Milky Way disc dynamics and kinematics from mock data

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CU9 member: validation of CU6 and CU8 data

Outline

- **Analysis of the disc mock datasets:**

  density waves pattern speeds, dark matter halo parameters

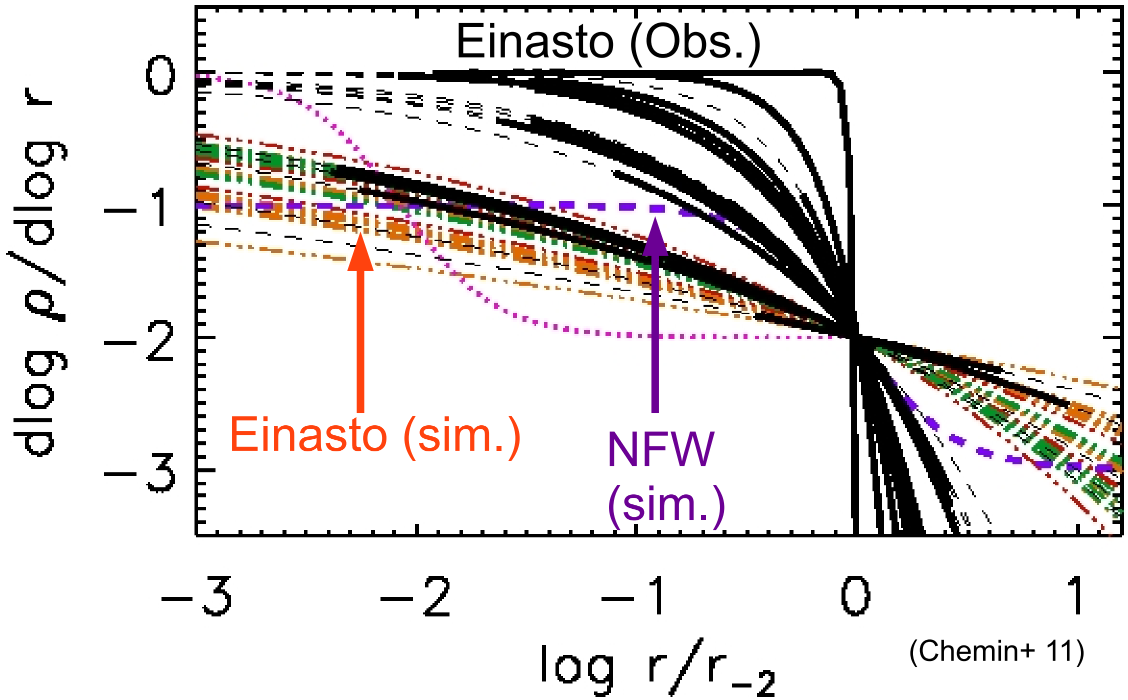
GREAT - Gaia Challenge
August 19-23, 2013, U. Surrey

Mass models from mock data

Motivations

- Mass profile of the MW
- Inner slope of DM density
- Comparison with LCDM cosmology and with Local Universe spirals

- Cuspy like in CDM simulations?
  - Which cusp?
    (Navarro+ 96, 97, Moore+ 99, Diemand+ 04, 05, Merritt+06, Graham+06, Navarro+ 04, 10)
- Cored like in most disc galaxies?
  - Which core?
    (de Blok & Bosma 02, Swaters+ 03, Oh+ 08, Kuzio de Naray+08, Spano+ 09, Chemin+ 11)

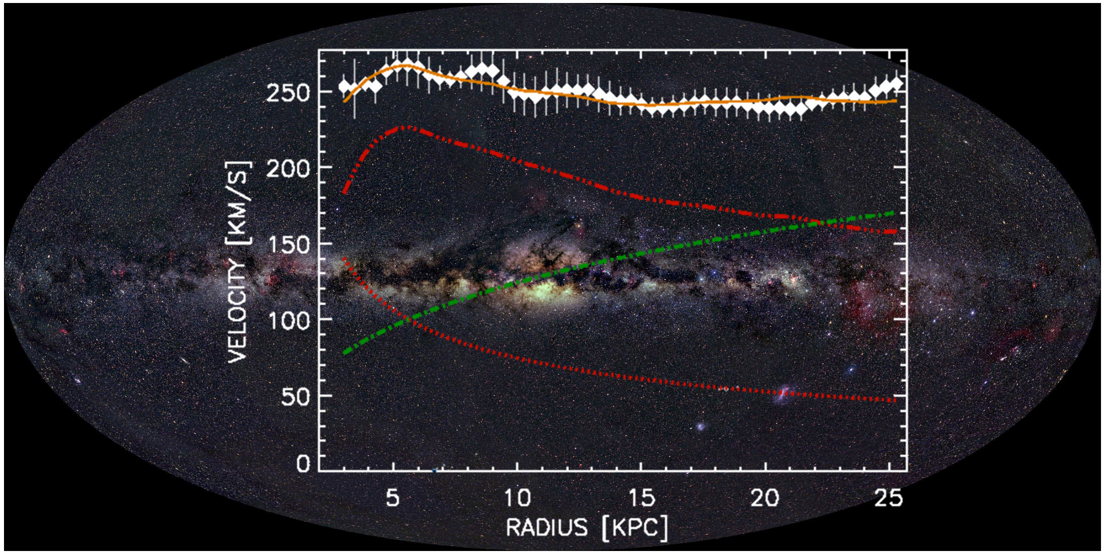


(Chemin+ 11)

Mass models from mock disc data

Methodology

- Adopt a simple 'extragalactic' point-of-view, behave with data like any other discs
  - '1D' analysis: Decompose V(R) into DM & baryons
  - Need:
    - a rotation curve
    - velocity dispersions
    - BM surface density profiles (bulge, discs, etc.)
    - a DM density profile model (spherical distribution)

