

Dark Matter in the Milky Way:

II. Evidence

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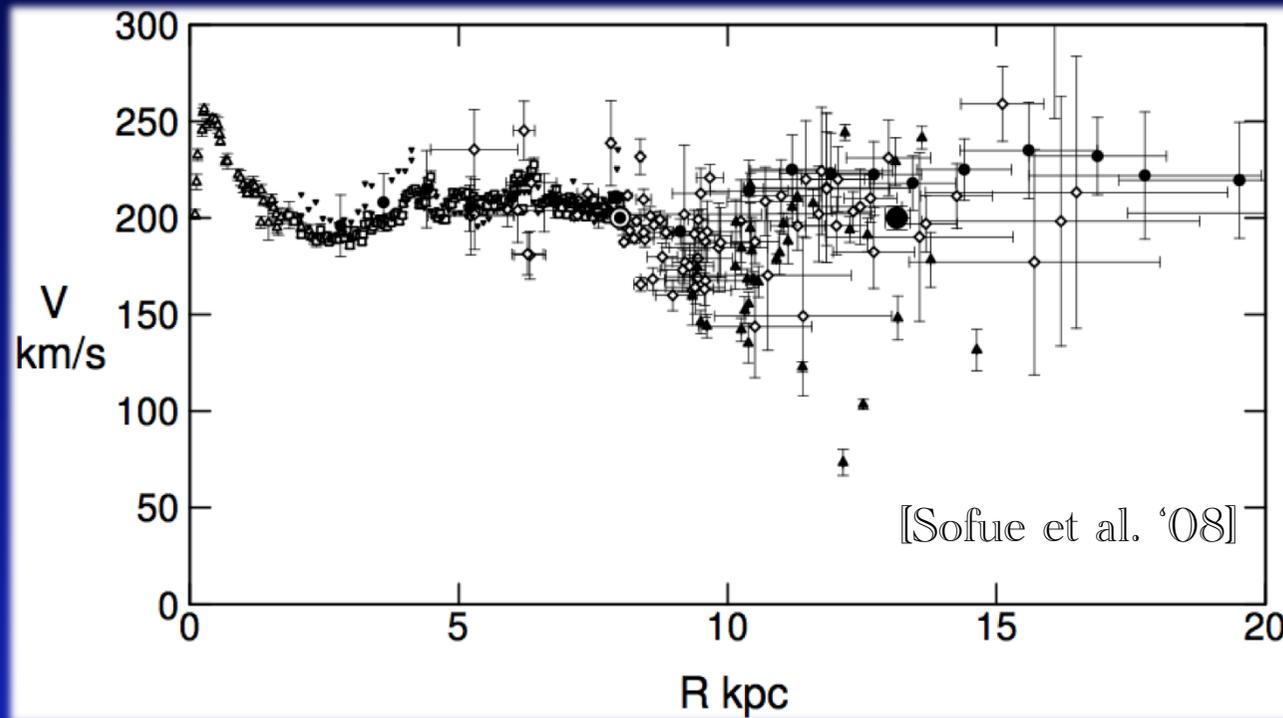
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How do we know about DM (in the Milky Way)



Observed Rotation Curve

Forthcoming new compilation of data updated with:
over 2000 new (old!) data points added

Break down in different type of observables

(see Pato's talk, public code soon available) [Pato & FI, in progress]

And what Rotation Curve would we expect?

