No X-shape in the Milky Way bulge

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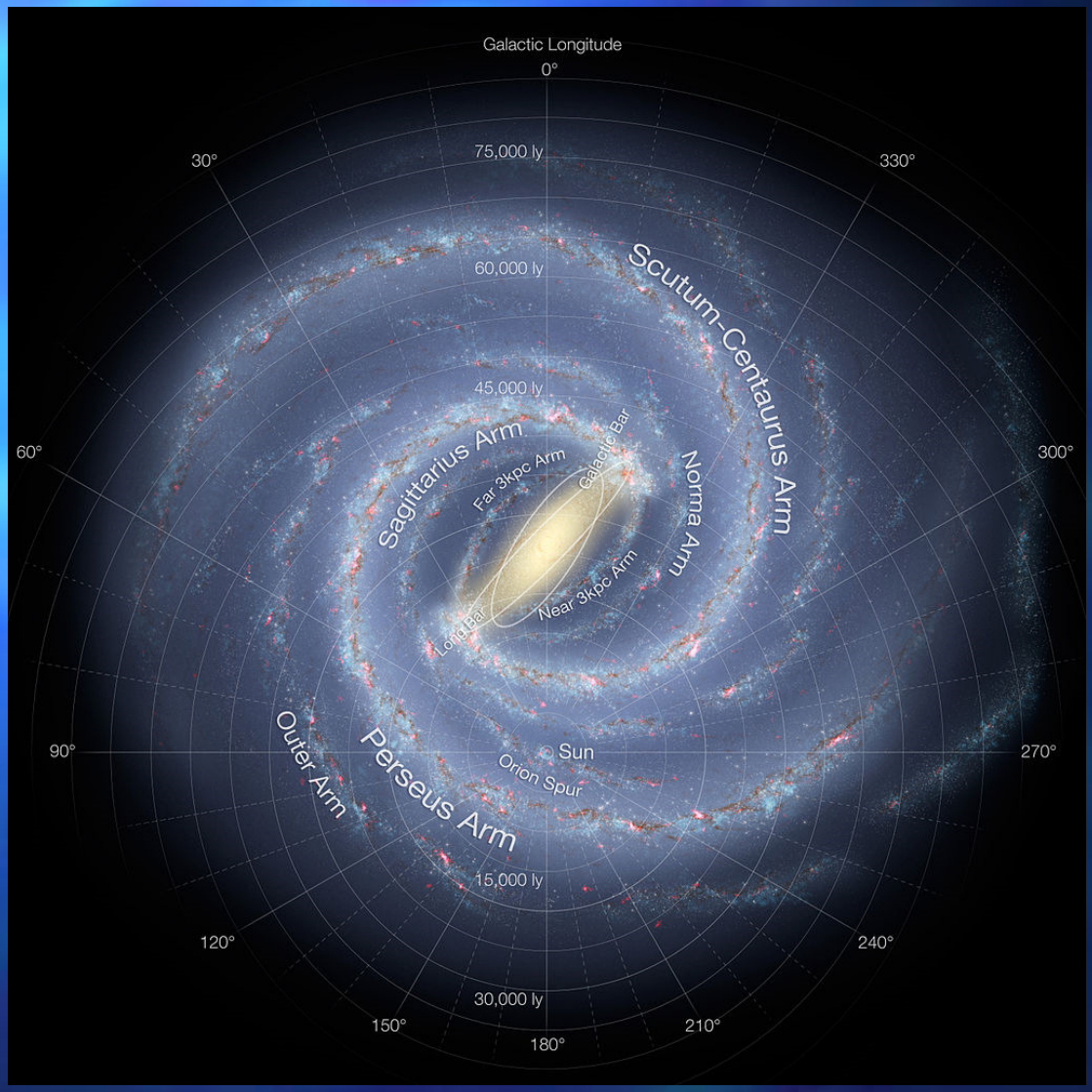
Main references:

- López-Corredoira (2016, A&A, 593, A66)
- López-Corredoira (2017, ApJ, 835, 218)

