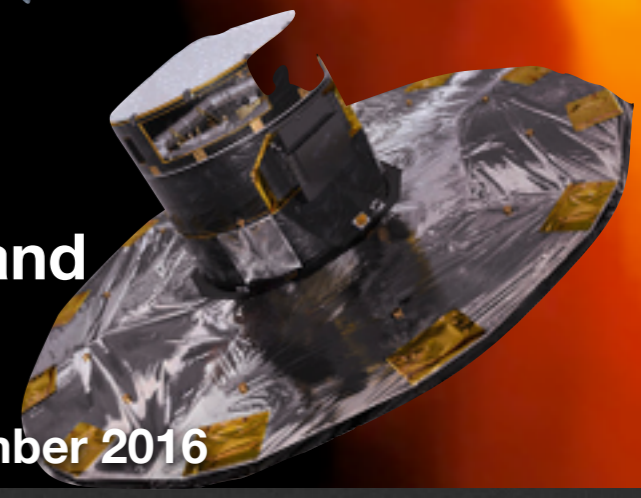


# Tidal Disruption Events in OGLE and Gaia surveys

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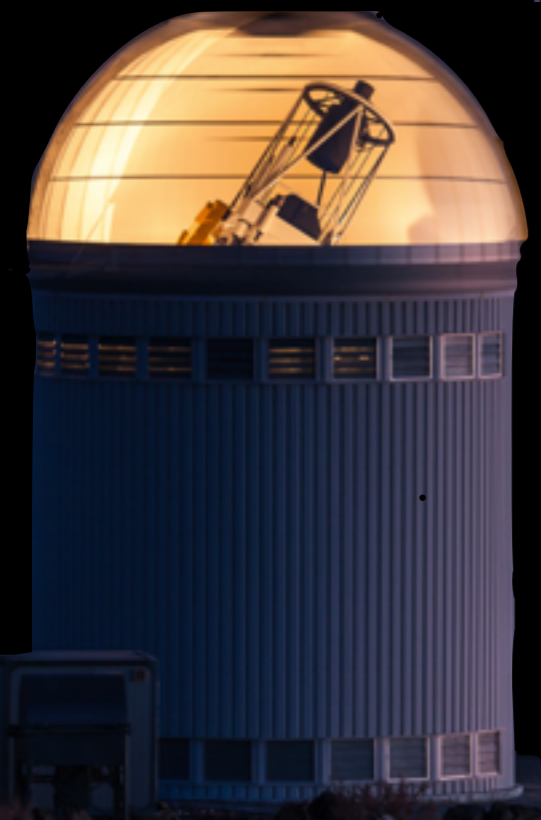
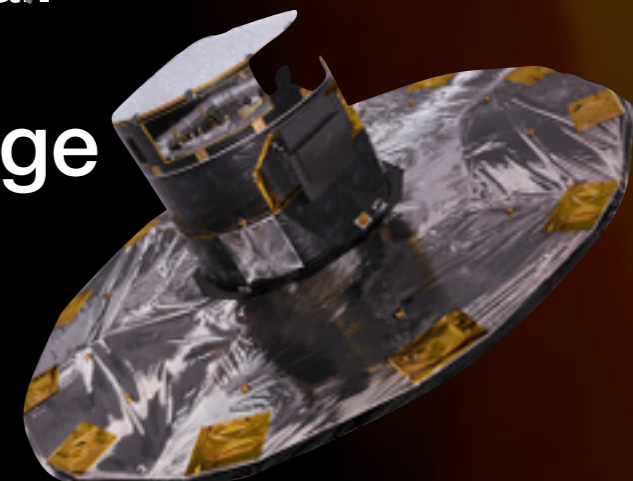
Odessa/Warsaw

**Zuzanna Kostrzewa-Rutkowska**  
SRON, NL



Iair Arcavi, James Guillochon, Morgan Fraser, et al.

**Gaia Science Alerts team in Cambridge**  
**OGLE team in Warsaw**





# Unbiased OGLE and Gaia hunt for TDEs

**OGLE**

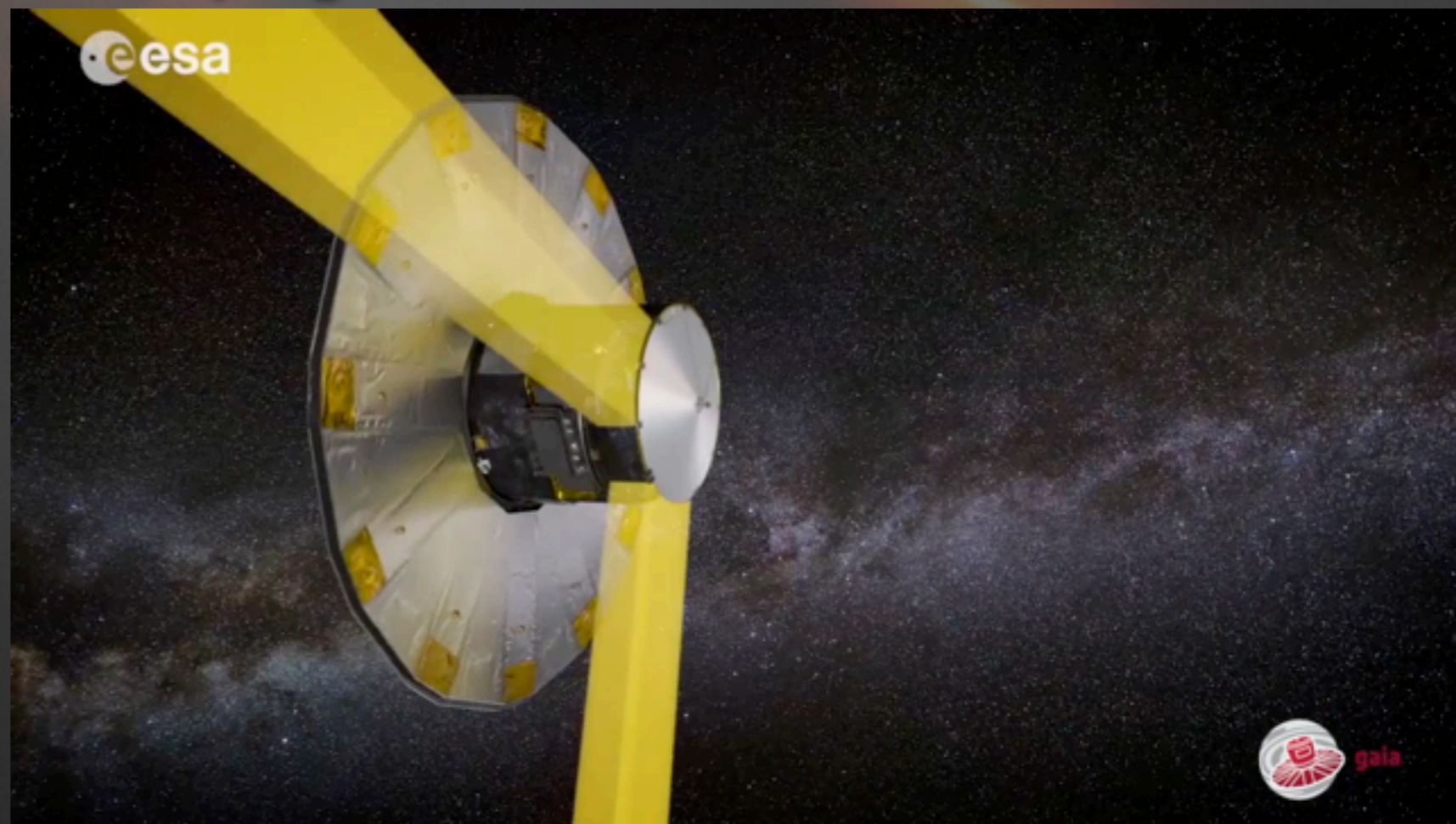
<http://ogle.astrouw.edu.pl>



Polish 1.3m dedicated telescope  
in Las Campanas, Chile  
Surveying continuously since 1992.

**Gaia Science Alerts**

<http://gsaweb.ast.cam.ac.uk/alerts>

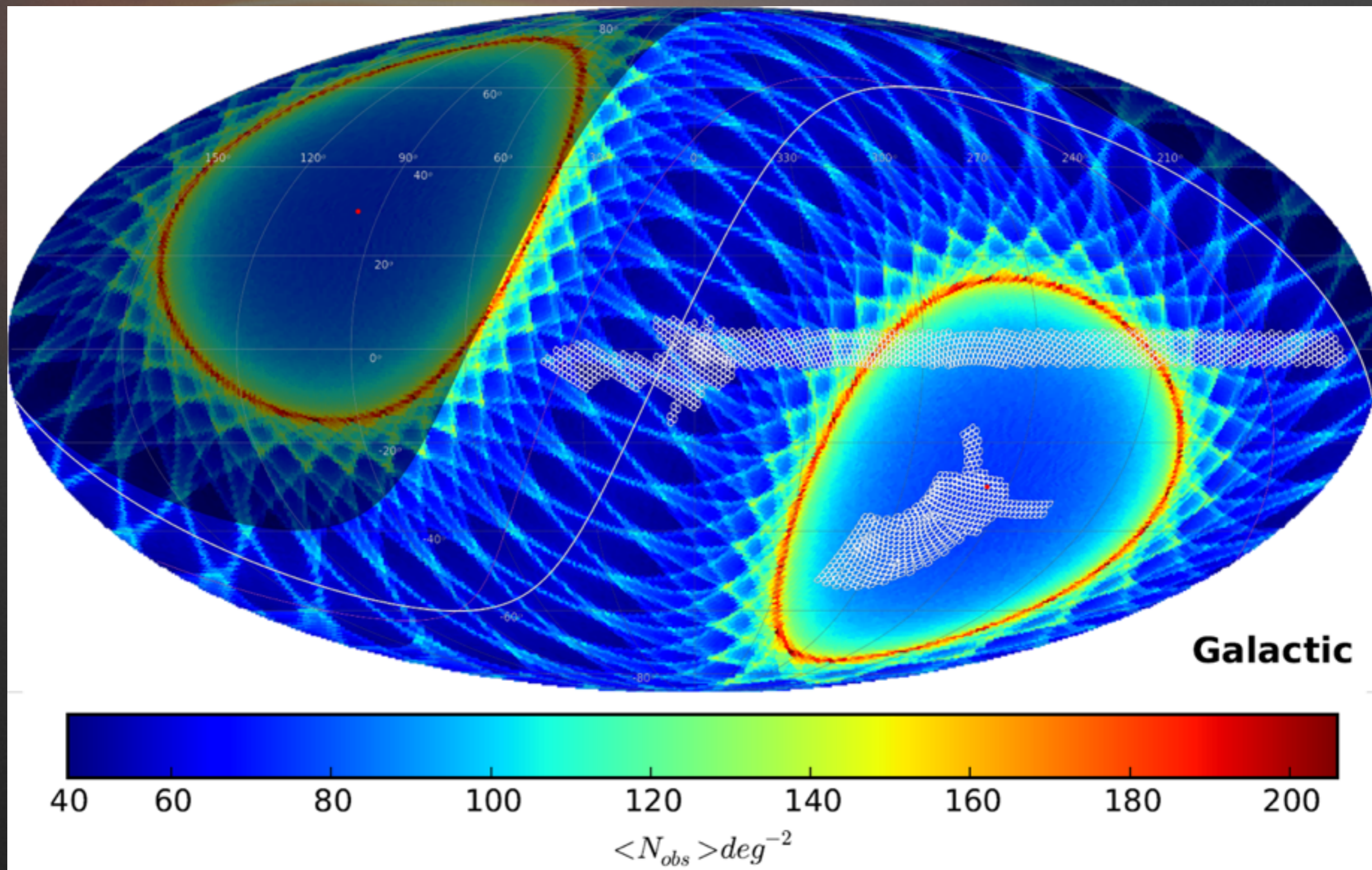


ESA space mission with 2x1.4m telescopes located in L2.  
In operation since 2014.

