

Outer Bulge RR Lyrae stars in the VVV Survey

Felipe Gran

Dante Minniti and Roberto Saito

6th VVV Meeting – Puerto Varas, March 11-12



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Presentation, plots, and python codes available !

fegran.github.io



Motivation

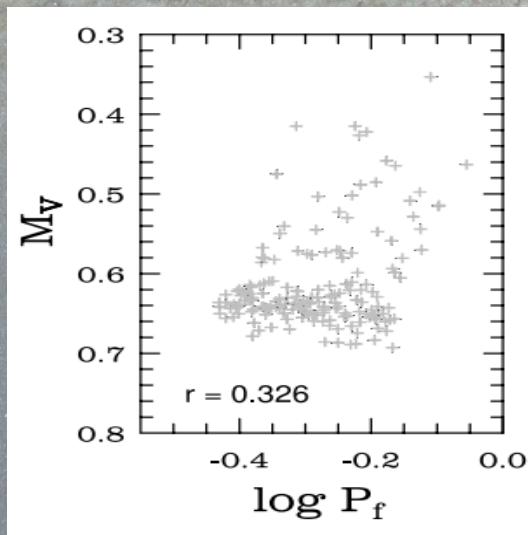
- ★ Vista Variables in the Vía Láctea (VVV) is a currently ongoing ESO Public Survey (Minniti et al. 2010)
- ★ VVV uses **near-IR filters** (ZYJHK_s) to observe ~300 deg² in the Galactic bulge
 - ★ ZYJH one epoch at the first year of operation
 - ★ K_s-band variability survey: ~100 epochs
- ★ “Outer bulge” avoided by other variability surveys:
 - ★ OGLE, MACHO, EROS
 - ★ Explore Sgr dSph RR Lyr candidates

$\ell \leq -8$ deg

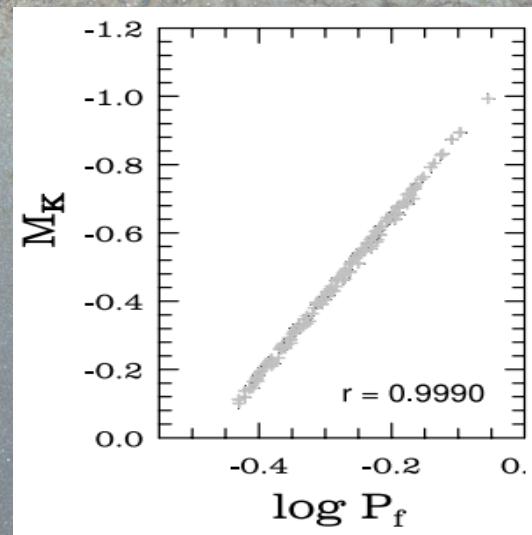
M54: $(\ell, b) \sim (5, -14)$ deg, $d \sim 25$ kpc

Motivation

**RR Lyr stars are excellent distant indicators !!
(follow precise P-L Relation in the near-IR)**



Optical (V) v/s near-IR (K)



