PLAsTiCC transient metrics

federica b. bianco, NYU
The Transient and Variable Stars LSST Collaborations

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LSST Science Collaborations

There are currently eight active LSST Science Collaborations. Additional information about their work and membership can be found at the links below or by contacting the individual chairs, or the LSSTC Science Collaborations Coordinator (LSSTCSCC), Lucianne Walkowicz.

Galaxies

Michael Cooper (UC Irvine); Brant Robertson (University of California, Santa Cruz);

Stars, Milky Way, and Local Volume

John Bochanski (Rider University); John Gizis (University of Delaware); Nitya Jacob Kallivayalil (University of Virginia);

Solar System

Meg Schwamb (Gemini Observatory, Northern Operations Center); David Trilling (Northern Arizona University);

Dark Energy

Rachel Bean (Cornell University); Jeffrey Newman (University of Pittsburgh);

Active Galactic Nuclei

Niel Brandt (Pennsylvania State University);

Transients/variable stars

Federica Bianco (New York University); Ashish Mahabal (Caltech); Rachel Street (LCO);

Strong Lensing

Charles Keeton (Rutgers-The State University of New Jersey); Aprajita Verma (Oxford University);

Informatics and Statistics

Tom Loredo (Cornell University); Chad Schafer (Carnegie Mellon University);

TVS Science Collaboration

Transients & Variable Stars collaboration co-chairs

Federica Bianco

Ashish Mahabal → Rachel Street

Nearly 180 members!

Each member declares a *primary* affiliation and up to 3 *secondary* affiliations

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Subgroups

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- Cosmological
- Classification/Characterization
- Distance Scale
- Fast Transients
- Galactic
- Interacting Binaries
- Magnetically Active Stars
- Microlensing Subgroup
- Multiwavelength Characterization/Counterparts
- Non-degenerate Eruptive Variables
- Pulsating Variables
- Supernovae Subgroup S. Valenti
- Tidal Disruption Events
- Transiting Planets

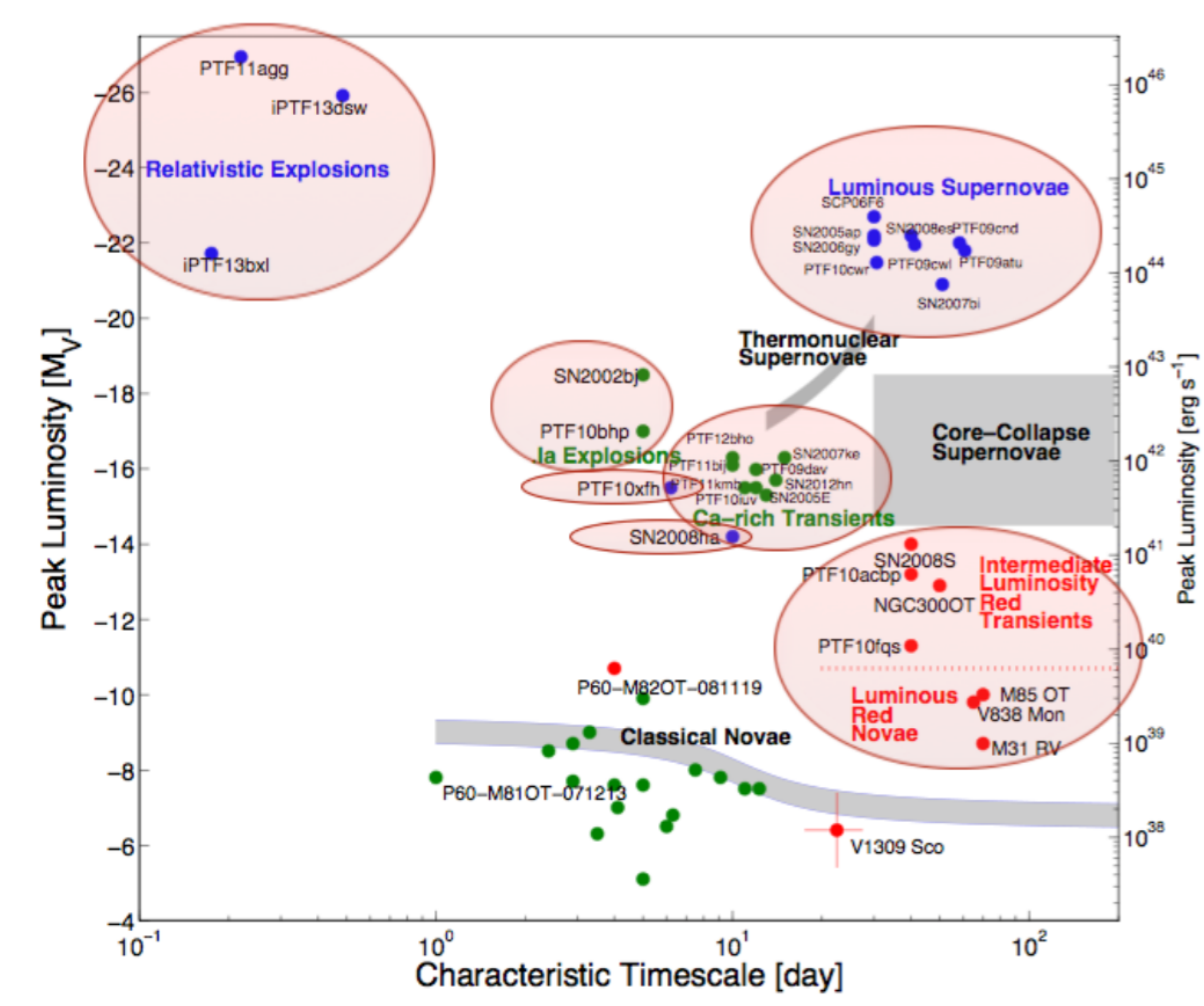
Science Drivers

- Dark energy and dark matter (via measurements of strong and weak lensing, large-scale structure, clusters of galaxies, and supernovae)
- Exploring the transient and variable universe
- Studying the structure of the Milky Way galaxy and its neighbors via resolved stellar populations
- An inventory of the Solar System, including Near Earth Asteroids and Potential Hazardous Objects, Main Belt Asteroids, and Kuiper Belt Objects

Science Drivers

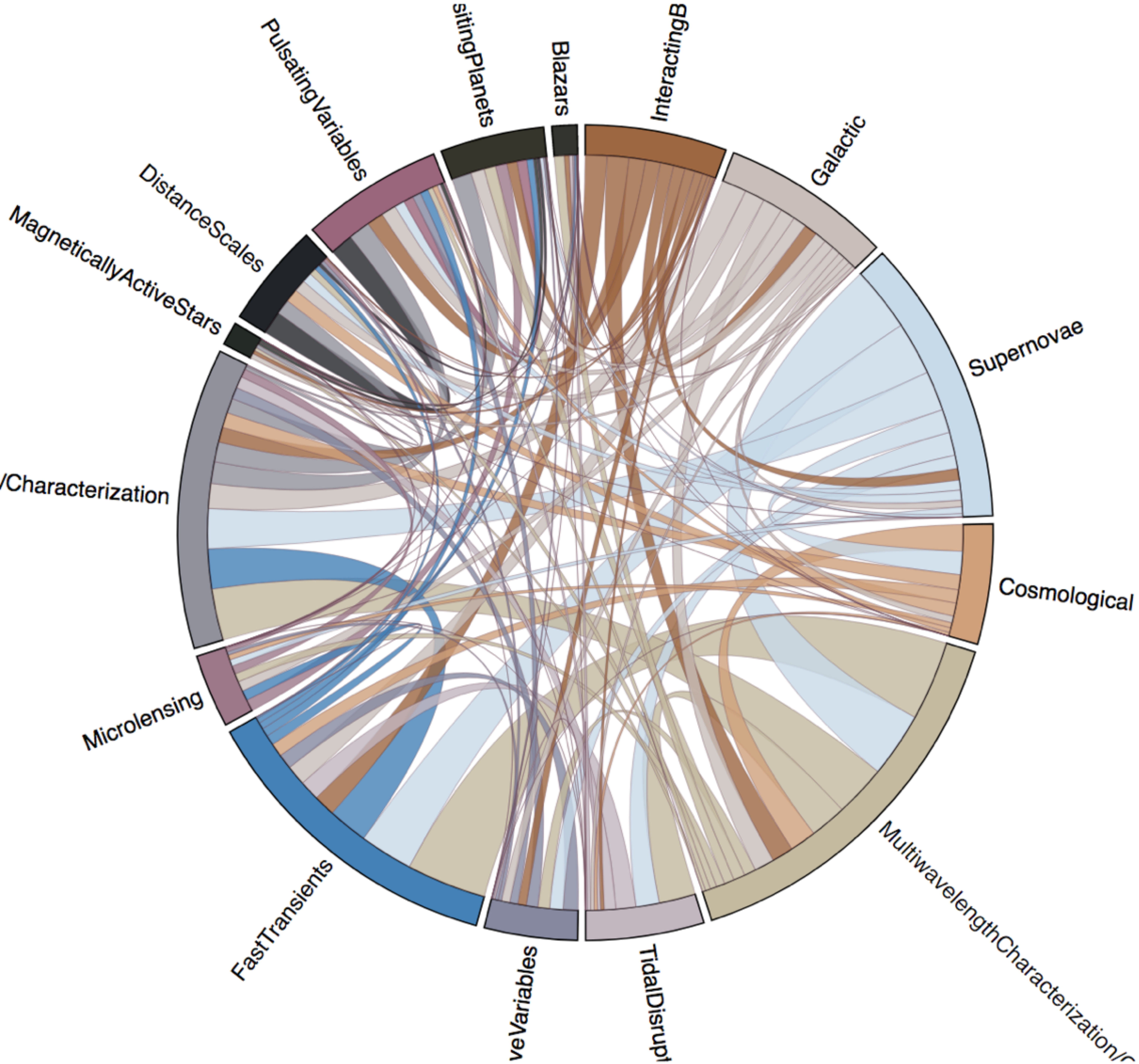
all relevant to transients + variable Universe!

