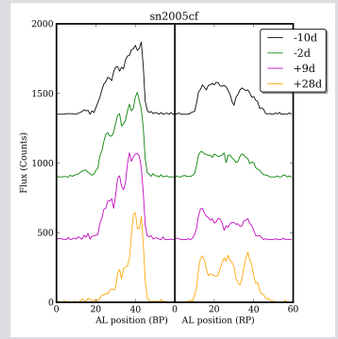


Nuclear transients with Gaia

IoA, SEES, 24th September 2015

Nadejda Blagorodnova

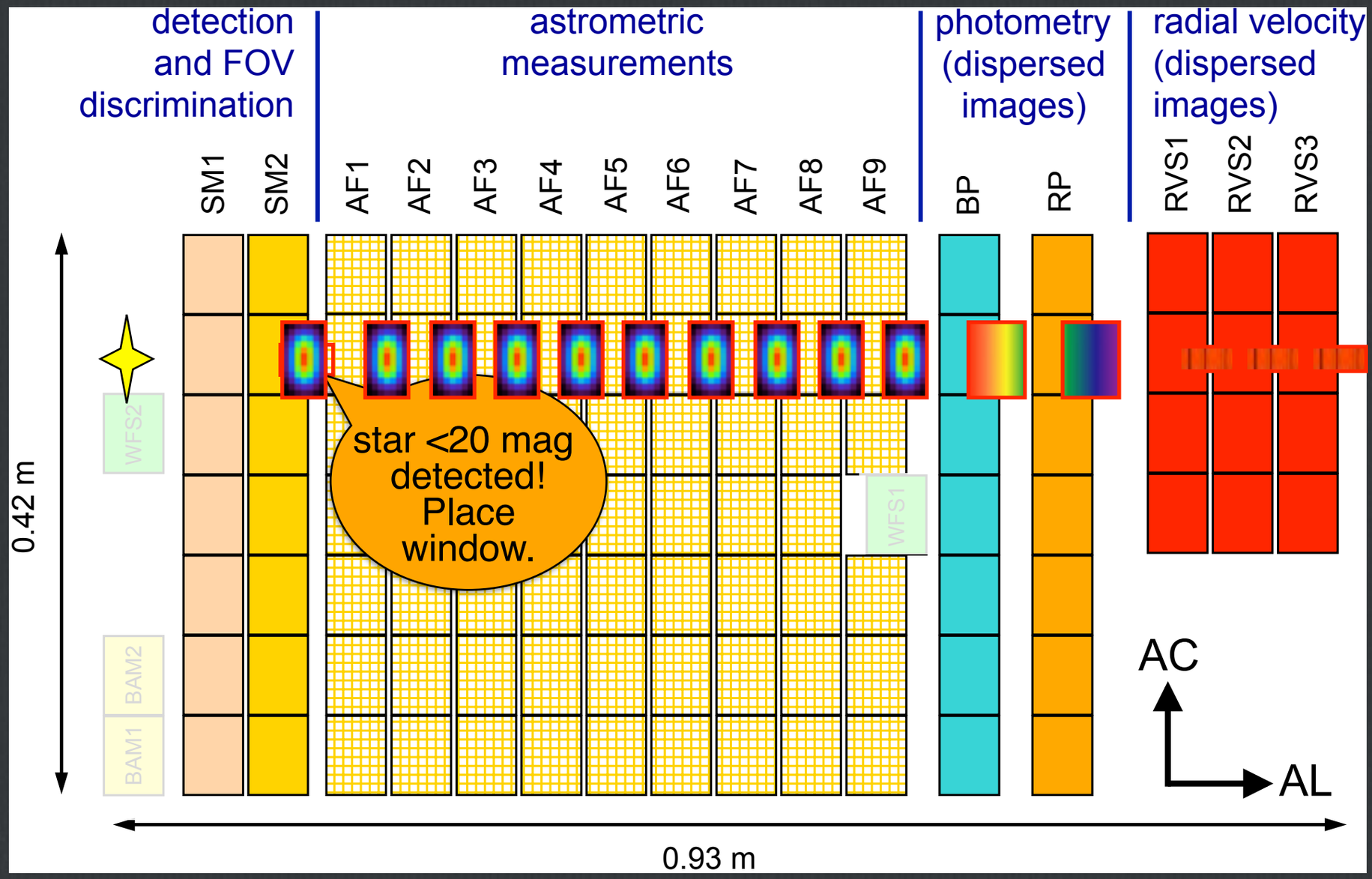
& Gaia Science Alerts DPAC team

Single Gaia observation = Transit

Camera:

0.75 deg²

pixel:
10x30 μm
(59x177 mas)

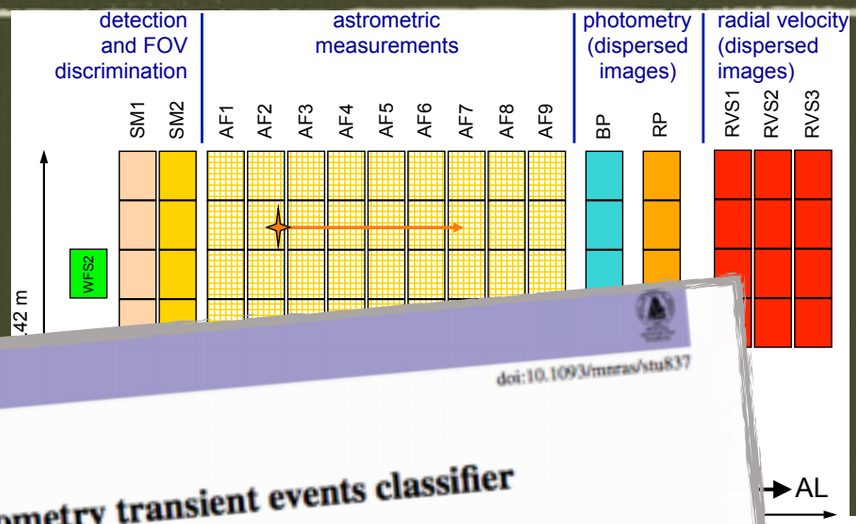


Animation by Berry Holl, Geneva

windows observed:

~4.4 sec

~45 sec



Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS 442, 327–342 (2014)
doi:10.1093/mnras/stu837

GS-TEC: the *Gaia* spectrophotometry transient events classifier

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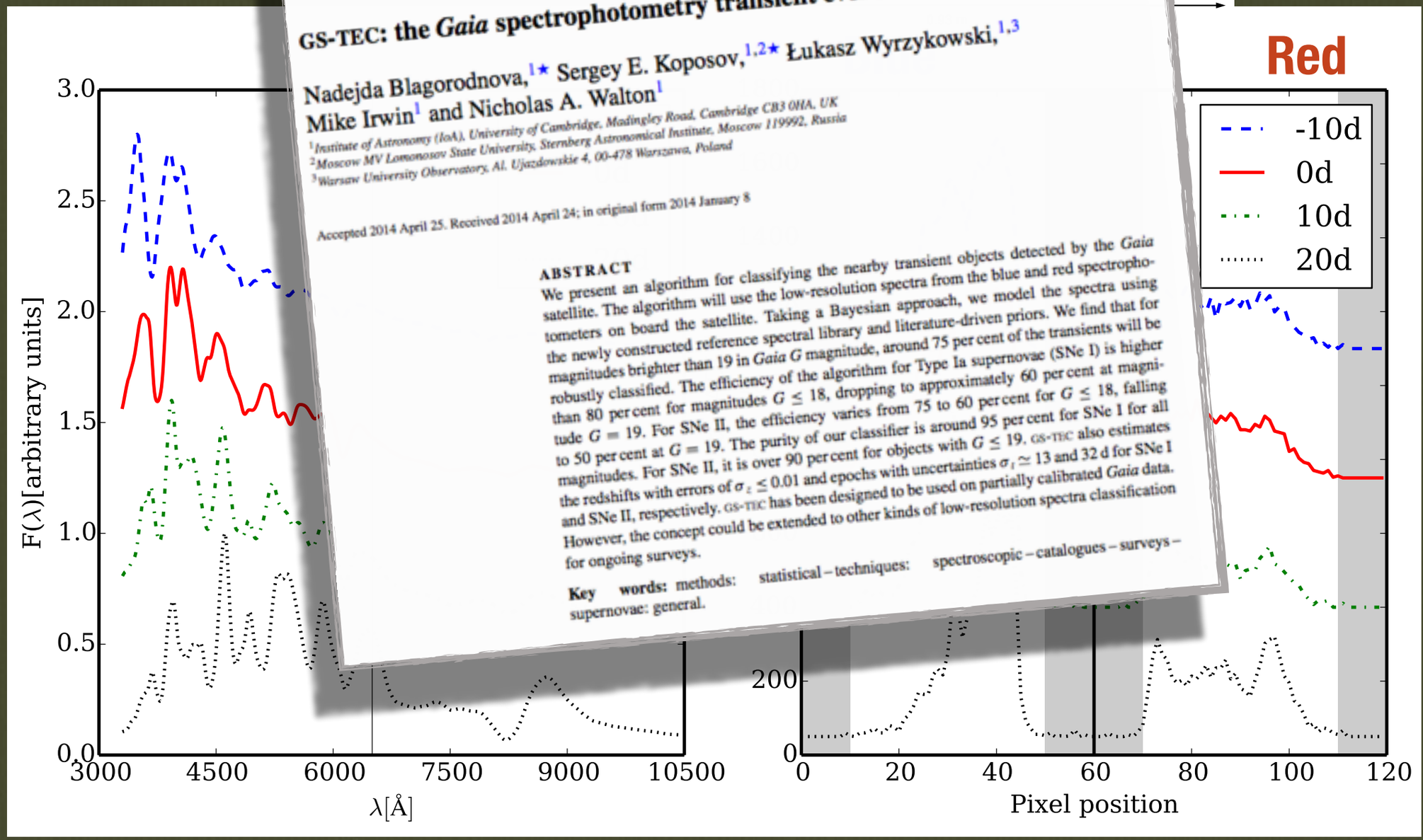
ABSTRACT

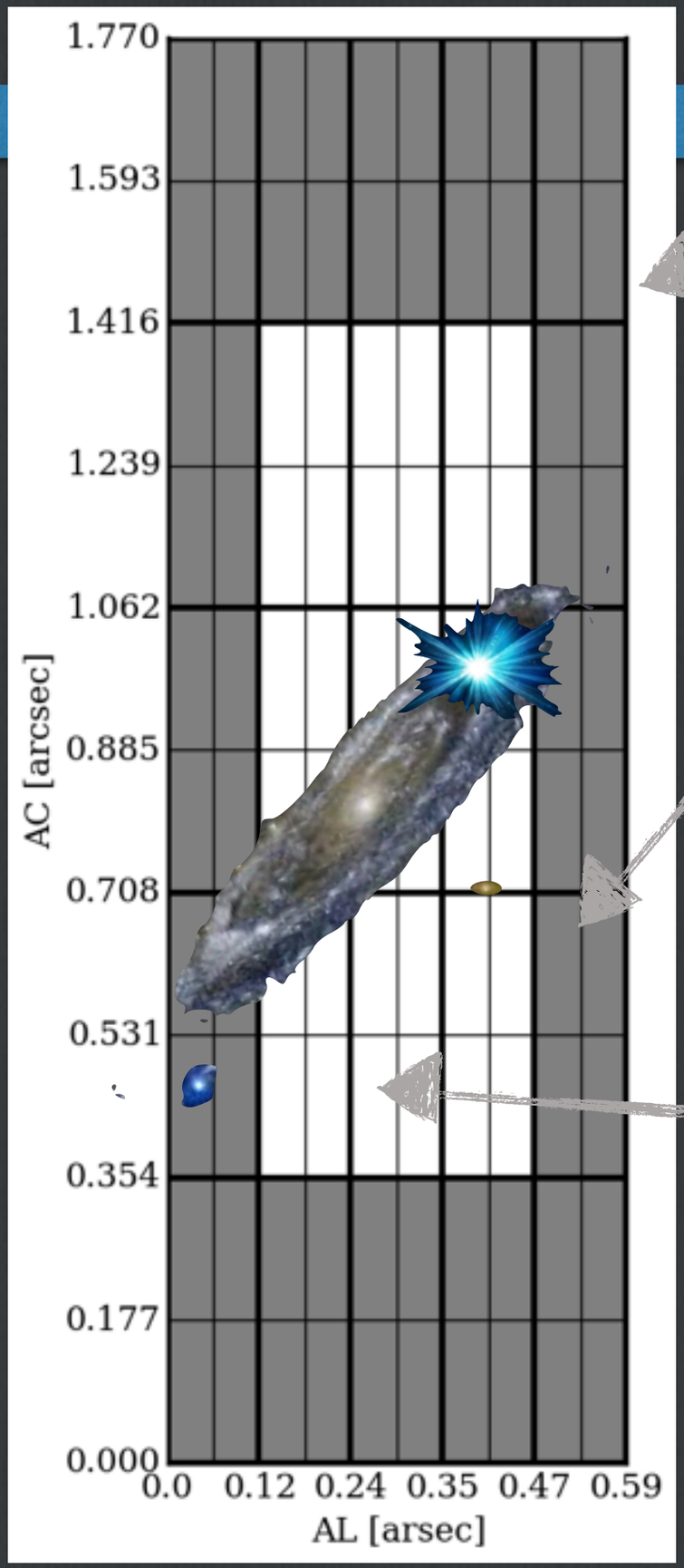
We present an algorithm for classifying the nearby transient objects detected by the *Gaia* satellite. The algorithm will use the low-resolution spectra from the blue and red spectrophotometers on board the satellite. Taking a Bayesian approach, we model the spectra using the newly constructed reference spectral library and literature-driven priors. We find that for magnitudes brighter than 19 in *Gaia G* magnitude, around 75 per cent of the transients will be robustly classified. The efficiency of the algorithm for Type Ia supernovae (SNe I) is higher than 80 per cent for magnitudes $G \leq 18$, dropping to approximately 60 per cent at magnitude $G = 19$. For SNe II, the efficiency varies from 75 to 60 per cent for $G \leq 18$, falling to 50 per cent at $G = 19$. The purity of our classifier is around 95 per cent for SNe I for all magnitudes. For SNe II, it is over 90 per cent for objects with $G \leq 19$. GS-TEC also estimates the redshifts with errors of $\sigma_z \leq 0.01$ and epochs with uncertainties $\sigma_t \simeq 13$ and 32 d for SNe I and SNe II, respectively. GS-TEC has been designed to be used on partially calibrated *Gaia* data. However, the concept could be extended to other kinds of low-resolution spectra classification for ongoing surveys.

