THE VVVX SURVEY OF THE MILKY WAY: STATUS AND NEW RESULTS

with R. K. Saito, J. Alonso-Garcia, R. Contreras Ramos, M. Catelan, M. Zoccali, D. Geisler, M. Hempel, J. Borissova, R. Kurtev, V. Ivanov, P. W. Lucas, T. Palma, J. B. Pullen, D. Majaess, E. Valenti, L. Smith, V. Braga, M. Rejkuba, G. Navarro, M. Gomez, et al.

VVVX Survey

THE VVVX SURVEY OF THE MILKY WAY: STATUS AND NEW RESULTS

DANTE MINNITI [1,2,3,4]

- 1. Universidad Andres Bello,
- 2. Millennium Institute of Astrophysics,
- 3. Center for Astrophysics and Associated Technologies,
- 4. Vatican Observatory

ABSTRACT: The ESO Public Survey VISTA Variables in the Via Lactea (VVV) has been mapping the Milky Way bulge and the Southern mid-plane in the near-IR since 2010. An extension of this survey started to map the gaps left between the coverage of the VISTA Hemisphere Survey and the VVV Survey. This VVV eXtended Survey (VVVX) would take about 200 nights in total in 2017-2020, covering 2x10^9 point sources within an area of about 1700 sq deg. The area survey includes about 50 known globular clusters and >1000 known open clusters, with many more clusters to be found. The final products will be deep JHKs-band images, and catalogues of variable point sources, and of proper motions. The main aims are to study the different stellar populations present in the inner Galaxy, and to produce a 3-D map of the surveyed region using well-known distance indicators (such as RR Lyrae, Cepheids, and red clump giants). In order to do all this, it is critical to do a variability search, and to have a good understanding of the effects of reddening and extinction in the near-IR. Within the existing bulge VVV area proper motions would also be available. In particular, the VVVX results will be an essential complement to forthcoming near-IR multiplexing spectrographs (MOONS, APOGEE). In addition, the VVVX survey results will complement the expected measurements from important space missions (GAIA, WFIRST).

SPECTROSCOPIC IR SURVEYS

- Apogee (Majewski +)
- Moons (Cirasuolo, Gonzalez +)

GROUND BASED IR SURVEYS OF THE MILKY WAY

PHOTOMETRIC IR SURVEYS

- 2MASS (Skrutskie, Cutri +)
- UKIDSS GPS (Lucas +)
- VVVX (Minniti, Lucas +)

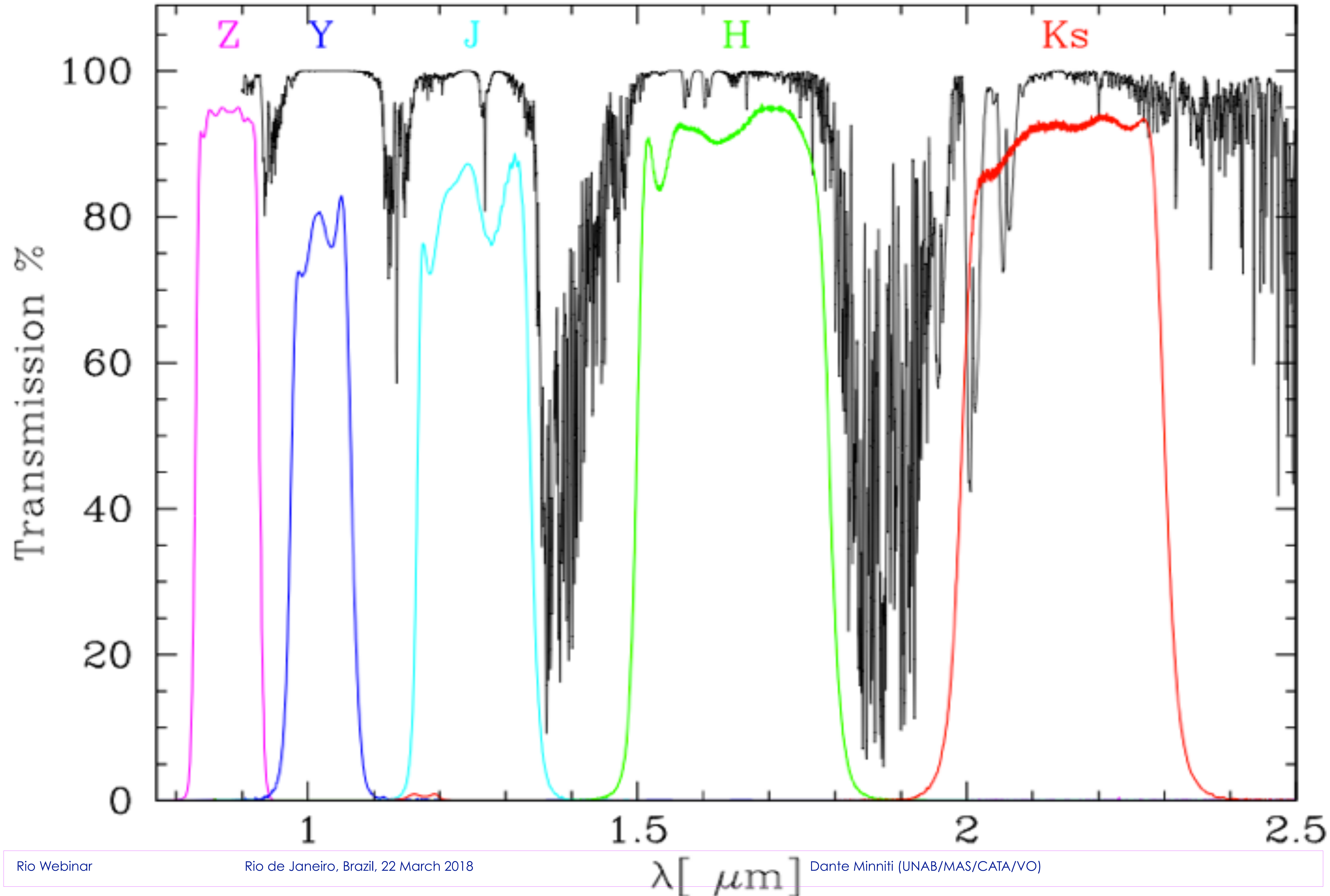
WHY THE NEAR-IR?

The interstellar medium (ISM) reddens, dims and polarises the stellar light.

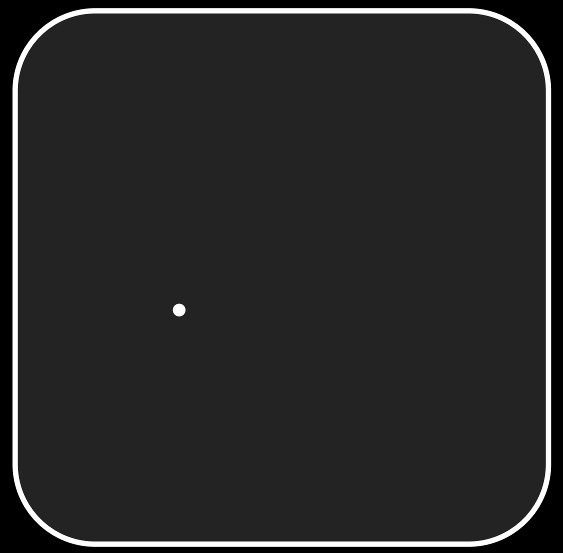
The ISM is more transparent in the near-IR.

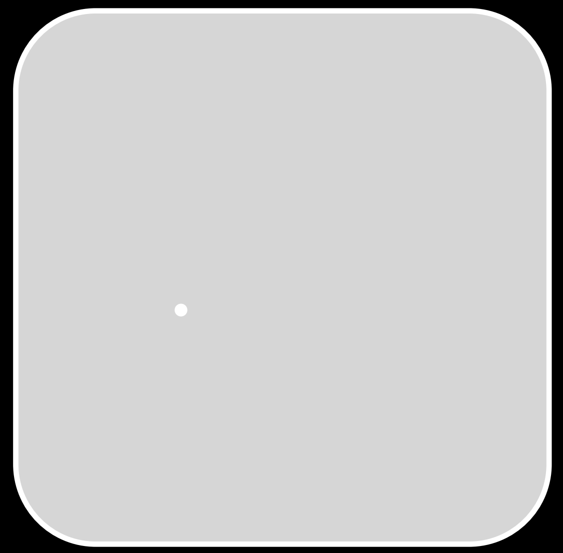
VISTA FILTER TRANSMISSIONS

The Earth's atmosphere is opaque in the near-IR, except for a few Atmospheric Windows



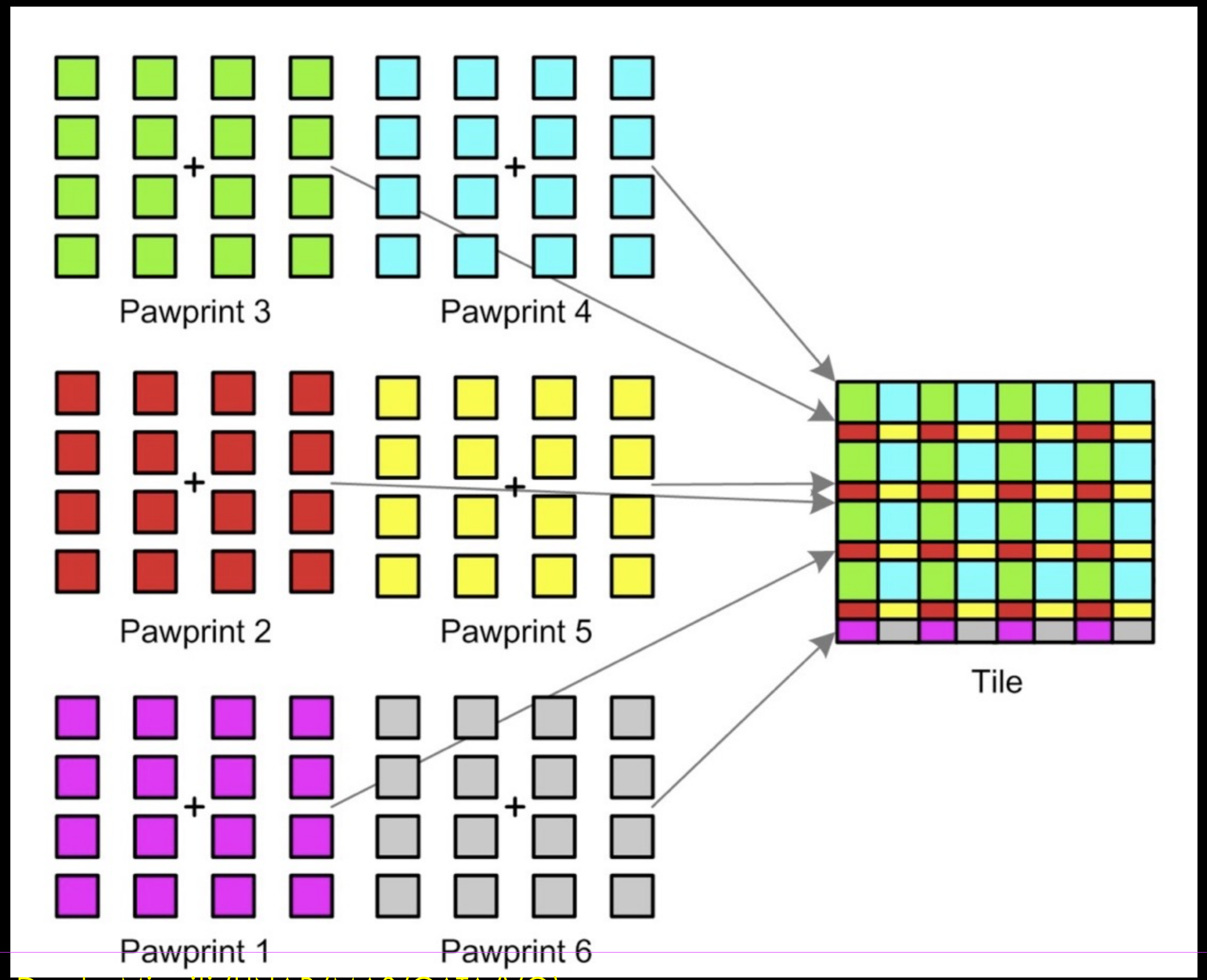
A WORD ABOUT GROUND-BASED IR PHOTOMETRY





Tricky...

because the sky background is very bright in the IR, and therefore we need to do mosaicing.



WHY THE NEAR-IR?

The Galactic extinction is much reduced: Ak~0.1Av

The Cepheid and RR Lyrae PL relations are tighter in the near-IR

The red giants peak in the near-IR

Some problems:

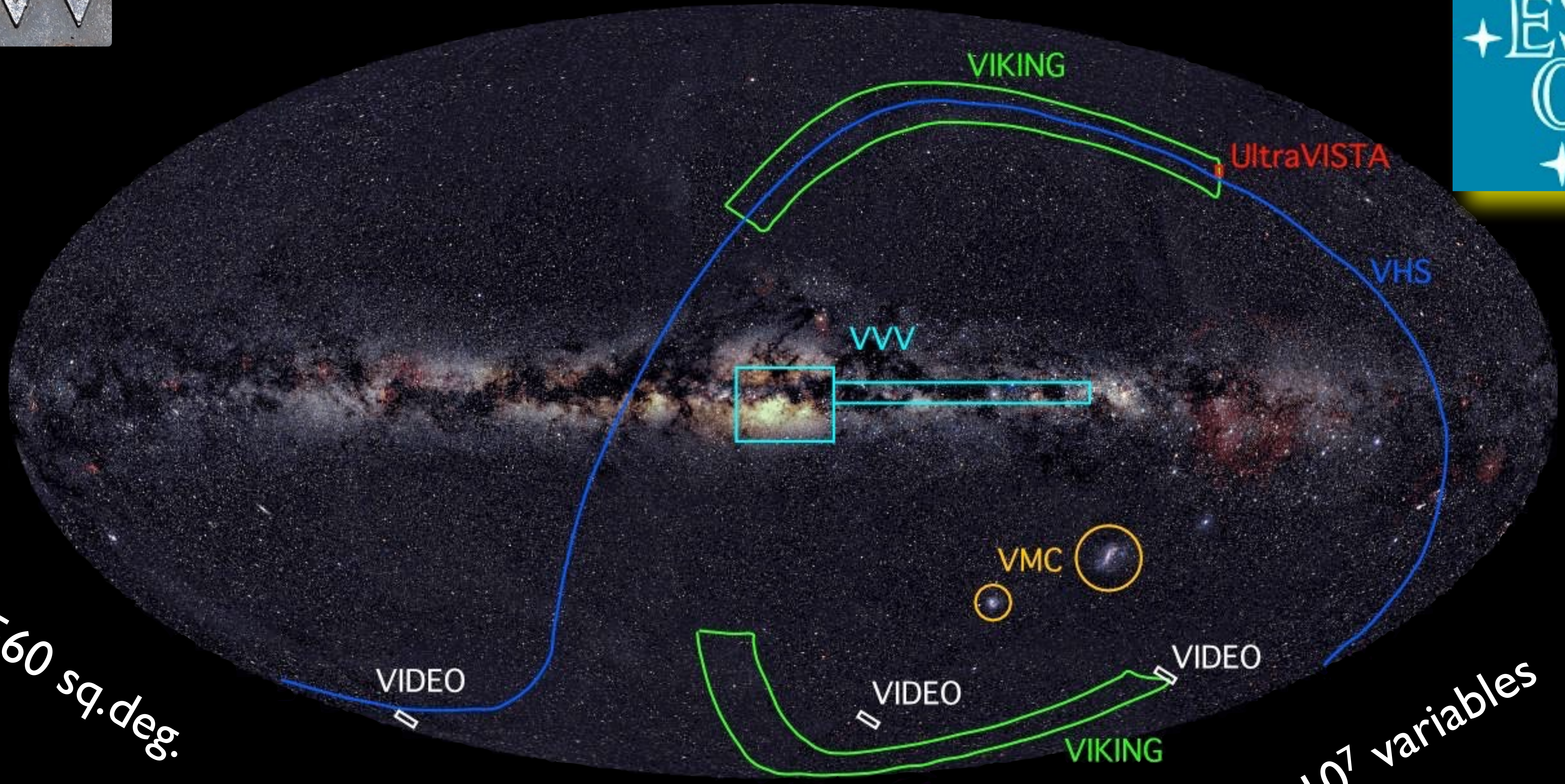
— the near-IR sky background is very high

— the near-IR data rate is very large

— variable star amplitudes are smaller in the near-IR

— variations in the Galactic reddening law

— we see all the way through the MW



560 sq.deg.

~10^9 stars

~100 epochs

~10^7 variables

VISTA PUBLIC SURVEYS

VISTA VARIABLES IN THE VIA LACTEA (VVV)

R. K. Saito[1], M. Hempel[1], D. Minniti[1,2,3], P. W. Lucas[4], M. Rejkuba[5], I. Toledo[6], O. A. Gonzalez[5], J. Alonso-García[1], M. J. Irwin[7], E. Gonzalez-Solares[7], S. T. Hodgkin[7], J. R. Lewis[7], N. Cross[8], V. D. Ivanov[9], E. Kerins[10], J. P. Emerson[11], M. Soto[12], E. B. Amôres[13,14], S. Gurovich[15], I. Dékány[1], R. Angeloni[1], J. C. Beamin[1], M. Catelan[1], N. Padilla[1,16], M. Zoccali[1,17], P. Pietrukowicz[18], C. Moni Bidin[19], F. Mauro[19], D. Geisler[19], S. L. Folkes[20], S. E. Sale[1,20], J. Borissova[20], R. Kurtev[20], A. V. Ahumada[9,15,21], M. V. Alonso[15], A. Adamson[22], J. I. Arias[12], R. M. Bandyopadhyay[23], R. H. Barbá[12,24], B. Barbuy[25], G. L. Baume[26], L. R. Bedin[27], R. Benjamin[28], E. Bica[29], C. Bonatto[29], L. Bronfman[30], G. Carraro[9], A. N. Chenè[19,20], J. J. Clariá[15], J. R. A. Clarke[20], C. Contreras[4], A. Corvillón[1], R. de Grijs[31,32], B. Dias[25], J. E. Drew[4], C. Fariña[26], C. Feinstein[26], E. Fernández-Lajús[26], R. C. Gamen[26], W. Gieren[19], B. Goldman[33], C. González-Fernández[34], R. J. J. Grand[35], G. Gunthardt[15], N. C. Hambly[8], M. M. Hanson[36], K. Helminiak[1], M. G. Hoare[37], L. Huckvale[10], A. Jordán[1], K. Kinemuchi[38], A. Longmore[39], M. López-Corredoira[34,40], T. Maccarone[41], D. Majaess[42], E. Martín[34], N. Masetti[43], R. E. Mennickent[19], I. F. Mirabel[44,45], L. Monaco[9], L. Morelli[46], V. Motta[20], T. Palma[15], M. C. Parisi[15], Q. Parker[47,48], F. Peñaloza[20], G. Pietrzyński[18,19], G. Pignata[49], B. Popescu[36], M. A. Read[8], A. Rojas[1], A. Roman-Lopes[12], M. T. Ruiz[30], I. Saviane[9], M. R. Schreiber[20], A. C. Schröder[50,51], S. Sharma[20,52], M. D. Smith[53], L. Sodré Jr.[25], J. Stead[37], A. W. Stephens[54], M. Tamura[55], C. Tappert[20], M. A. Thompson[4], E. Valenti[5], L. Vanzi[16,56], N. A. Walton[7], W. Weidmann[15], and A. Zijlstra[10]

THE VVV SCIENCE TEAM

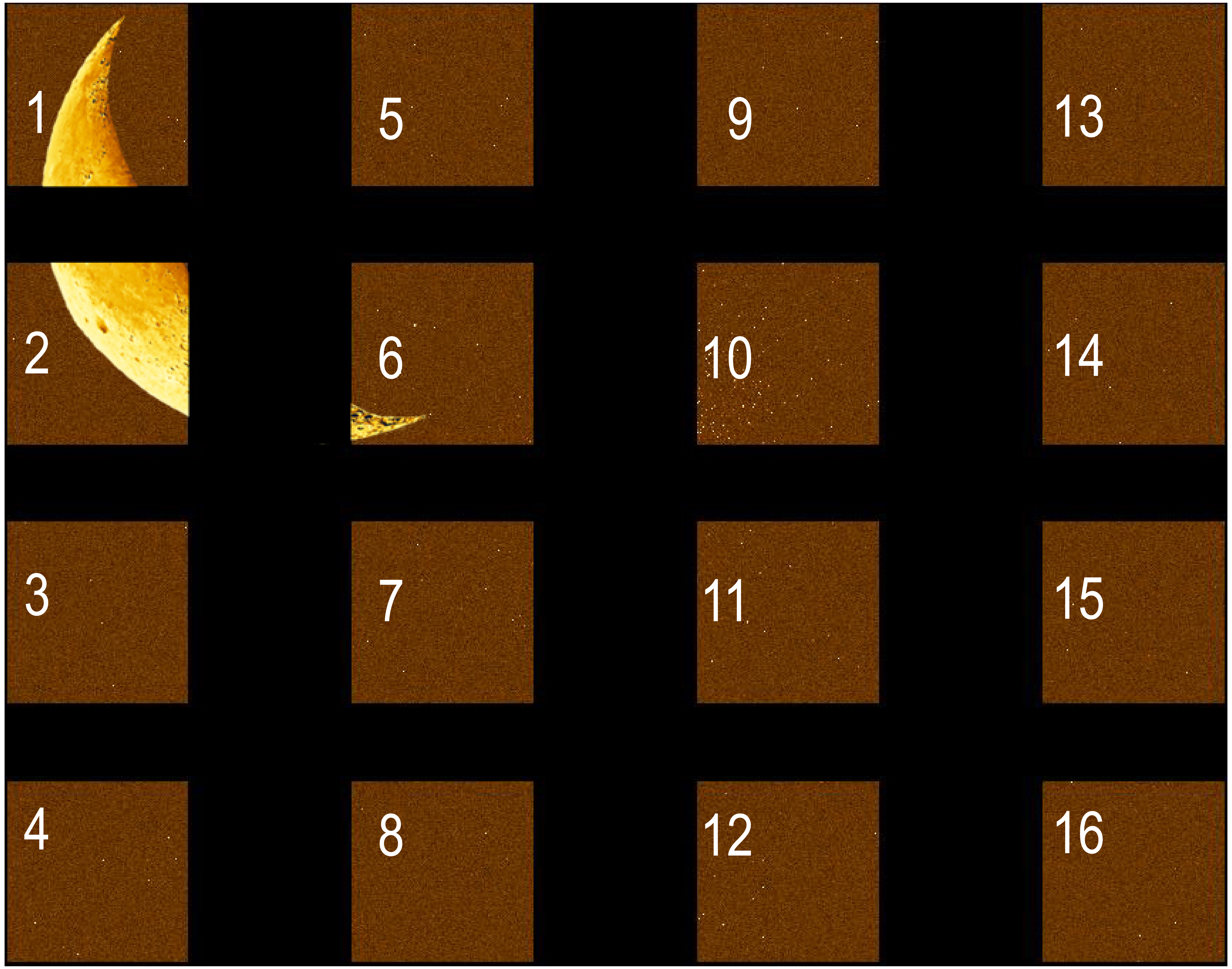
VISTA TELESCOPE

- 4m diameter
- IR optimized
- large field of view
- small pixel scale

VIRCAM DETECTORS

vvvsurvey.org

- 16x 2048x 2048 VIRGO IR detectors
- many hot pixels & dead zones in detector 1
- sensitivity: 0.84 to 2.5 microns
- filters: Z, Y, J, H, Ks
- pixel scale: 0.34¨
- active optics
- “tile” field of view: 1.0x1.5 deg (6 pointings)
- best image quality: 0.6¨ (incl. seeing, optics, sampling)
- image distortion: <15% PSF at field corners




Eta Sgr

VVVX Survey

MAIN GOAL

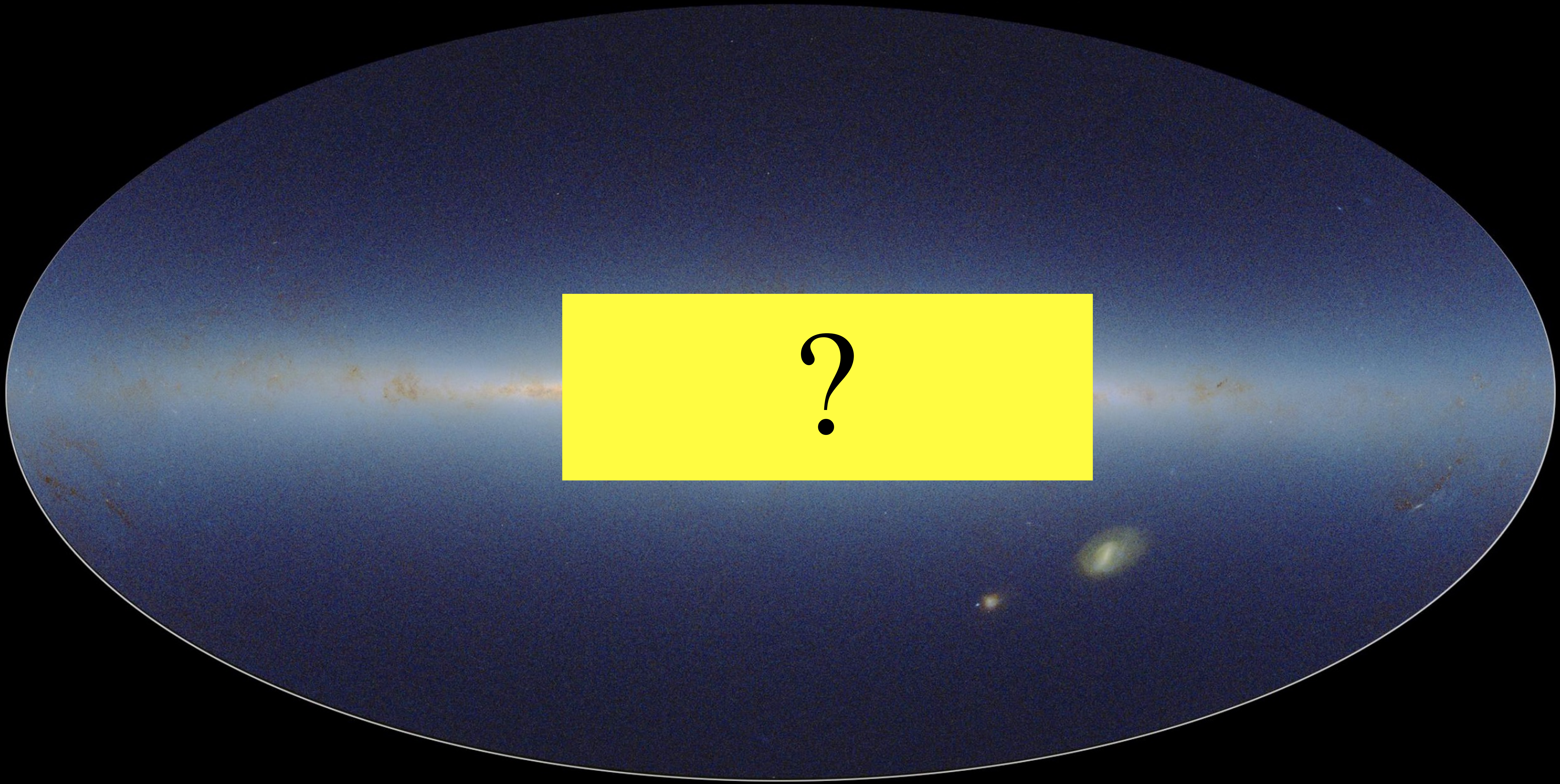
What is the 3-D structure of the Milky Way

We use RRLyrae, Cepheids, and clump giants to investigate this.

