

# The first confirmed microlensing event in a globular cluster



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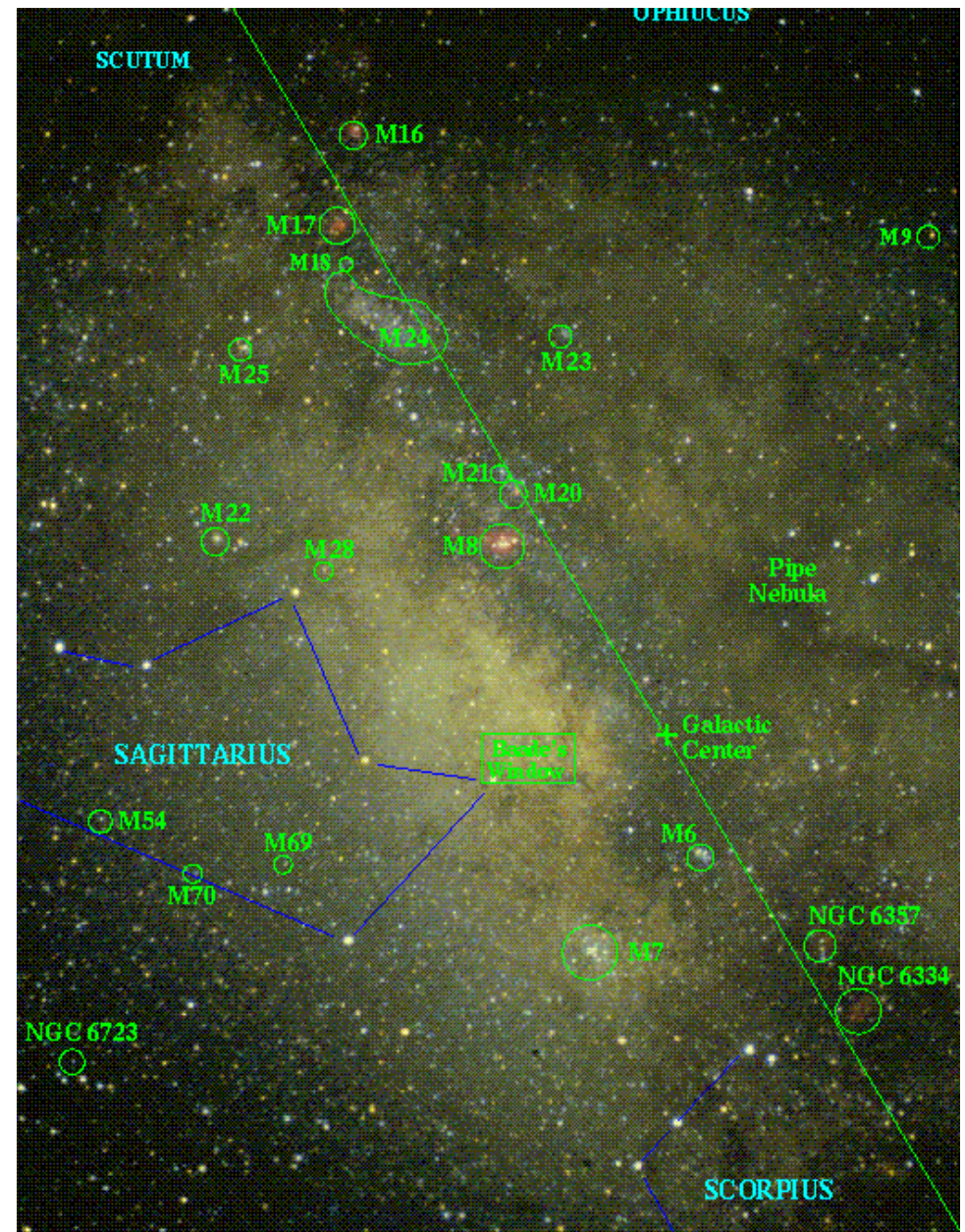
*&*

*D. Minniti, Ph. Jetzer, J. Alonso-Garcia, A. Udalski*

# The Paczyński's idea

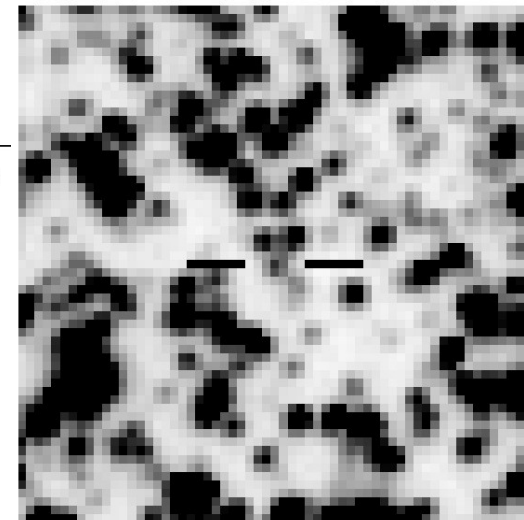
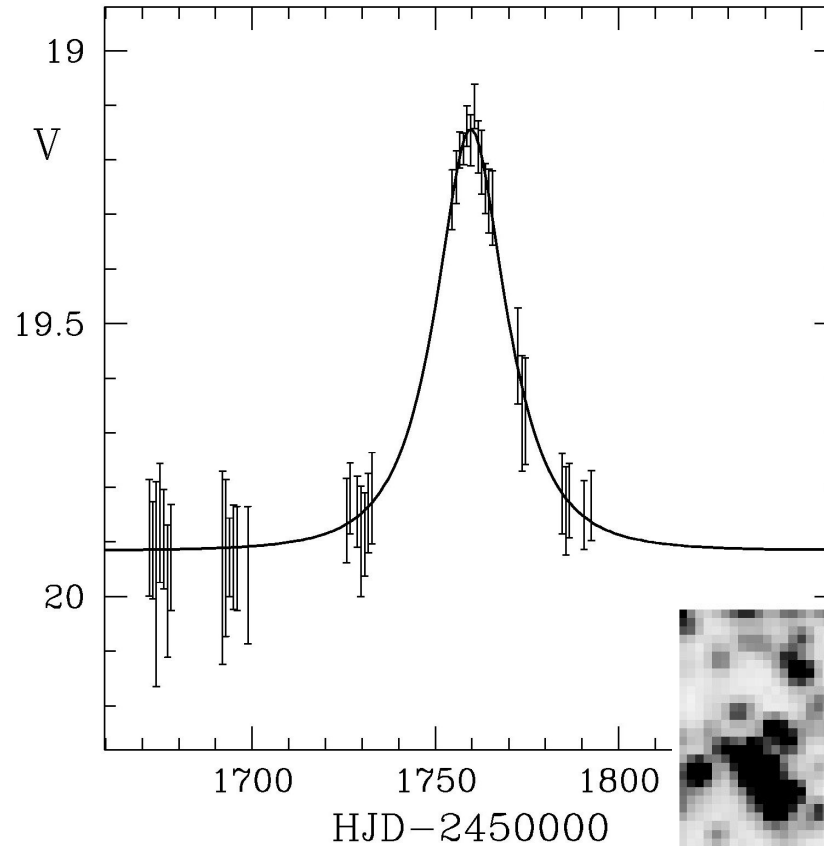
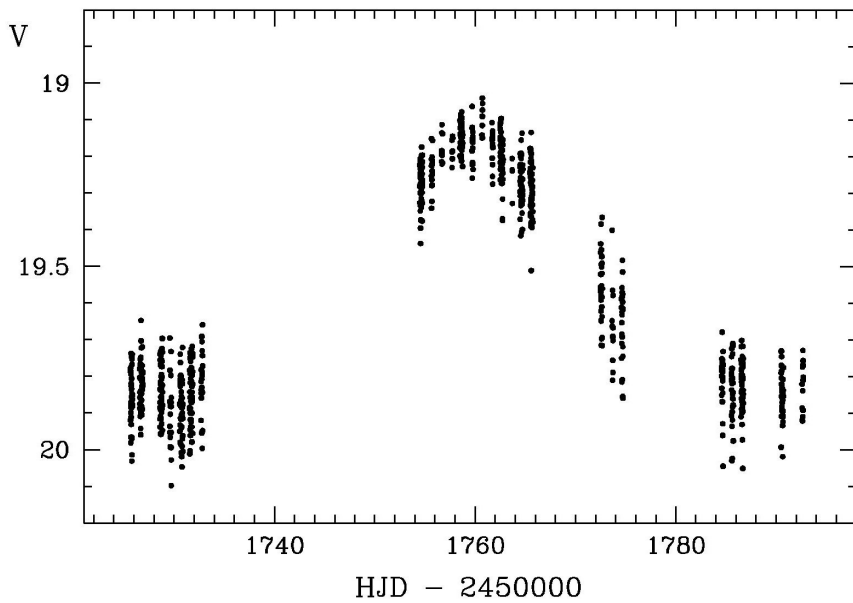
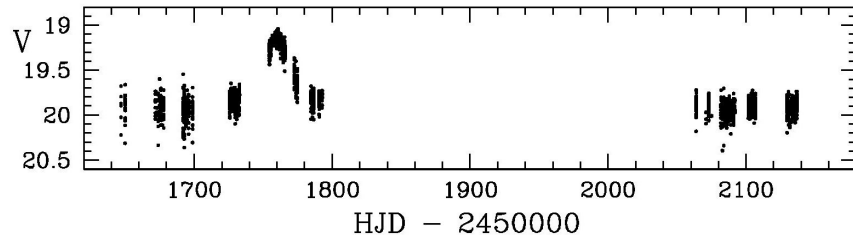


