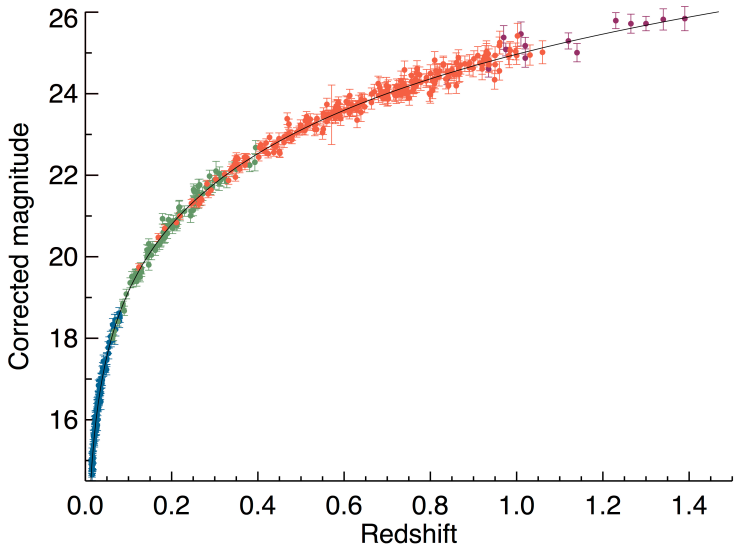
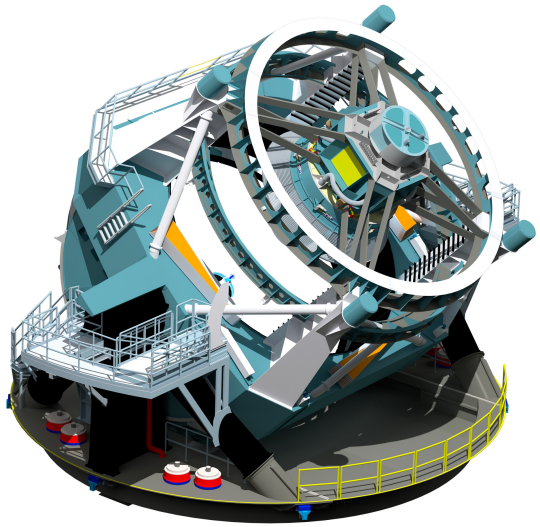
Transients and variables

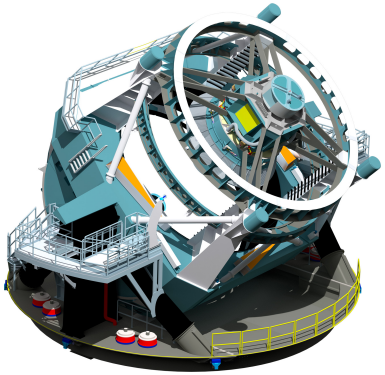
Mark Sullivan, Southampton

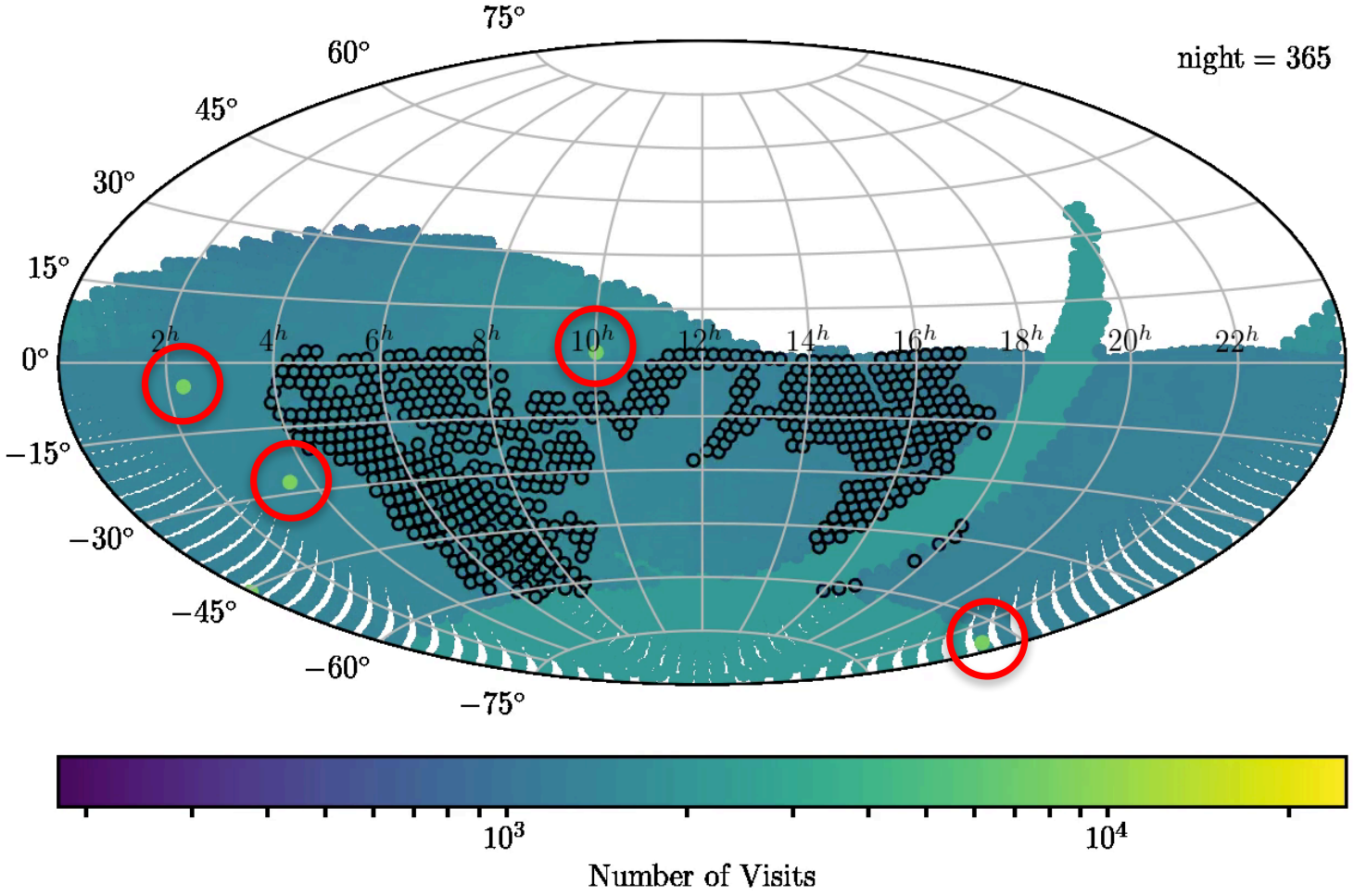
On behalf of LSST:UK DESC-SN and TVS groups





LSST and the time variable sky





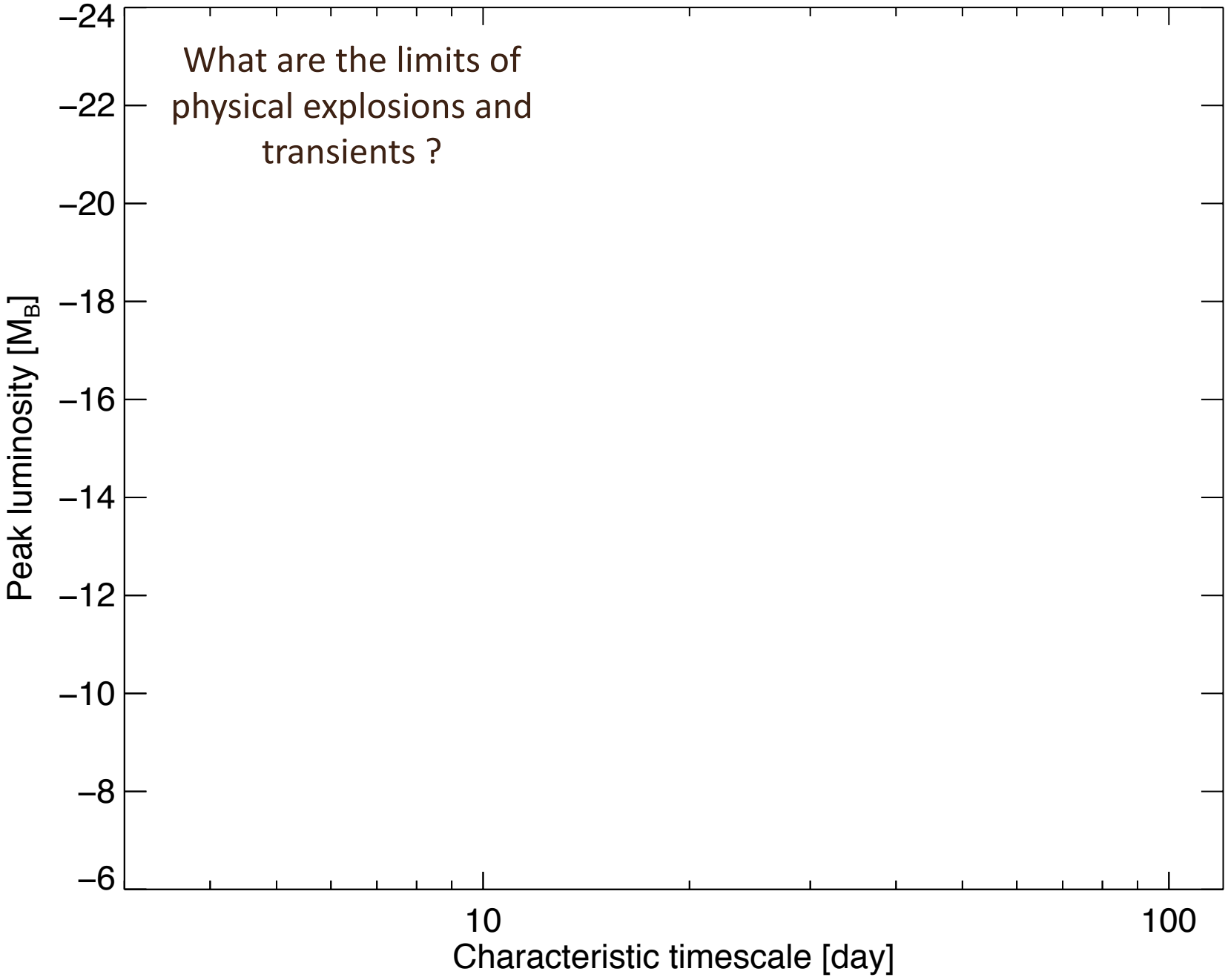
Wide-Fast-Deep: the whole sky every few days; tens of millions of alerts per year

Deep Drilling Fields: small areas visited every night

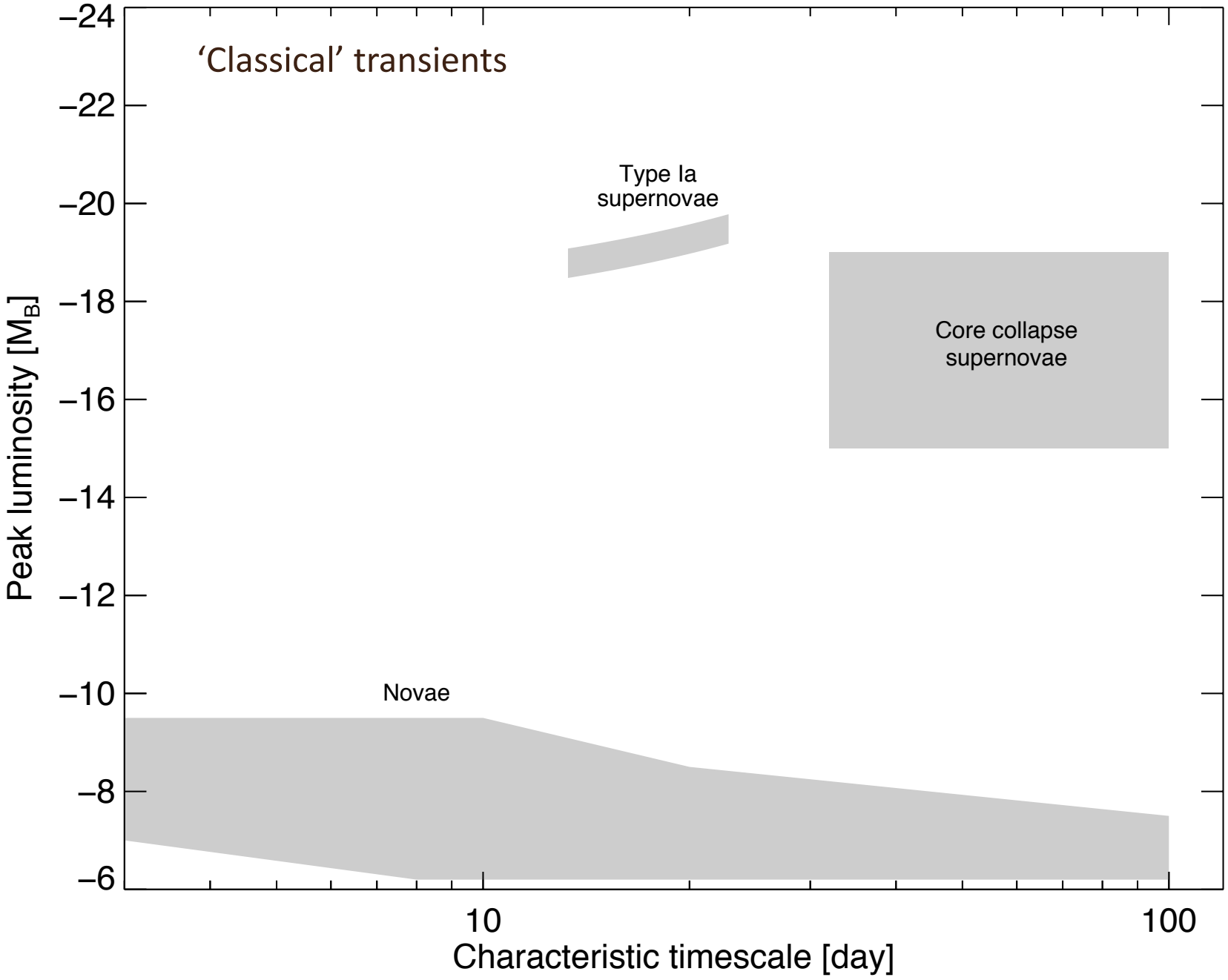
The whole sky every few days; tens of millions of alerts per year

