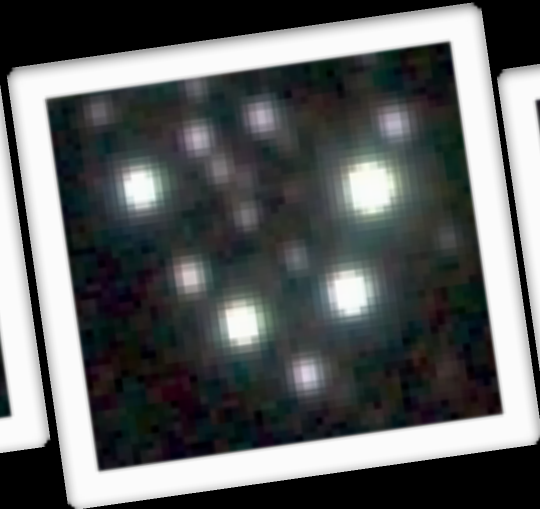
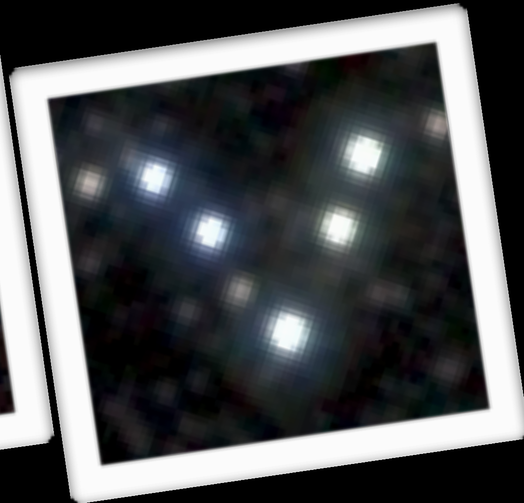
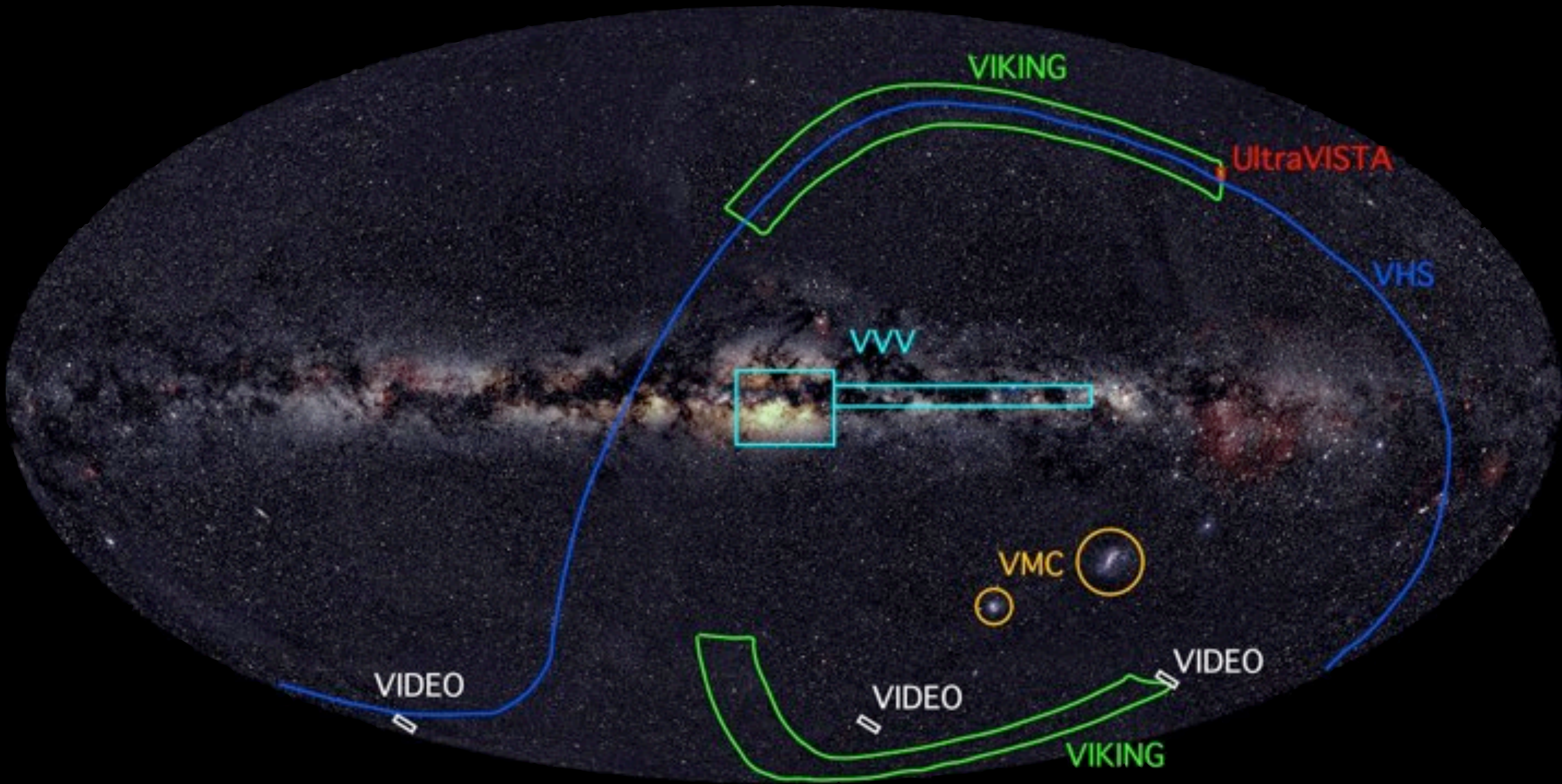




Exoplanets: the Potential of the VVV Survey i. Introduction

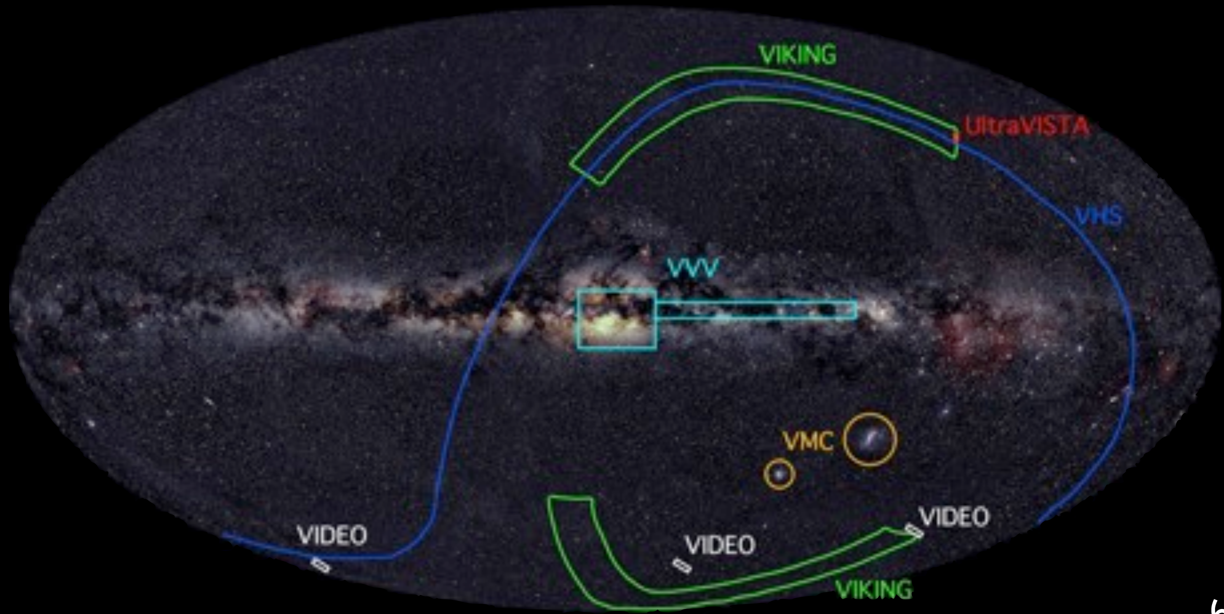
D. Minniti

VISTA PUBLIC SURVEYS



VISTA PUBLIC SURVEYS

VVV

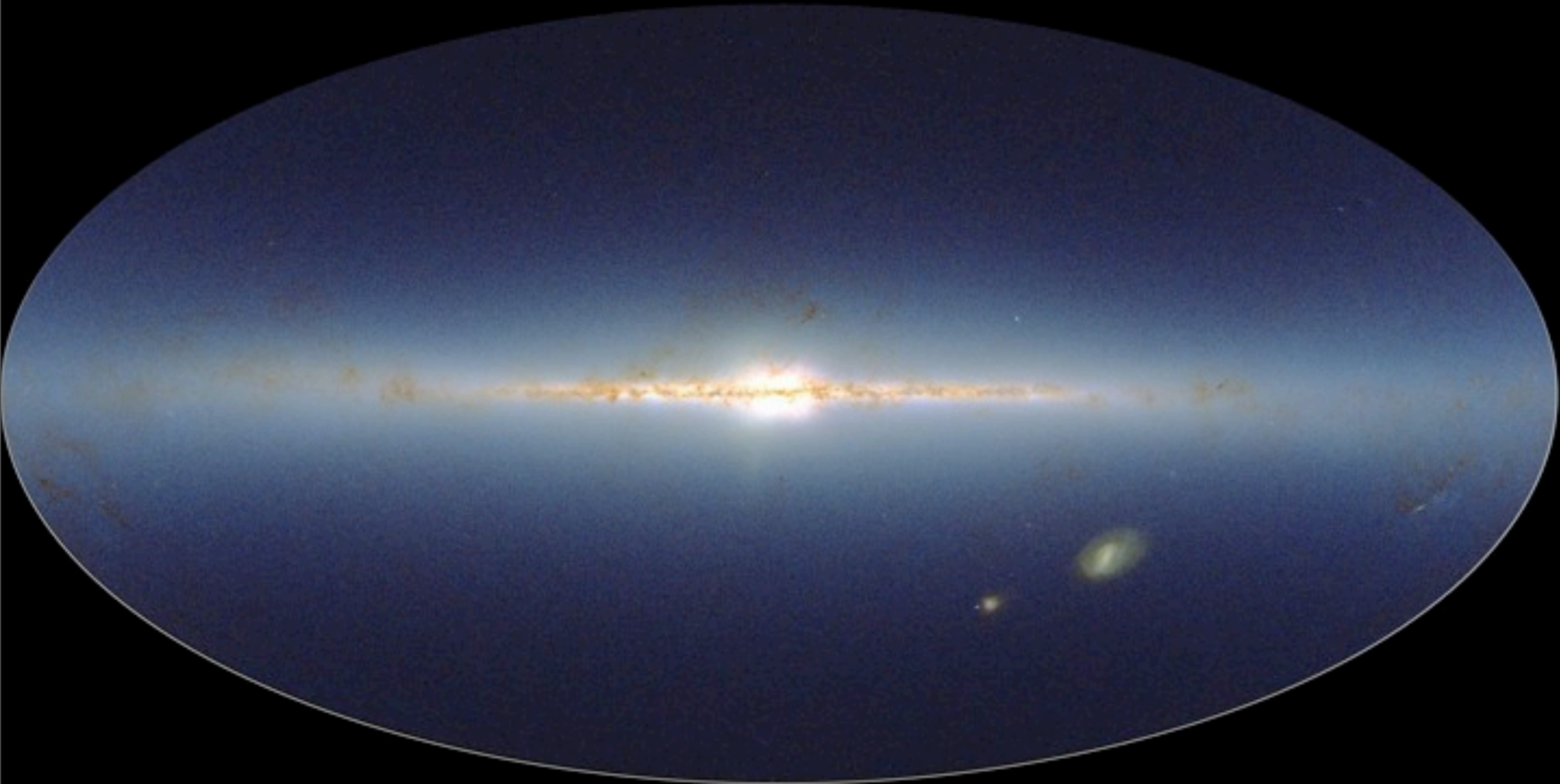


520 sq.deg.

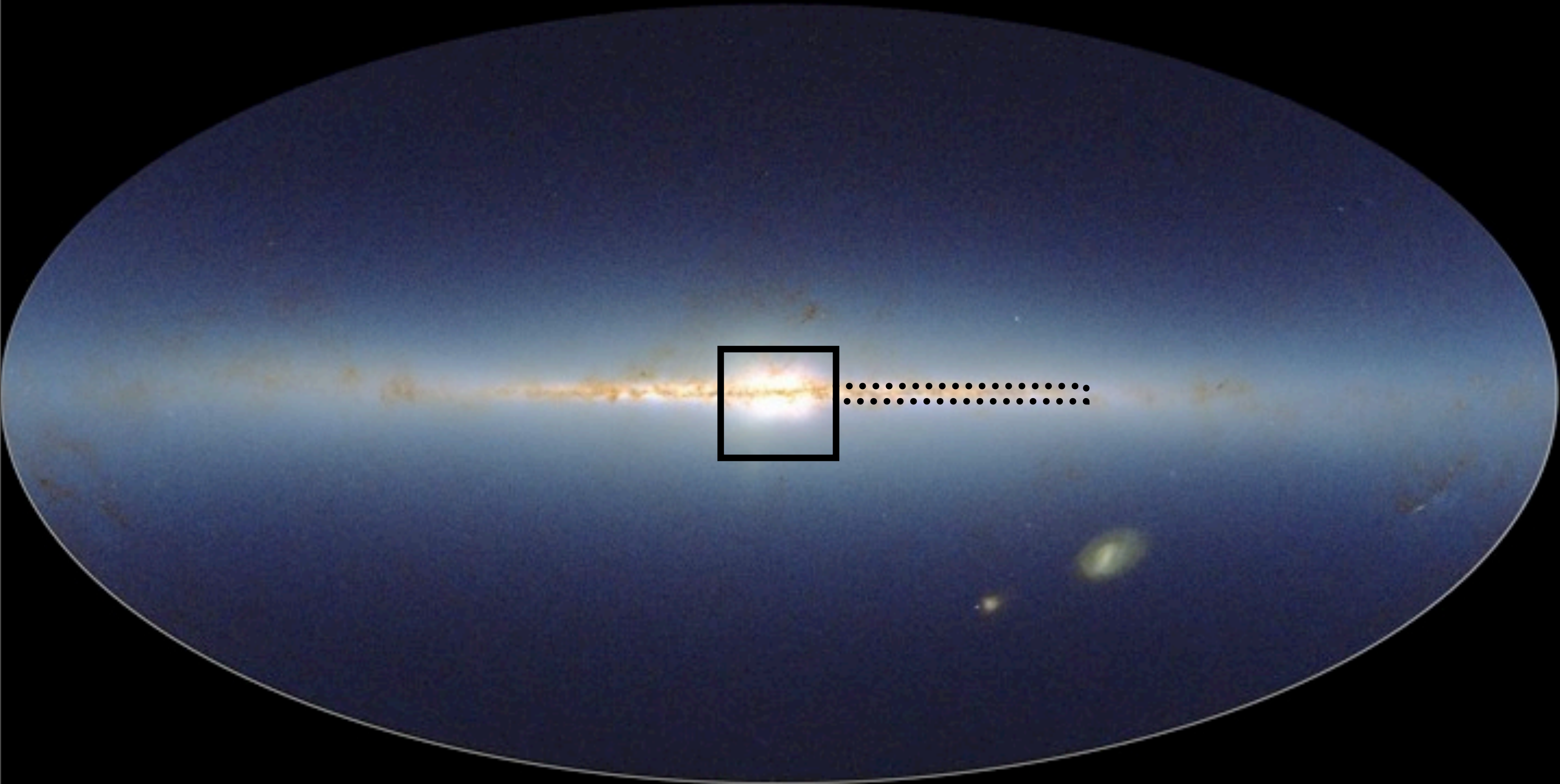
~10^9 stars

~100 epochs

~10^6 variables



2MASS JHK 2000



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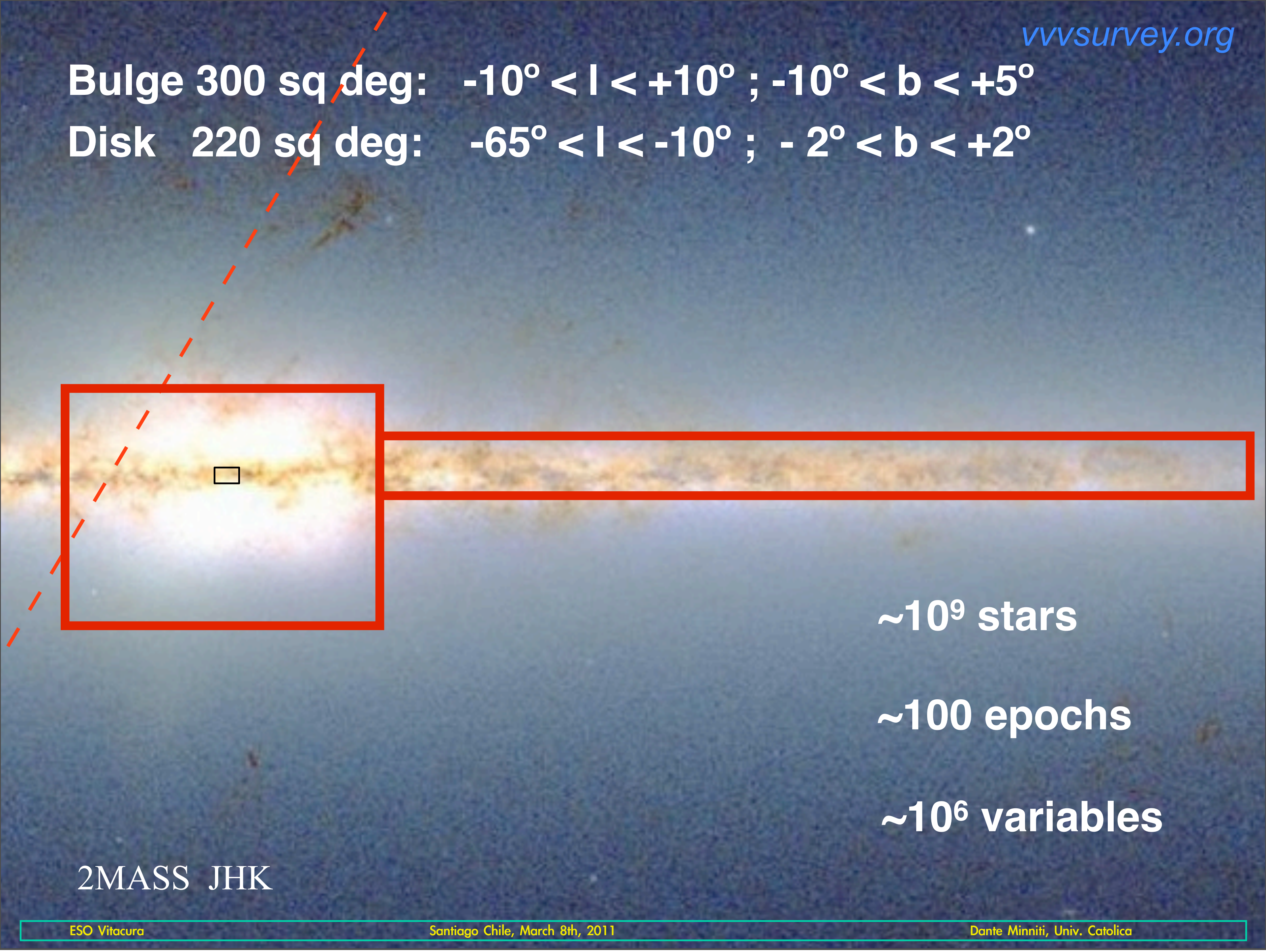
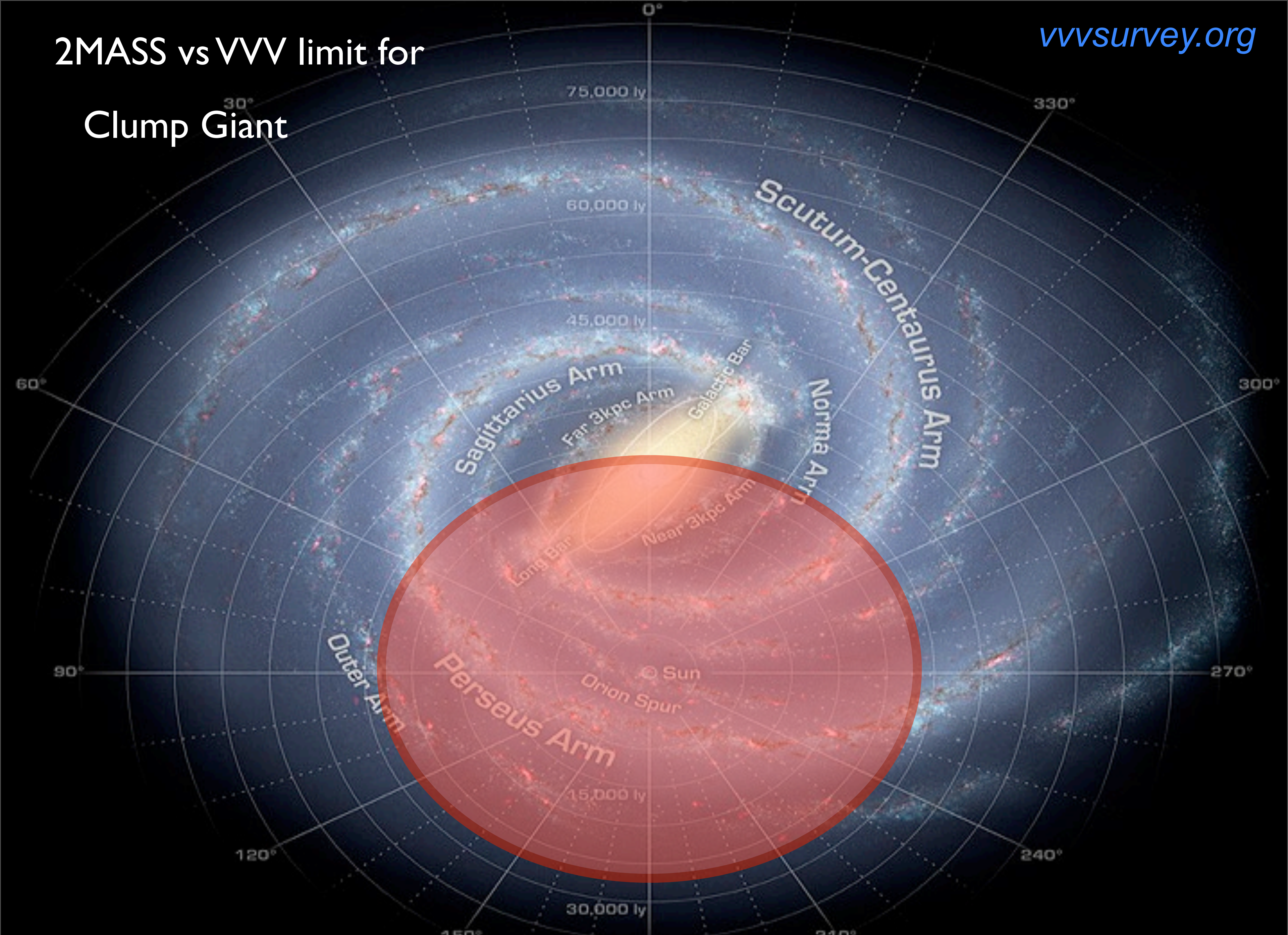
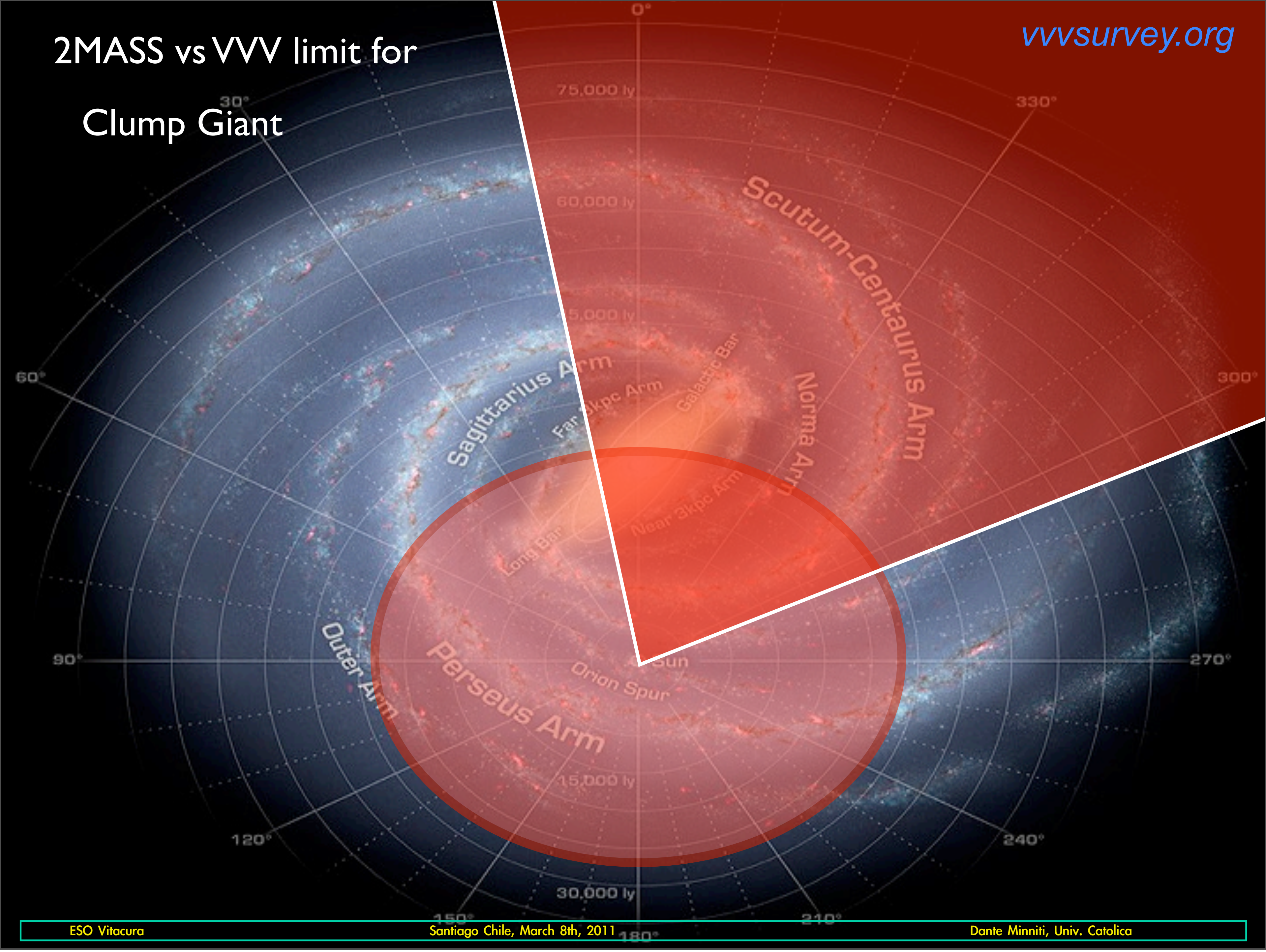


