Sexten Workshop on

"Formation and Evolution of the Galactic Bulge"

The VVV Survey: New Results (Part i)

Dante Minniti

20 Jan 2014

VVV Survey of the Milky Way Bulge

The VVV Science Team

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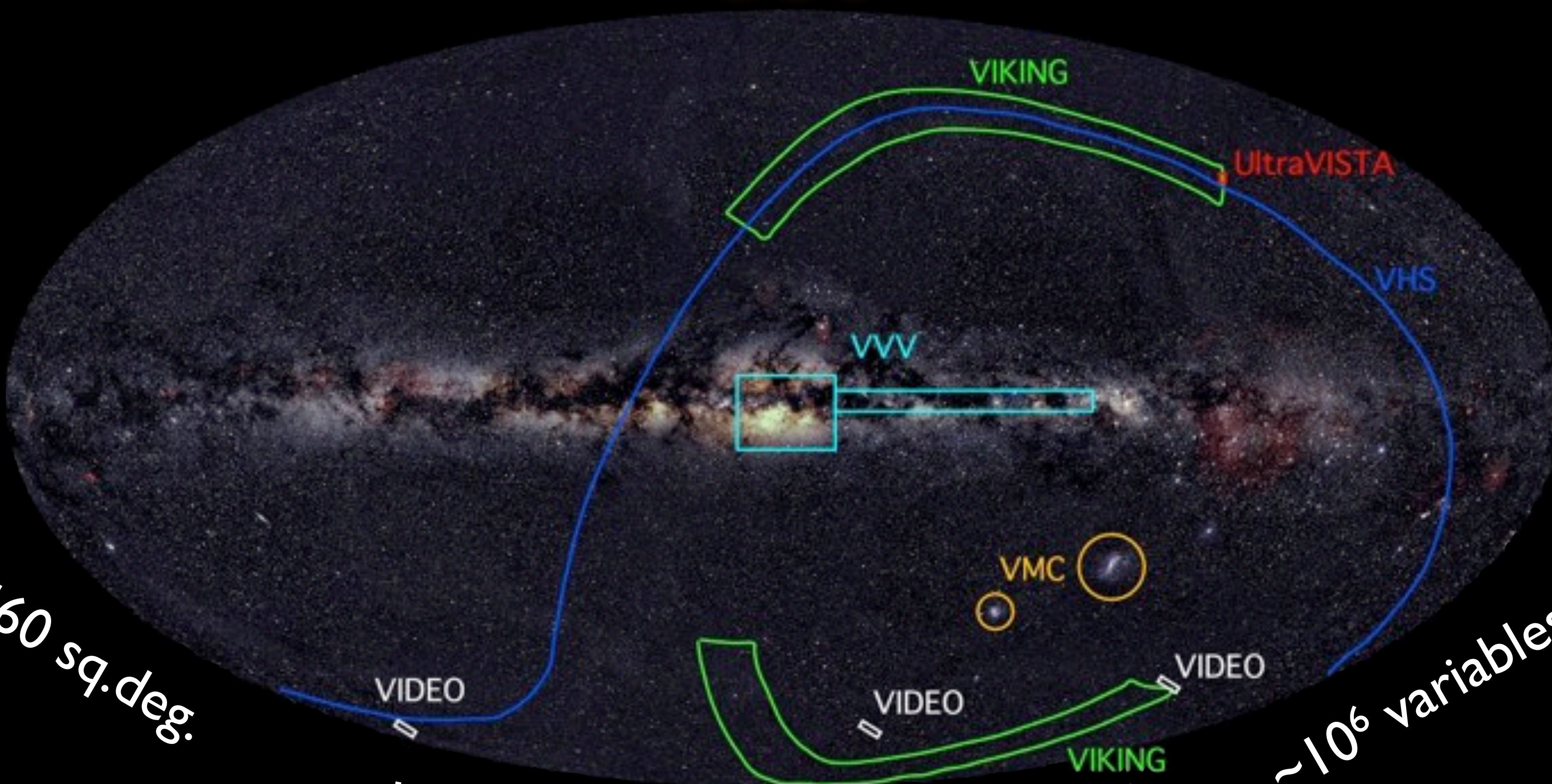
The VVV Science Team

VISTA PUBLIC SURVEYS
VISTA VARIABLES IN THE VIA LACTEA

VVV

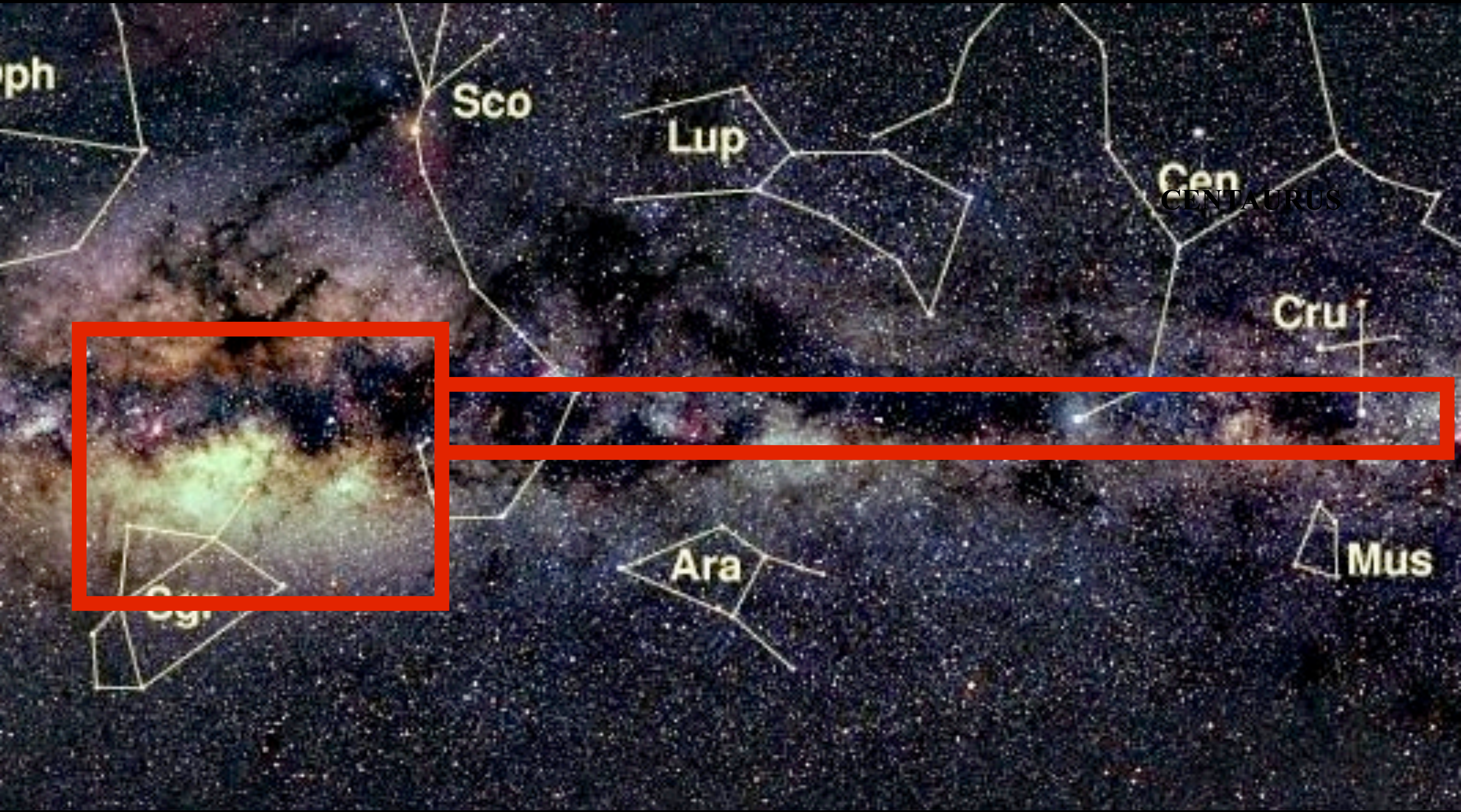


560 sq.deg.

~10^9 stars

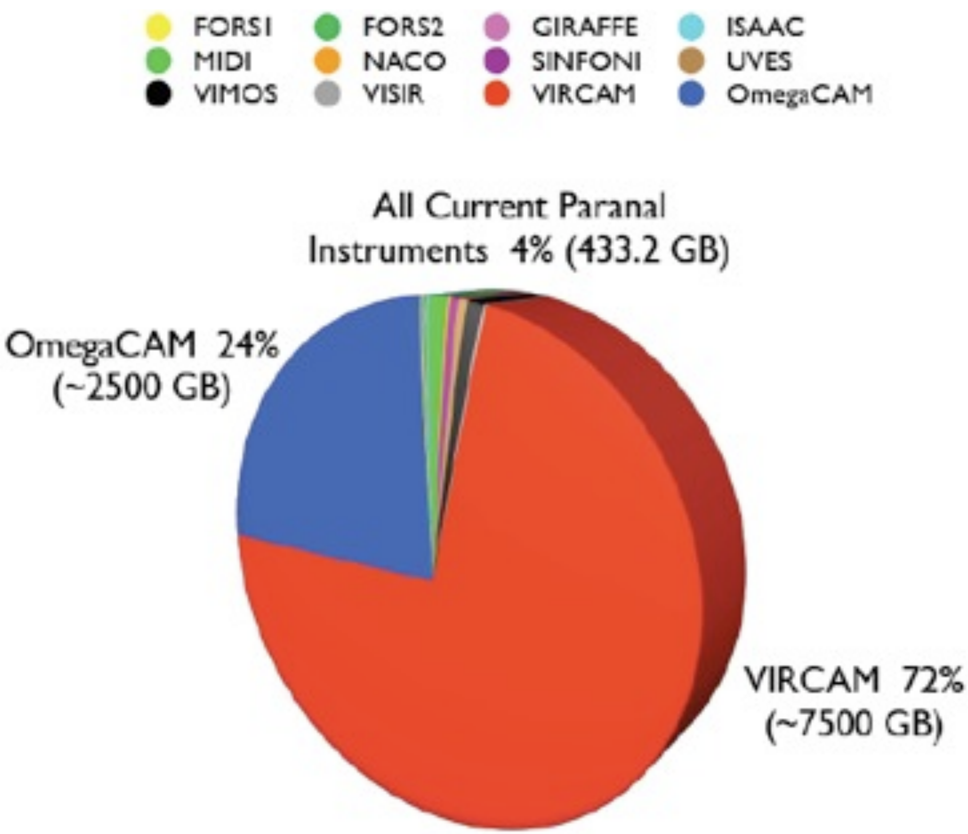
~100 epochs

~10^6 variables



VVV maps 560 sqdeg in the central region of our galaxy

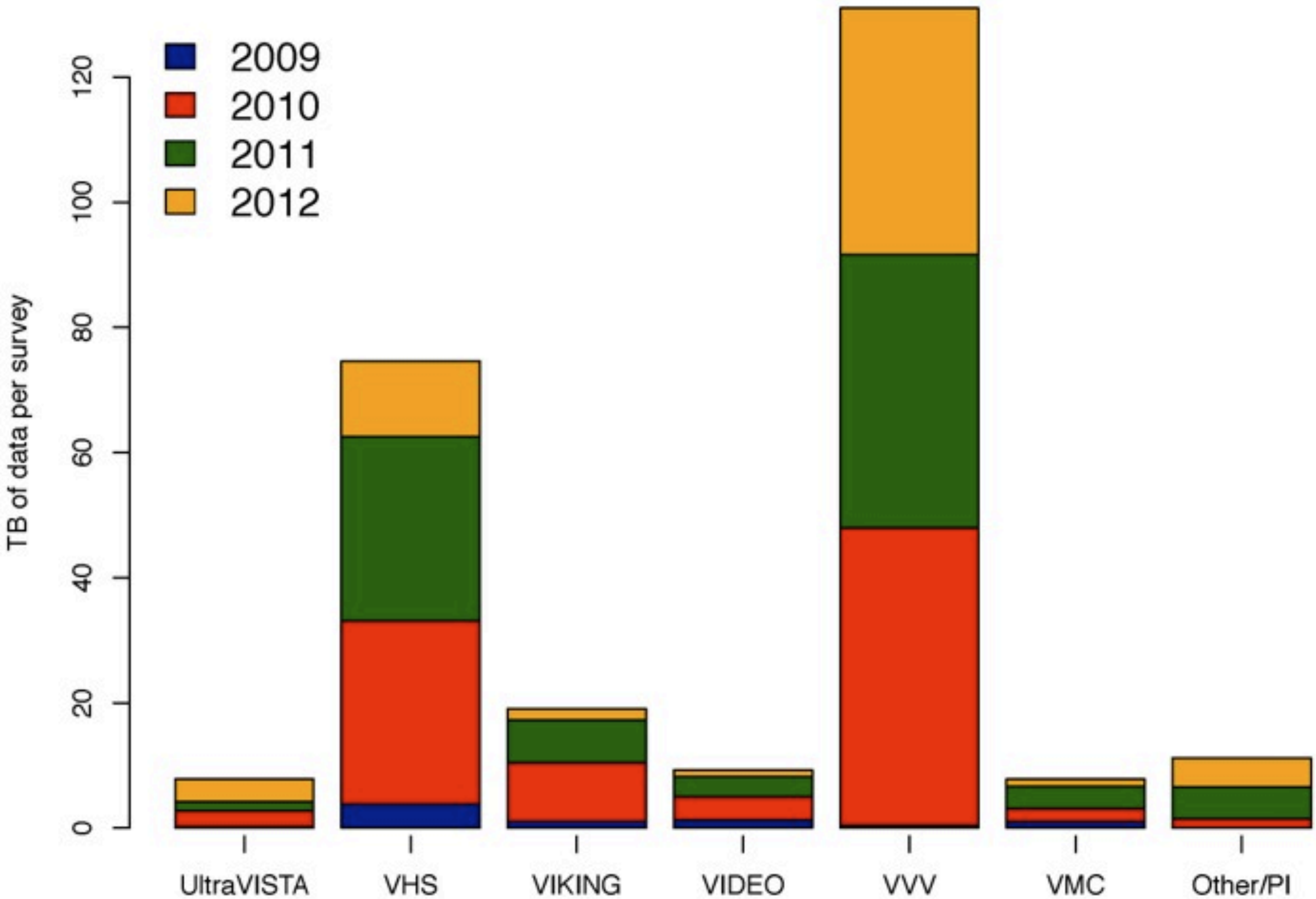
Expected monthly dataflow: raw calibrations and science frames



Magda Arnaboldi (EDT)

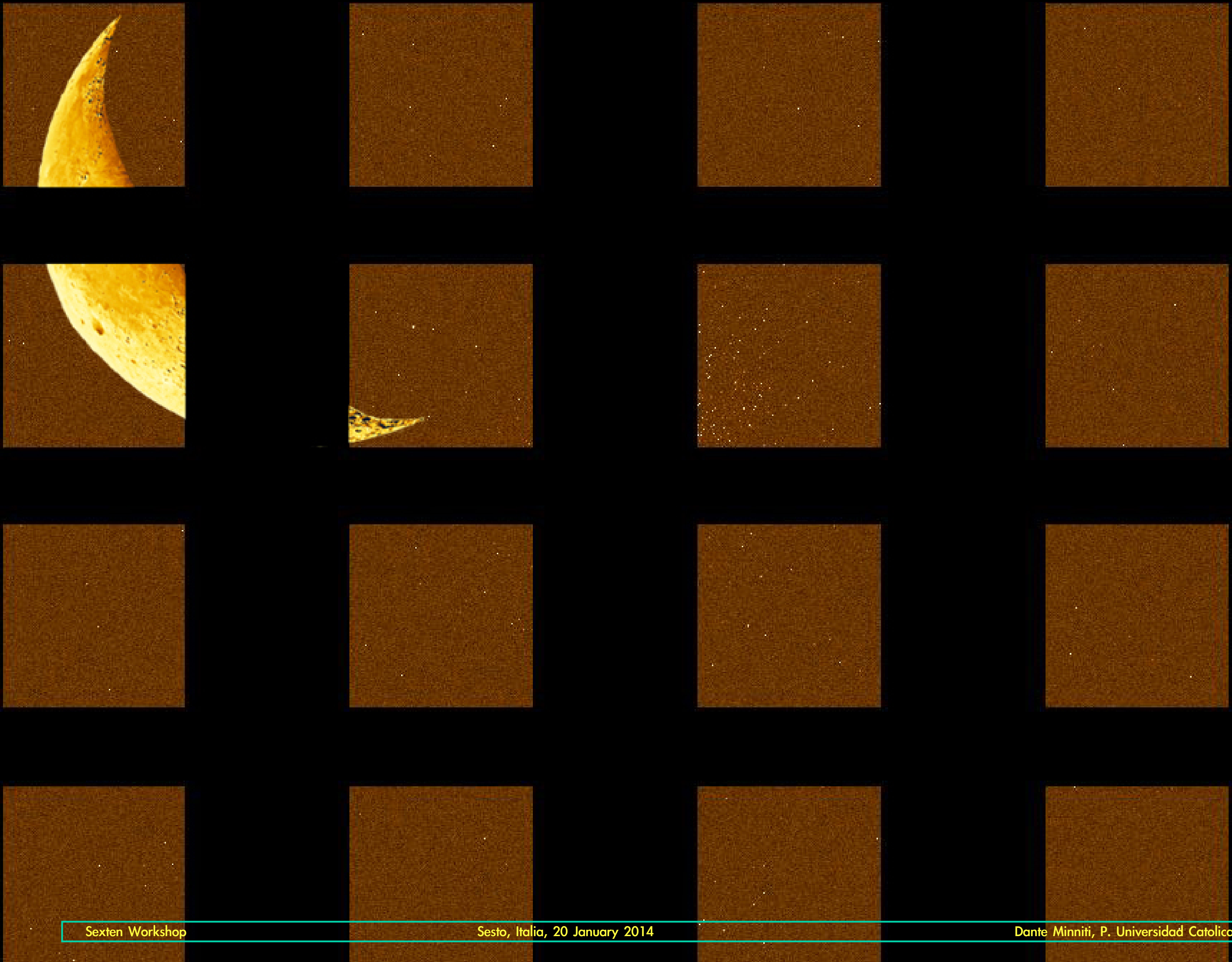
Data Volumes produced by CASU

Jim Emerson

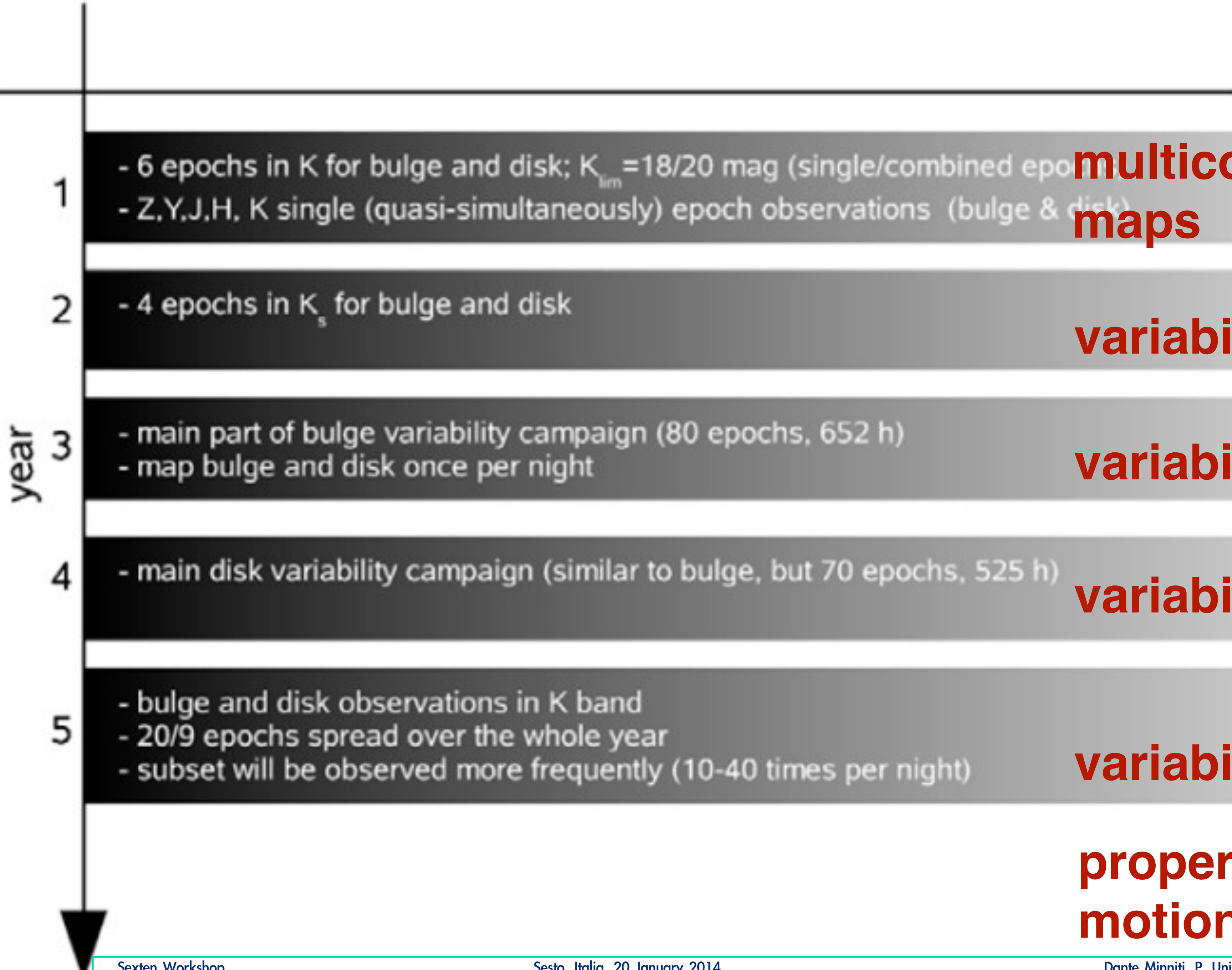


VISTA Near-IR Wide Field Camera

vvvsurvey.org



The VVV Survey: Timeline



multicolor maps 2010

variability 2011

variability 2012

variability 2013

variability 2014

proper motions 2015

...