Morphological
distr. of baryons. ρ_{bar}
Observ inferred

$$\rho_{\text{bar}} = \boxed{\rho_{\text{bulge}} = \rho_0 f(x, y, z)} + \boxed{\rho_{\text{disk}} = \rho_0 f(x, y, z)}$$

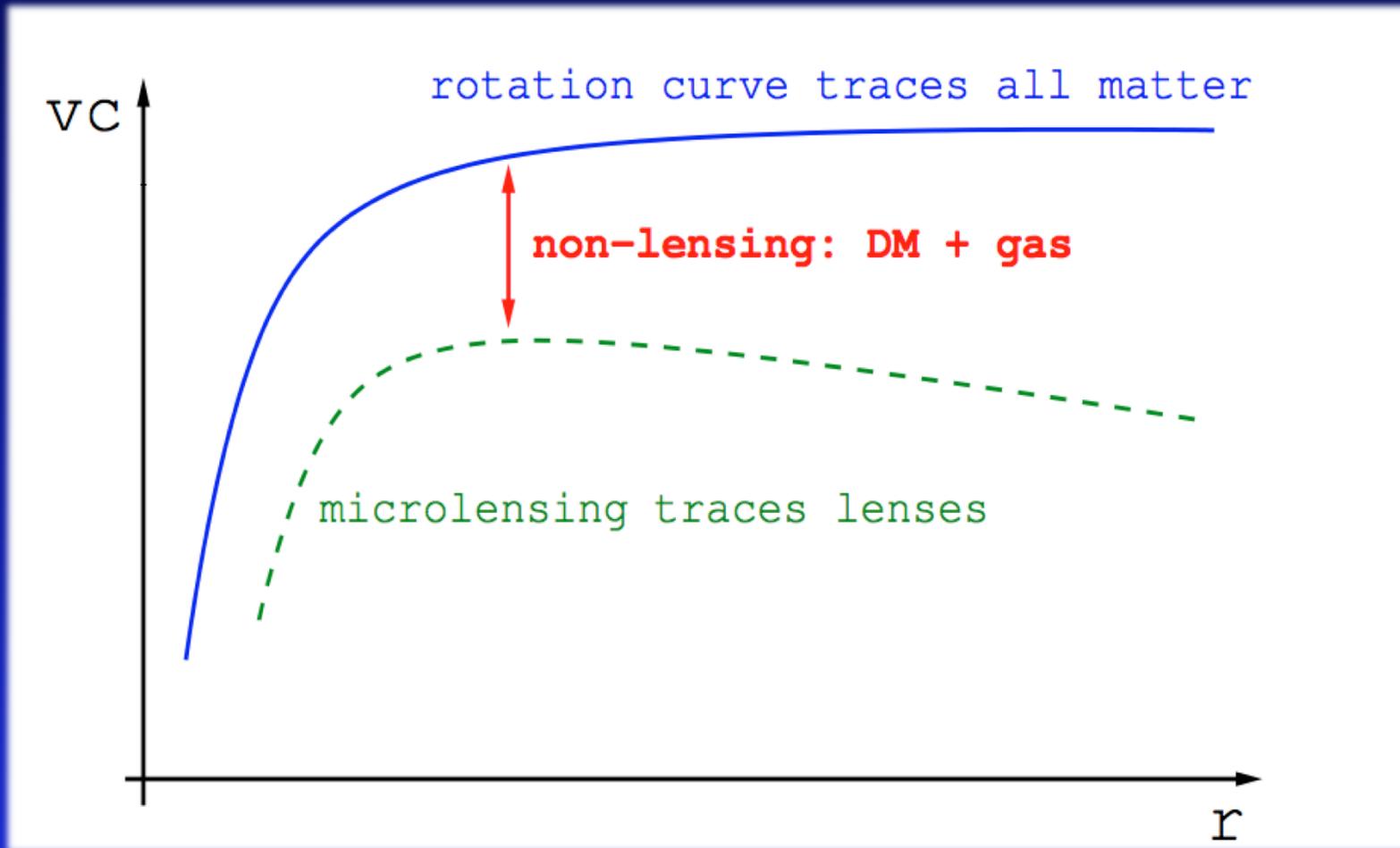
$$\rho_i(x, y, z) \rightarrow \phi_i(r, \theta, \varphi) \rightarrow v_{c,i}^2(R) = \sum_{\varphi} R \frac{d\phi_i}{dr}(R, \pi/2, \varphi)$$

$$v_{c,\text{baryons}}^2 = \sum_i v_{c,i}^2$$

from baryon observations in our Galaxy
Updated library with bulge, thin & thick disks, gas
(details available upon request, see Pato's talk)