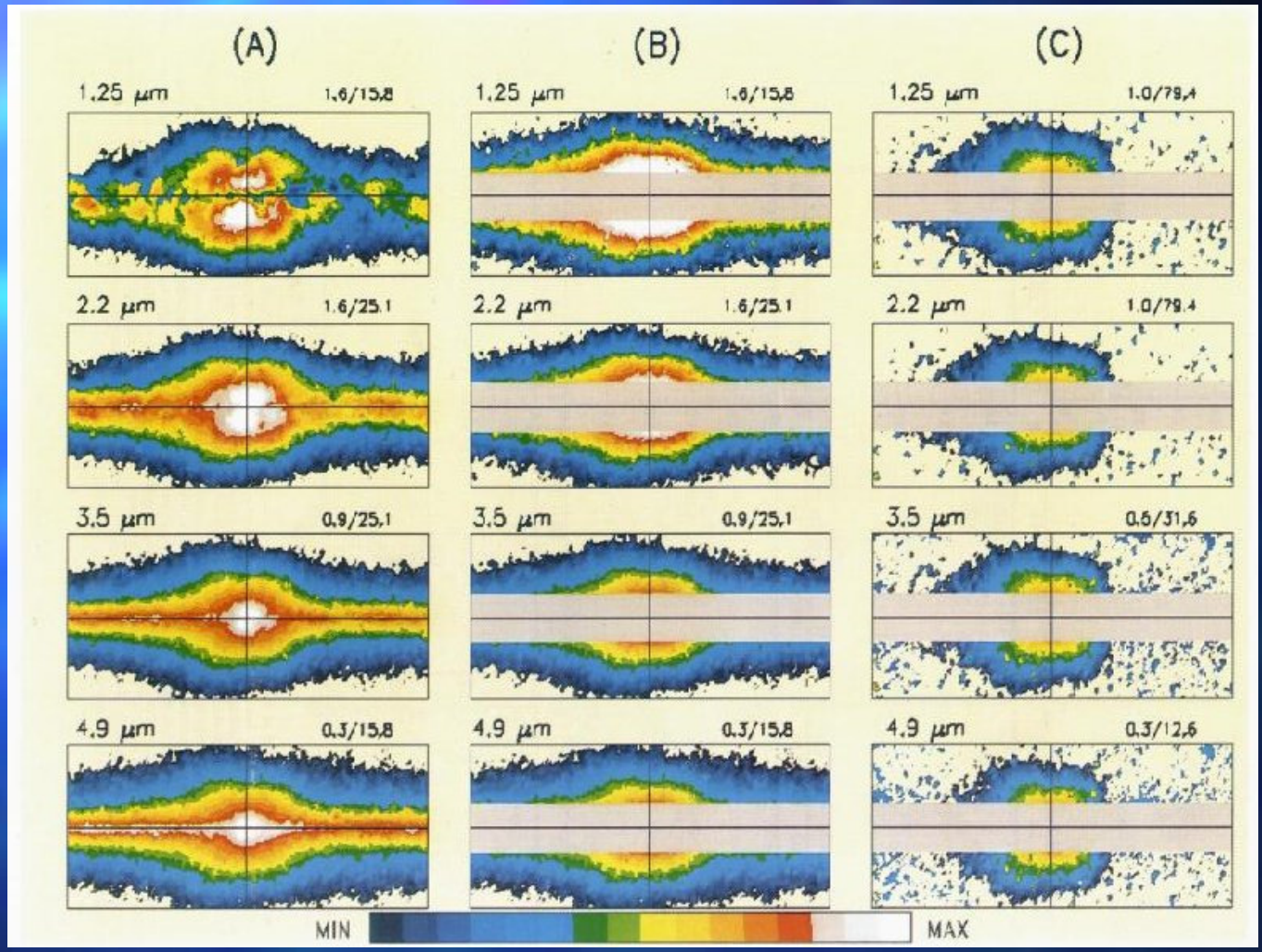
OGLE25 conference, July 2017

MORPHOLOGY OF THE MILKY WAY



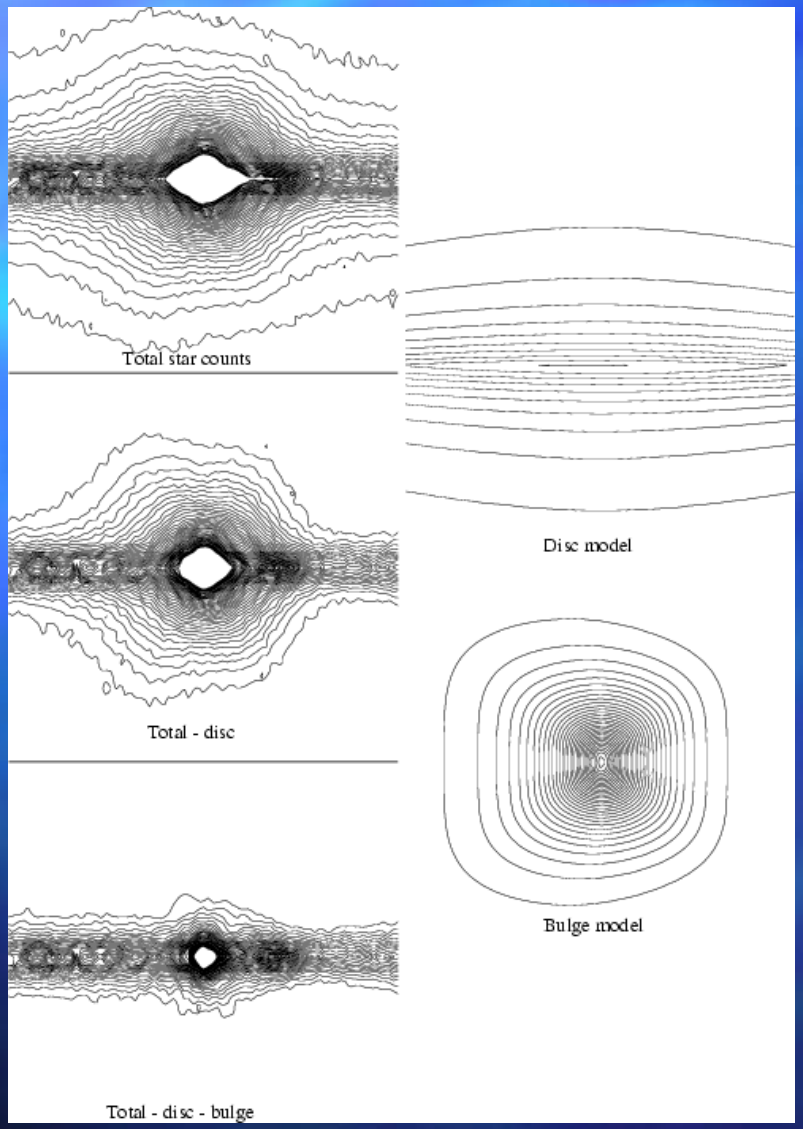
Source: Wikipedia, "Milky Way"

TRIAXIAL/BARRED BULGE



Weiland et al. (1994): COBE-DIRBE maps at $|\ell|<30^{o}$, $|b|<10^{o}$.
(A) Total flux; (B)=(A)+Extinction corrected; (C)=(B)+Disc subtracted

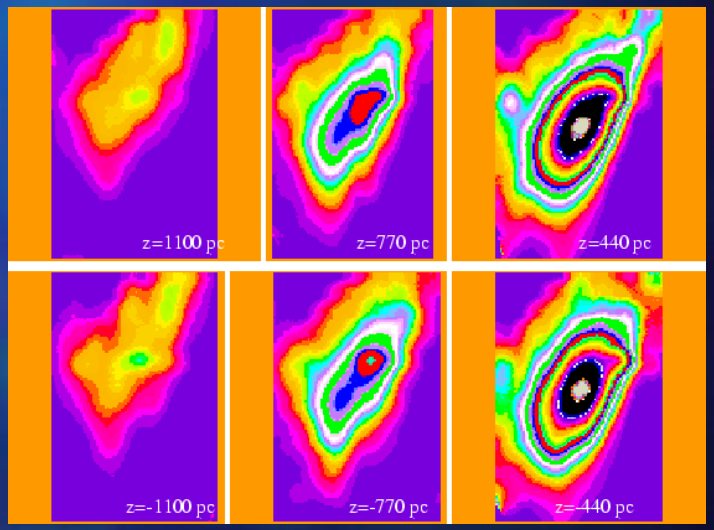
TRIAXIAL/BARRED BULGE



BOXY BULGE

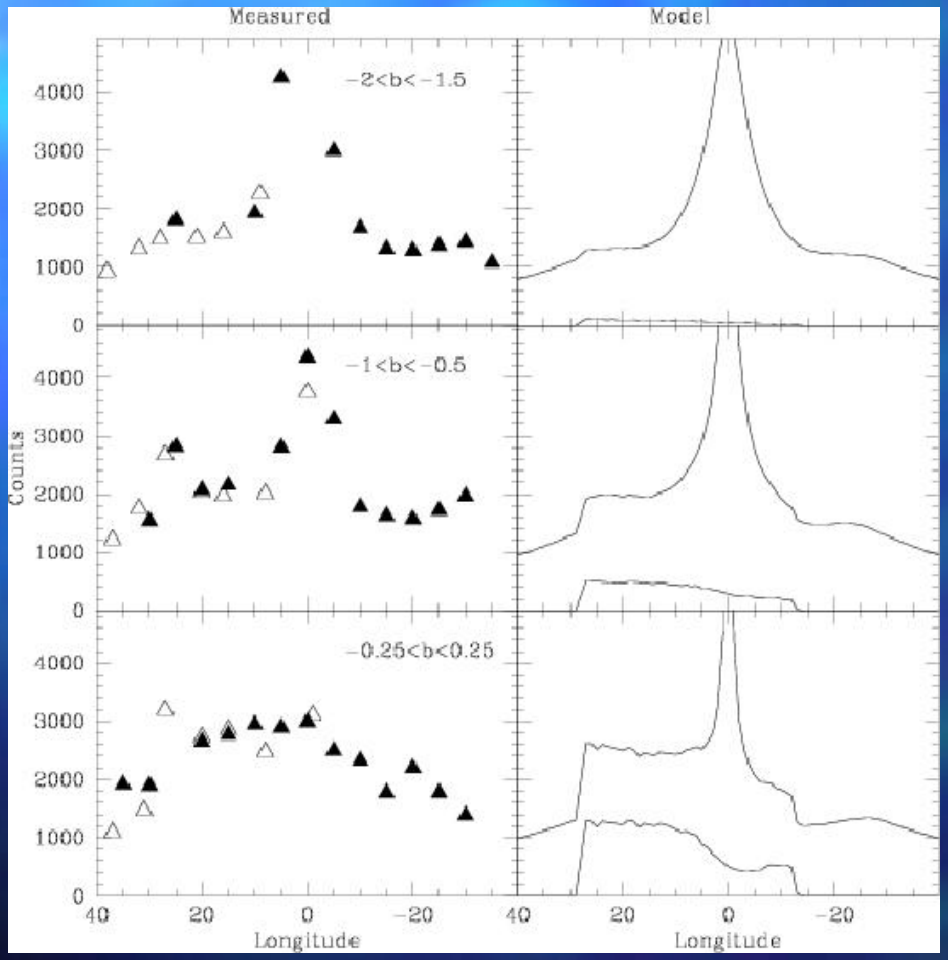
López-Corredoira et al. (2005): 2MASS K-band star counts, at $|\ell|<20^{o}$, $|b|<12^{o}$

Method: Inversion of stellar statistics equation
(see López-Corredoira et al. 1997, 2000 for application to TMGS data)

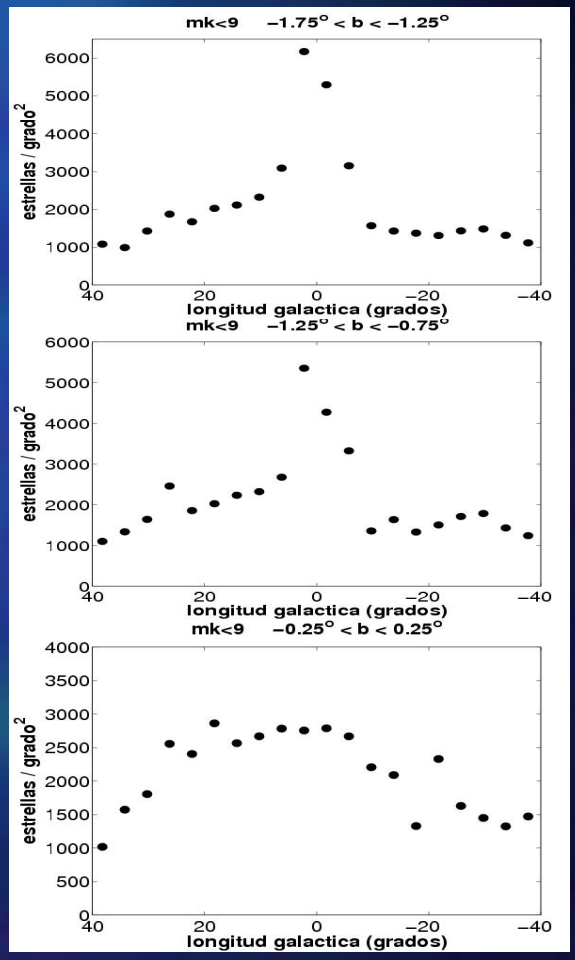


LONG BAR

- Strong asymmetry in the star counts for $|b|<1^0$, but not for $1.5^0 < |b| < 2.5^0 \Rightarrow$ the disc is not responsible *(López-Corredoira et al. 2001)*.

