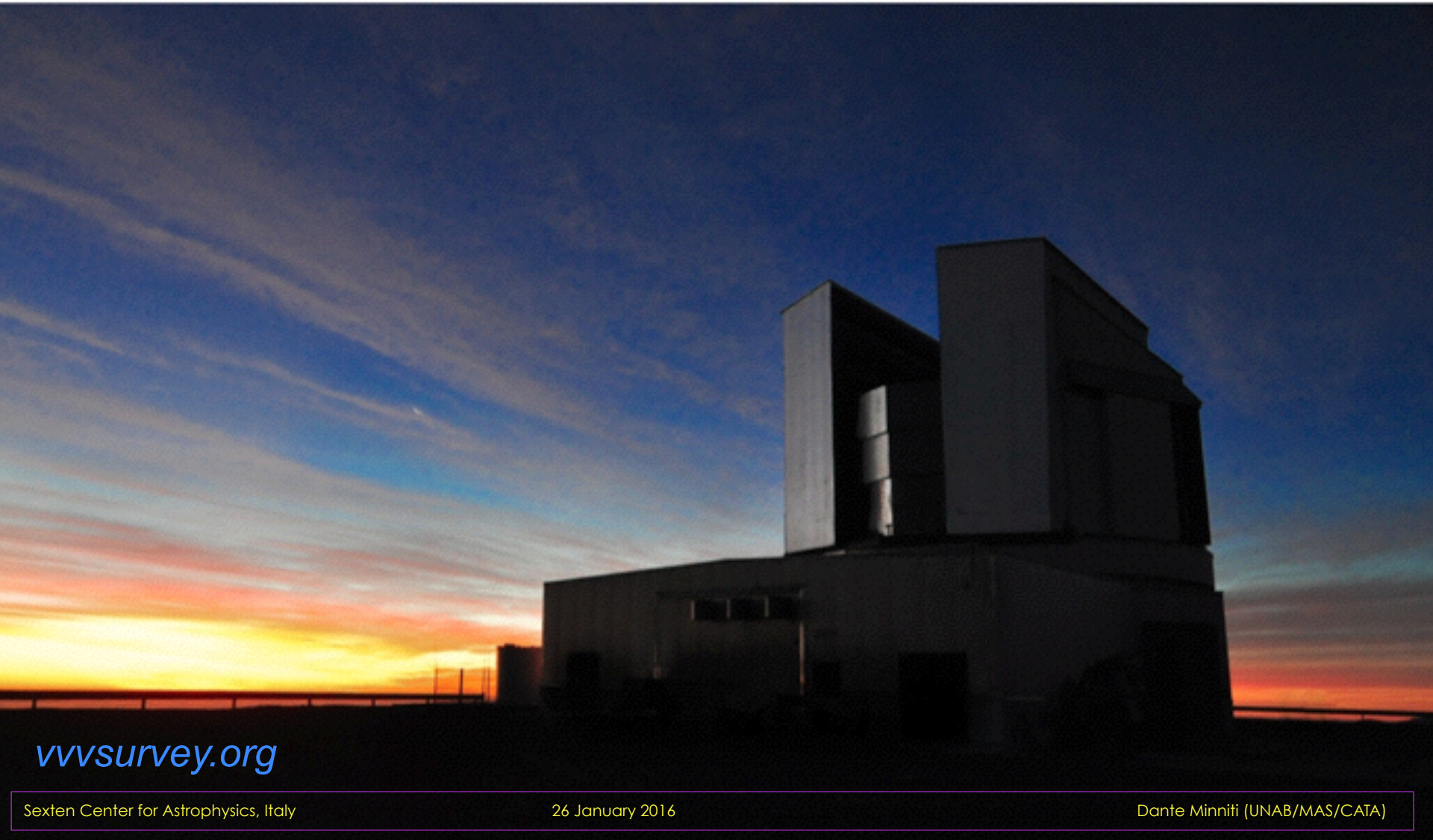
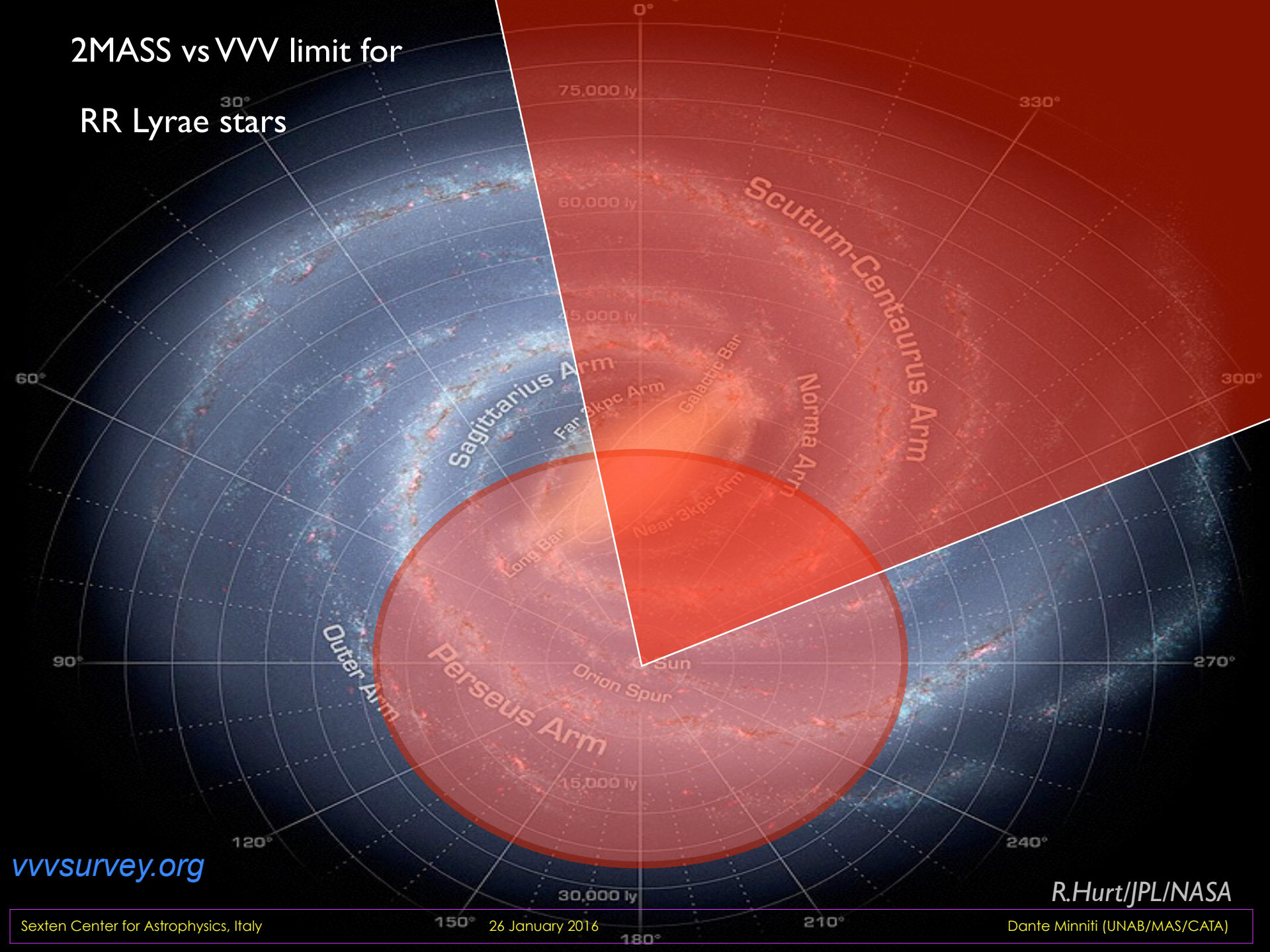
Vista Variables in the Via Lactea



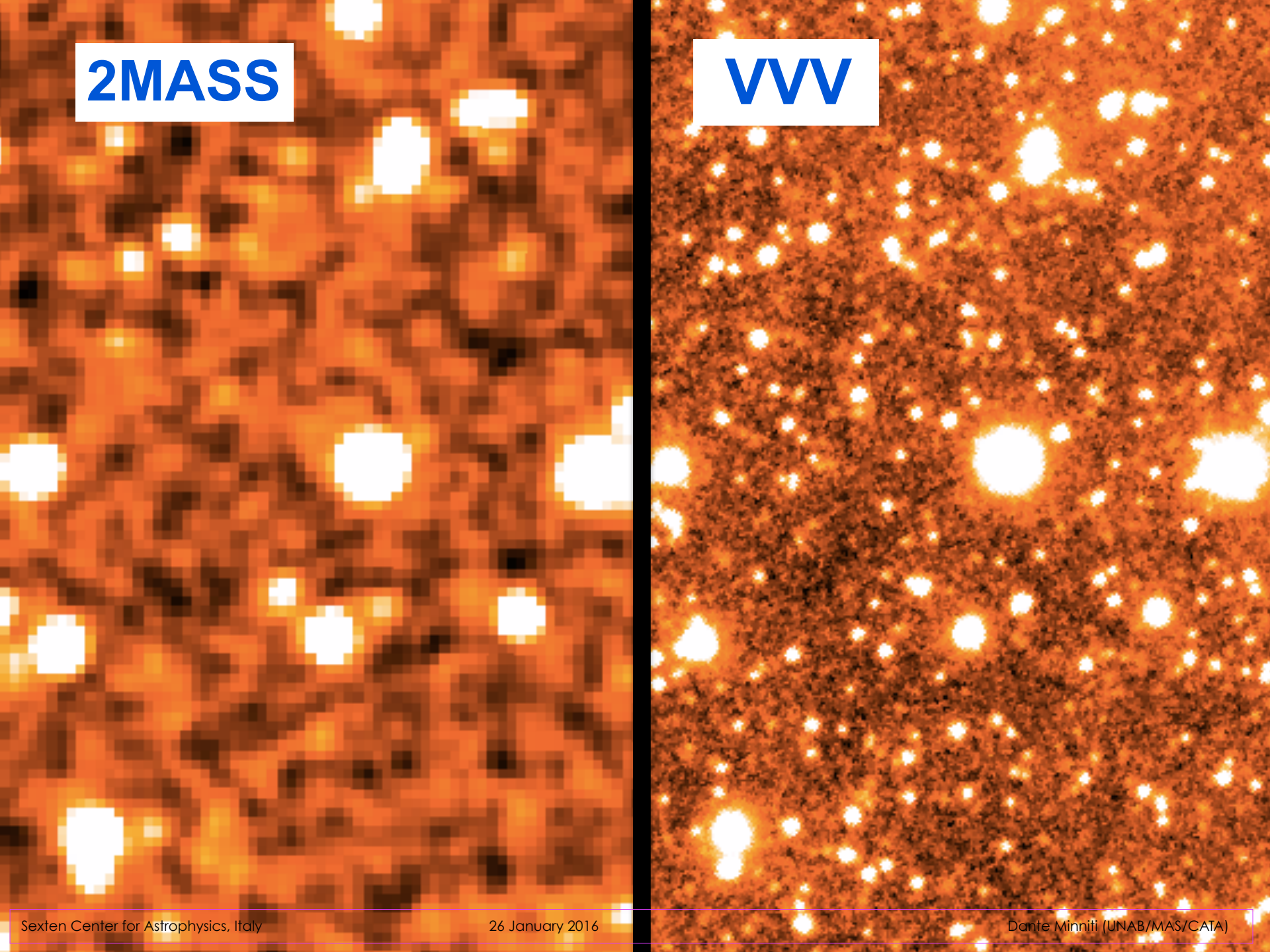
vvvsurvey.org

2MASS vs VVV limit for RR Lyrae stars



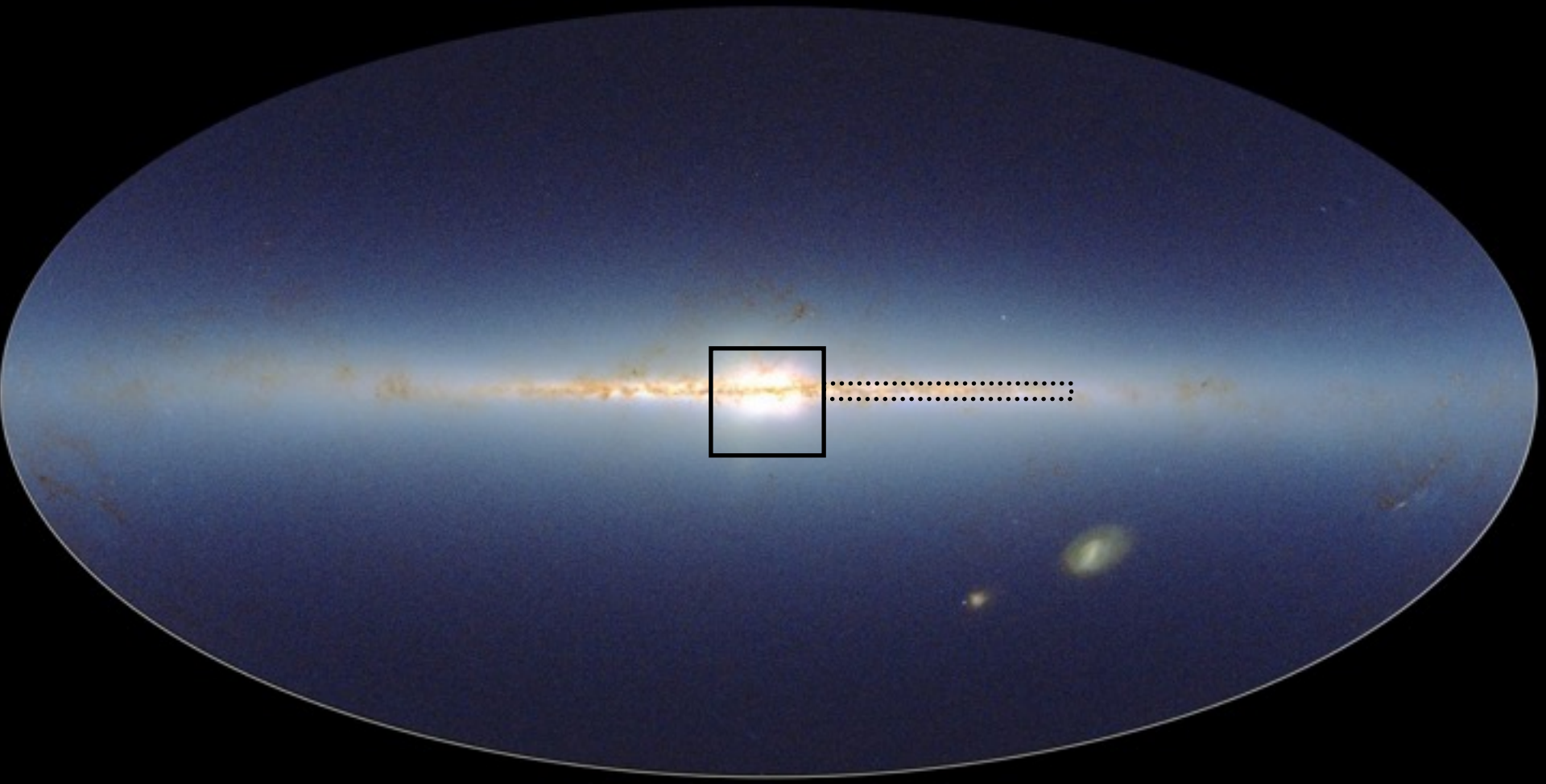
vvvsurvey.org

R.Hurt/JPL/NASA


2MASS
VVV

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

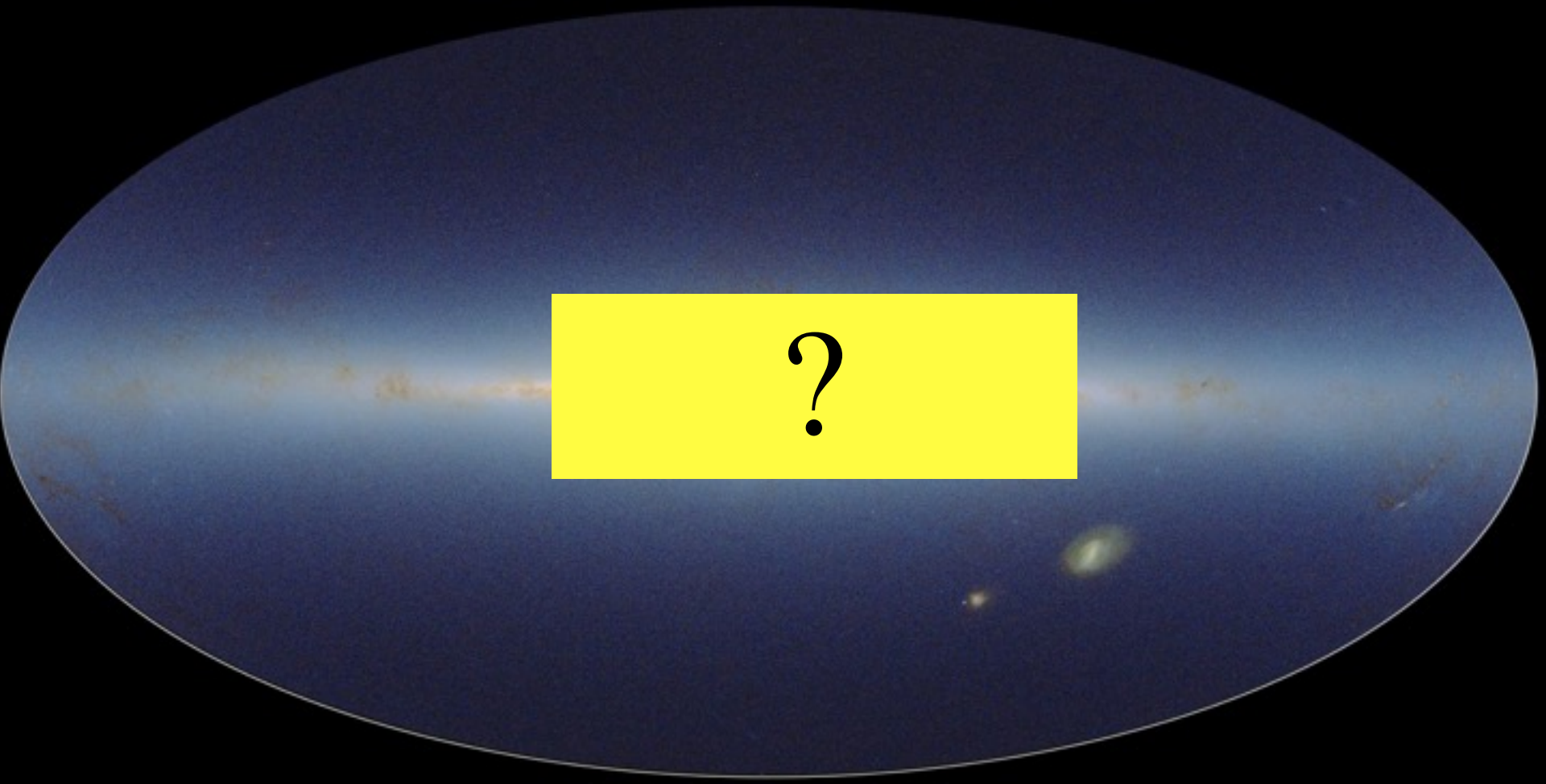
vvvsurvey.org



2MASS IMAGE OF THE MILKY WAY

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

vvvsurvey.org



2MASS IMAGE OF THE MILKY WAY

Goal

What is the 3-D structure of the Milky Way

VVV Observations

- The VVV observations are successfully completed
- >200 nights service observing
- Huge success for

VVV Processing

- The VVV data processing is completed
- Largest astronomical database
- Huge success for CASU and also VSA

VVV Data Releases

- VVV DR4 is done, online at the ESO Archive soon
- Now working on the final VVV DR!