The VVV Survey: Timeline

Multicolor Photometry: ZYJHKs

Variability: Ks

Proper Motions: Ks

DEEPER AND HIGHER RESOLUTION

Main differences with 2MASS

2MASS covers the whole sky, VVV only 1.3%

VVV has higher resolution (0.34”/pix)

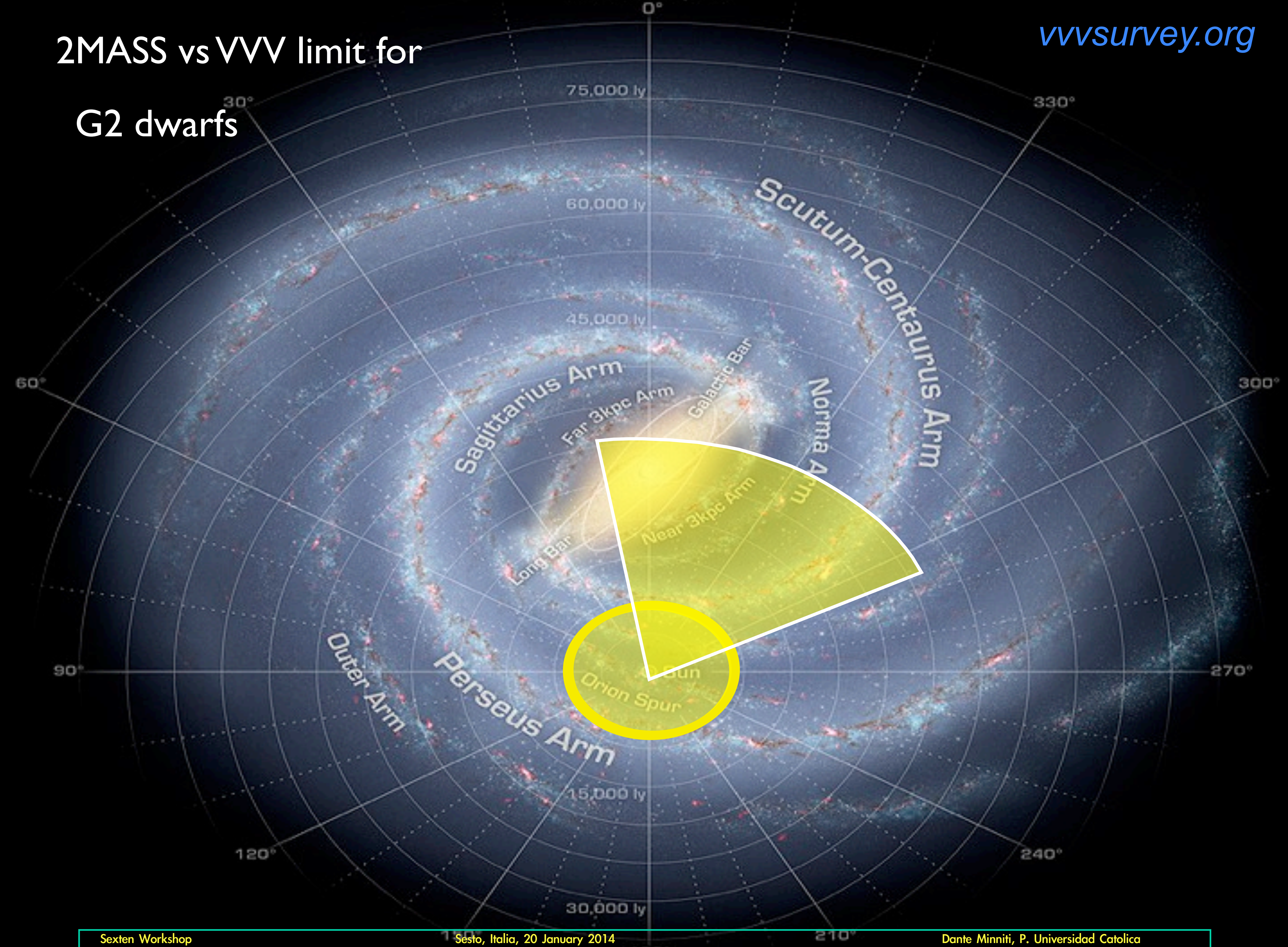
VVV is deeper (Ks<18)

VVV has 5 filters (ZYJHKs)

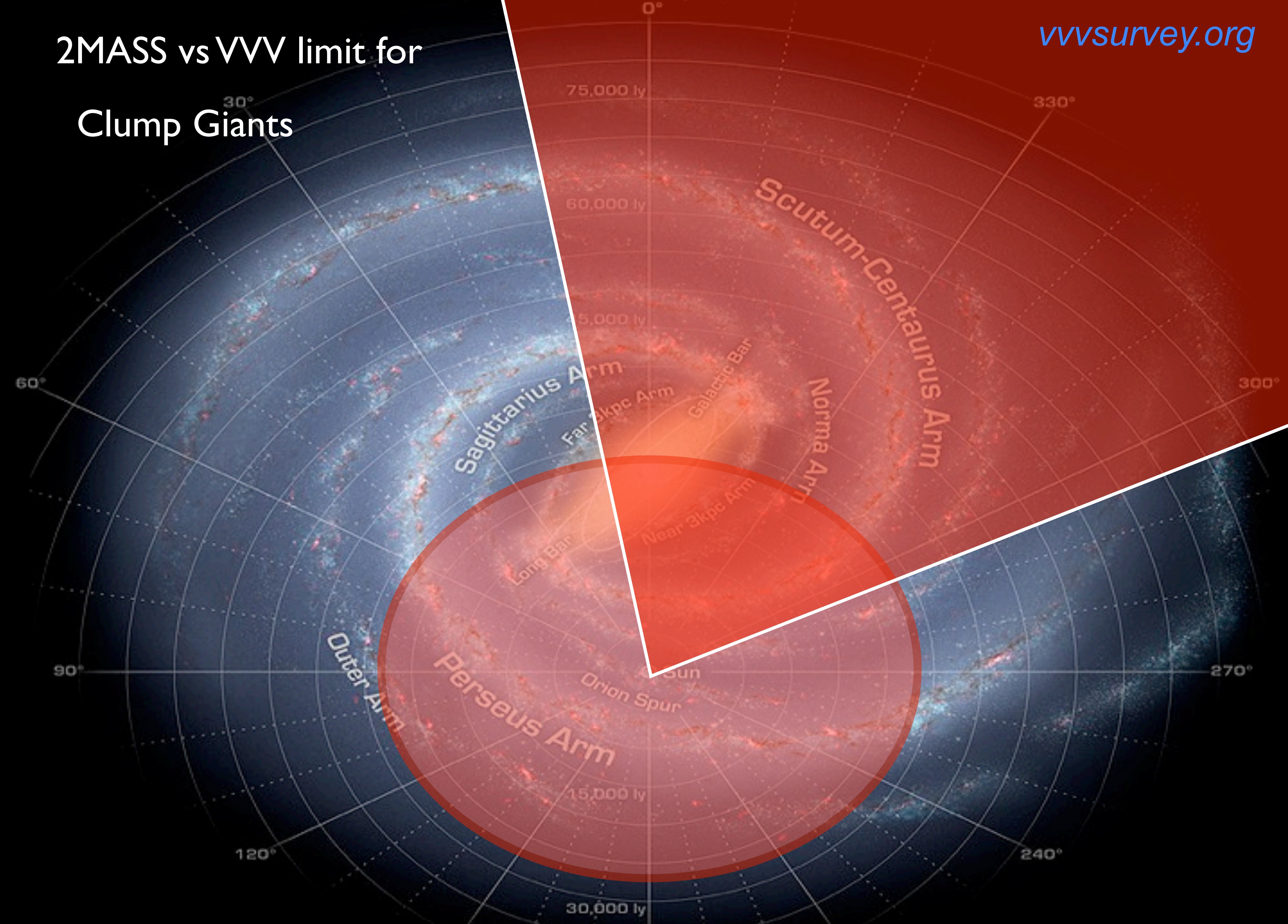
VVV is a multiepoch survey (~100 epochs)

