VVV

VISTA VARIABLES IN THE VIA LACTEA

GES

GAIA-ESO SURVEY

Bárbara Rojas-Ayala,
Dante Minniti & the
VVV Science Team

IA-CAUP

U. Andrés Bello

The VVV Science Team

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]

VISTA Telescope

- 4.1m diameter
- IR optimized
- large field

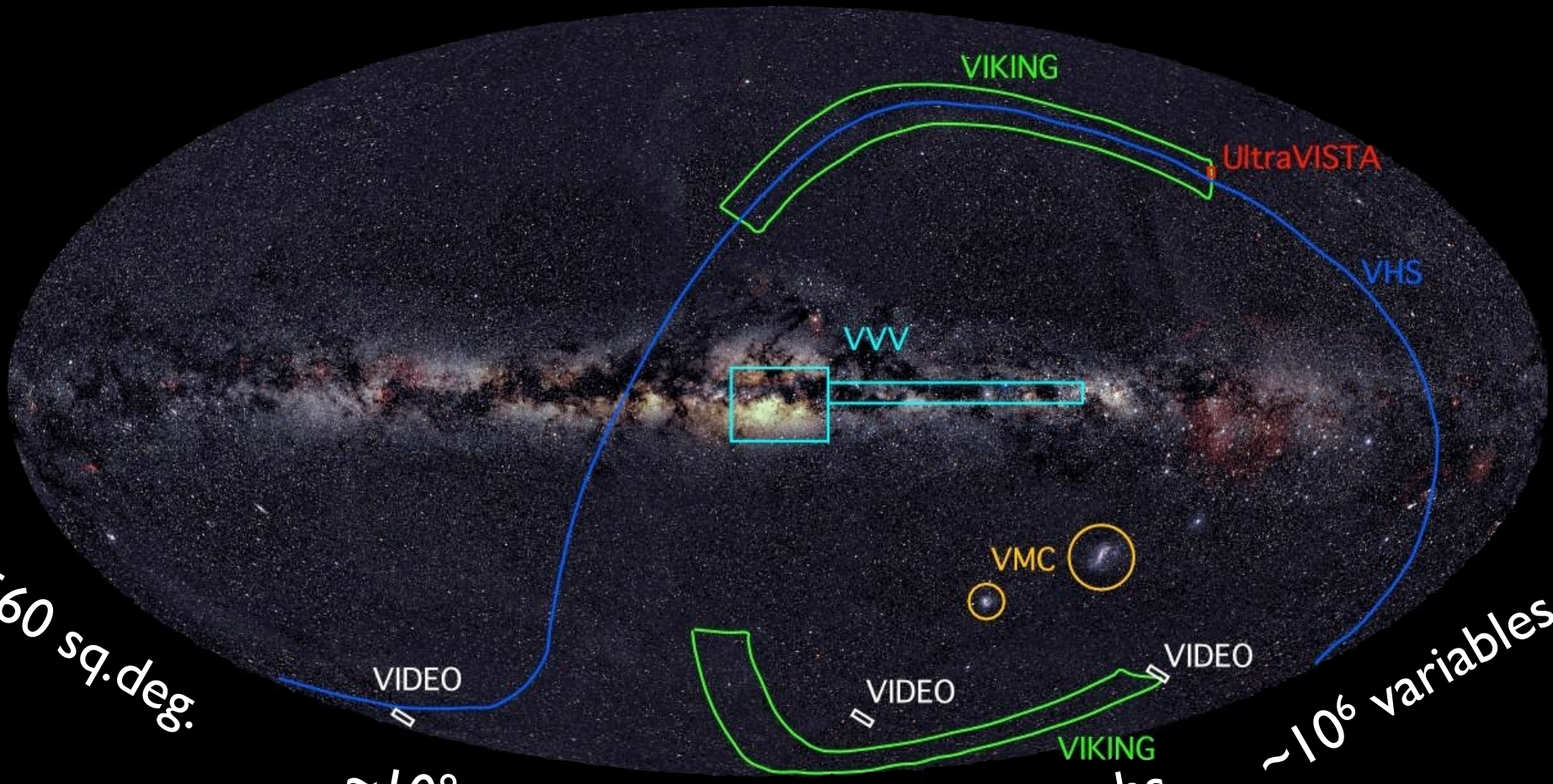
vvvsurvey.org

Visible and Infrared Survey Telescope for Astronomy @Paranal

VISTA PUBLIC SURVEYS

VISTA VARIABLES IN THE VIA LACTEA

VVV

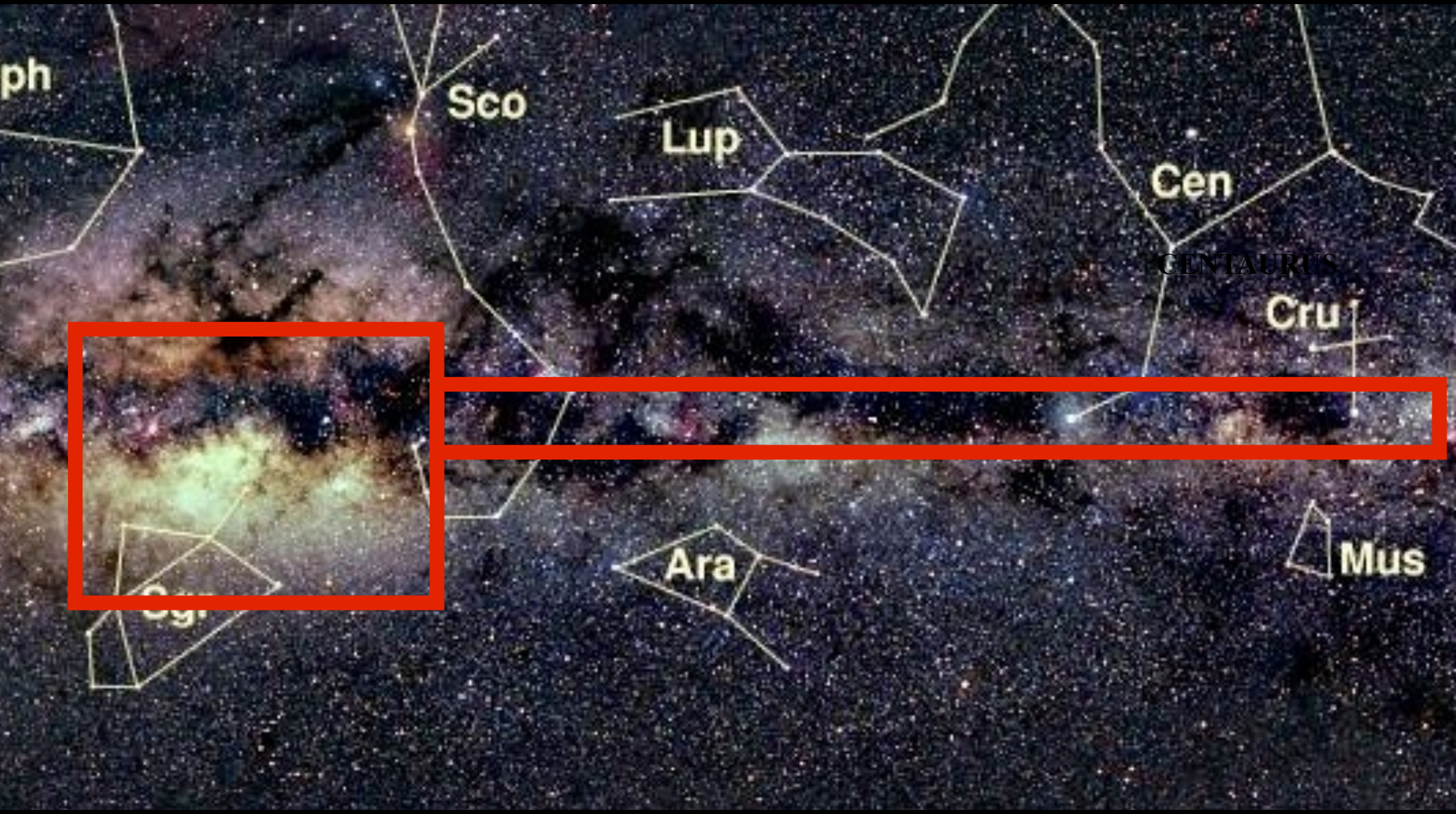


560 sq.deg.

~10^9 stars

~100 epochs

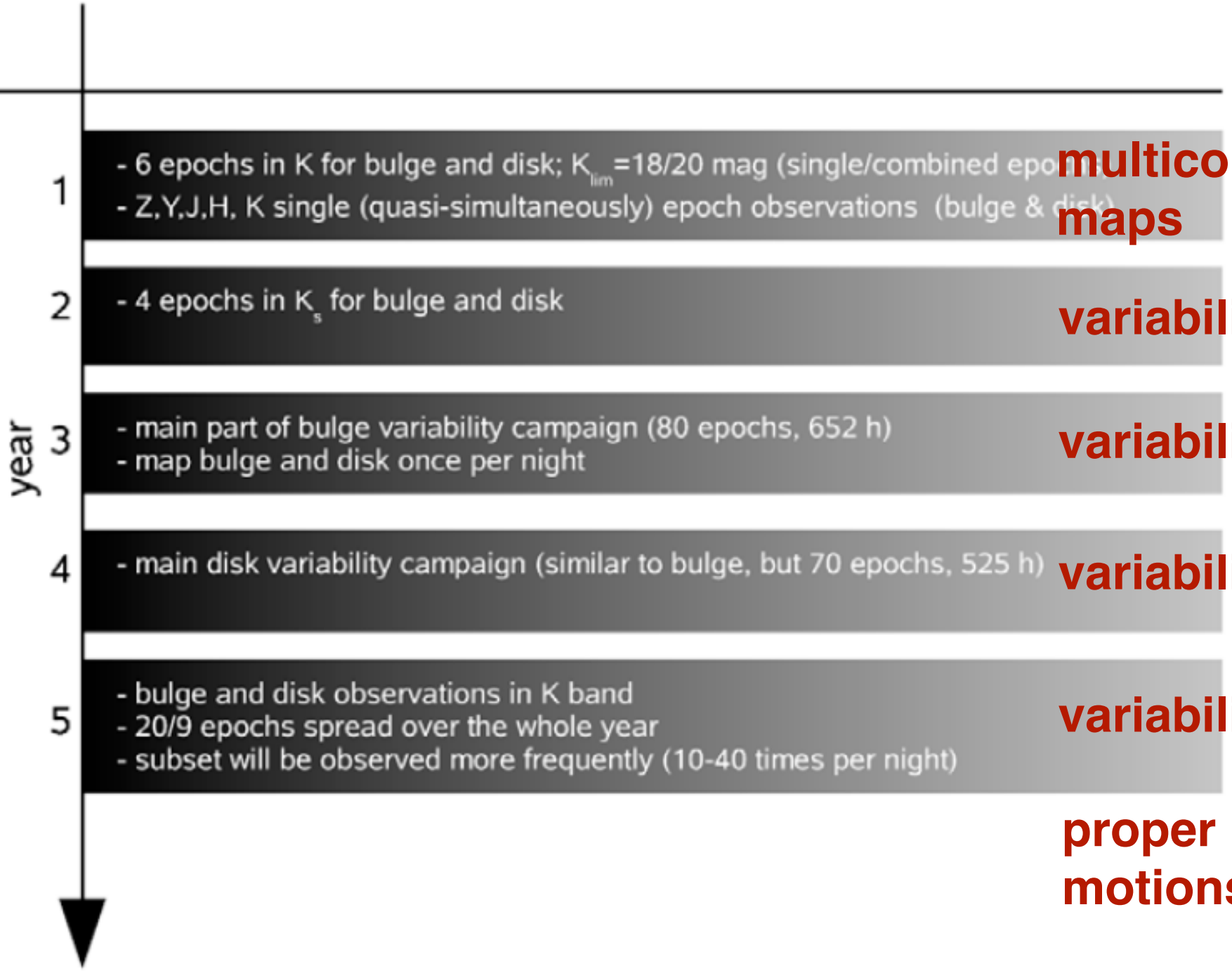
~10^6 variables



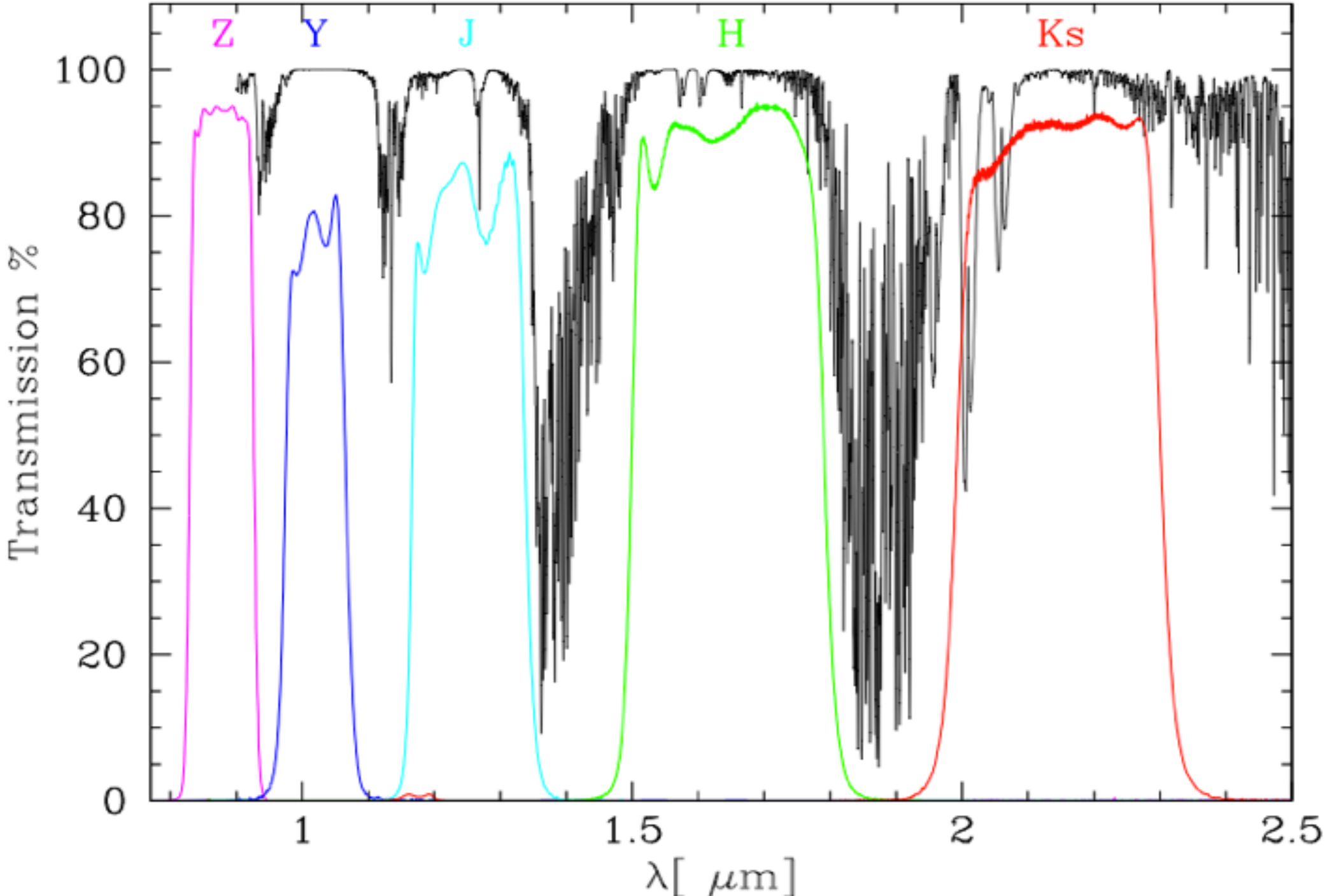
VVV maps 560 sqdeg in the central region of the MW.