**First Gaia Data Release: 14.Sep 2016**

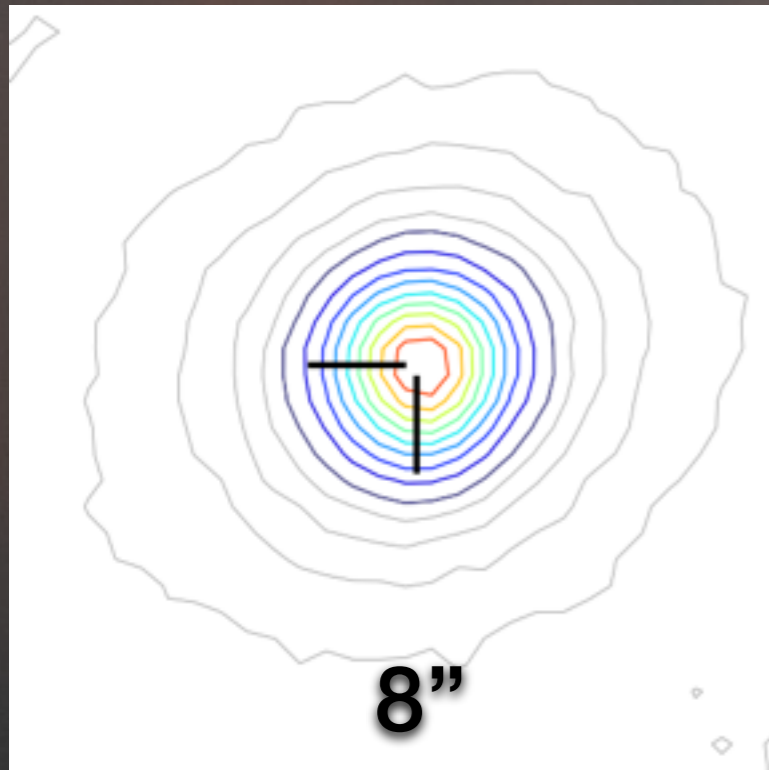


# Unbiased OGLE and Gaia hunt for TDEs





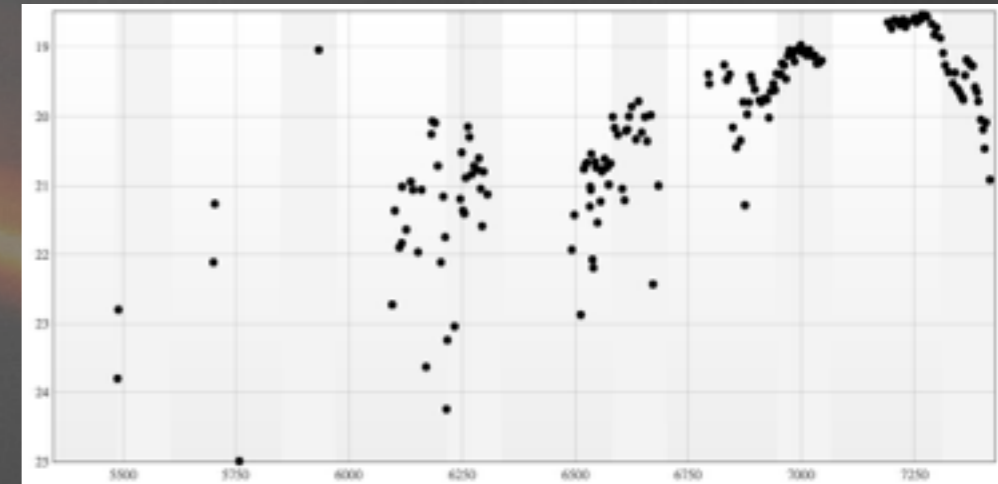
# OGLE Nuclear Transients



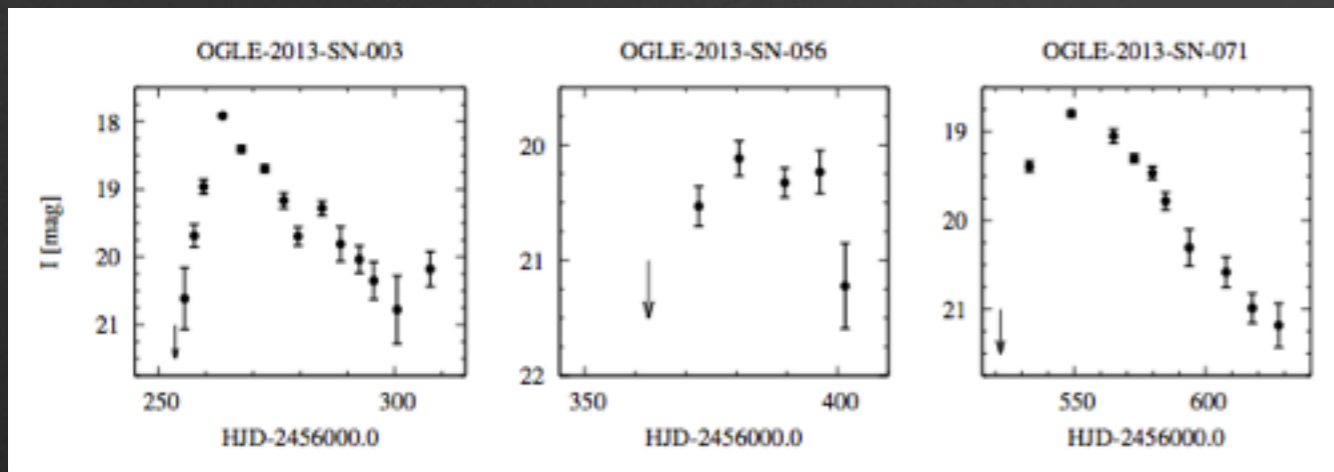
Real-time and archive search.  
<http://ogle.astrouw.edu.pl/ogle4/transients>

Difference Imaging data for 6 million centres of galaxies.

Astrometric accuracy 130mas

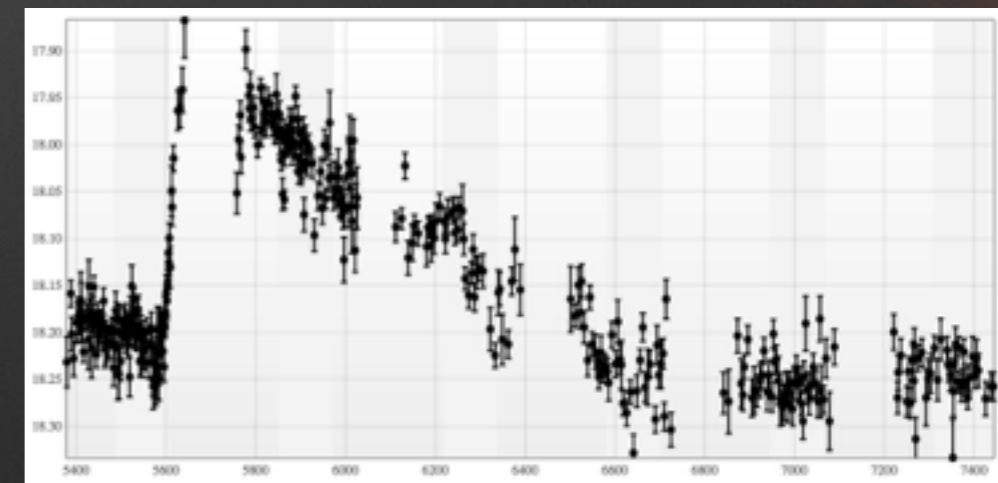


Example AGN light curve 6 years of photometry



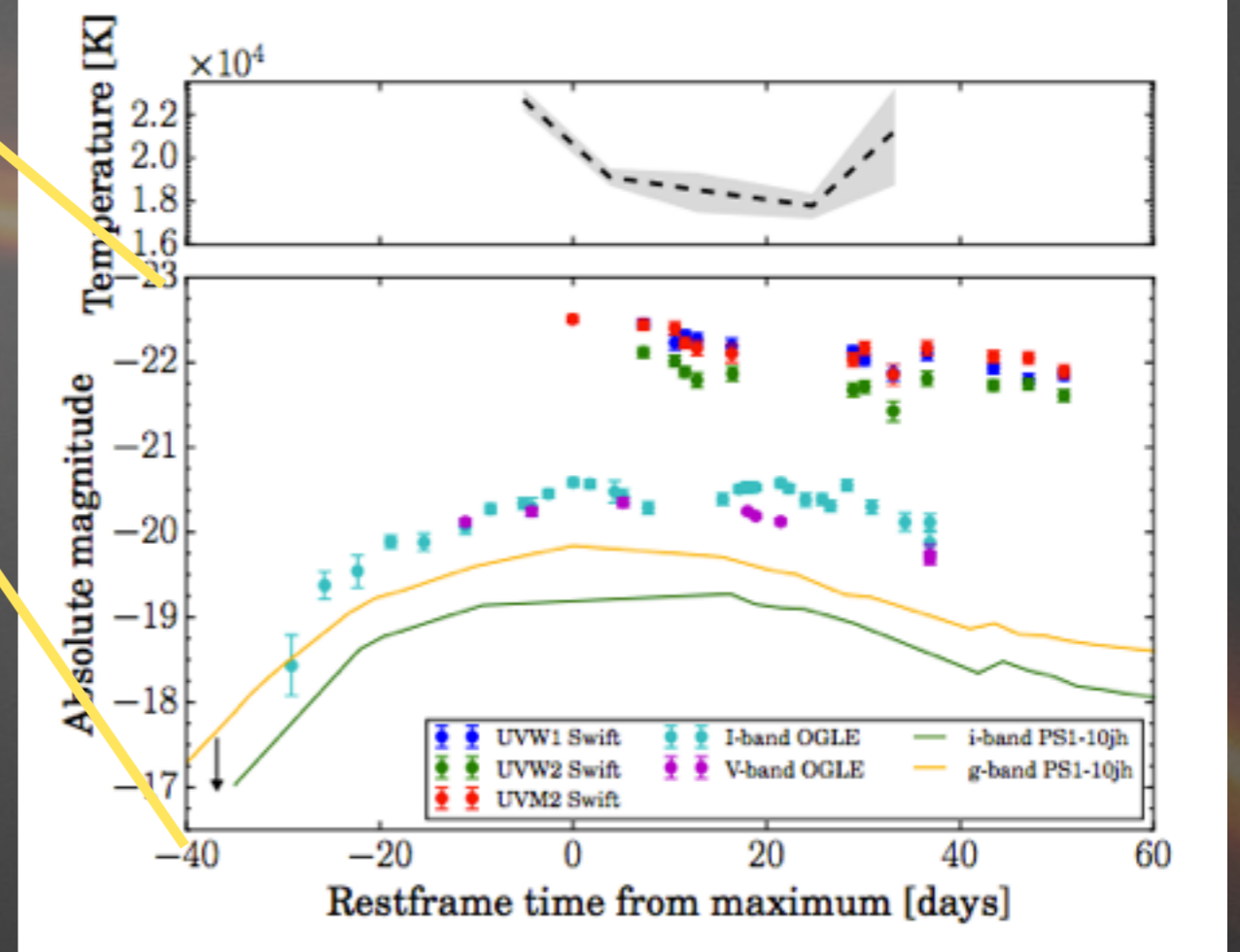
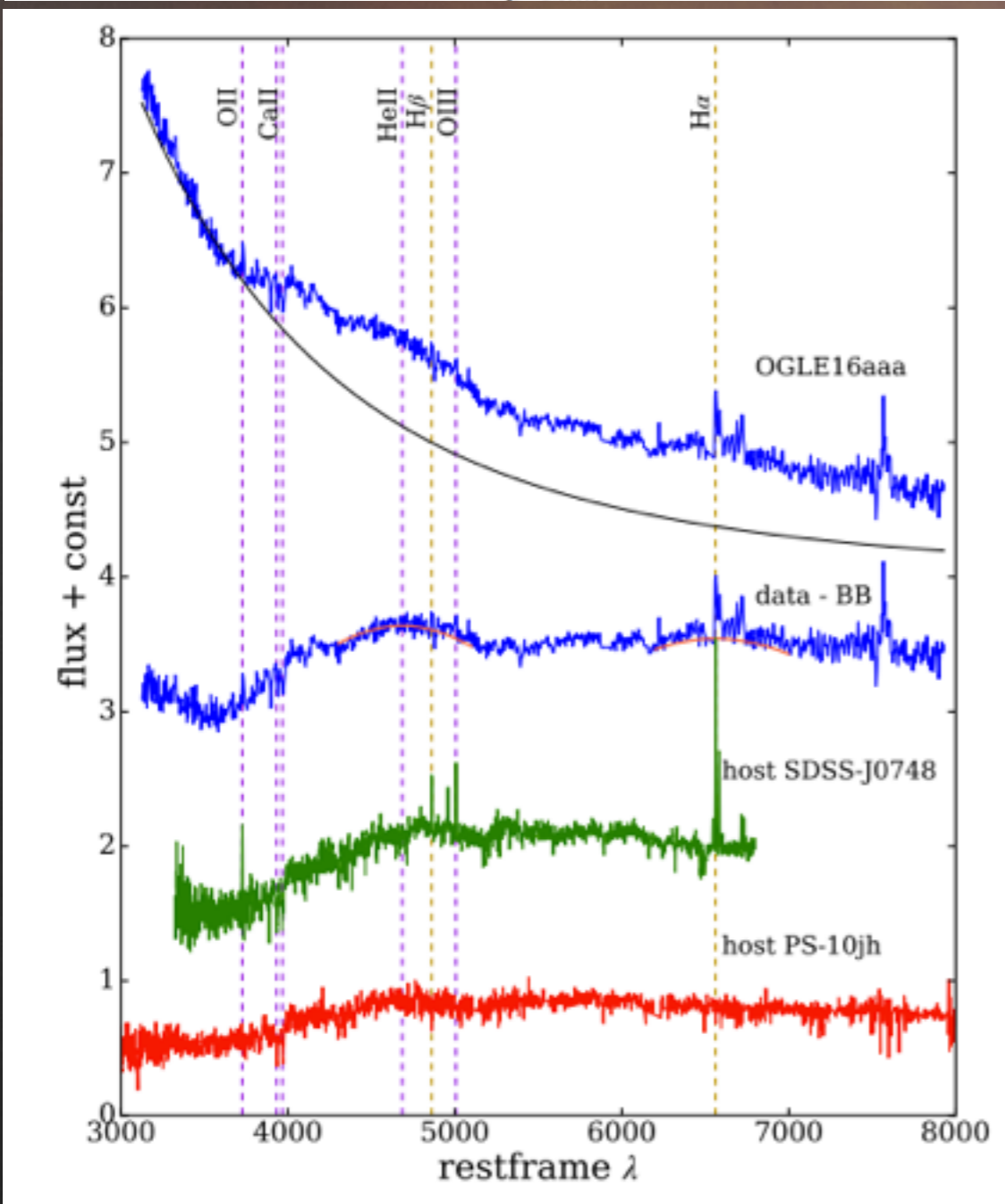
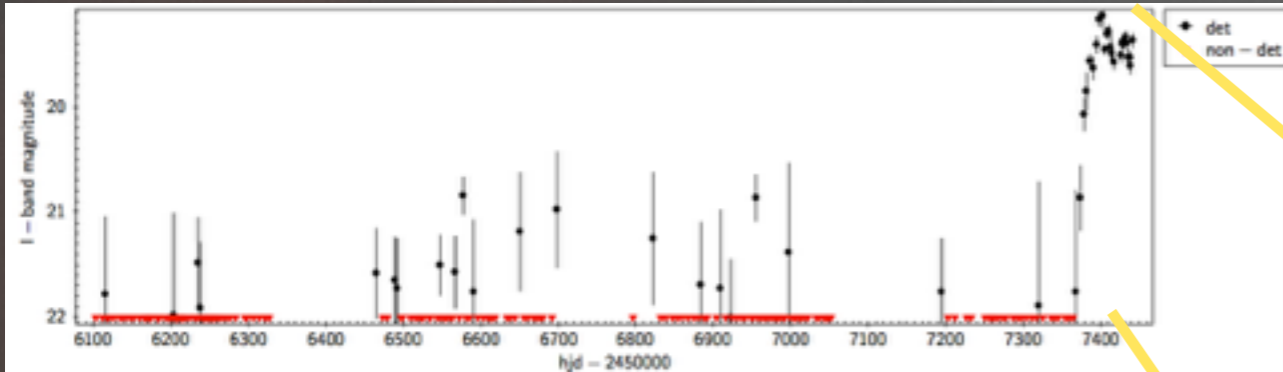
mysterious short nuclear transients:

- TDEs of low mass stars?
- low mass black-holes?



Candidate TDE  
4 years long nuclear flare

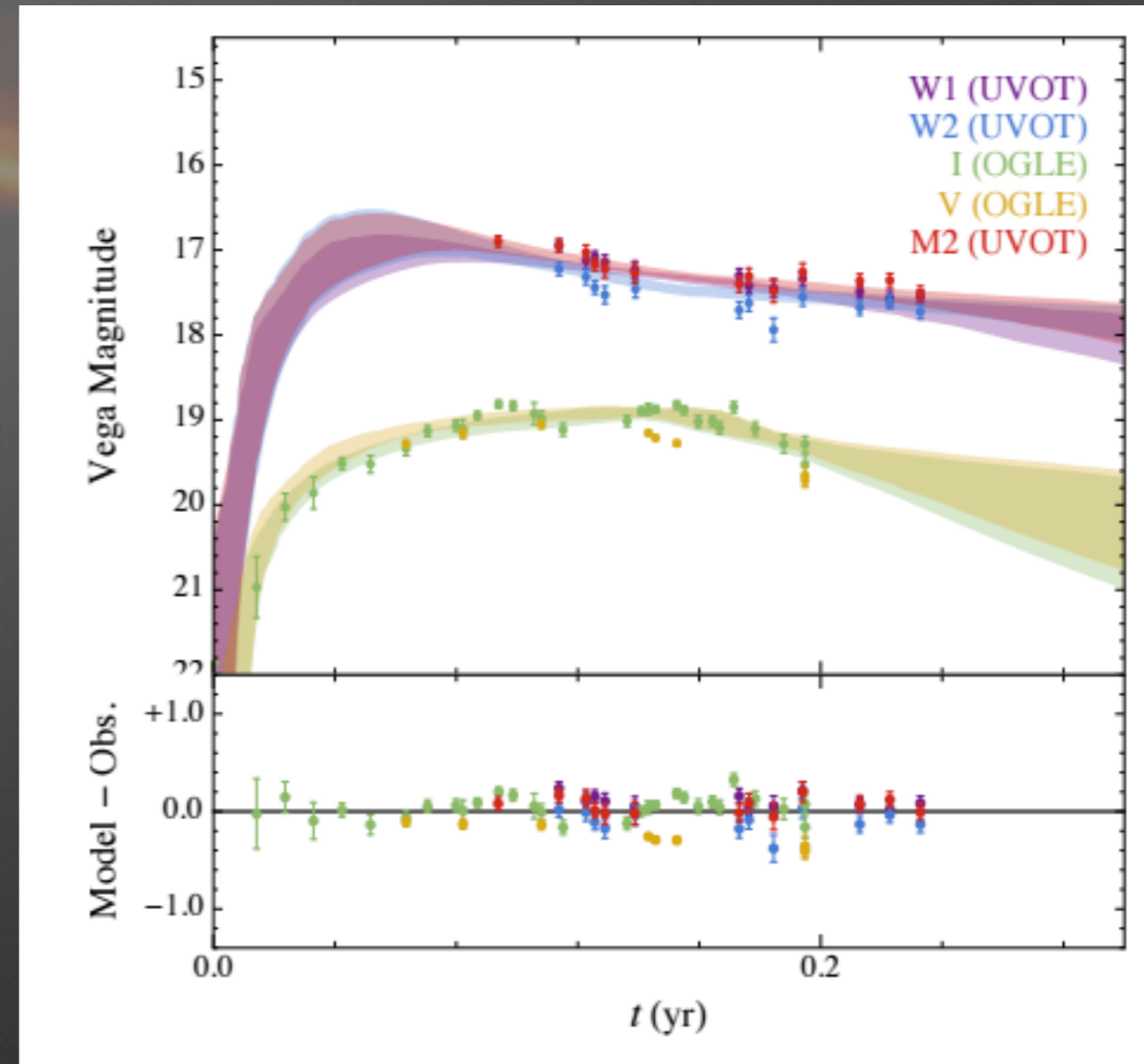
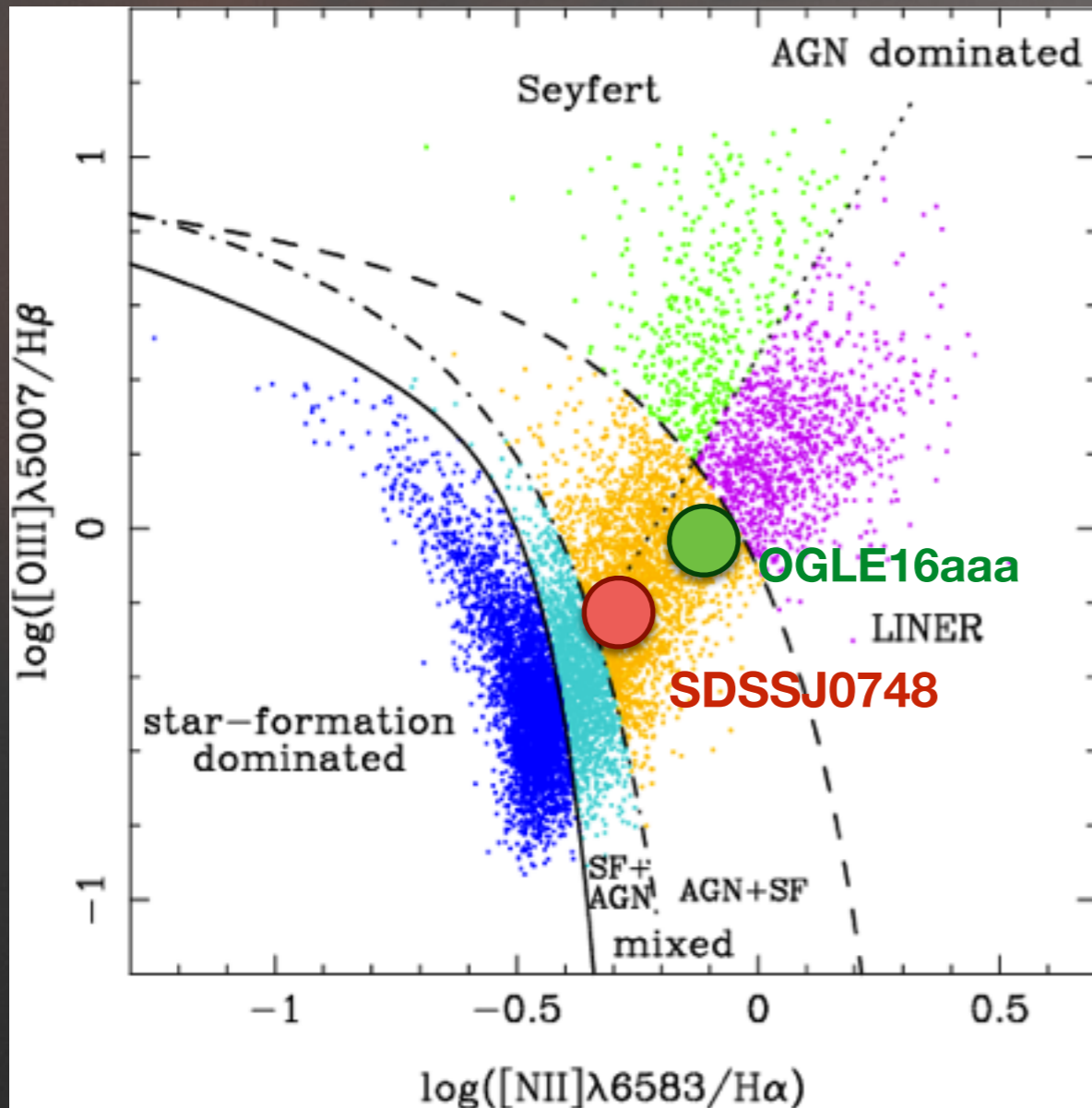
# OGLE16aaa - Hungry SMBH



- $z=0.167$ , peak absolute mag  $M=-20.5$
- slowly rising I-band light curve ( $\sim 30d$ )
- very broad HeII and H $\alpha$  emission
- hot black-body flare spectrum: 22,000K
- host shows weak narrow AGN lines (not E+A)
- no photometric activity in 3.5 yrs prior to the flare
- possible variability?



