Image credit: NAOJ

Shock breakout delay due to circumstellar material seen in most Type II supernovae

nature astronomy

ARTICLES

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The delay of shock breakout due to circumstellar material evident in most type II supernovae

F. Förster[1,2,3*], T. J. Moriya[4], J. C. Maureira[1], J. P. Anderson[5], S. Blinnikov[6,7,8], F. Bufano[9], G. Cabrera-Vives[2,10], A. Clocchiatti[2,11], T. de Jaeger[12], P. A. Estévez[2,13], L. Galbany[14], S. González-Gaitán[1,15], G. Gräfener[16], M. Hamuy[2,3], E. Hsiao[17], P. Huentelemu[12], P. Huijse[2,12], H. Kuncarayakti[18,19], J. Martínez[1,2,3], G. Medina[3], F. Olivares E.[2,3], G. Pignata[2,20], A. Razza[3,5], I. Reyes[2,13], J. San Martín[1], R. C. Smith[21], E. Vera[1], A. K. Vivas[21], A. de Ugarte Postigo[22,23], S.-C. Yoon[24,25], C. Ashall[26], M. Fraser[27], A. Gal-Yam[28], E. Kankare[29], L. Le Guillou[30], P. A. Mazzali[26,31], N. A. Walton[32] and D. R. Young[29]

Francisco Förster
Takashi Moriya
and collaborators

CMM Center for Mathematical Modeling

NLHPC National Laboratory for High Performance Computing Chile

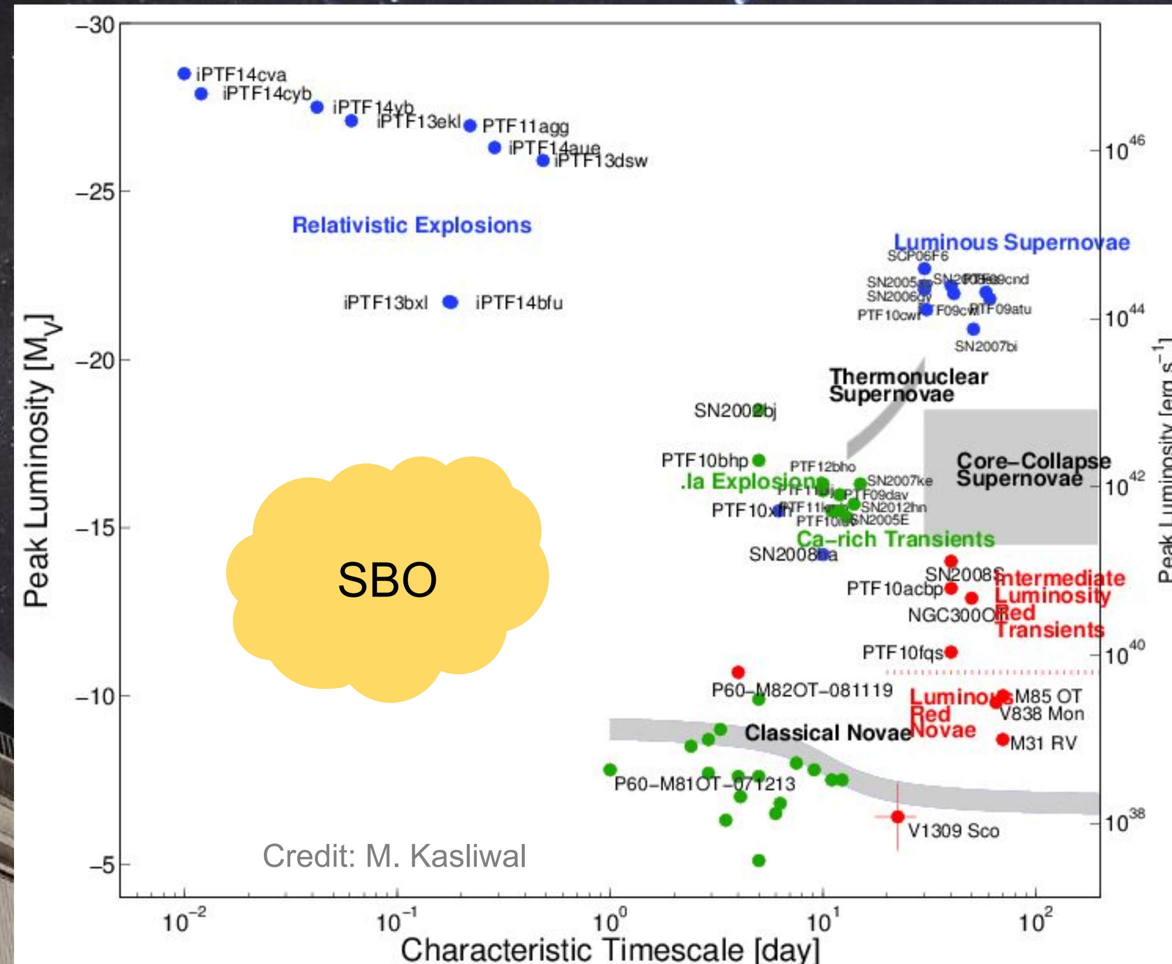
MILLENNIUM INSTITUTE OF ASTROPHYSICS

CONICYT Ministerio de Educación Gobierno de Chile

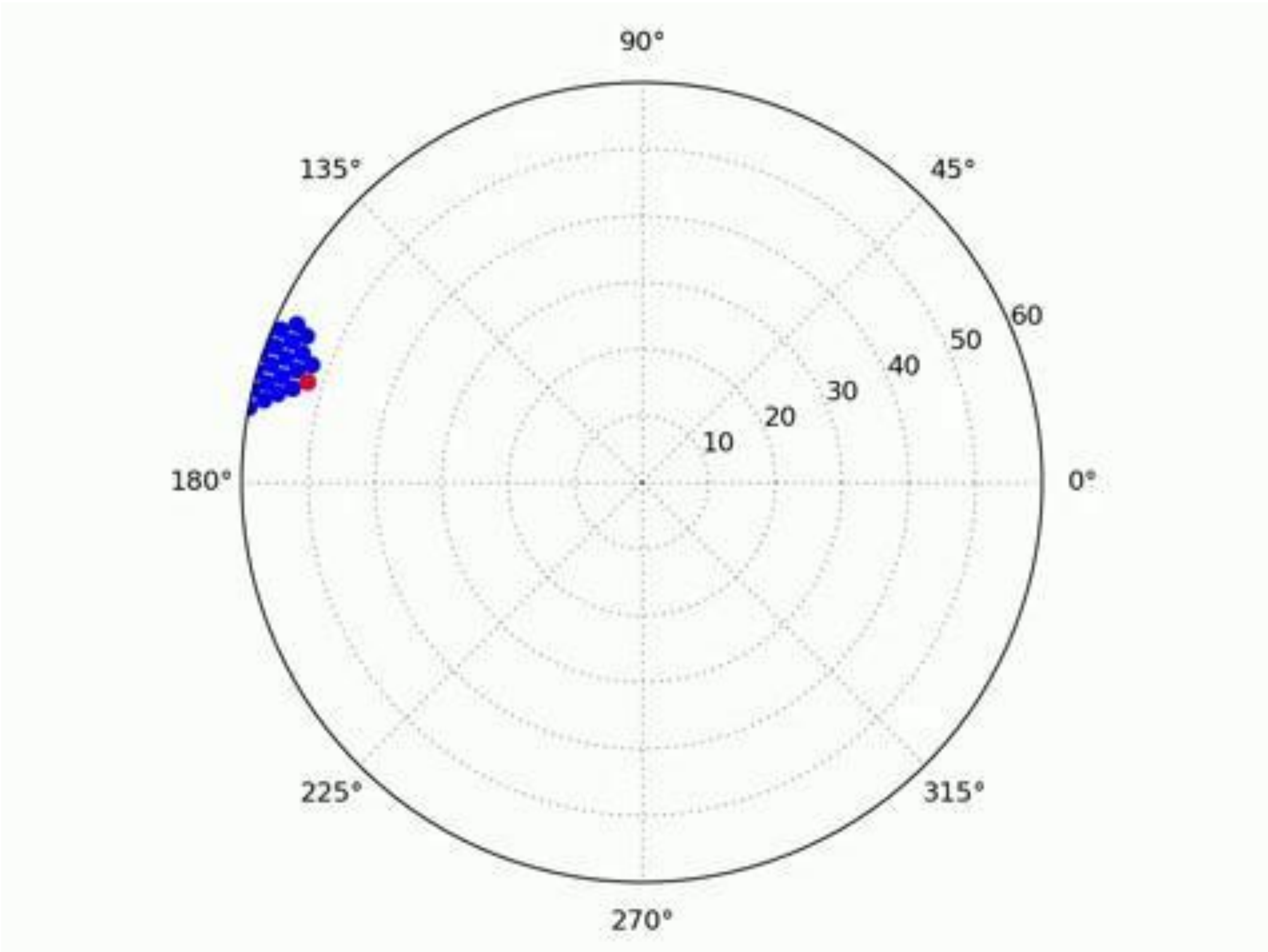
ALeRCE Automatic Learning for the Rapid Classification of Events

Outline:

