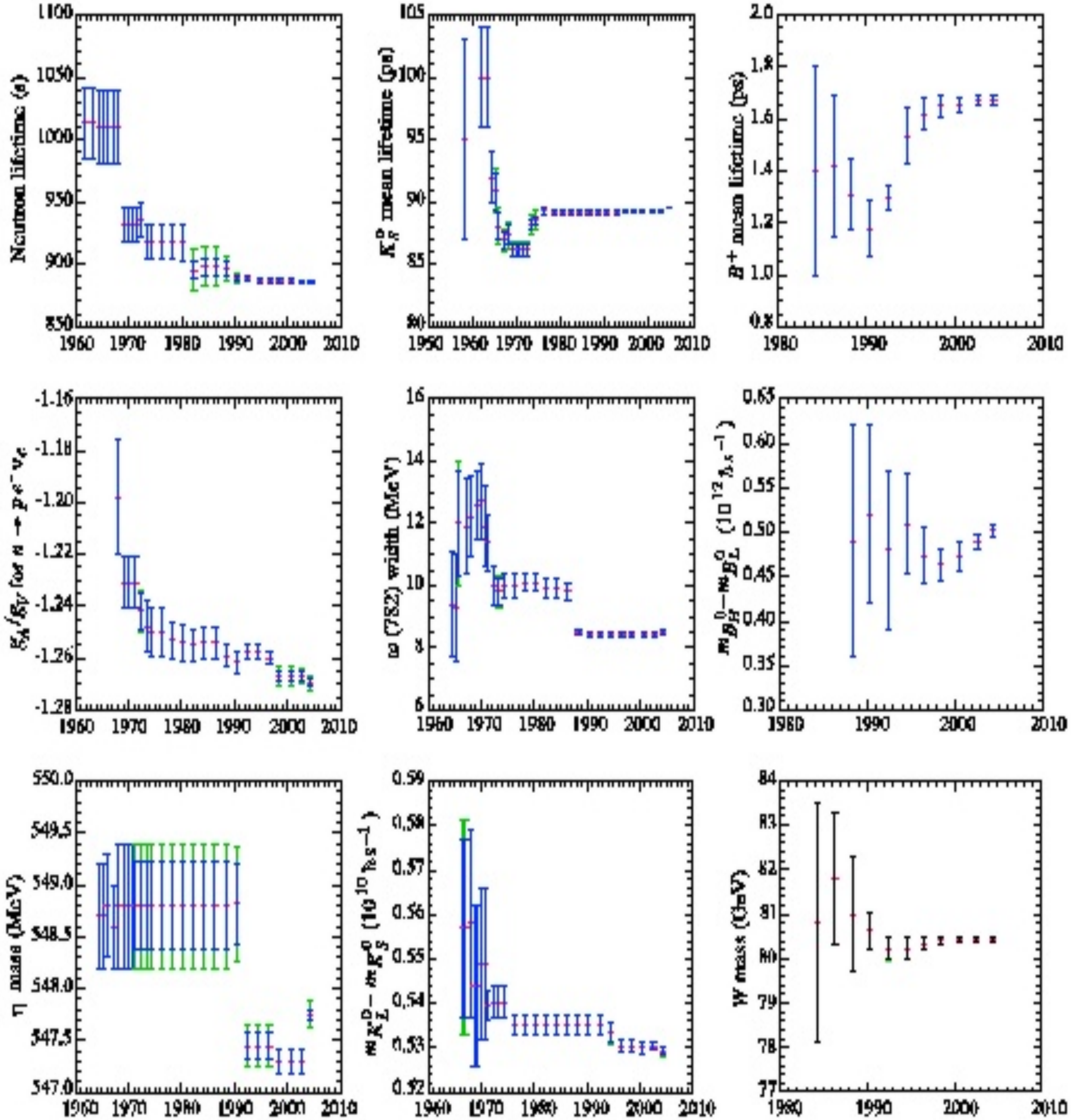
- Calibrating surveys is a Herculean/Sisyphean challenge
- Science verification is the most reliable method
- "Science Verification" means finding the faults in the data!
- ➔ new results need to be examined with due care and scepticism

- Then models tested, discovery made.