VVV Bonuses

- In addition to the promised survey products, we give:

psf photometry

IR color maps

deeper Ks maps

proper motion maps

variability catalogs

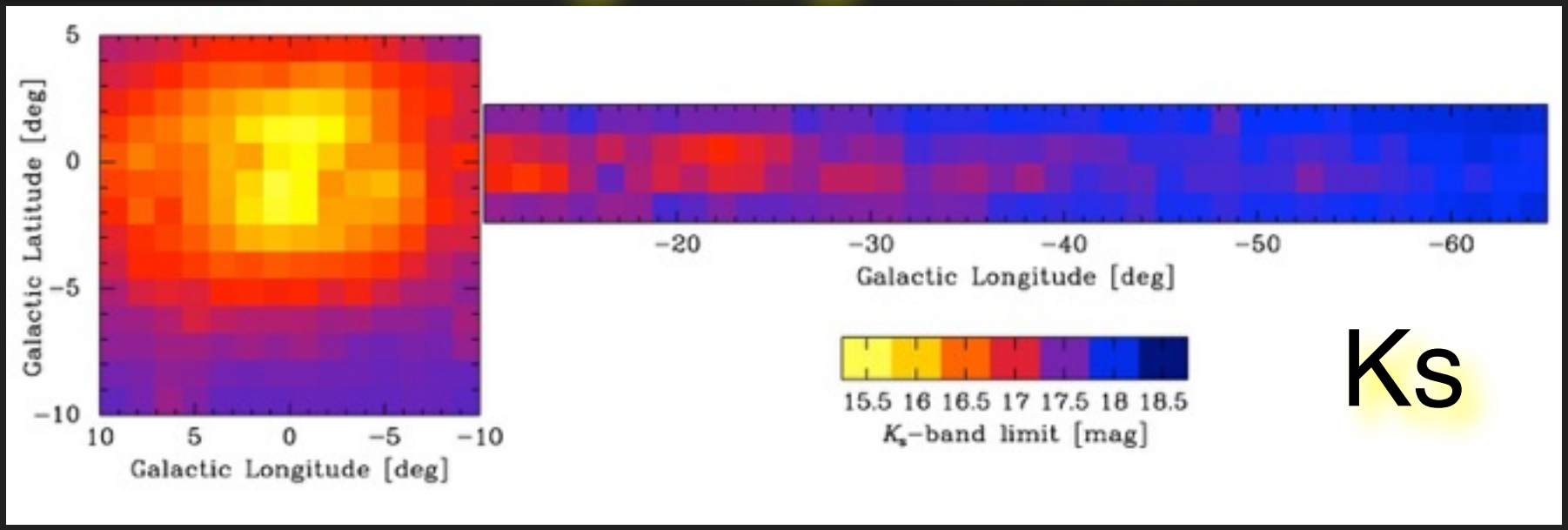
completeness maps

light curves templates for the near-IR

proper motion catalogs

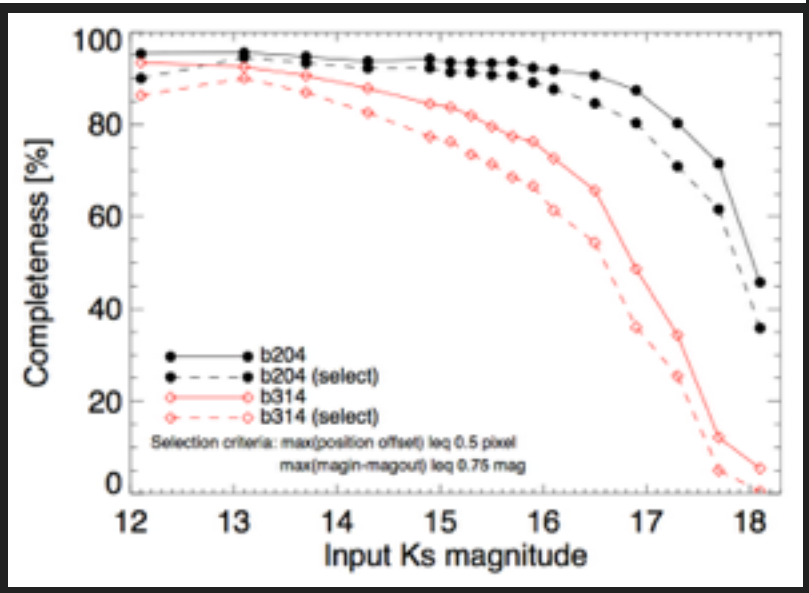
limiting magnitudes

vvvsurvey.org

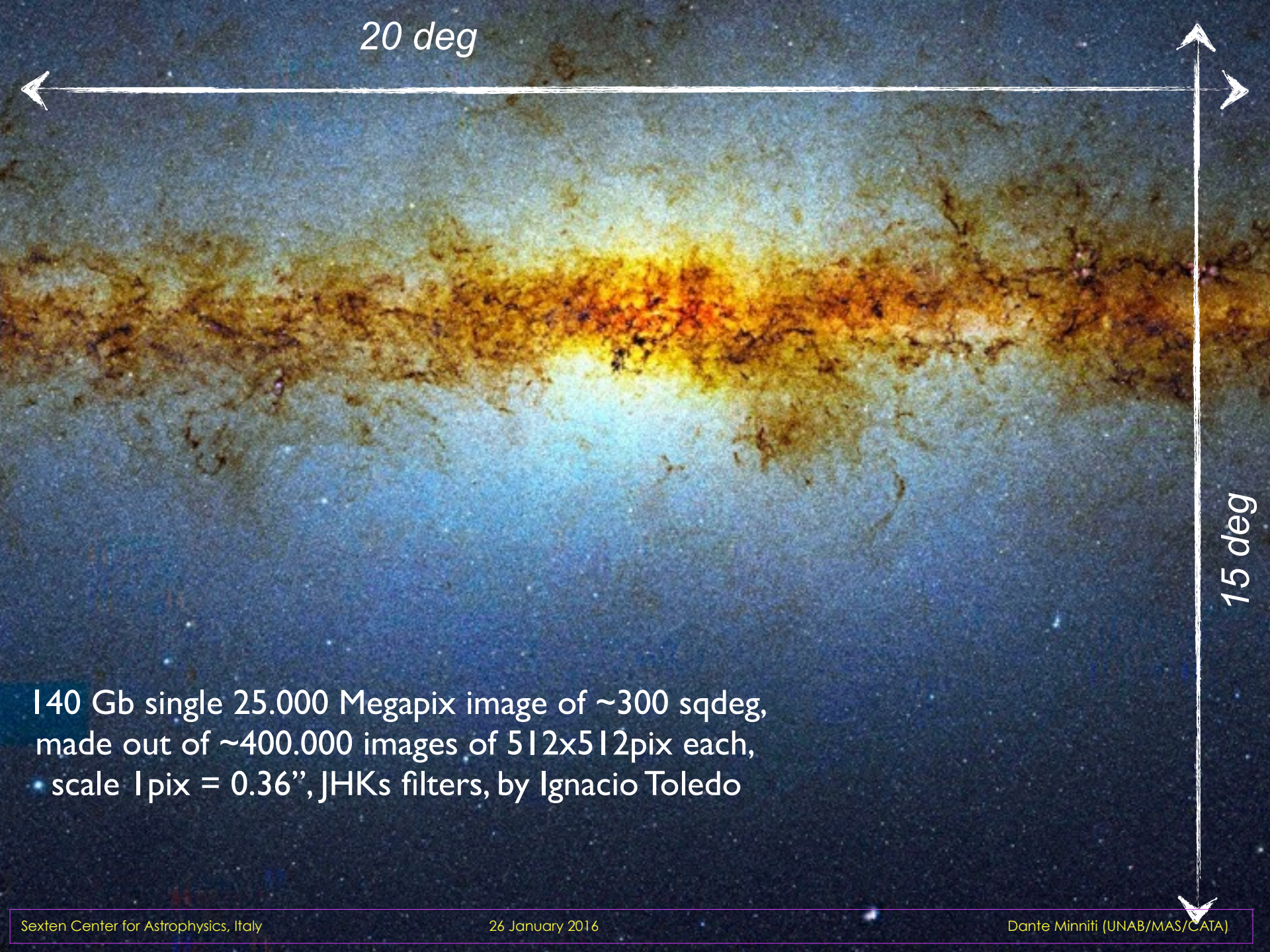


R. Saito

Completeness tests



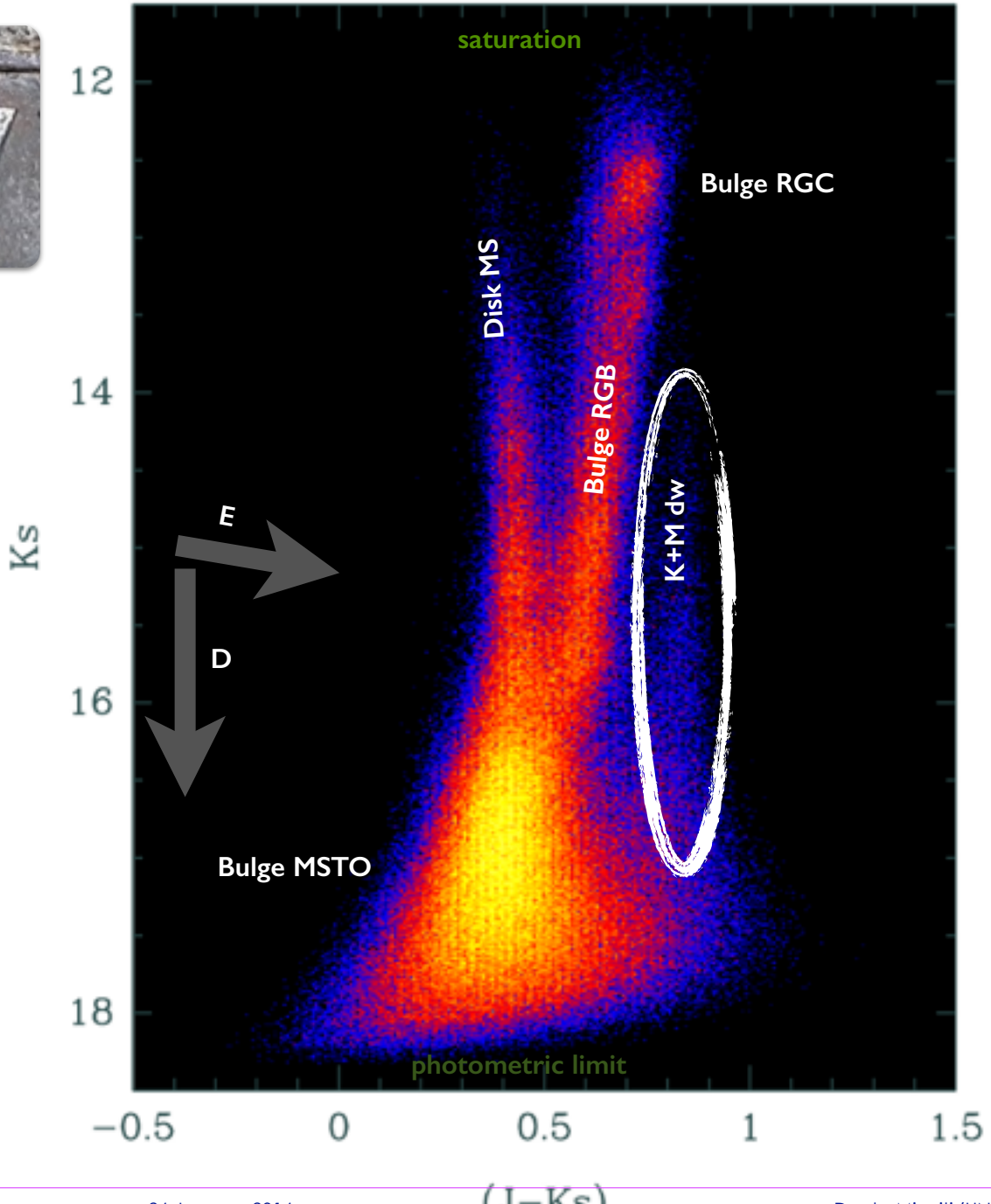
M. Hempel, E. Valenti



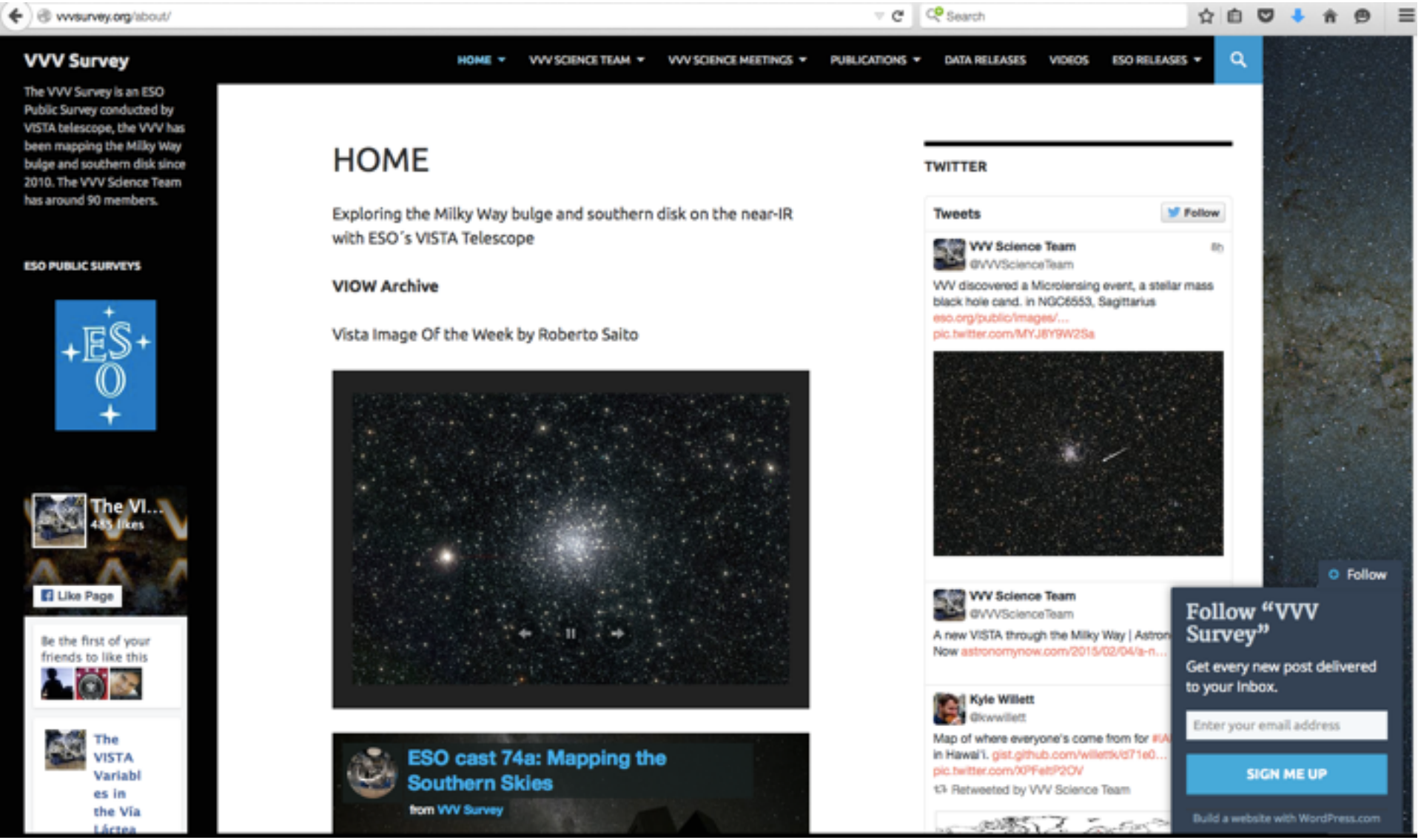
140 Gb single 25.000 Megapix image of ~300 sqdeg,
made out of ~400.000 images of 512x512pix each,
scale 1pix = 0.36", JHKs filters, by Ignacio Toledo