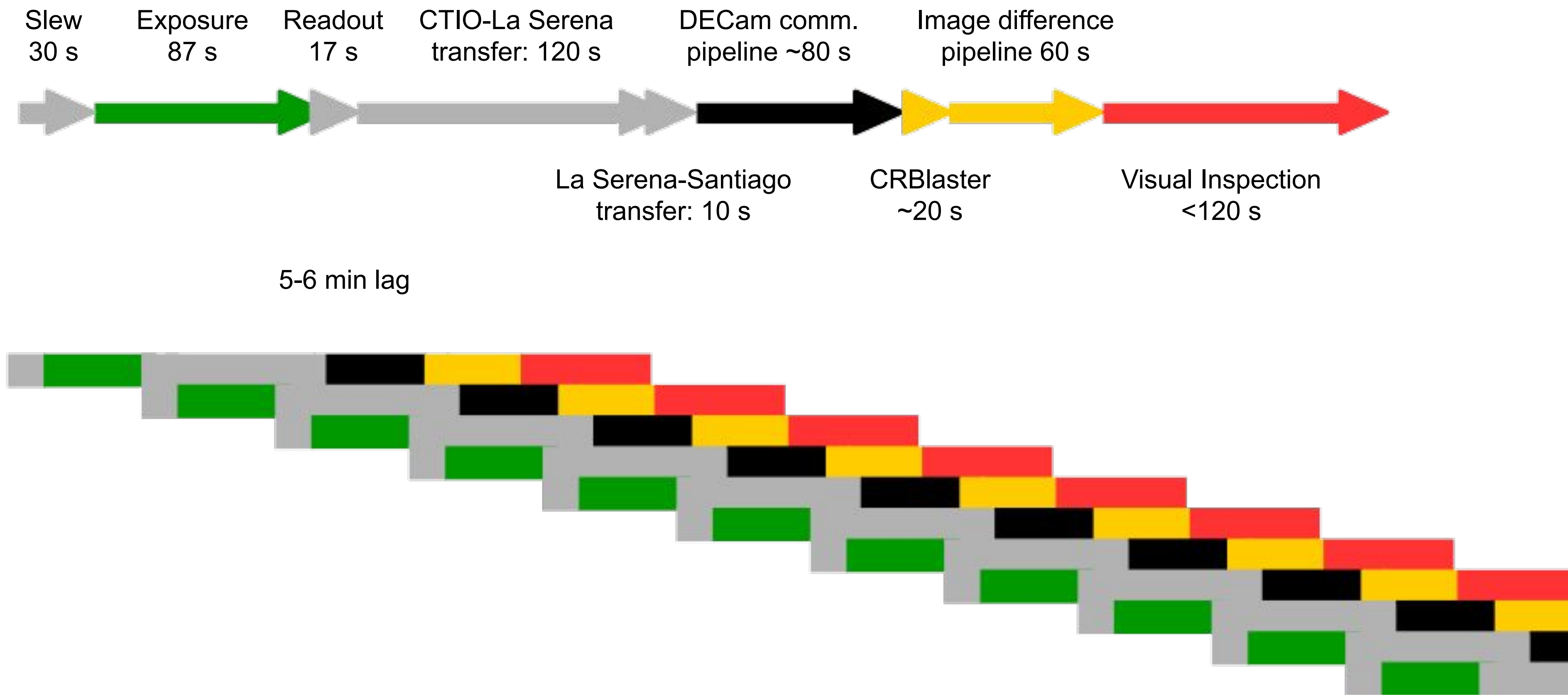
1. The High cadence Transient Survey (HiTS)
2. Search for RSG envelope SBO
3. Evidence for RSG CSM SBO
4. Inferring physical parameters
5. Building an alert broker (ALeRCE)



HiTS observational strategy



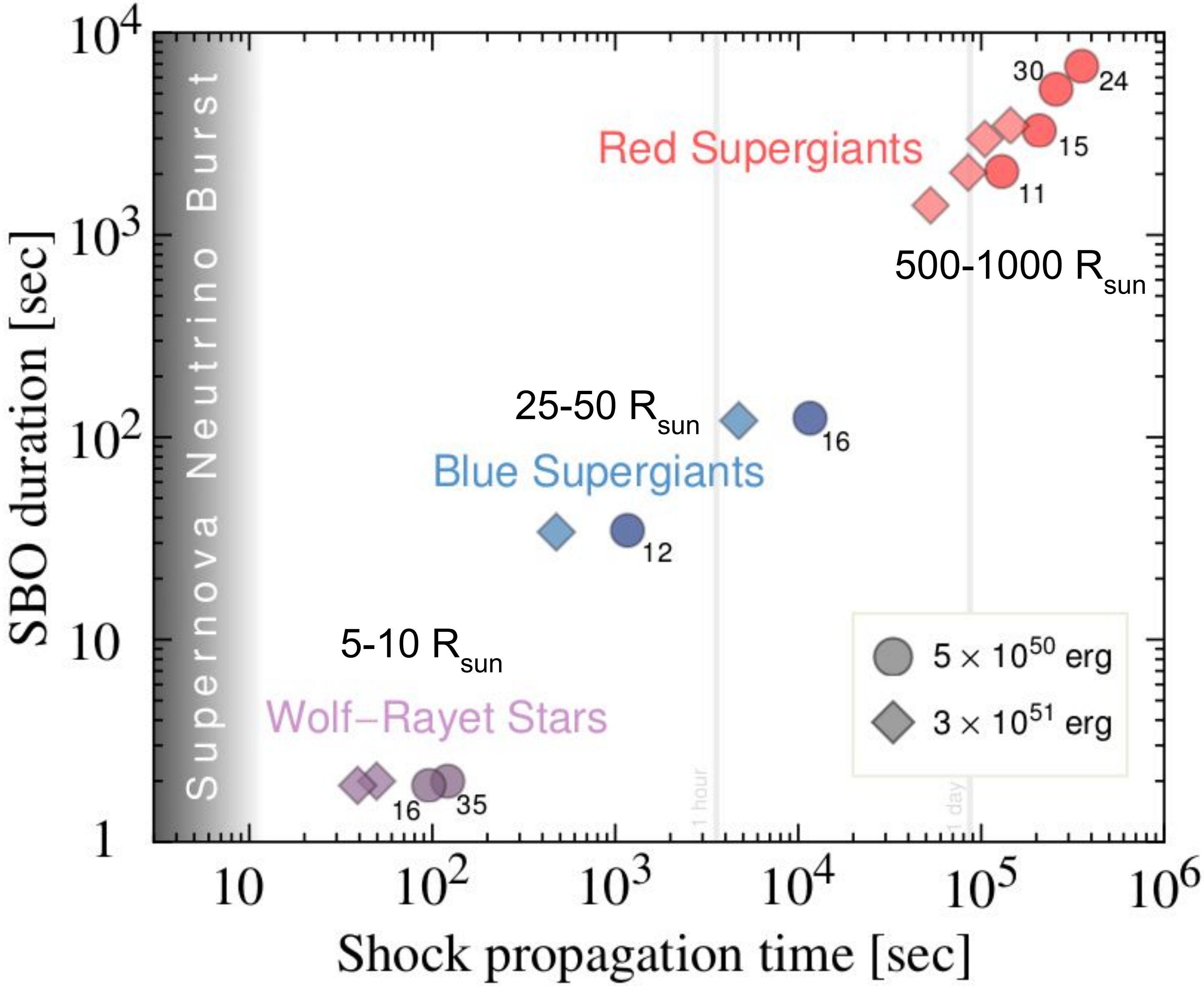
Pipeline flow outline



$\sim 10^{12}$ pixels, $\sim 10^{8}$ candidates, $\sim 10^{6}$ filtered candidates (ML)

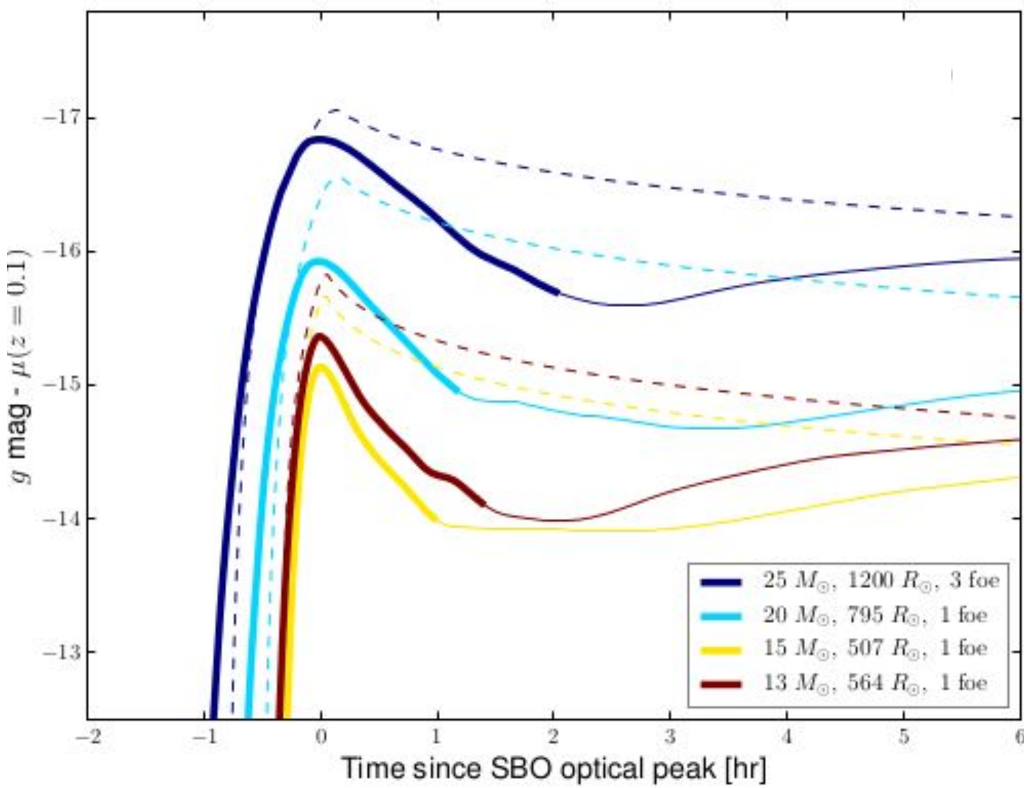
$\sim 10^{4}$ visual inspections, 125 SNe