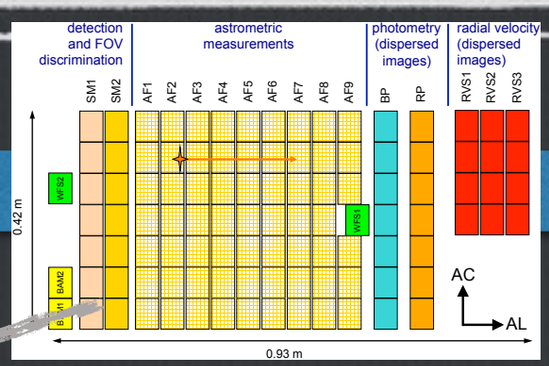
Key words: methods: statistical – techniques: spectroscopic – catalogues – surveys – supernovae: general.



SNIa templates from Hsiao et. al 2007

How good is Gaia detecting nuclear transits?



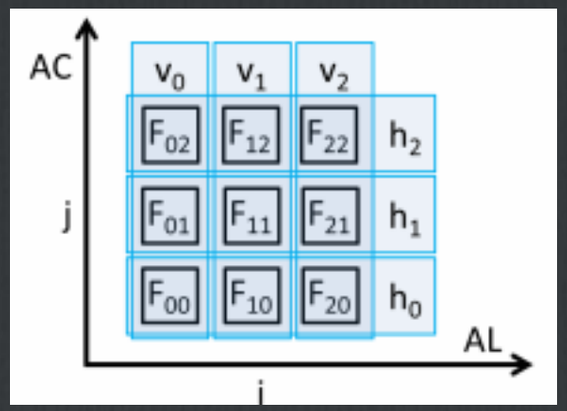


Scan motion

Background estimation:

- 5th lowest value of 16 samples
- Background subtracted from central 3x3

Source detection 3x3 window

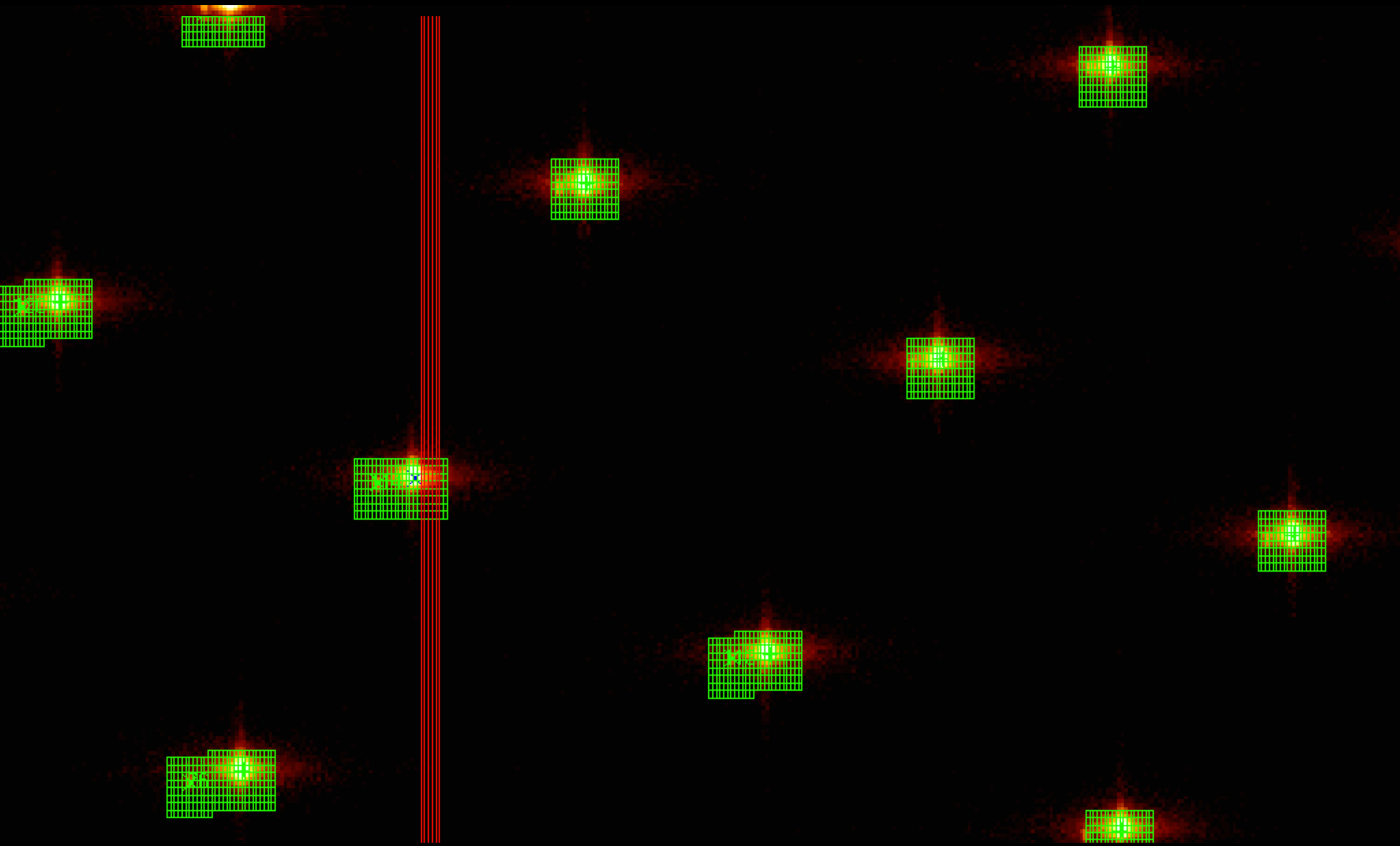


Flux estimation

The Gaia Sky

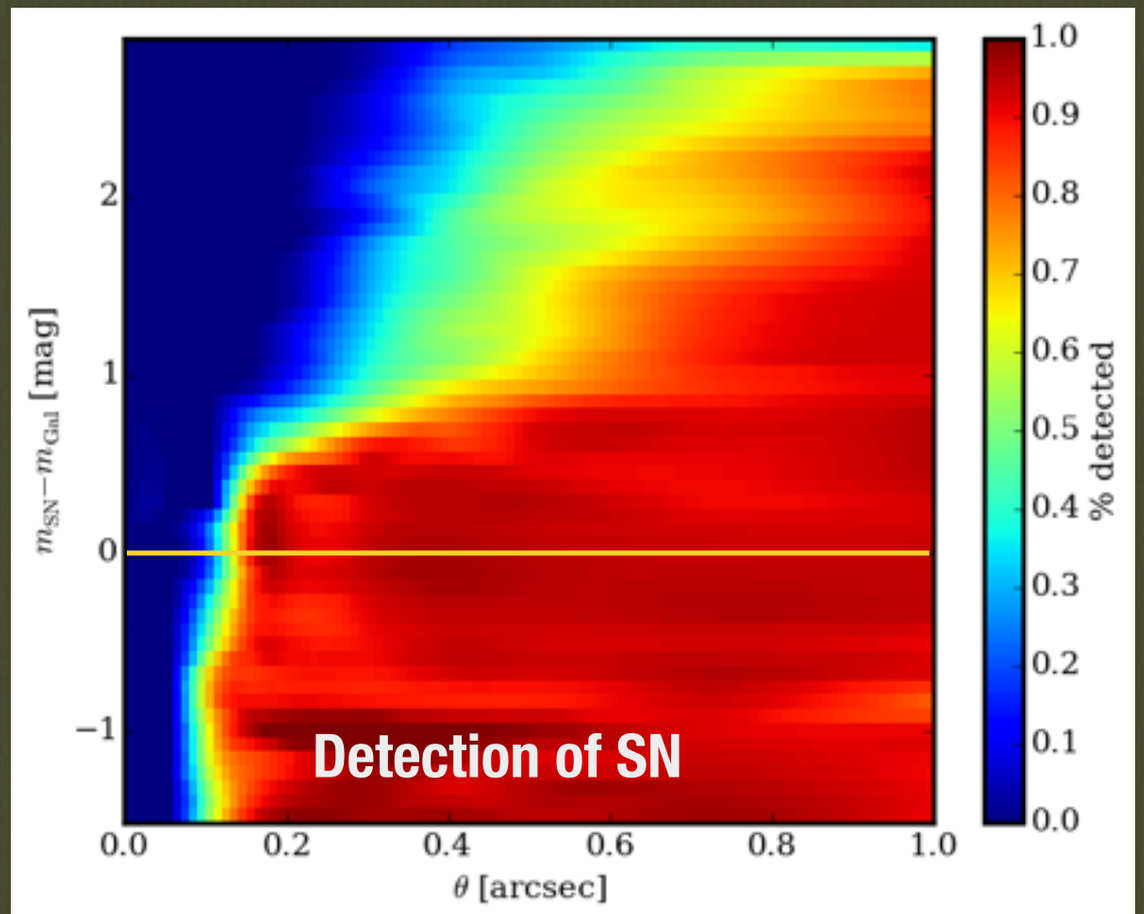
Simulated view of R136 (Jos de Bruijne and Guido de Marchi

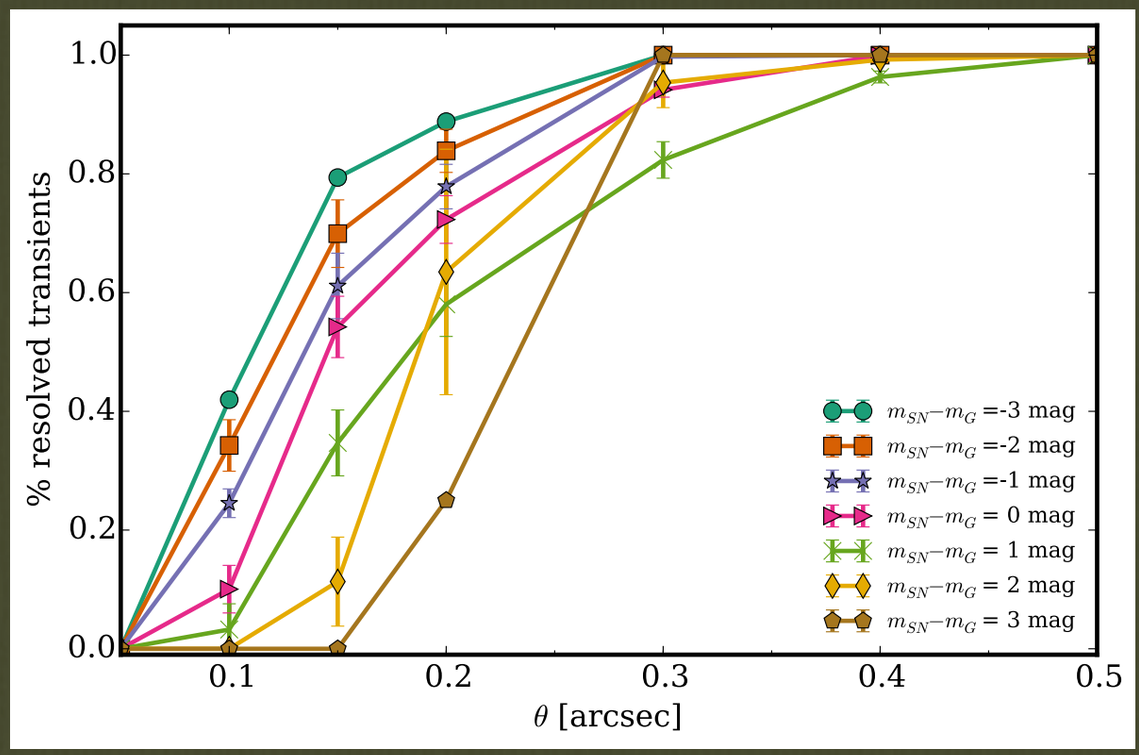
GIBIS: Gaia Instrument and Basic Image Simulator