SINGLE TILE COLOR-MAGNITUDE DIAGRAM

CMD for b201
300.000 stars

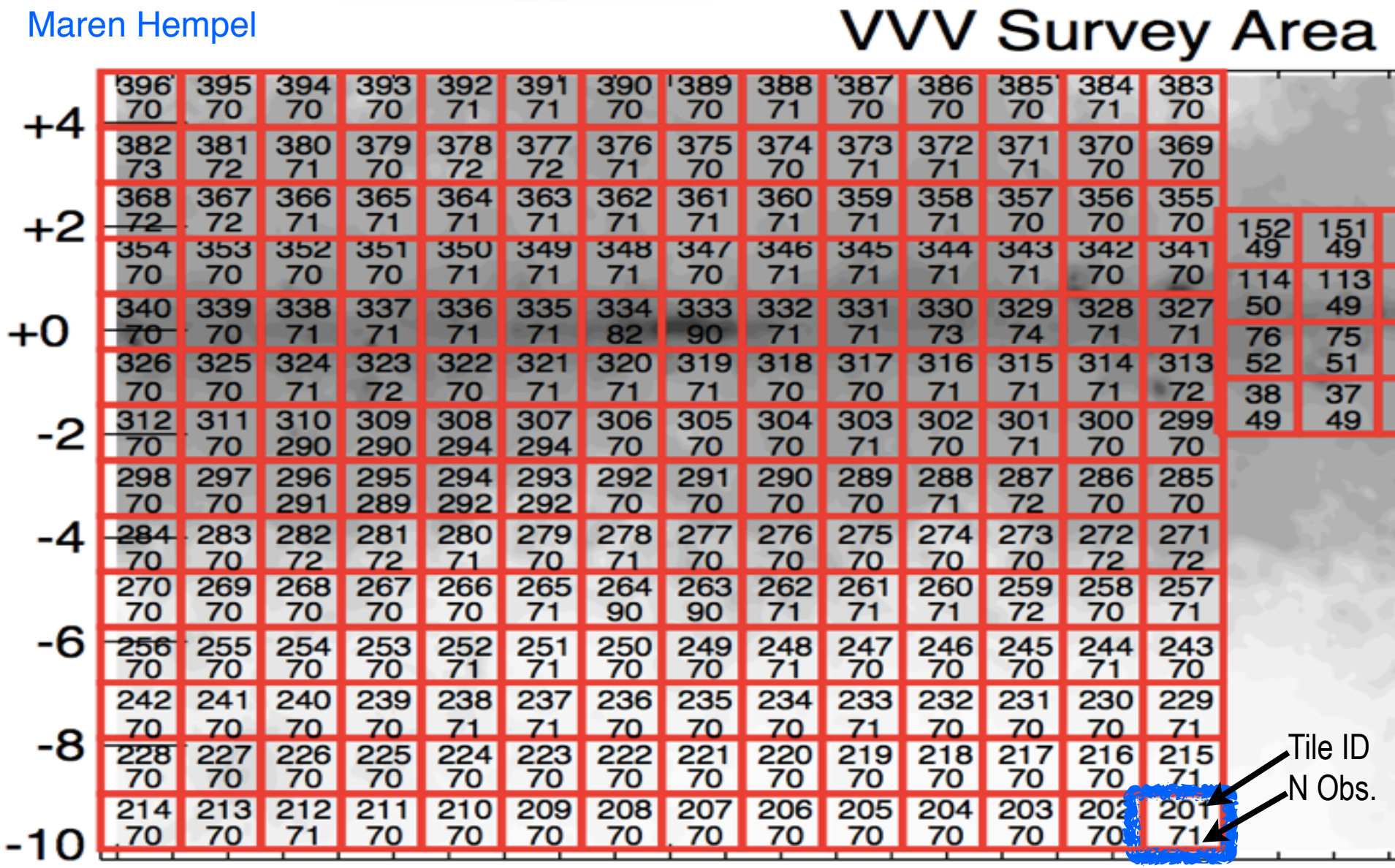


vvvsurvey.org



VVV Legacy

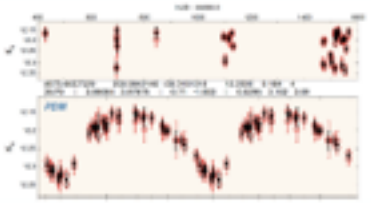
Maren Hempel

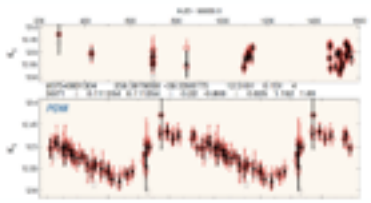


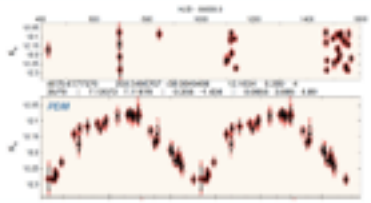
VVV Legacy

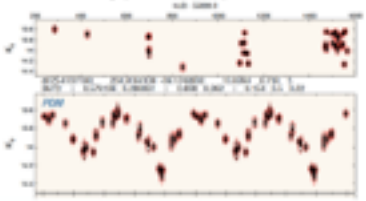
stellar populations
star formation
star clusters
variable stars
microlensing
exoplanets-BDs
proper motions
Galactic structure
bulge-halo connection
disk-bulge connection
spiral arms
warp, flare

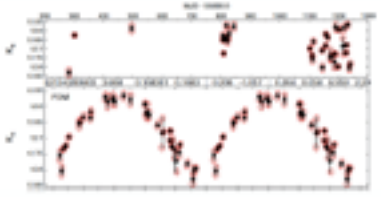
Variability

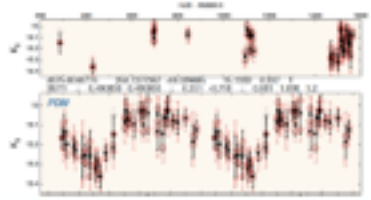

Type II Cepheid

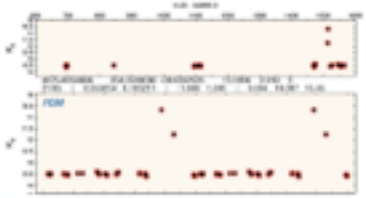

Delta Scuti

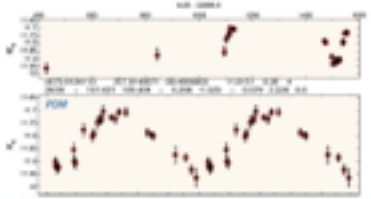

Classical Cepheid

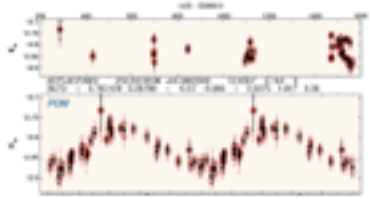

Eclipsing binary

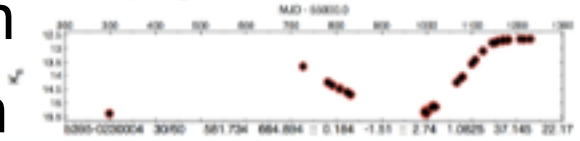

Contact binary

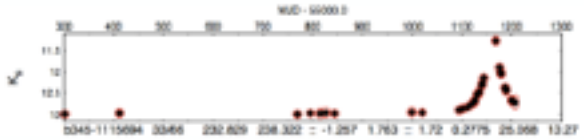

Distant RRab

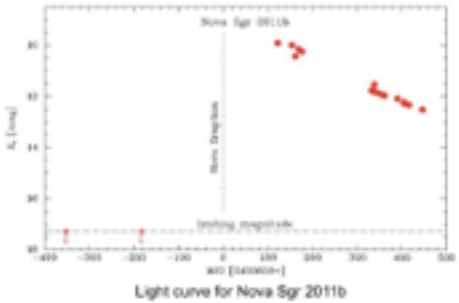

Erupting variable


Long period Cepheid


Nearby RRab


Long period variable


Microlensing event


Light curve for Nova Sgr 2011b

Discovery of novae in the Galactic disk
(R. Saito et al. 2014)

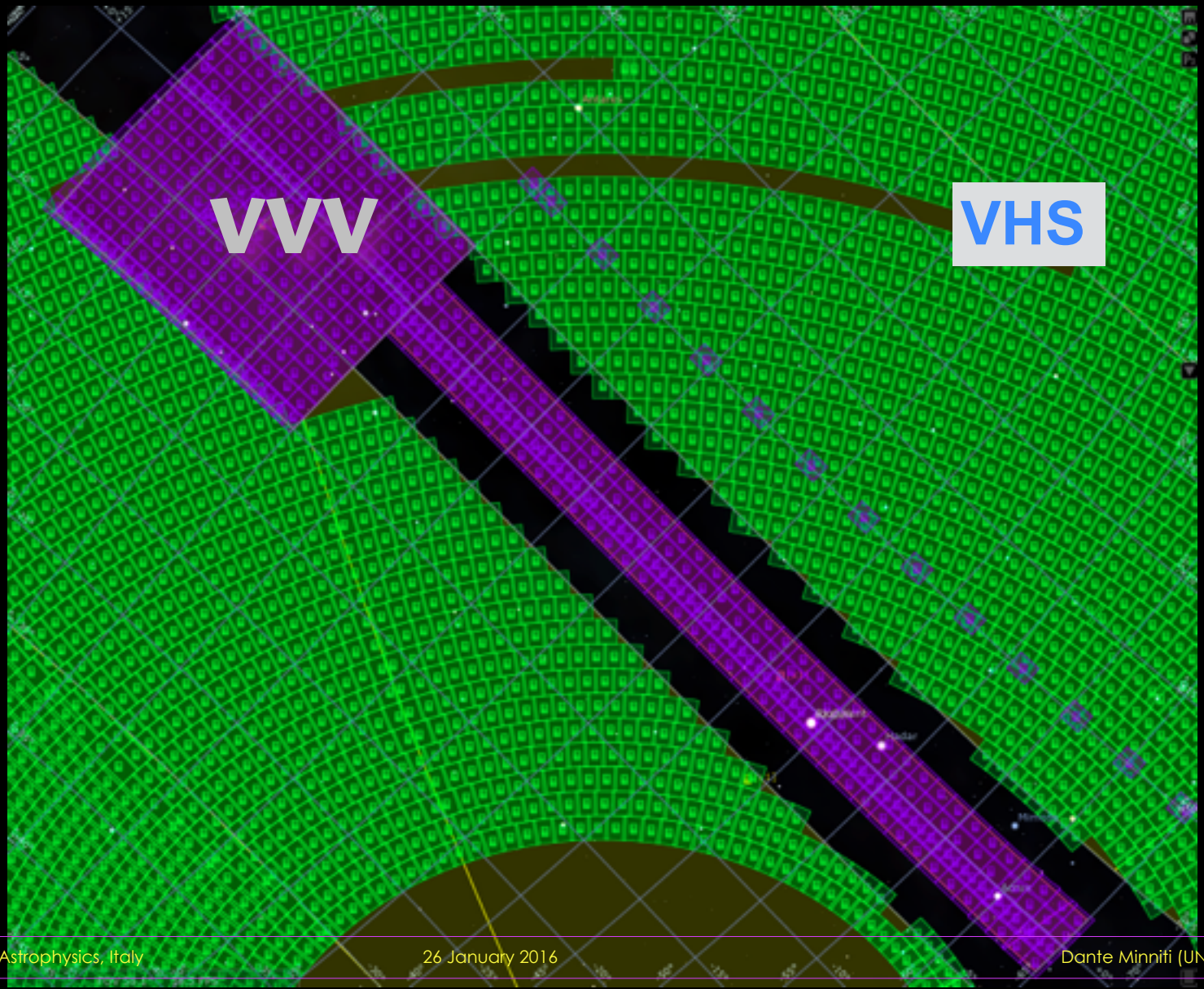
VVV Future

VVV X

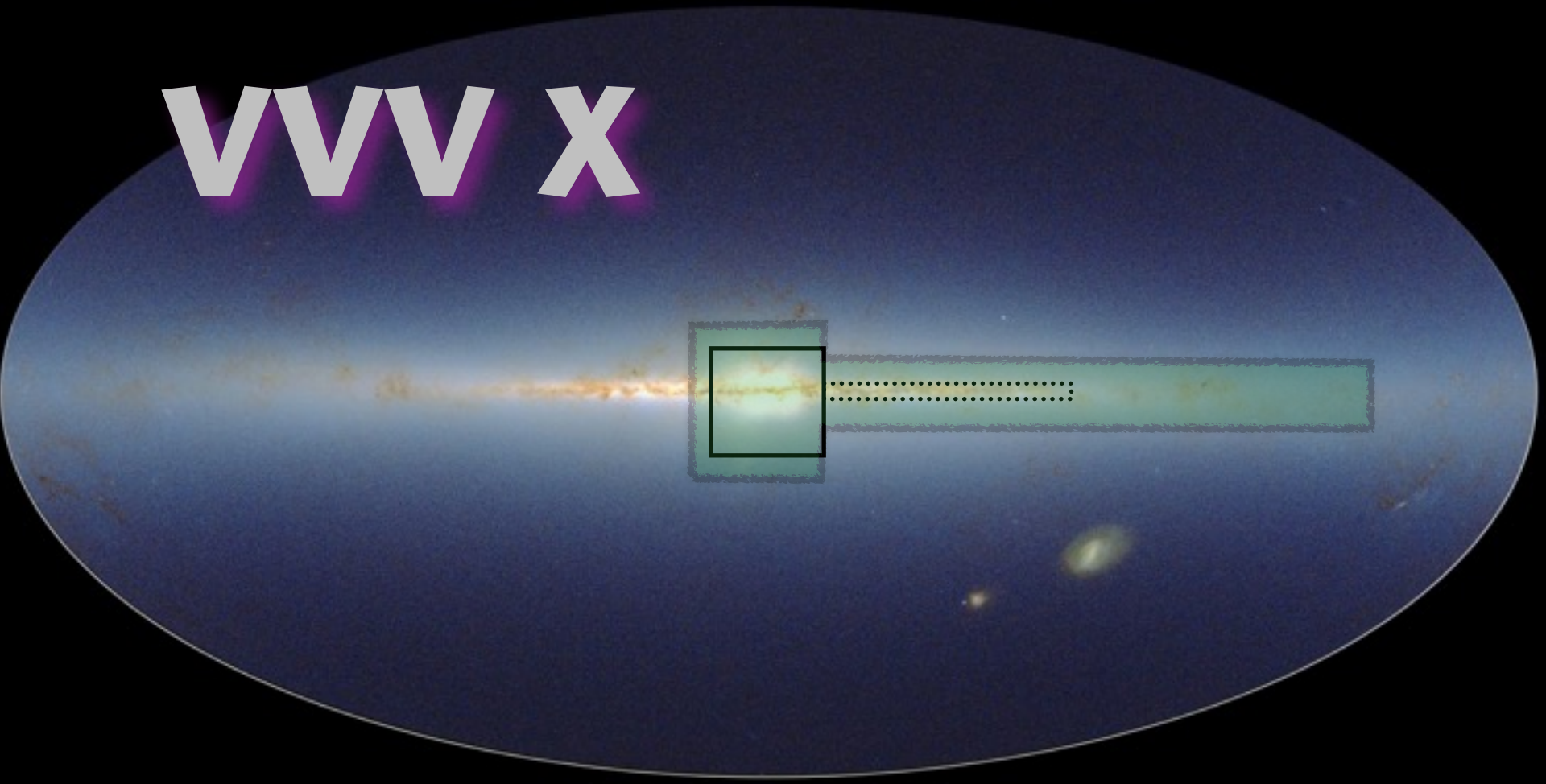
A New Survey of the Inner Milky Way, Disk, and Halo

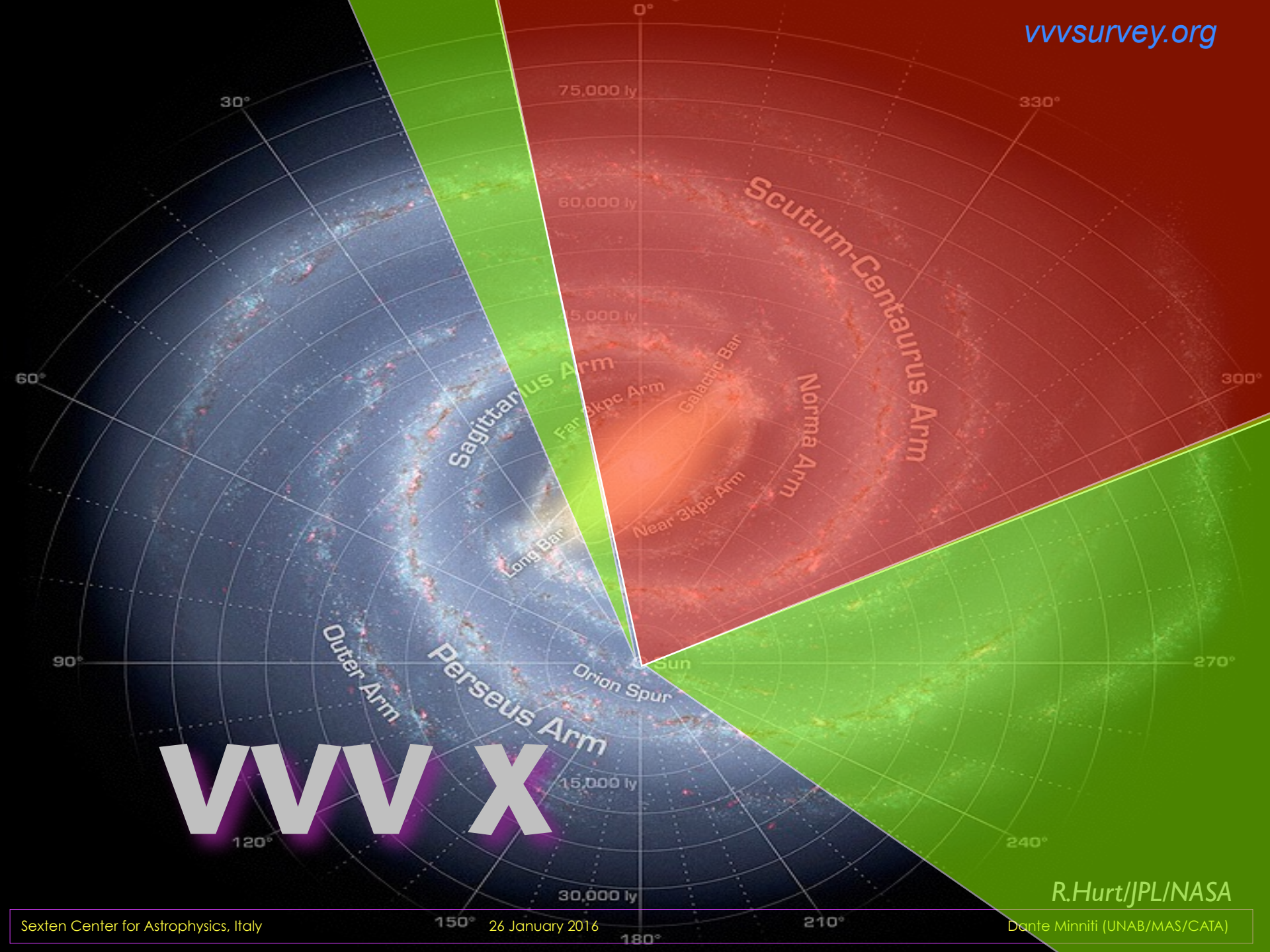
- VVVX proposal submitted to ESO in 2015