OUR GALAXY, THE MILKY WAY

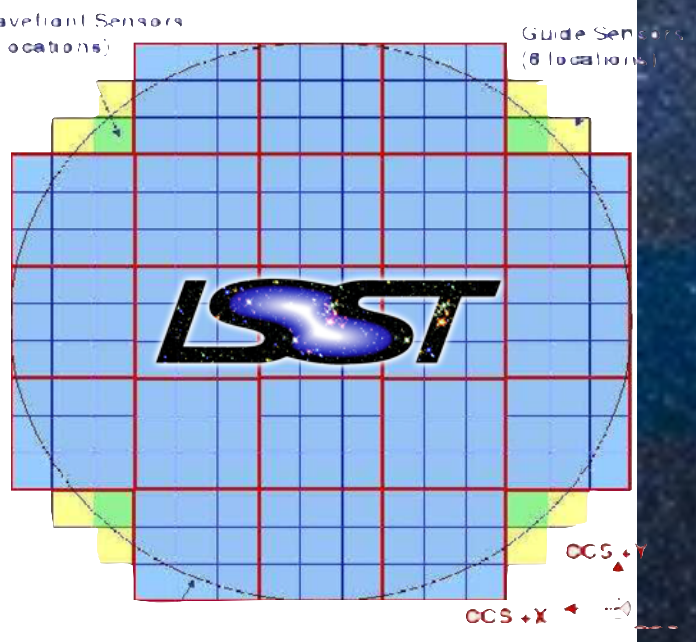
The photo album of the MW is not complete yet!!!

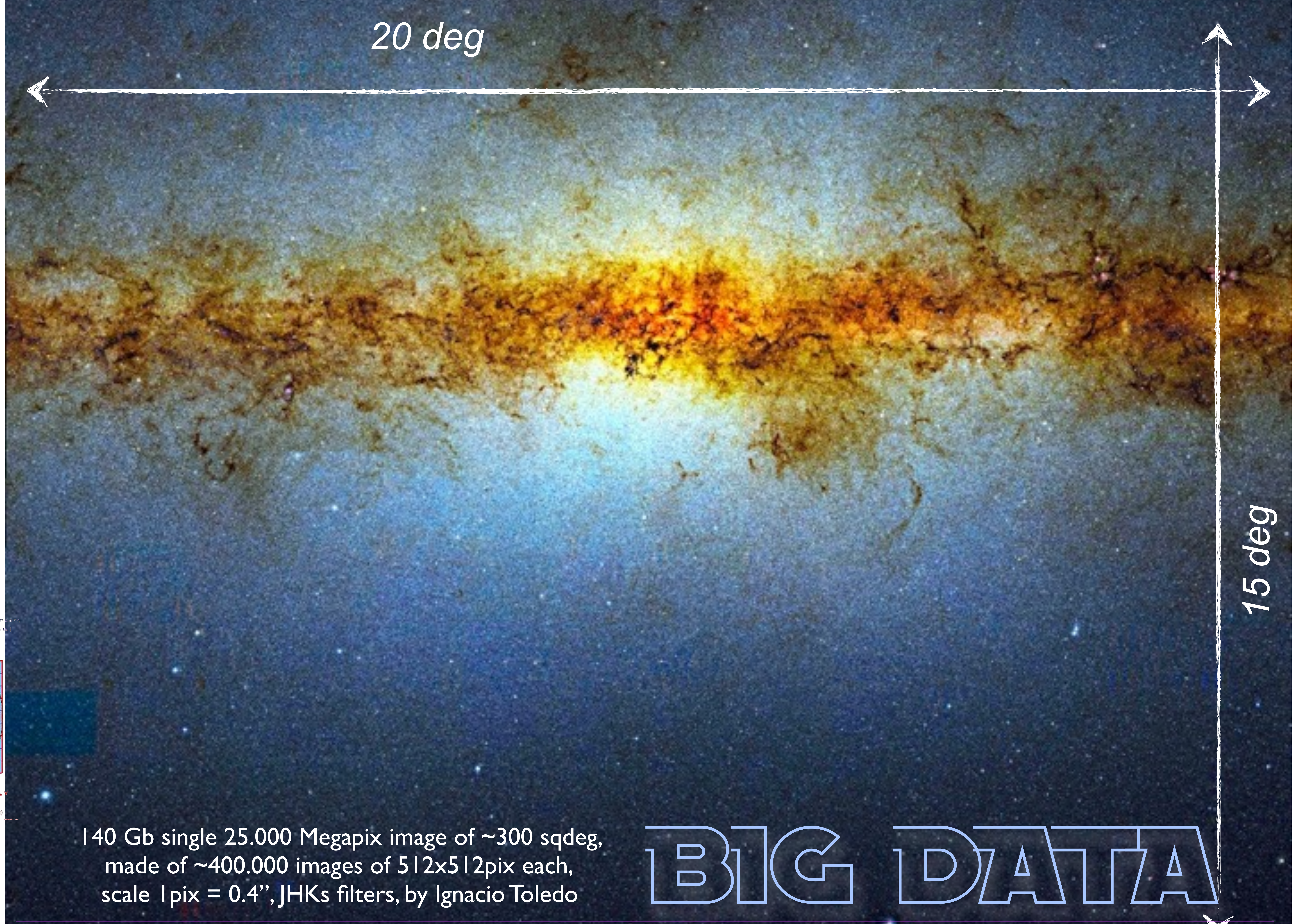
vvvsurvey.org



2MASS IMAGE OF THE MILKY WAY

~30 LSST Fields





140 Gb single 25.000 Megapix image of ~300 sqdeg,
made of ~400.000 images of 512x512pix each,
scale 1pix = 0.4'', JHKs filters, by Ignacio Toledo

vvvsurvey.org

VISTA DATAFLOW

vvvsurvey.org

VISTA — Telescope Raw Data Acquisition

PSO — Paranal Science Operations processing

CASU — Cambridge Astronomical Survey Unit

WFAU — Wide Field Astronomy Unit

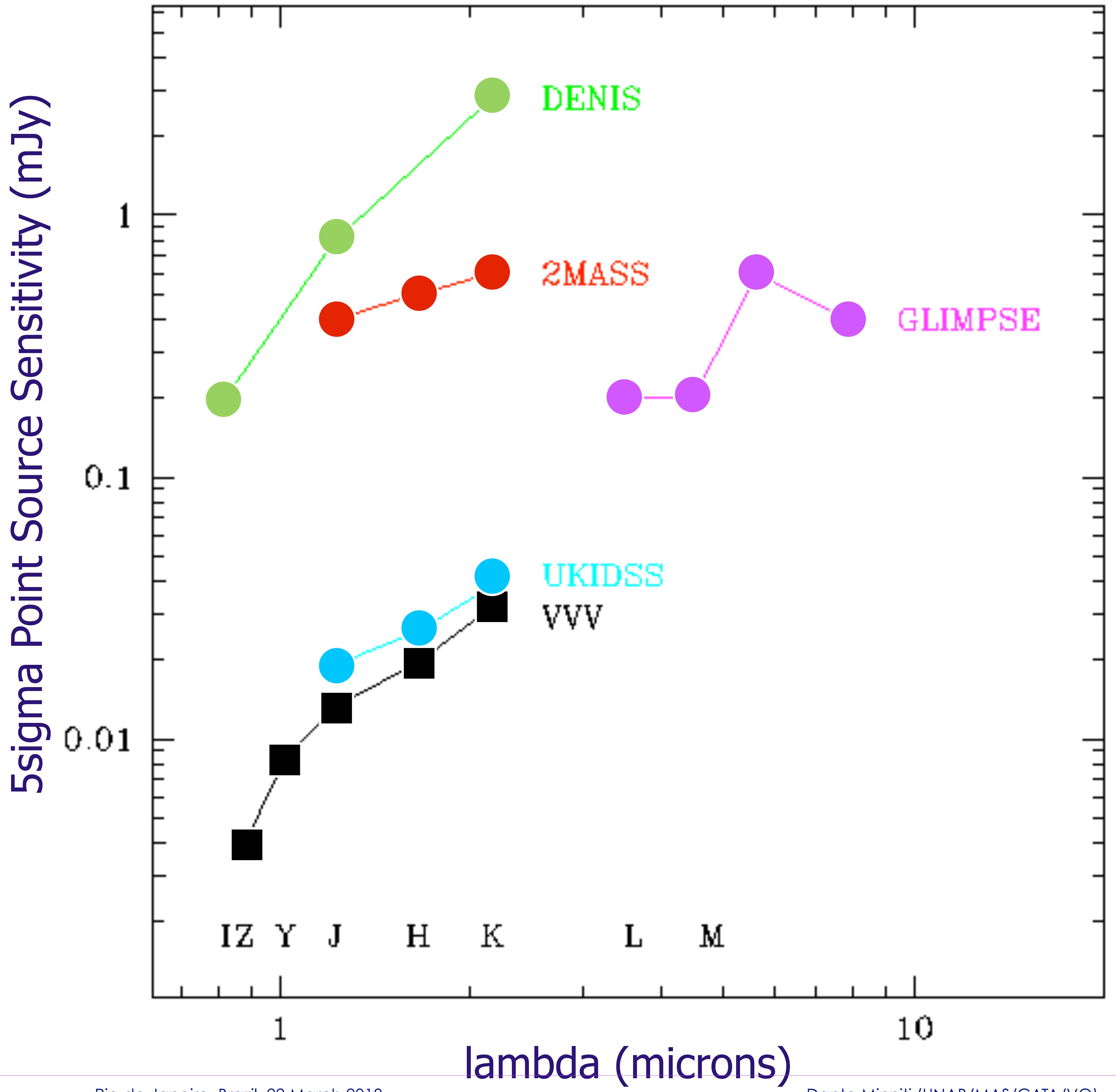
VVV — VVV Science Team

ESO — ESO Science Archive


VVV
vvvsurvey.org
0°
330°
300°
270°
240°
210°
180°
150°
120°
90°
60°
75,000 ly
60,000 ly
45,000 ly
30,000 ly
15,000 ly
Scutum-Centaurus Arm
Norma Arm
Galactic Bar
Far 3kpc Arm
Sagittarius Arm
Near 3kpc Arm
Long Bar
Outer Arm
Perseus Arm
Orion Spur
Sun
2MASS
R.Hurt/JPL/NASA

VVV IN CONTEXT

vvvsurvey.org



Valentin Ivanov


2MASS


VVV

Main differences with 2MASS

2MASS covers the whole sky, VVV only 1.3%

VVV has higher resolution (0.34”/pix)

VVV is deeper (Ks<18)

VVV has 5 filters (ZYJHKs)

VVV is a multiepoch survey (~100 epochs)

DEEPER AND HIGHER RESOLUTION


vvvsurvey.org
0°
30°
330°
60°
300°
90°
270°
240°
180°
75,000 ly
60,000 ly
45,000 ly
15,000 ly
30,000 ly
Scutum-Centaurus Arm
Sagittarius Arm
Far 3kpc Arm
Galactic Bar
Norma Arm
Near 3kpc Arm
Long Bar
Sun
Orion Spur
Perseus Arm
Outer Arm
VVVX
Survey

THE VVV EXTENDED SURVEY

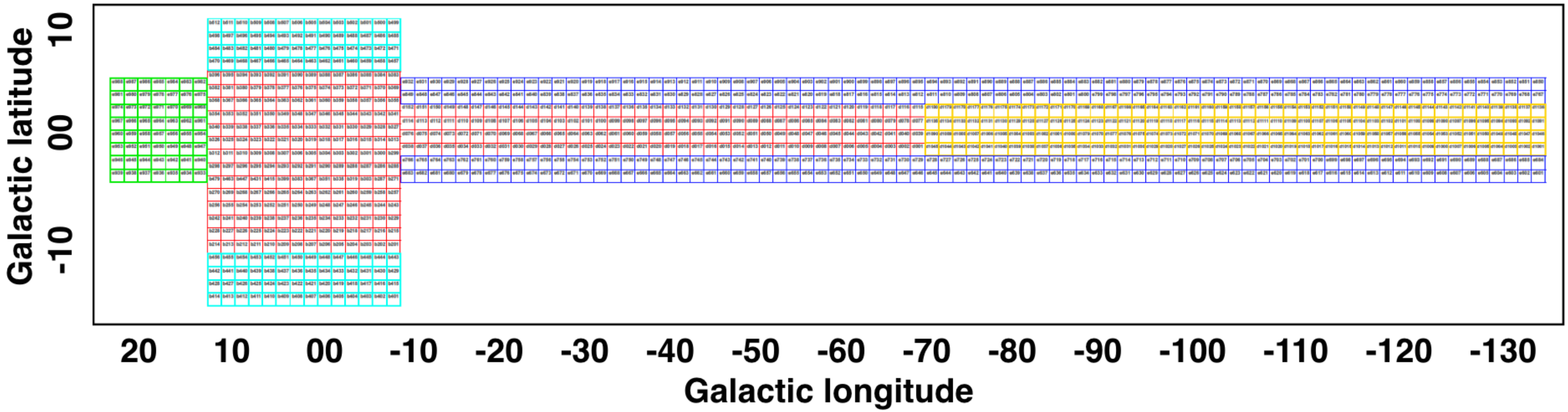
Total Area 1700 sqdeg
Total Time 2000 hs

VVVX Survey

~50% of the MW stars

vvvsurvey.org

The VVVX survey: 1028 tiles



VVV X Survey

Our main scientific goal:

To unveil the structure of the inner bulge, disk and halo.

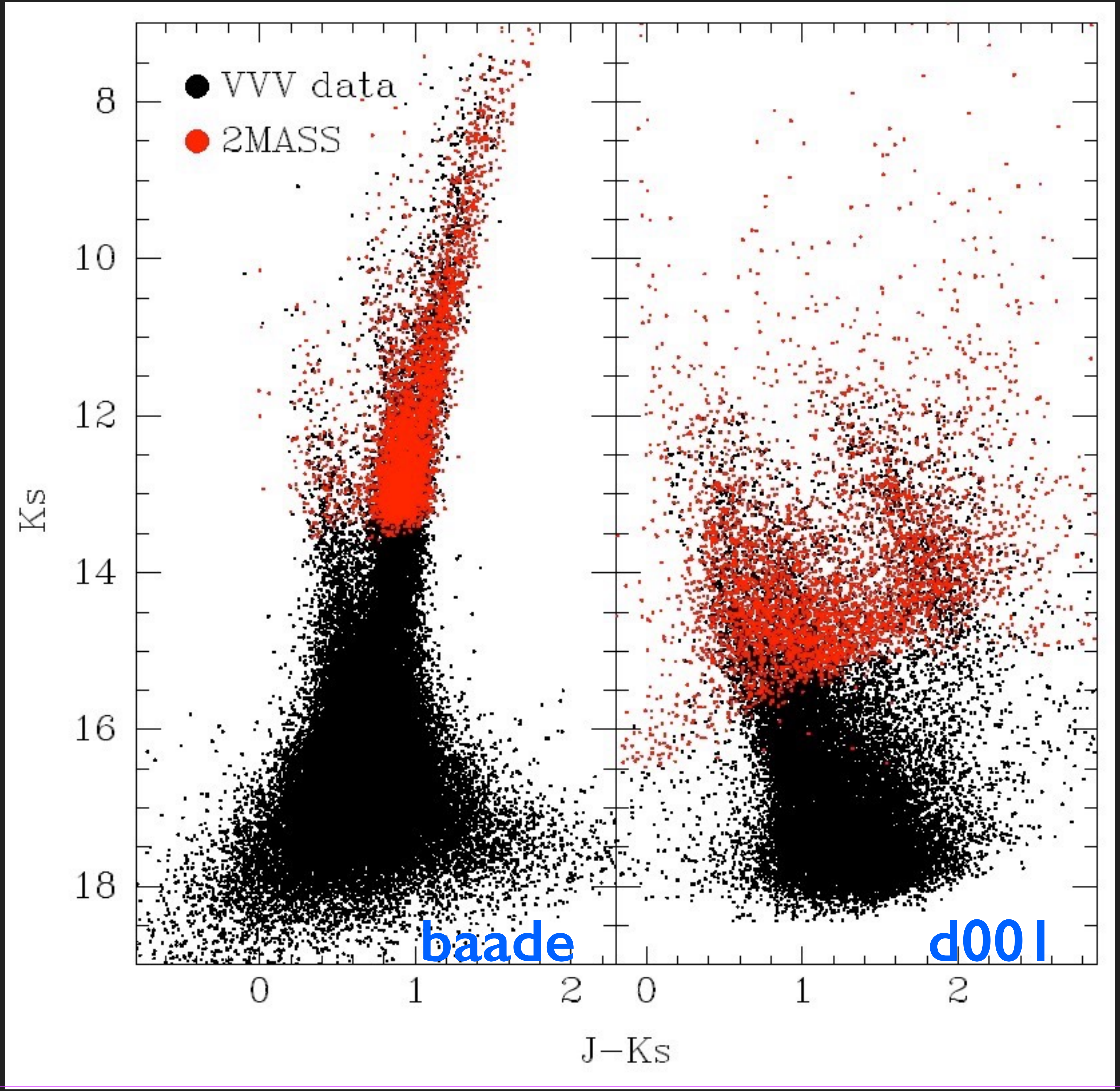
In order to do this, we search for (discover, characterize, study) a variety of objects of astrophysical interest.

Javier Alonso-García et al. (2018, in prep.)

In Z, 667 million stars
In Y, 707 million stars
In J, 922 million stars
In H, 990 million stars
In Ks, 779 million stars

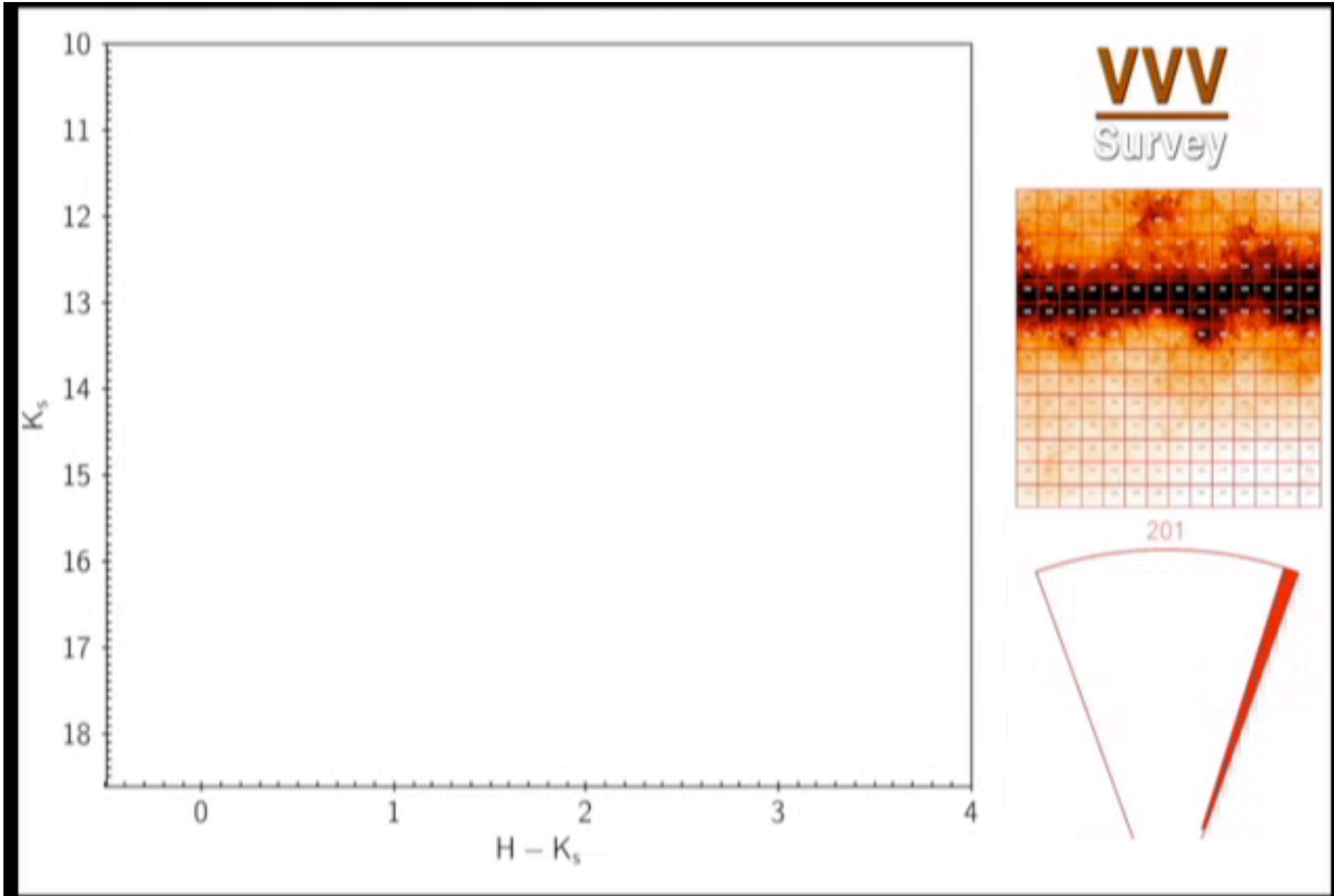
VVV Giga-CMDs

VVV CMDS



Color-magnitude diagrams of bulge and disk fields compared with 2MASS.

Oscar Gonzalez



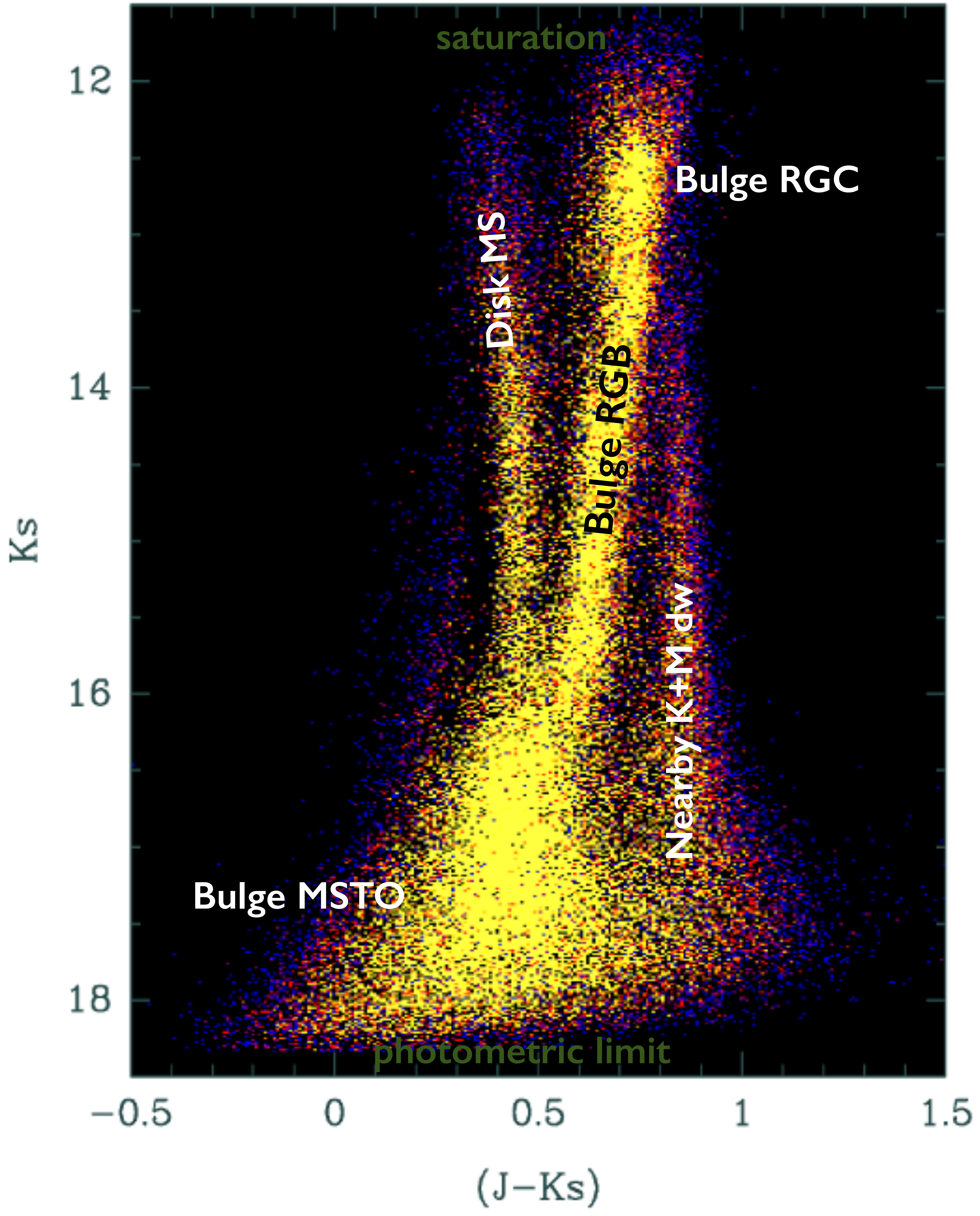
10
11
12
13
14
15
16
17
18
K_s
0
1
2
3
4
$H - K_s$
VVV
Survey
201

Elena Valenti, Manuela Zoccali, Oscar Gonzalez, Marina Rejkuba, Maren Hempel, et al.