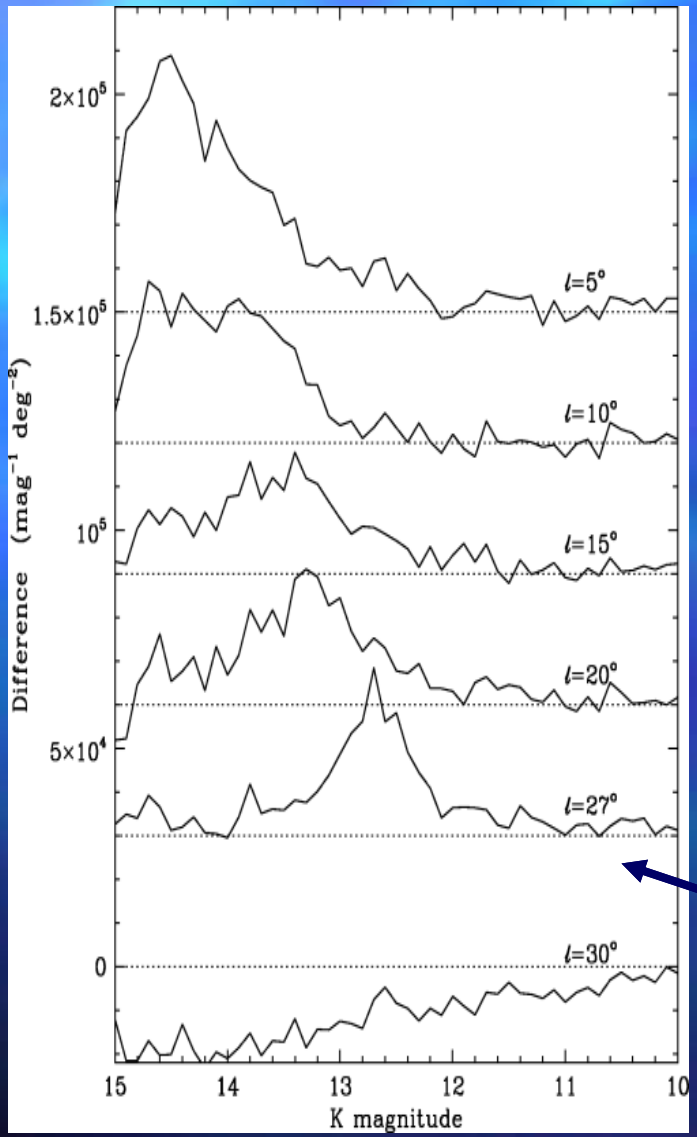


DENIS + TMGS (2001)



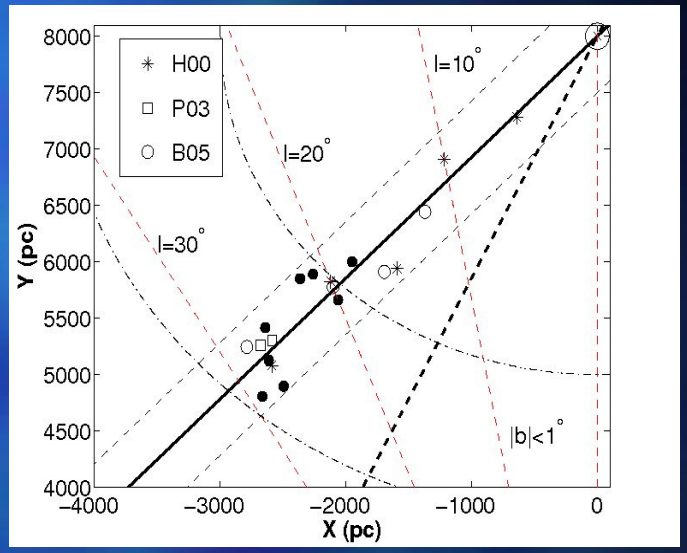
2MASS (2005)

LONG BAR



Red Clumps:

Maximum densities along the lines of sight:



- Parameters in-plane bar:

Position angle: $43^0 \pm 7^0$

Half-length: 3.9 ± 0.4 kpc

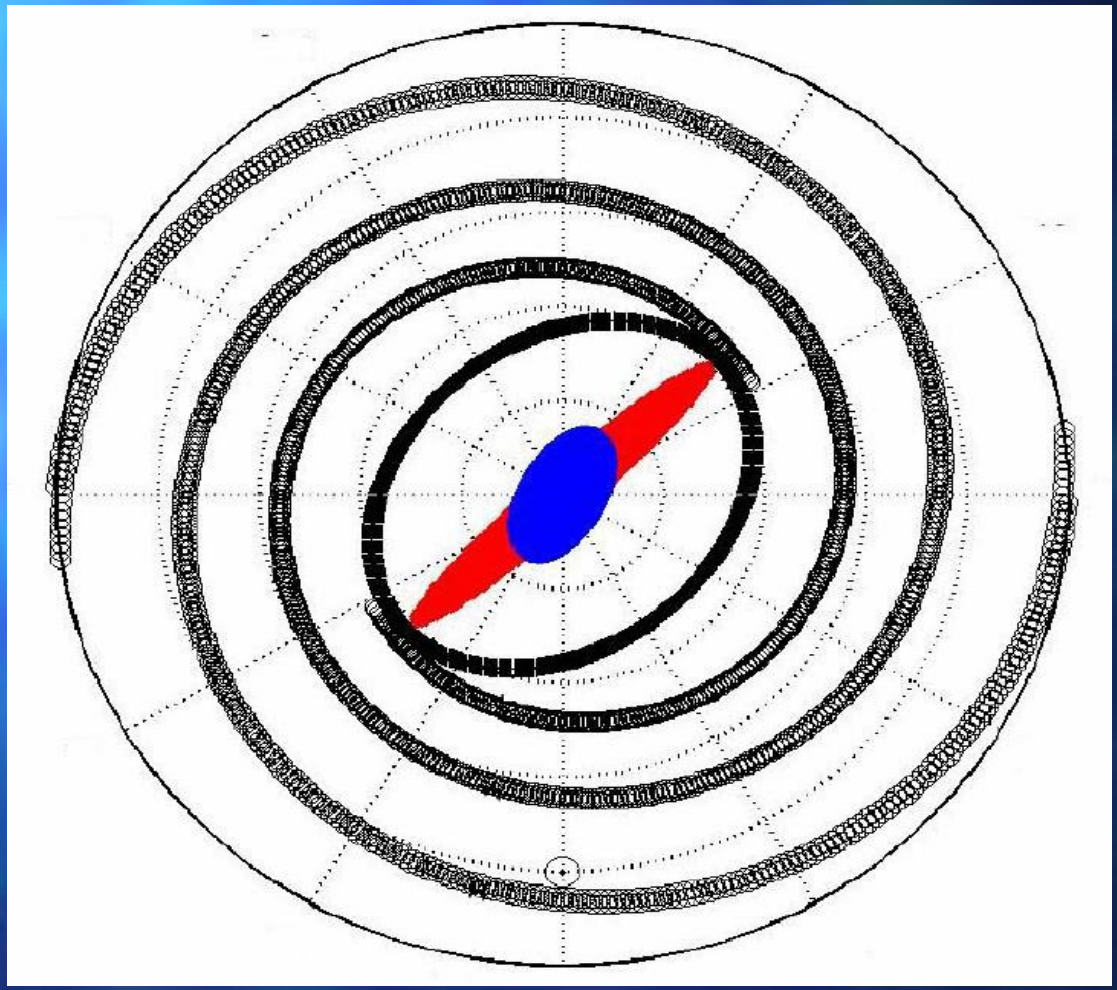
(Hammersley et al. 2000)