VISTA SURVEYS: MILKY WAY SKY COVERAGE



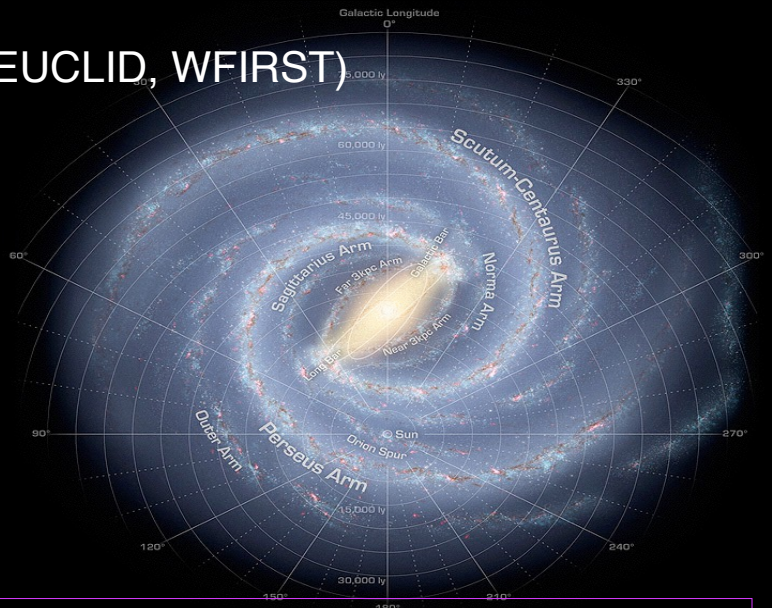
VVV X




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

VVV X Science

- Follow up VVV (SN, LPVs, PMs and parallaxes, MOONS targets, etc.)
- Carina arm region (Cepheids, clusters, Galactic structure, GAIA, etc.)
- Map the Northern bulge and extend to Northern disk (globular clusters, bar end)
- Map the bulge-halo transition and the Sgr dwarf galaxy (RR Lyrae, globulars)
- Map the Galactic disk (thin vs thick disk, warp, flare, etc.)
- Bulge microlensing (free-floating planets, K2, EUCLID, WFIRST)



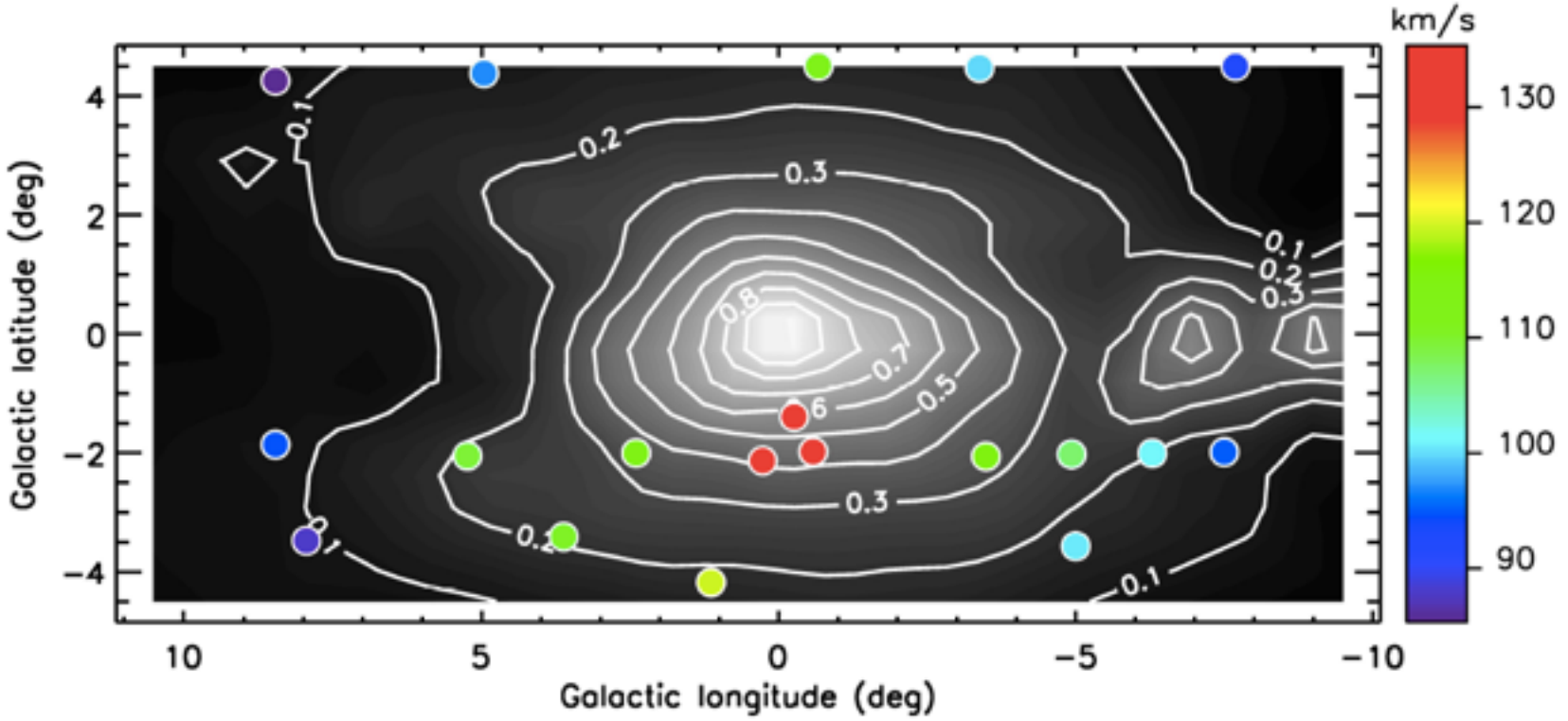
vvvsurvey.org

VVV Latest Results

1. The Mass of the Milky Way Bulge
2. RR Lyrae in the Bulge-Halo Transition Region
3. Cepheids in the Inner Bulge
4. Mapping the Distant Spiral Arms
5. Structure of the Milky Way Bulge
6. Dust Distribution and the Reddening Laws
7. Catalog of Proper Motions and Parallaxes
8. Variable YSOs
9. Template Light Curves
10. Hundreds of New Star Clusters

The Mass of the Milky Way Bulge

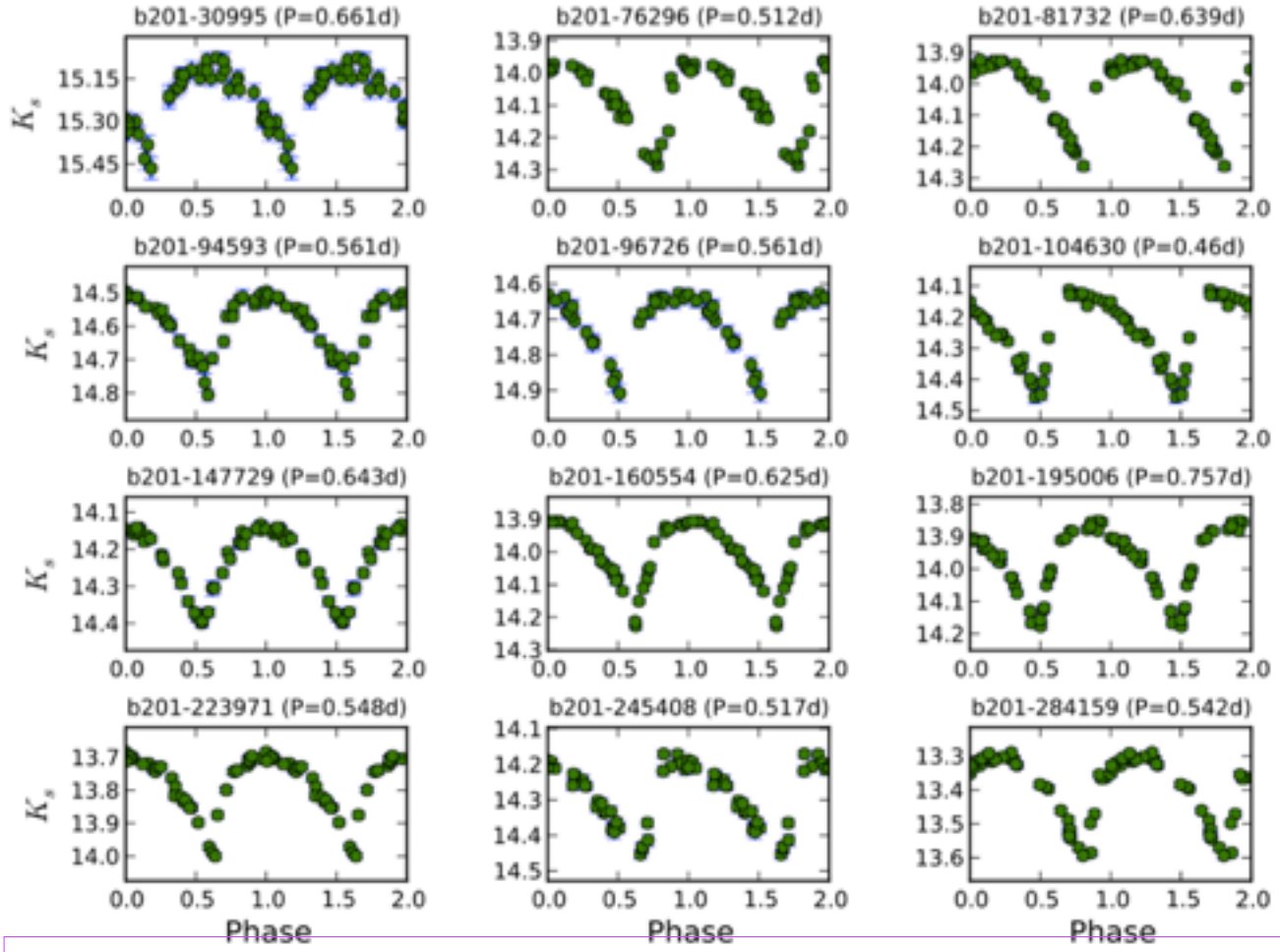
Valenti et al. 2016. A&A. in press (arXiv:1510.07425)



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

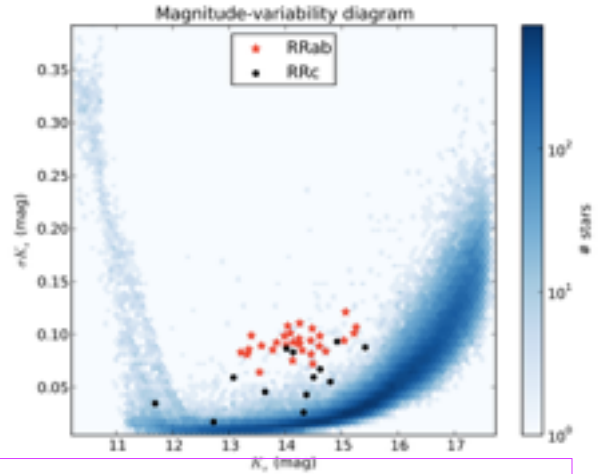
RR Lyrae in the Bulge-Halo Transition

Dekany et al. 2013, ApJL, 776, L19 (arXiv:1309.5933)
Gran et al. 2015, A&A, 575, 114 (arXiv:1501.00947)
Gran et al. 2016, A&A, submitted

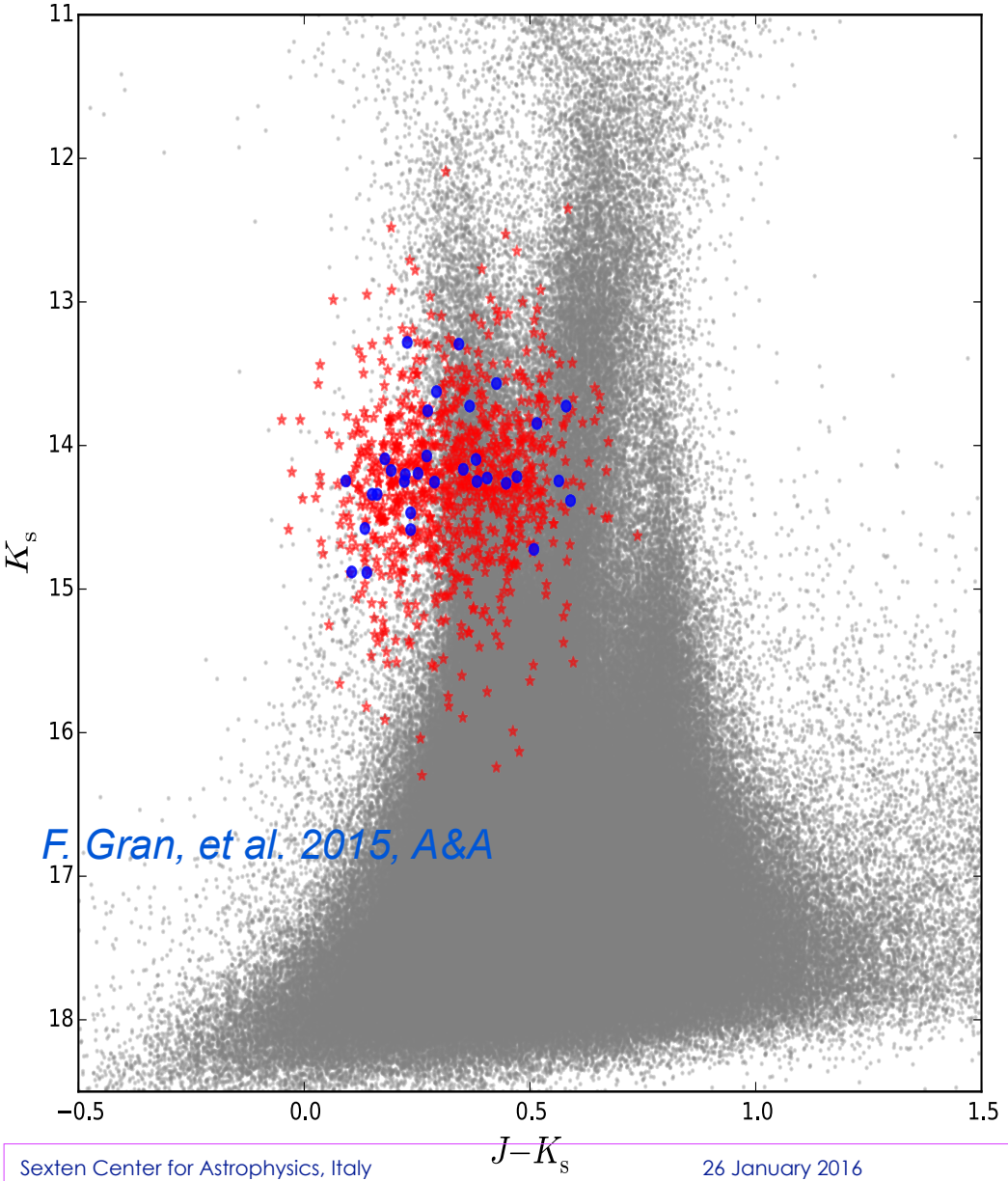


- RR Lyrae are metal-poor, and represent the oldest stellar populations.

- RR Lyrae stars are excellent primary distance indicators.