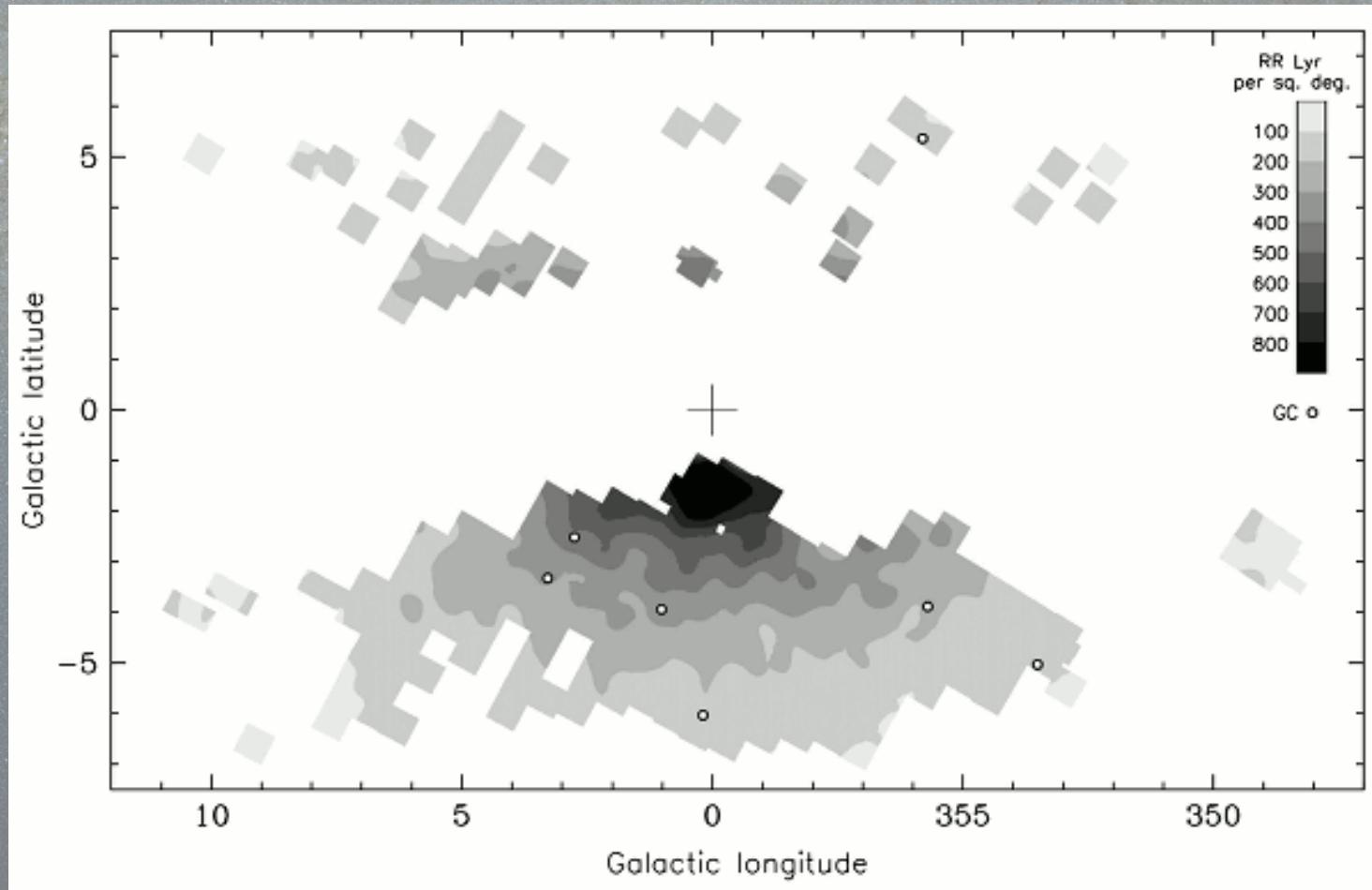
Catelan et al. 2004



High number density in the bulge

