Dynamical models of the Galactic Bulge based on survey data

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ESO Rainbows on the Southern Sky, Wednesday October, 7th

Outline

Dynamical modeling of the Galactic B/P bulge

Wegg & Gerhard, MNRAS, 435, 1874 (2013)

Portail, Wegg, Gerhard & Martinez-Valpuesta , MNRAS, 448, 713 (2015)

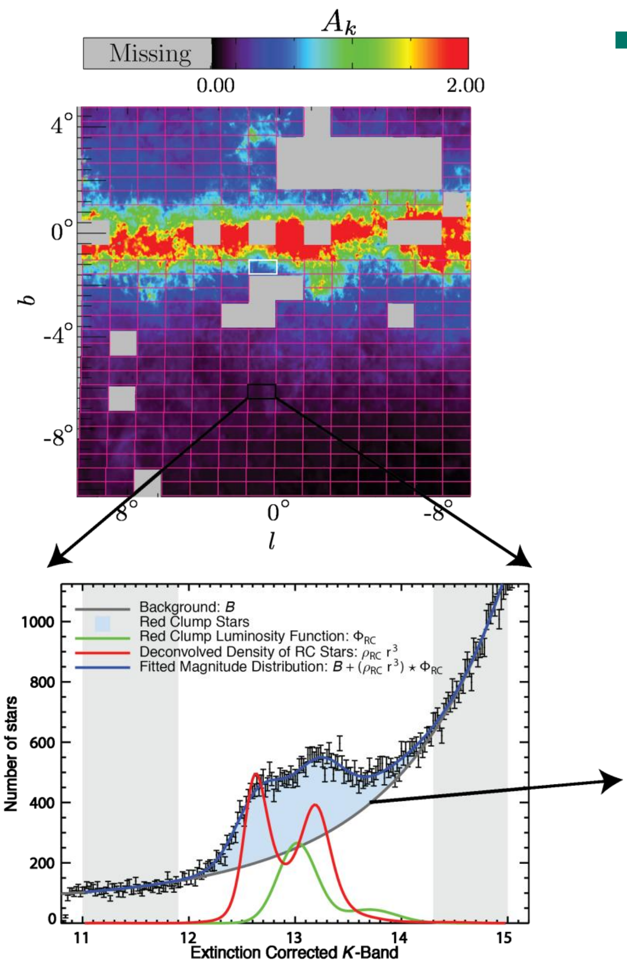
Total mass and Dark Matter - IMF relation

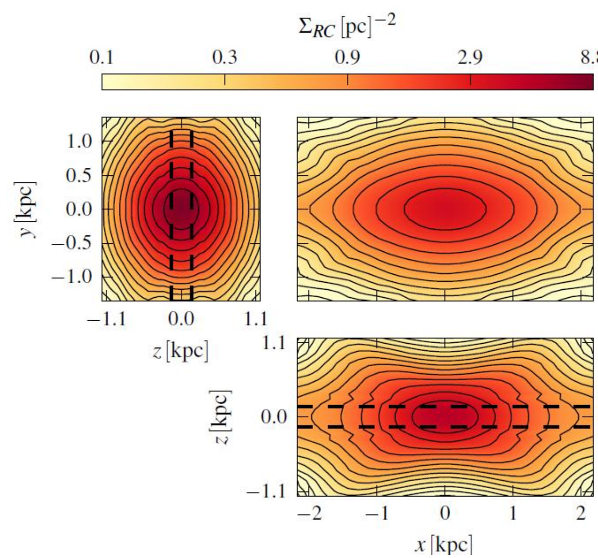
Orbital structure of Box/Peanut bulges

+ Portail, Wegg & Gerhard MNRAS, 450, 66L (2015)

The 3D density of the Galactic bulge

- Deconvolution of magnitude distributions from the VVV survey using Red Clump stars as tracers
- The stellar density is proportional to Red Clump density for an old population