# OGLE16aaa - Hungry SMBH



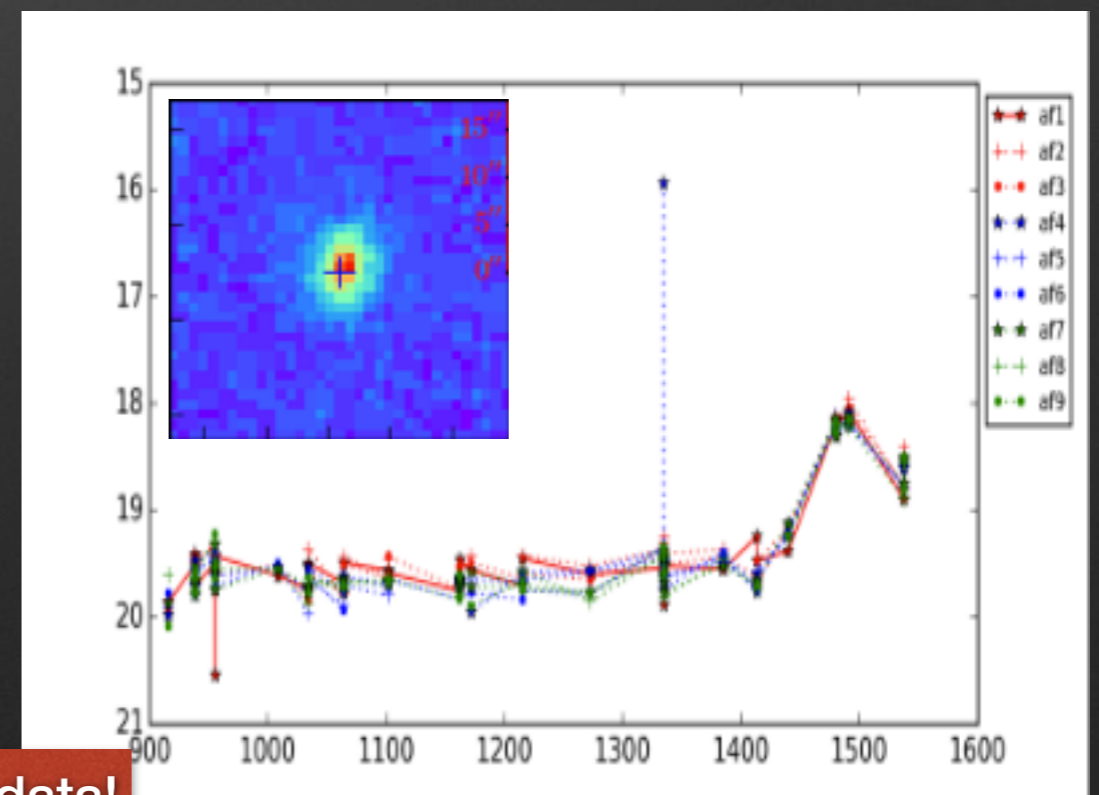
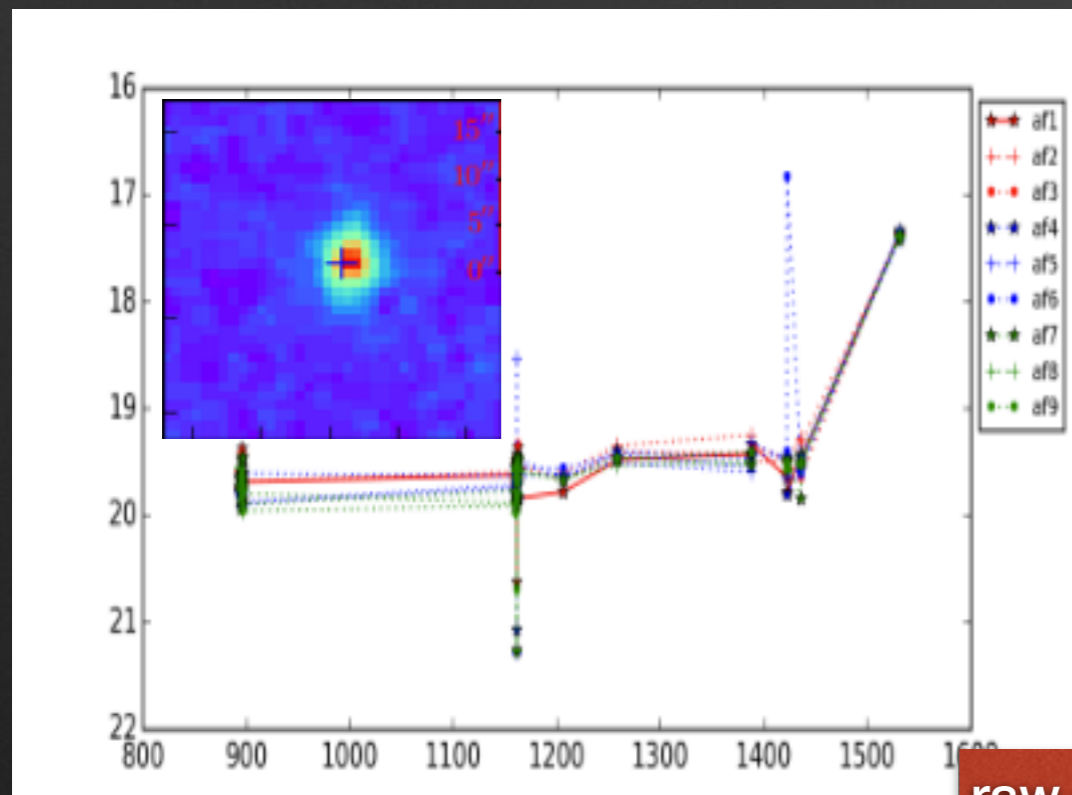
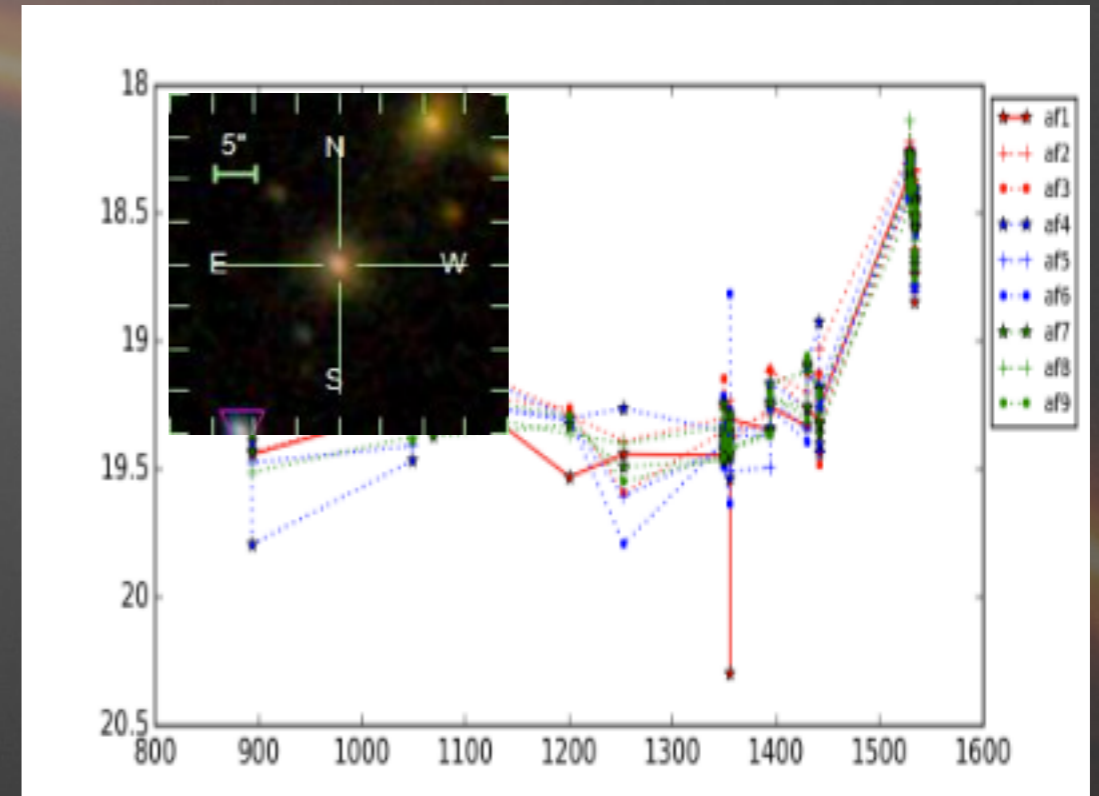
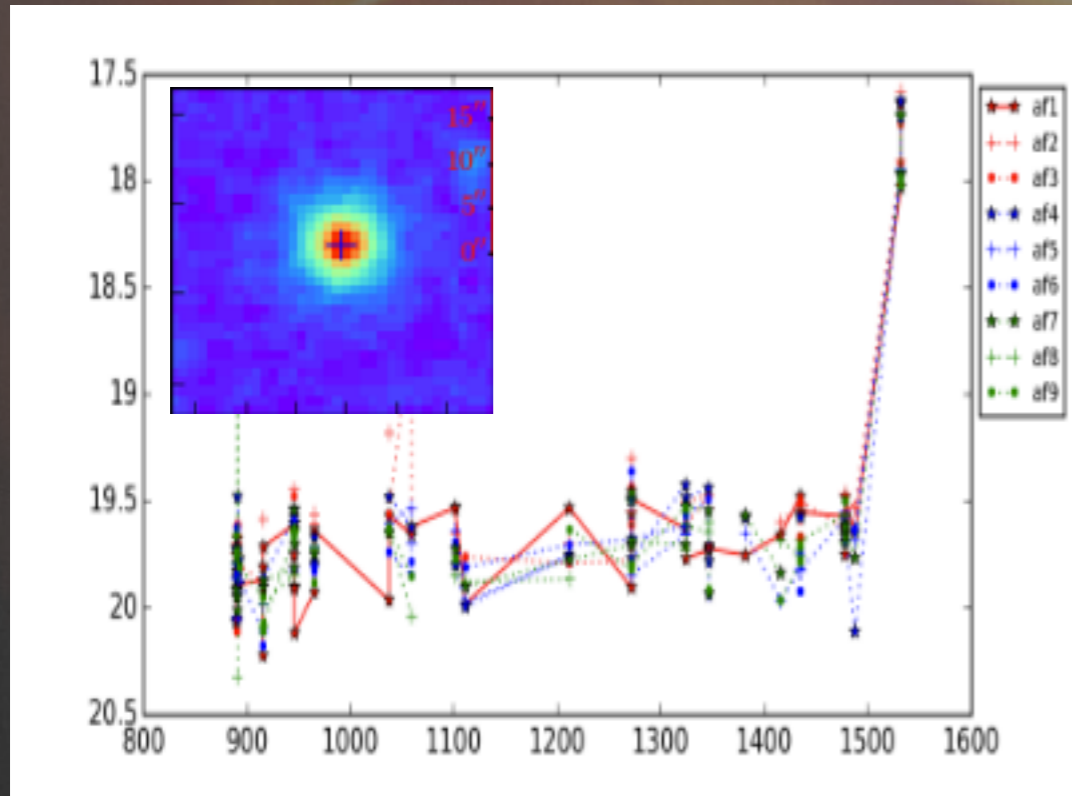
SMBH:  $10^{6.5}$  MSun, star: 0.3 MSun

**TDE in a weakly active SMBH?  
left-overs from previous TDE?**

**Bias in optical-TDEs selection?**

# Nuclear transients in Gaia

Gaia's advantage: superb astrometry

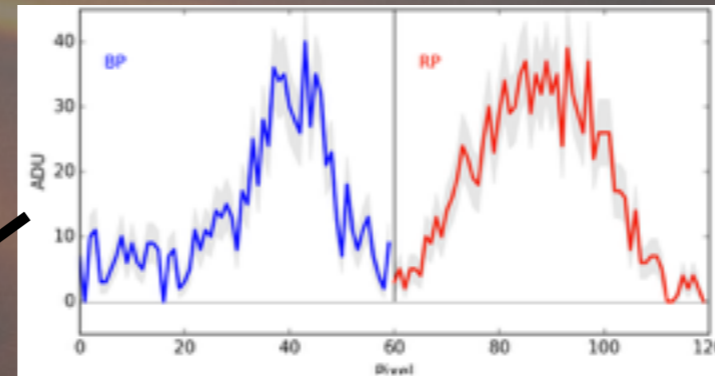
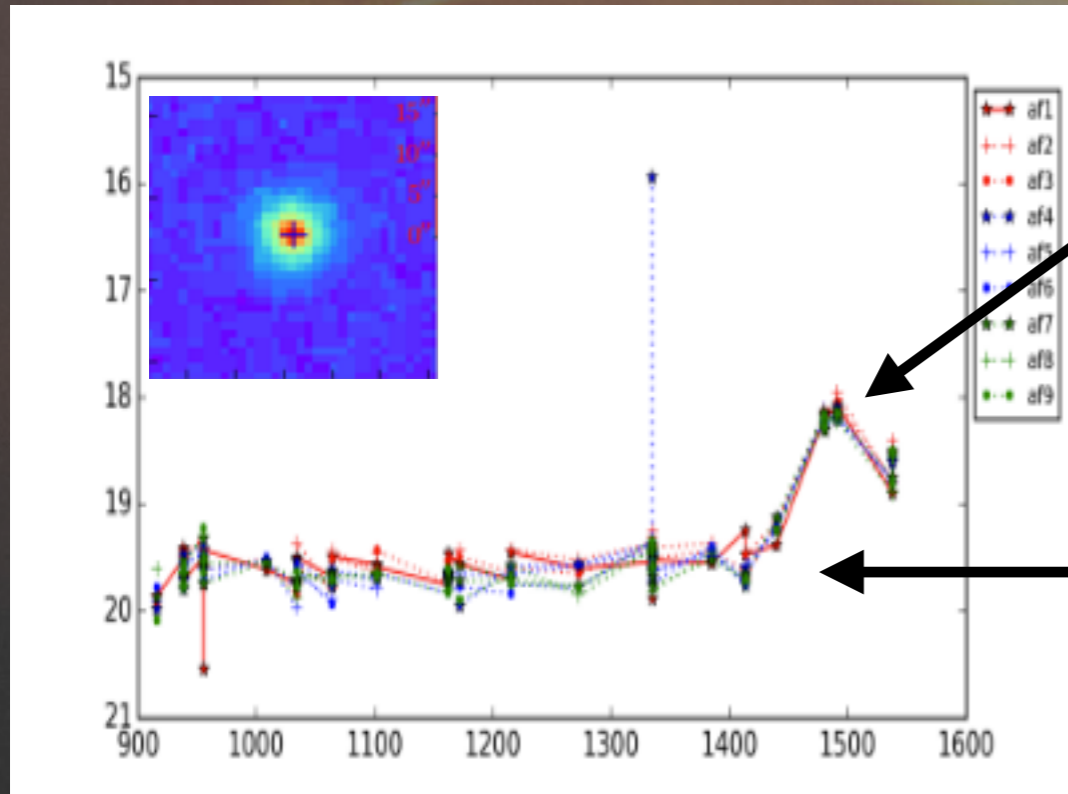


raw public Gaia data!