Motivation

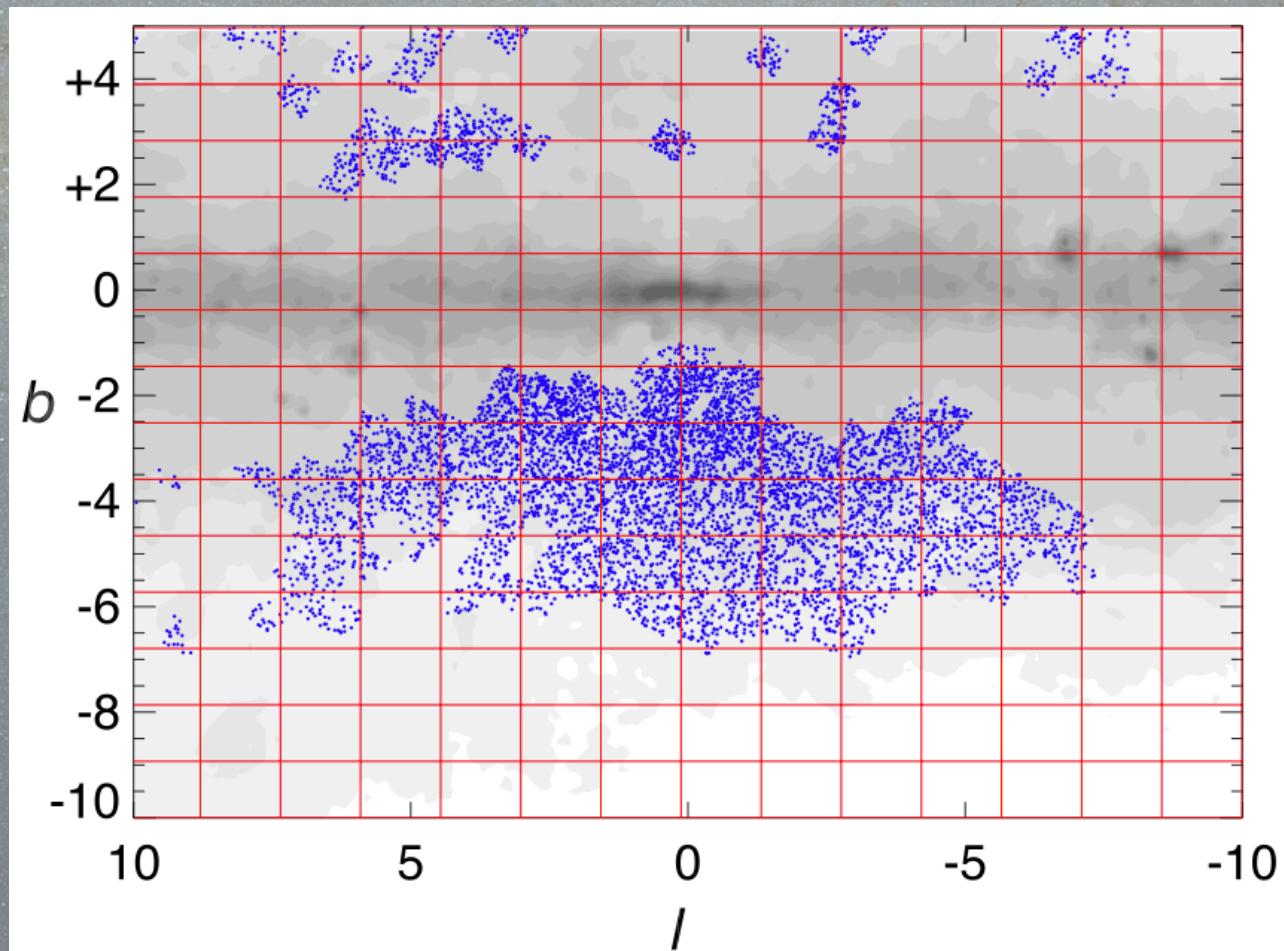
OGLE III – 16836 bulge + 394 Sgr dSph RR Lyr stars