Friday, March 23, 2012

2MASS vs VVV limit for Clump Giant



2MASS vs VVV limit for Clump Giant



DEEPER AND HIGHER RESOLUTION

All in all the VVV survey is 2x bigger than 2MASS

Main differences with 2MASS

2MASS covers the whole sky, VVV only 1.3%

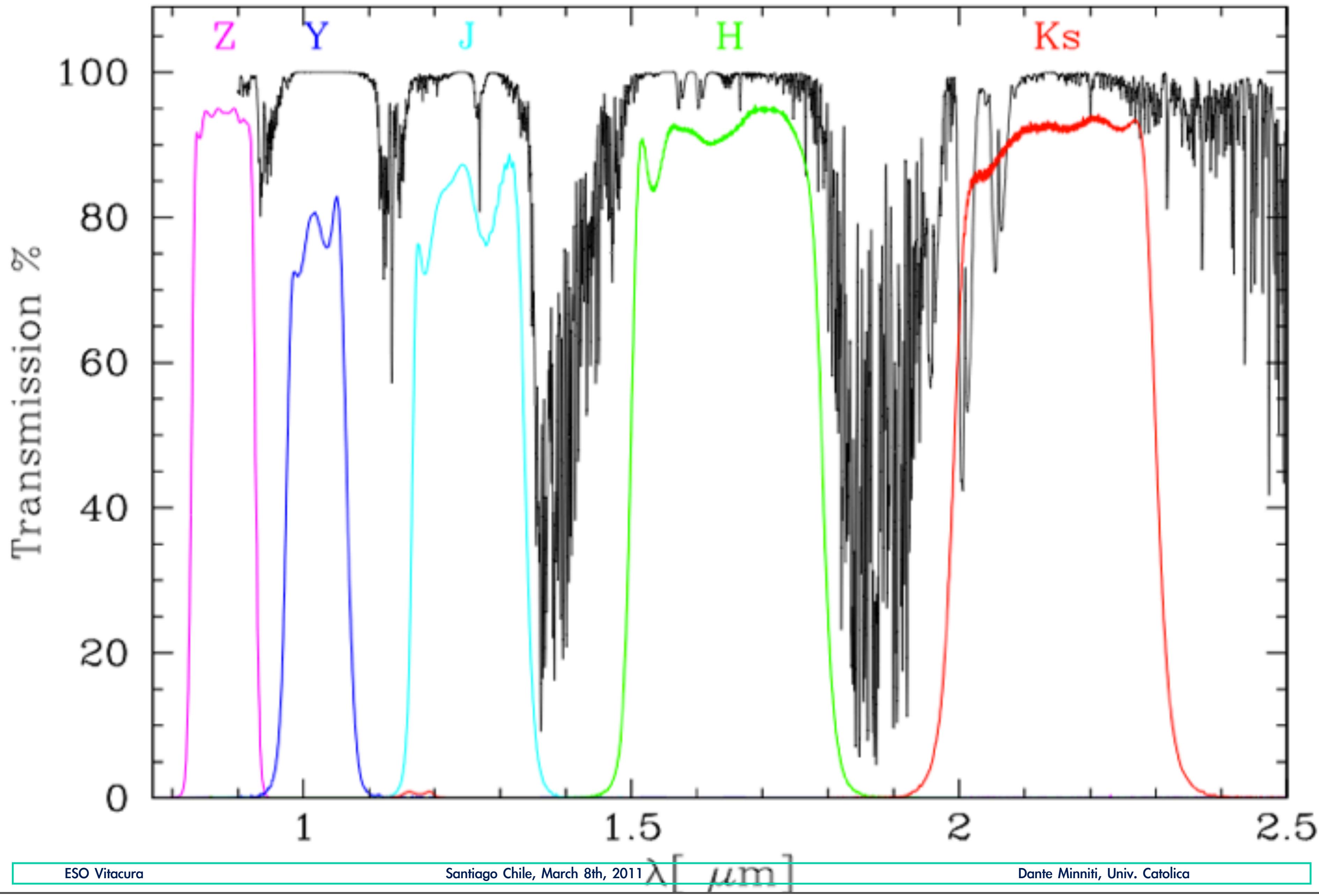
VVV has higher resolution (0.34”/pix)

VVV is deeper (Ks<18)

VVV has 5 filters (ZYJHKs)

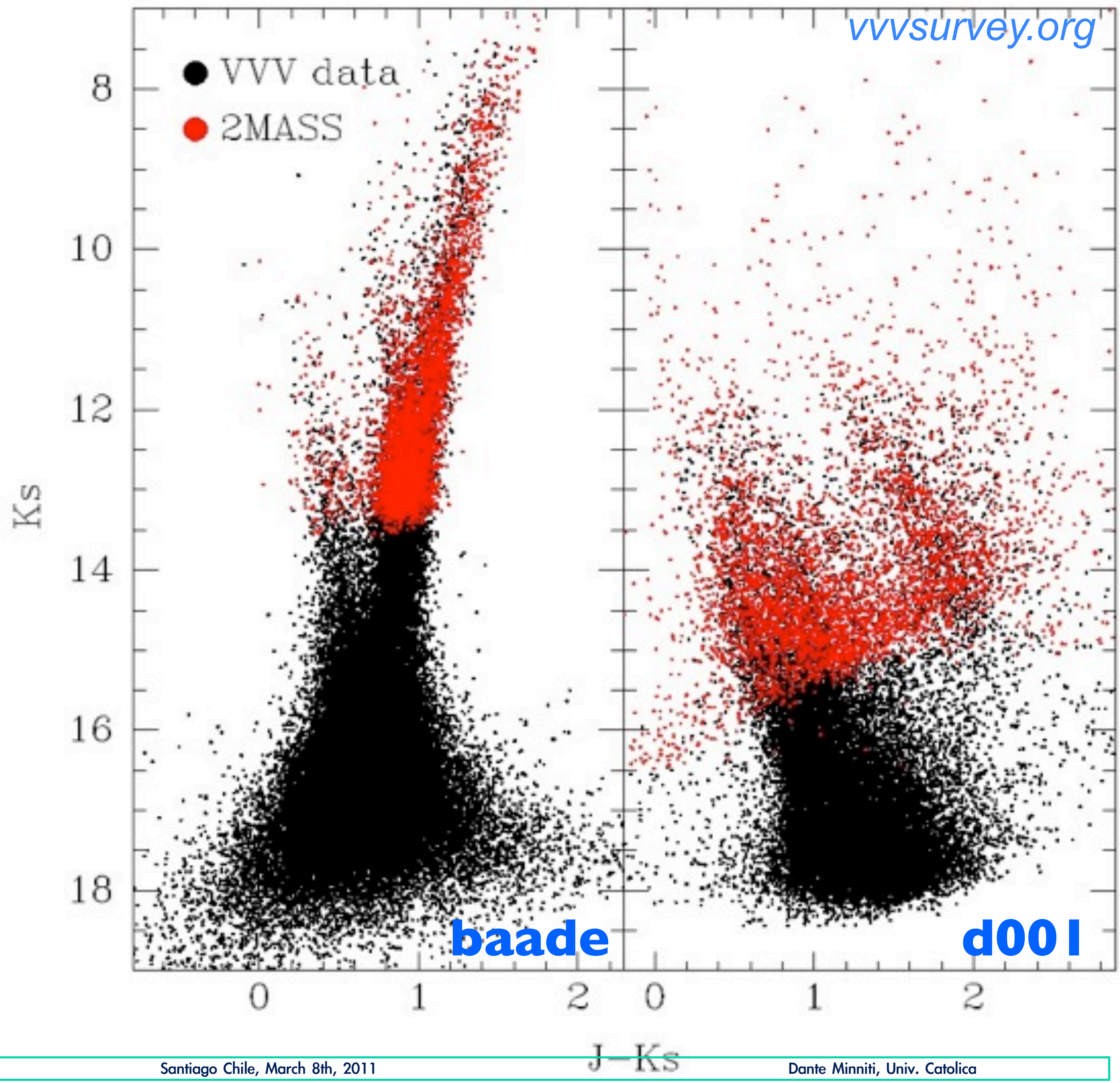
VVV is a multiepoch survey (~100 epochs)

VISTA filter transmissions

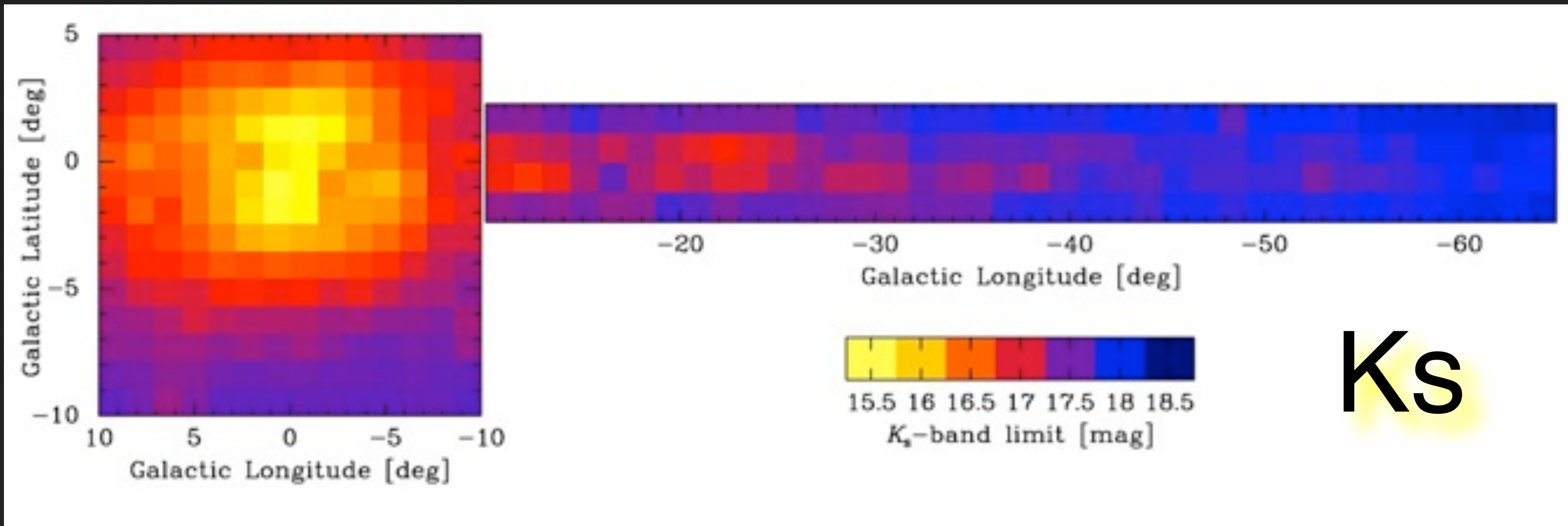


VVV CMDs

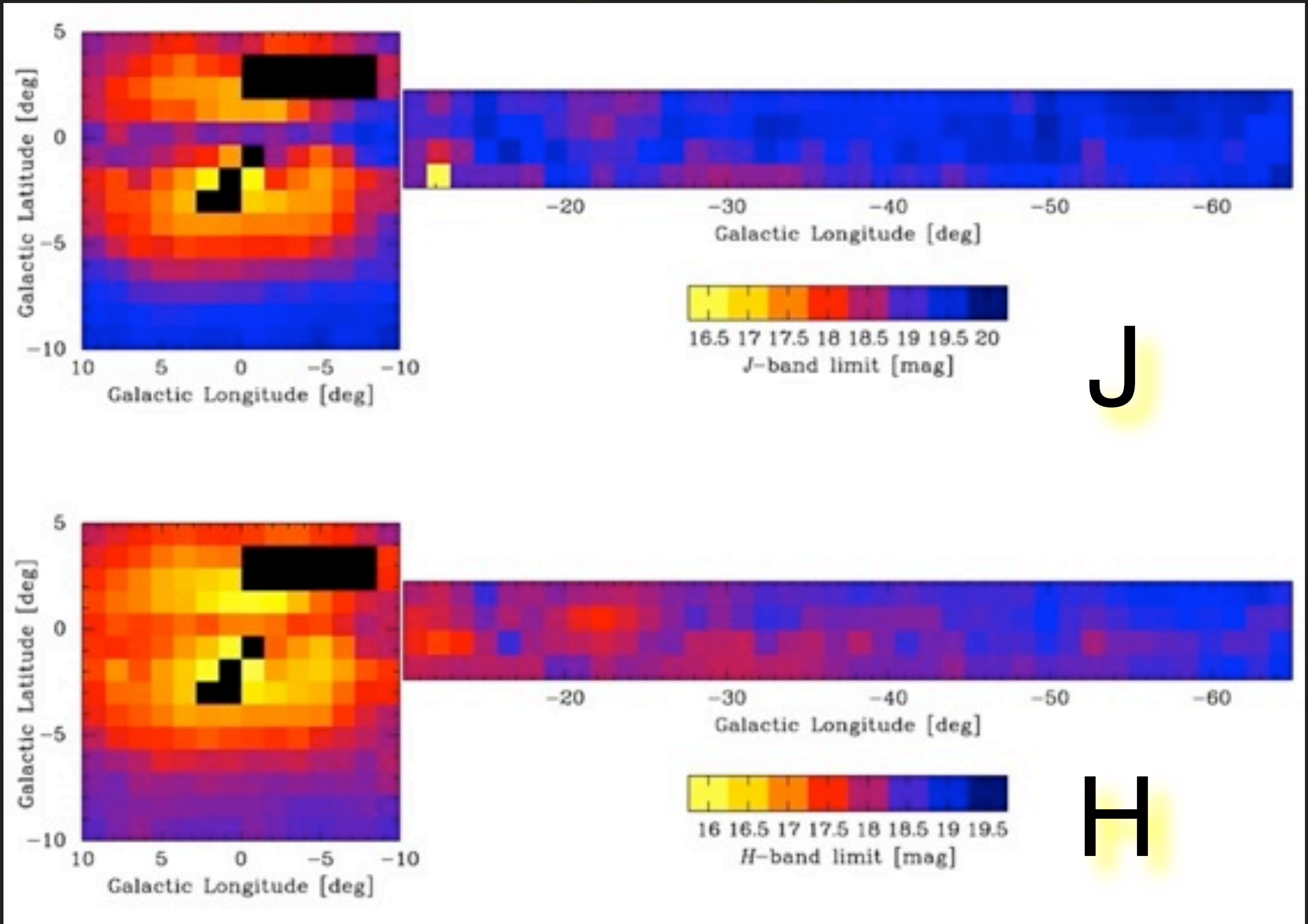
Color-magnitude diagrams of bulge and disk fields compared with 2MASS.



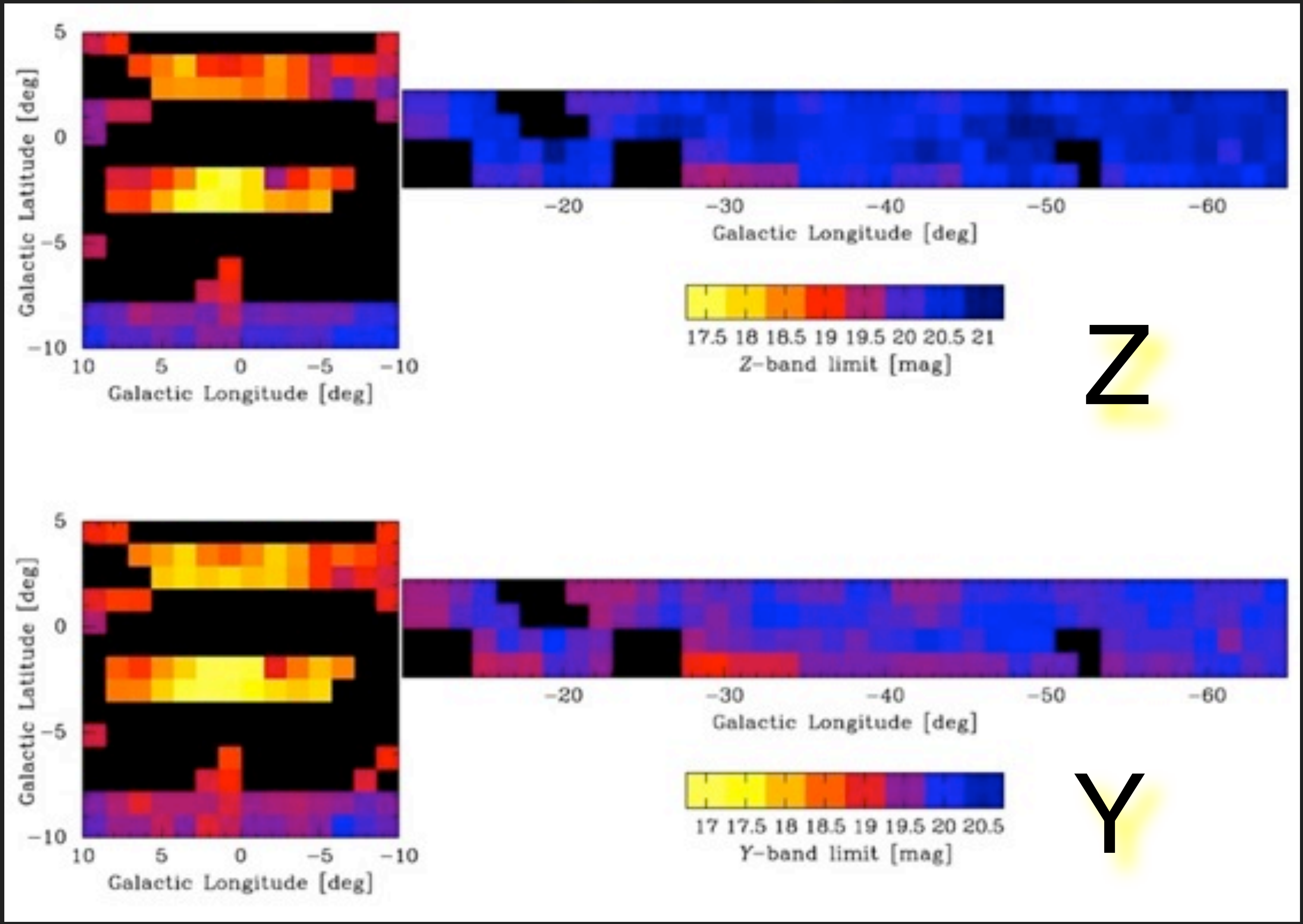
VVV limiting magnitudes



VVV limiting magnitudes



VVV limiting magnitudes



VVV Phase 2

vvvsurvey.org

YR1: ~2500 OBs

- all 348 disk and disk tiles observed in 2010A:
  - multicolor ZYJHKs
  - Ks 5 epochs

YR2 ~ 5400 OBs

- multiepoch Ks band of bulge+disk observed in 2011A

YR3 ~ 13500 OBs

- multiepoch Ks band of bulge to be acquired in 2012A

VVV Phase 3

Handing the processed data (images and catalogues) to the ESO Archive.