The most difficult region of our galaxy...

The VVV Survey: Timeline

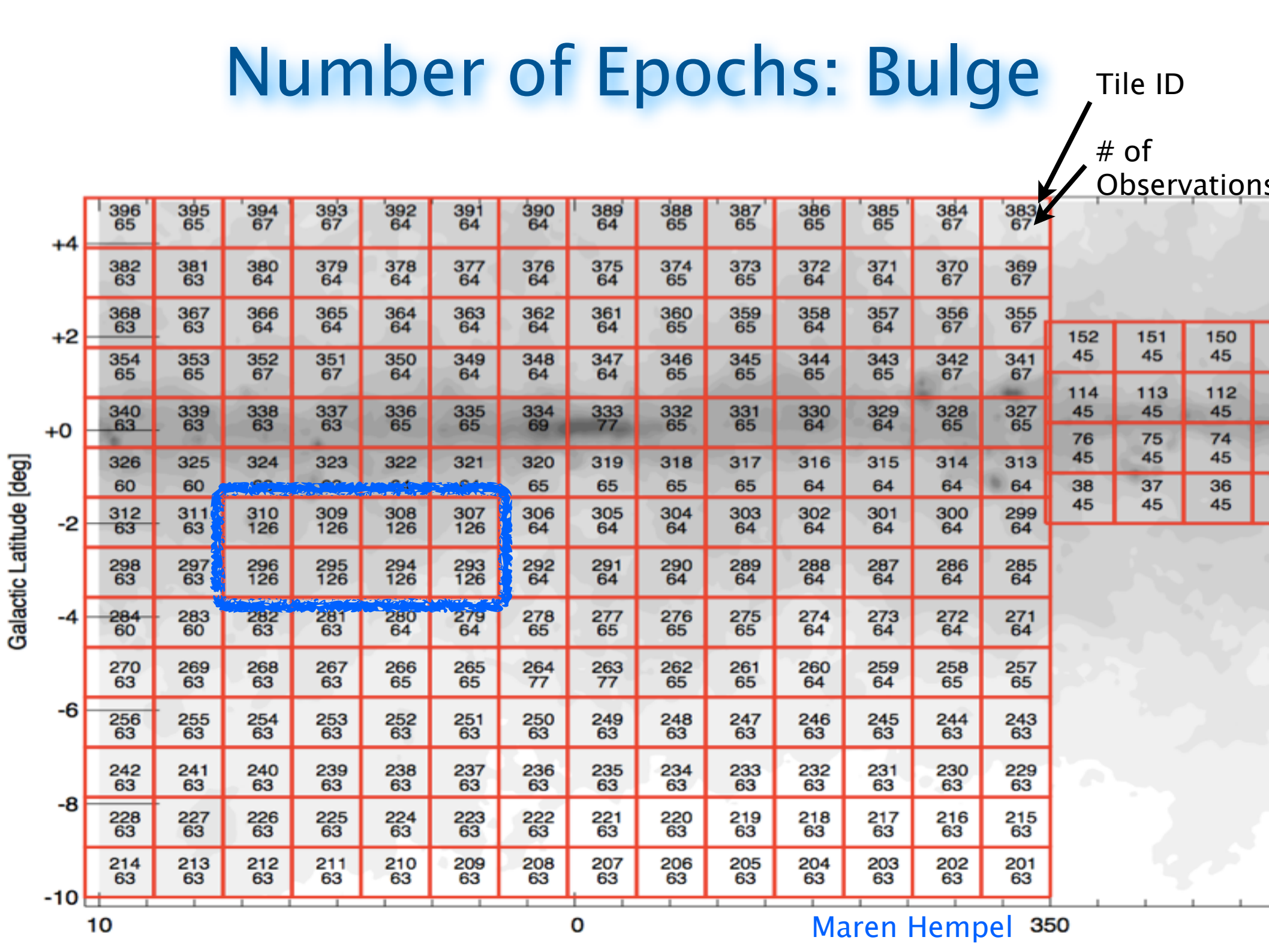


VISTA filter transmissions




VVV
Survey

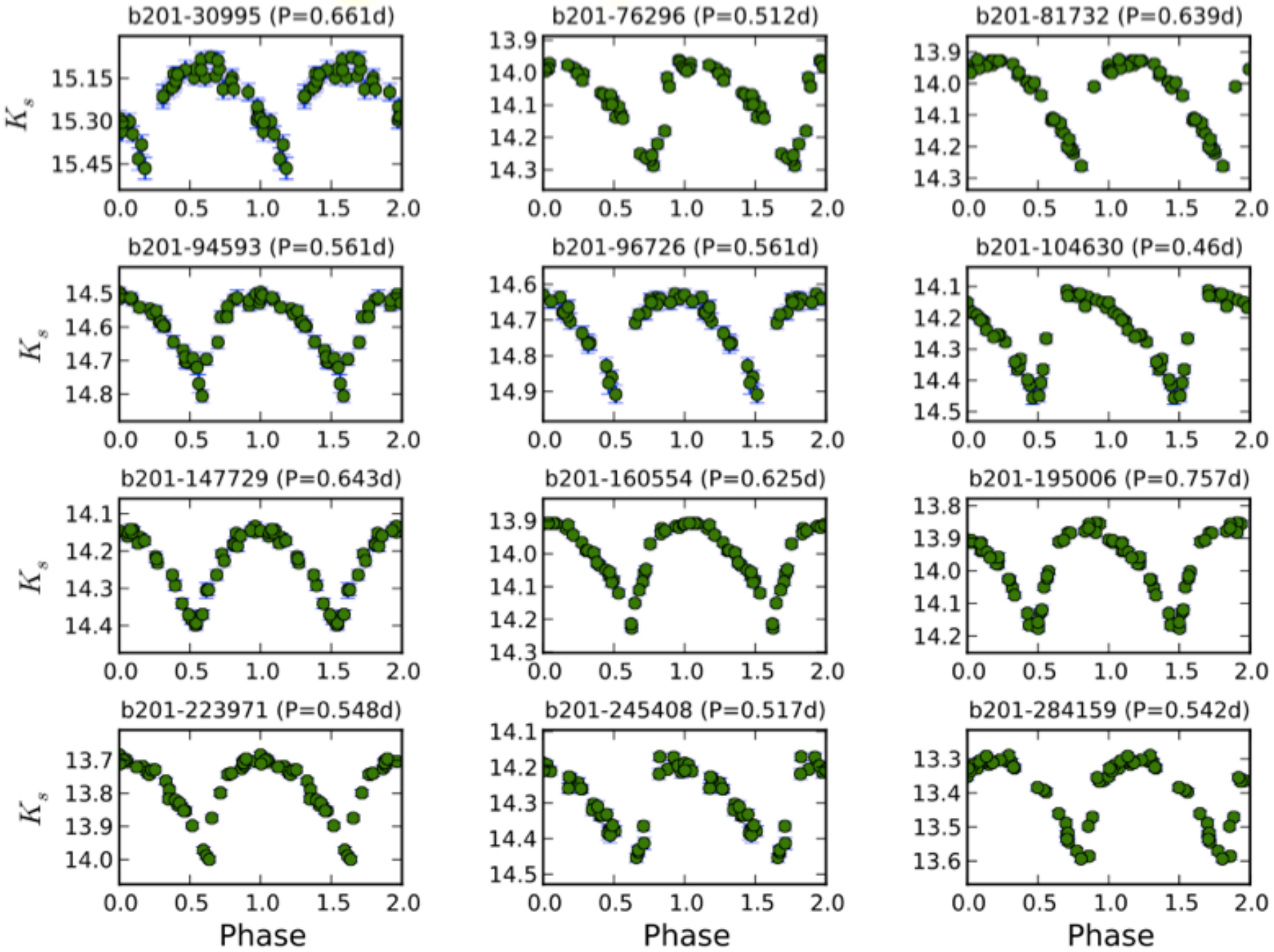
Number of Epochs: Bulge



Maren Hempel

Bulge RR Lyrae

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



The VVV Stages

Multicolor Photometry: ZYJHKs

Star clusters, stellar pops, extinction, metallicities, galaxies...

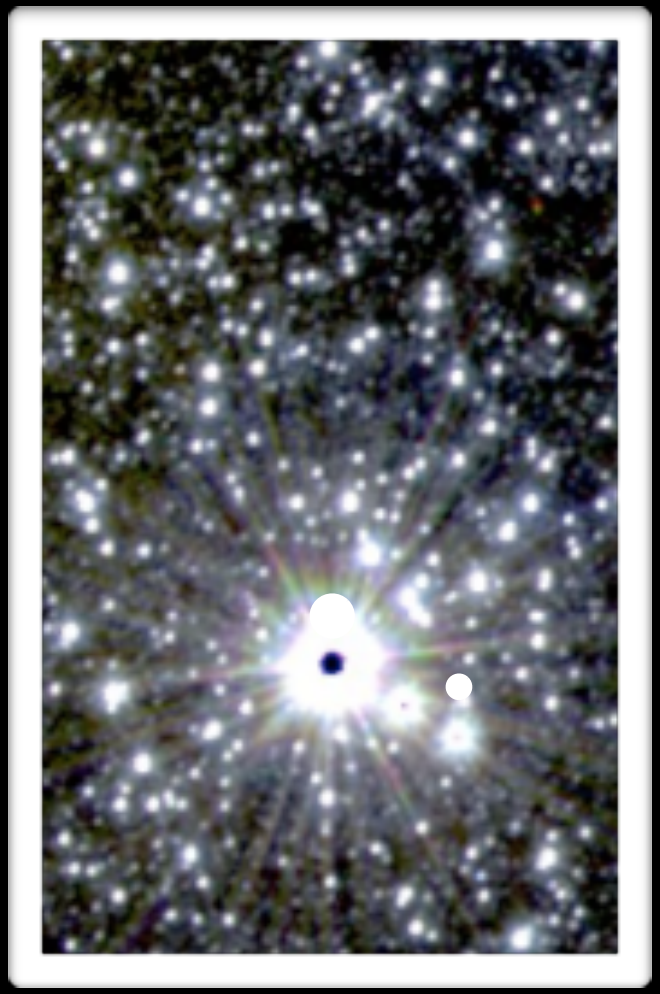
Variability: Ks

LPVs, Cepheids, RR Lyrae, Binaries, Novae, Microlensing...

Proper Motions: Ks

Nearby stars, BDs, WDs, Asteroids, Hyper-Velocity Stars...

DEEPER AND HIGHER RESOLUTION



VVV

2MASS

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)

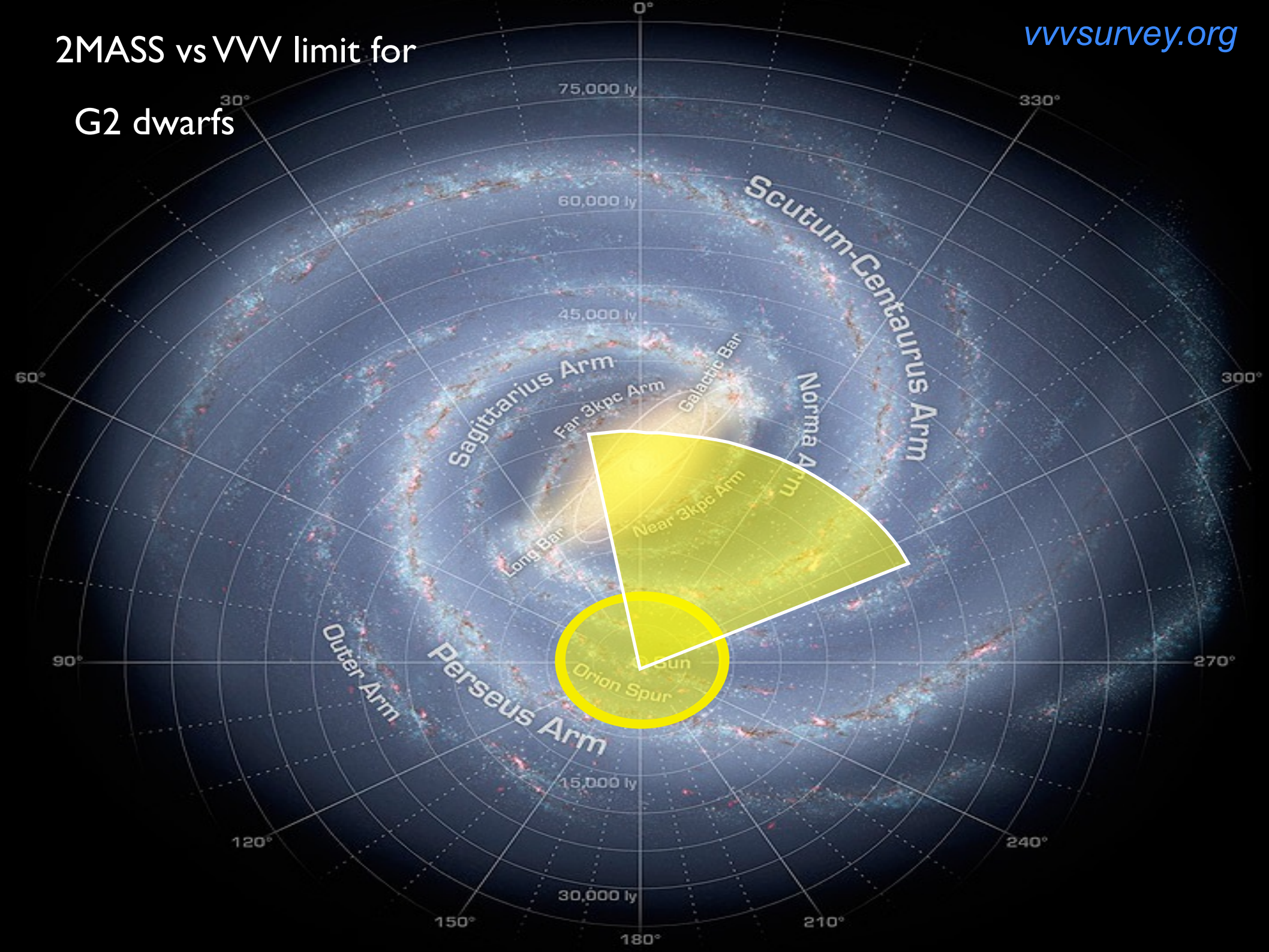
VVV has 5 filters (ZYJHKs)