Soszyński et al. 2011 + Pietrukowicz et al. 2012

Motivation

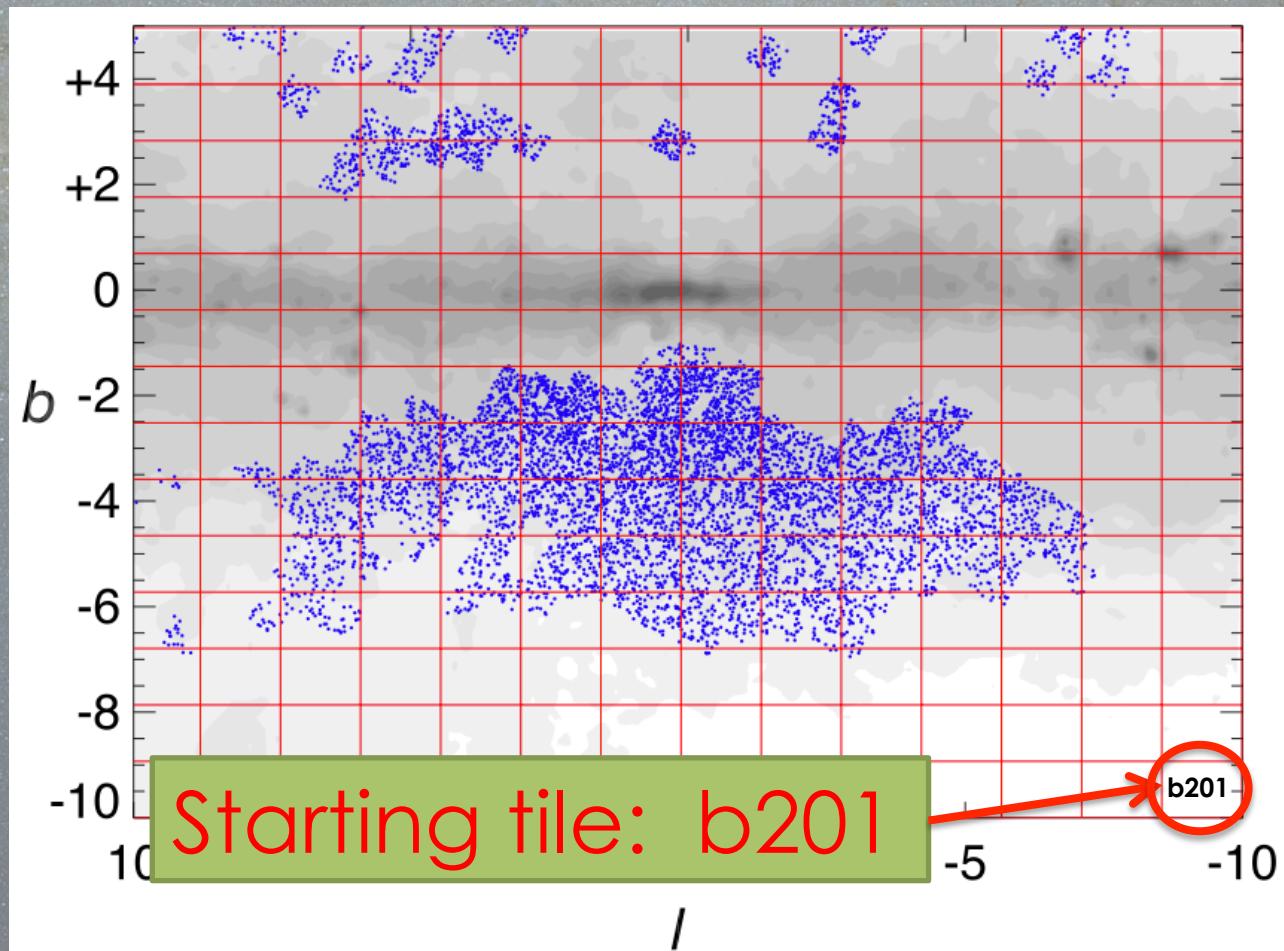
VVV – 7663 bulge RR Lyr stars



Dékány et al. 2013

Motivation

VVV – 7663 bulge RR Lyr stars



Dékány et al. 2013

“Bulge RR Lyrae stars in the VVV tile b201”

Bulge RR Lyrae stars in the VVV tile b201*

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ABSTRACT

Context. The VISTA Variables in the Vía Láctea (VVV) Survey is one of the six ESO public surveys currently ongoing at the VISTA telescope on Cerro Paranal, Chile. VVV uses near-IR ($ZYJHK_s$) filters that at present provide photometry to a depth of $K_s \sim 17.0$ mag in up to 36 epochs spanning over four years, and aim at discovering more than 10^6 variable sources as well as trace the structure of the Galactic bulge and part of the southern disk.

Aims. A variability search was performed to find RR Lyrae variable stars. The low stellar density of the VVV tile *b201*, which is centered at $(\ell, b) \sim (-9^\circ, -9^\circ)$, makes it suitable to search for variable stars. Previous studies have identified some RR Lyrae stars using optical bands that served to test our search procedure. The main goal is to measure the reddening, interstellar extinction, and distances of the RR Lyrae stars and to study their distribution on the Milky Way bulge.

Methods. For each star in the tile with more than 25 epoch ($\sim 90\%$ of the objects down to $K_s \sim 17.0$ mag), the standard deviation and χ^2 test were calculated to identify variable candidates. Periods were determined using the analysis of variance. Objects with periods in the RR Lyrae range of $0.2 \leq P \leq 1.2$ days were selected as candidate RR Lyrae. They were individually examined to exclude false positives.

Results. A total of 1.5 sq deg were analyzed, and we found 39 RR Lyr stars, 27 of which belong to the ab-type and 12 to the c-type. The analysis recovers all the previously identified RR Lyrae variables in the field and discovers 29 new RR Lyr stars. Extinction toward all the RRab stars in this tile were derived, and distance estimations were obtained. Despite the limited amount of RR Lyrae stars studied, our results are consistent with the Cardelli or Nishiyama extinction relation. Nevertheless, a larger area must be analyzed to definitively rule out the Nishiyama extinction relation.

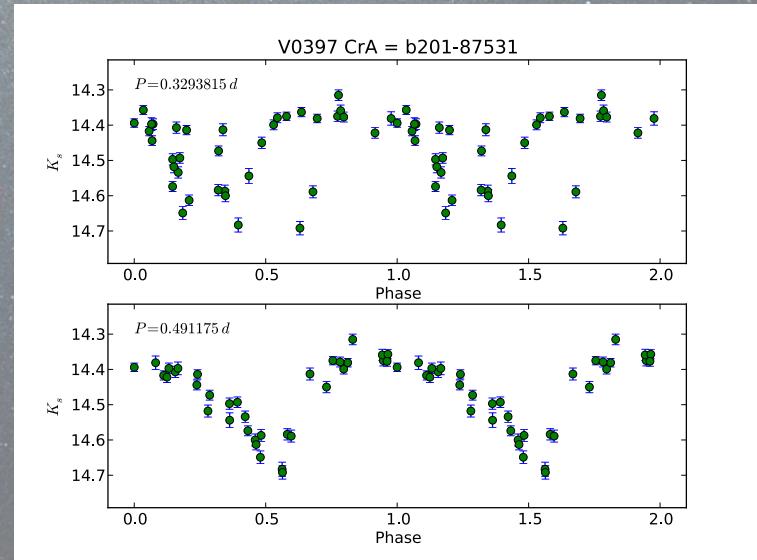
Key words. Galaxy: bulge – Galaxy: stellar content – Va

A green diagonal banner across the top of the page with white text. The text reads "arxiv.org/abs/1501.00947" and "A&A in press!!".