The Mass of the Galactic Bulge

VVV STARS CMD

outer bulge fields
b209-b211



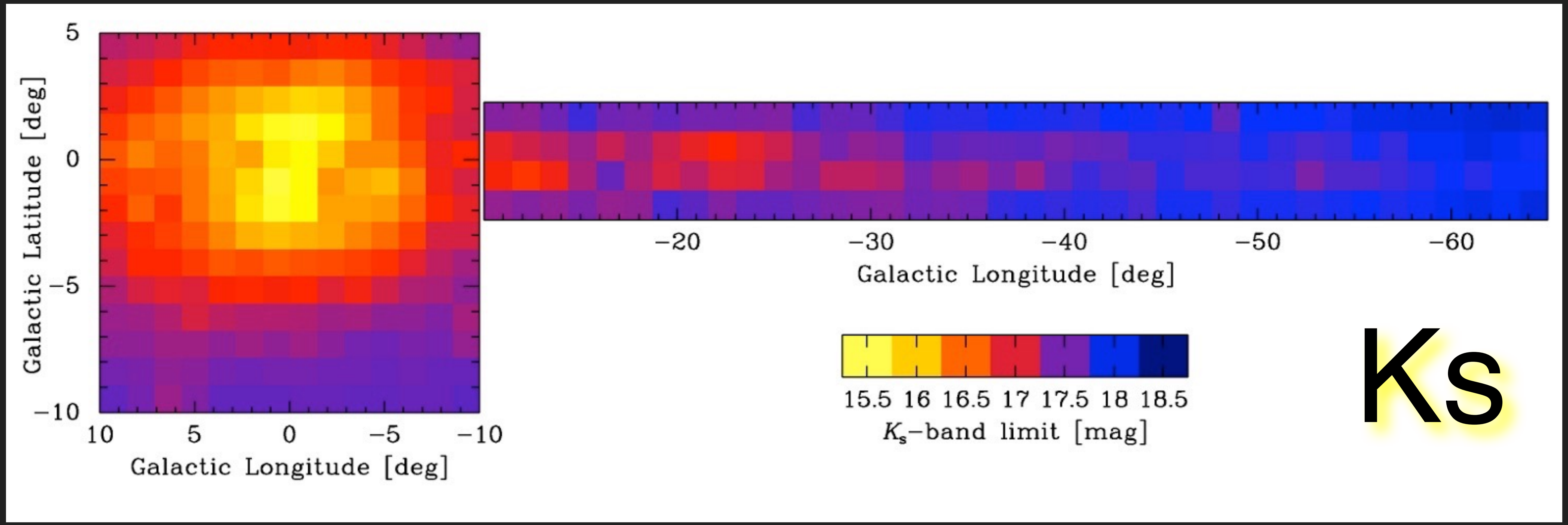
We first measure hundreds of millions of stars…

vvvsurvey.org

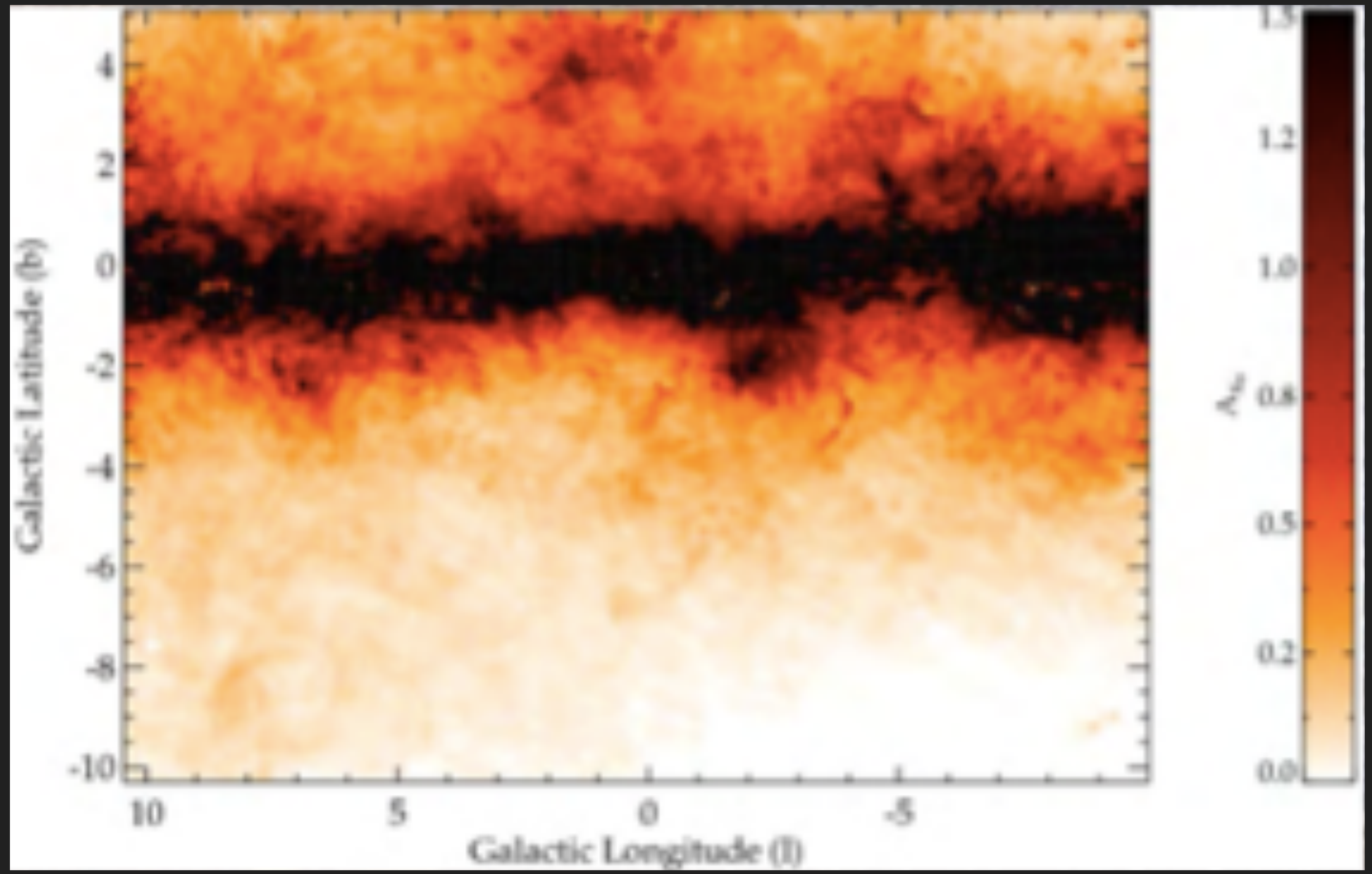
Then we make some corrections…

Limiting magnitudes

R. Saito

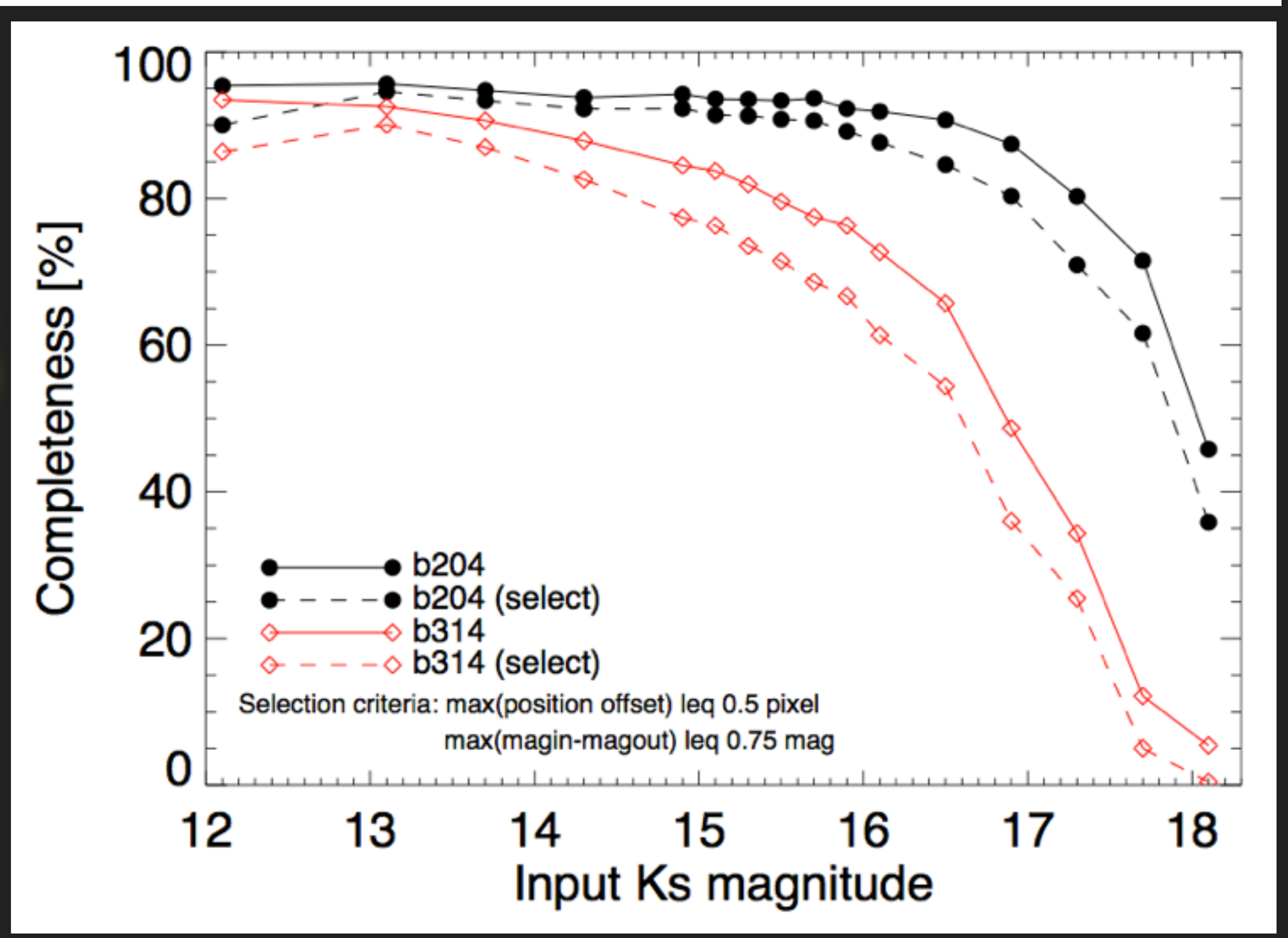


Reddening maps



O. Gonzalez

Completeness tests

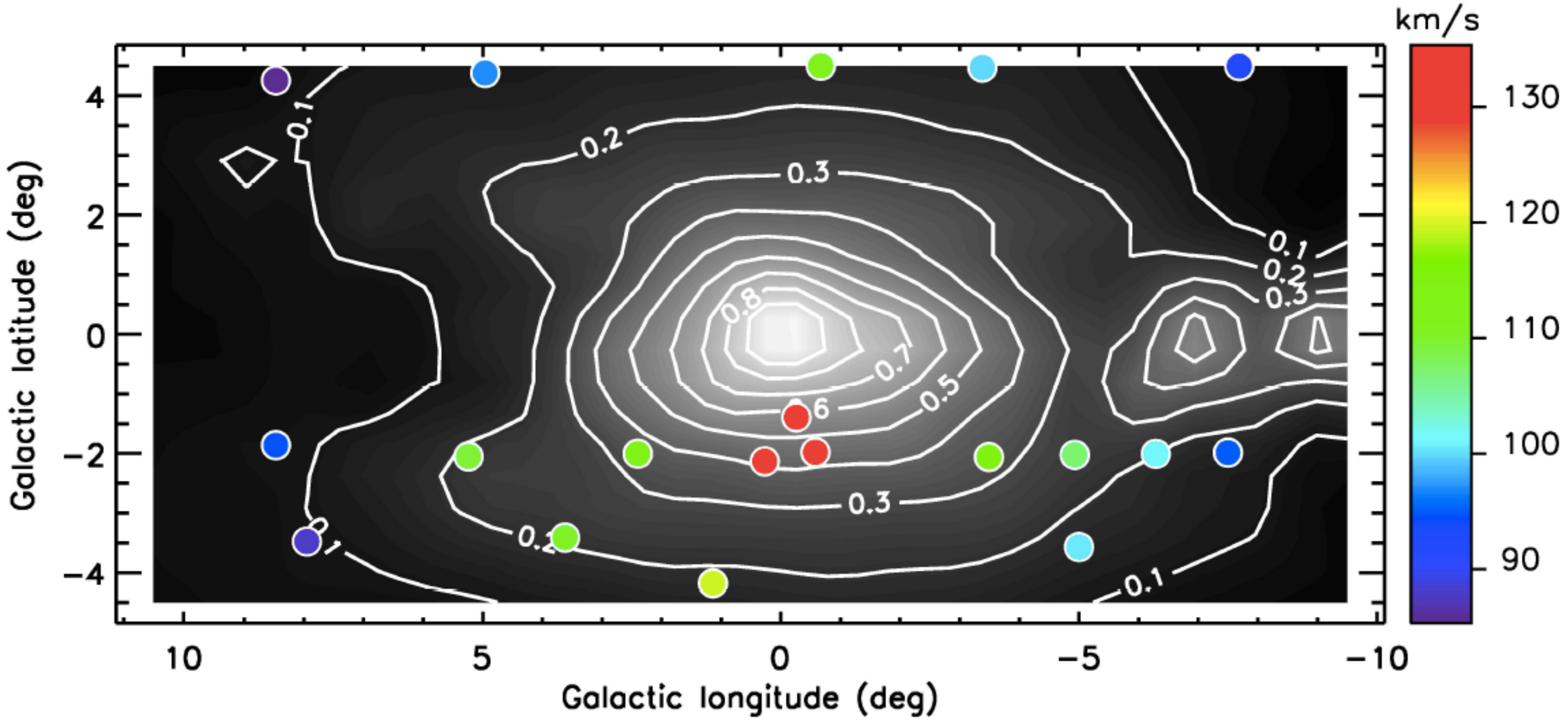


M. Hempel, E. Valenti

IAU Rio Webinar Rio de Janeiro, Brazil, 23 March 2018 Dante Minniti (UNAB/MAS/CATA)

… And we obtain the total bulge mass:

The mass of stars and remnants within $(|b| < 9.5°, |l| < 10°)$ is $2.0 \pm 0.3 \times 10^{10} M_\odot$



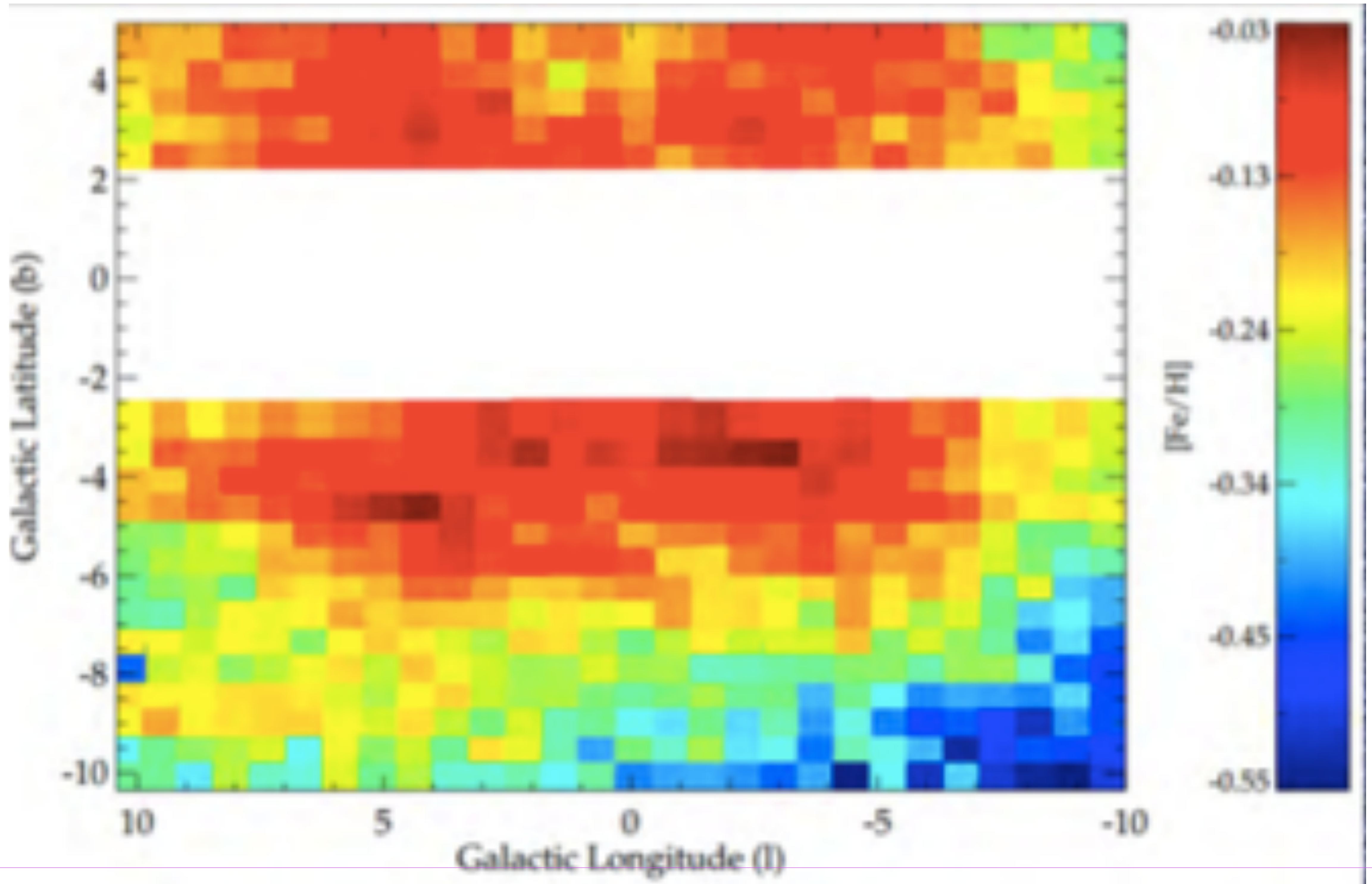
Stars density map of the inner Bulge from VVV data

E. Valenti et al. 2016, A&A, 587, L6

STRUCTURE OF THE MILKY WAY BULGE

Gonzalez et al. 2015, A&A (arXiv.1510.05943)
Valenti et al. 2013, A&A, 559, 98 (arXiv:1309.4570)
Dekany et al. 2013, ApJL, 776, L19 (arXiv:1309.5933)
Vazquez et al. 2013, A&A, 555, 91 (arXiv:1304.6427)
Saito et al. 2013, A&A, 545, 147, 201 (arXiv:1208.5178)
Gonzalez et al. 2013 A&A, 552, 110 (arXiv:1302.0243)
Gonzalez et al. 2012 A&A, 543, 13 (arXiv:1204.4004)

The global metallicity map of the MW bulge



Some Successful Models

Wegg & Gerhard, MNRAS 2016

Athanassoula et al., A&A 2017

Debattista et al., MNRAS 2017

Tissera et al., MNRAS 2018

The Future:

We need multi object NIR spectrographs

APOGEE-S

MOONS

22 Debattista et al.

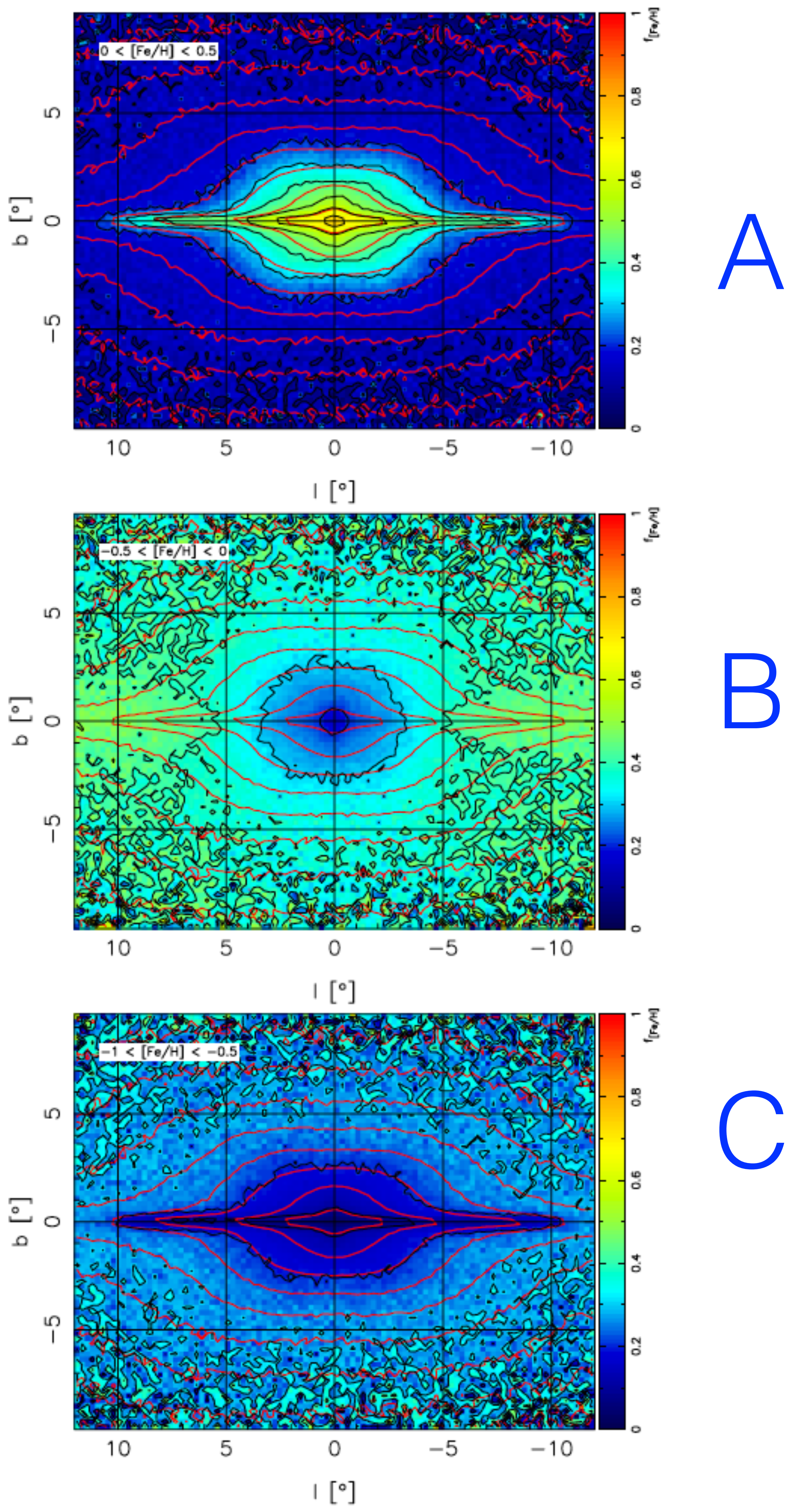


Figure 24. The fraction of stars in the star-forming simulation in different metallicity bins (as indicated at top-left) corresponding to the populations A (top), B (middle) and C (bottom) of Ness et al. (2013a). Black contours show constant fractions while red contours show constant overall surface density. Metal-rich stars dominate at small |b| while the intermediate-metallicity stars dominate everywhere else, as in ARGOS.

Ness et al. (2013, MNRAS)

Javier Alonso, Rodrigo Contreras, Istvan Dekany, Marcio Catelan, Joyce Pullen, Tali Palma, Felipe Gran, Roberto Saito, et al.

VVV

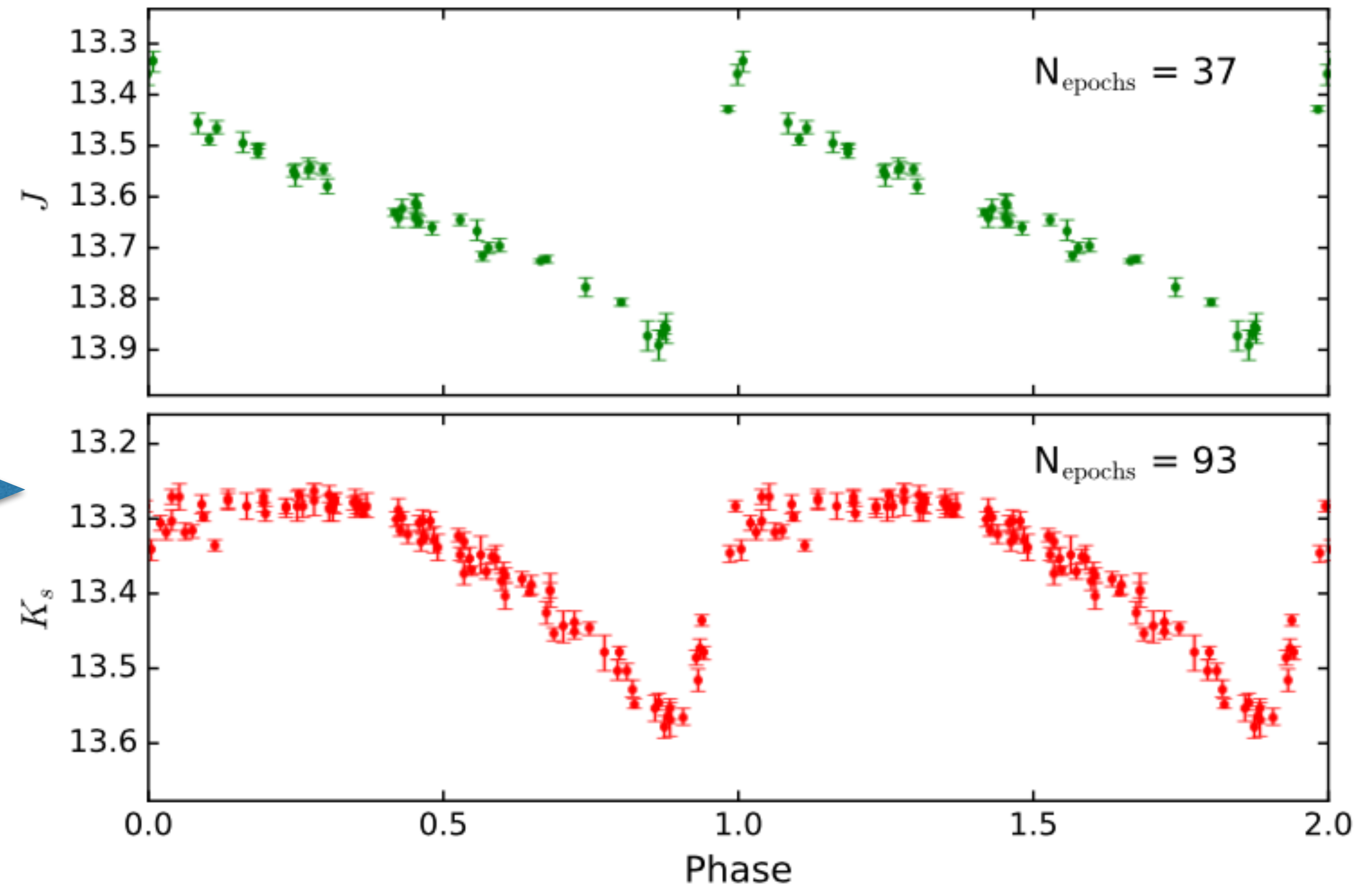
RRLyrae

Galactic structure,
stellar evolution,
star clusters,
interstellar medium,
…

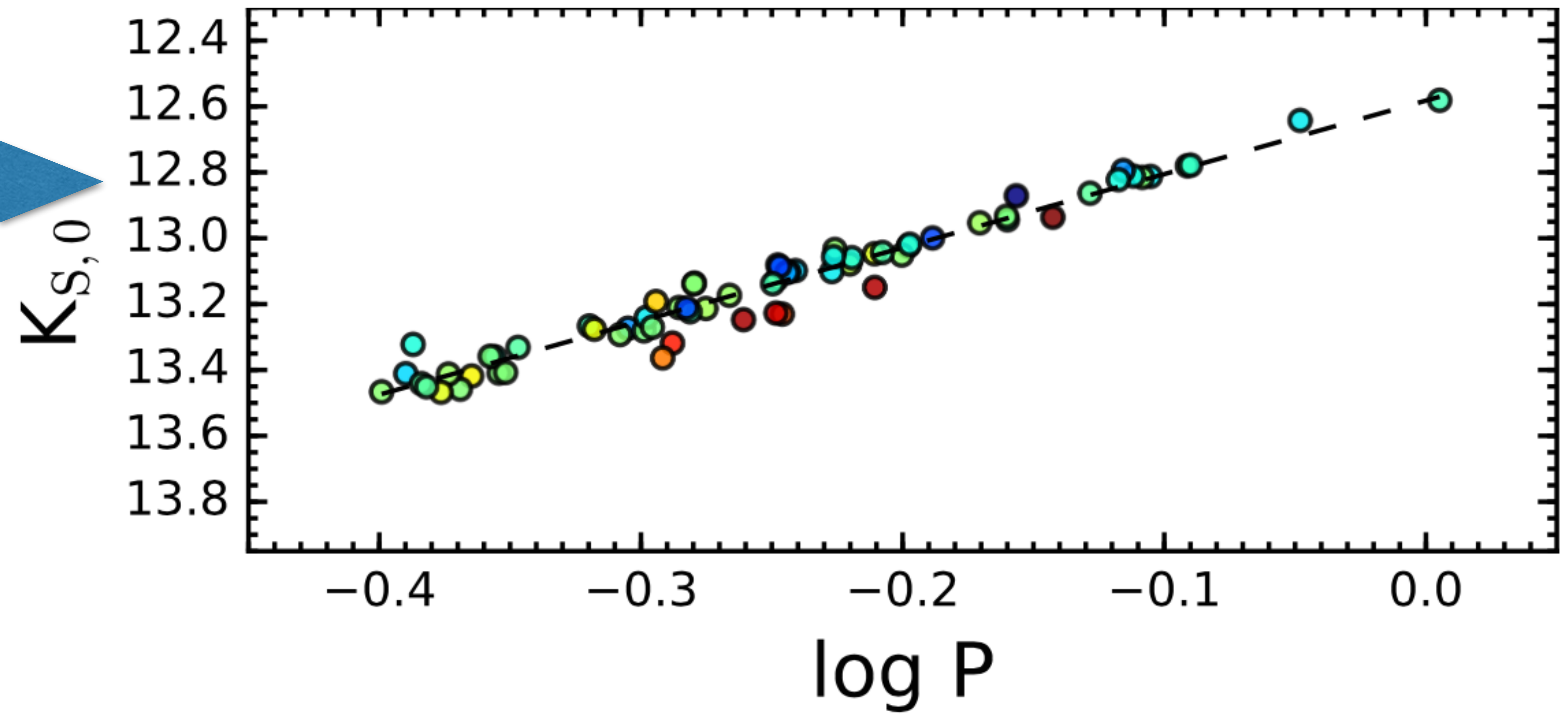
VVVX Survey

VVV RRLYRAE

- RR Lyrae are pulsating variable stars.
- Their characteristic light curves make them simple to identify.