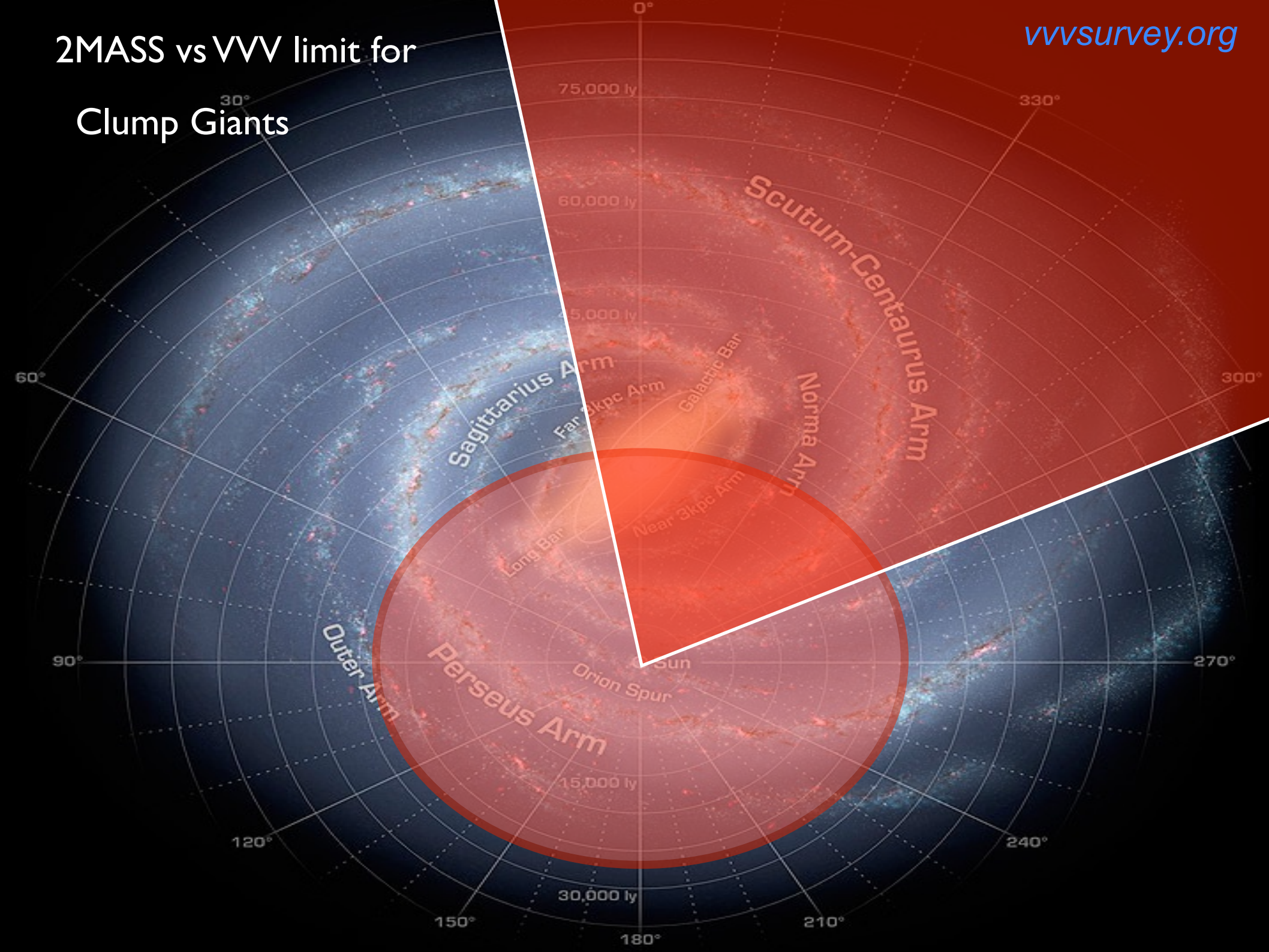
VVV is a multiepoch survey (~100 epochs)

2MASS vs VVV limit for

G2 dwarfs

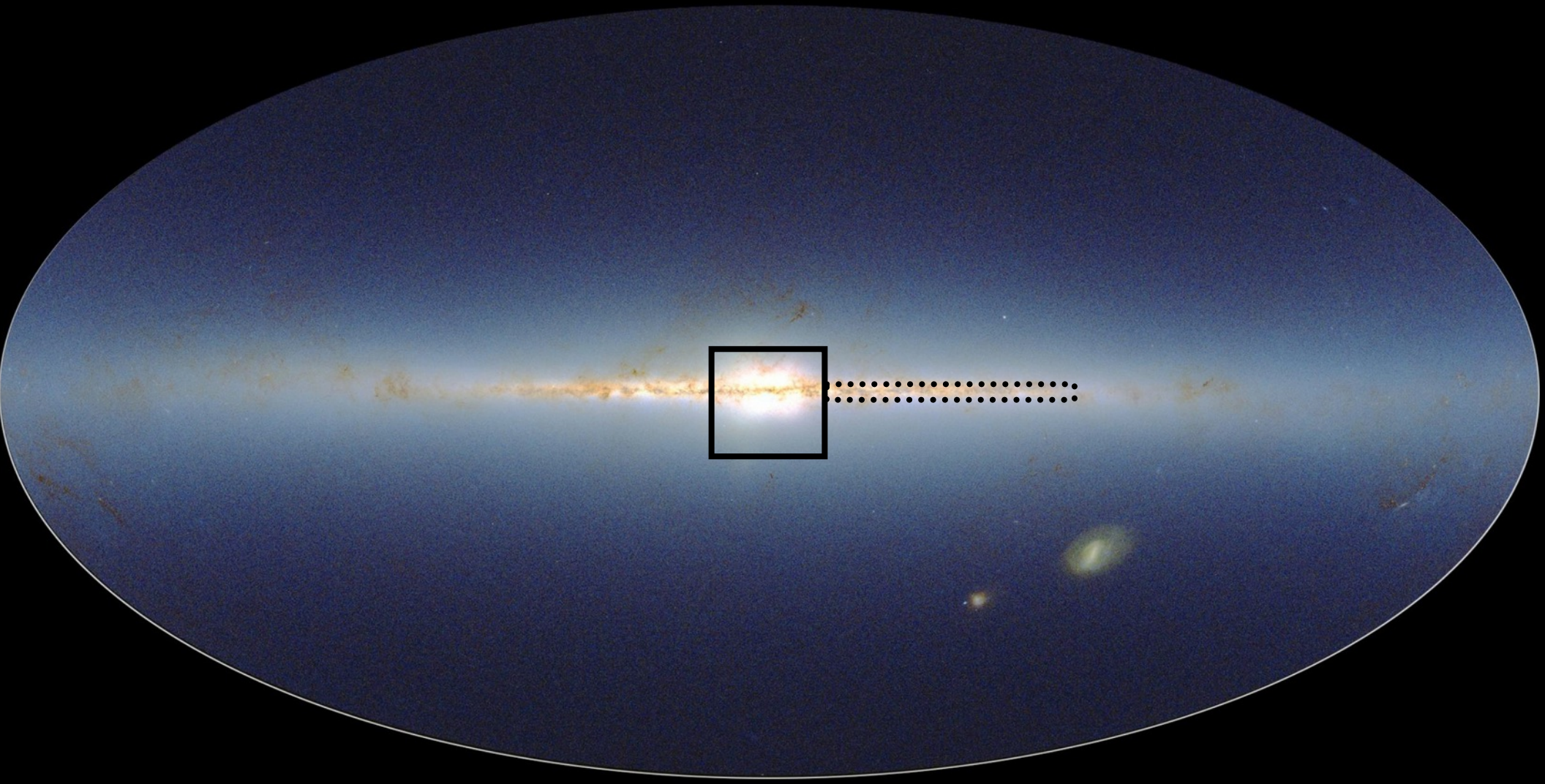
vvvsurvey.org




2MASS vs VVV limit for
Clump Giants
vvvsurvey.org
0°
30°
330°
60°
300°
90°
270°
120°
240°
150°
210°
180°
75,000 ly
60,000 ly
30,000 ly
15,000 ly
Scutum-Centaurus Arm
Sagittarius Arm
Perseus Arm
Outer Arm
Norma Arm
Galactic Bar
Long Bar
Near 3kpc Arm
Orion Spur
Sun

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

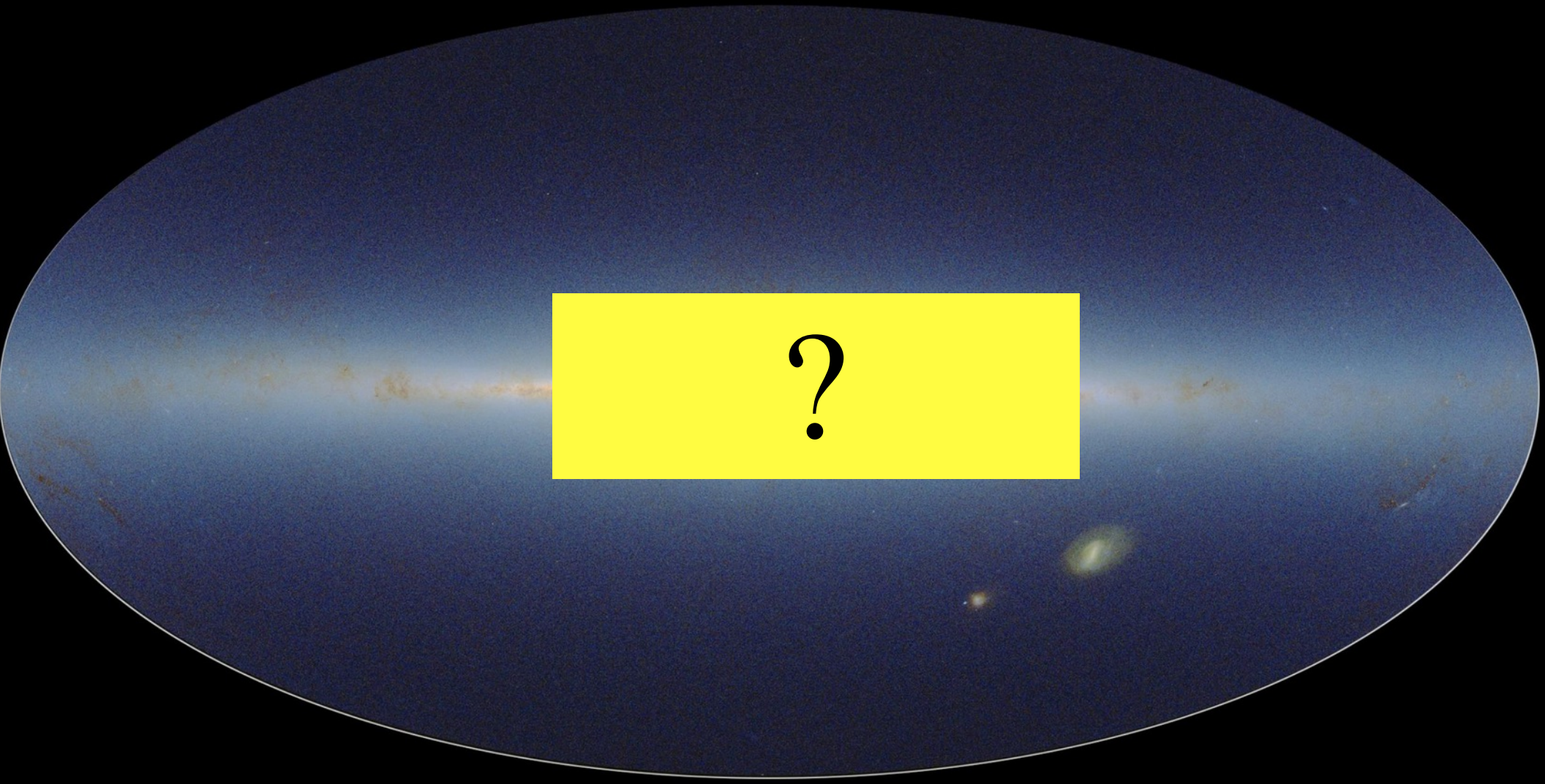
vvvsurvey.org



2MASS IMAGE OF THE MILKY WAY

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

vvvsurvey.org



2MASS IMAGE OF THE MILKY WAY

VVV Goal

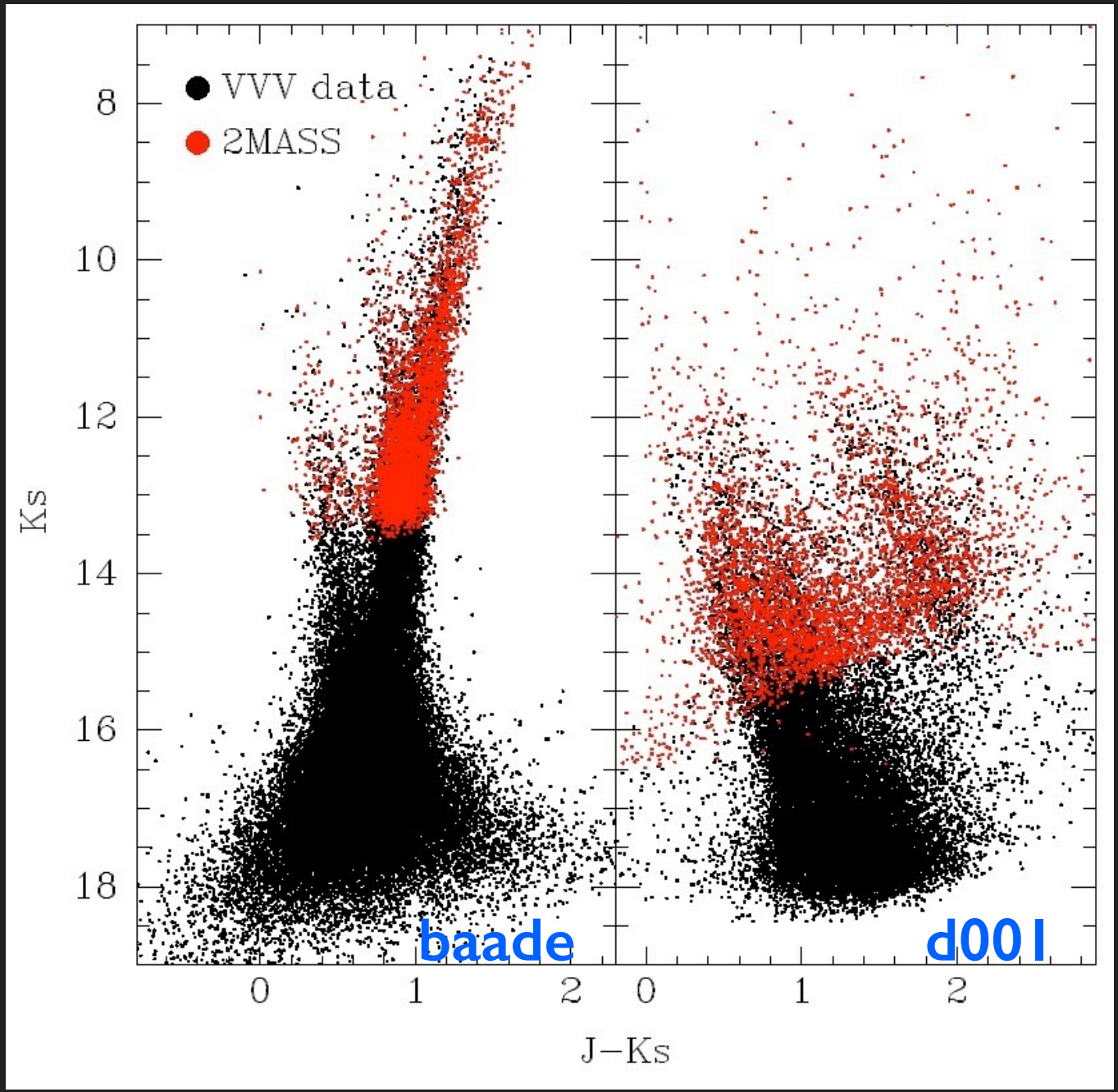
What is the 3-D structure of the Milky Way