Bohdan Paczyński (1940-2007)



Paczyński (1994, Acta Astronomica, 44, 235)

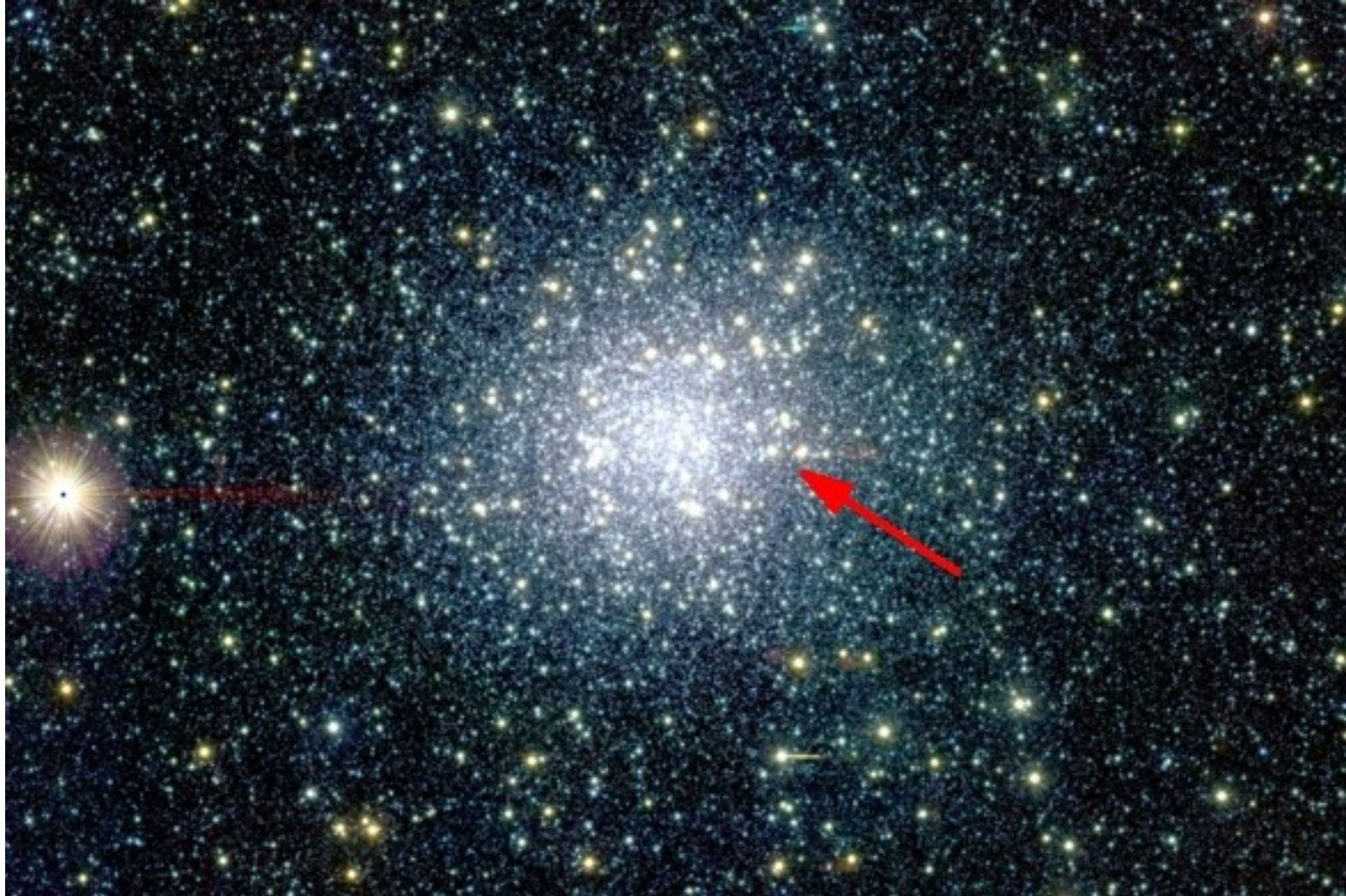
# An episode in M22 in 2000



Probable lens:

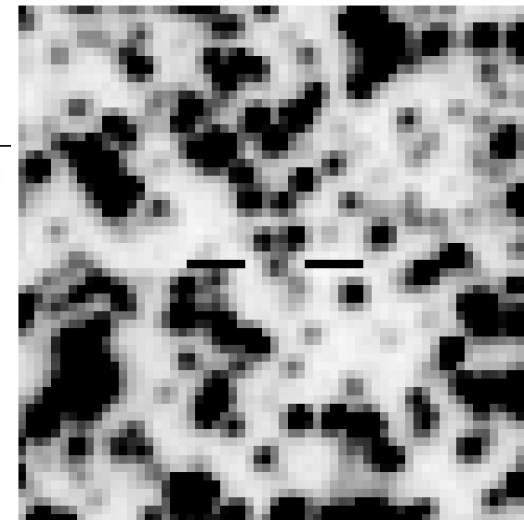
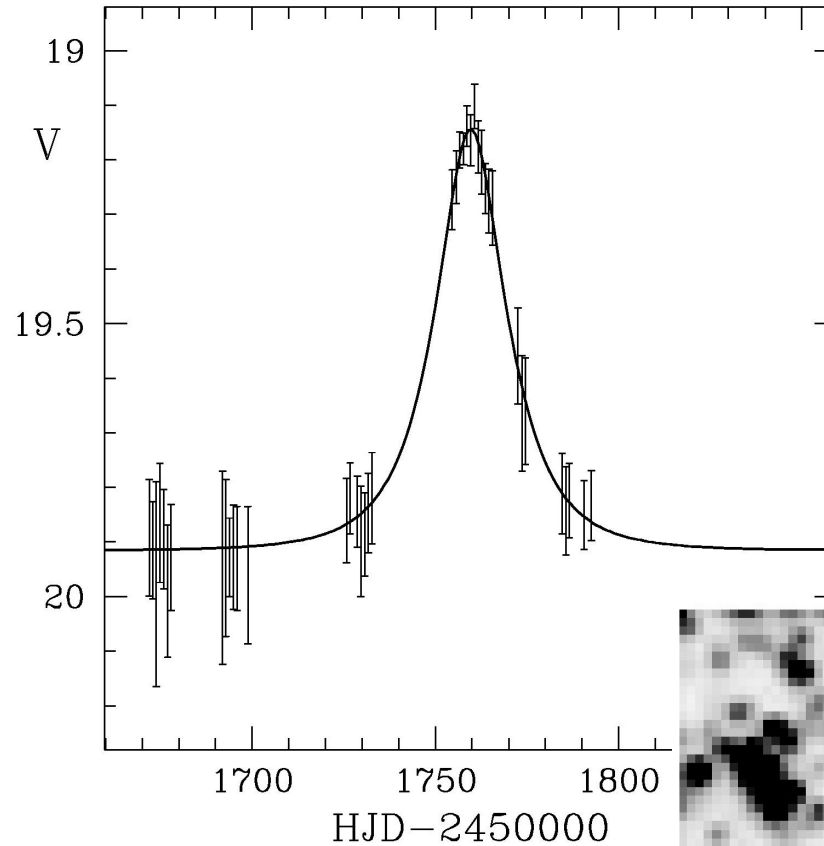
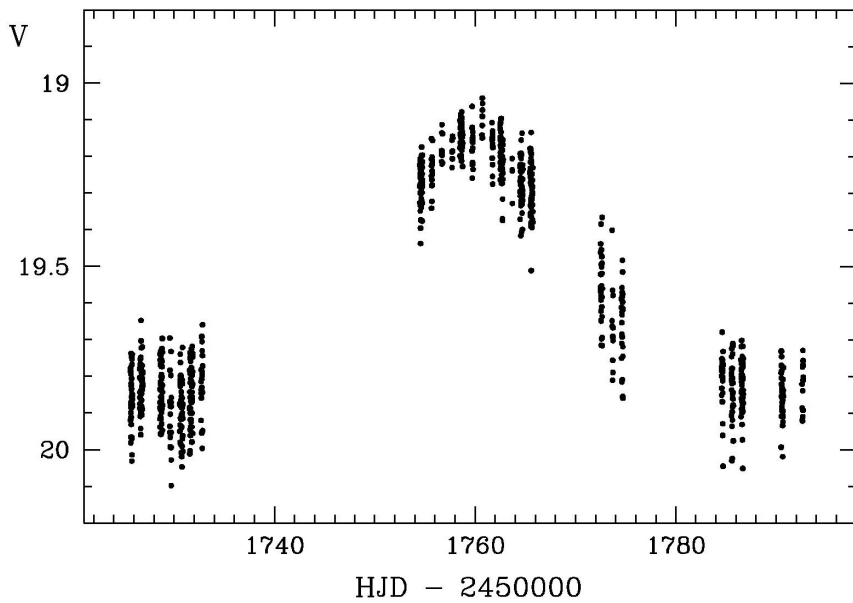
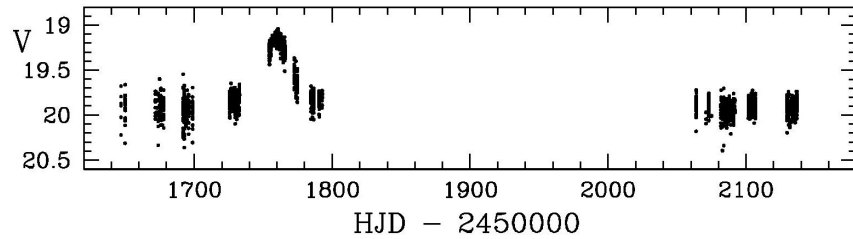
M5 dwarf,  $M = 0.14 \pm 0.10 / -0.02 M_{\text{sun}}$