Supernova shock breakout (SBO) timescales

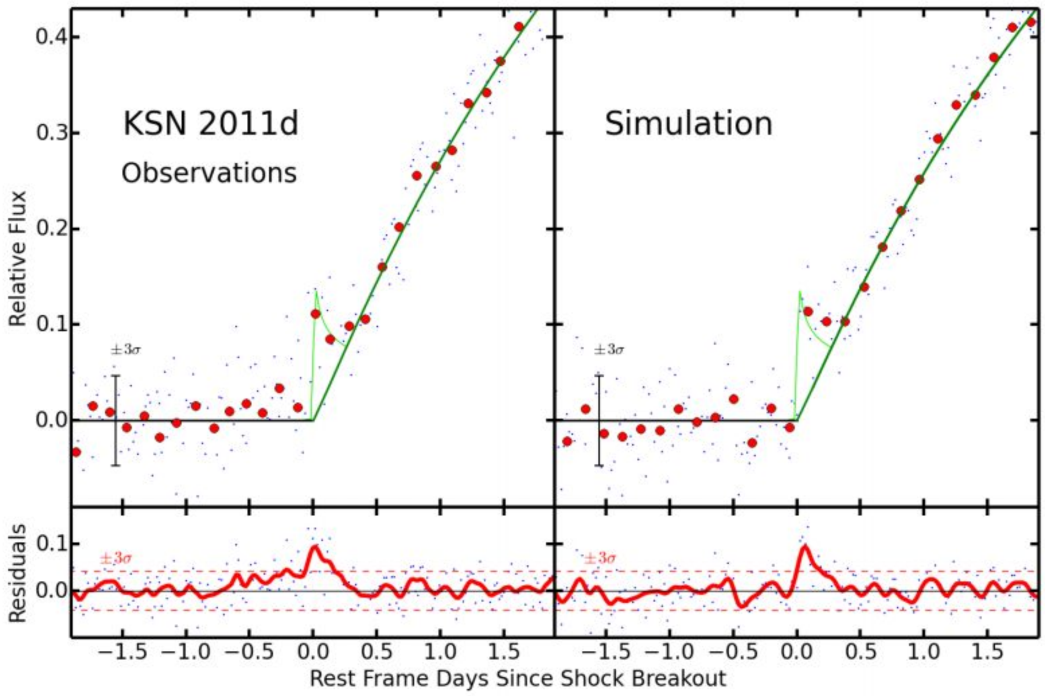


Kistler, Haxton & Yüksel 2014

High density RSG envelope SBO in the optical

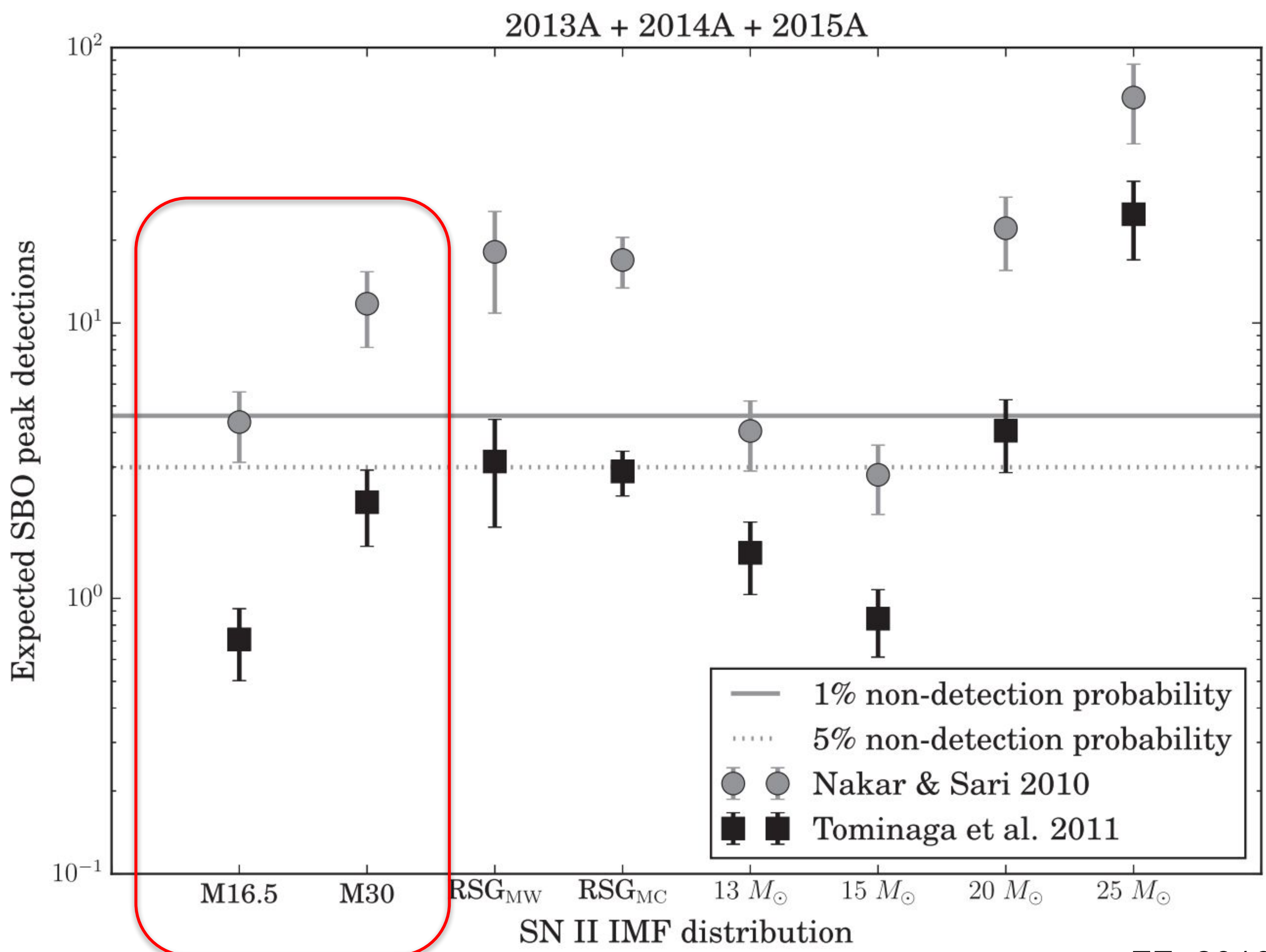


Continuous: Tominaga+11
Dashed: Nakar & Sari 2010



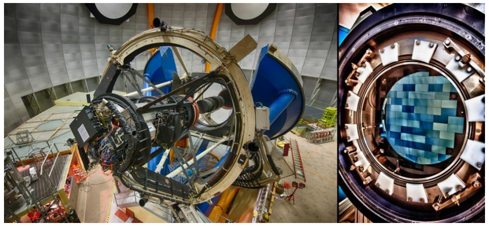
Garnavich+2016

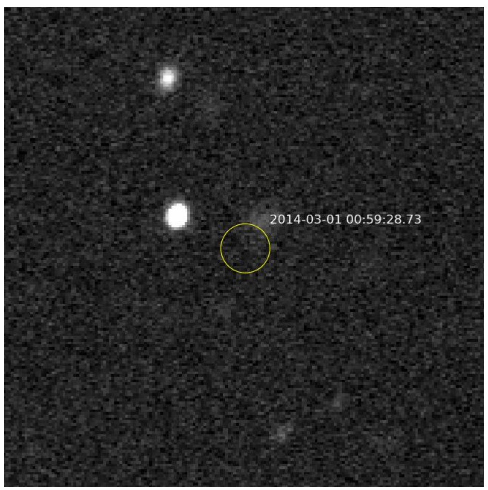
Envelope SBO + SN II IMF constraints



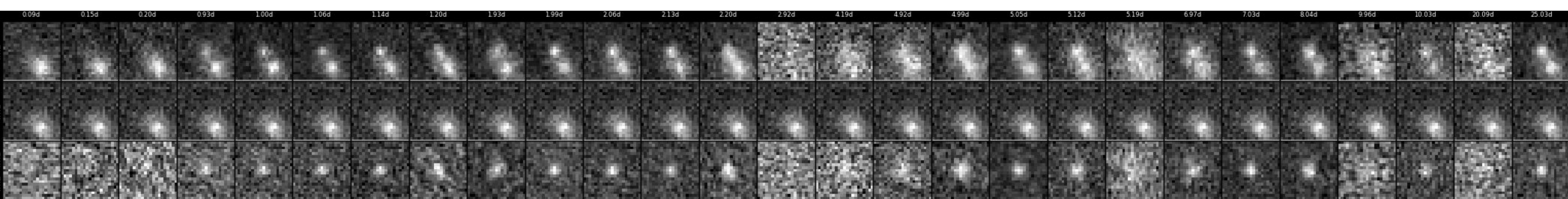
FF+2016

High cadence Transient Survey (HiTS) in a nutshell

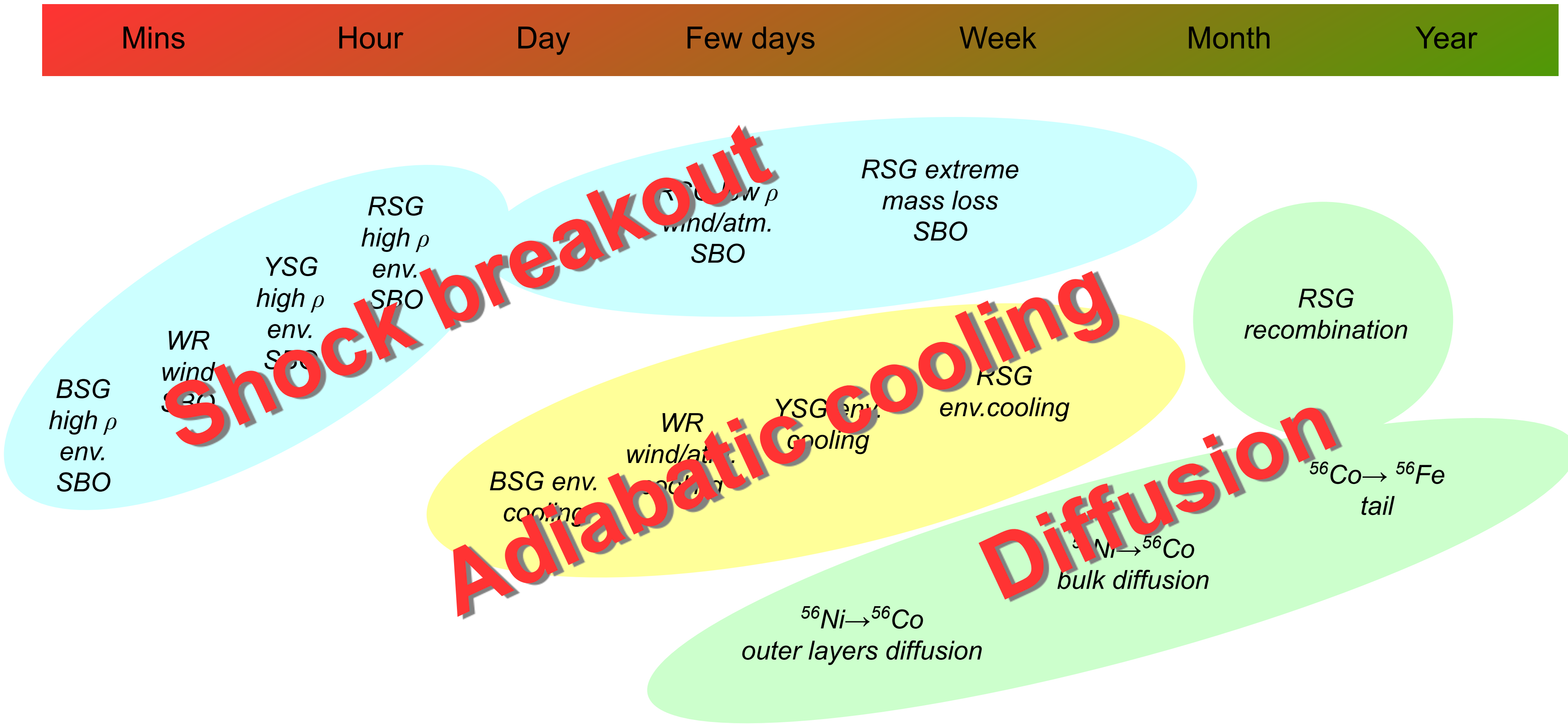