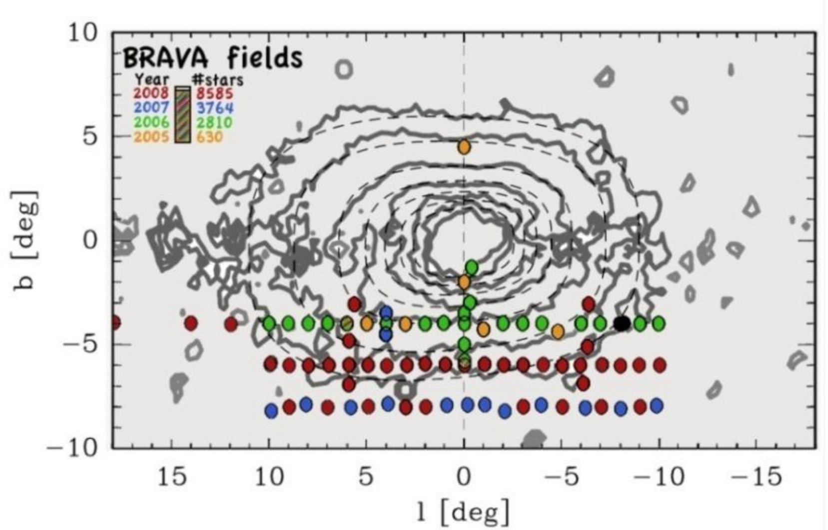




Wegg & Gerhard (2013)

BRAVA kinematics

- BRAVA survey obtained radial velocity for about 10 000 M giants
- Provide mean line-of-sight velocity and dispersion in about 80 fields through the bulge

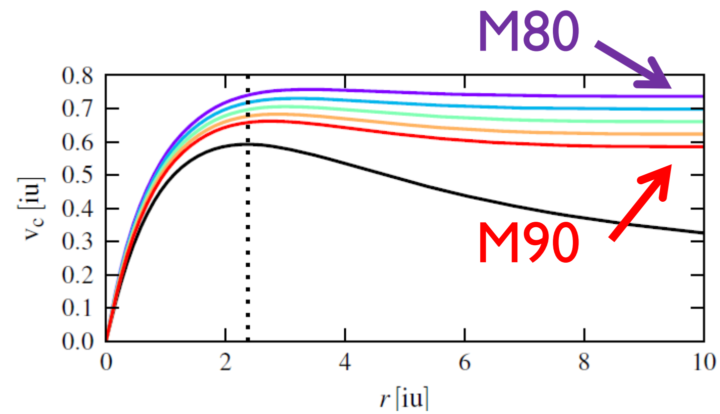


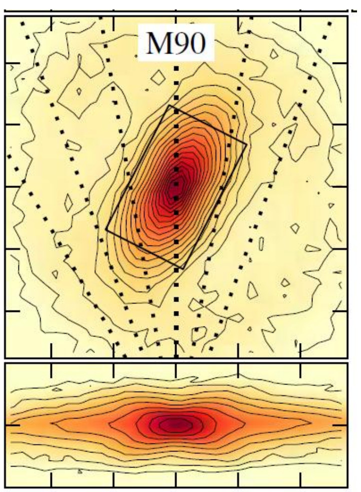
- We are now working on including data from more recent surveys (ARGOS & APOGEE)

Rich et al. (2007)

Dynamical modeling – M2M method

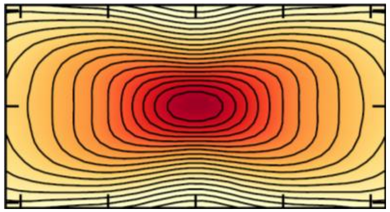
- We evolve a near-equilibrium stellar disk embedded in different dark matter haloes.