Detecting resolved transients

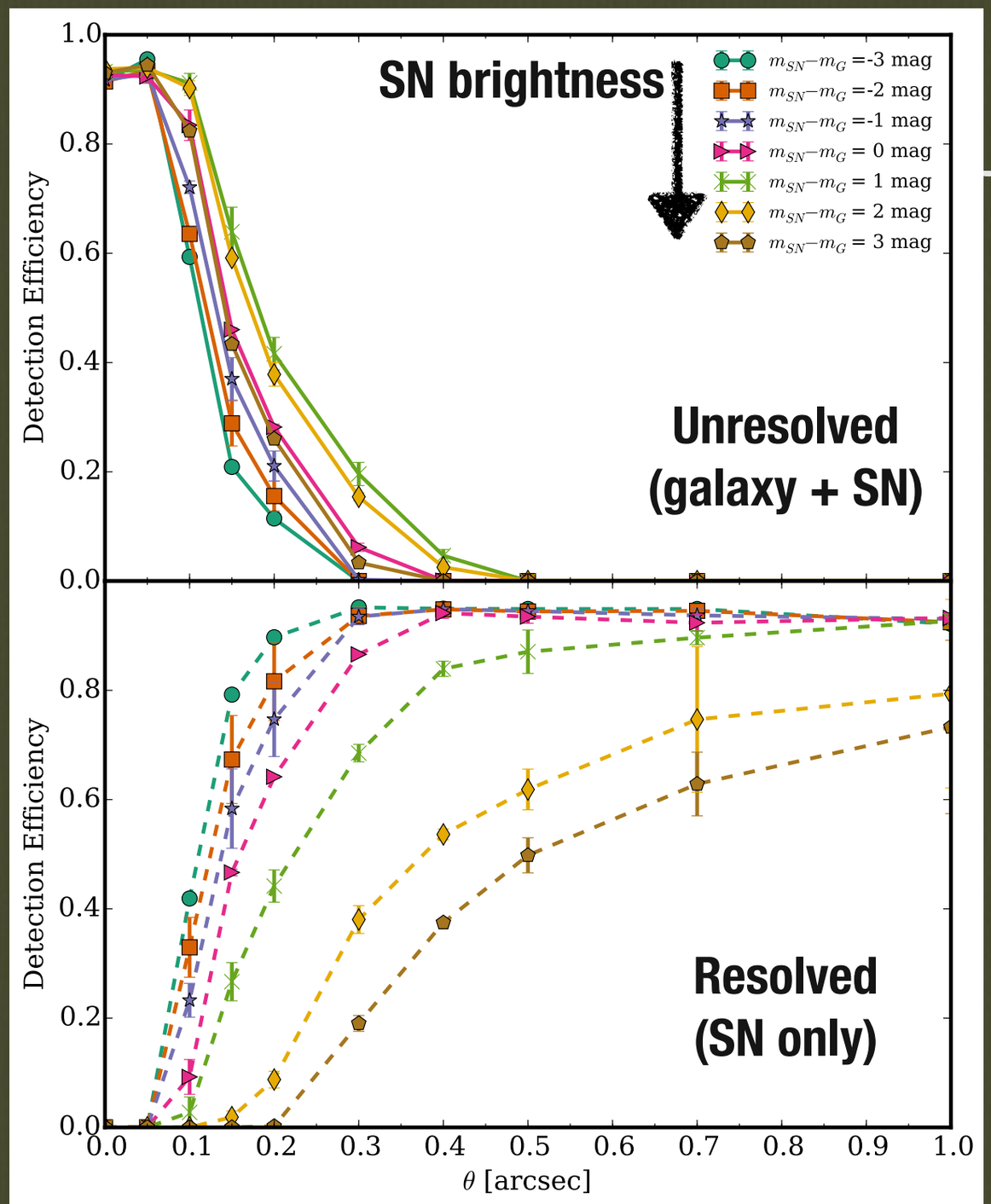
Bulge is brighter

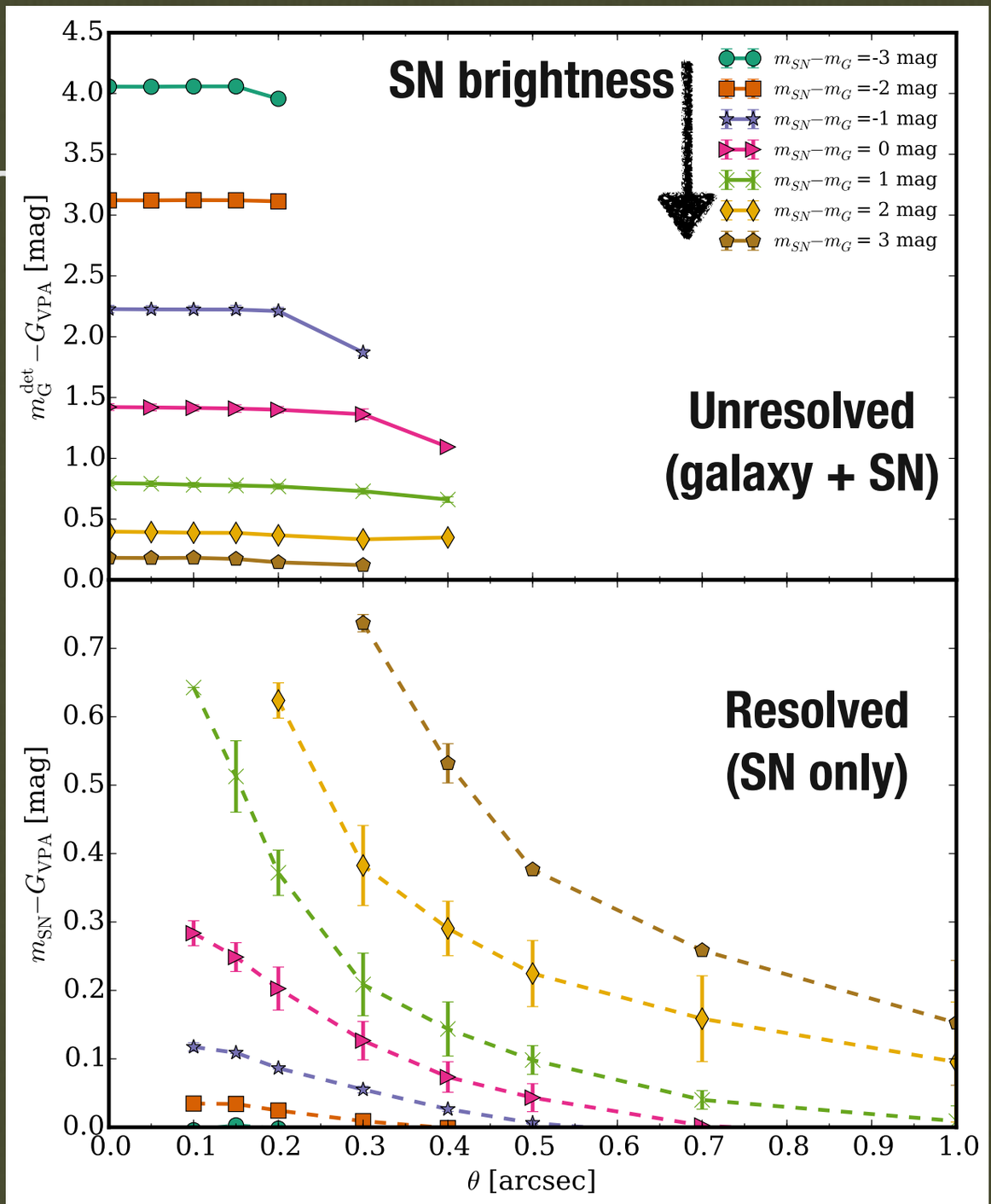




SN is brighter

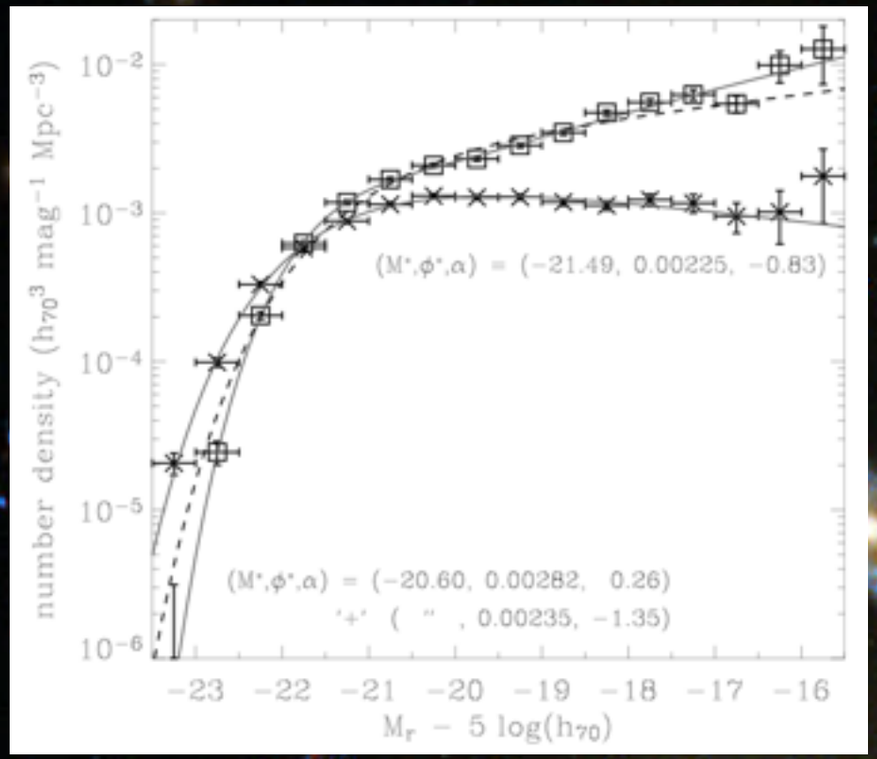
Simulation for a 17.5 mag bulge with Re=1 arc sec


SN brightness
$m_{SN}-m_G$ =-3 mag
$m_{SN}-m_G$ =-2 mag
$m_{SN}-m_G$ =-1 mag
$m_{SN}-m_G$ = 0 mag
$m_{SN}-m_G$ = 1 mag
$m_{SN}-m_G$ = 2 mag
$m_{SN}-m_G$ = 3 mag
Unresolved
(galaxy + SN)
Resolved
(SN only)
Detection Efficiency
θ [arcsec]

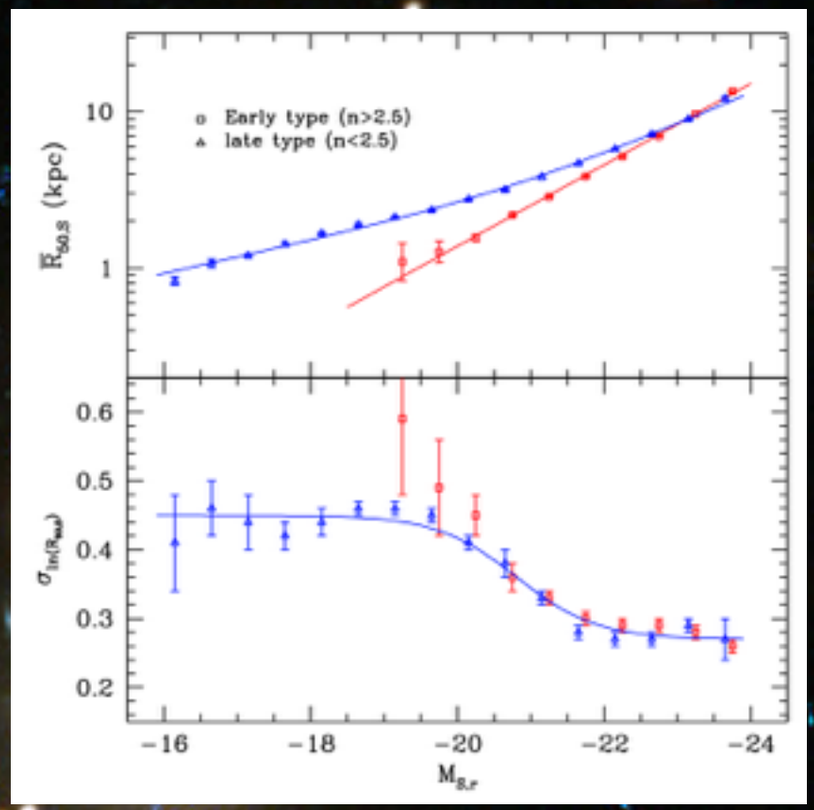

SN brightness
$m_{SN}-m_G$ =-3 mag
$m_{SN}-m_G$ =-2 mag
$m_{SN}-m_G$ =-1 mag
$m_{SN}-m_G$ = 0 mag
$m_{SN}-m_G$ = 1 mag
$m_{SN}-m_G$ = 2 mag
$m_{SN}-m_G$ = 3 mag
Unresolved
(galaxy + SN)
Resolved
(SN only)
$m_G^{\rm det}-G_{\rm VPA}$ [mag]
$m_{\rm SN}-G_{\rm VPA}$ [mag]
θ [arcsec]

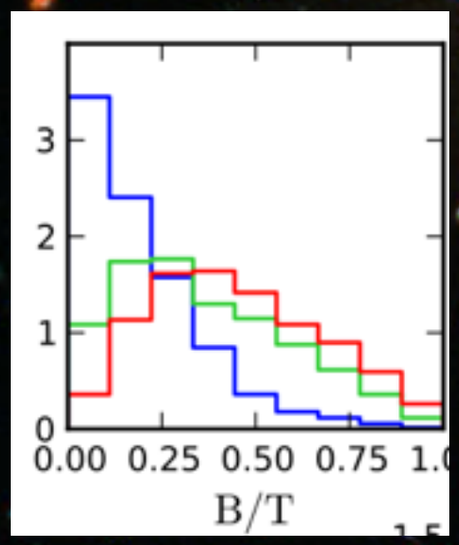
How this affects the detectability of transients?