# Episode in M22 in 2000



*JHK*s combined image from VISTA Variables in the Via Lactea (VVV) survey

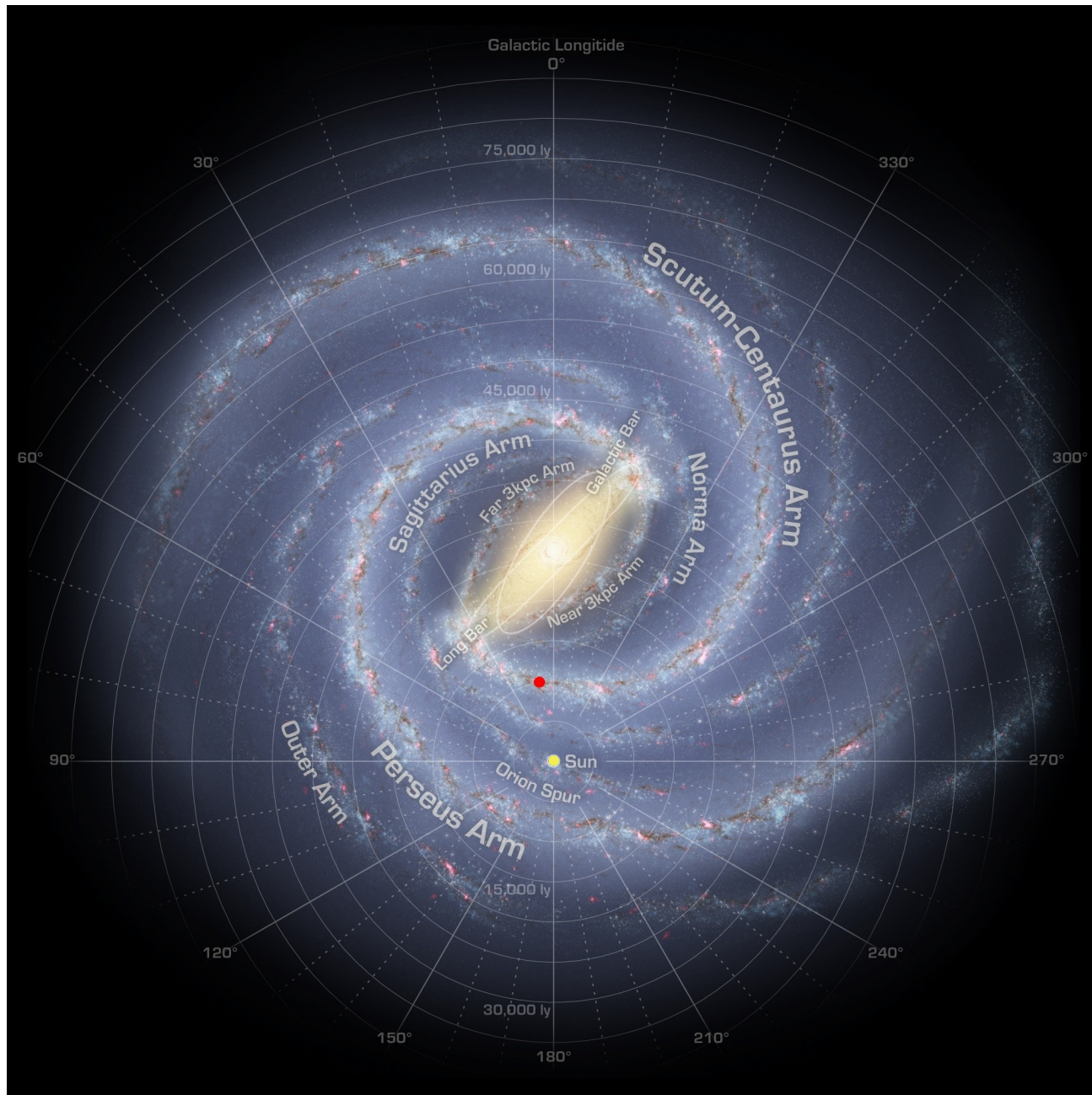
# An episode in M22 in 2000



Probable lens:

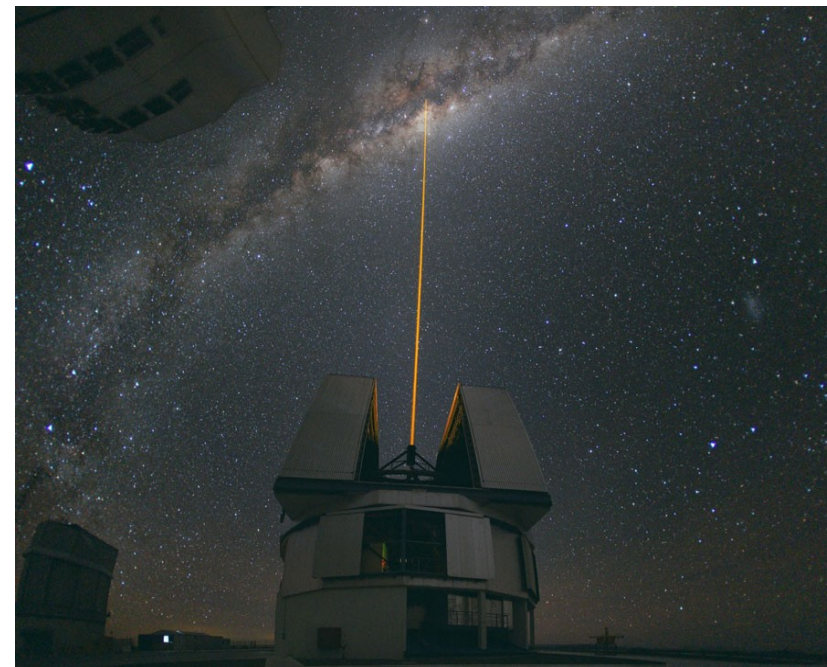
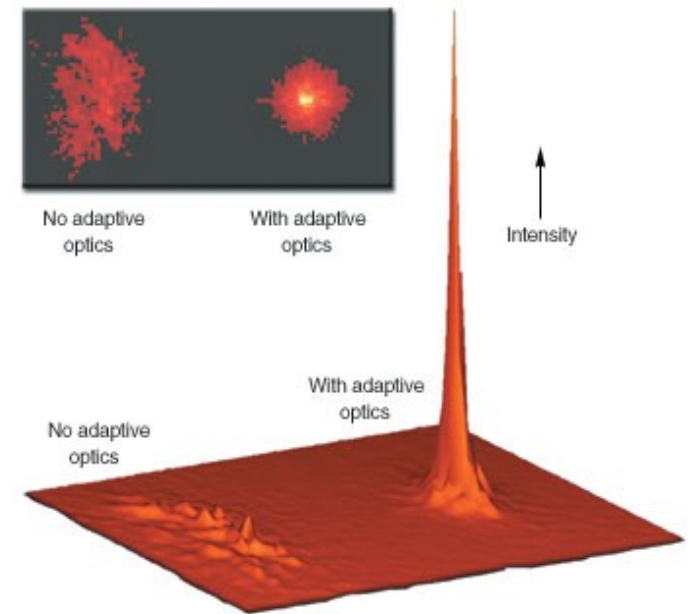
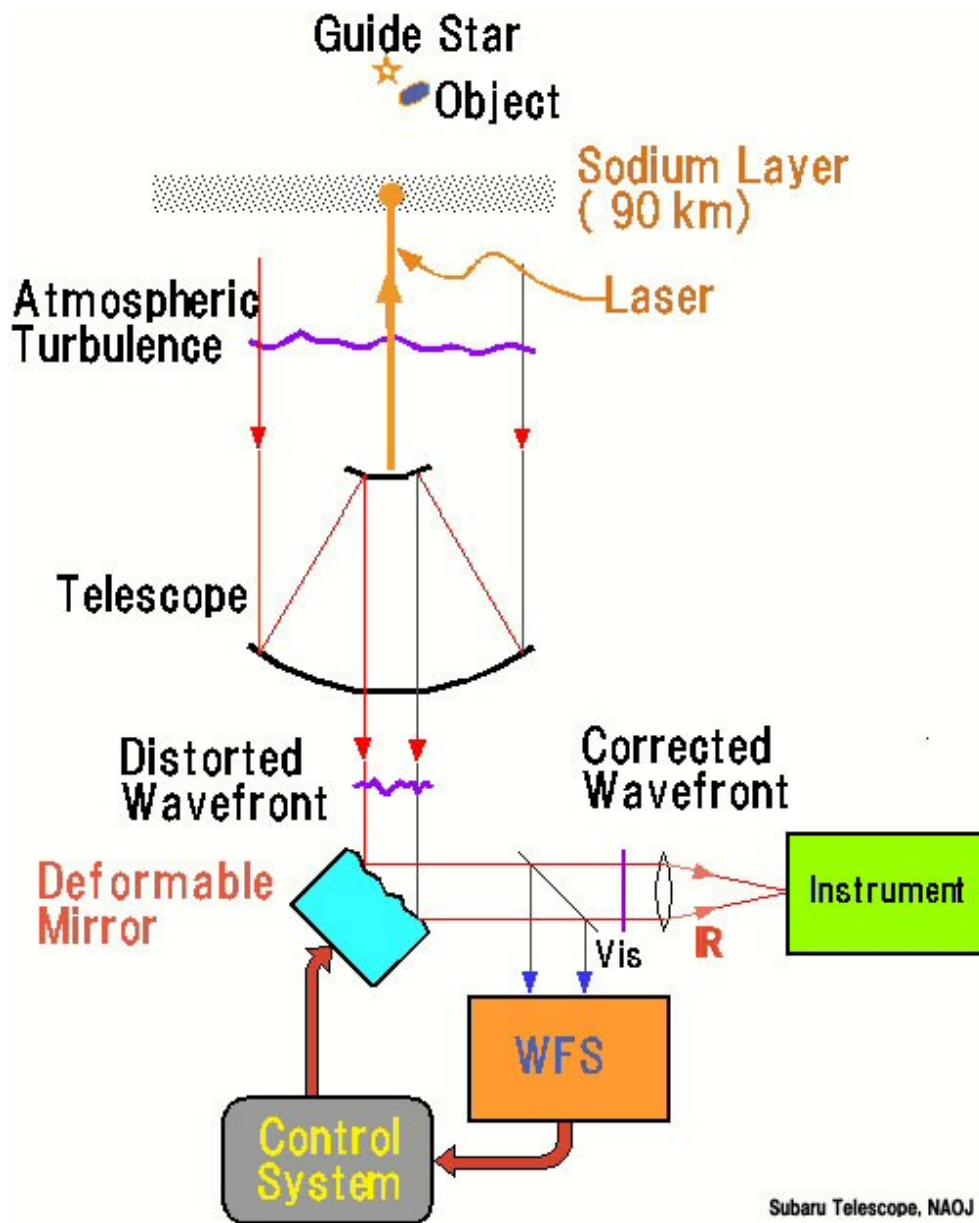
M5 dwarf,  $M = 0.14 \pm 0.10 / -0.02 M_{\text{sun}}$

