



OGLE-IV TRANSIENT SEARCH

ŁUKASZ WYRZYKOWSKI (*pron: Woocash Vizhikovsky*)

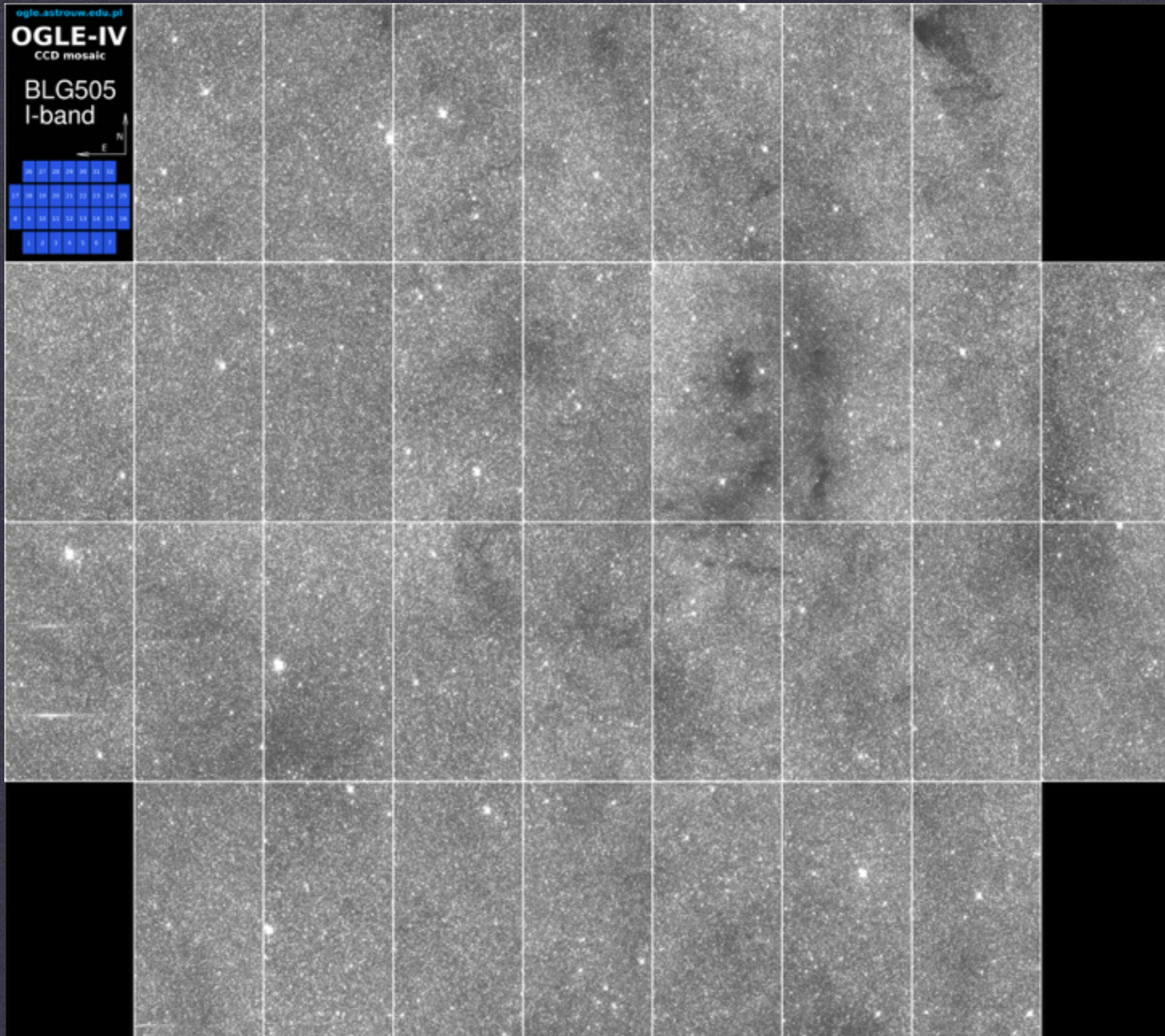
WARSAW UNIVERSITY OBSERVATORY

with:

*Zuzanna Kostrzewa-Rutkowska, Szymon Kozłowski,
Kris Rybicki, Jakub Klencki and OGLE Team in Warsaw*

SEES Workshop
Cambridge 22-25.Sep 2015

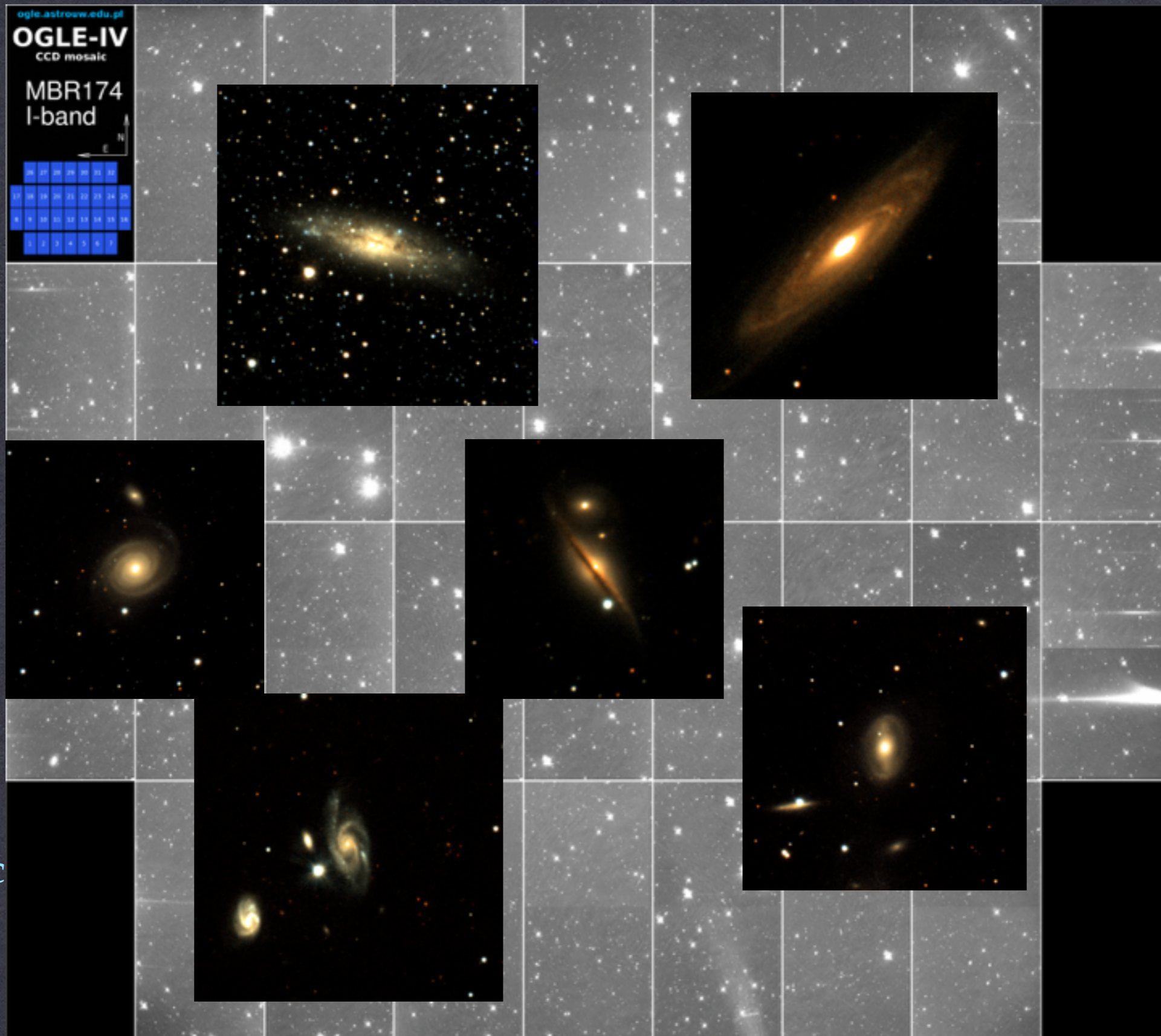
5 MILLION STARS EVERY 2 MINUTES



Bulge

fov=1.4
sq.deg.
down to
21 mag
in I-band

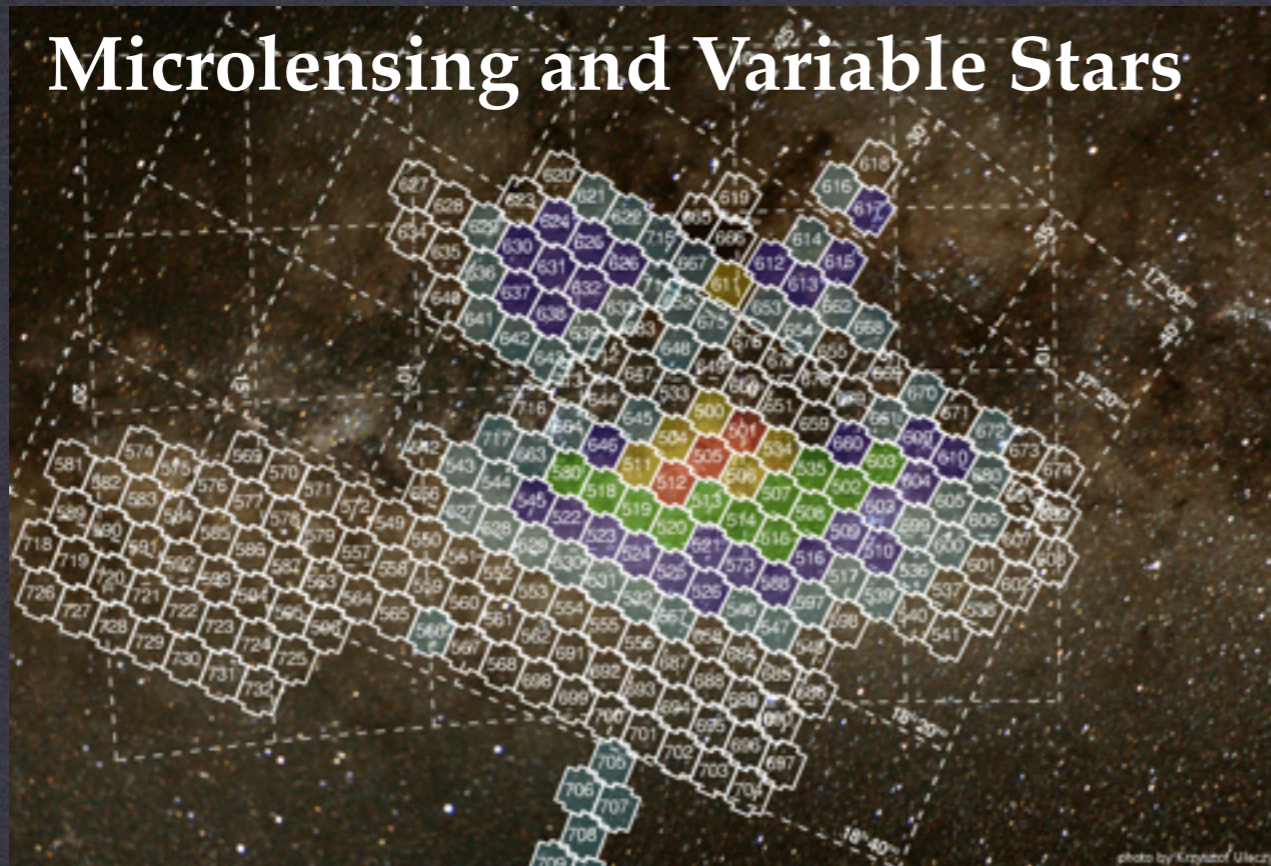
1 THOUSAND GALAXIES EVERY 3 MINUTES



Magellanic
Bridge

OGLE SKY

Microlensing and Variable Stars



Bulge
half-billion stars
down to 20.5mag

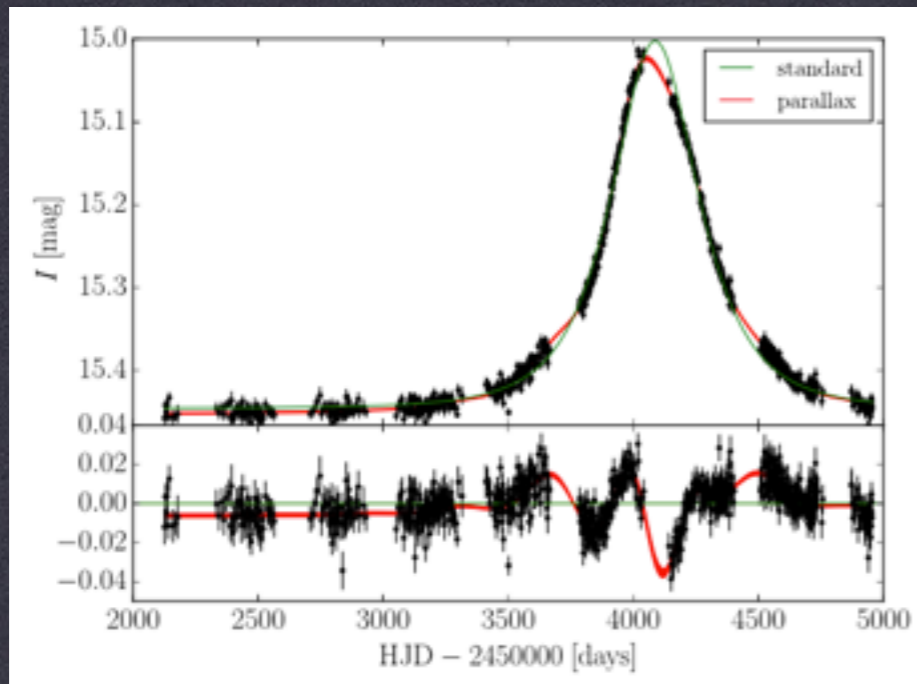
Cadence:

- red – ~30 epochs/night
- yellow – ~10 epochs/night
- green – ~3 epochs/night
- blue – ~1 epoch/night
- cyan – ~1 epoch /2 nights