- Dark energy and dark matter (via measurements of strong and weak lensing, large-scale structure, clusters of galaxies, and ***supernovae***)
- Exploring the ***transient and variable universe***
- Studying the structure of the Milky Way galaxy and its neighbors via ***resolved stellar populations***
- An inventory of the Solar System, including Near Earth Asteroids and Potential Hazardous Objects, Main Belt Asteroids, and Kuiper Belt Objects moving objects



Updated from Kasliwal 2011 (PhDT)

E. Bellm



LSST TVS Science Collaboration

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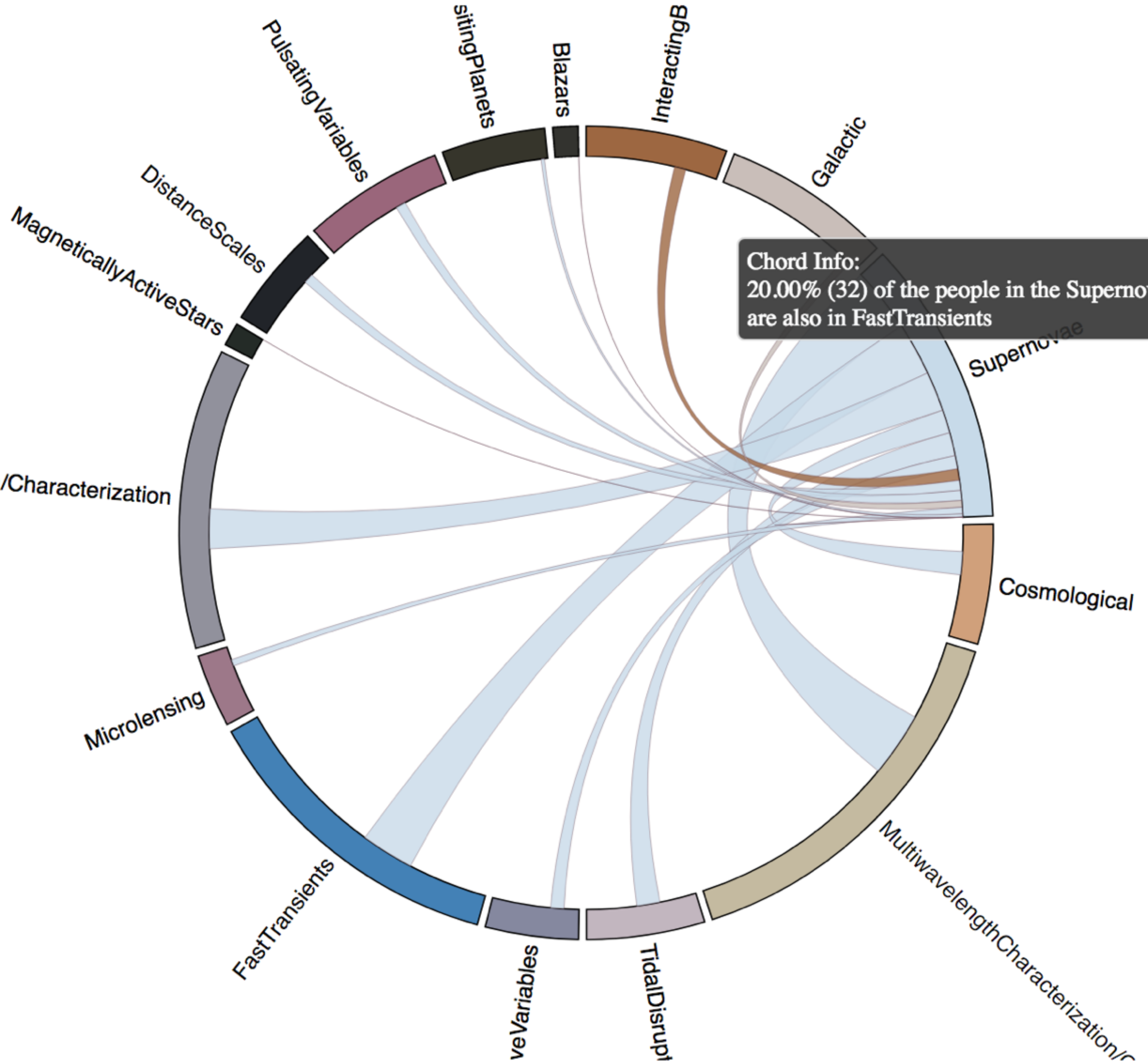

TVS Science Collaboration

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OBSERVING STRATEGY WHITE PAPER

Prepared by the LSST Science Collaborations,

with contributions from the LSST Project.

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Science-Driven Optimization of the LSST Observing Strategy

a *science based evaluation* of the proposed LSST observing strategies

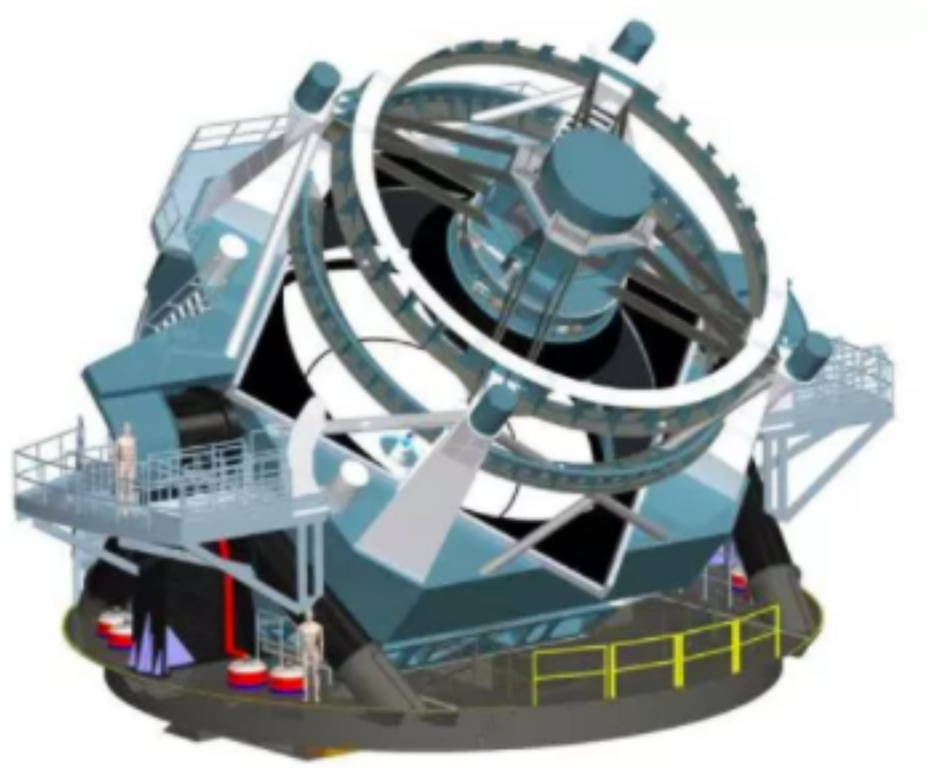
http://www.slac.stanford.edu/~digel/ObservingStrategy/whitepaper/LSST_Observing_Strategy_White_Paper.pdf

https://github.com/LSSTScienceCollaborations/ObservingStrategy

The success of TRANSIENTS & VARIABLES related science is tied to cadence choices

Classification

Classification



PHOTOMETRIC LSST ASTRONOMICAL TIME-SERIES CLASSIFICATION CHALLENGE (PLASTICC)

periodic recurring fast slow

different variable and transient phenomena benefit from different observing strategies

periodic recurring fast slow

different variable and transient phenomena benefit from different observing strategies

metrics leverage either color or sampling density

- color or sampling? (SN/GW vs GRB)
- dense sampling or duration? (SN vs TDE/LBV)
- context information-location/host/neighboring stars (Ia vs CC)

periodic recurring fast slow

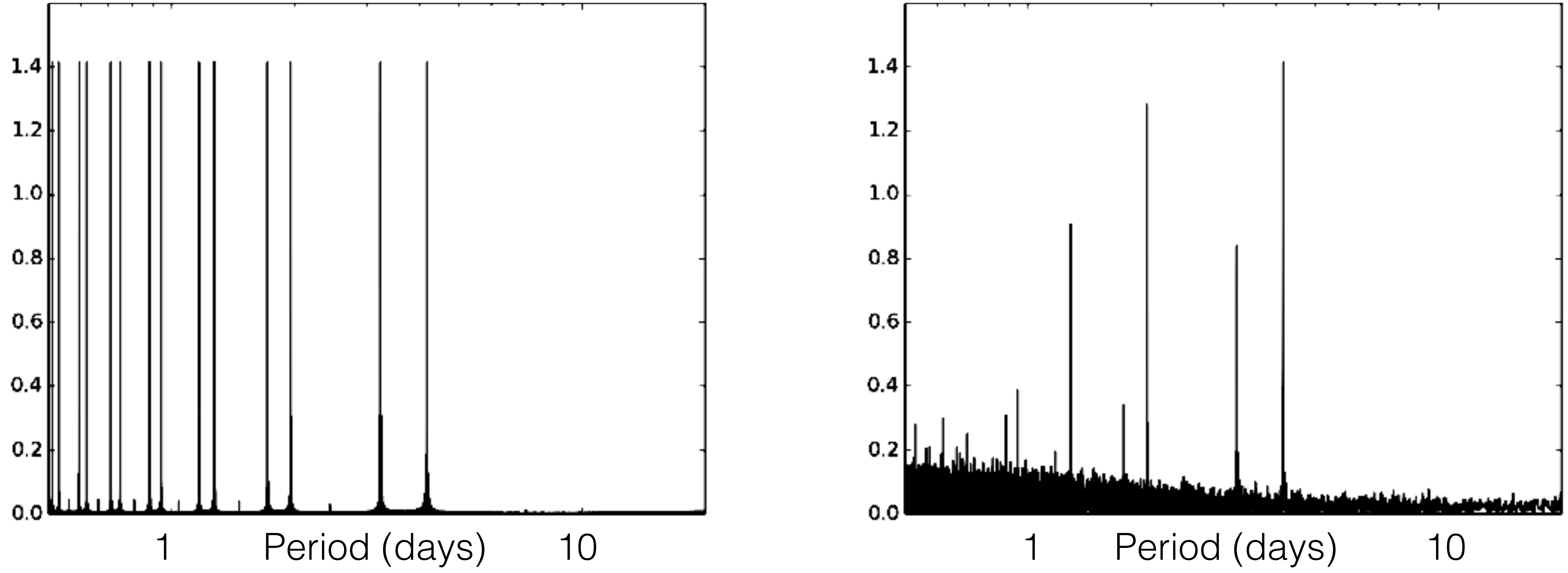
- *planets*
- *EB*
- *periodic variables*

can you identify periodic transients?