RR Lyrae in the Bulge-Halo Transition



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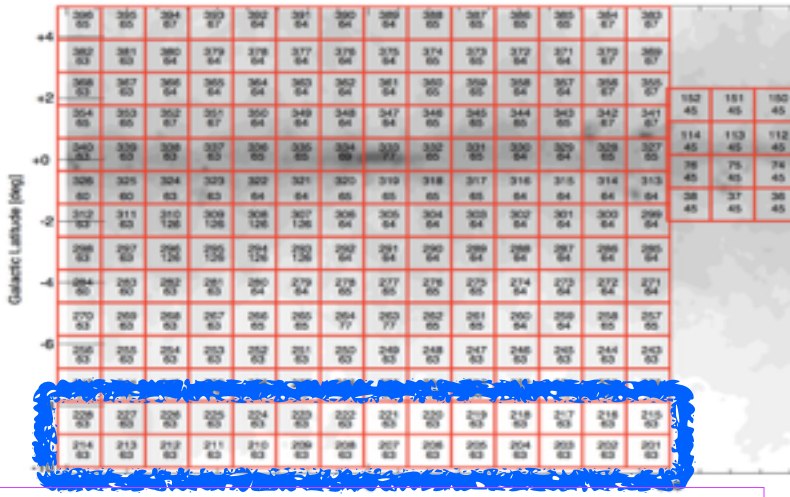
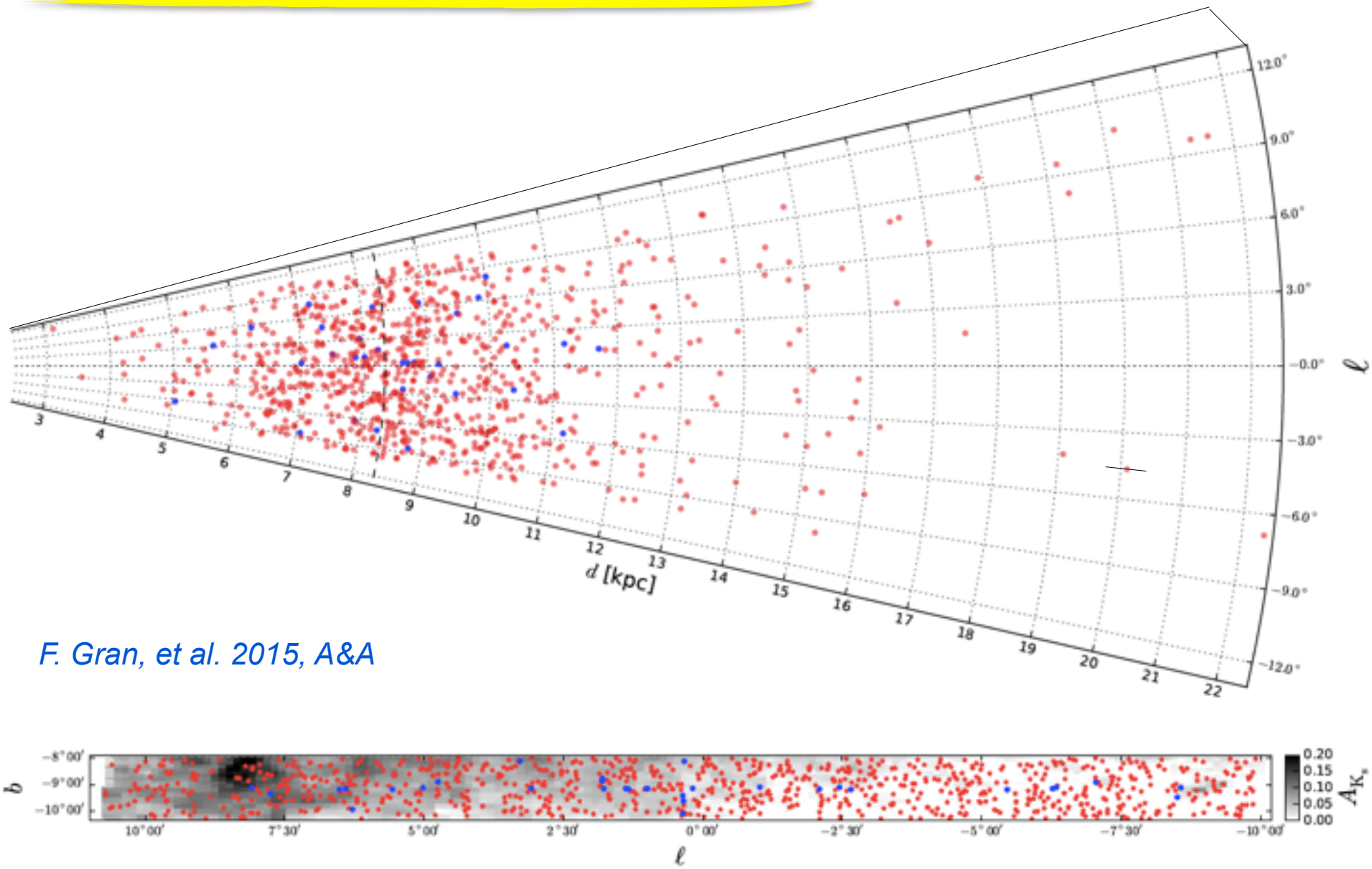
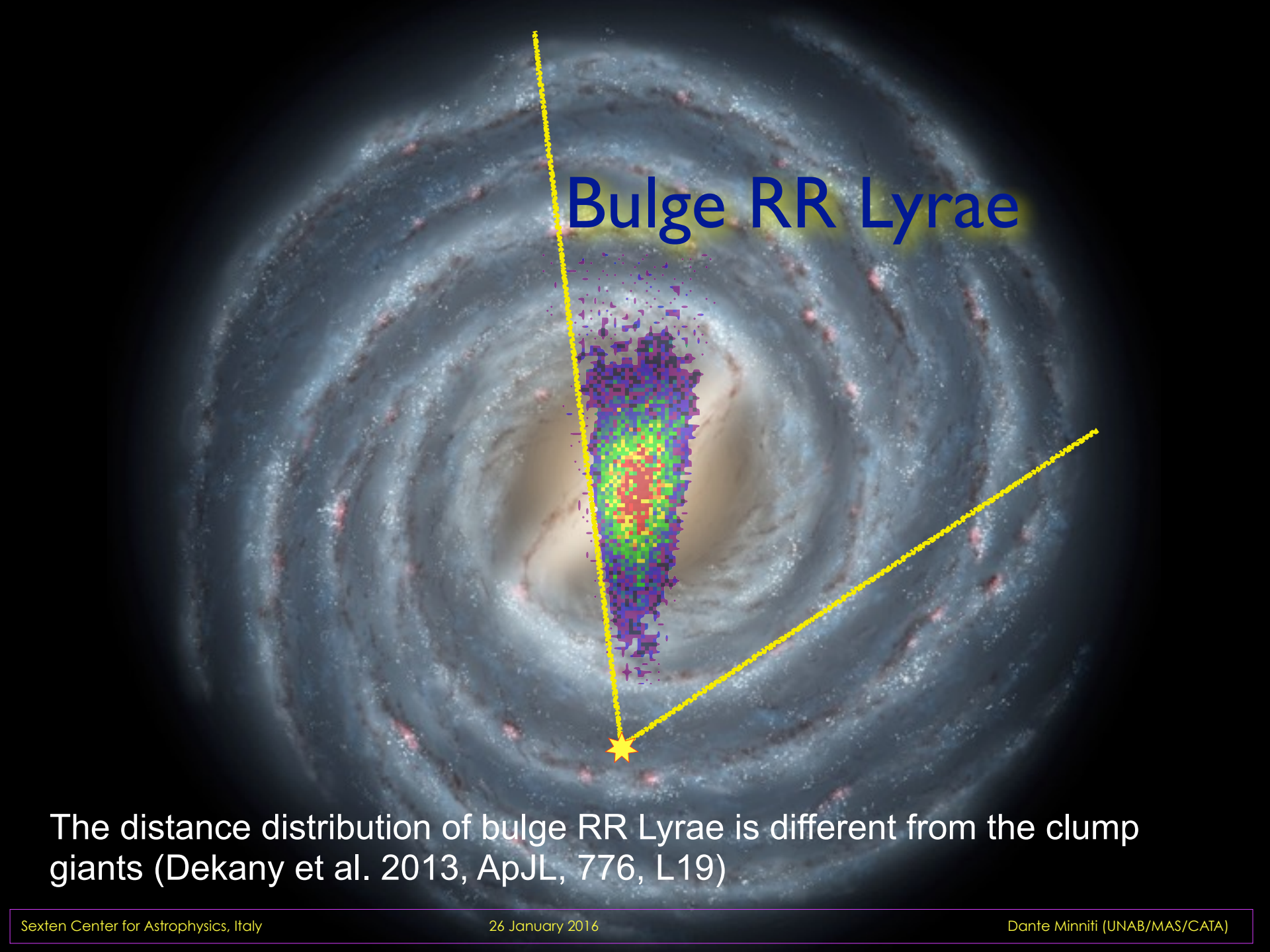


RR Lyrae in the Bulge-Halo Transition



F. Gran, et al. 2015, A&A



The distance distribution of bulge RR Lyrae is different from the clump giants (Dekany et al. 2013, ApJL, 776, L19)

Bulge RR Lyrae

1. The RR Lyrae distance distribution is different from RC giants
2. The RR Lyrae do not trace the bar
3. The RR Lyrae do not trace the X-shape

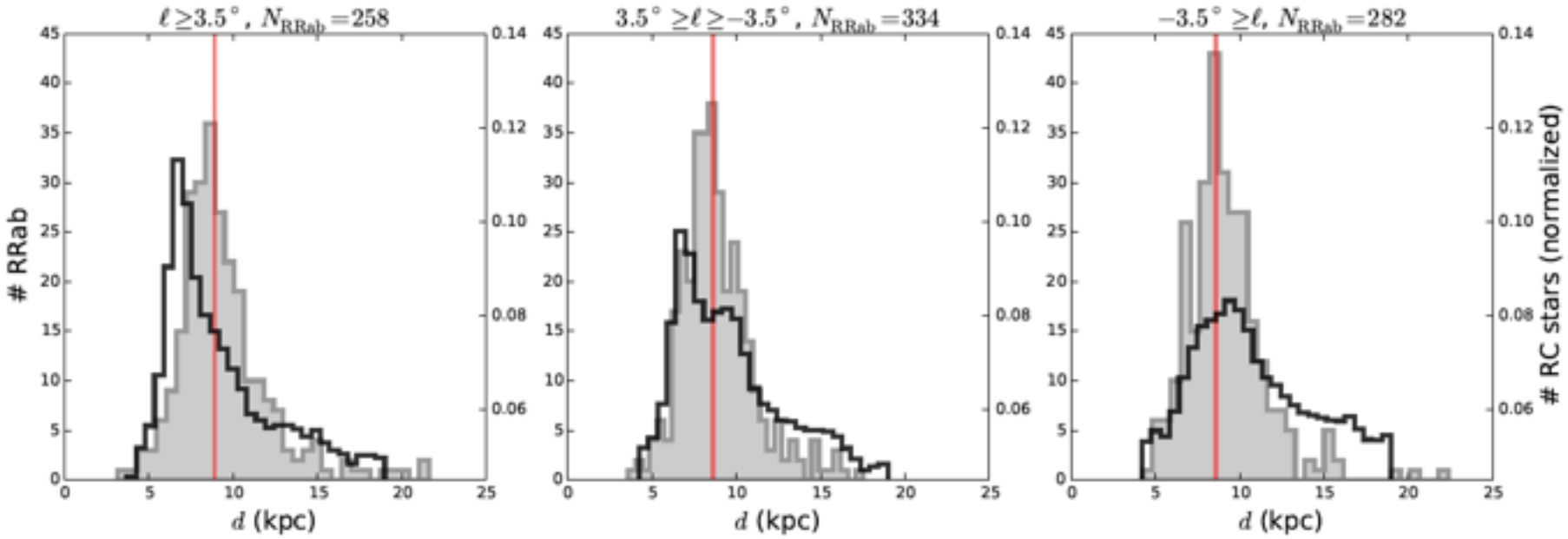
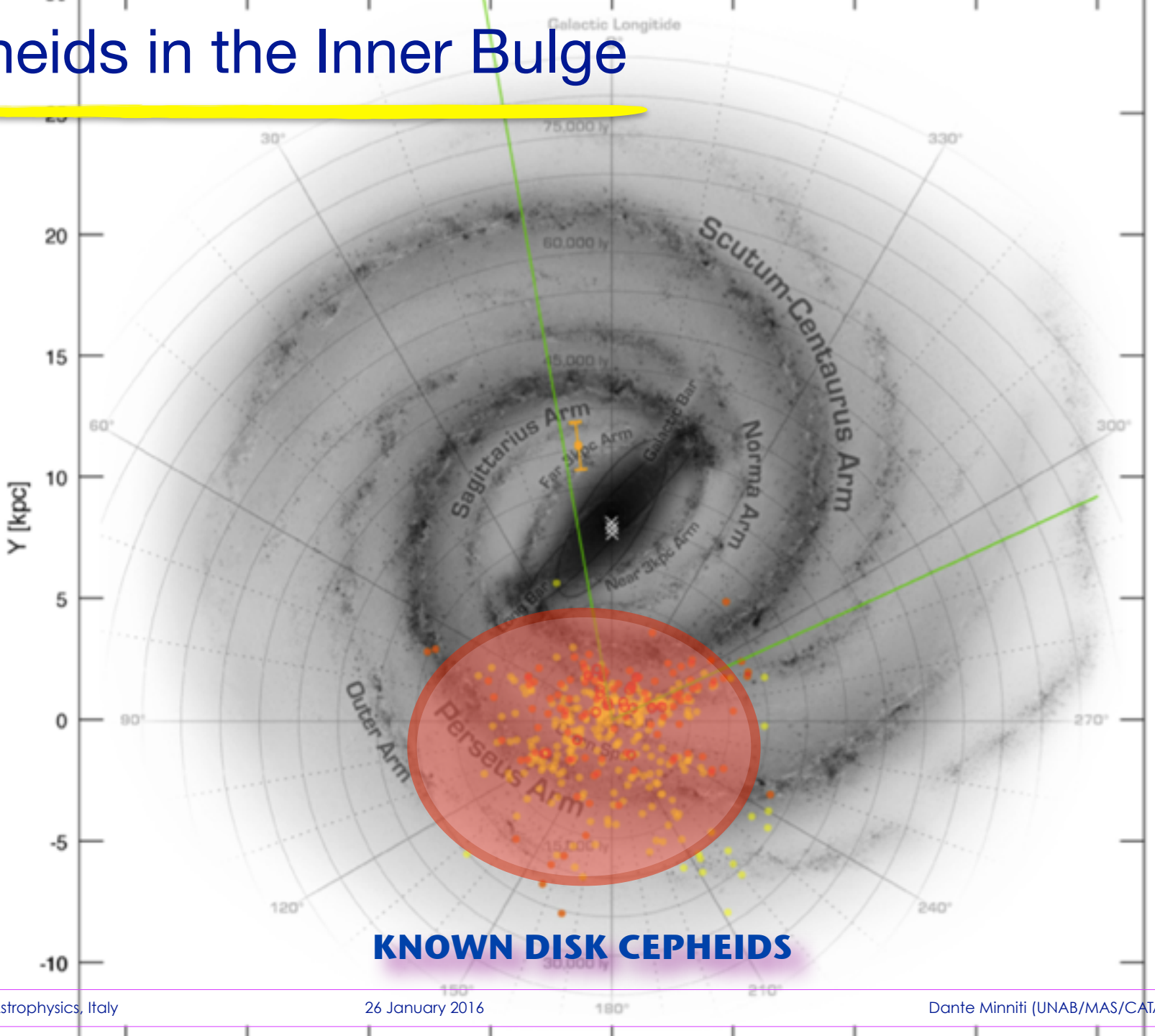


Fig. 8. Histogram of distances of RR Lyrae (gray filled) and RC stars (black steps) as function of galactic latitude (ℓ). Since the total number of RC stars in the same areas overwhelms the number of RR Lyrae, the histogram showing their distribution in distance was normalized for visualization purposes.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

Cepheids in the Inner Bulge



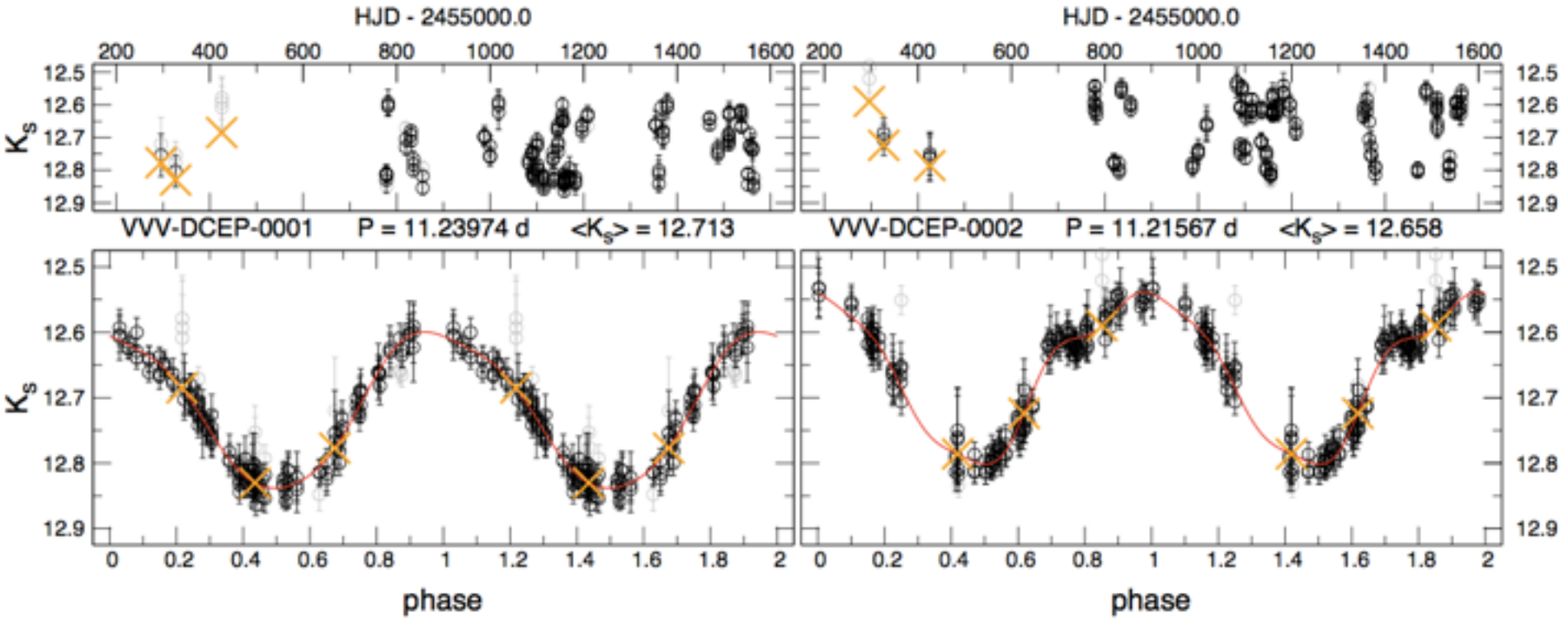
KNOWN DISK CEPHEIDS

I.

Cepheids in the Inner Bulge

Dekany et al. 2015b ApJL 812, L29 (arXiv:1509.08402)

Dekany et al. 2015a ApJL 799, L11 (arXiv:1412.8658)



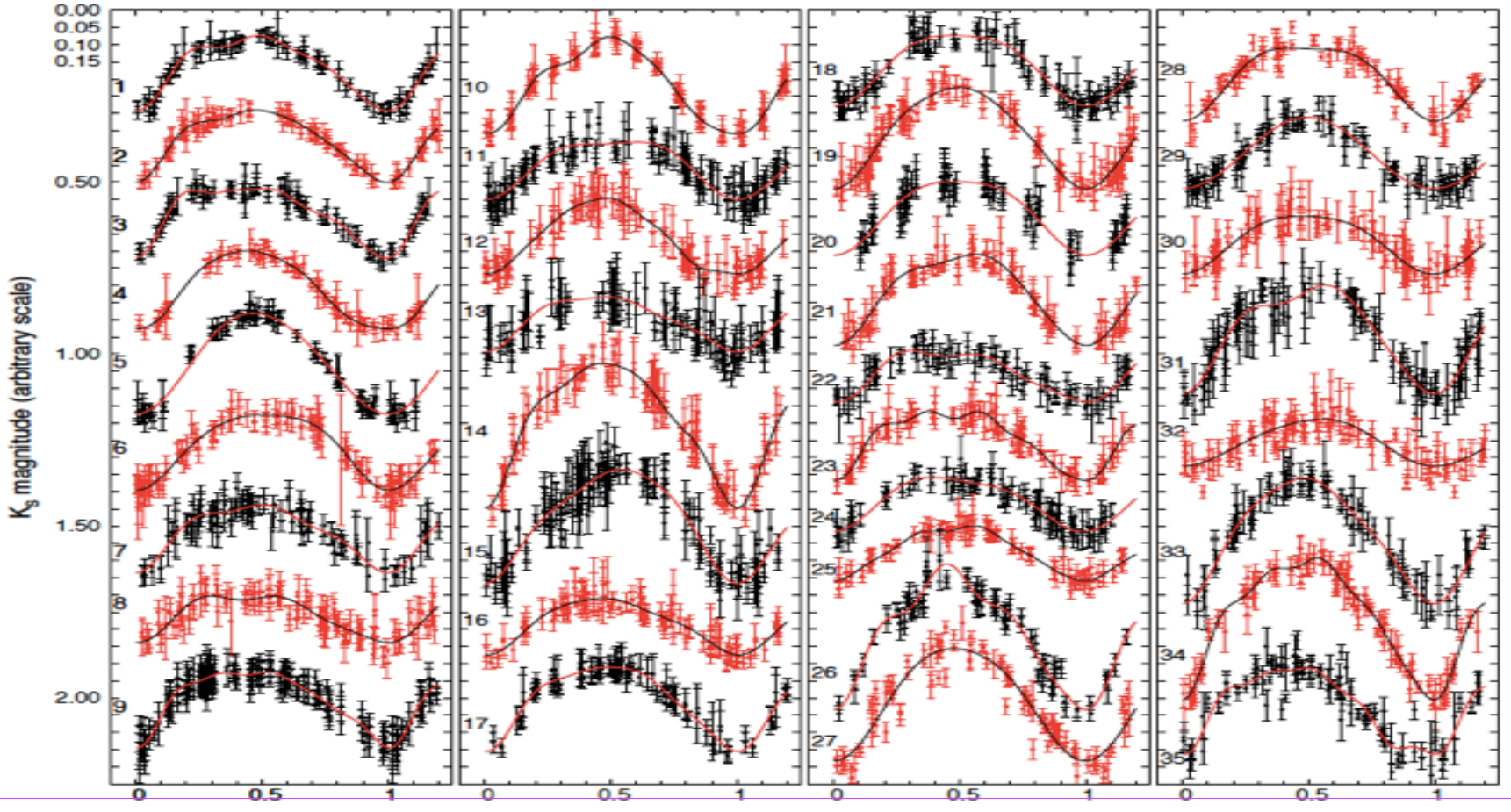
The VVV Survey reveals a number of classical Cepheids that trace a young and thin stellar disk across the Galaxy's bulge.