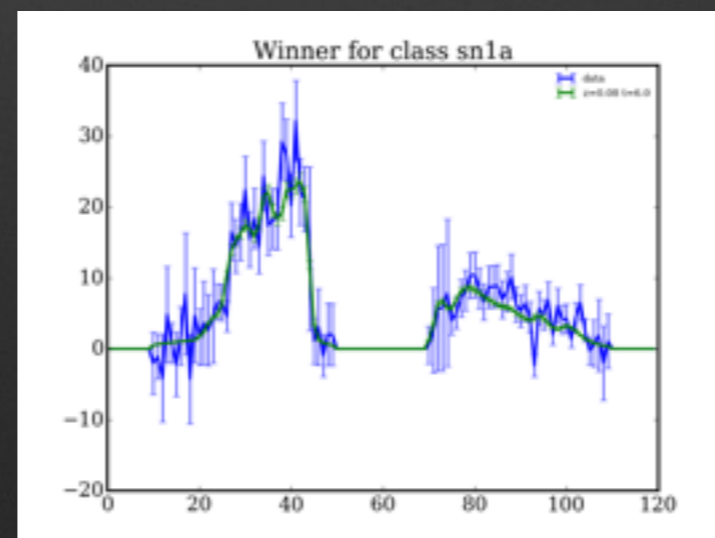
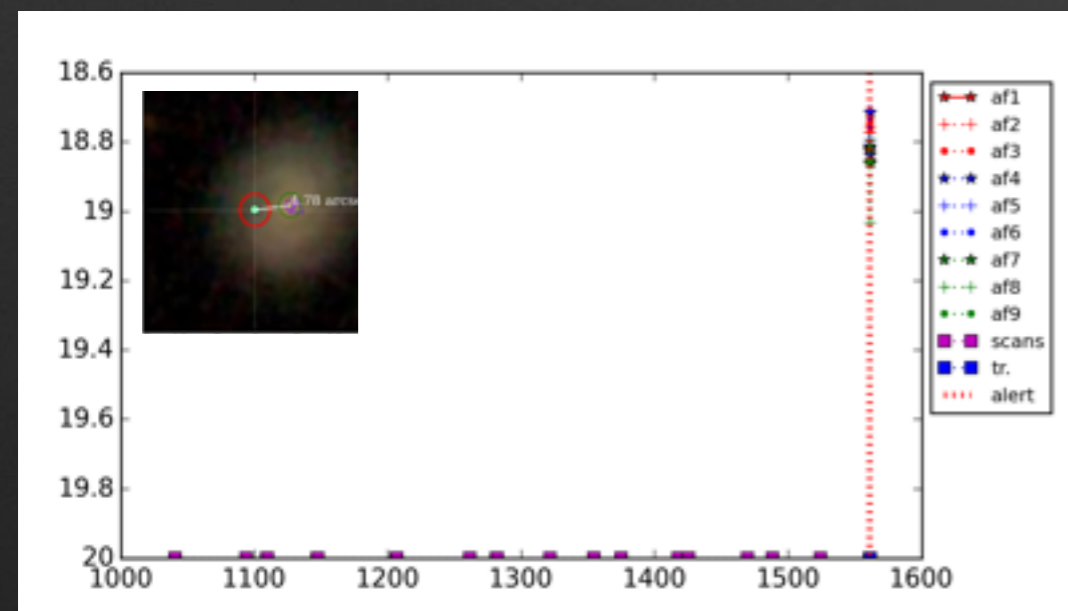
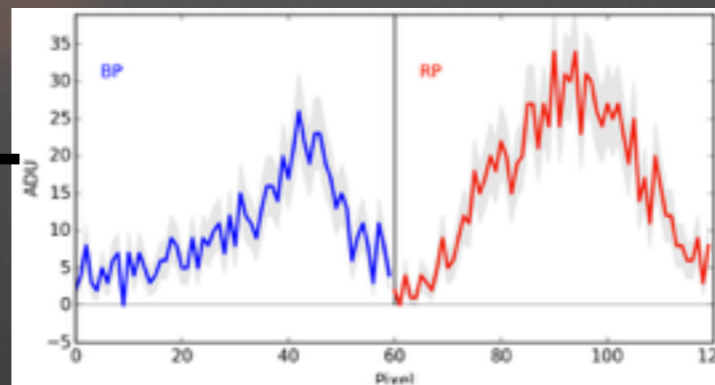


# Nuclear transients in Gaia

Gaia's advantage: instantaneous low-res spectra



even raw BPRP spectra indicate the detected flare is blue

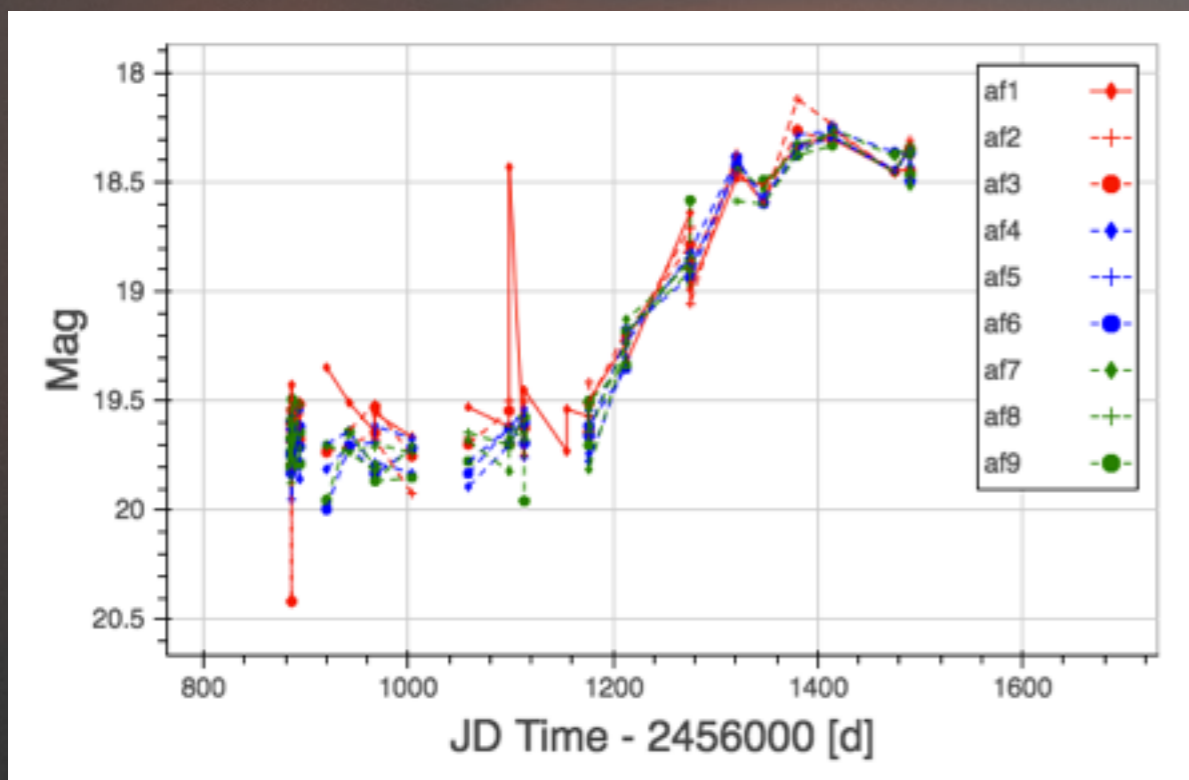


single BPRP spectra at <19mag can recognise SN Ia from other types

# Gaia16aax

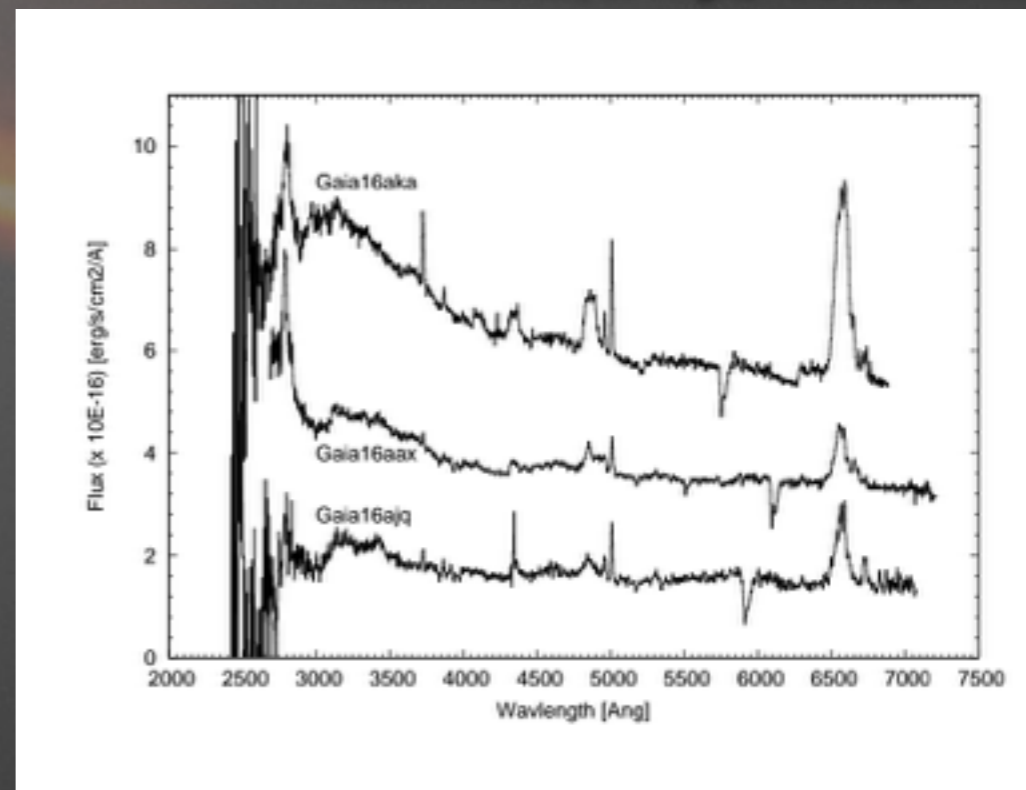
Changing-Look QSO or Stripping (Partial) TDE

with: P.Hewett, J.Pringle, P.Jonker, M.Fraser

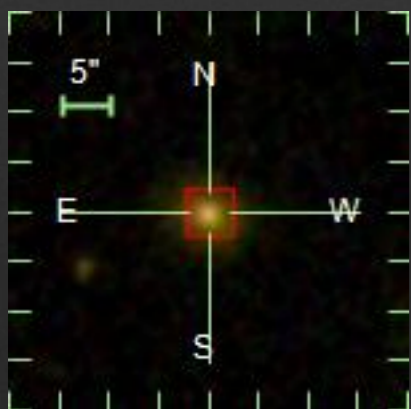


Gaia alert light curve

also:  
Gaia16aka  
Gaia16ajq



NUTS@NOT (Feb 2016)

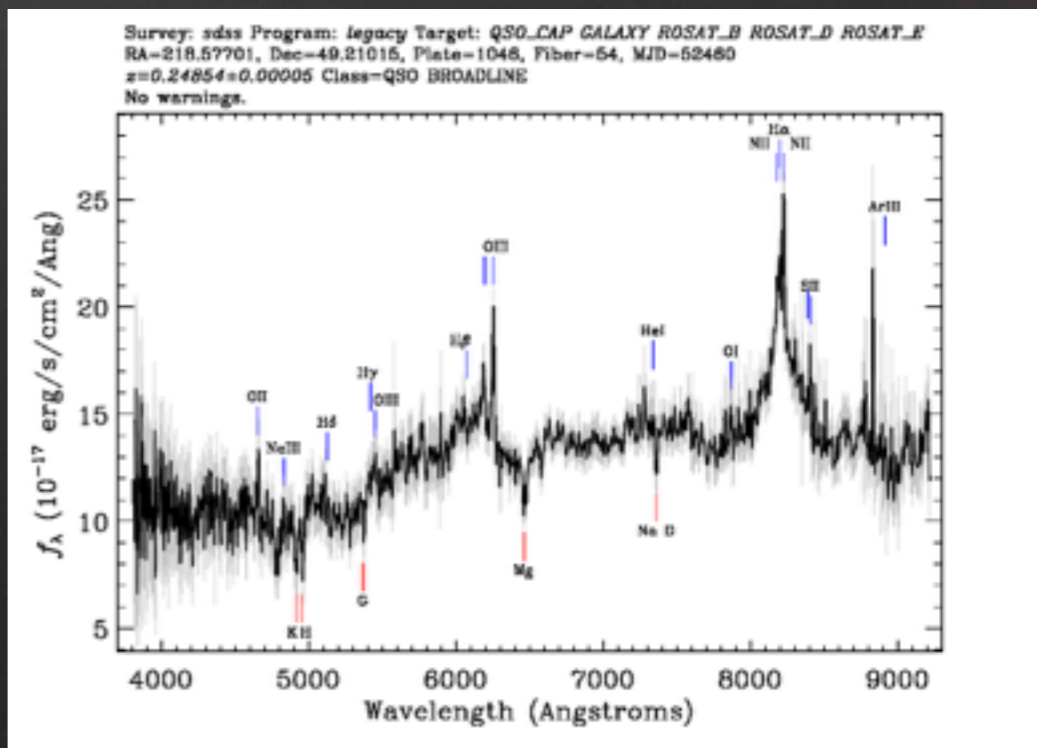


SDSS image

Light curve and spectra consistent with  $A_V=1$  mag change in extinction (hole in the dust?) but the time-scale way too short!