Galaxy LF: Baldry et. al. 2004



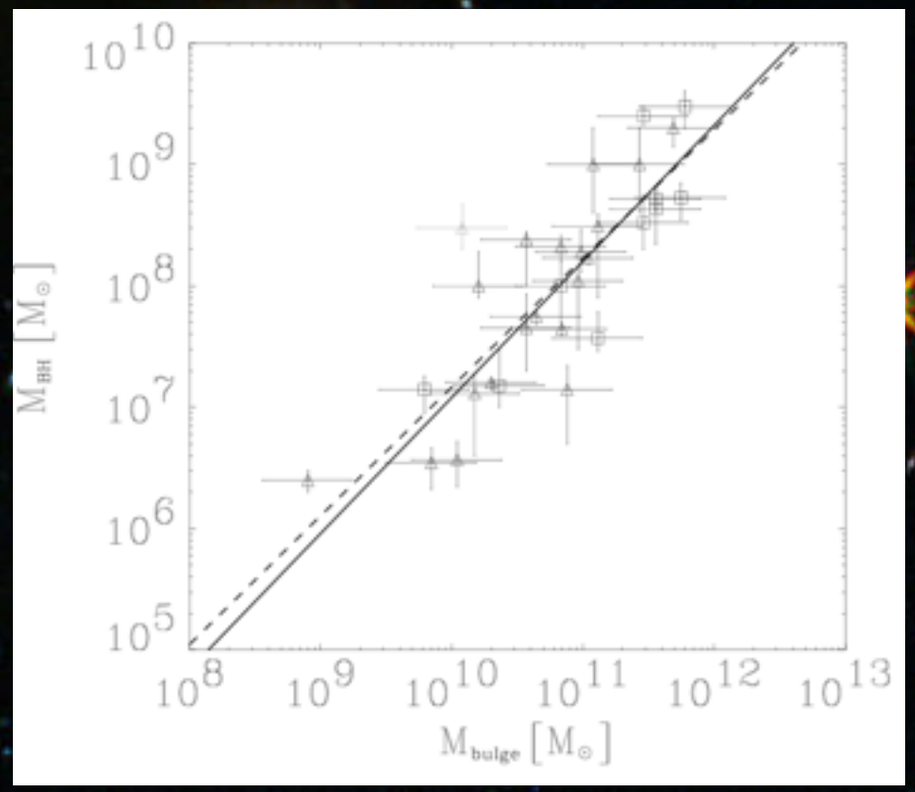
Galaxy size: Shen et. al. 2003



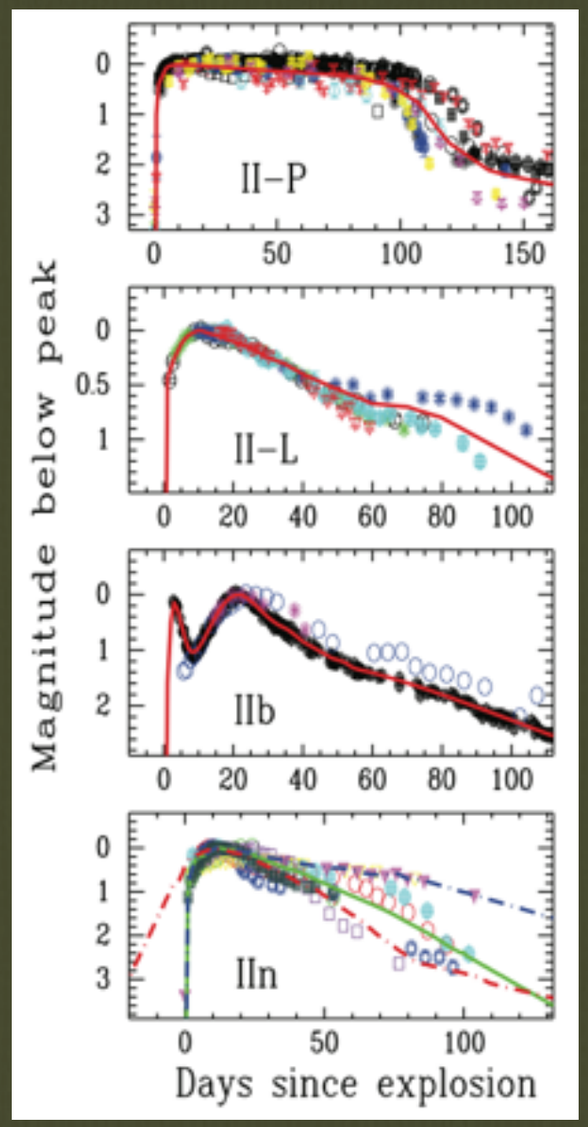


B/T: Lackner & Gunn, 2011

MBH: Haring & Rix, 2004



Transient Characterisation

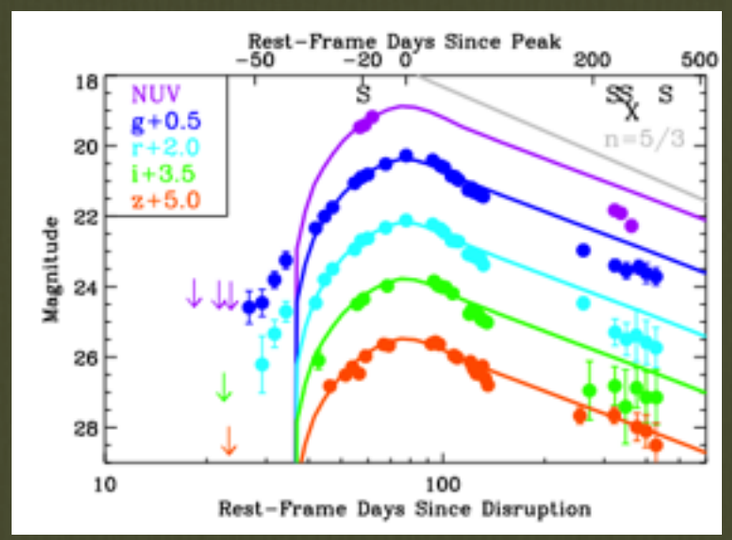


Li et. al. 2011

- SN rates per galaxy
- Absolute magnitude distribution
- Rates per galaxy type

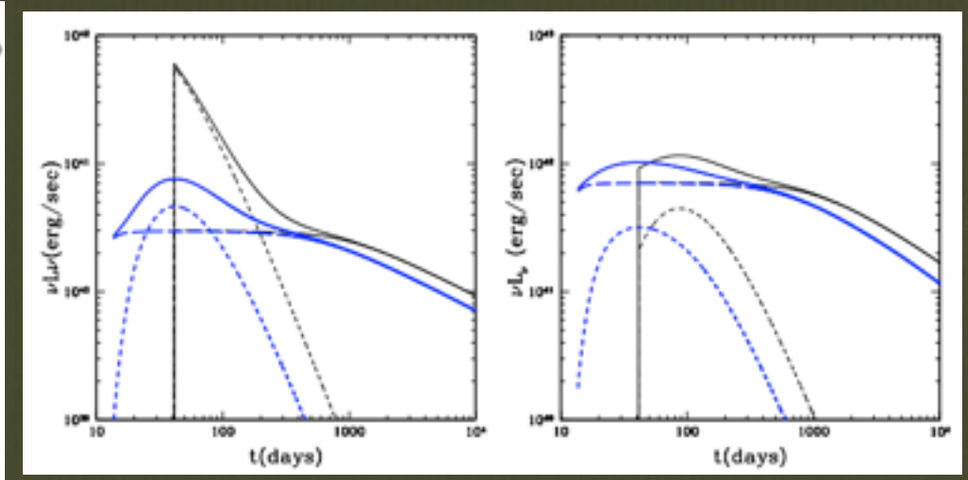
Gezari et. al. 2012, Chornock et. al. 2014