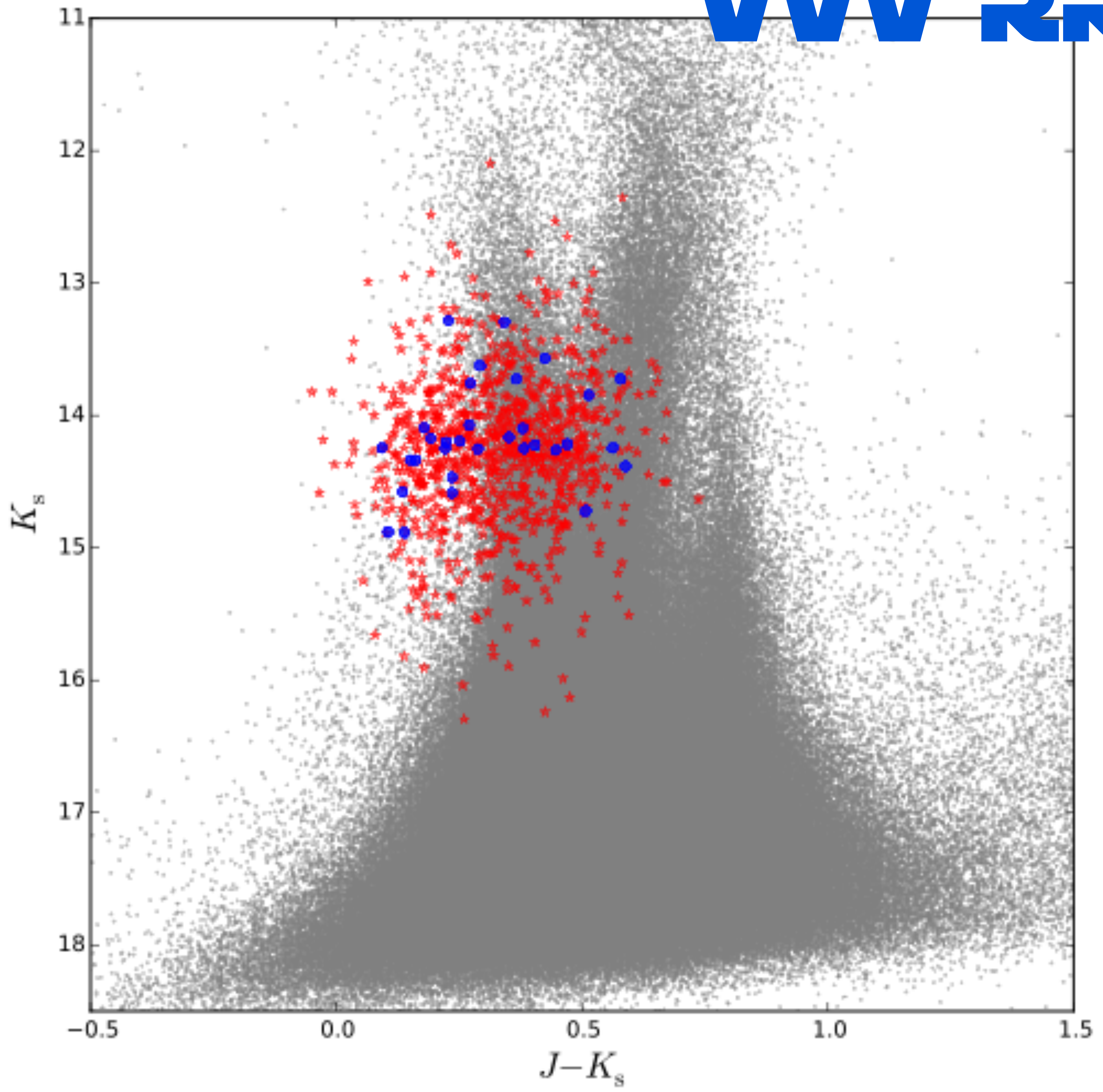


- They represent and old and metal-poor population.
- They are present in globular clusters.
- They follow a Period-Luminosity relation

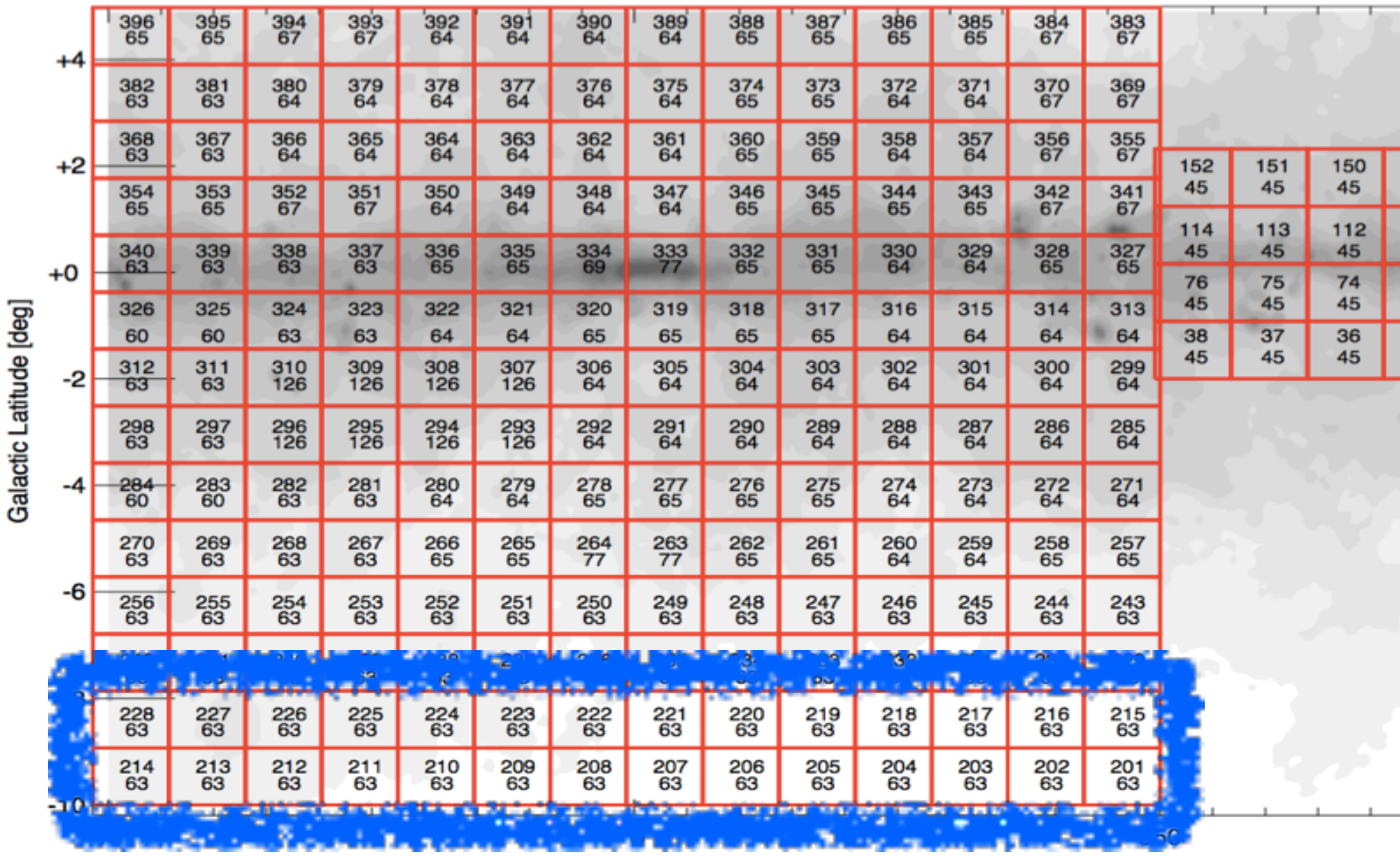


- RR Lyrae are primary distance indicators.

VVV RRLYRAE



- RR Lyrae represent an old and metal-poor stellar population.
- RR Lyrae stars are excellent distance indicators.



OUTER BULGE RR LYRAE

F. Gran, et al. 2014, A&A

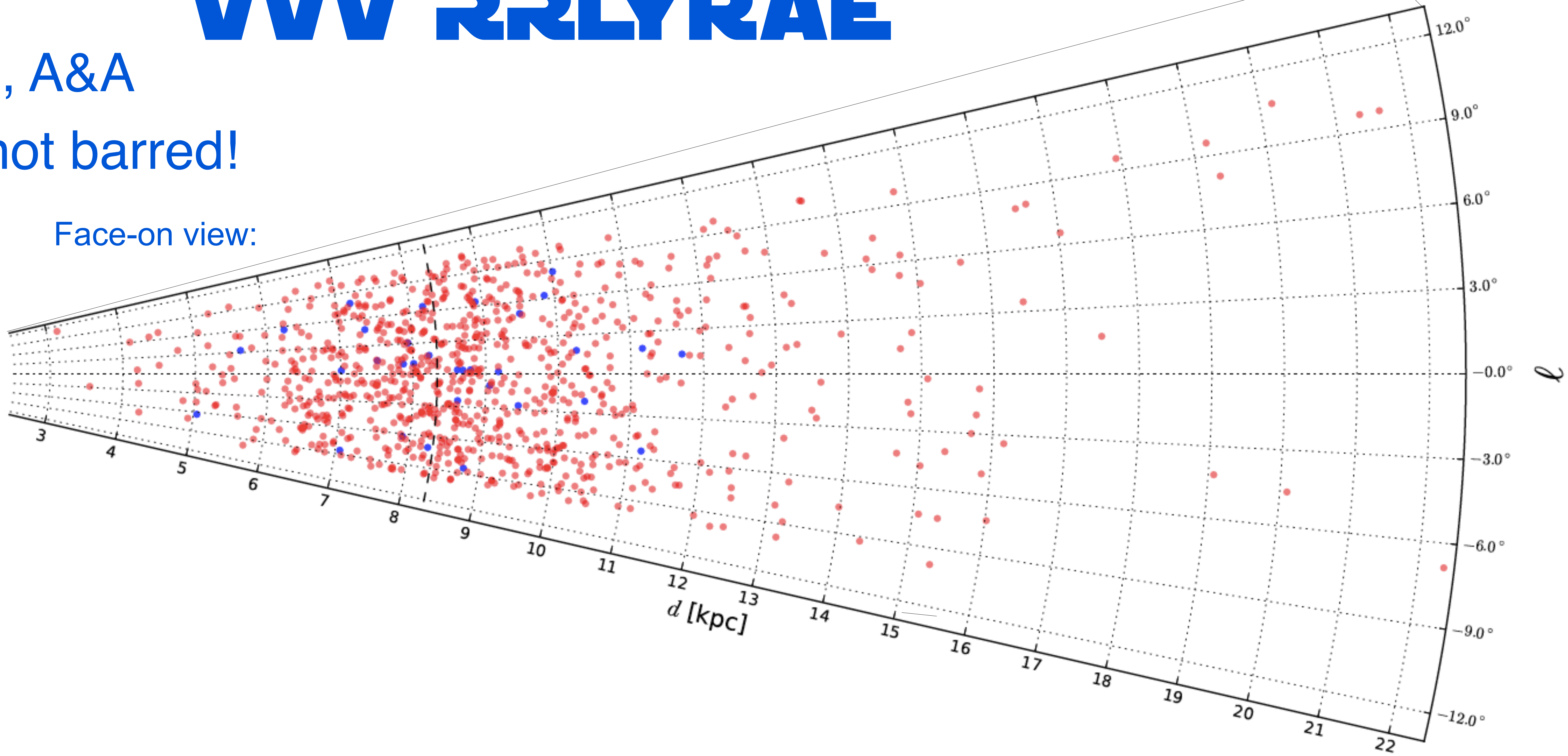
F. Gran, et al. 2016, A&A

VVV RRLYRAE

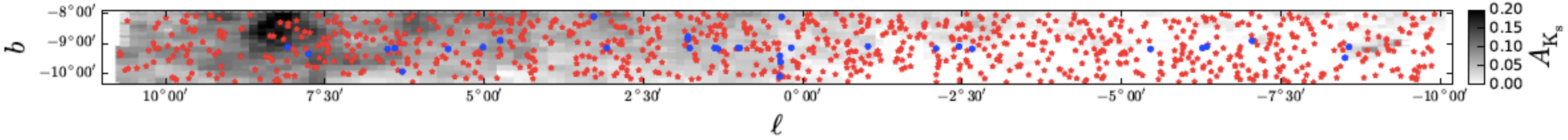
F. Gran, et al. 2016, A&A

The distribution is not barred!

Face-on view:



Edge-on view:



OUTER BULGE RR LYRAE

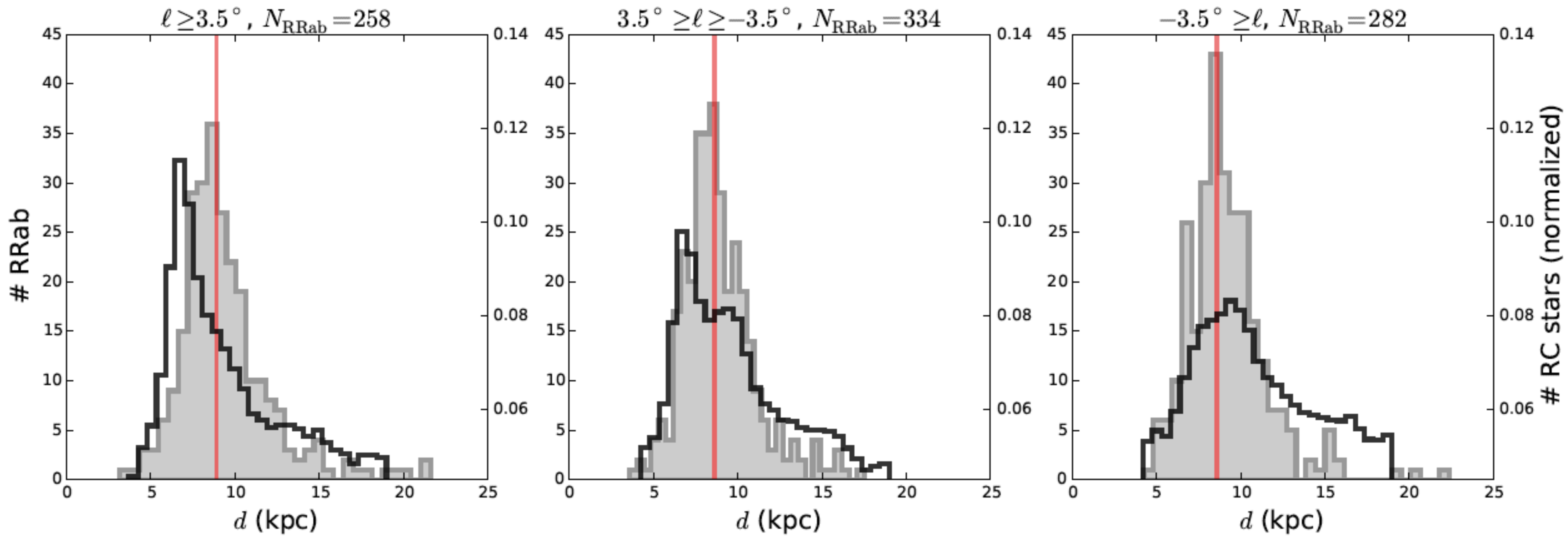


Fig. 8. Histogram of distances of RR Lyrae (gray filled) and RC stars (black steps) as function of galactic latitude (ℓ). Since the total number of RC stars in the same areas overwhelms the number of RR Lyrae, the histogram showing their distribution in distance was normalized for visualization purposes. The vertical line represents the RR Lyrae median distance of each region.

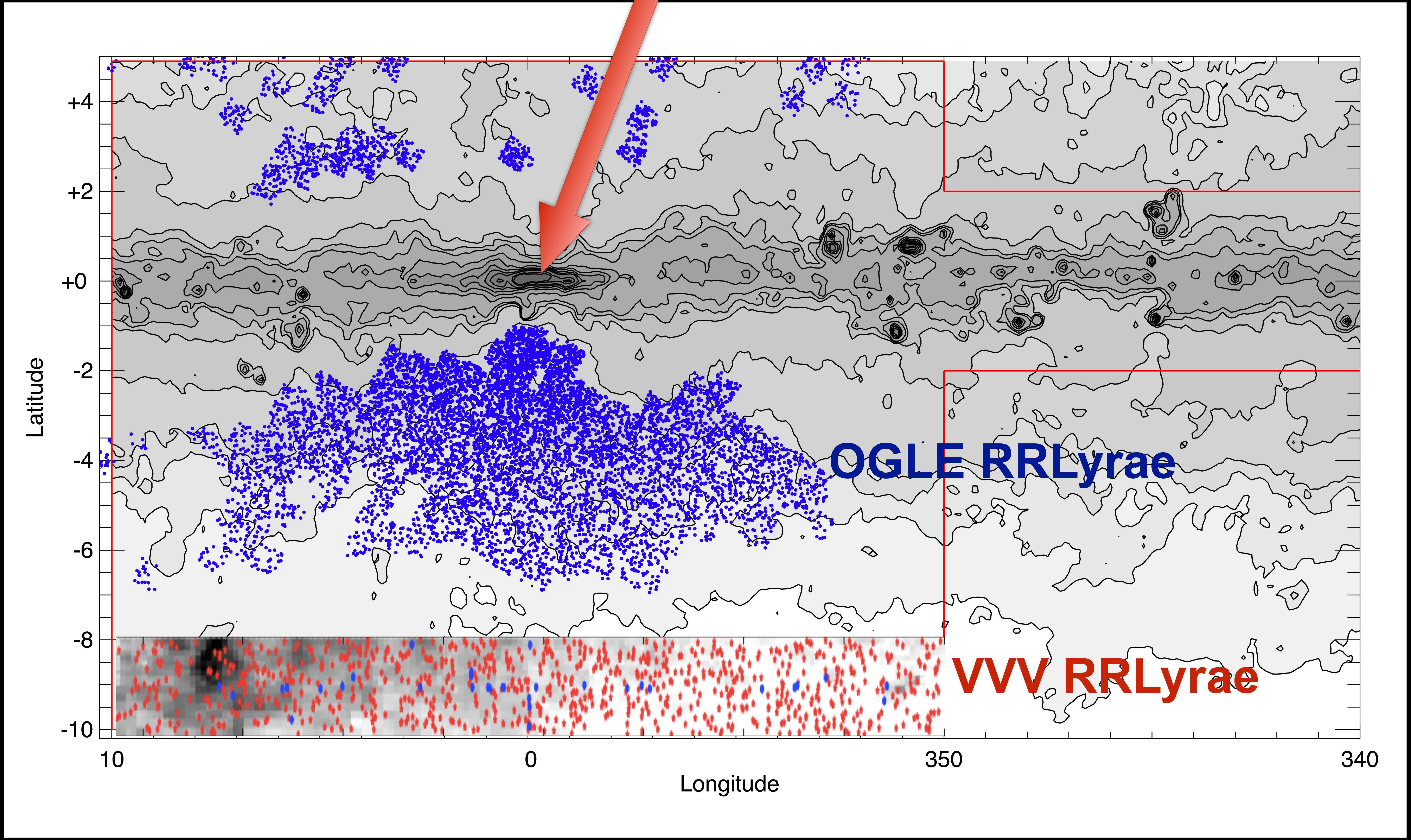
The VVV spatial distribution of known bulge RR Lyrae is different from the clump giants: there is no bar and there is no X-shape (Gran et al. 2016).

This contrasts with the inner bulge RR Lyrae from OGLE (Pietrukowicz et al. 2015).

The kinematics favor an axisymmetric population (Kunder et al. 2016)

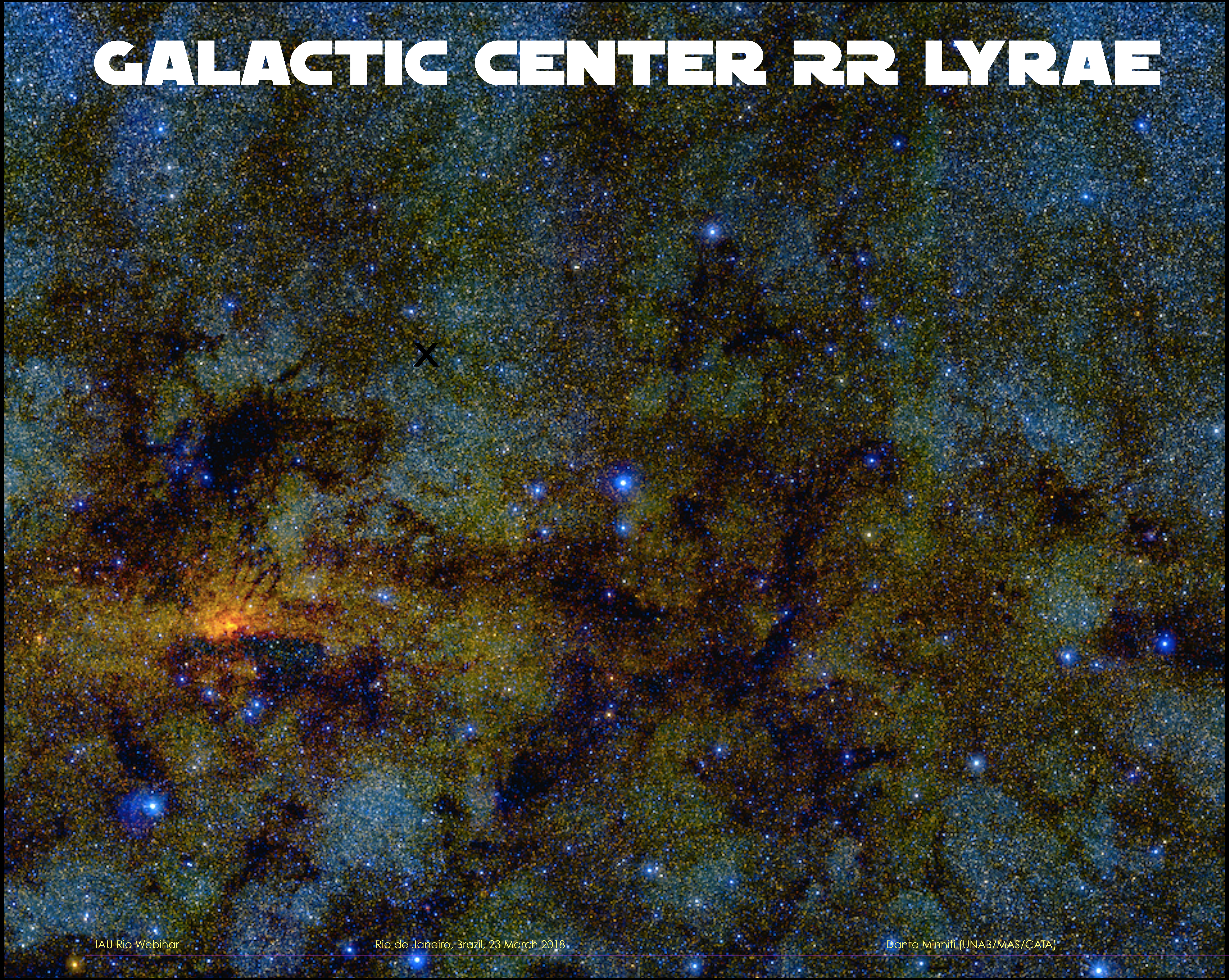
OUTER BULGE RR LYRAE

GALACTIC CENTER RR LYRAE



THE OLDEST STARS IN THE MW?