Choose your survey, them examine it closely...



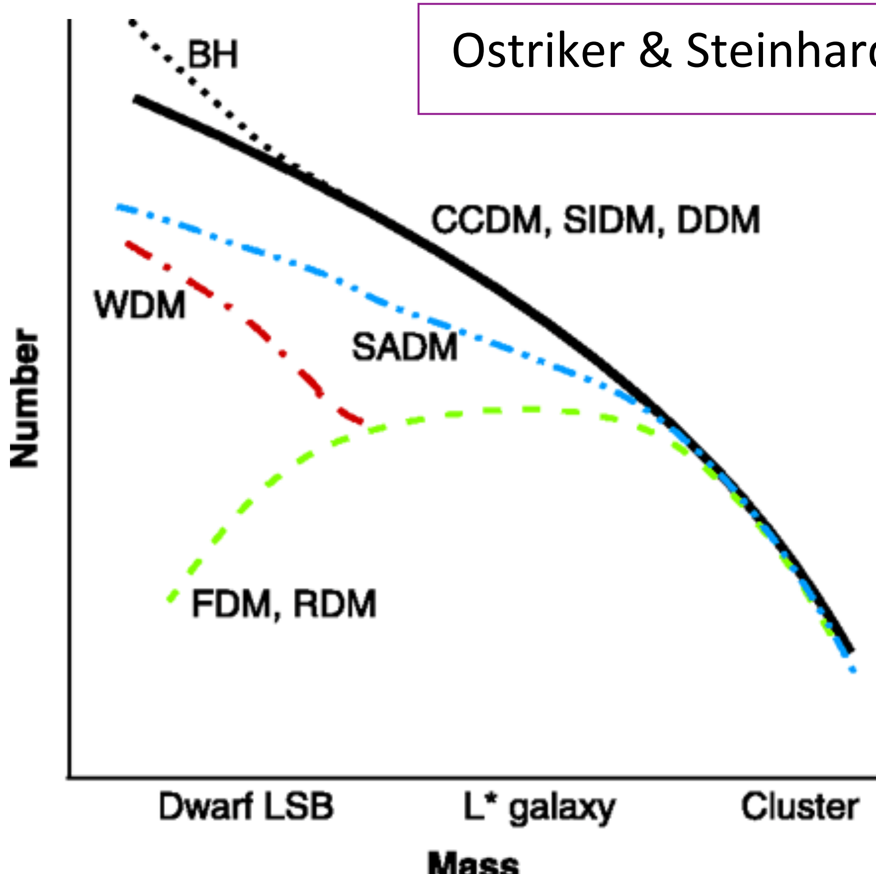
Consistency does not imply correctness & vice versa