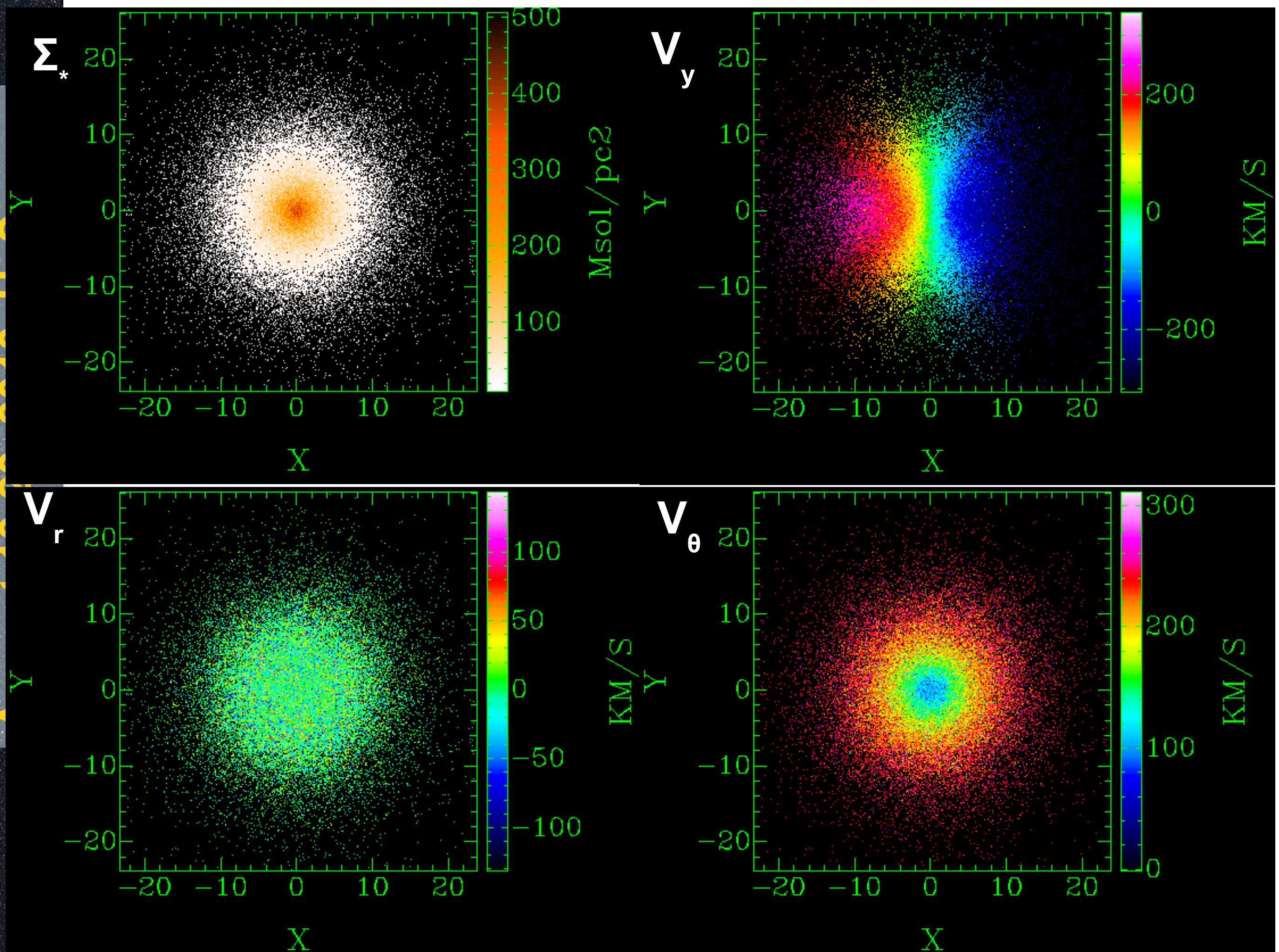


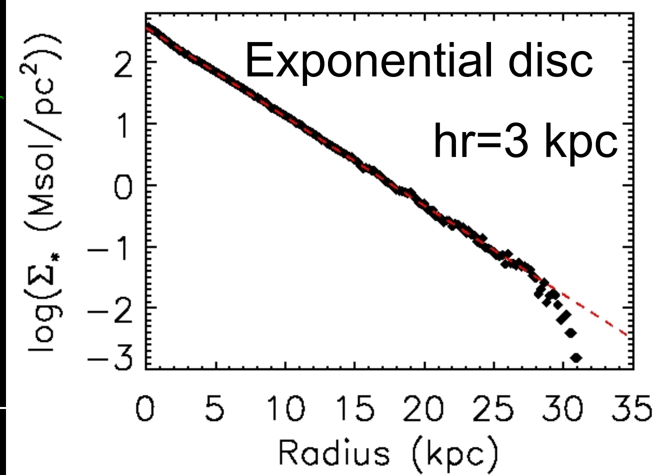
- ~10^4-10^5 pixels/spaxels/spectra versus ~10^7-10^8 points for Gaia
    - Need to develop numerical tools for rotation curve/surface density

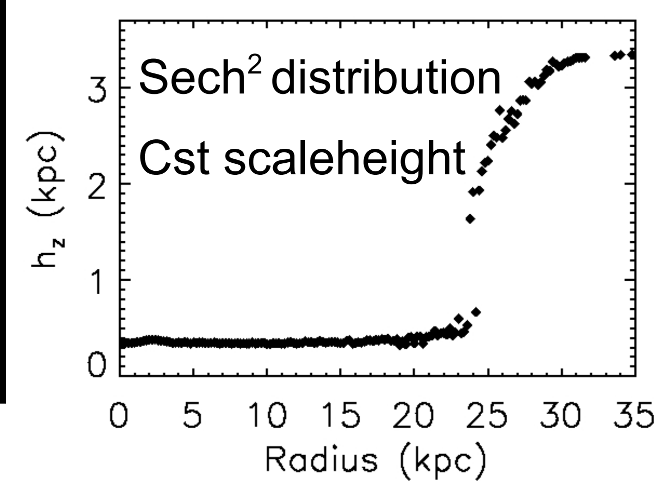
- Gaia Challenge: 'Super Gaia' mock discs data: no errors, no extinction

Mass models from mock disc data

1st exercise : unperturbed disc simulation (GD1 Hunt+ 13)   Whole disc







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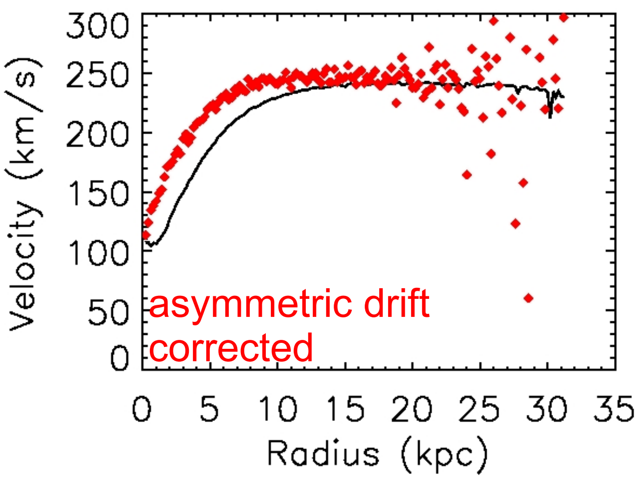
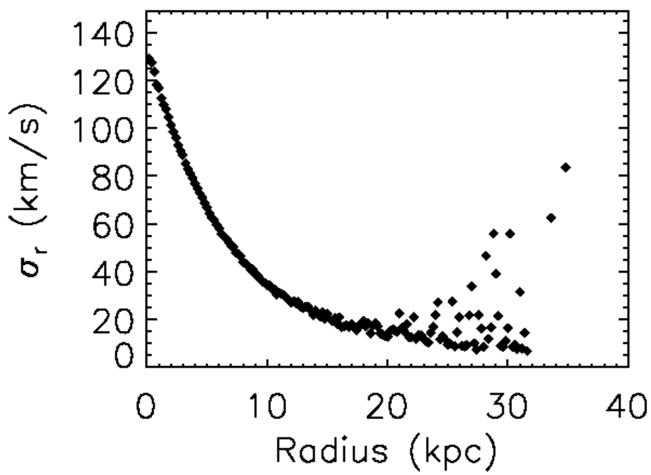
Mass models from mock disc data

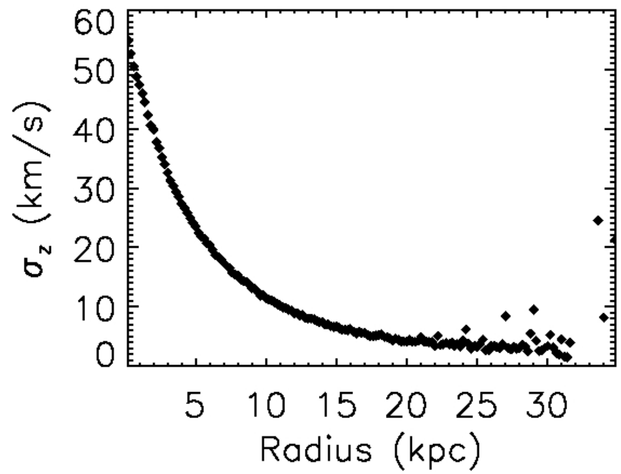
1st exercise : unperturbed disc simulation (GD1 Hunt+ 13)