GALACTIC CENTER RR LYRAE

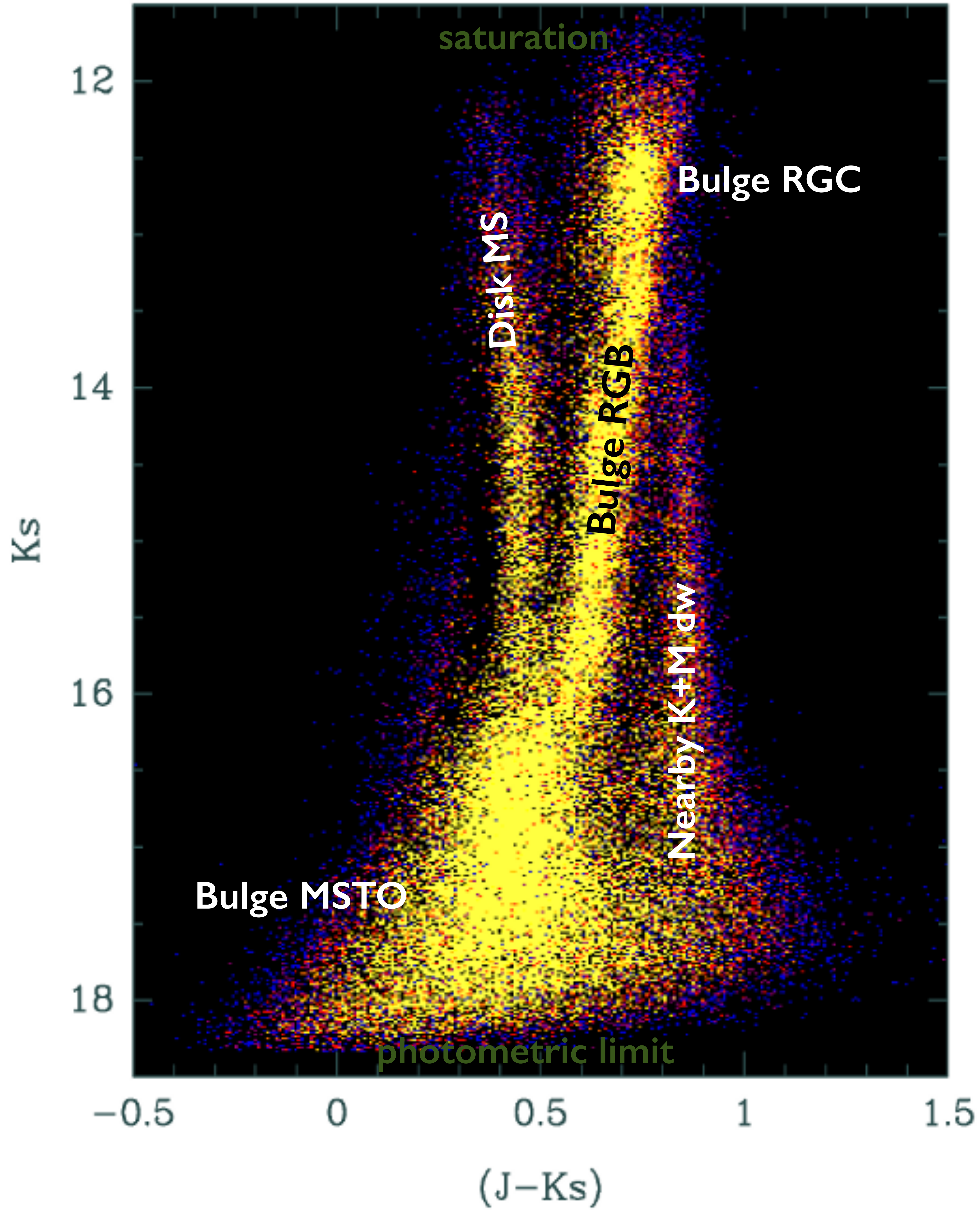


VVV Image of the Galactic center

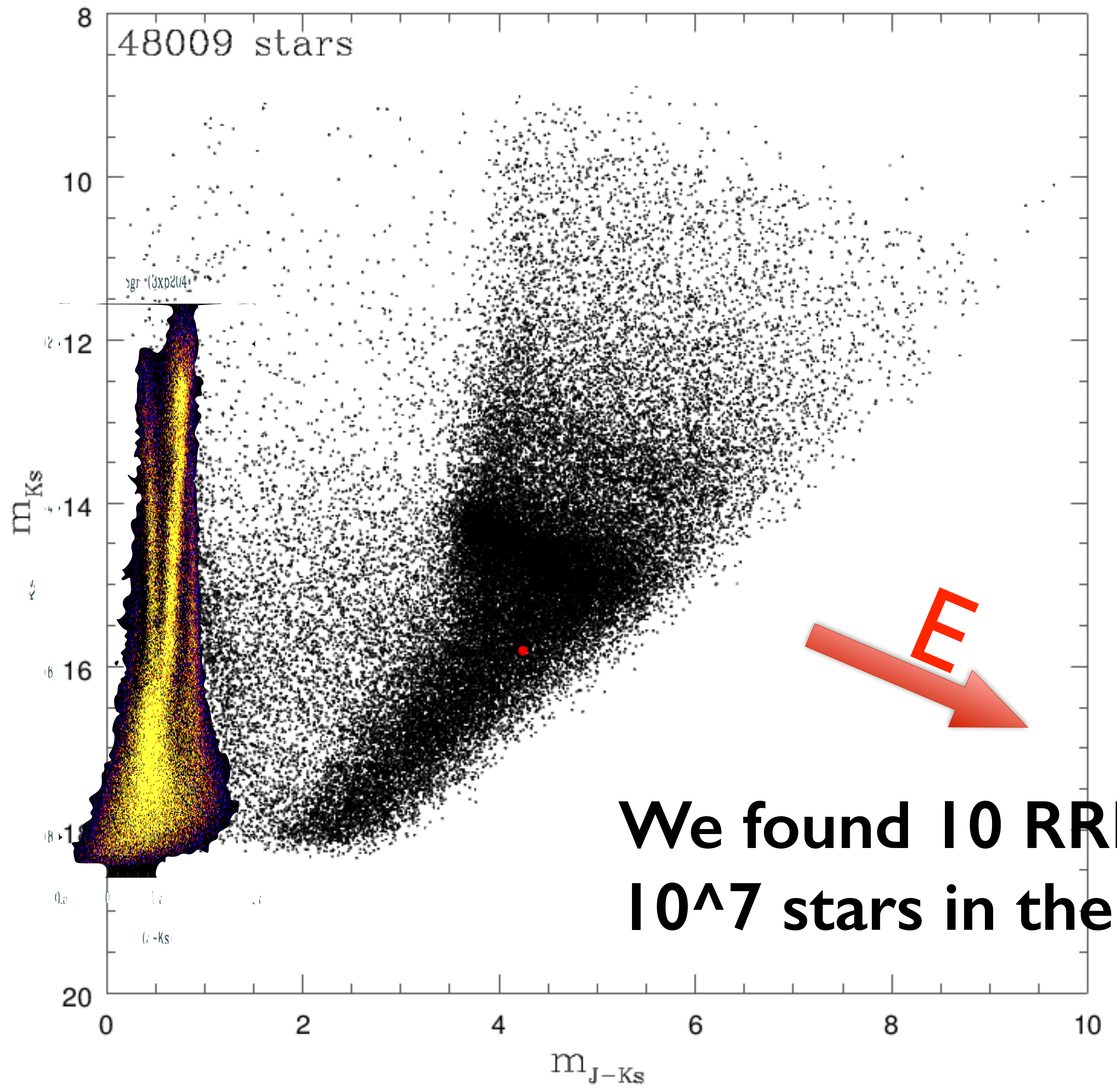
1x1.5 sqdeg

outer bulge fields
b209-b211

VVV STARS CMD

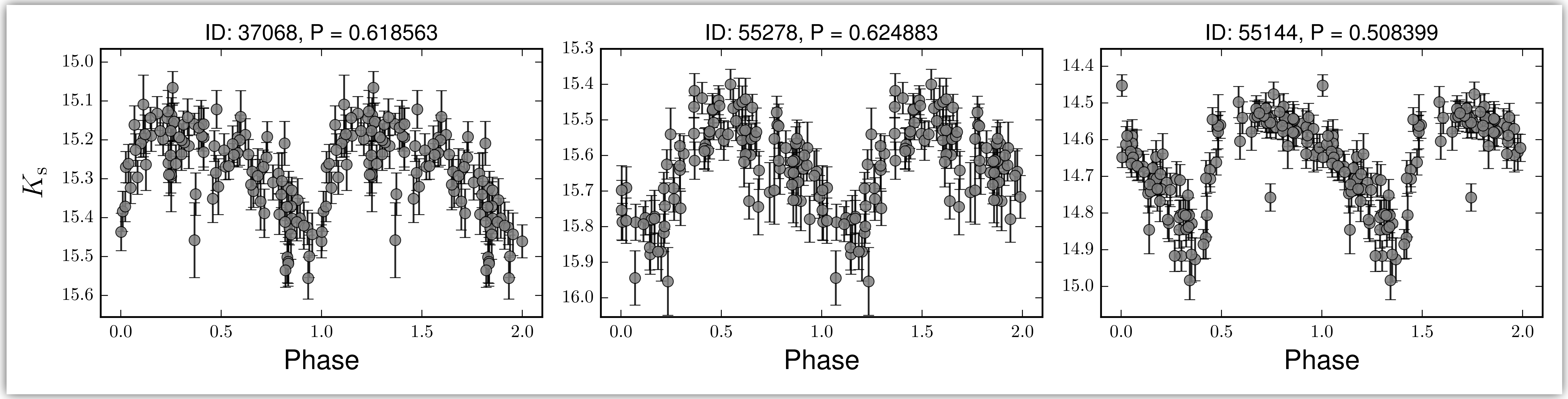


CMD of 1 chip

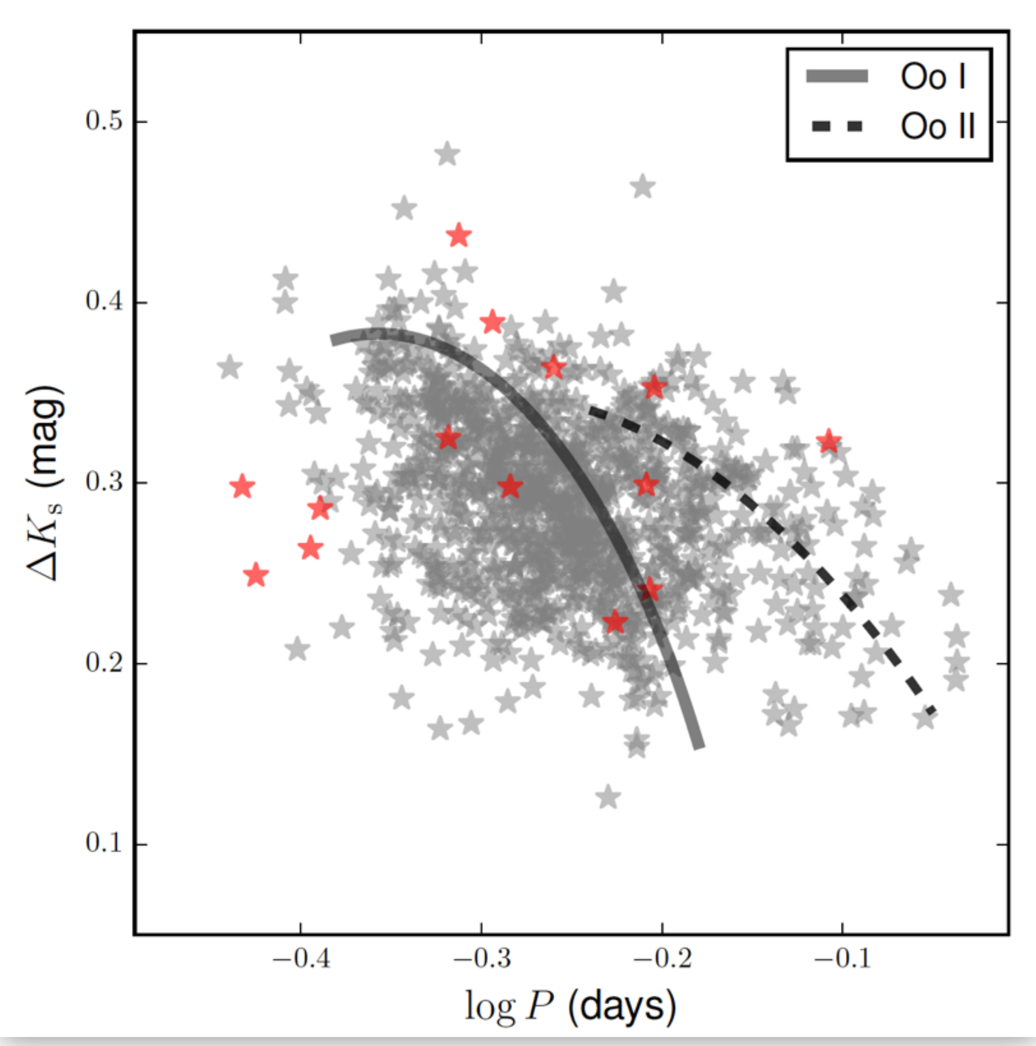


We found 10 RRLyrae out of 10^7 stars in the GC region

GALACTIC CENTER RR LYRAE

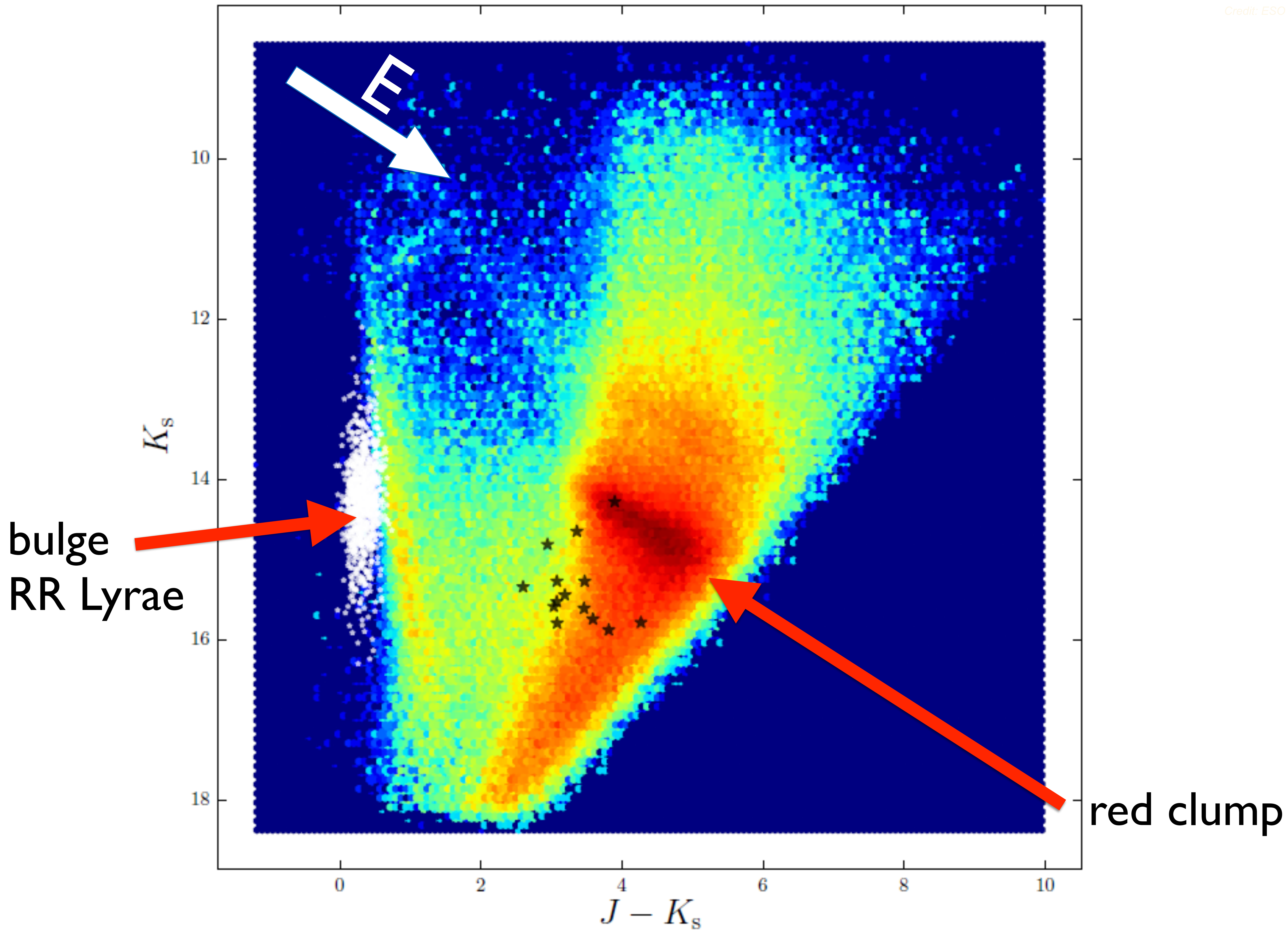


D. Minniti, et al. 2016, ApJL

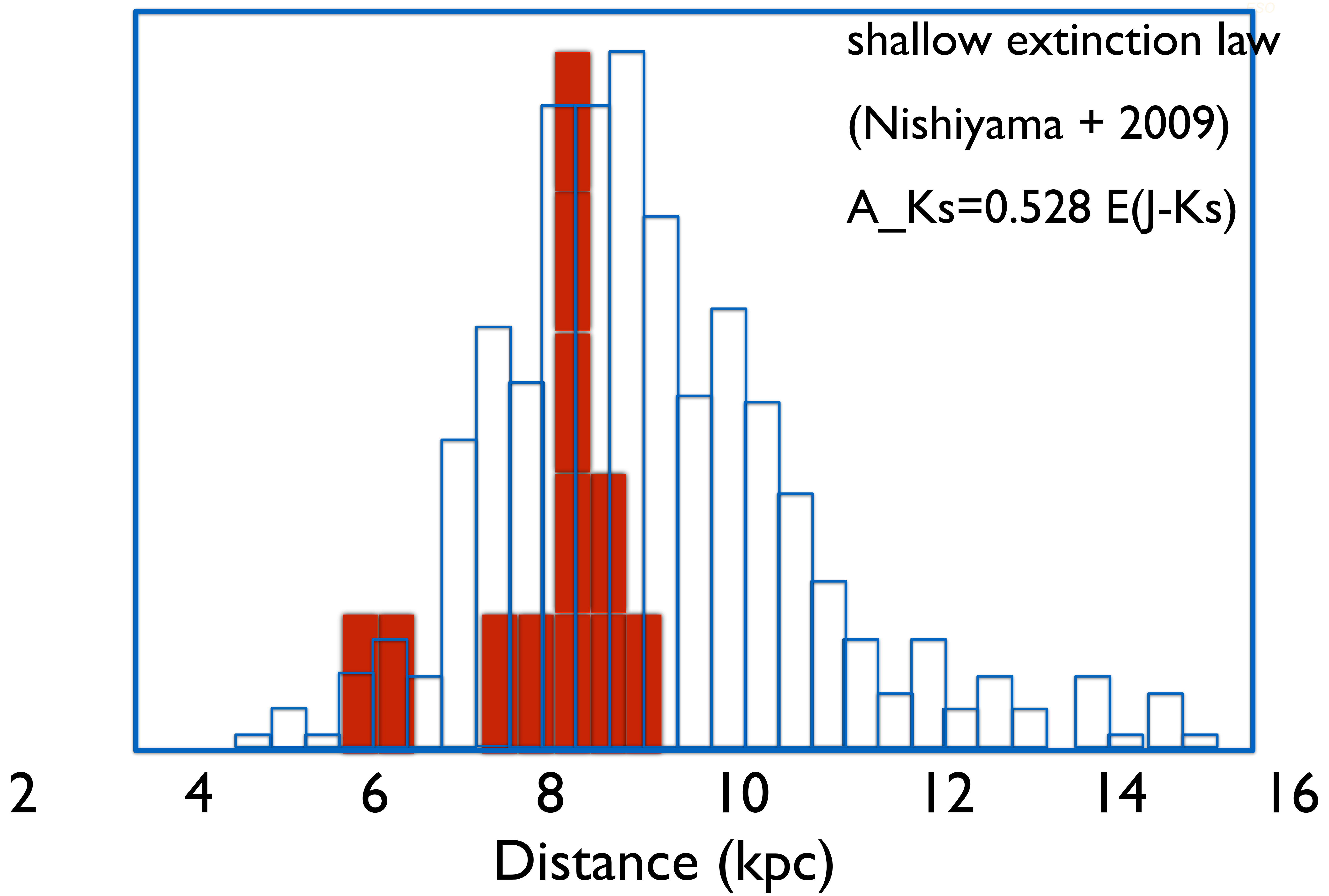


- typical light curves
- clear discrimination from contact binaries
- somewhat noisier than VVV bulge RR Lyrae
- period distribution indicates an Oosterhoff type I population

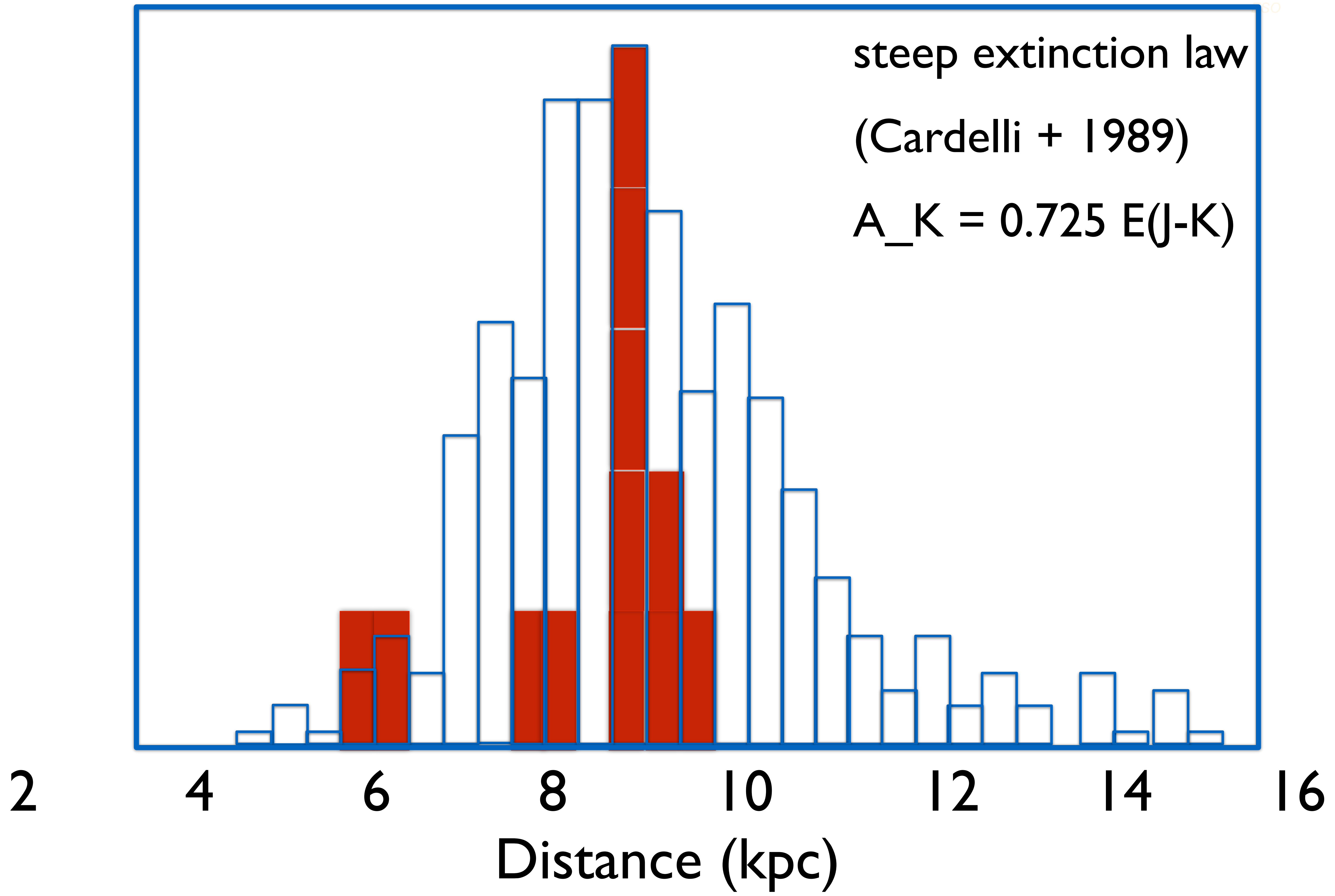
GALACTIC CENTER RR LYRAE



GALACTIC CENTER RR LYRAE

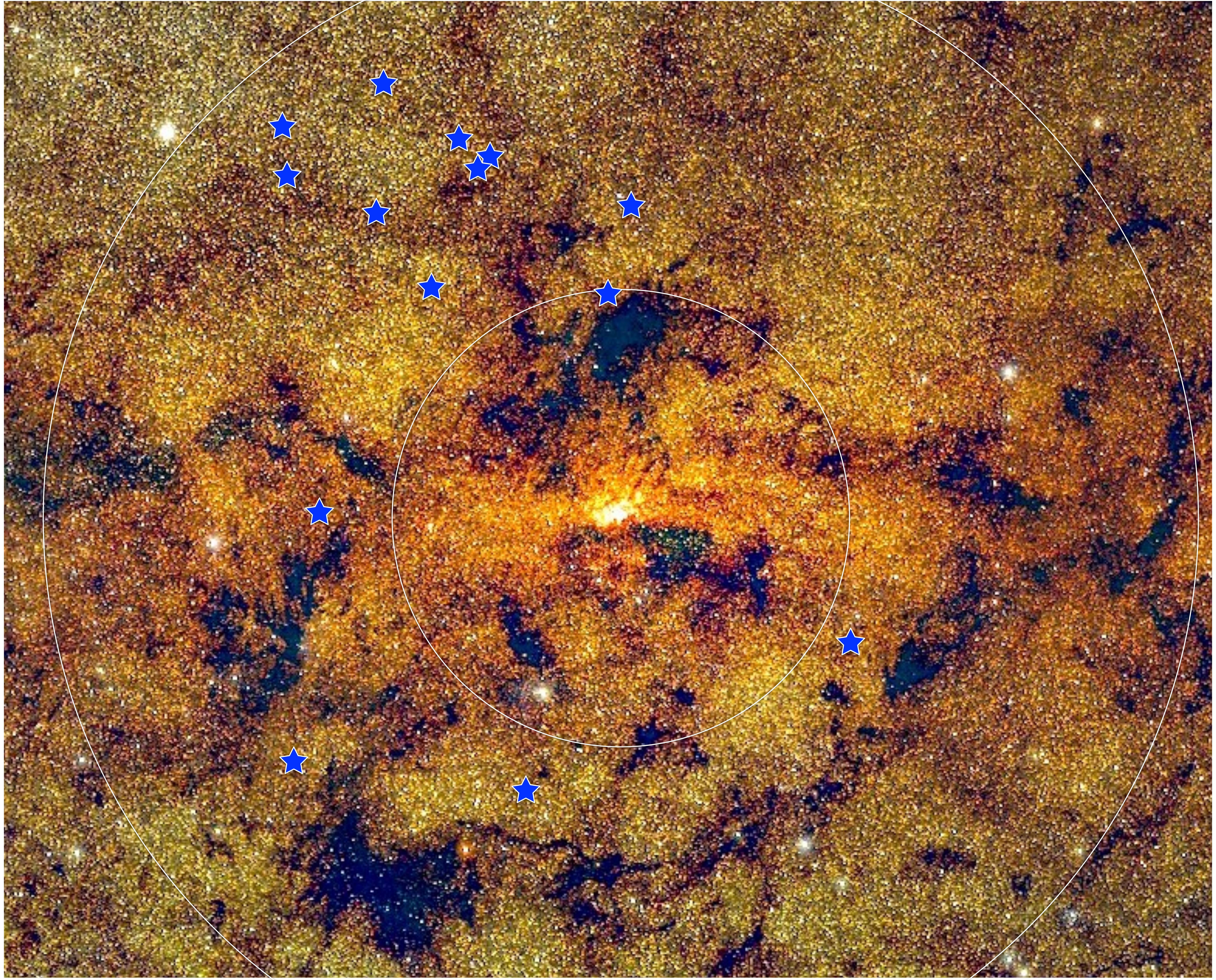


GALACTIC CENTER RR LYRAE



4th VVV Science Meeting Viña del Mar, Chile, March 23, 2013 I. Dékány, P. Universidad Católica de Chile

GALACTIC CENTER RR LYRAE



GALACTIC CENTER RR LYRAE

RESULTS:

- We discovered a dozen RR Lyrae ab-type stars in the nuclear stellar bulge of the Milky Way.
- This suggests that Galactic center contains an old and metal-poor population, detected here for the first time.
- One implication is that the Galactic center is very old.
- Another implication is that the merger of primordial globular clusters could have contributed to building up the high stellar density in the Galactic center (R. Capuzzo-Dolcetta 1993).
- What next?
  - 1. Make a full census.
  - 2. Measure proper motions.
  - 3. Obtain spectra.

D. Minniti, et al. 2016, ApJL

GALACTIC CENTER RR LYRAE

VVV Star Clusters

Roberto Saito, Jura Borissova, Rudy Kurtev, Rodolfo Barbá, Sebastián Ramírez, Javier Alonso-García, Christian Moni-Bidin, Roger Cohen, Rodrigo Contreras Ramos, Maren Hempel, Marcio Catelan, Doug Geisler, Tali Palma, et al.

STAR CLUSTERS IN THE MILKY WAY

Star clusters are very important laboratories for stellar evolution.

Their stars share the same distance, age and chemical compositions.

HUNDREDS OF NEW VVV STAR CLUSTERS

Borissova et al. 2015 A&A (arXiv:1406.7051)
Barba et al. 2015 A&A (arXiv:1505.02764)

Discovery of >700 star clusters.

Make CMDs and measure their proper motions, sizes and reddenings.

Estimate their ages, masses, and distances.

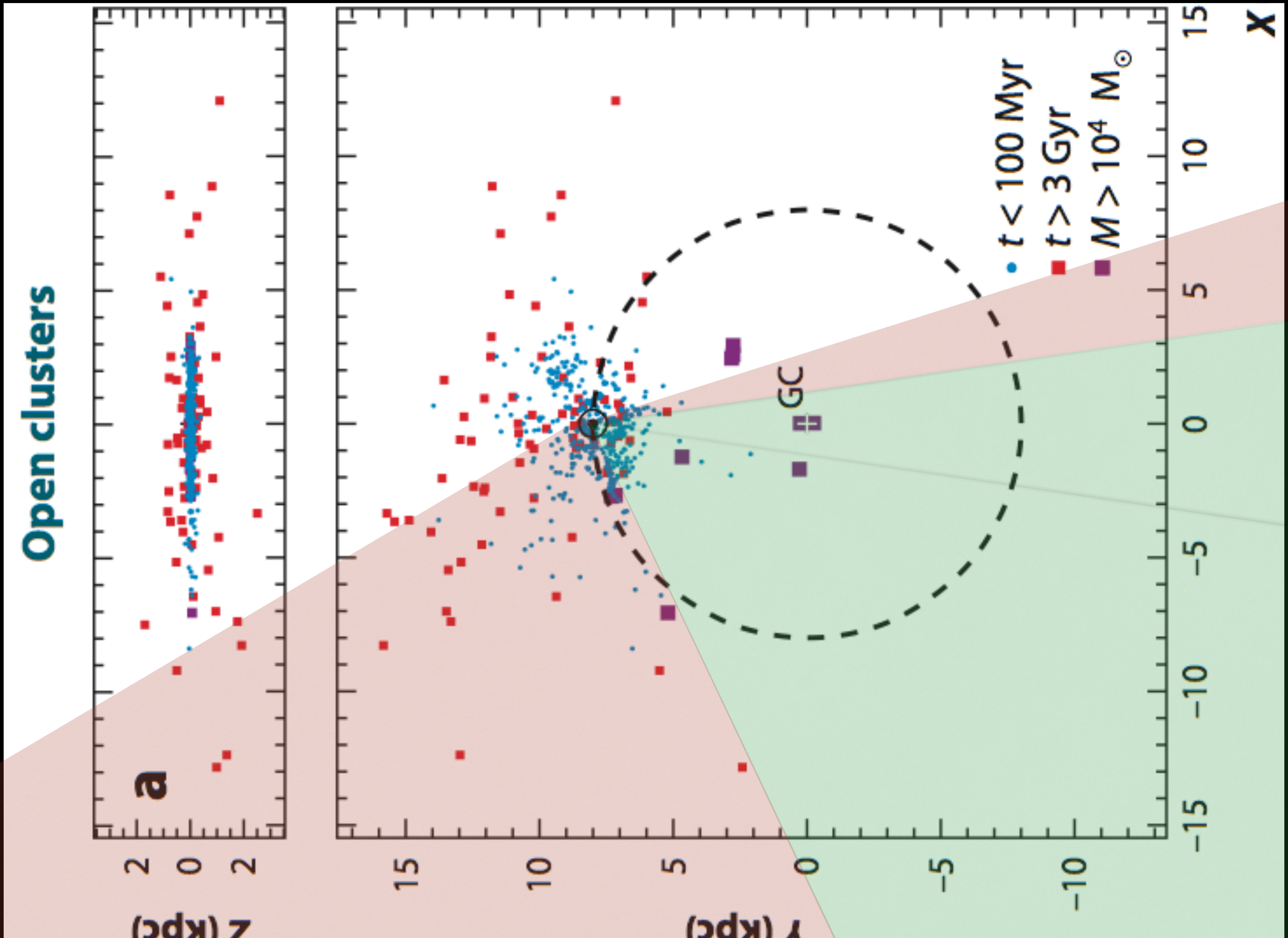
Spectroscopic follow-up: measure their chemical compositions and VRs.

OPEN CLUSTERS

P. Zwarts, ARAA 2013

There are N~20000 clusters estimated to be in our Galaxy.

We only know now N~3000 clusters, and there are many many more waiting to be discovered.



plot from Zwart 2010 ARAA

STAR CLUSTERS IN THE MILKY WAY

VVVX Survey

J. Borissova, S. Ramirez, A. Chene, R. Kurtev, R. Barba, J. Alonso-Garcia, R. Contreras Ramos, R.K. Saito, et al.

THE GLOBULAR CLUSTERS ARE ASTROPHYSICALLY VERY IMPORTANT...

Age of the Universe,
Chemical evolution Universe,
Stellar evolution,
Galactic structure,
Formation of the Milky Way,
Distance scale,
Collissionless systems,
Interestellar medium,
…

GLOBULAR CLUSTERS

Globular clusters are the oldest objects in the Universe.
There are N=177 globular clusters known in our Galaxy.
Many more are hidden in the most obscured regions…

How many GCs missing in the MW?