Axial ratios: 1:0.15:0.03

(López-Corredoira et al. 2007)

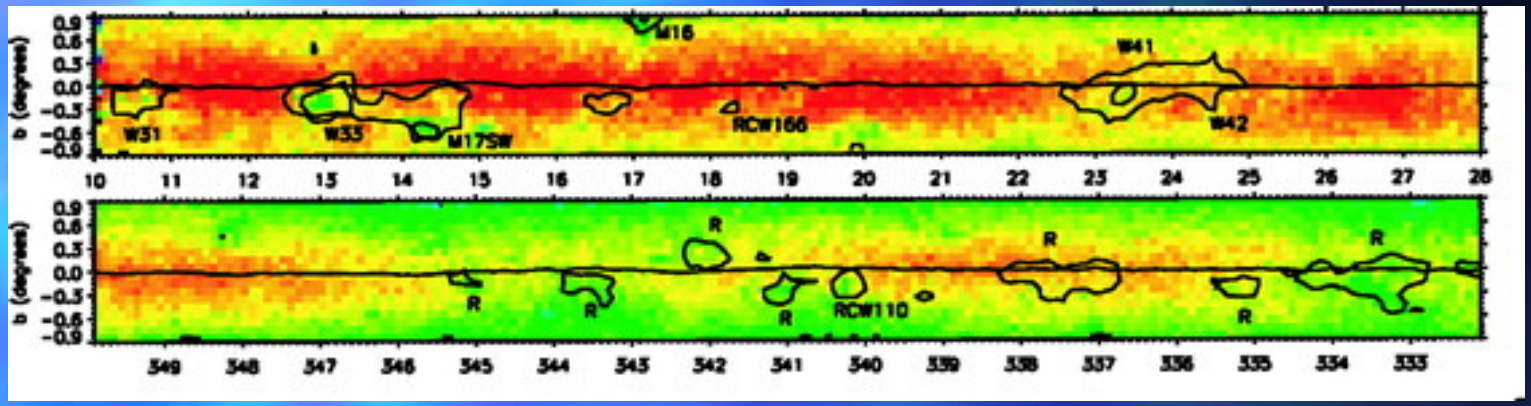
(Cabrera-Lavers et al. 2007)

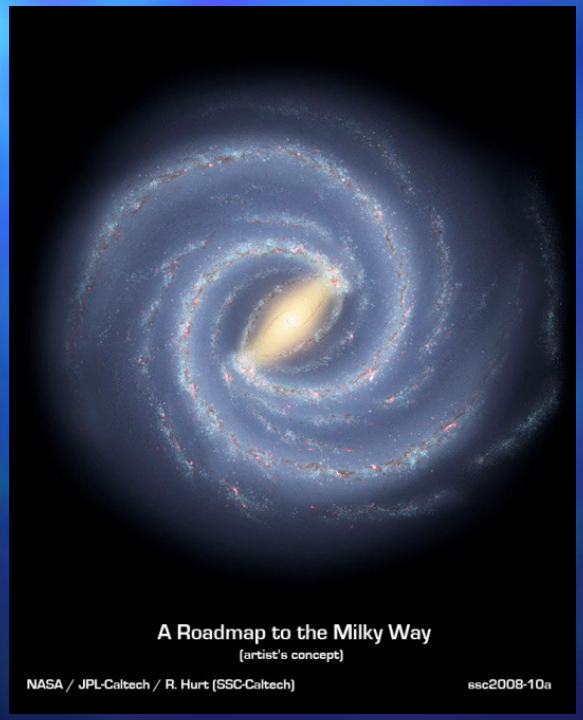
BULGE + LONG BAR



BULGE + LONG BAR

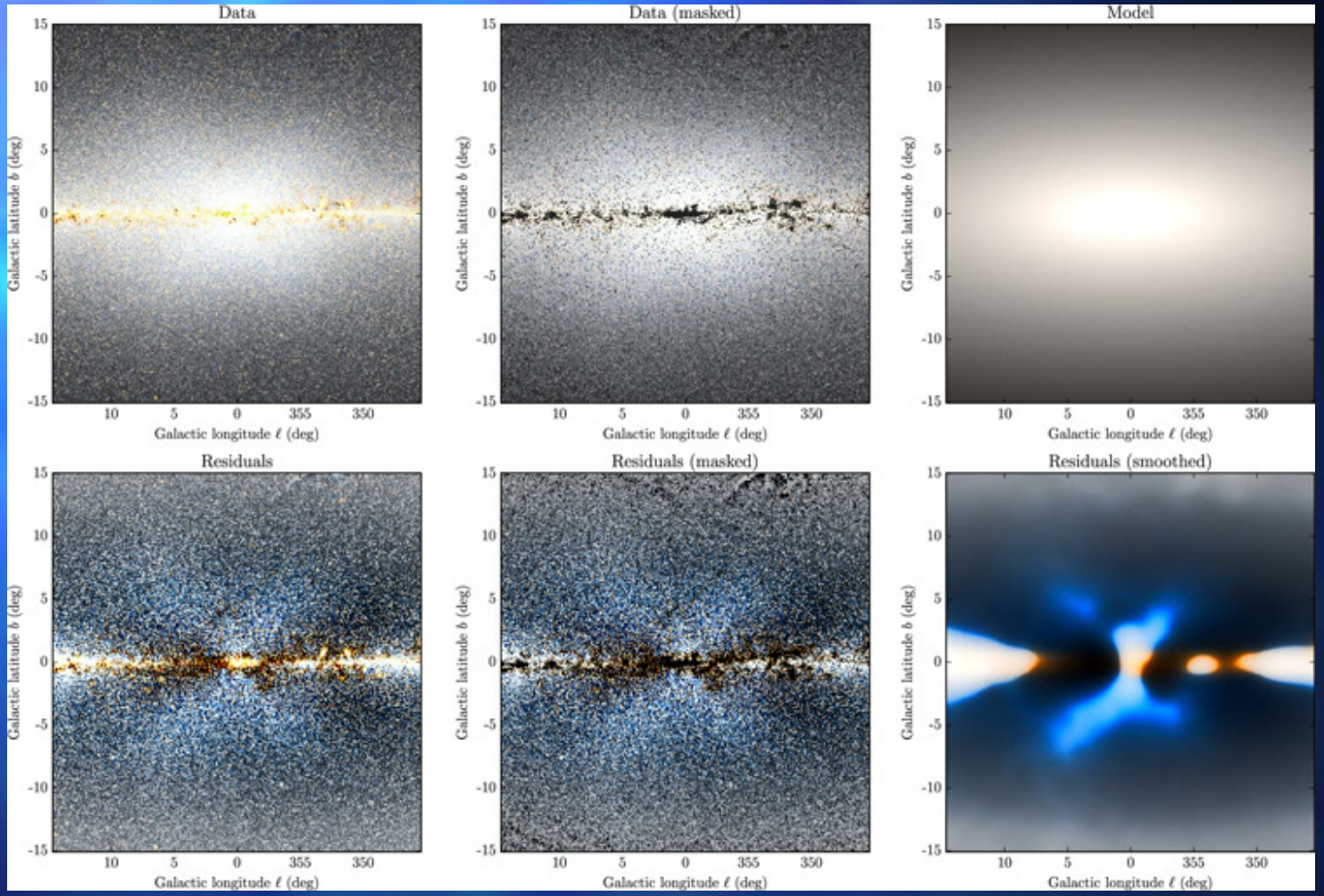
SPITZER-GLIMPSE data





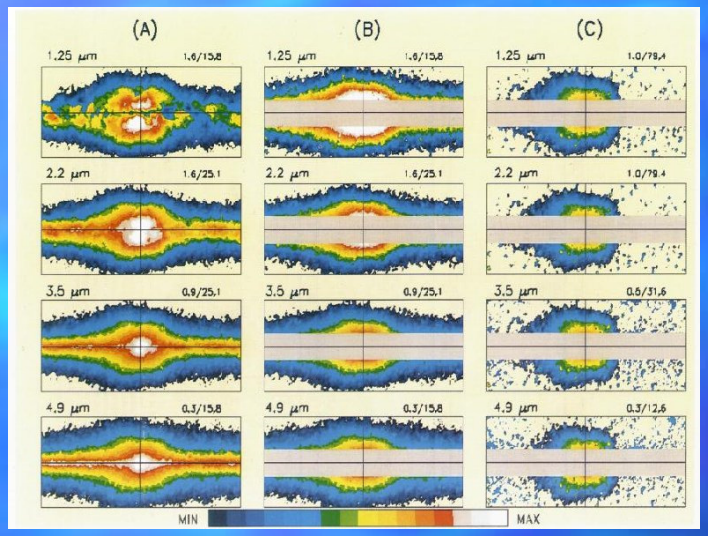
Benjamin et al. (2005)