Otherwise framed:

do observed RC and theoretical (observation inferred) one, really mismatch? (and esp. so in the inner Galaxy)

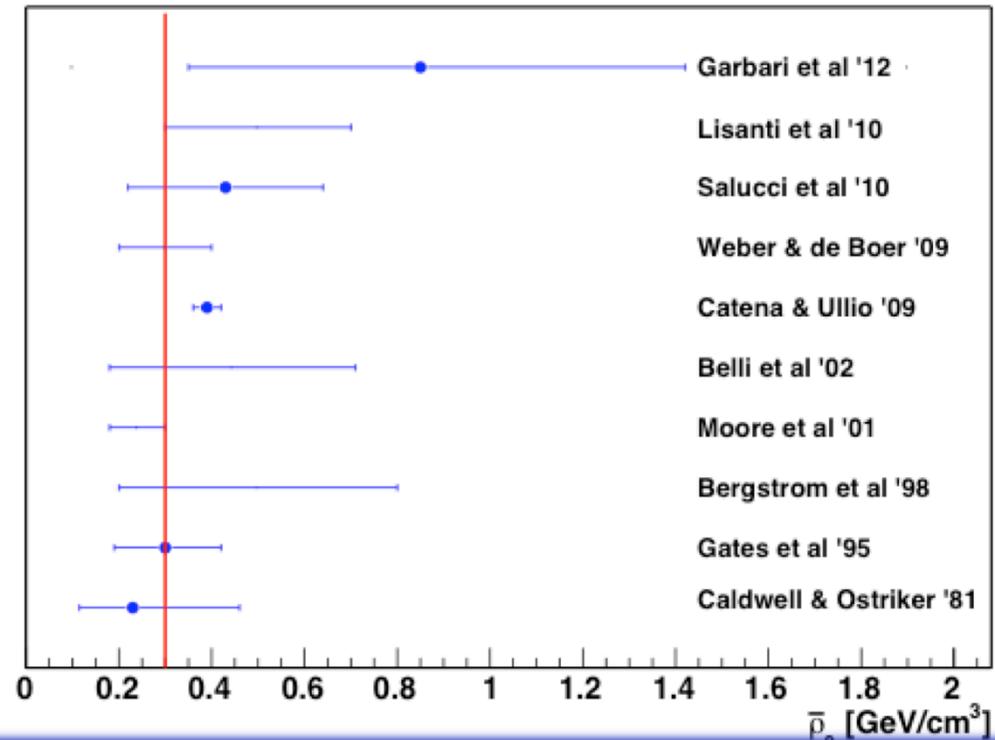


Determining the local DM density ρ_0

Local observables
(e.g. Garbari et al.)