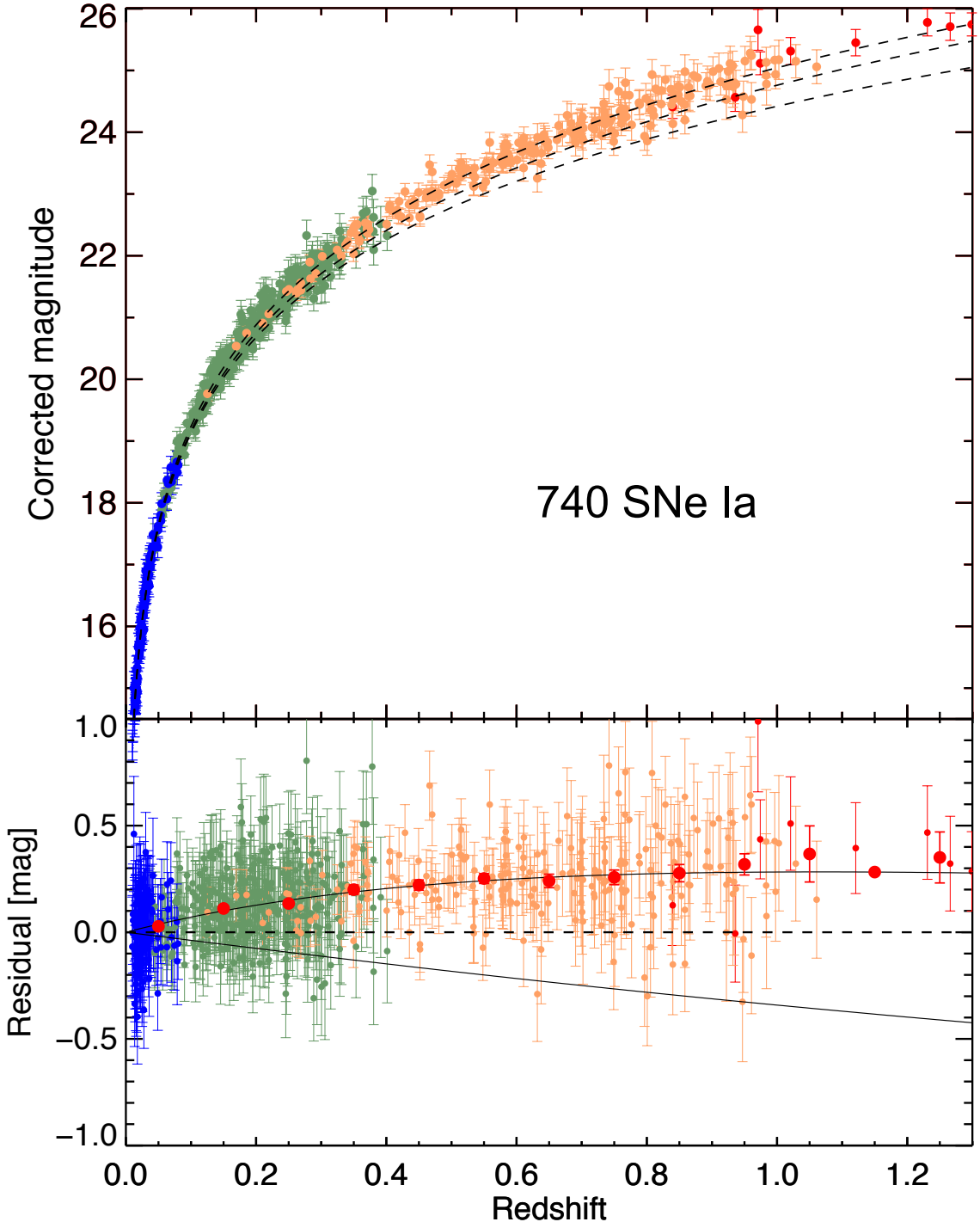
Movie from R. Firth

Transient parameter space



Transient parameter space

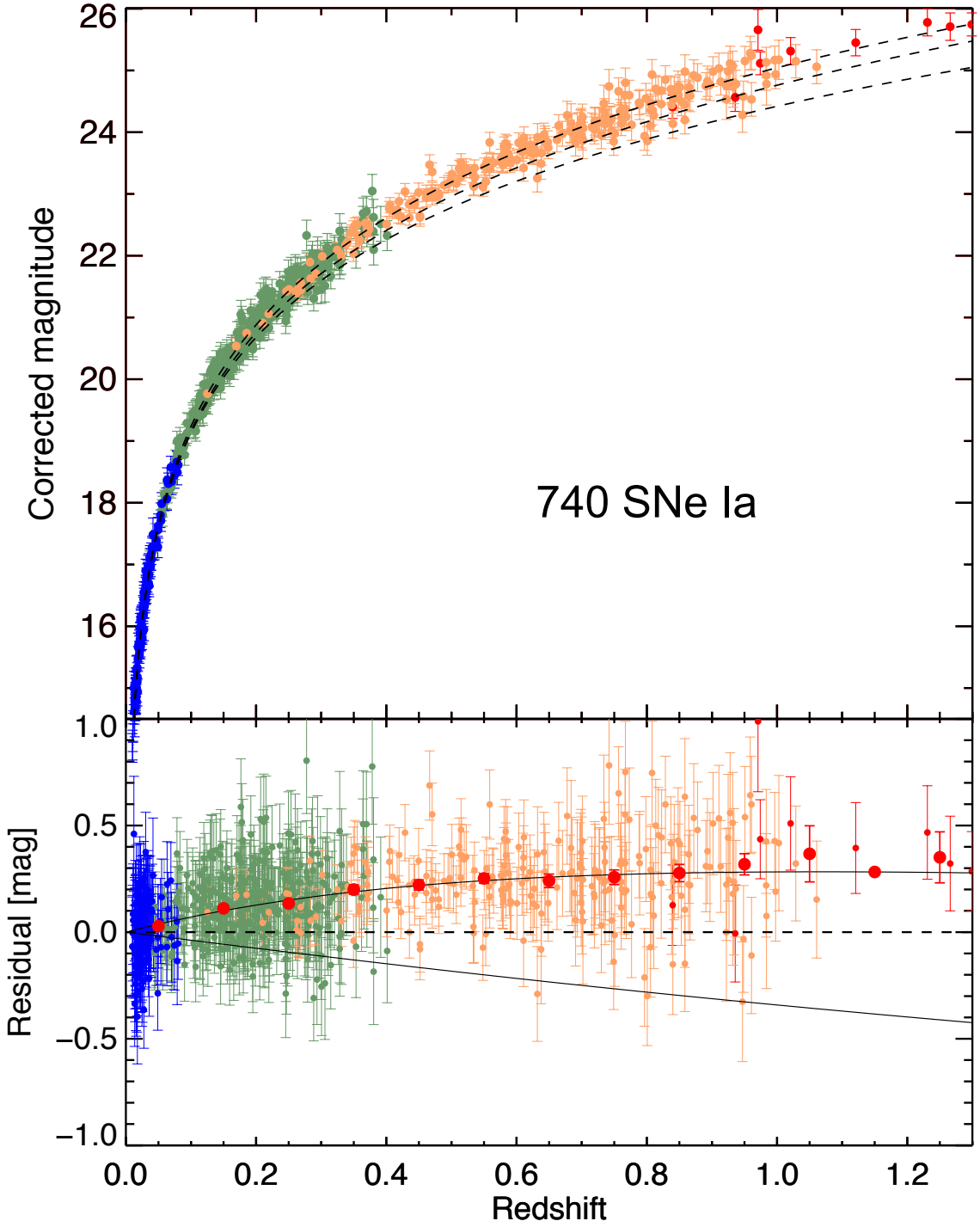




SNe Ia: the nature of dark energy

Includes data from Supernova Legacy Survey, SDSS-SN Survey, HST and Low-z surveys

Betoule et al. 2014



SNe Ia: the nature of dark energy

Current samples systematics limited: LSST will not be

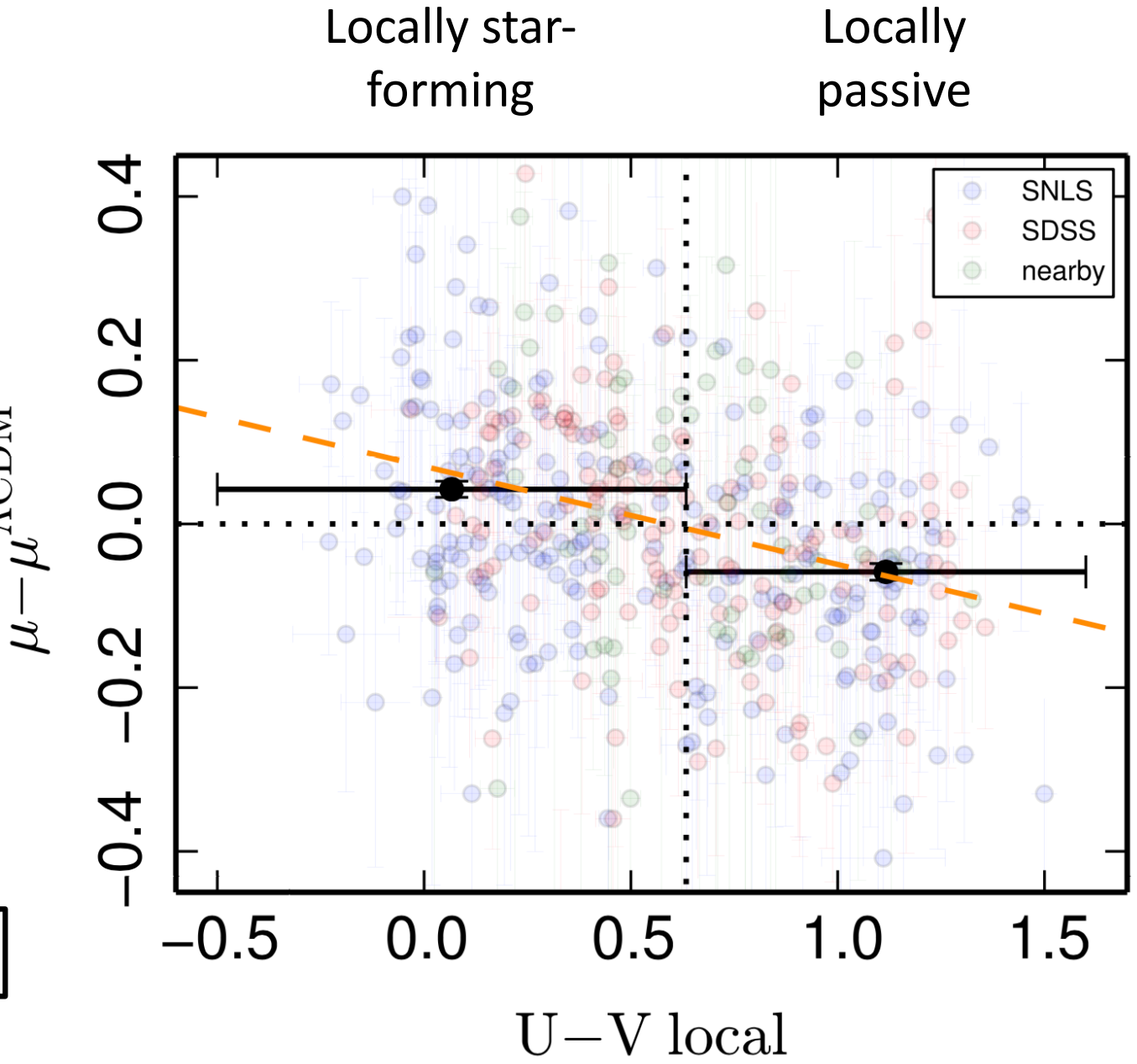
Significant increase in statistical power

Ability to select SNe Ia into ~10000 event sub-samples

Why are subsamples important?

Correlation between Hubble residuals and *local* rest-frame colour (SFR)

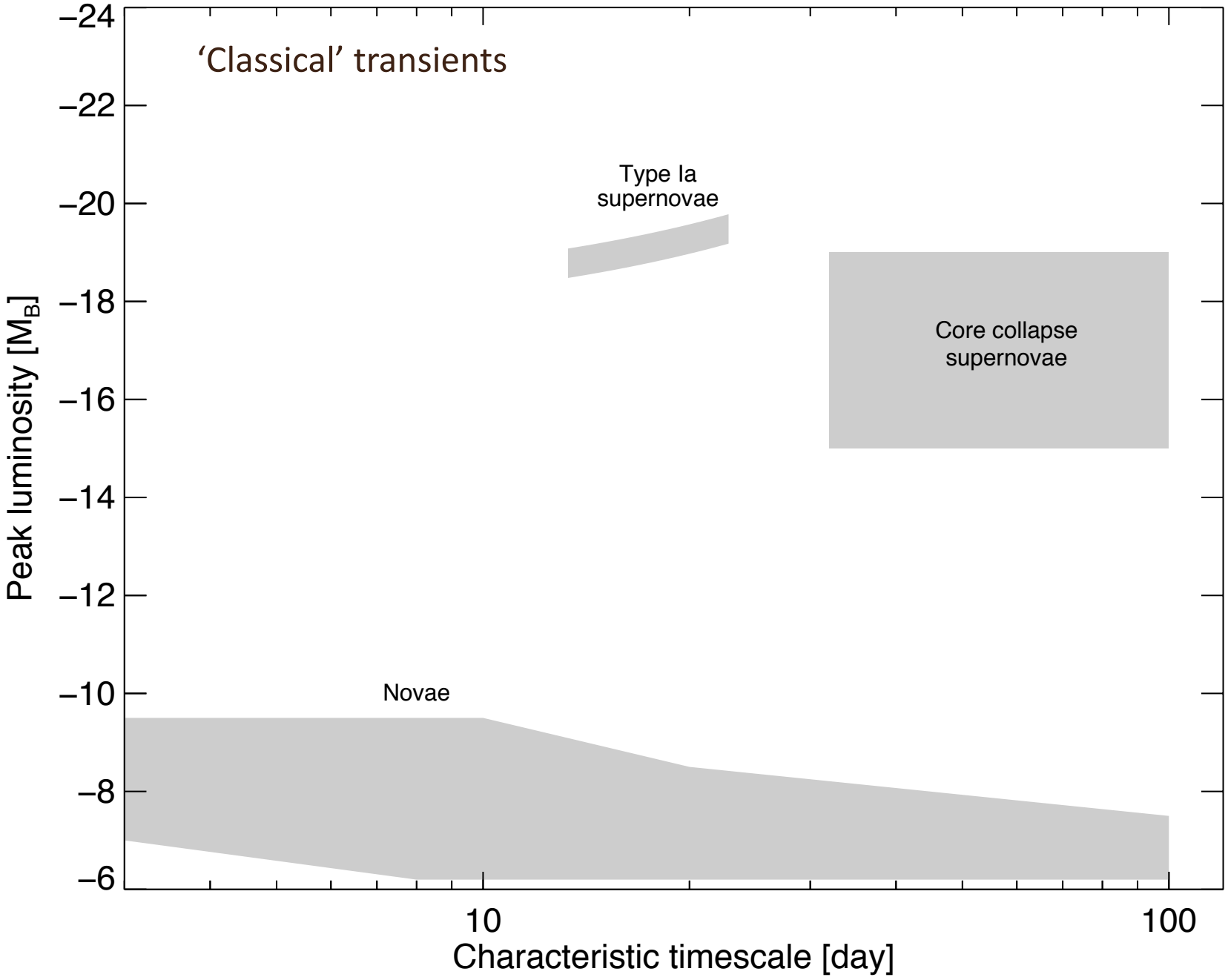
0.10 ± 0.014 mag



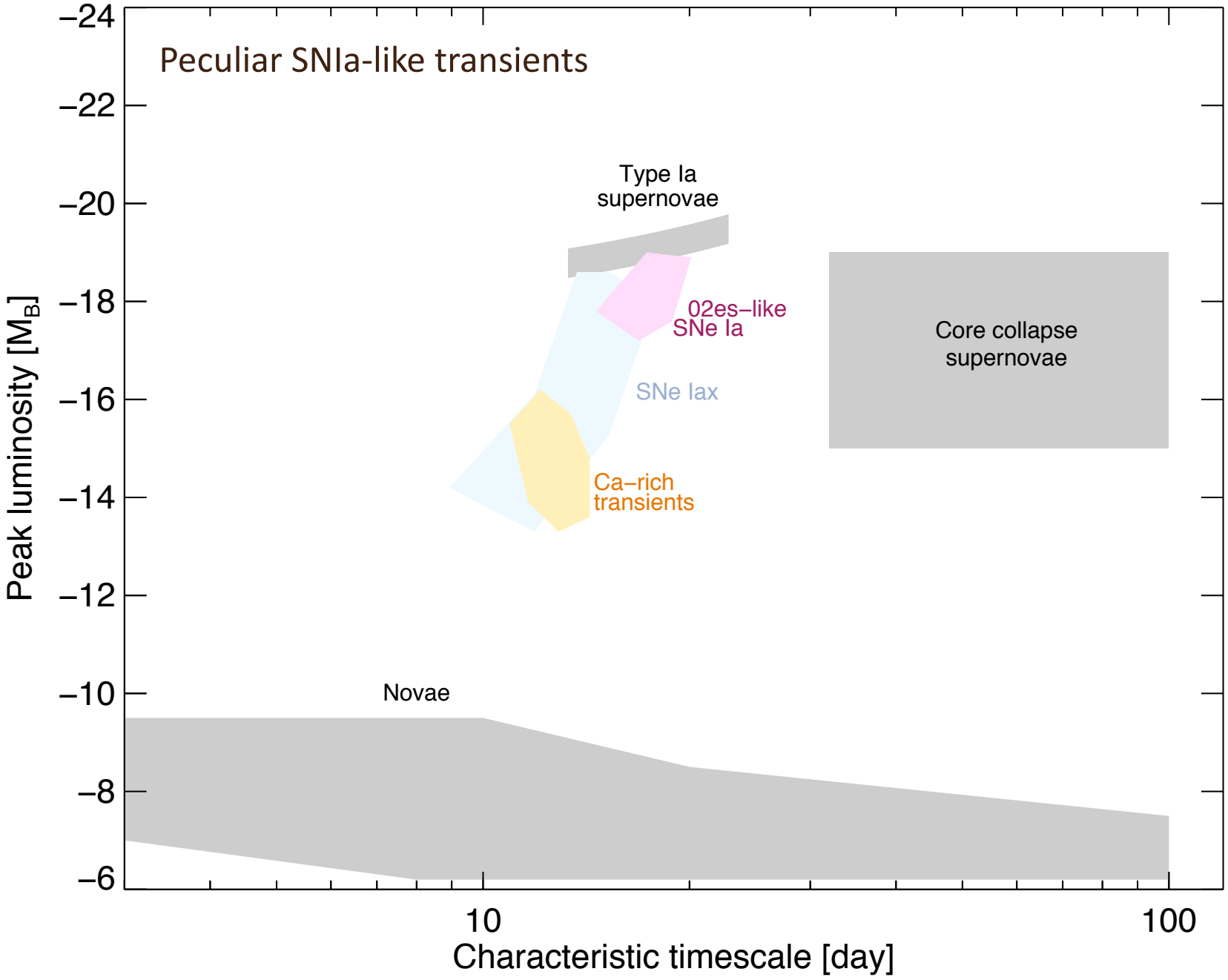
Indicates progenitor age is a key variable

