

No X-shape in the Milky Way bulge

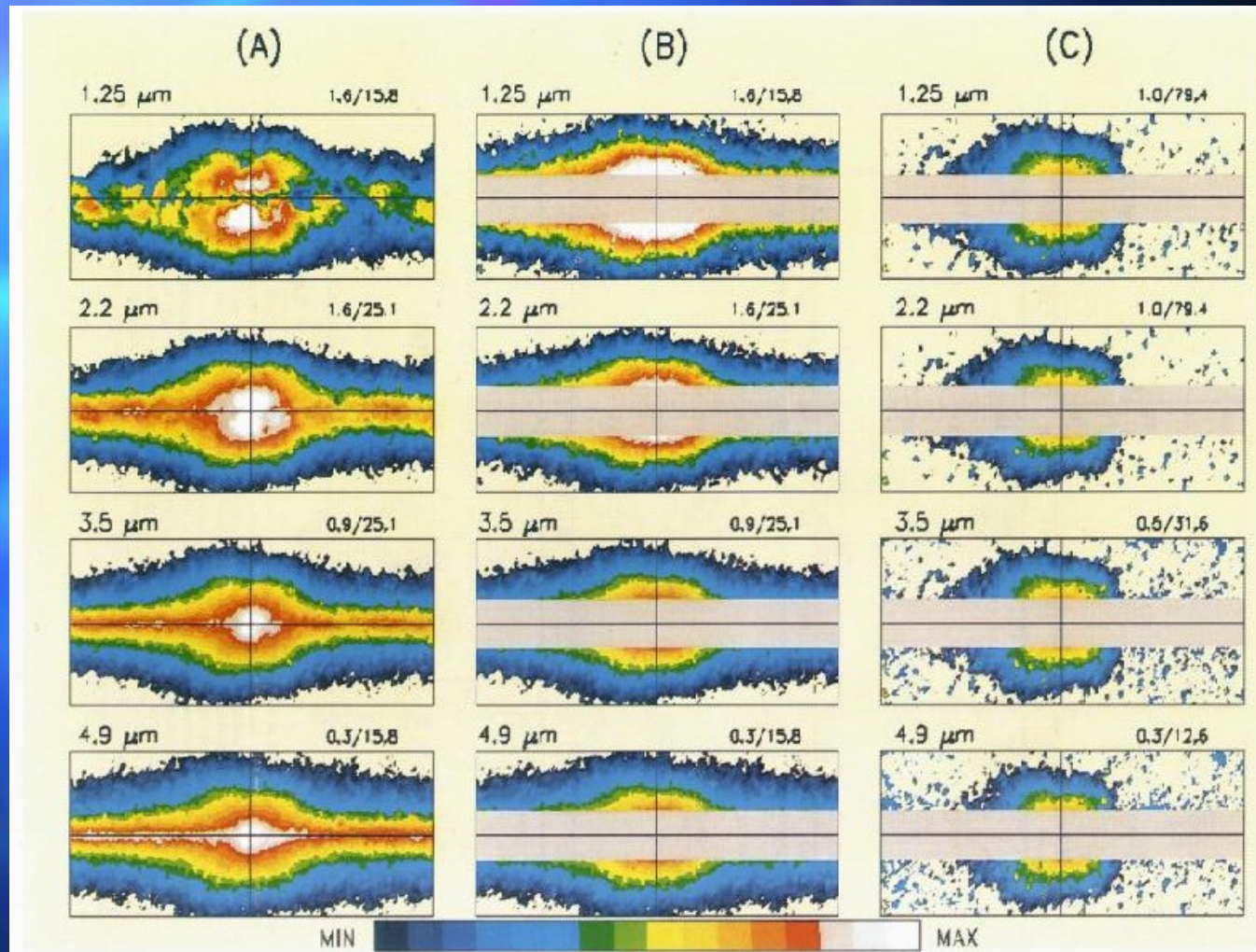
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Main references:

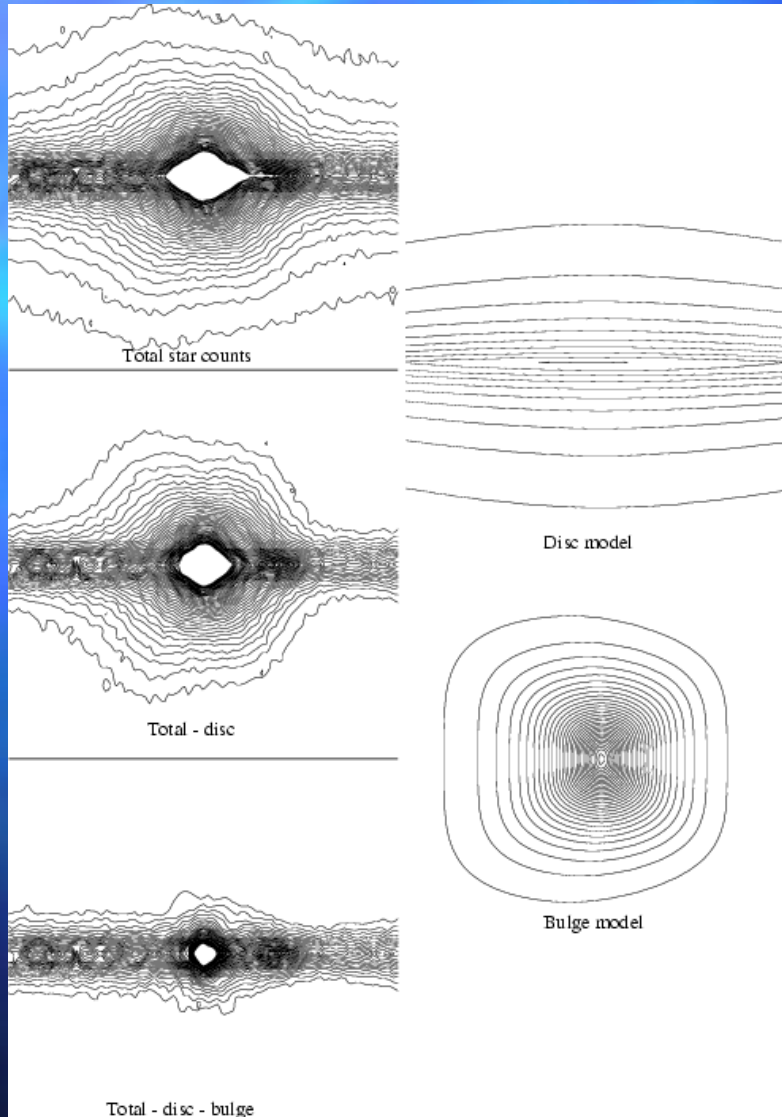
- López-Corredoira (2016, *A&A*, 593, A66)
- López-Corredoira (2017, *ApJ*, 835, 218)