single band sampling regularity
or reliable SED models and sampling in any band

LombScargle periodogram

sampling regular to 0.1 days sampling regular to 1 days



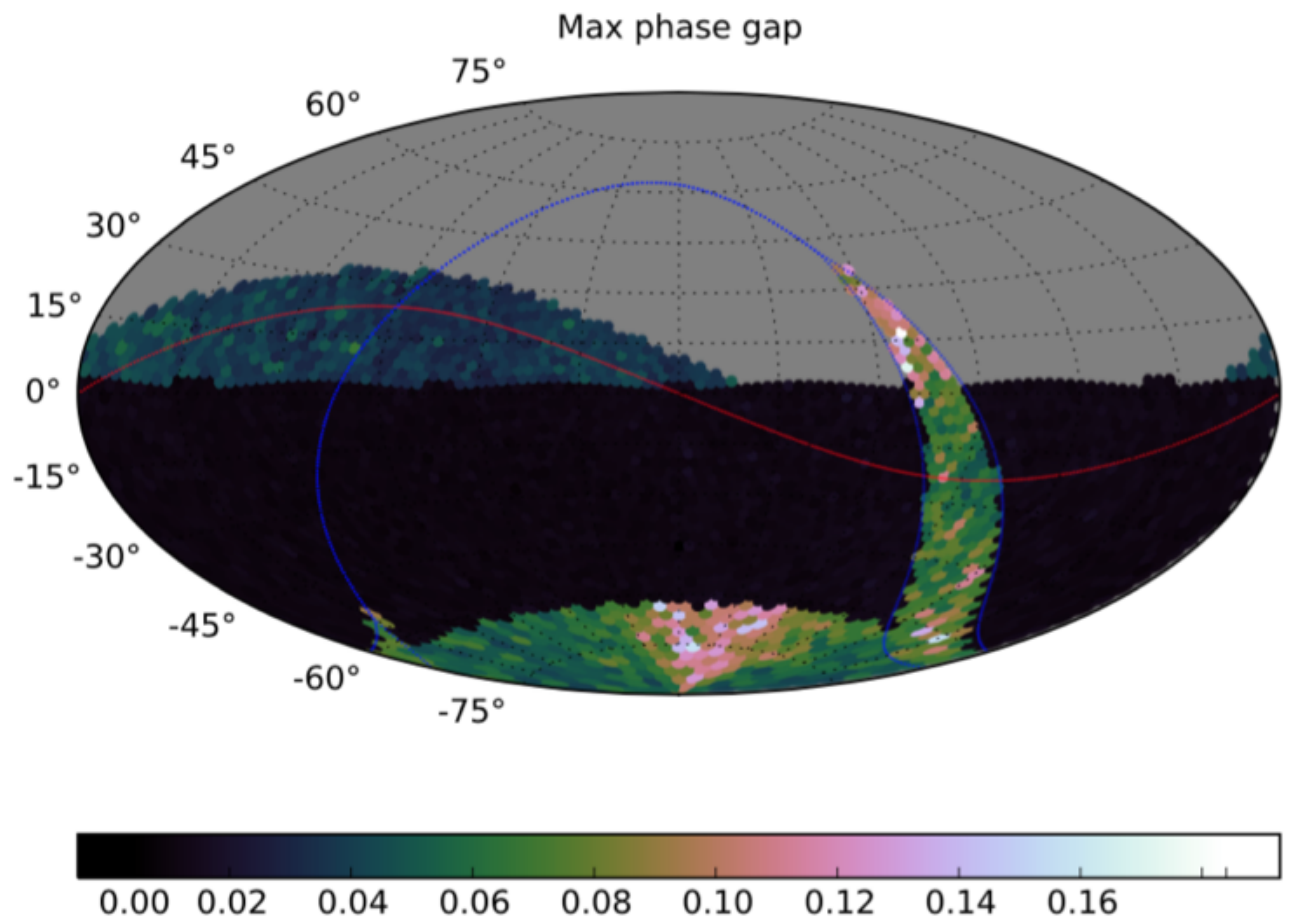
Lund+ 2016

Leveraging sampling rate/density

periodic recurring fast slow

can you identify periodic transients?

single band sampling regularity
or reliable SED models and sampling in any band



Metric	Description
Eclipsing/transiting system discovery	Fraction of discoveries vs fractional duration of eclipse
Lightcurve shape recovery	...
Phase gap	Histogram vs period of the median and maximum phase gaps achieved in all fields
Period determination (period dependent)	Fraction of targets vs survey duration, for which the period can be determined to 5-sigma confidence
Period variability (period dependent)	Fraction of targets vs survey duration, for which a period change of 1% can be determined with 5-sigma confidence

For a given point in the sky, a series of periods are randomly selected (by default, 5 periods), with a default minimum of 3 days and maximum of 35 days. The largest phase gap for each period is calculated, and the metric plots the median (Figure 5.2) and maximum (Figure 5.3) of this subset of values that contains the maximum phase gap per period. The Phase Gap Metric is part of varMetrics.

Leveraging sampling rate/density

- *SN precursors*
- *recurring variables*

periodic **recurring** fast slow

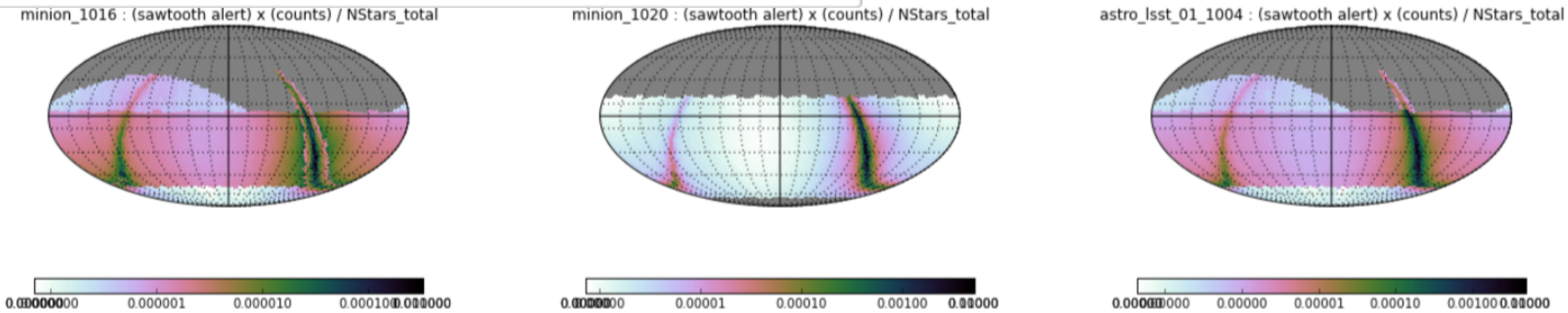
can you see SN precursors?

depends on regular sampling any band

4 The Milky Way Galaxy

Chapter editors: *Will Clarkson, Kathy Vivas*

Contributing authors: *Beth Willman, David Nidever, Željko Ivezić, Colin Slater, Peregrine McGehee, Chris Britt, Dave Monet, Jay Strader, Dana I. Casetti-Dinescu, John E. Gizis, Michael C. Liu, Victor Debattista, Laura Chomiuk, Peter Yoachim*



FoM 3.1 - Fraction of Galactic supernovae for which LSST would detect variability ***before*** **the main Supernova event:** We have implemented a simple FoM for the Galactic Supernova case, using the parameters of SN2010mc as an example whose pre-SN outburst could be discovered first by LSST. The FoM is defined as the density-weighted average fraction of transient events recovered, where the average is taken over the sight-lines within the simulated strategy:

$$FoM_{preSN} \equiv \frac{\sum_i^{sightlines} f_{var,i} N_{*,i}}{\sum_i^{sightlines} N_{*,i}} \qquad (4.1)$$

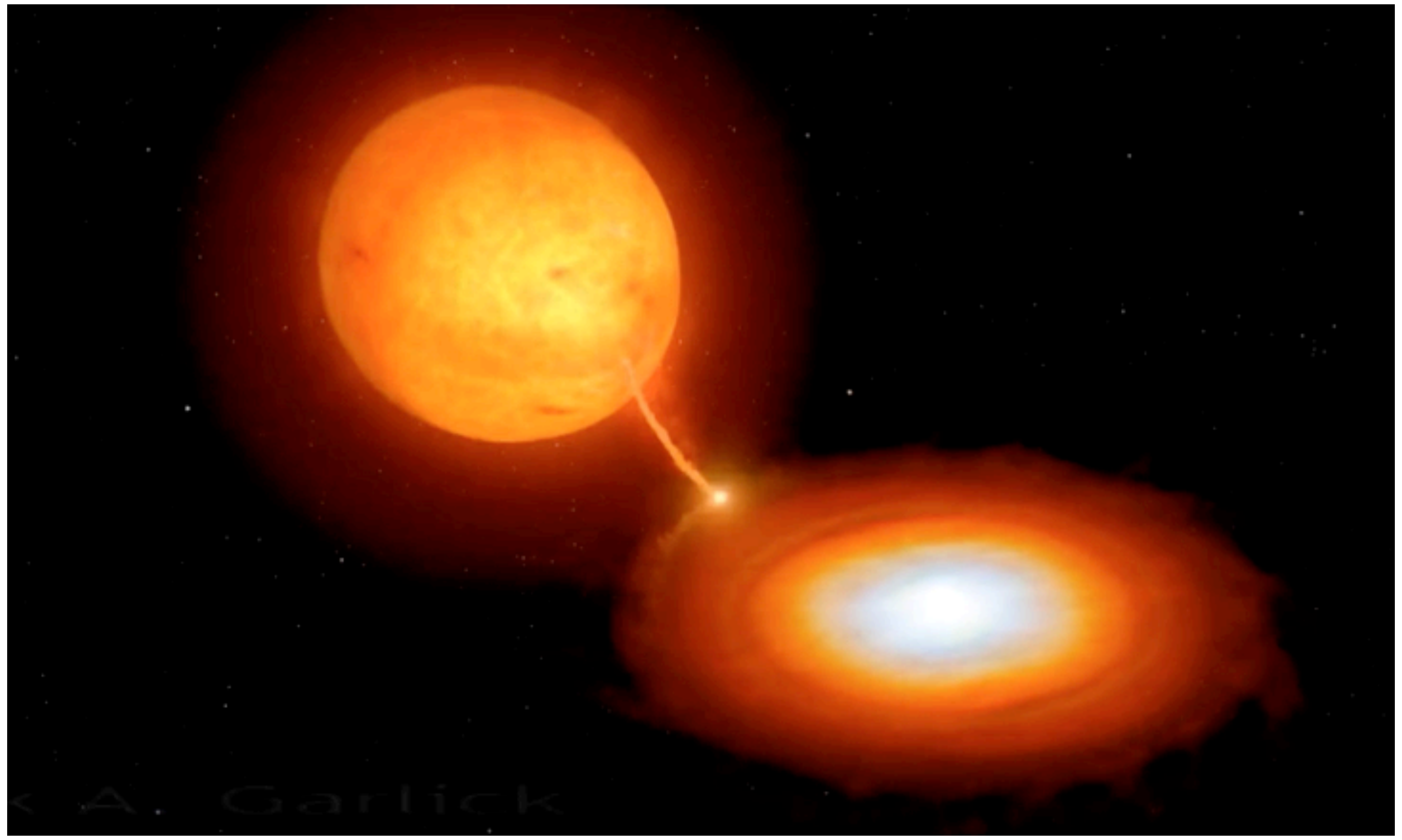
Leveraging sampling rate/density

federica bianco NYU

periodic **recurring** fast slow

can you detect/classify CV?

minutes	flickering in dwarf novae/novalikes, pulsations in accreting WD in the instability strip, orbital periods of AM CVn systems
hours	orbital periods of novae
days	normal outburst lengths of dwarf novae
weeks	outburst length of superoutbursts in short orbital period dwarf novae, outburst recurrence in short orbital period dwarf novae
months	normal outburst length of dwarf novae
years	outburst recurrence of longer period dwarf novae, the decline in novae



all CVs are bluer during outburst and high states of accretion (*u*-*g* filters).