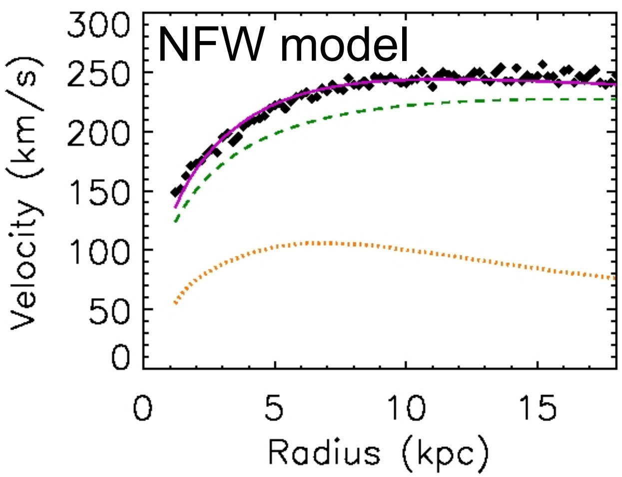
Whole disc

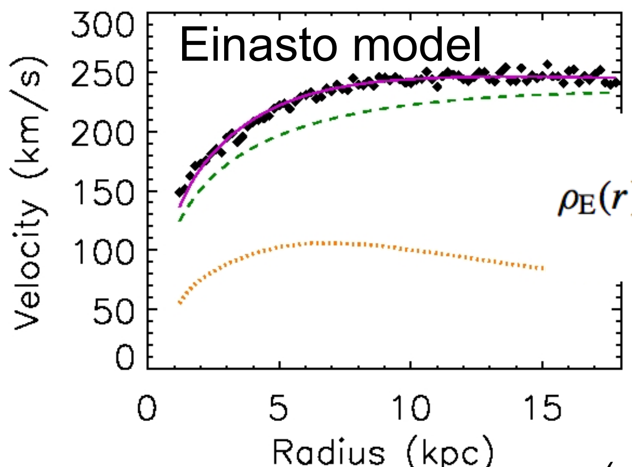
Flat rotation curve











$$\rho_E(r) = \rho_{-2} \exp\left\{-2n\left[\left(\frac{r}{r_{-2}}\right)^{1/n} - 1\right]\right\}$$

3 parameters

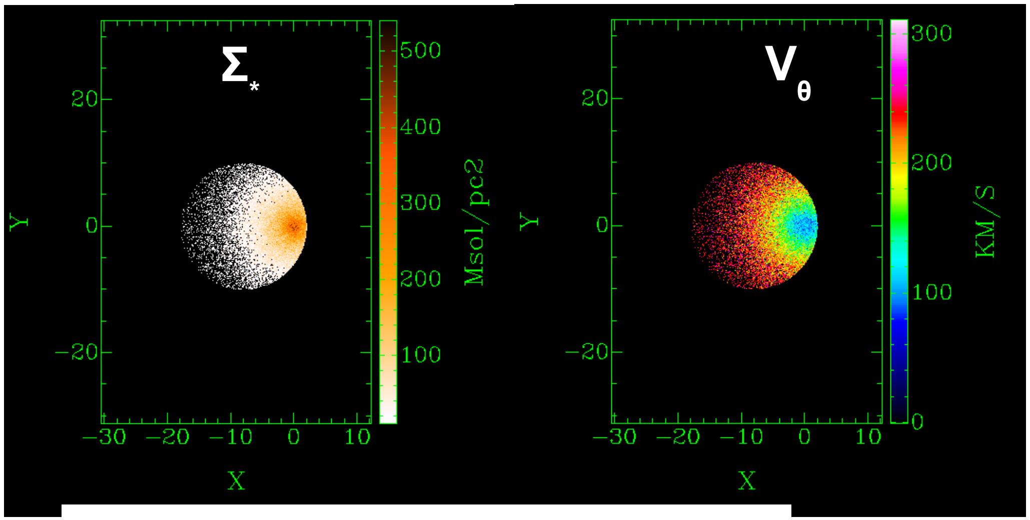
n=Einasto index

(n=5-7 for CDM cusps, Navarro+ 04, 10)

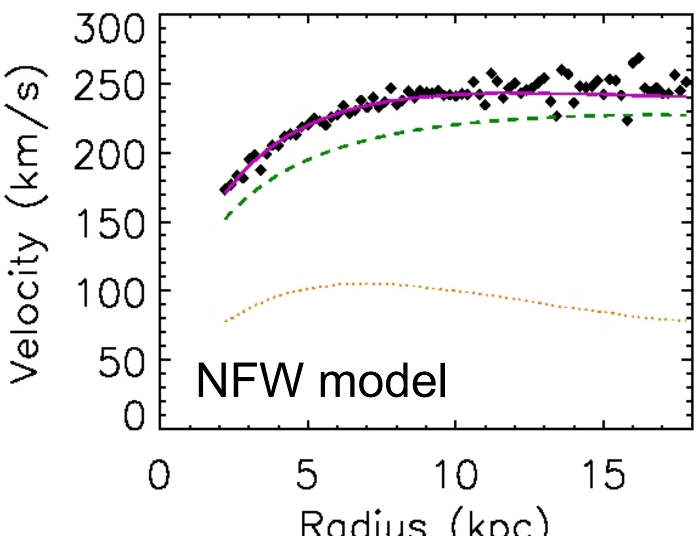
Mass models from mock disc data

2nd exercise : unperturbed disc simulation (GD1 Hunt+ 13)

Limited volume



All radial profiles show perfect agreement with whole

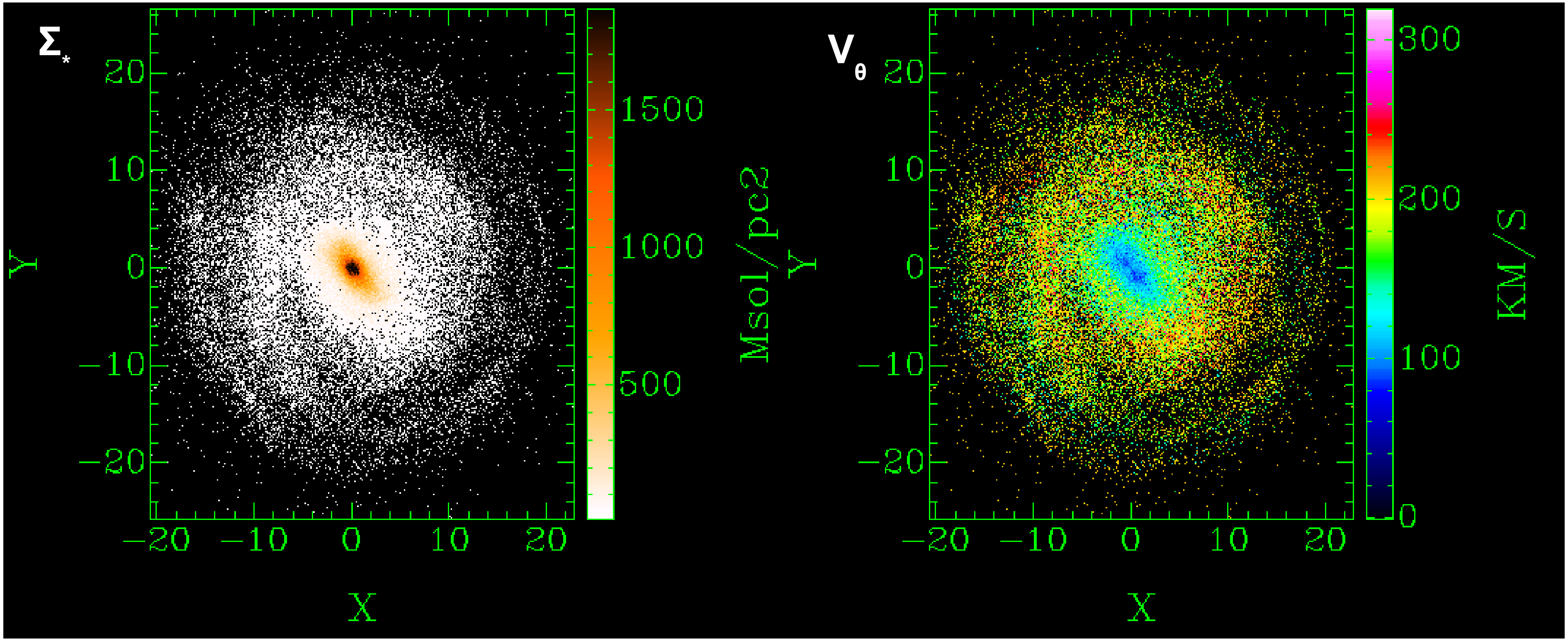


Model X^2	Whole disc	Limited volume
NFW	338	898
Einasto Cusp n=5	222	1129

Cuspy Einasto models (fixed n=5) fit the data better than NFW, but not for a limited volume