TRIAXIAL/BARRED BULGE



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

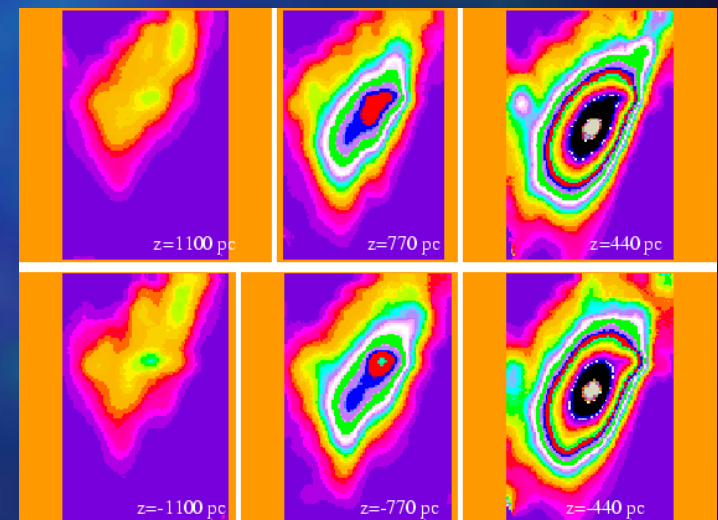
TRIAxIAL/BARRED BULGE



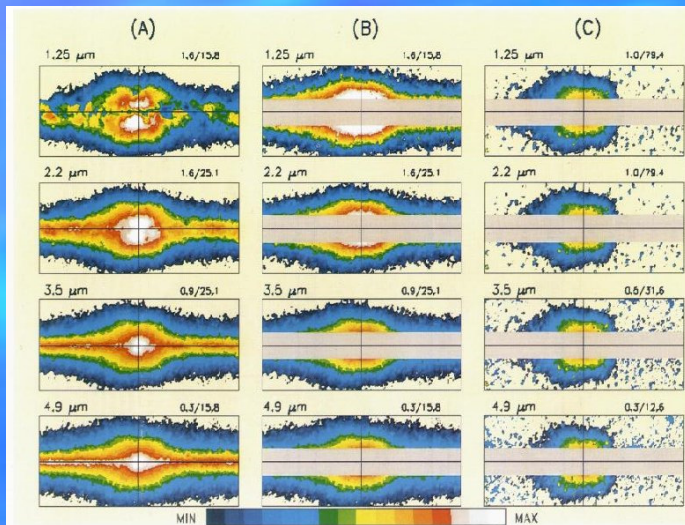
BOXY BULGE

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

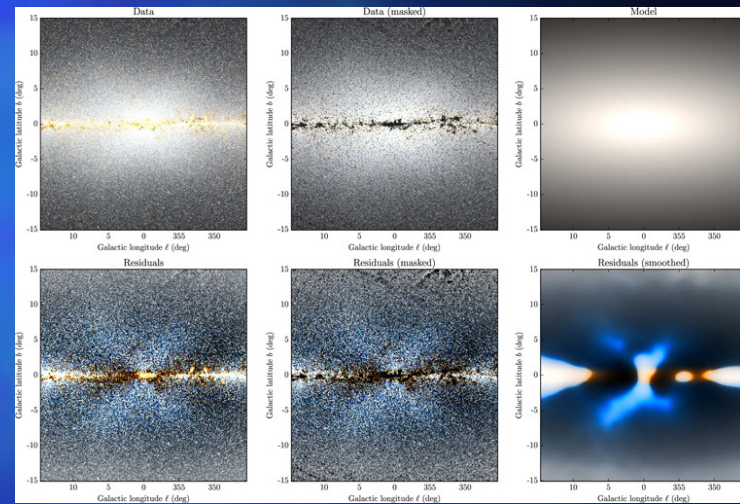
Method: Inversion of stellar statistics
equation
(see López-Corredoira et al. 1997, 2000 for
application to TMGS data)



X-shaped bulge



Weiland et al. (1994): ellipsoidal bulge

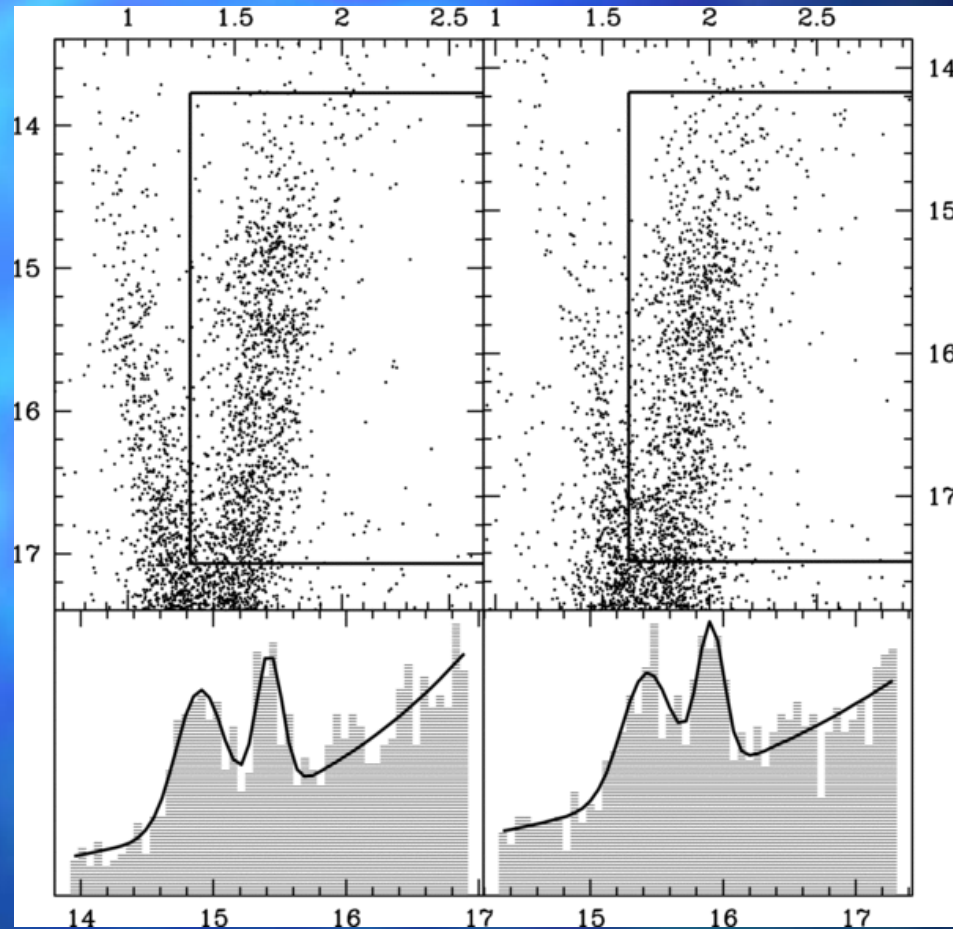


Ness & Lang (2016): X-shaped bulge

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 (Lee & Jang 2016; Han & Lee 2018)
- Maybe wrong extinction correction was applied (Han & Lee 2018)