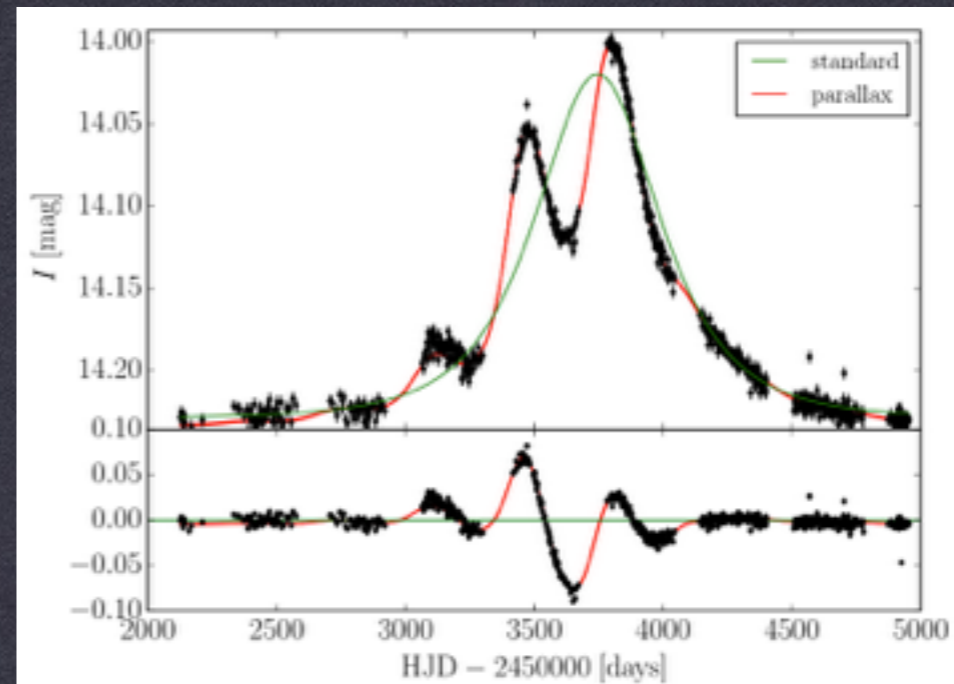
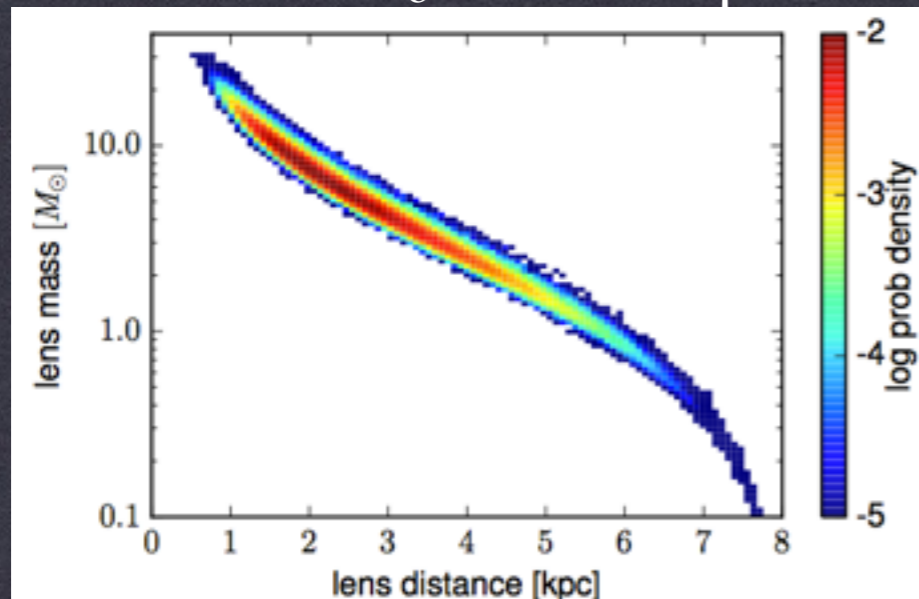
some parts
observed
continuously
since 1992!

MICROLENSING BY BLACK HOLES

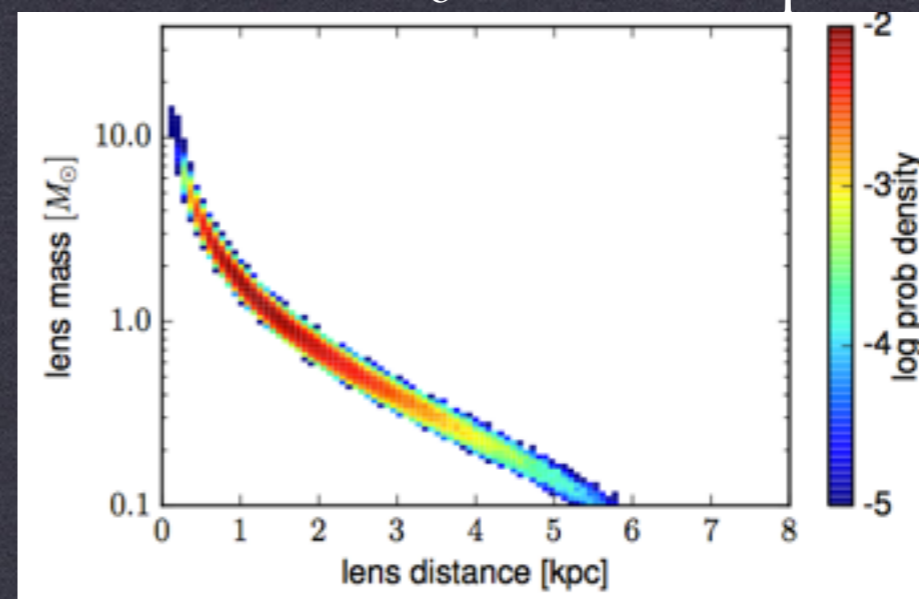
long baseline observations help find long events with strong microlensing parallax
- possibility to constrain mass / distance for an isolated (non-binary) lens



99.9% BH candidate
 $M=6.9 M_{\odot}$ $D=1.9$ kpc



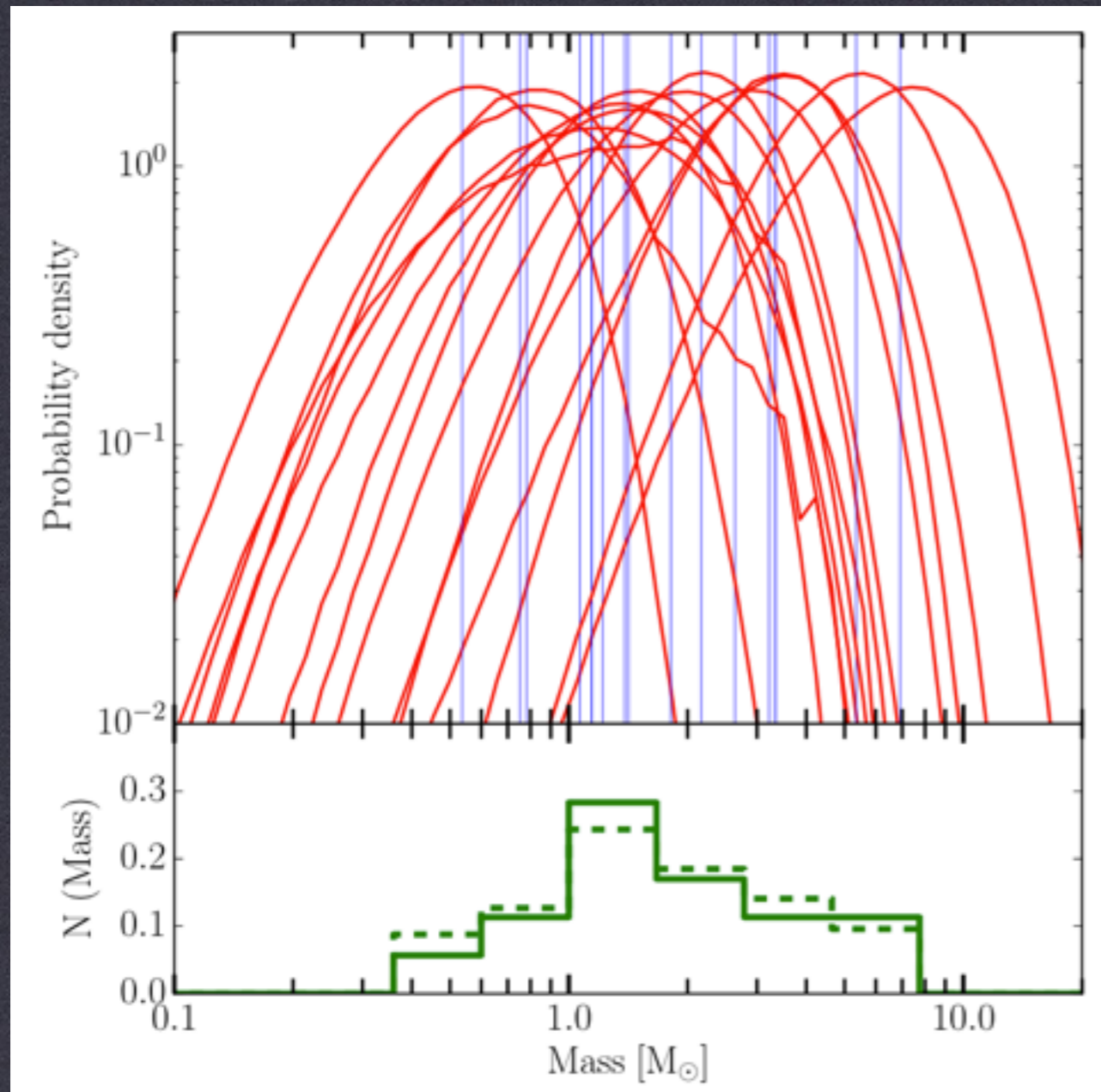
nearby WD/NS/MS candidate
 $M= \sim 1.3 M_{\odot}$ $D= \sim 0.6$ kpc



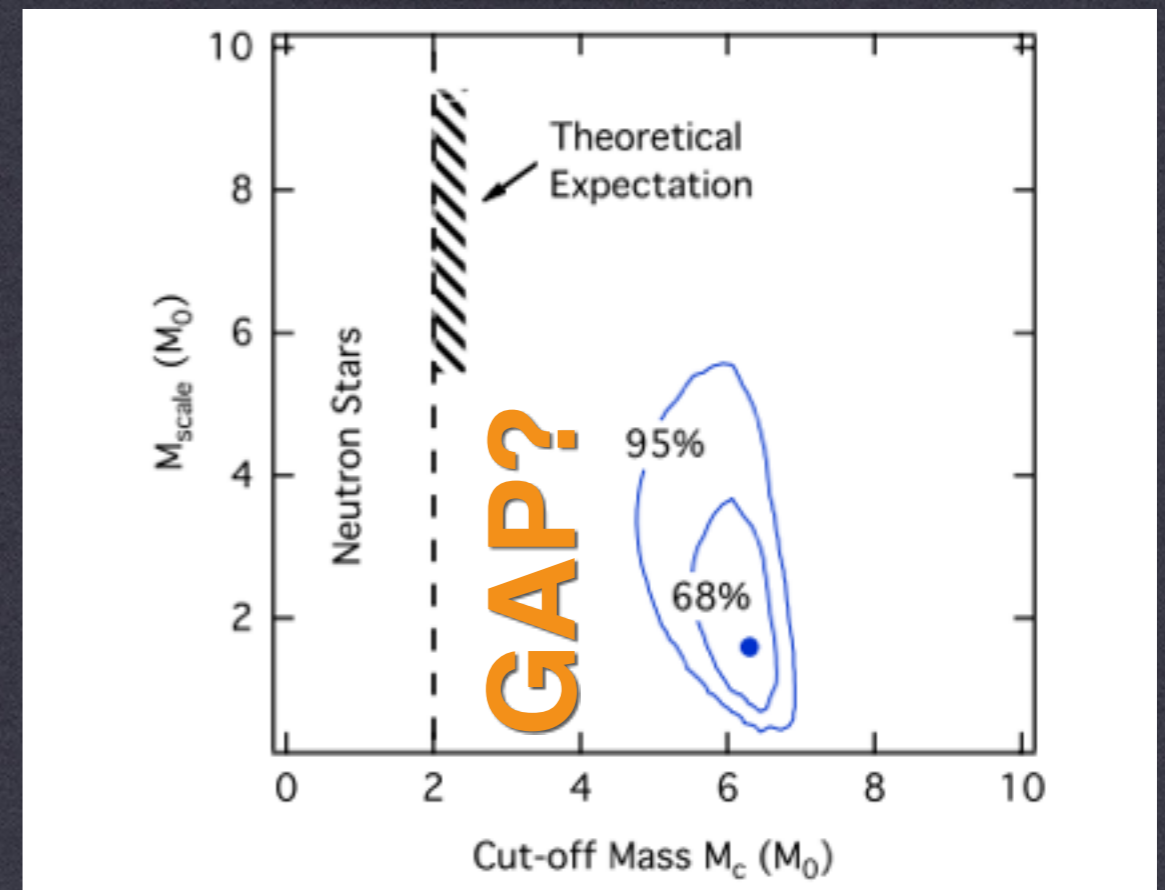
MICROLENSING BY BLACK HOLES

mass distribution for 15 dark lens candidates - no mass gap between NS and BH?