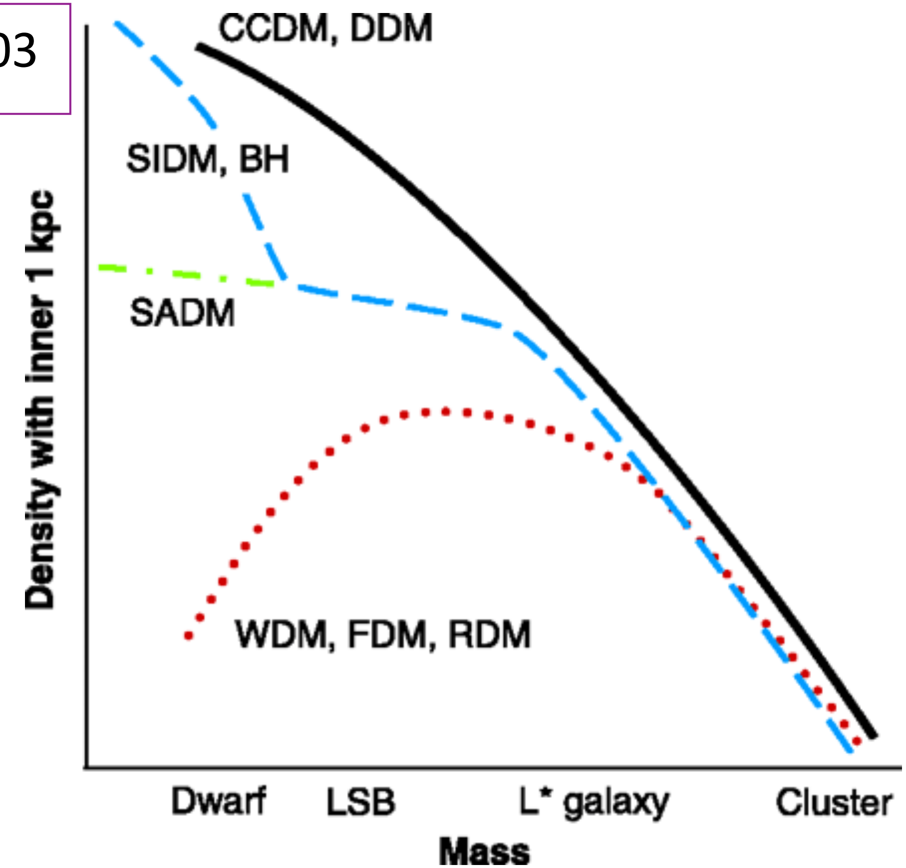


particle data properties vs time

ΛCDM cosmology extremely successful on large scales. Galaxies are the scales on which one must see the nature of dark matter & galaxy formation astrophysics