Phase 3 YR1: completed, all YR1 data at ESO archive

Credits: Maren Hempel, Roberto Saito, Phil Lucas, et al.

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vvvsurvey.org

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all YR1 data at ESO archive

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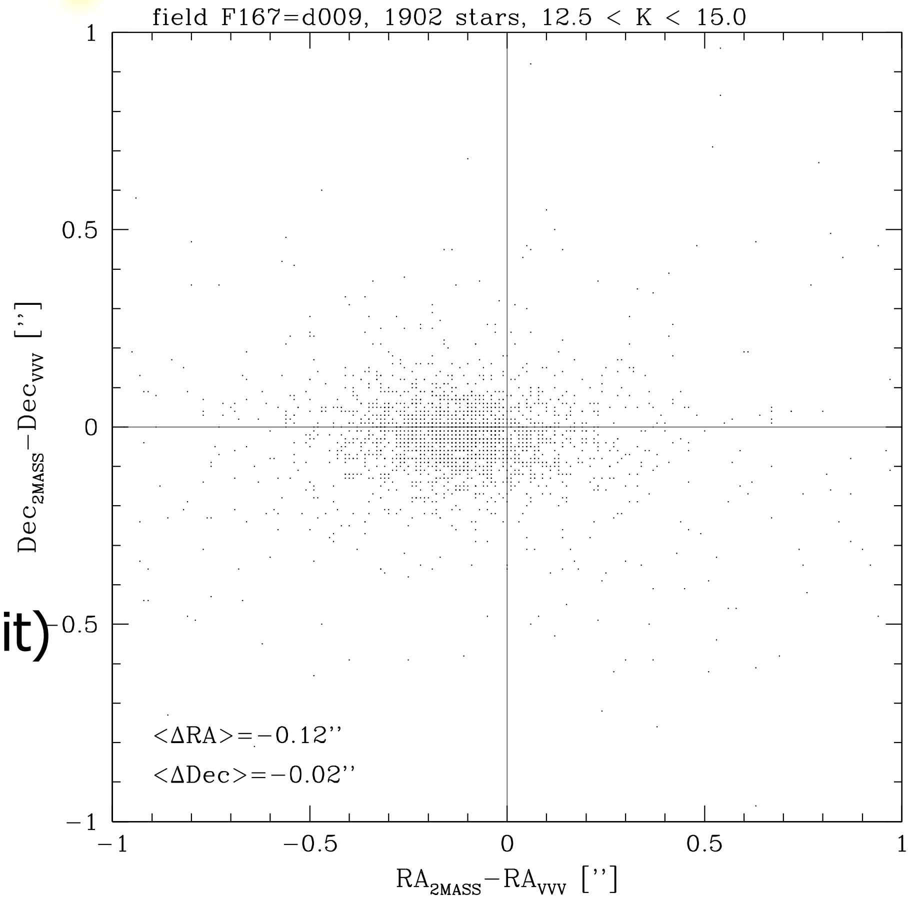
Year 1 Astrometry

vvvsurvey.org

Pixel scale: 0.34″

Typical image seeing: 1″

Best image: 0.6″ (including telescope, instrument, seeing)



Typical astrometric accuracy (rms per visit)

→~35 mas for Ks=15

→~175 mas for Ks=18

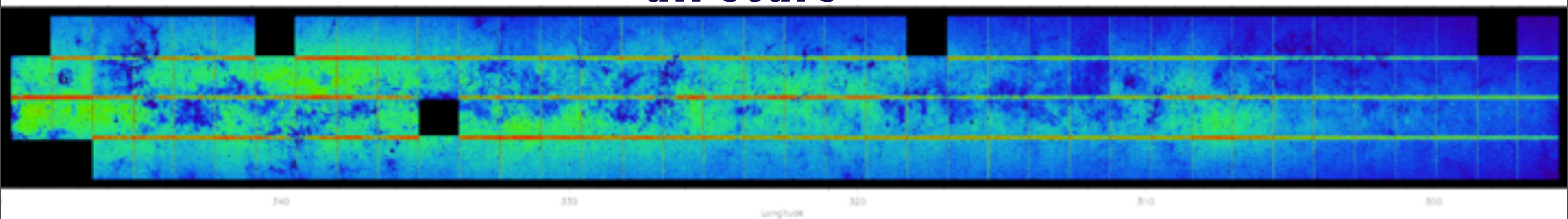
Typical proper motion accuracy (after 5yr long survey)

→~7 mas/yr for Ks=15

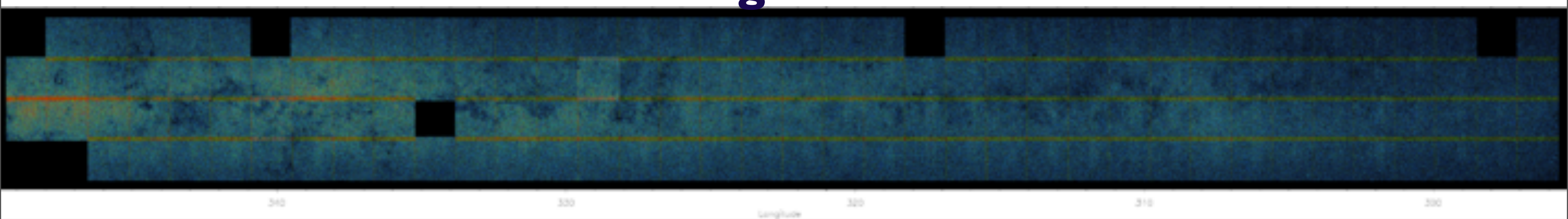
→~15 mas/yr for Ks=18

tile IDs

all stars



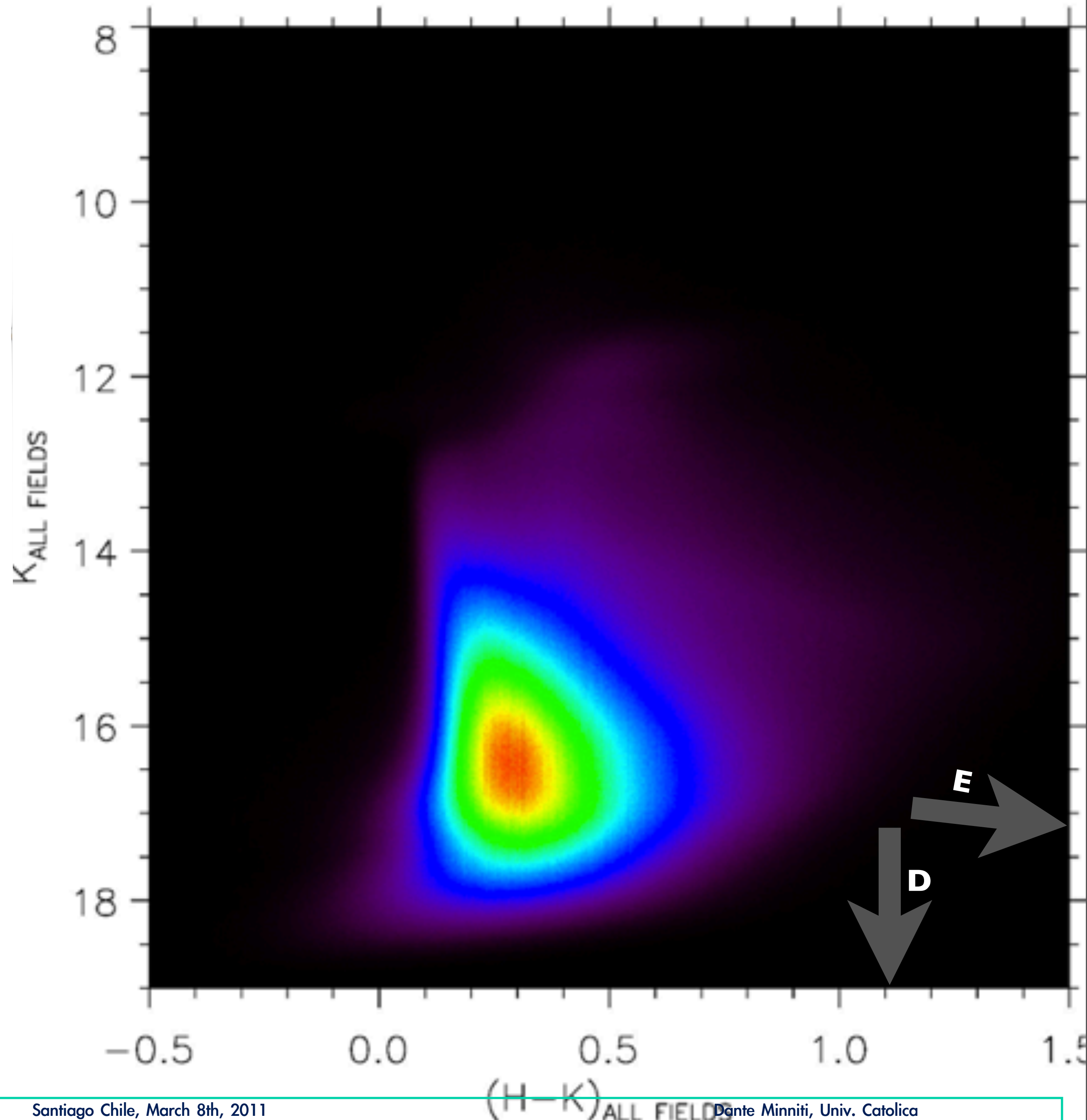
red giants



VVV DISK DENSITY MAP

Figures from M. Soto, M. Hempel, R. Saito

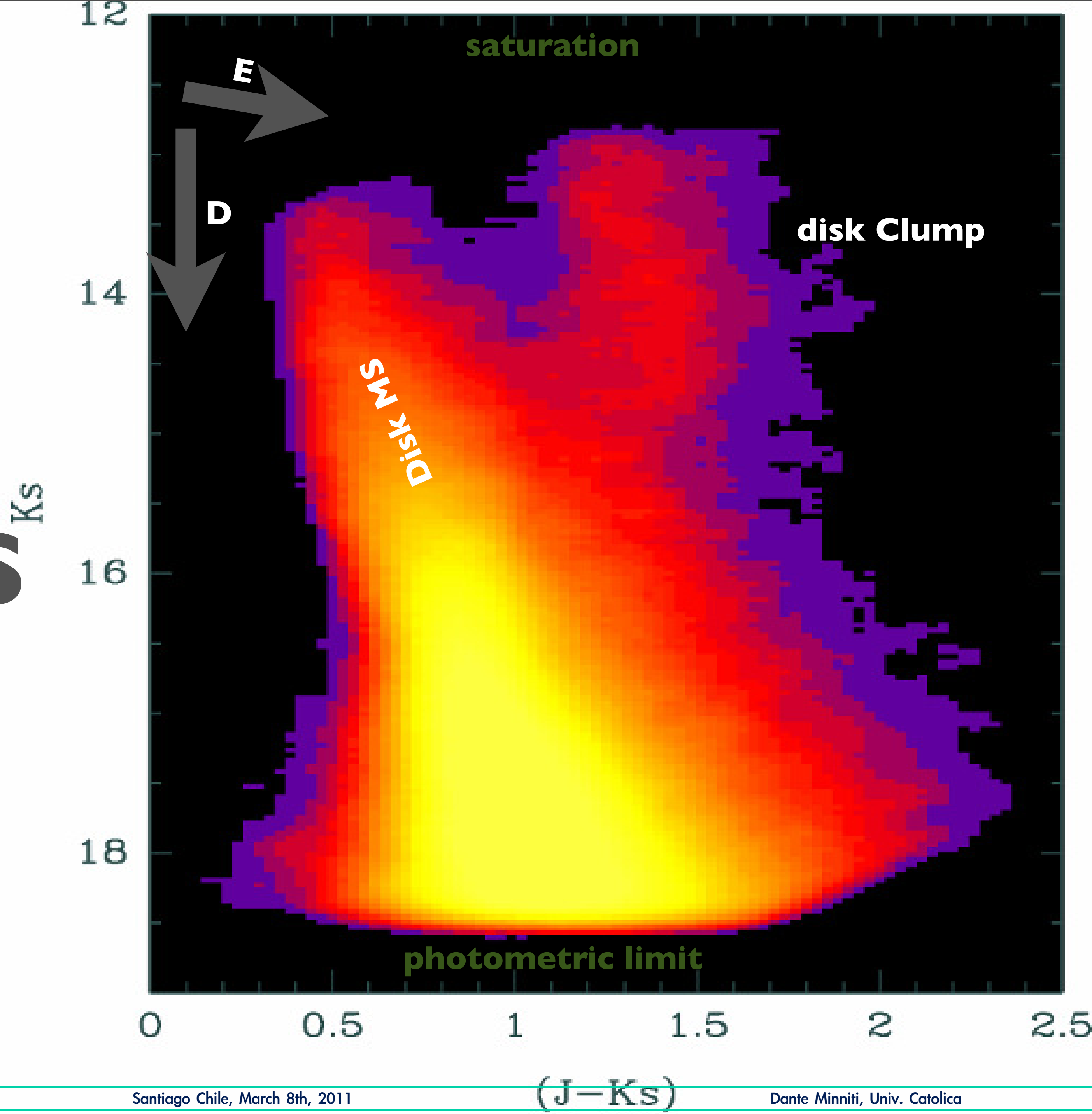
VVV DISK 140M STARS



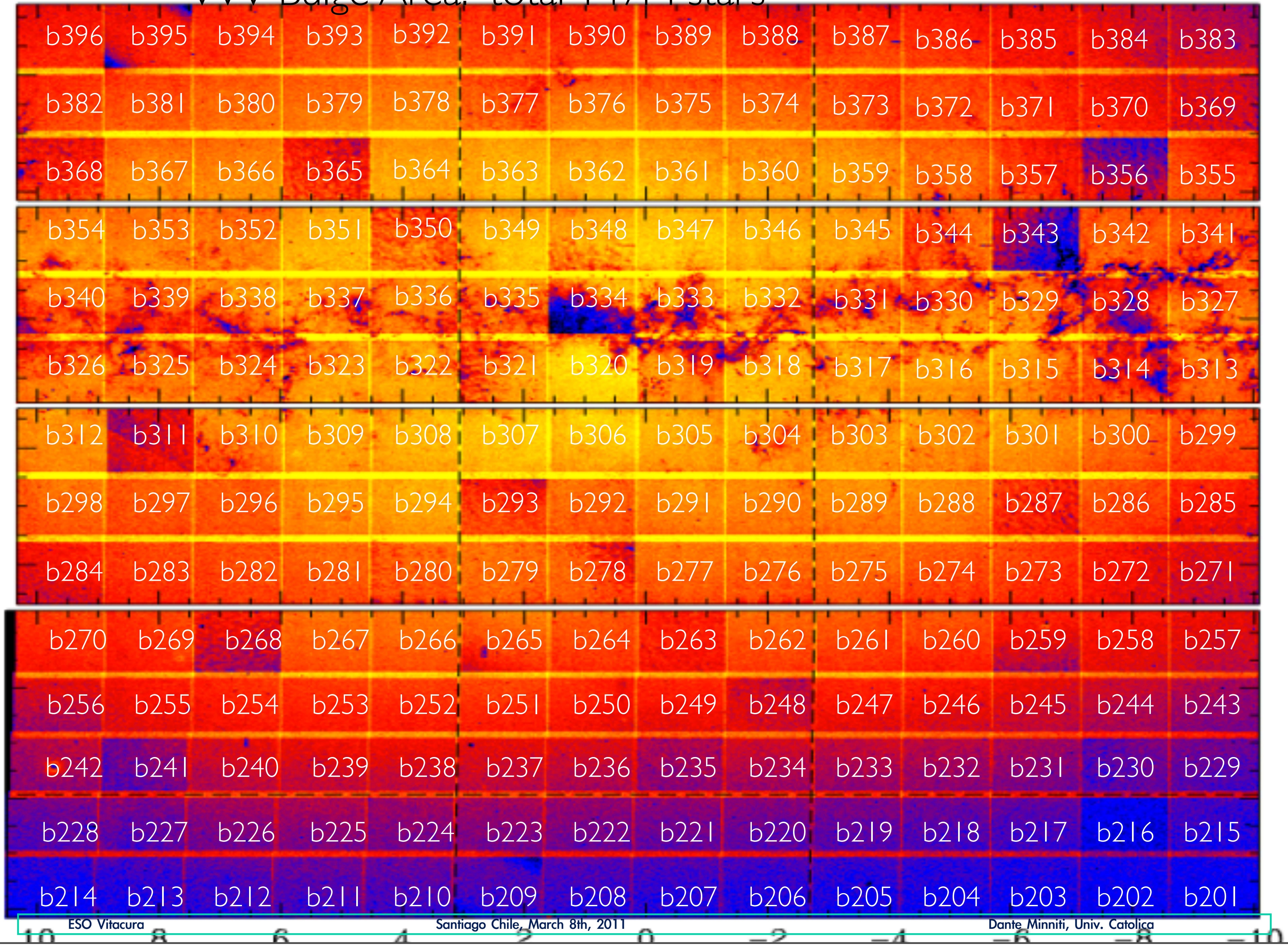
Mario Soto

VVV 0.5M STARS CMD

d003 field

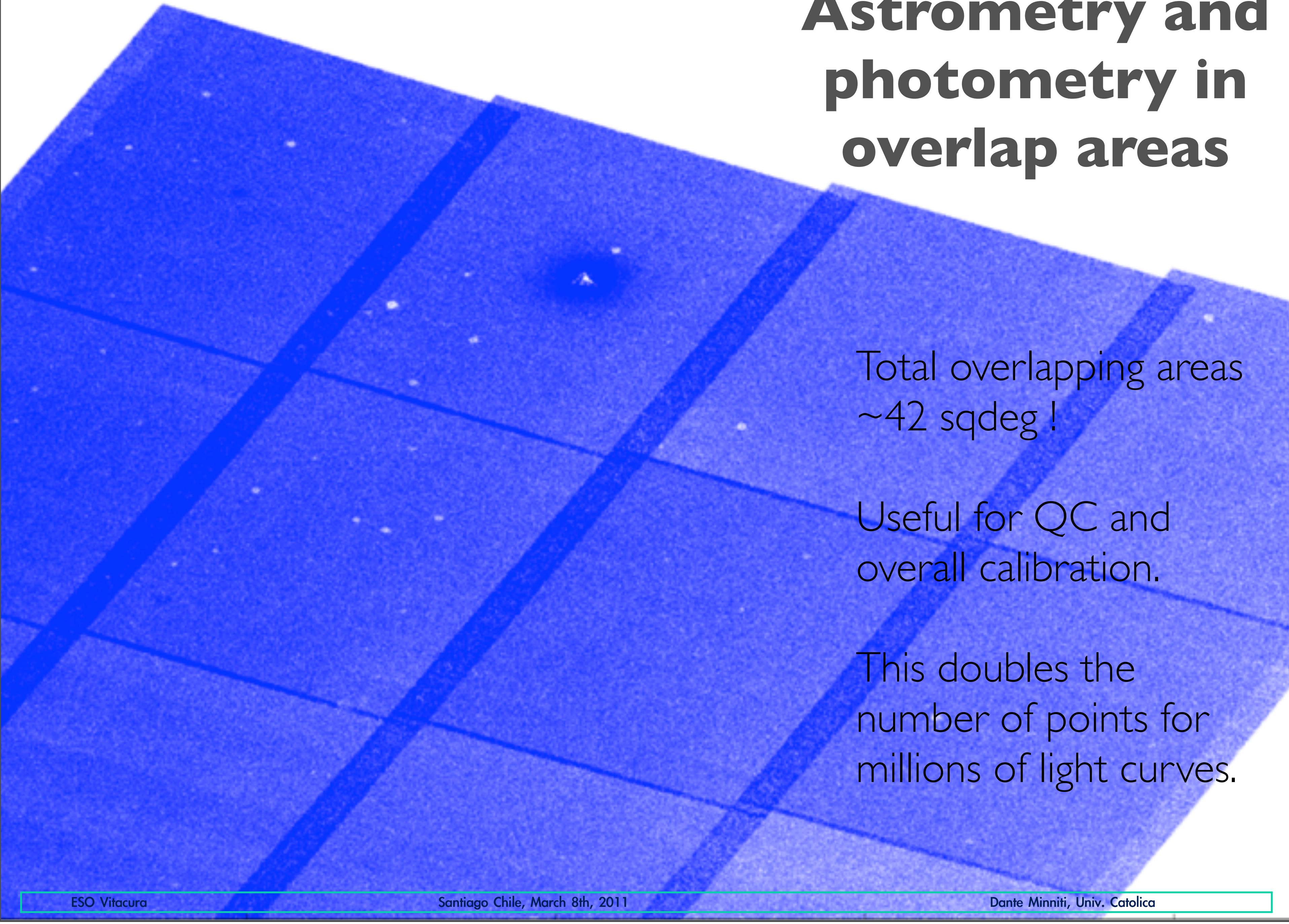


VVV Bulge Area: total 147M stars



Friday, March 23, 2012

Astrometry and photometry in overlap areas

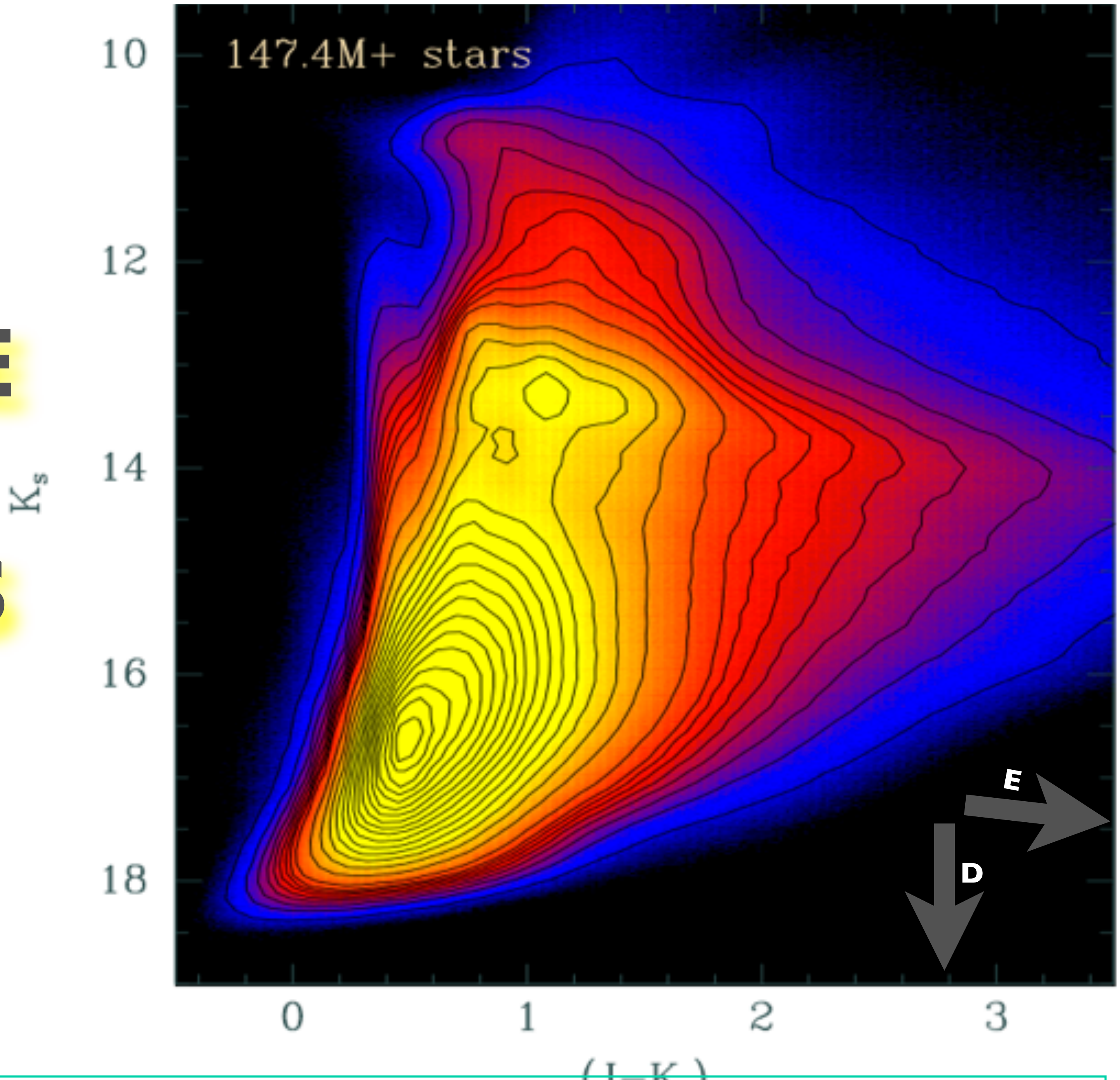


Total overlapping areas ~42 sqdeg !