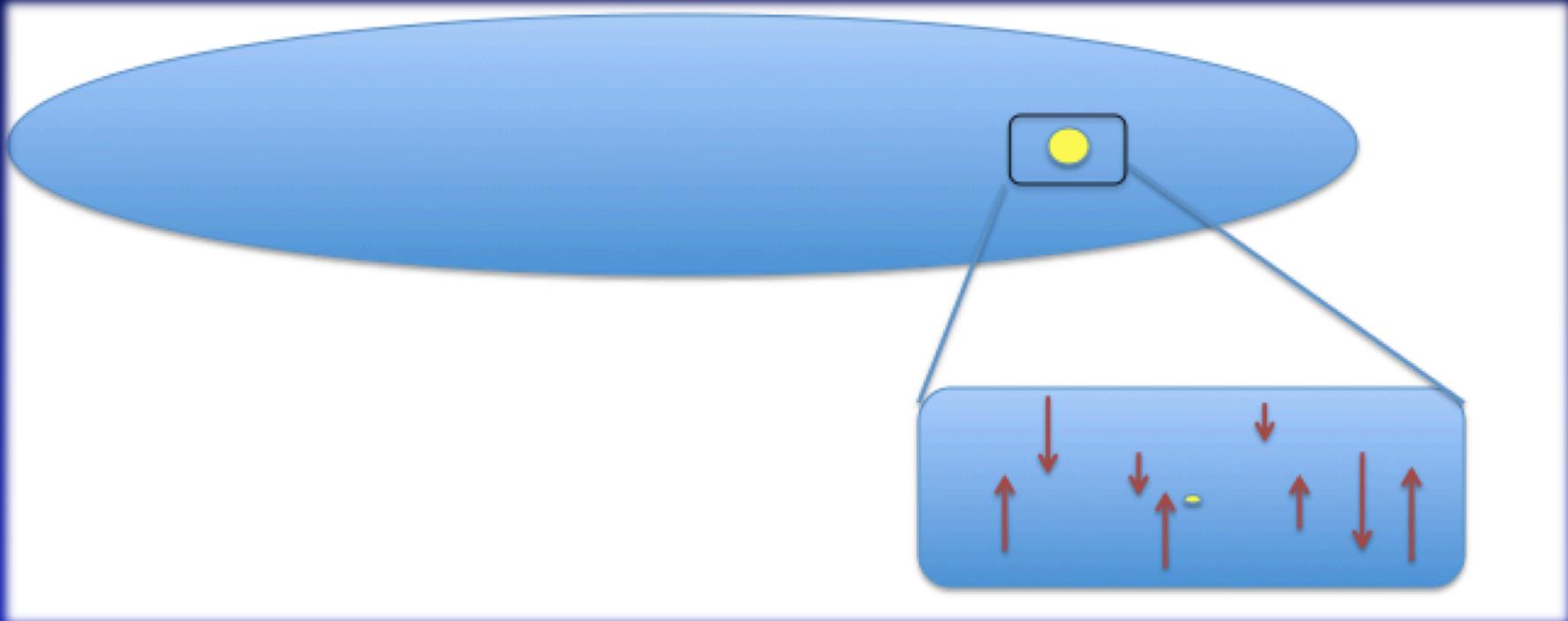
VS

global modelling of MW
(e.g. Catena & Ullio)