# Episode in M22 in 2000



map from Churchwell et al. (2009)

# Adaptive optics



# VLT/NACO observations



Location: Cerro Paranal, Chile

Telescope: 8.2m UT4

Instrument: NAOS-CONICA

Mode: service

Date: 2011 July 17

Filter:  $K_s$



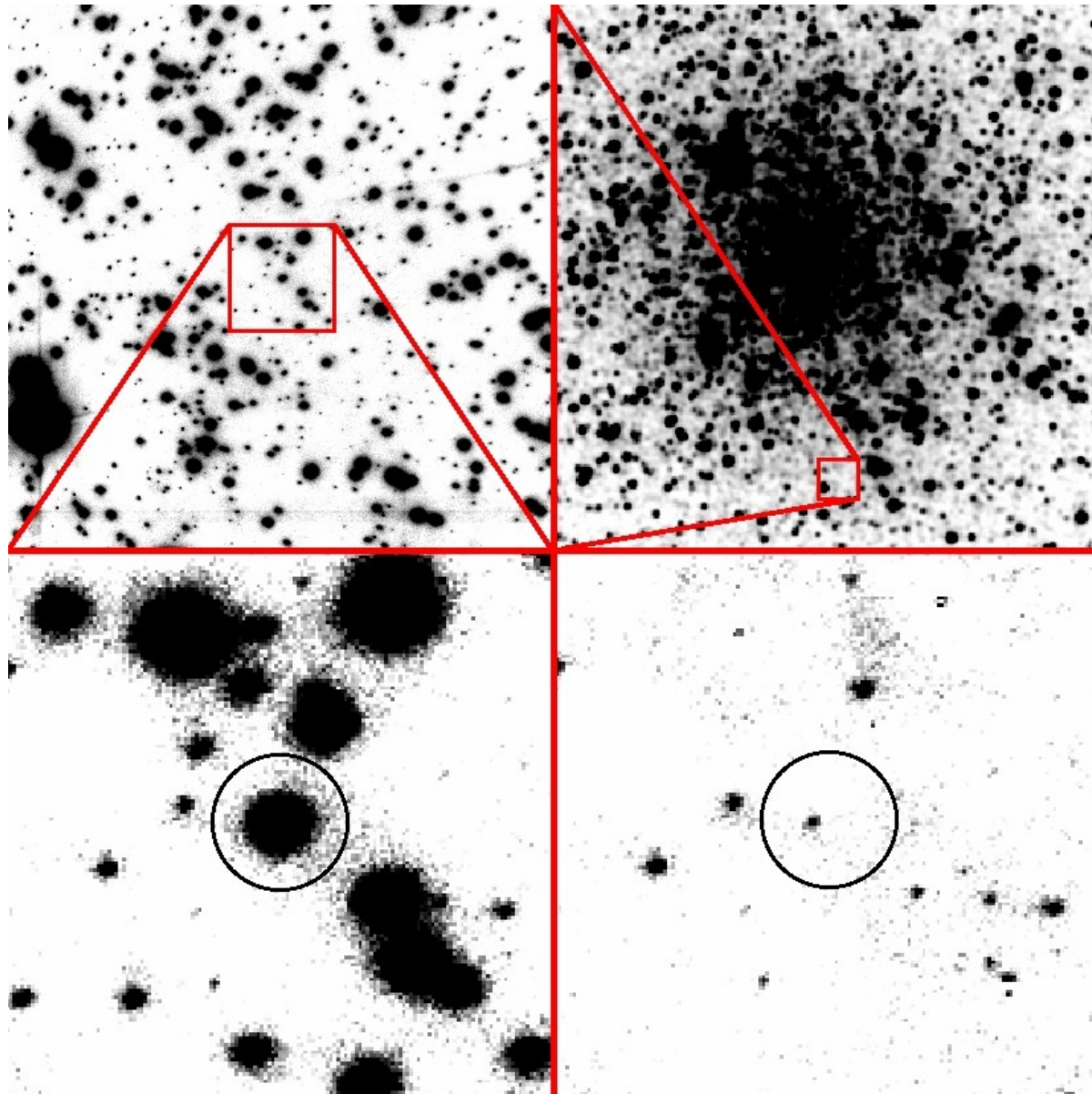
V~14 mag star as the natural guide source

20 x 110 s exposures

FWHM = 0.11 arcsec



# 11 years after the event

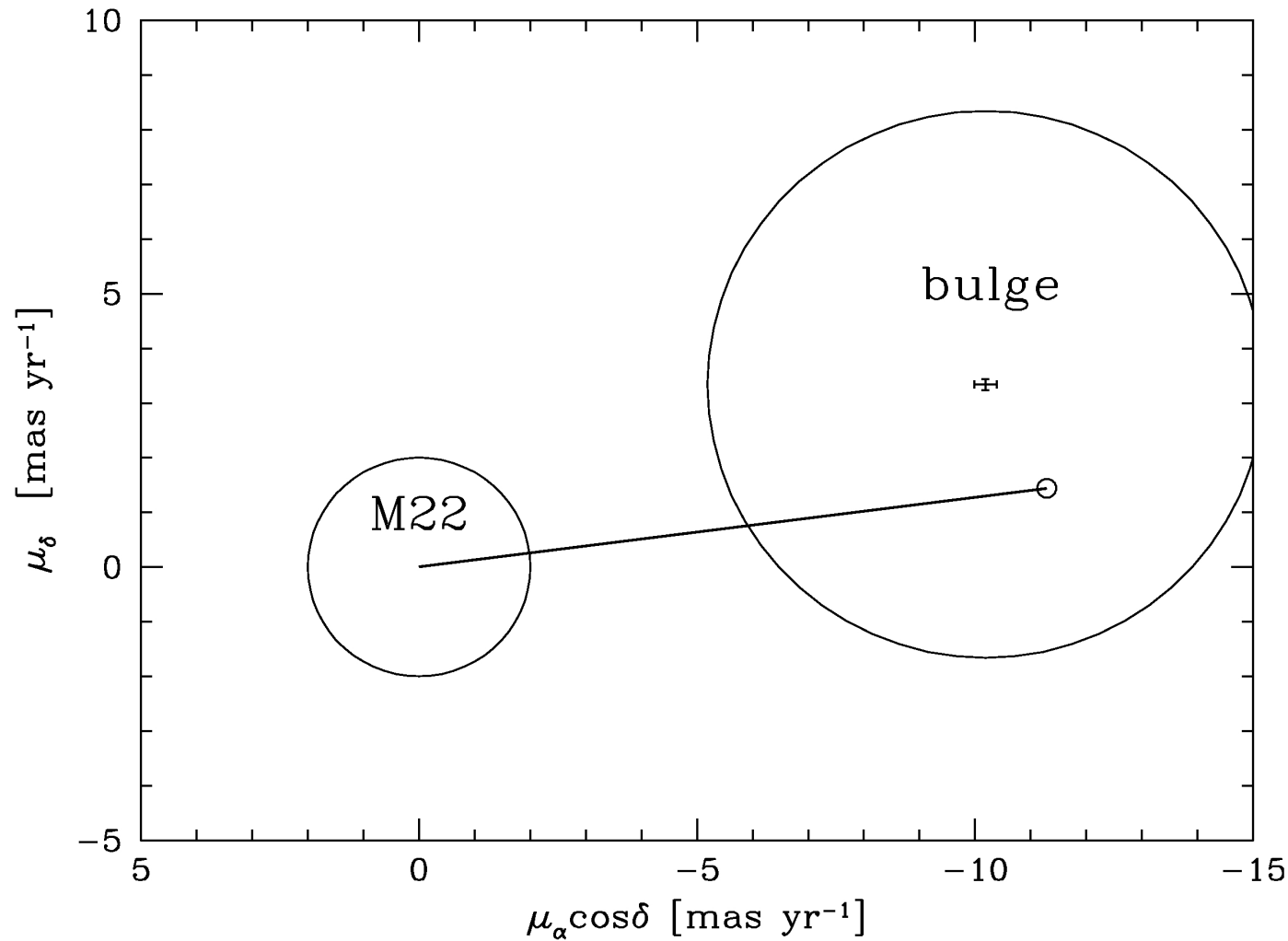


Source-lens  
separation:  
0.125"