Mass models from mock disc data

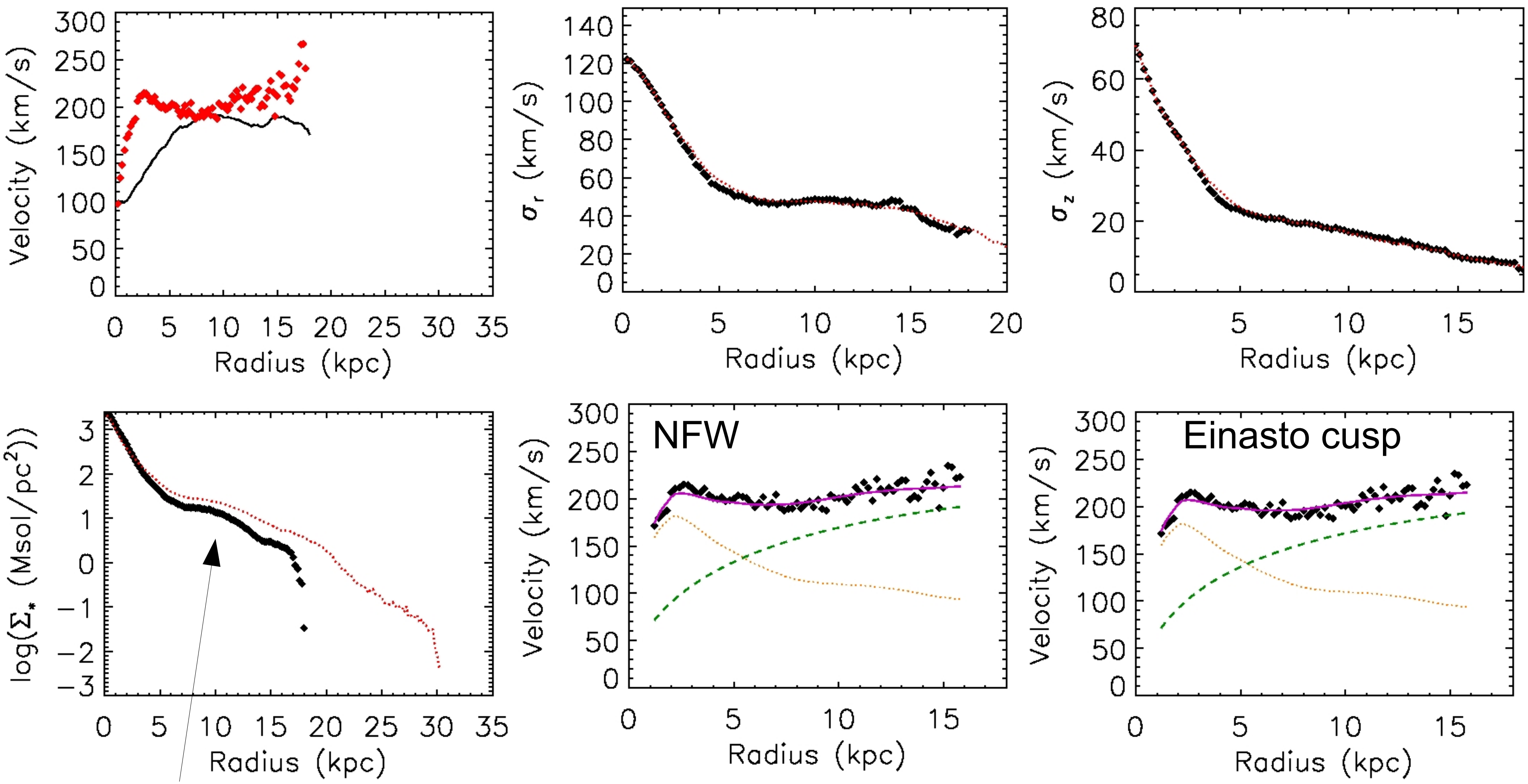
3rd exercise : barred-spiral disc simulation (GD2 Hunt+ 13)



Mass models from mock disc data

4th exercise : barred-spiral disc simulation (GD2 Hunt+ 13)

Results for limited volume only



Missing baryons: azimuthal effect to take into account

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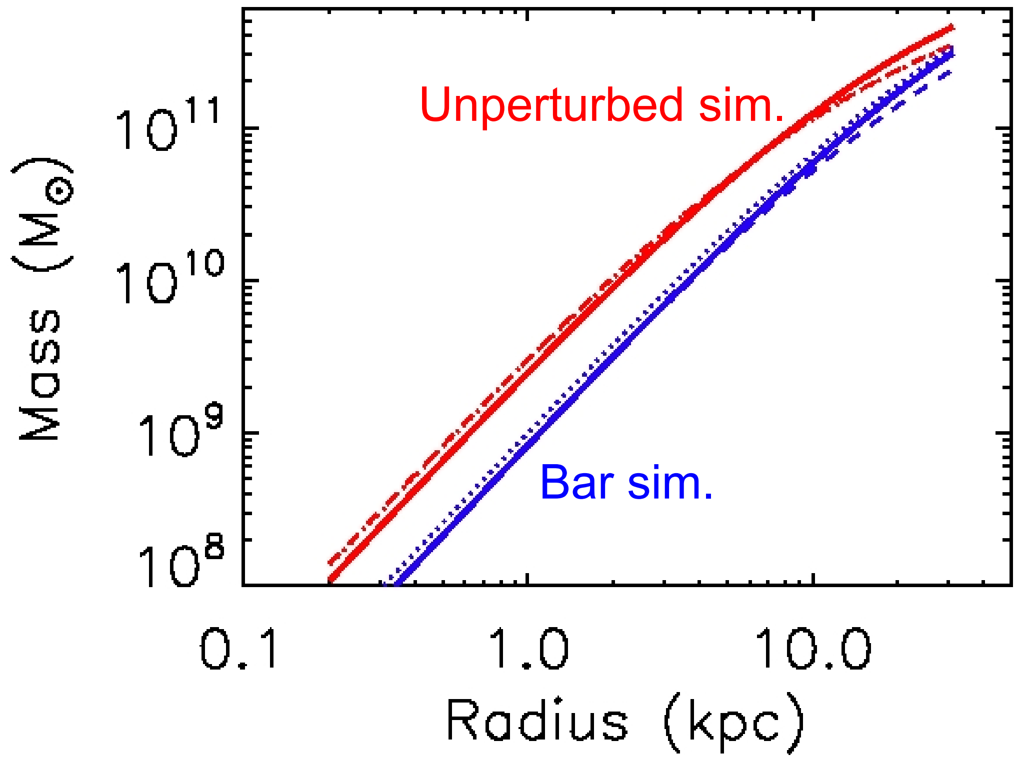
Mass models from mock disc data

4th exercise : barred-spiral disc simulation (Hunt+ 13)

Model X^2	Whole disc	Limited volume
NFW	291	1061
Einasto Cusp n=5	264	980

Cuspy Einasto models (fixed n=5) fit the data better than NFW

DM halo parameters in full agreement with input halo

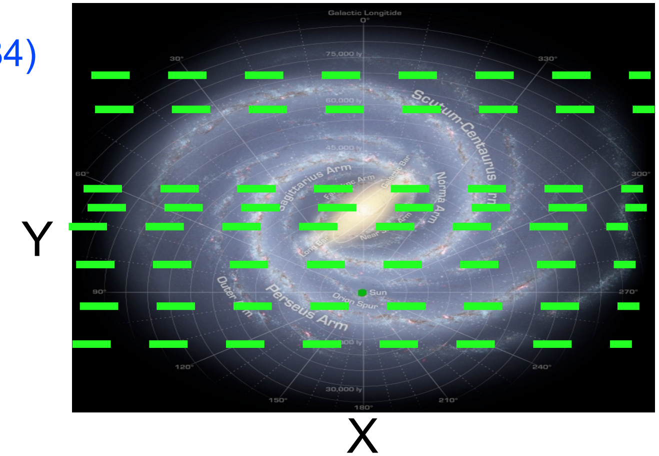


Bar & spiral pattern speeds

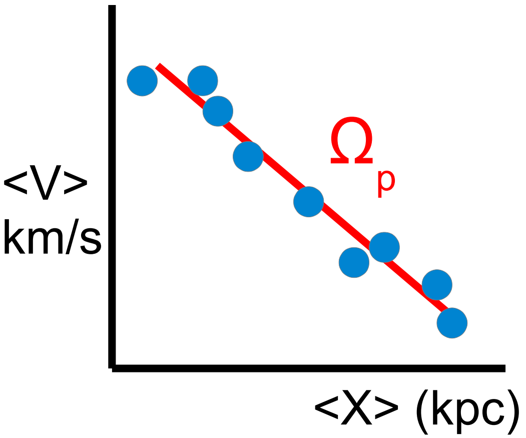
Why pattern speeds are important? cf Monari, Santi-Fabrega & Penniger' talks on monday