... try and take over the Galaxy!

vvvsurvey.org

VVV CMDs

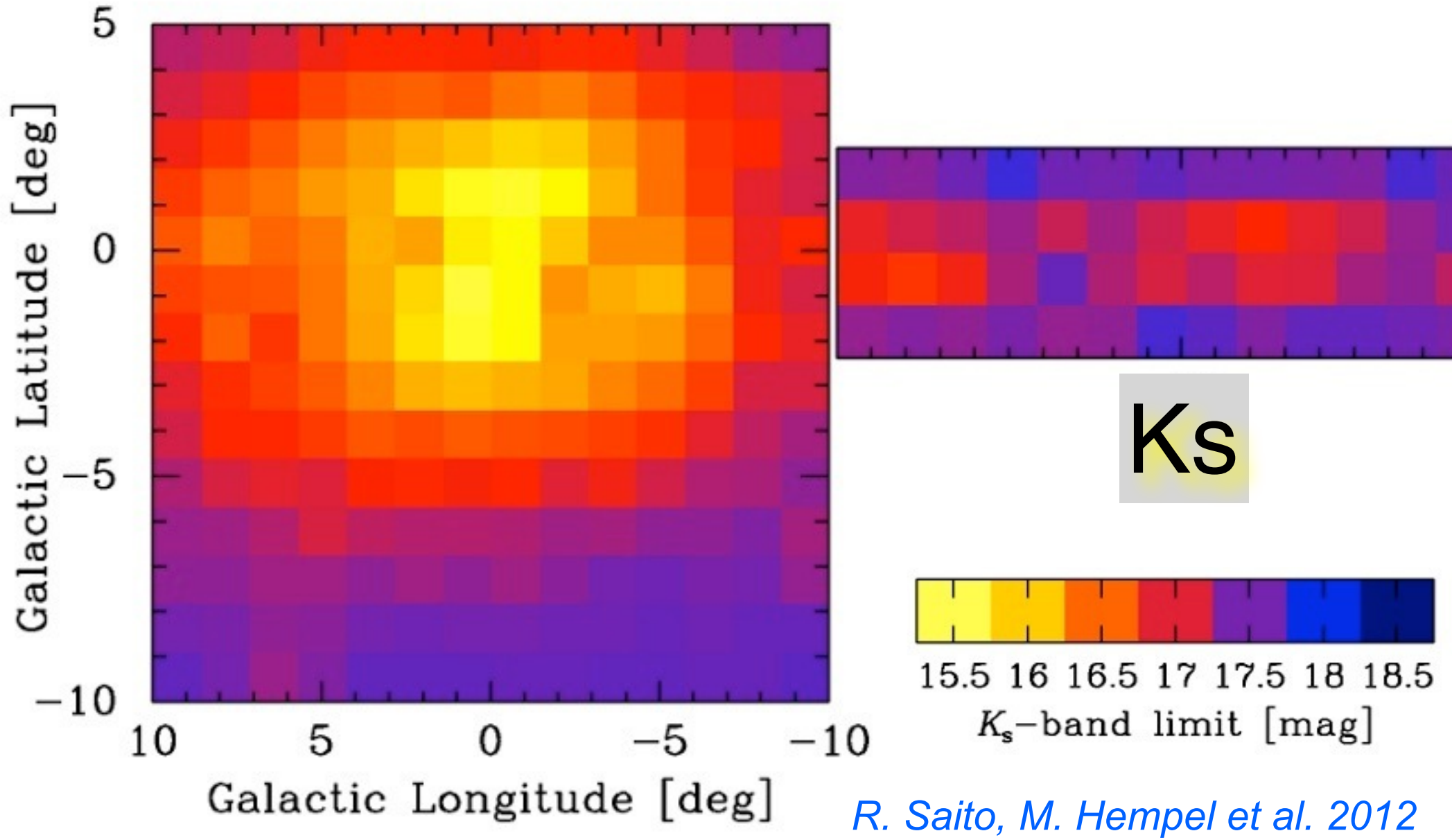
Color-magnitude diagrams of bulge and disk fields compared with 2MASS.



Oscar Gonzalez

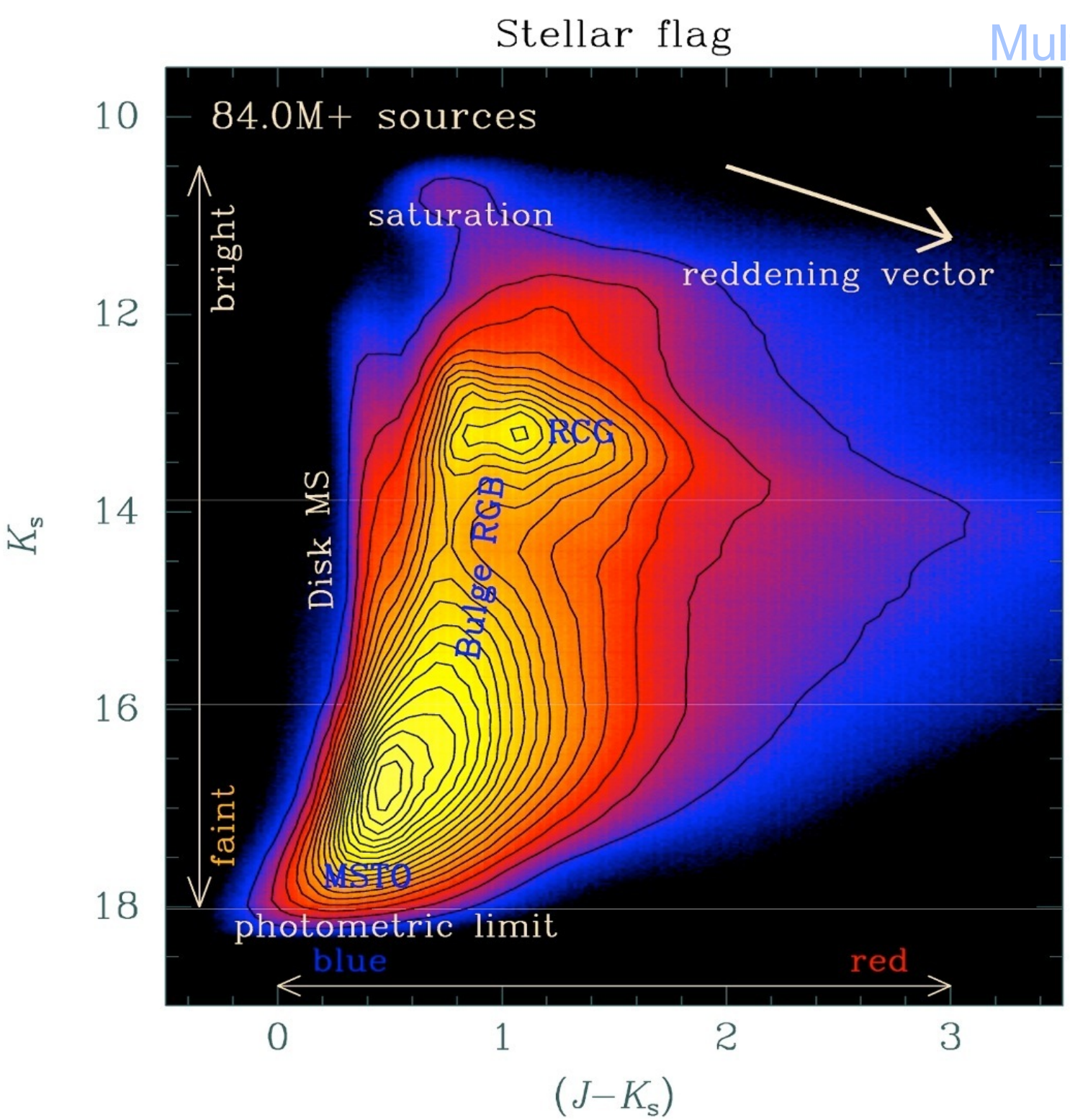
VVV limiting magnitudes

vvvsurvey.org



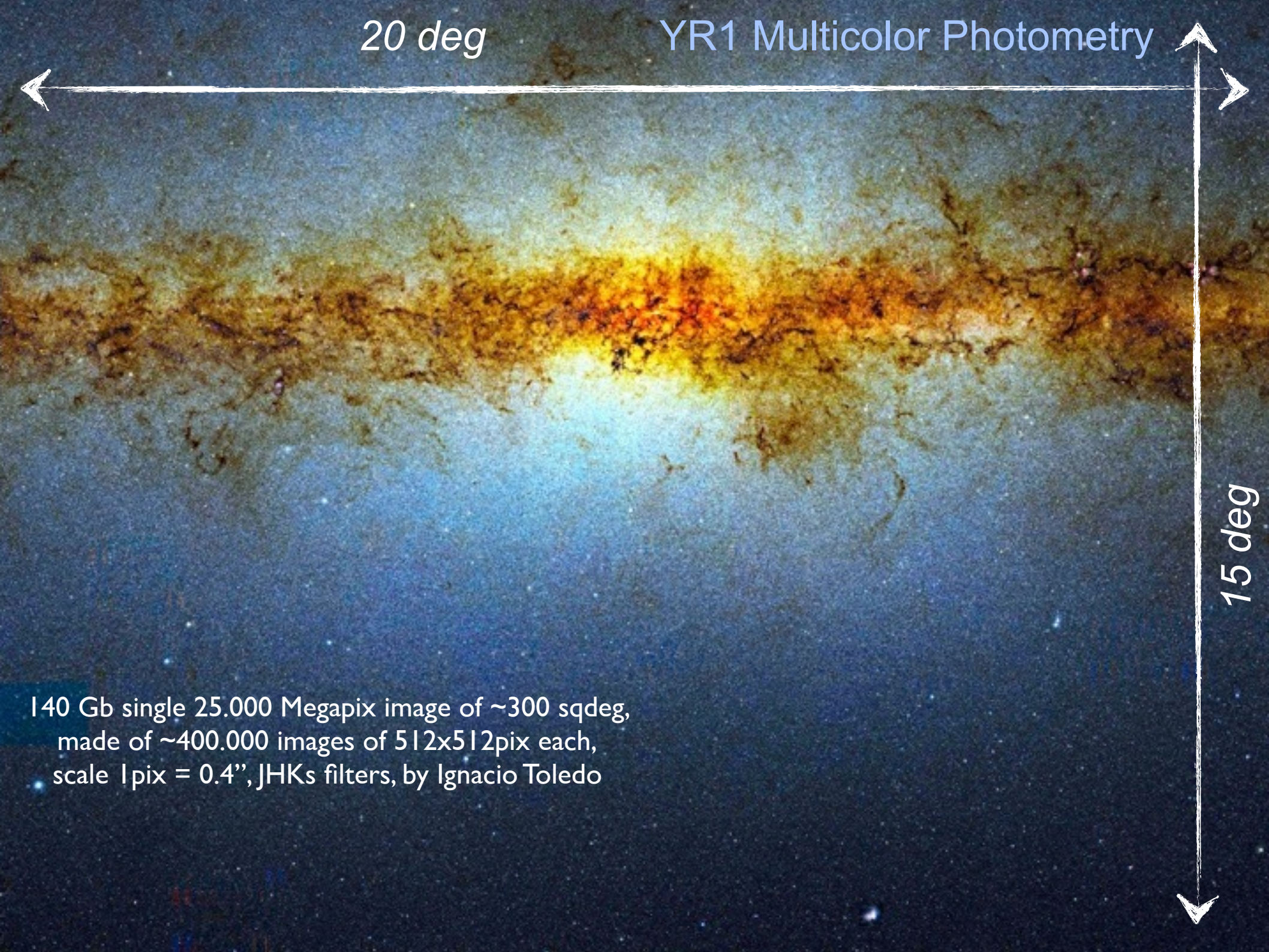
R. Saito, M. Hempel et al. 2012

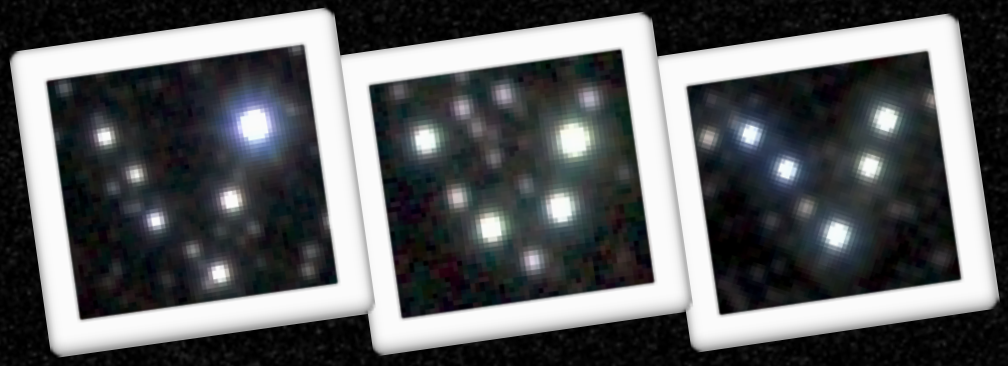
Multicolor photometry



VVV 84M STARS BULGE CMD

R. Saito et al. 2012


20 deg
YR1 Multicolor Photometry
15 deg
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