Leveraging sampling rate/density & color

- *young transients*
- *GRB*
- *kilonovae*
- *early features in long transients*

periodic recurring **fast** slow

- *young transients*
- *GRB*
- *kilonovae*
- *early features in long transients*

for early classification the history of the pixel would not be available

periodic recurring **fast** slow

6.2 Realtime Identification of Young Transients

Stefano Valenti, Federica B. Bianco

can you separate young transients?

rapid single band sampling at early time

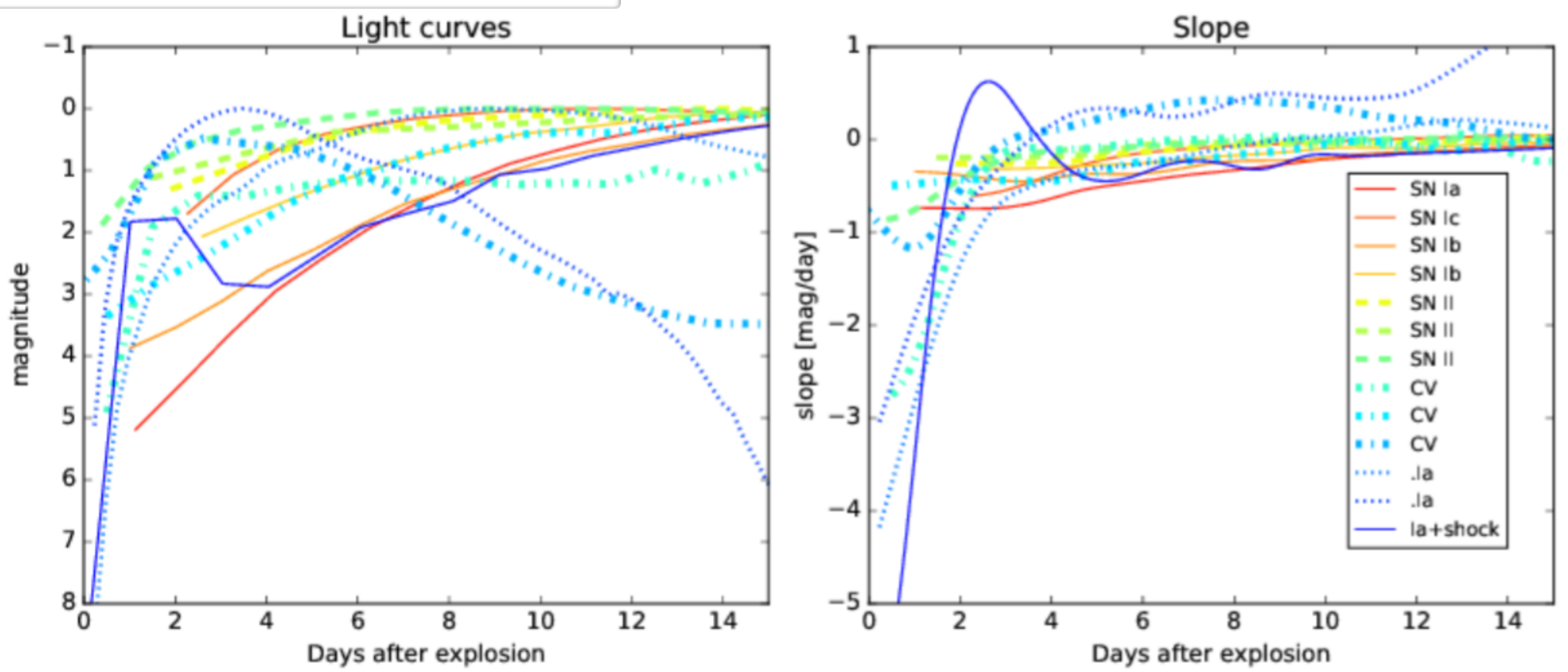
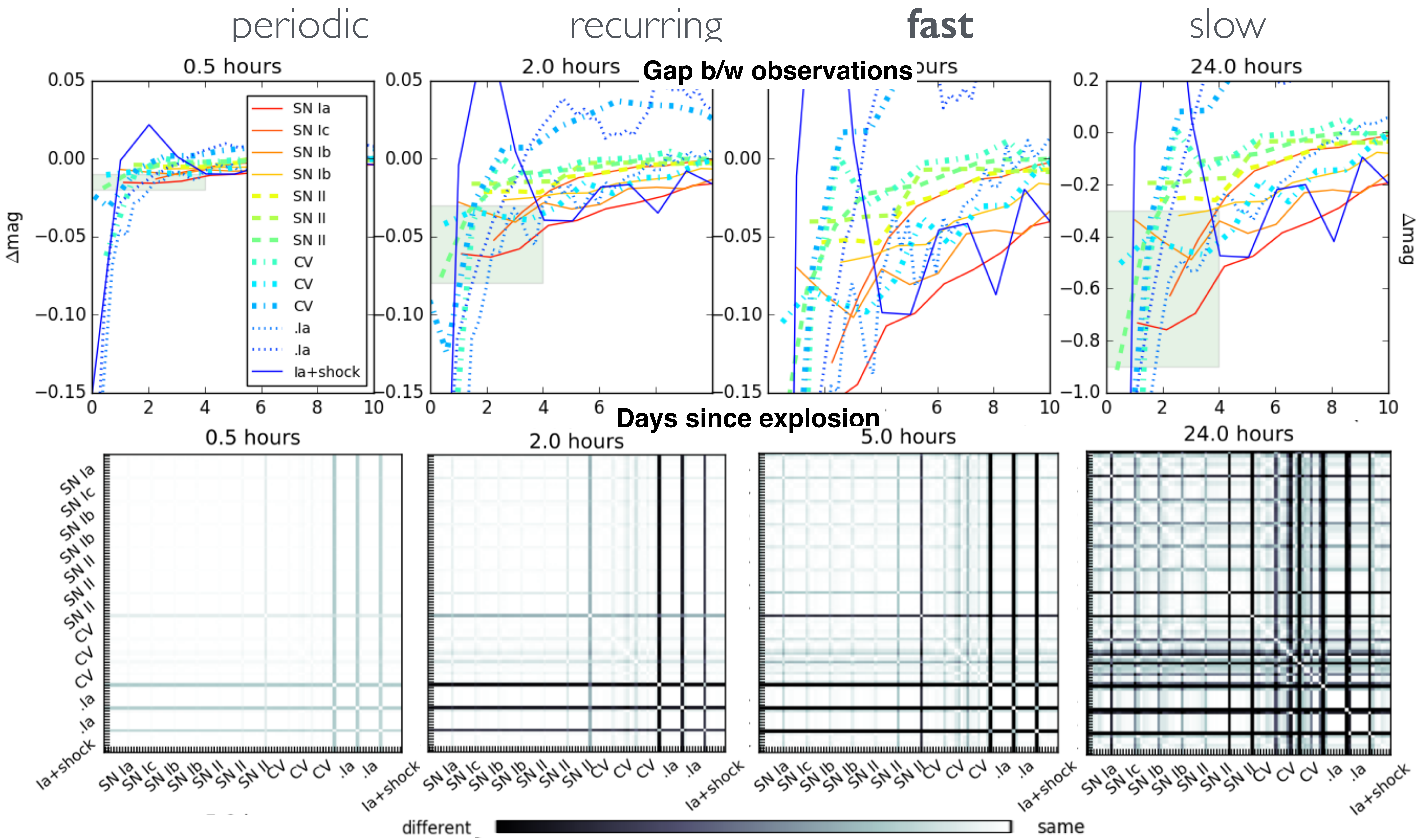


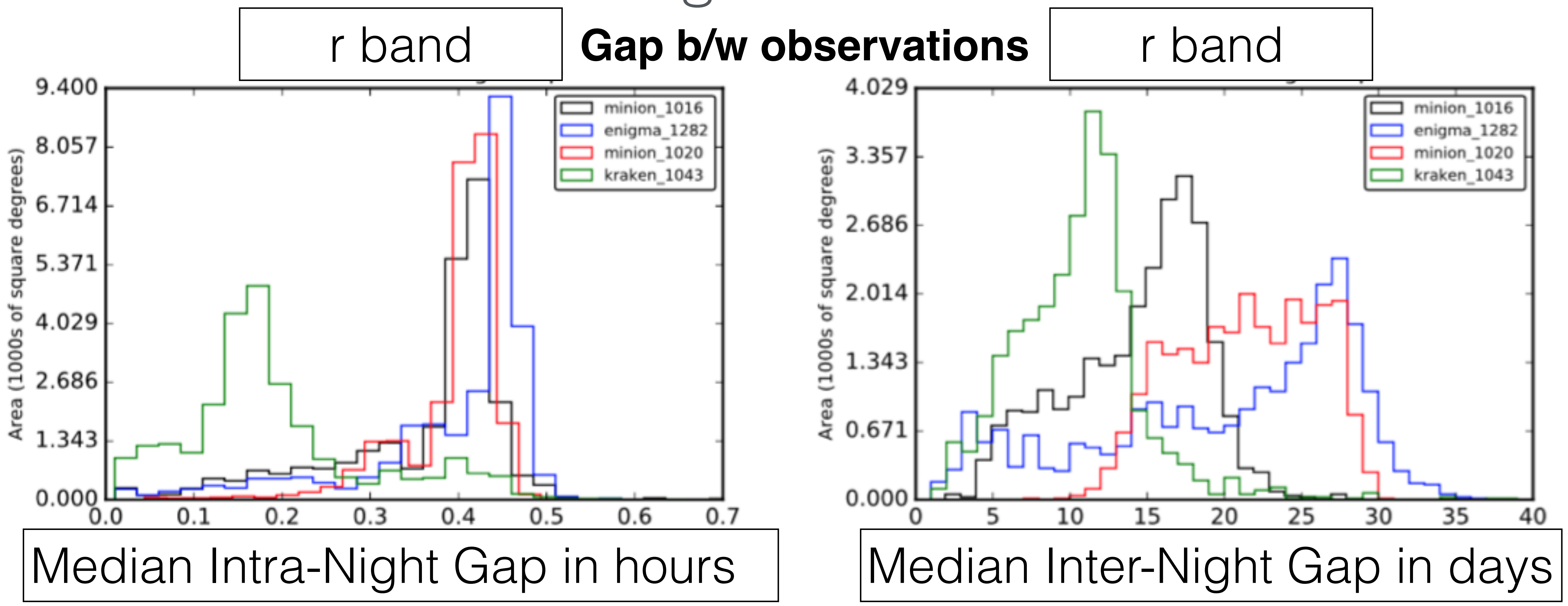
Figure 6.4: *Left*: r'-band light curve for representative transients as function of the phase from the beginning of the transient outburst/explosion for the first few days of the transient life. *Right*: slope of the transient evolution. Data from: SN Ia, Olling et al. (2015); SNII, Rubin et al. (2016); SN .Ia, Shen et al. (2010); SN Ib, Valenti et al. (2011), Cao et al. (2013); SN Ic, Mazzali et al. (2002); CV, Sokoloski et al. (2013), Finzell et al. (in prep), SN Ia+interaction (see Section 6.3)