Roman et al. (2017)

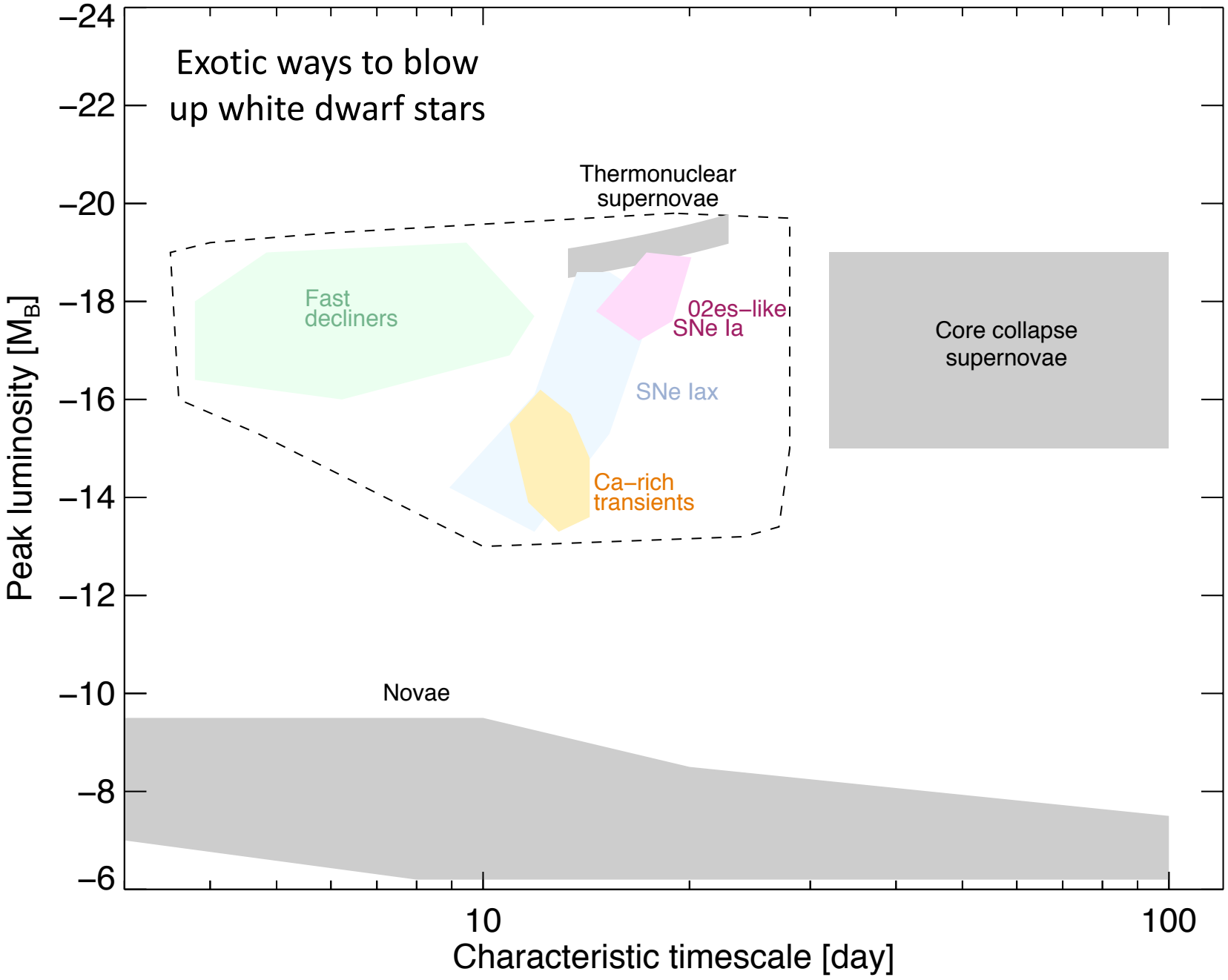
Transient parameter space



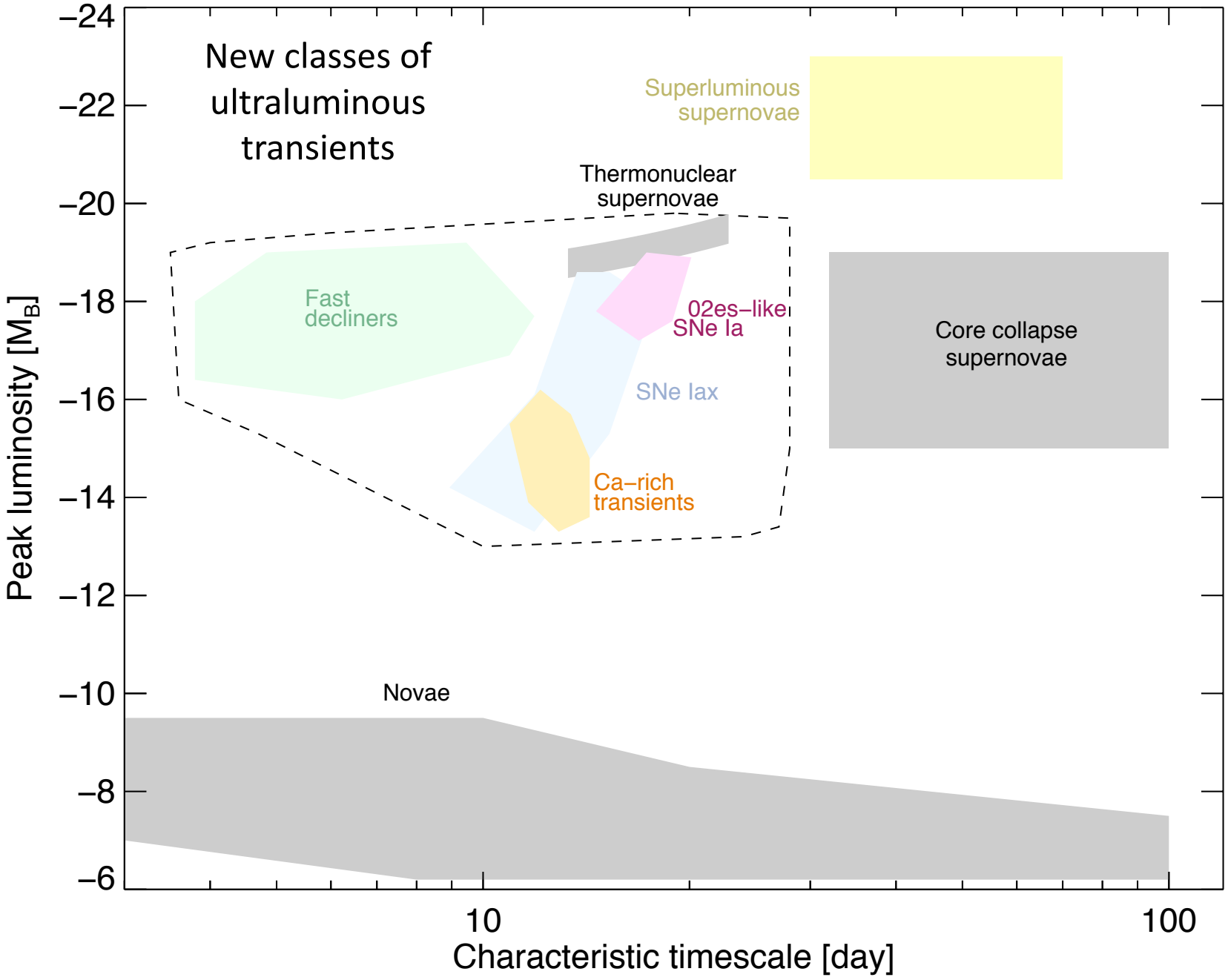
Transient parameter space



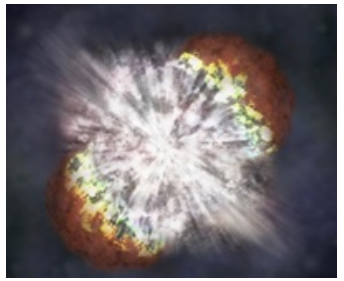
Transient parameter space



Transient parameter space



Superluminous supernovae



Alternative standard candles to SNe Ia?

New classes of superluminous SNe

→ 50 times brighter than SNe Ia

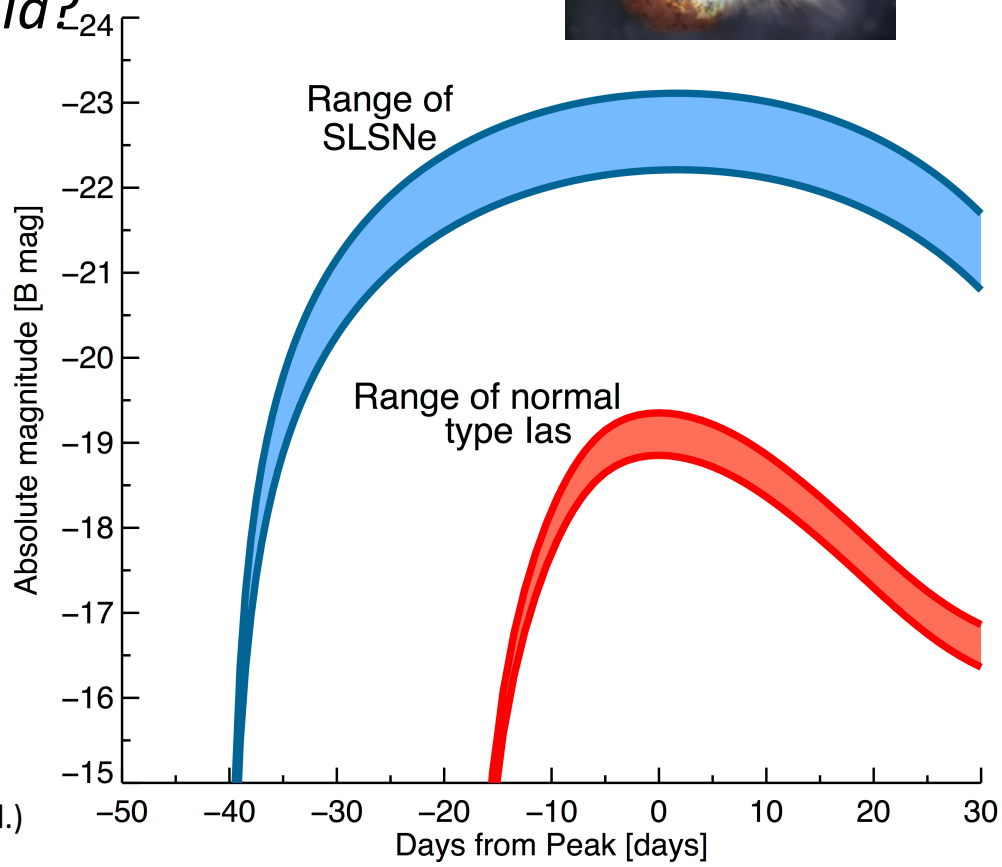
→ Seen to z=4 (Cooke, Sullivan et al. 2012, Nature)

What is their physical nature?

→ Not ^{56}Ni! Magnetar?

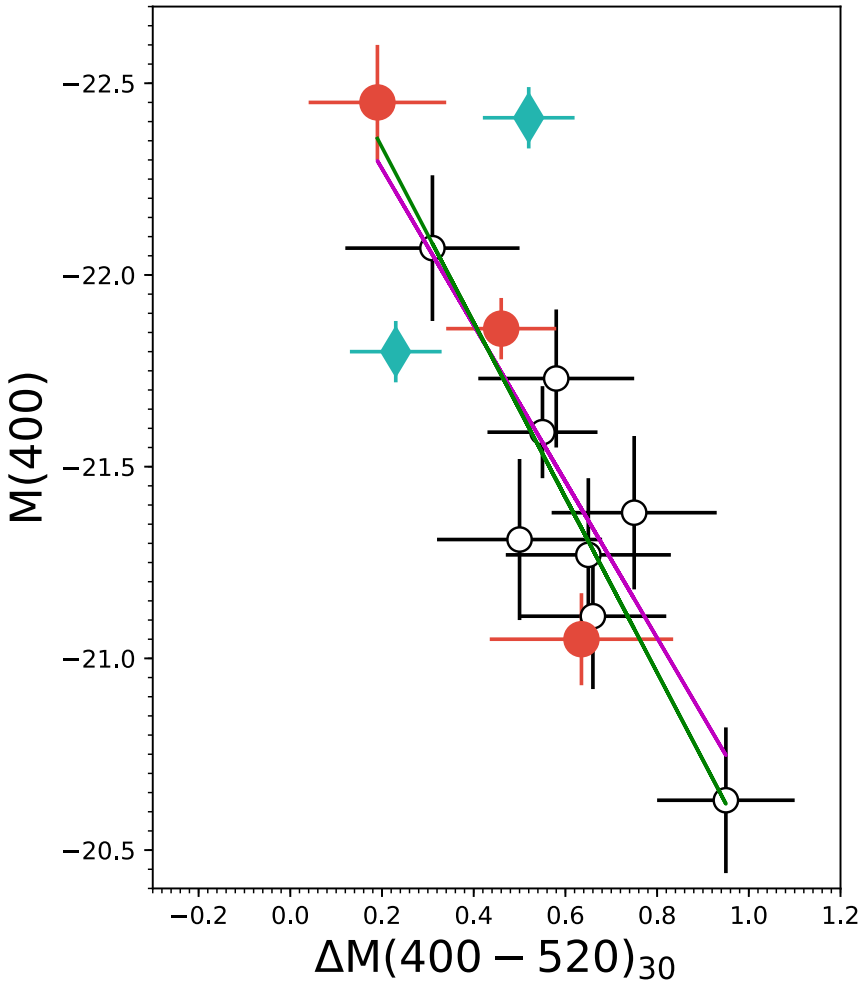
Can they be standardised?

→ Current dispersion 0.20 mag (Inserra et al.)