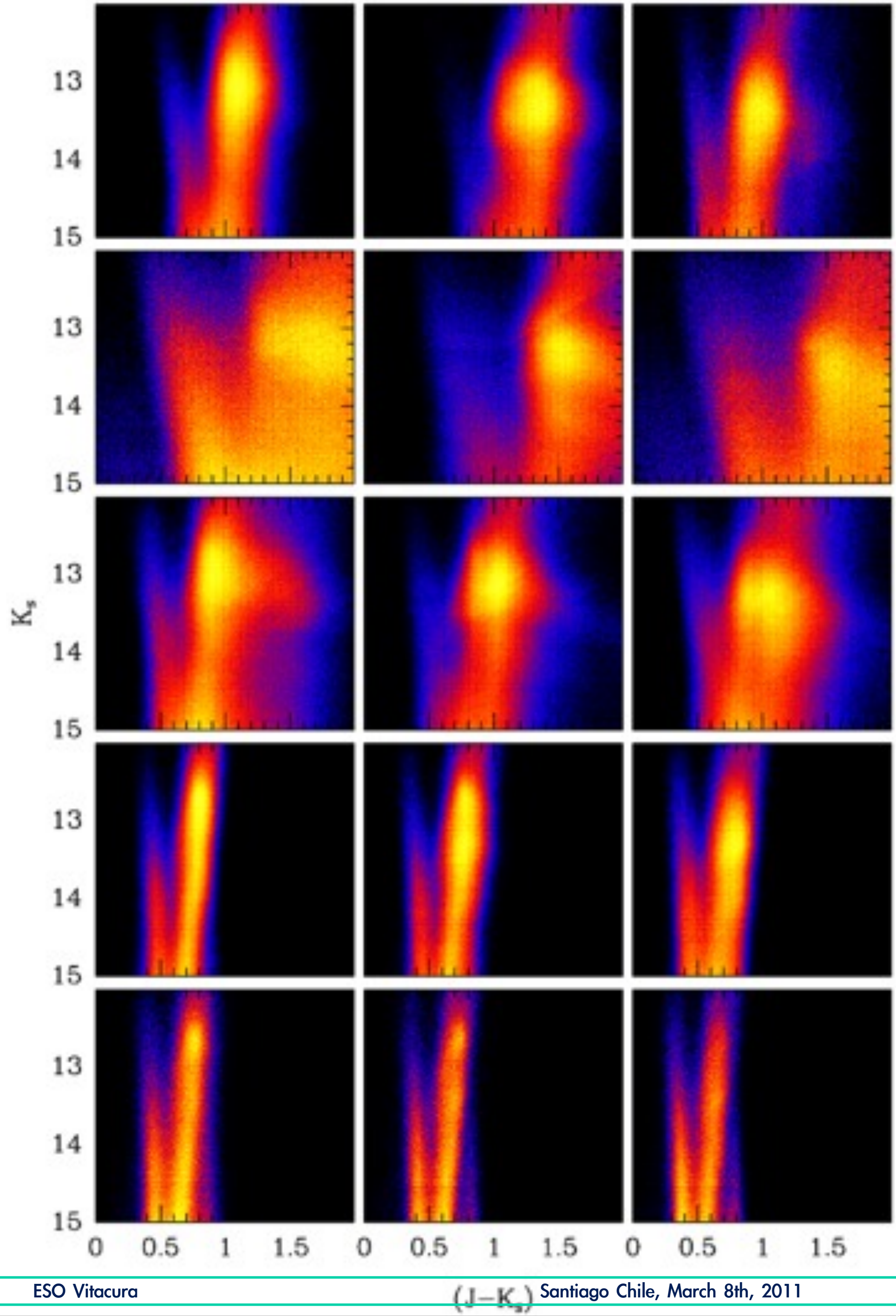
Useful for QC and overall calibration.

This doubles the number of points for millions of light curves.

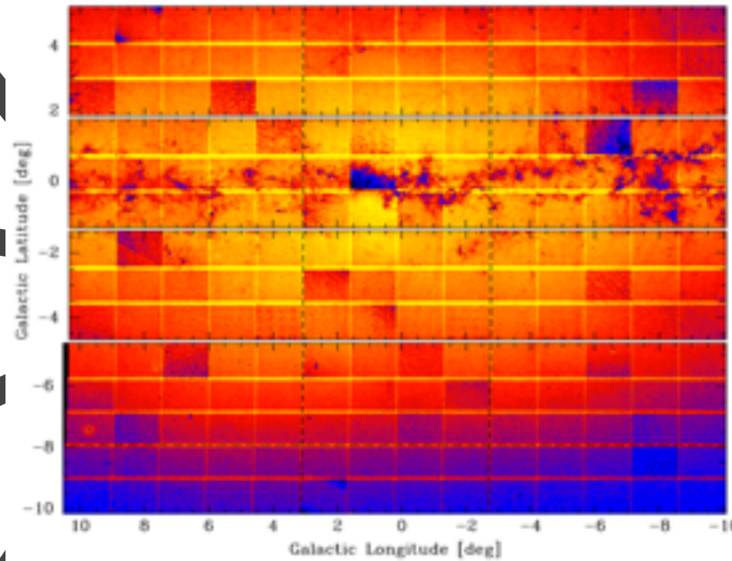
VVV BULGE 150M STARS



Roberto Saito



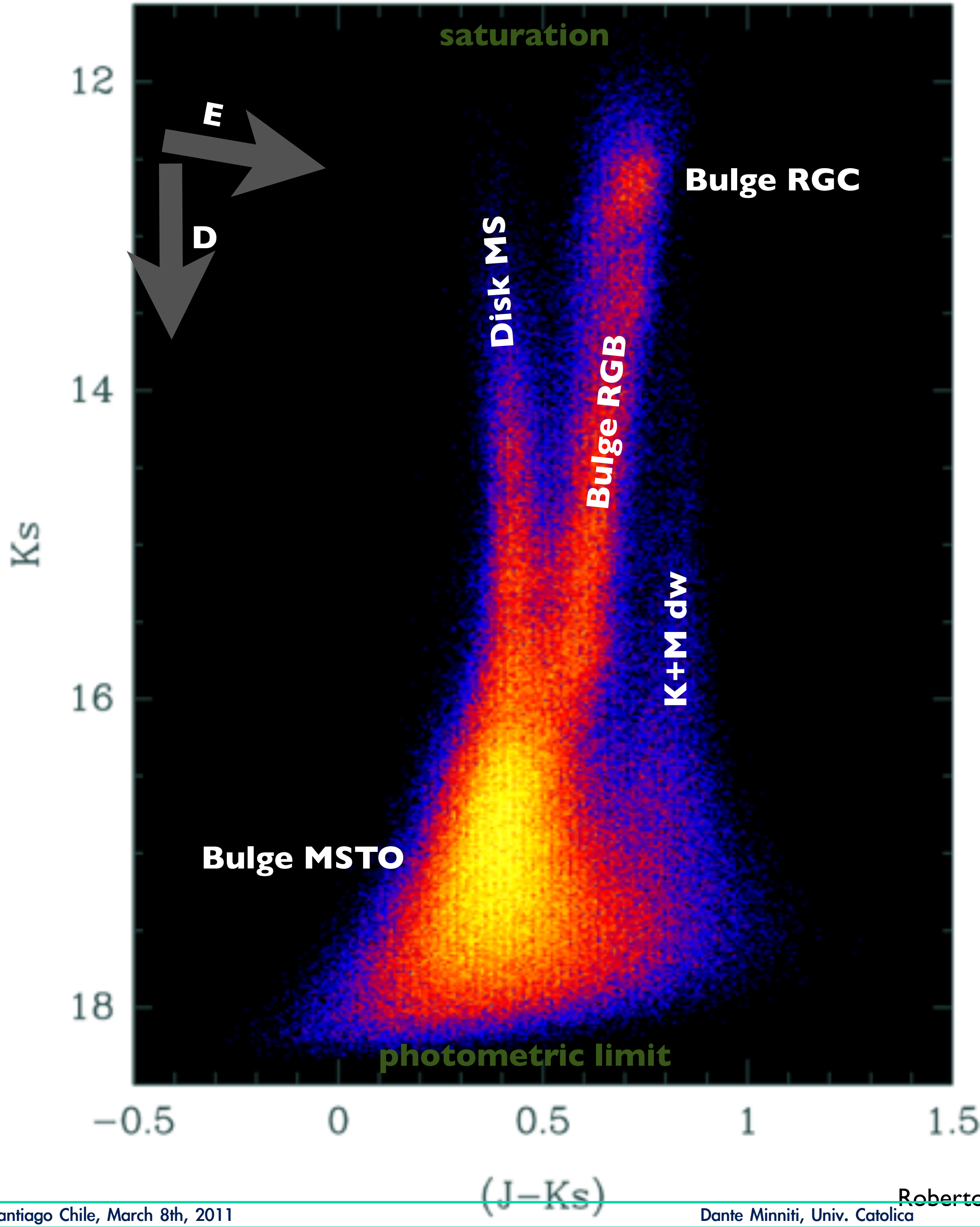
Interpretation of the Galactic bulge CMDs: RGB clump region



Roberto Saito

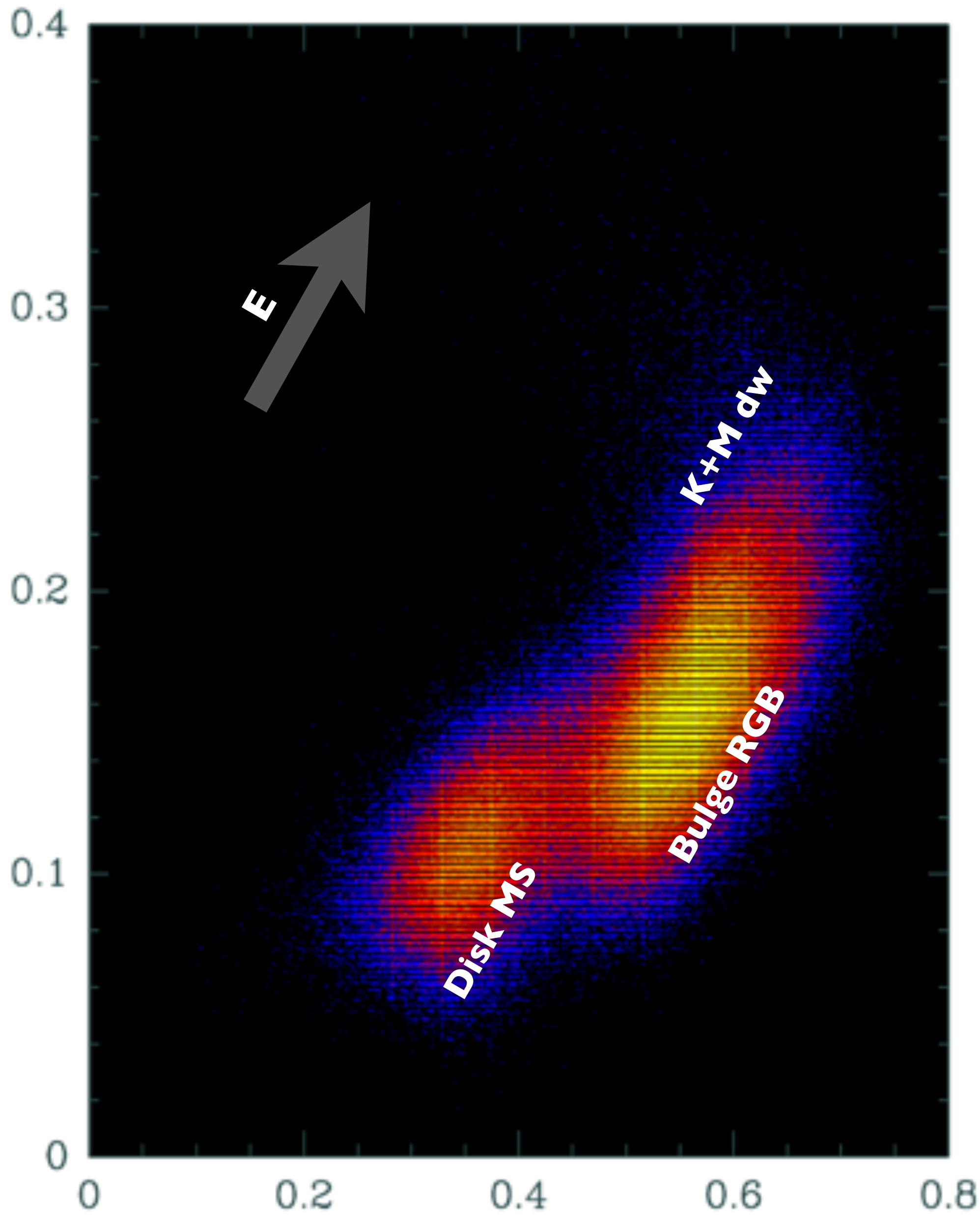
VVV BULGE 0.6M STARS

b209+b210+b211

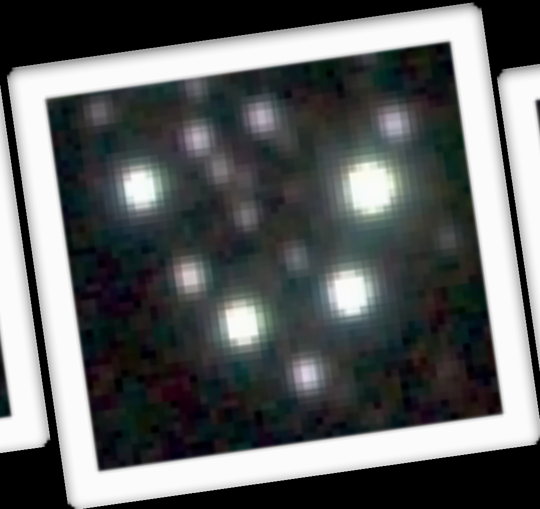
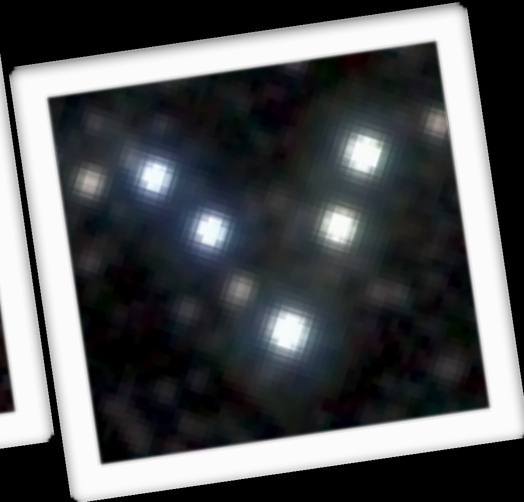


Roberto Saito

VVV BULGE 0.6M+ STARS



4.5 sqdeg
b209+b210+b211

Exoplanets: the Potential of the VVV Survey ii. Transits

V. Ivanov, R. Saito, I. Dekany, C. Caceres, A. Jordan, J.C. Beamin, I. Toledo, K. Helminiak

Transits

- Need exquisite measurements of the stellar brightness, sensitive to giant planets.
- Knowing the dependence of R_* with M_* for MS stars, the transit time depends on the orbital period and the star mass as:

$$t_T=13(M_*/M_o)^{1/2}(a/1AU)^{1/2} \text{ hours}$$

- The transit depth depends on the relative planet and star sizes:

$$A=(R_p/R_*)^2$$

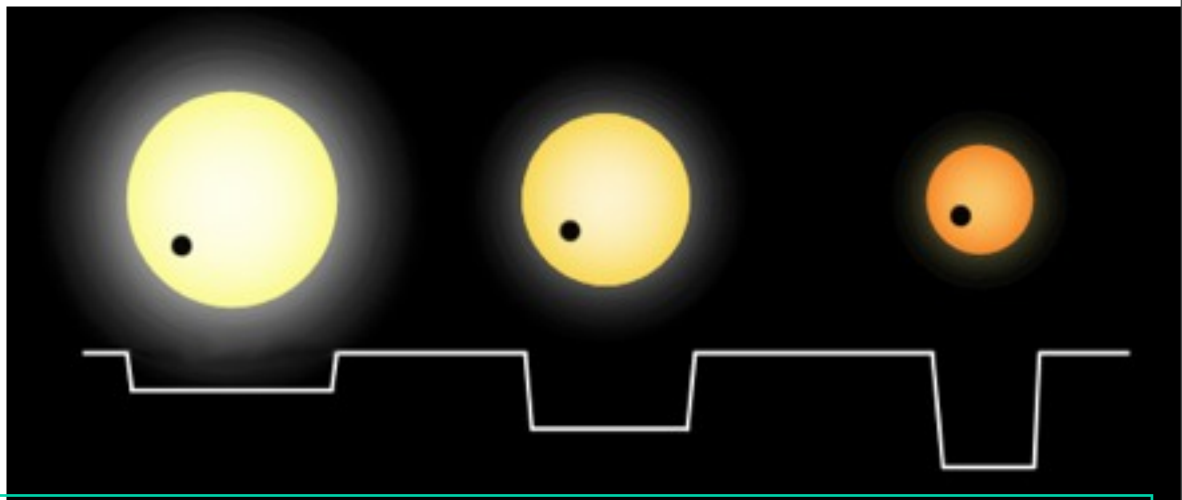
- For typical main-sequence stars:
  - Transit durations 2h – 20 h
  - Transit depths 0.0001-0.01 mag

M-dwarf exoplanets: shorter & deeper transits

- Examples:

Jupiter transit 0.01 mag, t_T=30h

Earth transit 0.000084 mag, t_T=13h



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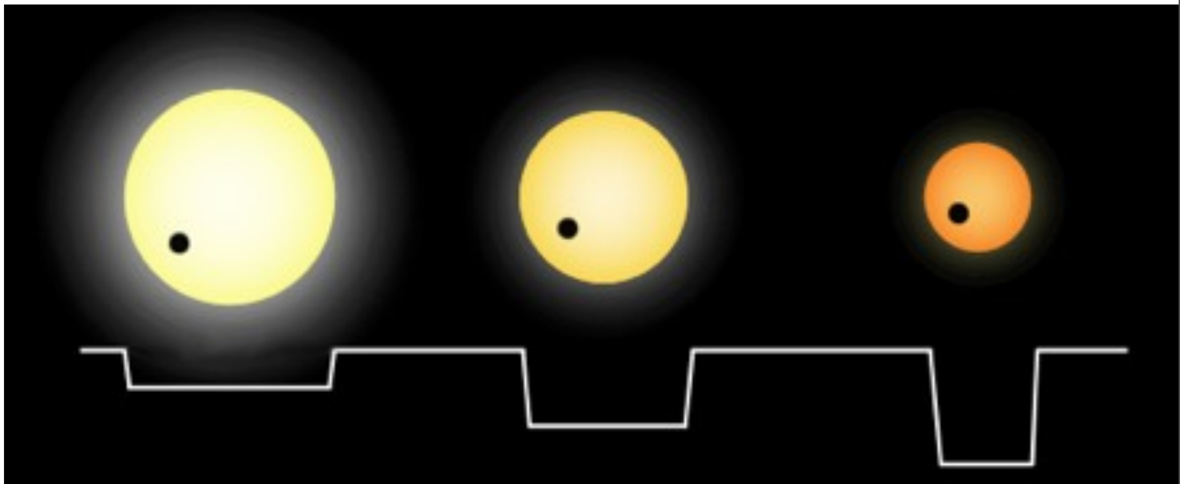


- Examples:

Jupiter transit 0.01 mag, t_T=30h

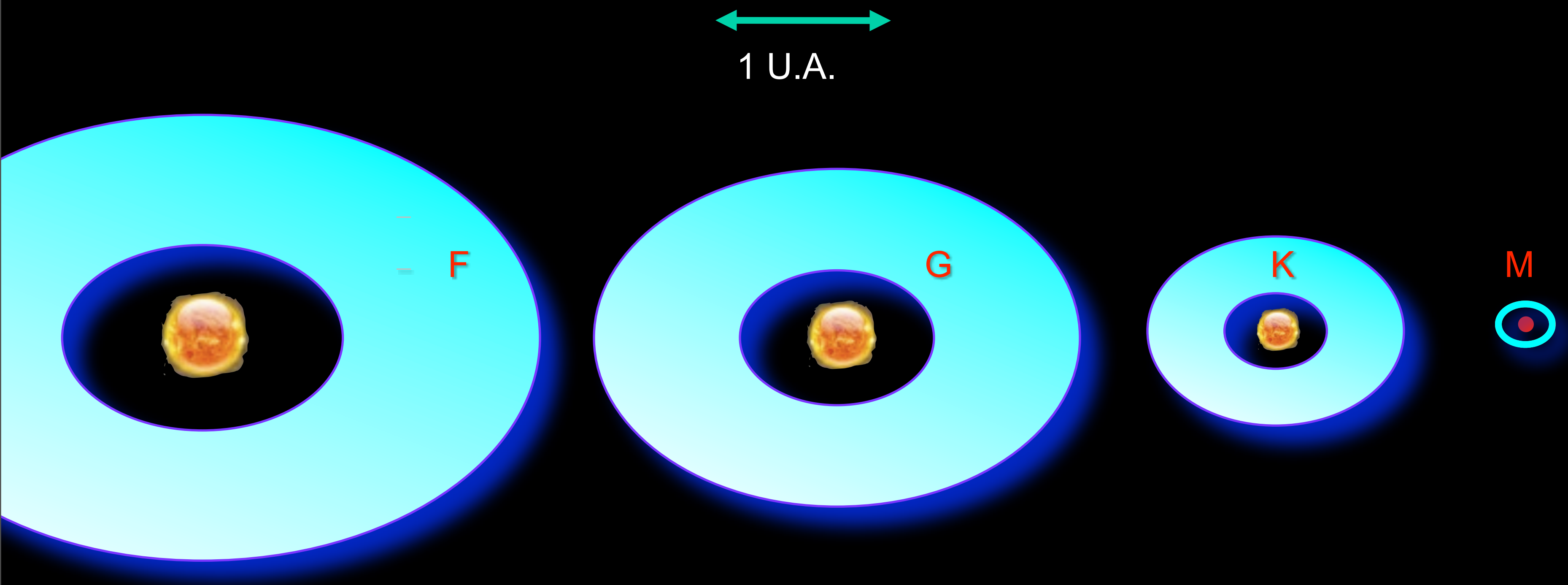
Earth transit 0.000084 mag, t_T=13h

Stellar Habitable Zone

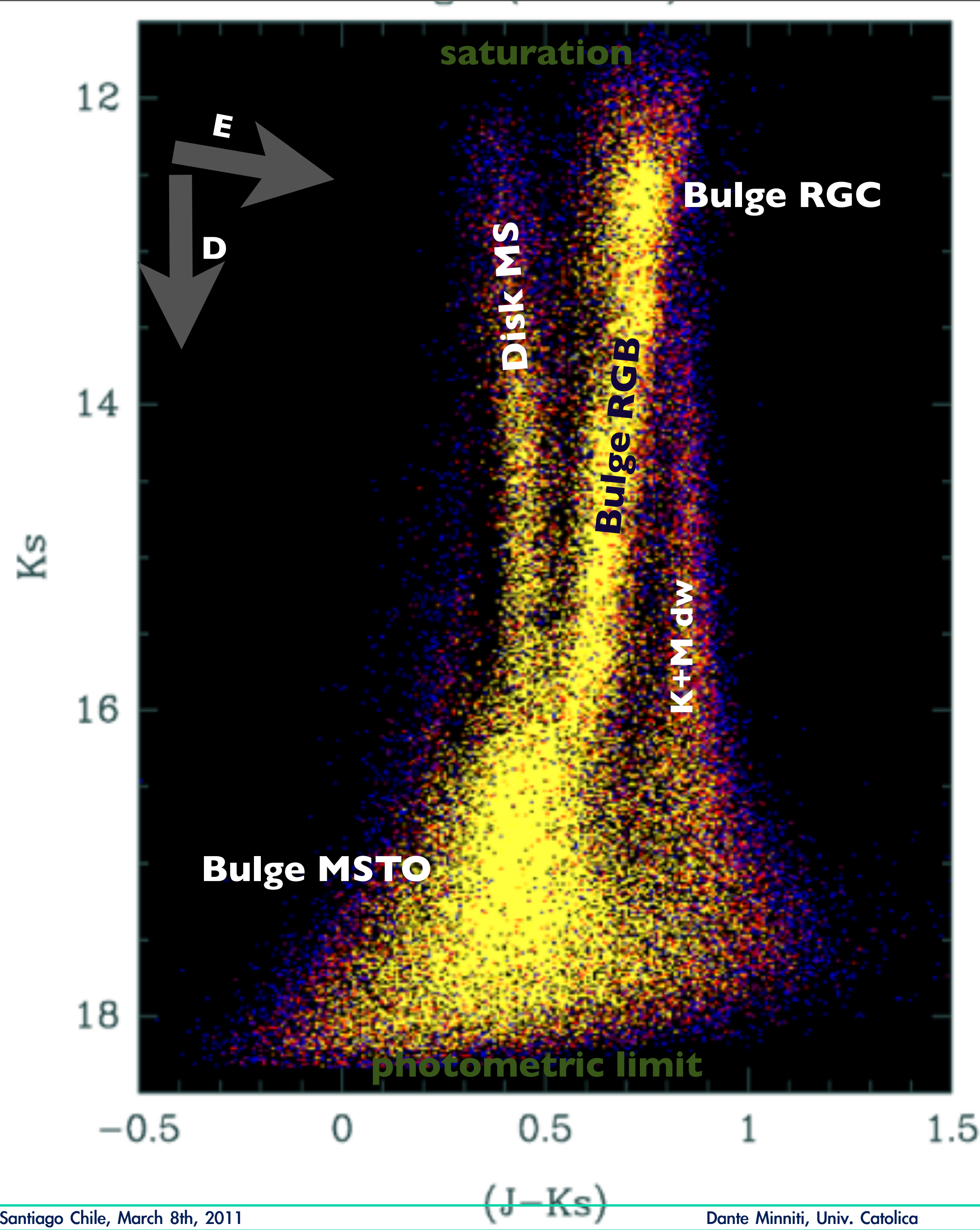
HZ: the region where water remains liquid. It depends on the stellar spectral type.

Focus on M-type stars: they are the most common stars in our Galaxy, the most favorable targets for astrometric detection of planets, and have small habitable zones that are closer in to the stars.

Complementary to Kepler and other transit surveys.



VVV STARS CMD



- Why M dwarfs

- Selection of M-stars

in the MW disk

in the MW bulge

- Photometry

variability, depth, accuracy

- Sampling

normal survey

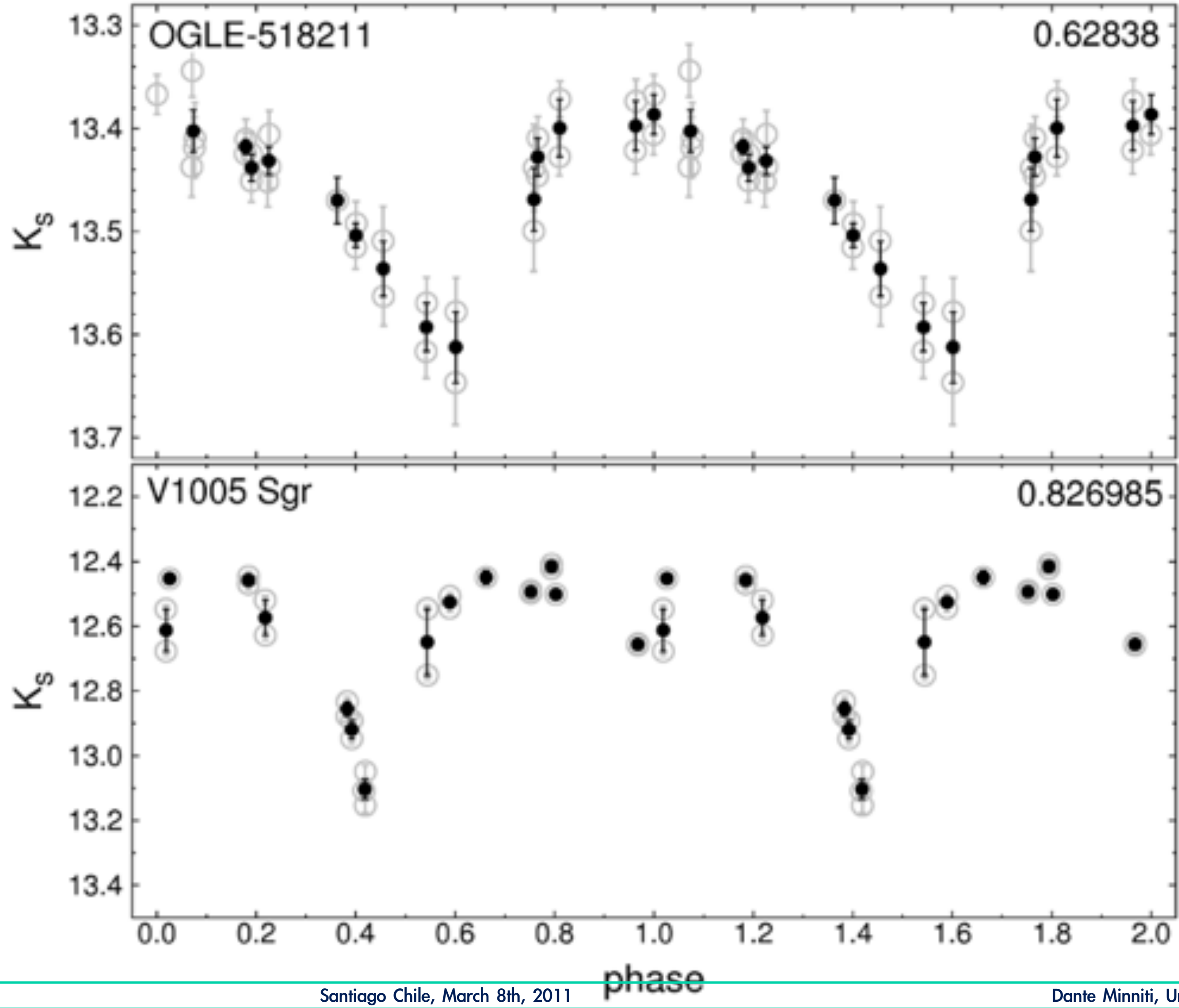
overlap regions

future plans

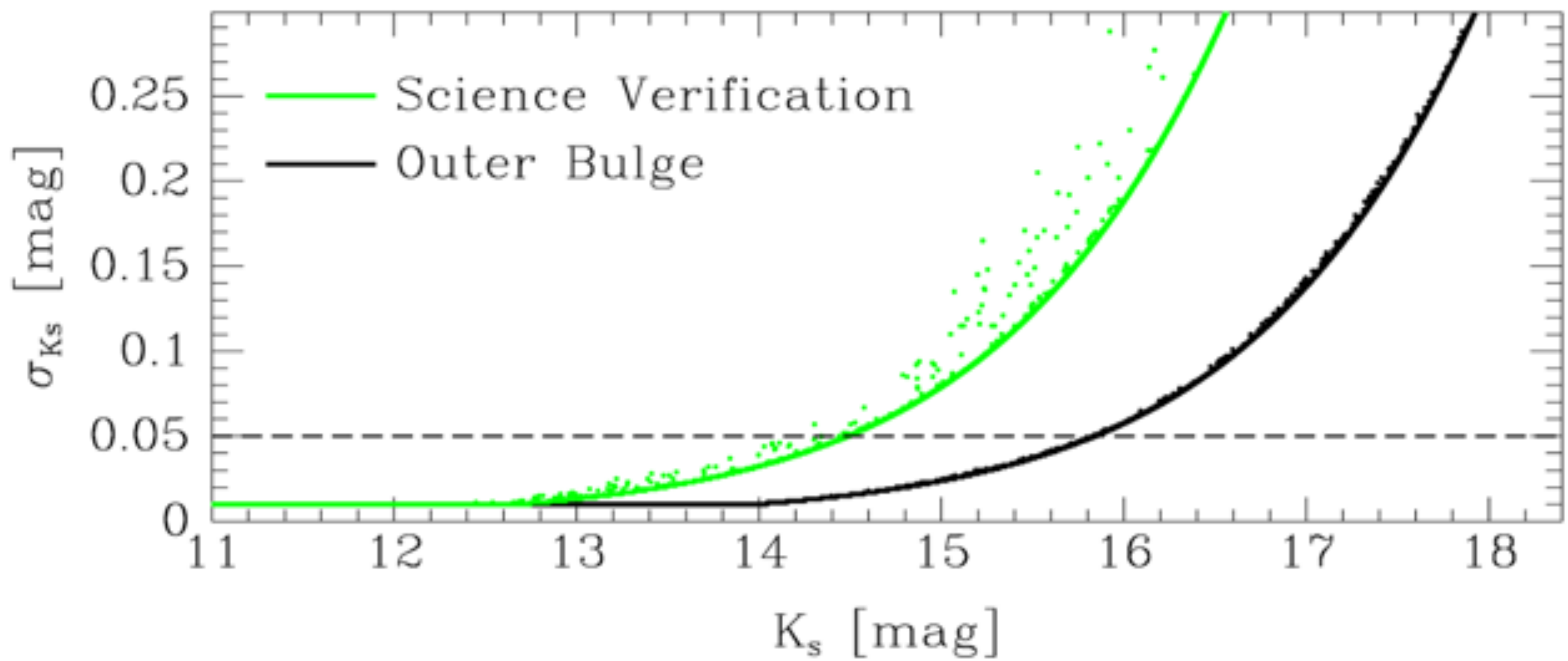
- Simulations

incorporate selection, photometry and sampling

Photometric errors and limits



Photometric errors and limits



The VVV Survey: Timeline

year

1 - 6 epochs in K for bulge and disk; K_{lim}=18/20 mag (single/combined epochs)
- Z,Y,J,H, K single (quasi-simultaneously) epoch observations (bulge & disk) — **2010**

2 - 4 epochs in K_s for bulge and disk — **2011**

3 - main part of bulge variability campaign (80 epochs, 652 h)
- map bulge and disk once per night — **2012**

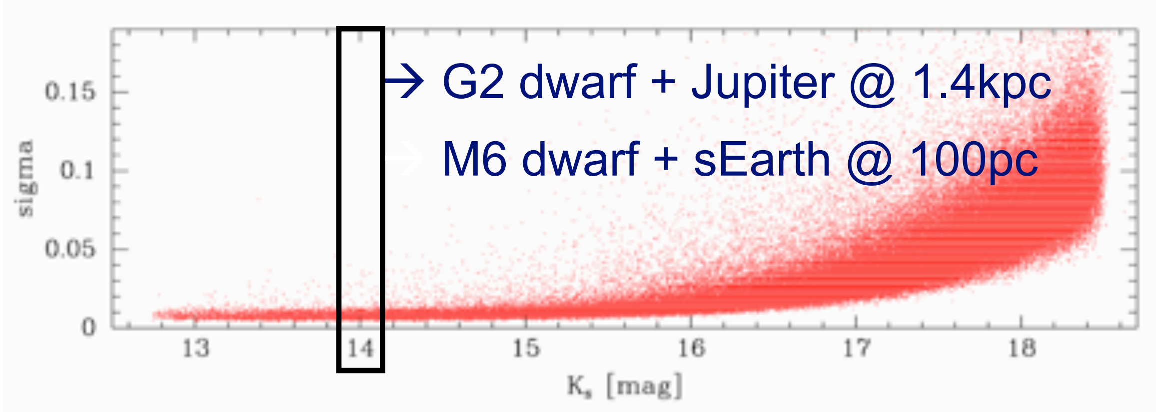
4 - main disk variability campaign (similar to bulge, but 70 epochs, 525 h) — **2013**

5 - bulge and disk observations in K band
- 20/9 epochs spread over the whole year
- subset will be observed more frequently (10-40 times per night) — **2014**

2015

...

SEARCH FOR TRANSITING EXTRASOLAR PLANETS

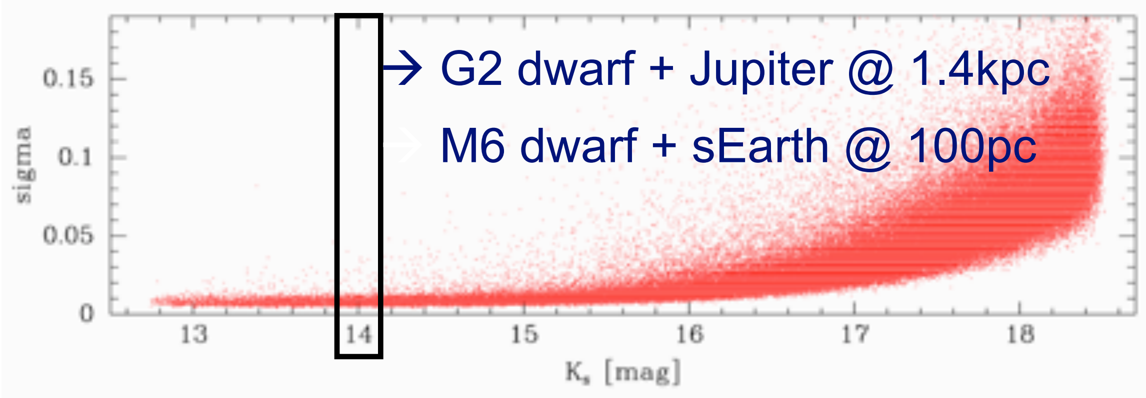


We can search for transits of Neptunes and **super-Earths** orbiting M-type dwarf stars.

Simulaciones de tránsitos:

Roberto Saito

SEARCH FOR TRANSITING EXTRASOLAR PLANETS



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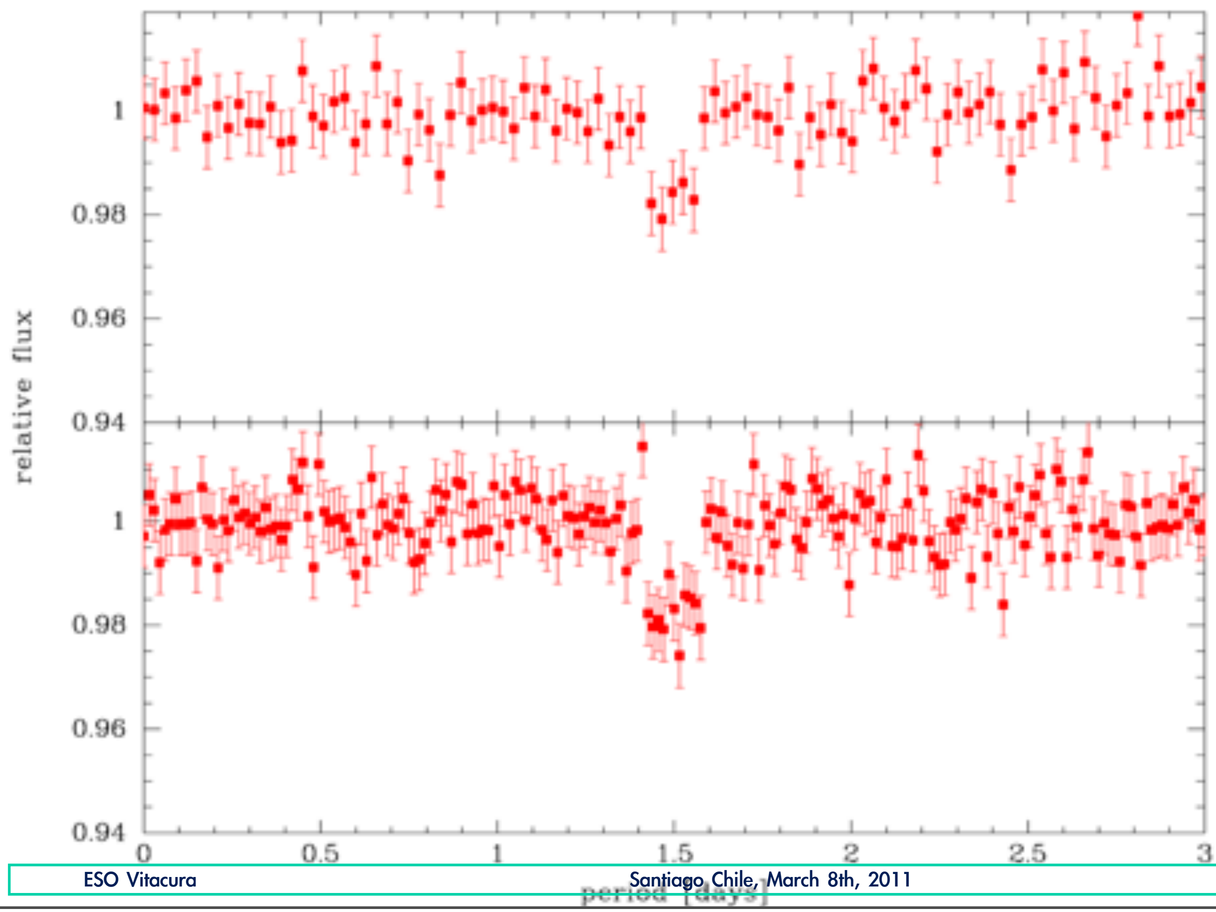
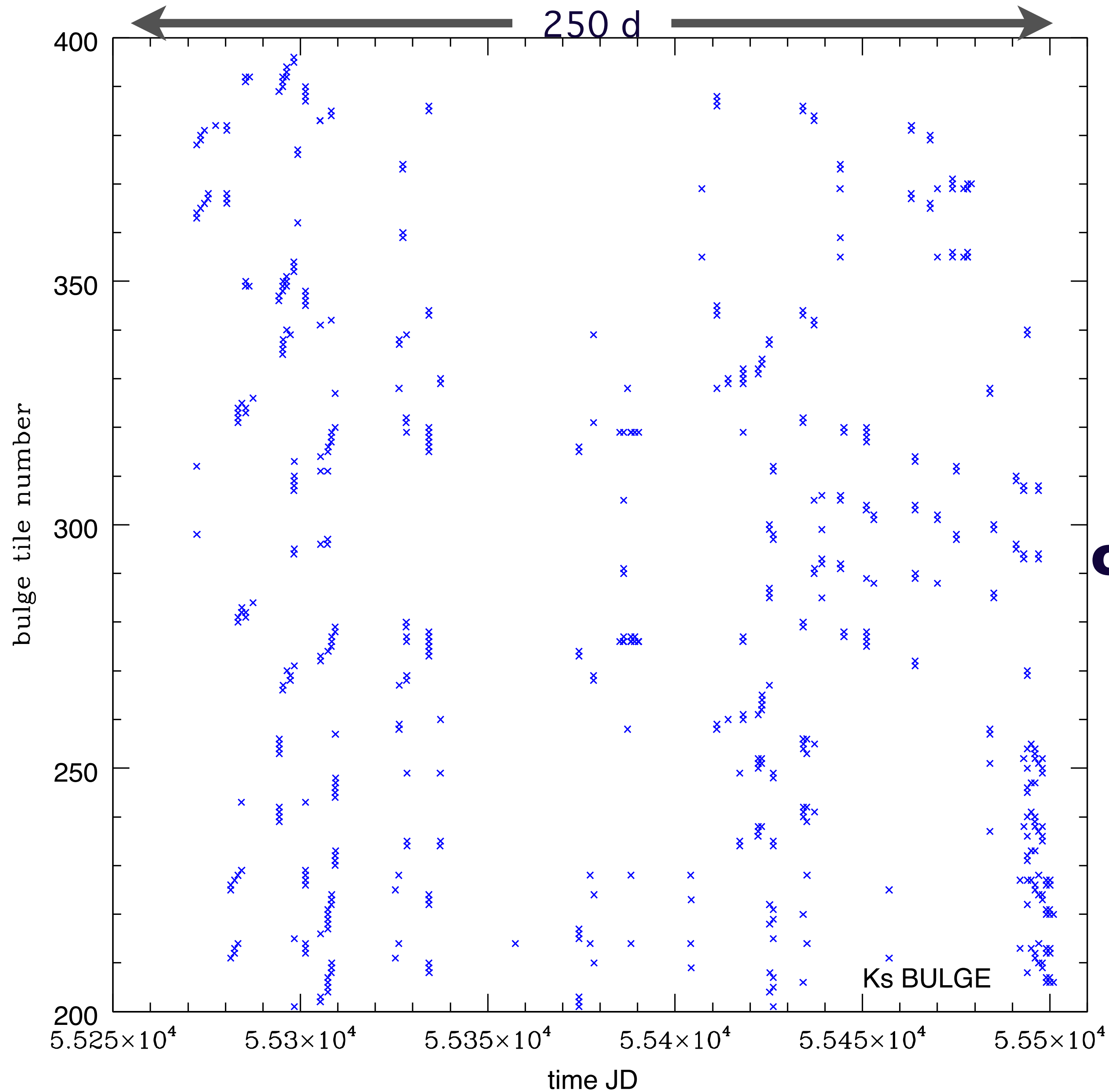