Seeing:  
0.7-1.0"

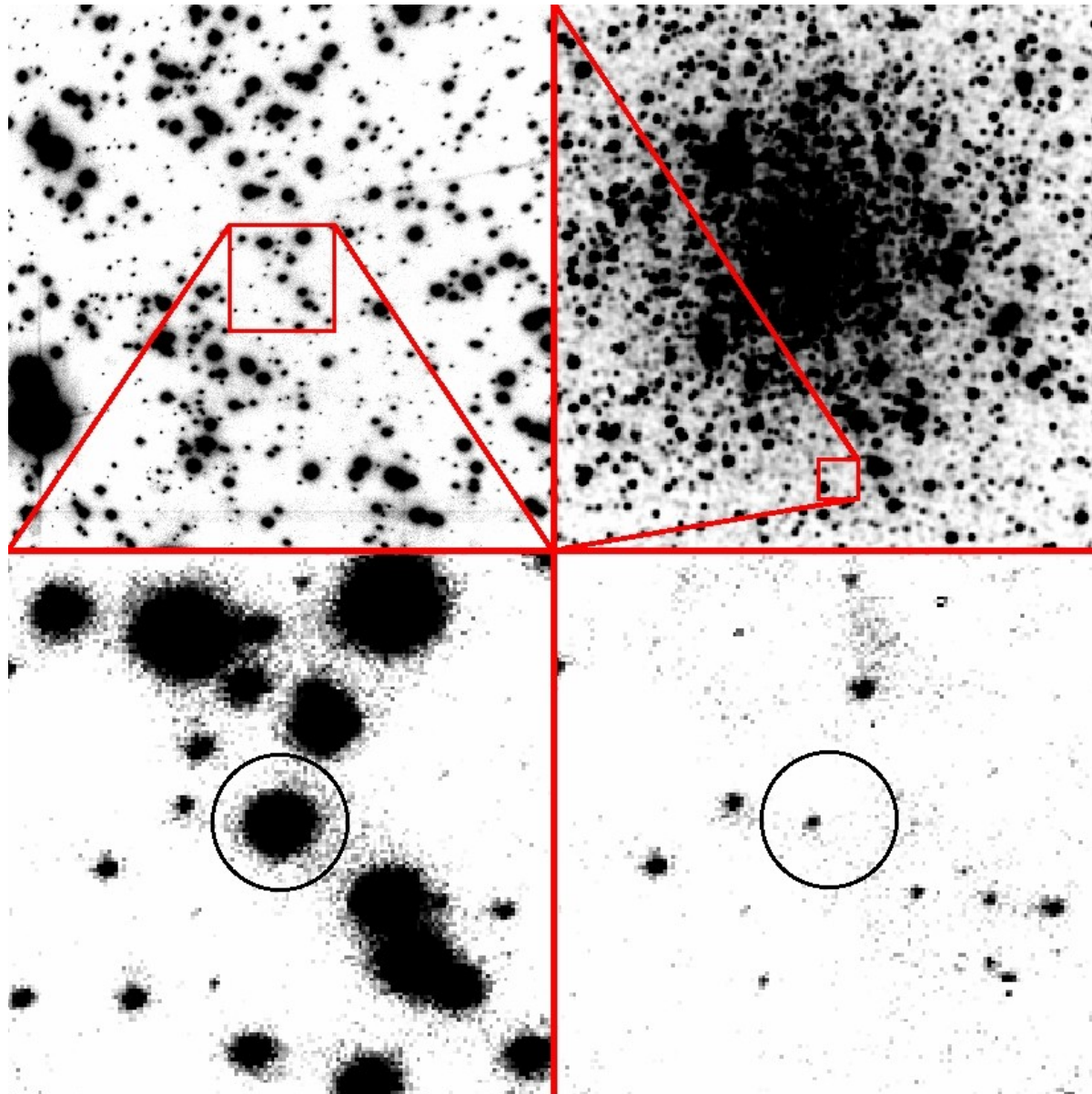
FWHM:  
0.11"

# Confirmation of the event: relative proper motion



M22-bulge relative pm  
from Chen et al. (2004)

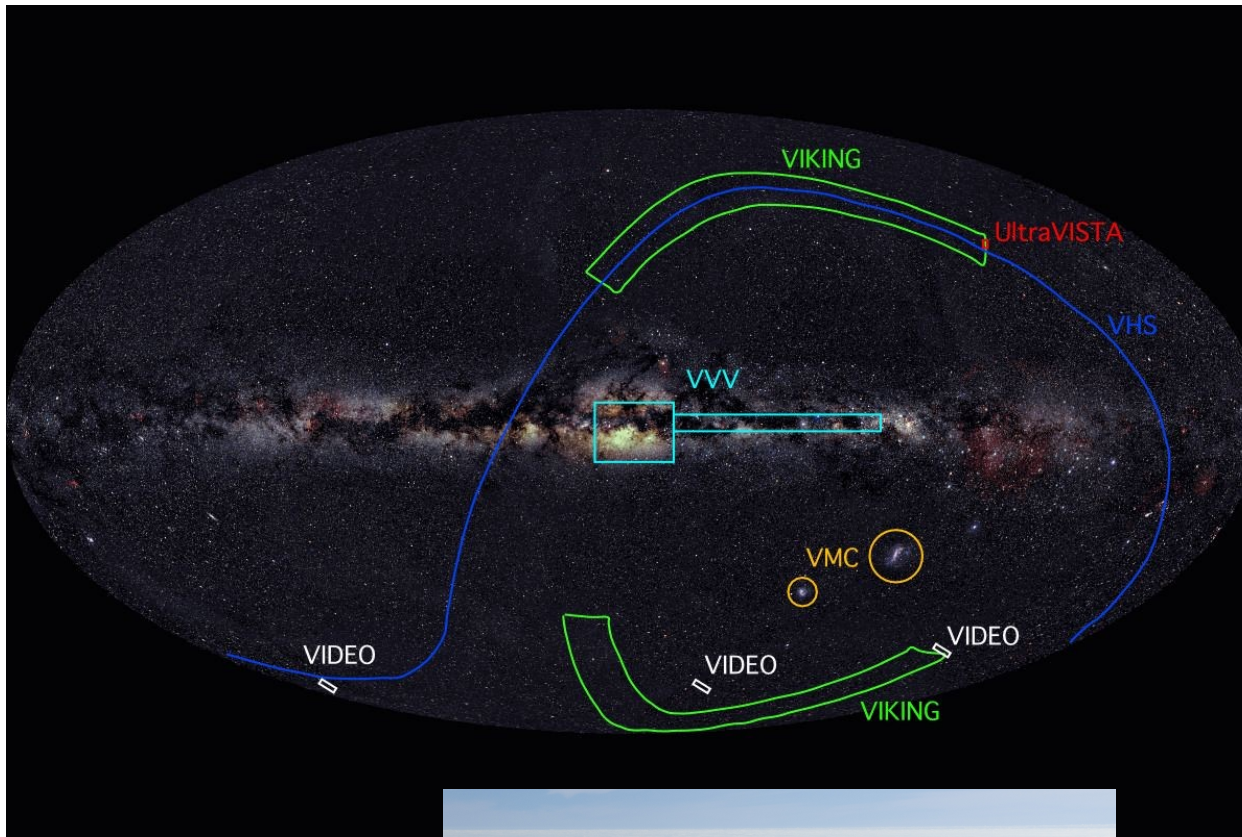
# 11 years after the event



Source:  
 $K_s = 17.37$  mag

Lens:  
 $K_s = 20.57$  mag

# VISTA Variables in the Via Lactea (VVV)



One of 6 ESO Public Surveys  
in 2010-2014

4.1m VISTA telescope at Paranal,  
Chile

16-chip camera

1.5 sq. deg field of view

Scale of 0.37 arcsec/pix

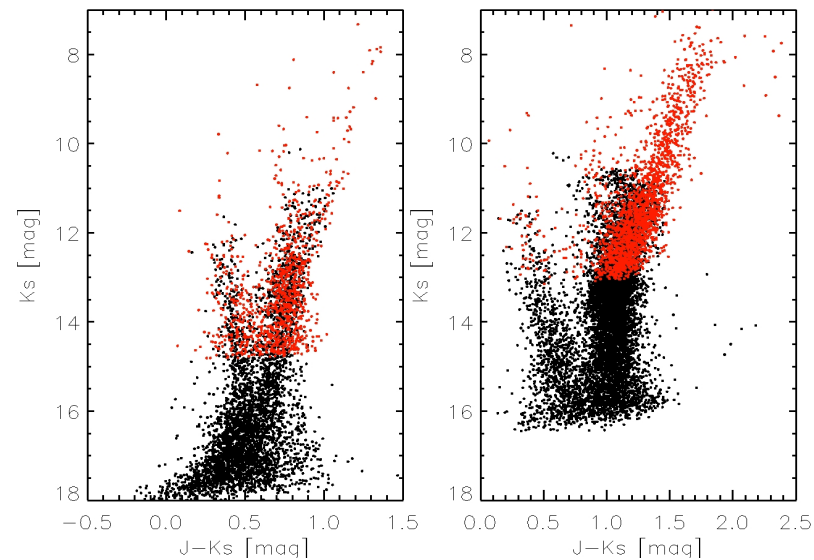
*ZYJHK<sub>s</sub>* filters

PI: Dante Minniti (Chile)