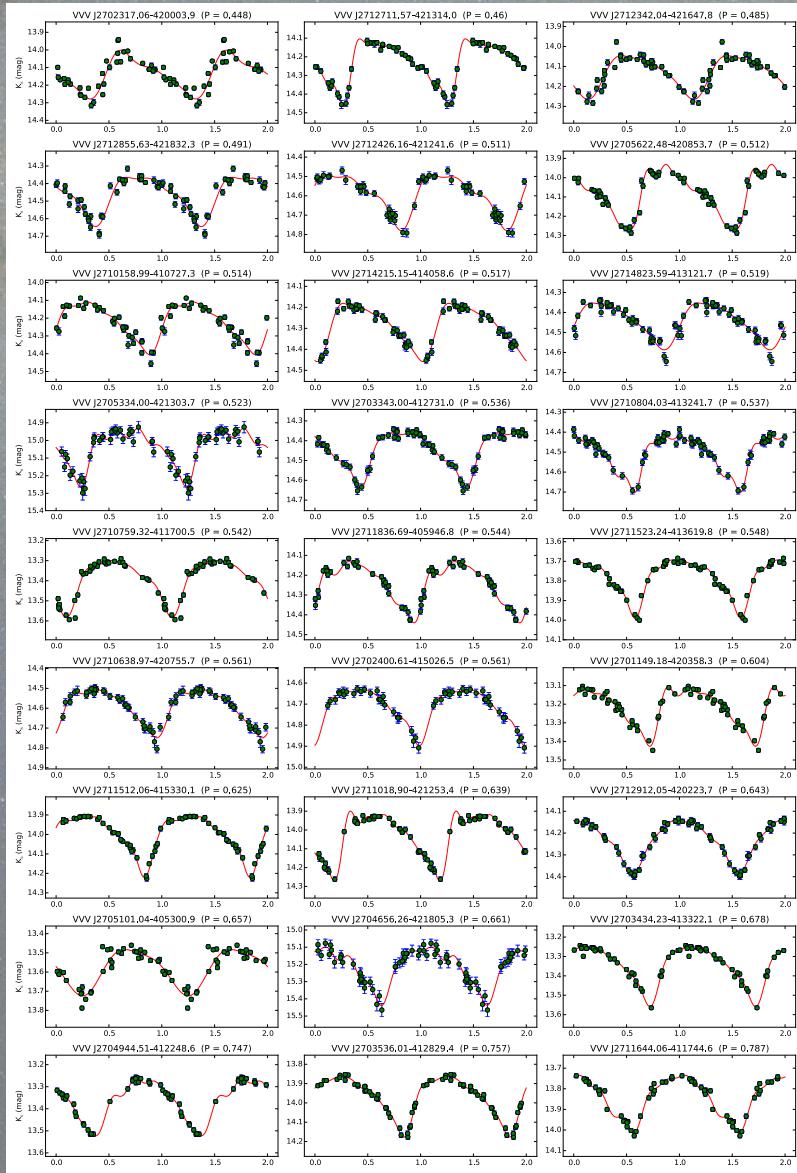
“Bulge RR Lyrae stars in the tile b201”

- ★ Low crowding and extinction
- ★ Optical works found 10 RR Lyr in the field
- ★ 39 RR Lyr stars: 27 ab- and 12 c-type
- ★ New periods for MO, V397 and V467 CrA
- ★ $\Delta P = P_{\text{Lit}} - P_{\text{VVV}} \sim 10^{-3}$ days

GCVS	P _{Lit} (days)	P _{VVV} (days)	d (")
MO CrA	---	0.657005	0.475
V397 CrA	0.3293815	0.491175	0.771
V463 CrA	0.6040585	0.604052	0.139
V467 CrA	0.4480160	0.359989	1.931
V475 CrA	0.5119430	0.511933	17.41
V482 CrA	0.5417140	0.541714	2.725
V483 CrA	0.4850490	0.485059	0.105
V486 CrA	0.4601694	0.460161	0.573
V493 CrA	0.5194291	0.519429	31.26



“Bulge RR Lyrae stars in the tile b201”



$$\begin{aligned}
 + E(J-K_s) &\leftrightarrow (J-K_s) - (J-K_s)_0 \\
 + [Fe/H] &\leftrightarrow OGLE [Fe/H] \sim -1 \\
 + A_{K_s} &\leftrightarrow 0.698 E(J-K_s) \\
 + P-L \text{ Relation} &\leftrightarrow \text{Catelan et al. (2004)} \\
 &\quad \text{Alonso-García et al (2015)}
 \end{aligned}$$

DISTANCES

$$\log d = 1 + 0.2(K_{s,0} - M_{K_s})$$

★ Completed:

b201

★ To analyze:

195 bulge tiles (b202 – b396)

★ Completed:

b201

★ To analyze:

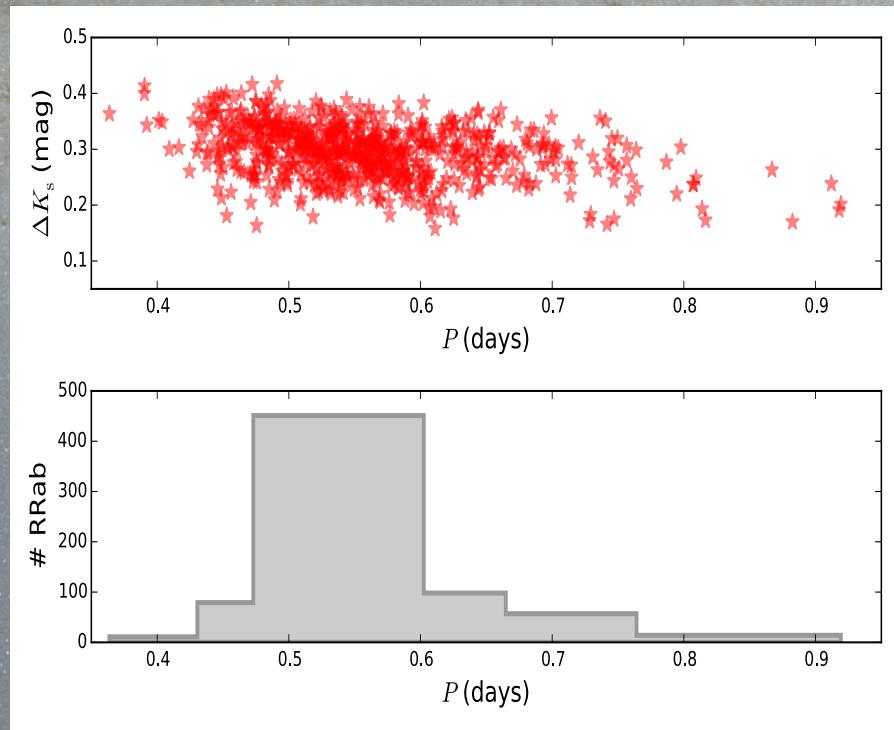
195 bulge tiles (b202 – b396)

★ But our goal is the
outer bulge!

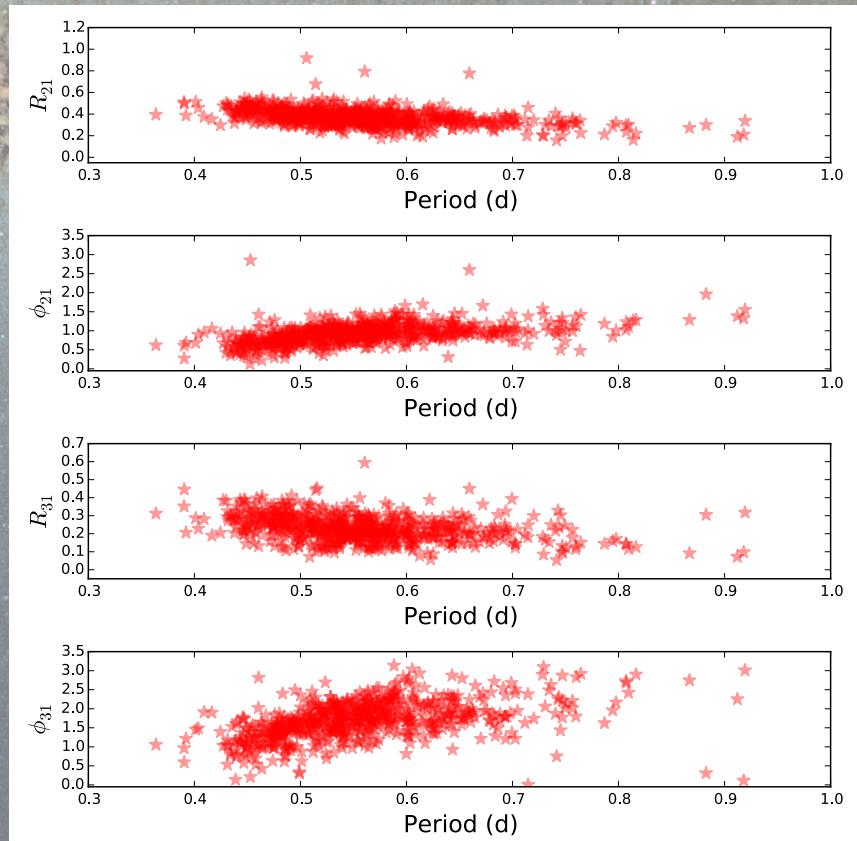


Outer Bulge RR Lyrae stars in the VVV Survey

In 22 tiles ~ 700 RRab stars were found.