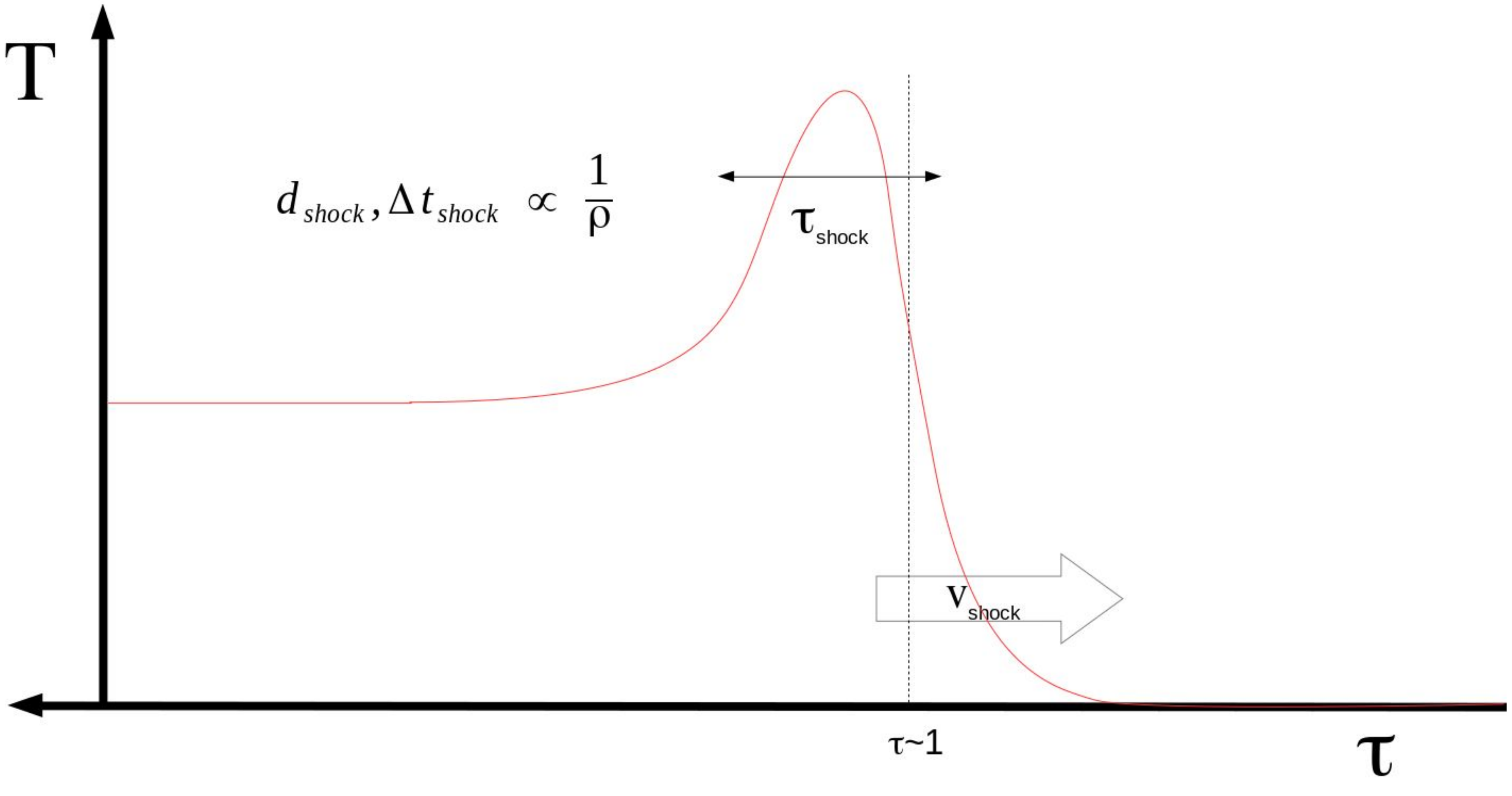
- 320 deg^2 deep & high cadence survey
- 1st real time analysis of DECam data (Feb 2014)
- 125 supernova detected (ATELs)
- **SBO model constraints (Förster+16, ApJ)**
- 1st CNN real/bogus filter (Cabrera-Vives+17, ApJ)
- 18 distant RR Lyrae (Medina+17,18, ApJ)
- ~10k new asteroids (Peña+18, AJ)
- ~22M public variable catalog (Martínez+18, AJ)
- **CSM delayed SBO (Förster+18, Nat. Ast.)**



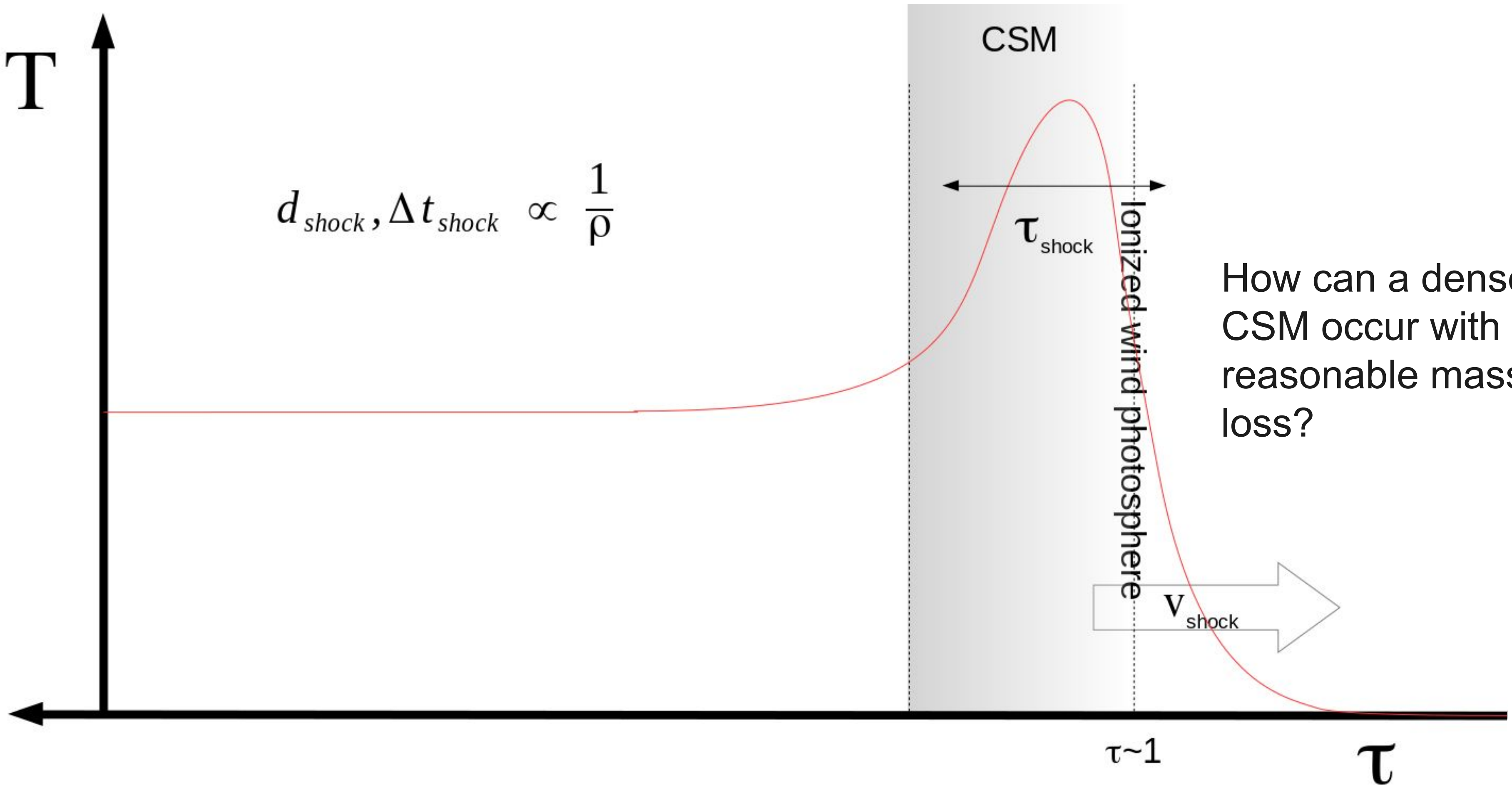
Physical processes and timescales in supernovae