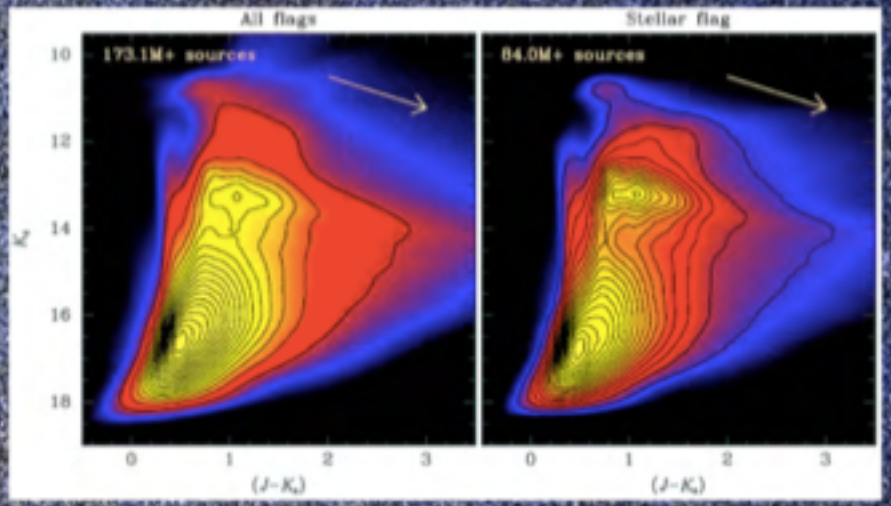
Discoveries

Globular Clusters
Open Clusters (incl. WR clusters)
Galactic Novae and other transients
Nearby Brown Dwarfs
Companions to Nearby Stars
Galaxies & Clusters in the Avoidance Zone
IR Counterparts of High Energy Sources
Candidate microlensing events
Candidate extrasolar planetary transits
Variable stars in clusters

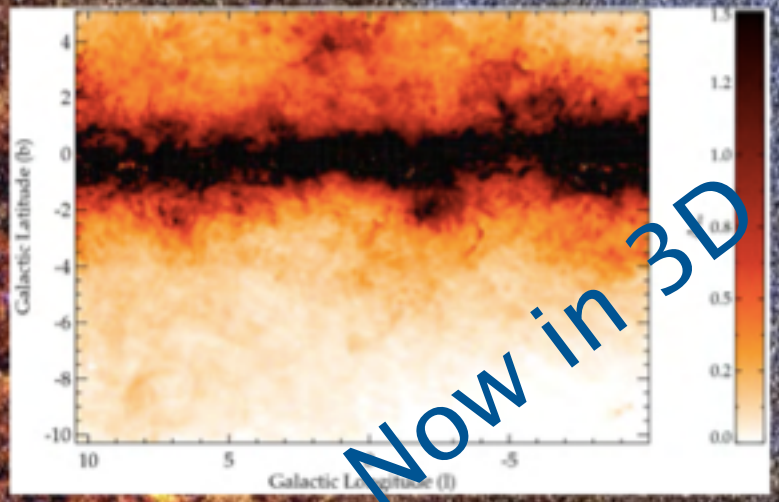
The Milky Way and the Local Group

Science highlights:

84M-star CMD for the inner Milky Way
(Saito et al. 2012, A&A, 545, A147)

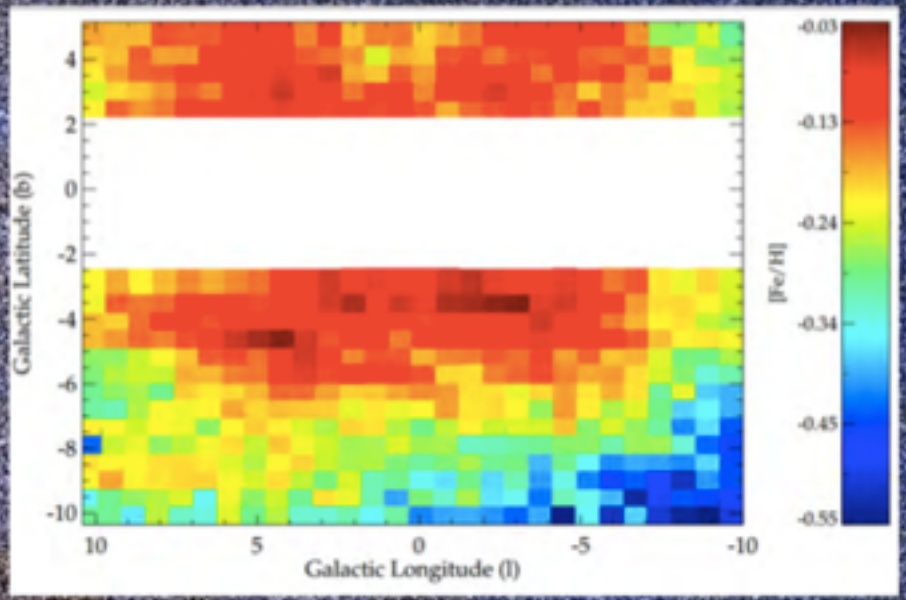


Reddening map for the inner Milky Way
(Gonzalez et al. 2012, A&A, 543, A13)

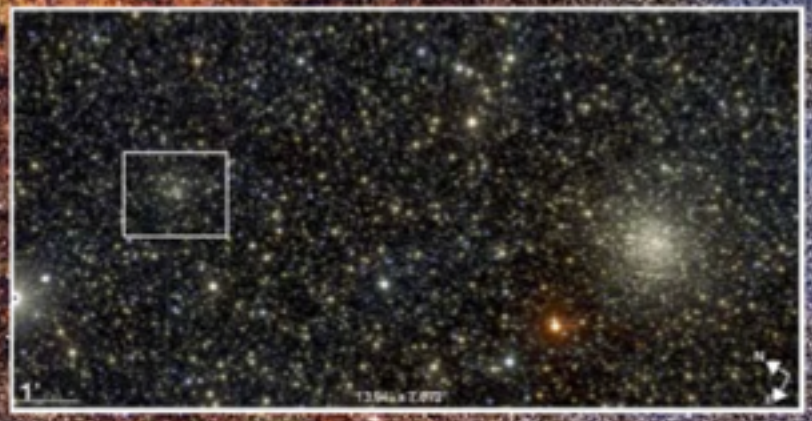


Now in 3D

Metallicity map for the Galactic bulge
(Gonzalez et al. 2013, A&A, 552, A110)



First new globular cluster discovery
(Minniti et al. 2011, A&A, 527, A81)



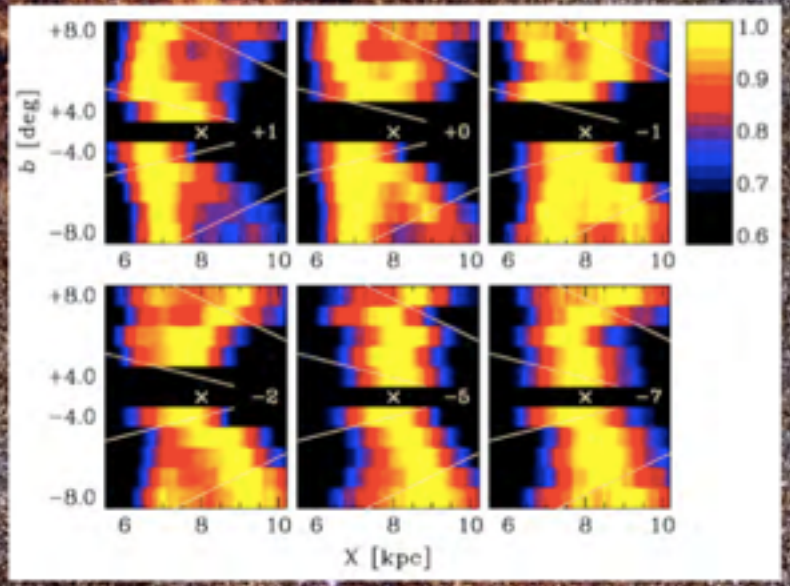
The Milky Way and the Local Group

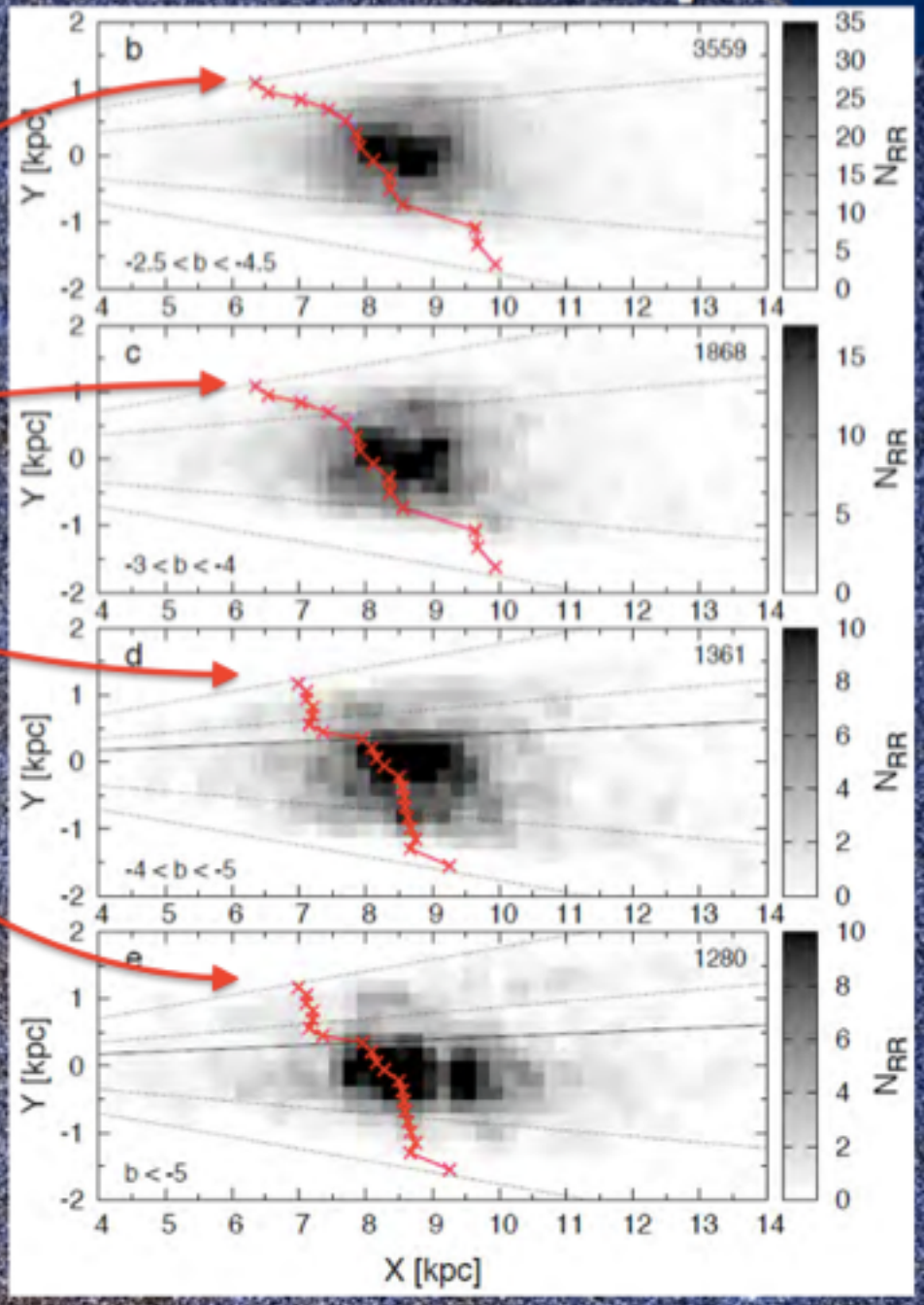
Dékány et al. (2013, ApJ Letters, 776, L19)

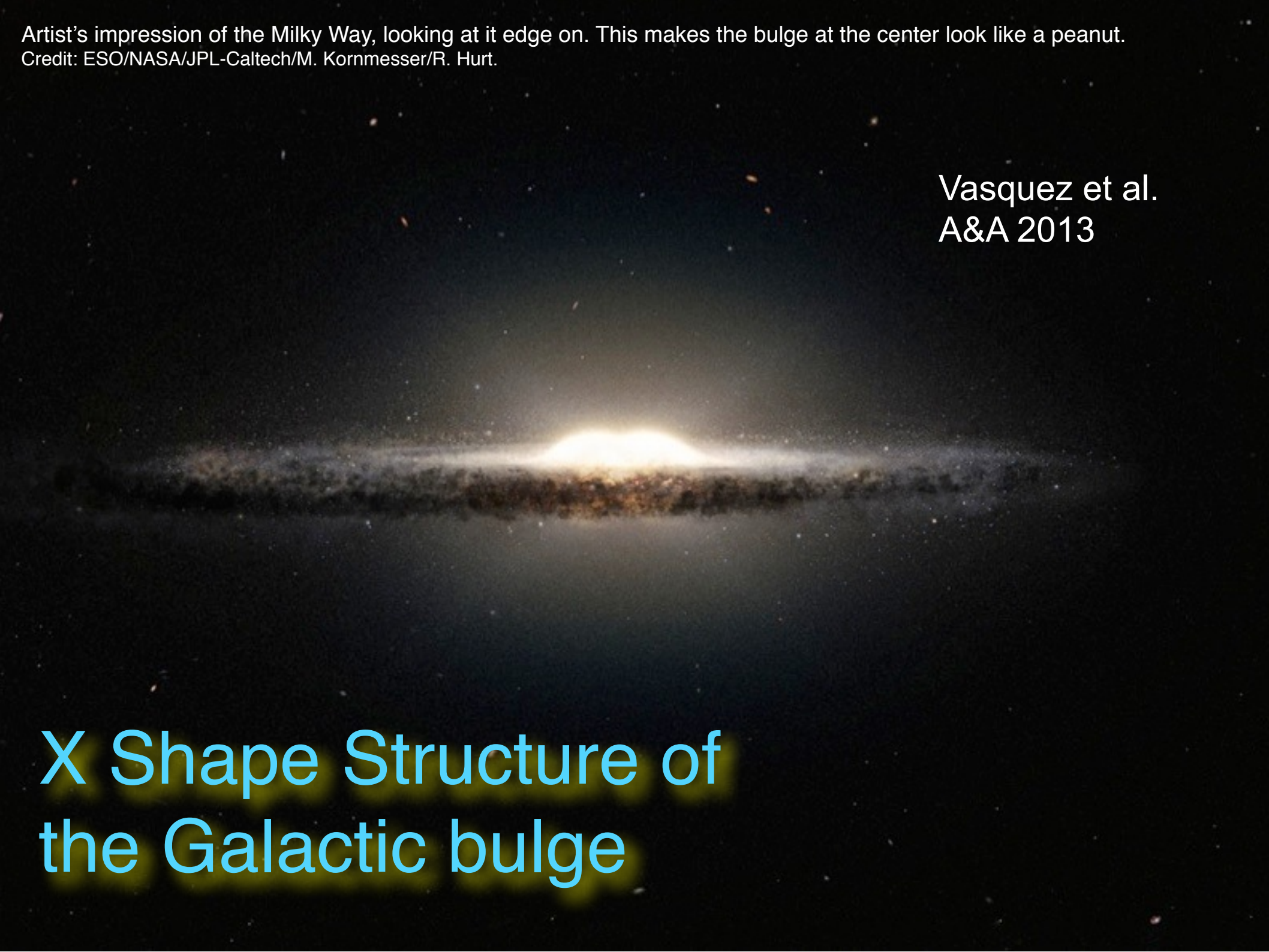
Science highlights:

Position of the long bar (Gonzalez et al. 2011, 2012)

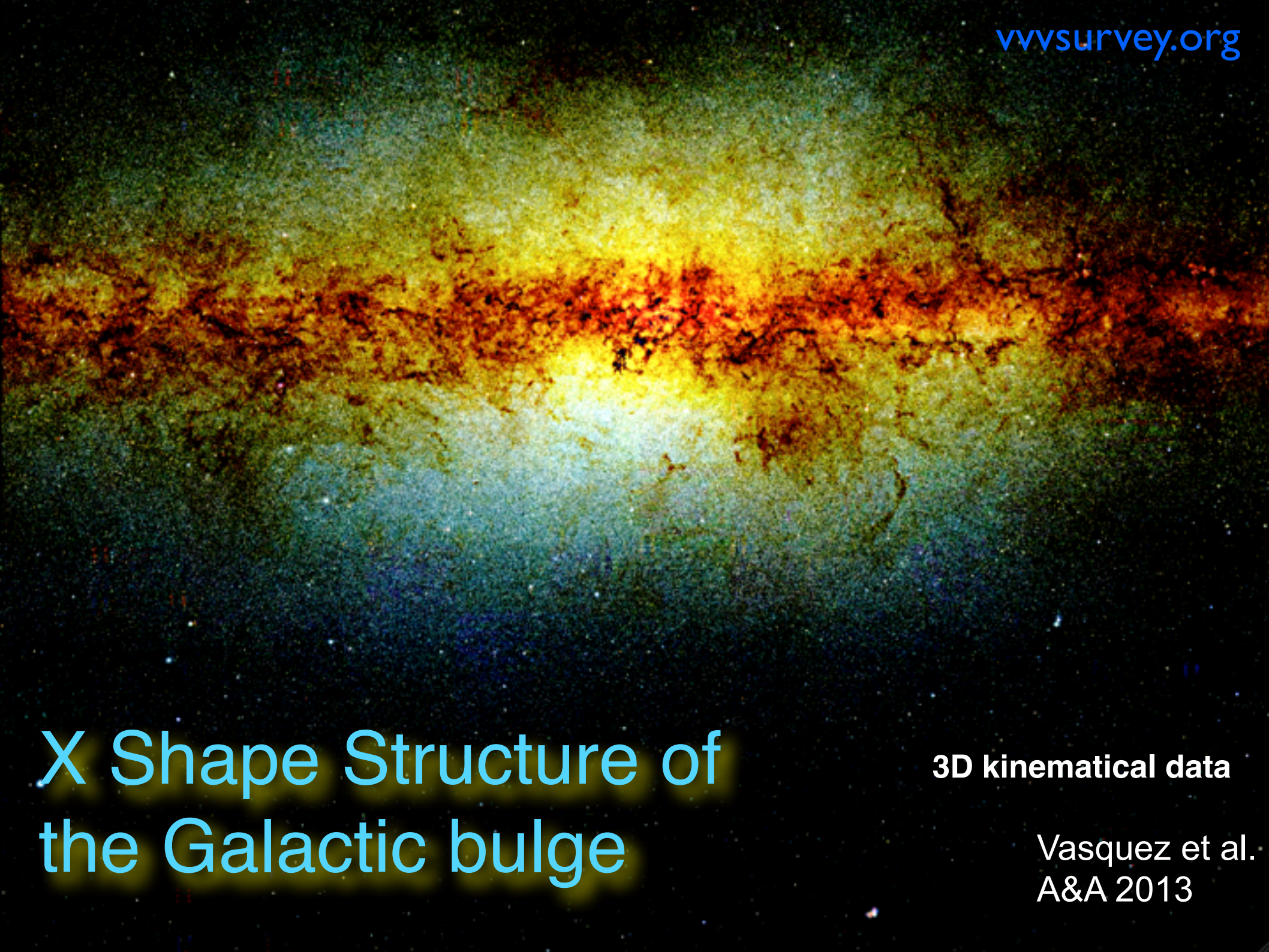
The X-shaped Galactic bulge (Saito et al. 2011, AJ, 142, 76)



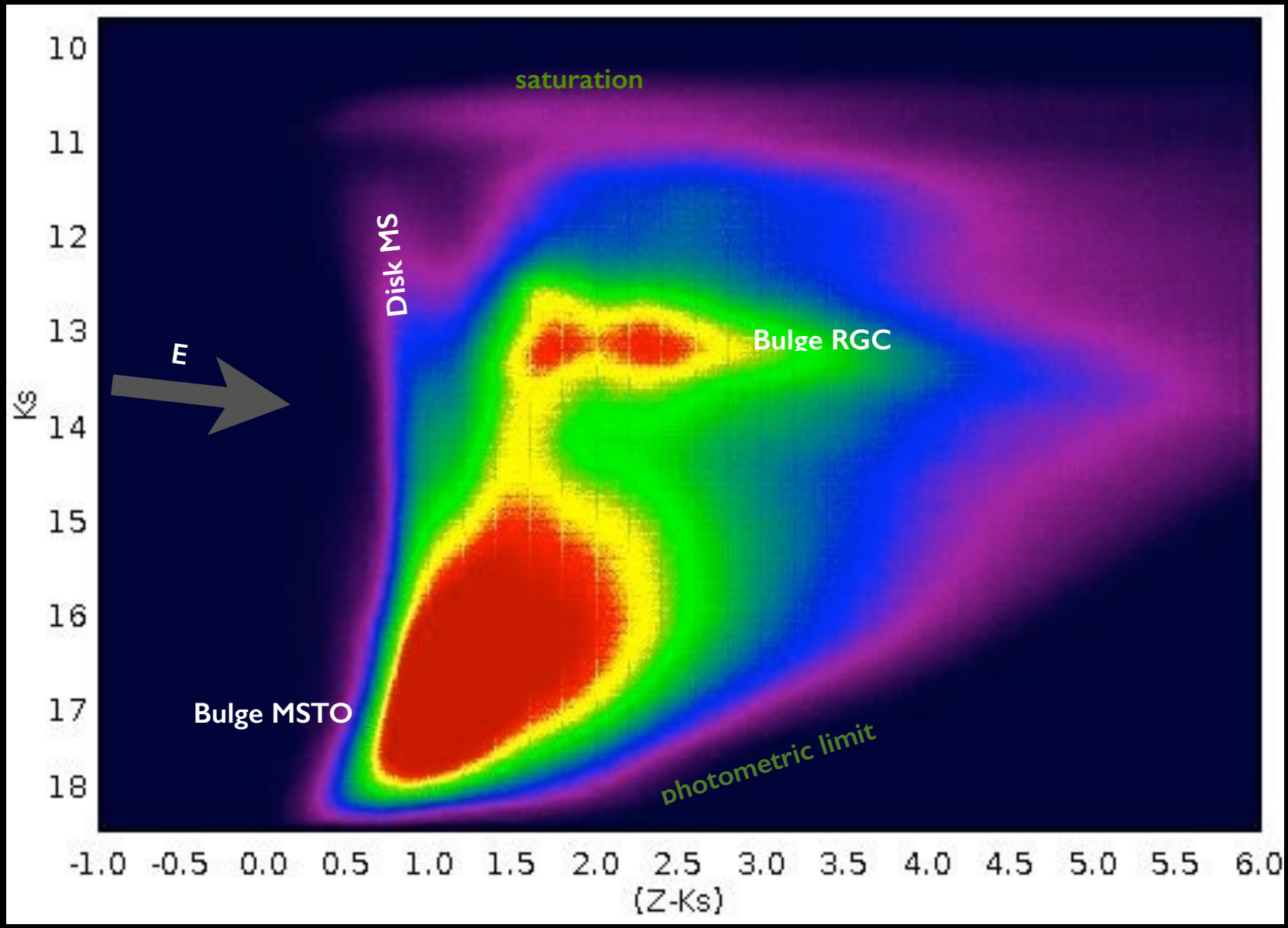




Artist's impression of the Milky Way, looking at it edge on. This makes the bulge at the center look like a peanut.
Credit: ESO/NASA/JPL-Caltech/M. Kornmesser/R. Hurt.

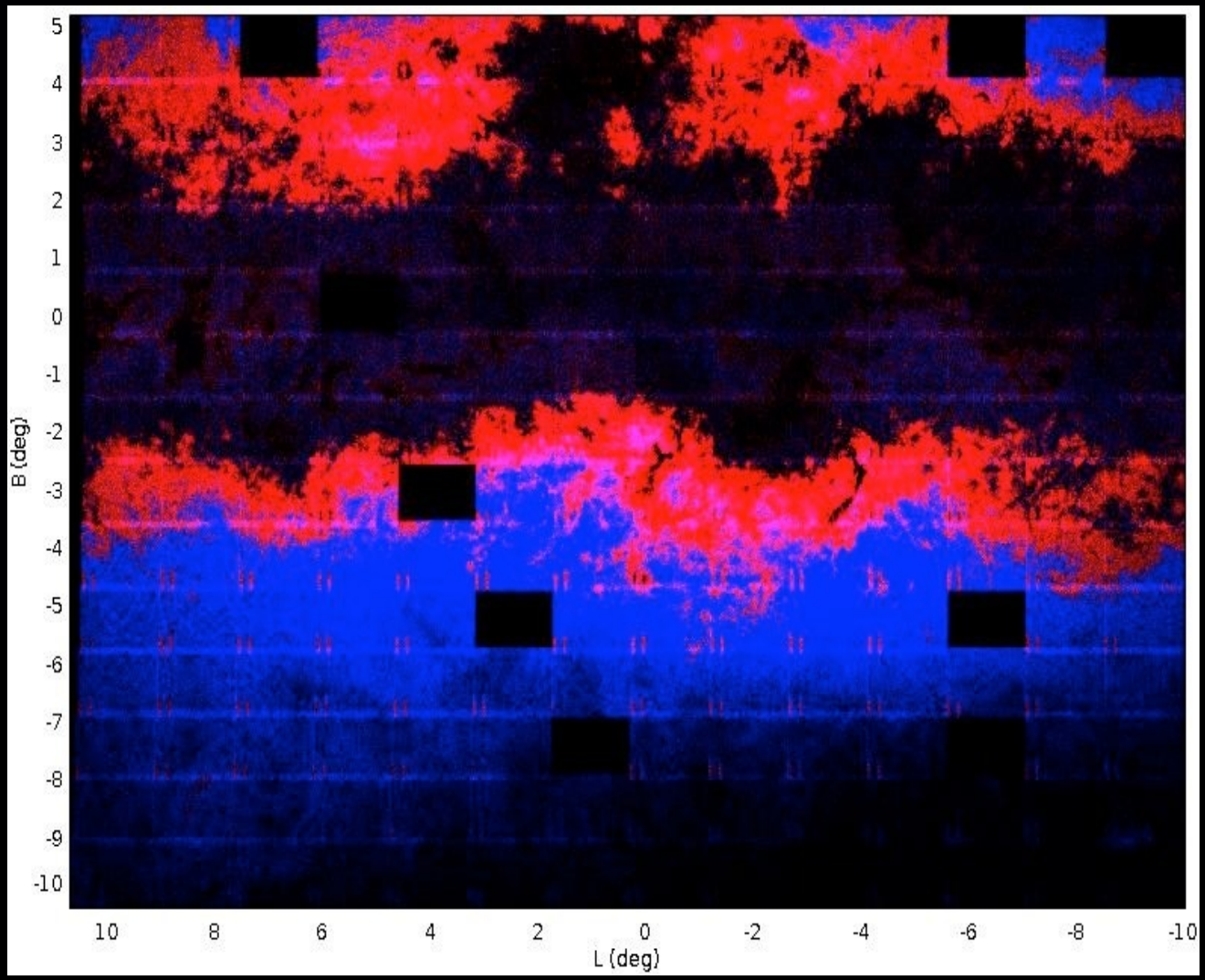

vvvsurvey.org
X Shape Structure of the Galactic bulge
3D kinematical data
Vasquez et al. A&A 2013

VVV 157M STARS BULGE CMD



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

D. Minniti et al. 2014

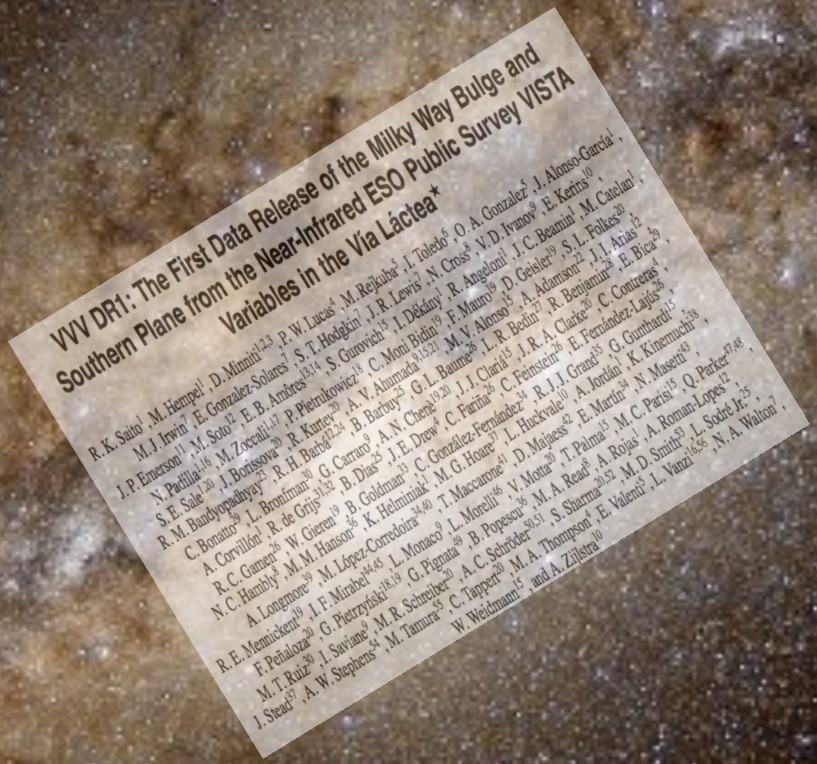


THE CMD REVEALS THE GALACTIC GREAT DARK LANE:
A COHERENT CLOUD STRUCTURE THAT STRETCHES FOR >20 DEG ABOVE AND BELOW THE PLANE OF THE MW