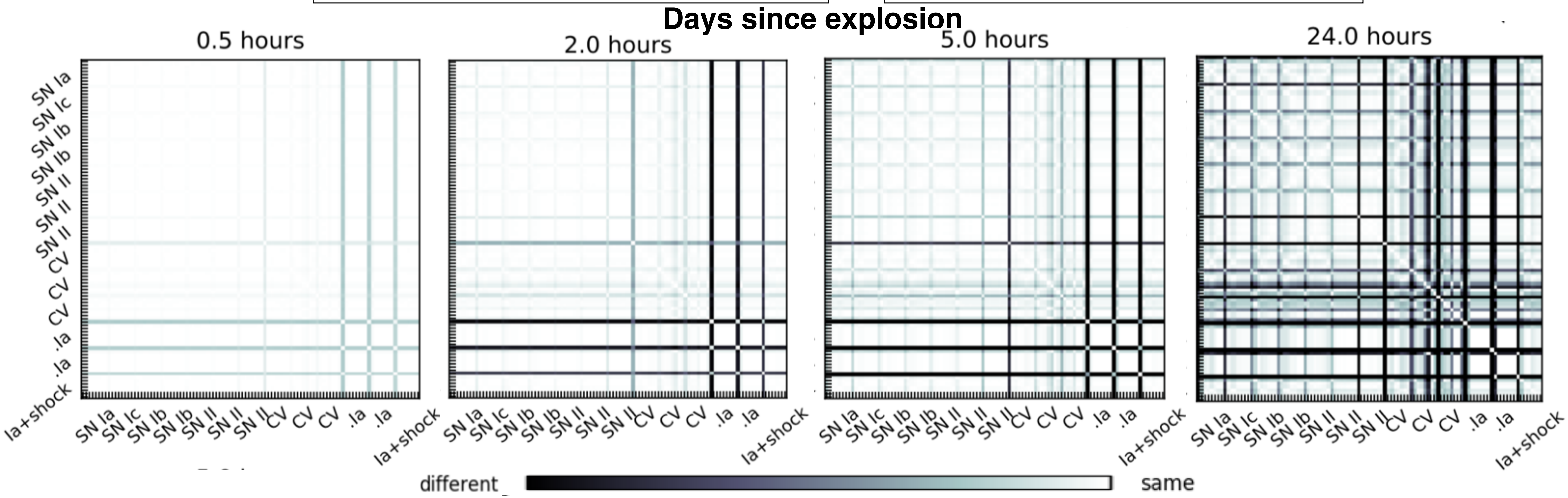
Leveraging sampling rate/density at early time



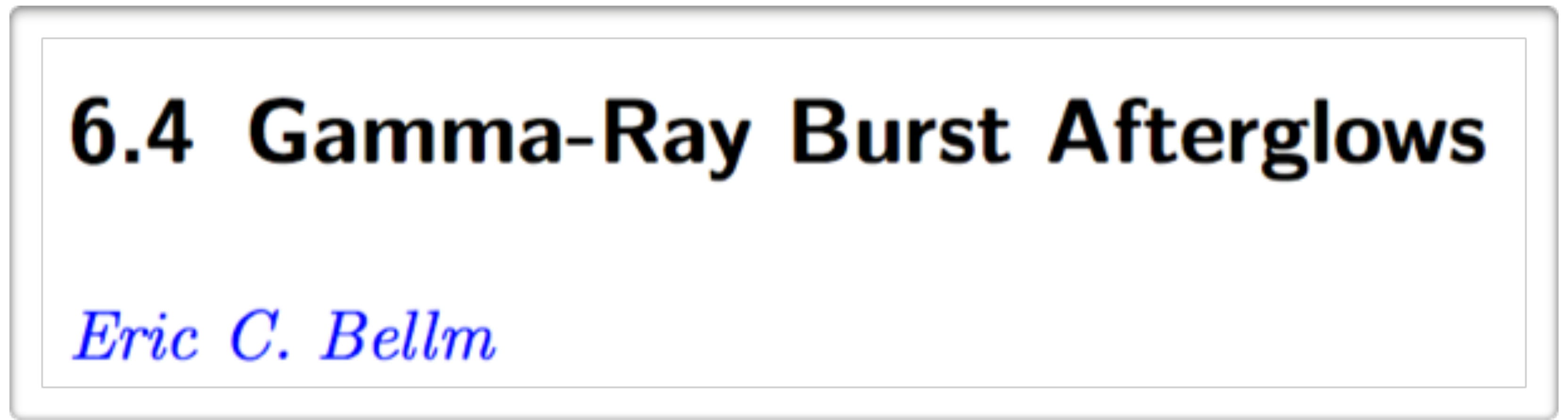
Leveraging sampling rate/density at early time

periodic recurring **fast** slow





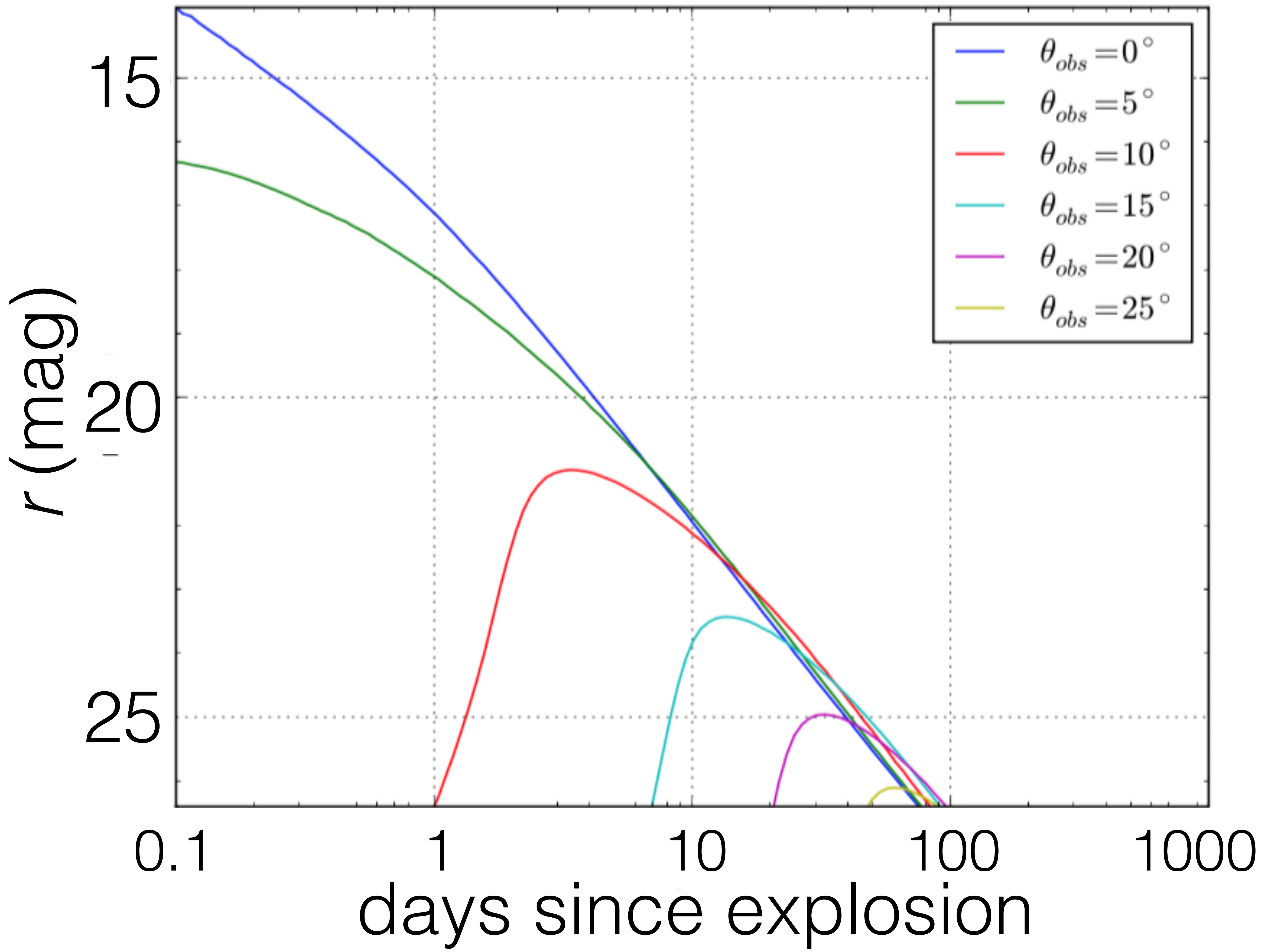
Leveraging sampling rate/density at early time



can you detect different GRBs?

single band sampling at early time

GRB afterglow $\theta_j = 4^o$



Distinguishing orphan afterglows from on-axis GRB

- baryon loading
- constraints on the jet opening

GRBTransientMetric replaces the linearly rising and decaying lightcurve in TransientMetric with the $F \sim t^{-\alpha}$ decay characteristic of on-axis afterglows.