2MASS vs VVV limit for G2 dwarfs

vvvsurvey.org

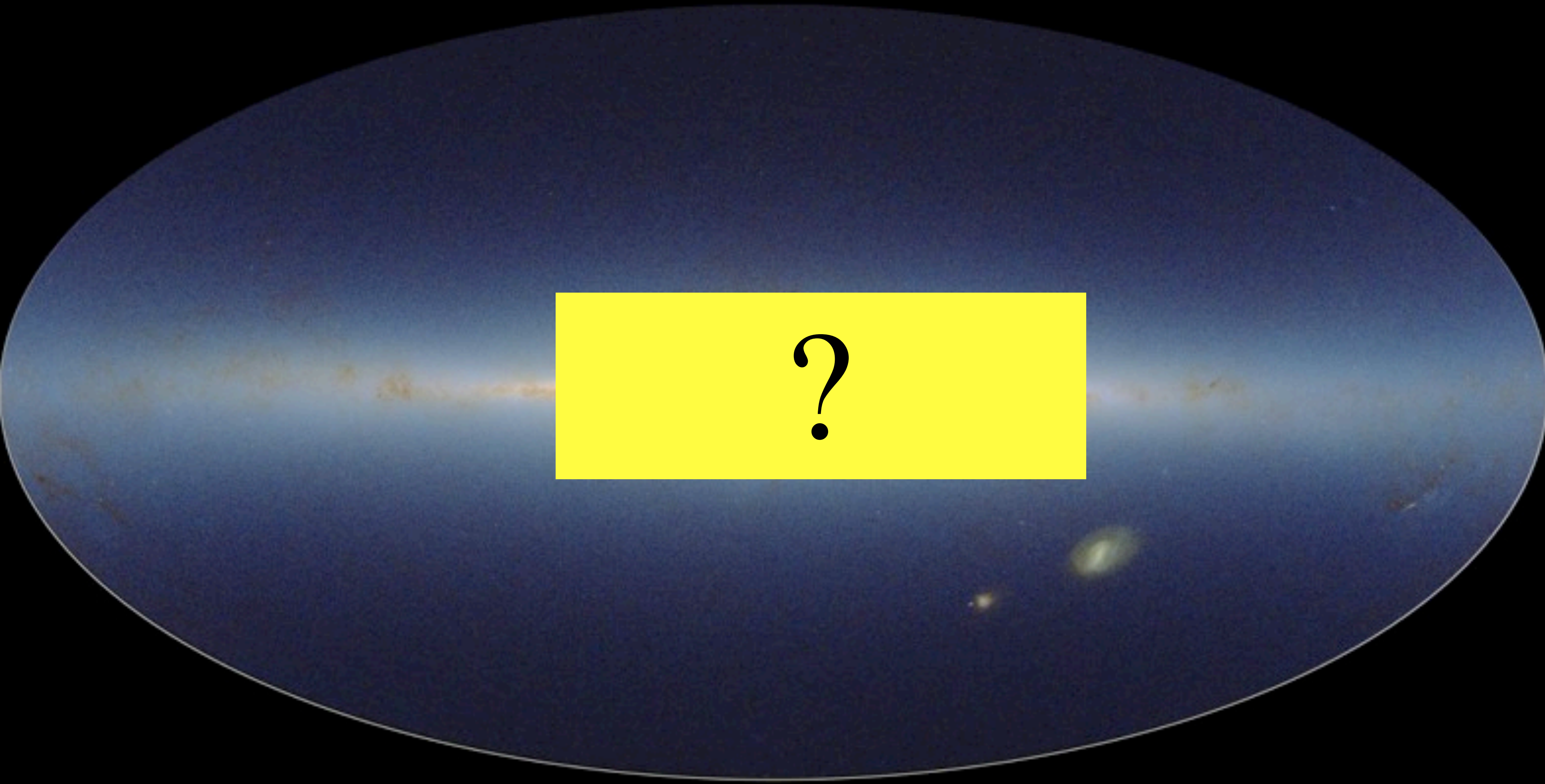


2MASS vs VVV limit for Clump Giants



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

vvvsurvey.org

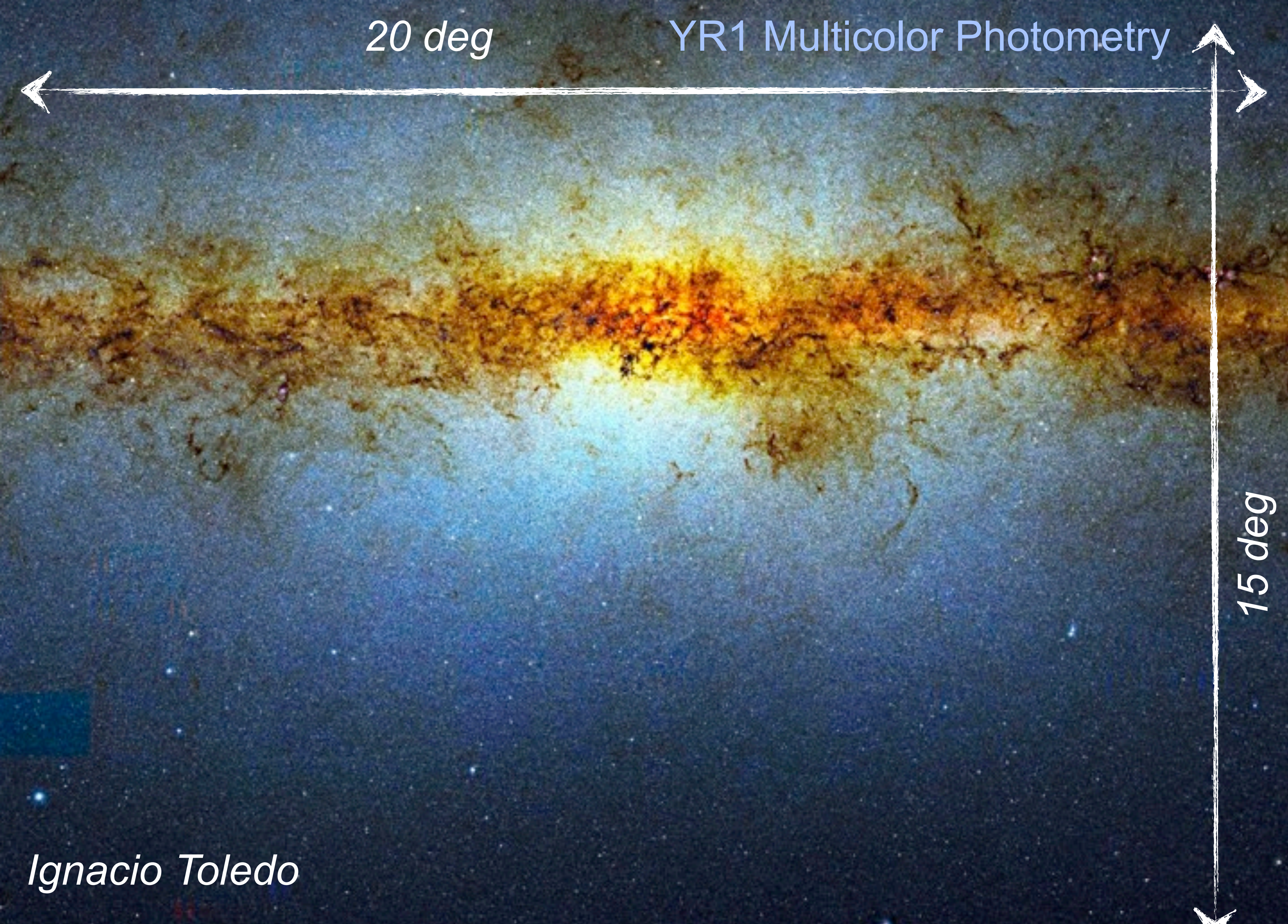


2MASS IMAGE OF THE MILKY WAY

VVV Goal

What is the 3-D structure of the Milky Way

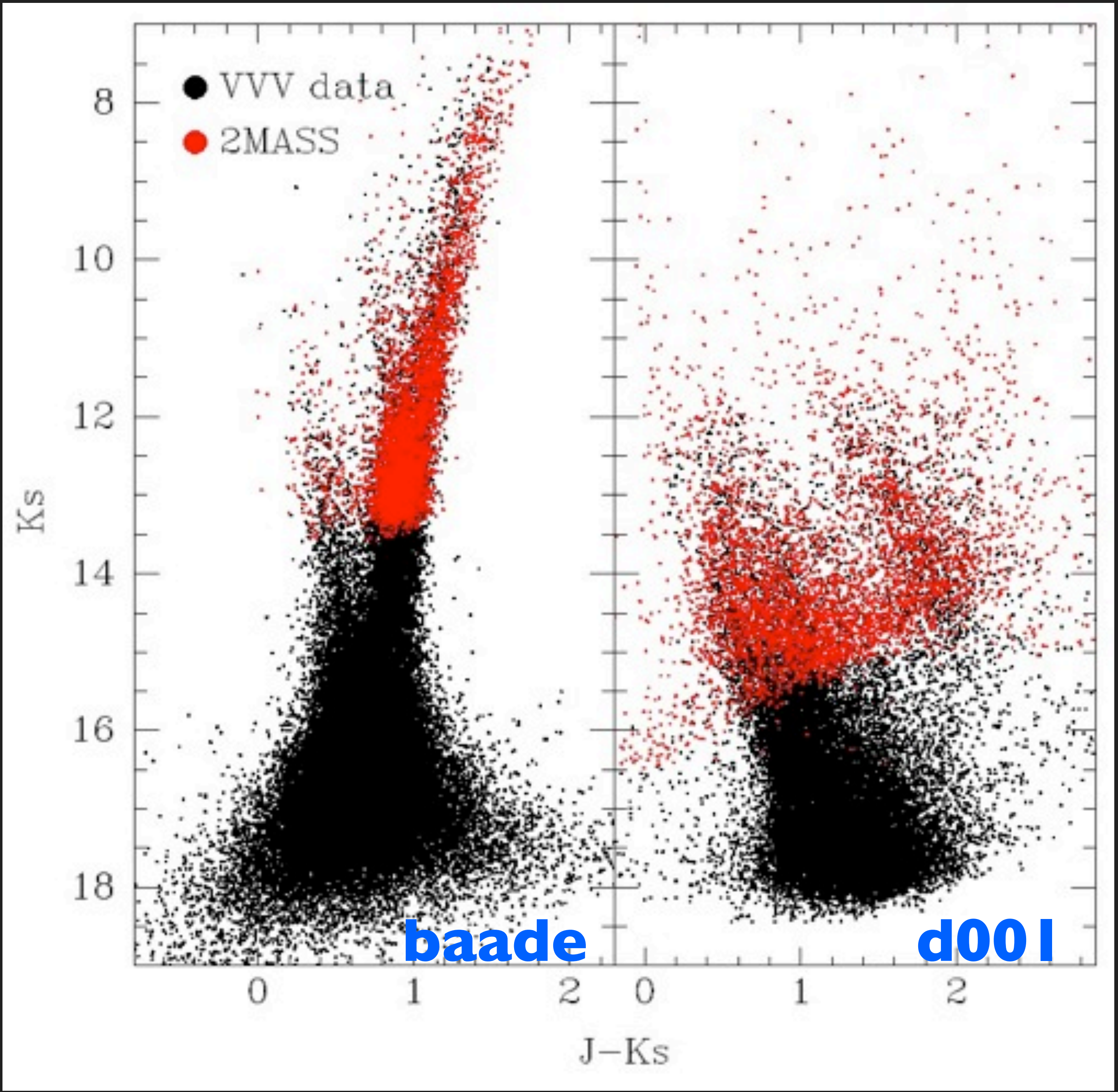
YR1 Multicolor Photometry



Ignacio Toledo

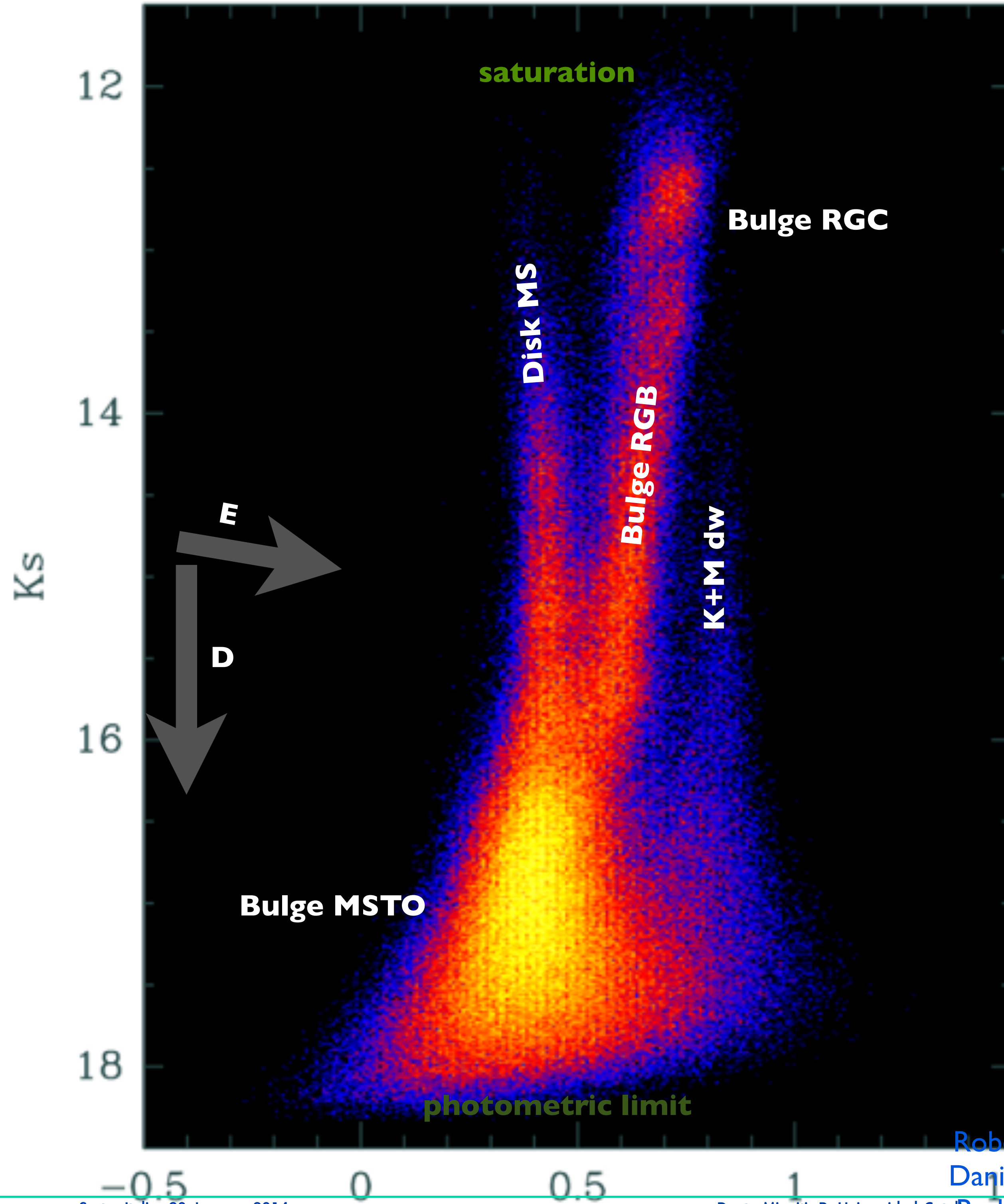
VVV CMDs

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

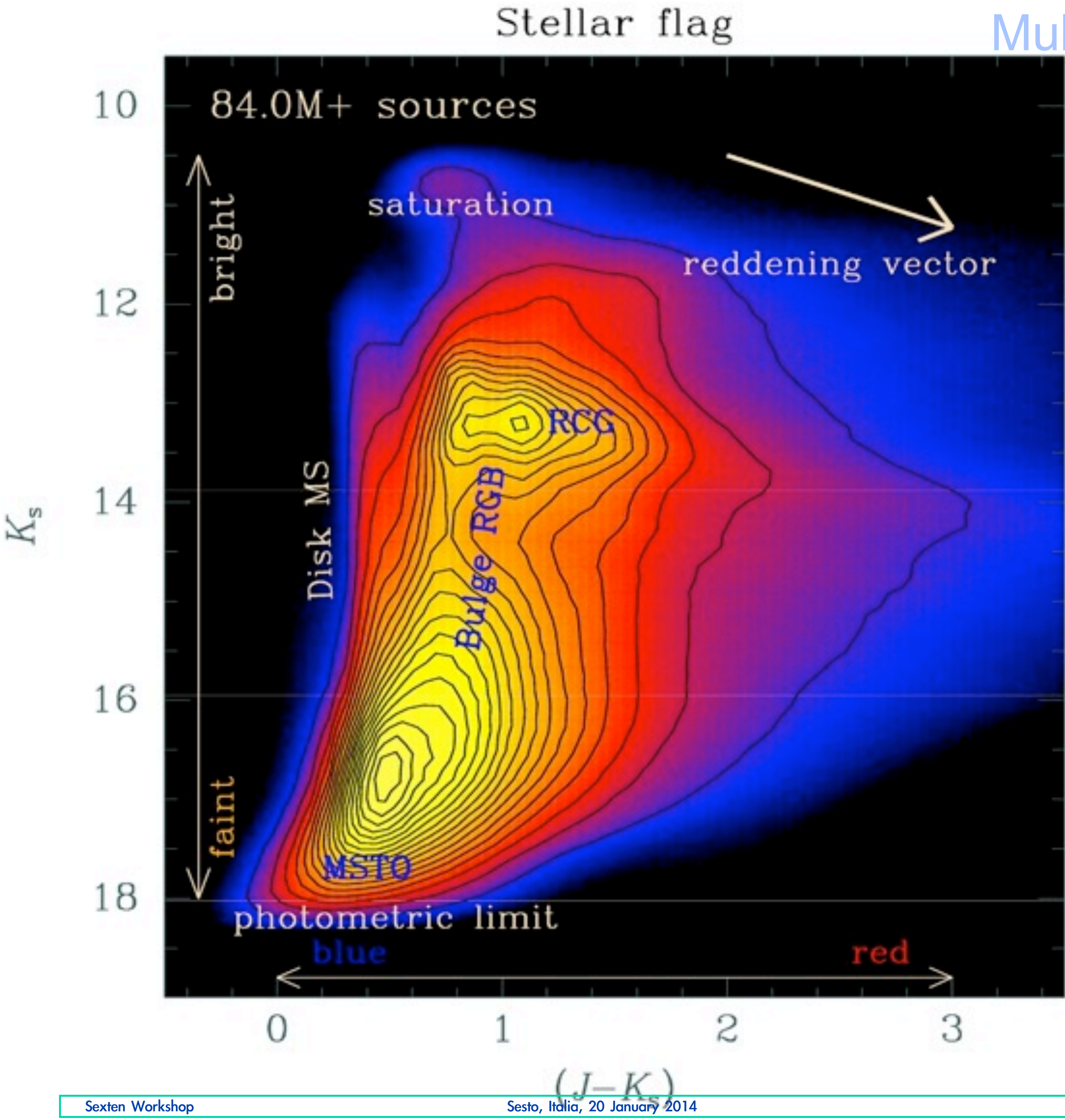


Oscar Gonzalez

VVV 0.3M SINGLE TILE BULGE CMD



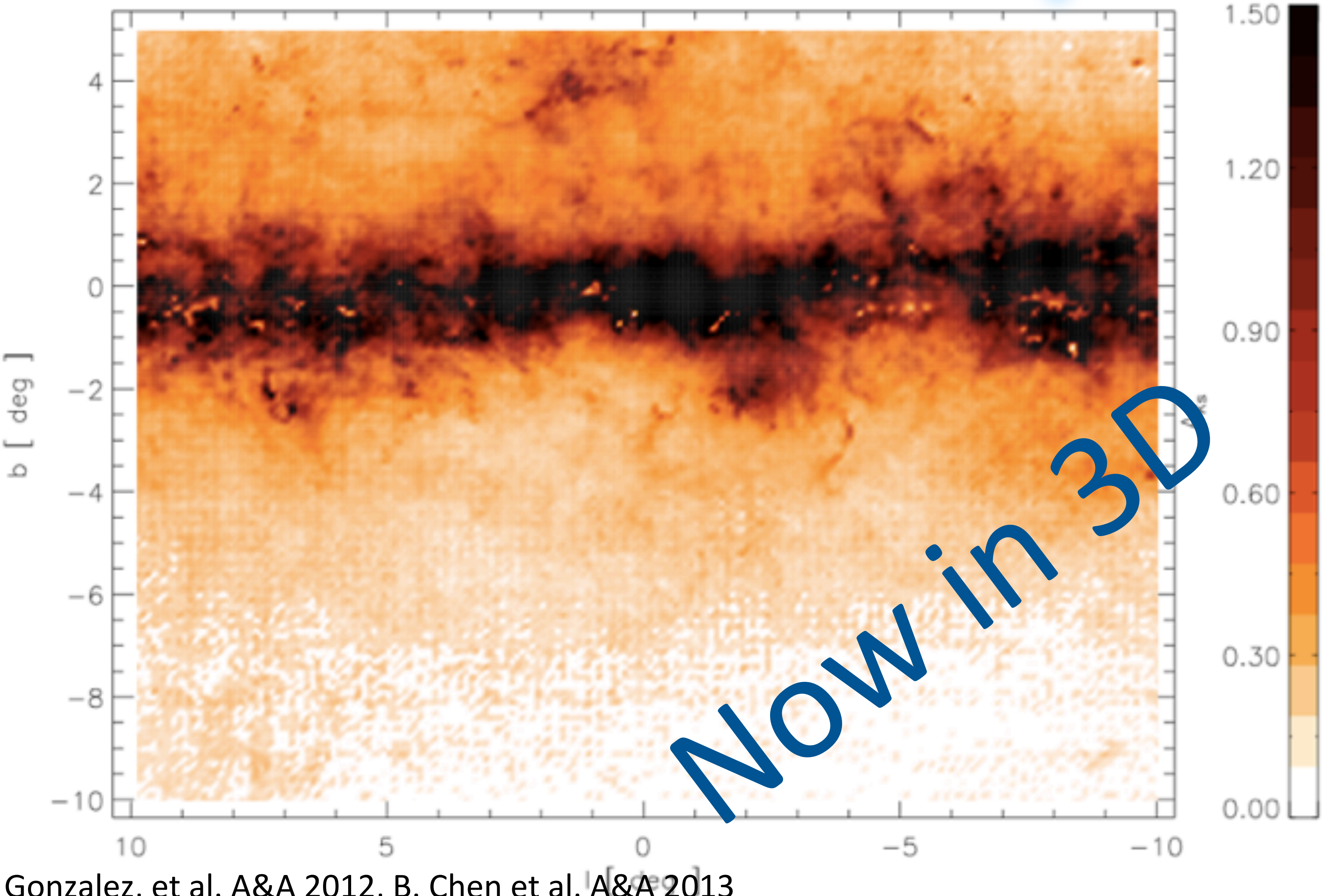
Roberto Saito,
Daniela Iglesias
Barbara Rojas



VVV 84M STARS BULGE CMD

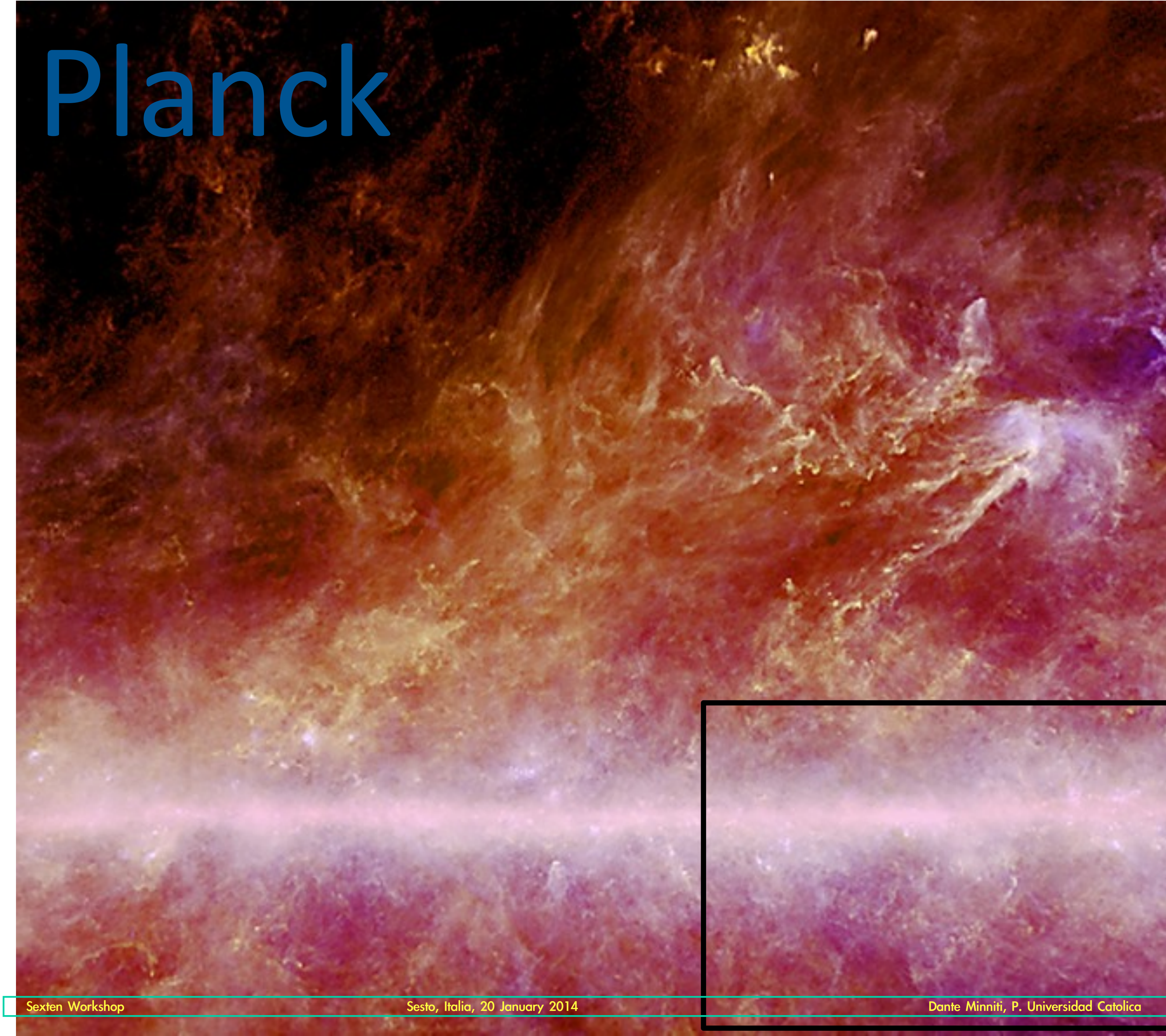
R. Saito et al. 2012

Extinction Maps

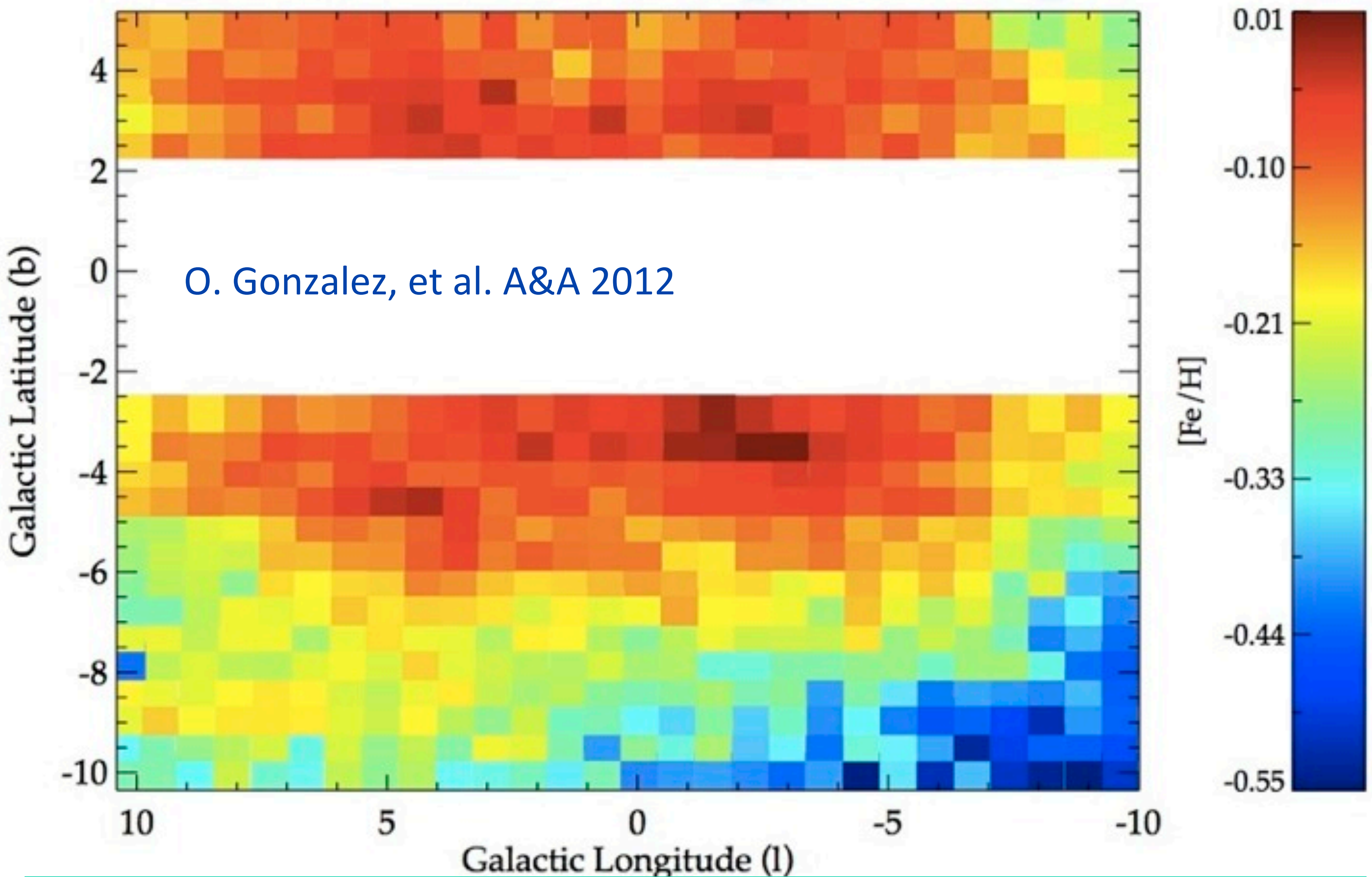


O. Gonzalez, et al. A&A 2012, B. Chen et al. A&A 2013

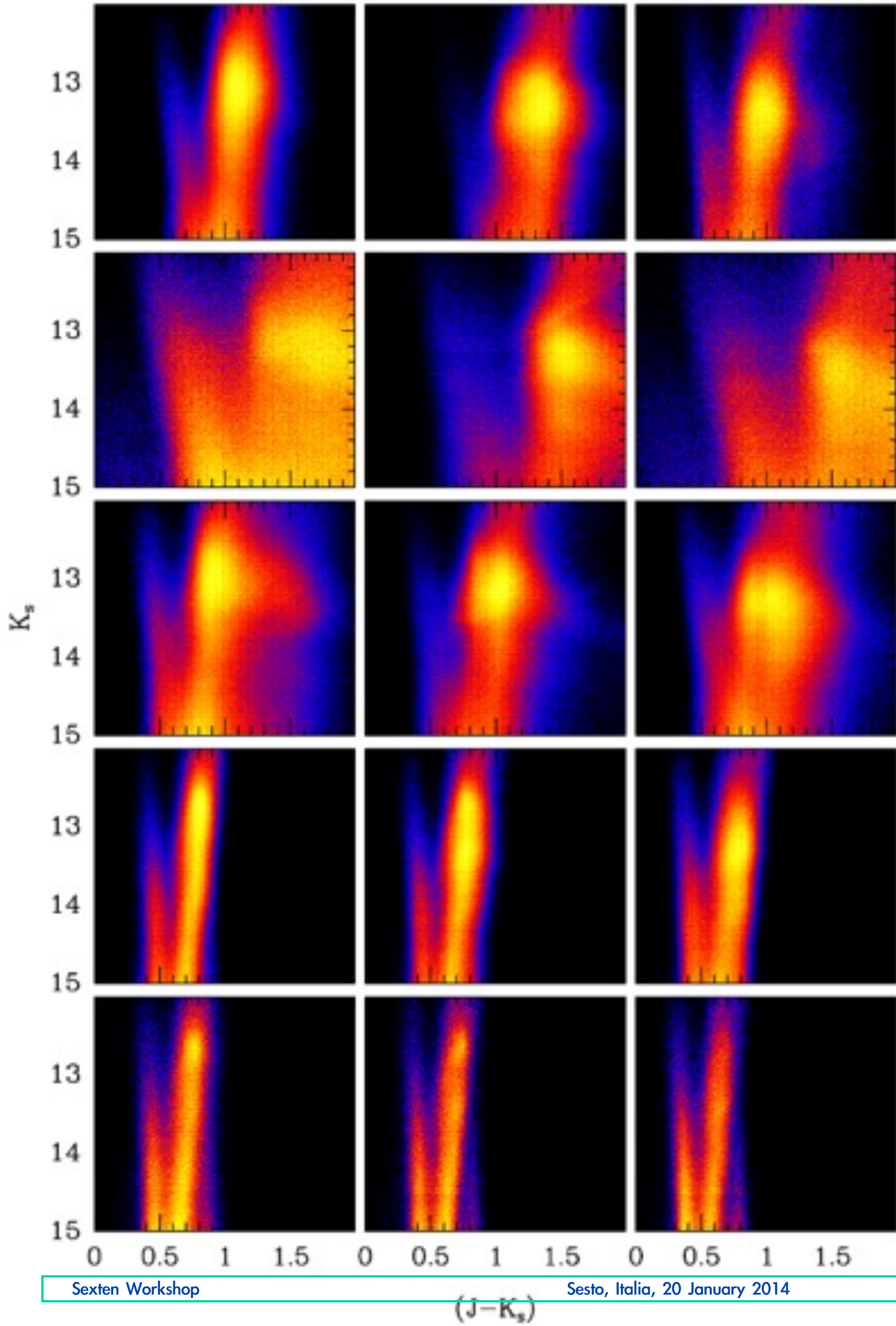
Planck

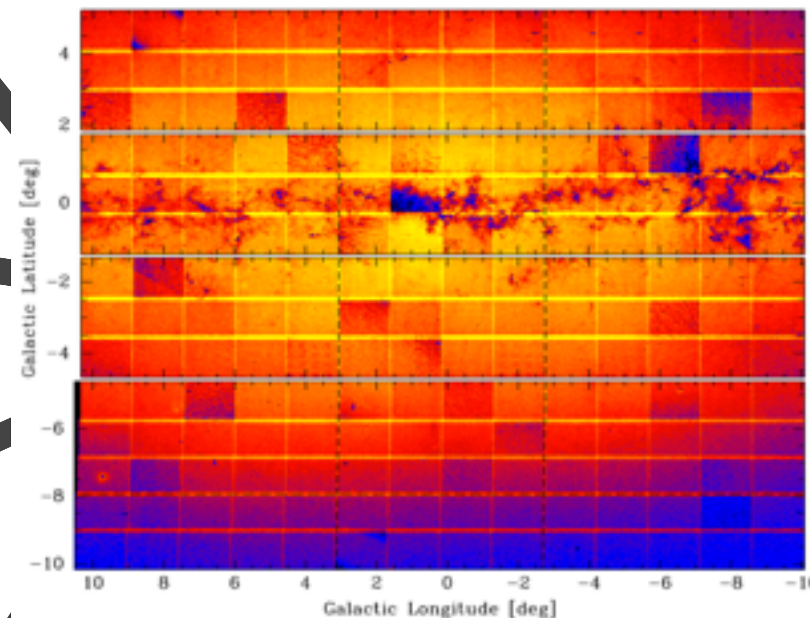


Metallicity Maps



Interpretation of the Galactic bulge CMDs: RGB clump region

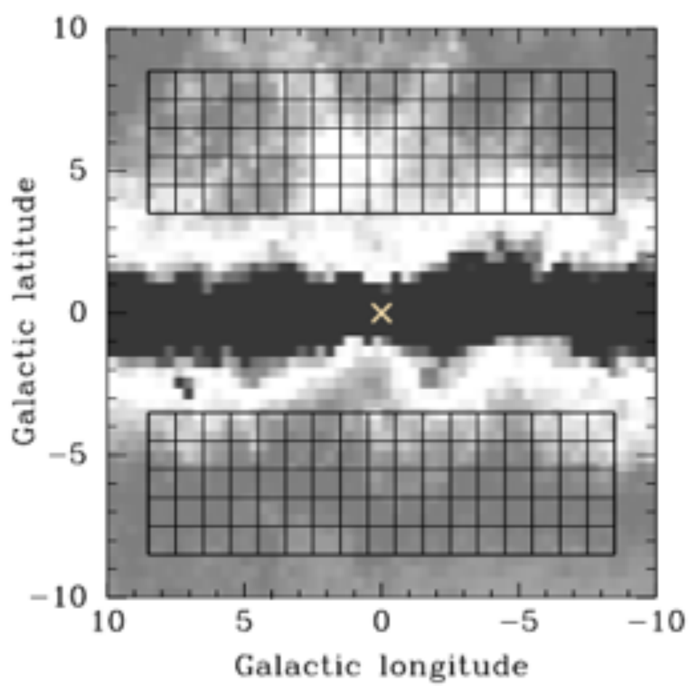


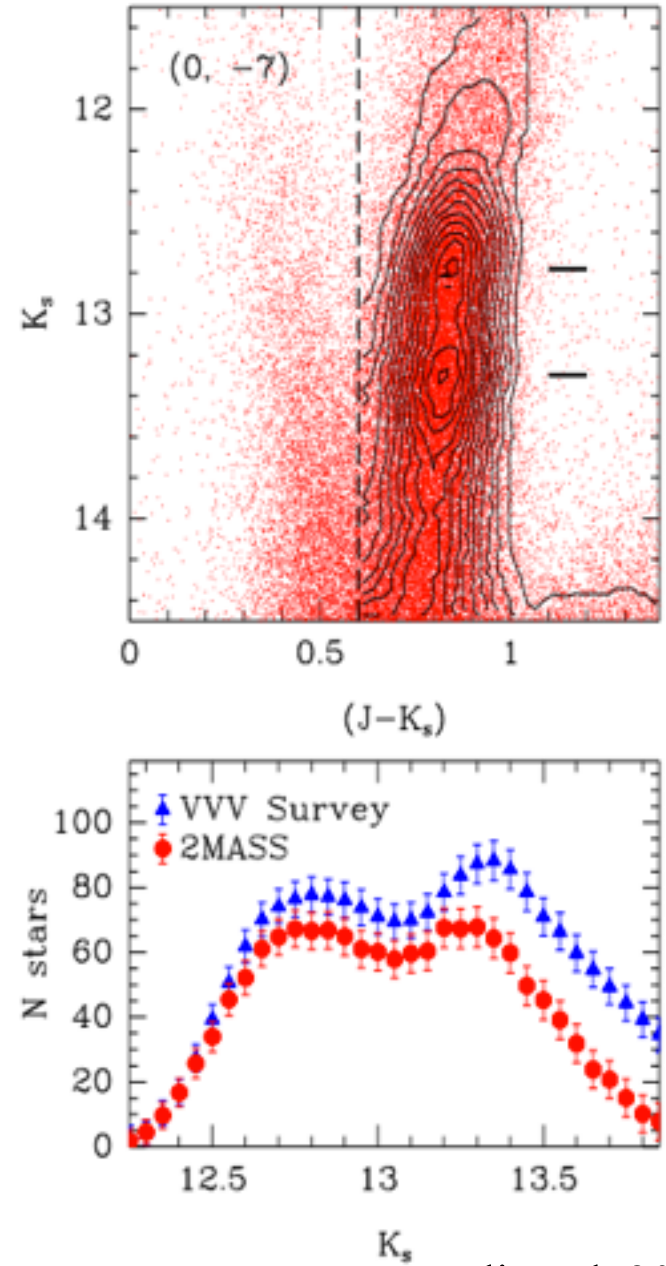


Roberto Saito

The X-shaped structure of the galactic bulge

A double clump structure is seen along different directions towards the bulge.
This is present in 2MASS and VVV data.