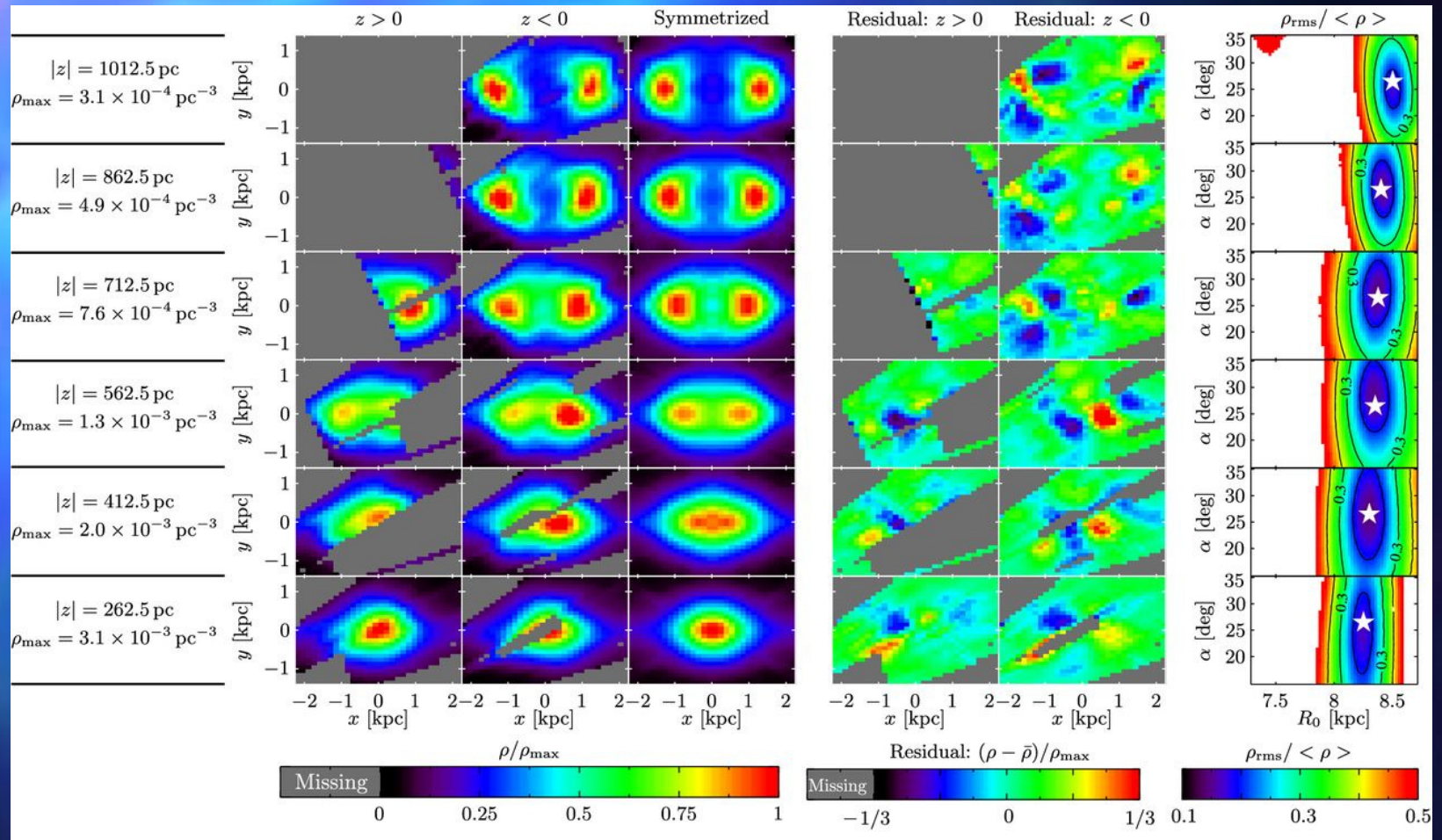
X-shaped bulge: Red Clumps



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

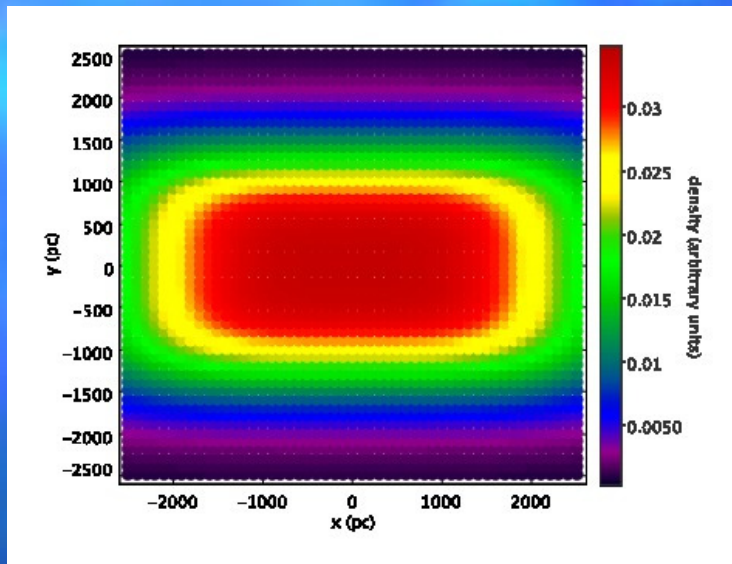
RED CLUMP METHOD

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."