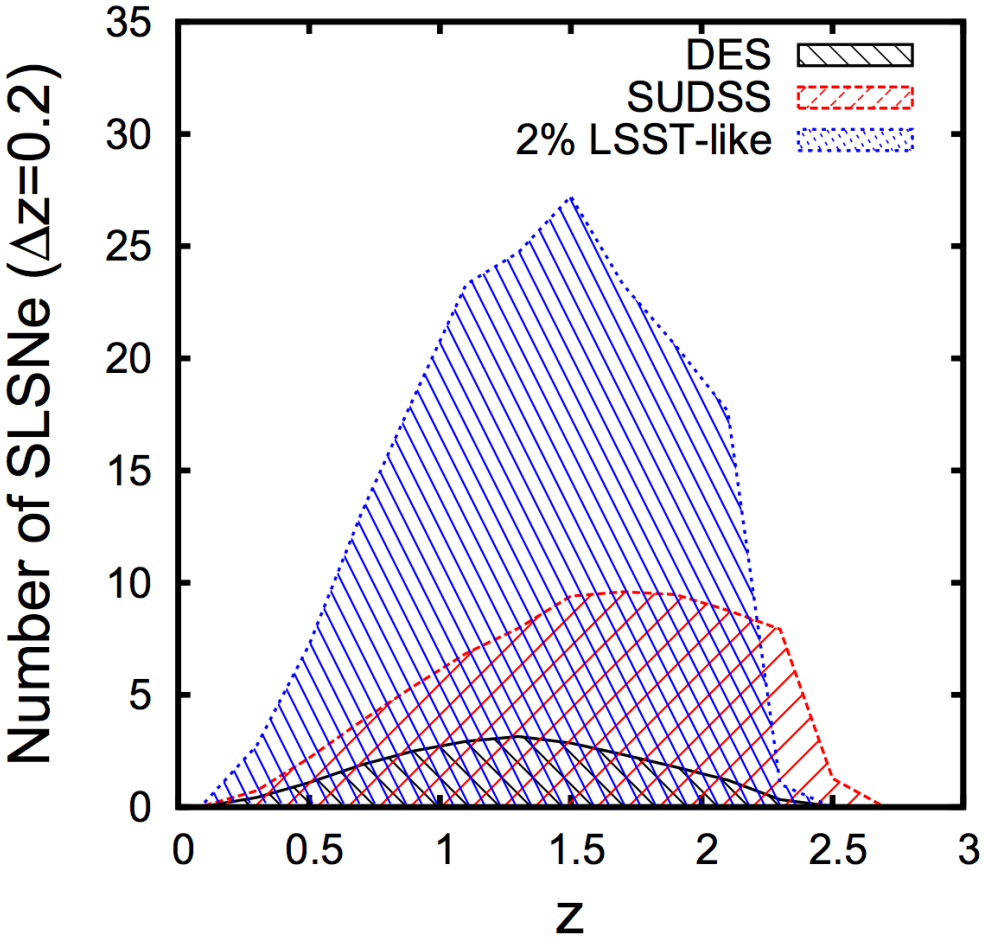


The first cosmological samples are now appearing

Standardisable?