Ostriker & Steinhardt 03

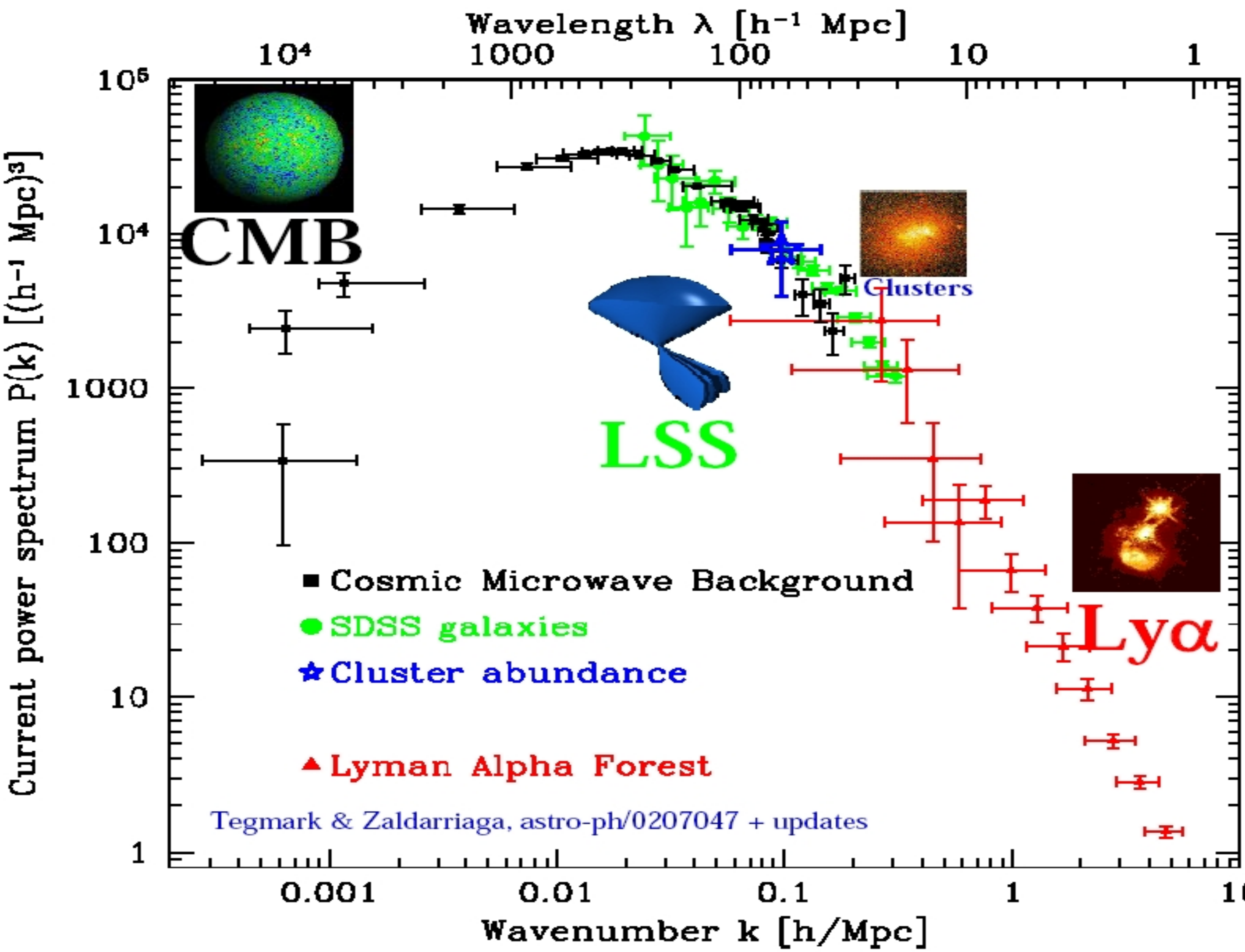




Galaxy mass function depends on DM type

Inner DM mass density depends on the type(s) of DM

LCDM: impressive consistency over five orders in length scale

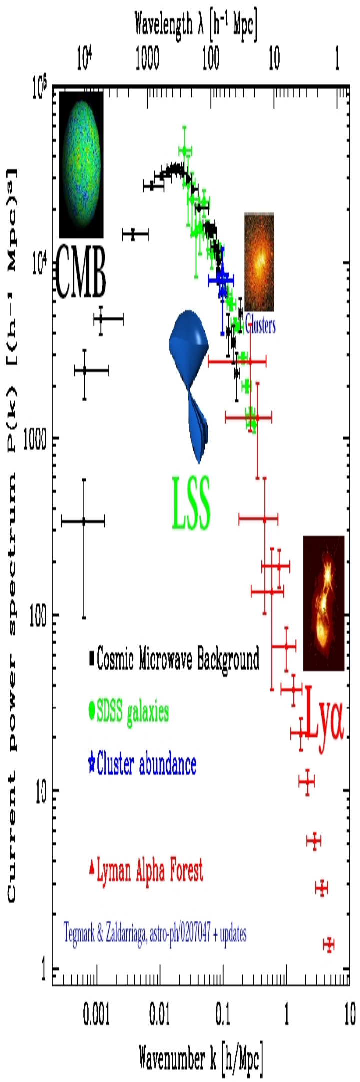


Impressive consistency over five orders in length scale

95 out of 100 orders leaves lots of discovery space

There are 60+ orders of magnitude here, smoothed by inflation?