single

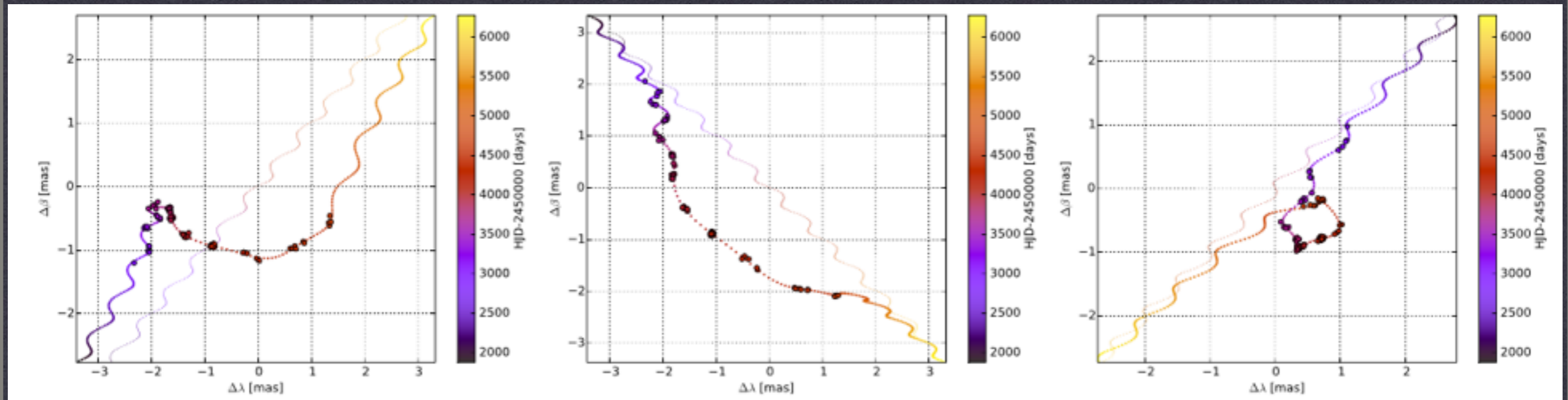


binary systems



MICROLENSING BY BLACK HOLES IN GAIA

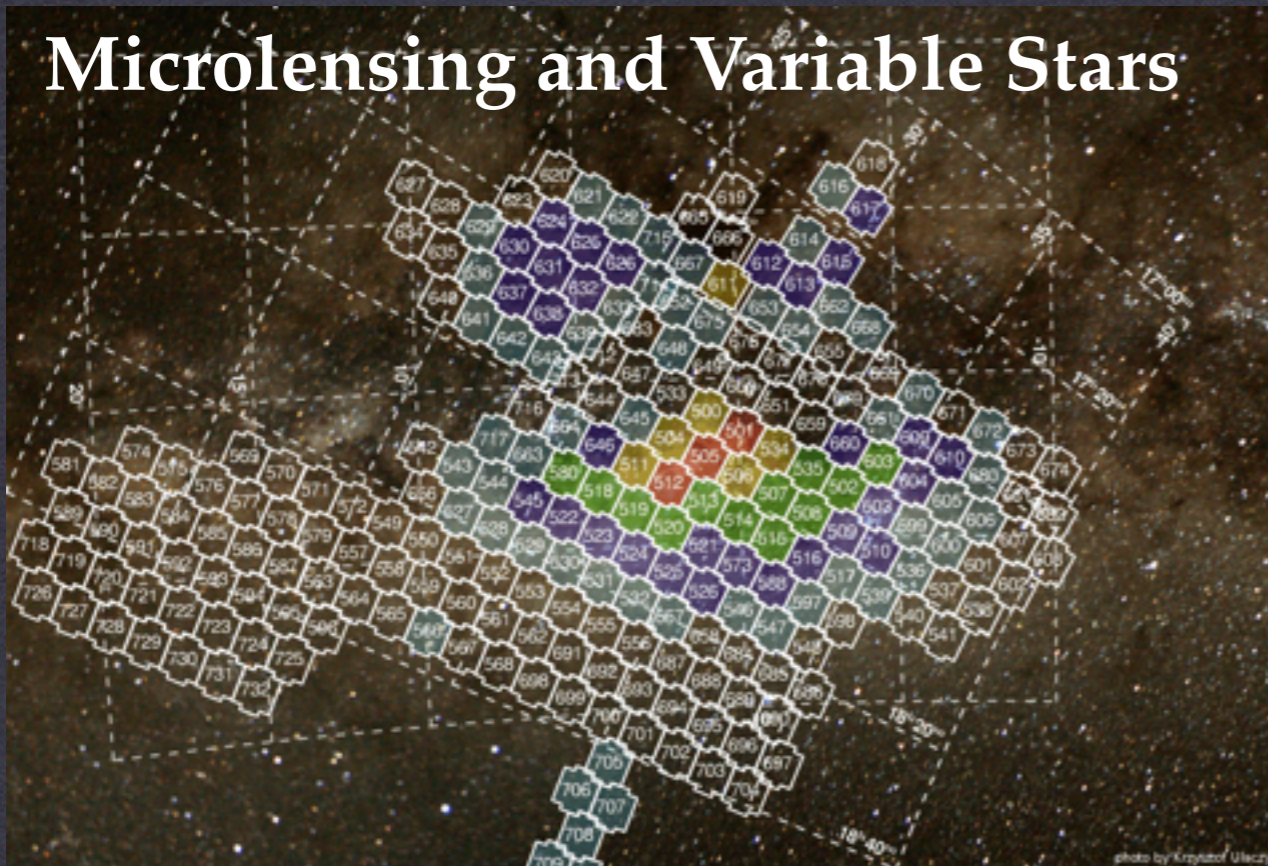
predictions for astrometric Gaia time-series for a BH microlens



Wyrzykowski+2015b
Rybicki in prep.

OGLE SKY 2010-2015A

Microlensing and Variable Stars



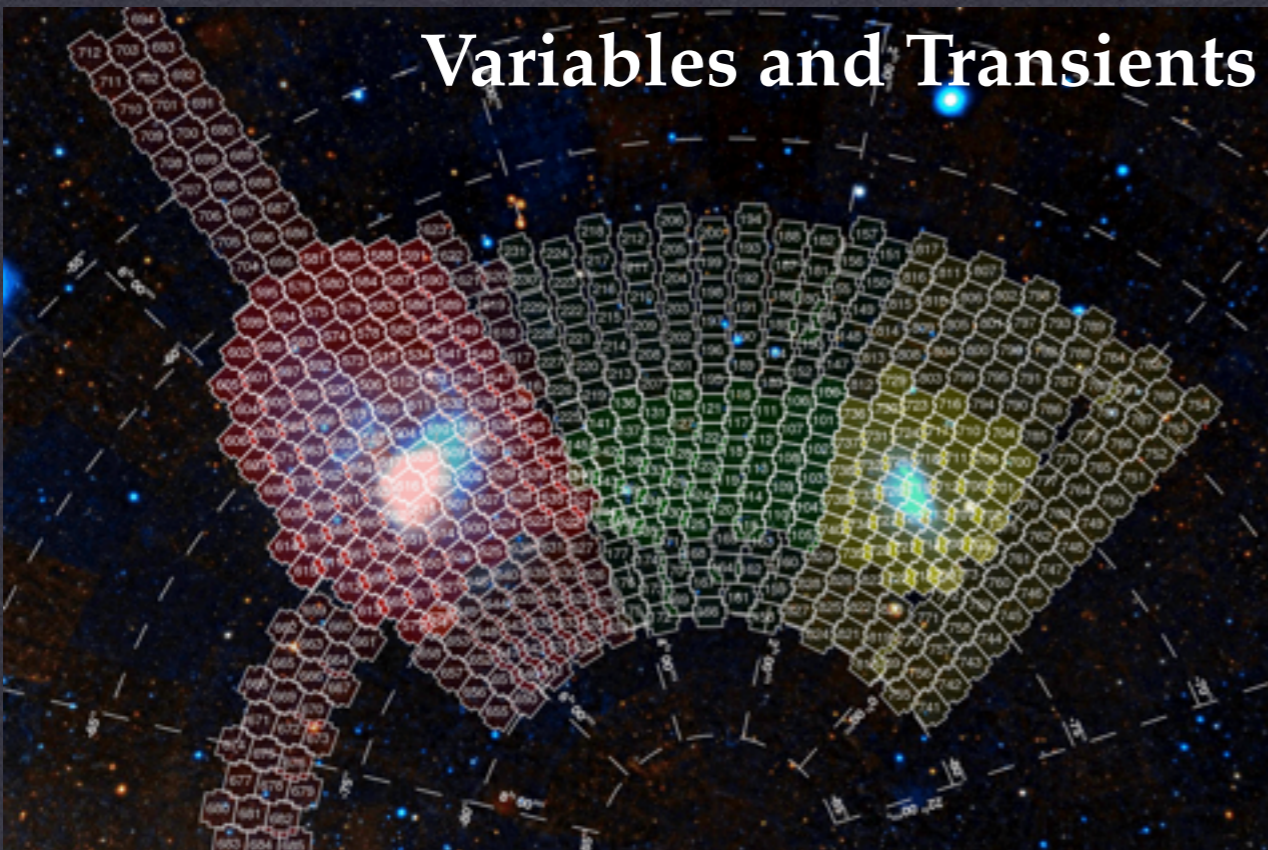
Bulge
half-billion stars
down to 20.5mag

Cadence:

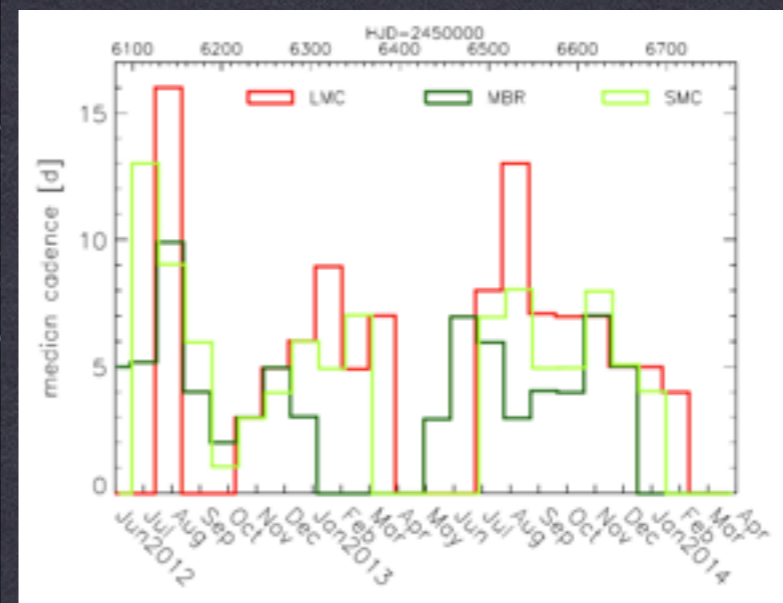
- red – ~30 epochs/night
- yellow – ~10 epochs/night
- green – ~3 epochs/night
- blue – ~1 epoch/night
- cyan – ~1 epoch /2 nights