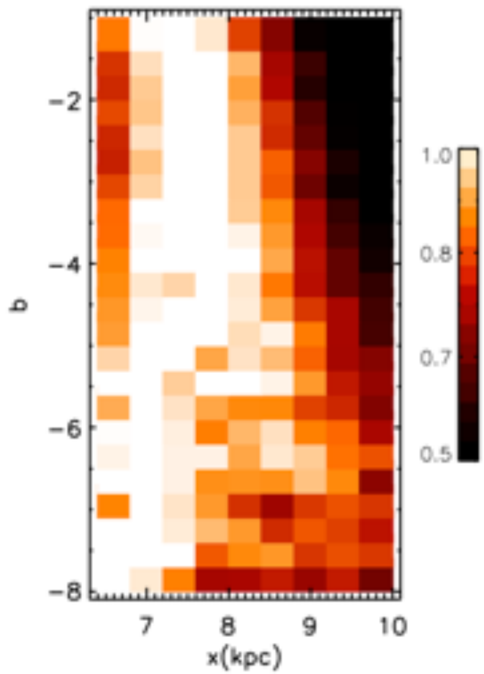




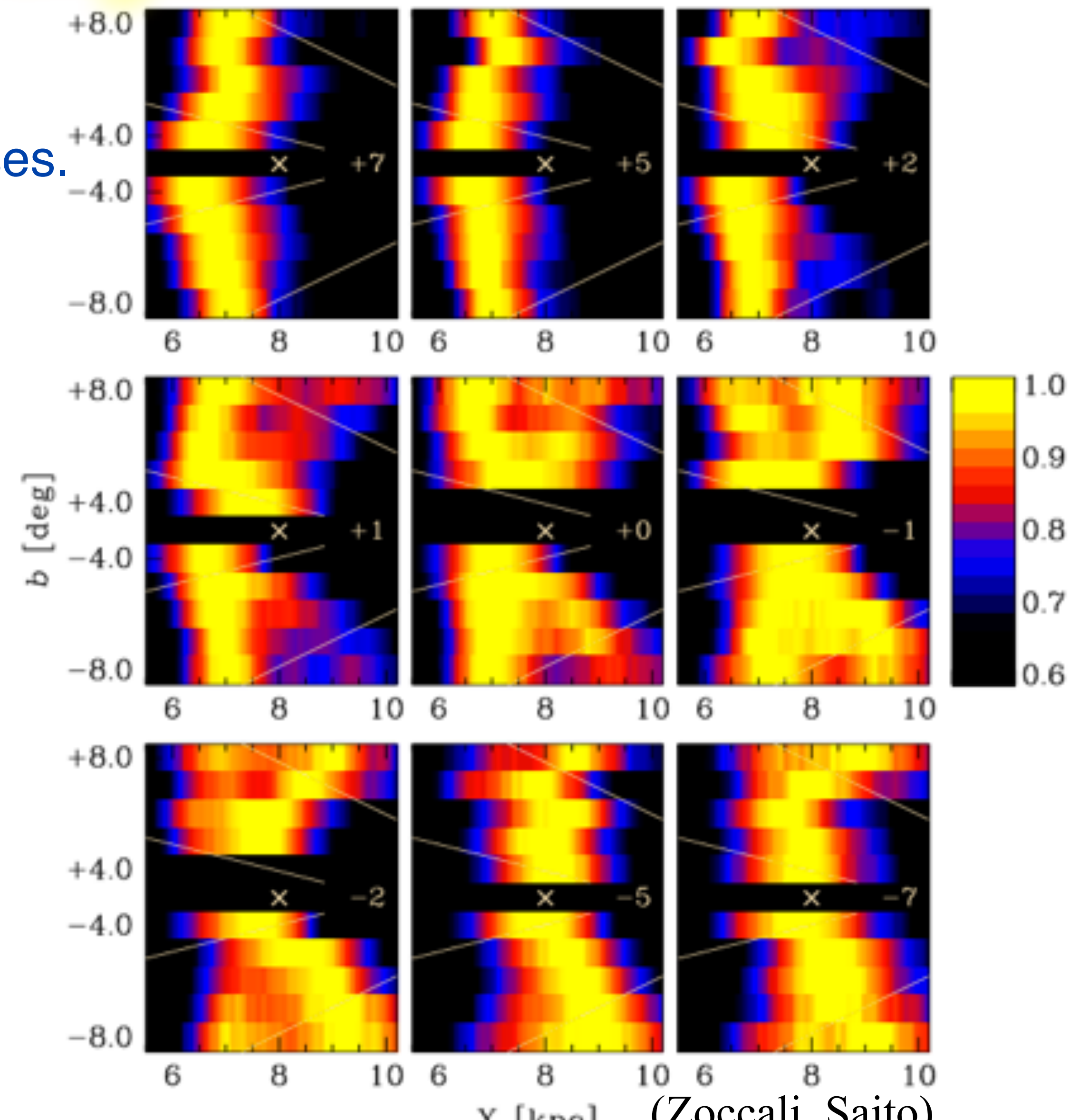
Zoccali et al. 2011

The X-shaped structure of the galactic bulge

The Milky Way bulge is X-shaped.
Two independent datasets and analyses.



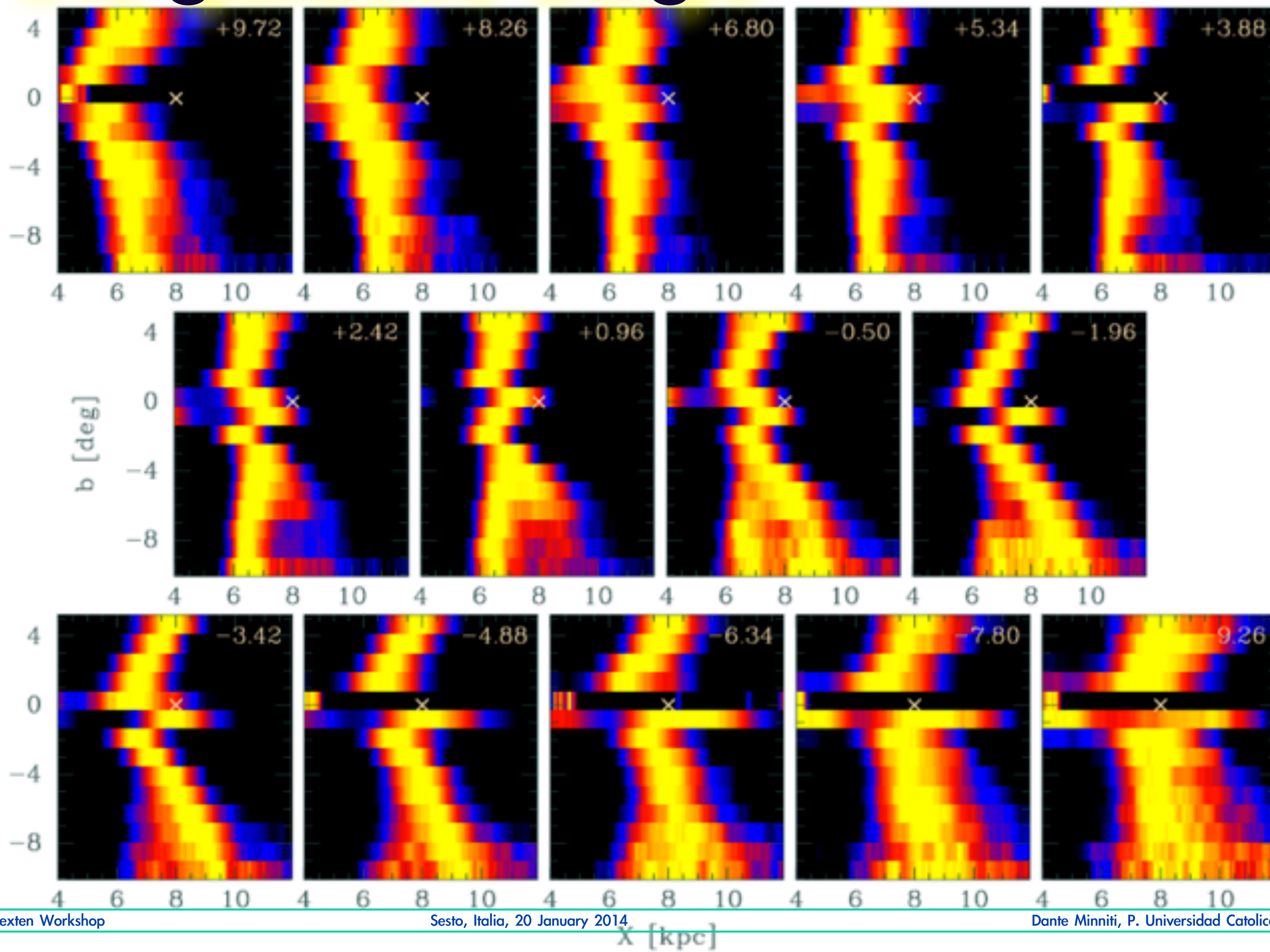
(Gonzalez, Rejkuba)



(Zoccali, Saito)