Tremaine-Weinberg method (Tremaine & Weinberg 1984)

$$\Omega_p \sin i \int_{-\infty}^{\infty} \Sigma(X,Y)\, X\, dX = \int_{-\infty}^{\infty} \Sigma(X,Y) V_{\|}(X,Y)\, dX.$$



- Independent from dynamical modeling
- A few tens of bar pattern speeds determined (e.g. Gerssen+99, Debattista & Williams 04, Hernandez+05, Fahti+07, Chemin & Hernandez 09)
- Fast bars in early type and/or massive discs
- Slow bars (Ω_p < 20 km/s/kpc) in late type



Bar pattern speed
Lindblad resonances

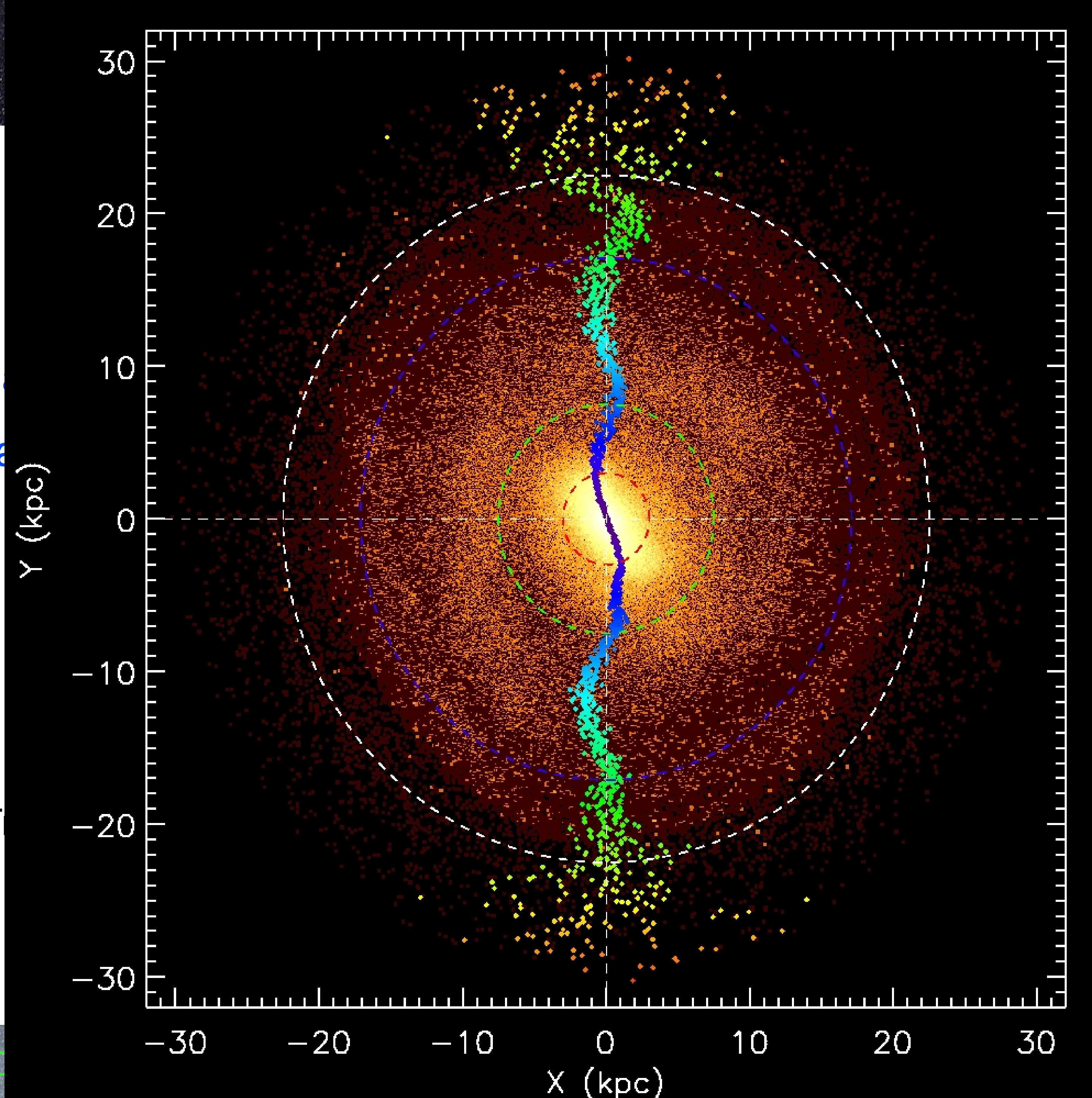
Can the MW bar and spiral pattern speeds be derived from Gaia data with the TW method?

$$\Omega_p \int_{-\infty}^{\infty} \Sigma(x, y, t)\, x\, dx = \int_{-\infty}^{\infty} \Sigma(x, y, t)\, v_y(x, y, t)\, dx$$

$$v_y = v_\theta \cos(\theta) + v_r \sin(\theta)$$

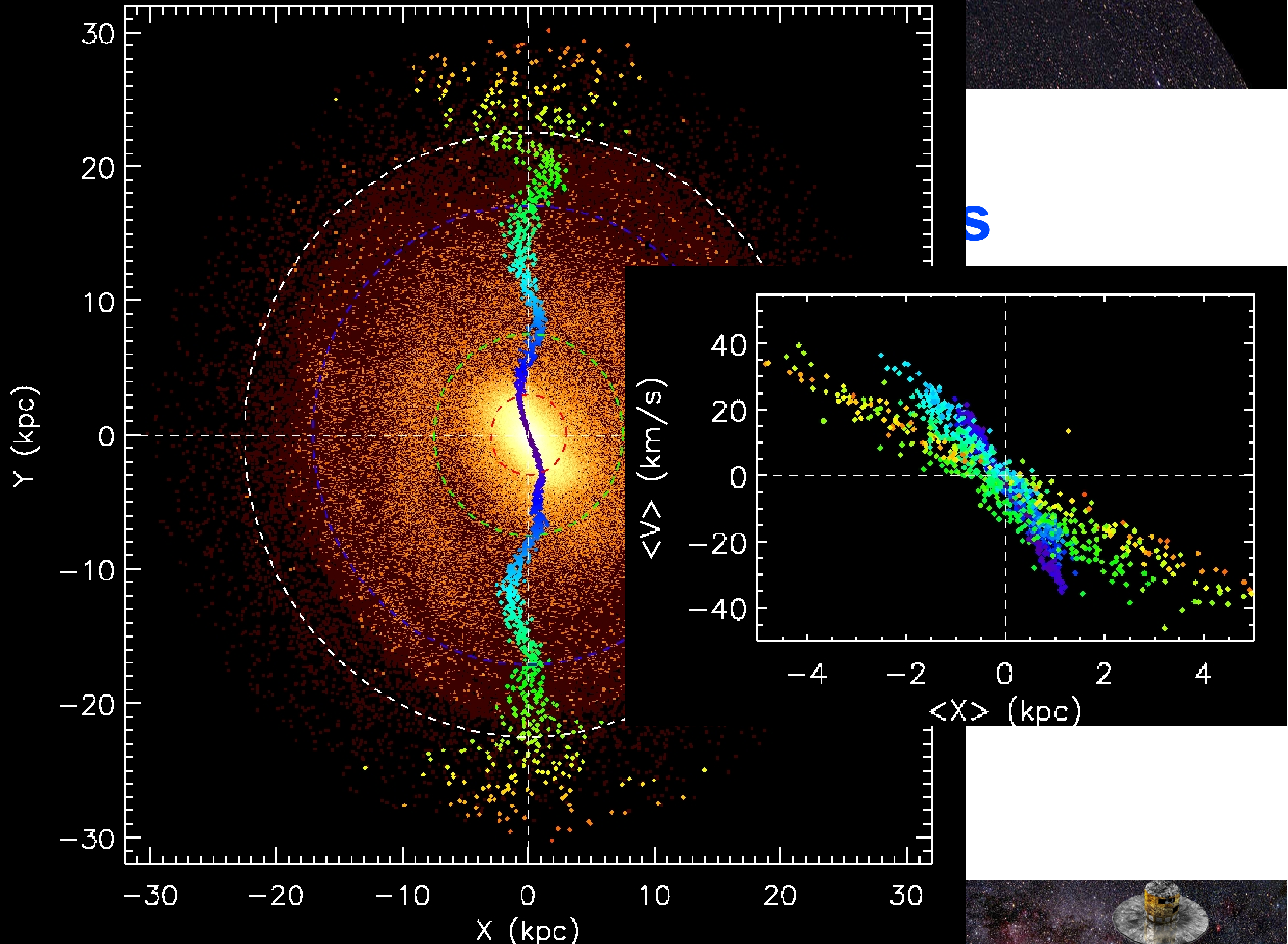
Try with mock data simulations of a barred spiral galaxy (GD2, Hunt et al. 2013)