->fraction of events which have at least one, two, or three detections *in any single filter*

Leveraging sampling rate/density at early time

periodic recurring **fast** slow

6.5 Gravitational Wave Sources

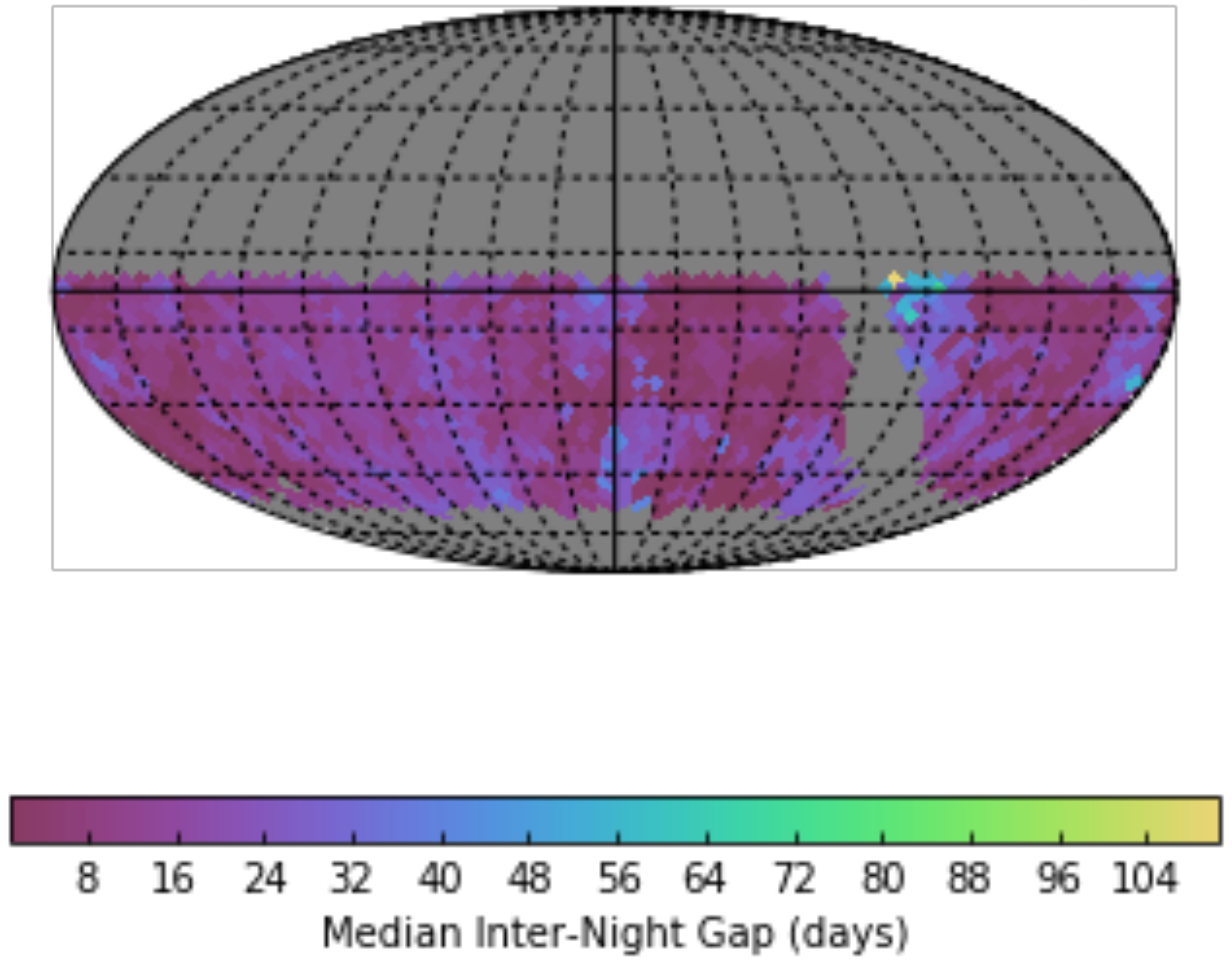
Raffaella Margutti, Zoheyr Doctor, Wen-fai Fong, Zoltan Haiman, Vassiliki Kalogera, Virginia Trimble, Bevin Ashley Zauderer

can you detect kilonovae?

rapid single band sampling in red filters
color to reject false positives

To identify kilonova candidates we need at least 2 observations acquired within $\sim$ 1 week of the GW event (Cowperthwaite & Berger 2015). Using the inter-night gap distribution for visits in the y filter (which is the most promising filter for a kilonova search), the area of the sky covered with cadence $\Delta t < 7$ days at any given time, is $A_{sky} \sim 3000$ deg^2 (including deep drilling fields). This is the area that can be searched for fast evolving transients. Two important considerations follow:

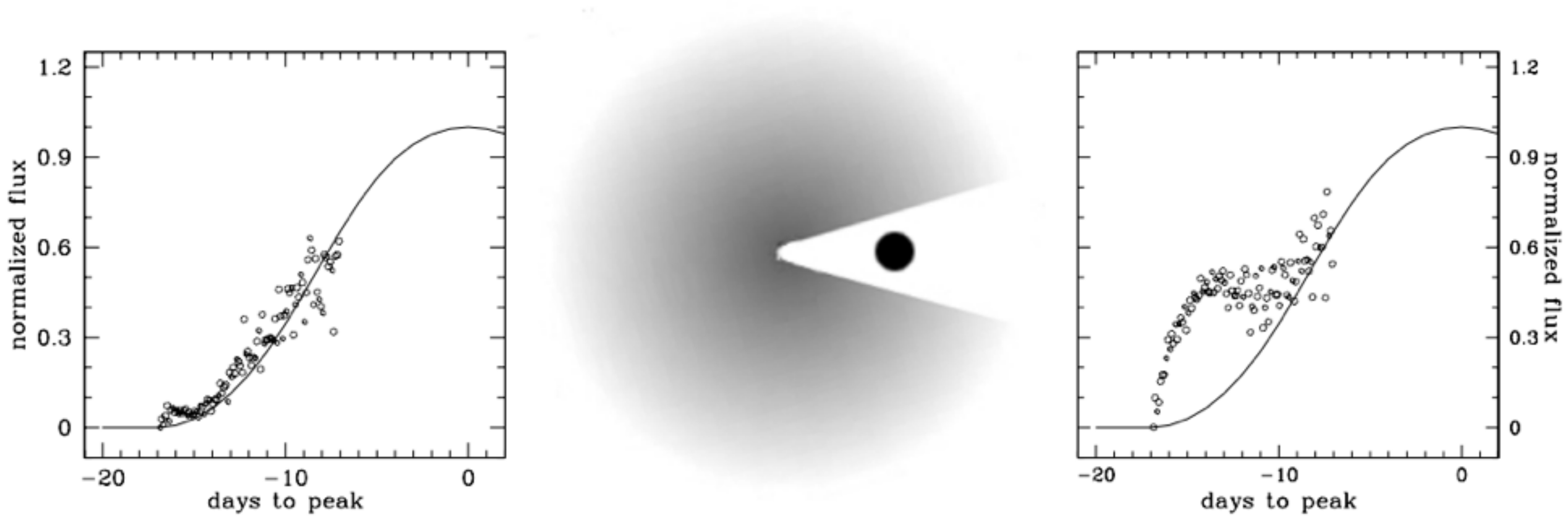
minion_1016 night between 1095.750000 and 1461.000000 and y: Median Inter-Night Gap



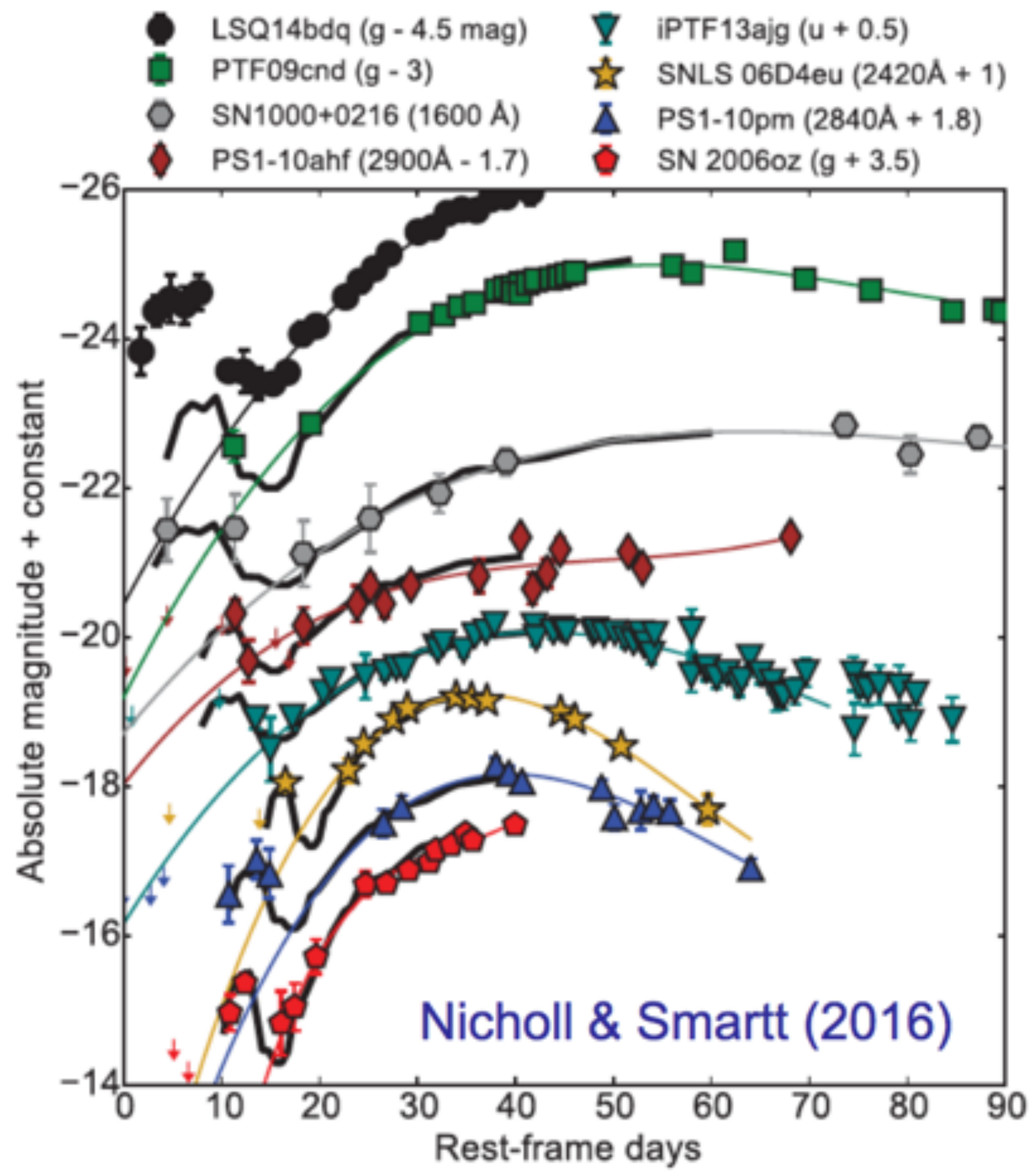
Leveraging sampling rate/density at early time & color