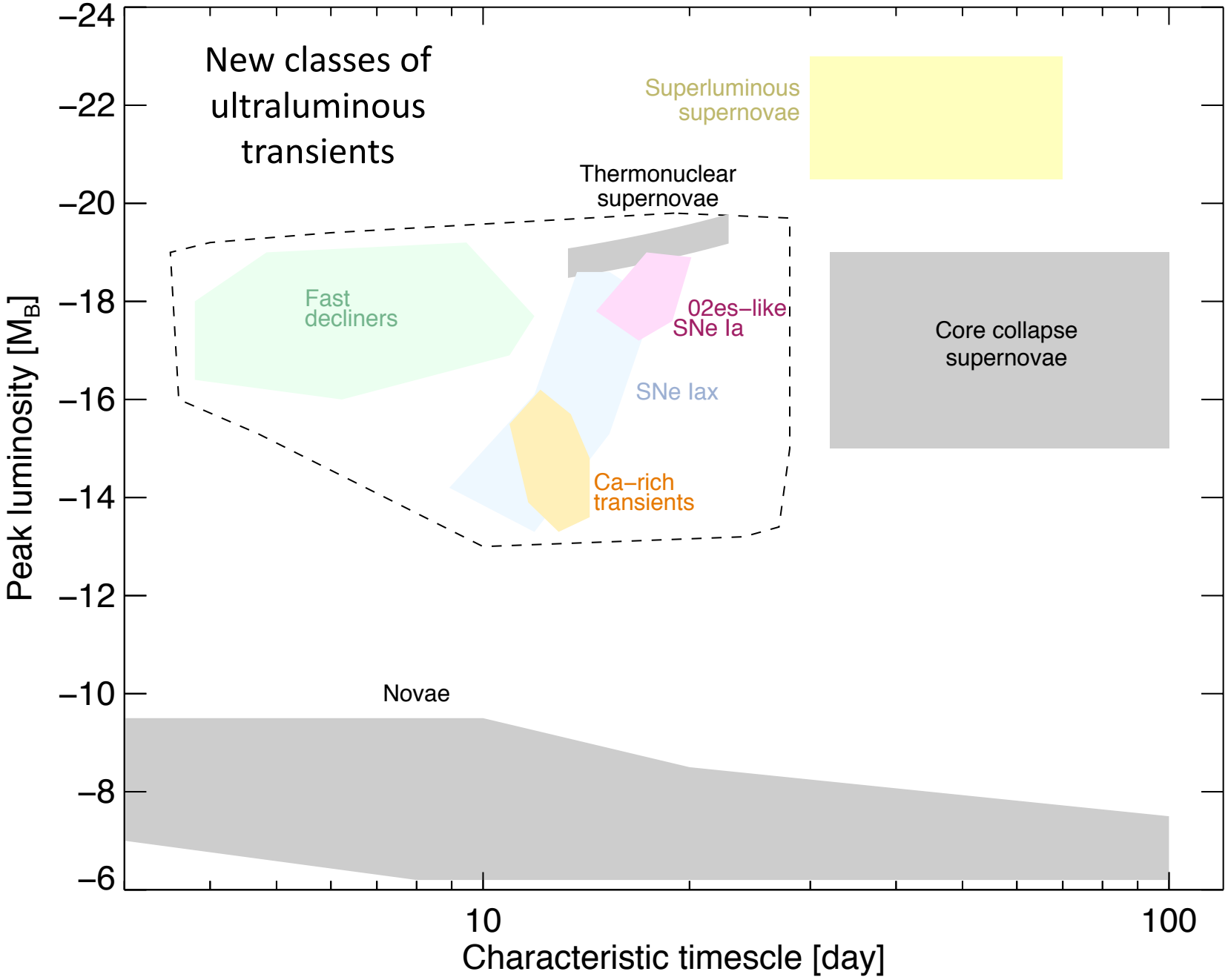


Inserra et al. 2017; update from Inserra & Smartt 2015

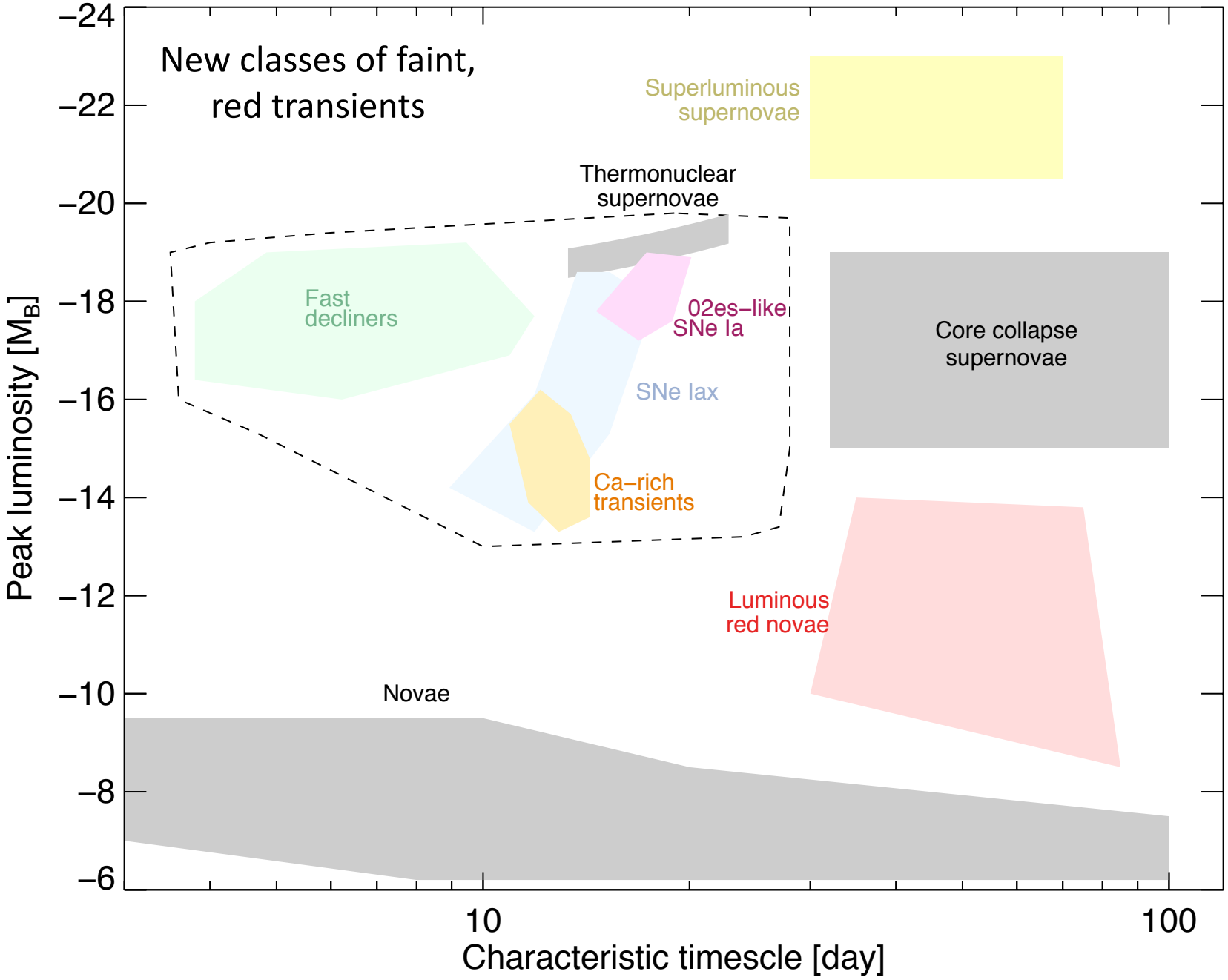


LSST-like survey: 10,000 events
Scovacricchi et al. 2016

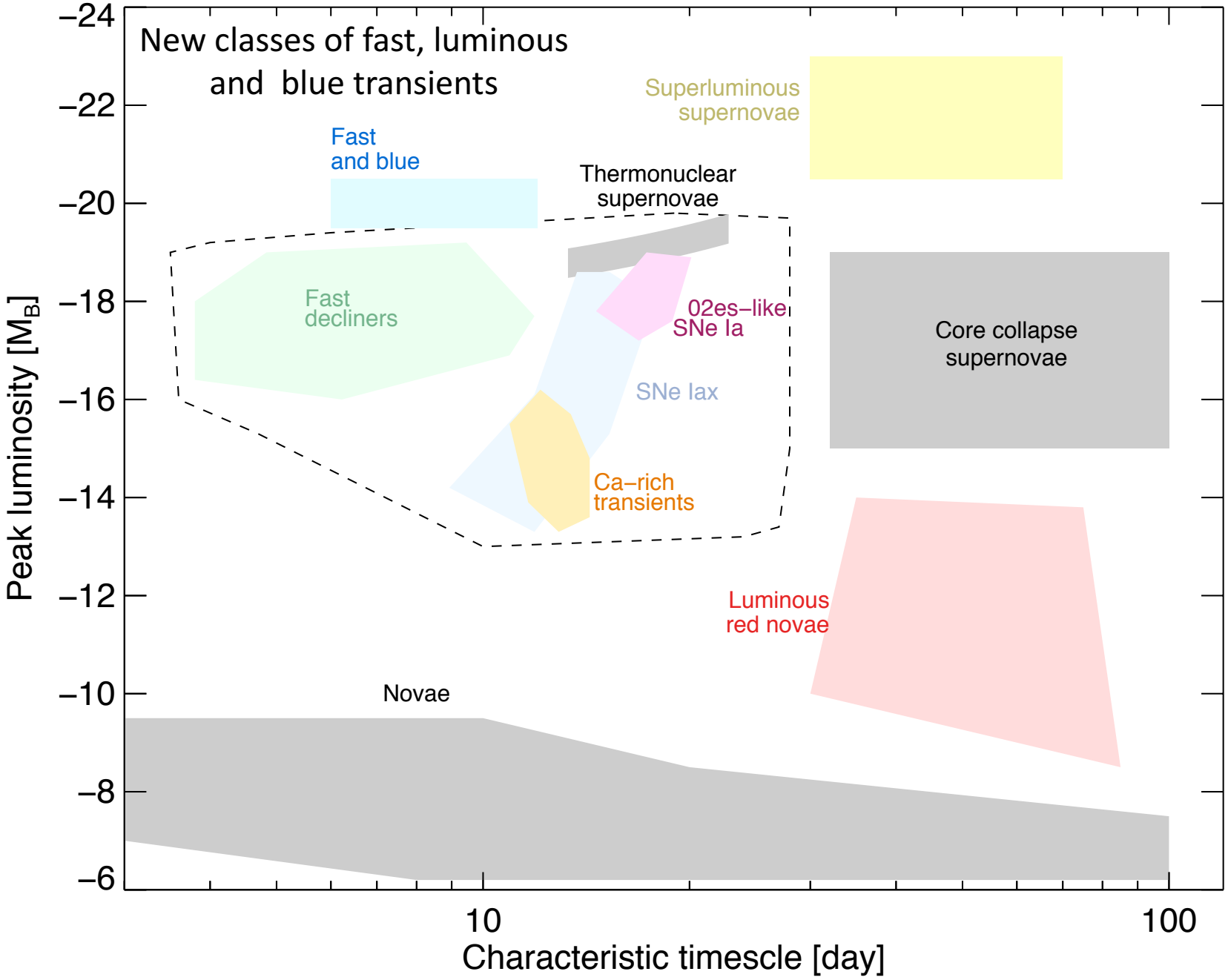
Transient parameter space



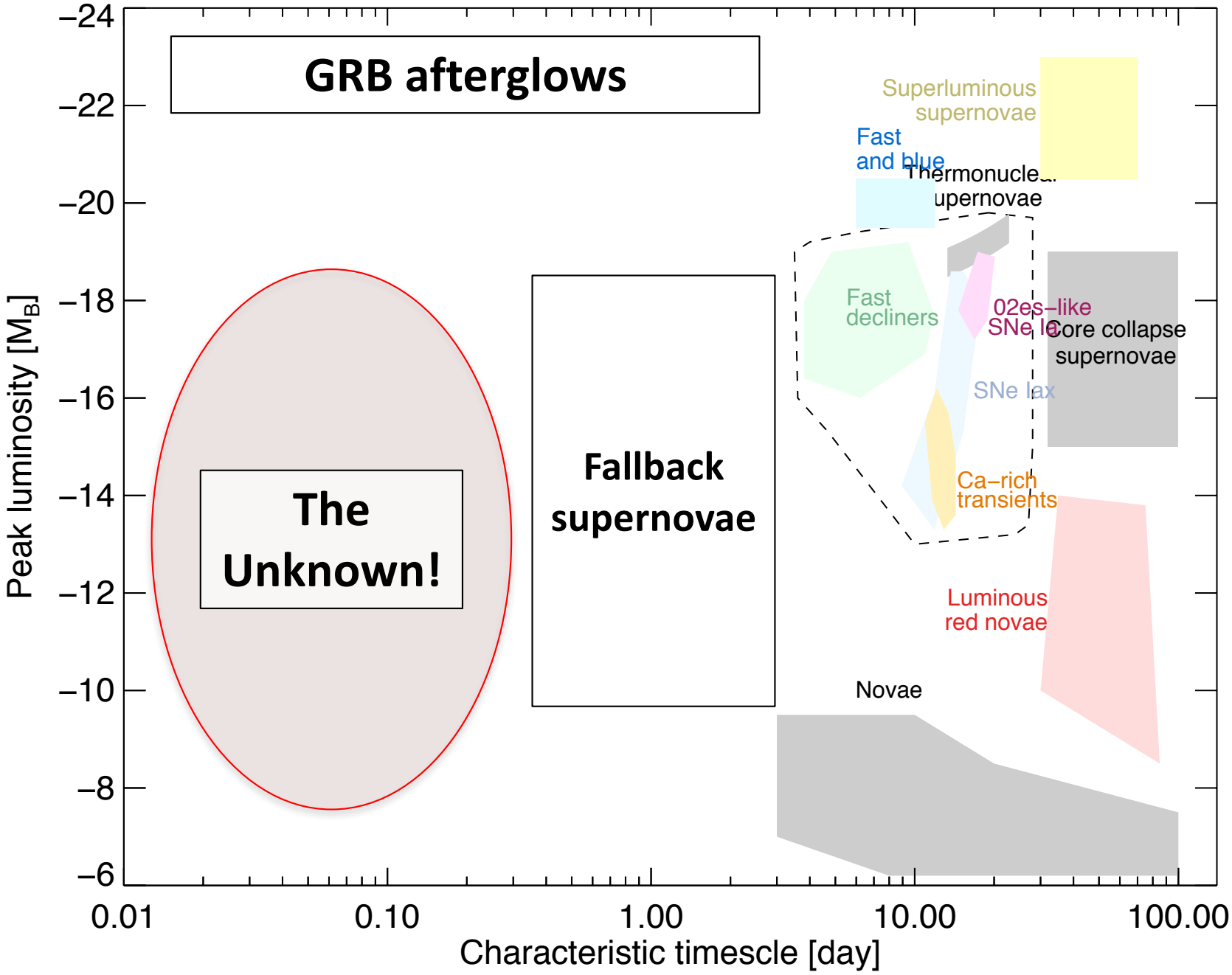
Transient parameter space



Transient parameter space



Transient parameter space

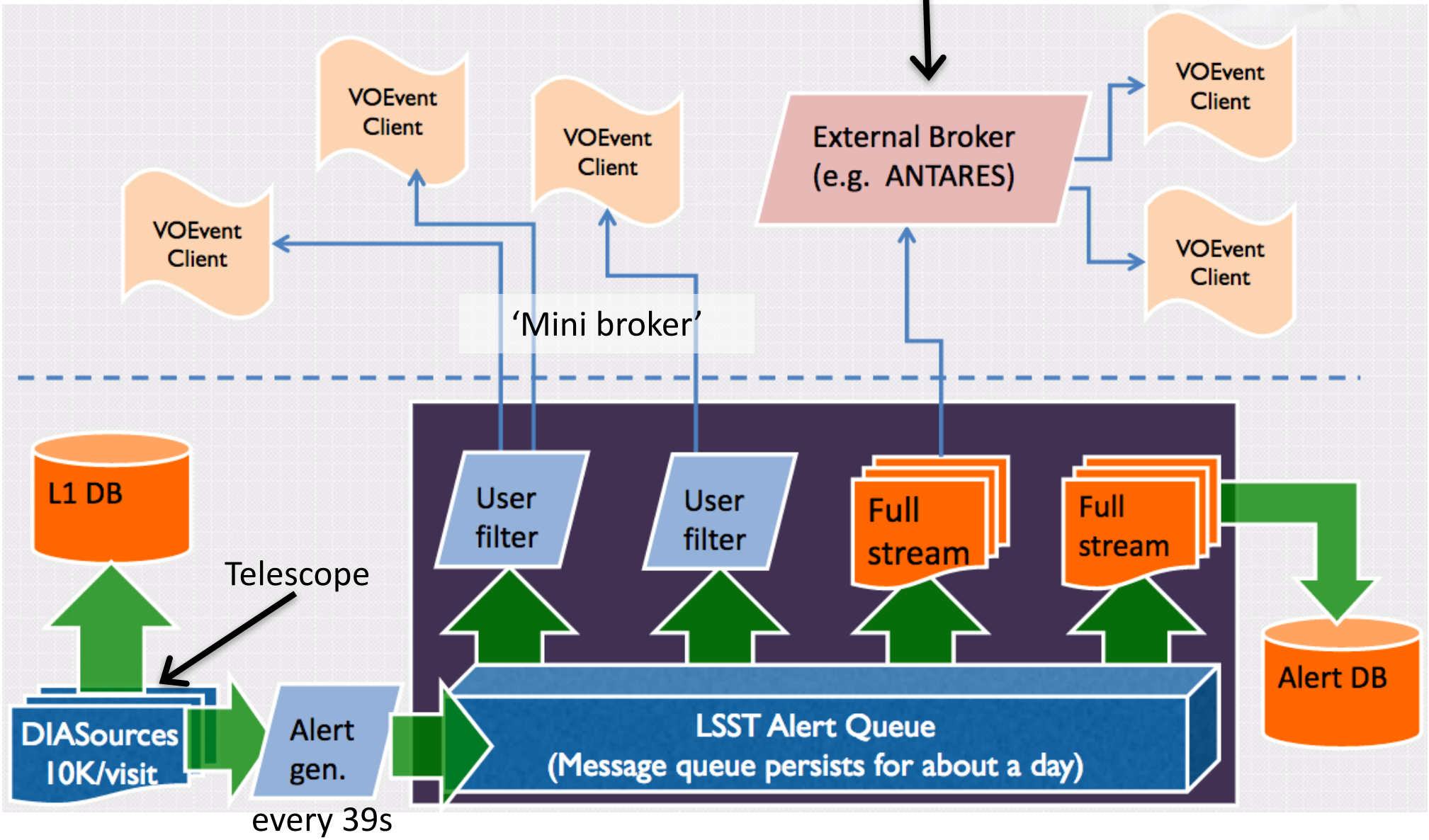


Alert stream

- 400-600 GB *per night*
  - *Each 'visit' is 2 back-to-back 15s exposures*
  - *10,000 events every 39s through the night*

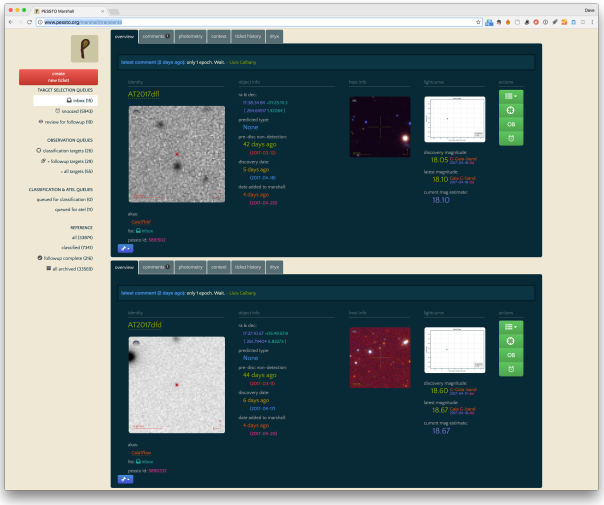
- *Most science users want filtering – a subset:*
  - Limited LSST filtering services ('mini-broker')
  - External value-adding systems ('brokers')

What should this look like?



UK leadership: ePESSTO Marshall

Feeder Surveys and Streams



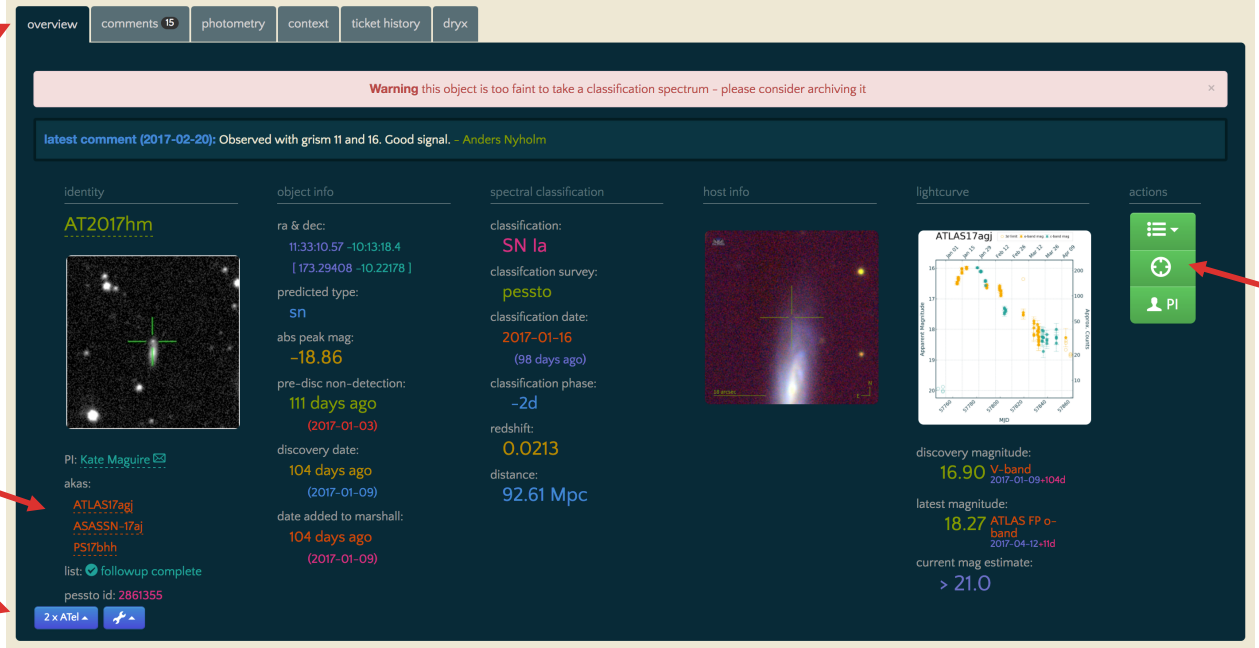
PESSTO Marshall Inbox

http://www.pessto.org/marshall/transients

Comments, Photometry, Contextual Classification, Ticket Histories

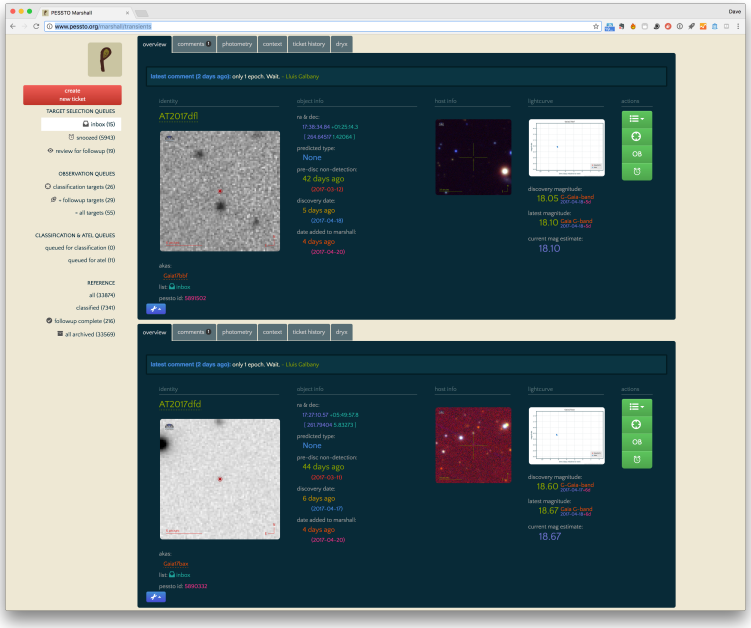
Transient AKAs

External Service Links



Workflow Actions

Object Ticket



PESSTO Marshall Inbox

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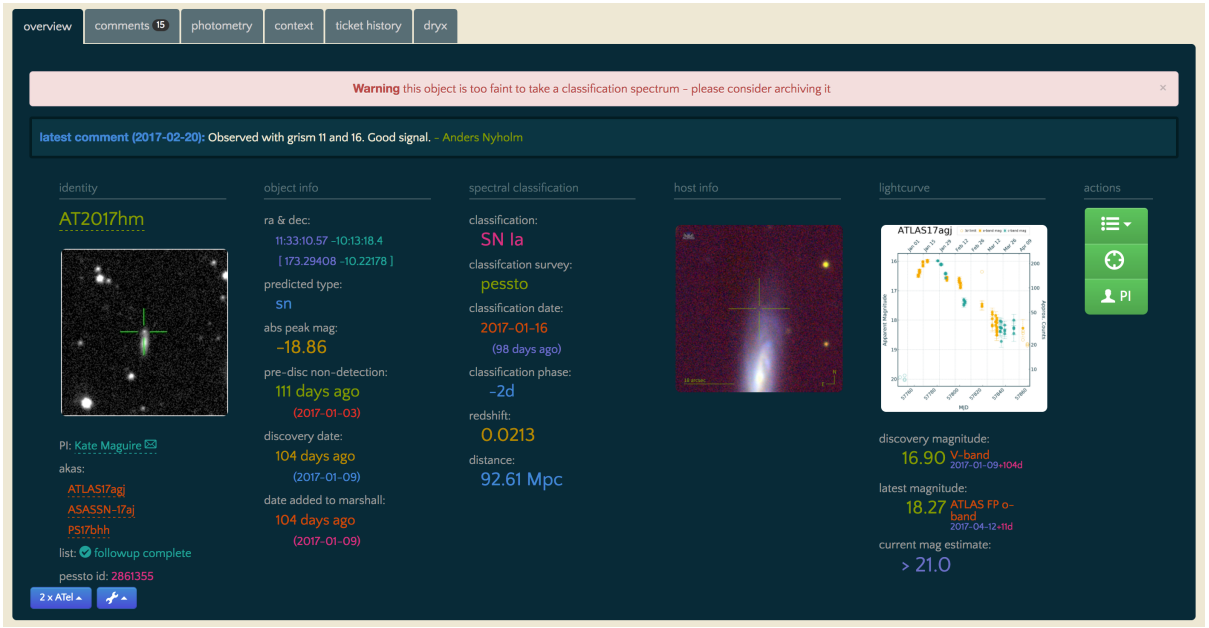