Follow-up: Gaia  
NOT, WHT (spec+grizJHK)  
XMM

work in progress



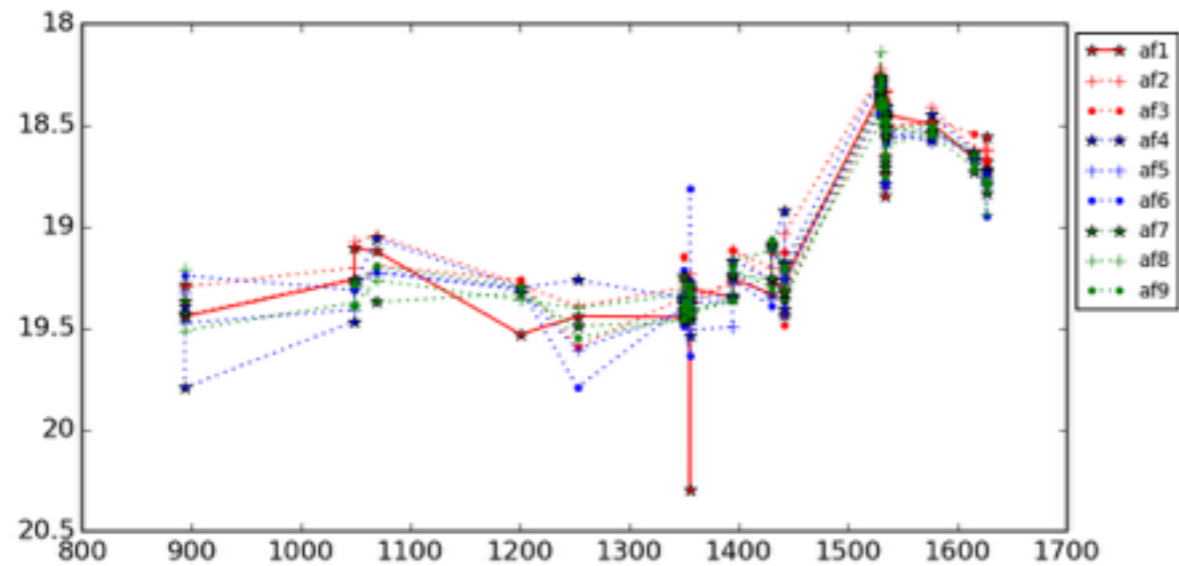
Archival (low-state) SDSS spectrum



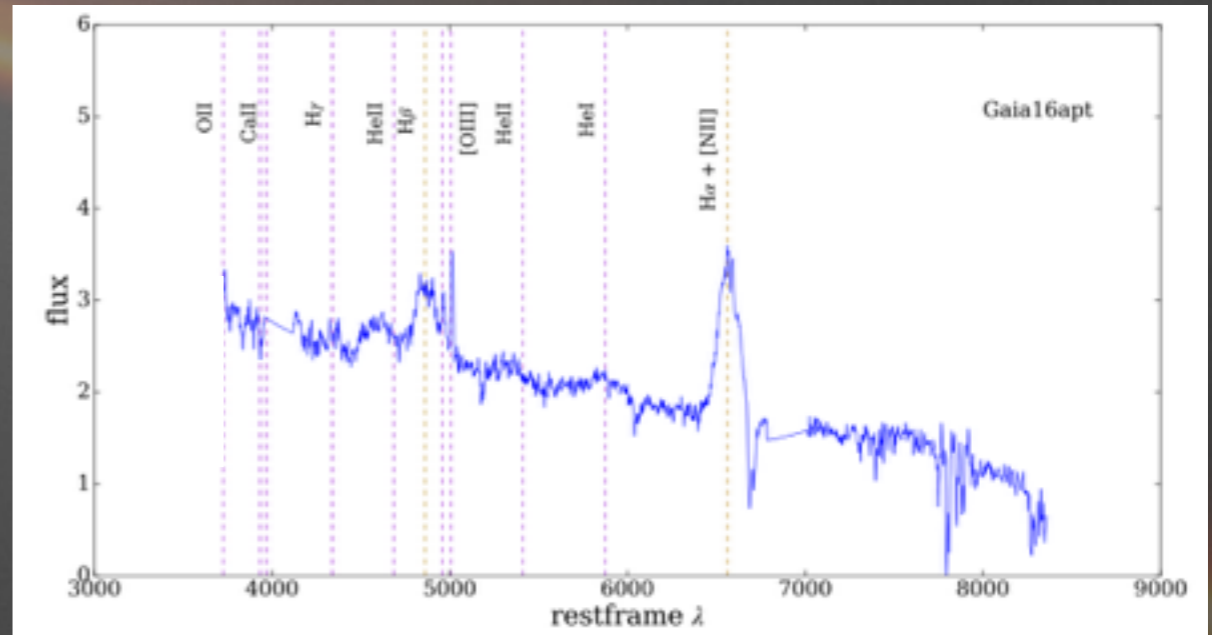
# Gaia16apt

## TDE? AGN Flare?

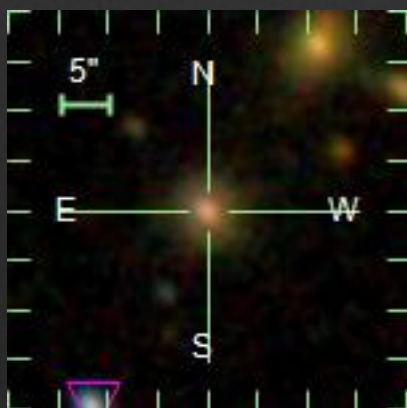
with: A.Hamanowicz, N.Britavsky



Gaia alert light curve



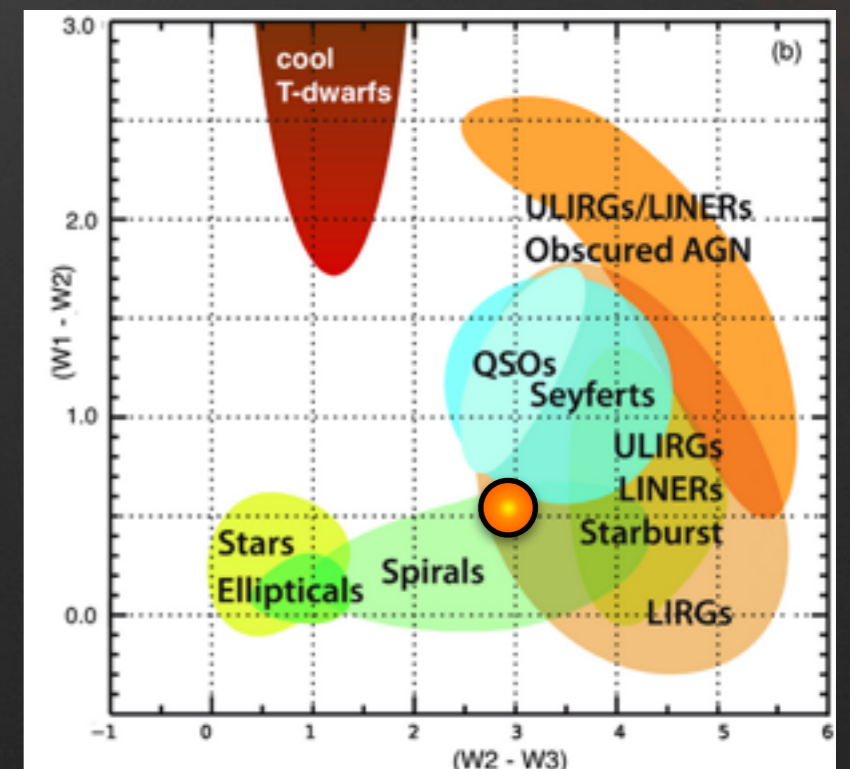
SALT spectrum, July 2016  
blue continuum, broad lines



SDSS image

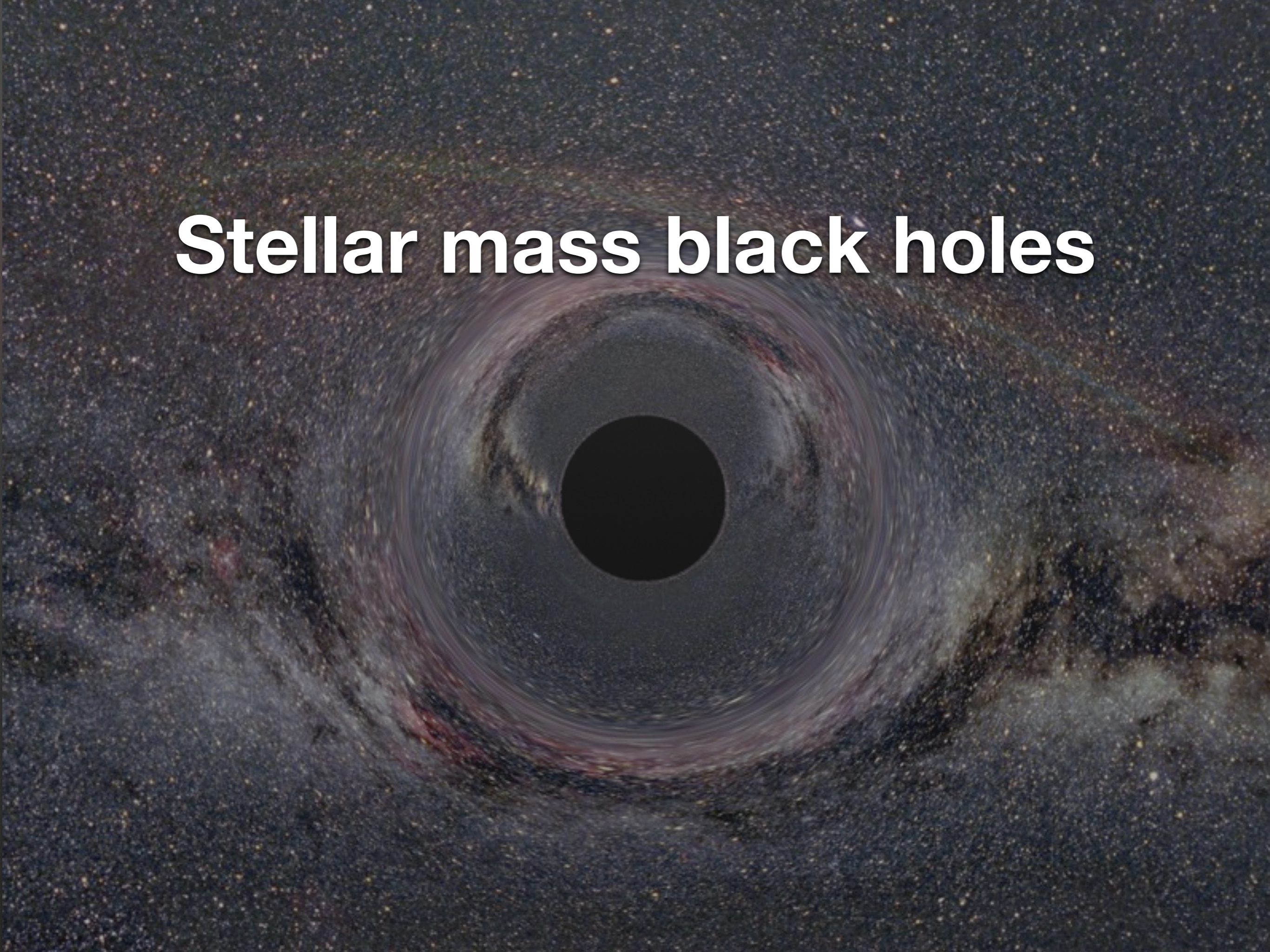
1 mag flare, slow decline  
WISE colours = AGN Flare?  
broad Ha, Hb, HeII?  
 $z=0.136$   
abs mag about -19.6 (no host)