Co-PI: Phil Lucas (UK)

<http://vvvsurvey.org>

# VISTA Variables in the Via Lactea (VVV)



Scientific goals:

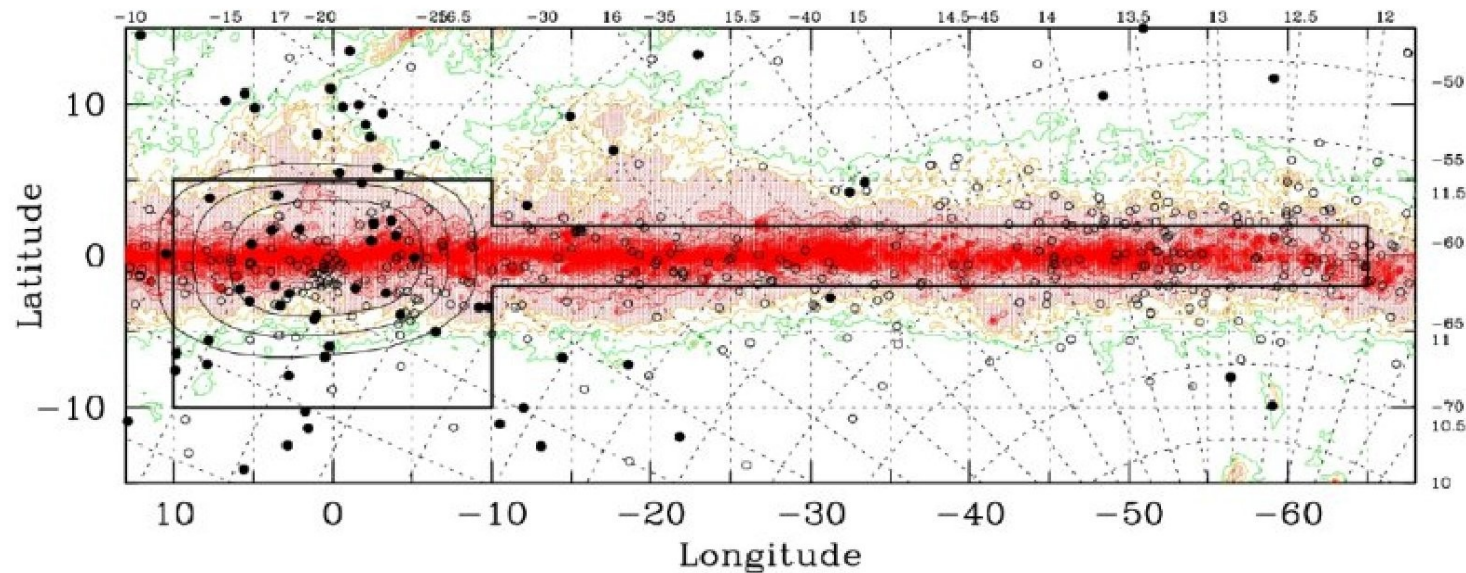
Near-IR atlas ( $3 \times 10^8$  point sources, published!)

Construction of 3-D maps (based on RR Lyr stars)

Searching for new clusters (recently 3 new GCs, 96 OCs)

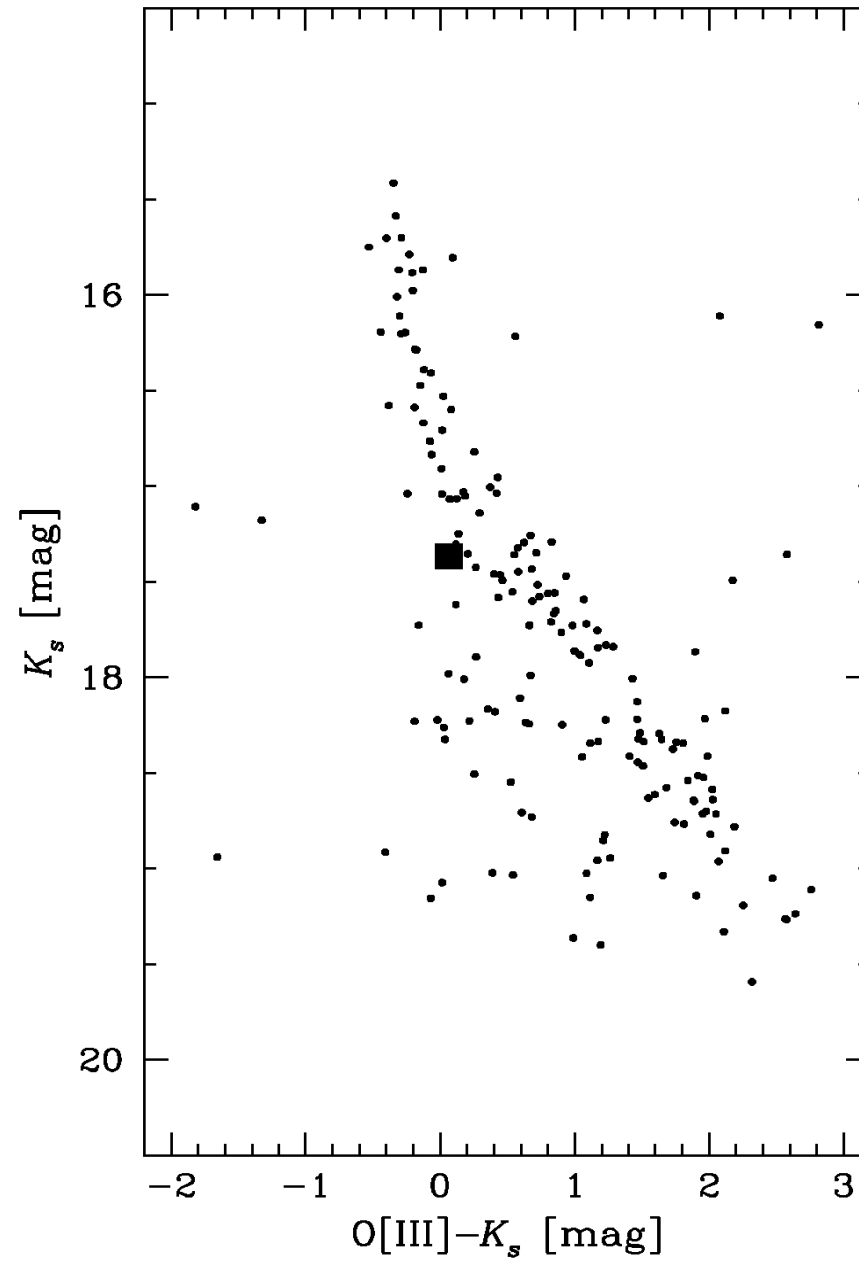
Looking for highly reddened variables, lensing events, etc.

Proper motion studies

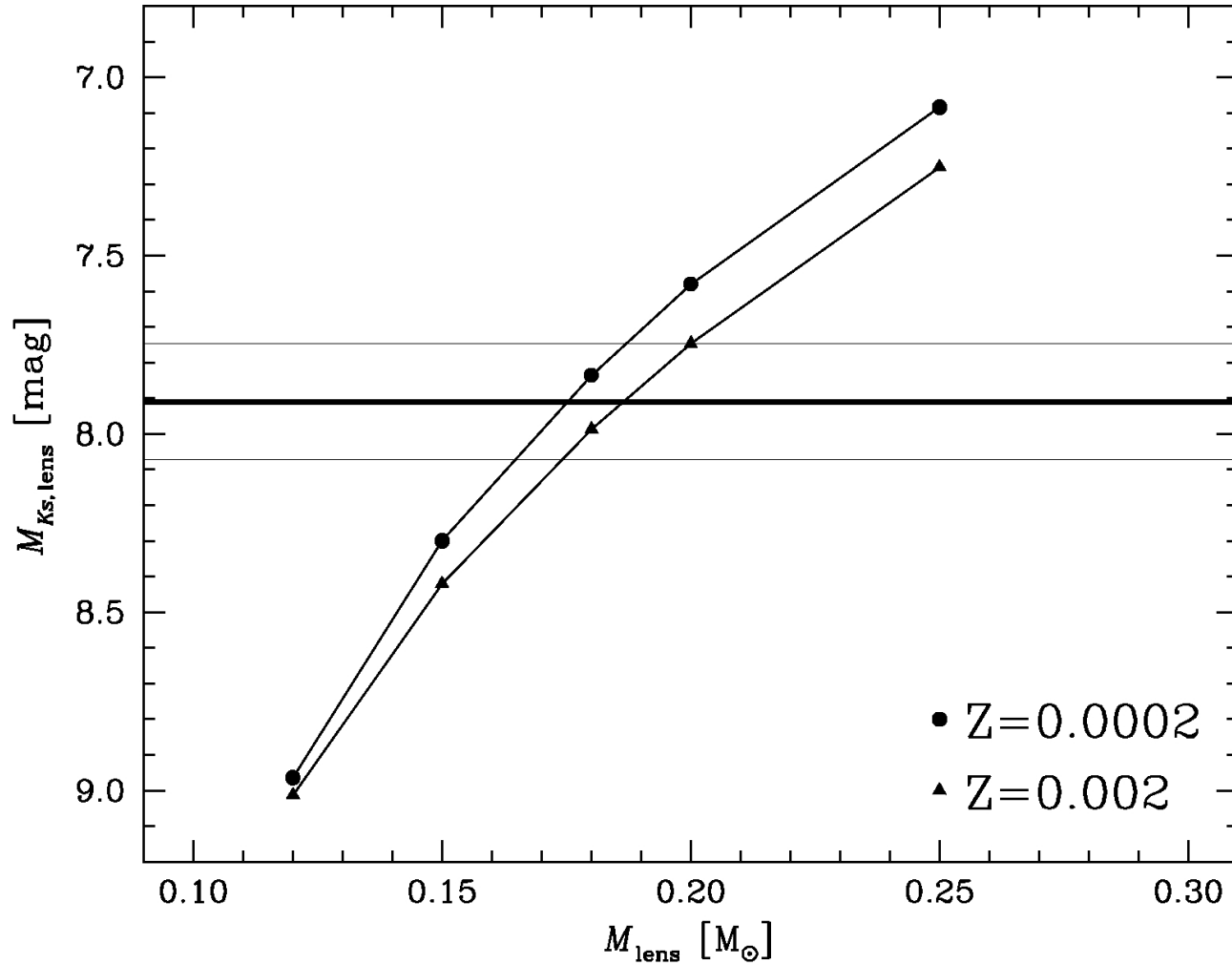


Minniti et al. (2010)