Give consistent results

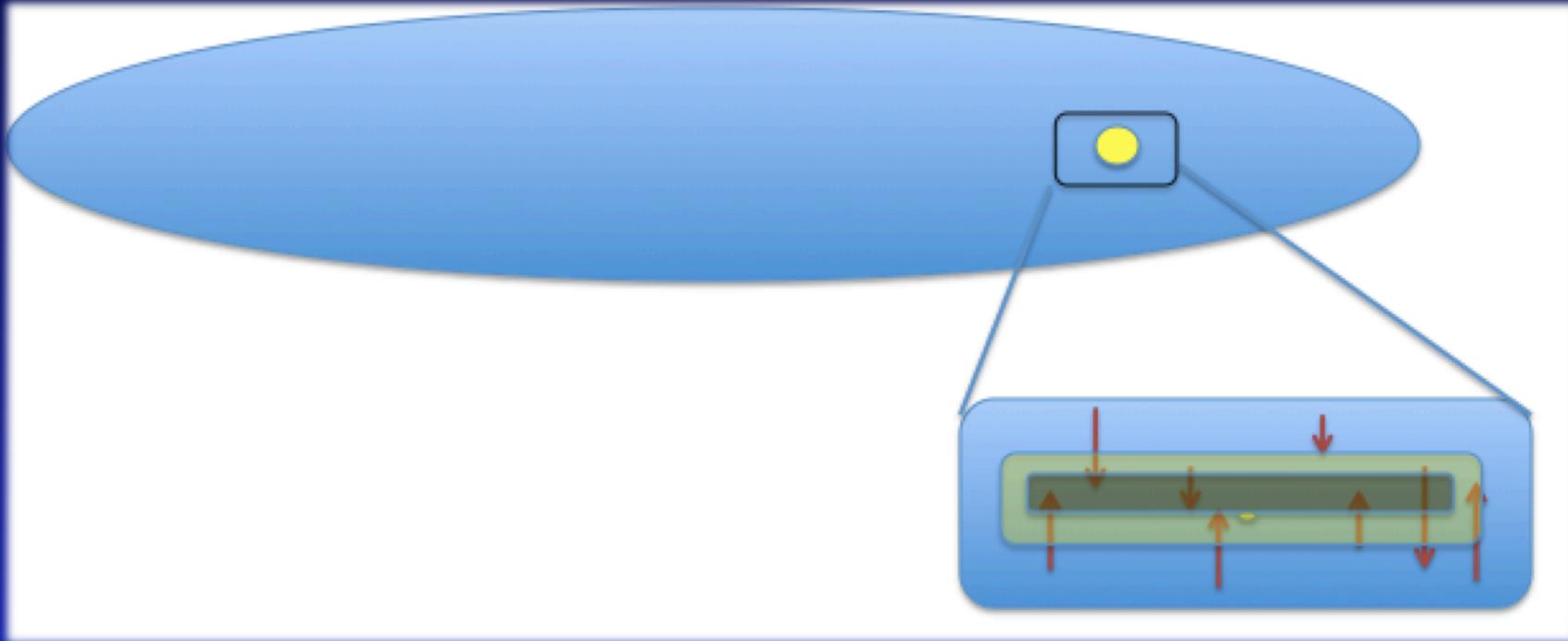
Local determination of ρ_0



Vertical motion of stars, determining the whole local potential

See talk from J Read

Local determination of ρ_0

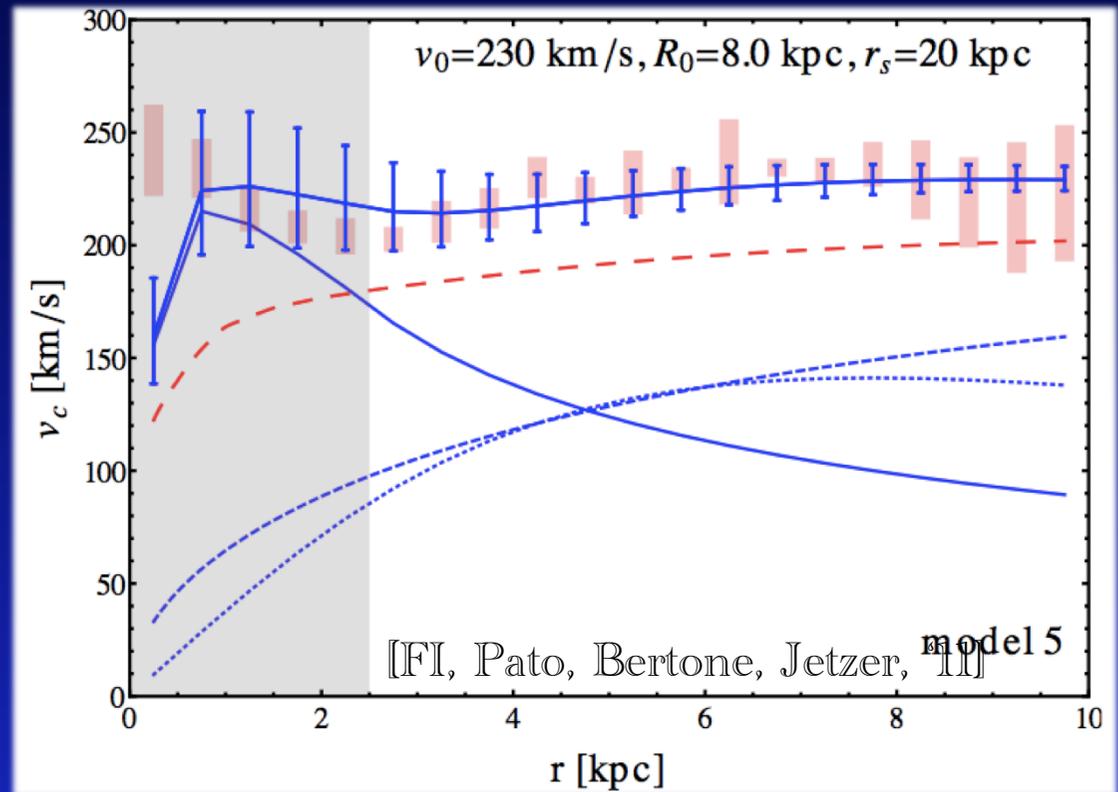


Subtracting local baryonic (stellar) contribution to get DM