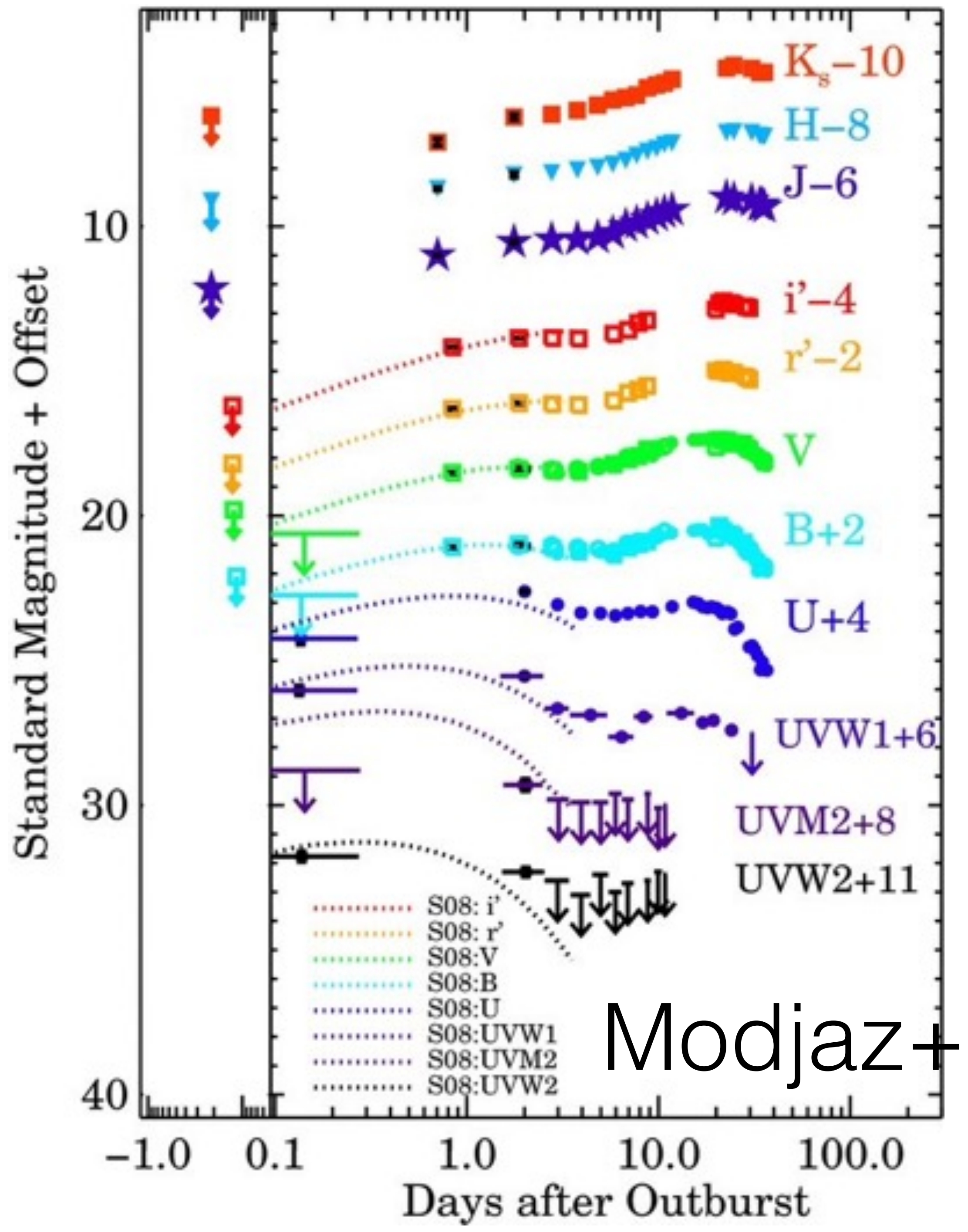
periodic recurring **fast** slow

can you detect fast components in slower light curves?



Kasen 10, Bianco+11





Modjaz+09

Observations of light curve ~days-weeks after explosion provide key information about SNe and their progenitors

1. "Shock cooling" measures the radius of the exploding star
2. Interaction with a companion constrains progenitors models
3. Probes circumstellar material reflecting activity of the progenitor before death

(T. Piro's LSST revolution talk)

Leveraging sampling/density & color at early time

periodic recurring **fast** slow

can you detect companion interaction or breakout cooling?

color at early time

6.3 Supernovae as Transients

Federica B. Bianco

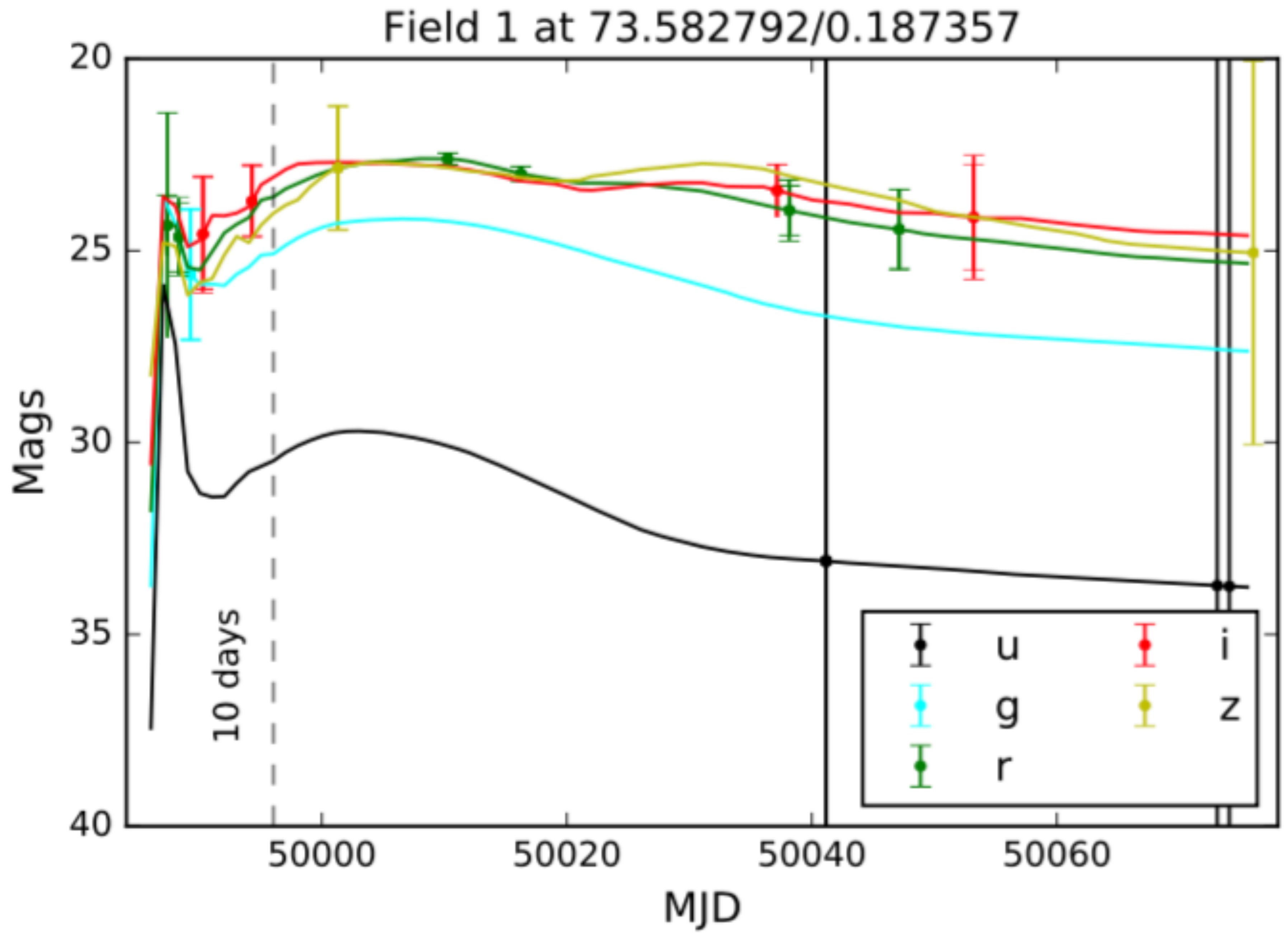


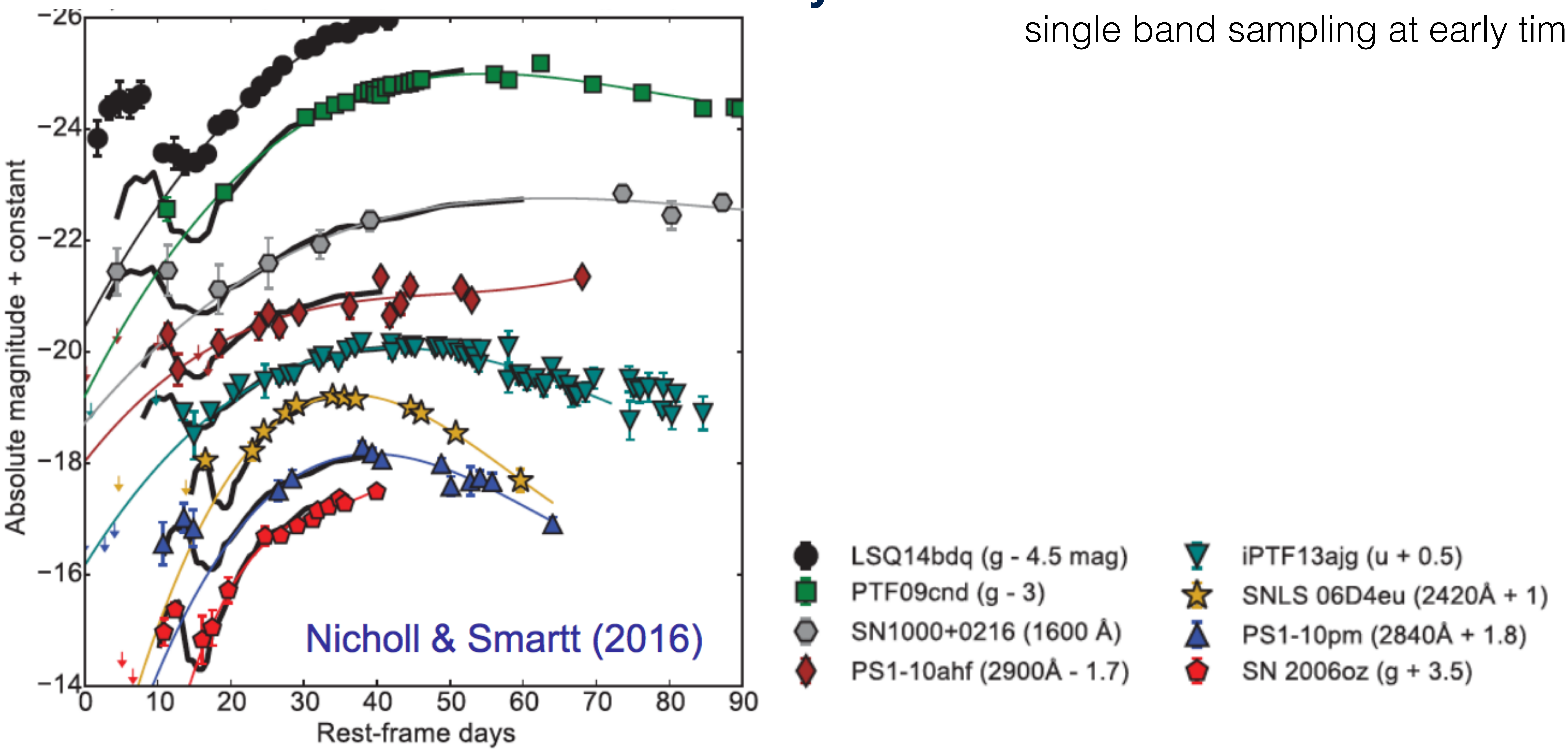
Figure 6.6: A normal SN Ia lightcure at z=0.5 showing interaction with a RG companion as seen from the most favorable viewing angle: the effect of interaction as simulated by Kasen (2010) is added on top of a lightcurve simulated from the Nugent et al. 2002 templates. The data points represent one possible set of LSST observations of this transient, obtained by running the **transientAsciiMetric**. This particular event is detected in g', r', and i' within the first 10 days.