VVVX Survey

vvvsurvey.org

THE GALACTIC GLOBULAR CLUSTER SYSTEM

M31 has N=600-700 GCs in total.

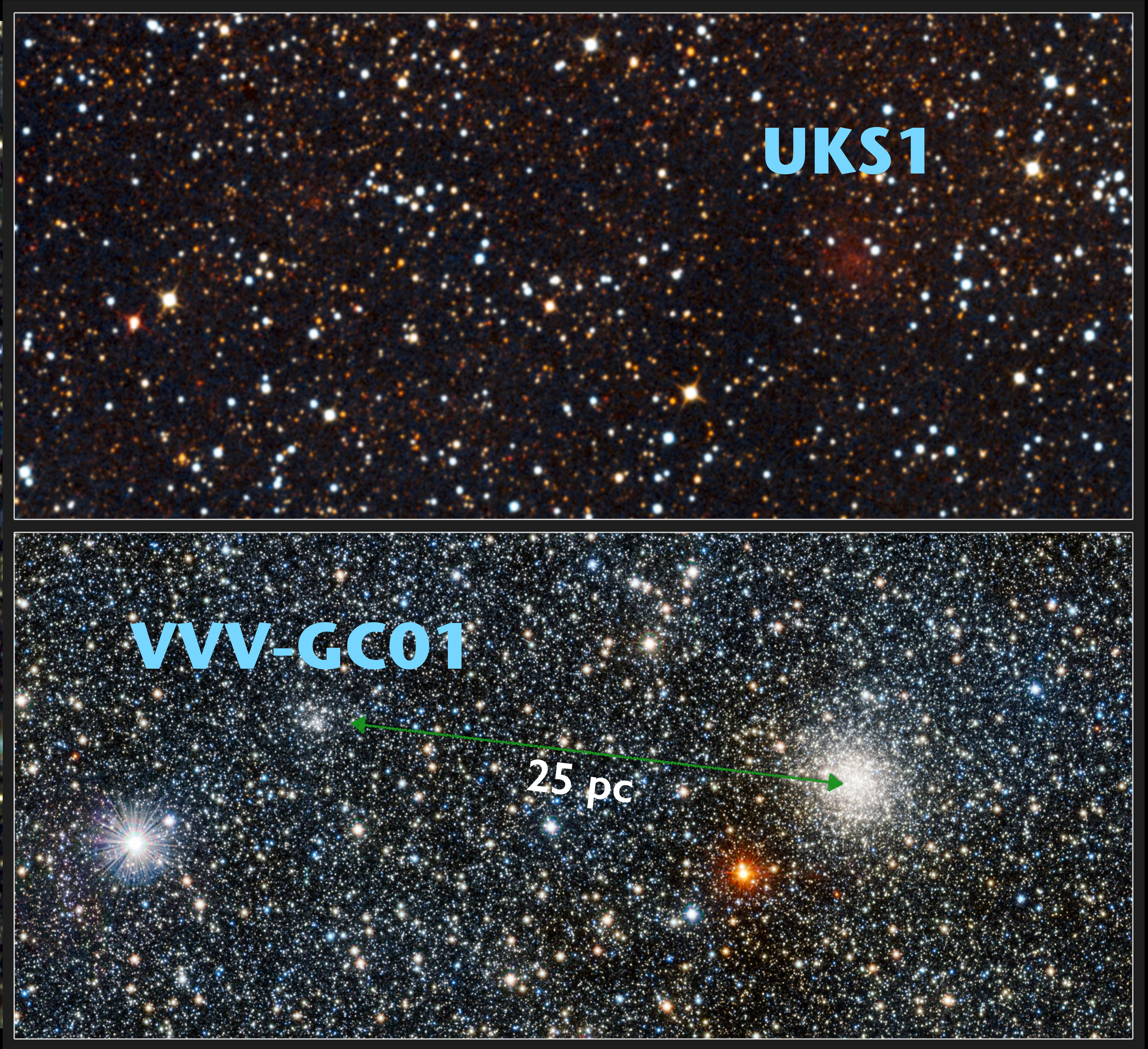
But our Galaxy only has
N=157 GCs (Harris 1996 catalog)
+20 recent discoveries recientes (including 5 VVV)
N=177 globular clusters in the Galaxy.
How many more are missing?

M31

N_{M31}>600 globular clusters

N_{MW}<200 globular clusters?

NEW GLOBULAR CLUSTERS



D. Minniti, M. Hempel, R. K. Saito, et al. 2011, ApJL

vvvsurvey.org

NEW GLOBULAR CLUSTERS

C. Moni-Bidin, et al. 2014, A&A

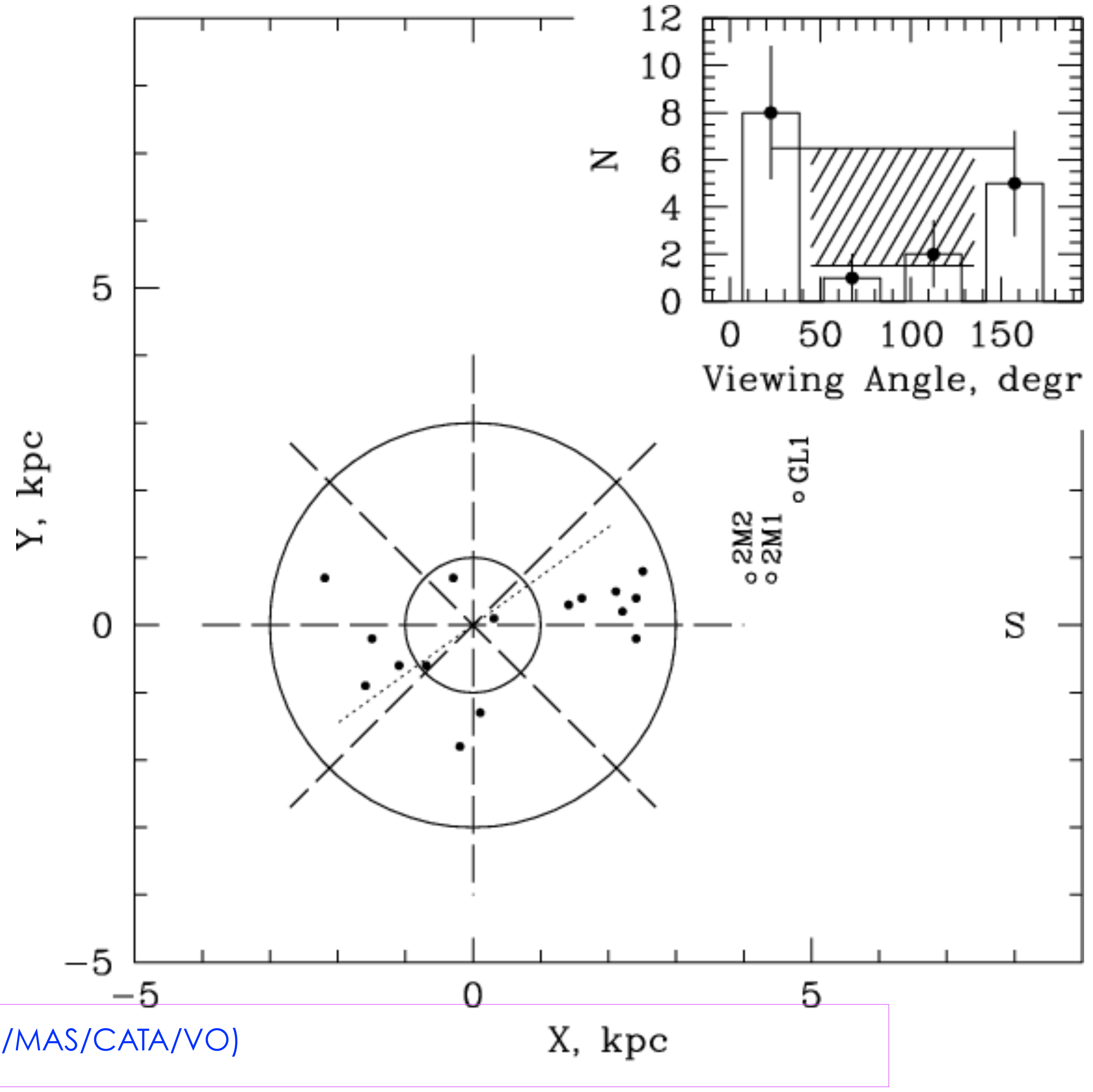
VVVX Survey

LOCATION OF KNOWN GCS IN THE MW EXTINCTION MAP

M. HEMPEL

HOW MANY GCS IN THE MW?

The GC distribution projected in the galactic plane is asymmetric within |Z|<0.5kpc and R_gal<3kpc. The Sun is marked with S, the Galactic Center lies at the origin of the plot, and the dotted line shows the MW bar. The inset histogram shows the distribution of the GCs by Galactic quadrants, as seen by an observer located at the Galactic Center. The viewing angle is 0 deg in the direction toward the Sun, and bins are marked on the main plot with dashed lines. The shaded zone limited by the average levels of the outer and the inner bins corresponds to the expected number of missing inner GCs (10+/-3).

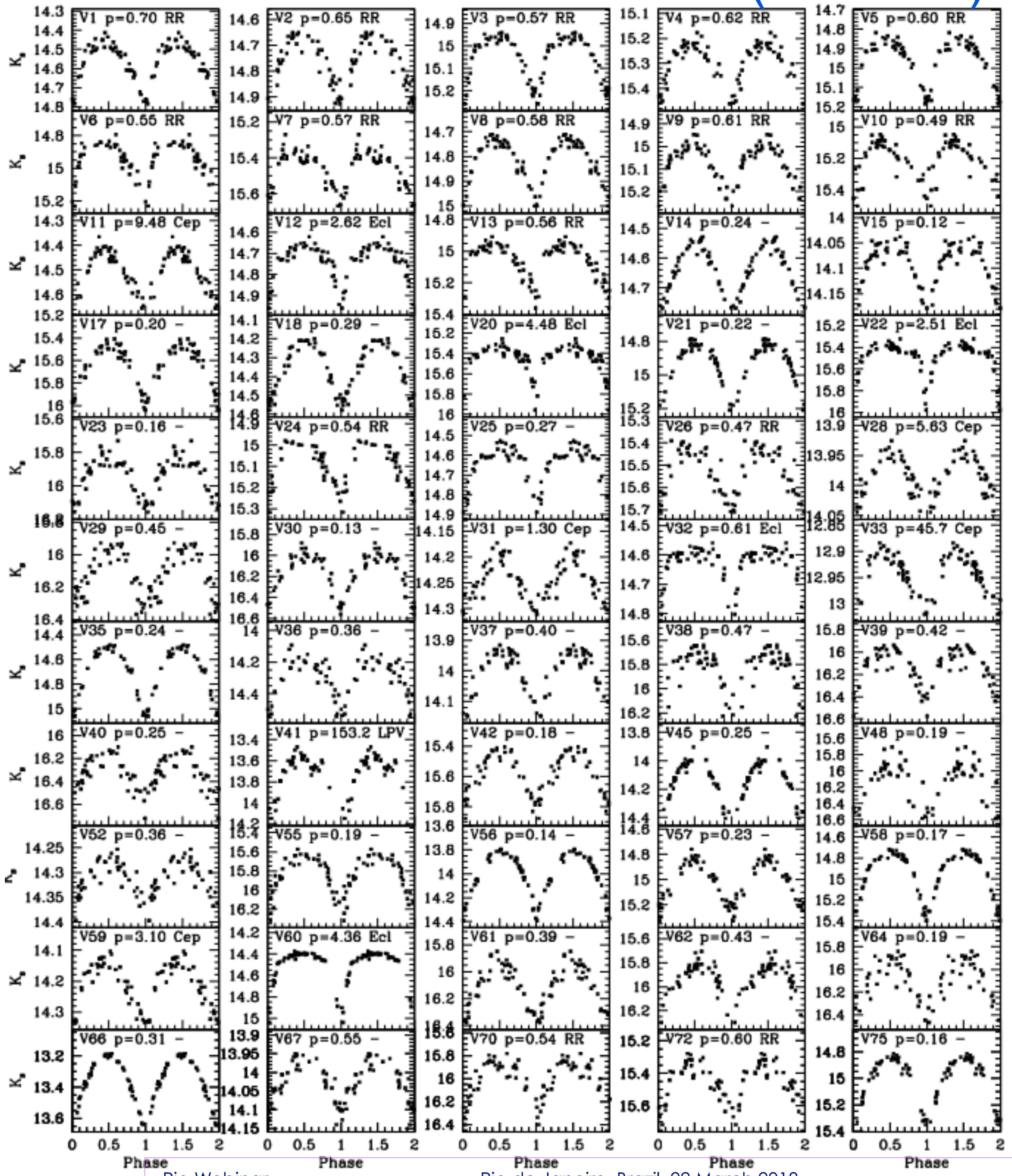


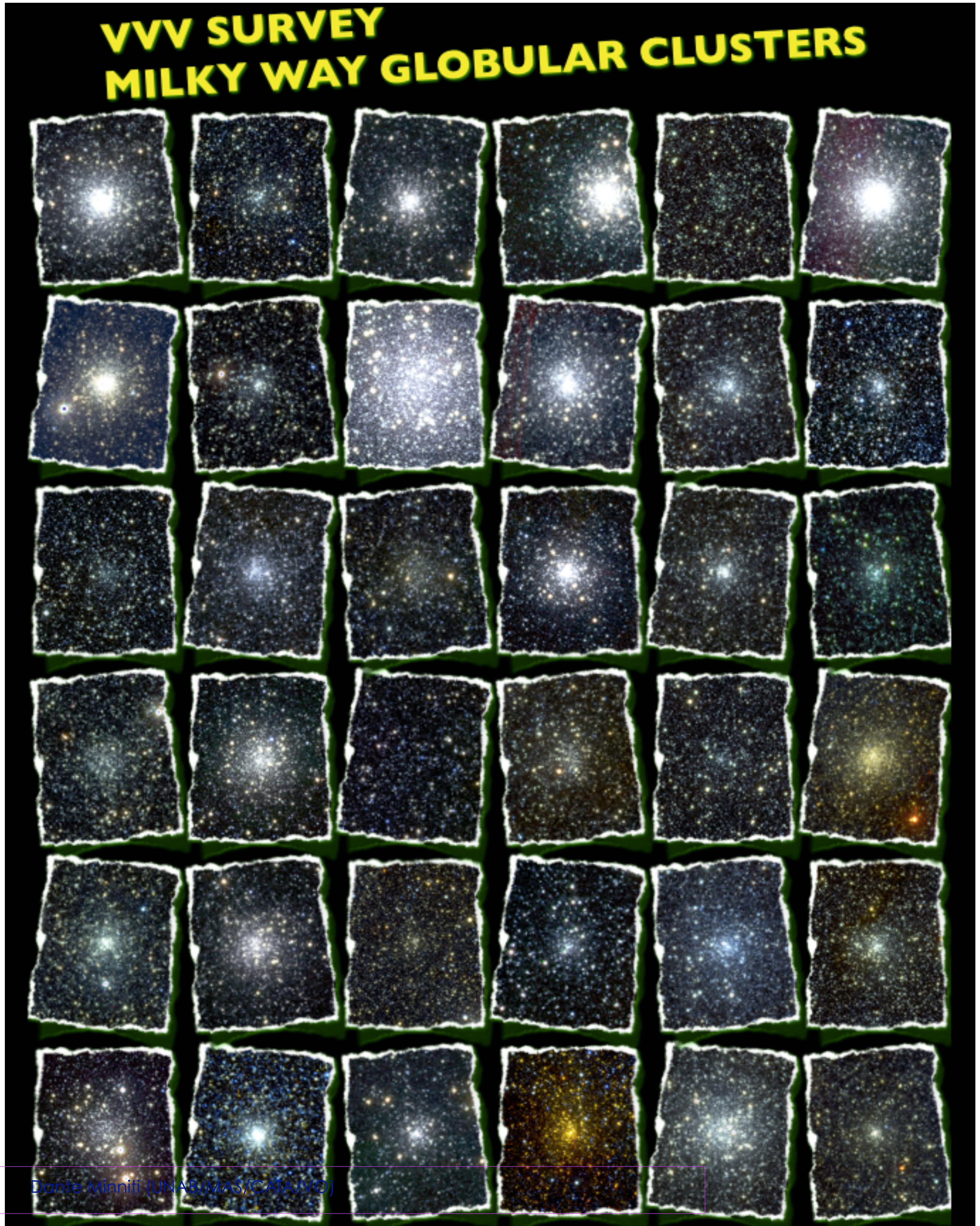
V. IVANOV, R. KURTEV & J. BORISSOVA 2005 A&A

Variable stars in the VVV globular clusters

J. Alonso-Garcia et al. (AJ 2015)

RR LYRAE IN GCS





Variable stars in the VVV globular clusters

2MASS-GC02 J. Alonso-Garcia et al. (AJ 2015)

RR LYRAE IN GCS

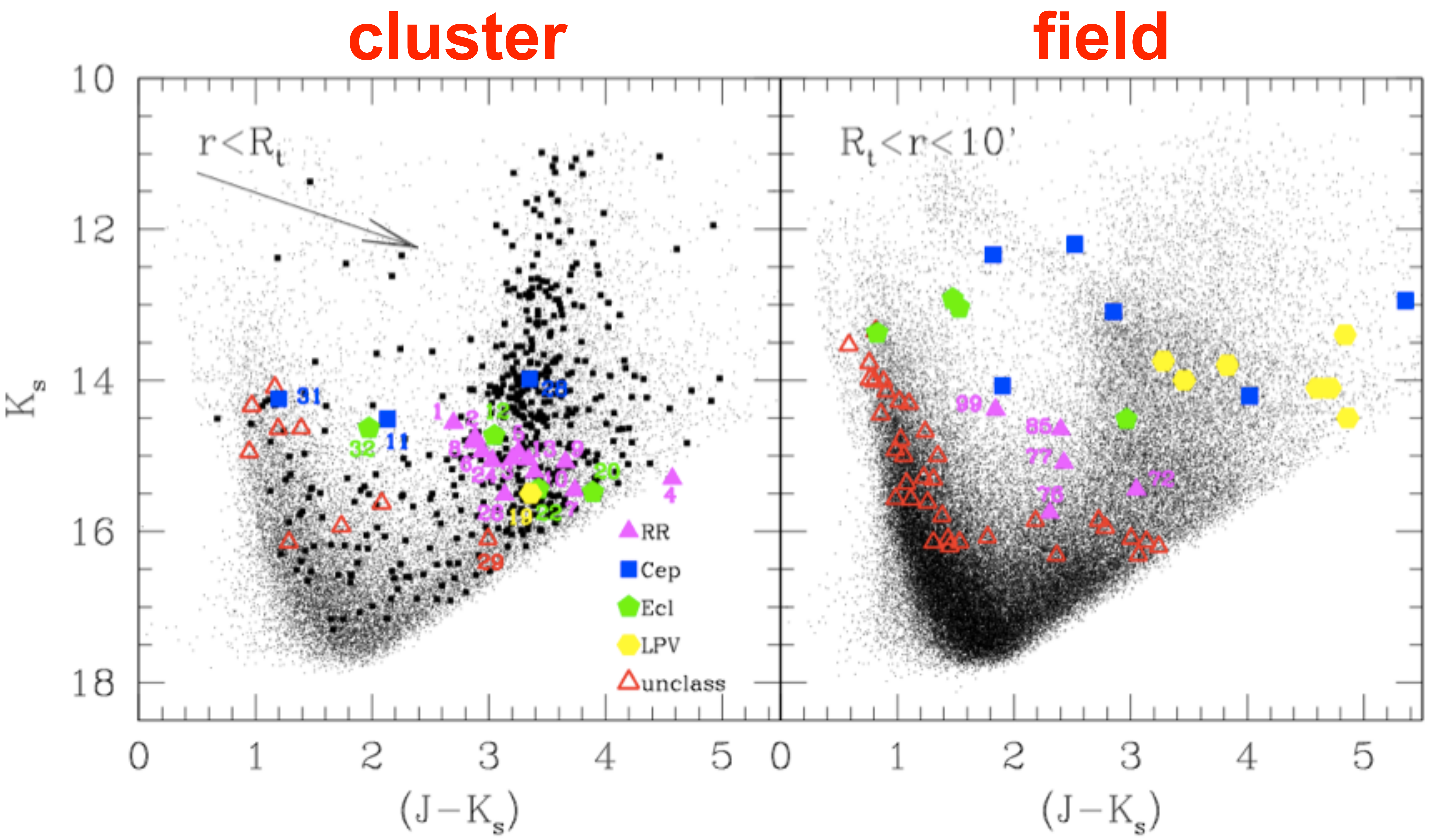


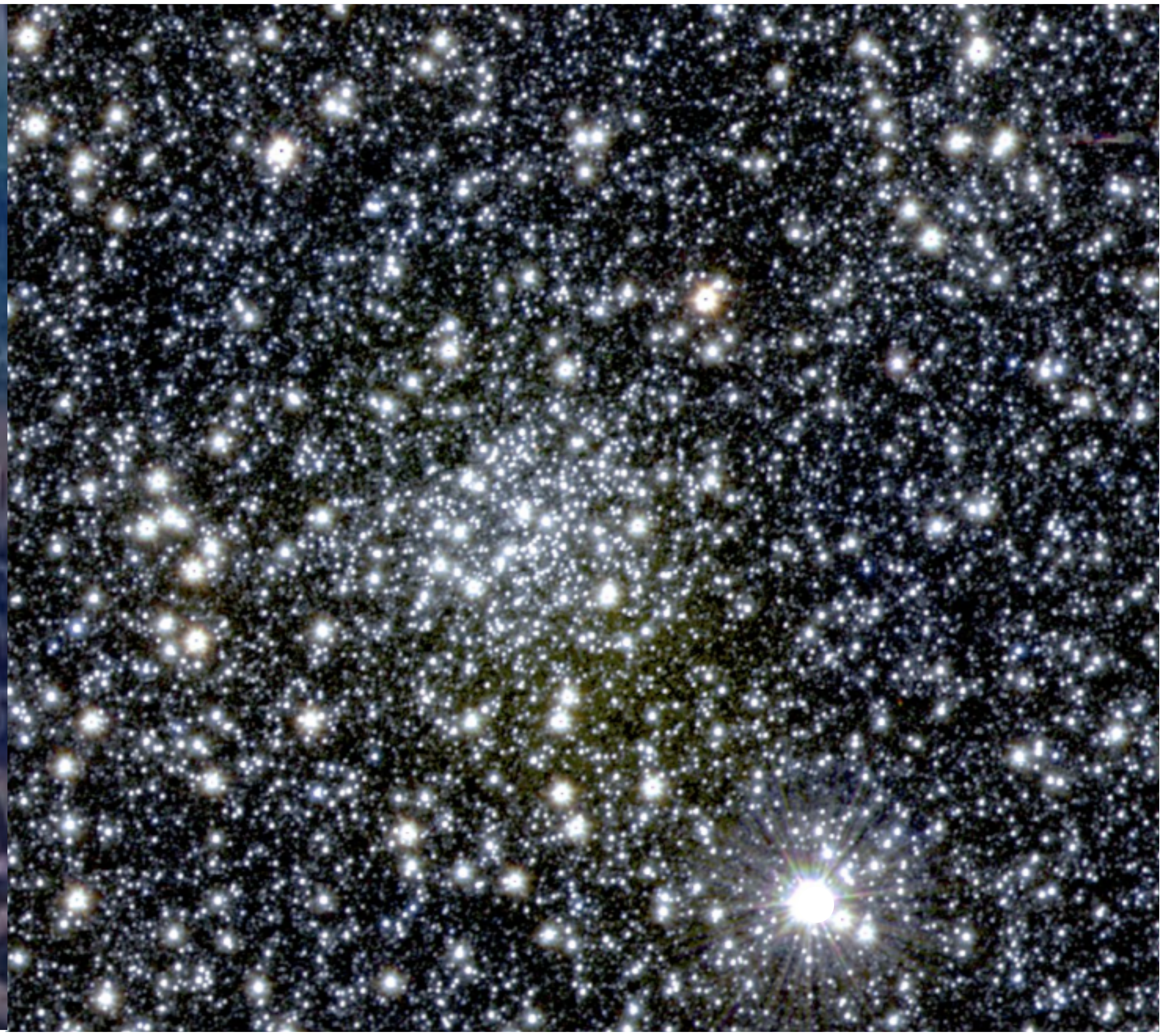
Fig. 1.— $J-K_s$ vs. K_s CMDs of 2MASS-GC02, out to its tidal radius $r_t = 4.9'$ (left), and of its surrounding region (right). The arrow shows the reddening vector according to Nishiyama


EXTREMELY REDDENED GLOBULAR CLUSTERS
2MASS-GC02 Distance 4.9 kpc → 7.1 kpc
Using Ak = 0.40 Ej-k from Alonso-García (AJ 2015)
vvvsurvey.org

GLOBULAR CLUSTERS IN THE INNER MILKY WAY

SKELETONS IN THE ELEPHANT'S GRAVEYARD

Dynamical processes affect the survival of Galactic globular clusters:



dynamical friction,
bulge shocking,
disk shocking,
tidal disruption,
evaporation,
...

Fall & Rees 1977, 1985

These processes are stronger in the Galactic bulge, deep in the potential well.

DISRUPTED GLOBULAR CLUSTERS

Where would you find the clusters on the verge of disruption, and their debris?
— Dying clusters and their skeletons would be found in **the elephant graveyard = the Galactic bulge**.
— When a cluster gets disrupted, it yields its constituent stars to the field.

Some globular metal-poor clusters are rich in RR Lyrae and T2C variable stars.
The bulge RR Lyrae and T2C can be used as tracers of the old and metal-poor stellar populations.