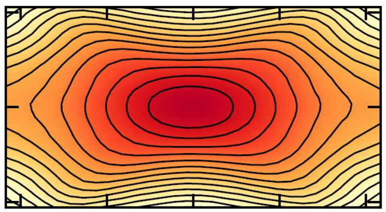


Self-graviting N-body model

Model observables



Real data with errors



Compare

Update the particle masses

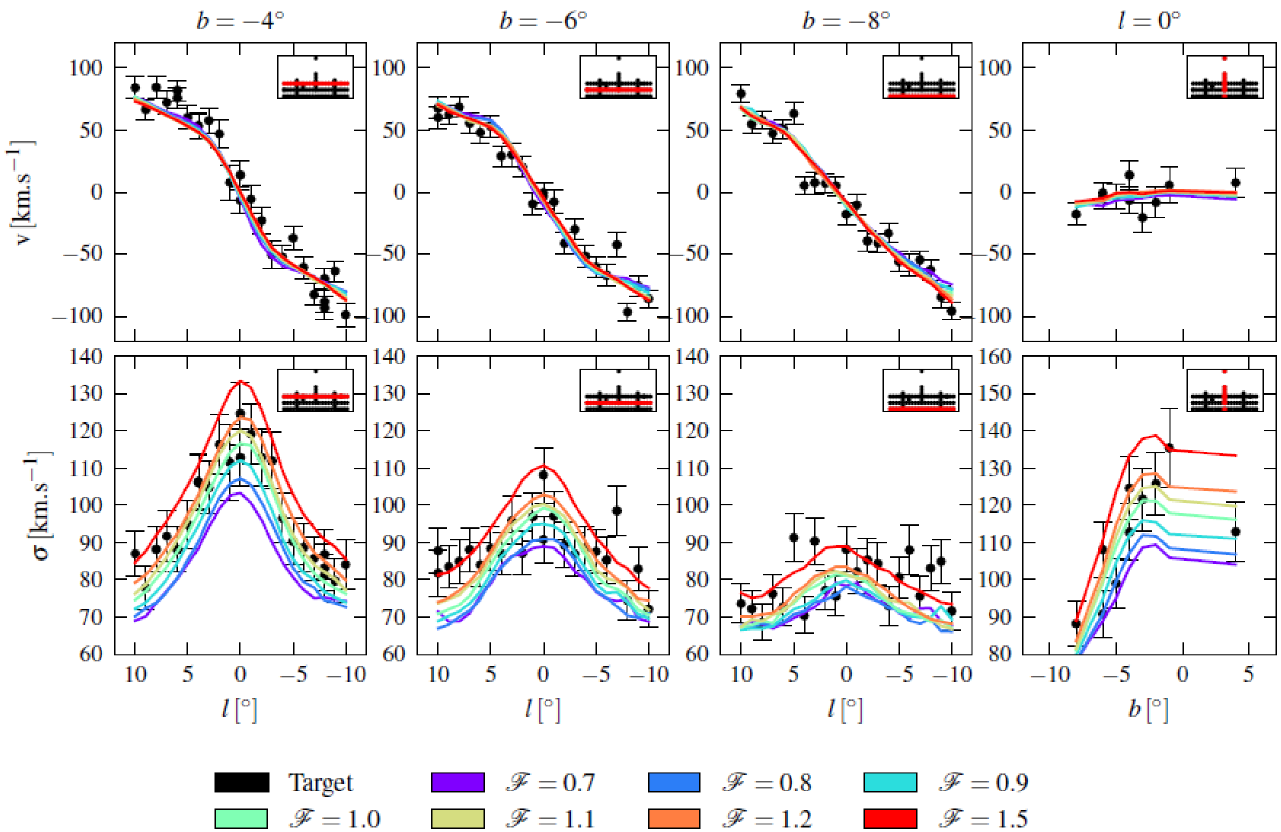
$$\frac{dw_i}{dt} = \varepsilon w_i \frac{\partial F}{\partial w_i}$$

Syer & Tremaine (1996), De Lorenzi et al. (2007)

M2M modeling of the Galactic Bulge

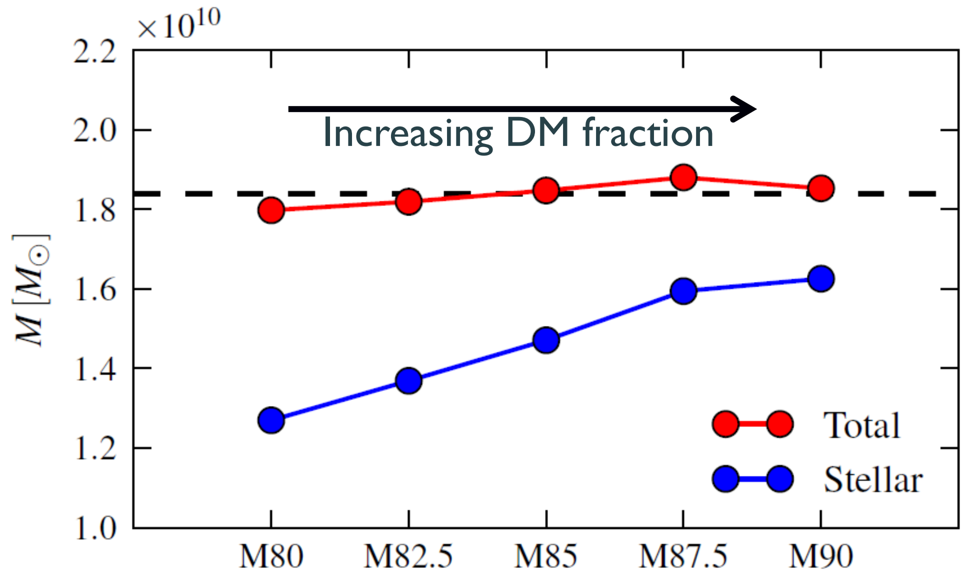
- We can recover the stellar mass required by the model to match the BRAVA dispersion in its dark matter halo.