Searches for non-Gaussianity are standard cosmology



14 orders here to smallest bound systems – solar radius

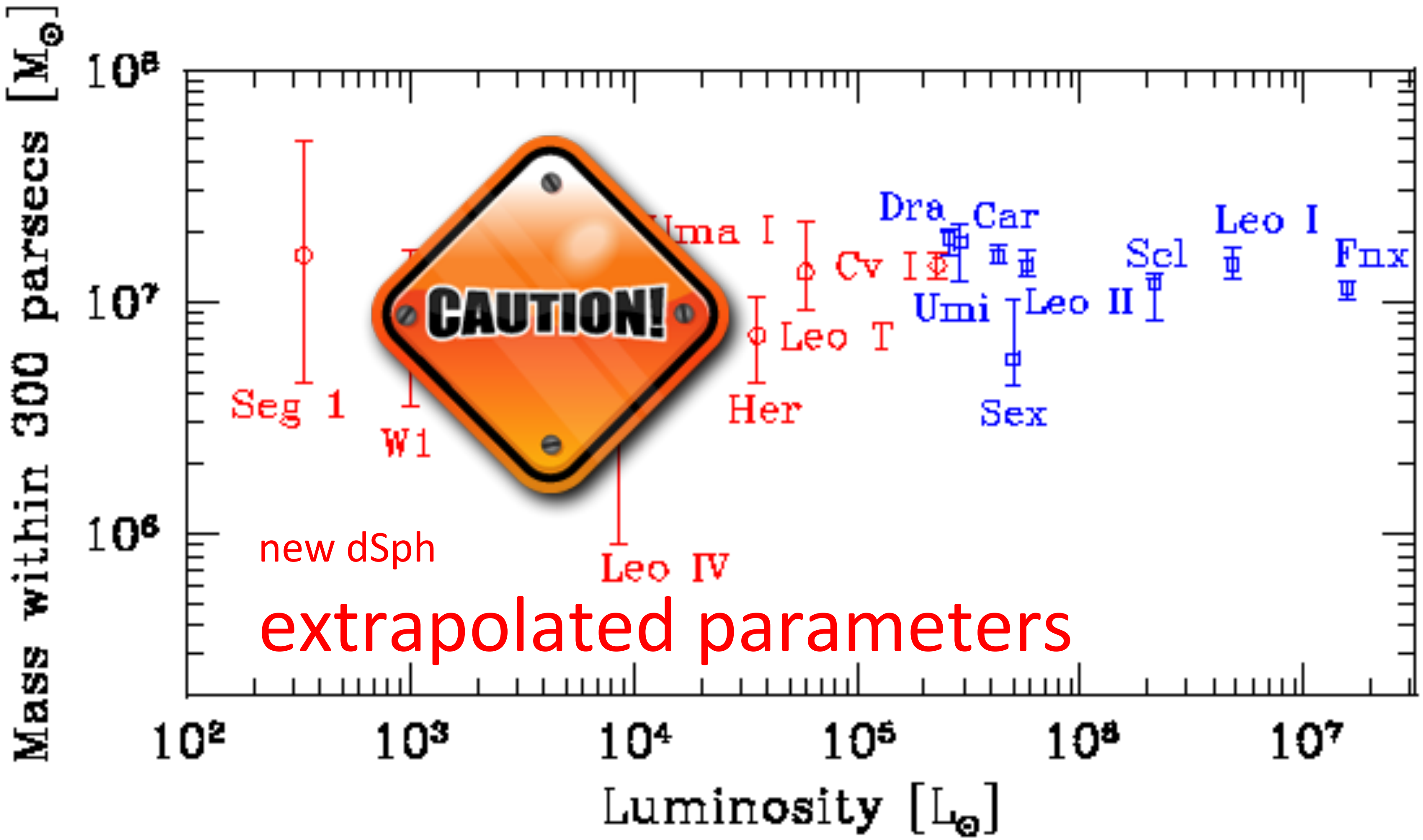
37 orders to particle scales: electron radius

Compress kinematics to an enclosed mass in a metric size:

Concept valid only when constrained by luminosity data

– M300 mixes data and model.