SEARCH FOR GLOBULAR CLUSTERS

GC searches are done by visual inspection or automatic selection algorithms.
They appear as round concentrations of stars, showing up as overdensities above the background in the optical or near-IR images.
At the distance of the bulge their typical sizes would be:

For Ro=8.0 kpc
R = 2 pc = 51" = 0.8' = 151pix
R = 5 pc = 129" = 2.1' = 379pix
R = 10pc = 258" = 4.2' = 758pix

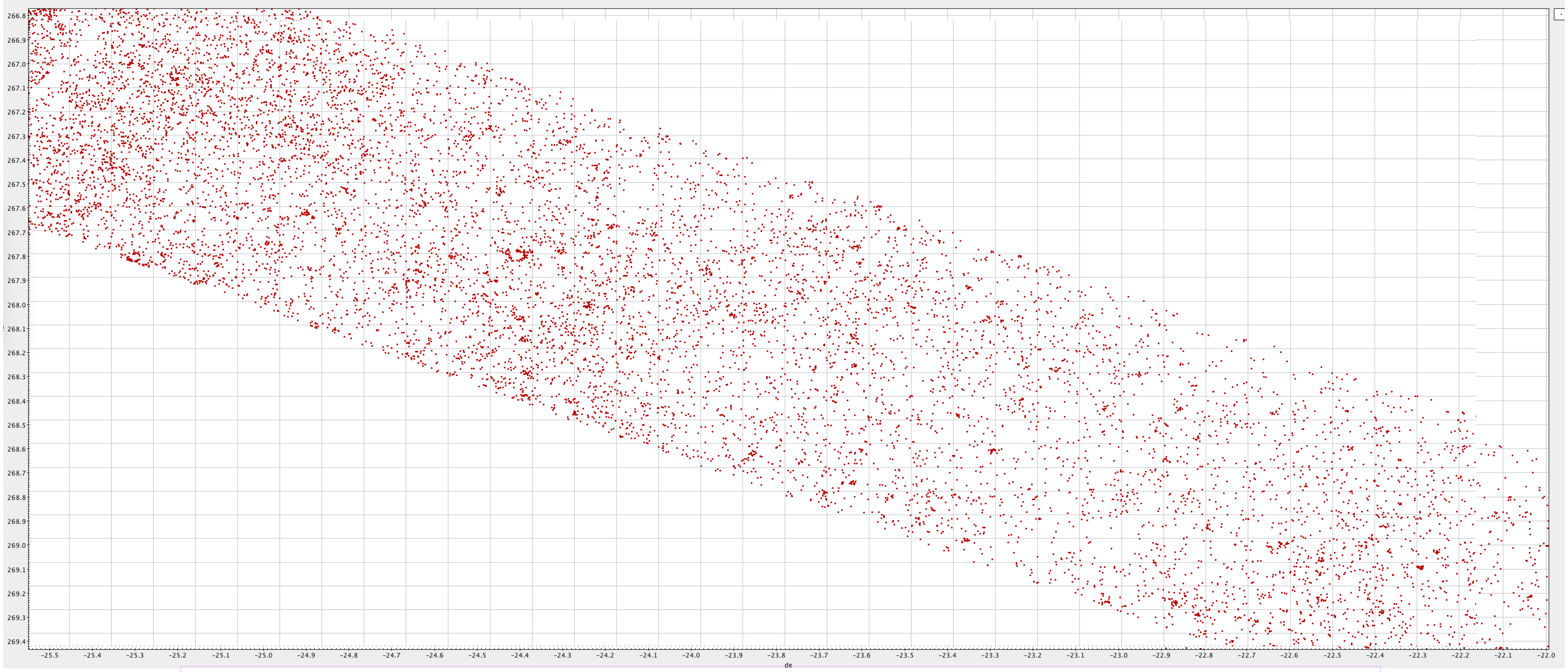
SEARCH FOR GCS IN THE BULGE

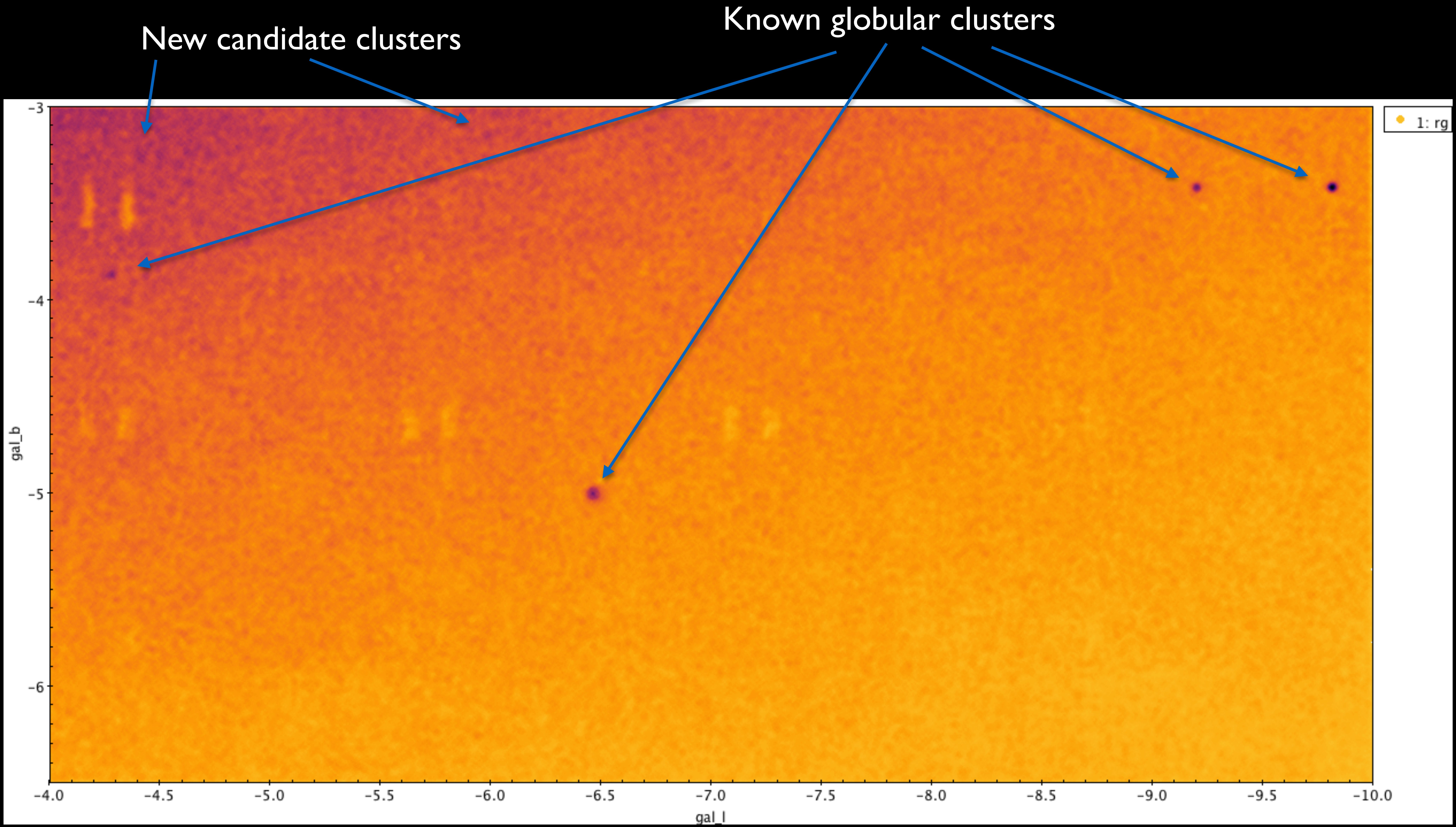
Searching for globular clusters in the Galactic bulge is **very tricky!**
New Galactic globular clusters in the bulge are very difficult to find, due to
— high stellar density
— variable extinction

Why the Near-IR?

SEARCH FOR GLOBULAR CLUSTERS

We use stellar tracers (clump giants, RR Lyrae) in order to find new clusters.





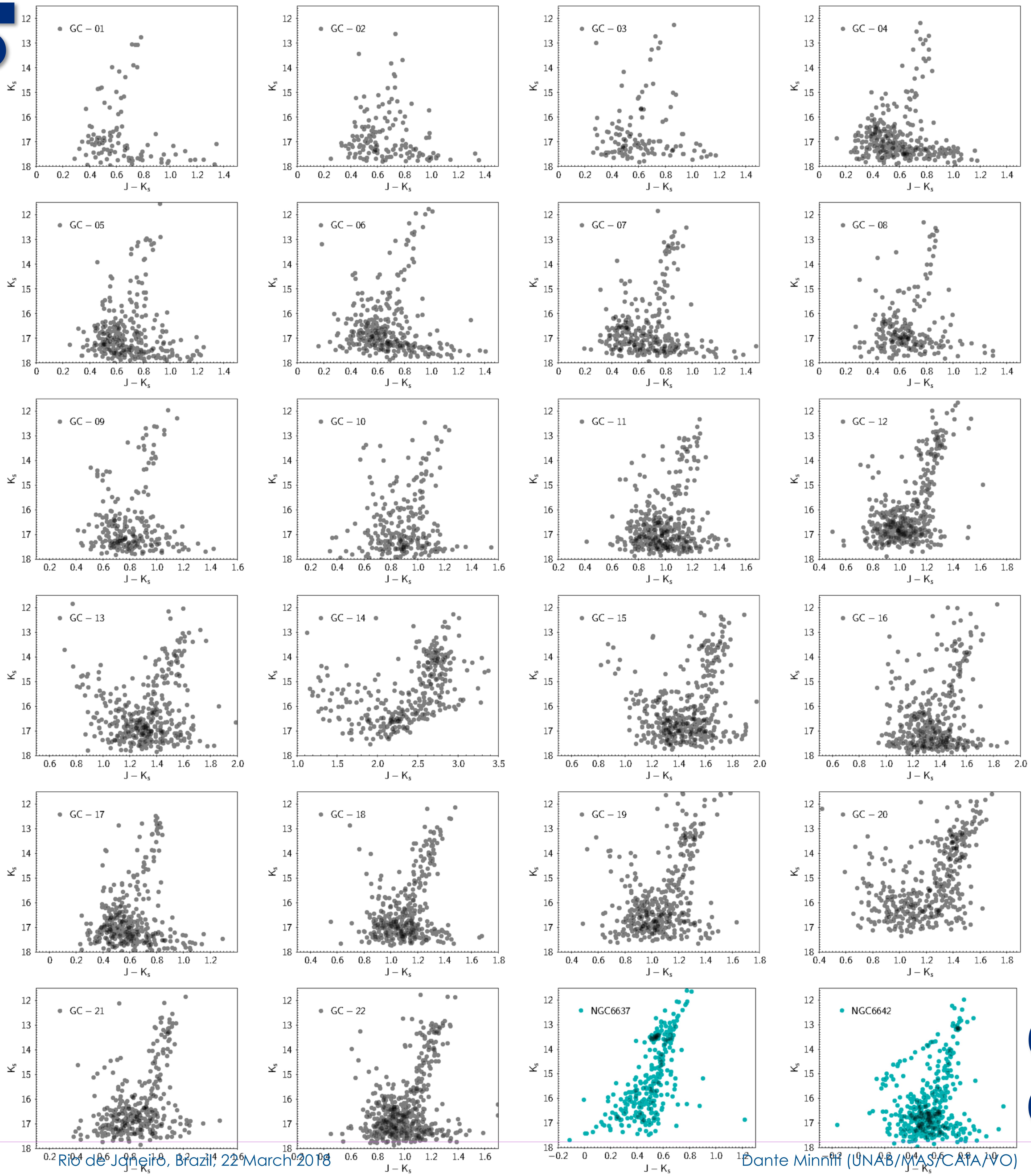
We make density maps preselecting red giants from the Wesenheit colour-magnitude diagrams


+4
+2
+0
-2
-4
-6
-8
-10
B
10
0
350
340
L
KNOWN GCS


+4
+2
+0
-2
-4
-6
-8
-10
B
10
0
350
340
L
New Candidates
KNOWN GCS

NEW GCS

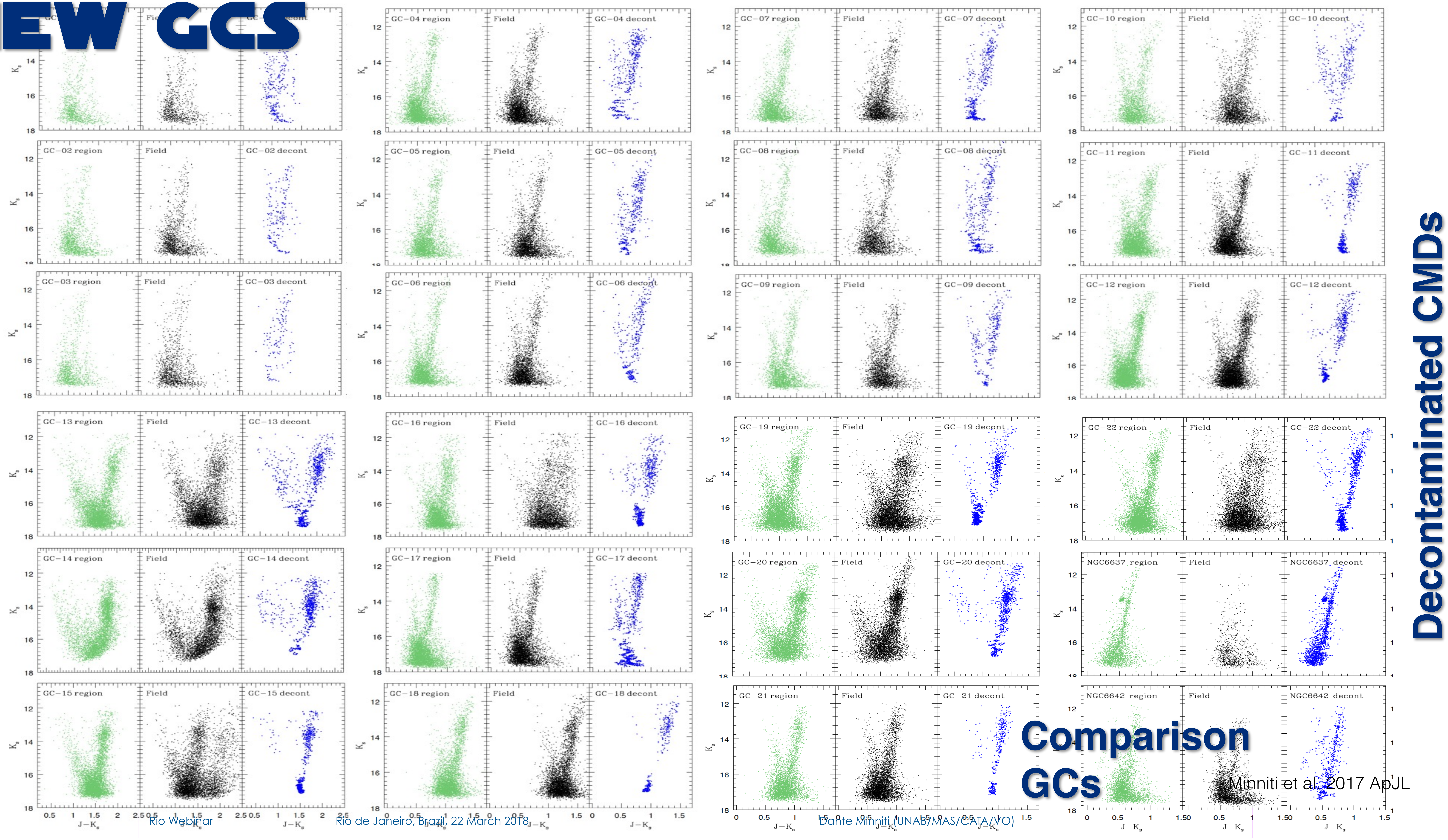
CMDs
Minni 01 — 22



Comparison GCs

Minniti et al. 2017 ApJL

NEW GCS


GC−02 region
Field
GC−02 decont
GC−03 region
GC−03 decont
GC−04 region
GC−04 decont
GC−05 region
GC−05 decont
GC−06 region
GC−06 decont
GC−07 region
GC−07 decont
GC−08 region
GC−08 decont
GC−09 region
GC−09 decont
GC−10 region
GC−10 decont
GC−11 region
GC−11 decont
GC−12 region
GC−12 decont
GC−13 region
GC−13 decont
GC−14 region
GC−14 decont
GC−15 region
GC−15 decont
GC−16 region
GC−16 decont
GC−17 region
GC−17 decont
GC−18 region
GC−18 decont
GC−19 region
GC−19 decont
GC−20 region
GC−20 decont
GC−21 region
GC−21 decont
GC−22 region
GC−22 decont
NGC6637 region
NGC6637 decont
NGC6642 region
NGC6642 decont
K_s
$J-K_s$
Decontaminated CMDs
Comparison GCs
Minniti et al. 2017 ApJL

CONFIRMATION OF GLOBULAR CLUSTERS IN THE BULGE

How to decide if a **candidate** is a **real** globular cluster?

Confirming a globular cluster in the Galactic bulge is also tricky!

The requirements for globular clusters in the bulge should be stringent, due to the large extinction and background contamination.

There is not a unique recipe, but one can use one or a few of the following methods:

— Color-magnitude diagrams
— Radial velocities
— Proper motions
— Chemical footprint
— Stellar tracers (RRLyr)

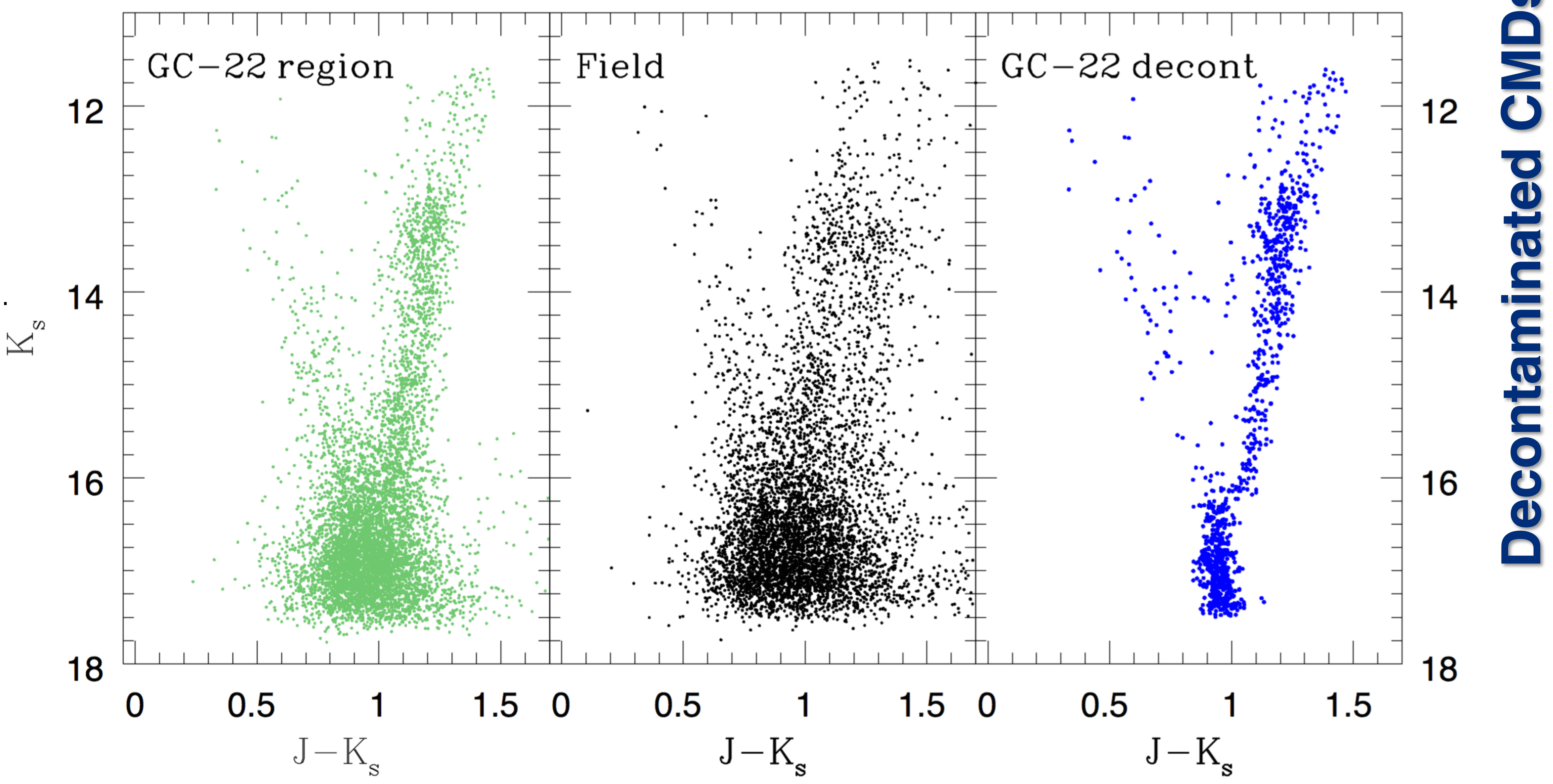
NEW GCS

The globular cluster Minni22 is classified as metal-poor based on the CMD.

It also has 3 RRab within 2’ of its center.

We use the statistical field decontamination procedure of Palma et al. (2016) in order to clean up the VVV near-IR CMD.

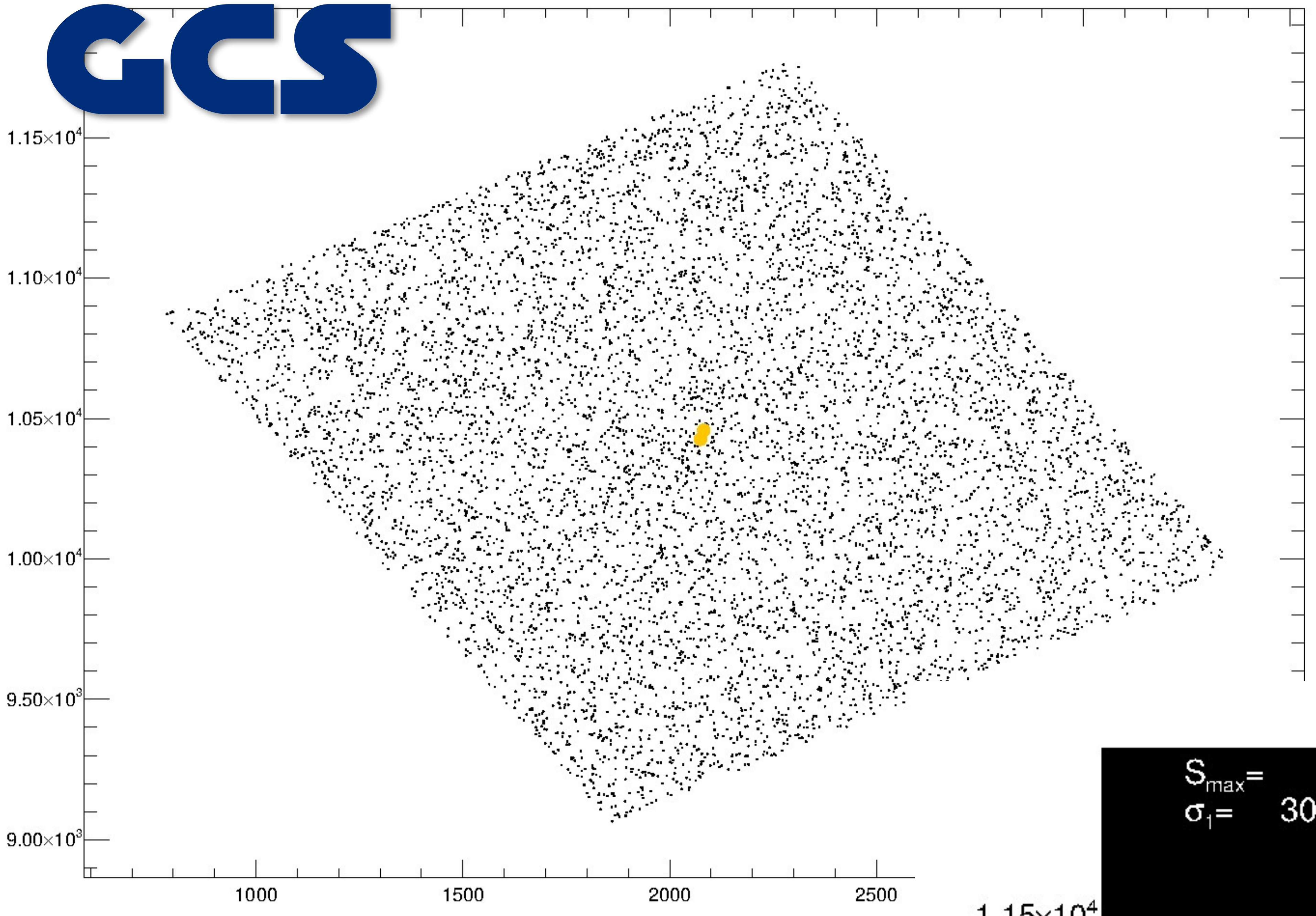
The luminosity function of the decontaminated cluster shows a prominent RGB bump with Ks=13.30+/- 0.03 mag



Minniti et al. 2017 ApJL

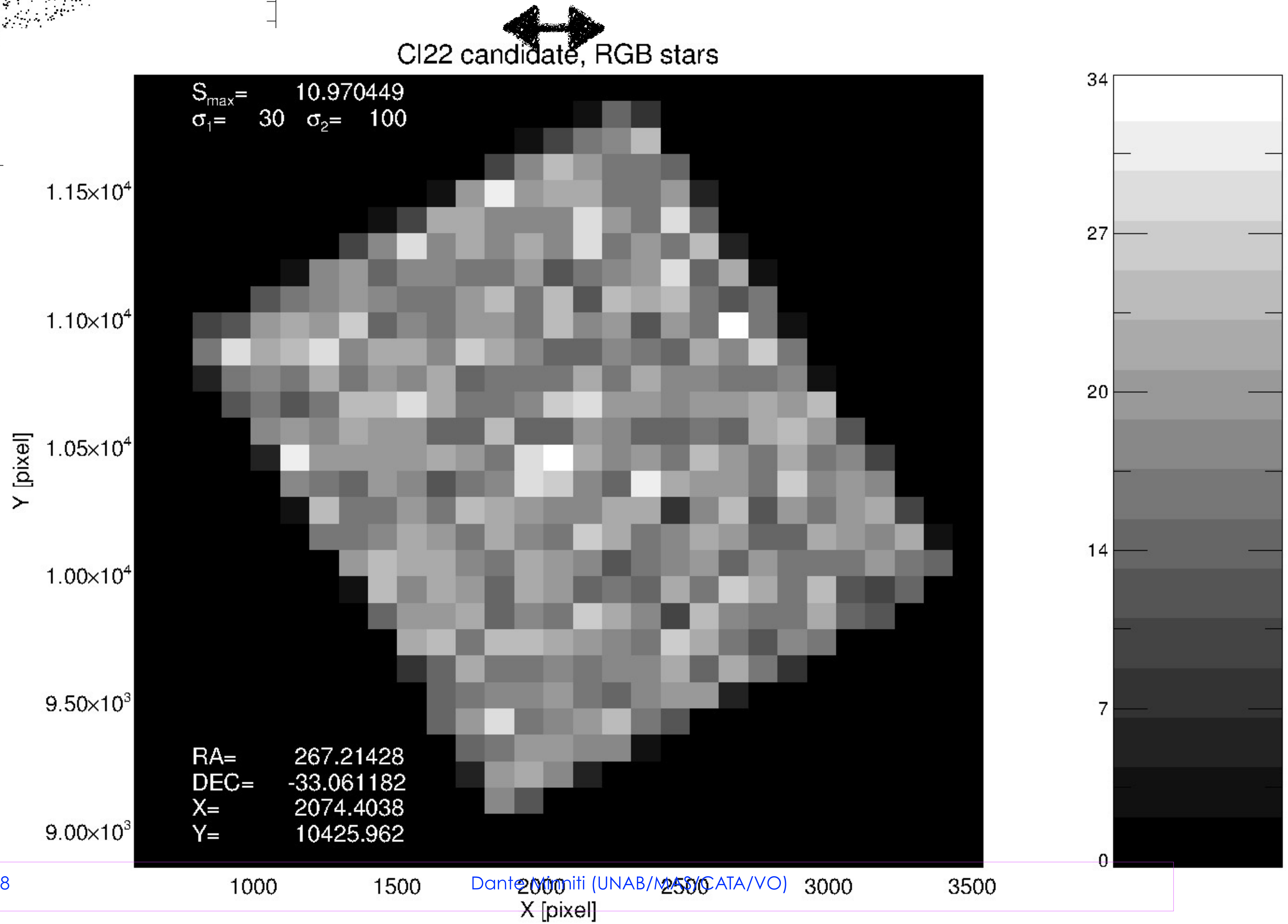

FOV = 6'x3.5'
RRLyr
RRLyr
RRLyr
Mira
RRLyr
Mira
Minni22
vvvsurvey.org
Rio Webinar
Rio de Janeiro, Brazil, 22 March 2018
Dante Minniti (UNAB/MAS/CATA/VO)

NEW GCS



cl22 density maps made by Maren Hempel show a concentration of red giants.

2’=352pix



cl22 is one of the smallest clusters that we found

R = 1 pc = 25” = 0.4’ = 75pix

CONFIRMATION OF GLOBULAR CLUSTERS IN THE BULGE

The **RR Lyrae** are representative of old and metal-poor stellar populations.

They are found frequently in the Galactic halo and bulge, and in globular clusters.

The presence of RR Lyrae in a star cluster guarantees that this is a GC.

They are also excellent distance indicators, as well as reddening indicators.