(no implicit assumption on DM presence)

See talk from J Read

Global determination of ρ_0

Fitting a DM profile to the Rotation Curve, on top of other components



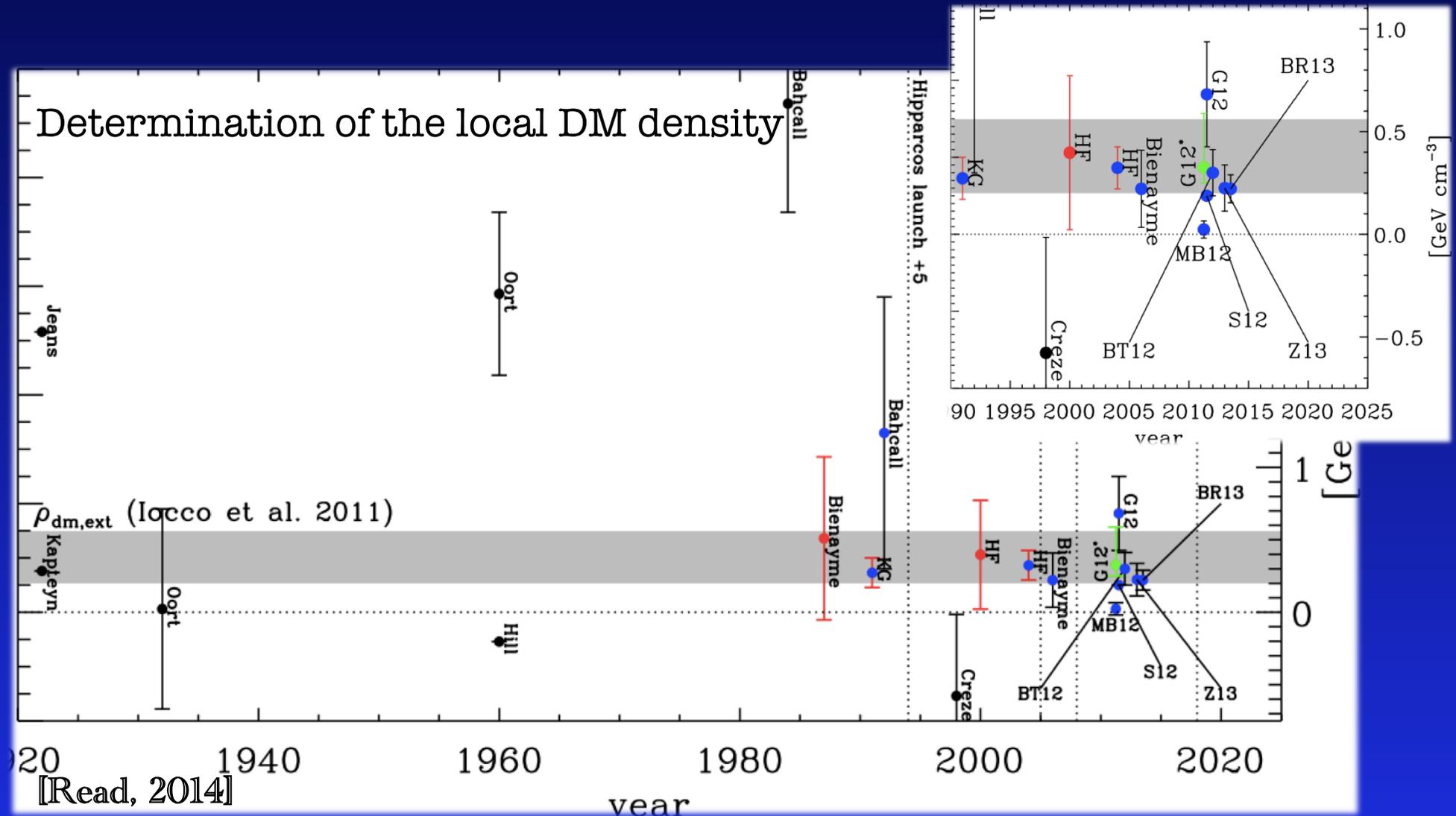
$$\phi_{\text{tot}} = \phi_{\text{bulge}} + \phi_{\text{disk}} + \phi_{\text{gas}} + \phi_{\text{dm}}$$