The X-shaped structure of the galactic bulge

Saito, Zoccali et al. 2012



The X-shaped structure of the galactic bulge

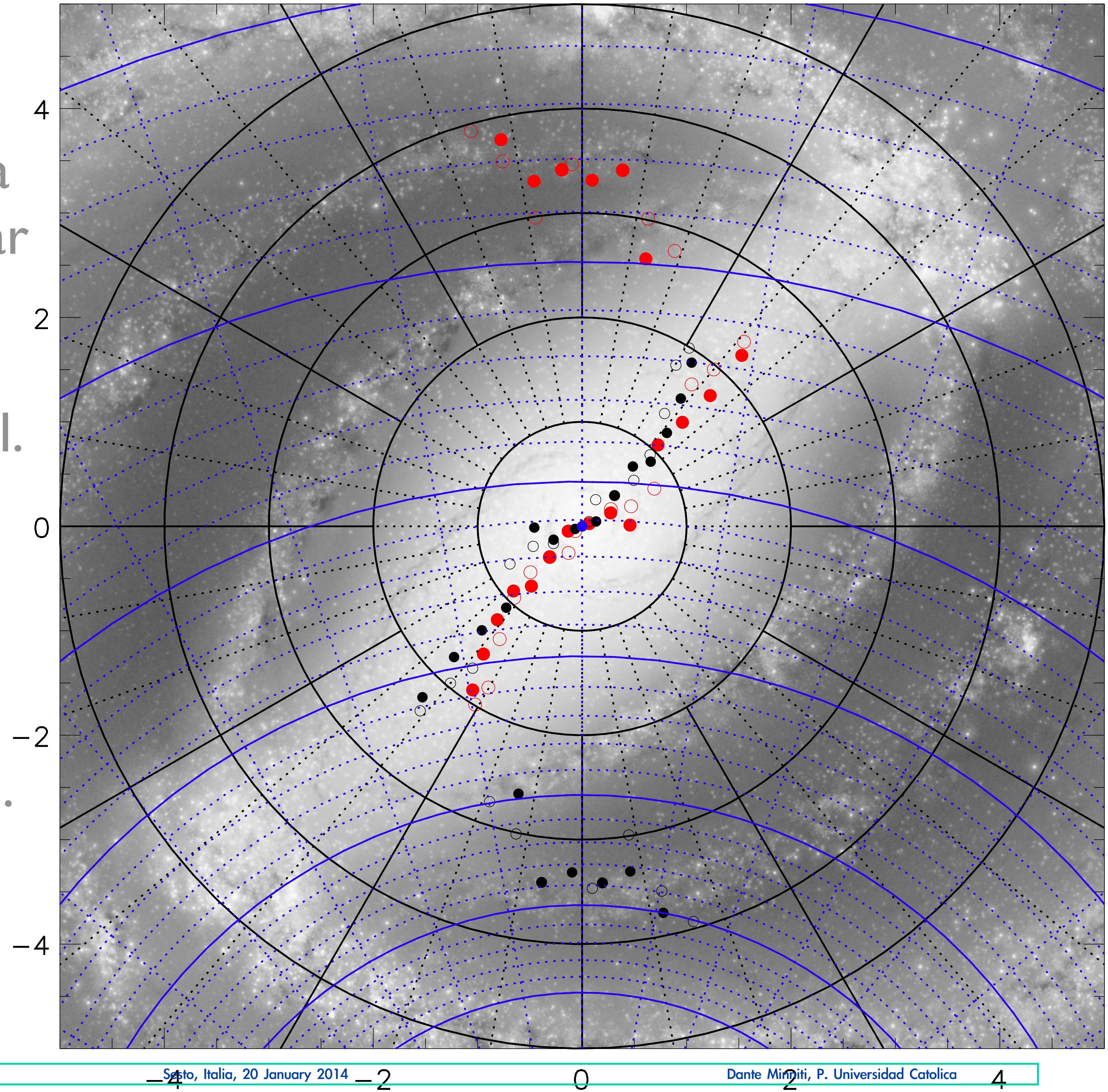
Proper motions:
Vasquez et al.
A&A 2013

NGC1365: two nested bars with two arms

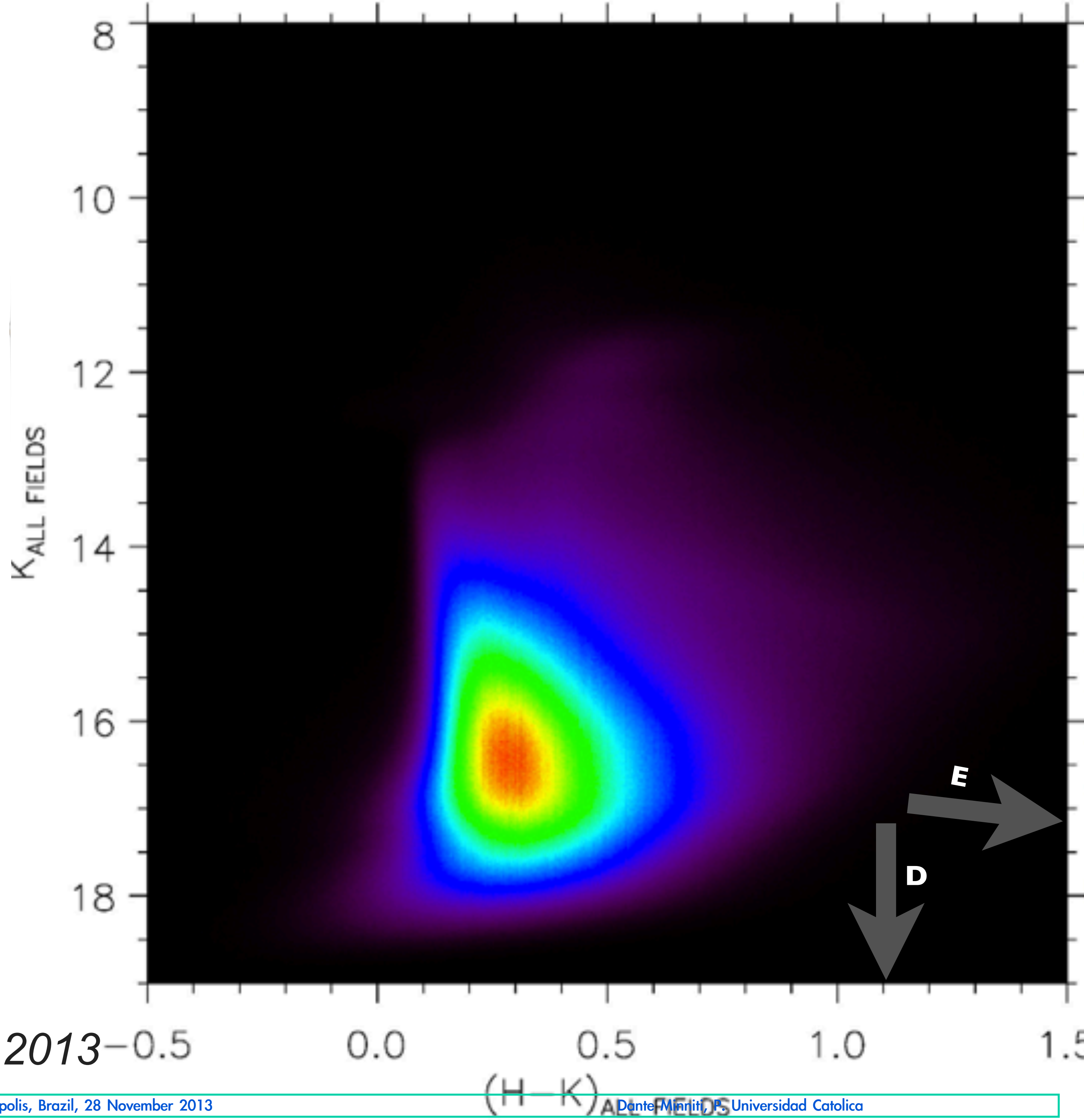
VLT INFRARED

Evidence for a tilted inner bar from bulge clump giants Gonzalez et al. A&A 2012

Or projection effects Valpuesta et al. 2012

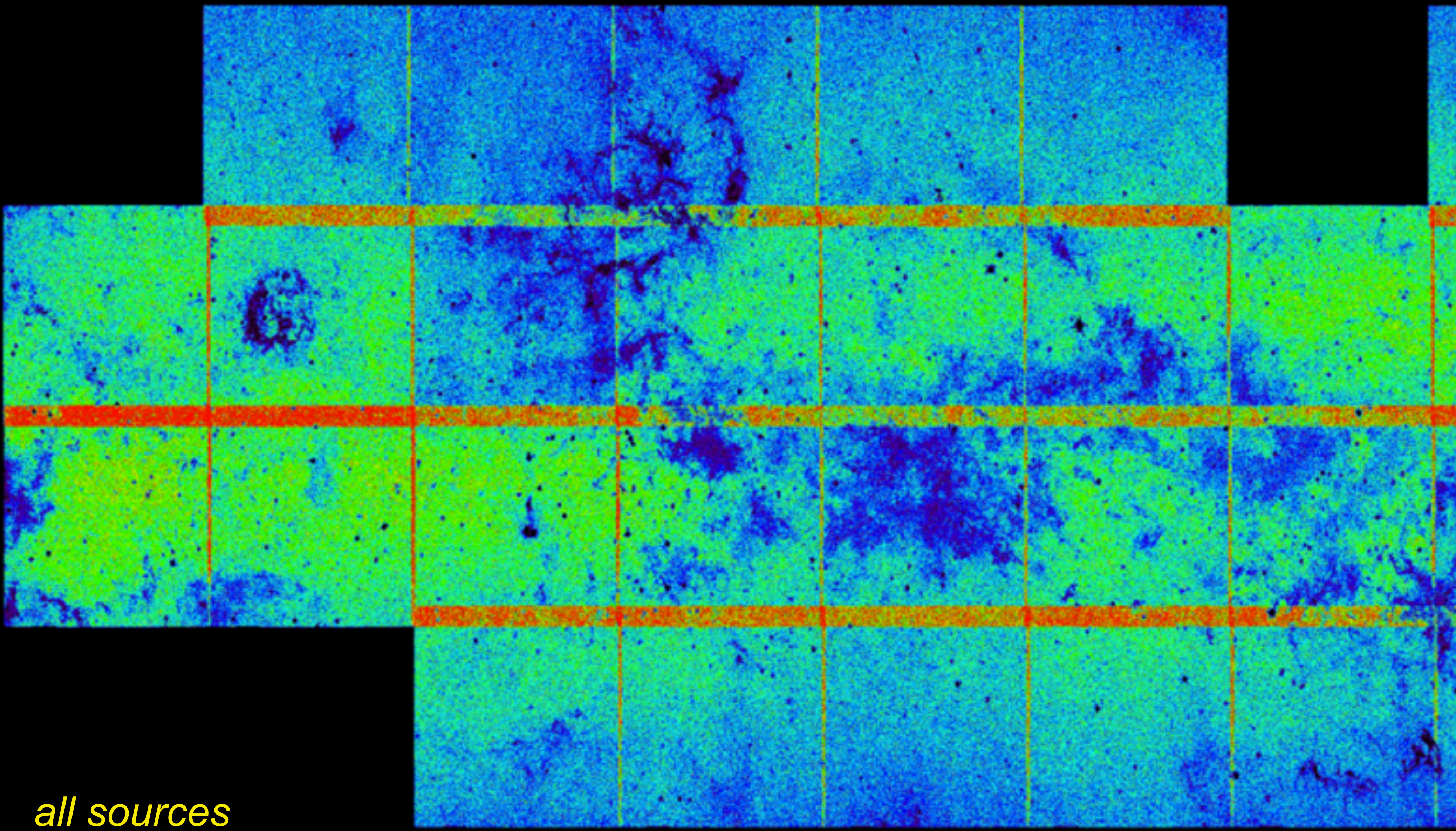


VVV DISK 140M STARS



M. Soto, R. Barba, et al. 2013

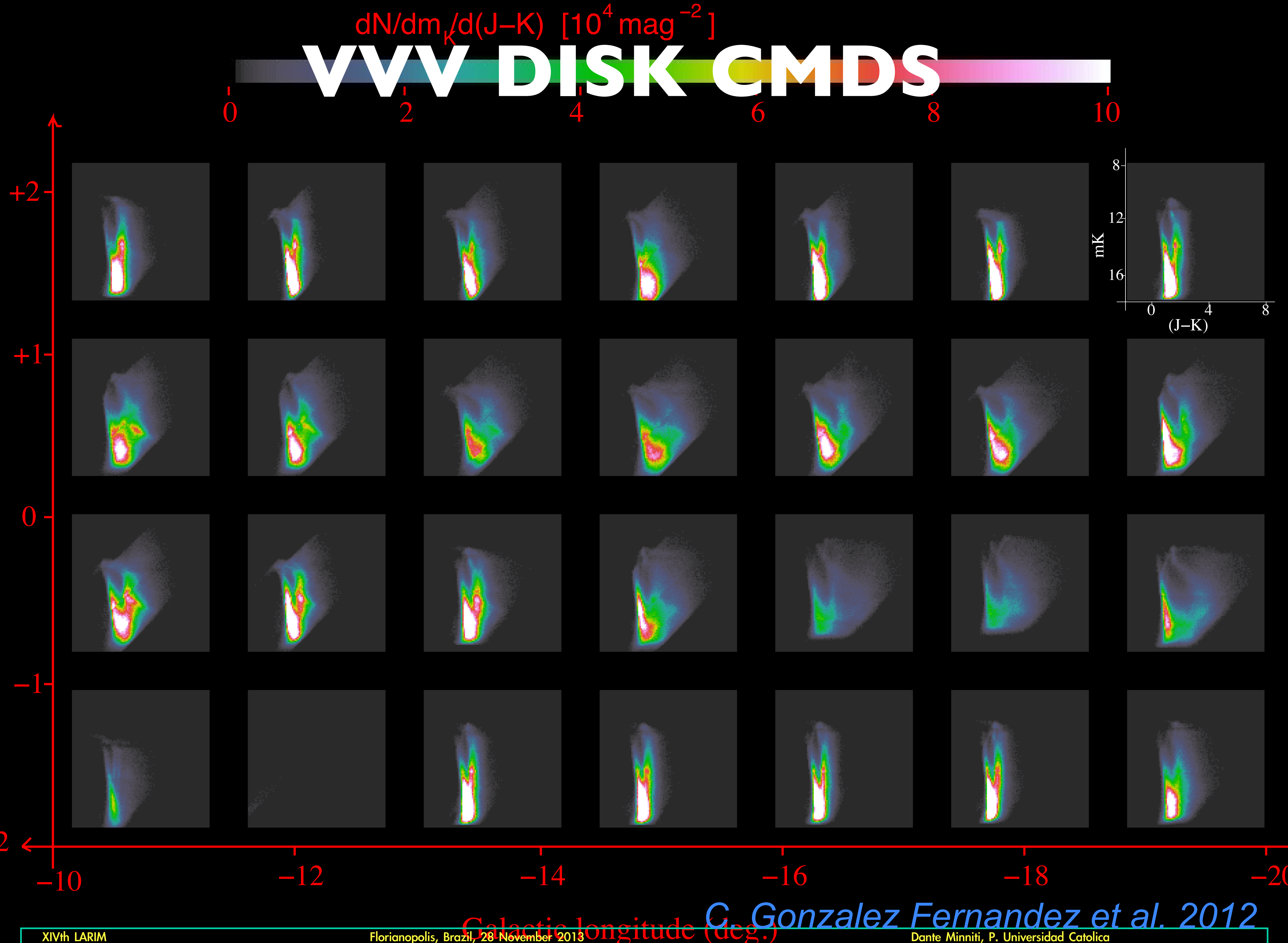
VVV DISK DENSITY MAPS



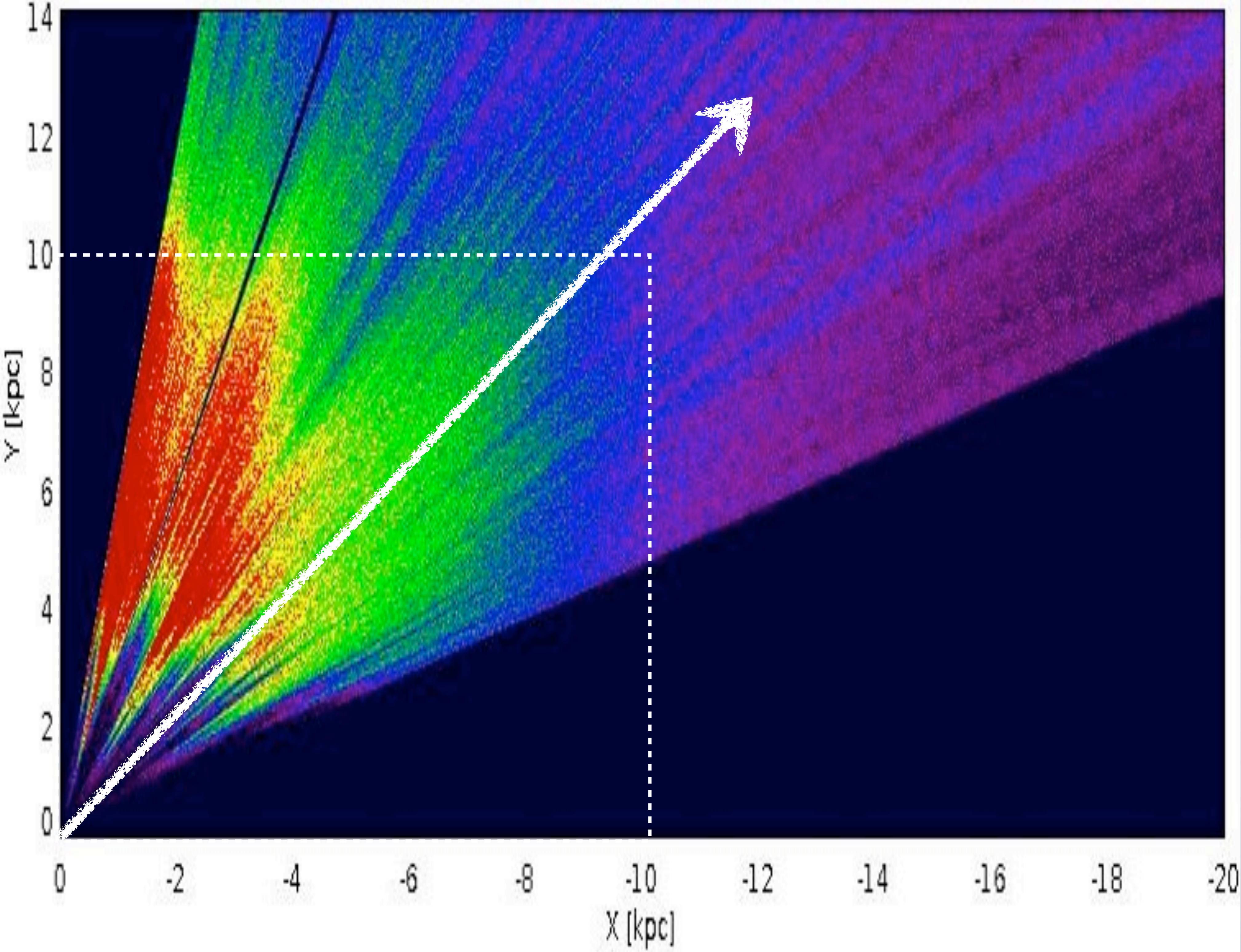
all sources

M. Soto, R. Barba

VVV DISK CMDS

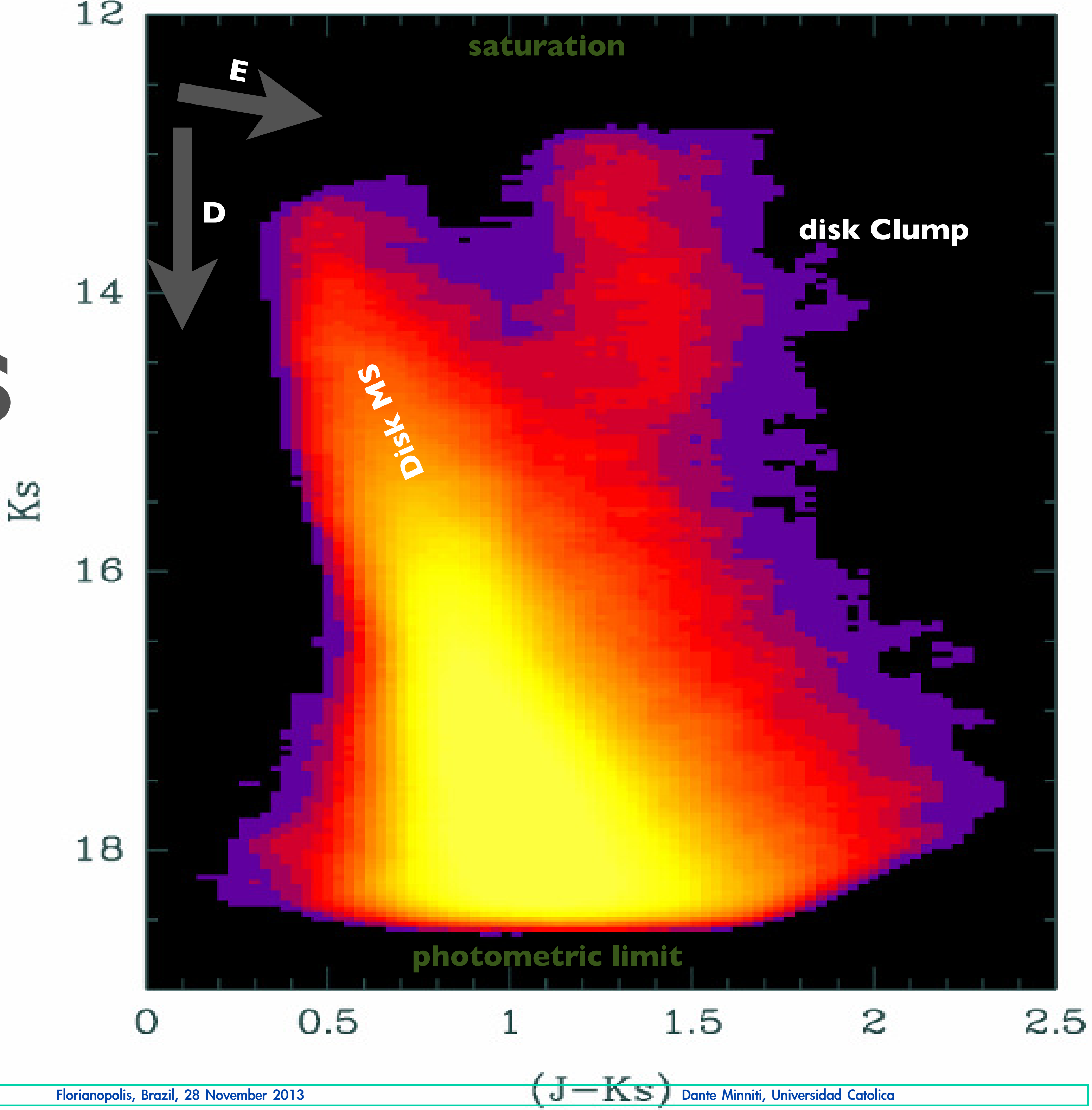


C. Gonzalez Fernandez et al. 2012



14
12
10
8
6
4
2
0
Y [kpc]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
X [kpc]

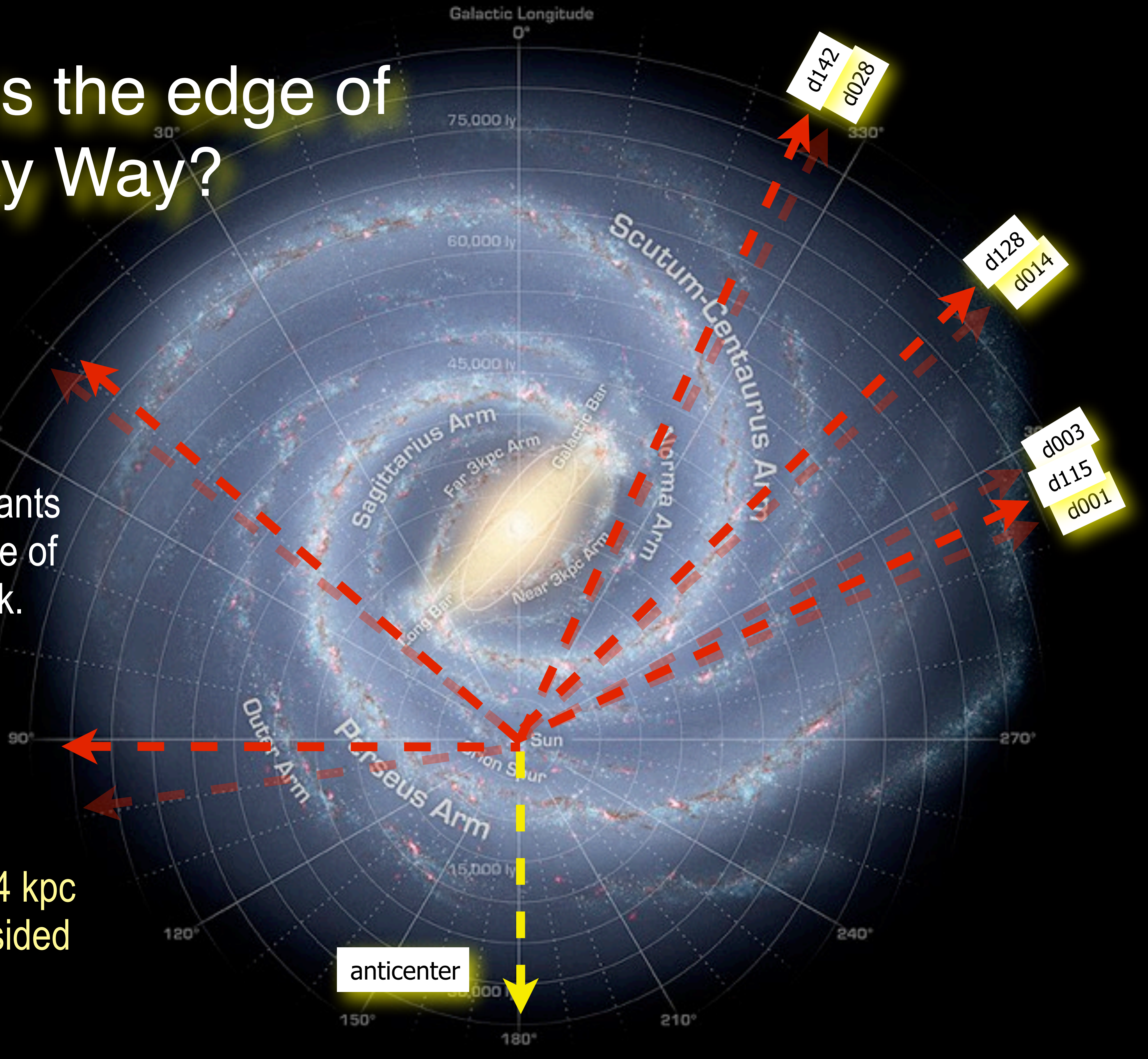
VVV 0.5M+ STARS DISK CMD



d003 field

Where is the edge of the Milky Way?

Using clump giants to map the edge of the galactic disk.

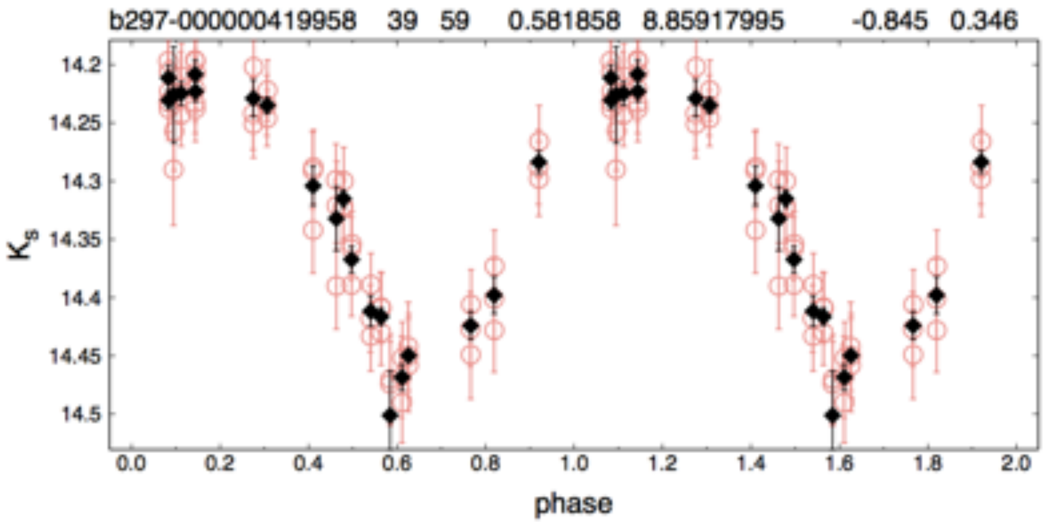


Results:

- R_edge = 14 kpc
- disk not lopsided

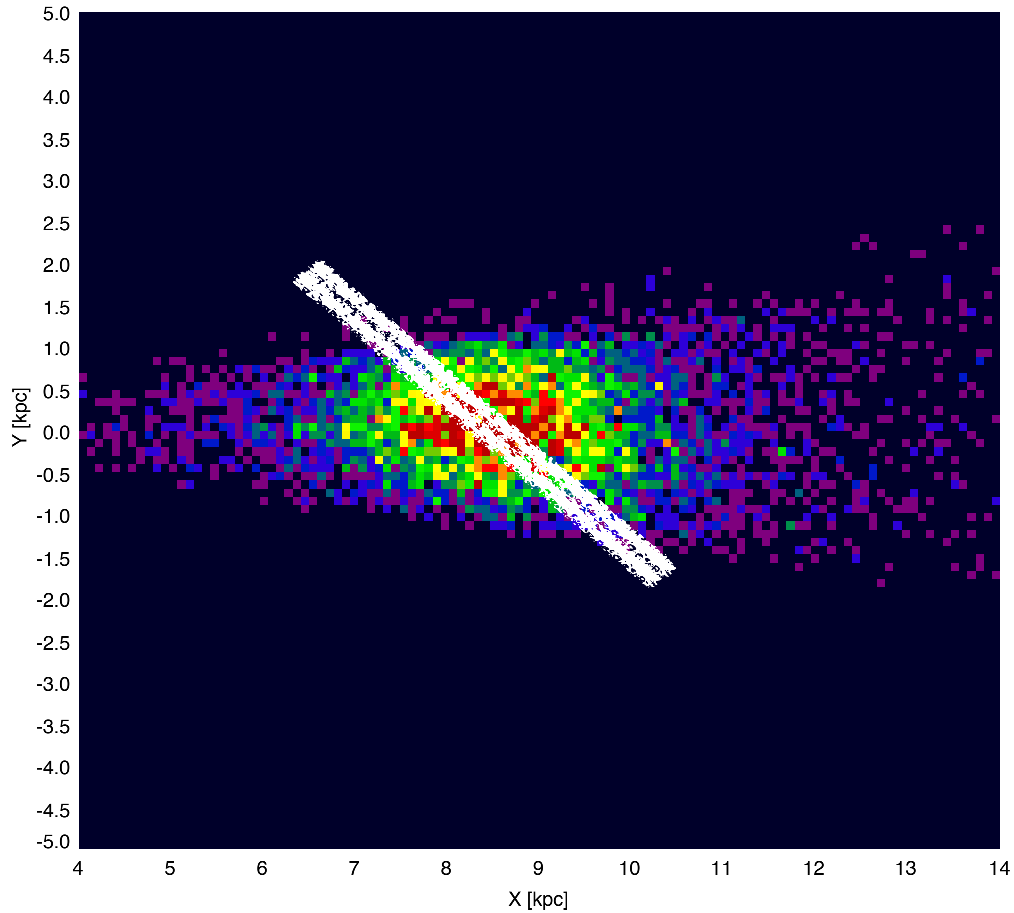
Bulge RR Lyrae

- RR Lyrae are metal-poor and represent the oldest stars.
- They are good primary distance indicators.



- We expect to find 100,000 RR Lyrae in the VVV database.

The VVV distance distribution of known bulge RR Lyrae is different from the clump giants!