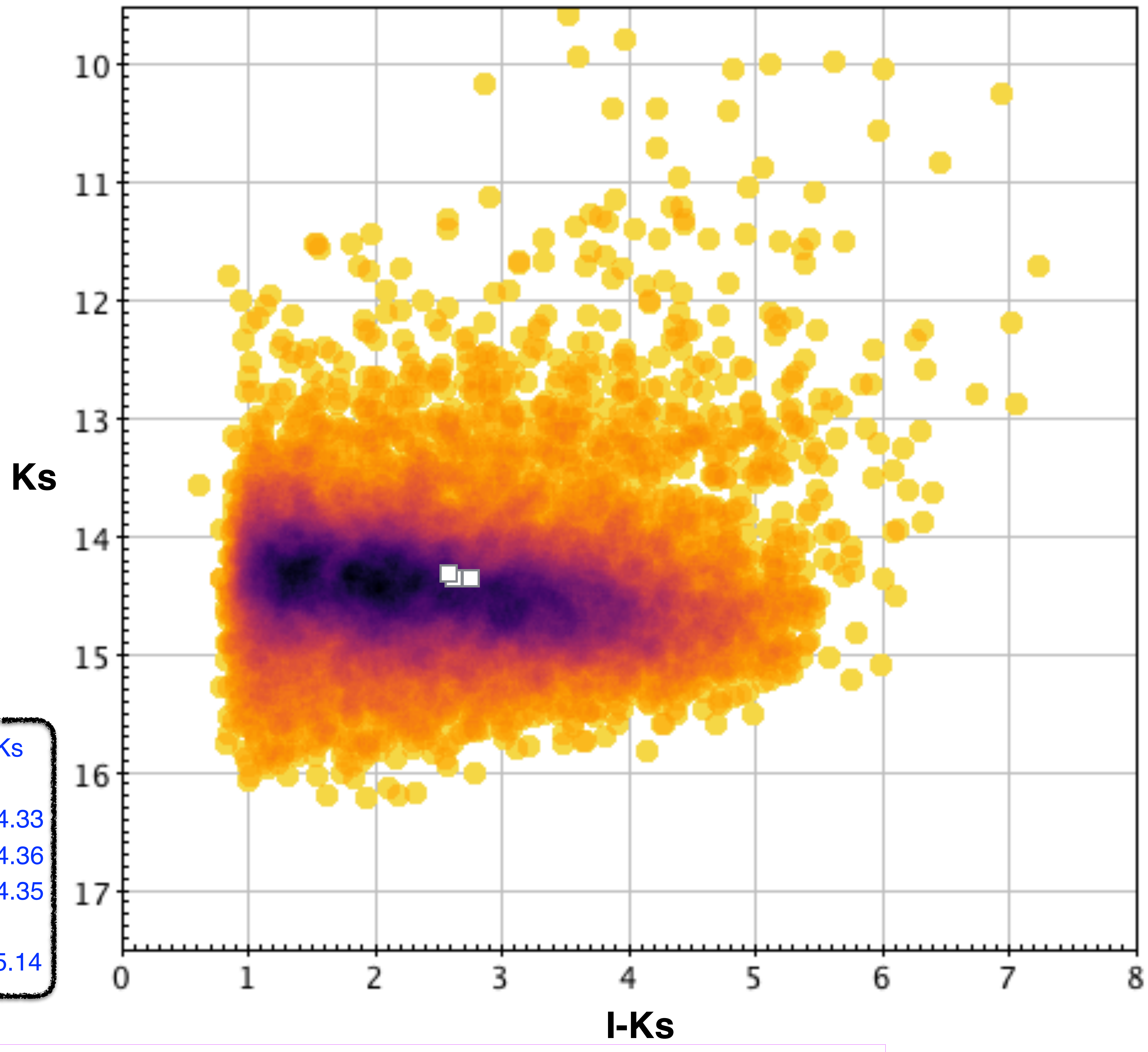
We can use tight groups of RR Lyrae variable stars in order to confirm a globular cluster.

In the cases of the bulge fields the concentration of RR Lyrae has to be at the same distance.

RR LYRAE IN MINNI22

There are 3 known OGLE RRab within 2' of the cluster centre. They all have similar colors and magnitudes, and are located at the same distance.
This matches the mean distance of the bulge.
There is also one RRc, but this is a background object.

RRLyr	RA(J2000)	DEC(J2000)	L	B	P(d)	V	I	J	Ks
3181	17 48 49.38	-33 03 03.0	356.8336	-02.7171	0.51239463	19.57	17.08	15.08	14.33
3178	17 48 49.02	-33 02 52.1	356.8355	-02.7144	0.58989198	19.40	16.92	15.23	14.36
3258	17 49 00.30	-33 03 35.7	356.8454	-02.7545	0.62030367	19.27	16.94	15.36	14.35
3266	17 49 01.31	-33 02 11.7	356.8672	-02.7455	0.25906458	19.64	17.49	15.88	15.14

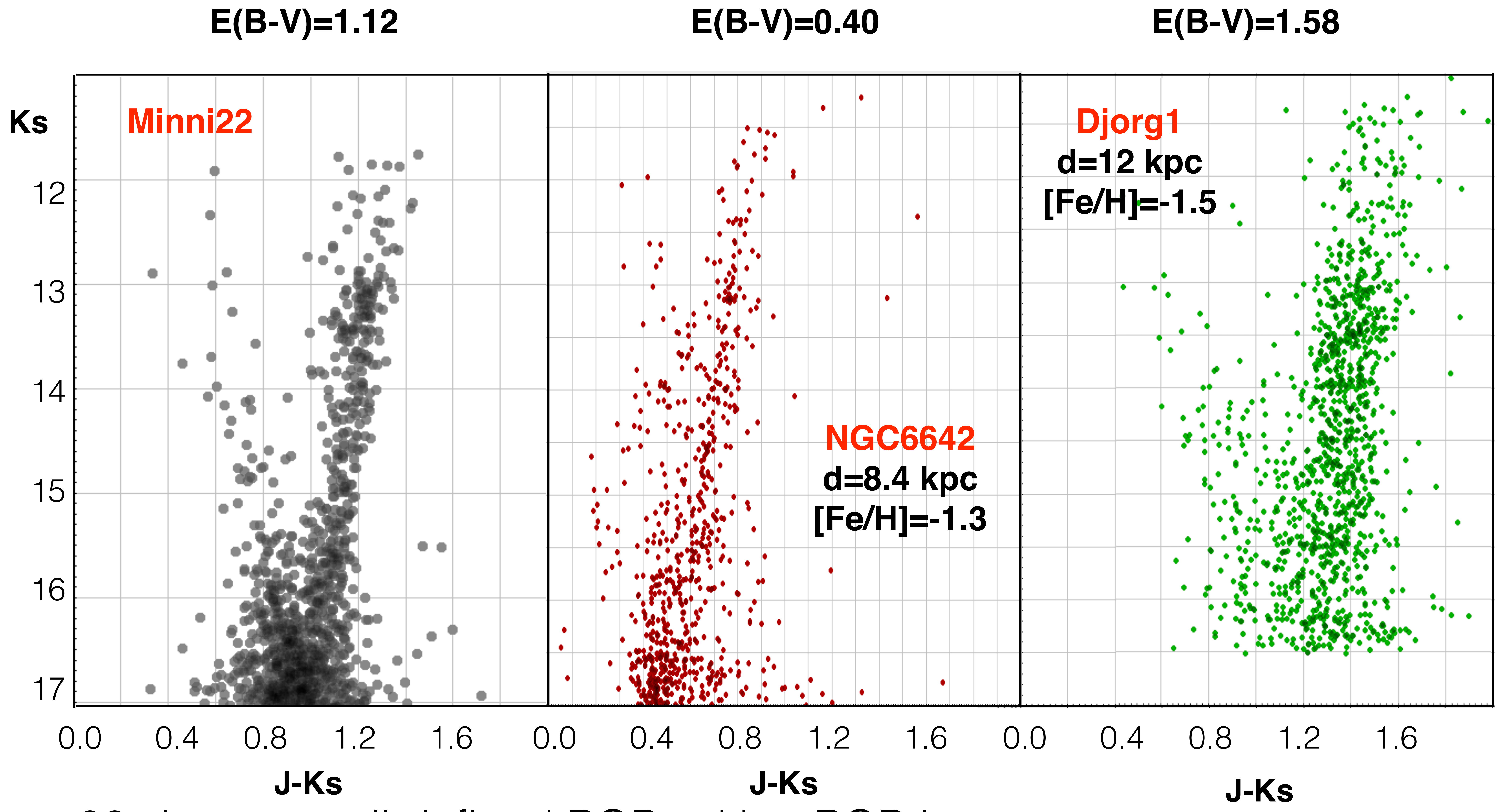


MW EDGE ON

2MASS IMAGE OF THE MILKY WAY

vvvsurvey.org

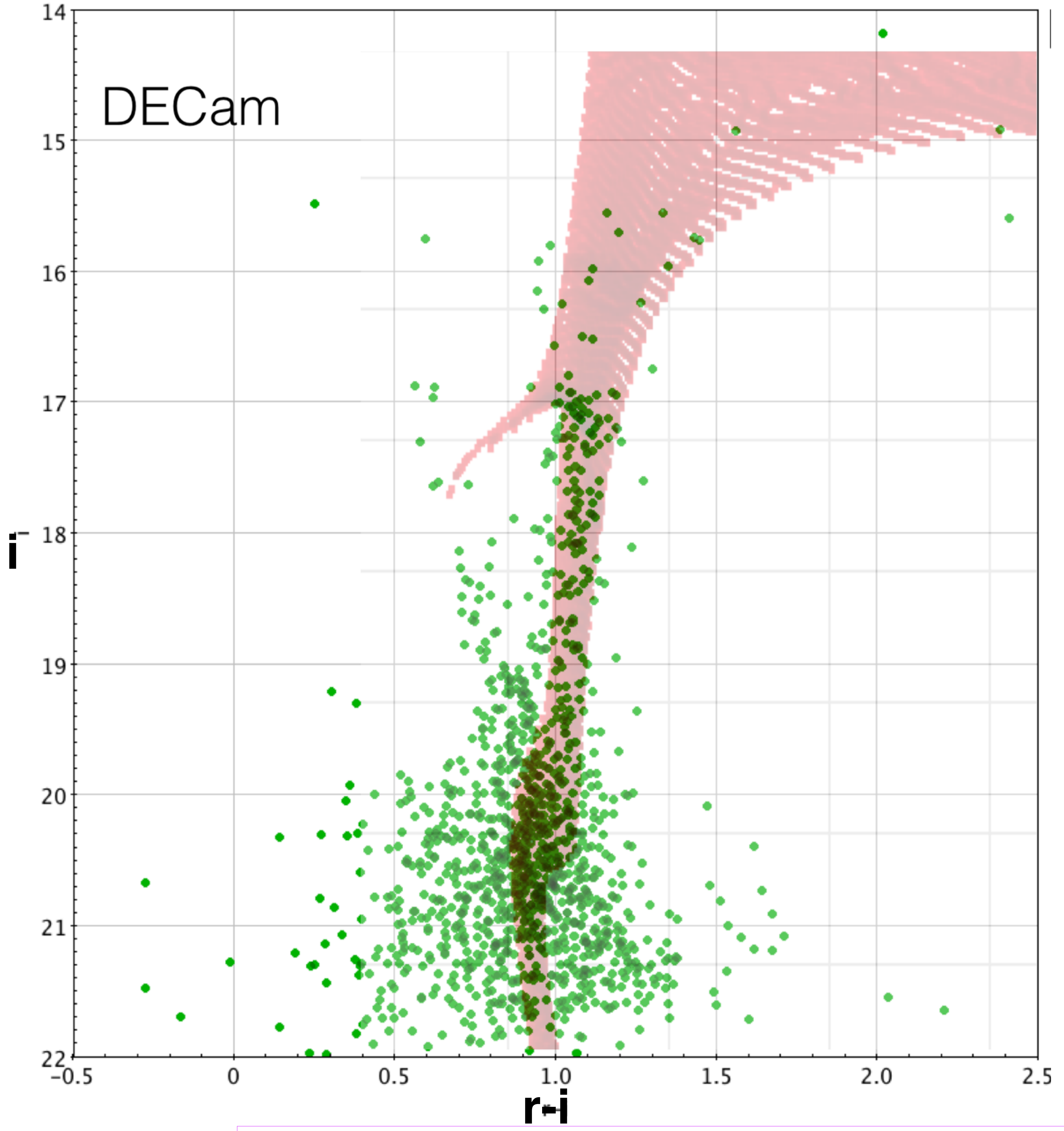
COMPARISON WITH KNOWN GLOBULAR CLUSTERS



Cluster 22 shows a well defined RGB, with a RGB bump.
It appears to be a metal-poor globular cluster, consistent with the presence of RR Lyrae variable stars.

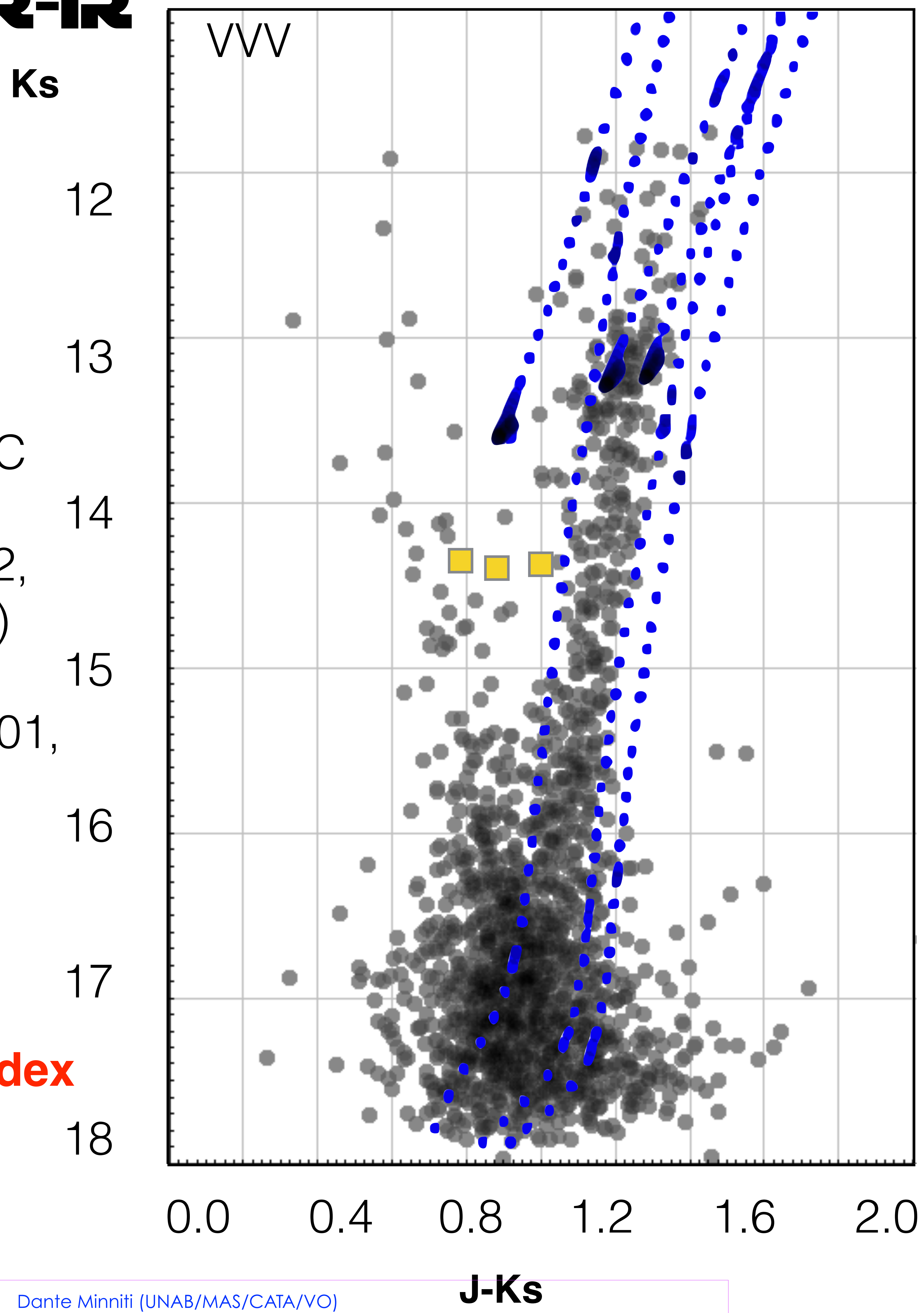
COMPARISON WITH OPTICAL AND NEAR-IR THEORETICAL ISOCHRONES

The optical photometry is provided by the DECaPS Survey (E. Schlafly, D. Finkbeiner, et al. 2017)



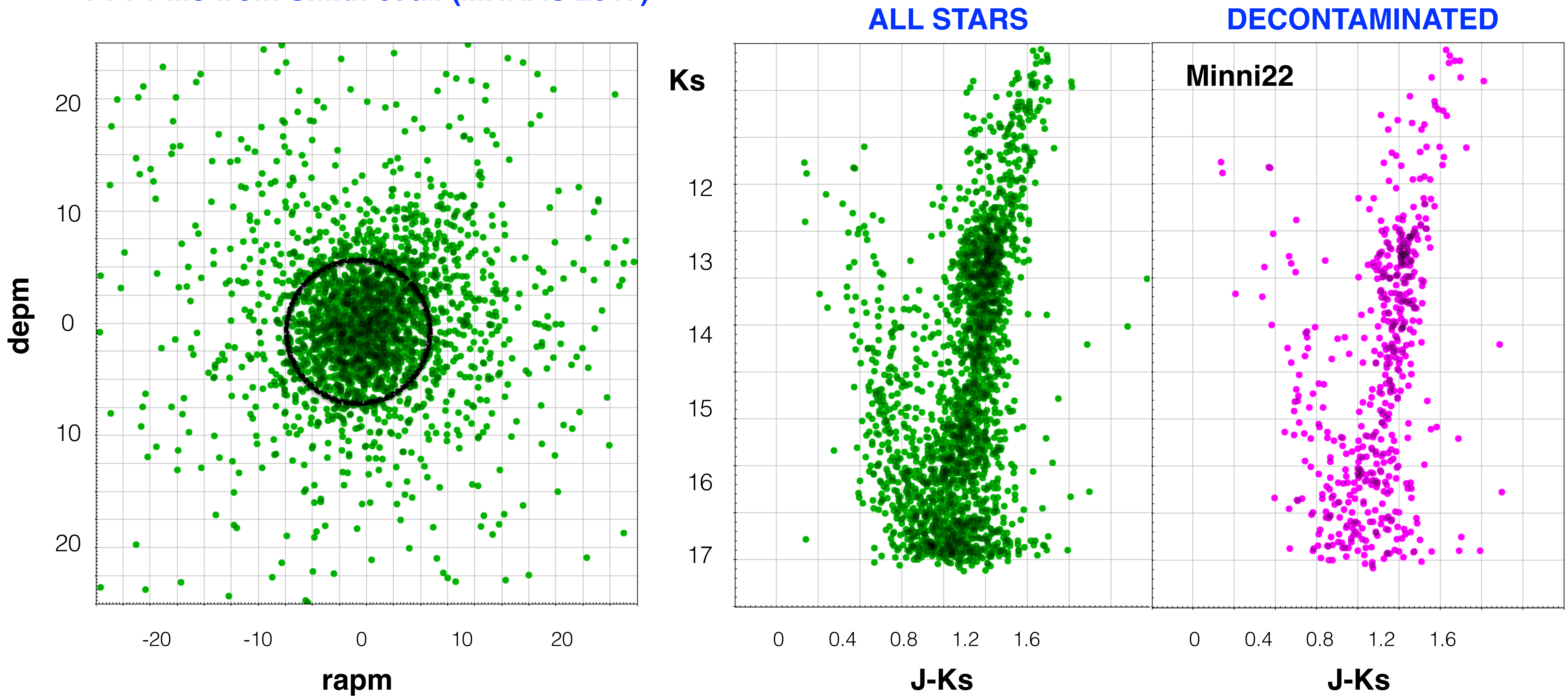
We use the PARSEC v1.2S isochrones (Bressan et al. 2012, Marigo et al. 2017) age = 11.2 Gyr metallicities z = 0.0001, 0.0008, 0.0125.

[Fe/H]=-1.3+/-0.3 dex



FIELD DECONTAMINATION USING PROPER MOTIONS

VVV PMs from Smith et al. (MNRAS 2017)



Proper motion decontamination works quite well eliminating foreground and background stars. The PMs show very well the RGBB, but do not reach the main-sequence TO.

NEW GLOBULAR CLUSTERS

We conclude that Minni22 is a **real globular cluster** located in the bulge. There are several lines of evidence.

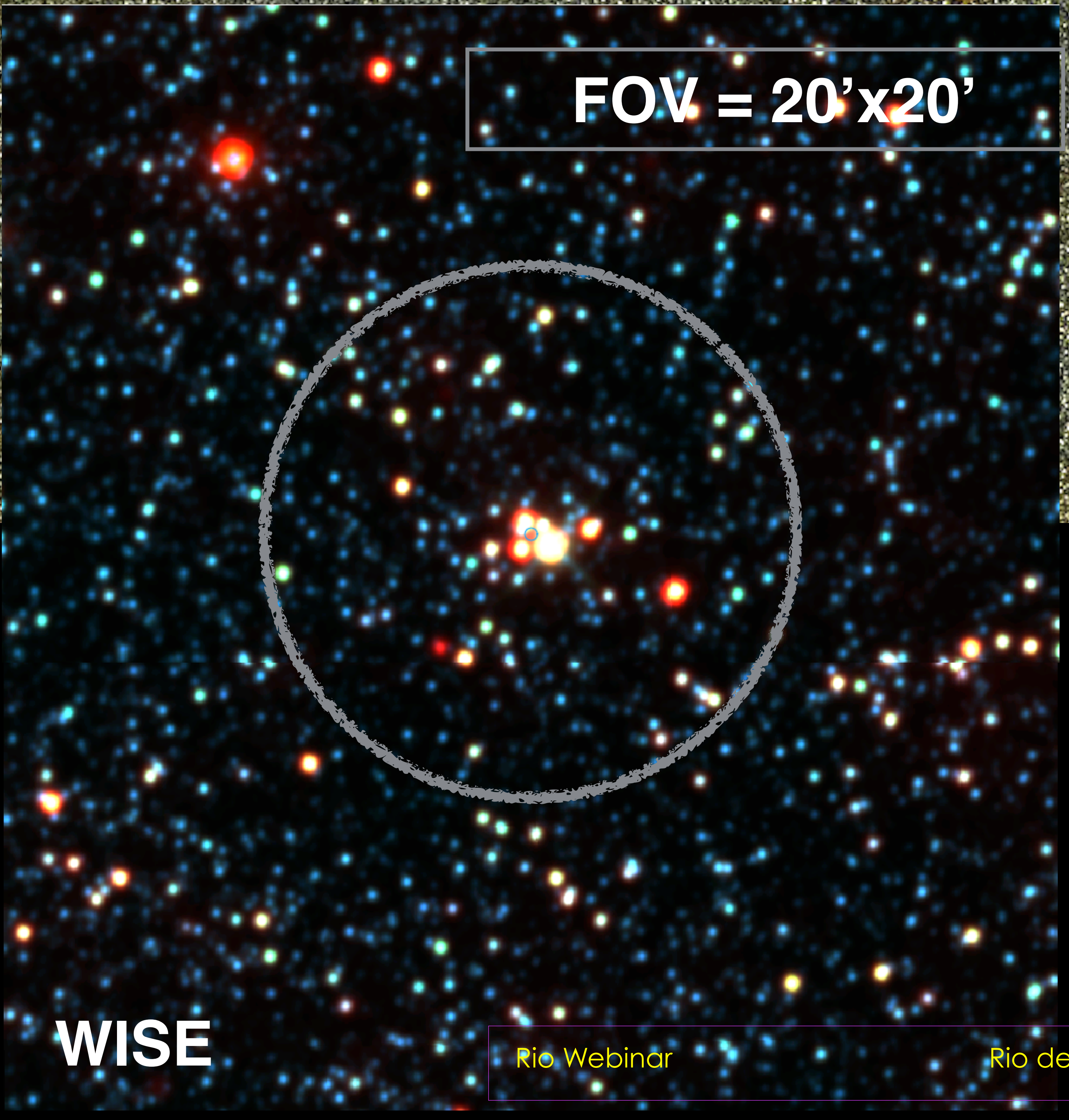
— The mear-IR CMD is similar to that of NGC6642.

— The optical and optical-IR CMDs resemble a metal-poor GC.

— It contains 3 RR Lyrae within 2’ of its centre.

We obtain D=7.4 kpc, [Fe/H]=-1.3, E(B-V)=1.12, Mv=-6.2.

Is this a new class of GC in the Galactic bulge?
It is very small, it can be a low luminosity dissolving cluster.
One of the skeletons in the elephant graveyard?



Not all the new GC candidates are faint.
Some seem to be quite luminous…

CONCLUSIONS

How many globular clusters in the Milky Way?

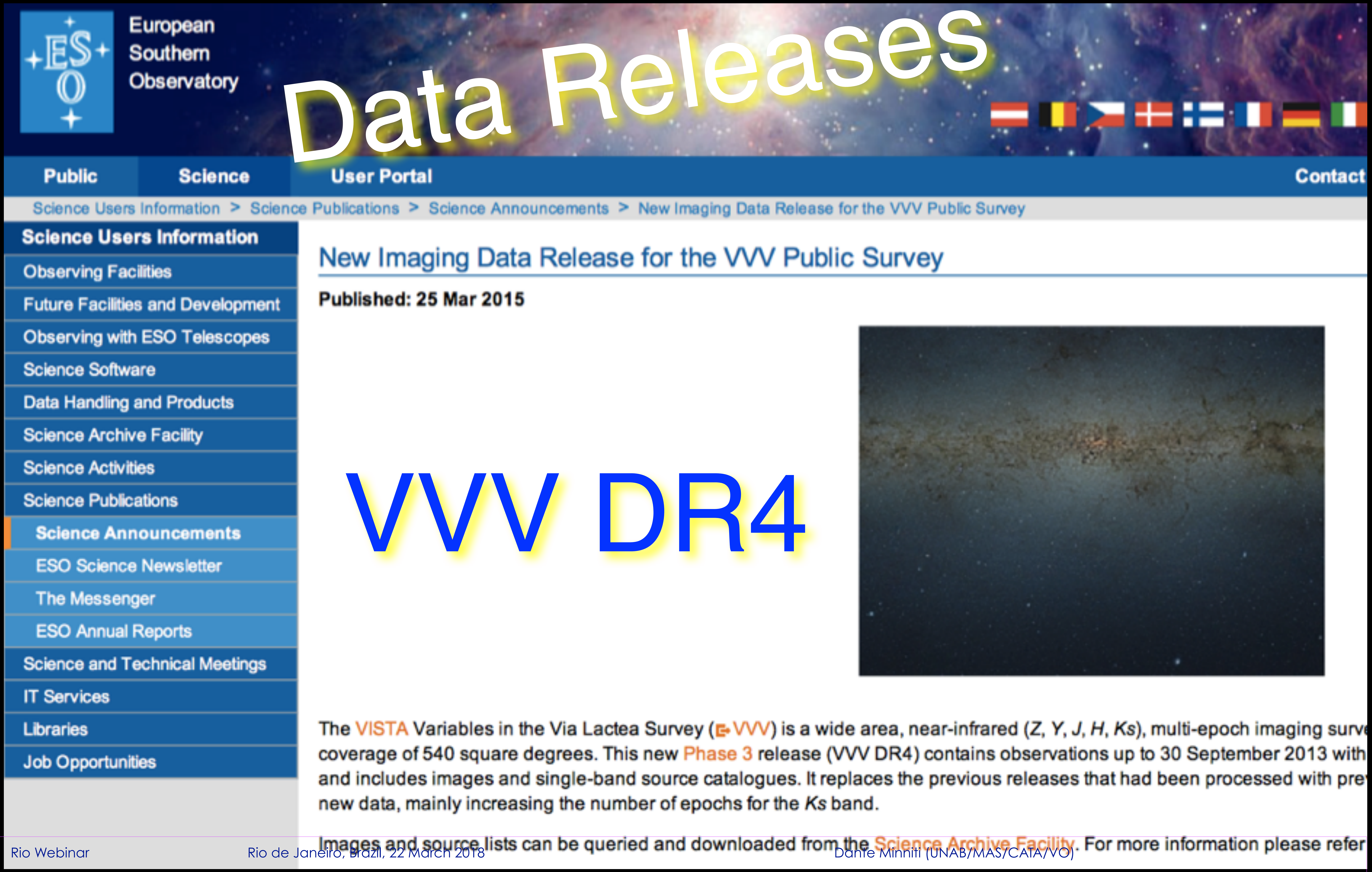
Many GCs (~100) may be still missing in the MW.

VVVX Survey **will find them!** LSST

- F. Gran +: Search for RR Lyrae in the bulge-halo transition region (A&A 2016)
- V. Ivanov +: Search for faint star clusters in stacked Ks-band images (A&A 2017)
- D. Minniti, M. Hempel, T. Palma +: The disk globular cluster FSR 1716 (ApJL 2017)
- P. Tissera +: The central spheroids of Milky Way mass-sized galaxies (MNRAS 2018 in press)
- D. Minniti, T. Palma, +: Characterization of the VVV Survey RR Lyrae Population Across the Southern Galactic Plane (2017 AJ)
- R. Contreras +: Proper Motions of the Globular Cluster NGC6544 (2017, A&A)
- D. Minniti, D. Geisler, J. Alonso-Garcia, +: New VVV Survey Globular Cluster Candidates in the Milky Way Bulge (2017, ApJL)

VVVSURVEY.ORG

ARCHIVE.ESO.ORG



VVVX Survey

A NEW NEAR-IR SURVEY OF THE MILKY WAY

DISCOVERING OUR OWN GALAXY,
PROMOTING ASTROPHYSICS AT EVERY LEVEL,
FOSTERING INTERNATIONAL COLLABORATIONS, AND
SECURING RESOURCES FOR THE FUTURE GENERATIONS.

Credito:Joyce Pullen