See Pato's talk

Underlying assumption on DM presence and distribution shape

An historical overview of ρ_0

(different methods give consistent results)



Some caveats

(repetita juvant)

- Local methods: no assumptions on DM existence but compatible with 0 at $\approx 3\sigma$
- Global methods: adopt DM profile shape
- All determinations compatible with 0 at $\approx 3\sigma$
(remember: at solar circle)

Otherwise framed:

can we infer a model-independent,
assumption-free evidence for DM? (and esp. so in the inner Galaxy)

Please be patient!

$R_0=8$ kpc
 $V_0=230$ km/s

First glance: it looks like

Please be patient!

$$\omega = V_c / R_c$$

$$R_0 = 8 \text{ kpc}$$
$$V_0 = 230 \text{ km/s}$$

Red: data (see Pato's talk) (public code soon available)

Grey: RC from (observation-based) baryon models
(details on models available upon request)

But first glances are dangerous: let's get quantitative

- Computing the “badness-of-fit” (discrepancy) of each baryon rot. curve (no DM!!) to observed one
- One COULD bin (and we have done it) but loss of information: using 2D chi-square (uncertainties on R, as well)

$$\chi^2 = \sum_{i=1}^N d_i^2 \equiv \sum_{i=1}^N \left[\frac{(y_i - y_{b,i})^2}{\sigma_{y,i}^2} + \frac{(x_i - x_{b,i})^2}{\sigma_{x,i}^2} \right]$$

Do the baryon-only curves fit
with the observed RC?

Please be patient!

Answer is NO:
Every single model above 5σ , already at $R < R_0$!!

Testing different setups (systematics and parameters)

Same conclusions if
scanning:

Spiral Arms syst.

LSR values

Please be patient!

Testing galactic parameter variation

Please be patient!

Same conclusions if scanning:

Local circular velocity

Solar distance

Dissecting Rotation Curve (testing separate trackers)

Please be patient!

Same conclusions if using:

Stellar objects only

Masers only

Gas kinematics only

CUNCTA STRICTE

- Model-independent, assumption-free analysis
 - Based on observational data only
 - DM “not included”
 - Evidence for discrepancy between Observed and theoretical (obs. infer.) RC
 - 5σ at $R < R_0$ (inner Galaxy)
- Analysis is solid against galactic parameter variation and systematics

One more slide, to take home

Please be patient!

Without fitting, NFW and Einasto smoothly fill the gap
(overlap on “residuals”)

Technical details

- Cut of the central 2.5 kpc (barred bulge)
 - Systematic due to spiral arms tested
 - Flattening of evidence at higher radii (saturation because of growth of uncert.)