One model, different stellar masses



Total mass of the bulge

- We measure the **total mass** in the bulge ± (2.2 x 1.4 x 1.2kpc) to be 1.84 10^{10} $M_\odot$



- We find a systematic error on the total mass of less than 5%

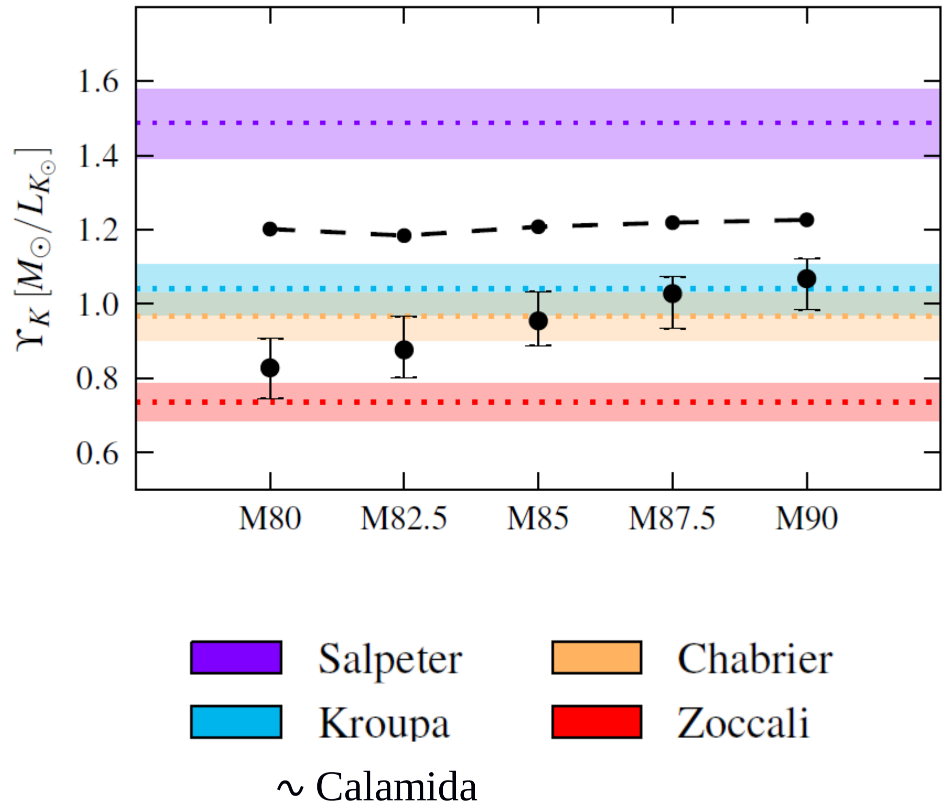
- We have equally good models of the bulge with different dark matter fraction.

Dark matter – IMF relation

- We use the COBE/DIRBE K-band measurements, and correct for extinction using the extinction map from Wegg & Gerhard (2013)

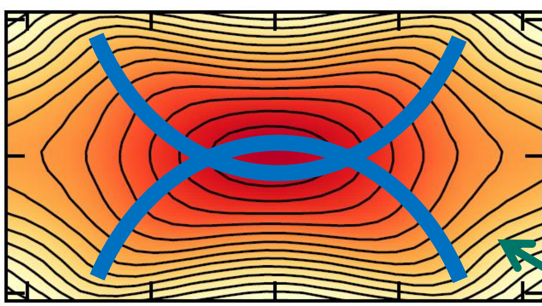
- The Salpeter IMF can be ruled out, predicting a too large mass-to-light ratio

- Zoccali IMF imply about 40% dark matter in the bulge while the Calamida IMF imply only about 12%.



Orbital structure of Box/Peanut bulges

- In 2D, the bar is mostly made out of elongated orbits called x_1 orbits
- In 3D, x_1 becomes unstable and leads to the birth of the x_1 tree
- The simplest member of the x_1 tree is the banana orbits (x_1 v_1)



- According to the literature, banana orbits form the backbone of Box/Peanut bulges.