Shock breakout

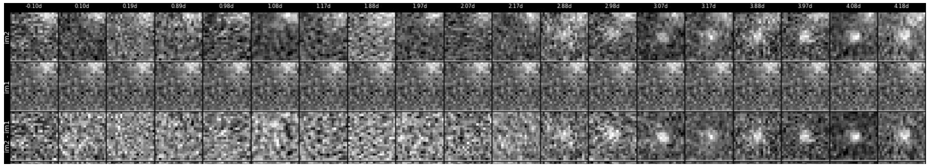


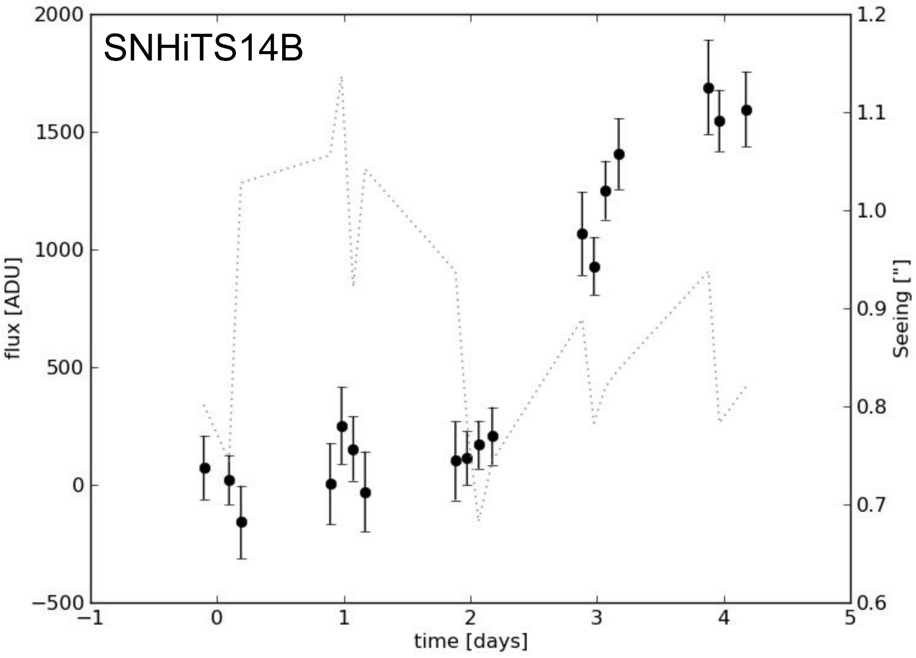
Shock breakout in dense CSM

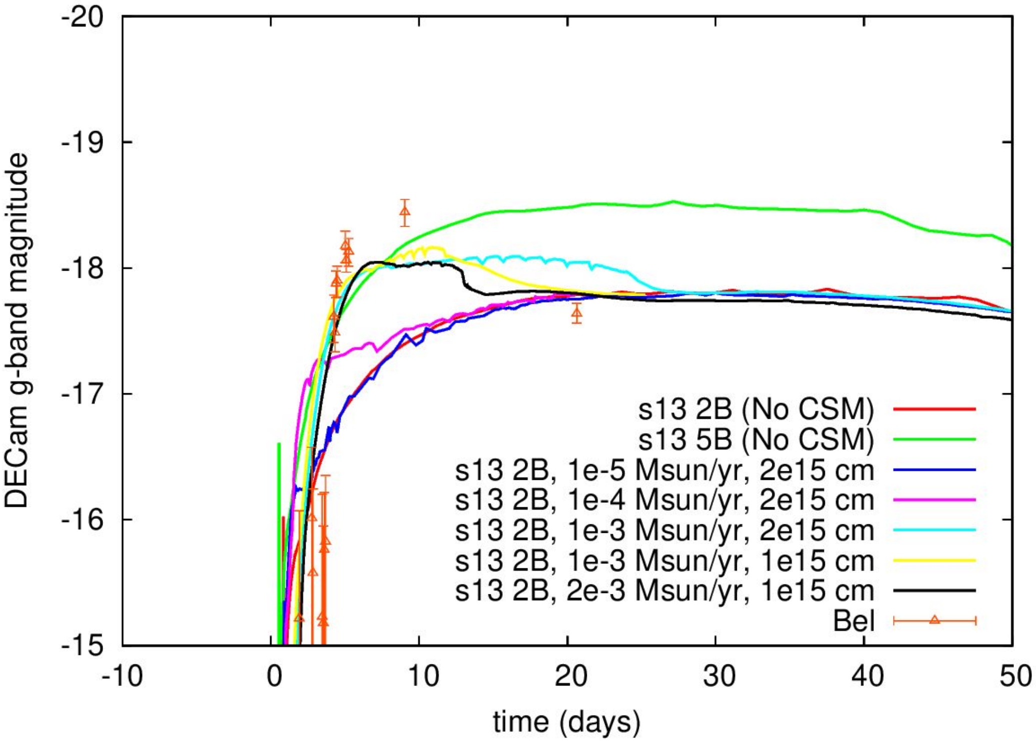


How can a dense CSM occur with a reasonable mass loss?

Fast rising SNe II: evidence for CSM SBO

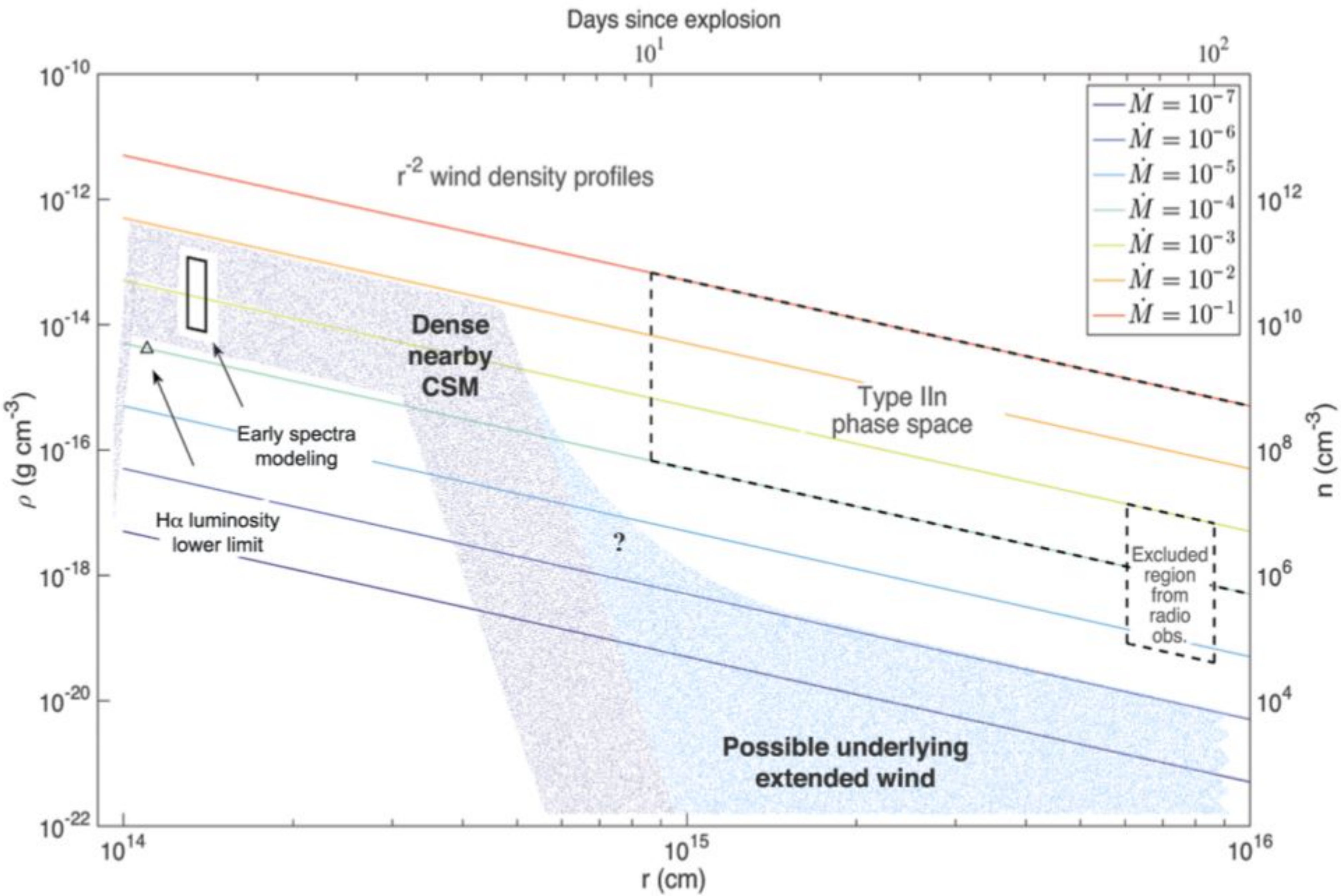






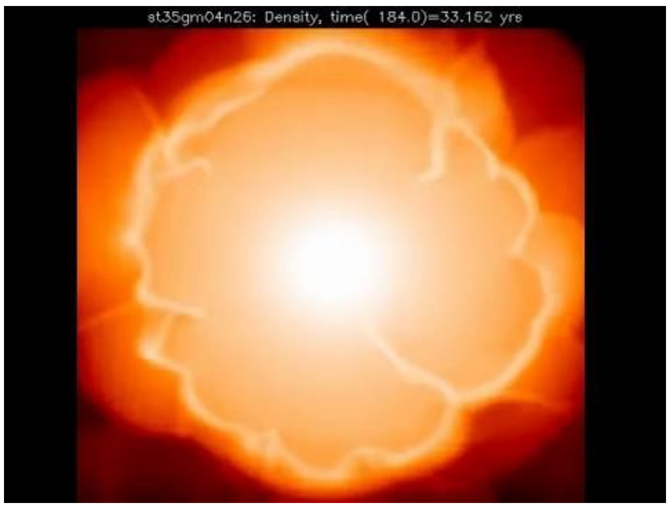
"..I think the model with ~1e-3 Msun/yr with the dense CSM radius of 1-2e15 cm can explain the LC and low velocity of the SN." (T. Moriya, **Oct 2014**)