some parts
observed
continuously
since **1992!**

Variables and Transients



Magellanic System (LMC+MBR+SMC)
700 sq.deg. limit: 22 mag in I-band

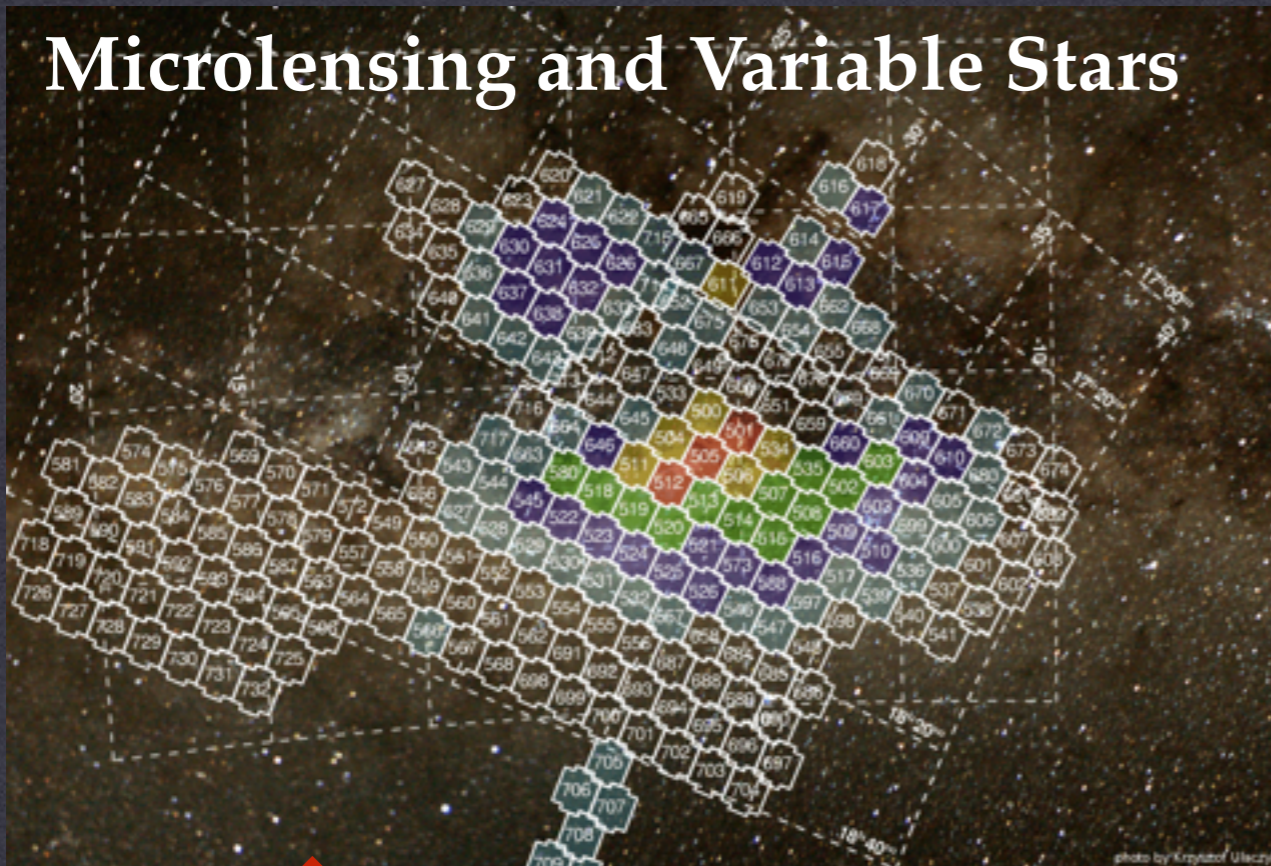


cadence:
2-5 nights

some parts
observed
continuously
since **1996!**

OGLE SKY FROM 2015B

Microlensing and Variable Stars

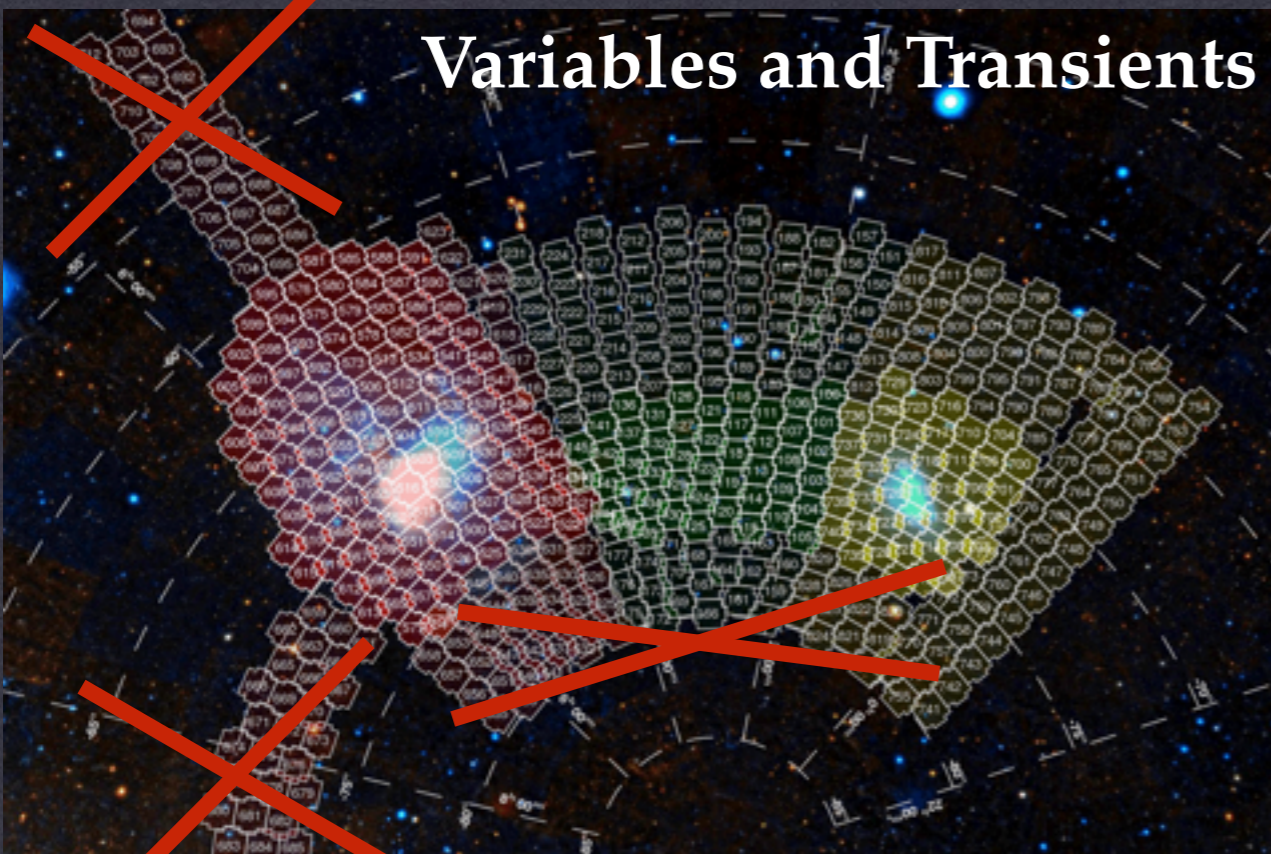


Bulge
half-billion stars
down to 20.5mag

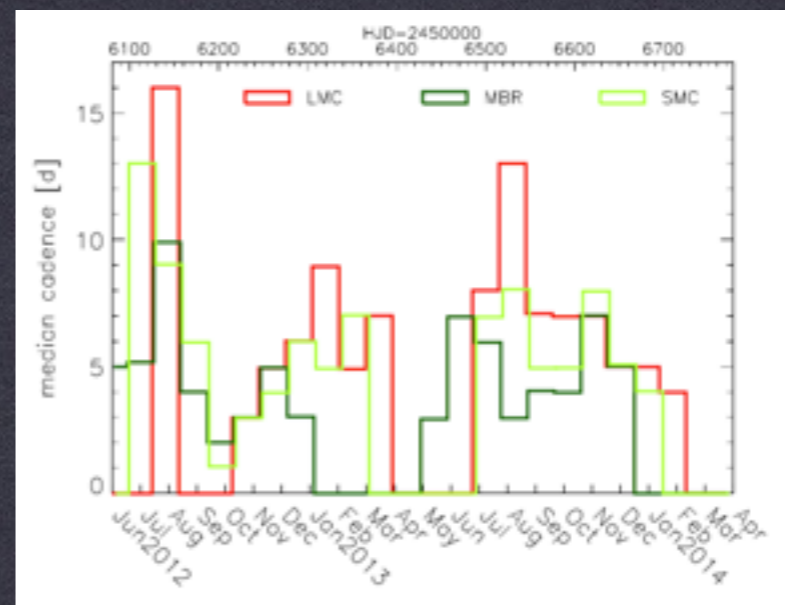
Cadence:

- red – ~30 epochs/night
- yellow – ~10 epochs/night
- green – ~3 epochs/night
- blue – ~1 epoch/night
- cyan – ~1 epoch /2 nights

Variables and Transients



Magellanic System (LMC+MBR+SMC)
550 sq.deg. limit: 22 mag in I-band



cadence:
2-4 nights

trimmed
fields
from 2015b

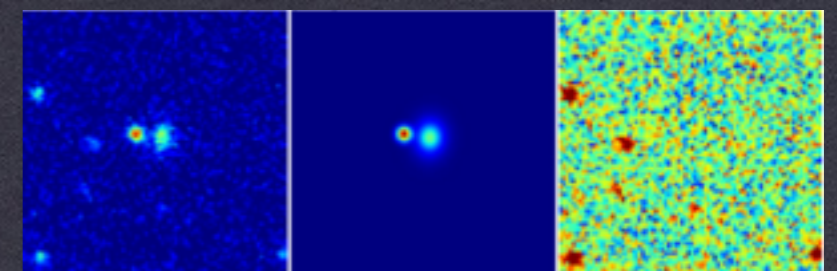
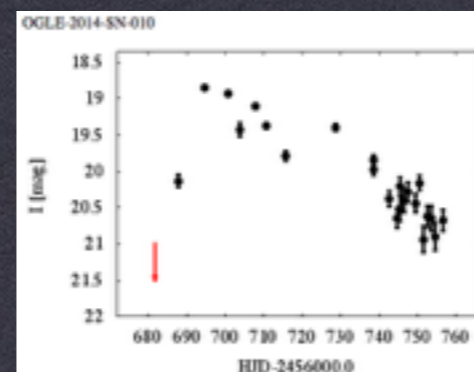
OGLE-IV Real-Time Transient Search

Ł. Wyrzykowski^{1,2}, Z. Kostrzewa-Rutkowska¹, S. Kozłowski¹,
A. Udalski¹, R. Poleski^{1,3}, J. Skowron¹, N. Blagorodnova²,
M. Kubiak¹, M.K. Szymański¹, G. Pietrzyński^{1,4}, I. Soszyński¹,
K. Ulaczyk¹, P. Pietrukowicz¹ and P. Mróz¹

[arxiv/1409.1095](https://arxiv.org/abs/1409.1095)

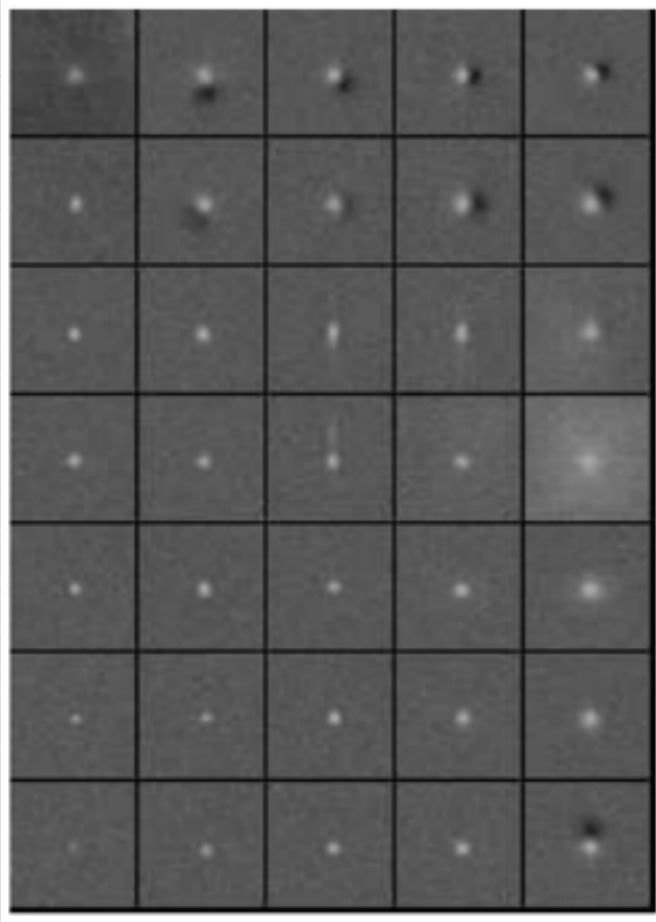
<http://ogle.astrouw.edu.pl/ogle4/transients/archive2012-2014/>

- 238 transients 2012-2014
- calibrated I+V photometry
- images
- host galfit models
- photometric classification



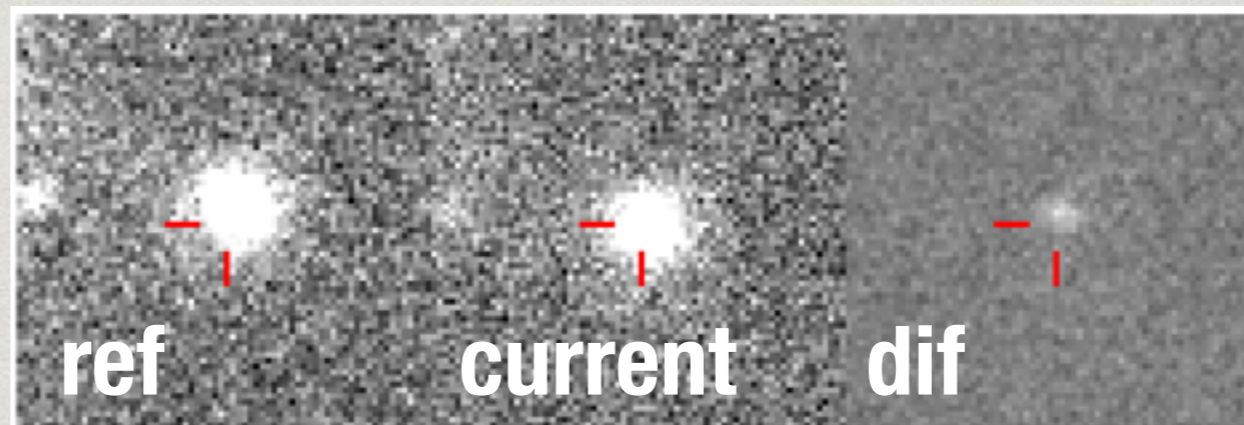
OGLE detection system

OLD



Real-Bogus SOM

- ~**50-70** fields per night (one shot in I)
- field observed again after **3-5** days
- occasional V-band observations (on request)
- ~**1000** new objects each night with min **2** points
- real-bogus classification with SOM
- about **100-300** left for eye-balling (*will be improved!*)
- **2-10** preselected for verification
(optimised difference imaging at exact location)
- **1-5** real transients found after each night

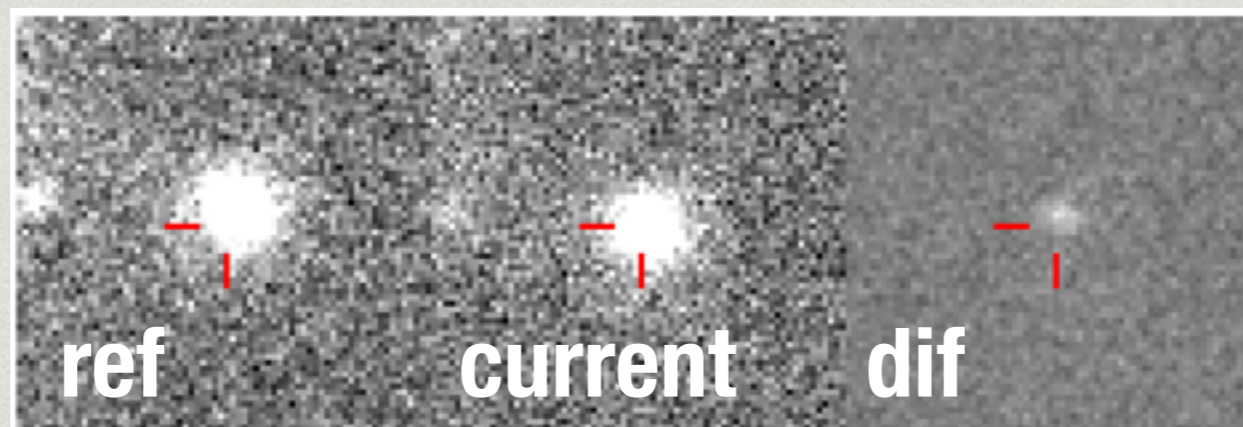


<http://ogle.astrouw.edu.pl/ogle4/transients/>

<http://ogle.astrouw.edu.pl/ogle4/transients/transients-lite.html>

new RAPID detection system

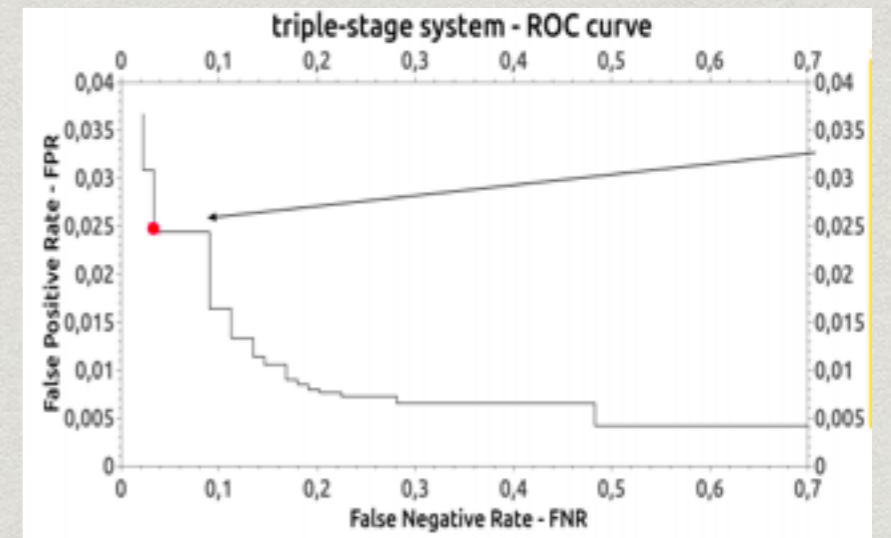
- ~**100** fields per night (one shot in I)
- field observed again after **3-5** days
- full reductions + object detection: **<15min!**
- ~**10000** new objects each night with **1** point (<19.2mag)
- autonomous decision
- **1-5** real transients found after each night
- among ~20 false detections (mostly cosmic rays)