Istvan Dekany, et al. 2013, ApJ Letters, in press

The VVV Stages

Multicolor Photometry: ZYJHKs

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

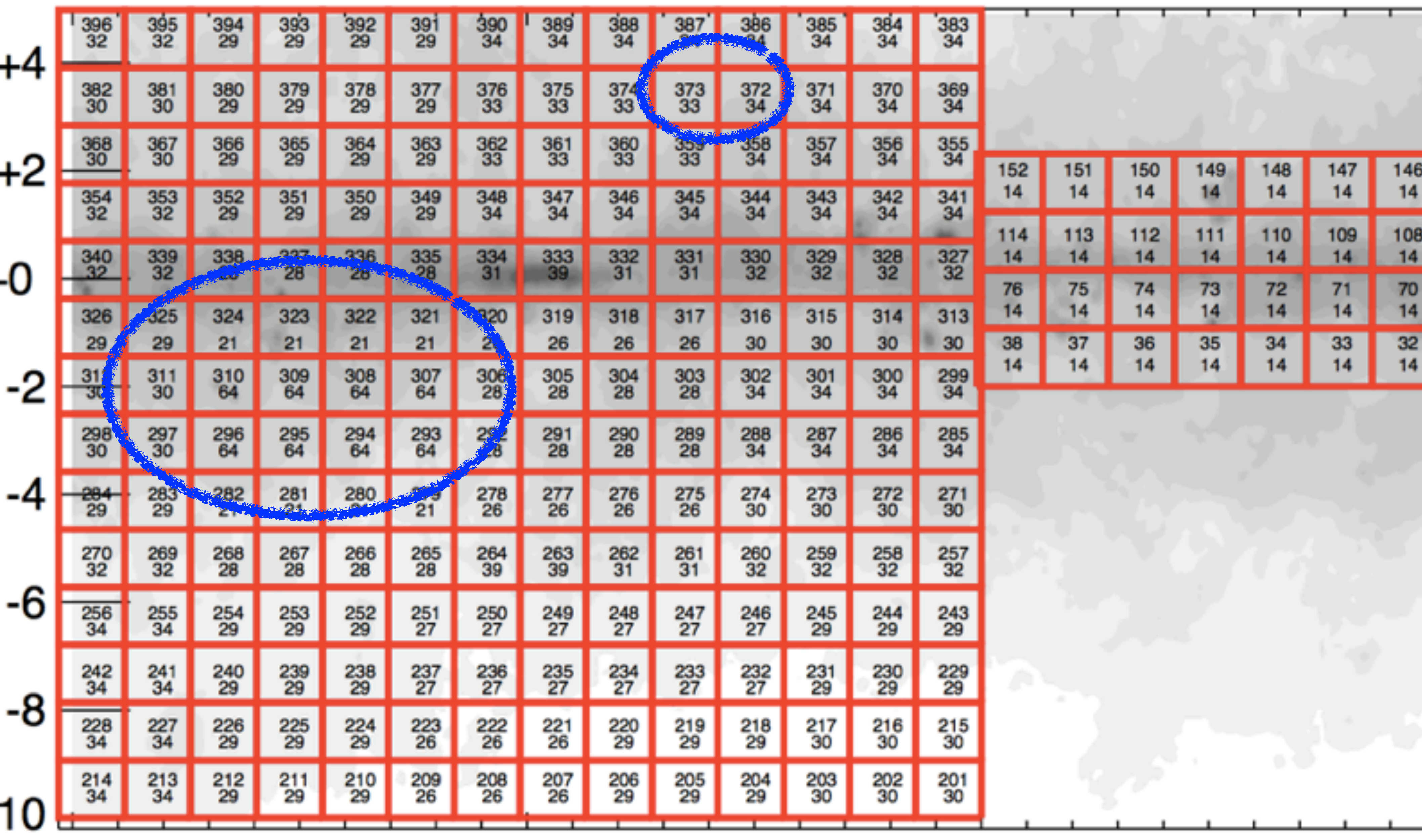
Variability: Ks

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

Proper Motions: Ks

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

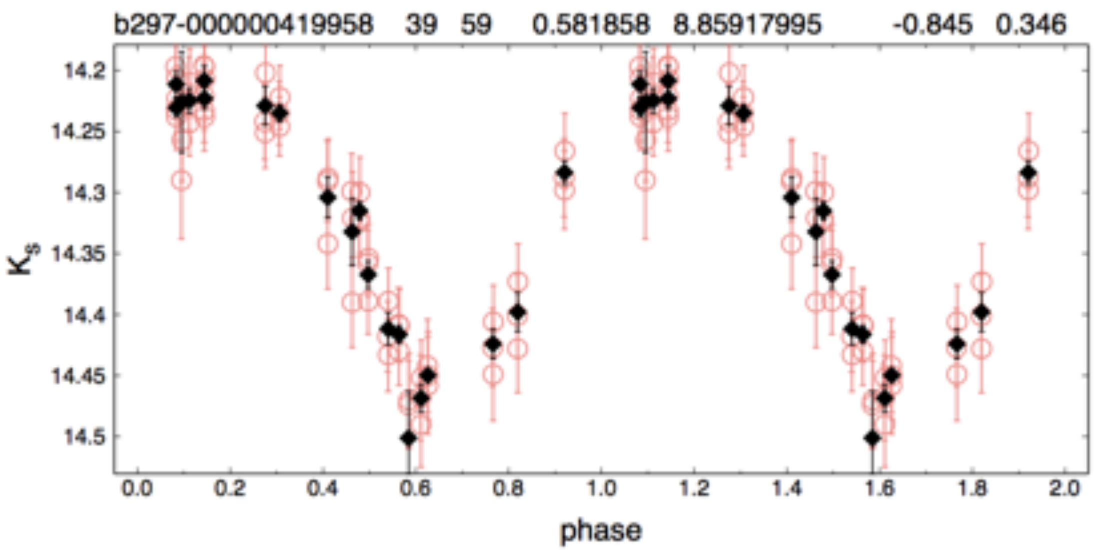
Number of Epochs: Bulge



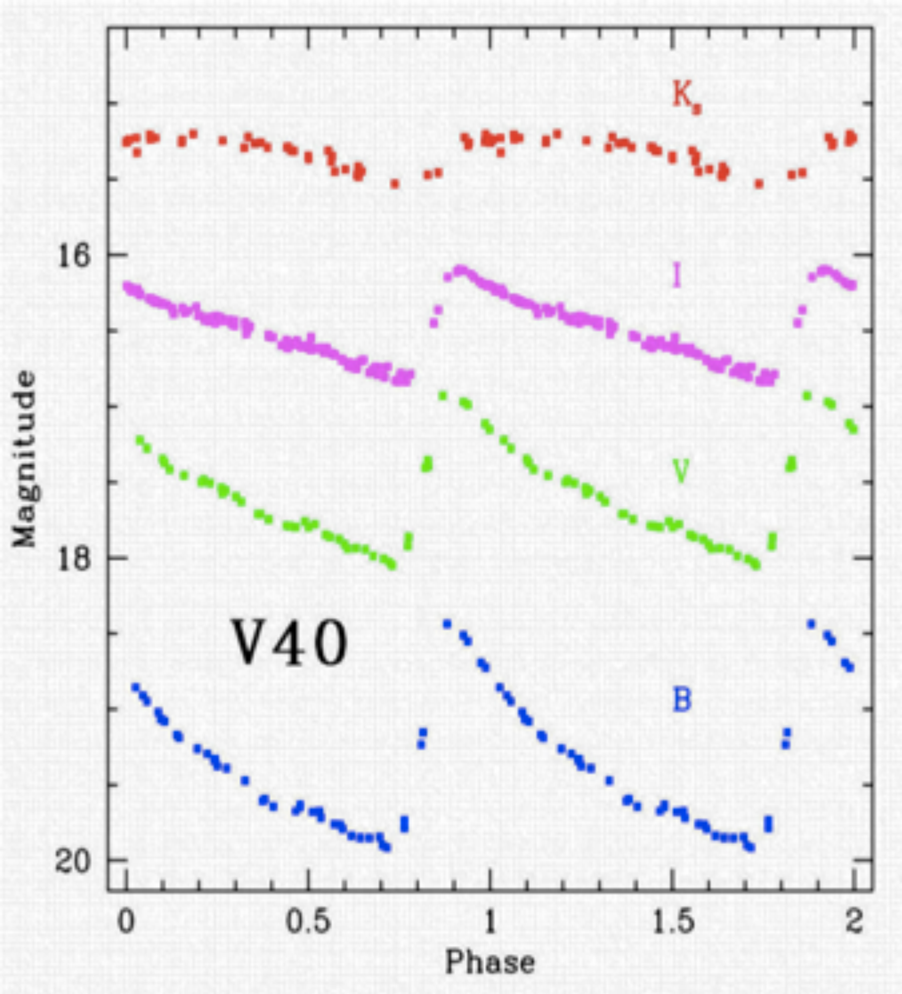
Maren Hempel

Bulge RR Lyrae:

P = 0.58 d

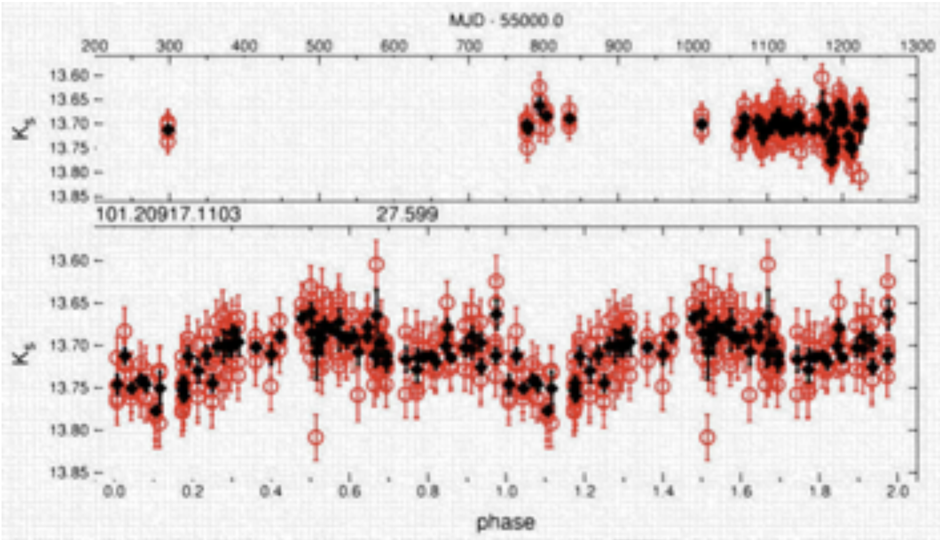


Comparison of optical and IR light curves

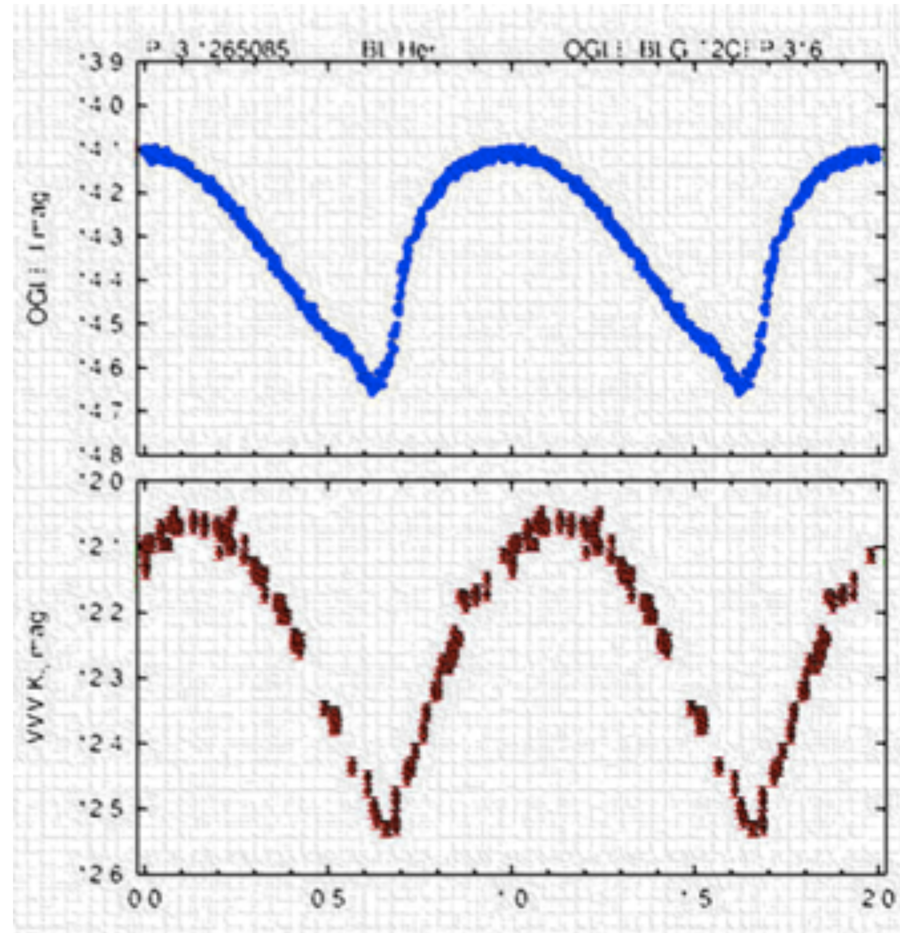


Istvan Dekany

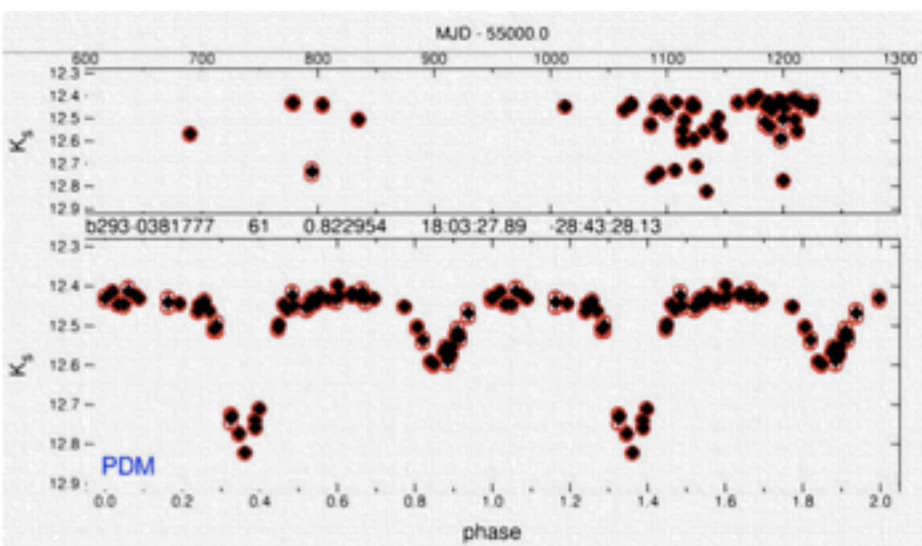
RSCVn type variable



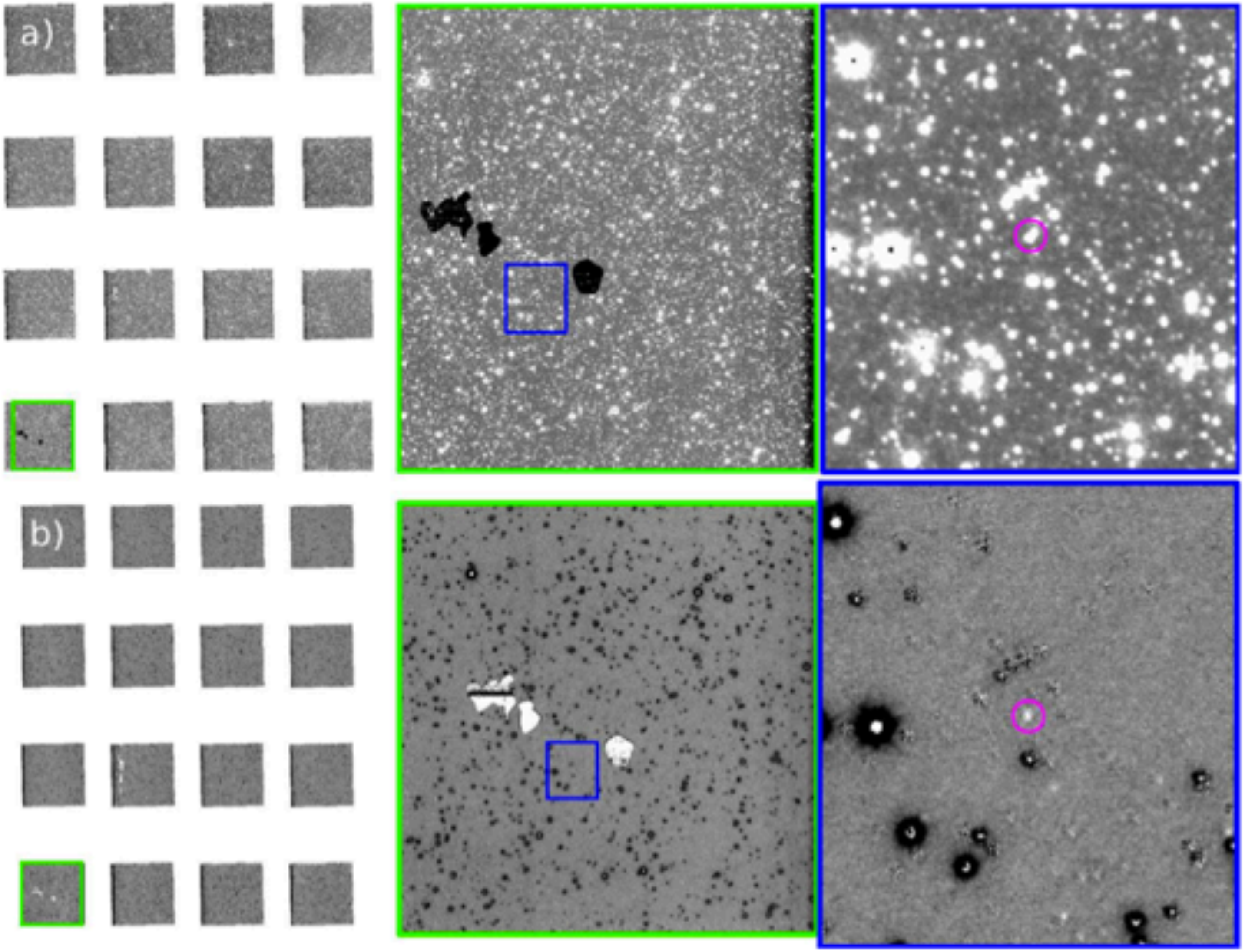
Bulge Type II Cepheid



Eclipsing Binary



DIA photometry



Main DIA problem: undersampling

Total in VVV Survey ~few millions of variables

Method based on Alard & Lupton 1998 ApJ

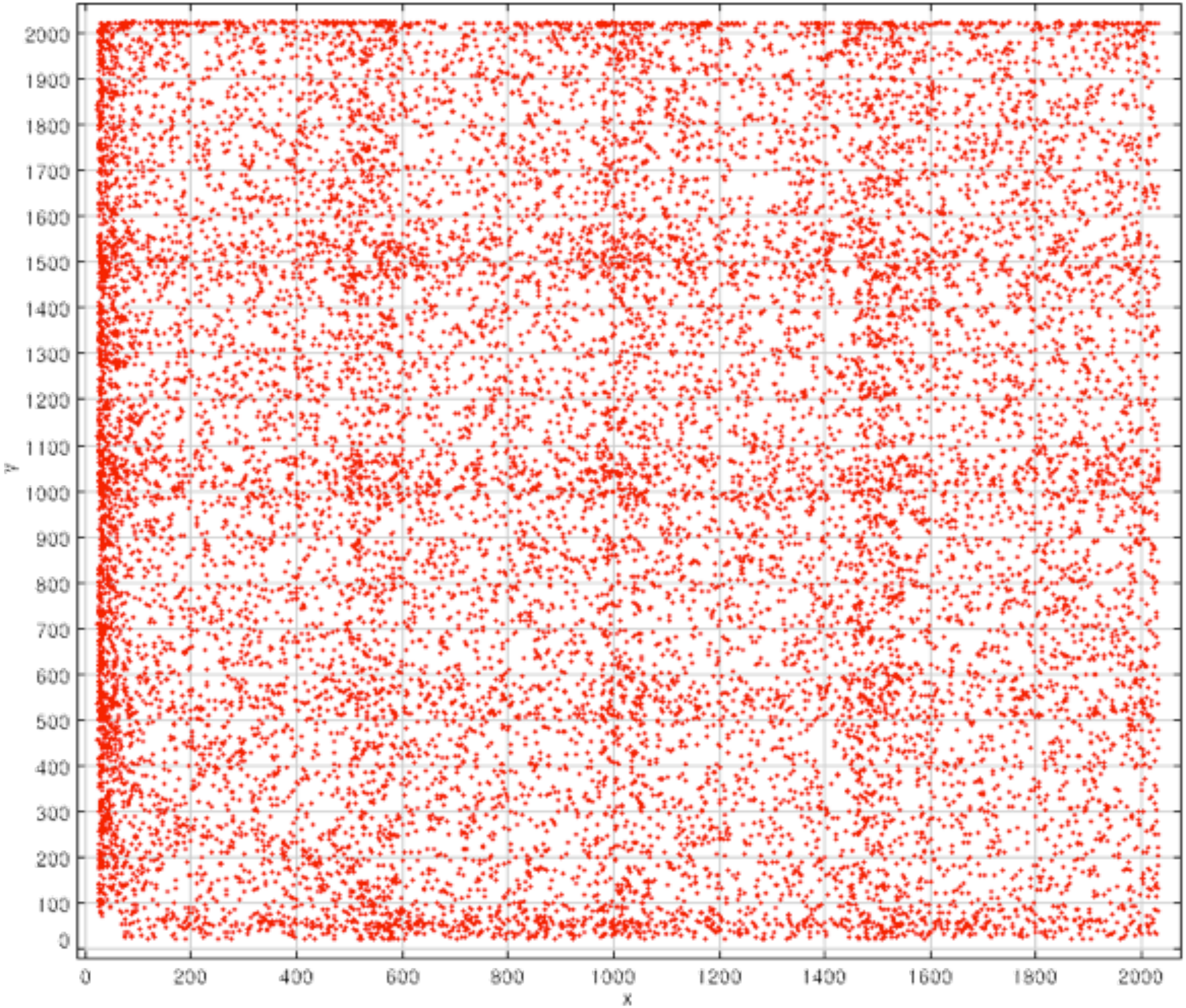
Fig. 17. (a) A K_s band pawprint from one VVV SV bulge field epoch showing views of: the full pawprint (left); a zoom into Array 1 (middle); and a further zoom centred on a circled variable object (right). (b) The bottom row shows the respective difference image views.