- TDE Lightcurves from PS1



Lodato and Rossi, 2011

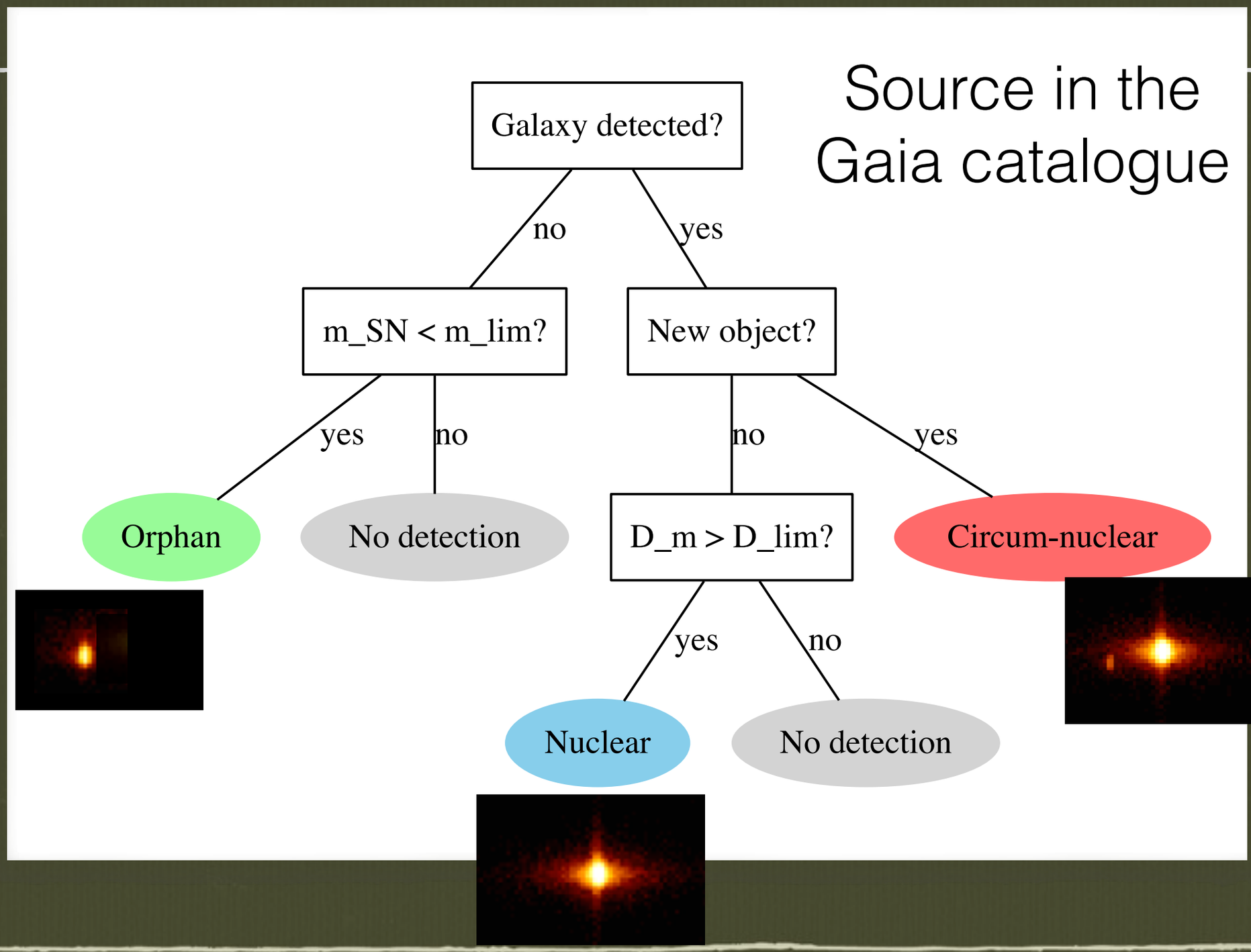
- Theoretical TDE Lightcurves



Van Velzen and Farrar, 2014

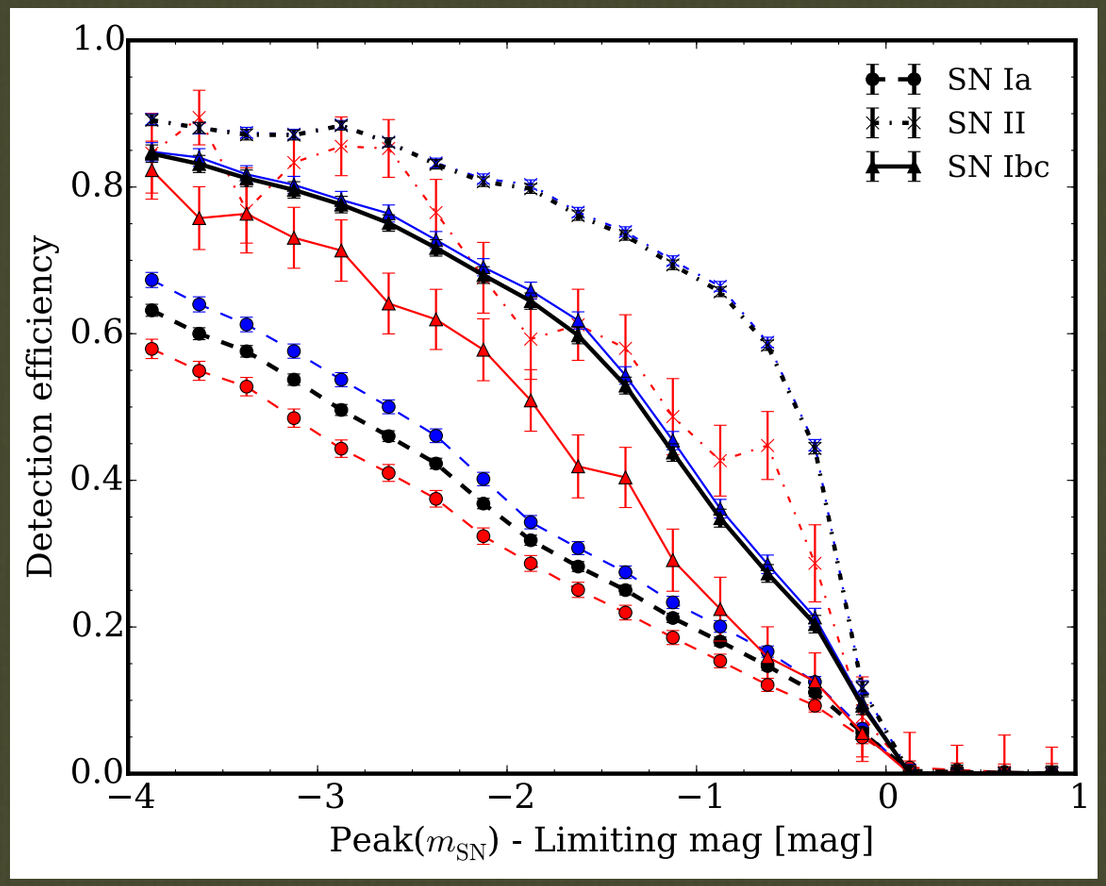
- TDE rate per galaxy

Detection process



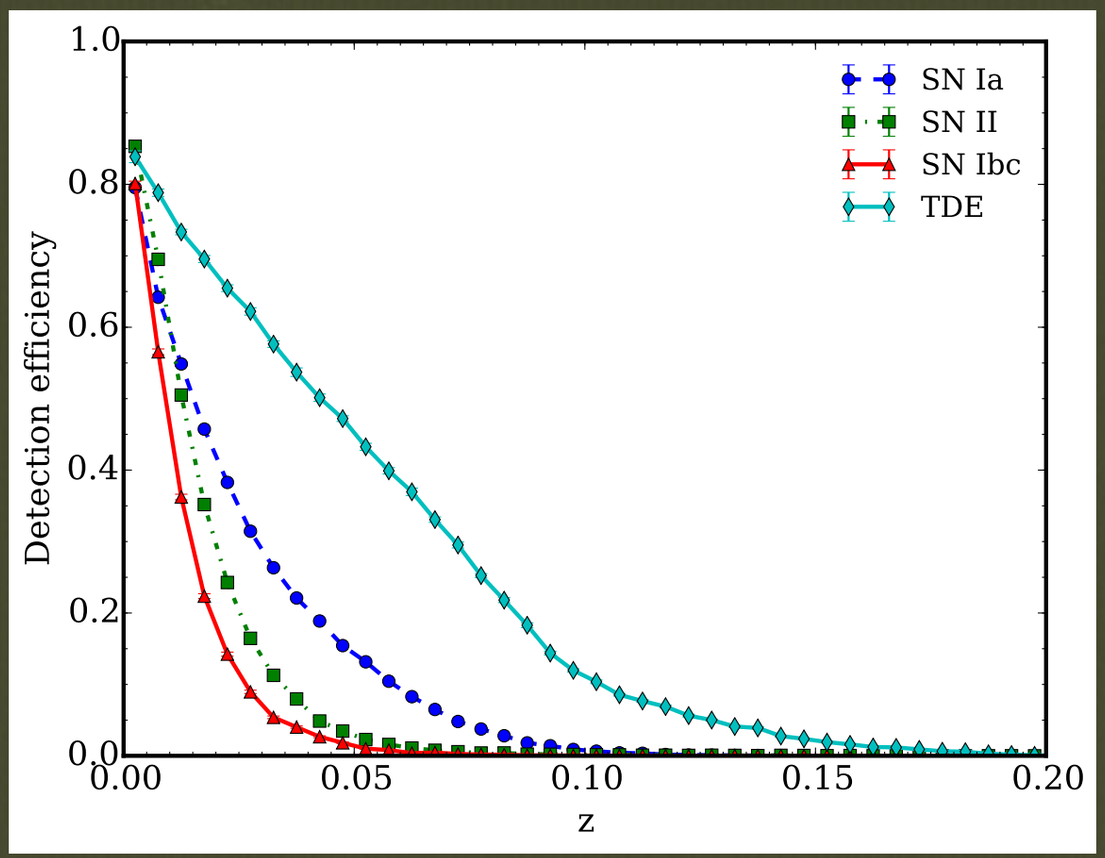
Detection efficiency

Detection efficiency



Limiting magnitude for candidates G = 19

Efficiency vs. Redshift

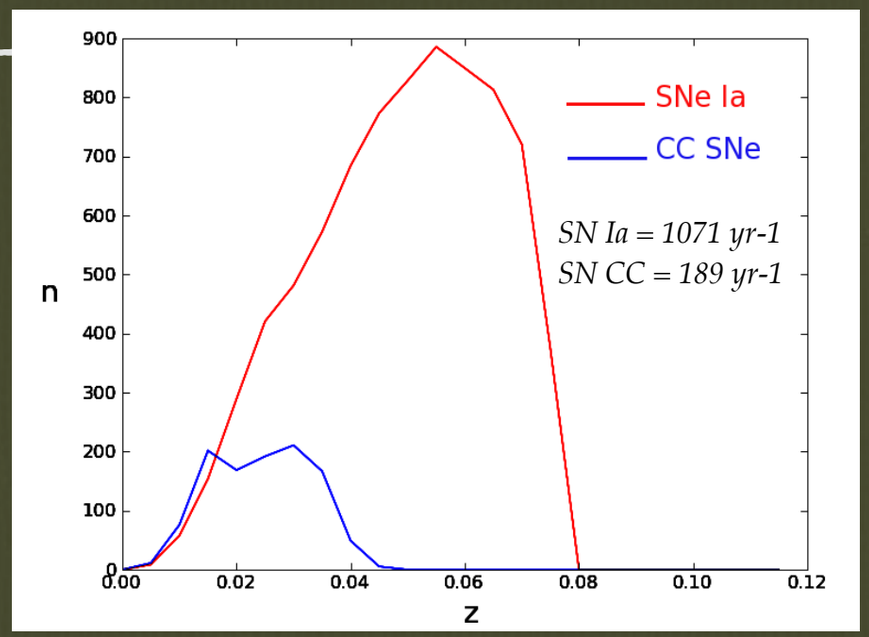


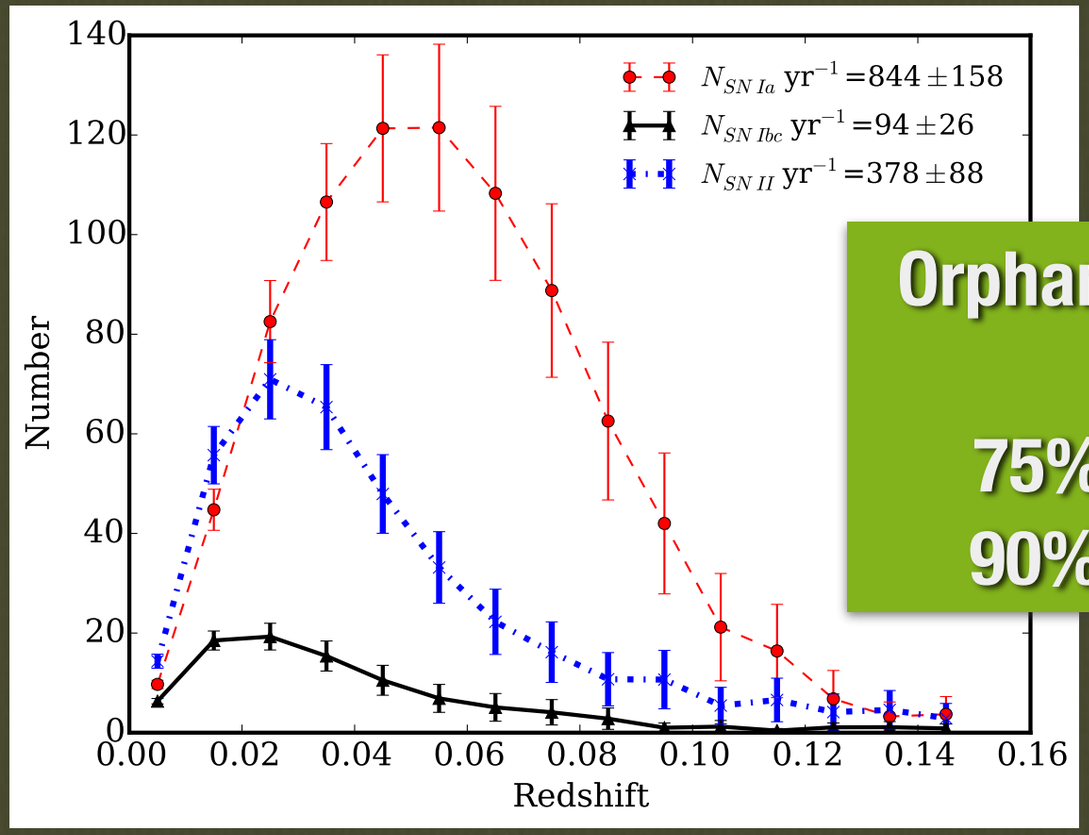
Expected number of SNe. Limiting Magnitude=19

Altavilla et. al. 2012

$$\rho(X,z) = \sum^{T} \int^{M} \phi^*(T,M)\mathrm{SNuB}(T,X,M)\varphi(T,M,z)\ dM$$

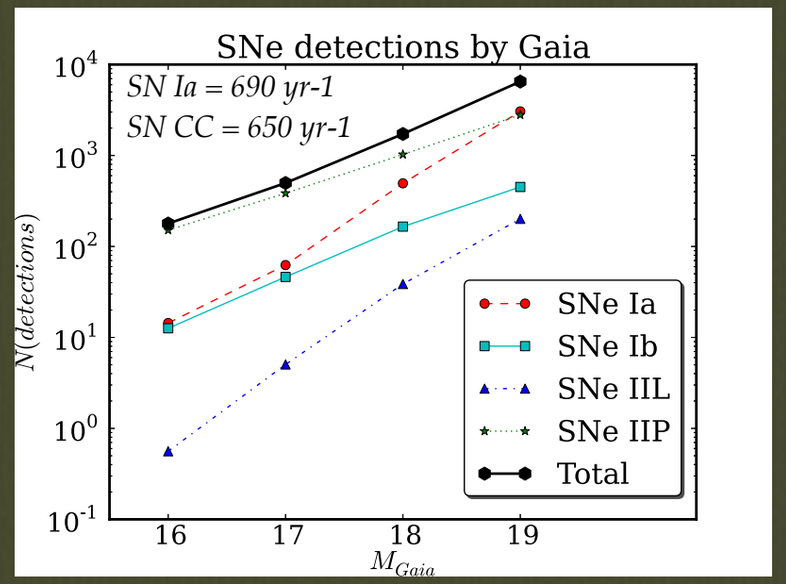
$$N_X\ \mathrm{yr}^{-1} = \int^{z} V_C(z)\rho(X,z)\ dz$$





Orphan in Gaia:

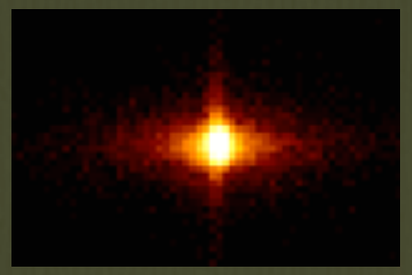
75% SN Ia
90% CCSN



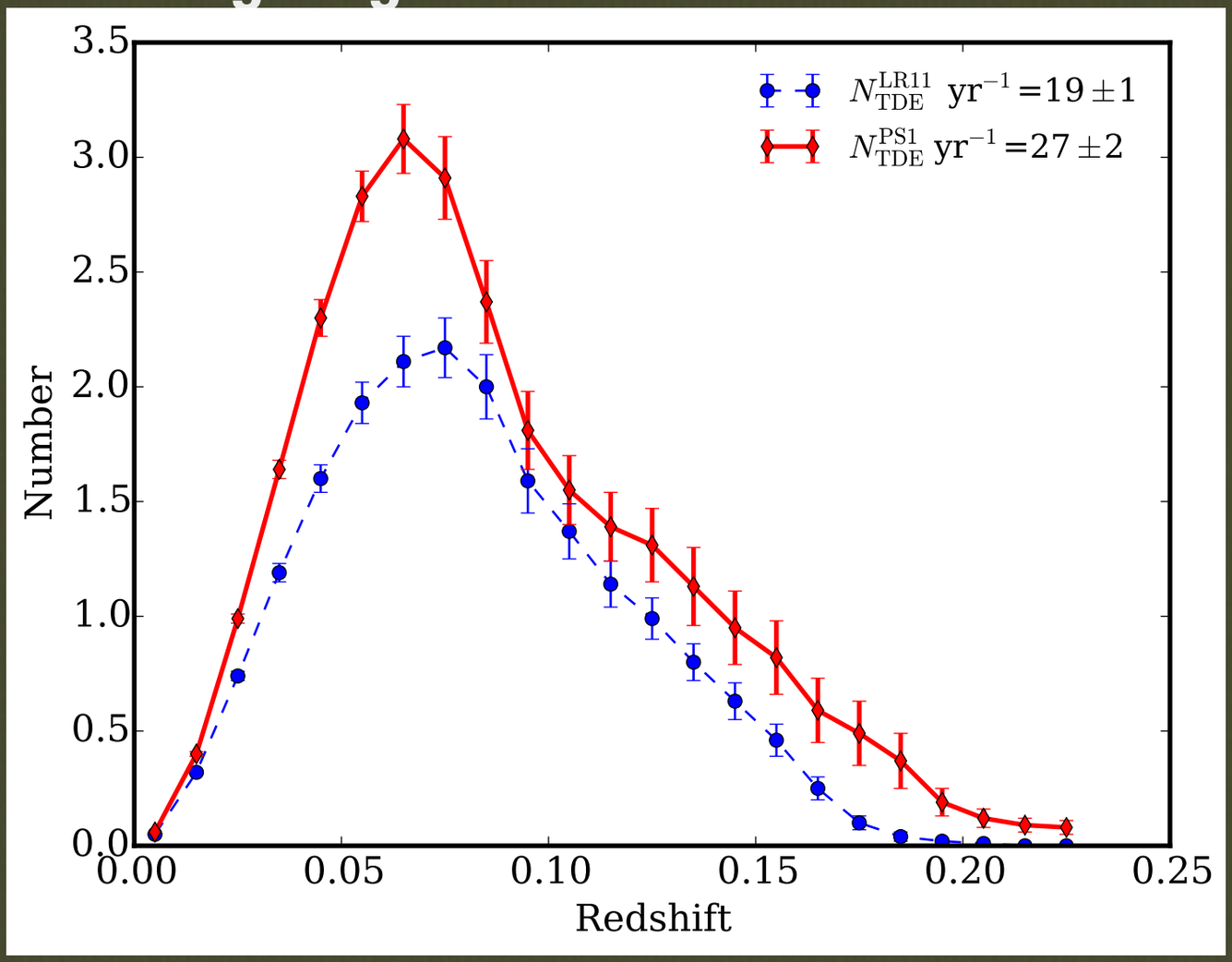
Blagorodnova et. al. 2015, submitted.

Belokurov, Evans 2003

TDE vs. SN - nuclear case



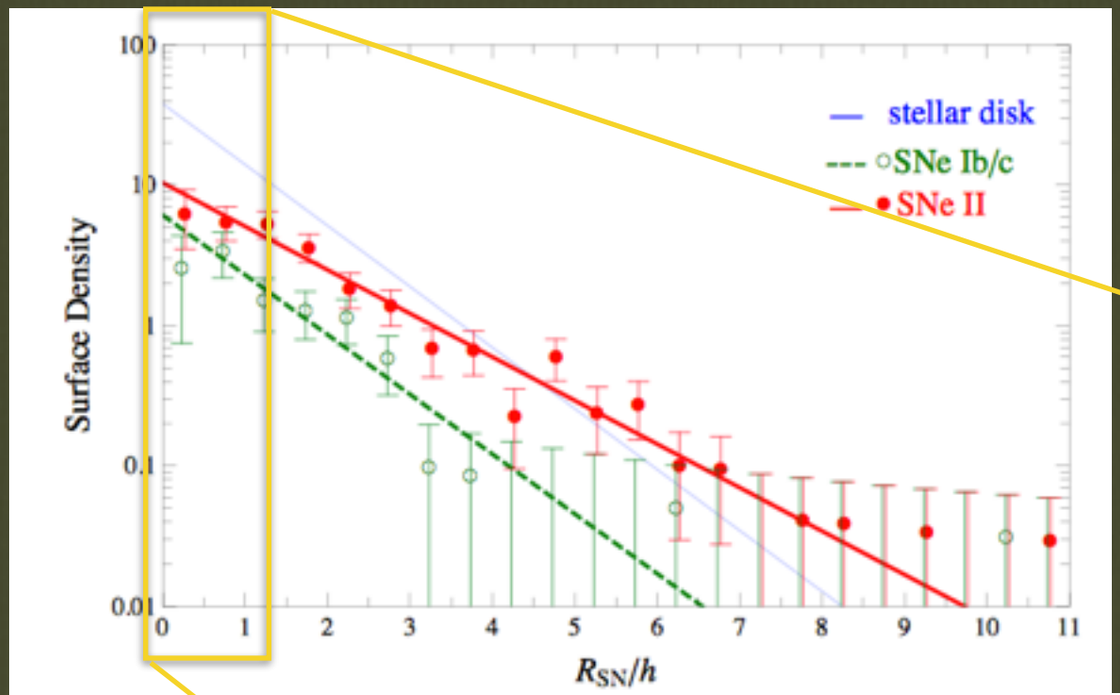
Limiting magnitude for candidates G = 19



Detected TDE = Detected SN nuclear regions

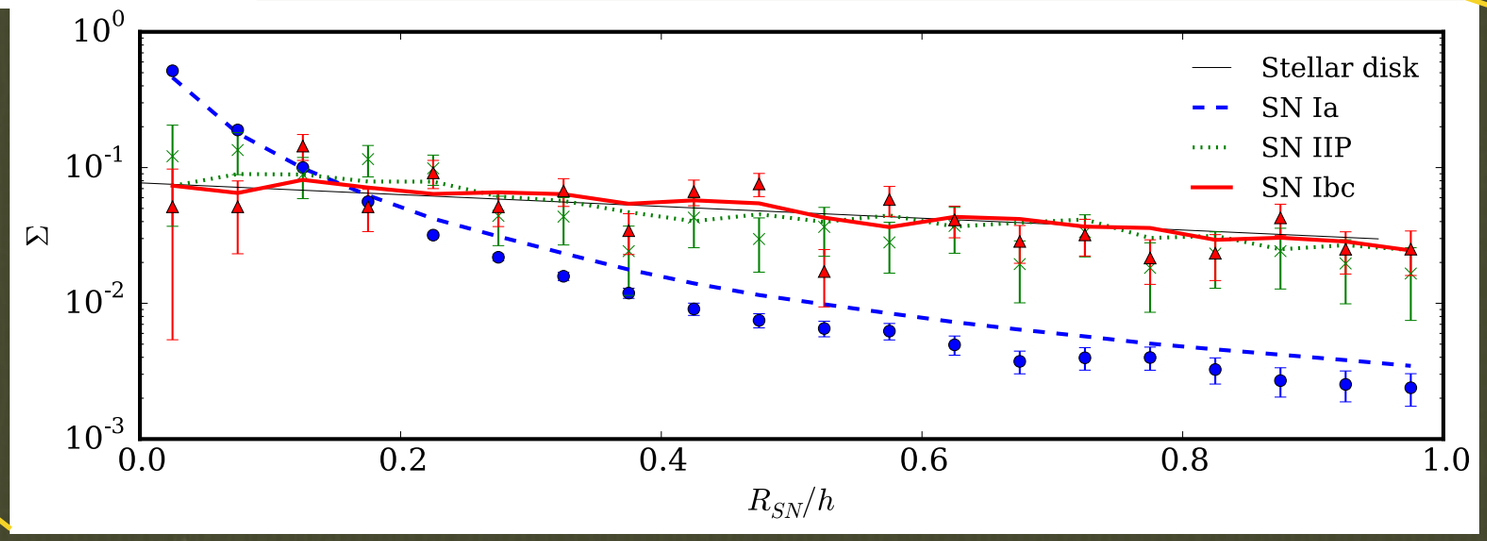
-> Low contamination!