X-shaped bulge

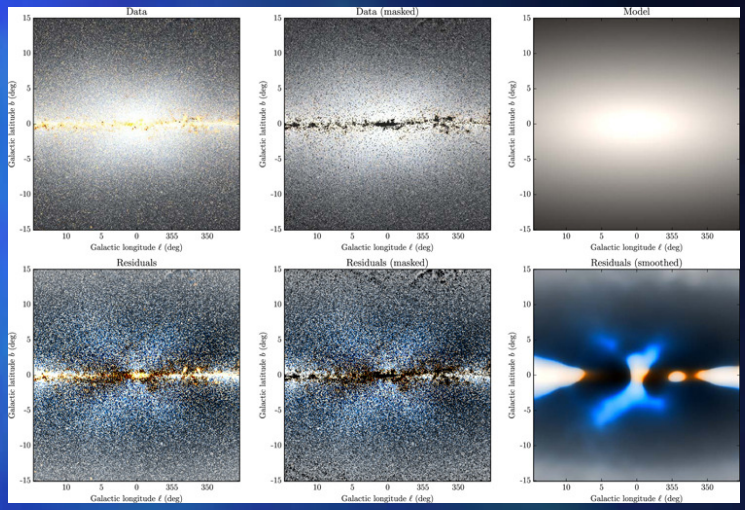


Ness & Lang (2016): WISE W1, W2 flux

X-shaped bulge



Weiland et al. (1994): elipsoidal bulge

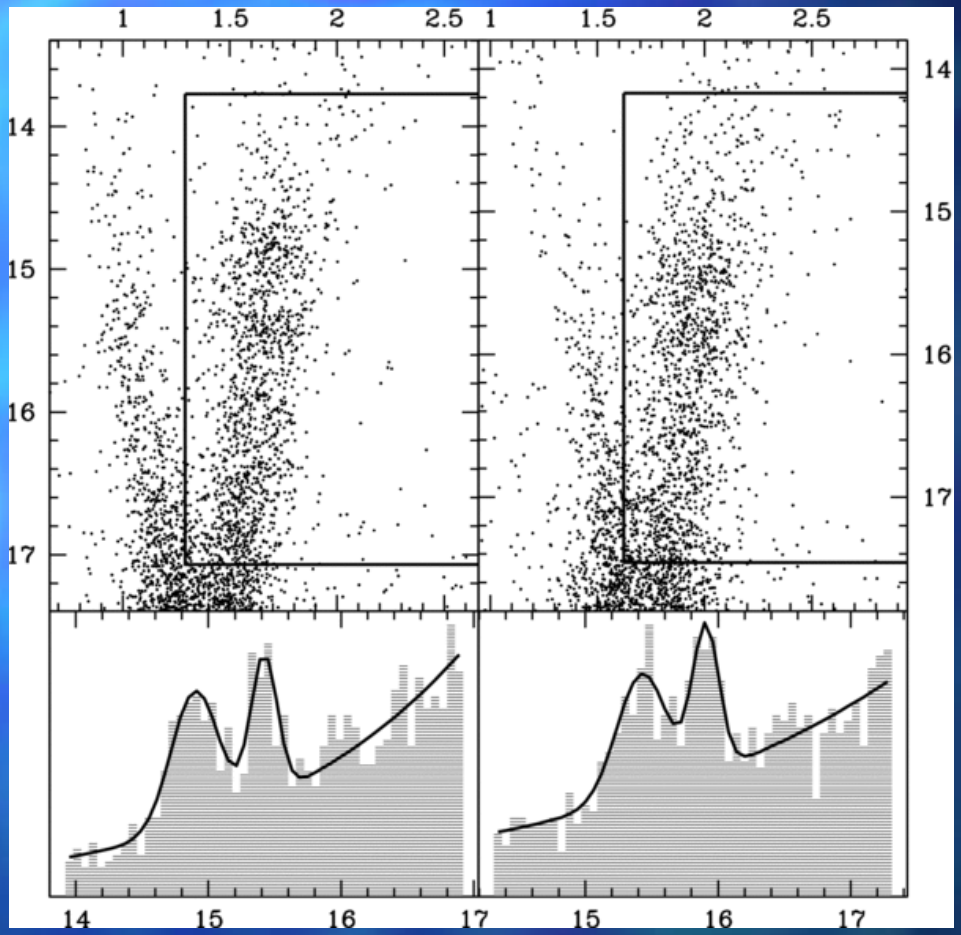


Ness & Lang (2016): X-shaped bulge

Why do we see now an X-shape bulge and not beforehand?

- Maybe some differences in the disc model subtraction
- Maybe some artifacts from subtracting the bulge as an ellipsoid instead of as a boxy bulge (as suggested by Lee & Jang 2016)

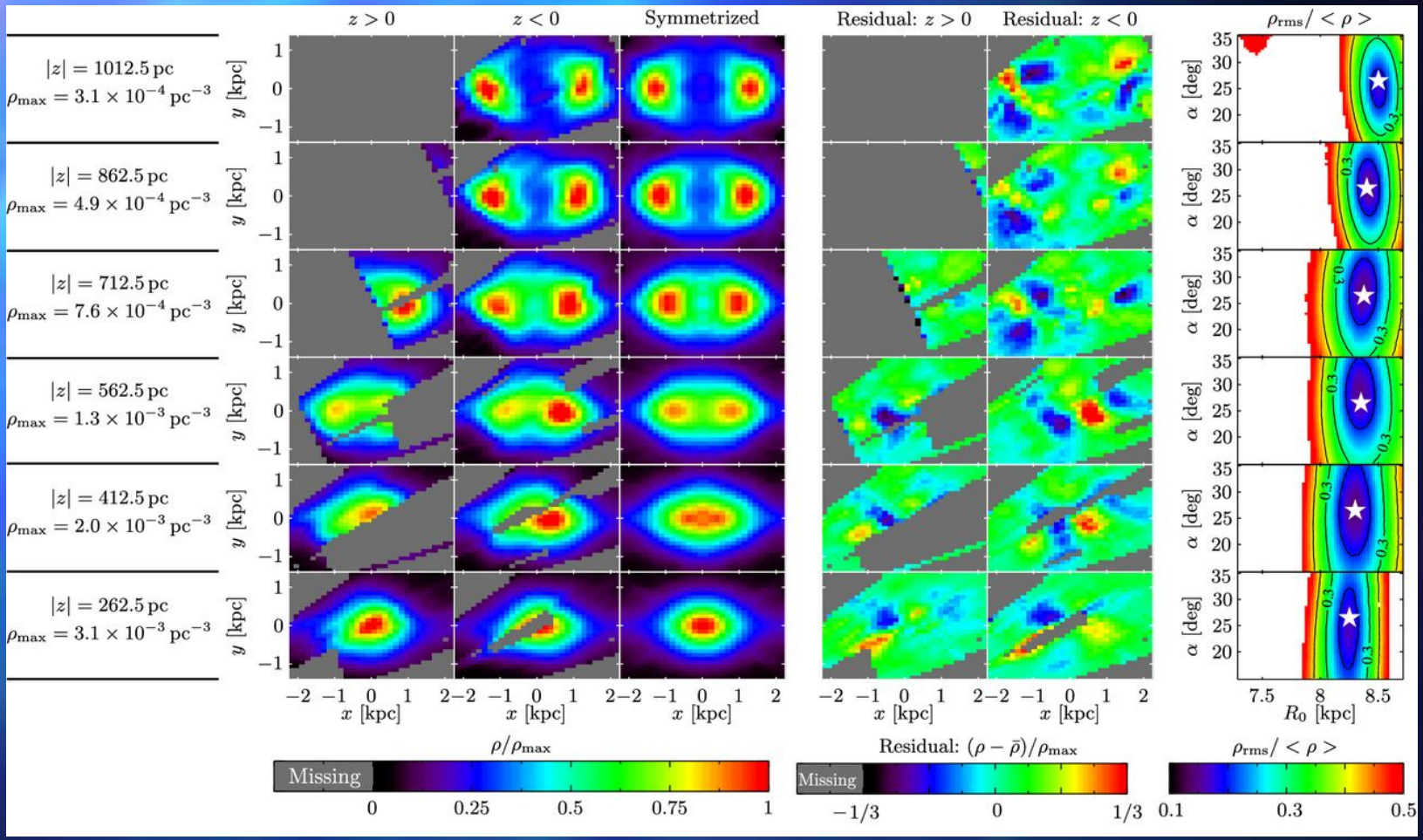
X-shaped bulge: Red Clumps



Nataf et al. (2010): I versus V-I; OGLE-III red clumps for two locations. Left: (l, b) = (0.27, − 5.77); Right: (l, b) = (−0.28, 5.76)