Cepheids in the Inner Bulge

Dekany et al. 2015b ApJL 812, L29(arXiv:1509.08402)

Main problem:

To separate classical Cepheids from Type II Cepheids (WVir)



Cepheids in the Inner Bulge

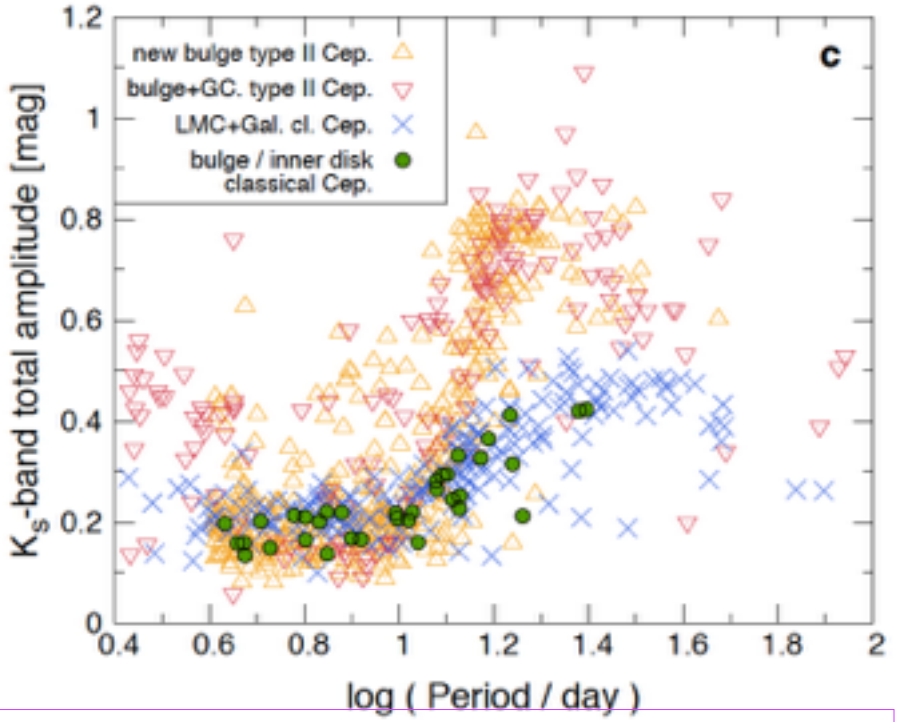
Dekany et al. 2015b ApJL 812, L29 (arXiv:1509.08402)

Main problem:

To separate classical Cepheids from Type II Cepheids (WVir)

The near-IR light curves are not enough, it is very tricky to discriminate among both possibilities using only the near-IR light curves

Solution 1: compare the dereddened distances and spatial distributions:
Type Is should be spread out across the plane
Type IIs should be concentrated to the bulge



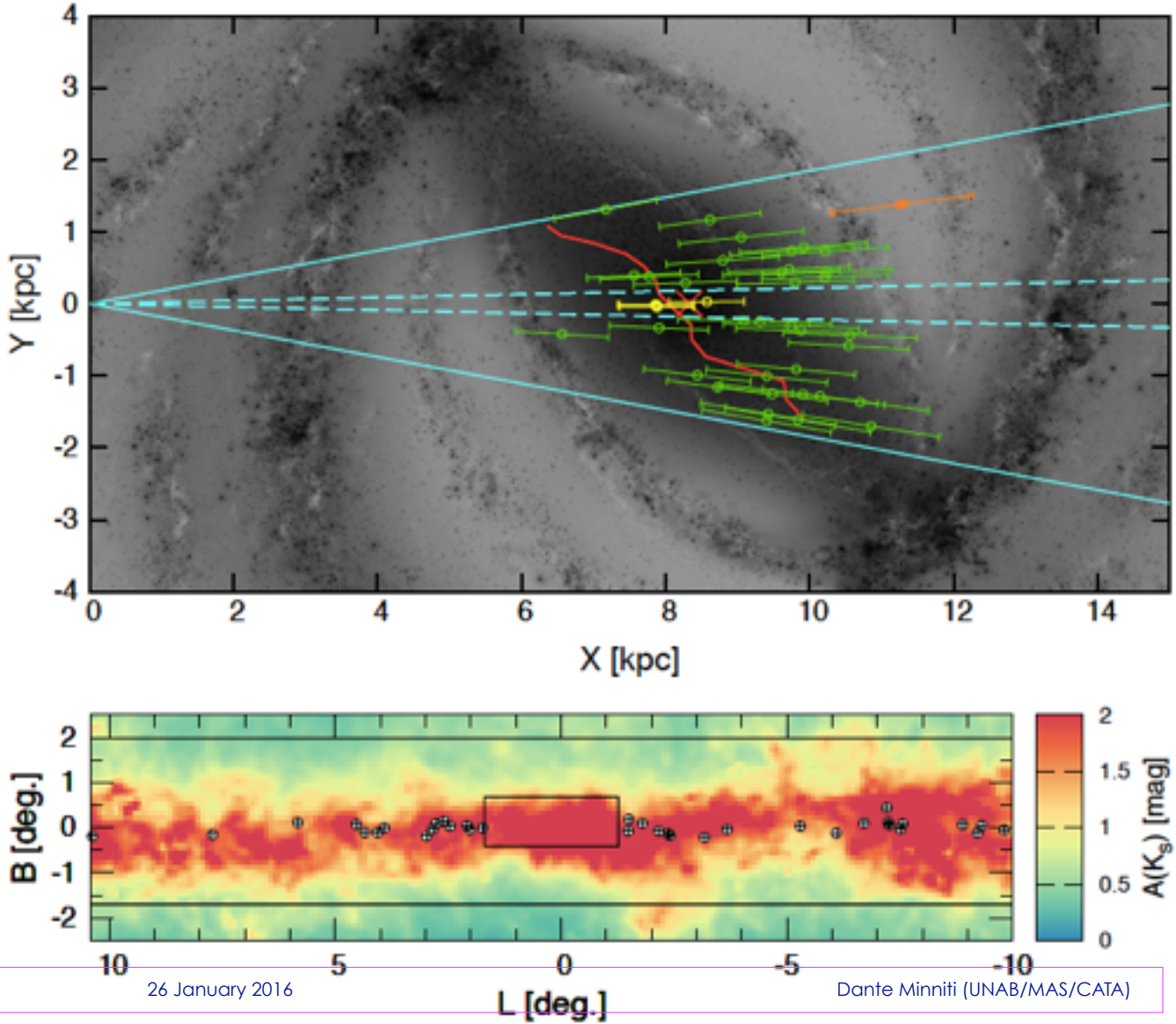
Cepheids in the Inner Bulge

Dekany et al. 2015b ApJL 812, L29 (arXiv:1509.08402)

Found a population of Classical Cepheids in the Galactic mid-plane, well within the bulge (35 Cepheids).

They trace a young and thin stellar disk all the way to the Galactic center.

Their period (age) spread indicate a continuous supply of newly formed stars over the past ~100 Myrs.



Mapping the Distant Spiral Arms

Dekany et al. 2016, in preparation

Main problem:
To separate classical Cepheids from Type II Cepheids (WVir)

The near-IR light curves are not enough, it is very tricky to discriminate among both possibilities using only the near-IR light curves

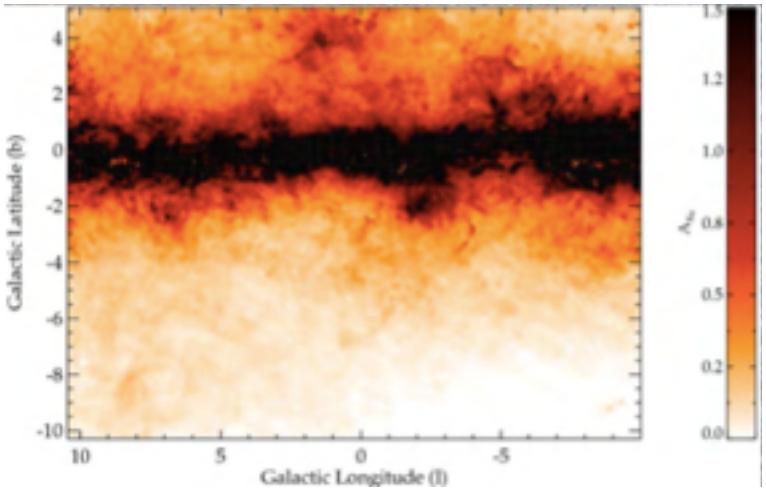
Solution 2: compare spectroscopic abundances and kinematics
Type Is should show disk RVs, be metal-rich and have Solar alpha elements
Type IIs should show larger RV spread, be metal-poor and alpha-enhanced

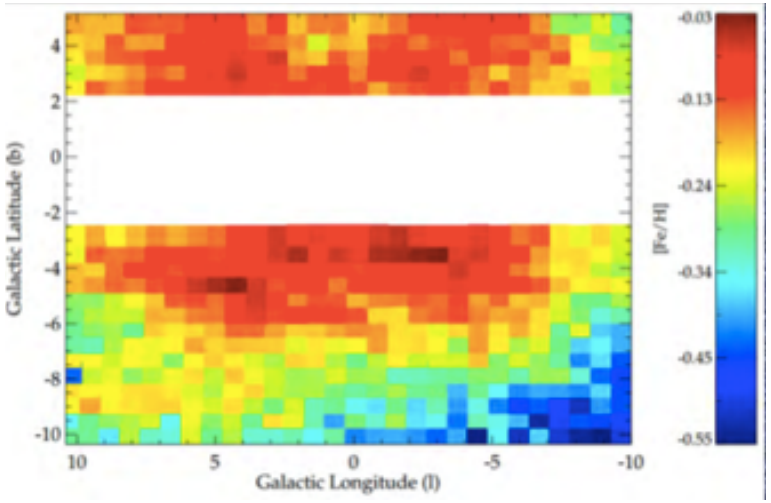
Work in progress:
We found ~600 distant Cepheids.
High S/N spectroscopy available for 52 of them.

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, 555A, 91V (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)
—> Bulge model by Wegg & Gerhard 2014

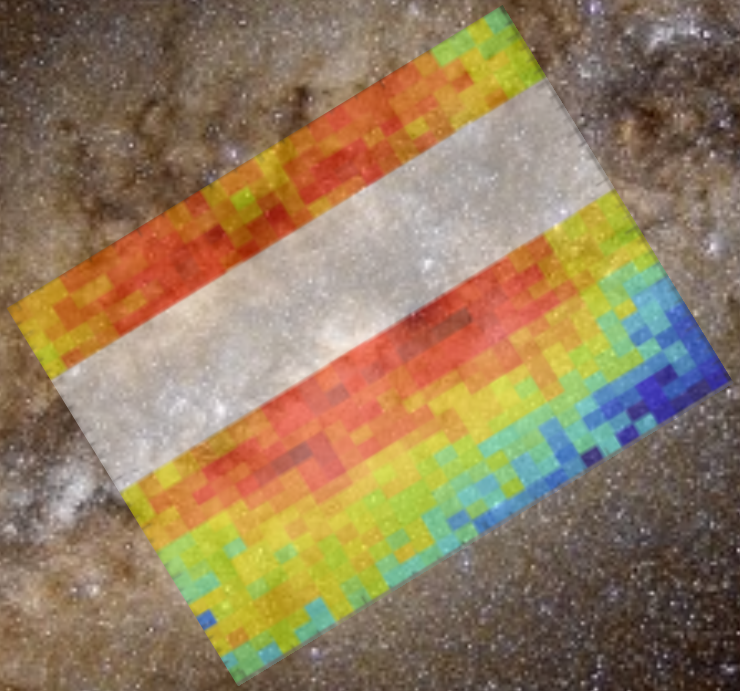
The global photometric reddening and metallicity maps of the MW bulge





Structure of the Milky Way Bulge

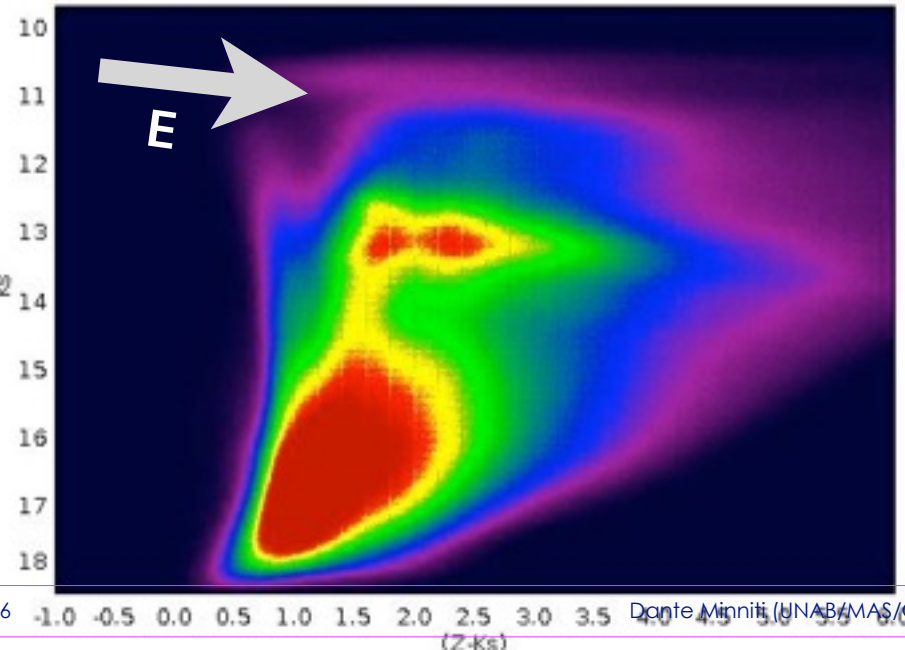
Feed targets for the GIBS spectroscopic survey
Zoccali et al. 2014



Dust Distribution and the Reddening Laws

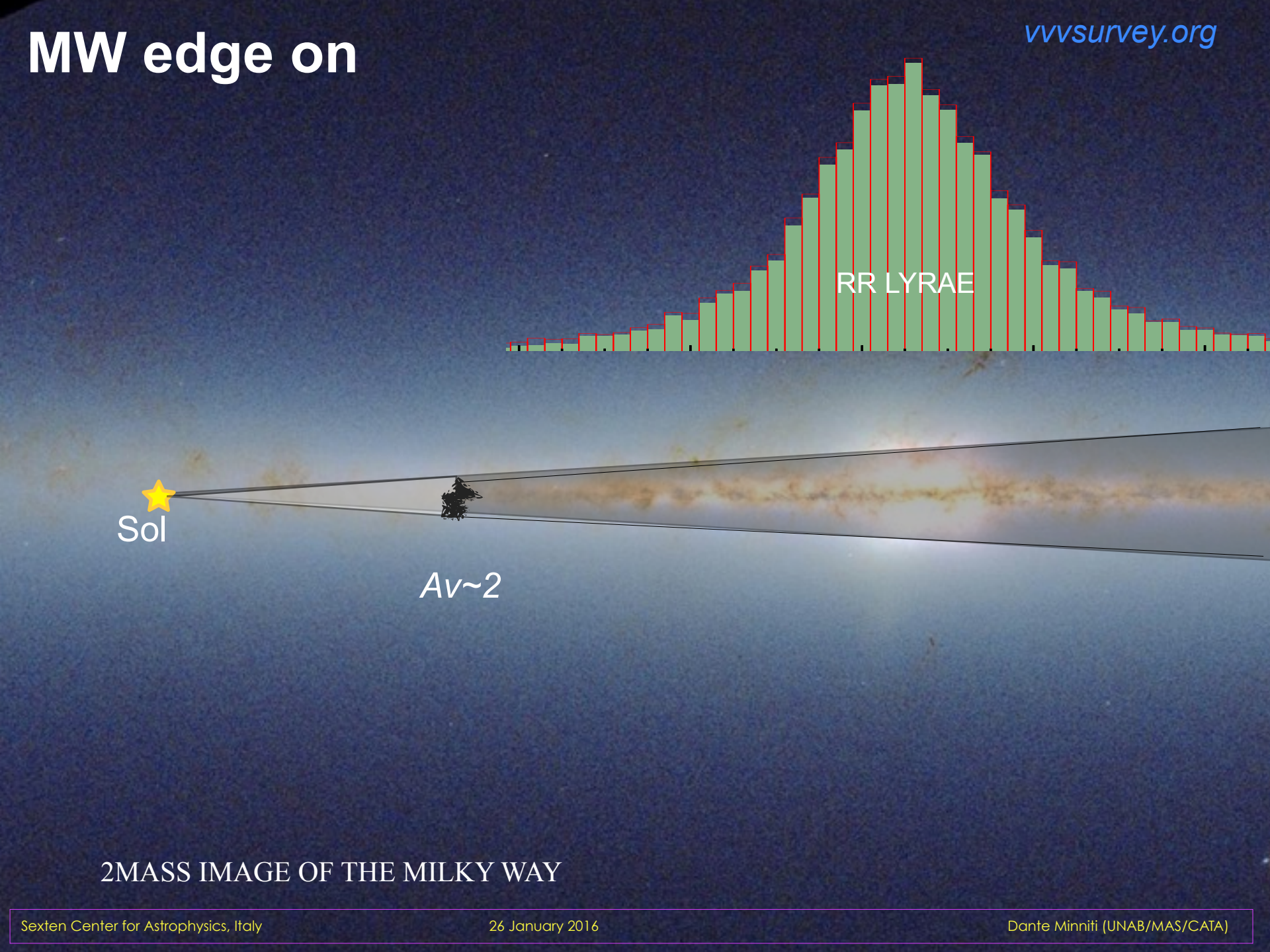
Gonzalez et al. 2012, A&A, 543, 13 (arXiv:1204.4004)
The first global photometric metallicity map of the Galactic bulge
Gonzalez et al. 2013, A&A, 552A, 110G (arXiv:1302.0243)
Chen et al. 2013, A&A, 550, 42 (arXiv:1211.3092)
Schultheis et al. 2014, A&A 566, 120 (arXiv:1405.0503)
Mapping the Milky Way Bulge at high resolution: the 3D dust extinction, CO and X factor maps
Minniti et al. 2015, A&A, 571, A91 (arXiv:1409.5836)
Nataf et al. 2015 ApJ in press (arXiv:1510.01321)
Interstellar Extinction Curve Variations Toward the Inner Milky Way