SN density distribution



Hakobyan et. al, 2008

No noticeable decrease in the number of detections close to nucleus

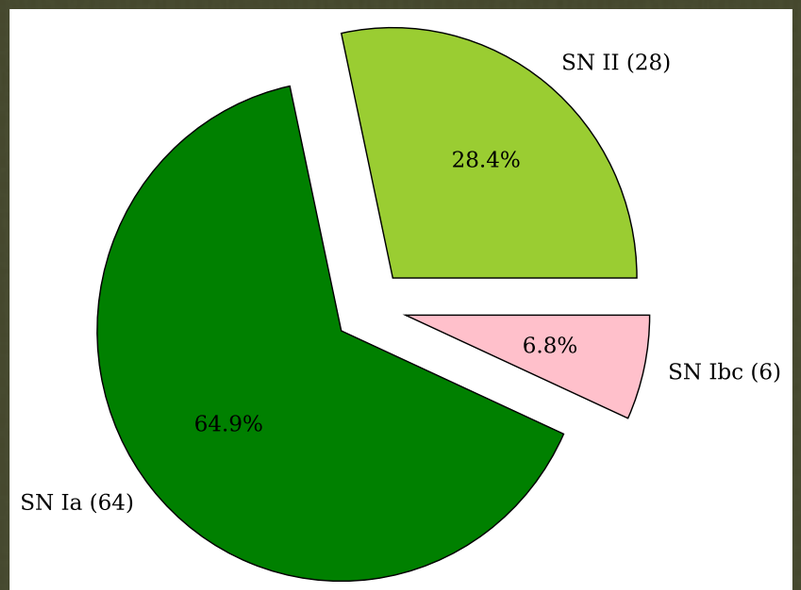


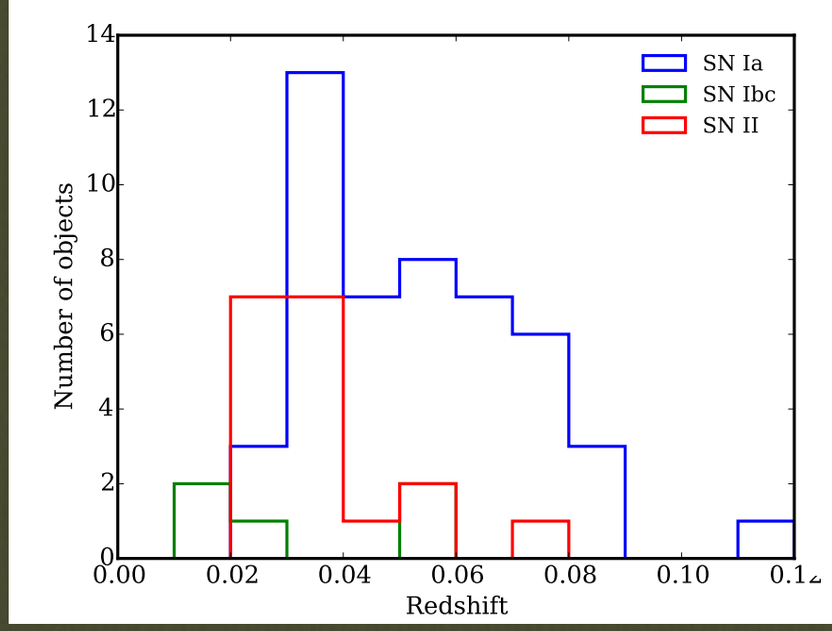
Blagorodnova et. al. 2015, submitted.

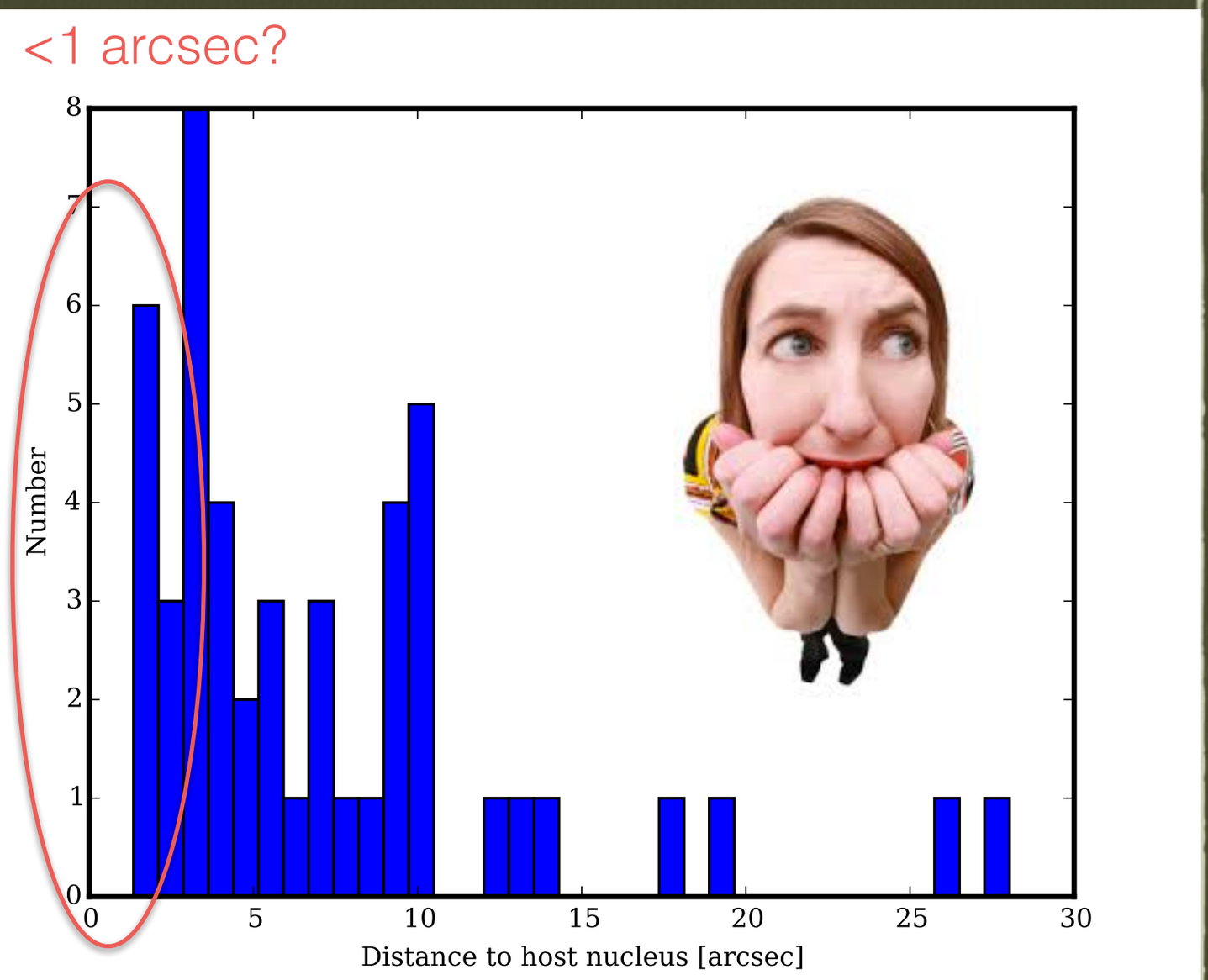
What is the current status?

Gaia Alerts (so far)

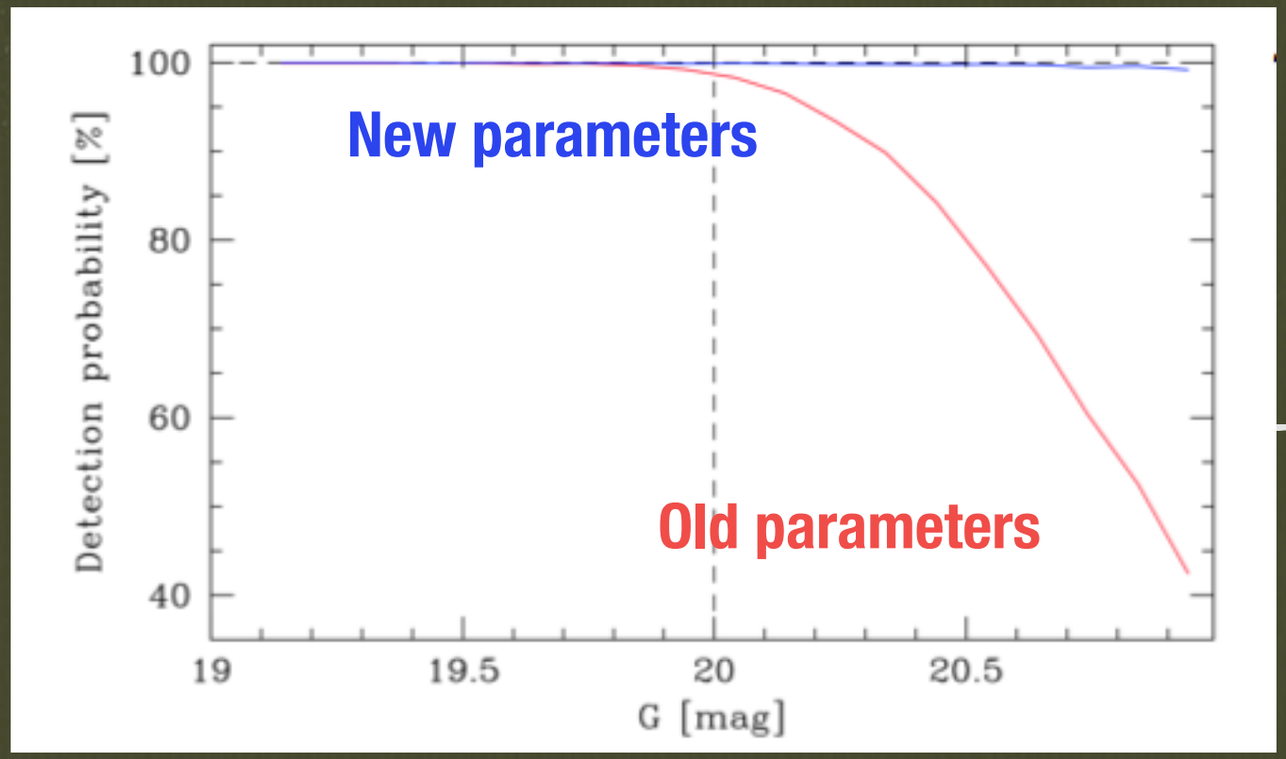
- 275 published alerts
- 98 spectroscopically confirmed SN
- apparent lack of nuclear SN?



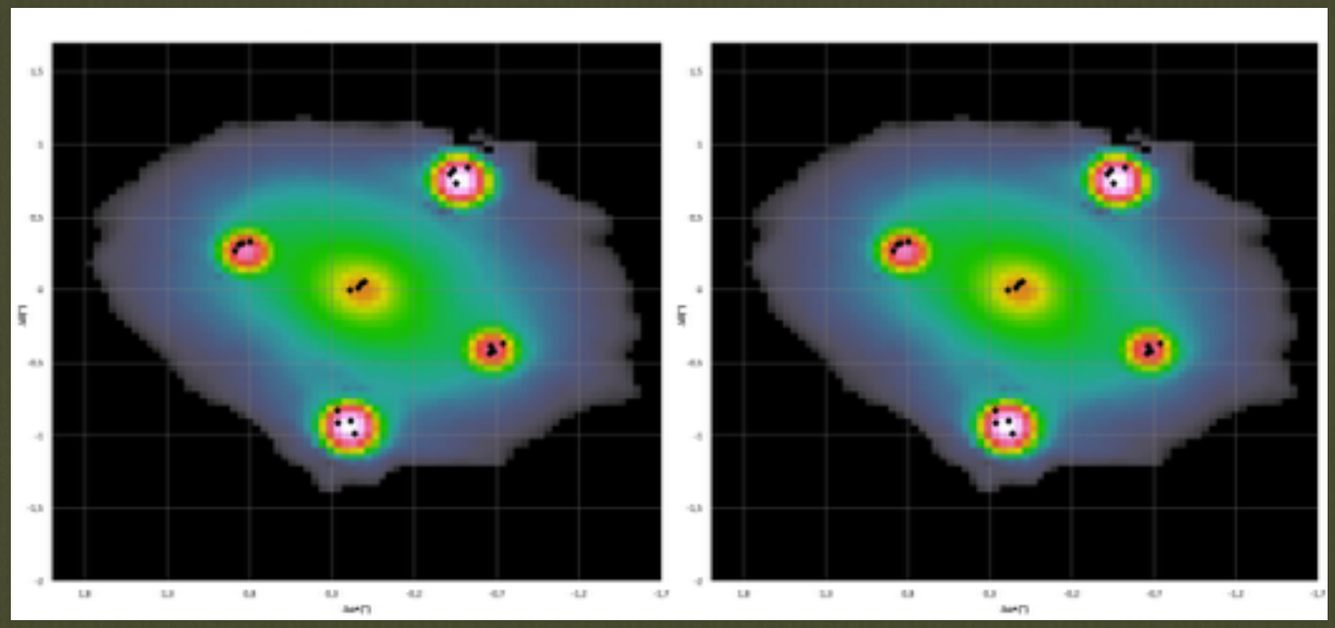




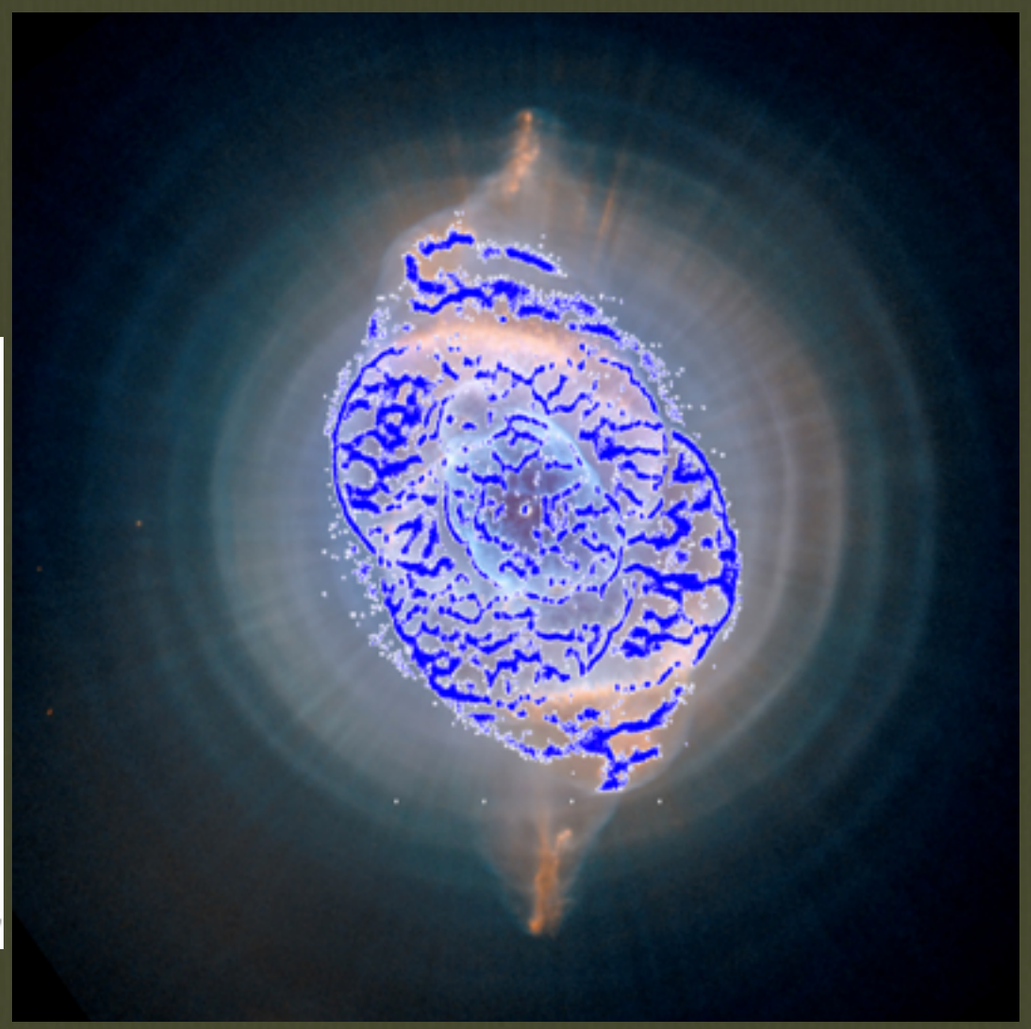
What's going on?