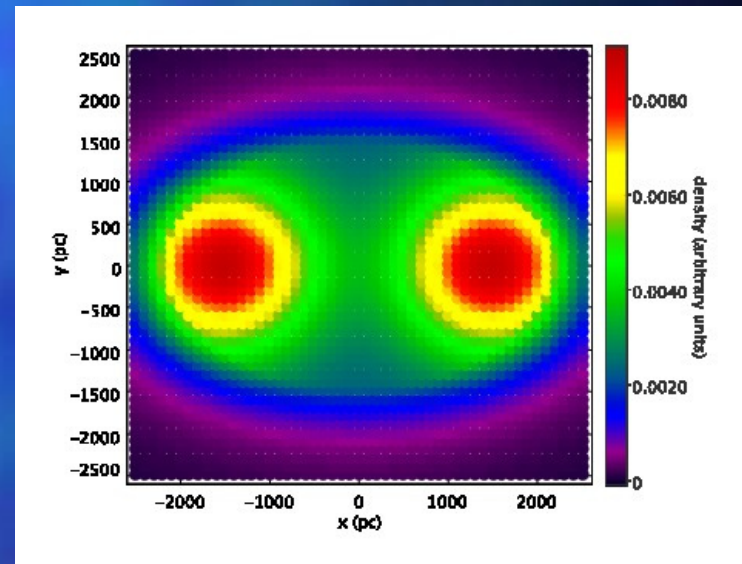
López-Corredoira (2016): F0-F5V stars of **VISTA-VVV**

BOXY BULGE



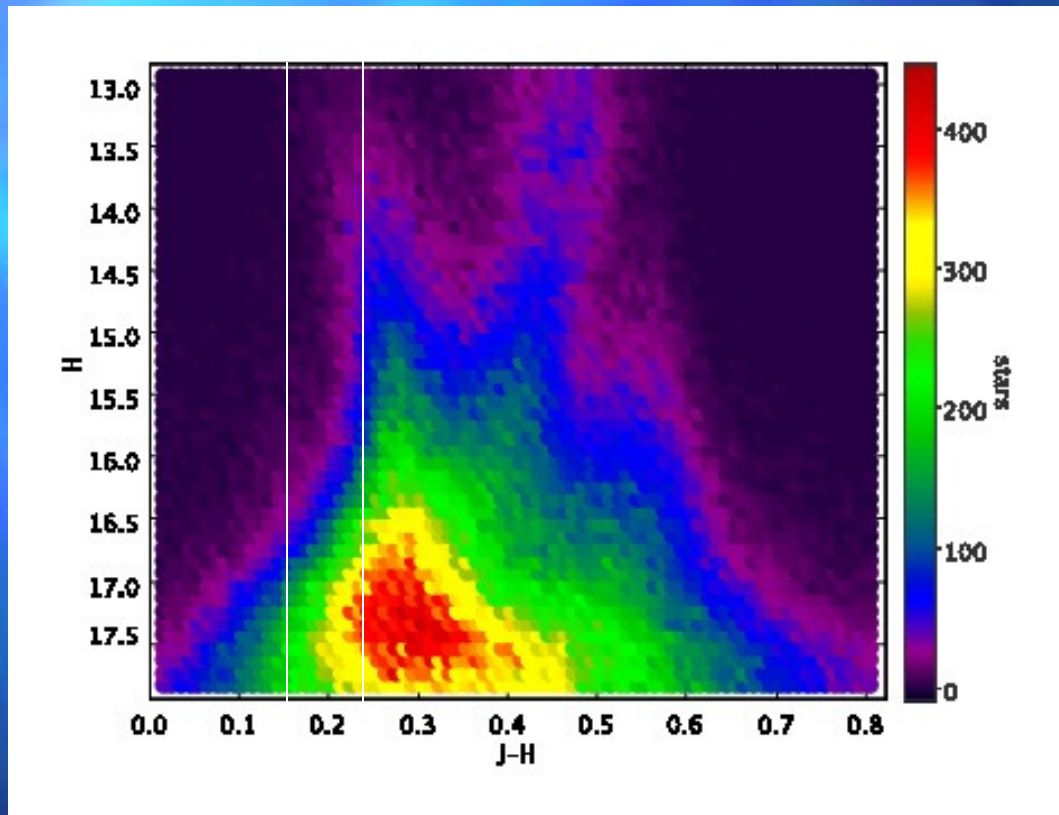
Density of the bulge at $z=1$ kpc in the boxy bulge (López-Corredoira et al. 2005).