Phase-folded light curve simulation for 5 years campaign

Transit simulations including more intensive (2x) observations during the last year

Roberto Saito

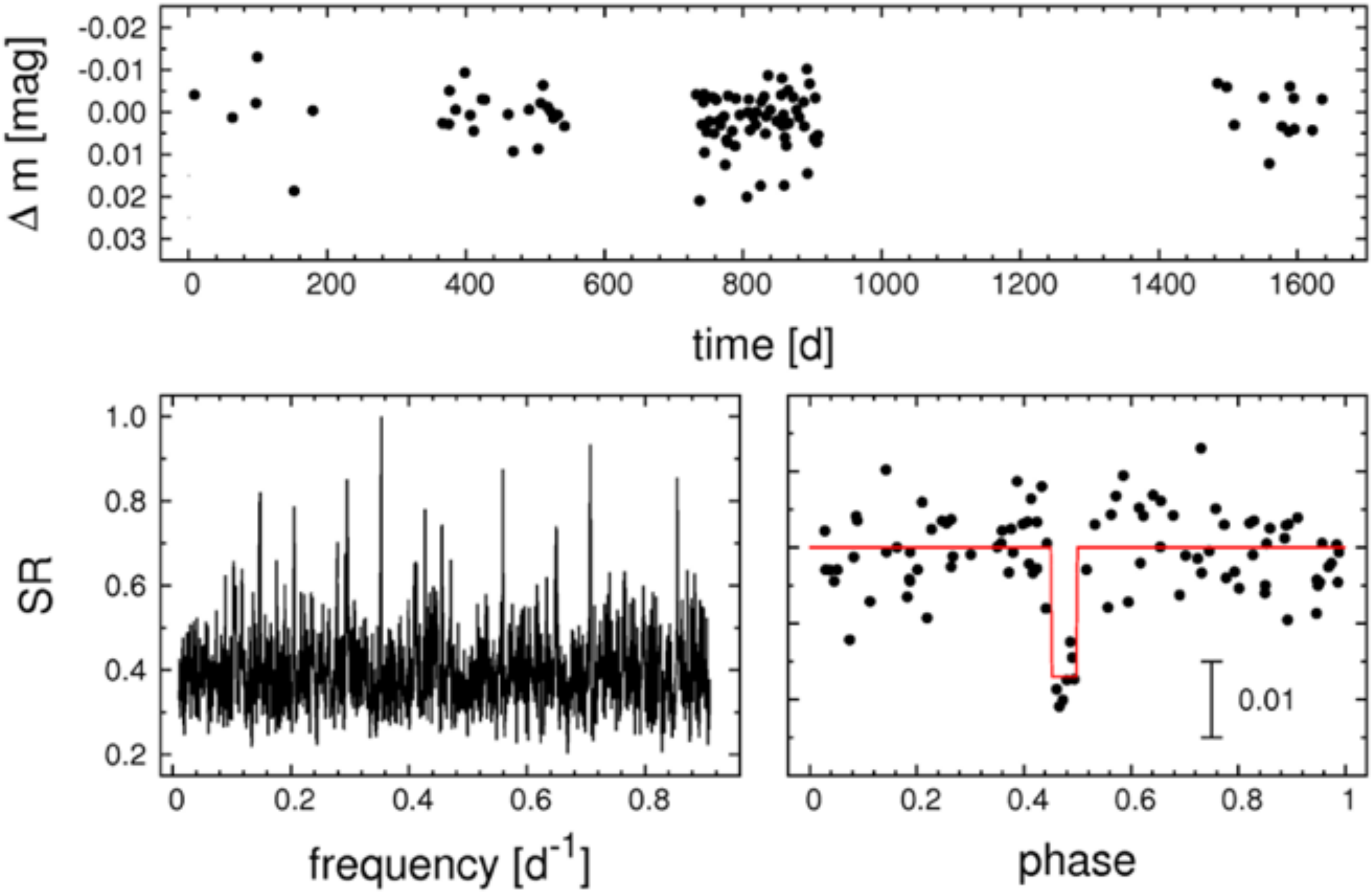


Sampling

Bulge Variability observations YR1

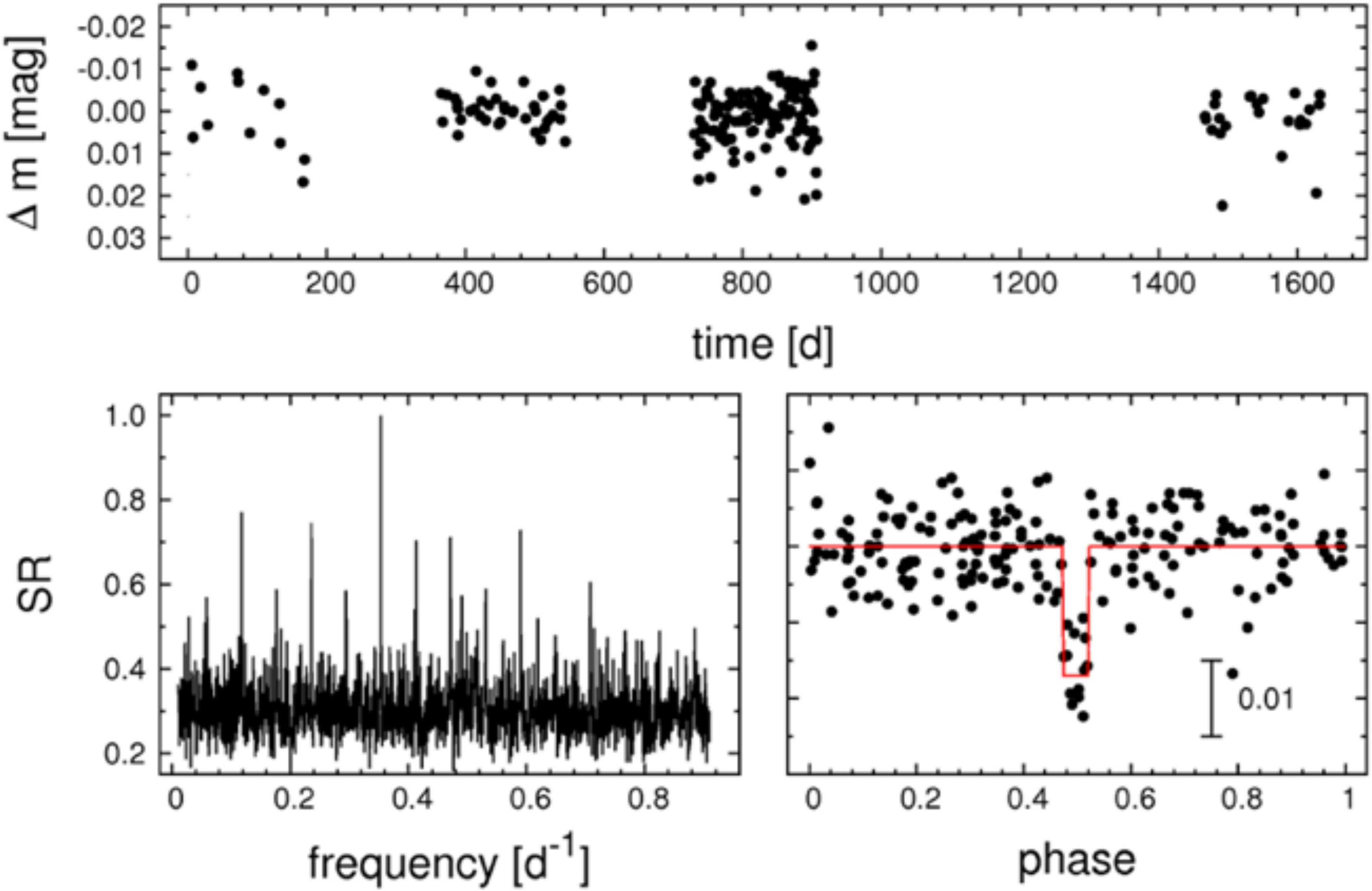
Valentin Ivanov

n



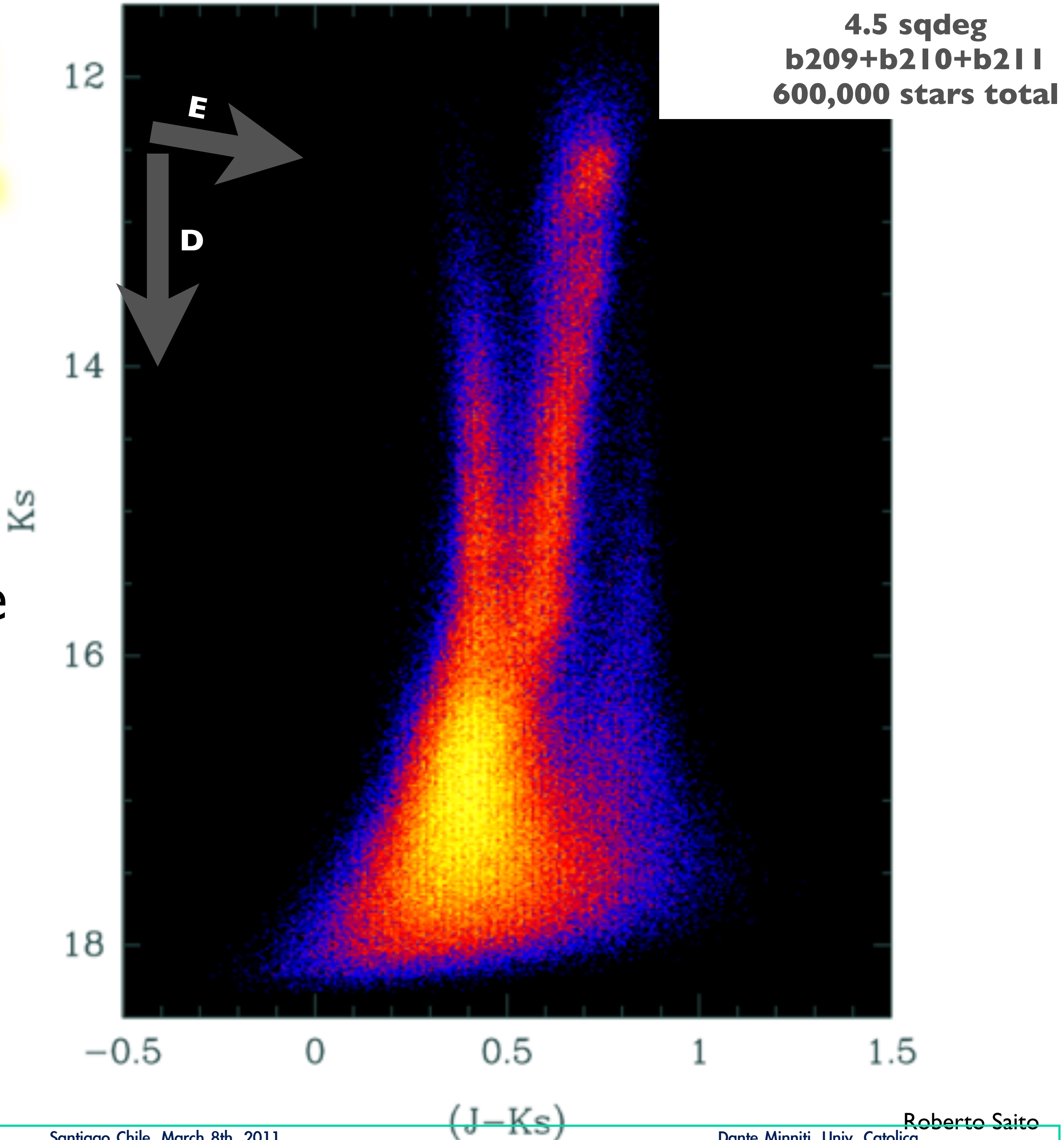
Δ m [mag]
-0.02
-0.01
0.00
0.01
0.02
0.03
0
200
400
600
800
1000
1200
1400
1600
time [d]
SR
1.0
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
frequency [d^-1]
0.01
0
0.2
0.4
0.6
0.8
1
phase

2n



-0.02
-0.01
0.00
0.01
0.02
0.03
Δ m [mag]
0
200
400
600
800
1000
1200
1400
1600
time [d]
1.0
0.8
0.6
0.4
0.2
SR
0
0.2
0.4
0.6
0.8
frequency [d^-1]
0.01
0
0.2
0.4
0.6
0.8
1
phase

SEARCH FOR TRANSITING EXTRASOLAR PLANETS



Main motivation: to build up the statistics: select a very large sample of small stars (K-M types) to search for extrasolar planetary transits

SEARCH FOR TRANSITING EXTRASOLAR PLANETS

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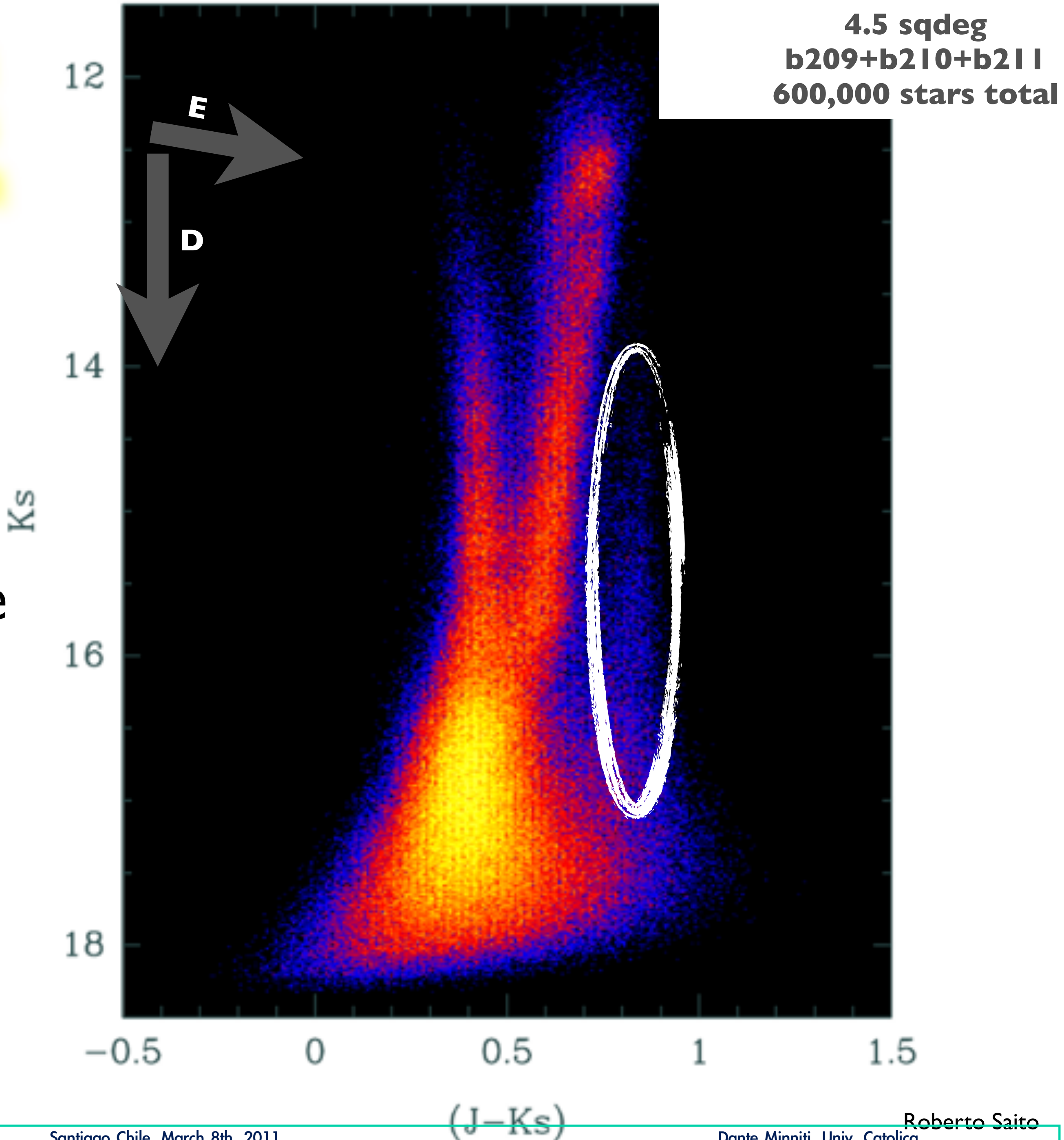
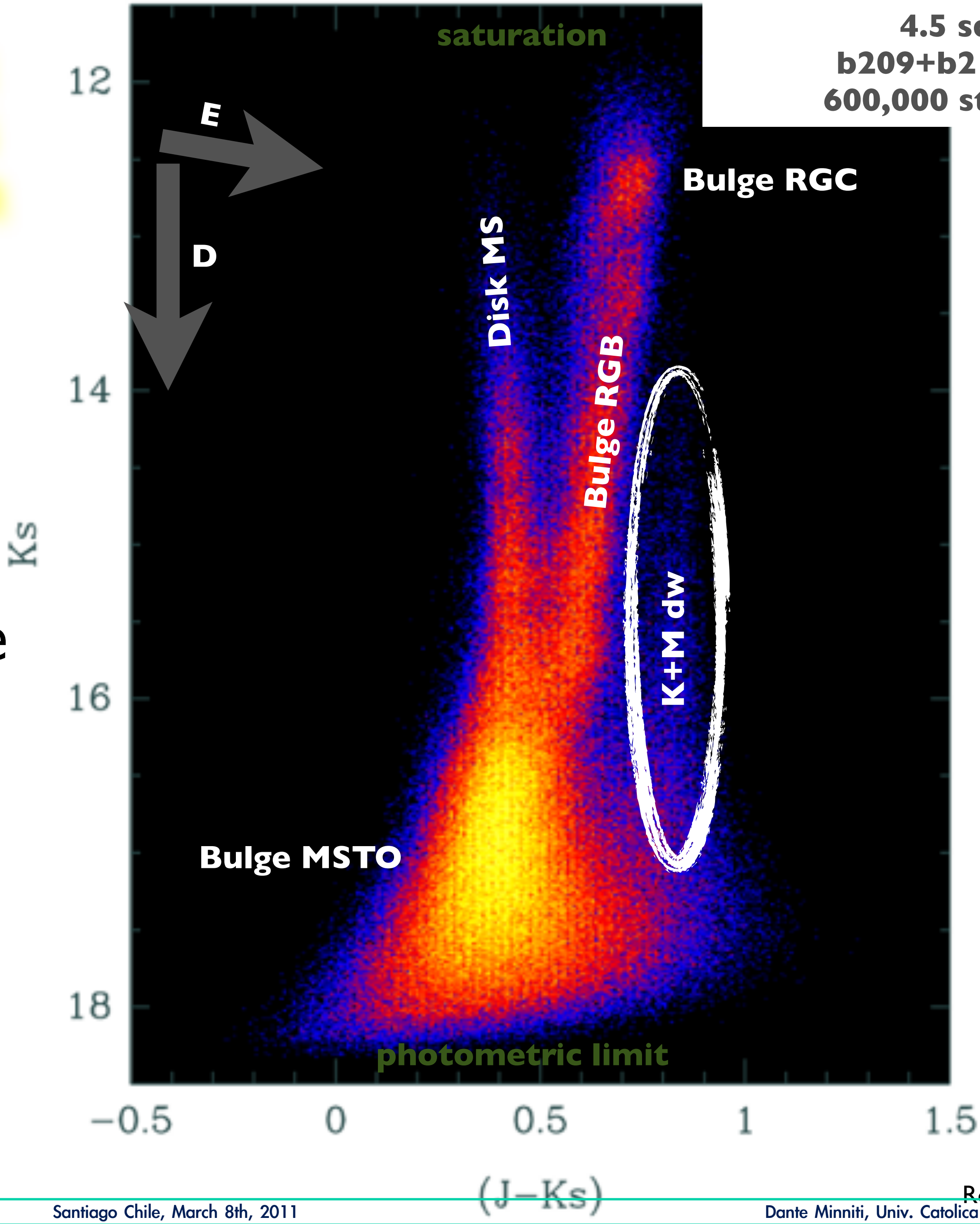