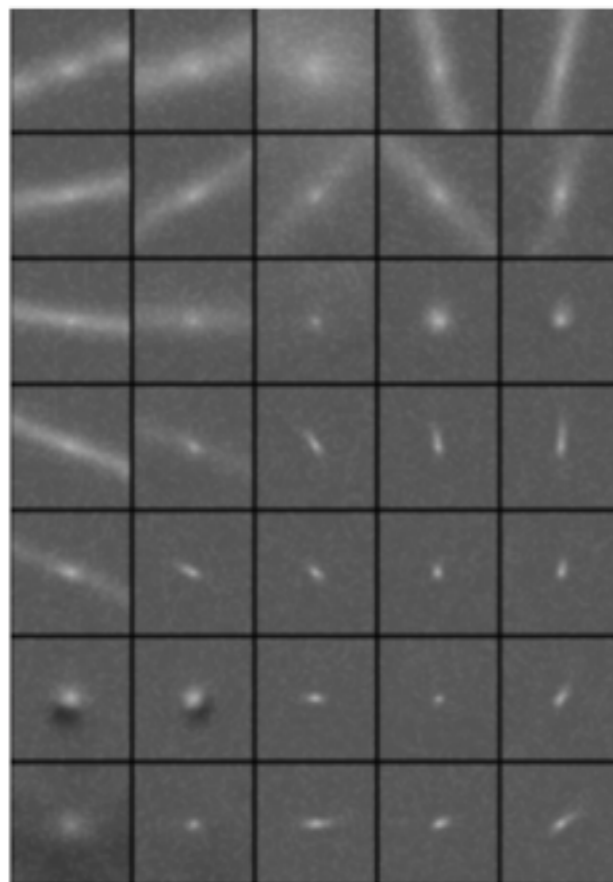
<http://ogle.astrouw.edu.pl/ogle4/transients/rapid/>

Improved Real-Bogus classification

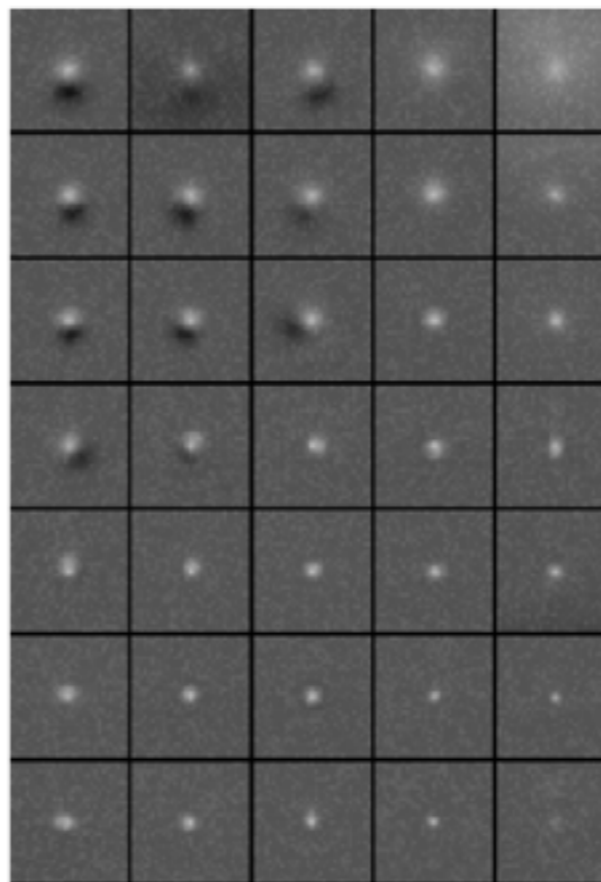
- Self-Organizing Maps (SOM)
- three stage classifier
- trained on ~20k examples
- tested on previously found SNe
- false positives: ~3%



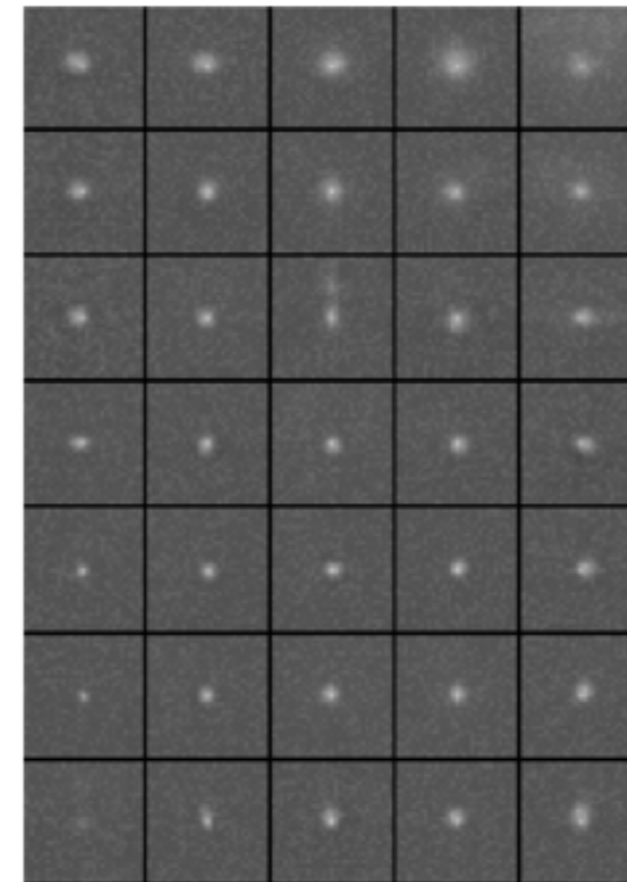
**First Stage:
anti-cosmic**



**Second Stage:
anti-yinyang**



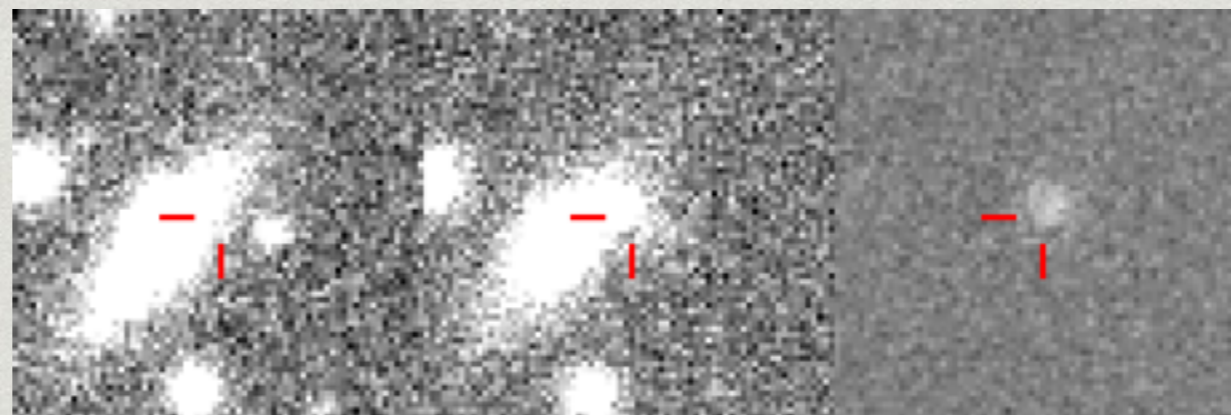
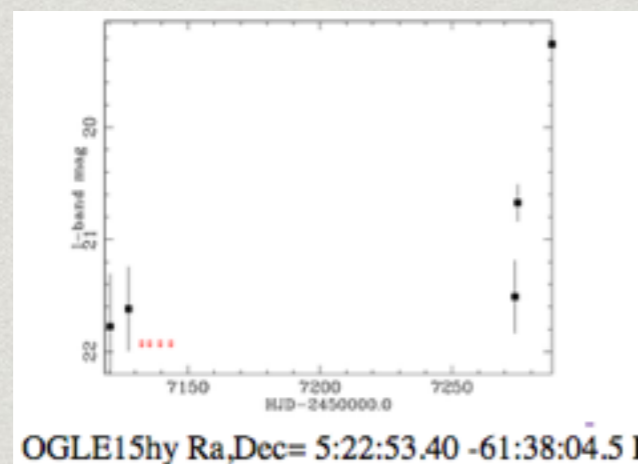
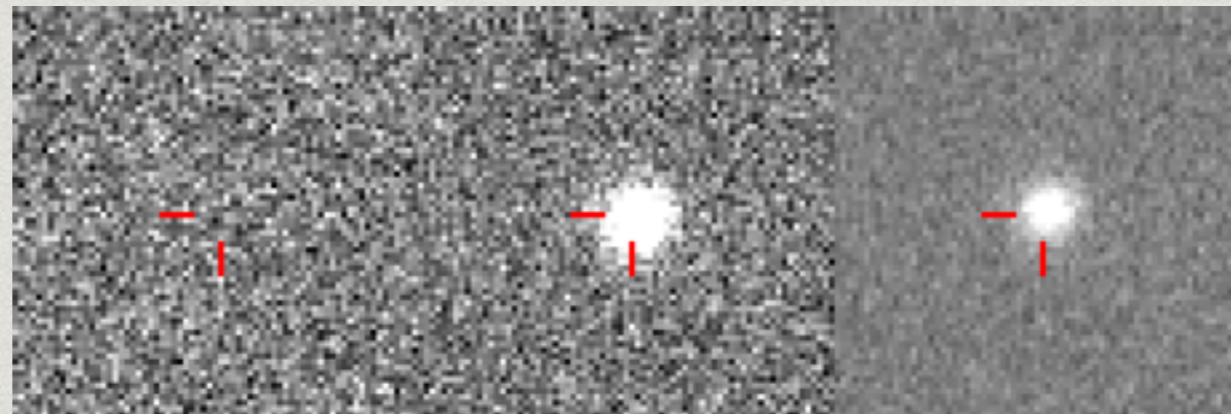
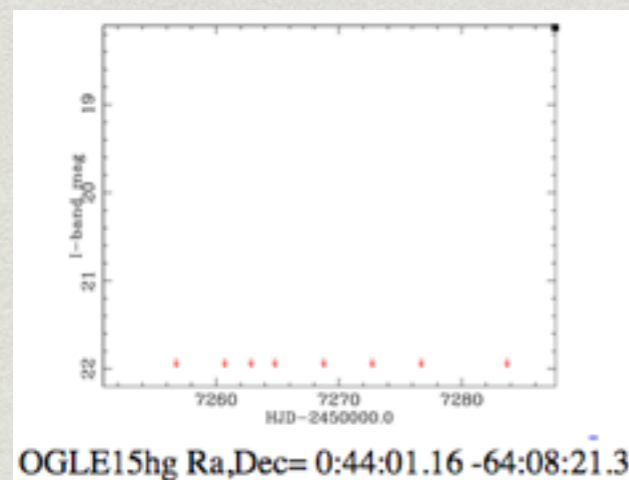
**Third Stage:
anti-faint**



Improvements

- automated transient classification
- host searched from **~10M** ~galaxies (DR0) down to 22 mag (to be cleaned and **photo-z**)
- **WISE** colours to rule out AGNs
- history of previous variability (last 10 frames)