RSG circumstellar density

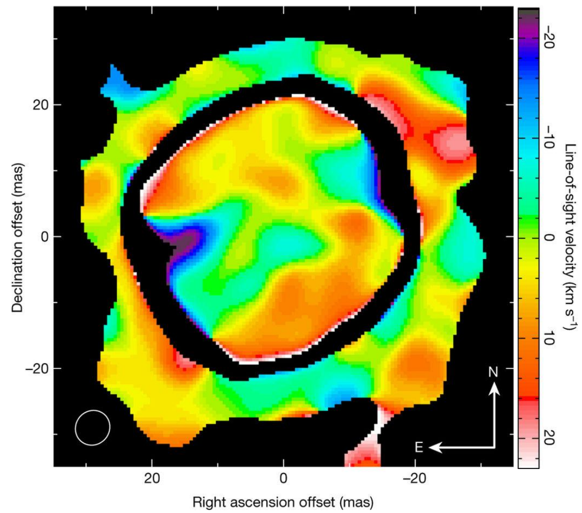


Yaron+2017, SN2013fs

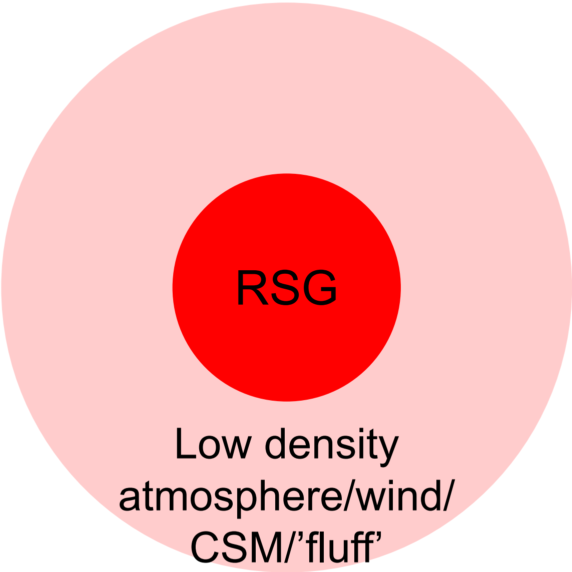
RSG circumstellar material

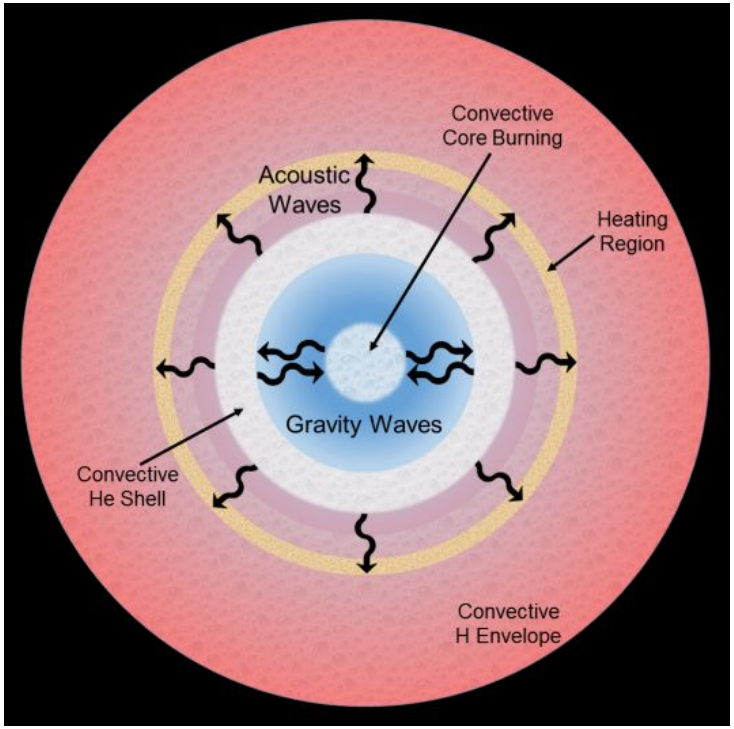


Freytag+17, MNRAS



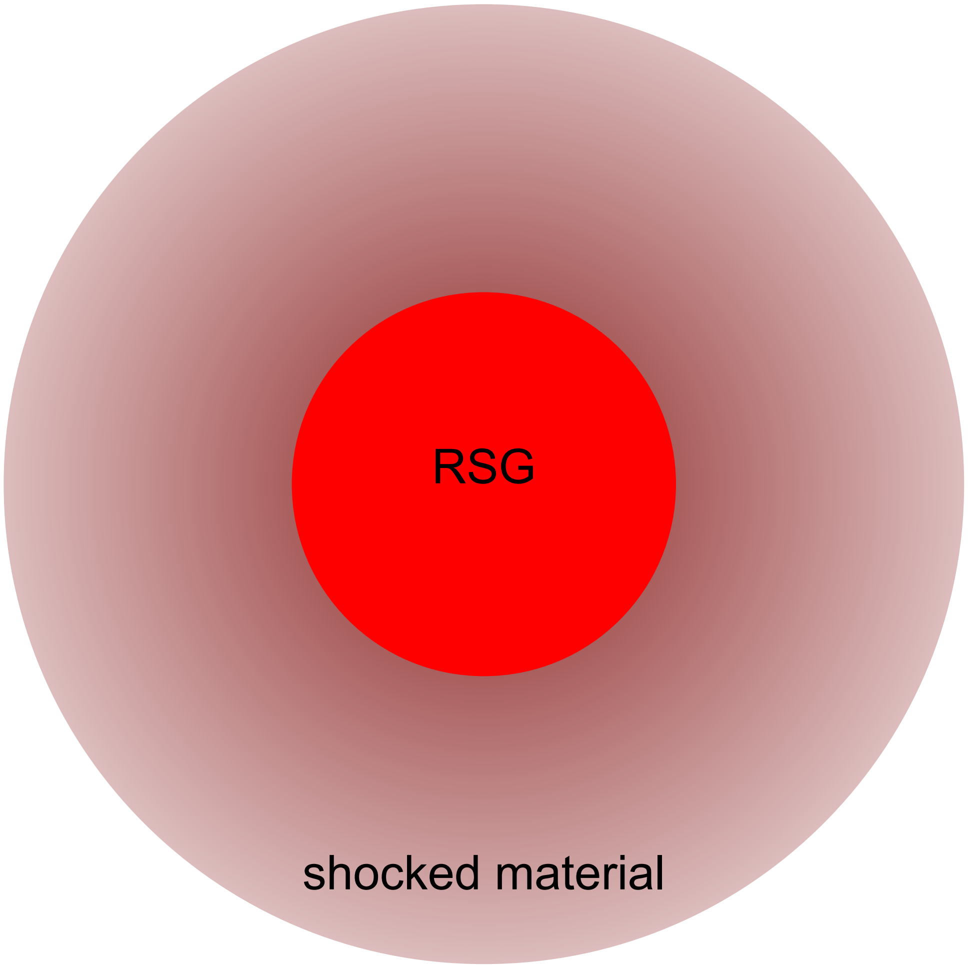
Ohnaka+17 Nature



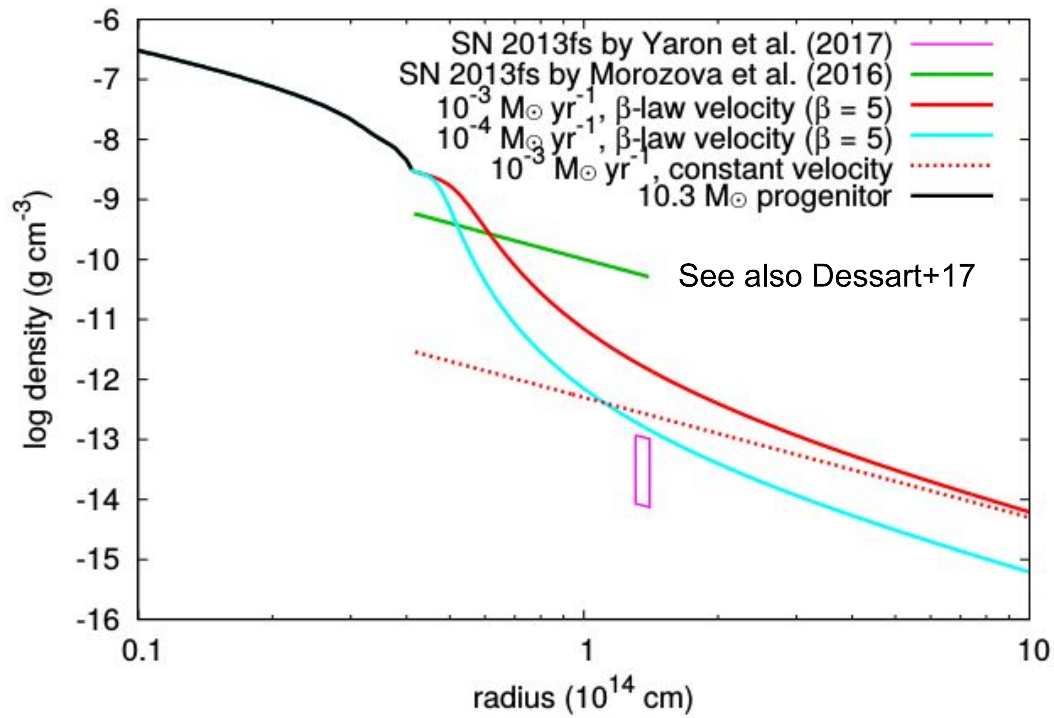


Fuller+2017, MNRAS

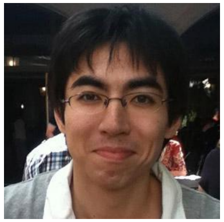
RSG winds including acceleration



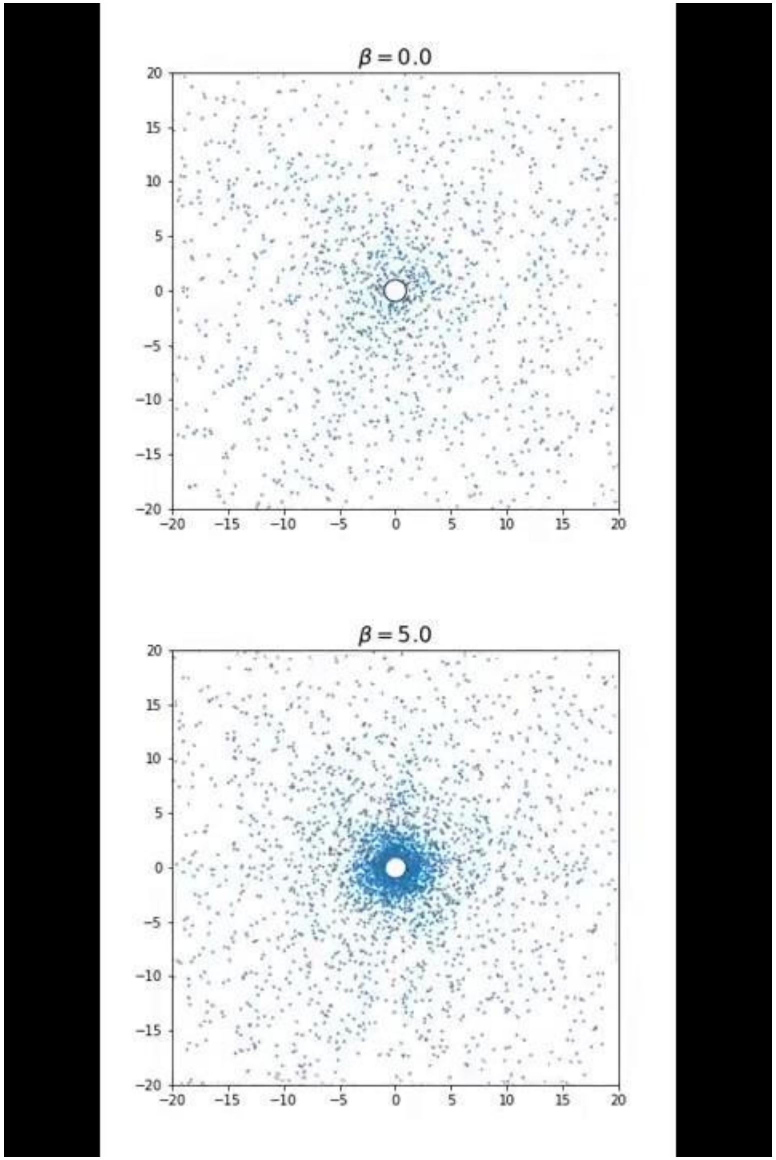
$$v_{\rm wind}(r) = v_0 + (v_\infty - v_0)\left(1 - \frac{R_0}{r}\right)^\beta$$