Friday, March 23, 2012

SEARCH FOR TRANSITING EXTRASOLAR PLANETS

4.5 sqdeg
b209+b210+b211
600,000 stars total

Main motivation:
to build up the statistics:
select a very large sample of small stars (K-M types) to search for extrasolar planetary transits



Some Problems:

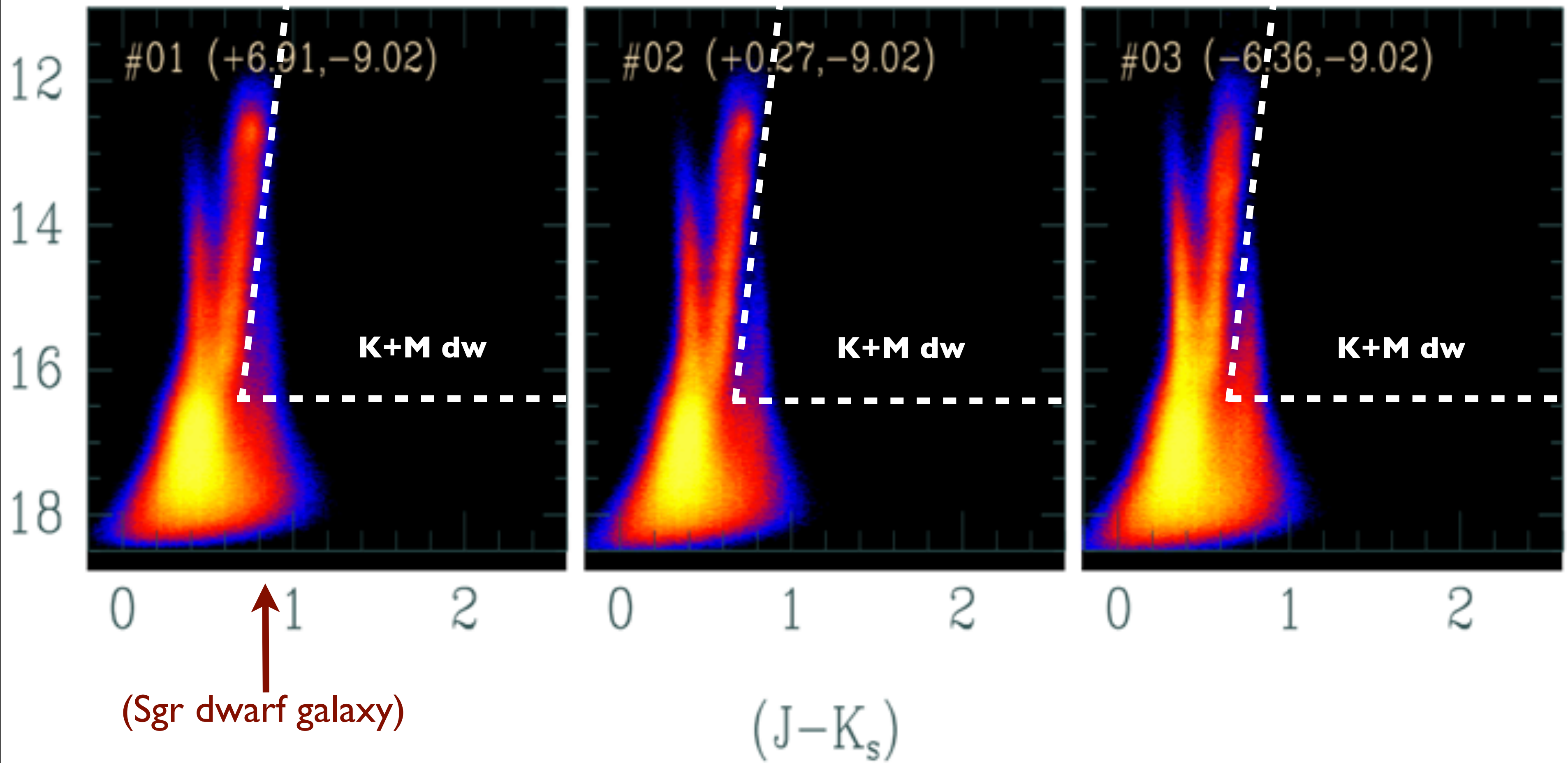
- Clump giants from the Sgr dwarf

- Active M-stars

- Sampling

- Faint targets, difficult spectroscopic follow-up
  - low res to discard blends
  - high res to measure RV curves

Selection of nearby late-type stars (spectral types K5 to M)



Late K + M dwarfs N ~ 500,000 with Ks < 16.5

(n ~ 20,000 good candidates per field, 10% of all sources)

Proper motions after a few years (~7 mas/yr)

Roberto Saito

Exoplanets: the Potential of the VVV Survey iii. Microlensing

J-P Beaulieu, S. Brilliant, P. Pietrukowicz, E. Kerins, P. Fouque, O. Gonzalez, M. Rejkuba

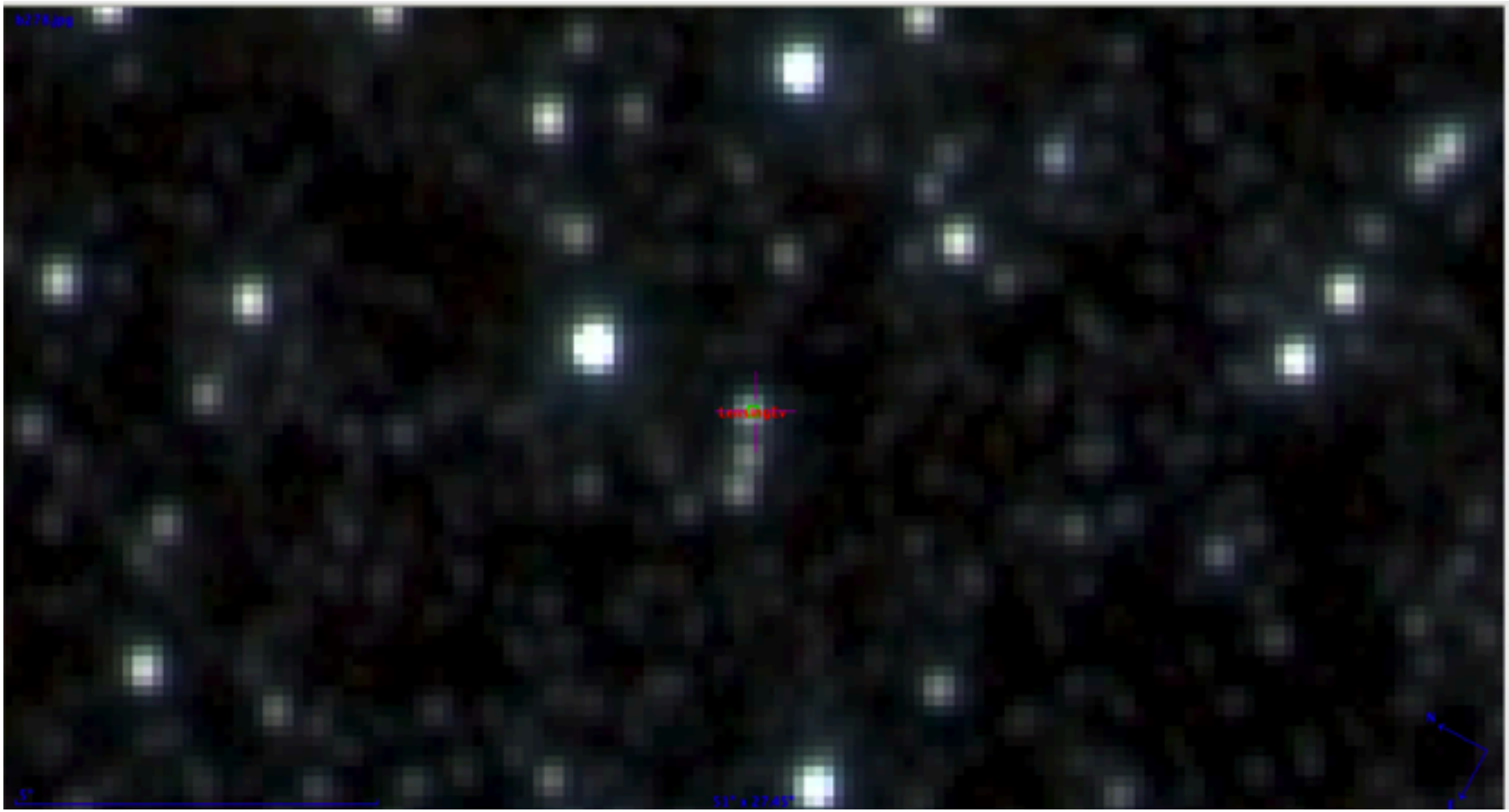
Microlensing

- Characterizing known microlensing events

- Microlensing in the IR with the VVV survey

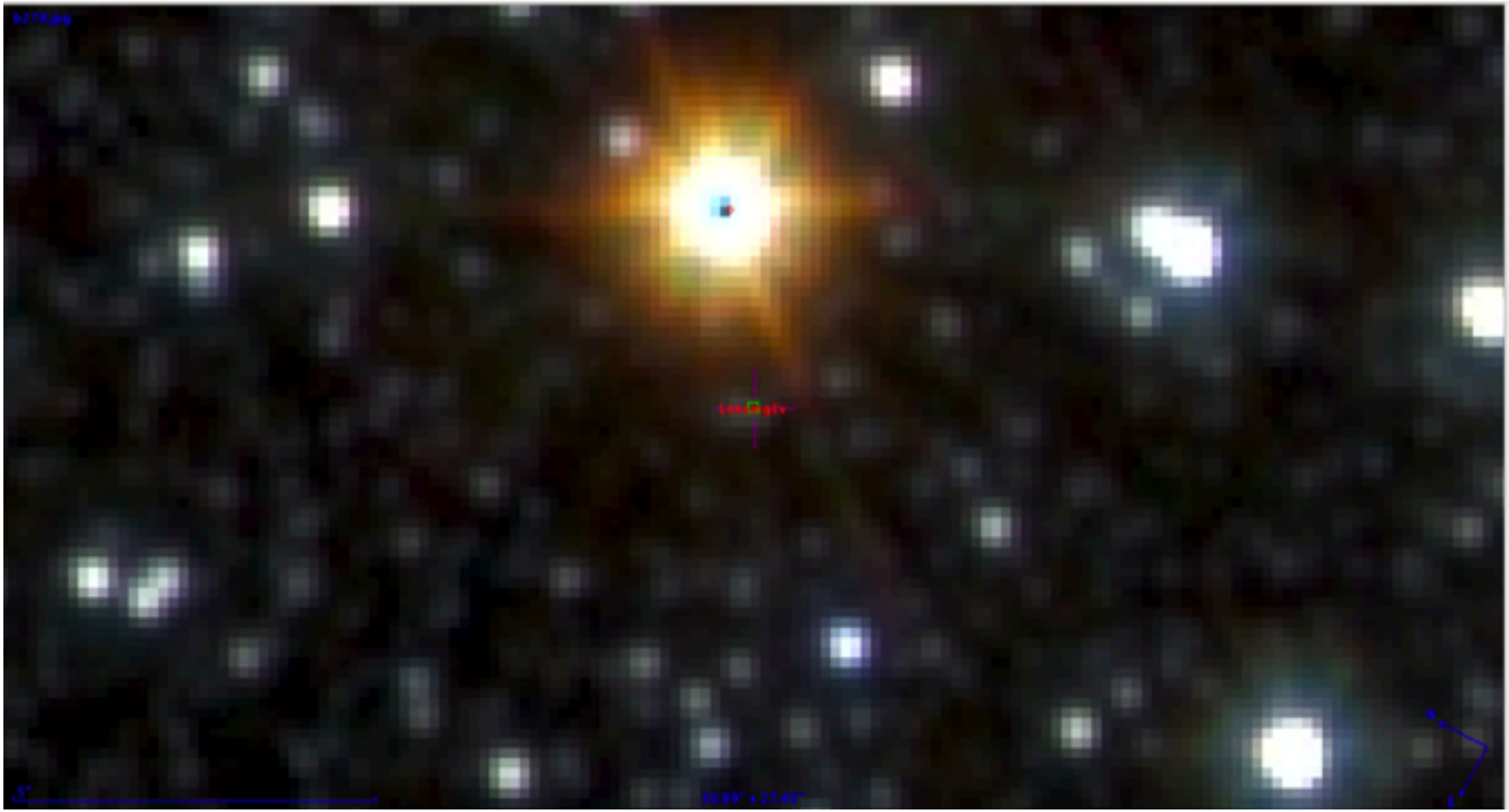
- Other microlensing jewels

Known microlensing events



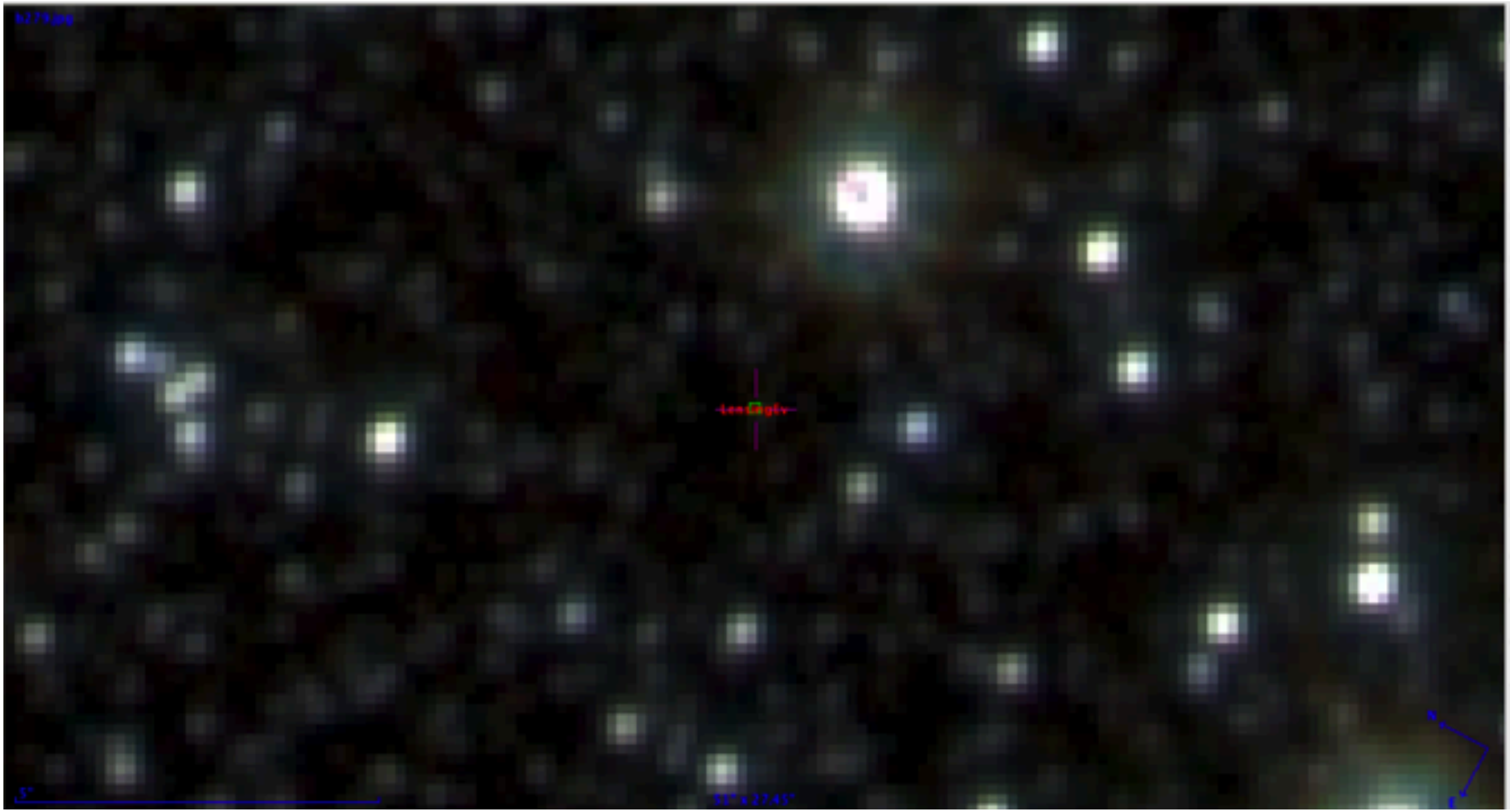
VVV will help to characterize known microlensing events.

Known microlensing events



VVV will help to characterize known microlensing events.

Known microlensing events



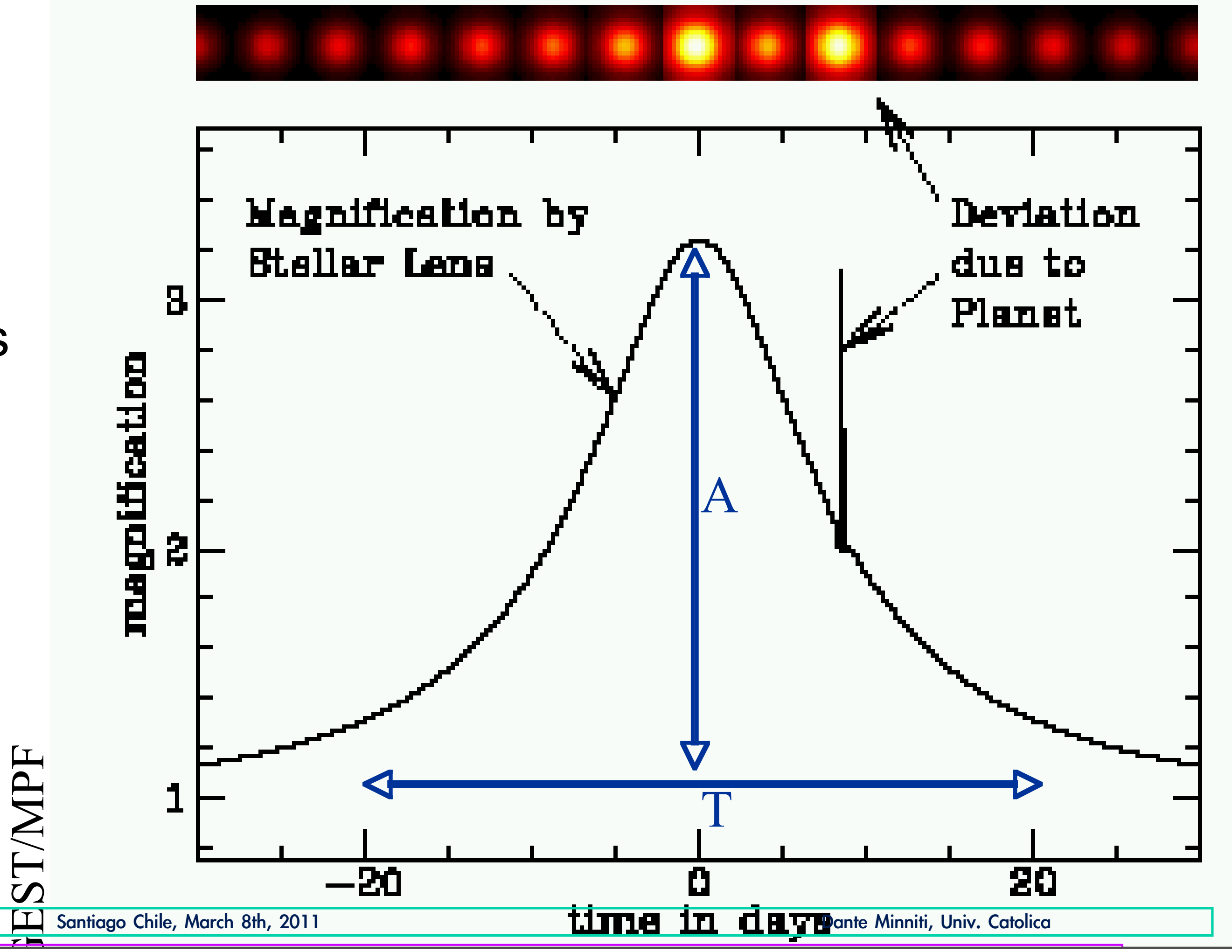
VVV will help to characterize known microlensing events.

Planetary Microlensing Events

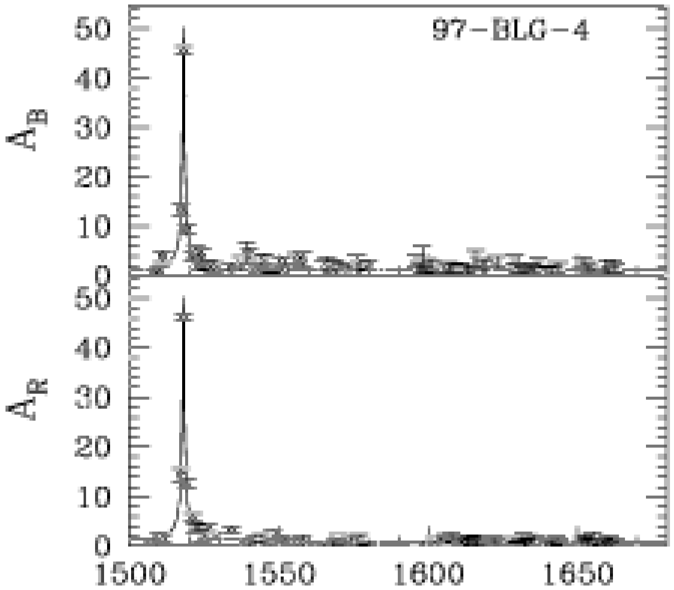
Observable: timescale

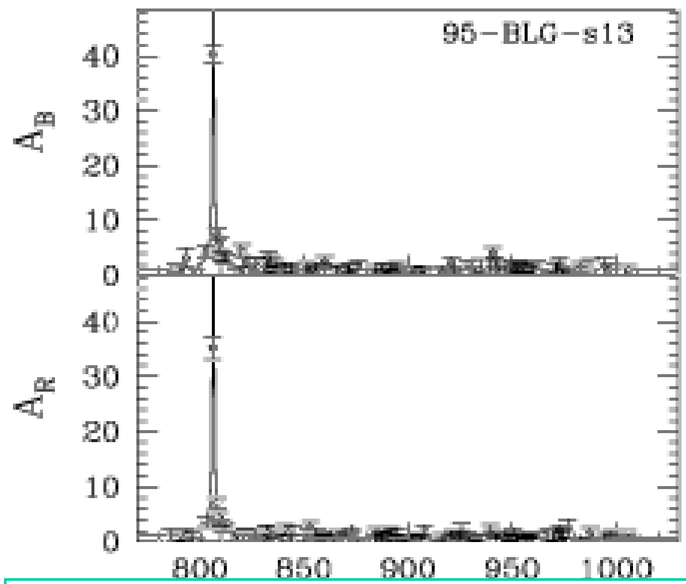
Unknowns: mass, relative distances, transverse velocity

- Gravitational microlensing: searching the short perturbation due to a planet orbiting the lensing star. We can think a star+planet as a special case of a binary star.