X-SHAPED BULGE



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

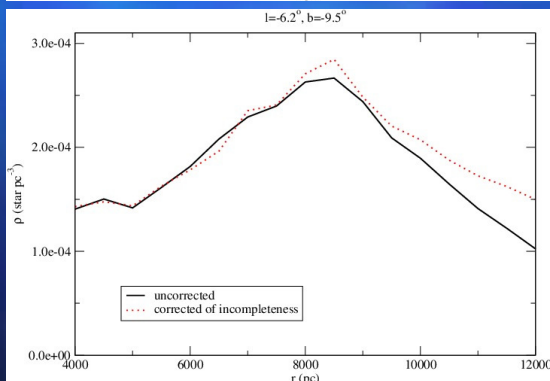
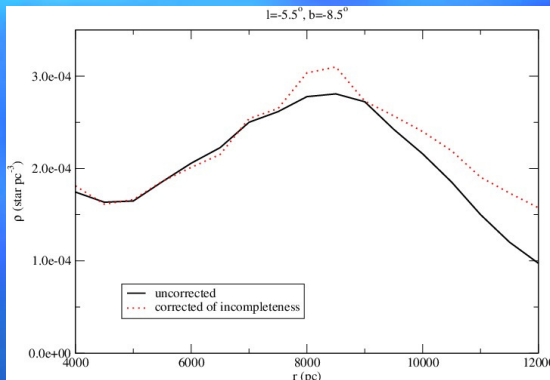
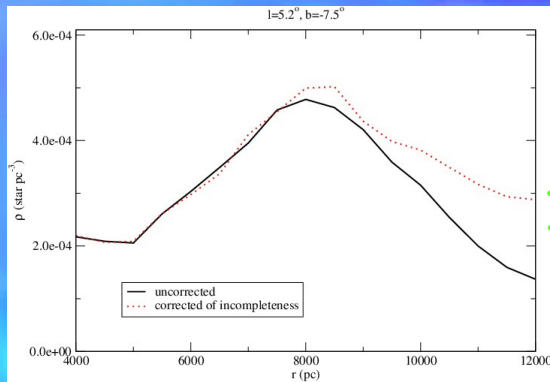
López-Corredoira (2016): F0-F5V stars of **VISTA-VVV**



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

Example of extinction-corrected
CMD in the region $\ell = -6.2^\circ$, $b = -$
 9.5° . The plot represents the
number of stars in bins of 0.01 mag

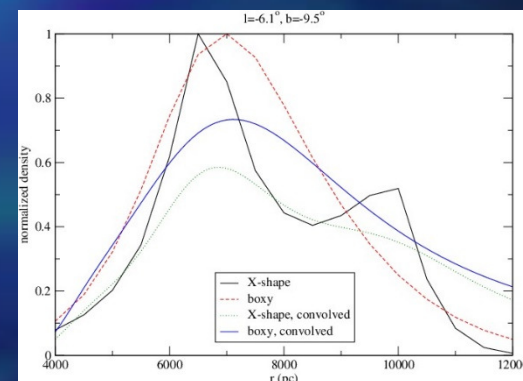
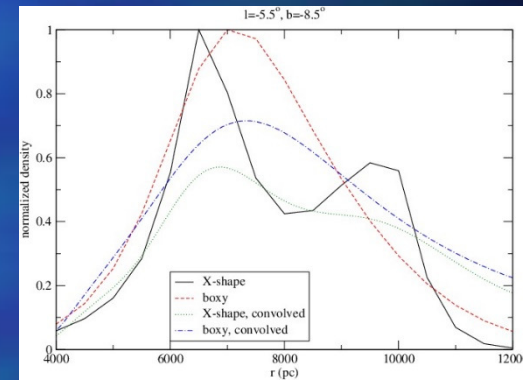
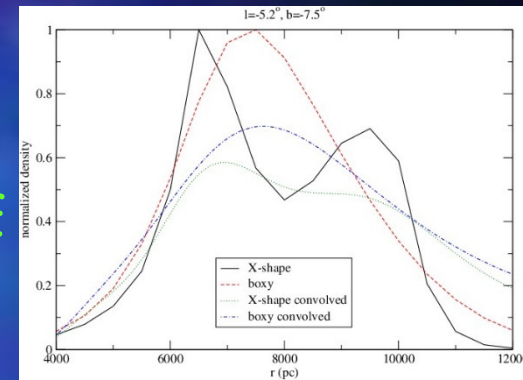
López-Corredoira (2016): F0-F5V stars of **VISTA-VVV**