De Bruijne et. al, 2015

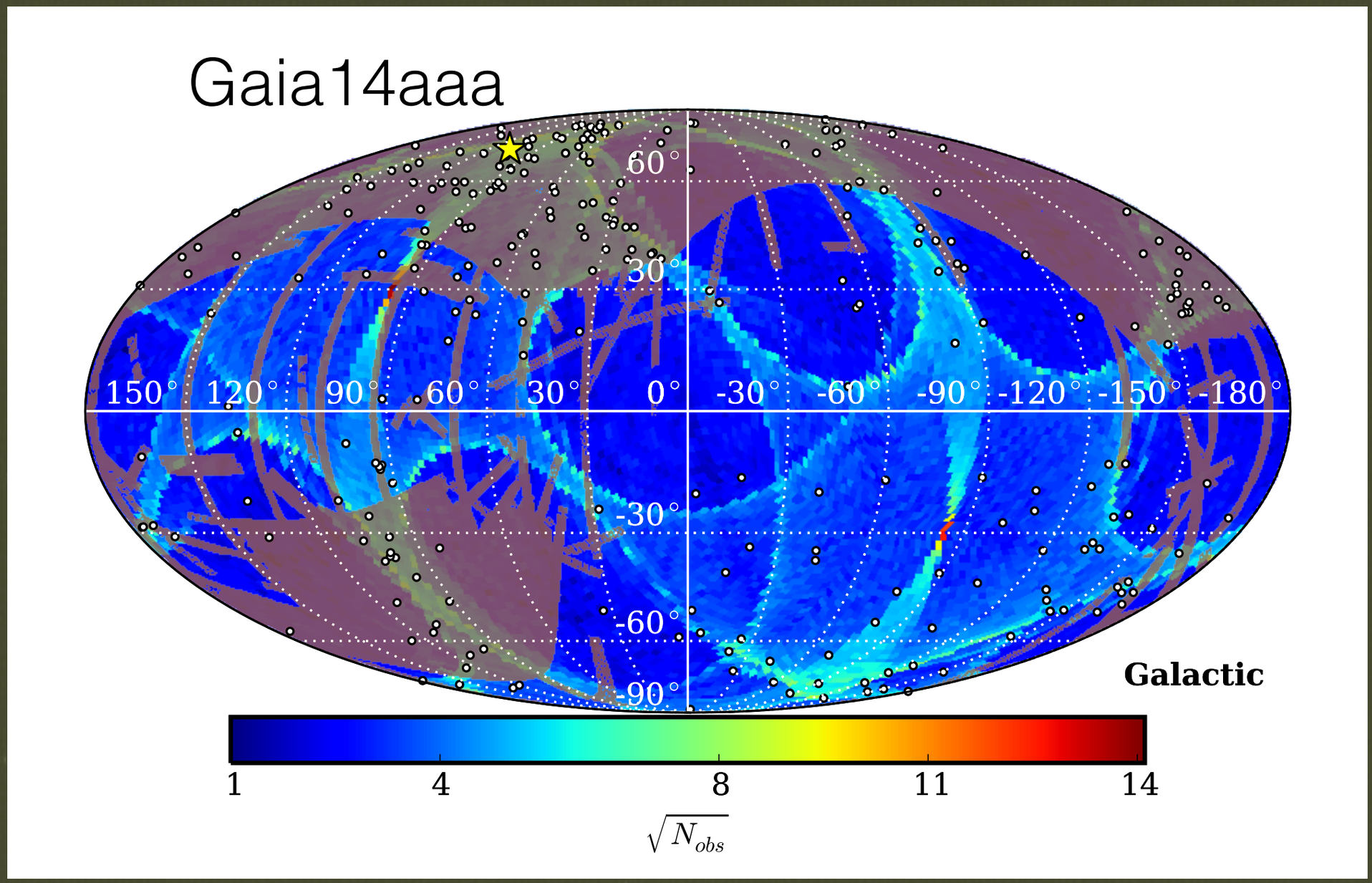


http://www.cosmos.esa.int/web/gaia/iow_20150409



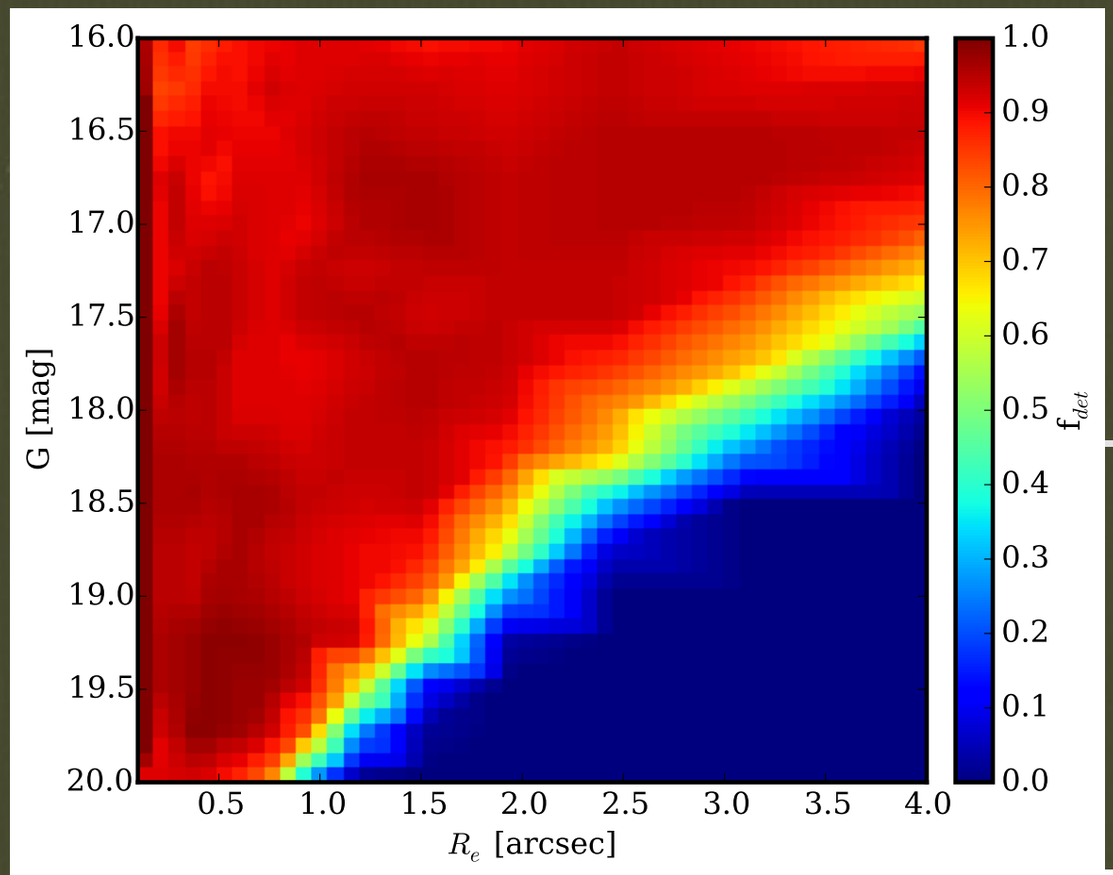
http://www.cosmos.esa.int/web/gaia/iow_20141205

Map published alerts



Validation phase and improvements

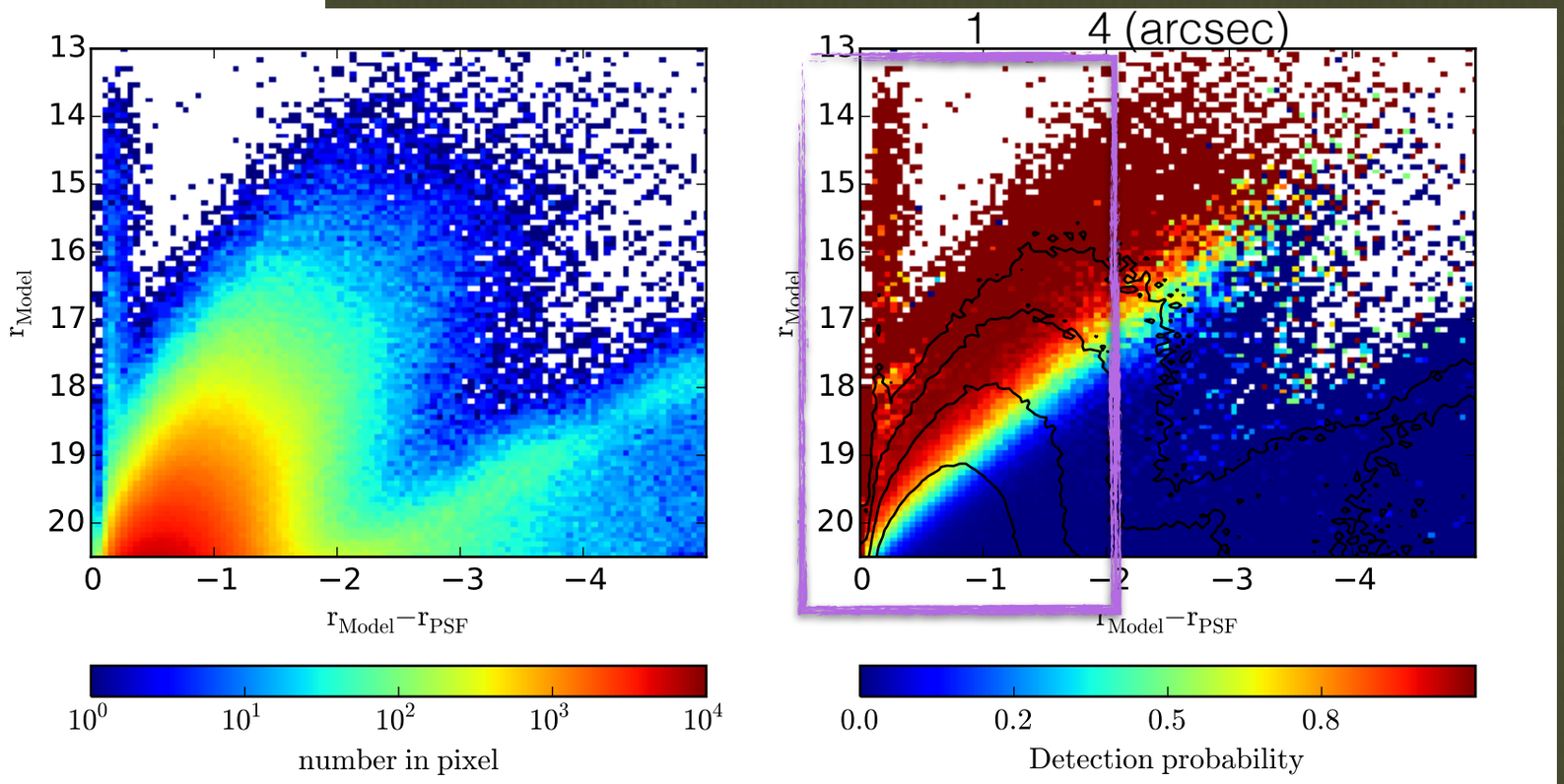
Good news?