LSST:UK transient broker

→ Different requirements for transients and variable stars

→ Cross-match and contextual information

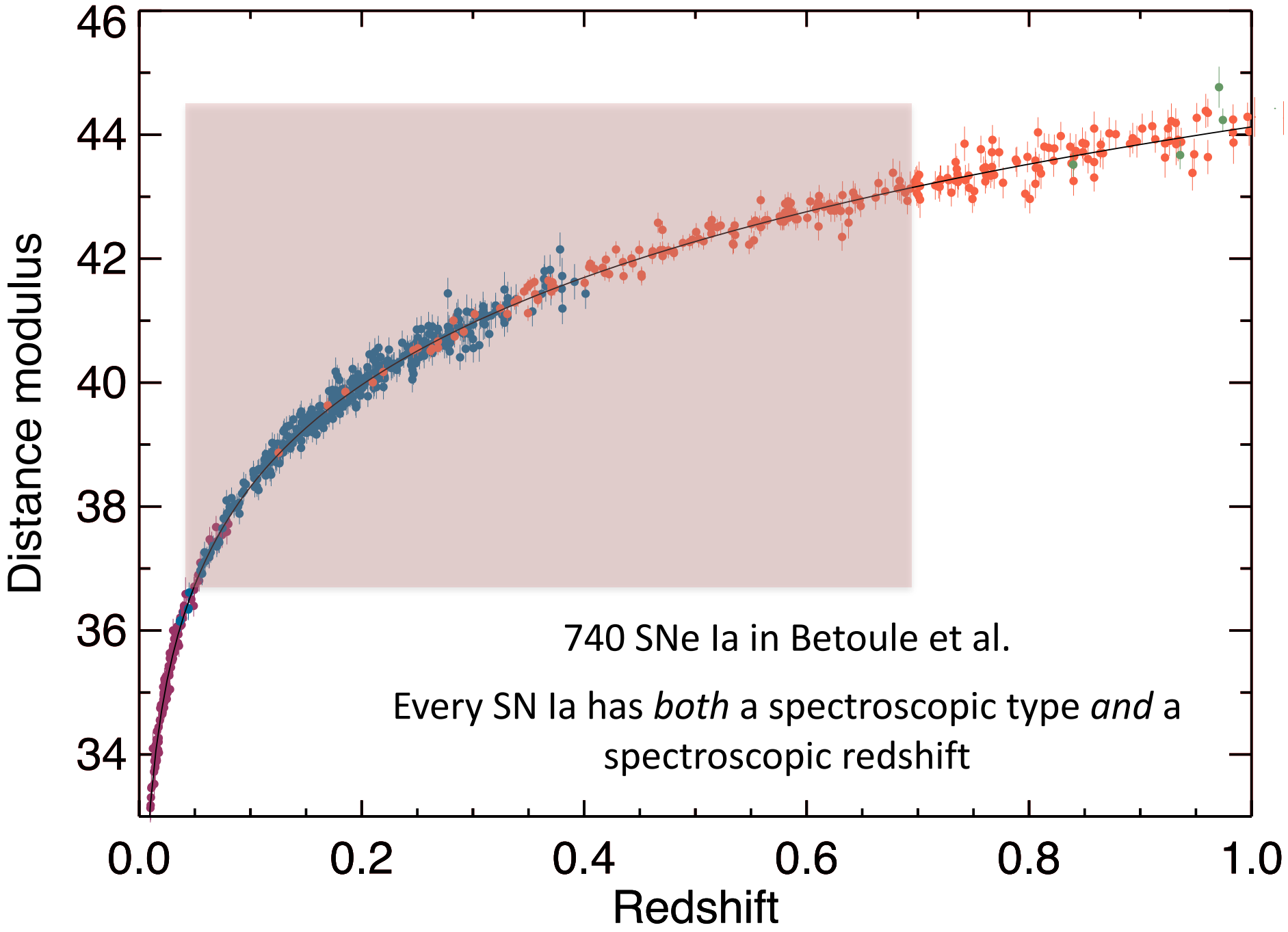
→ qserv: petascale database:
- → speed stress tests
- → ingesting 1000s sources w/ multiple simultaneous users)

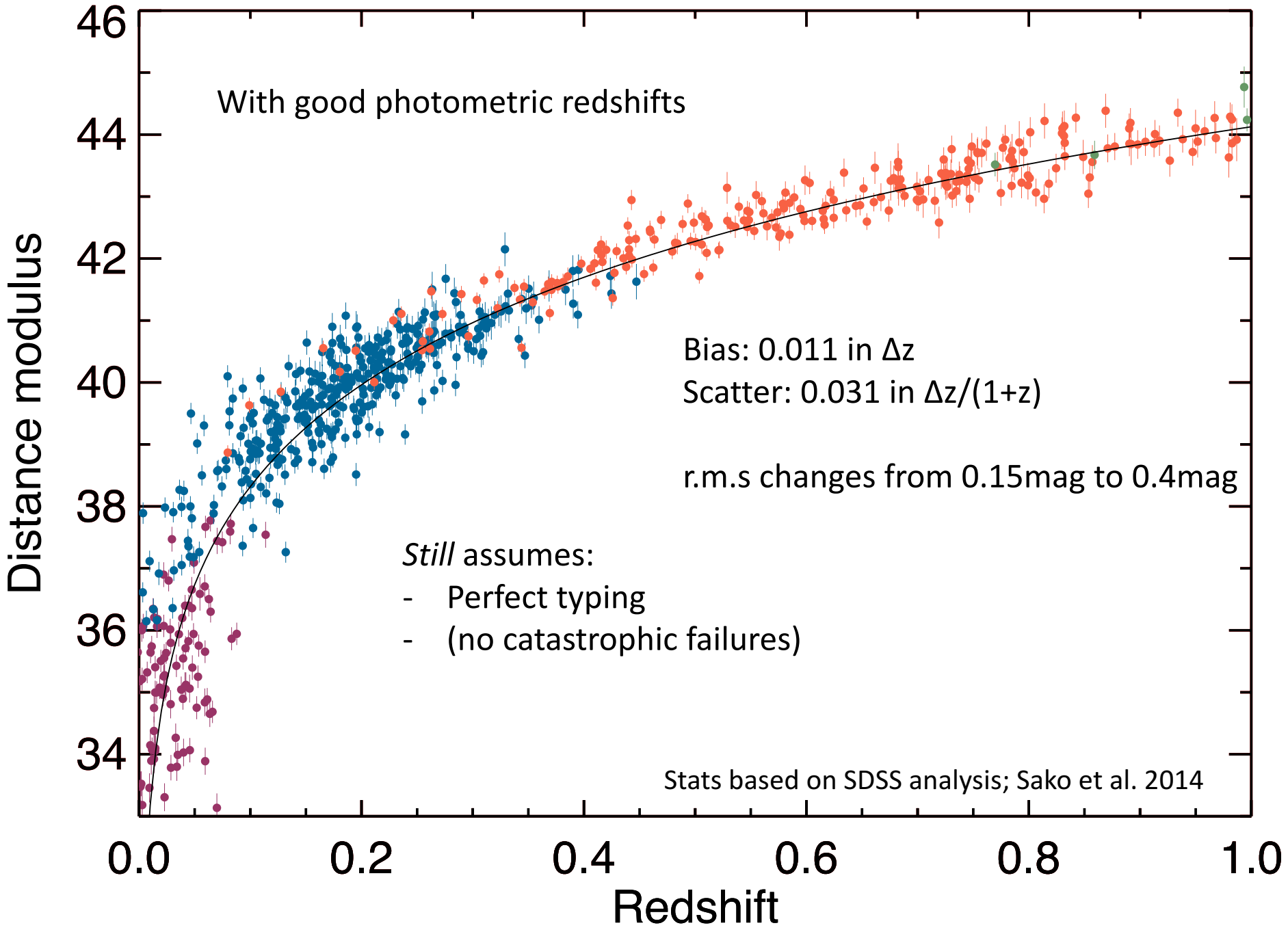
→ Real-time transient alerts

→ *Link to spectroscopic follow-up resources*

Why do spectroscopy?

- Samples of 20,000+ transients easily within grasp
- Enables nearly all ‘astrophysics’
- Systematics/biases in photometric-redshift cosmology difficult to quantify


46
44
42
40
38
36
34
Distance modulus
0.0
0.2
0.4
0.6
0.8
1.0
Redshift
740 SNe Ia in Betoule et al.
Every SN Ia has *both* a spectroscopic type *and* a spectroscopic redshift


With good photometric redshifts
Bias: 0.011 in Δz
Scatter: 0.031 in Δz/(1+z)
r.m.s changes from 0.15mag to 0.4mag
Still assumes:
- Perfect typing
- (no catastrophic failures)
Stats based on SDSS analysis; Sako et al. 2014
Distance modulus
Redshift
46
44
42
40
38
36
34
0.0
0.2
0.4
0.6
0.8
1.0

Why do spectroscopy?

- Samples of 20,000+ SNe easily within grasp
- Enables nearly all ‘astrophysics’
- Systematics/biases in photometric-redshift cosmology difficult to quantify
- Spectroscopy can provide ‘unbiased’ training samples for classification

PLAsTiCC: Photometric LSST Astronomical Time-series Classification Challenge

- Designed to address LSST-era transient classification
- Funded by LSST Enabling Science grant and LSST:UK
- Planning workshop: Simons Center, New York July 14th 2017
- Concluding workshop: here, March 2018

- Rich simulations of astrophysical populations: sources (SNe, AGN, etc.), spectral types, luminosity functions, dust extinction, host galaxy populations....
- Contextual information (e.g., nearest galaxies/stars to object, etc.)

- Best use of limited spectroscopic resources (e.g. training samples)
- Challenge data easy to update for different survey strategies

- *Notice of intent has been issued: respond by 1st June!*

(e)PESSTO

(*[extended]Public ESO Spectroscopic Survey for Transient Objects*)

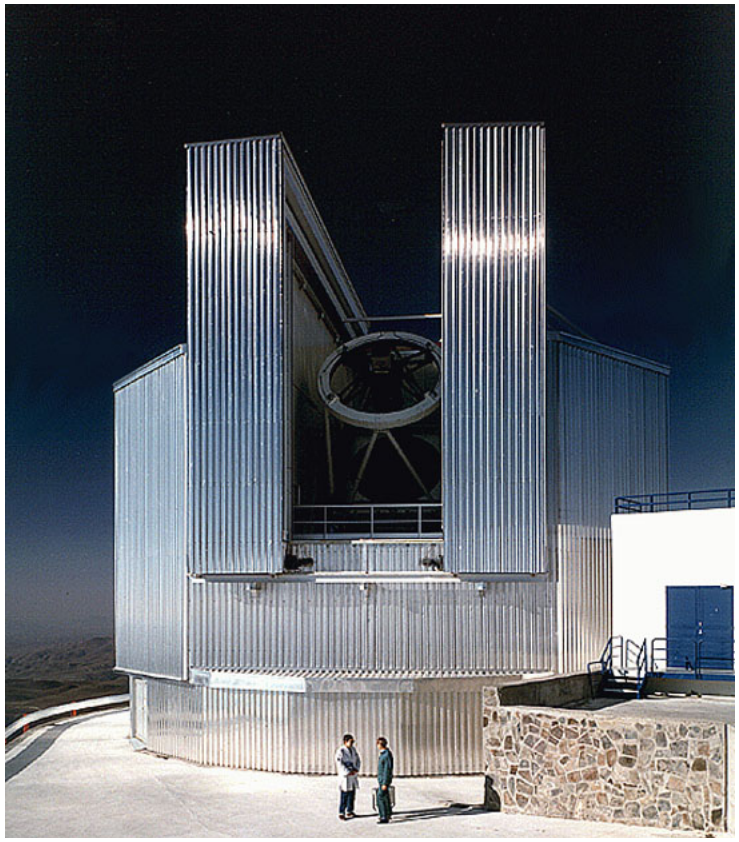
PESSTO uses 25% of the NTT since 2012

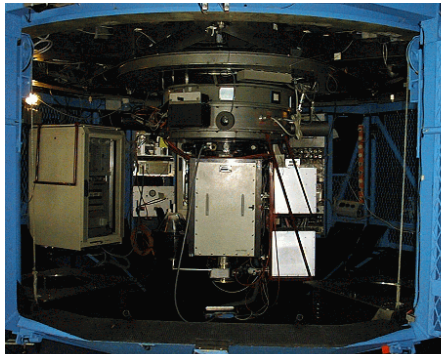
(1/3 of the time during 10 lunations a year)

Now extended until 2019

Studying all explosive transients, with an emphasis on the “exotic”

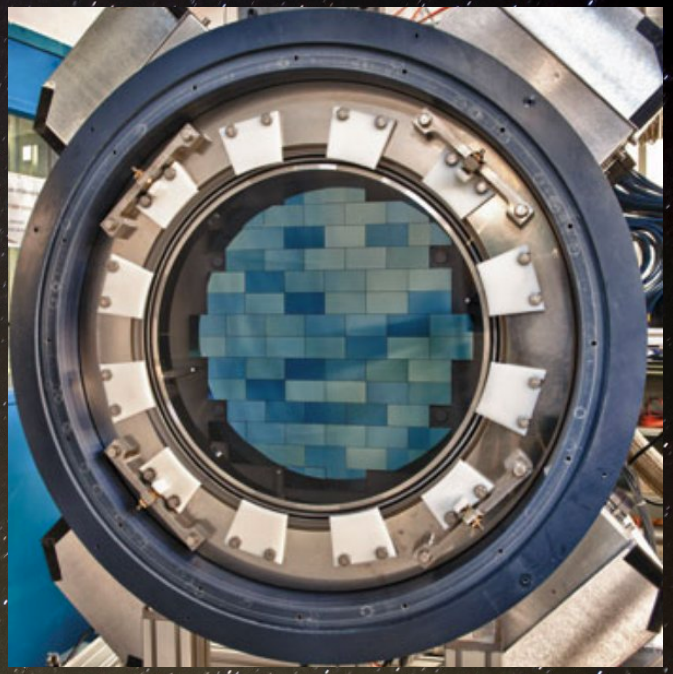
Transitions to SoXS around 2020





The Dark Energy Survey

Multi-component survey designed to probe *dark energy* and origin of cosmic acceleration



DES-Wide

- 5000 deg^2 in *grizY*: r_{AB} ~ 24.3, i_{AB} ~23.5 (10σ)
- Large Scale Structure; Weak Lensing; Galaxy Cluster