Bailey diagram + Period histogram

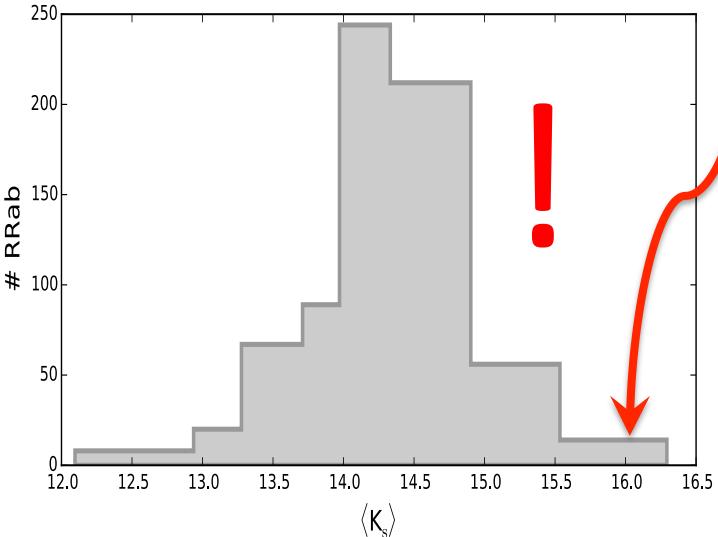


Coefficients of the Fourier decomposition

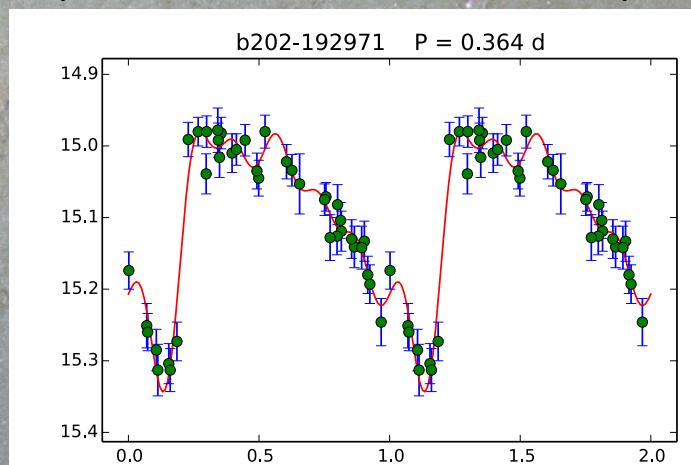
Kovacs & Kupi (2007)

Outer Bulge RR Lyrae stars in the VVV Survey

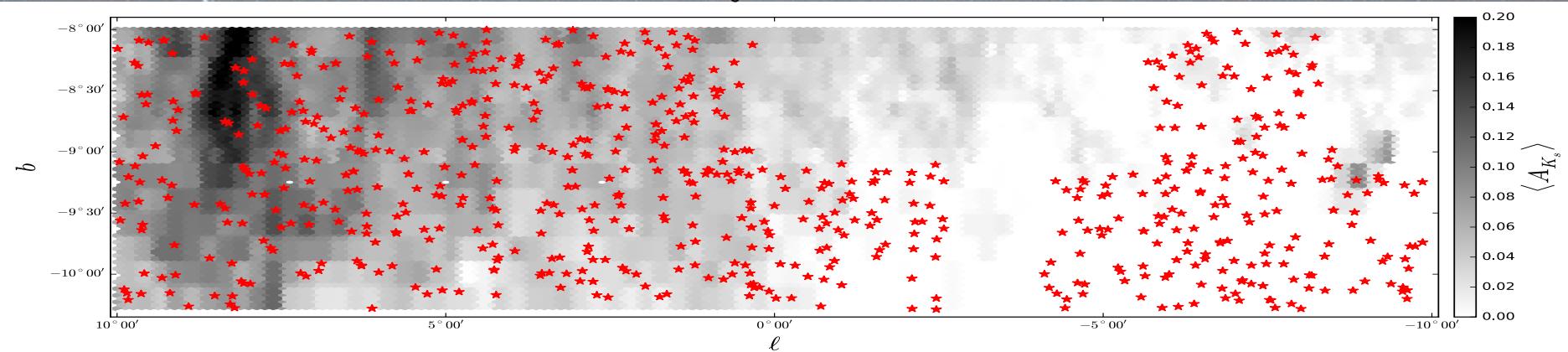
Sgr dSph RRab candidates?



Interesting case: shortest period for our RRab sample.