Moriya et al. 2017, 2018



RSG winds including acceleration



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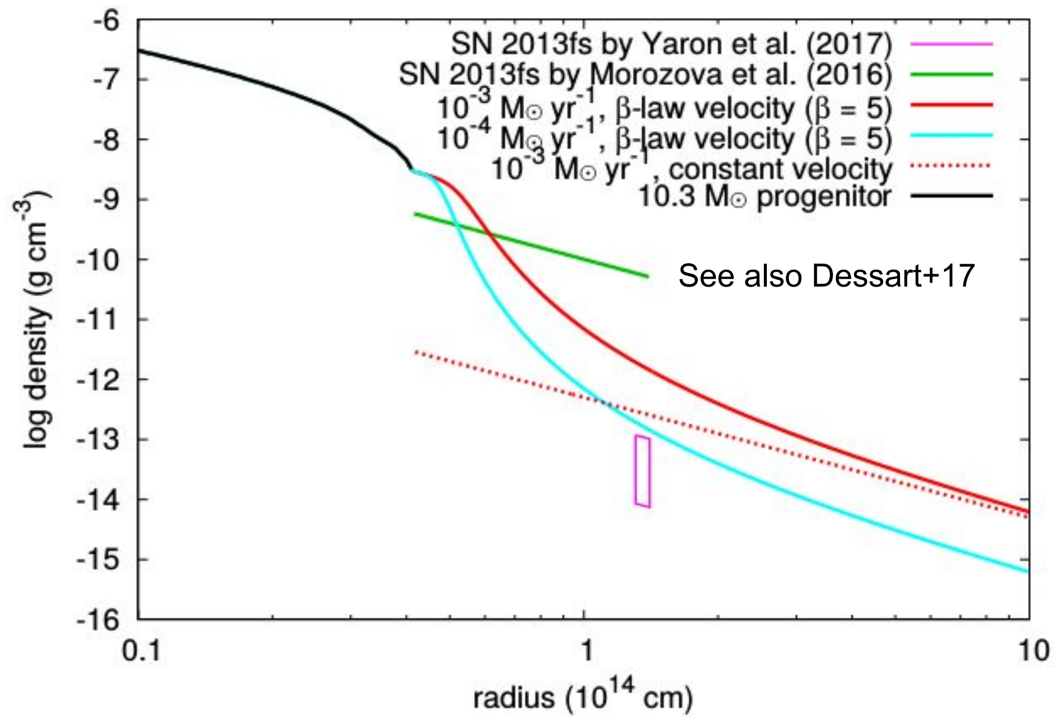
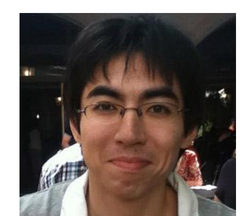
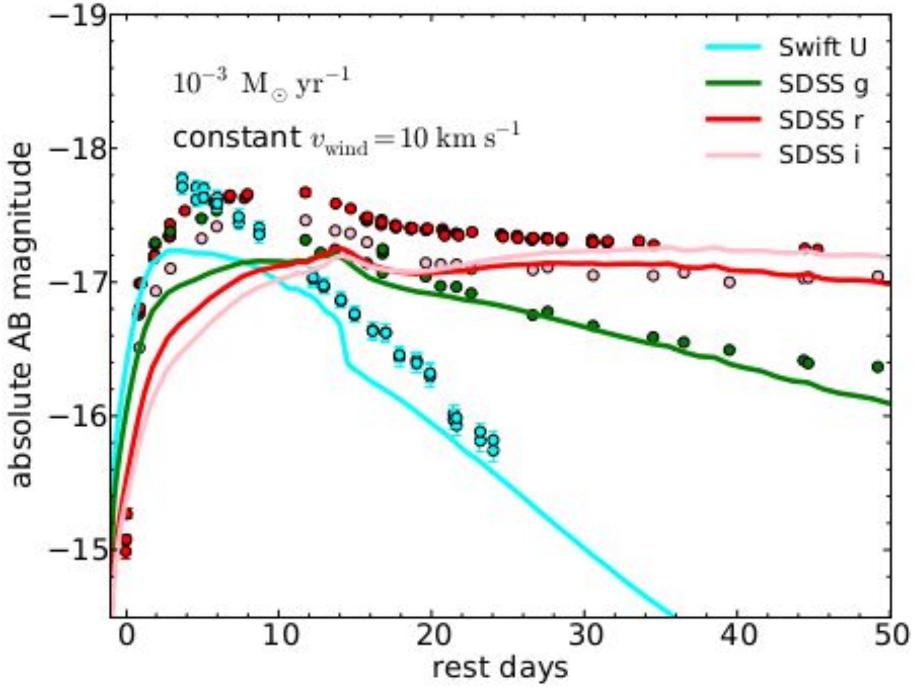
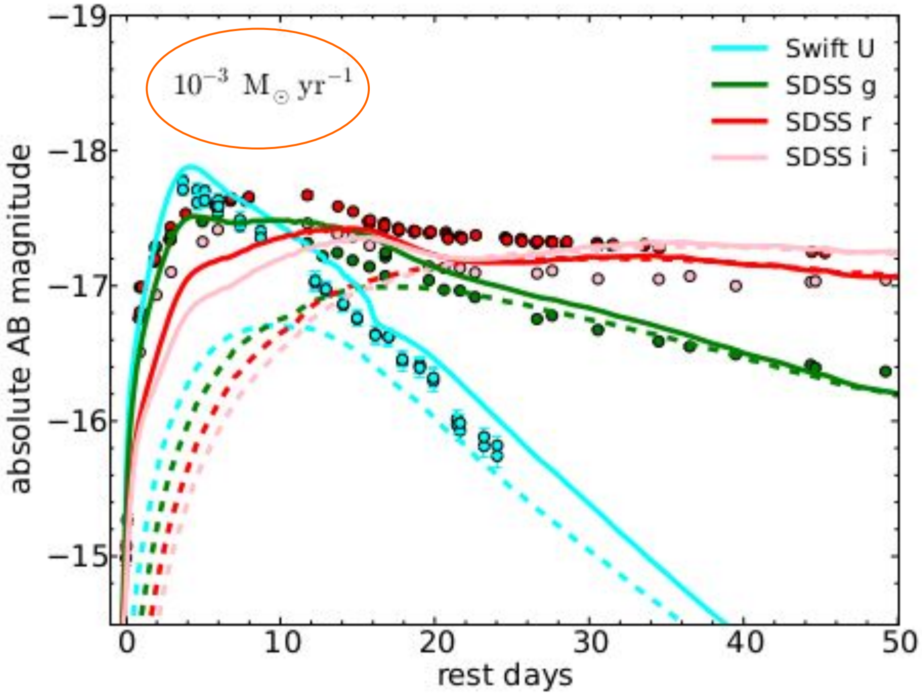