DES-SN

- ~ 6-day cadenced *griz survey* over 27 deg^2
- Type Ia Supernovae

Probes of both Distance vs. Redshift & Growth of Structure

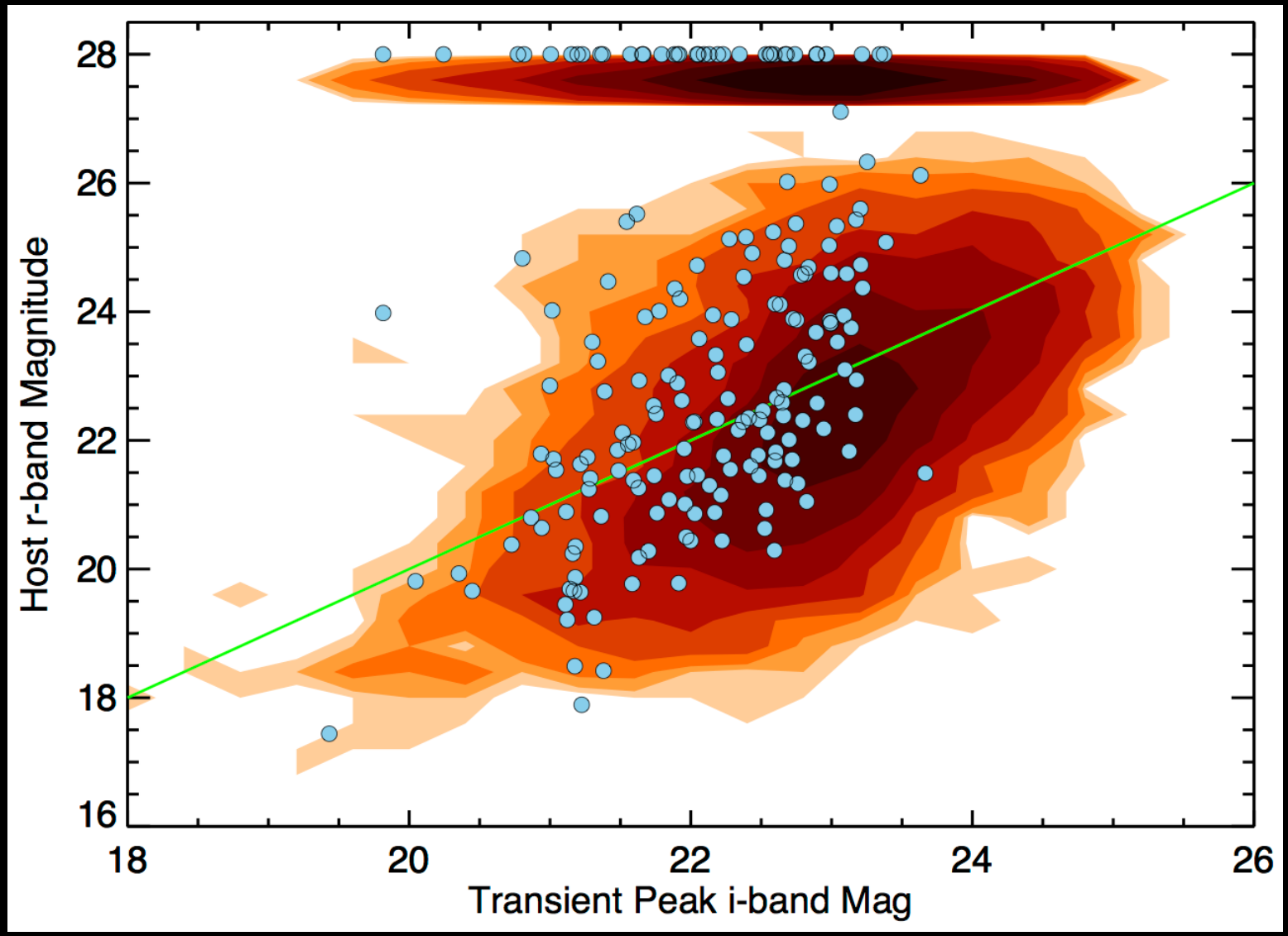
UK DES Collaboration

Cambridge ❖ Edinburgh ❖ Nottingham ❖ Portsmouth ❖ Sussex ❖ UCL

Dark Energy Camera (DECam) on 4m Blanco Telescope at CTIO

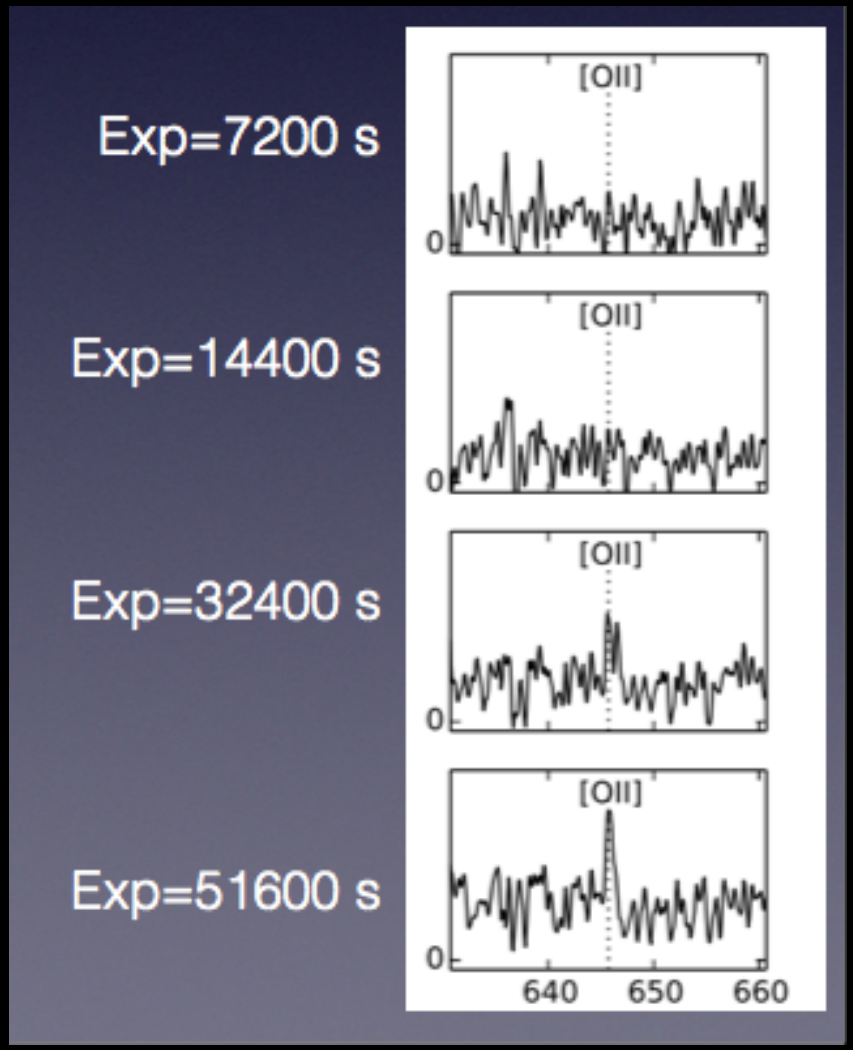
- 520 Mpx camera; 3 deg^2 FoV; deep-depleted LBNL CCDs
- Allocated 525 nights over 5 observing seasons (Aug - Feb, 2013 - 2018)
  - *DESY4 starts 13 August 2016*

DES HOST/TRANSIENT MAGNITUDE PARAMETER SPACE

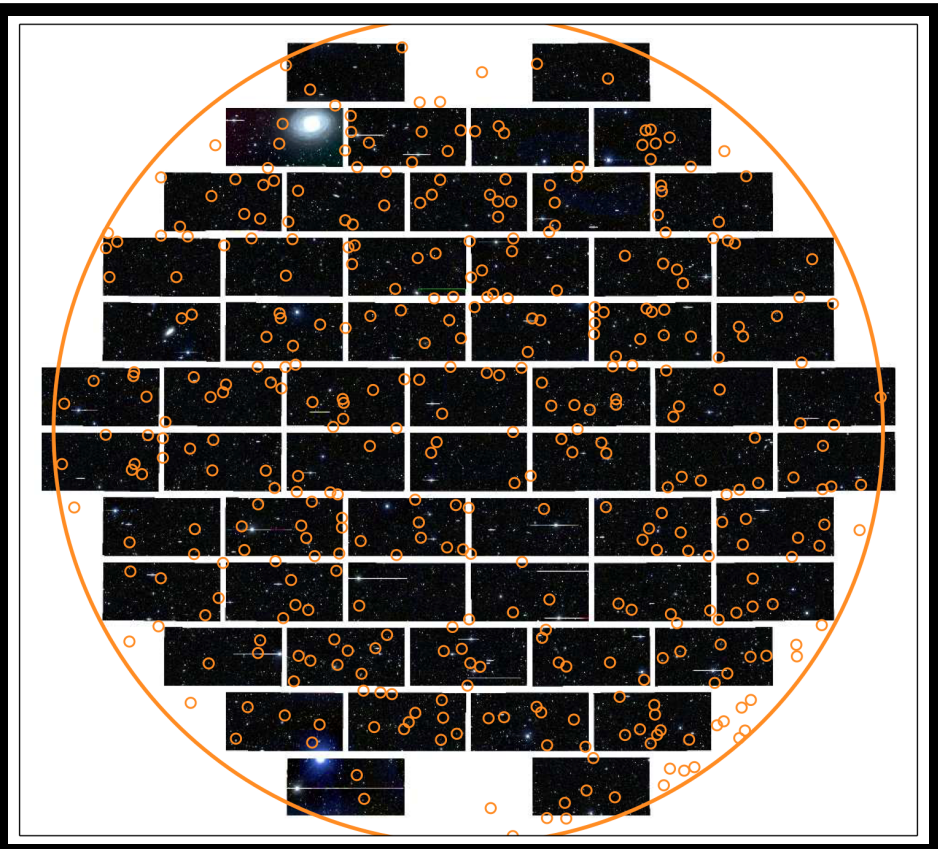


Example: AAT/OzDES

- 100 night program over 5 years overlapping with DES
- SN Hosts repeatedly targeted to build up depth;
  Live transients targeted as well



On target for ~4000 SN host redshifts



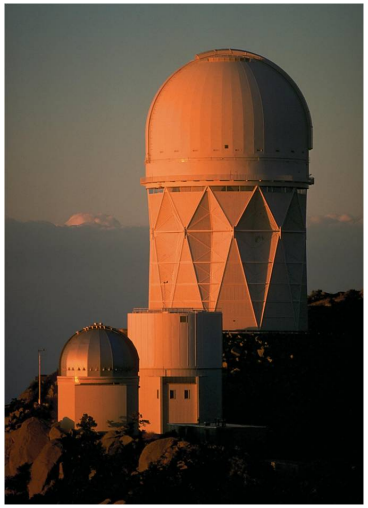
Courtesy C. Lidman

Large MOS follow-up of transients

Example: TIme Domain Extragalactic Survey (TiDES) [4MOST]

4MOST: ESO VISTA telescope

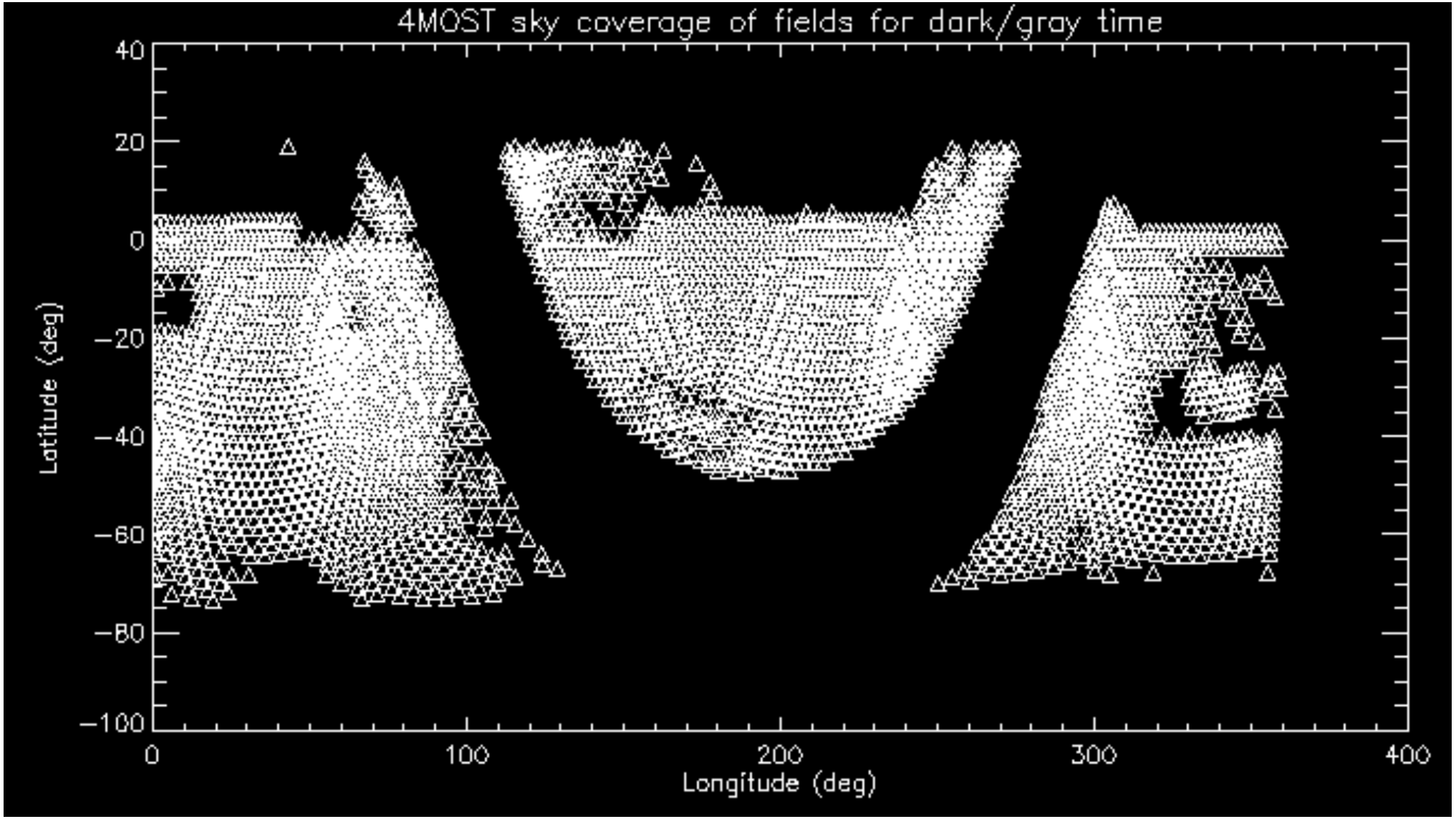
WEAVE: WHT



DESI: KPNO 4m

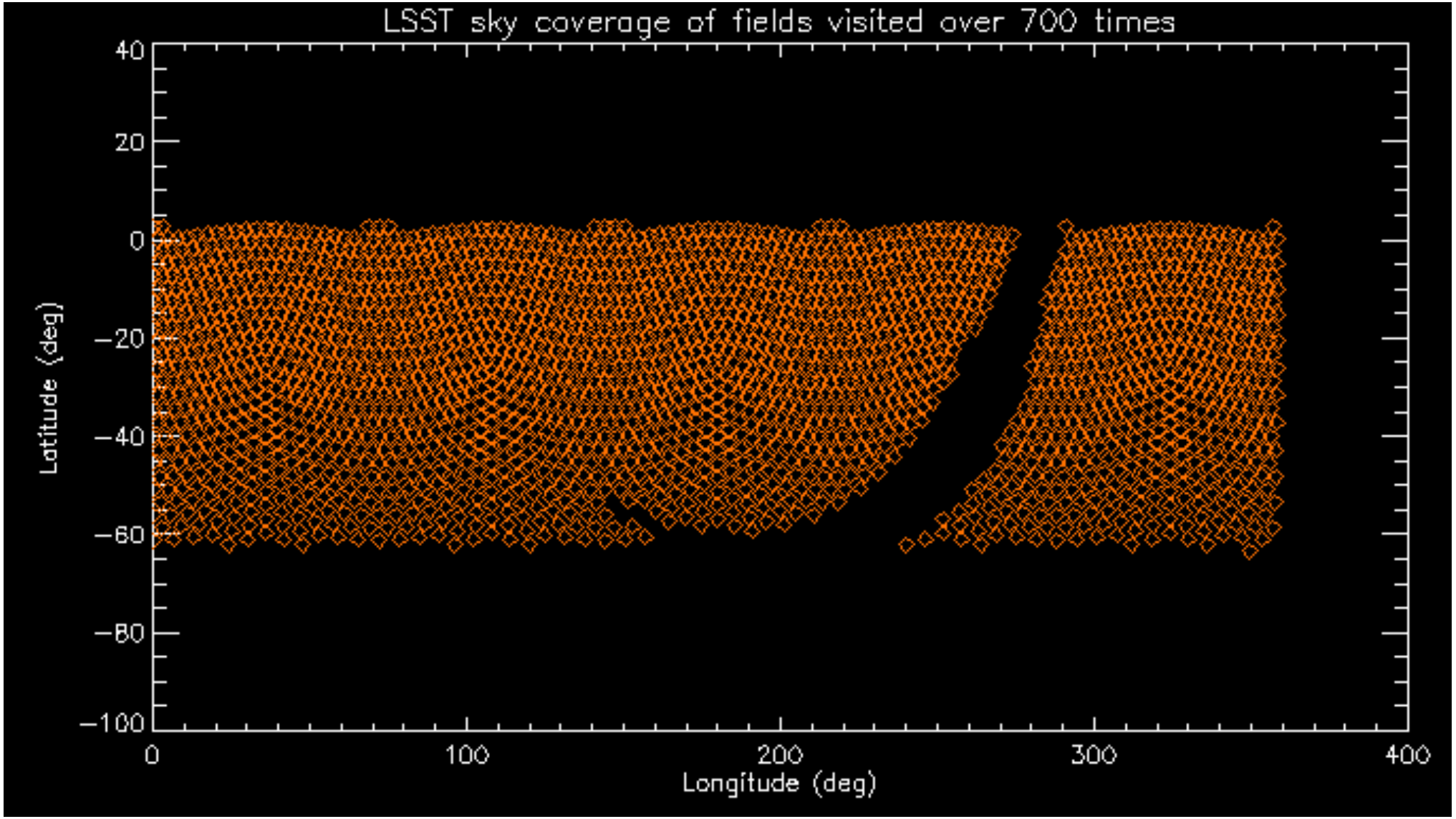
- DESC: Wherever 4MOST points, LSST will have previously discovered transients. Put fibre on host galaxy to get a redshift.
- TVS (+DESC): Do live transients in same fields; schedule 1-3 days ahead