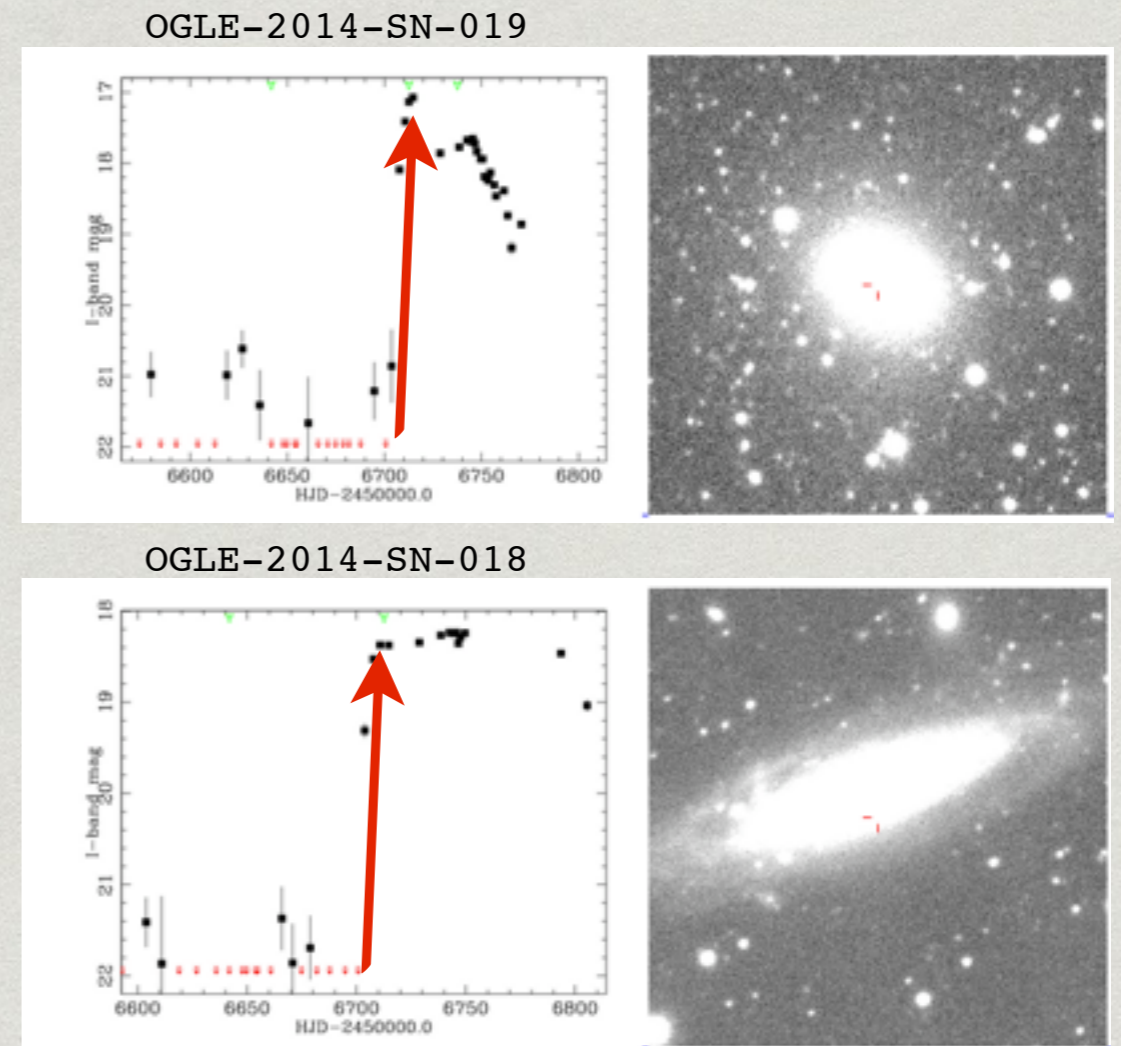
rapid findings of night 21/22 Sep 2015



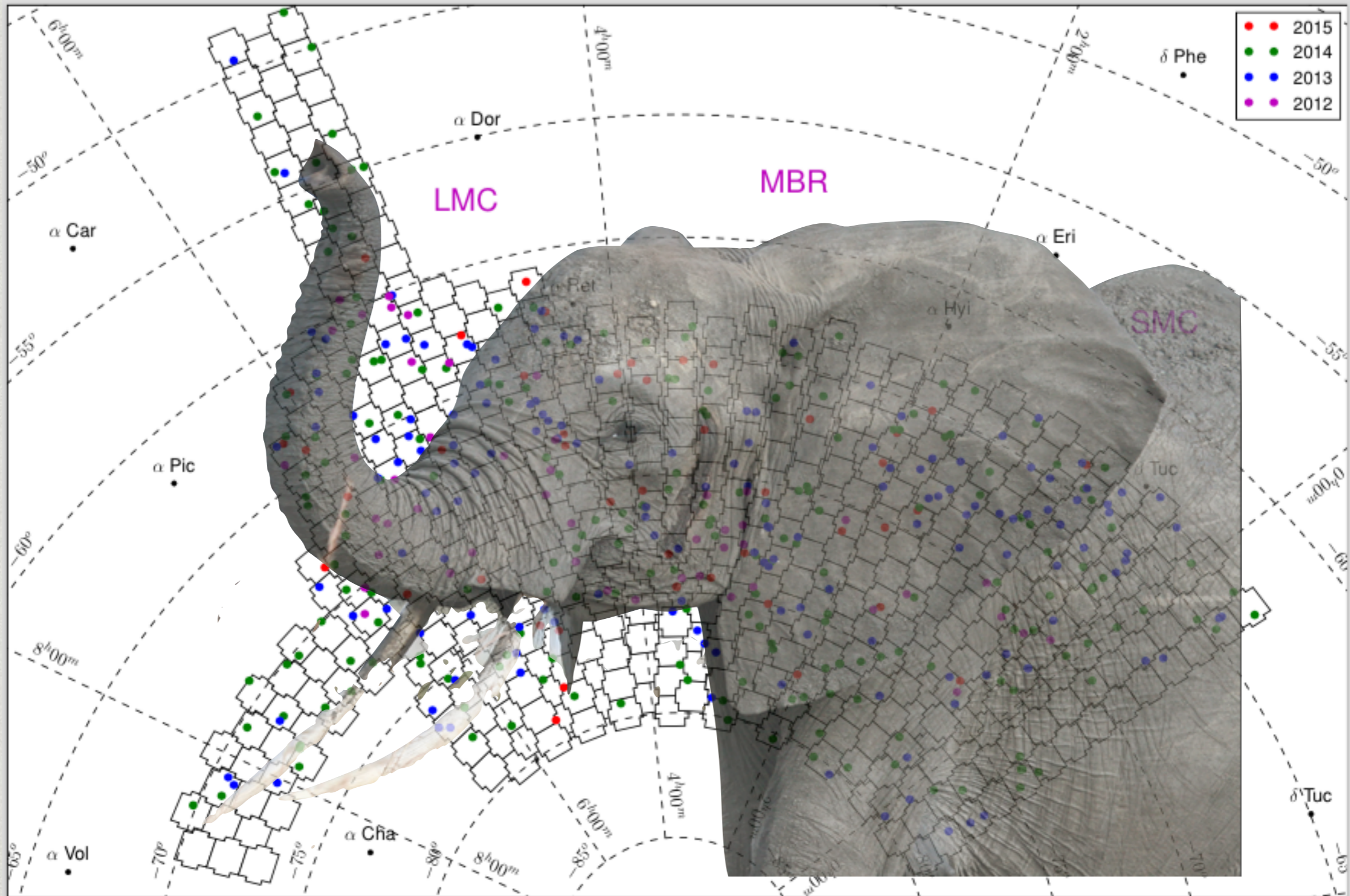
~30 min
from image
to alert!

Photometric classification

- simple parameters:
 - last non-detection
 - rising slope
 - max magnitude
- training set: 90 spectroscopically classified supernovae
- classifier: Random Forest
- correct answers: 84%
- separates SNe Ia, II, Novae, DNe with incomplete early light curves
- to be added to the autonomous rapid system



Statistics



Statistics

since Oct 2012

All OTDS SNe candidates: 501

Discovery rate: 0.54 SN/day

(~1 SN/day when corrected for season length)

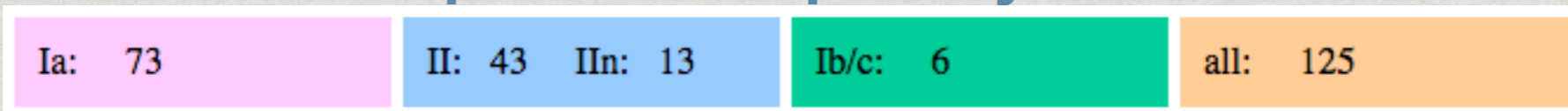
2012: 48

2013: 155

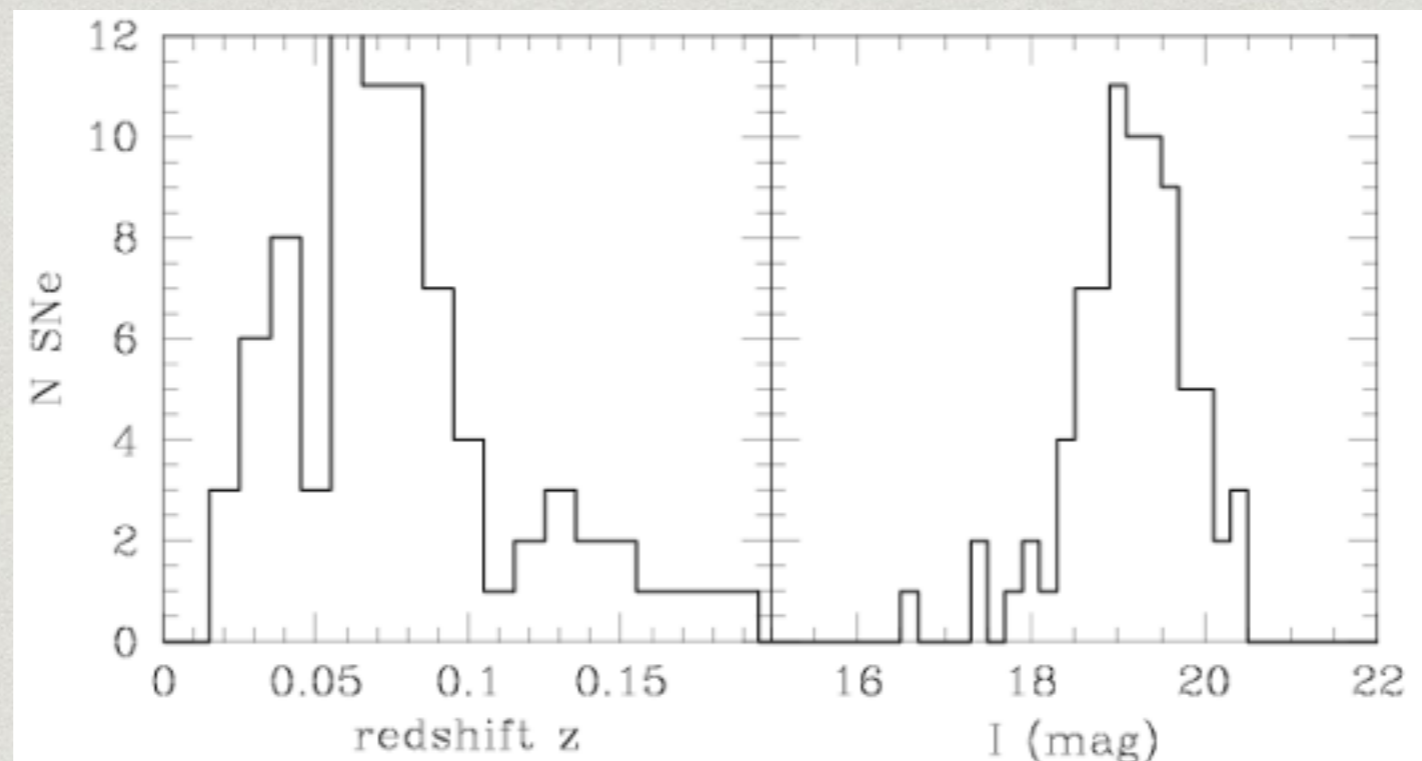
2014: 214

2015: 84

OGLE-IV Spectroscopically Confirmed SNe



~95% PESSTO!



Nearest SN $z=0.013966$
Most distant SN $z=0.19$

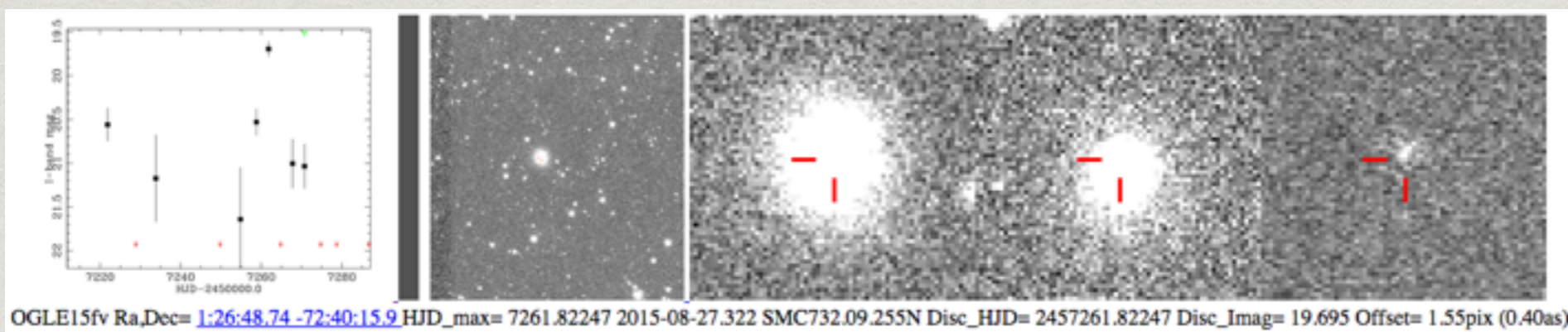
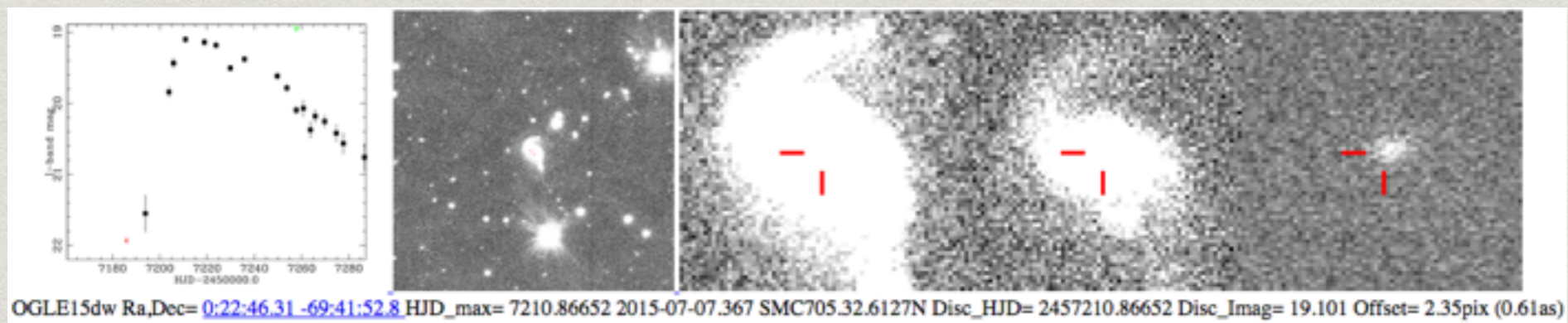
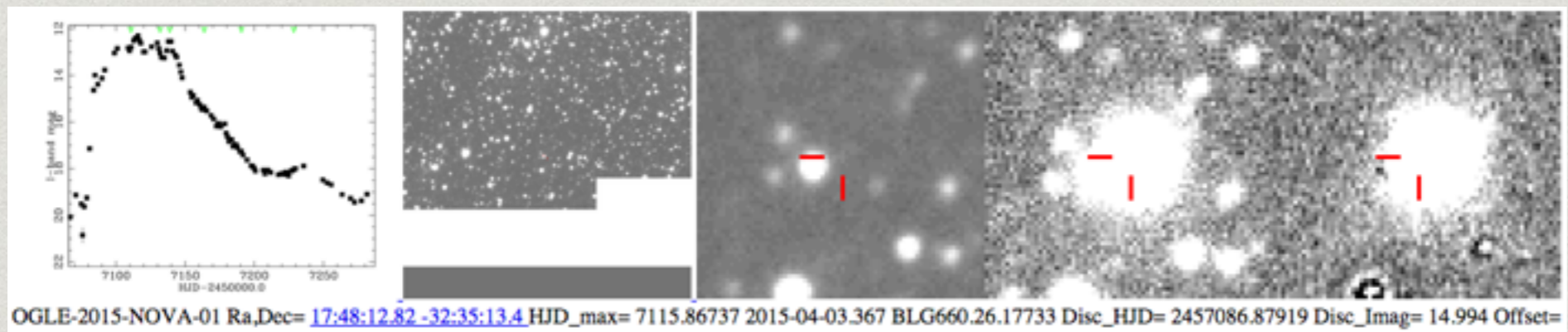
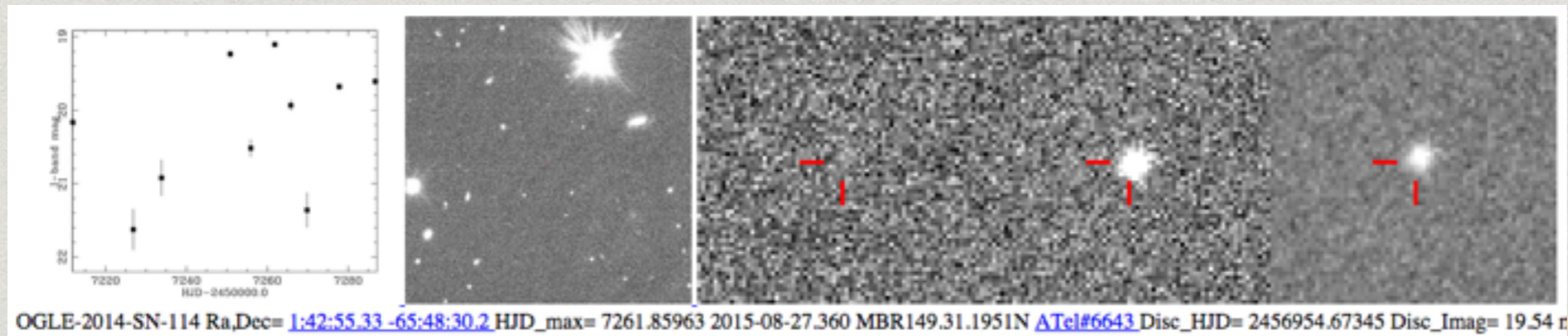
Type: Ia
Type: Ia