Ca … n Gaia
da

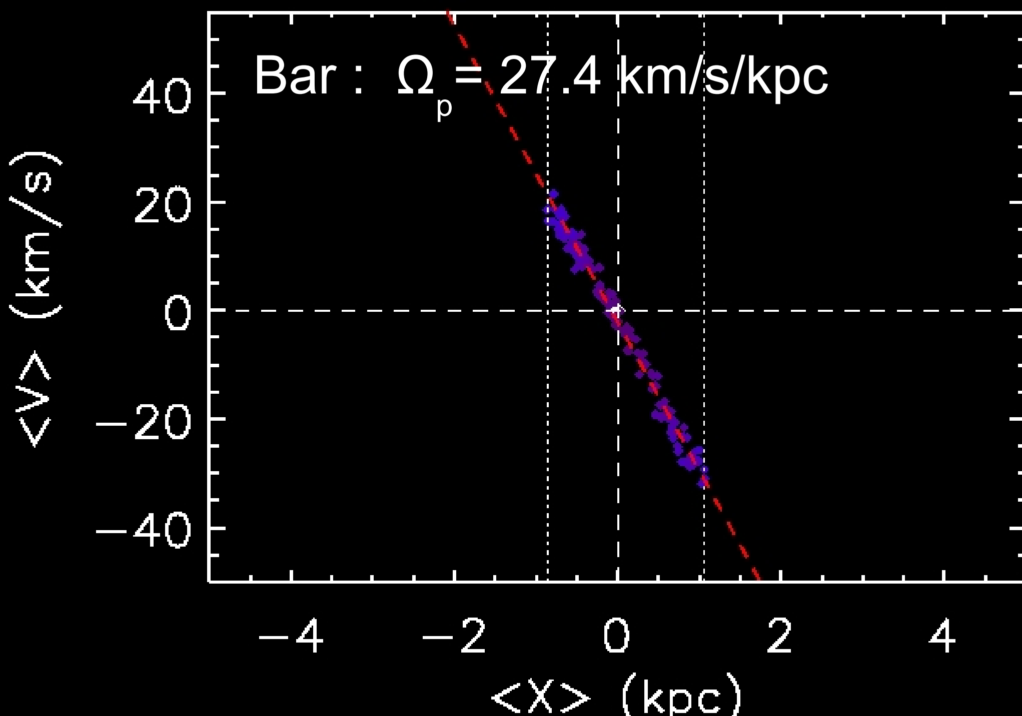


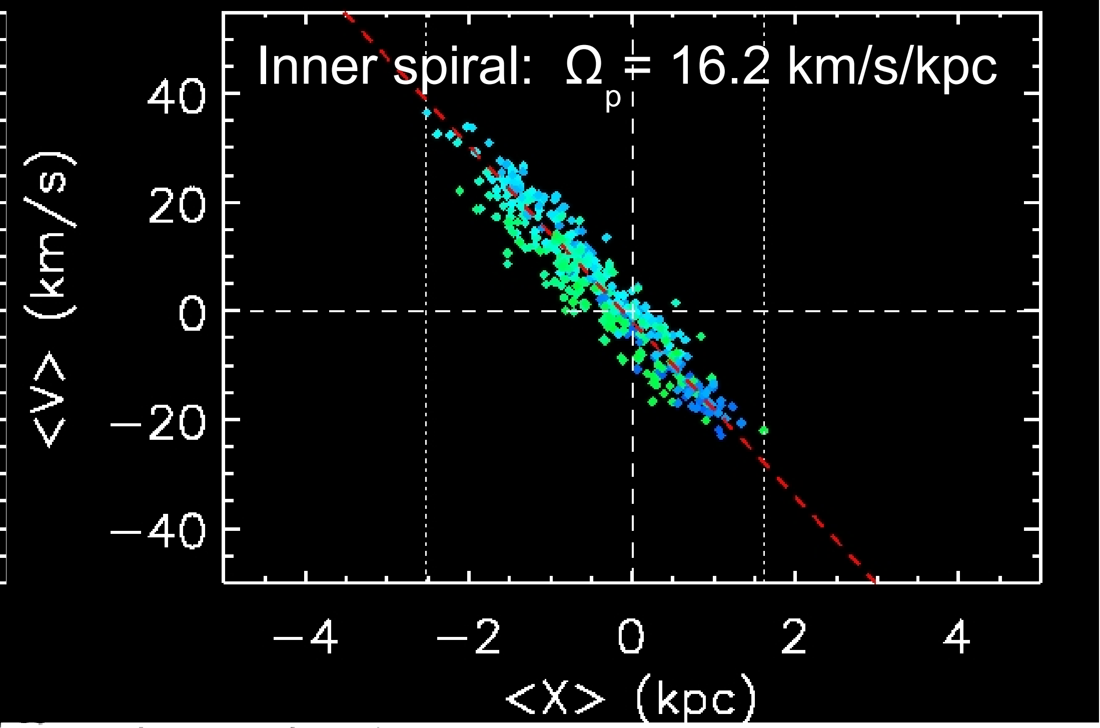
(θ)

T … 2013)