Mean red clump color difference (Z − Ks) = 0.55 mag, equivalent to AV = 2.0 mag

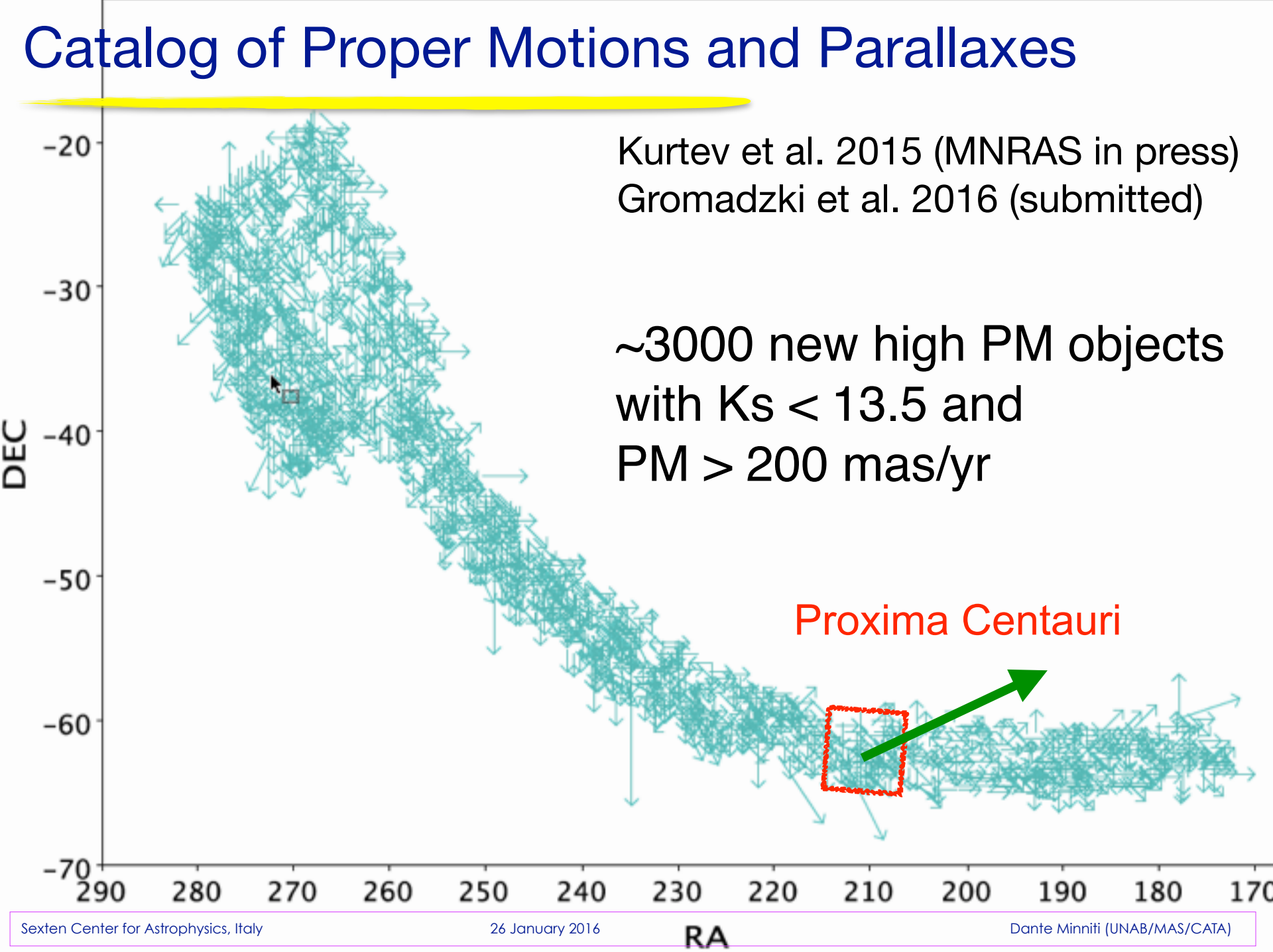


MW edge on

vvvsurvey.org



Catalog of Proper Motions and Parallaxes



Kurtev et al. 2015 (MNRAS in press)
Gromadzki et al. 2016 (submitted)

~3000 new high PM objects
with Ks < 13.5 and
PM > 200 mas/yr

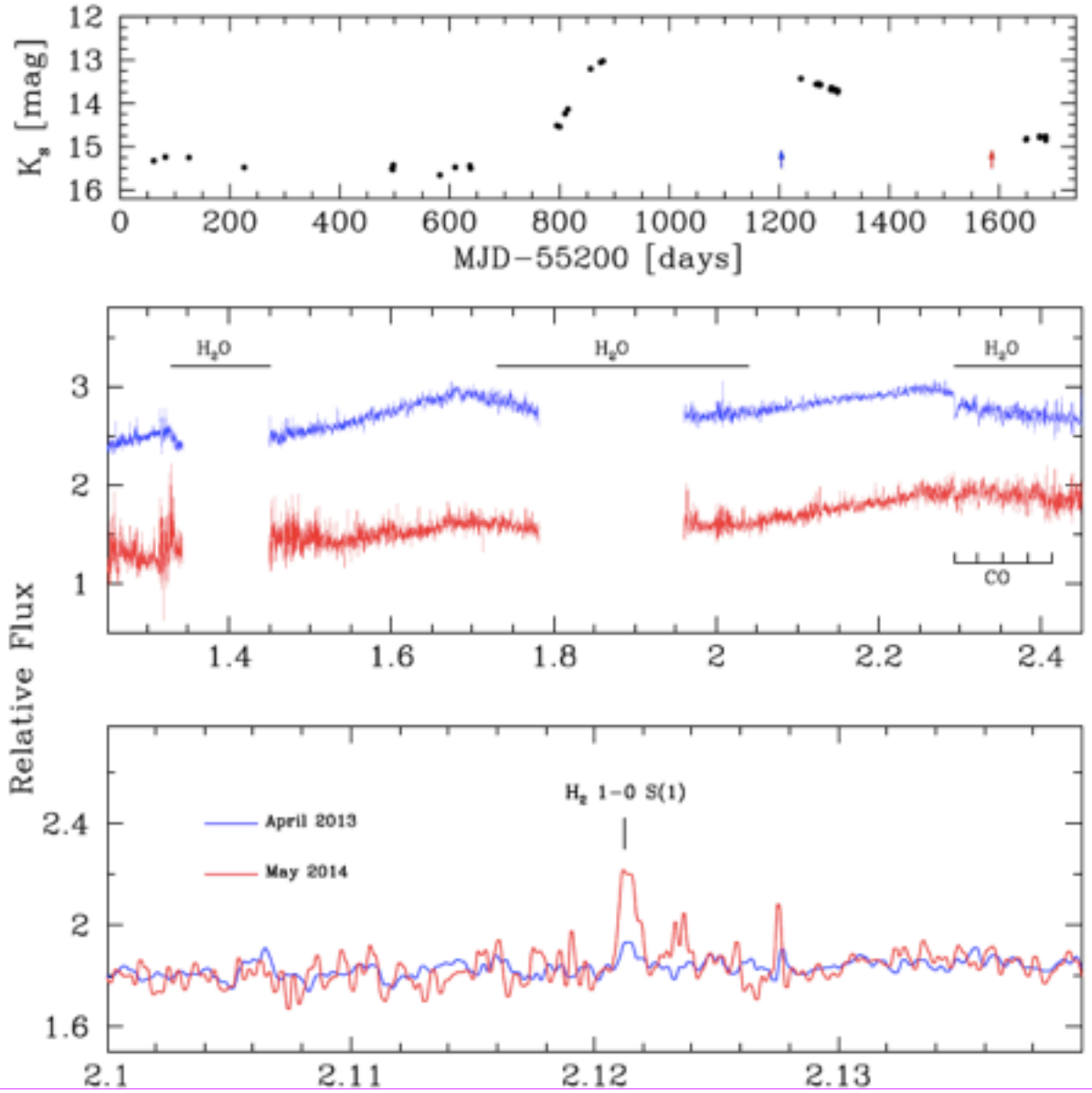
Proxima Centauri

Variable Youg Stellar Objects

Infrared spectroscopy of eruptive variable protostars from VVV

Contreras et al. 2015 (MNRAS in press),
Contreras et al. 2016 (submitted)

Eruptive variable protostars MNORs:
a new class of YSO variables



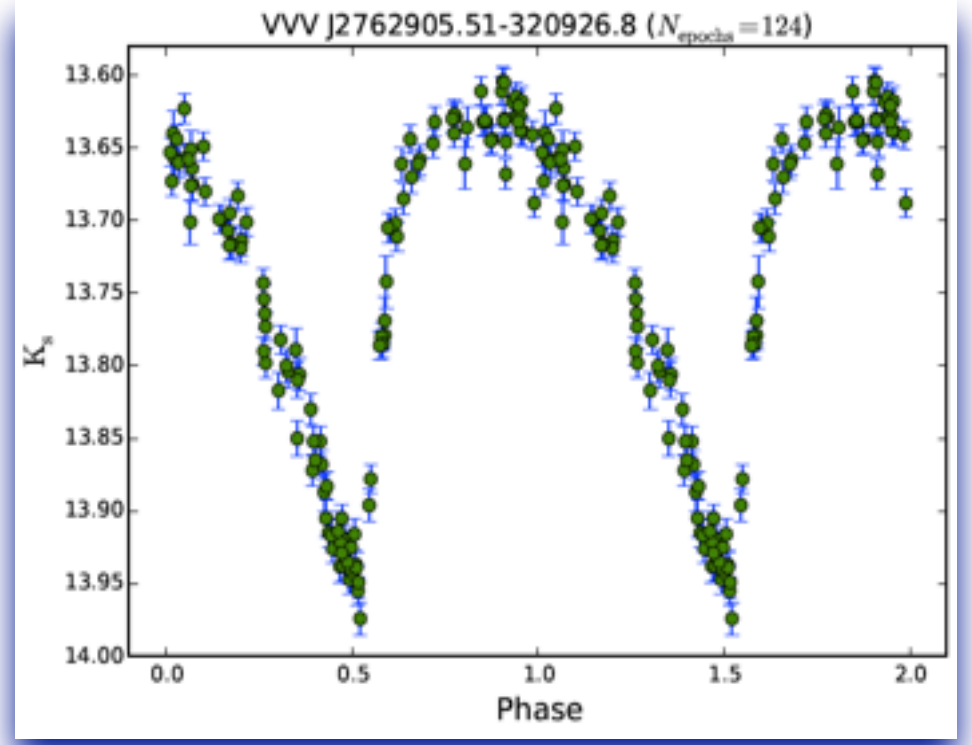
Template Light Curves Database

Angeloni et al. 2014, A&A 567, 100 (arXiv:1405.4517)

The VVV Templates Project Towards an Automated Classification of VVV Light-Curves: Building a database of stellar variability in the near-infrared. Our database contains near-IR light-curves for:

RR Lyrae
Cepheids
Eclipsing Binaries
Delta Scutis
Cataclysmic Variables
etc.

vvvsurvey.org



Hundreds of New Star clusters

Borissova et al. 2015 A&A (arXiv:1406.7051)
Barba et al. 2015 A&A 581, 120 (arXiv:1505.02764)

Discovery of >700 star clusters.

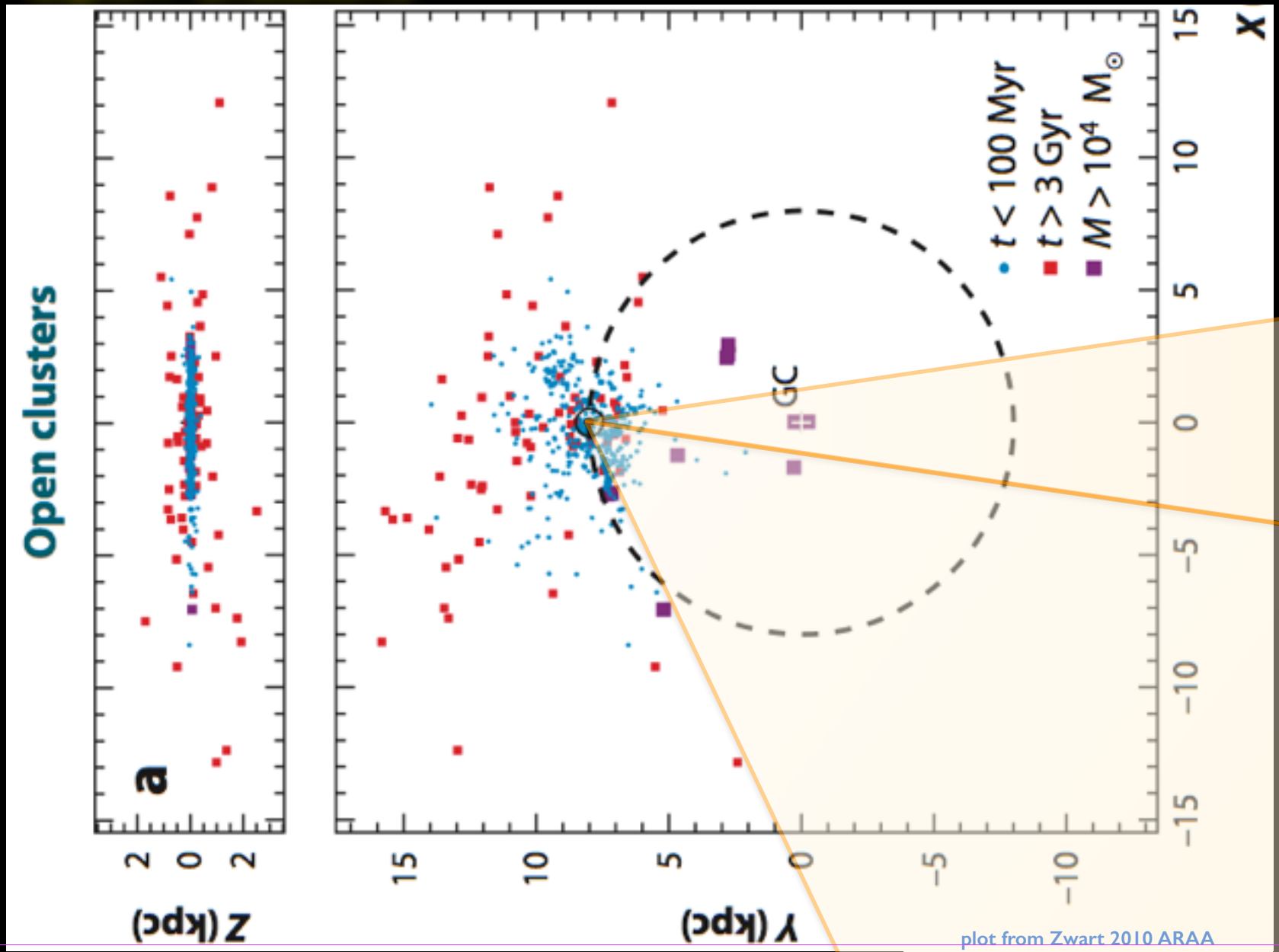
Make CMDs and measure their proper motions, sizes and reddenings.

Estimate their ages, masses, and distances.