Approx. dist. 58 Mpc
Approx. dist. 888 Mpc

(as on Thu 2015-Sep-22)

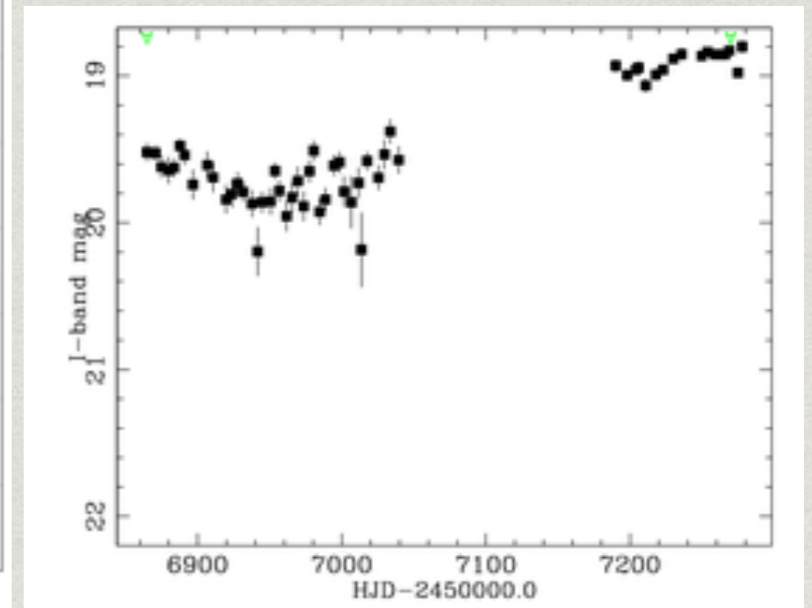
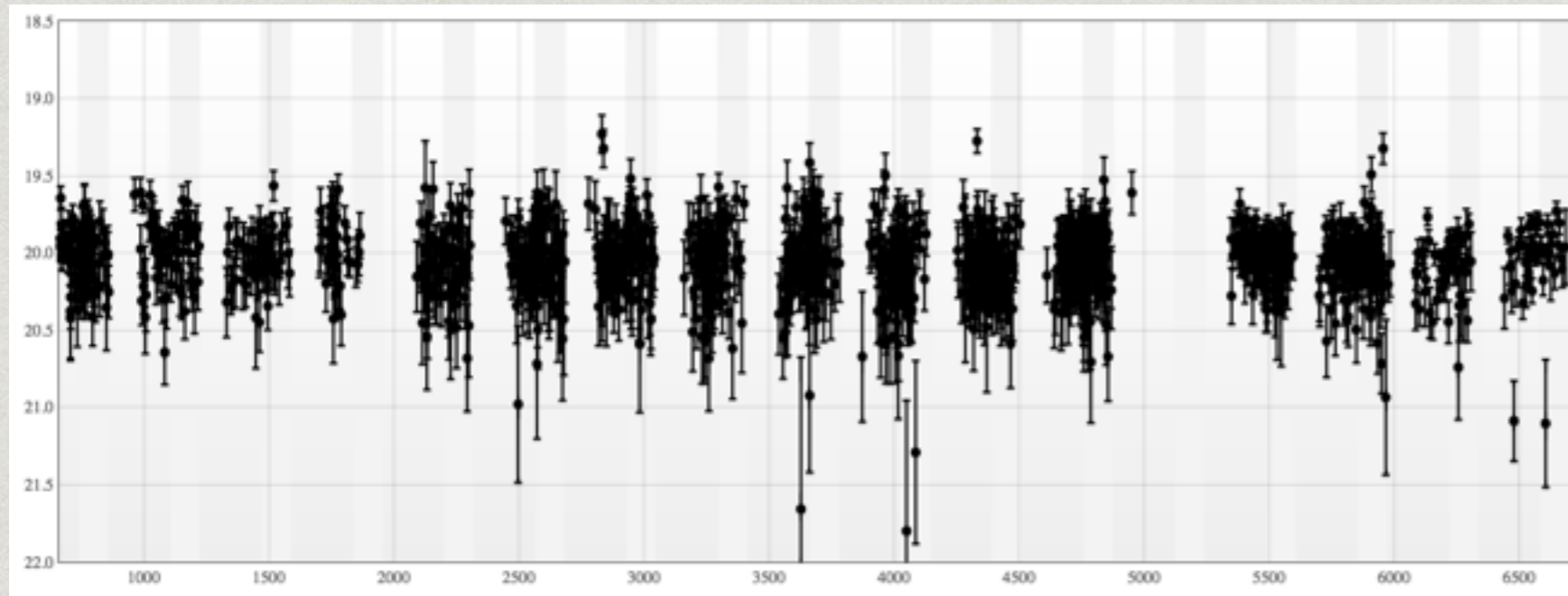
stats by Szymon Kozłowski

Weirdoes



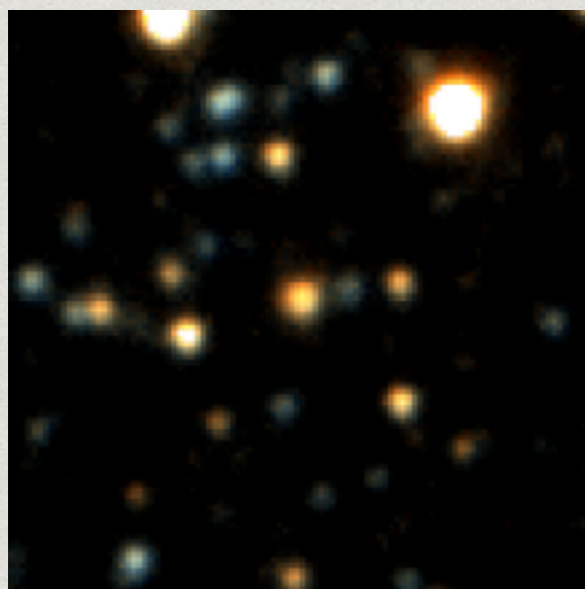
Mysterious transient in the SMC

OGLE15ga Ra,Dec= 0:41:24.30 -73:01:27.3

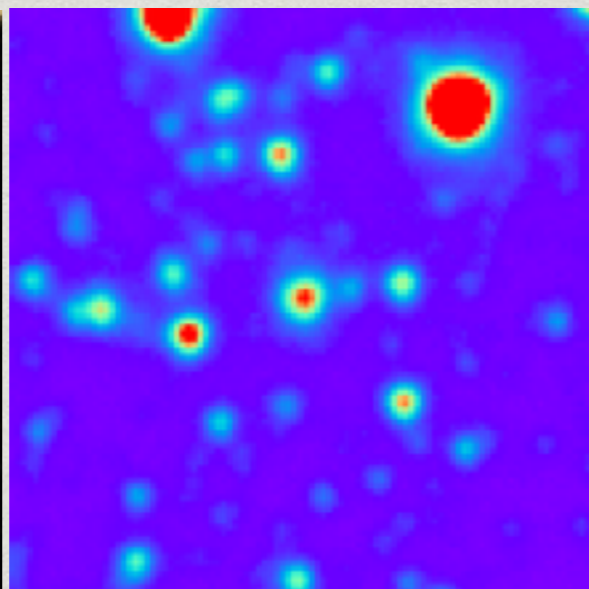


17 years of quiescence and slow brightening

OGLE V+I



OGLE I

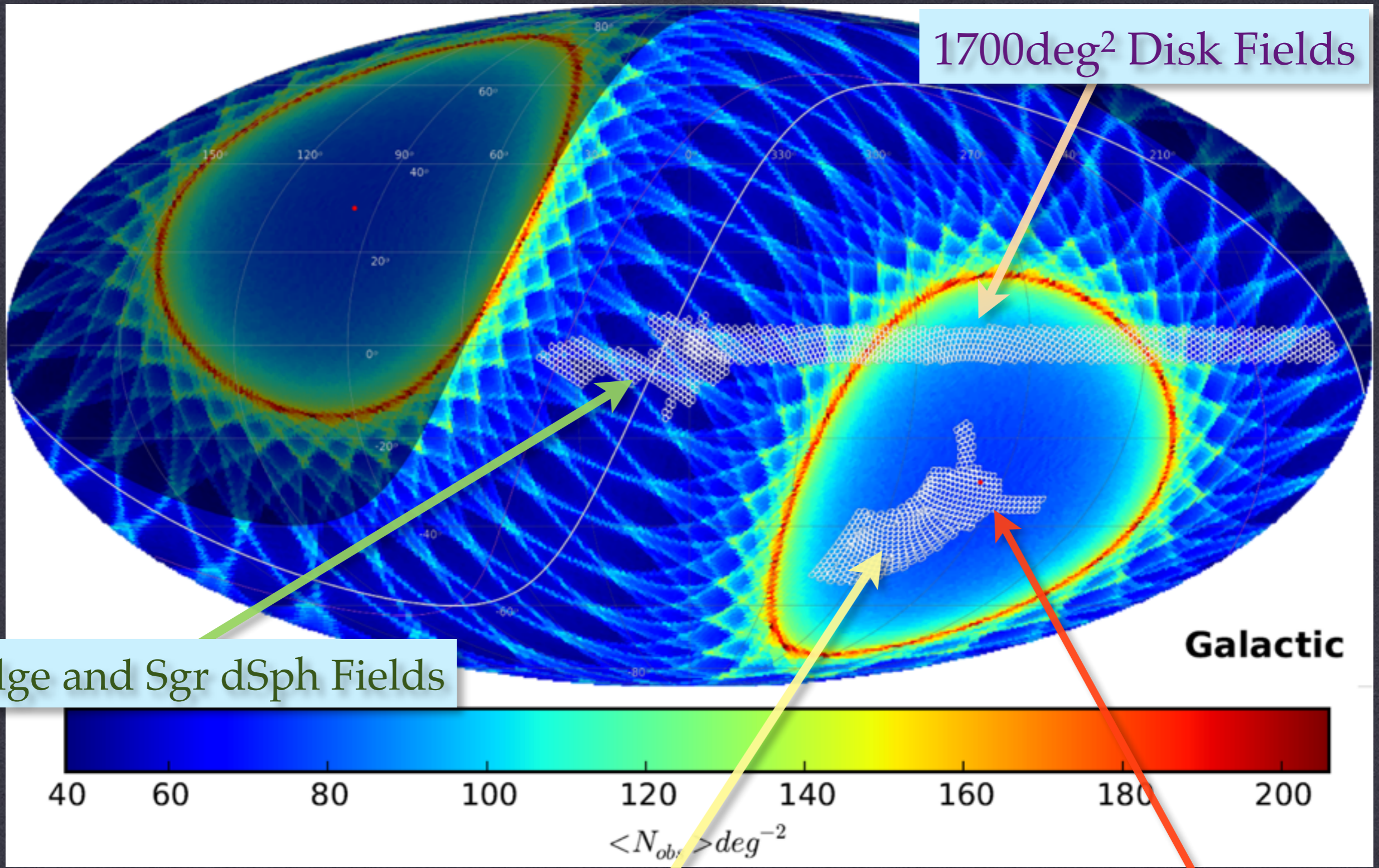


WISE



extended source!
Far IR source
FU Ori-type variable?