(Eamonn Kerins, Leo Huckvale)

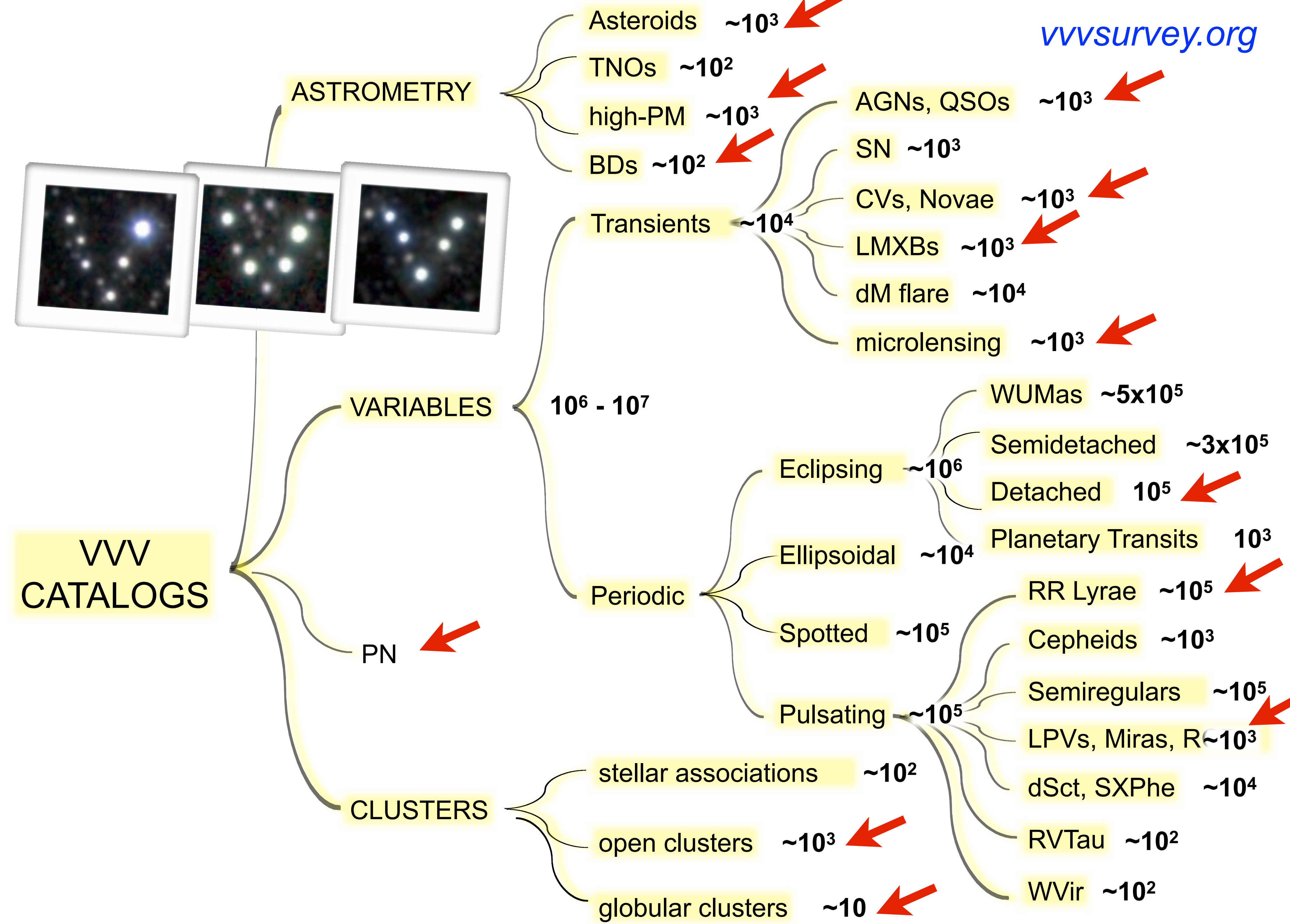
DIA photometry

DIA pipeline working

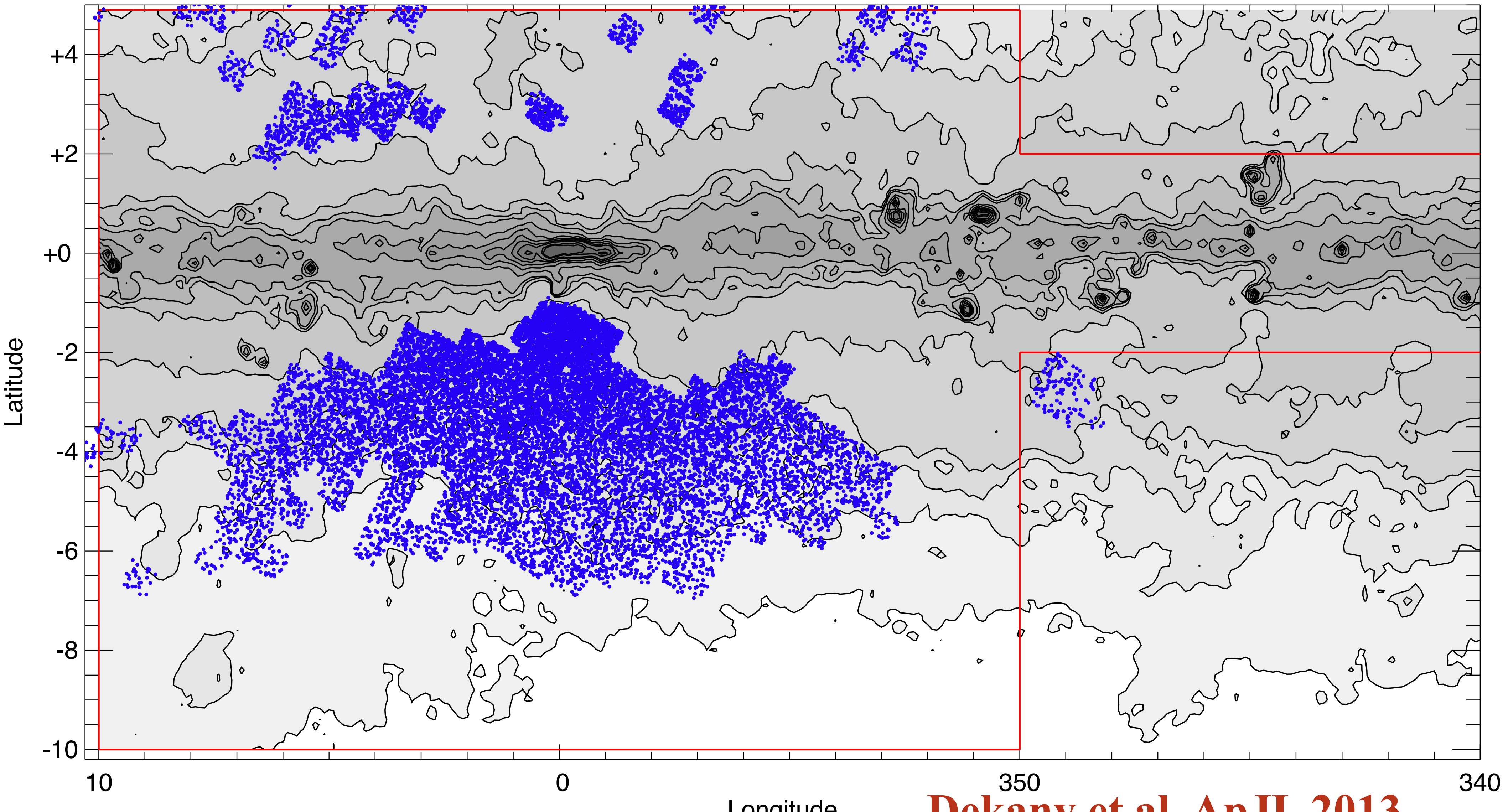
Example:
DIA Variables in tile d068



Eamonn Kerins, Leo Huckvale, Phil Lucas

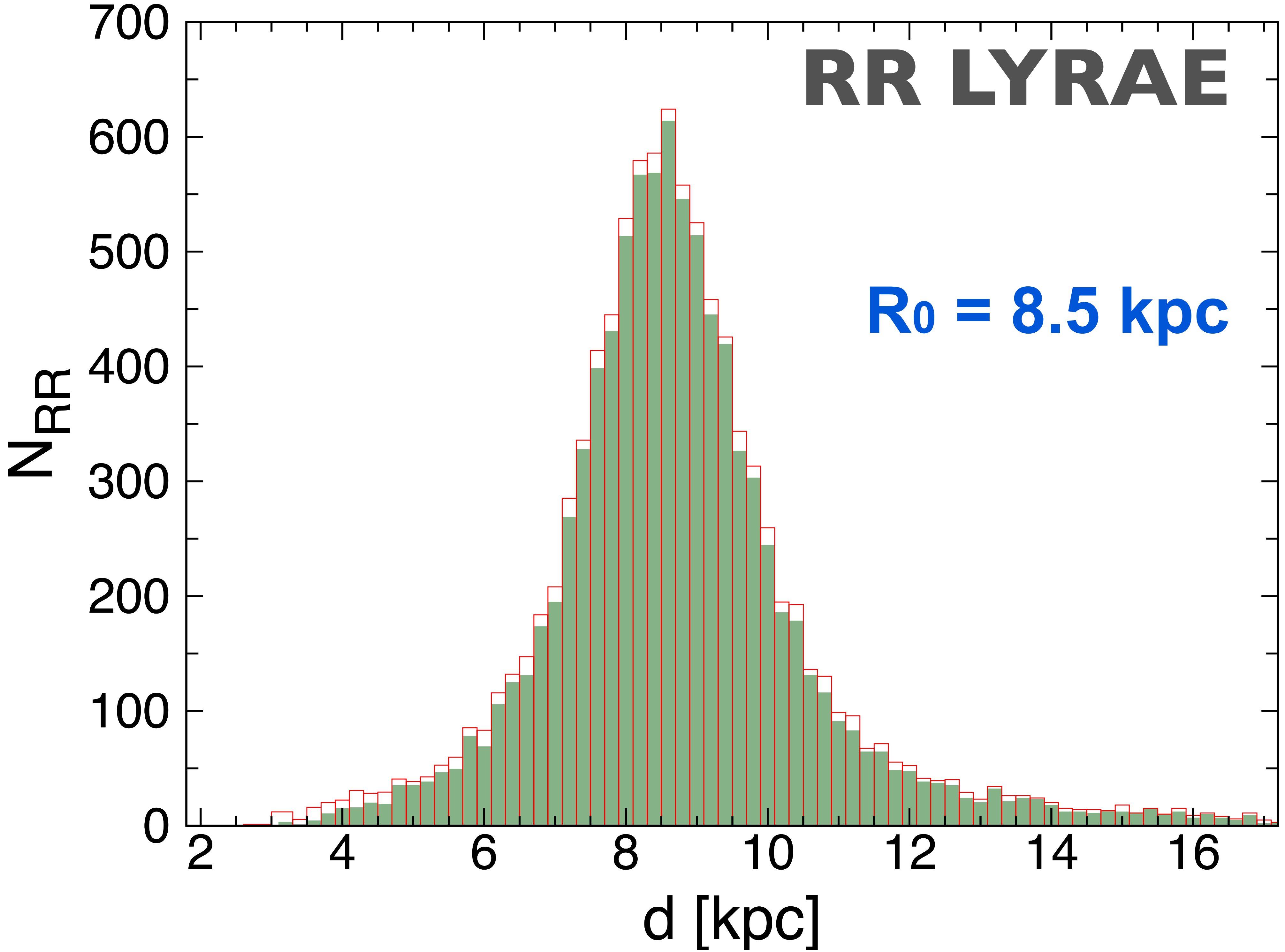

vvvsurvey.org
VVV CATALOGS
ASTROMETRY
Asteroids ~10^3
TNOs ~10^2
high-PM ~10^3
BDs ~10^2
VARIABLES
10^6 - 10^7
Transients ~10^4
AGNs, QSOs ~10^3
SN ~10^3
CVs, Novae ~10^3
LMXBs ~10^3
dM flare ~10^4
microlensing ~10^3
Periodic
Eclipsing ~10^6
WUMas ~$5x10^5$
Semidetached ~$3x10^5$
Detached 10^5
Planetary Transits 10^3
Ellipsoidal ~10^4
Spotted ~10^5
Pulsating ~10^5
RR Lyrae ~10^5
Cepheids ~10^3
Semiregulars ~10^5
LPVs, Miras, R
~10^3
dSct, SXPhe ~10^4
RVTau ~10^2
WVir ~10^2
PN
CLUSTERS
stellar associations ~10^2
open clusters ~10^3
globular clusters ~10