# Confirmation of the event: CMD



# Geometry of the event



models from Brocato et al. (1998)

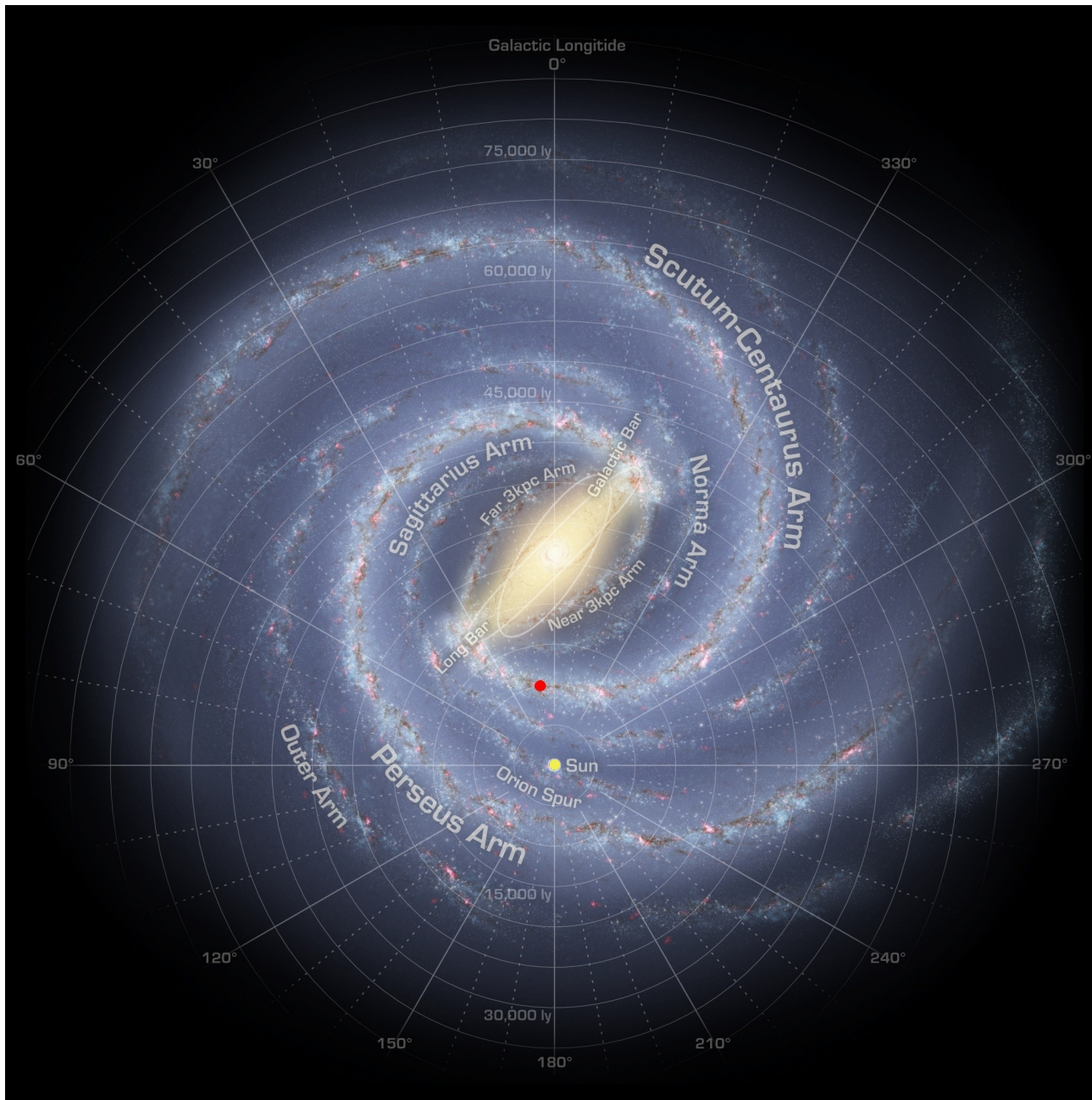
Lens:

$$d = 3.2 \pm 0.2 \text{ kpc}$$
$$M = 0.18 \pm 0.01 \text{ Msun}$$

Source:

$$d = 6.0 \pm 1.5 \text{ kpc}$$
$$M \sim 1 \text{ Msun}$$

# Geometry of the event



Lens:

$$d = 3.2 \pm 0.2 \text{ kpc}$$

$$M = 0.18 \pm 0.01 \text{ Msun}$$

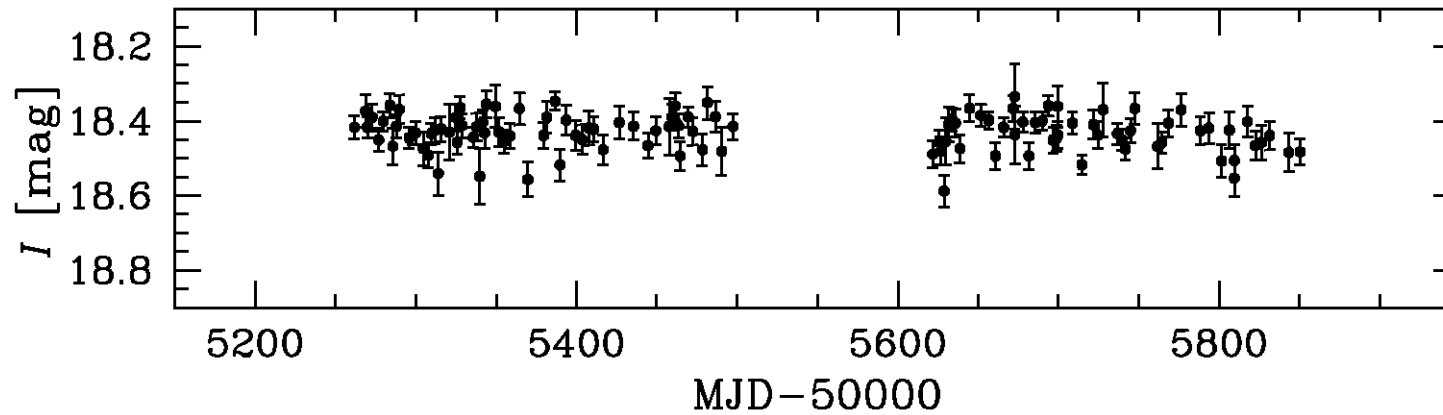
Source:

$$d = 6.0 \pm 1.5 \text{ kpc}$$

$$M \sim 1 \text{ Msun}$$



# Confirmation of the event: OGLE-IV light curve



# OGLE-IV – instrumentation



In operation since March 2010

1.3m Warsaw telescope at LCO, Chile

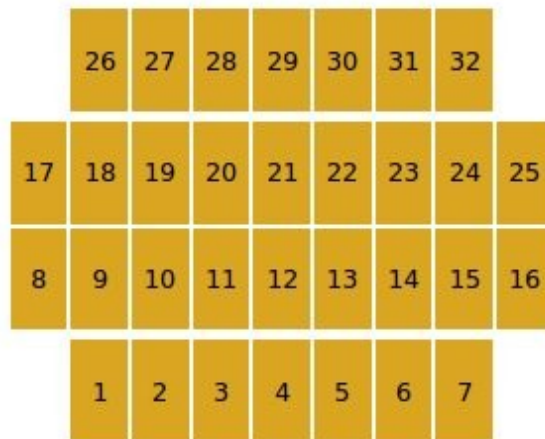
32-chip mosaic camera

1.4 deg<sup>2</sup> field of view

Scale of 0.26 arcsec/pix

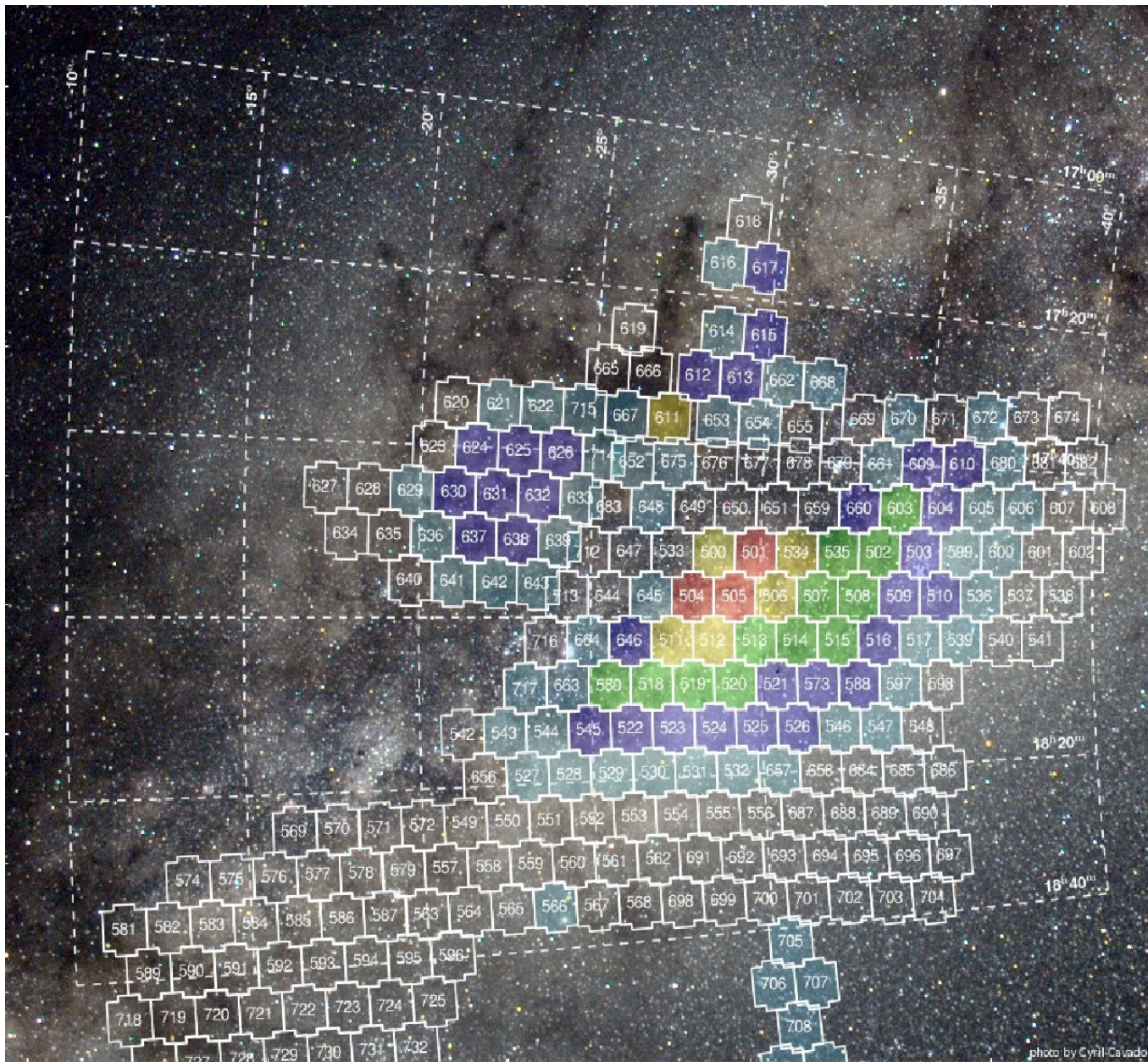
*VI* filters

Read-out time: 20 sec



<http://ogle.astrouw.edu.pl>

# OGLE-IV – bulge coverage



Cadence (visits per night):

Red:	10-30
Yellow:	3-10
Green:	1-3
Blue:	0.5-1
Cyan:	< 0.5
Transparent:	occasionally

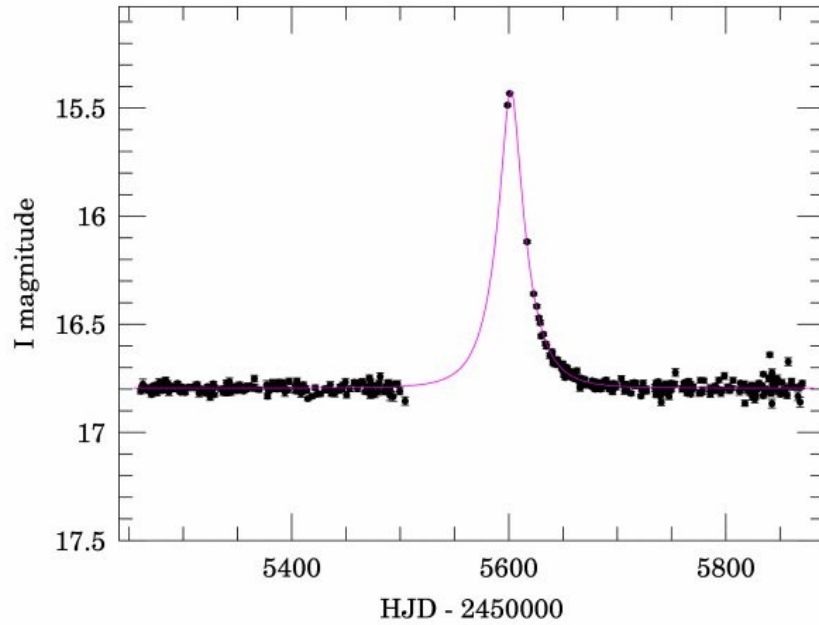
In 2011 bulge season:

1562 microlensing candidates  
63 events with  $t_E < 2$  days

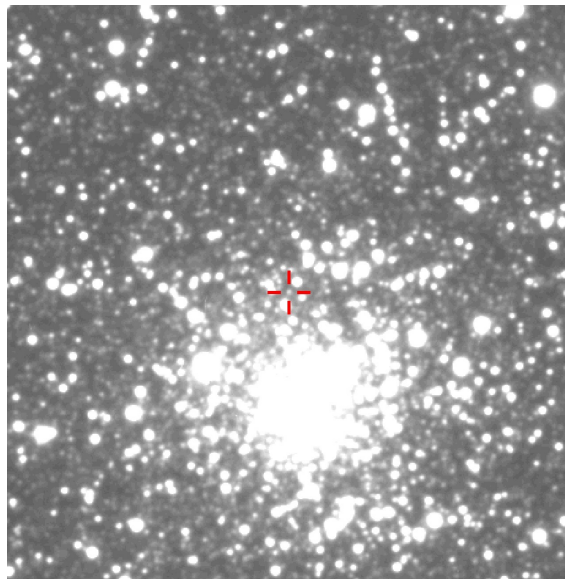
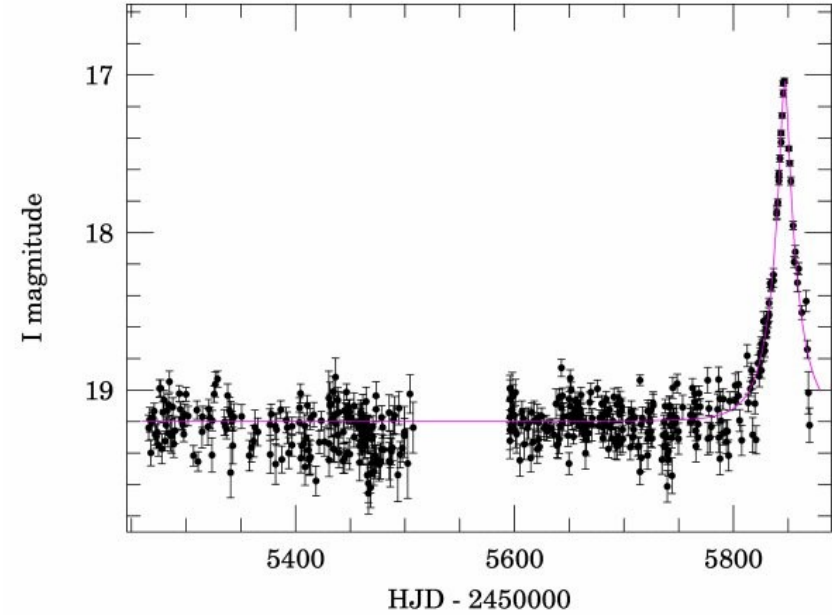
OGLE-IV covers 43 bulge GCs

# OGLE-IV – likely events in GCs

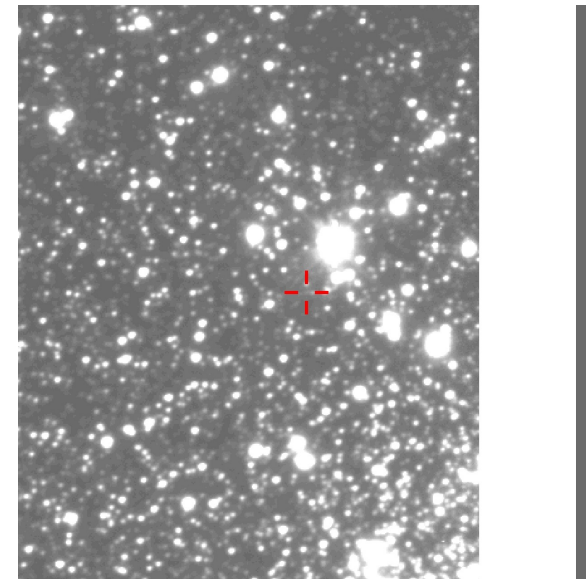
OGLE-2011-BLG-0123



OGLE-2011-BLG-1461



NGC 6522



NGC 6544



Thank you for your attention!

# Microlensing events in the fields of GCs

Survey	Years	Total number of events	Events at $r < r_t$	Events at $r < \sim r_h$
MACHO	1992-1999	564	34	0
EROS-2	1996-2002	120	2	0
MOA	2000-2010	2818	98	1
OGLE-I	1992-1995	20	13	0
OGLE-II	1998-2000	164	0	0
OGLE-III	2001-2009	4057	114	1
OGLE-IV	2011	1562	40	2

None of the event detected so far was observed in the core of a cluster!

# Two GCs in Baade's Window