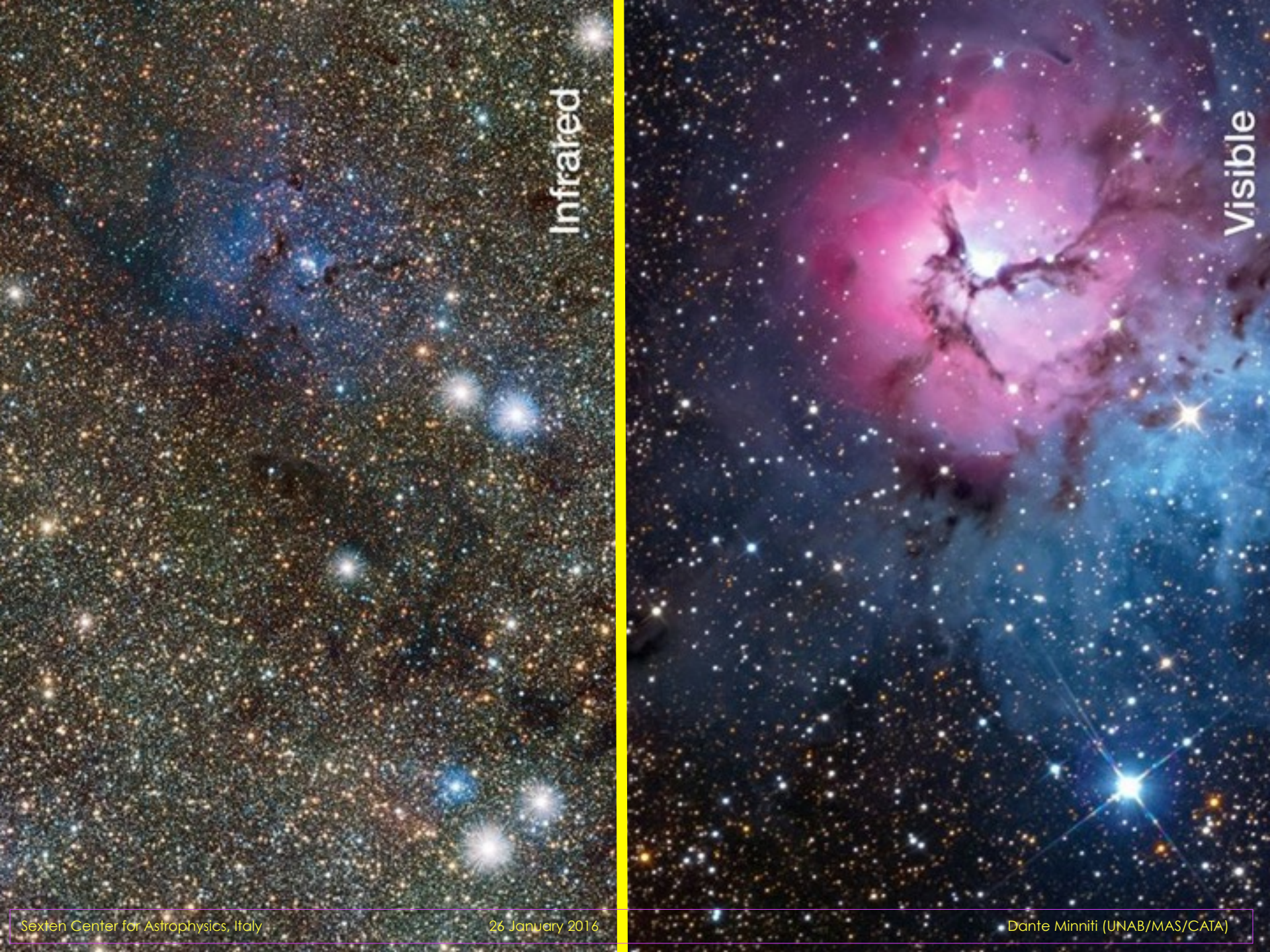
Spectroscopic follow-up: measure their chemical compositions and VRs.

Open Clusters

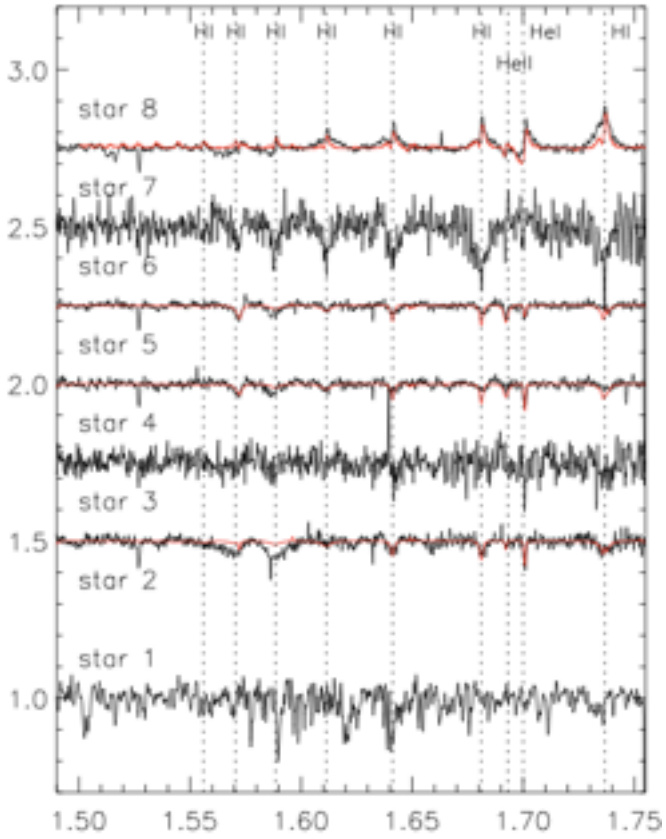
P. Zwarts, ARAA 2013



plot from Zwart 2010 ARAA


Infrared
Visible

A Very Massive Star Candidate



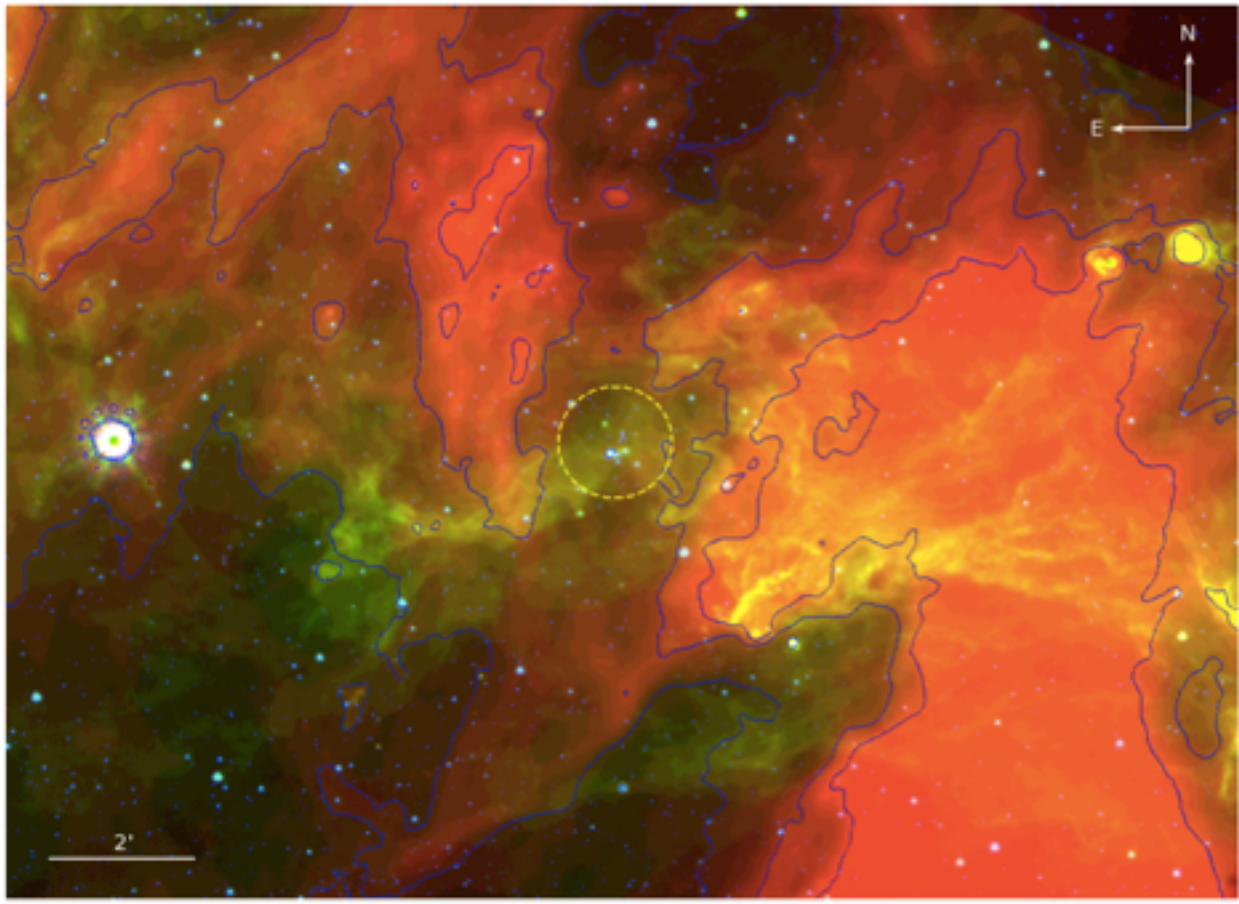


Fig. 7. Three-color K_S (blue), GLIMPSE 8 μm (green), and MIPS 24 μm (red) images of the region around VVV CL041. Blue lines are showing the 90, 170 and 250 MJy/sr contours in the MIPS image. The cluster is indicated by a yellow, dashed circle.

A. Chené et al. (2015)

A Very Massive Star Candidate

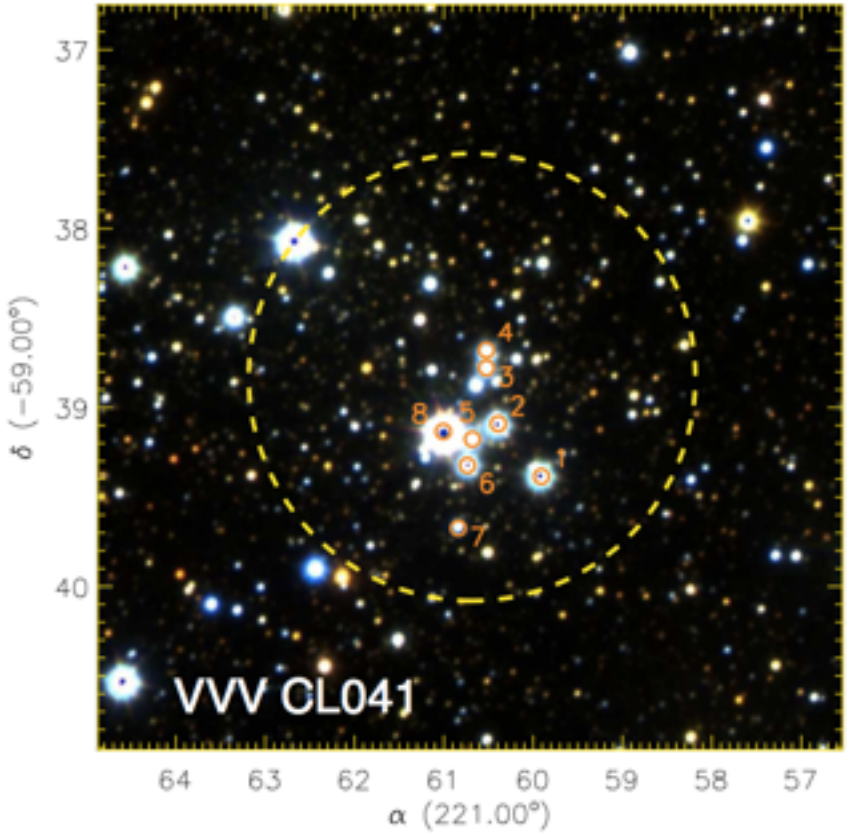


Fig. 1. *JHK*$_s$ false-colour images of VVV CL041. Stars marked with red circles were observed using near-IR spectrographs. Yellow dashed circles indicate the angular sizes of the cluster (see Section 3). Coordinates are given in the J2000 system.

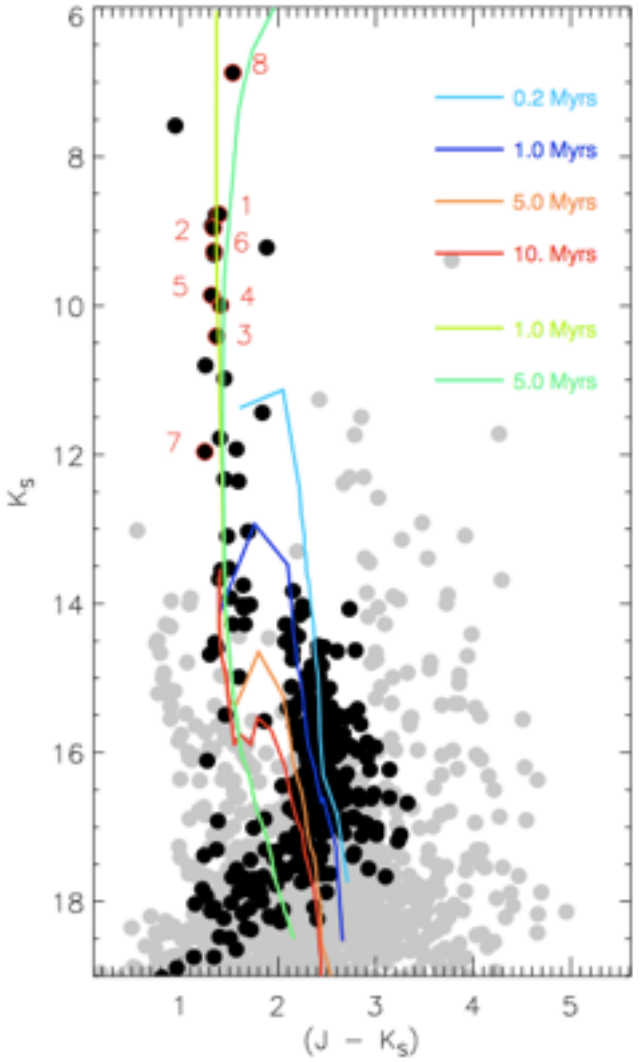
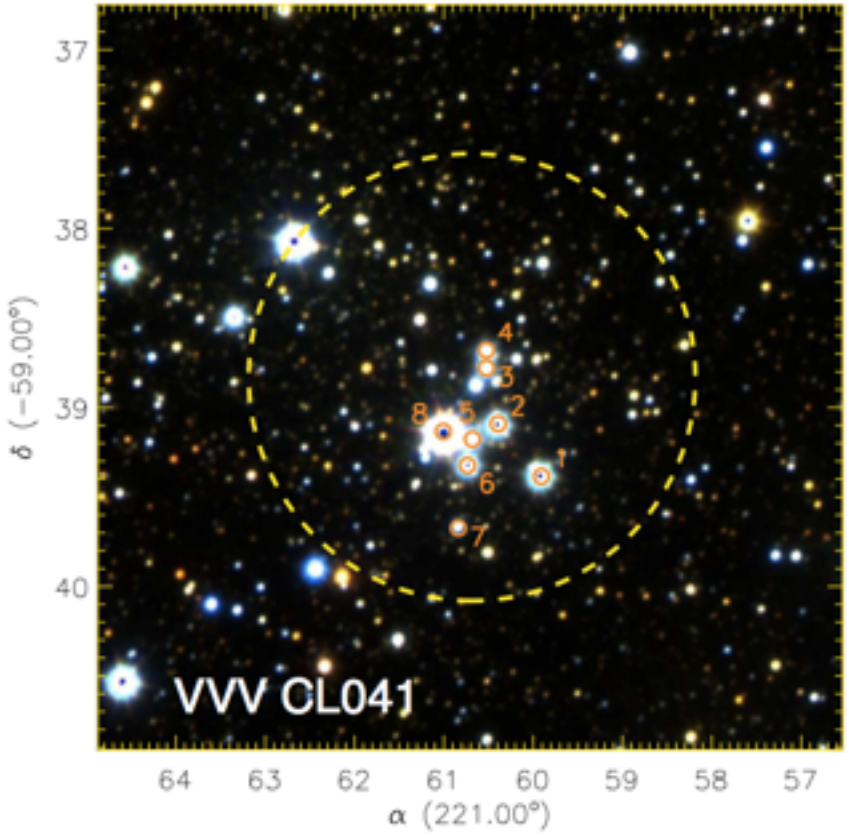


Fig. 4. $(J - K_s)$ vs. K_s colour magnitude diagram for VVV CL041. Spectroscopic targets are marked using red circles. The PMS isochrones are shown in light blue (0.2 Myr), dark blue (1.0 Myr), orange (5.0 Myr) and red (10 Myr), while the two upper and lower limits of fitted MS isochrones are shown in light and dark green.

A. Chené et al. (2015)

A Very Massive Star Candidate



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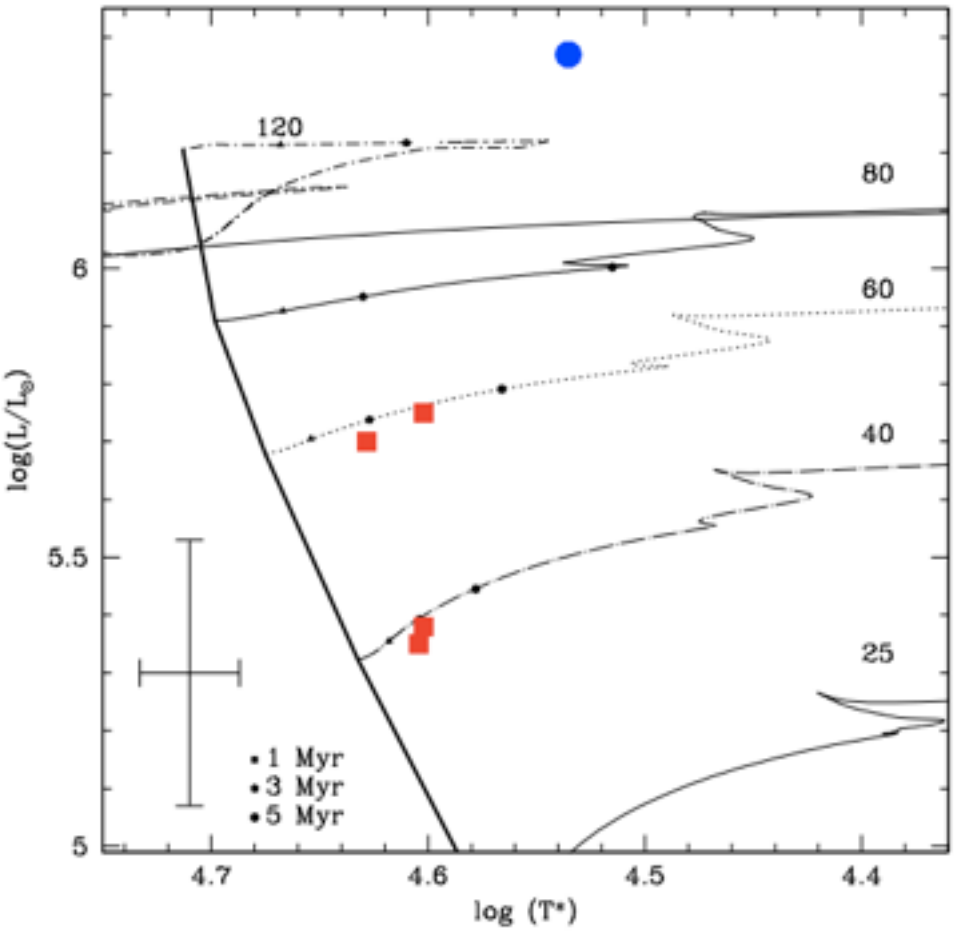

Fig. 6. HR diagram with the O and WNh stars shown respectively by squares and circles. The evolutionary tracks are from Chieffi & Limongi (2013). They include rotation. The symbols along the tracks correspond to ages of 1, 3 and 5 Myr.

A. Chené et al. (2015)

The vvvx Survey: A New Exploration of the Milky Way

exploring our own galaxy,
fostering international collaborations,
promoting Astrophysics at every level, &
securing resources for the future generations.