Better is the object-specific half-light scale



Strigari etal Nature 454 1096 2008; idea: Mateo 1992

Cosmological simulations are extremely impressive, but are limited: they are based on an extrapolation from observation, not on fundamental principles. This is good!
Comparing simulations to data is testing the physics which limits the extrapolation

Motivation 1: consistency

scale-invariant power spectrum leads to logarithmic UV-divergence

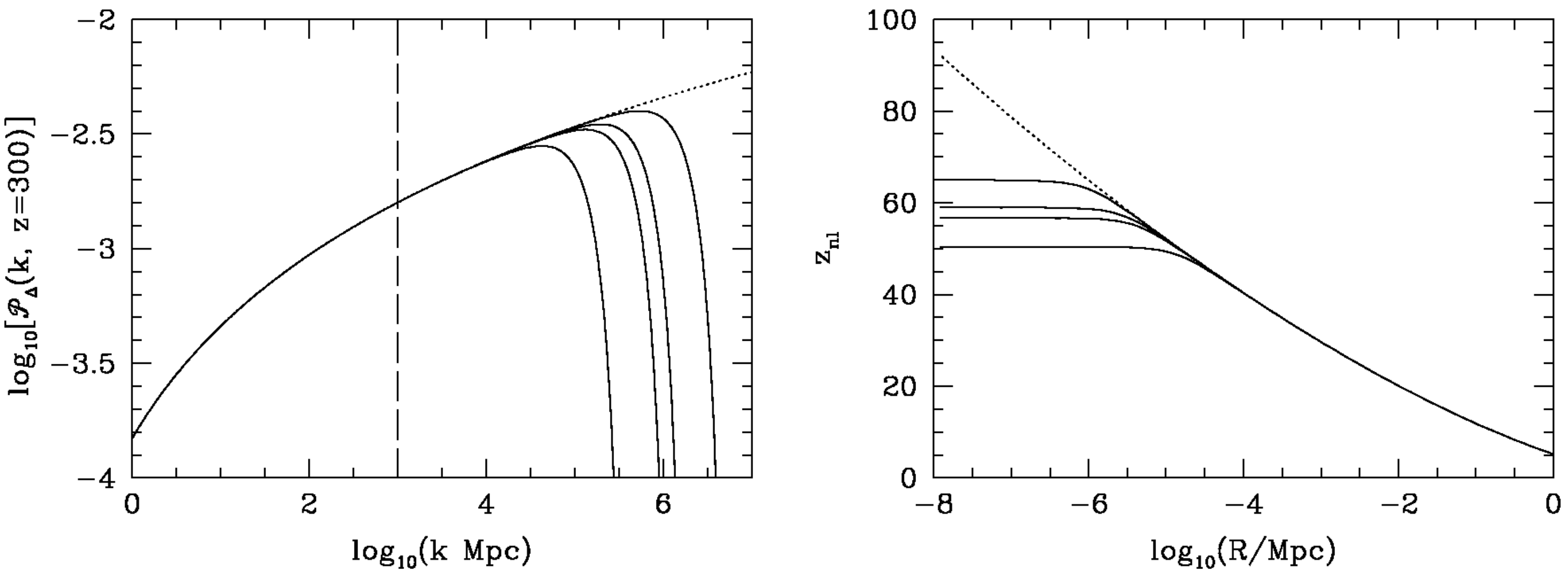
$\mathcal{P}_{\rm cdm}(k) \propto \ln^2(k/k_{\rm eq})$ at $k \gg k_{\rm eq}$