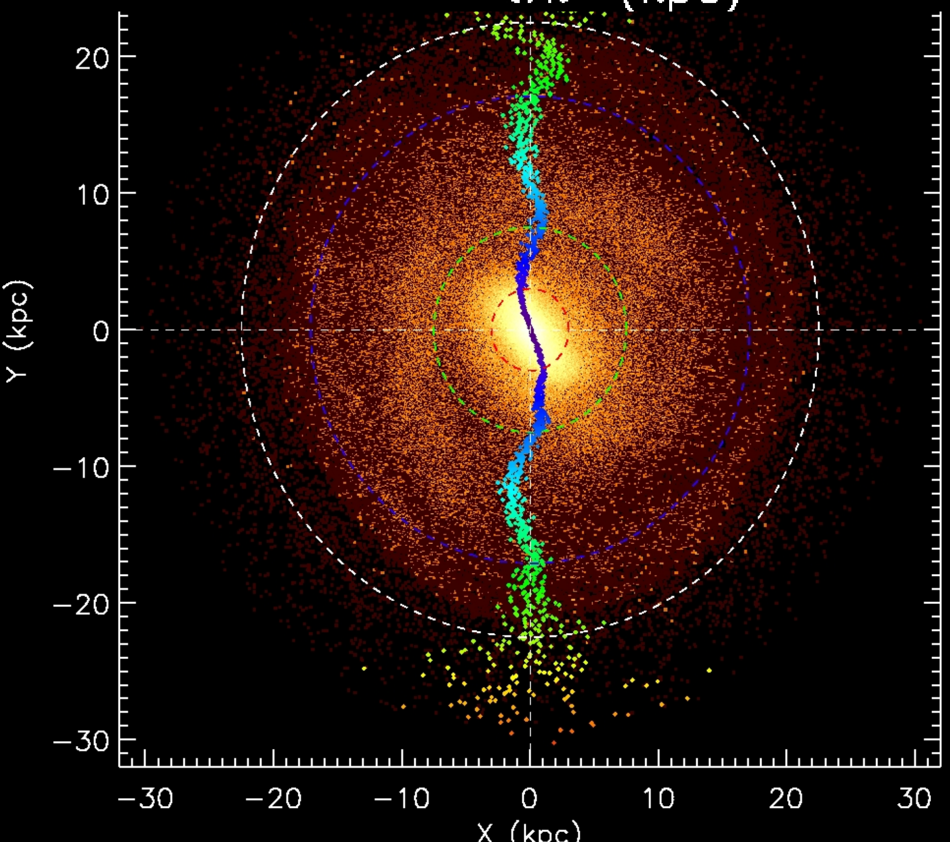


Y (kpc)
X (kpc)
30
20
10
0
−10
−20
−30
<V> (km/s)
<X> (kpc)
40
20
0
−20
−40
−4
−2
0
2
4