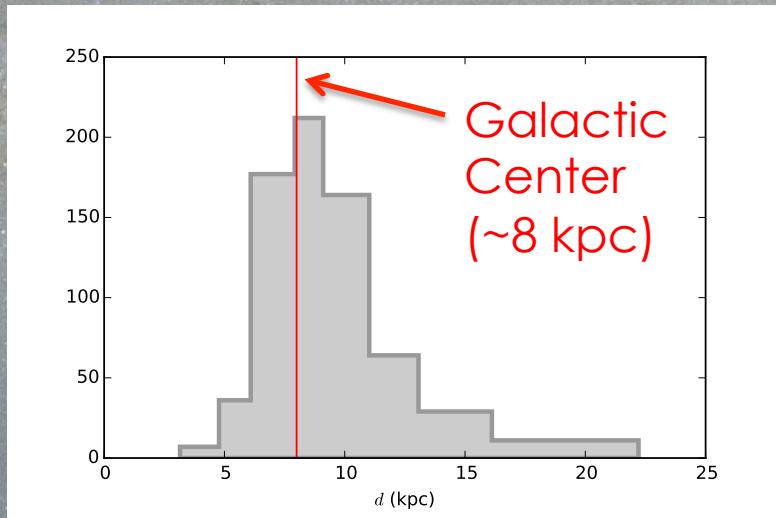


RRab stars + A_{K_s} (BEAM Extinction Map)

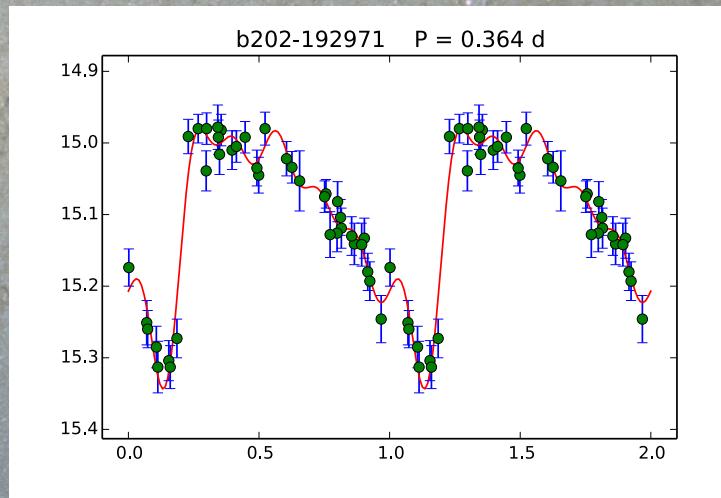


Outer Bulge RR Lyrae stars in the VVV Survey

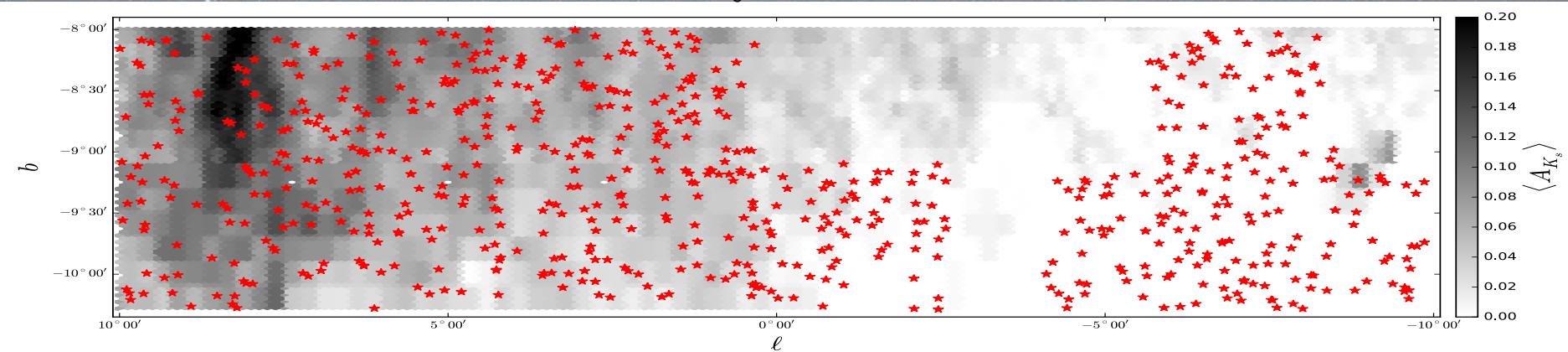
Distances to the RR Lyrae stars



Interesting case: shortest period for our RRab sample.



RRab stars + A_{K_S} (BEAM Extinction Map)



Summary & Future work

- ★ VVV is mapping the 3D structure of the Galaxy through RR Lyrae stars
- ★ Reddening and distance were derived for RRab stars in the *b201*. This was the first trial to extend the same analysis across other tiles
- ★ A total of ~700 RRab stars have been detected in 22 tiles of the outer bulge
- ★ There are still many tiles to analyze ...
... and a thesis to write/present !

{ Periods
Amplitudes
Fourier Coeff.
Mean mags.
Distances }

*Thanks for your
attention !!*