OBSERVED DENSITY

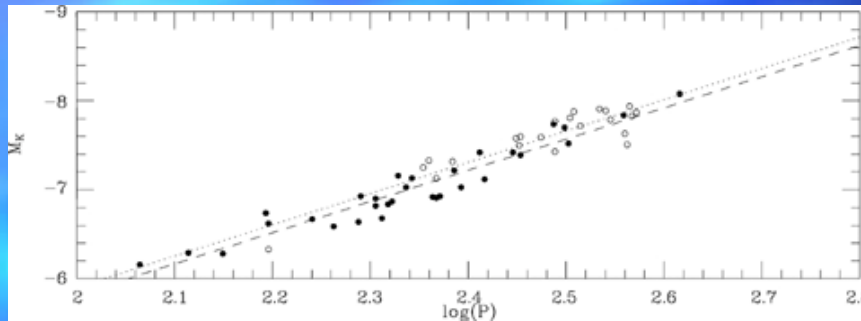
IT LOOKS LIKE
A BOXY BULGE

IT DOES NOT
LOOK LIKE A
X-SHAPED
BULGE

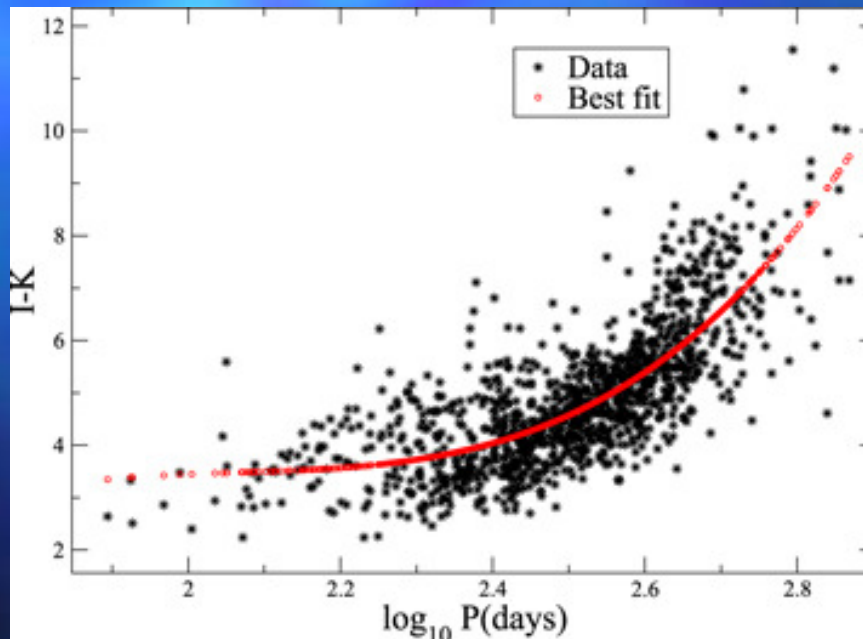


PREDICTED DENSITY (only bulge)

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:

$\langle \text{age} \rangle \sim 9 \text{ Gyr}$,

Distance from
Period-luminosity
Relationship

(using the average magnitudes
in the period, not a single epoch one)

Errors of distance $\sim 4\%$
(plus extinction error)