work in progress





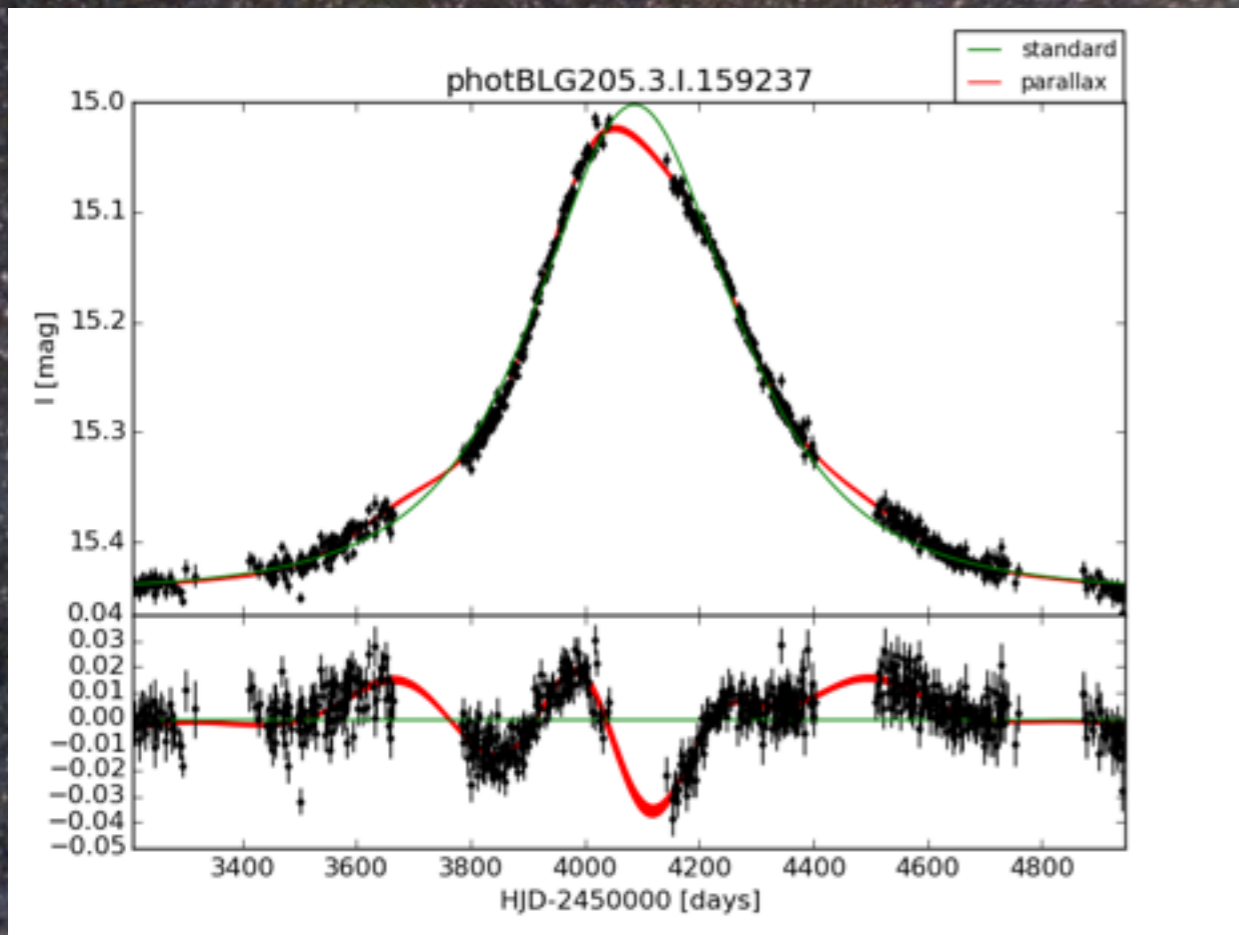
# Stellar mass black holes





# Stellar mass black holes

OGLE3-ULENS-PAR-02 - candidate  $\sim 9M_{\text{Sun}}$  BH



OGLE photometry  
from 2001-2008  
and microlensing model

Mass, Distance

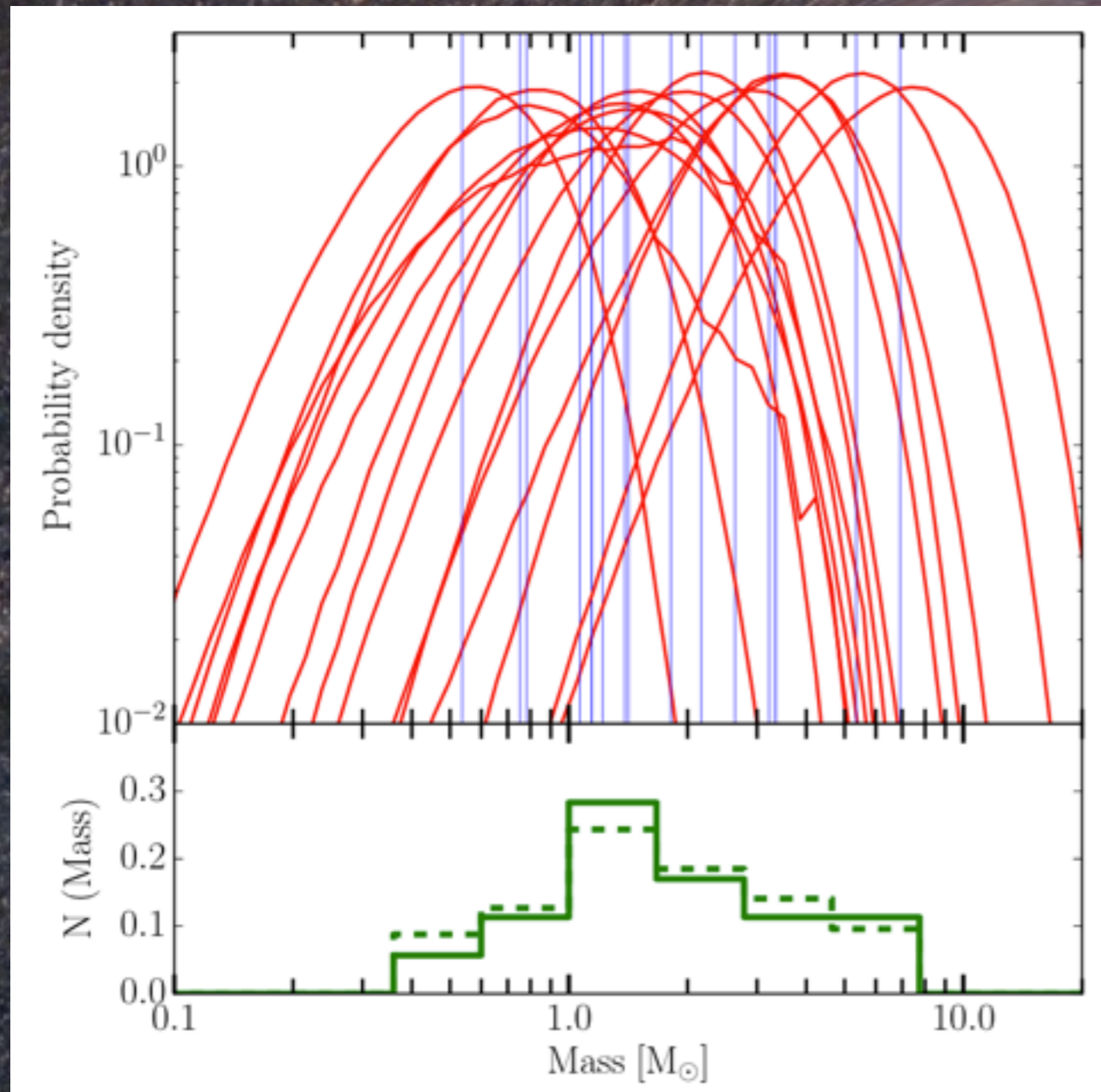
(estimate)