See also McWilliam & Zoccali 2010, Saito et al. 2011, Wegg & Gerhard 2013, Nataf et al. 2015

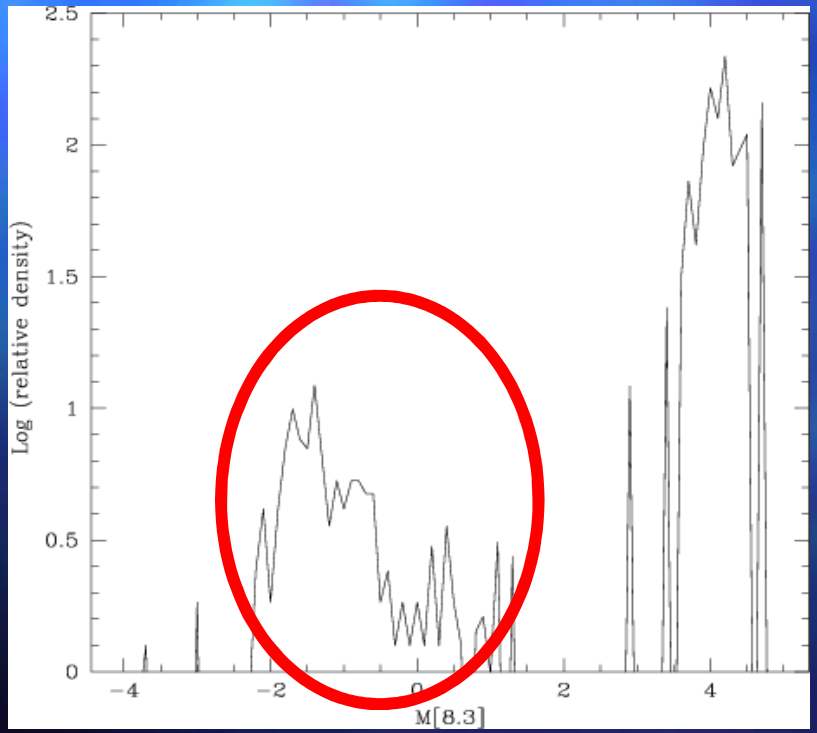
X-shaped bulge: Red Clumps

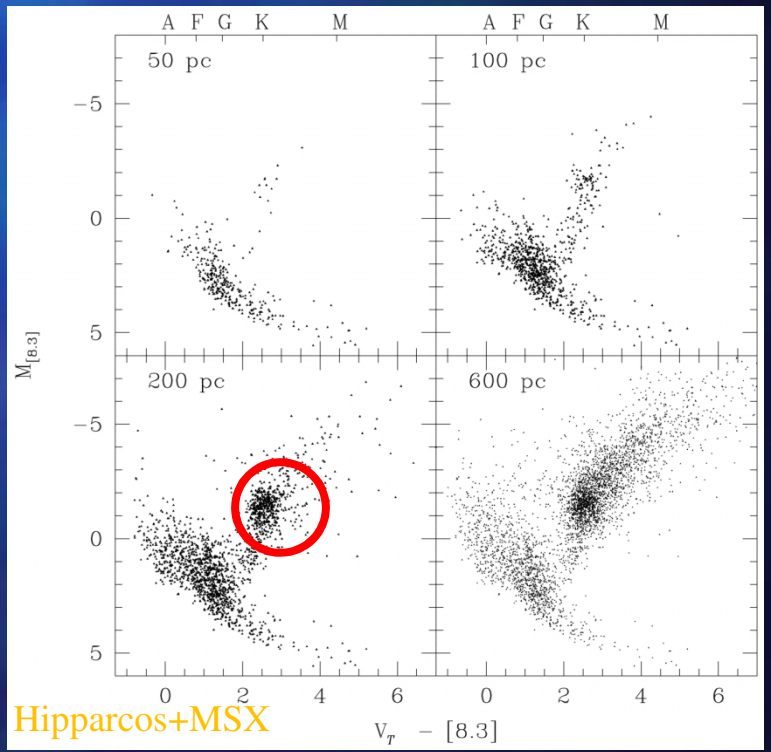


Wegg & Gerhard (2013): X-shaped bulge density from VISTA-VVV red clumps

RED CLUMP METHOD

- K2III population (*Red clump*) *as standard candles*: The more prominent population of the disc giants. *(Cohen et al. 2000; Hammersley et al. 2000)* .
- Mean absolute magnitude and intrinsic color with small dependence on metallicity and age in near infrared.





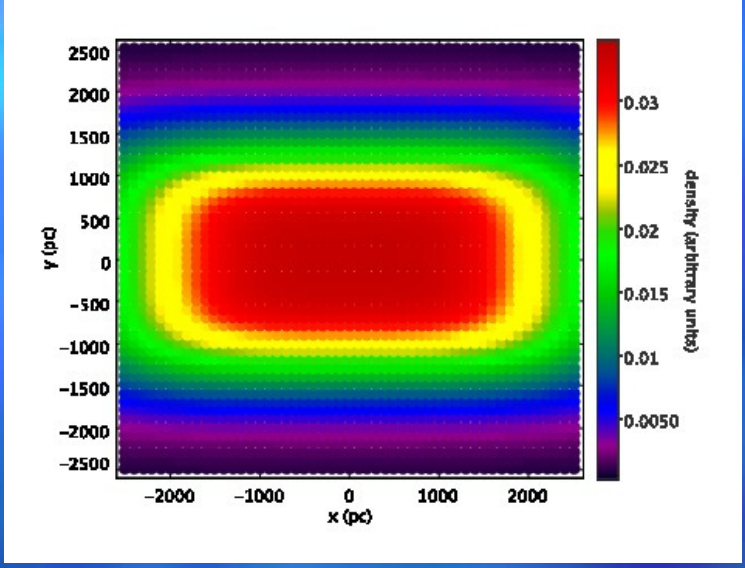
RED CLUMP METHOD

Lee et al. (2015): "The presence of two red clumps (RCs) in high-latitude fields of the Milky Way bulge is interpreted as evidence for an X-shaped structure originated from the bar instability. Here we show, however, that this double RC phenomenon is more likely to be another manifestation of multiple populations observed in globular clusters (GCs) in the metal-rich regime. As in the bulge GC Terzan 5, the helium enhanced second-generation stars in the classical bulge component of the Milky Way are placed on the bright RC, which is about 0.5 mag brighter than the normal RC originated from the first-generation stars, producing the observed double RC."

Girardi (1999): "…the clump of red giants in the colour—magnitude diagram (CMD) of composite stellar populations should present an extension to lower luminosities, which goes down to about 0.4 mag below the main clump. This feature is made of stars just massive enough to have ignited helium in non-degenerate conditions, and therefore corresponds to a limited interval of stellar masses and ages. In the present models, which include moderate convective overshooting, it corresponds to ~1 Gyr old populations. (…) The faint extension is expected to be clearly separated from the main clump in the CMD of metal-rich populations, defining a 'secondary clump' by itself. (…) secondary clumps similar to the model predictions are **observed in the CMD of nearby stars from Hipparcos data**, and in those of some Large Magellanic Cloud fields observed to date. "

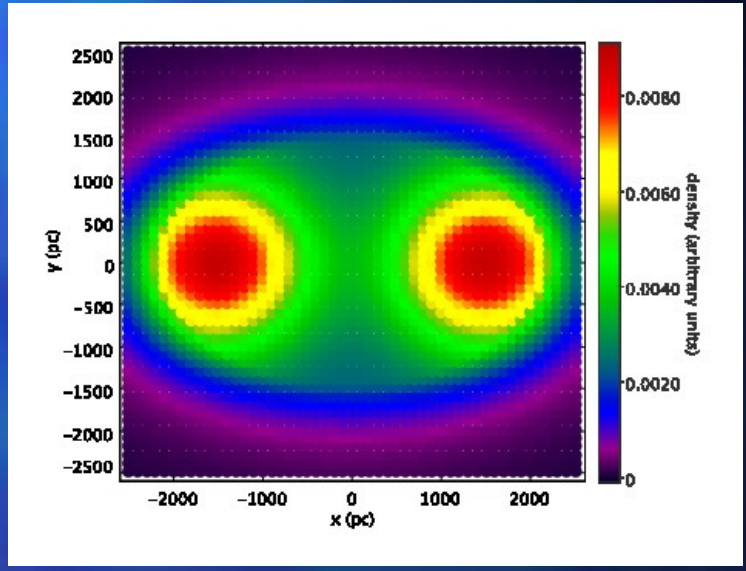
López-Corredoira (2016): F0-F5V stars of VISTA-VVV