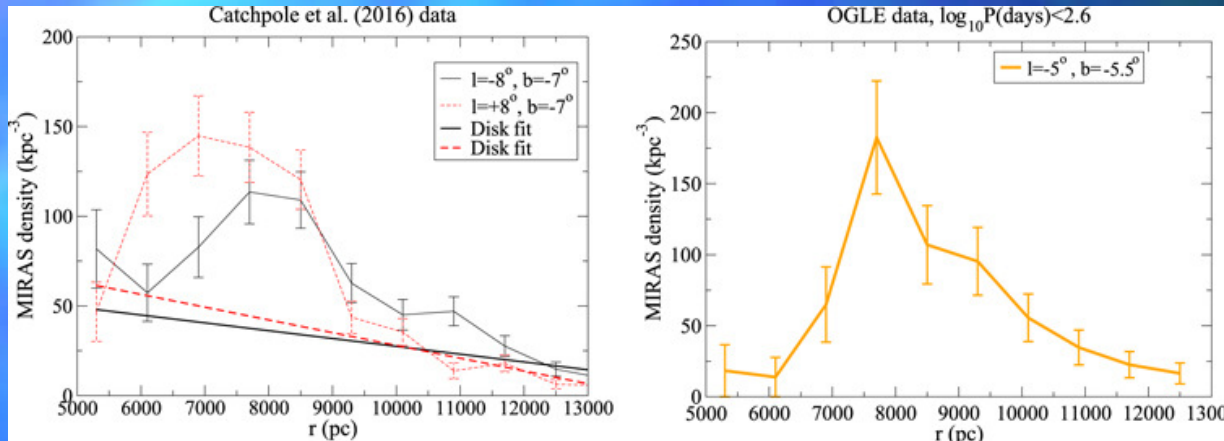
$$M_K = -3.51L - 7.25$$

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

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

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

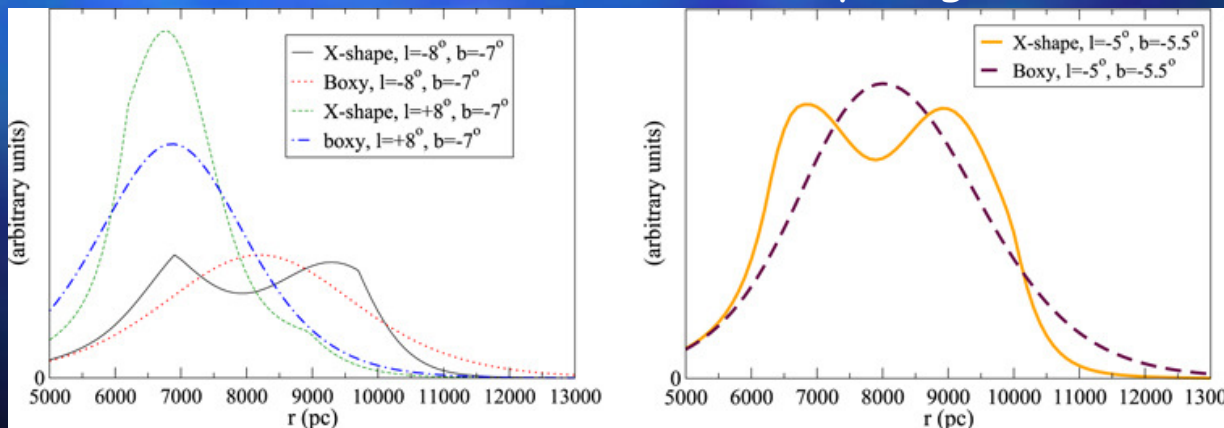
OBSERVED DENSITY



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

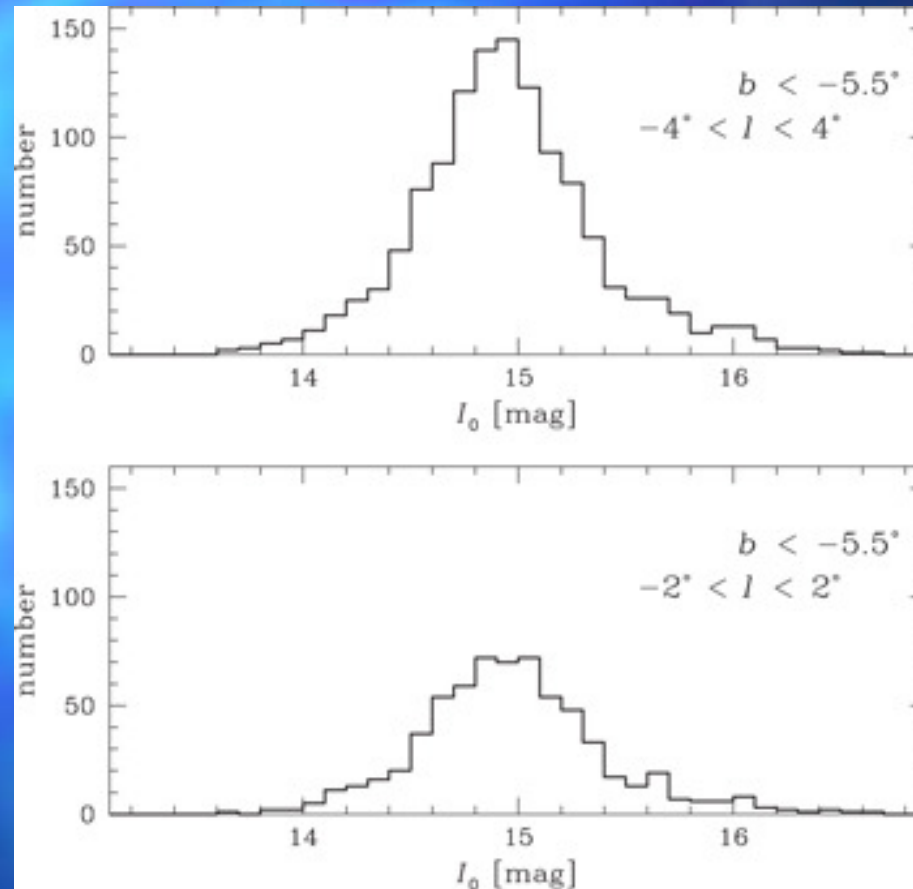
IT LOOKS LIKE
A BOXY BULGE
(within 1.2σ)

PREDICTED DENSITY (only bulge)



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

Pietrukovicz et al. (2015): RR-Lyrae



Distributions of the dereddened brightness I_0 for OGLE RRab stars in regions where intermediate-age red clump giants form a prominent X-shaped structure of the Galactic bar. There is no split in the old bulge traced by RR Lyrae stars.

X-shaped bulge?

- **RR Lyrae** (very old stars): **X-shaped NOT FOUND** (Dékány et al. 2013, Pietrukowicz et al. 2015).
- **O-rich Mira variables** (young-old stars): **X-shaped NOT FOUND** (López-Corredoira 2017).
- **F0-5V** (young, <5 Gyr) stars: **X-shaped NOT FOUND** (López-Corredoira 2016).
- **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.