RR LYRAE



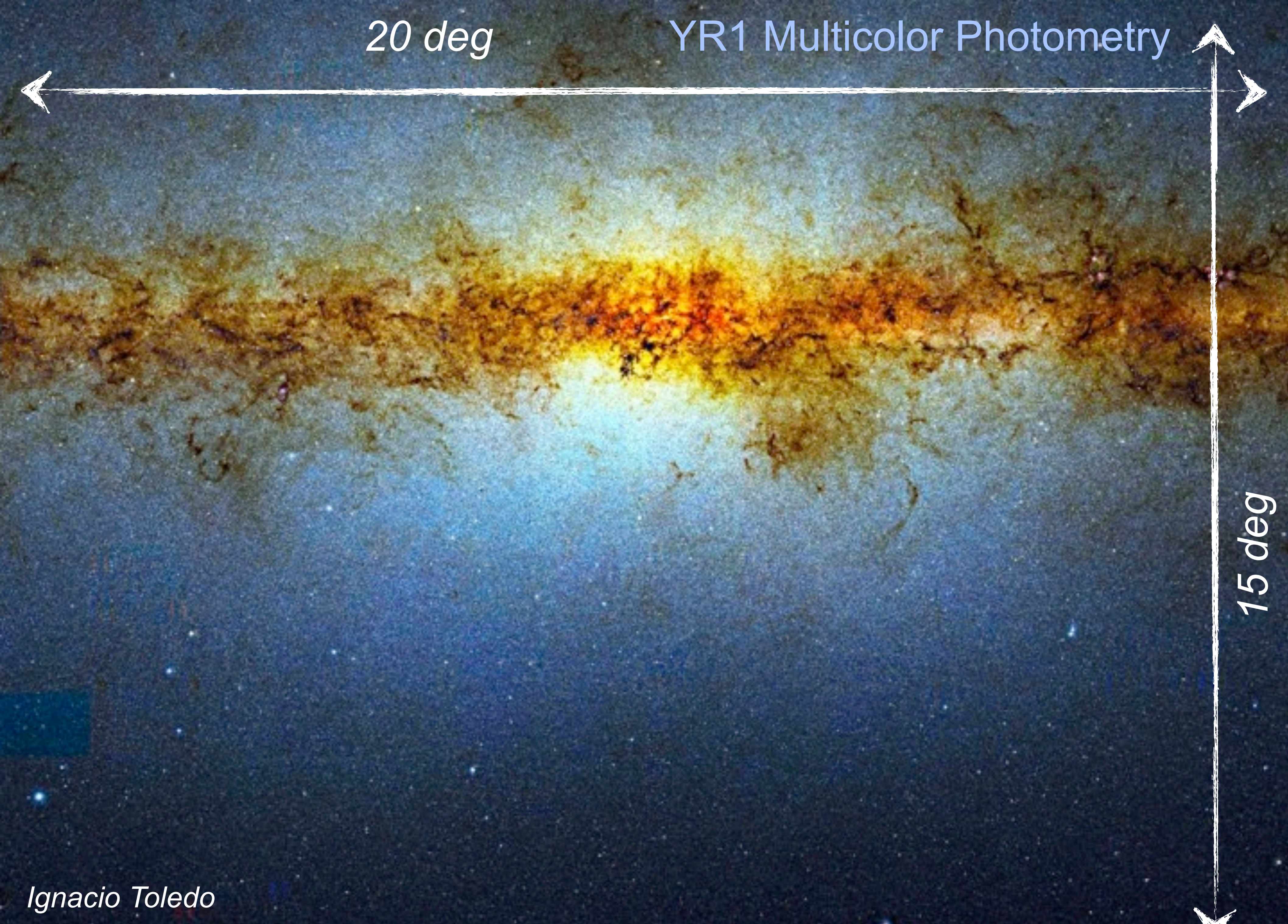
Dekany et al. ApJL 2013

figure by M. Hempel

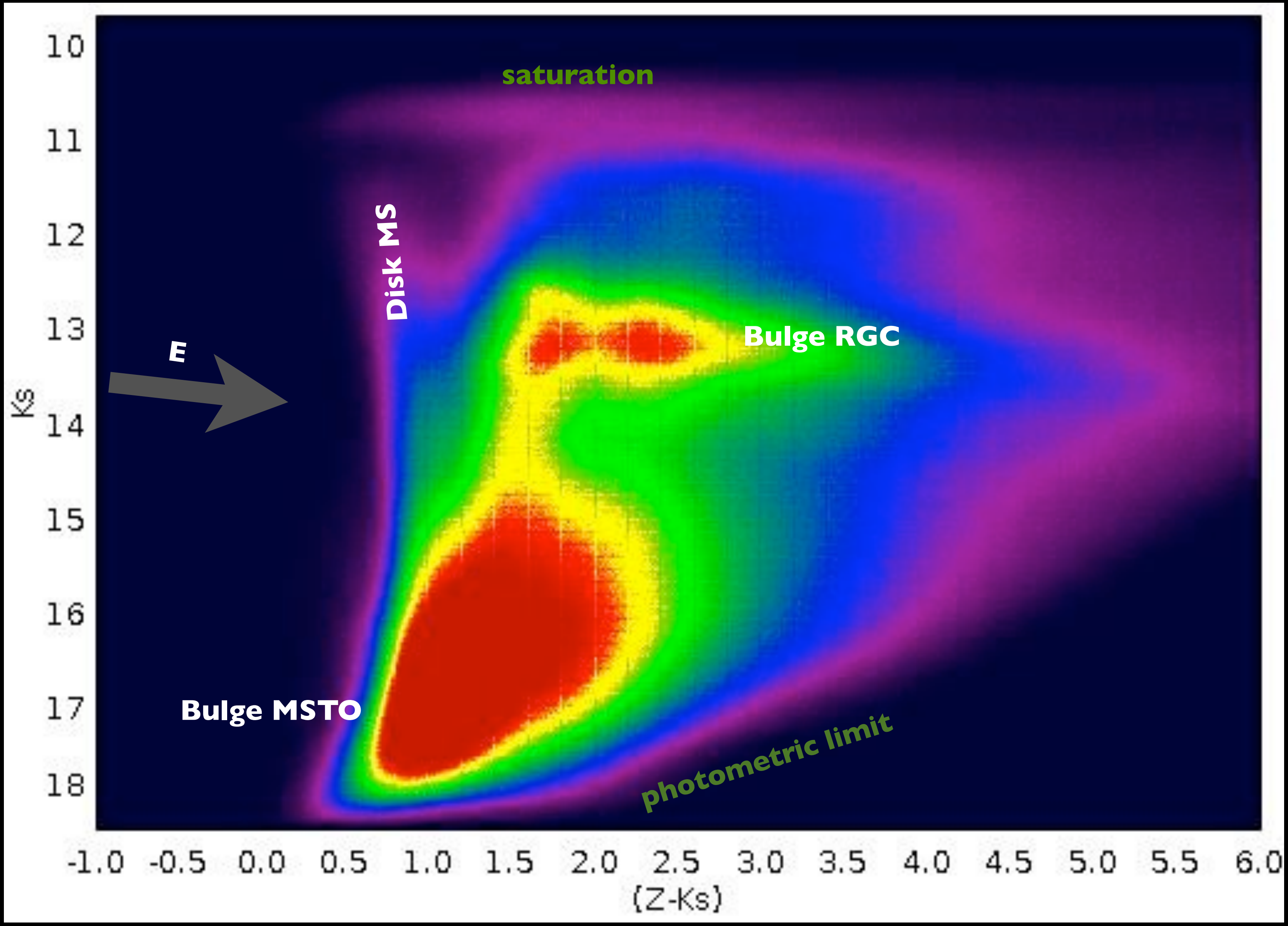


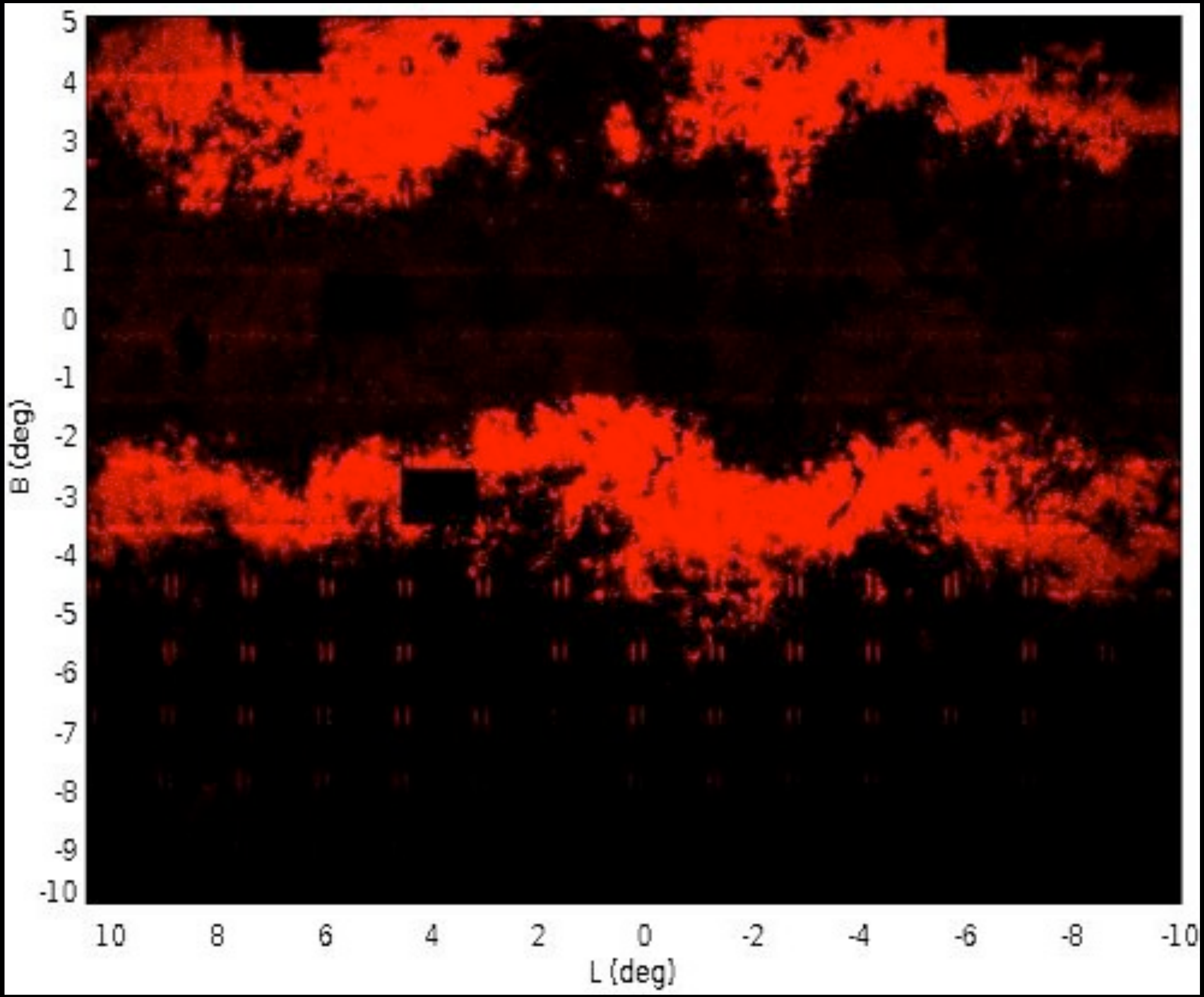
Dekány et al. ApJL 2013

YR1 Multicolor Photometry

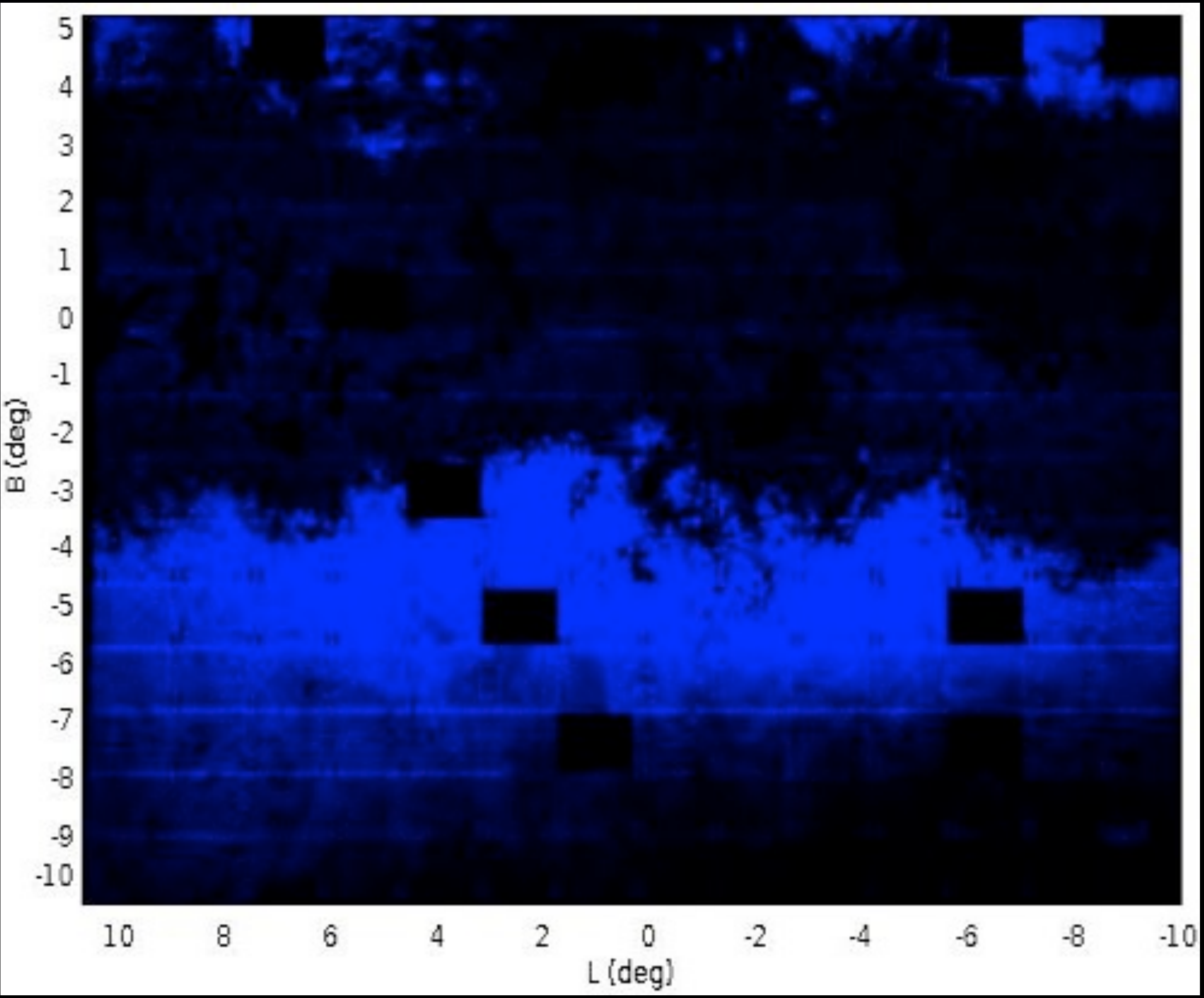


VVV 157M STARS BULGE CMD

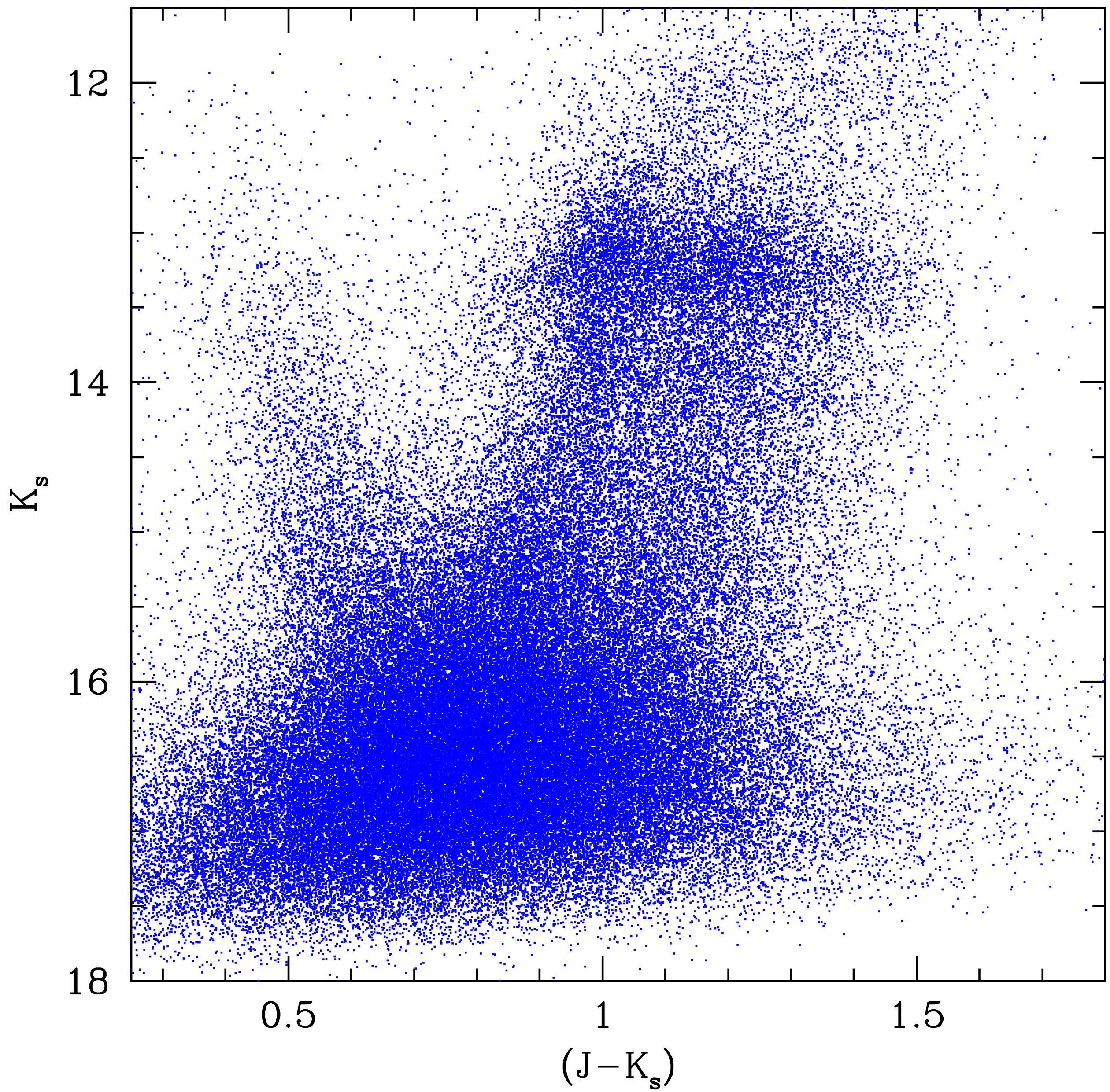




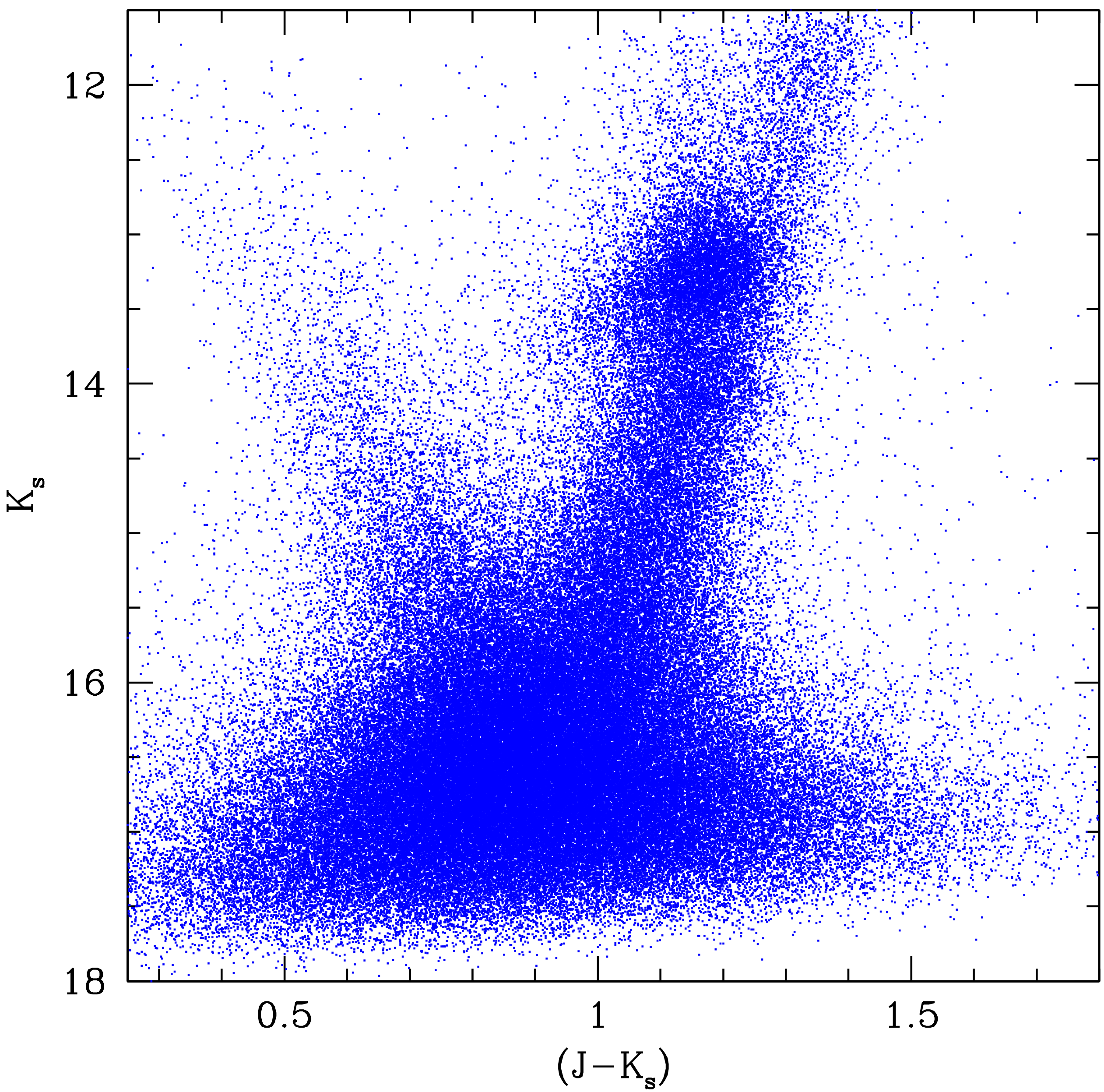
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
B (deg)
10
8
6
4
2
0
-2
-4
-6
-8
-10
L (deg)


B (deg)
L (deg)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
10
8
6
4
2
0
-2
-4
-6
-8
-10

VVV TILE B304 BULGE CMD



VVV TILE B248 BULGE CMD

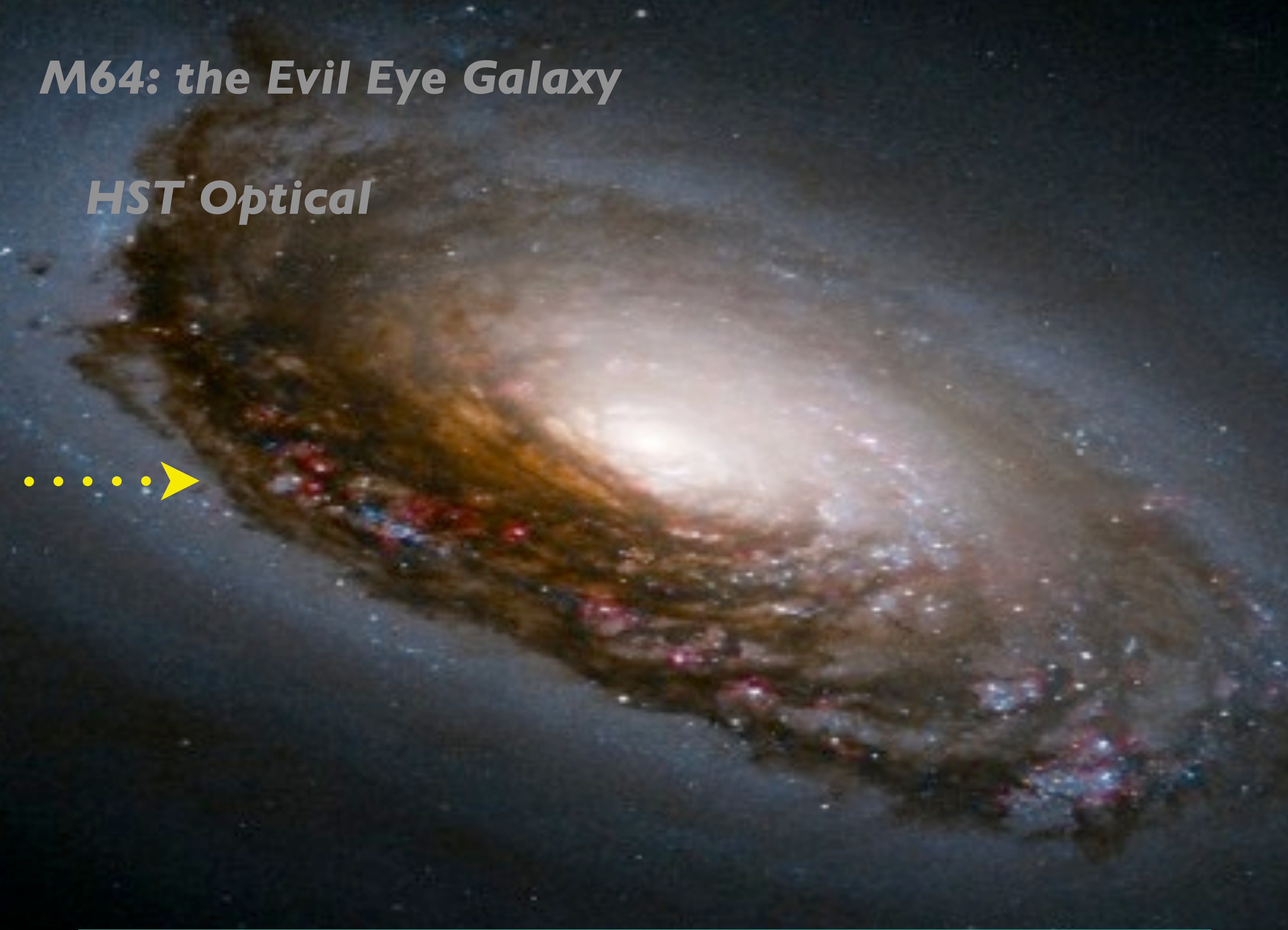


NGC1365: two nested bars with two arms

2MASS IMAGE OF THE MILKY WAY

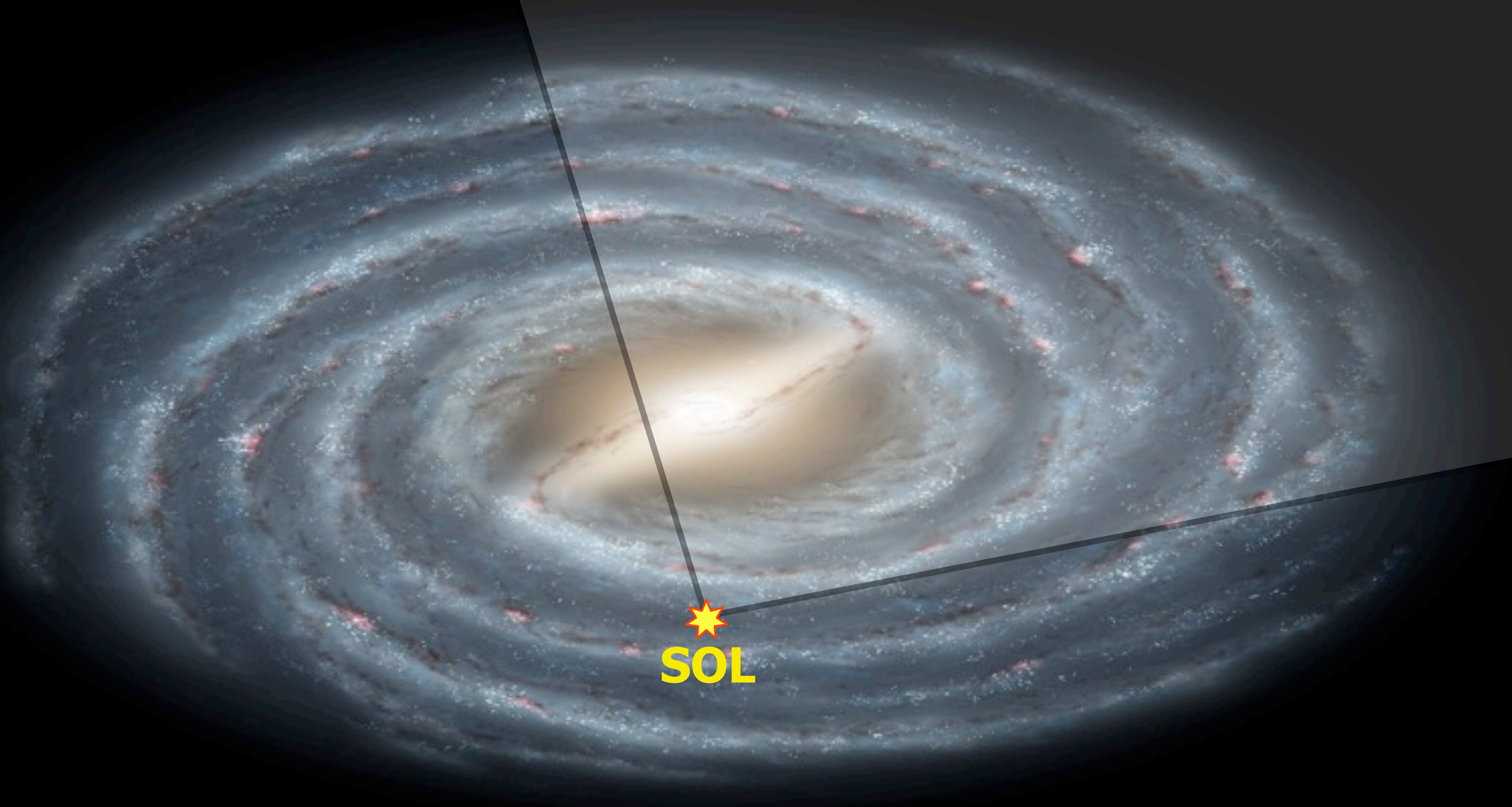
M64: the Evil Eye Galaxy

HST Optical



2MASS IMAGE OF THE MILKY WAY

~1/2 VVV



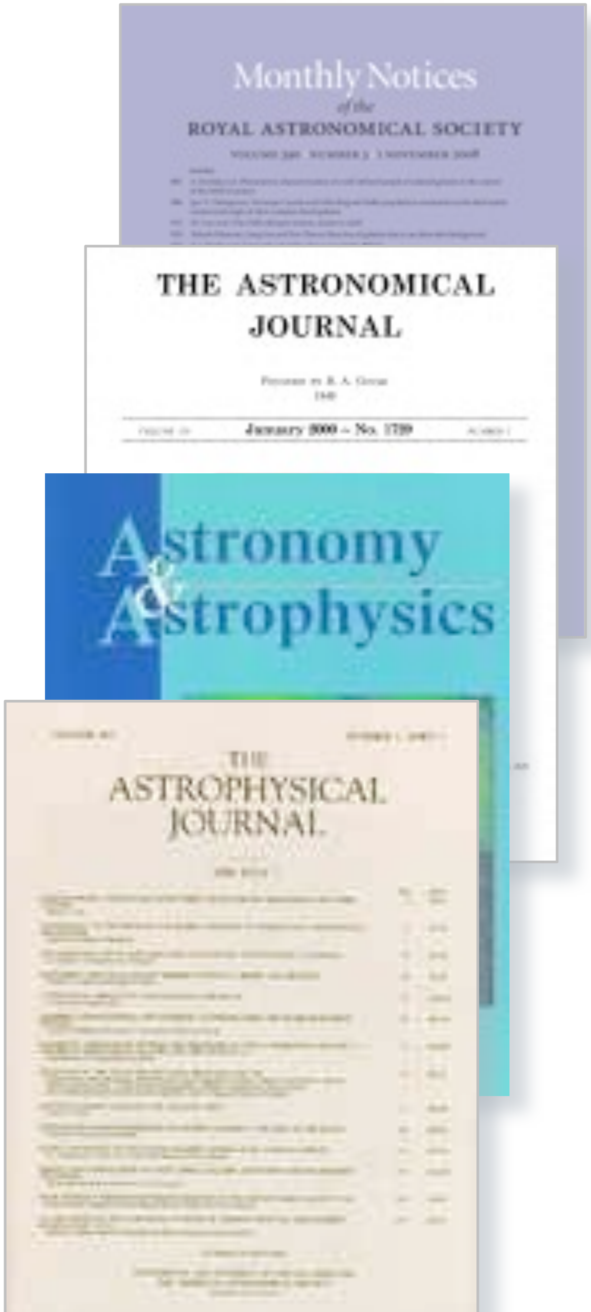
Conclusions

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

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

- We need help exploiting the VVV database and following up a wide variety of targets.

Not only papers...



but also:

outreach