BOXY BULGE



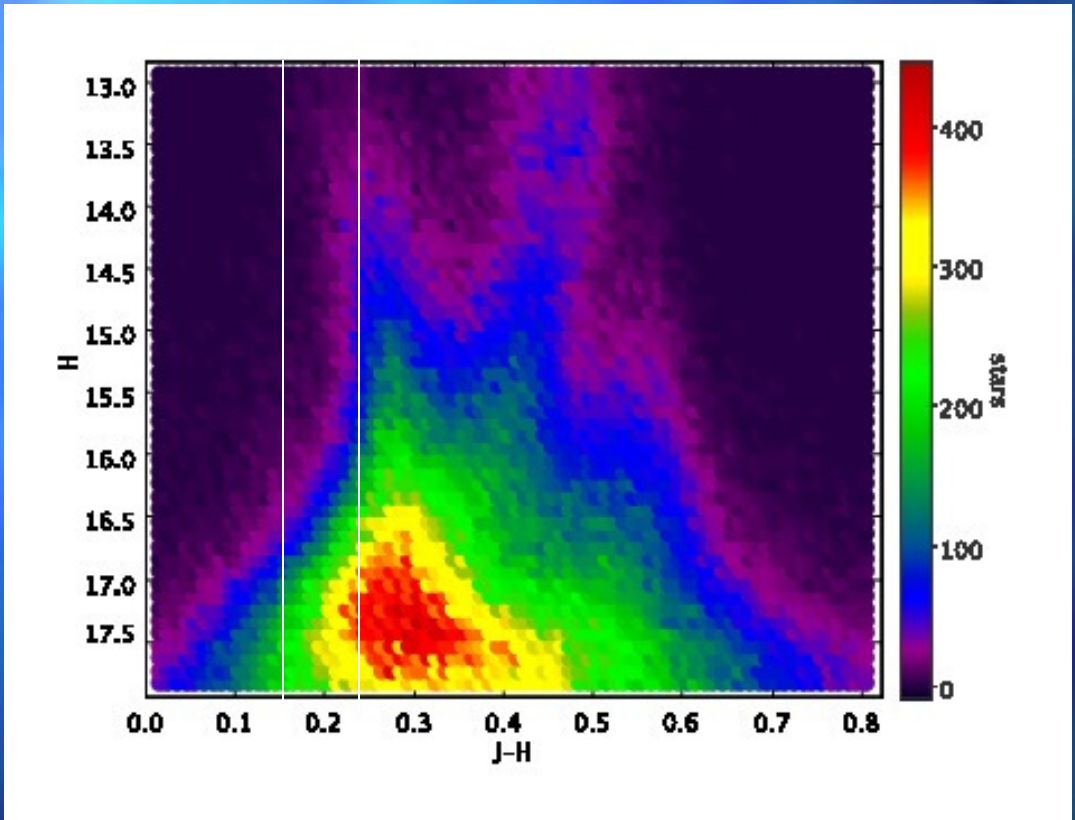
Density of the bulge at z=1 kpc in the boxy bulge (López-Corredoira et al. 2005).

X-SHAPED BULGE



Density of the bulge at z=1 kpc in the X-shaped bulge (Wegg & Gerhard 2013).

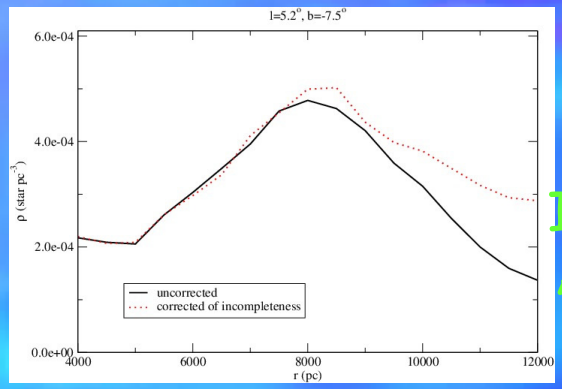
López-Corredoira (2016): F0-F5V stars of VISTA-VVV

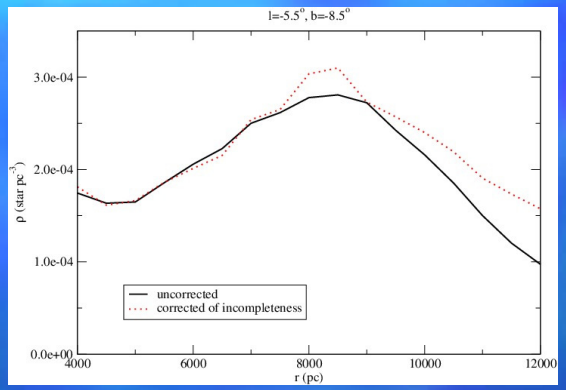


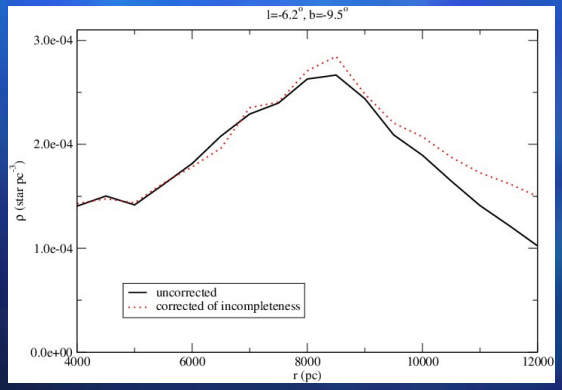
Example of extinction-corrected CMD in the region ℓ = –6.2°, b = -9.5°. The plot represents the number of stars in bins of 0.01 mag

We extract F0-F5V stars $0.15<(J-H)_0<0.23$, $\langle M_H \rangle = 2.40$, age<5 Gyr