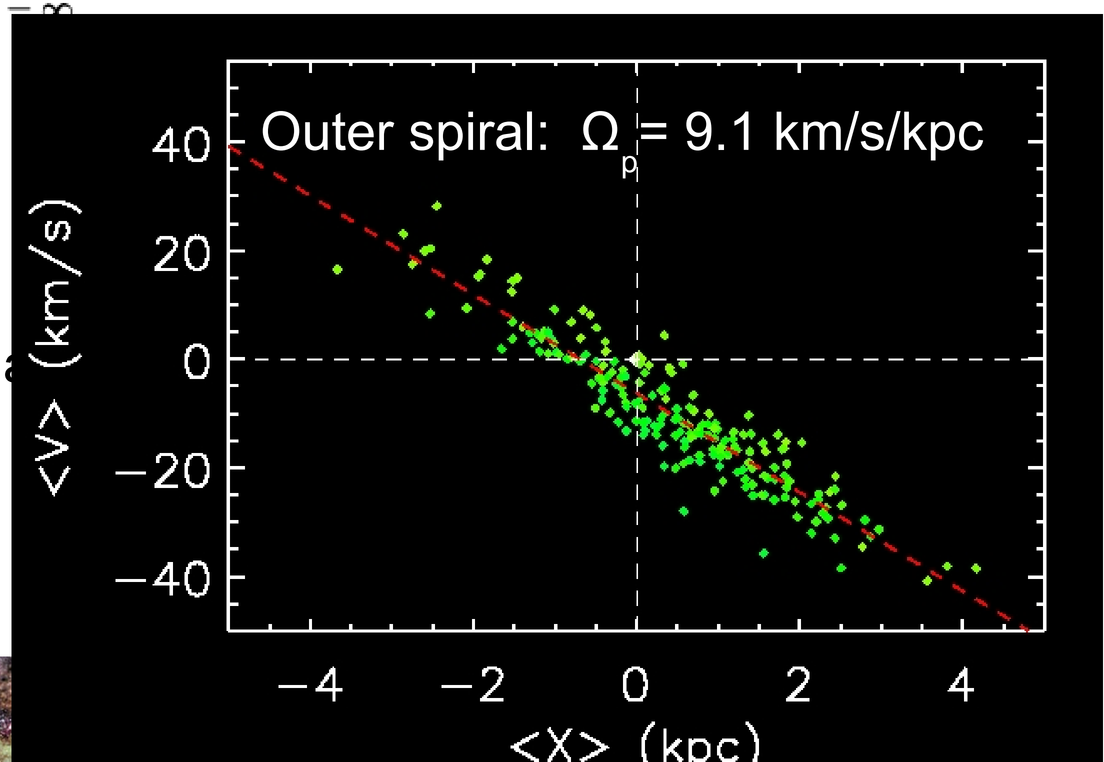


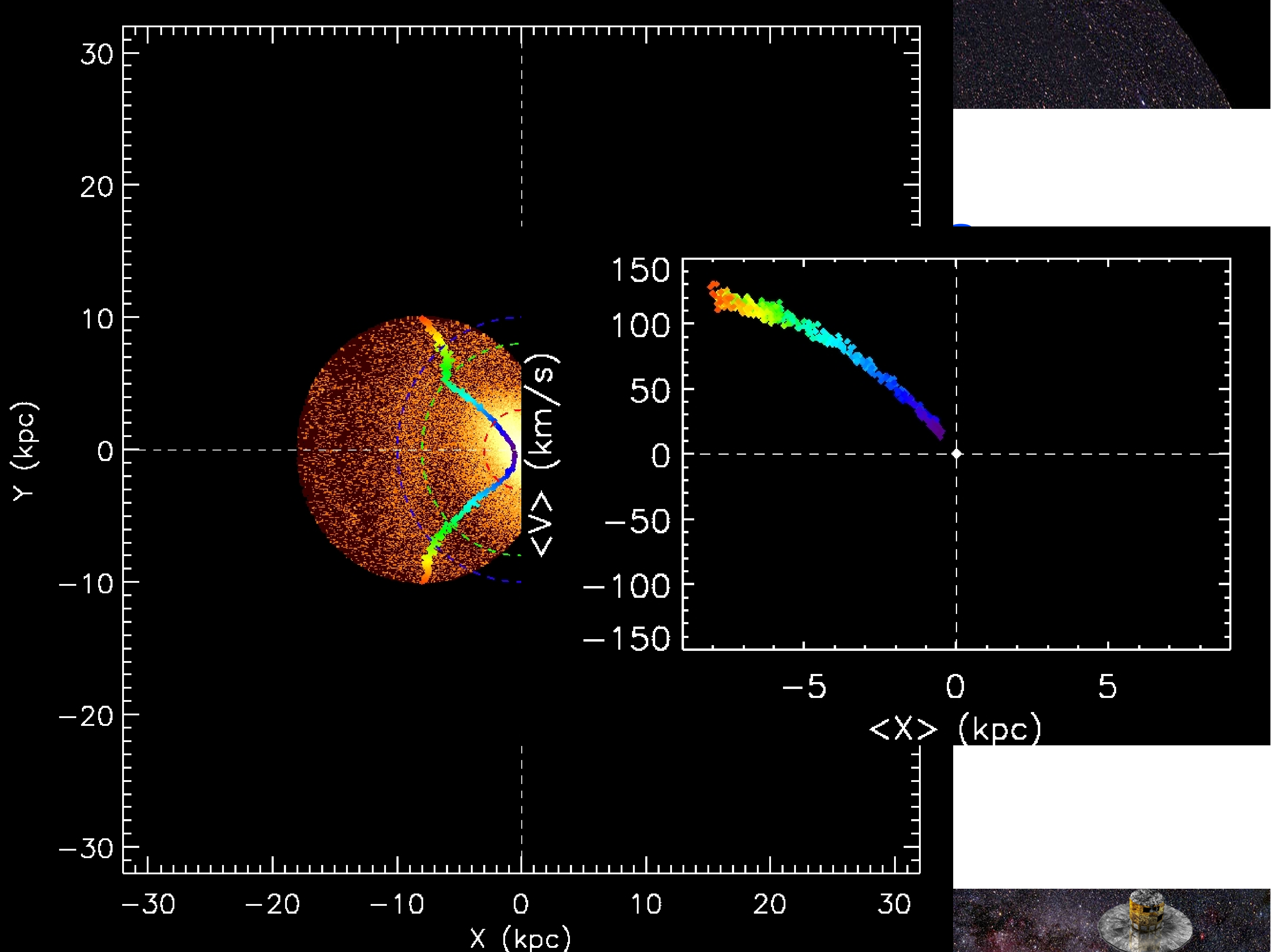


$\int_{-\infty} \Sigma(x, y, t) v_y(x, y, t)\, dx$

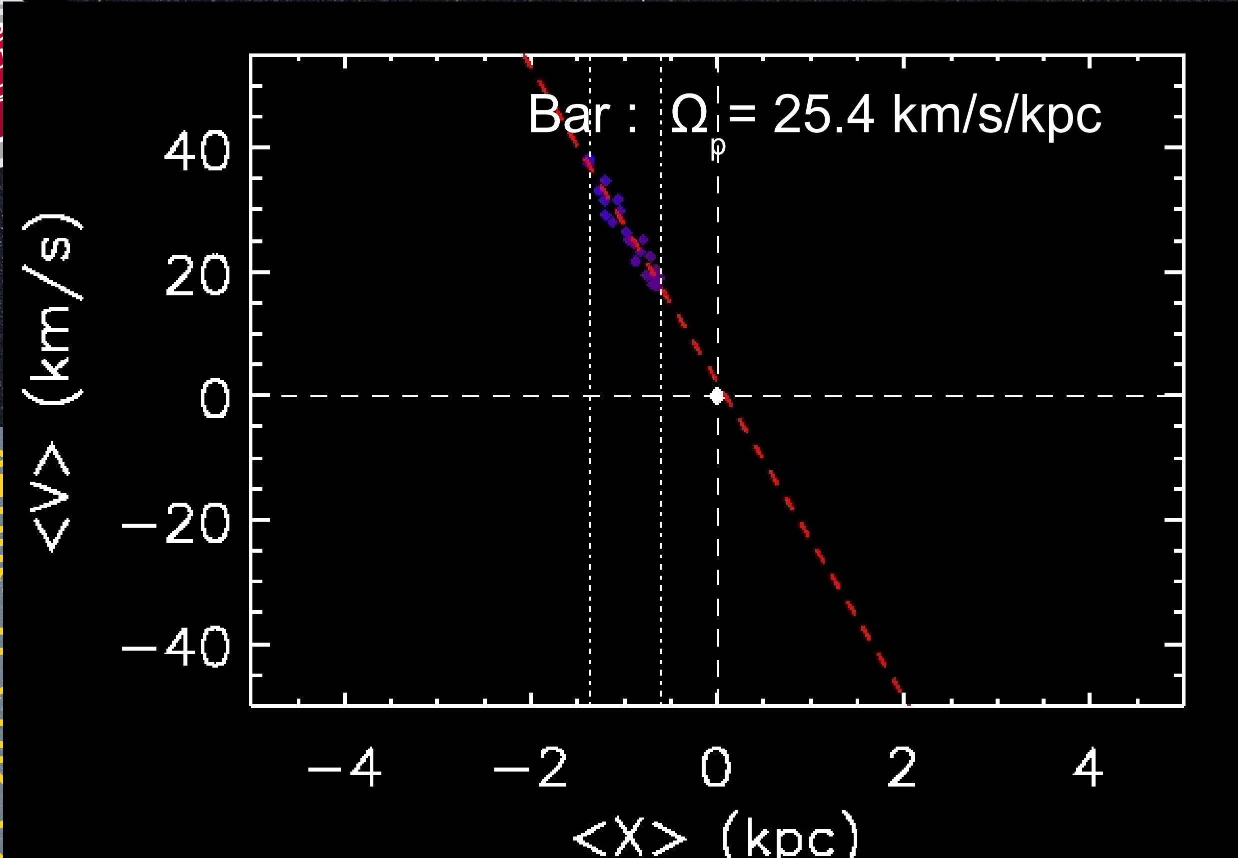


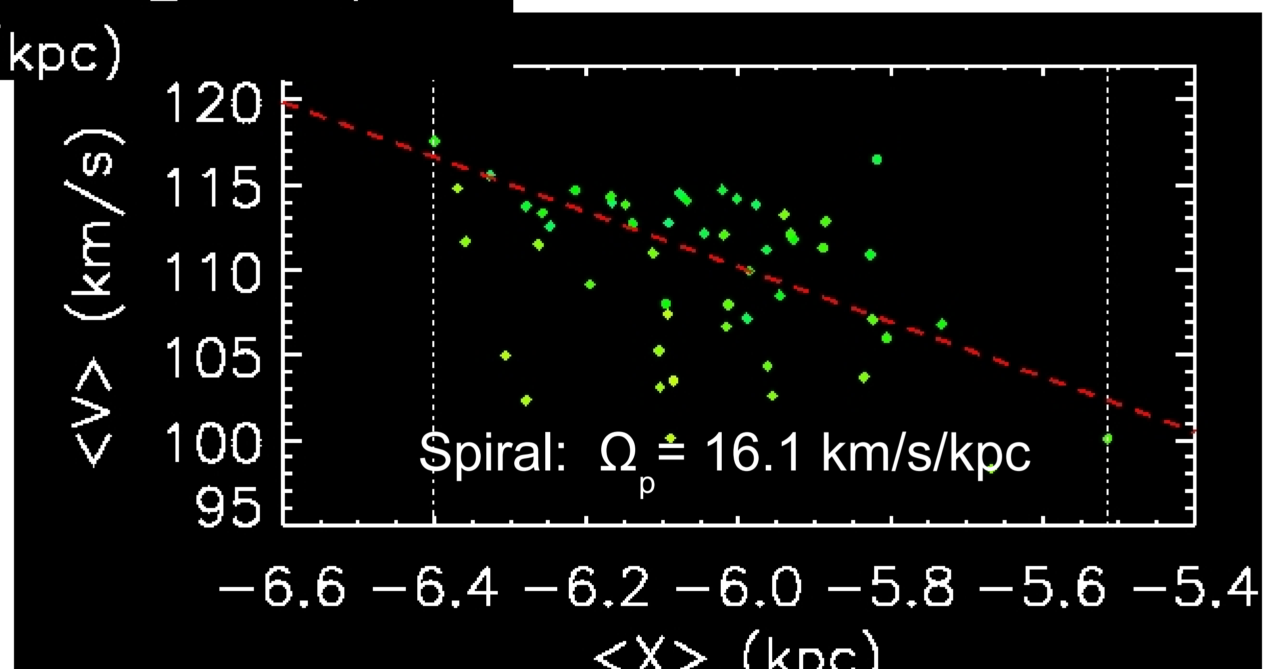
of a





Y (kpc)
X (kpc)
30
20
10
0
−10
−20
−30
−30
−20
−10
0
10
20
30
<V> (km/s)
<X> (kpc)
150
100
50
0
−50
−100
−150
−5
0
5


Bar : Ω_p = 25.4 km/s/kpc
<V> (km/s)
40
20
0
−20
−40
−4
−2
0
2
4
<X> (kpc)


Spiral: Ω_p = 16.1 km/s/kpc
<V> (km/s)
120
115
110
105
100
95
−6.6
−6.4
−6.2
−6.0
−5.8
−5.6
−5.4
<X> (kpc)

Density waves pattern speeds

Can we apply the TW method to Gaia data?

$$\Omega_p \int_{-\infty}^{\infty} \Sigma(x,y,t)\, x\, dx = \int_{-\infty}^{\infty} \Sigma(x,y,t)\, v_y(x,y,t)\, dx$$

It could provide a very good estimate of the local spiral arm pattern speed, and maybe a correct one for the bar

Future improvements with mock data simulations:

- Use simulations with reasonable errors and extinction effect
- Provide pattern speeds uncertainties
- Fine tuning of the radial range for linear fit
- Test the Radial TW method (Merrifield+ 06):

    alternately add masks to enhance regions of importance