Bananas orbits

Contopoulos & Barbanis (1994), Pfenniger&Friedeli (1991), Patsis' work

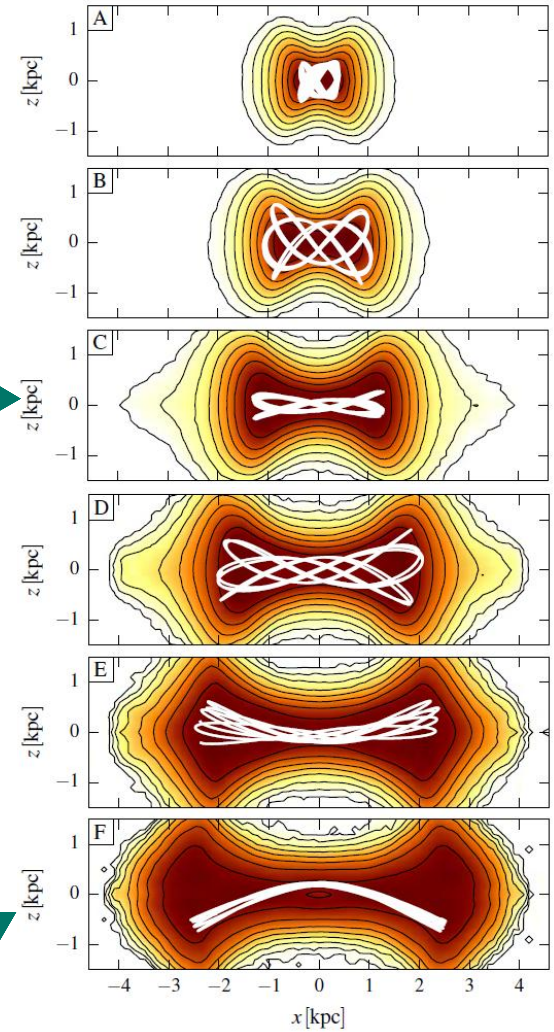
Peanuts, brezels and bananas:
food for thought on the orbital structure of the Galactic bulge

Portail, Wegg & Gerhard MNRAS, 450, 66L (2015)

- Orbit classification based on frequency analysis
- The peanut shape is the sum of embedded peanuts
- The bananas…
  - … extend too far out to make the X-shape
  - … contain only a small fraction of the mass
- Stars do not always « stream along the arms of the X-shape »

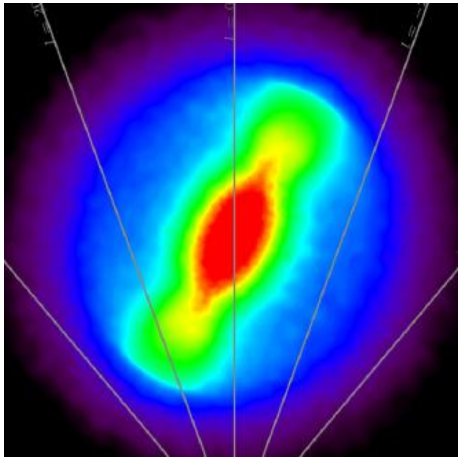
Brezel orbits

Bananas orbits

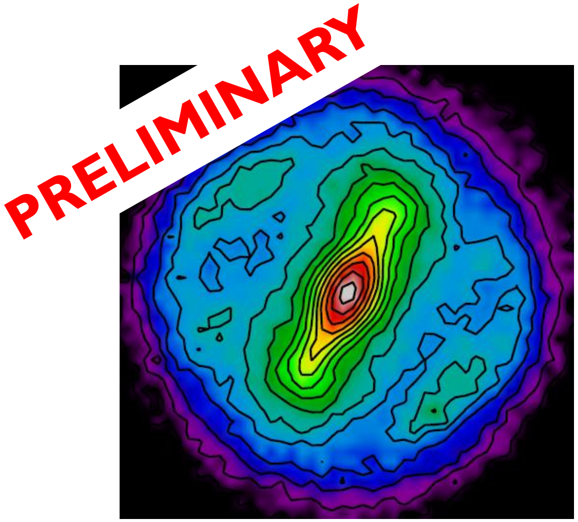


Work in progress

- Include more data from many surveys:
  - ARGOS
  - APOGEE
  - OGLE
  - GAIA
  - GAIA-ESO
  - …
- Construct a dynamical model of the long bar data (VVV+UKIDSS+2MASS)



Parametric model from Wegg et al. (2015)



M2M fit

Summary

- We made dynamical models of the Peanut shaped Galactic bulge using the **3D density of Red Clump stars** combined with stellar kinematics, in different dark matter halos.

- We measure the **total mass** of the bulge to be **$1.84\ 10^{10}\ M_\odot$** with an accuracy **<5%** (systematics). Measured IMFs imply dark matter fraction in the bulge between 12% and 40% (Calamida IMF or Zoccali IMF)

- B/P bulges and the MW's bulge can be made by brezel orbits instead of the usually claimed banana orbits.