Leveraging color at early time

periodic recurring **fast** slow

can you see/rule out SLSN double peak?

single band sampling at early time



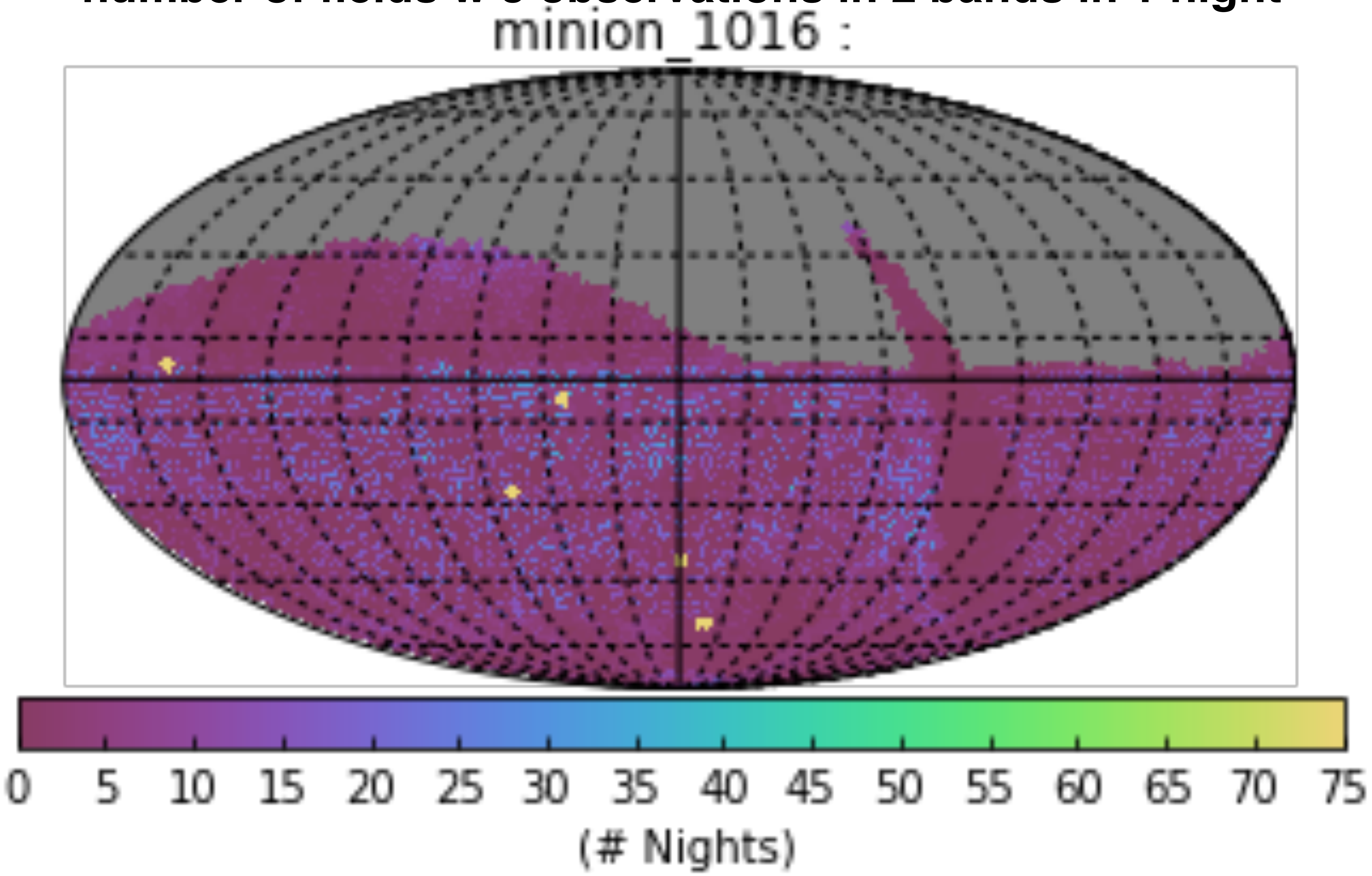
Leveraging sampling rate/density at early time

can you detect fast components in slower light curves?

color at early time

Maria's slides

number of fields w 3 observations in 2 bands in 1 night

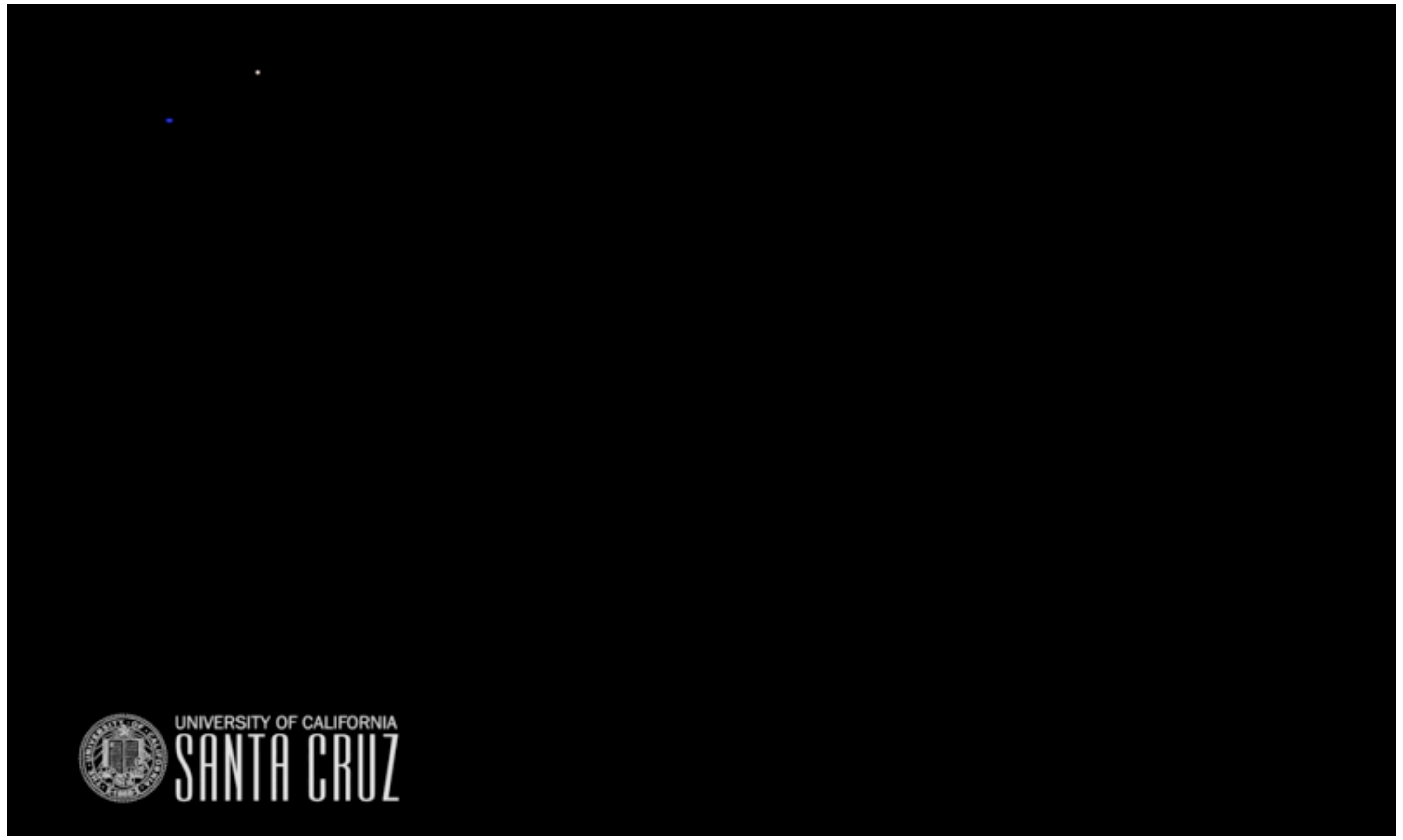


https://github.com/LSST-nonproject/sims_maf_contrib/blob/master/science/Transients/Transient_w_color.ipynb periodic recurring fast **slow**

- *TDE*
- *LBV*
- *AGN*

can you distinguish TDEs?

long term sampling with some color info



- slow evolving
- constant color
- $t^{-5/3}$ decay
- early time deviations diagnose star density

can you distinguish TDEs?

long term sampling with some color info

- slow evolving
- constant color
- $t^{-5/3}$ decay
- early time deviations diagnose star density

other slow varying transients that benefit from long term observations: LBV eruptions

microlensing by strings

ILOTs

YSO

discuss!!

chaotic eruptions

microlensing by planets

magnetically active stars