López-Corredoira (2016): F0-F5V stars of VISTA-VVV

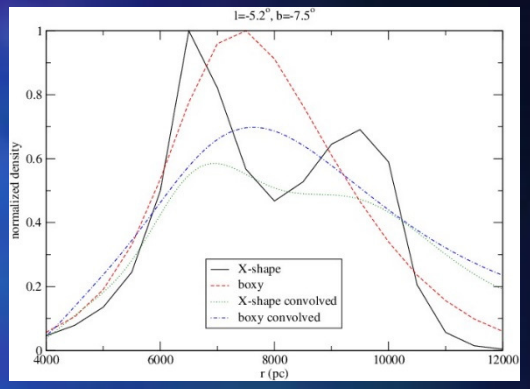


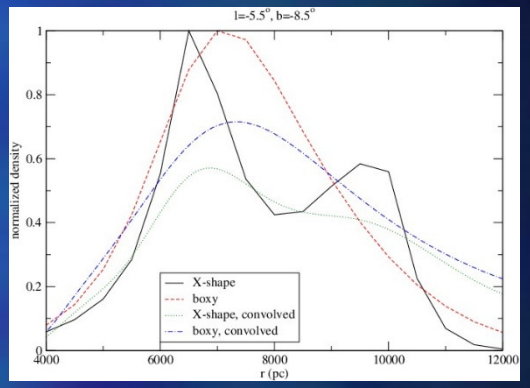


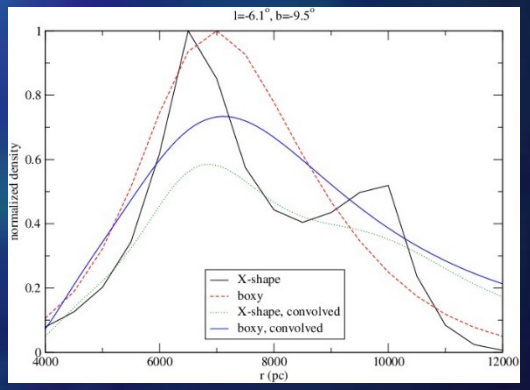


IT LOOKS LIKE A BOXY BULGE

IT DOES NOT LOOK LIKE A X-SHAPED BULGE



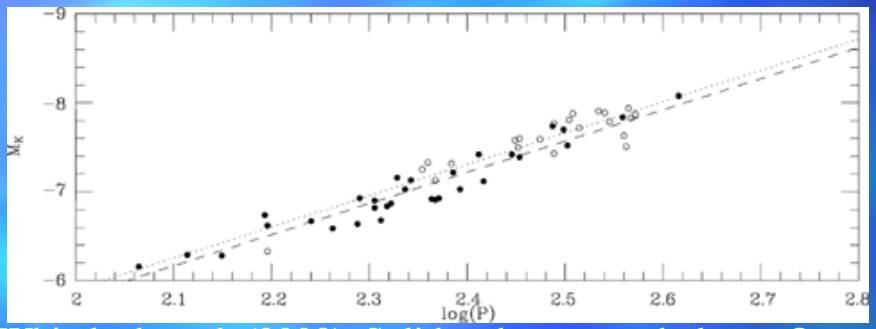




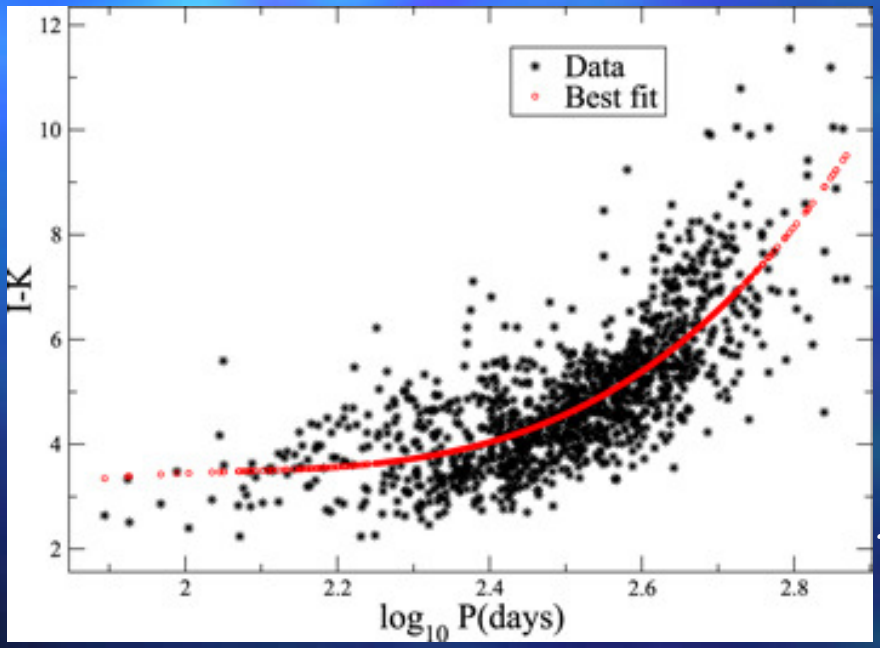
OBSERVED DENSITY

PREDICTED DENSITY (only bulge)

López-Corredoira (2017): O-rich Mira variable stars



Whitelock et al. (2008): Solid and open symbols are O- and C-rich, respectively. The dashed line is the fit to the O-rich stars.



López-Corredoira (2017)

O-rich Mira variables:

<age>~9 Gyr,
Distance from
Period-luminosity
Relationship
(using the average magnitudes
in the period, not a single epoch one)

Errors of distance ~4%
(plus extinction error)

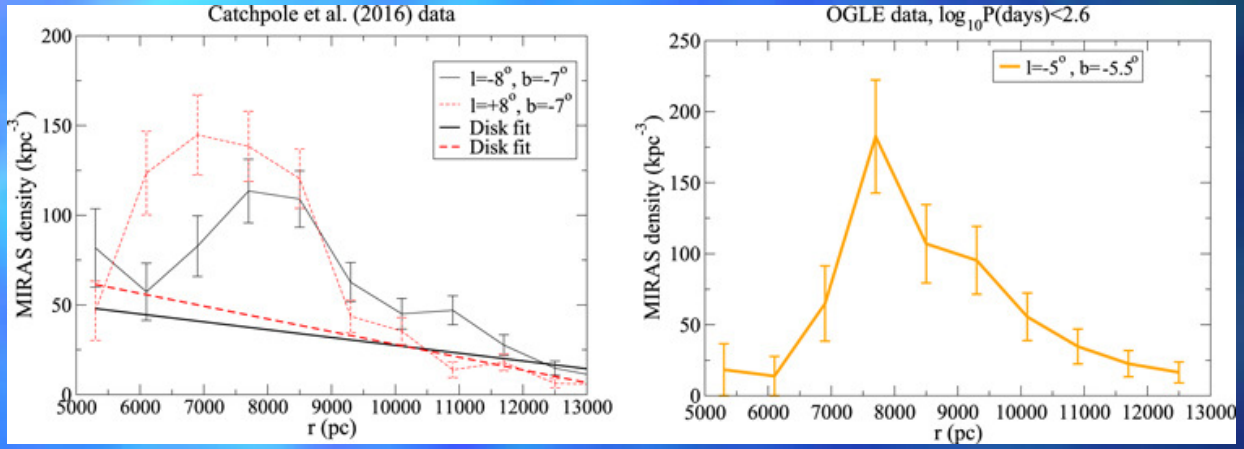
$M_K=-3.51L-7.25$

$I-K=3.96+3.69L+10.33L^2+10.98L^3$

$L=\log_{10}[P(days)]-2.38$

López-Corredoira (2017): O-rich Mira variable stars

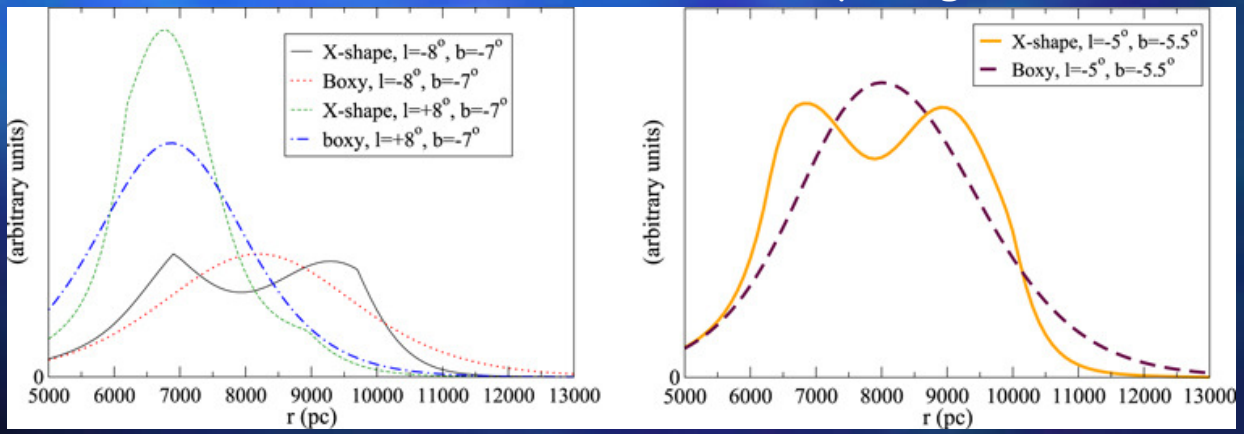
OBSERVED DENSITY



Data from Catchpole et al. (2016) and OGLE-III

IT LOOKS LIKE A BOXY BULGE (within 1.2σ)

PREDICTED DENSITY (only bulge)



IT DOES NOT LOOK LIKE A X-SHAPED BULGE (rejected at 3.3σ)

X-shaped bulge?

- **RR Lyrae (very old stars): X-shaped NOT FOUND (Dékány et al. 2013).**
- **O-rich Mira variables (young-old stars): X-shaped NOT FOUND (result here).**
- **F0-5V (young, <5 Gyr) stars: X-shaped NOT FOUND (result here).**
- **Red clumps (old) with metal poor stars: X-shaped NOT FOUND (Ness et al. 2012).**
- **Red clumps (old) with metal rich stars are X-shaped.**

X-shaped bulge?

SOLUTIONS:

- There are 4-5 bulges, only one with X-shape.
- Large errors in distances of any population different from Red Clumps; unable to distinguish two peaks along the line of sight.
- The Red Clumps luminosity function is contaminated with a secondary peak producing an erroneous apparent X-shape.