Bulge Microlensing





Alcock et al. 1999

- **Towards the MW bulge**

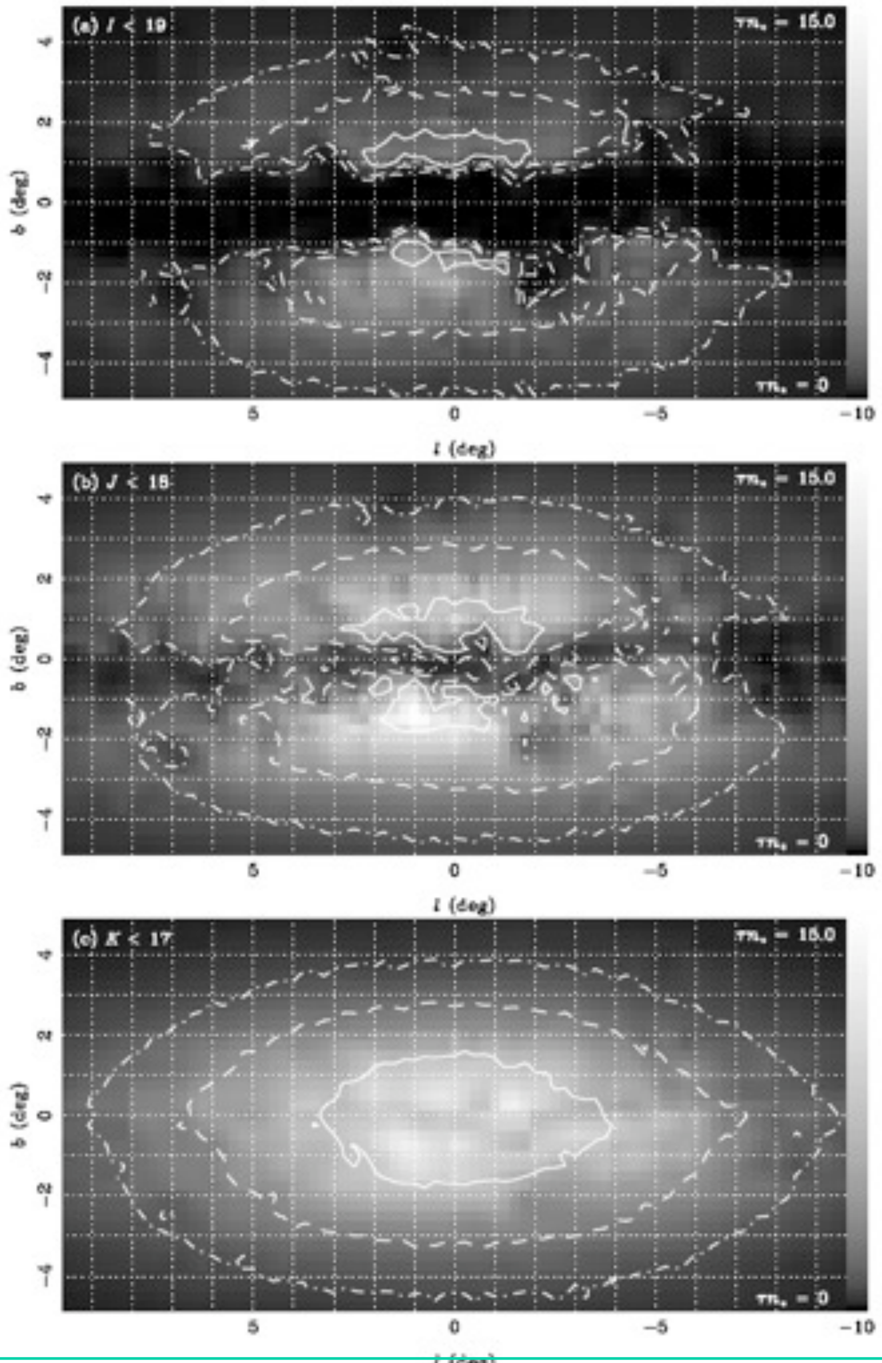
  $t = 40\ (M/M_O)^{1/2}$ *days*

OBJECT	*TIMESCALE*
Sun	*40 days*
Jupiter	*1 day*
Earth	*1 hour*

- **Einstein radius**

  $R_E = 3\ (M/M_O)^{1/2}$ *AU*

Optical depth



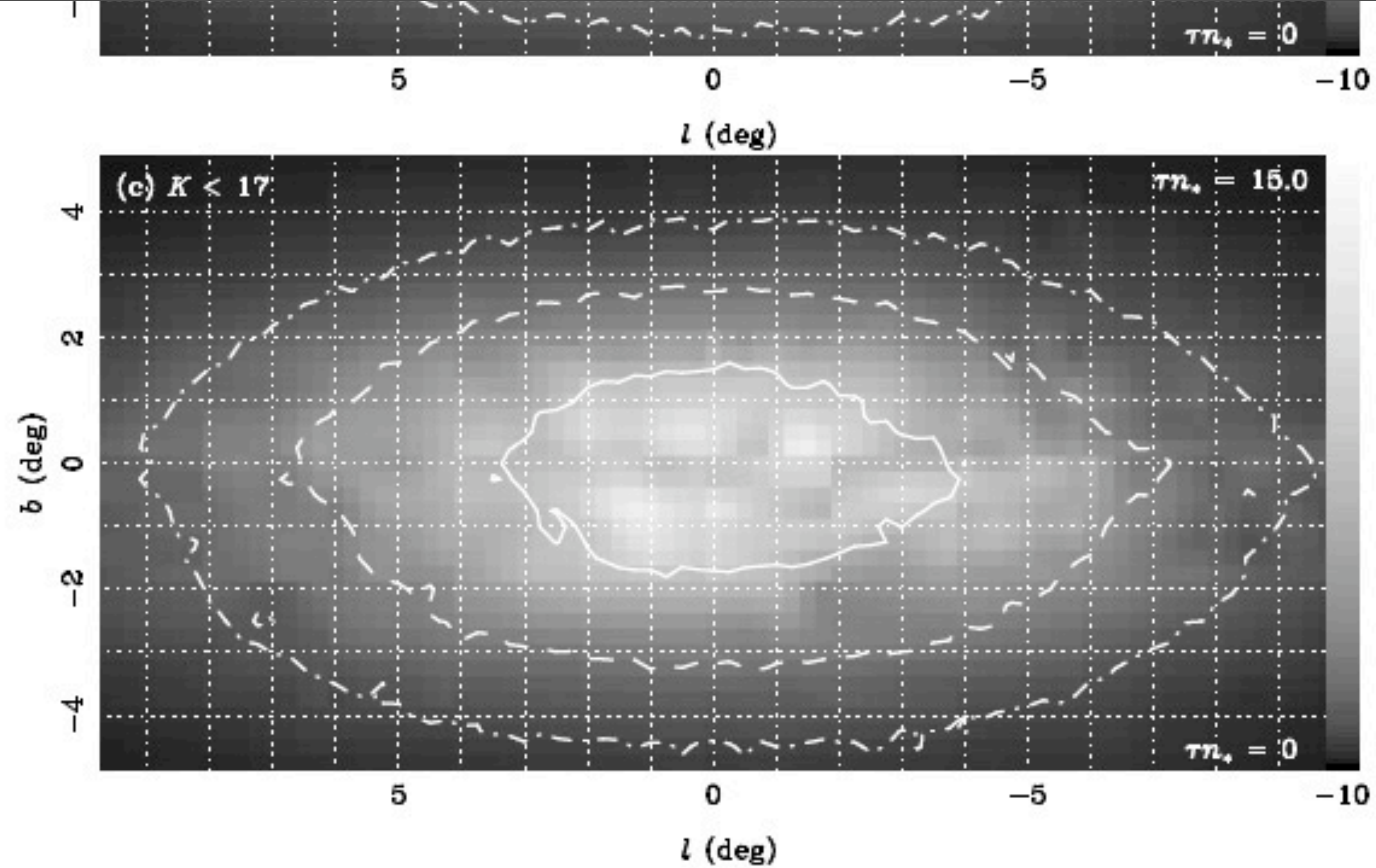
VVV will search for reddened bulge microlensing events, and produce a map of the optical depth T, tracing the 3D bulge mass distribution.

The near-IR advantage:

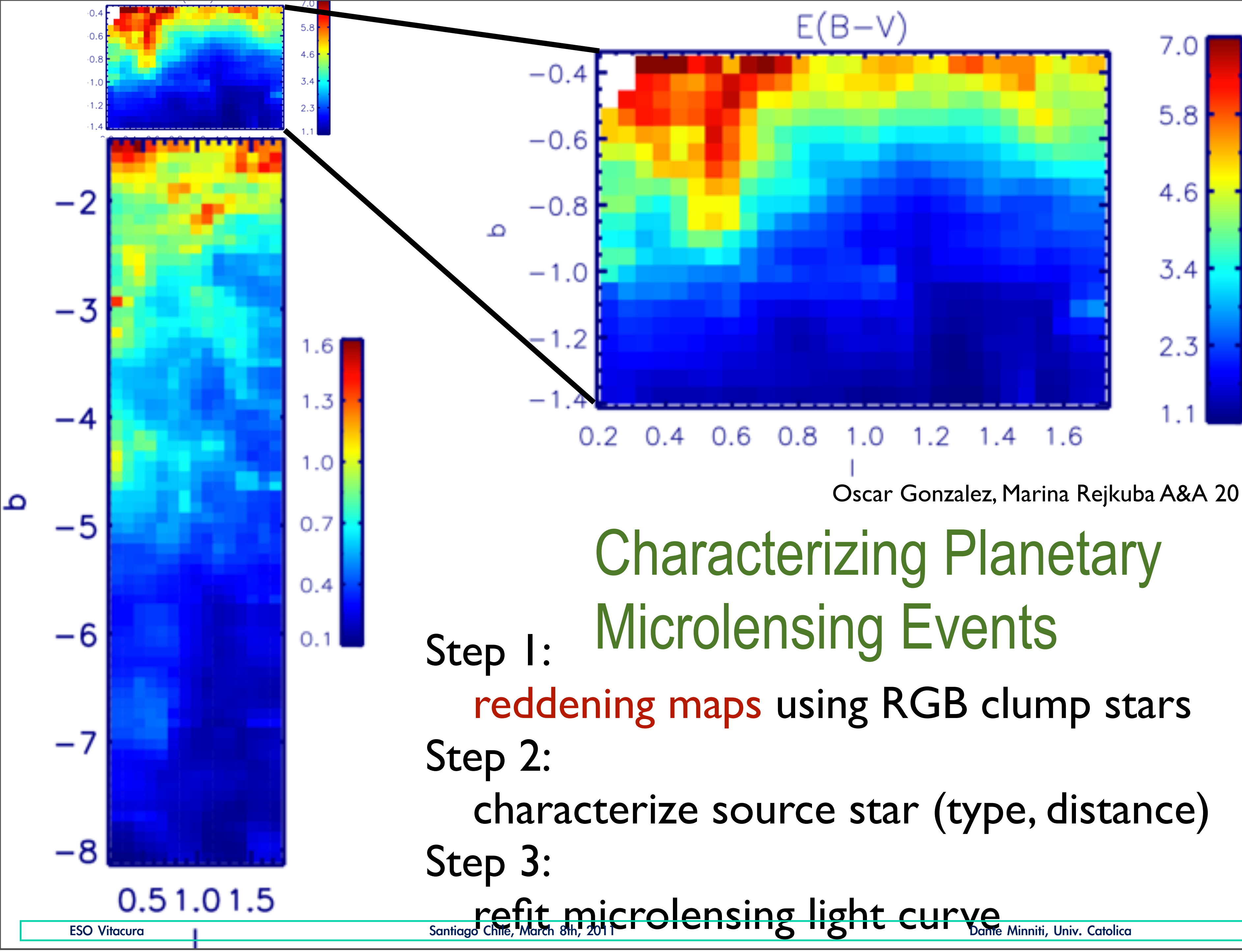
I, J and Ks-map event rates for sources with K<17.

Contours = 17.5, 35, 52.4 per sqdeg per year.

E. Kerins et al. 2008



E. Kerins et al. 2008



Oscar Gonzalez, Marina Rejkuba A&A 2011

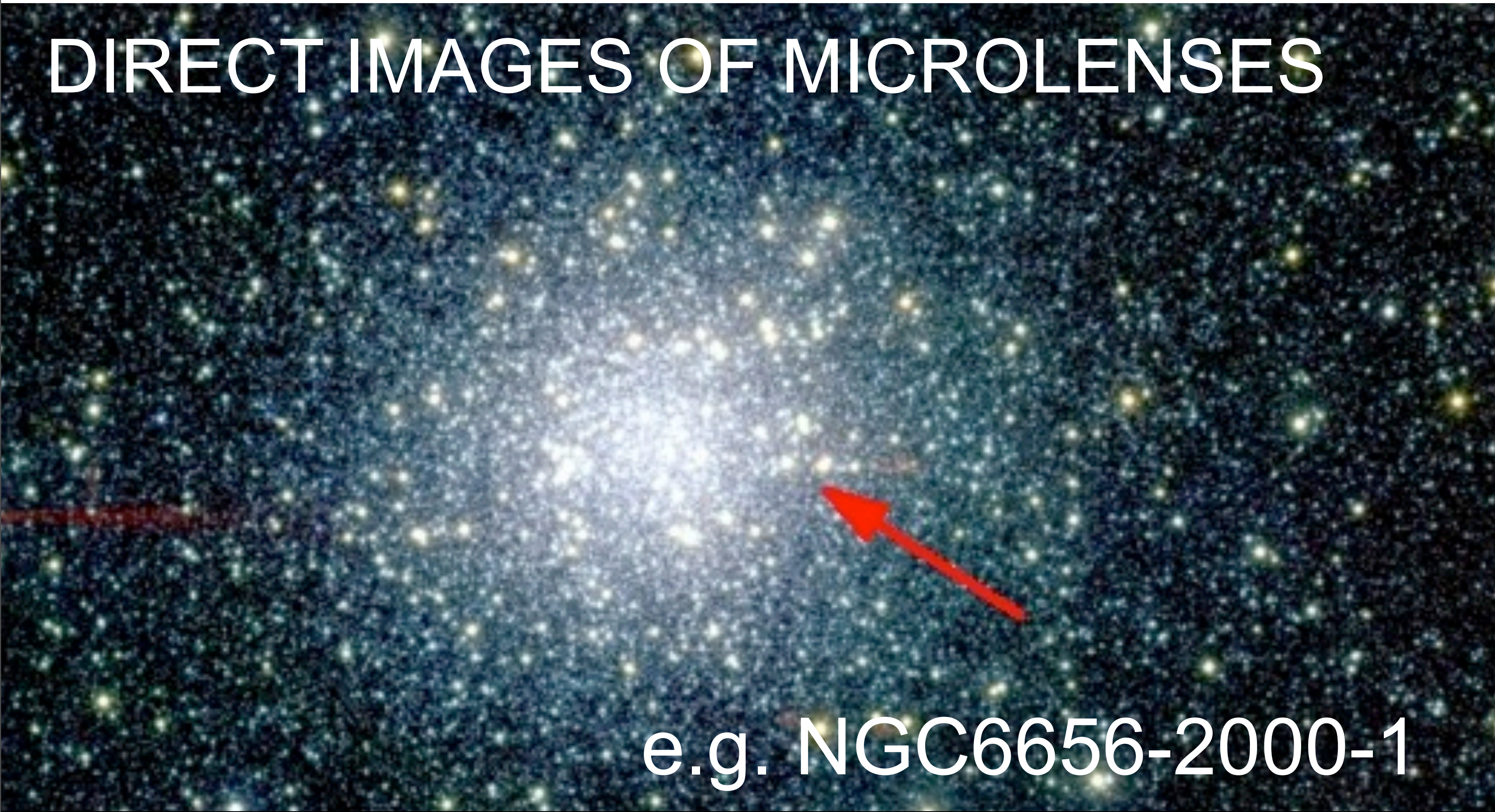
Characterizing Planetary Microlensing Events

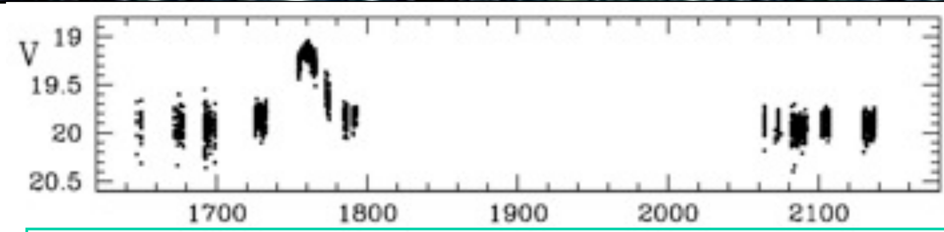
Step 1:
reddening maps using RGB clump stars

Step 2:
characterize source star (type, distance)

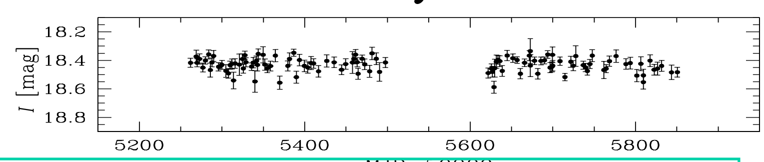
Step 3:
refit microlensing light curve

Other Microlensing Jewels

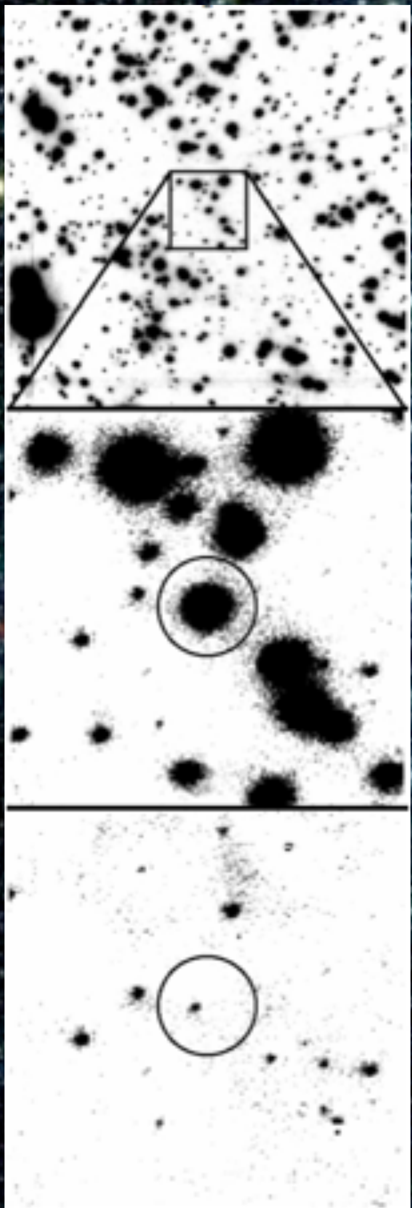




OGLE - 10 years later

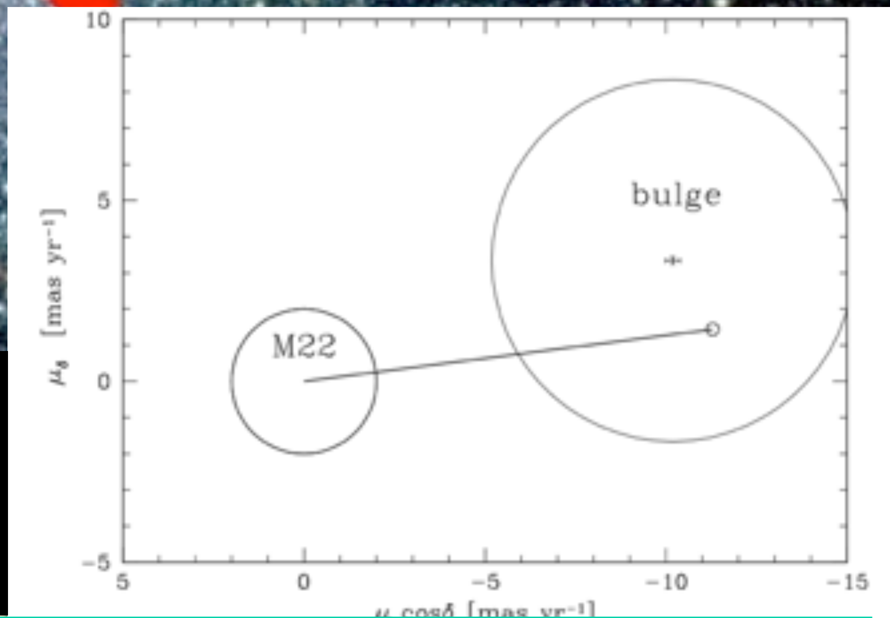


DIRECTLY IMAGE MICROLENSES e.g. NGC6656-2000-1



The first globular cluster microlensing event candidate was NGC6656-2000-1 (Pietrukowicz et al. 2005). Now we have directly detected the lens, which turns out to be a late M-star with 0.18Mo in NGC6656 that gravitationally focused the light from a K=17.37 mag solar-type star located in the Galactic bulge. VLT/NACO images 10 years after the event show that this MACHO moved **0.107”** on the sky.   (Pietrukowicz et al. ApJL, Jan 2012)

The VVV images were used to calibrate the AO photometry.



IR excess stars

C. Chavero, R. Saito (see poster)

VVV will also help to find and characterize new disks.

Extreme candidates: one in a million...

Summary

The VVV Survey

Exoplanet transits

Microlensing

VVV Science Workshop
Viña Del Mar
22-24 March

Acknowledgments:

The Scientist (Coldplay)
“Nobody said it was easy
No one ever said it would be so hard
I’m going back to the start”

Vatican Obs.