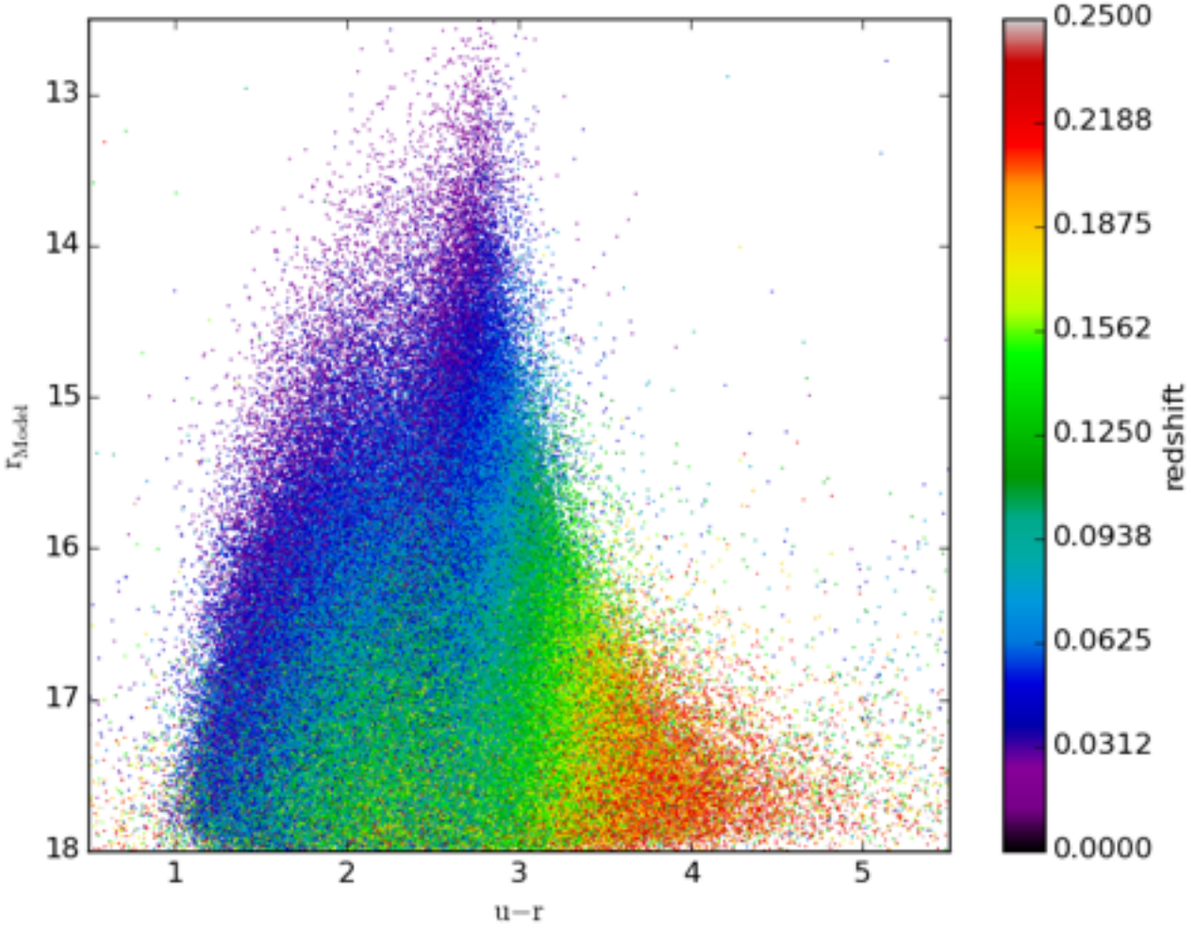
Simulated galaxy detectability

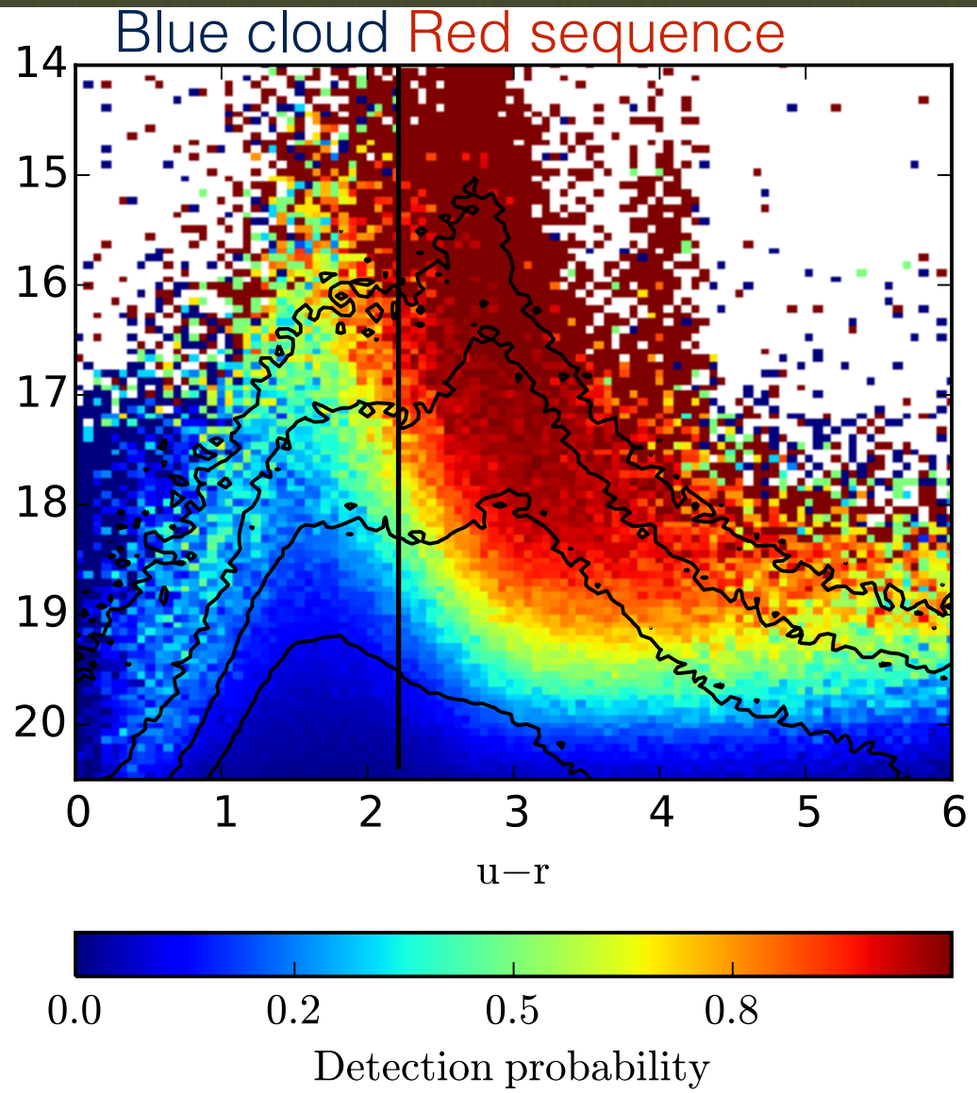
Real mission galaxy detectability

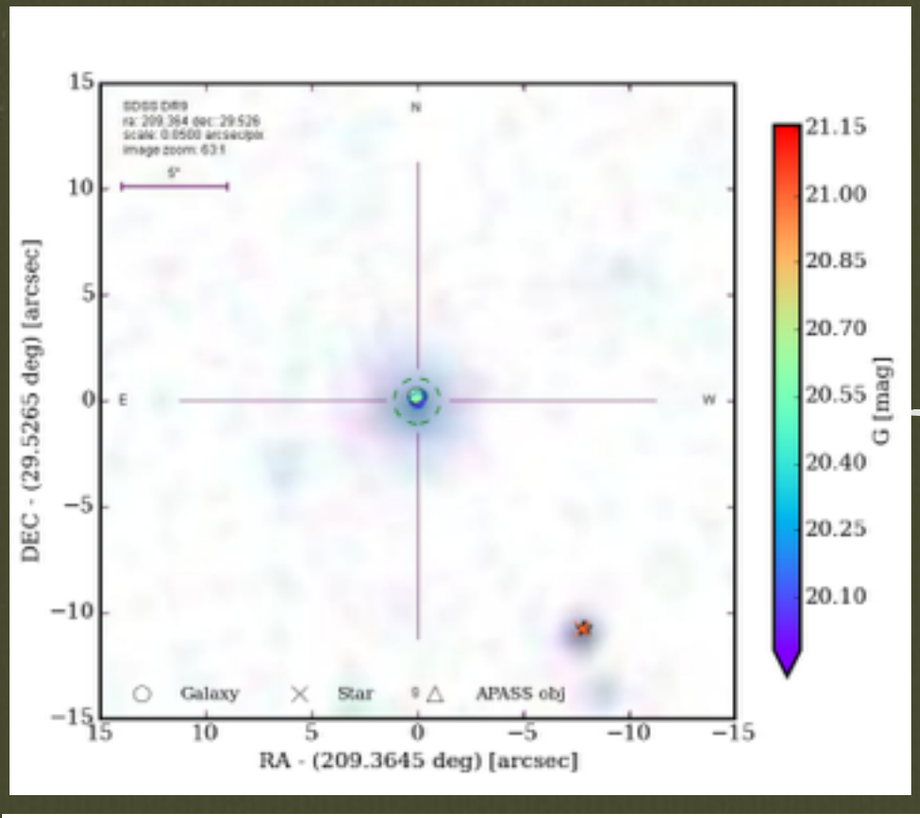
~25% galaxies detected from 1.3M from SDSS mag< 20

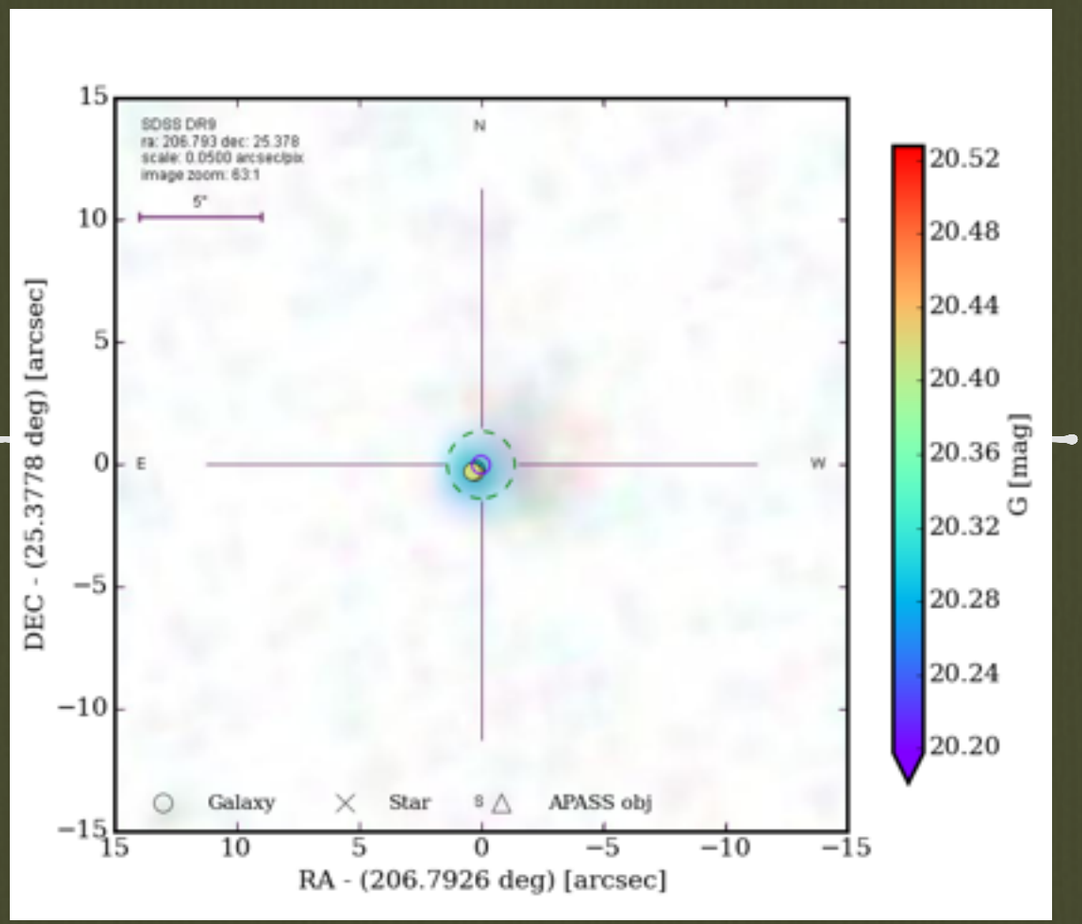


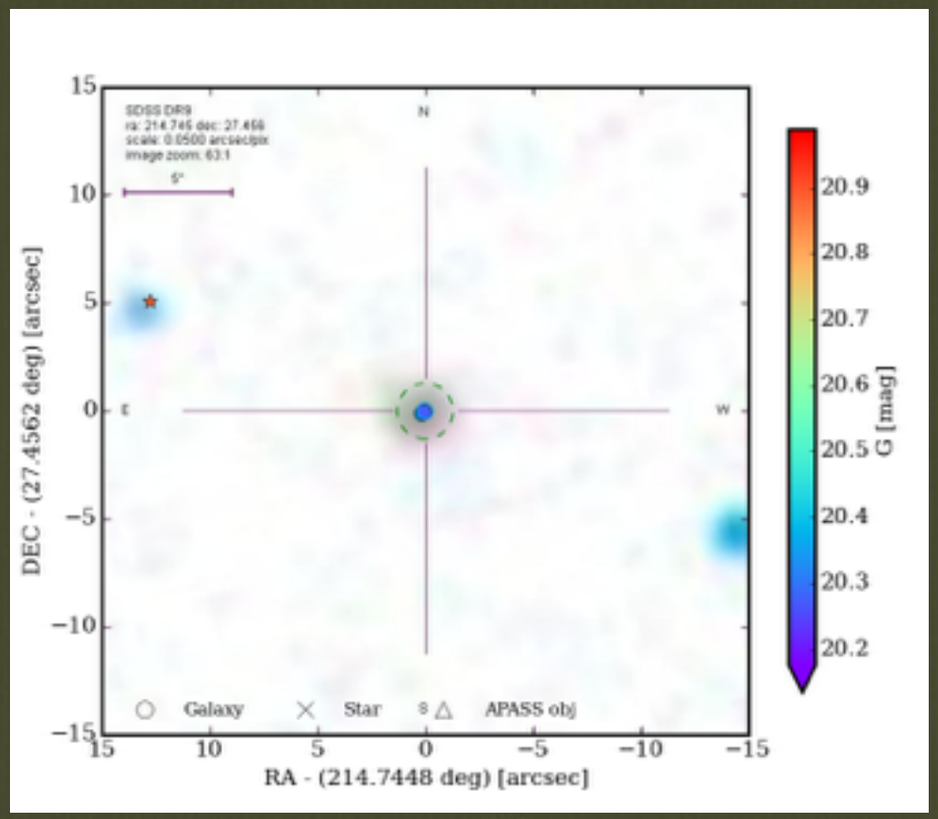
What galaxies are detected?



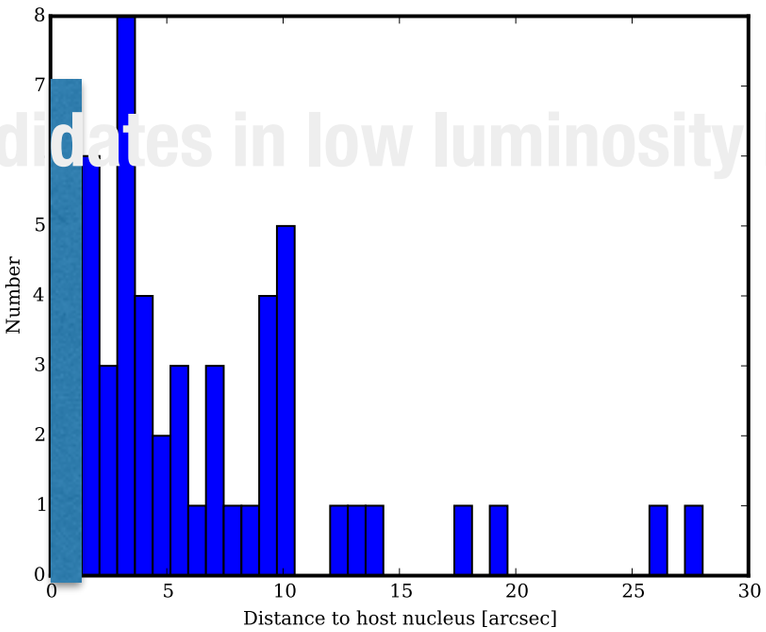








Candidates in low luminosity hosts



Conclusions

- Real data is more complex than simulated data.
- Current effort on approaching host galaxy nucleus
- First candidates on non-detected hosts possible now

Thank you!

Gaia DPAC
&
Heather Campbell
Morgan Fraser
Gerry Gilmore
Diana Harrison
Simon Hodgkin
Mike Irwin
Seppo Mattila
Sergey Koposov
Rubina Kotak
Guy Rixon
Sjoert Van Velzen
Lukasz Wyrzykowski
Nicholas A. Walton