4MOST pointings



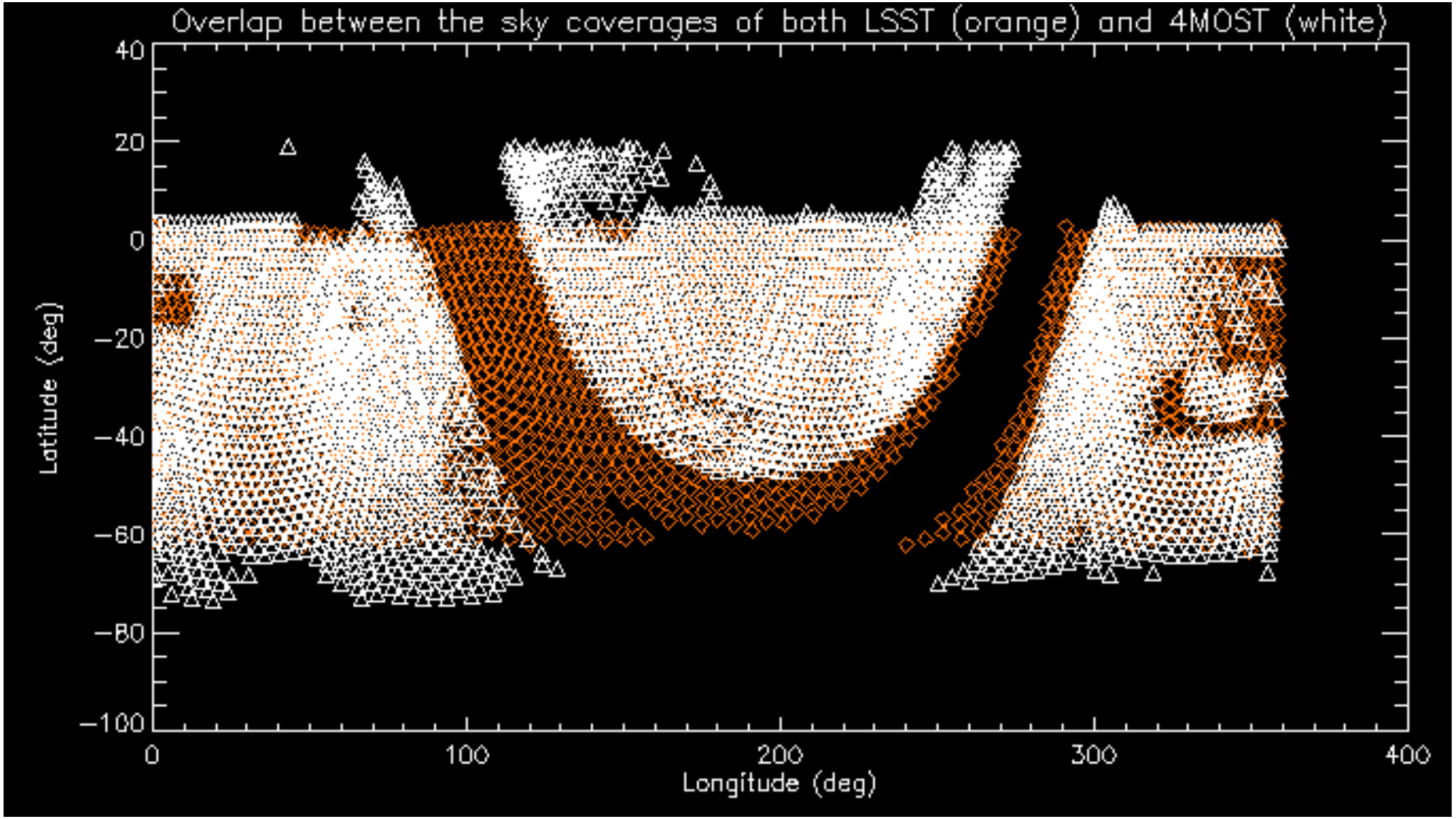
From B. Turpin and I. Hook

LSST pointings



From B. Turpin and I. Hook

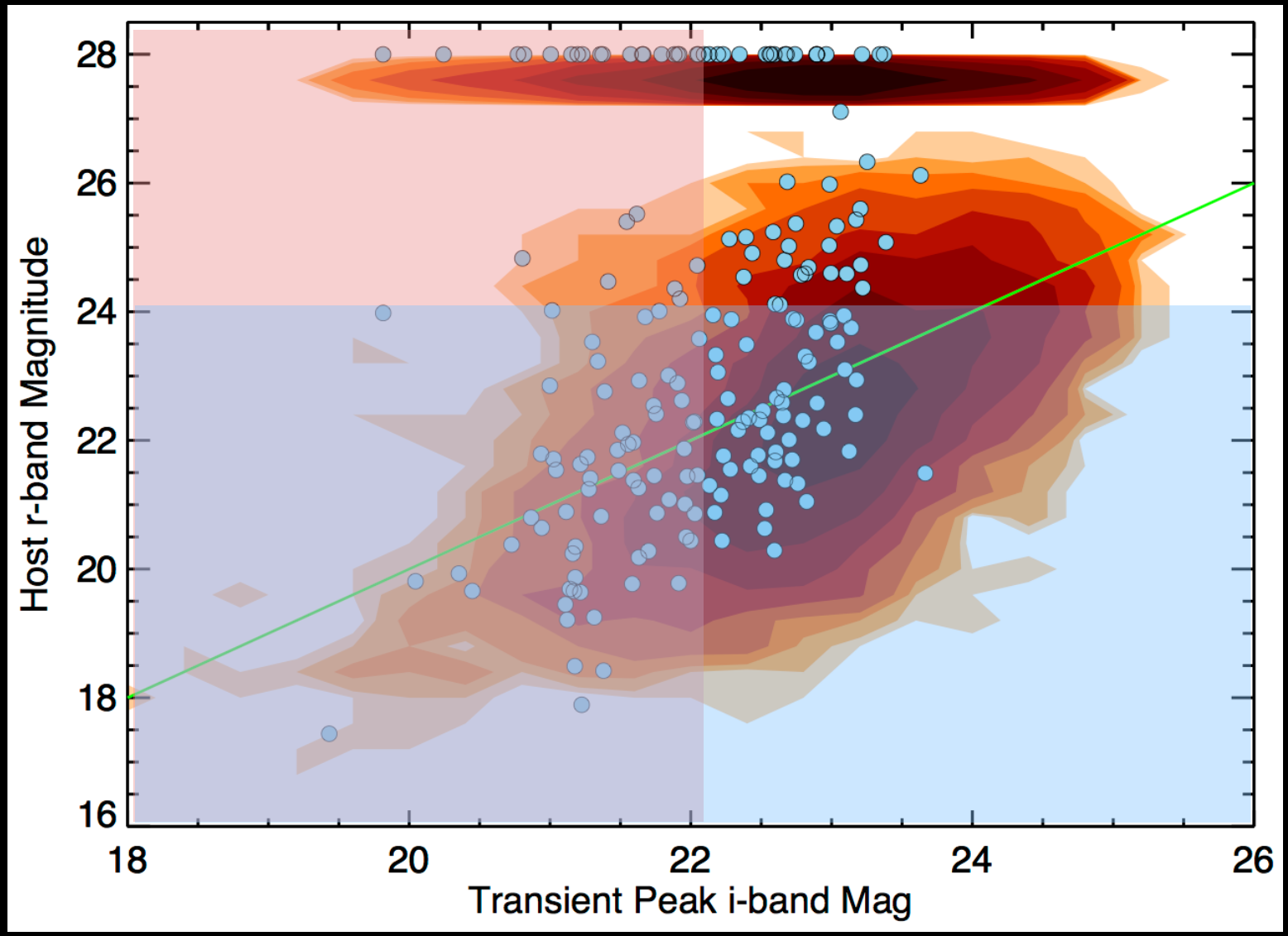
Combination



Capability of up to 50,000 transient spectra over 5 years

From B. Turpin and I. Hook

DES HOST/TRANSIENT MAGNITUDE PARAMETER SPACE

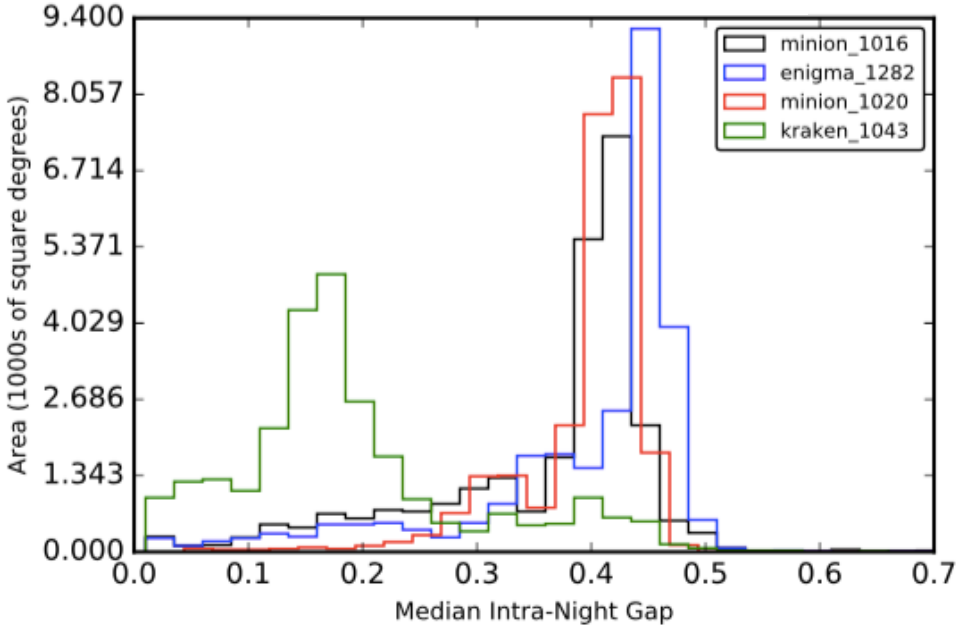


Follow-up during commissioning

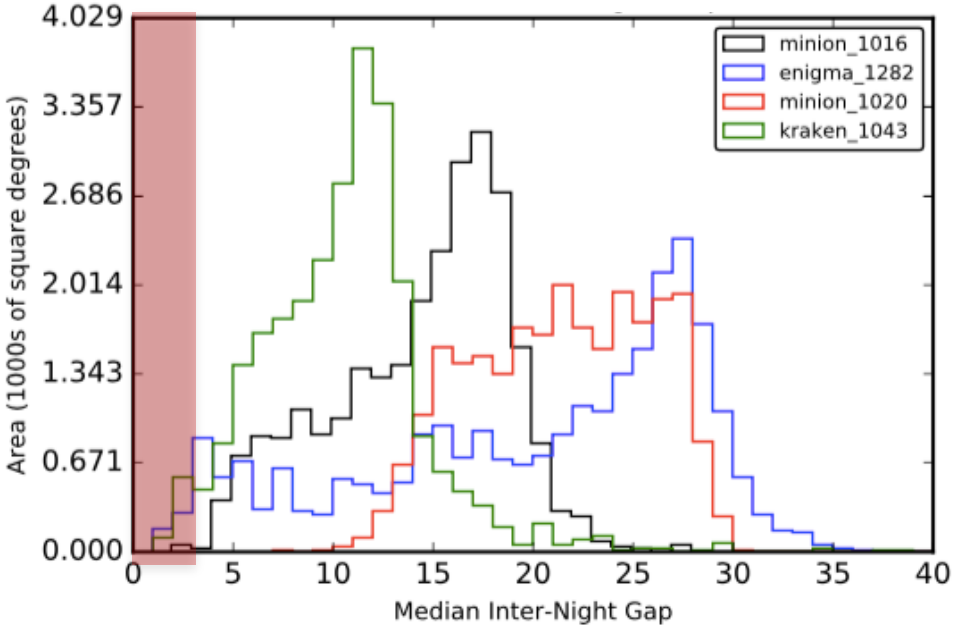
- Linking/excercising ‘transient broker’ and spectroscopic schedulers
  - Algorithms for target selection
  - *Needs to be operational by first light; test during commissioning*
- Optimise spectroscopic strategy
  - What samples are needed for photometric classification
  - Run proto-survey during commissioning (e.g., AAT)?
- Test classification algorithms on real LSST data
  - How does real-time classification work?
  - How does classification for SN cosmology survive contact with real data?

LSST “universal” cadence

Within a night



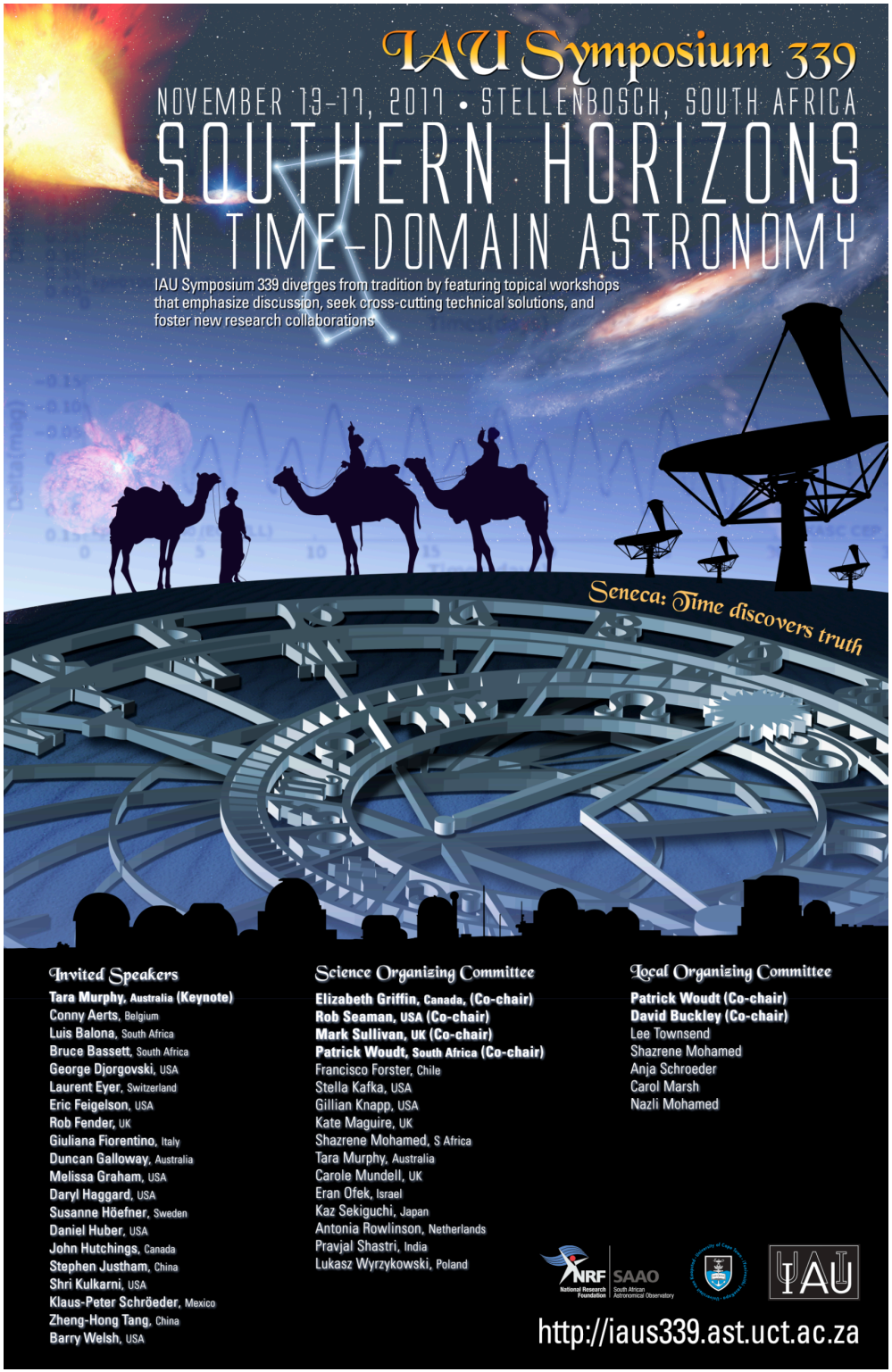
Between nights



From Bellm & Bianco in the Observing Strategy White paper

- LSST Cadence is ~3 days in *some* filter
- But is approx 15 - 30 days in any *specific* filter

- Mostly *not useful* for transients



Southern Horizons in Time Domain Astronomy

November 13th-17th in Stellenbosch, SA

Registration now open