D. Minniti et al. 2014

The VVV global photometric metallicity map of the Galactic bulge

Gonzalez, Rejkuba, Zoccali, et al. (2013, A&A, 552, 110)



VVV DR1: The First Data Release of the Milky Way Bulge and Southern Plane from the Near-Infrared ESO Public Survey VISTA

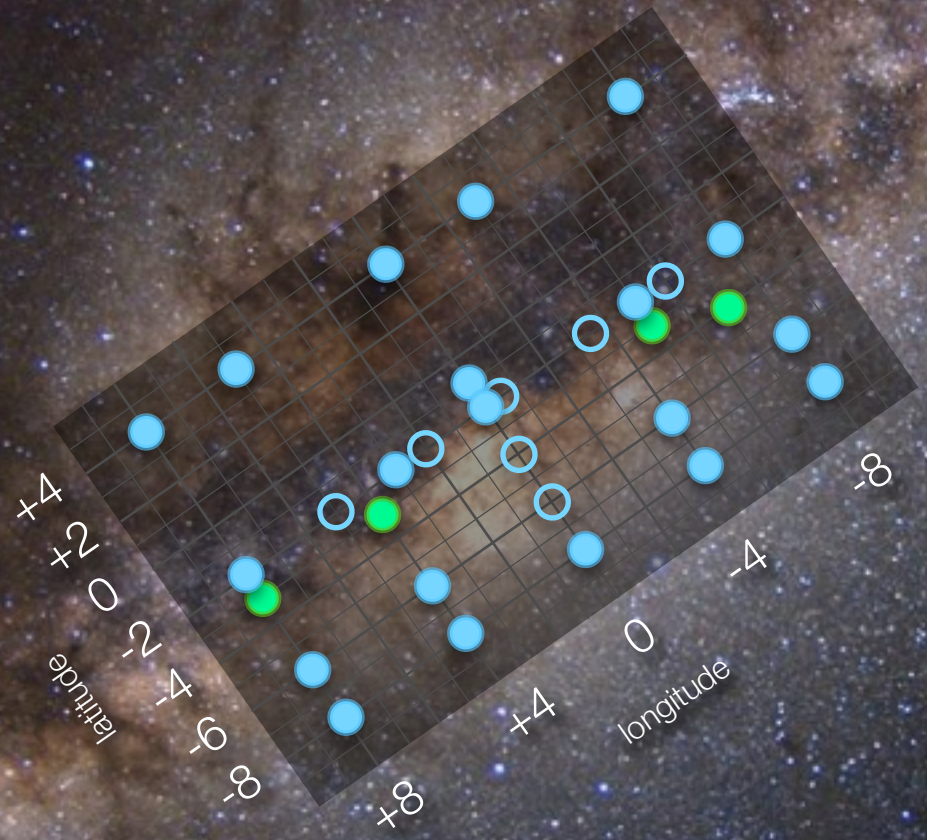
Variables in the Via Láctea*

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], C. Moni Bidin[16], F. Mauro[16], 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], R. Angeloni[1], J. C. Beamin[1], M. Catelan[1], S. E. Sale[1,20], J. Borissova[20], R. Kurtev[20], A. V. Ahumada[21,22,24], B. Barbuy[25], G. L. Baume[26], L. R. Bedin[27], R. Benjamin[28], E. Bica[29], R. M. Bandyopadhyay[22], R. H. Barbá[21,24], M. V. Alonso[15], A. Adamson[22], J. J. Arias[23], C. Bonatto[29], L. Bronfman[30], G. Carraro[9], A. N. Chené[19,20], J. J. Clariá[15], J. R. A. Clarke[20], C. Contreras[4], A. Corvillón[4], R. de Grijs[31,32], B. Dias[33], J. E. Drew[4], C. Fariña[34], C. Feinstein[35], E. Fernández-Laju[36], R. C. Gamen[26], W. Gieren[19], B. Goldman[33], A. N. Chené[19,20], J. J. Clariá[15], J. R. A. Clarke[20], C. Contreras[4], N. C. Hambly[37], M. M. Hanson[38], K. Helminiak[1], M. G. Hoare[39], C. González-Fernández[34], R. J. J. Grand[15], G. Gunthardt[15], A. Longmore[39], M. López-Corredoira[34,40], T. Maccarone[41], D. Majaess[42], E. Martin[34], N. Masetti[43], R. E. Mennickent[19], J. F. Muraveva[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[20], I. Saviane[9], M. R. Schreiber[20], A. C. Schröder[50,51], S. Sharma[20,52], M. D. Smith[53], L. Sodré Jr.[5], J. Stead[37], A. W. Stephens[54], M. Tamura[55], C. Tappert[20], M. A. Thompson[4], E. Valenti[15], L. Vanzi[16,56], N. A. Walton[7], W. Weidmann[15], and A. Zijlstra[10]

vertical metallicity gradient of ~0.04 dex/deg (~0.28 dex/kpc), with metal-rich stars ([Fe/H] ~ 0) dominating the inner bulge in regions closer to the Galactic plane ($|b| < 5$)

The Giraffe Inner Bulge Survey

PI: Manuela Zoccali



24 bulge fields

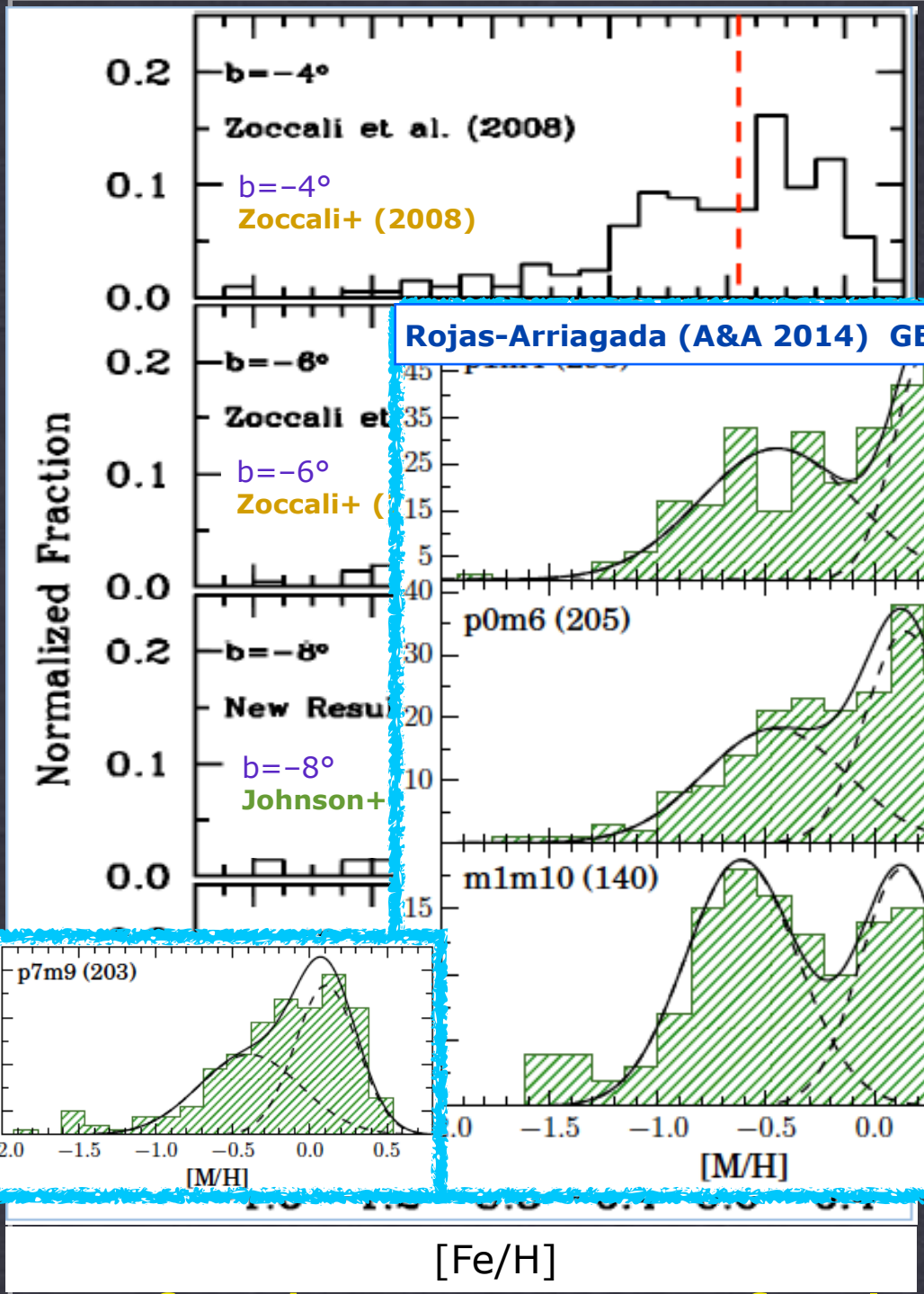
~ 5000 stars on CaT RVs - met

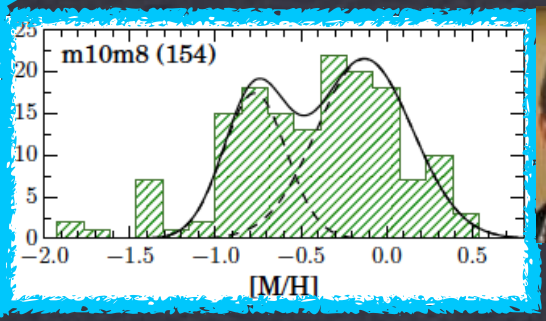
~ 450 stars at R~22,000

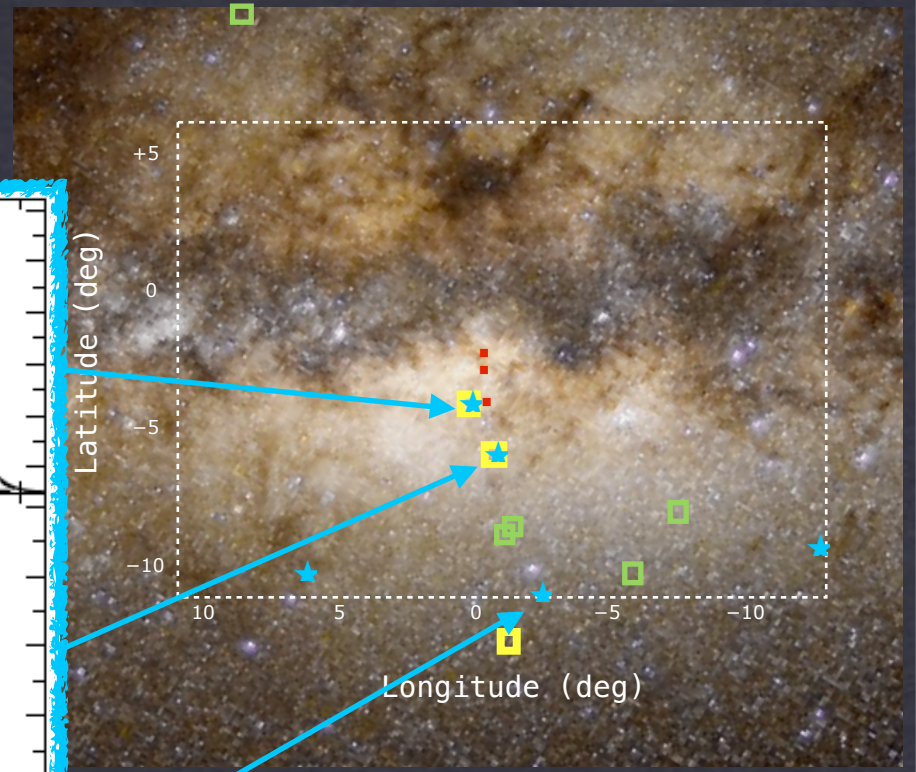
VVV feeding sources for large spectroscopic surveys

Bulge MDF

The GES Survey







VVV feeding sources for large spectroscopic surveys

The VVV Giga CMD

DoPhot PSF photometry of the bulge
J. Alonso et al. 2015, in prep.