$\Rightarrow$ physical cut-off required

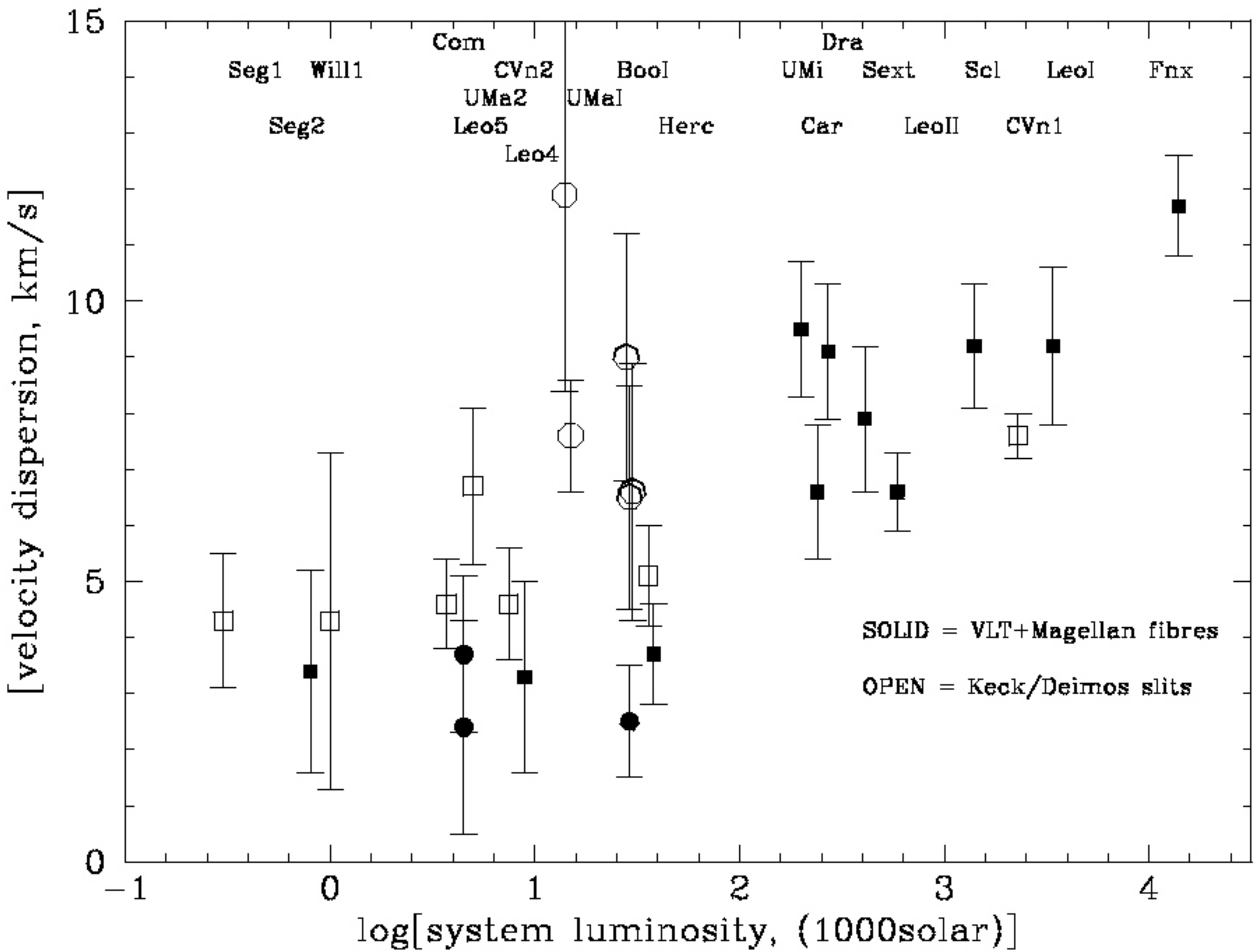
slide from Dominic Schwarz

Are there plausible predictions to test?

Linear power spectrum at z ~ 300, showing influence of
WIMP microphysics:
Physical scales of interest correspond to smallest galaxies
Anticipated DM effects on scales of parsec up ➔ first systems



Green, Hofmann & Schwarz 2005



Com
Dra
Seg1
Will1
CVn2
BooI
UMi
Sext
Scl
LeoI
Fnx
UMa2
UMaI
Seg2
Leo5
Herc
Car
LeoII
CVn1
Leo4
SOLID = VLT+Magellan fibres
OPEN = Keck/Deimos slits
[velocity dispersion, km/s]
log[system luminosity, (1000solar)]
15
10
5
0
−1
0
1
2
3
4