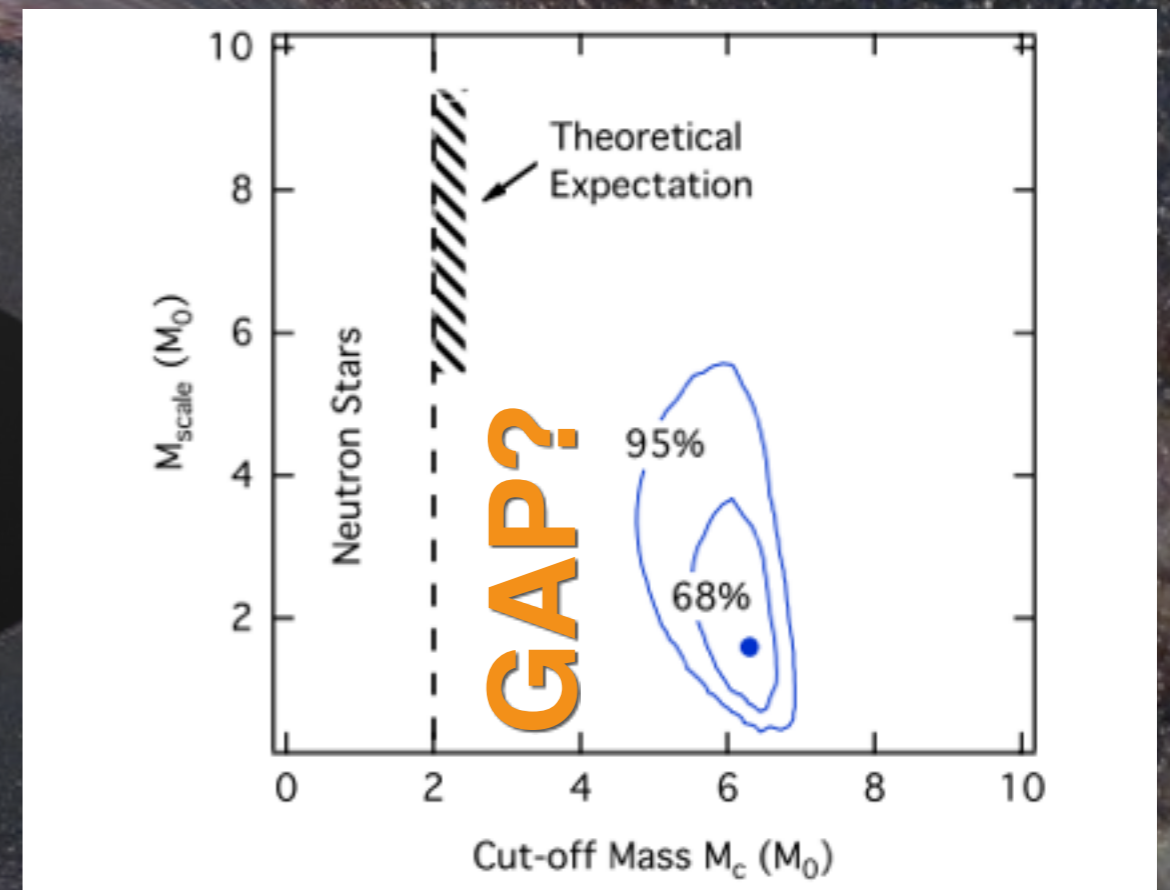
# Stellar mass black holes

OGLE-III long microlensing events with parallax effect

single



binary systems

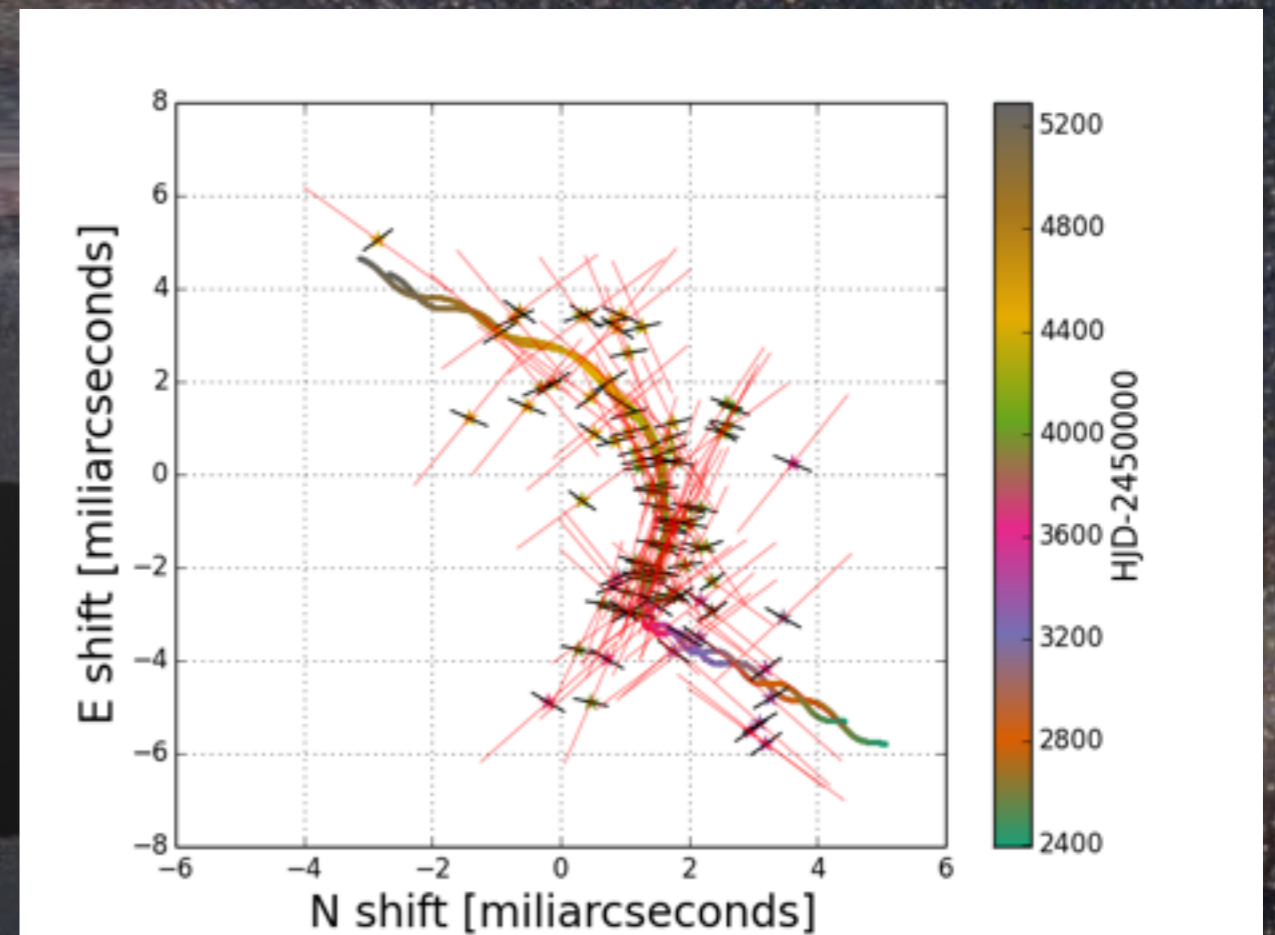
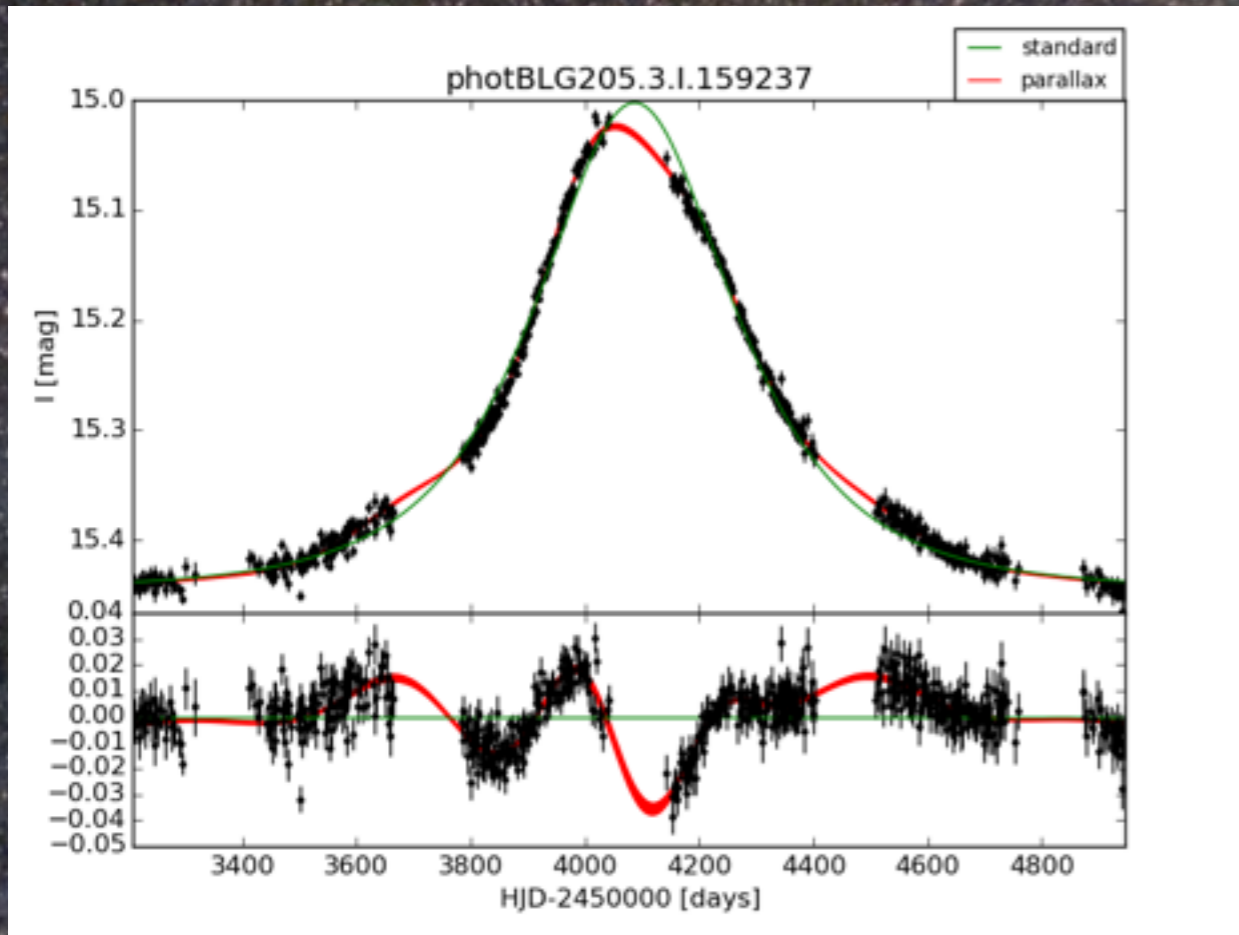


Ozel+2010



# Stellar mass black holes

OGLE3-ULENS-PAR-02 - candidate  $\sim 9M_{\text{Sun}}$  BH



OGLE photometry  
from 2001-2008  
and microlensing model

predicted  
Gaia astrometry  
for similar event

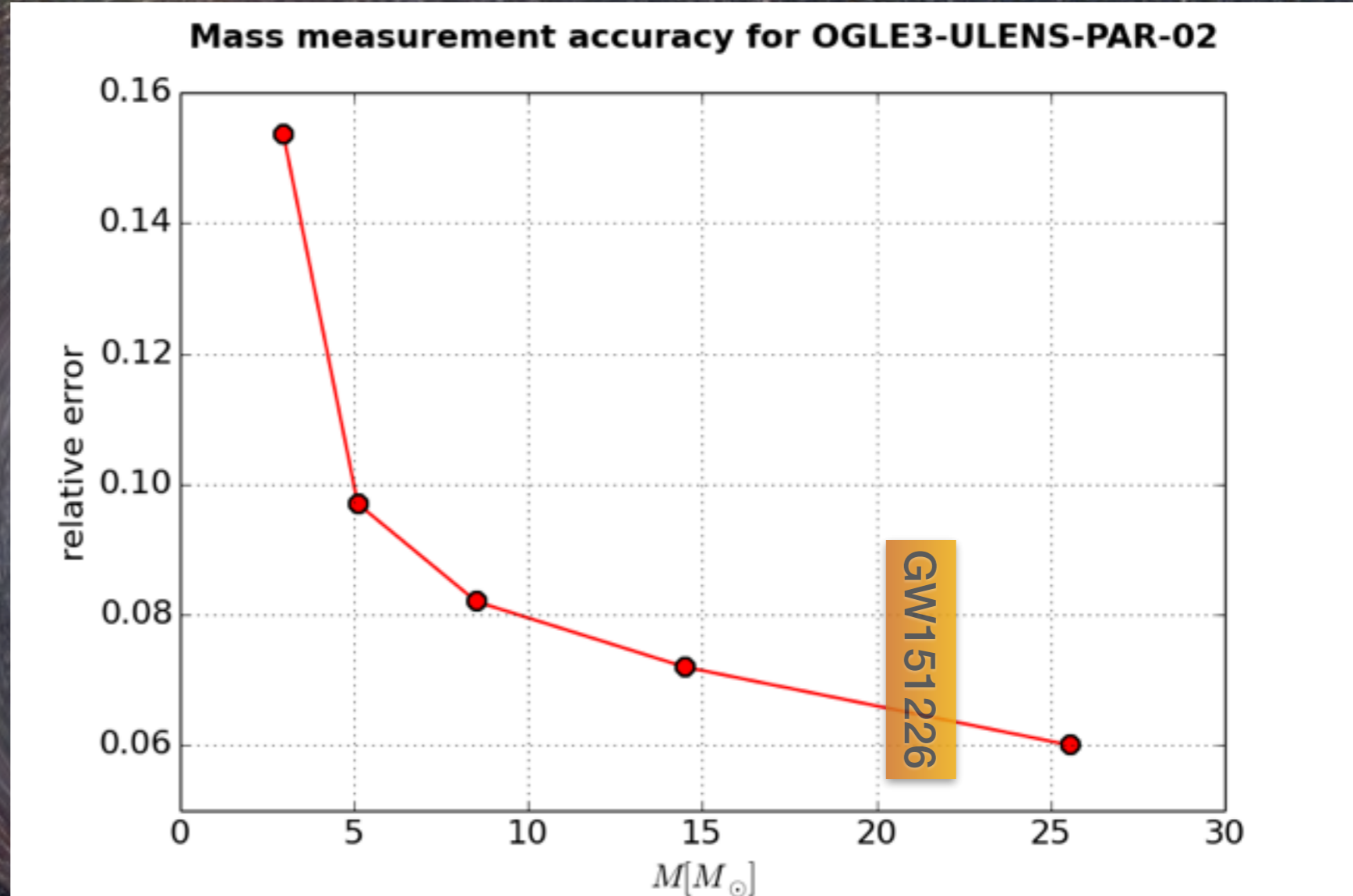
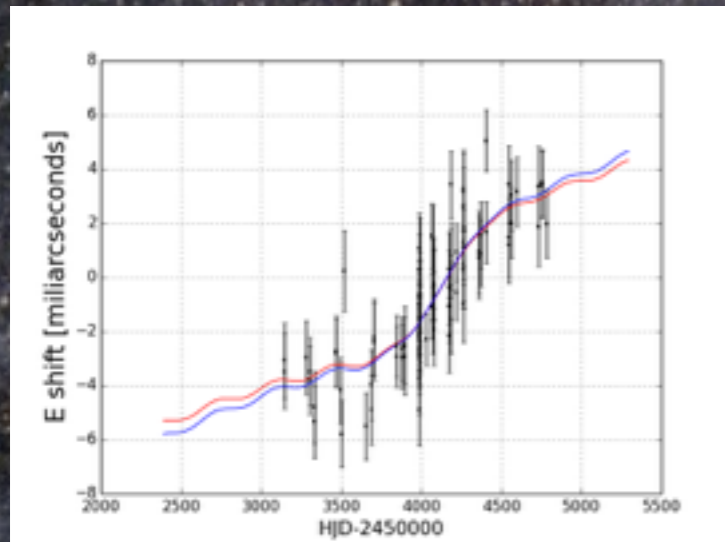
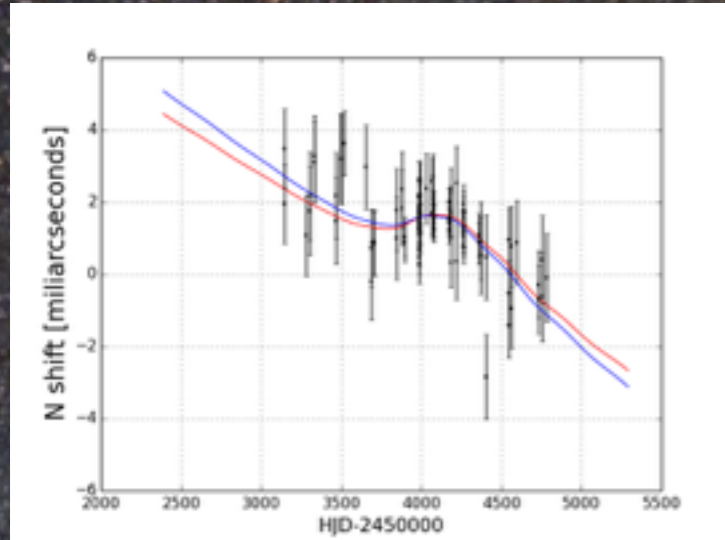


**Mass, Distance**



# Stellar mass black holes

OGLE3-ULENS-PAR-02 - candidate  $\sim 9M_{\text{Sun}}$  BH



Combination of ground-based photometry and Gaia astrometry for long events will yield masses of black holes accurate to  $\sim 1\%$  percent.



# Summary

- OGLE and Gaia are well suited for finding transients in galaxy centres
- Superb astrometry (Gaia, OGLE)  
Instantaneous low-res spectra (Gaia)
- TDEs can be found also around active black holes (OGLE16aaa) - TDE rate bias?
- Future: spectral follow-up of candidates on VLT, SALT, NOT, WHT
- Gaia will help find galactic single/binary stellar mass BHs via microlensing



A glowing orange and yellow light streak curves across the upper portion of the image against a dark background. The light has a soft, ethereal quality with some internal texture, suggesting a plasma or energy stream. The rest of the image is mostly black, with some faint, darker orange tones in the lower-left quadrant.

**THANK YOU!**