In Z, 667 million

In Y, 707 million

In J, 922 million

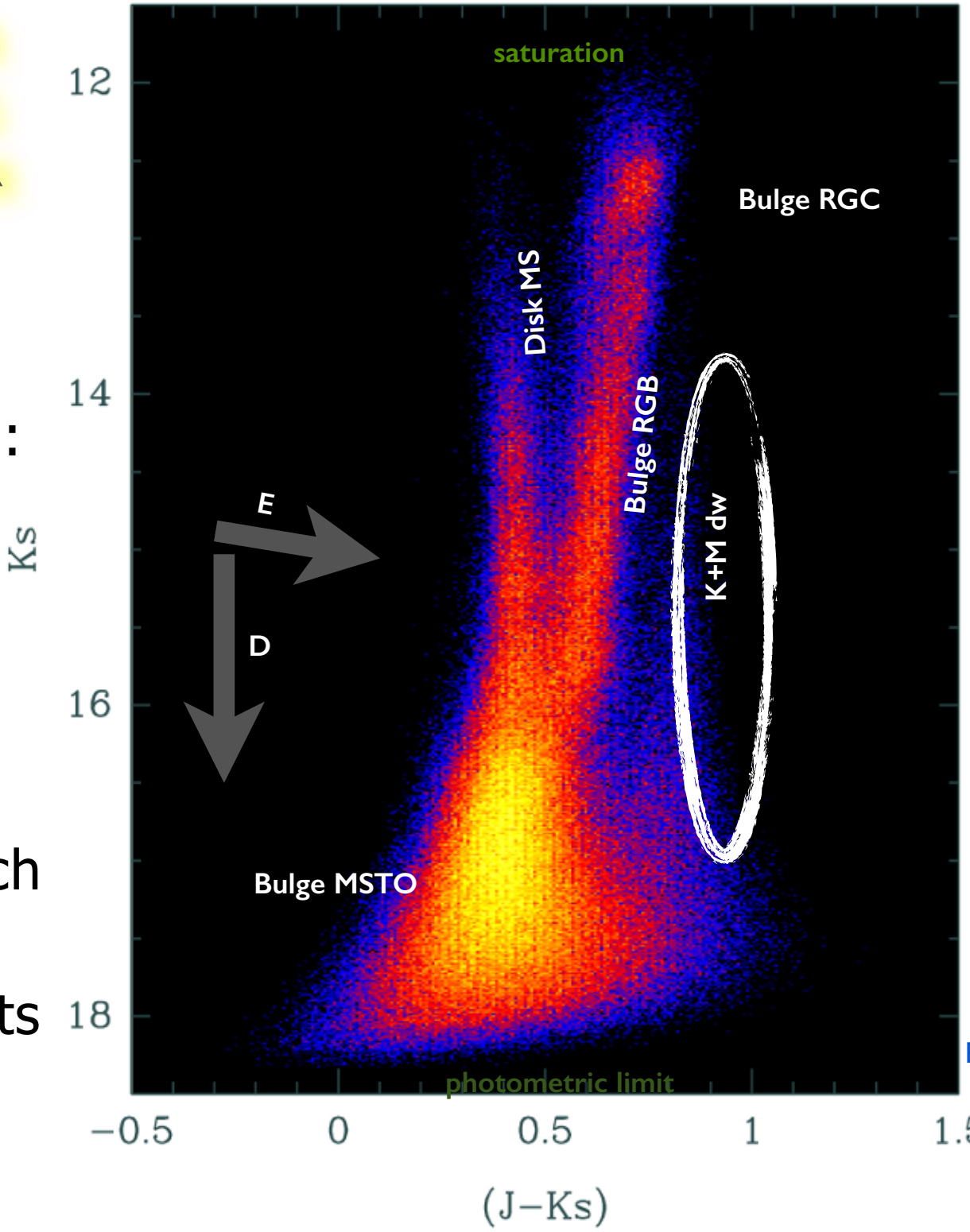
In H, 990 million

In Ks, 779 million

Combining J and Ks, 614 million

SEARCH FOR TRANSITING EXTRASOLAR PLANETS

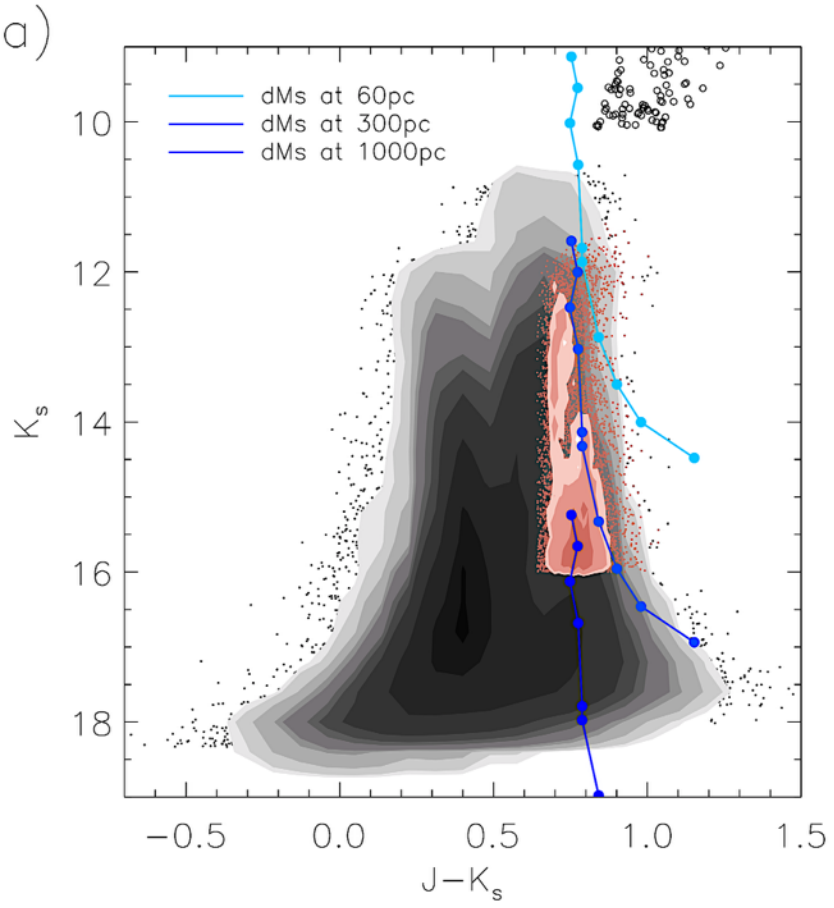
Main motivation: to build up the statistics by selecting a very large sample of small stars (M dwarfs) to search for extrasolar planetary transits

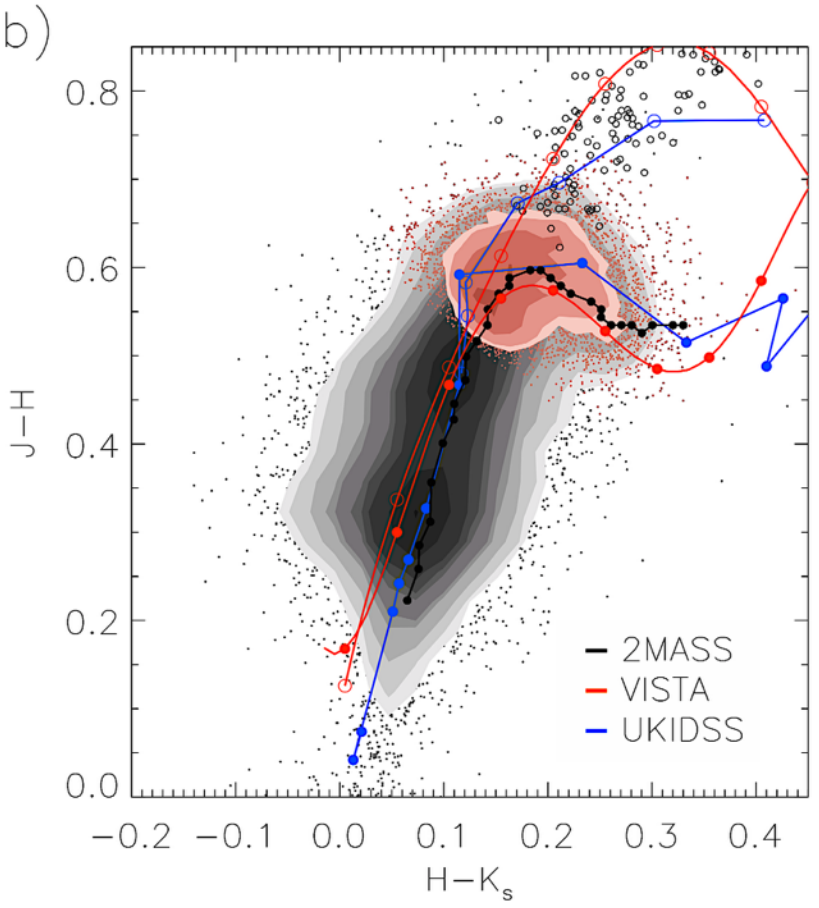


Saito et al. 2012

Barbara Rojas-Ayala
Roberto Saito,
Francisco Surot
Daniela Iglesias
Dante Minniti

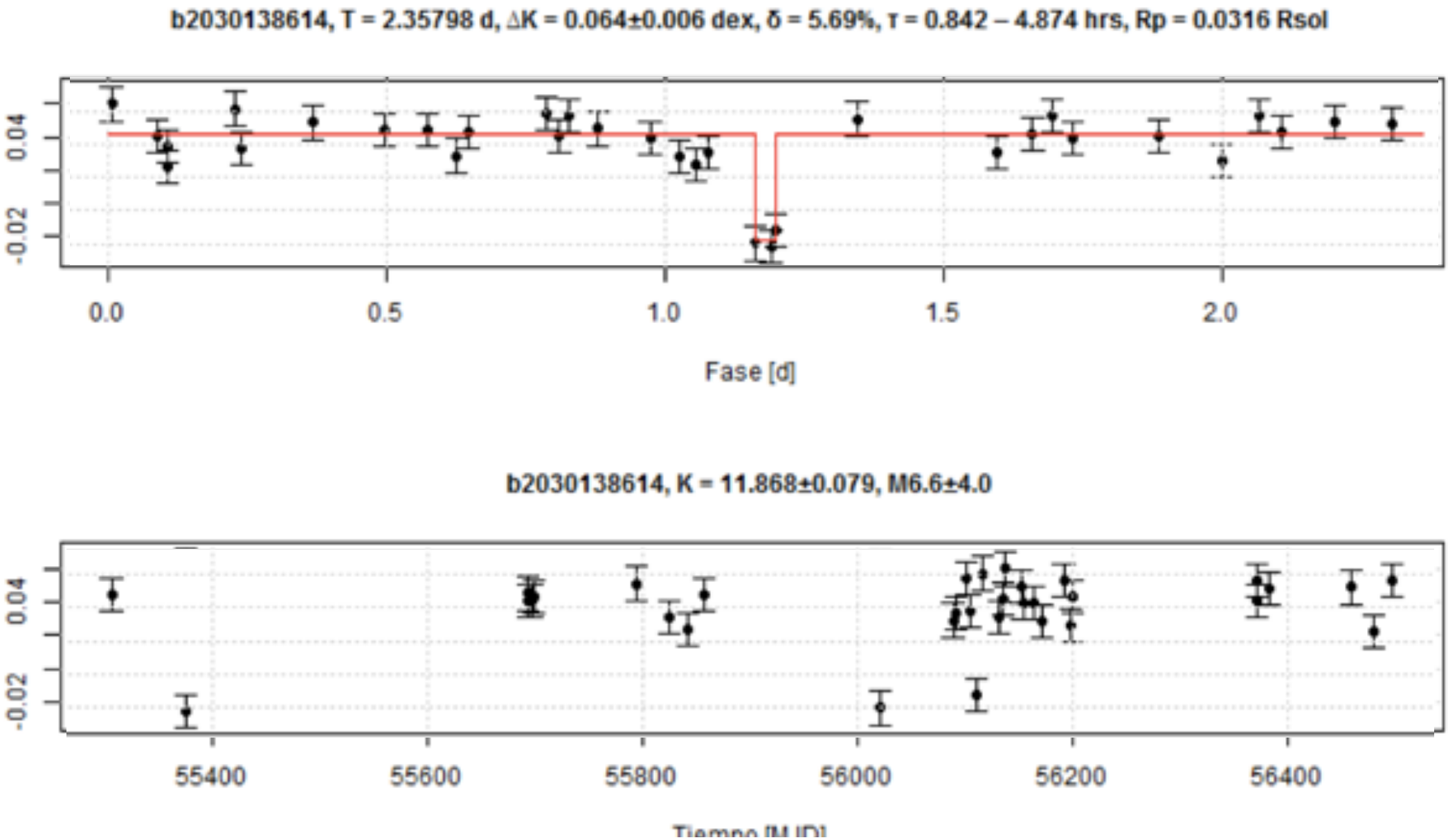
Selection of M-stars in the VVV tile b201 using multicolor photometry in ZYJHKs





23,345 M dwarfs, identification of giants by colour cuts and J-band reduced proper motions (H_J vs J-Ks)

Rojas-Ayala, et al. 2014, A&A



Example of a super-Earth transit candidate in a M6.6 star

Barbara Rojas-Ayala
Roberto Saito,
Francisco Surot
Daniela Iglesias
Dante Minniti

The Milky Way, our Galaxy

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Conclusions

- We are more than half way through the VVV Survey, with everything working well.

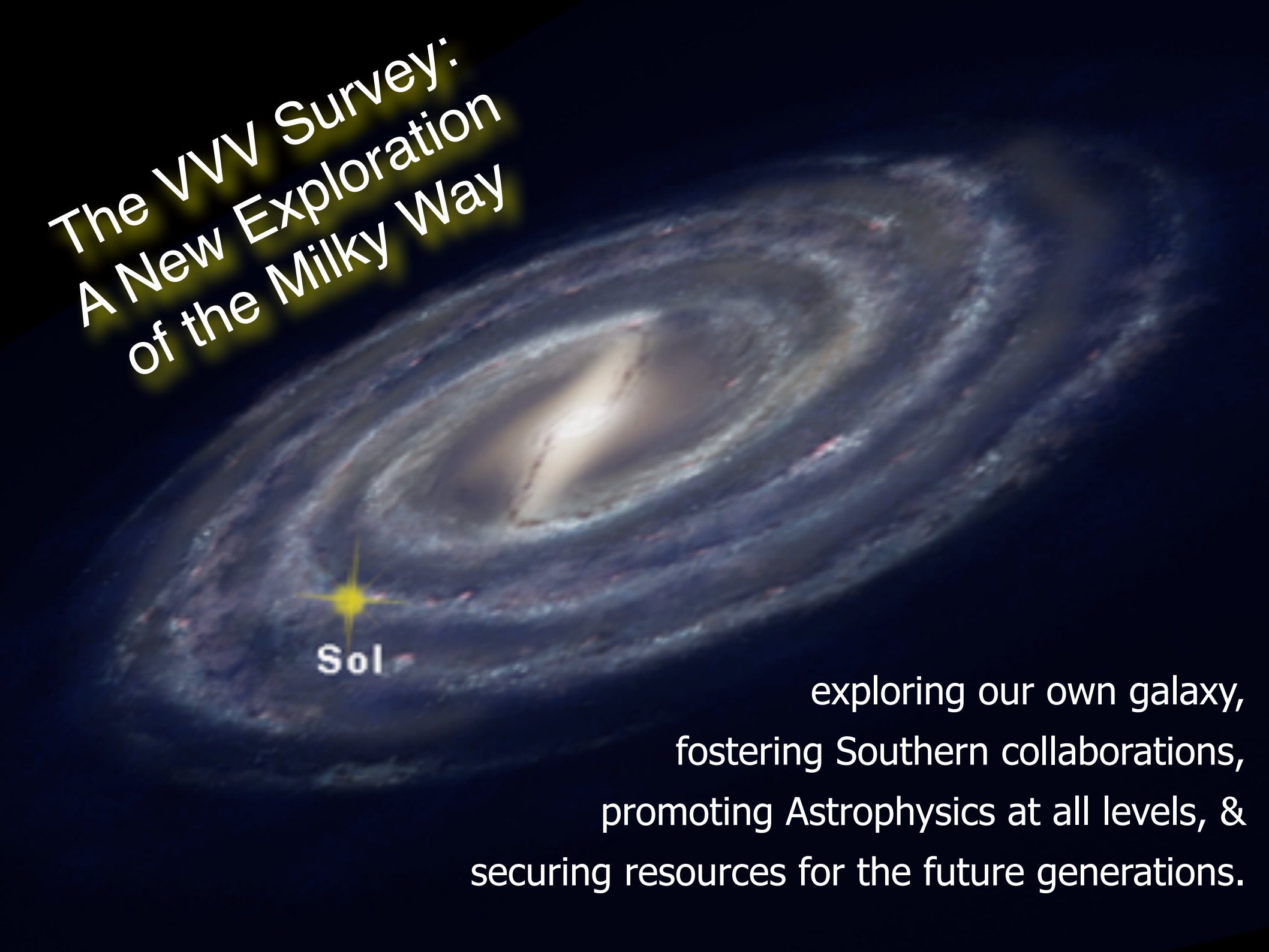
- Several discoveries have been made, with many more to come.

- We need help following up spectroscopically a wide variety of targets.

VVV
Survey

VVV images projected on the Chilean Government Palace,
Centro Cultural La Moneda, Santiago, 22 Oct 2014

The VVV Survey: A New Exploration of the Milky Way



exploring our own galaxy,
fostering Southern collaborations,
promoting Astrophysics at all levels, &
securing resources for the future generations.