OGLE-GAIA SKY



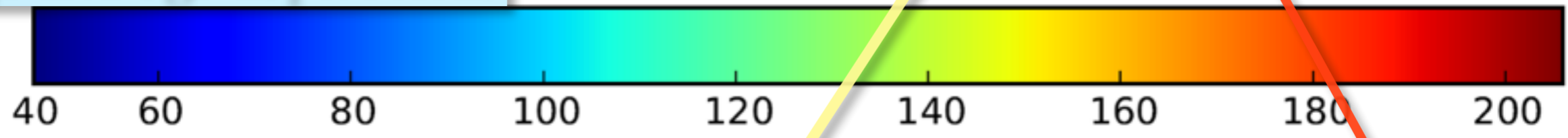
1700deg² Disk Fields

Bulge and Sgr dSph Fields

Supernovae Search Fields

LMC and SEP

Galactic

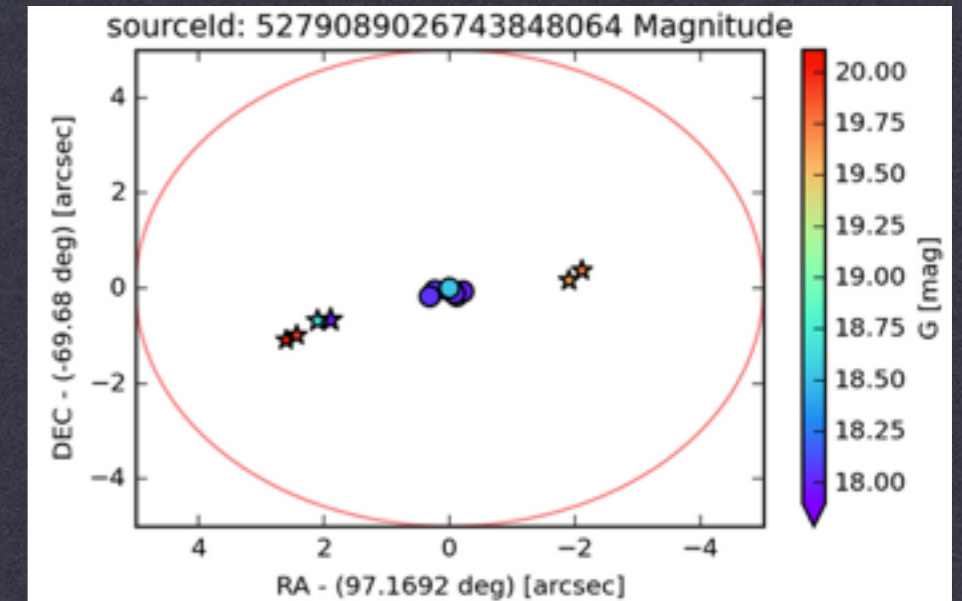
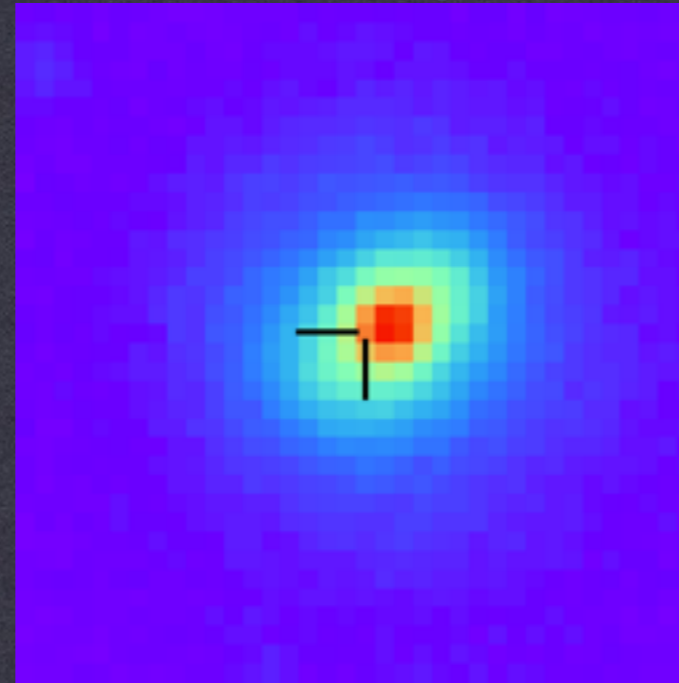
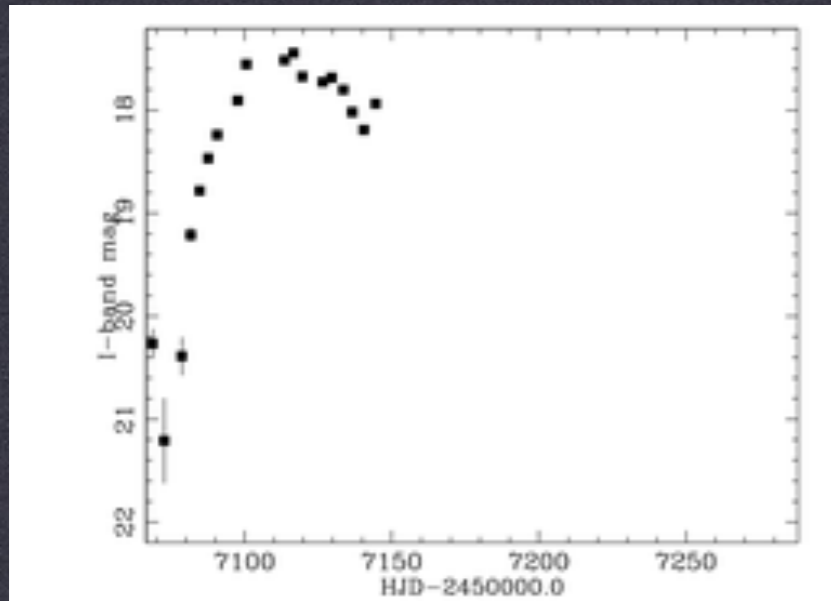


$\langle N_{obs} \rangle deg^{-2}$

OGLE-GAIA NUCLEARS

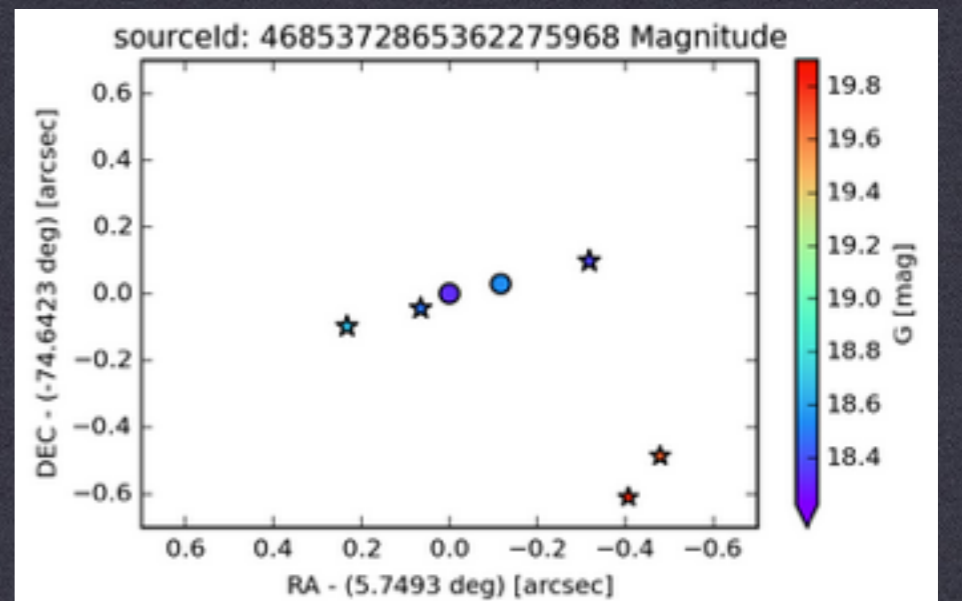
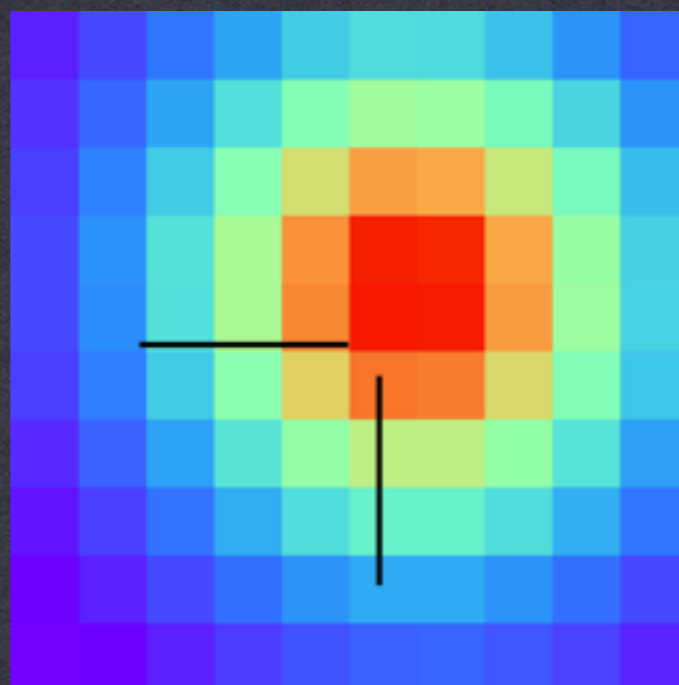
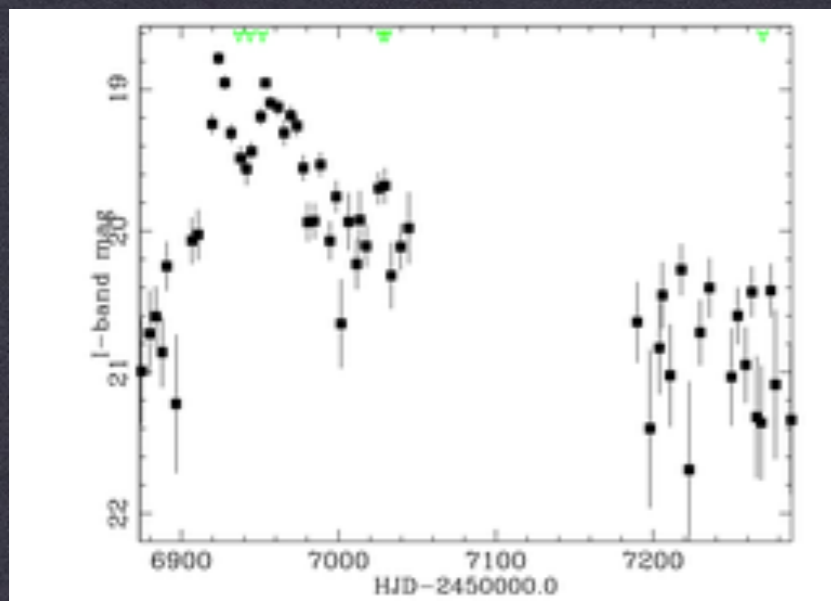
OGLE template

Gaia detections



OGLE-2014-SN-173 Ra,Dec= [6:28:40.64](#) -

class= II In z=0.0296 Offset= 0.91pix (0.24as)



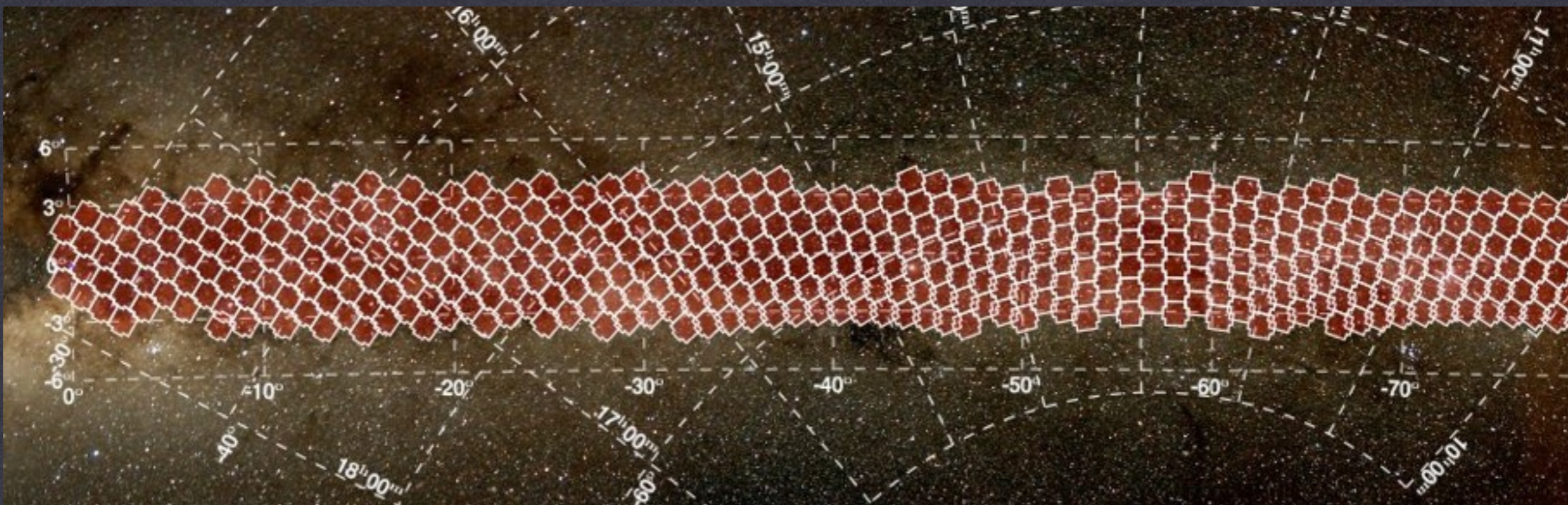
OGLE-2014-SN-081 Ra,Dec= [0:22:59.80](#) -

Offset= 0.53pix (0.14as)

PLANS

OGLE-IV has solid funding and will continue in next years...

...but continuation of the transient search programme strongly depends on availability of spectroscopic follow-up (and papers!)



Galactic Disk survey: >1700 sq. deg down to 19 mag monitored already for 3 years for variable stars.
Real-Time Transients Search will start 2015/2016

PLANS

- TDE search in OGLE 6 years long 700 sq.deg. area
- simulations and rates
- connect with Gaia TDE search (PL grant application pending)

Warsaw team for TDEs:

- Zuzanna Kostrzewa-Rutkowska, postdoc
- Kris Rybicki, PhD student
- Aleksandra Hamanowicz, Master student
- Jakub Klencki, Master student