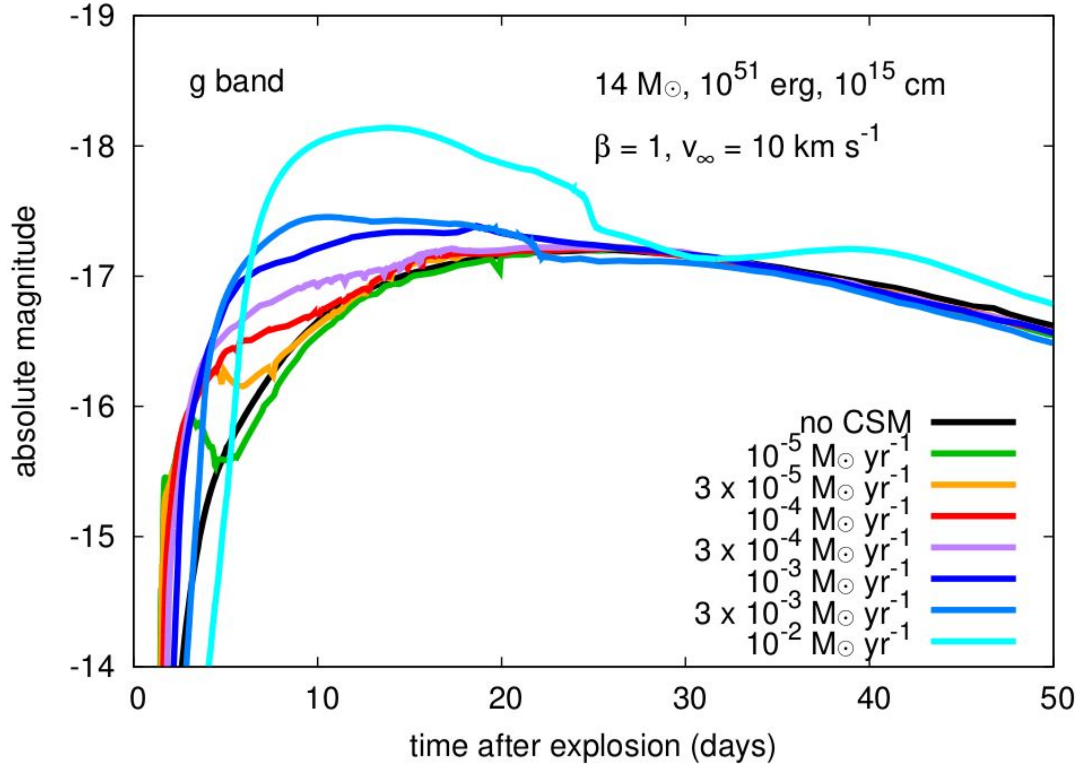


Moriya et al. 2017, 2018

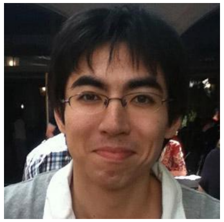
RSG winds including acceleration





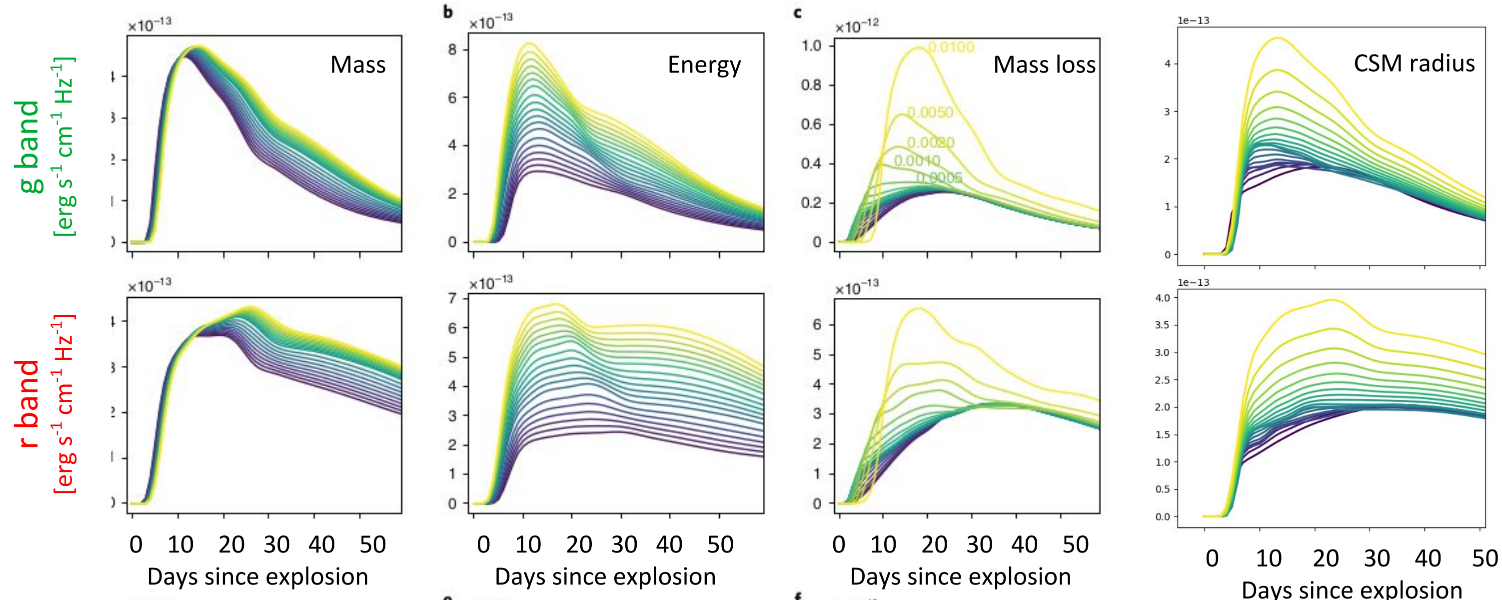


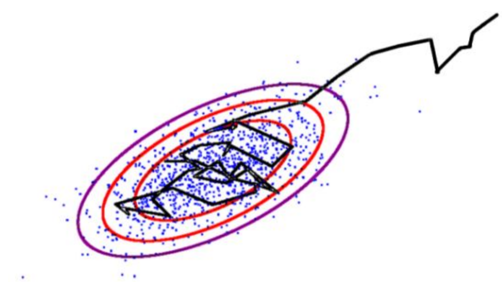
Moriya et al. 2017, 2018



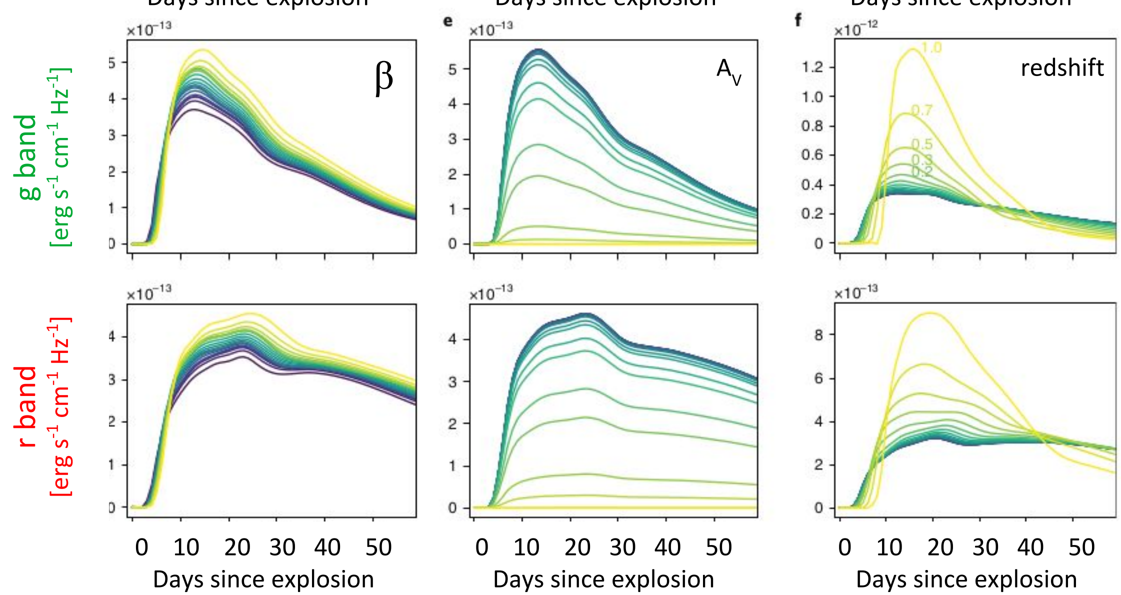
Inferring physical parameters from SN II light curves

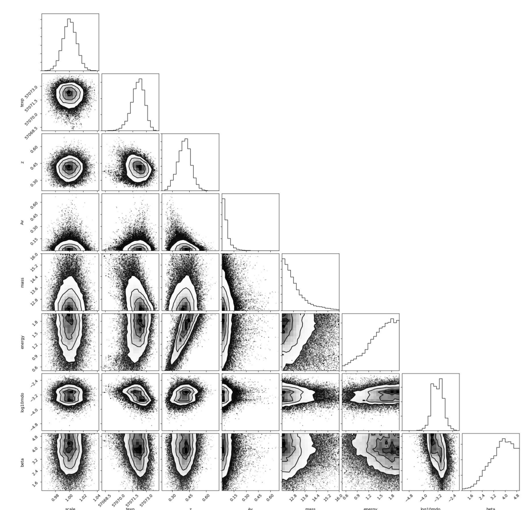
Time series of spectra SNe + CSM (Moriya+17,18) → LCs for progenitor, telescope, redshift, attenuation → Store light curves for fast evaluation → Fast physical parameter interpolation (emulation) → Fast evaluation of model likelihoods → Bayesian inference feasible (MCMC)





https://github.com/fforster/surveysim

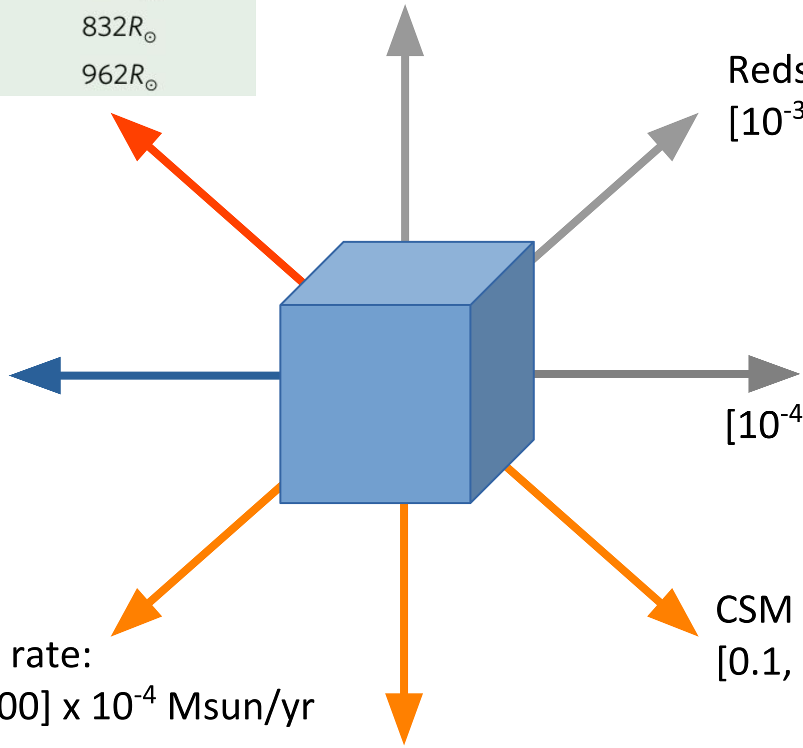




Emulation model grid

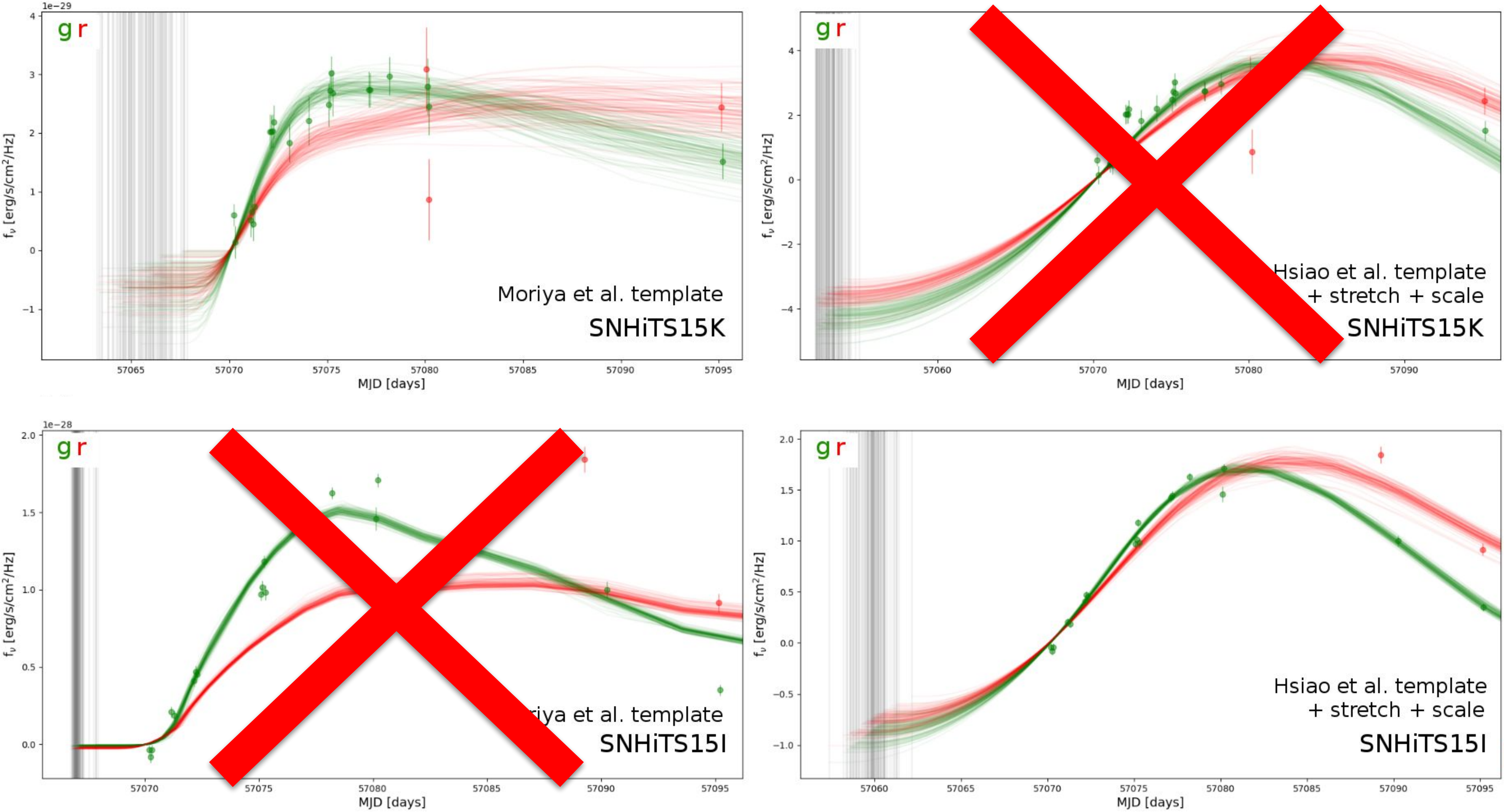
MESA models:

ZAMS mass	Final mass	Final hydrogen-rich envelope mass	Final radius
$12M_\odot$	$10.3M_\odot$	$6.1M_\odot$	$607R_\odot$
$14M_\odot$	$11.4M_\odot$	$6.2M_\odot$	$832R_\odot$
$16M_\odot$	$12.0M_\odot$	$5.8M_\odot$	$962R_\odot$

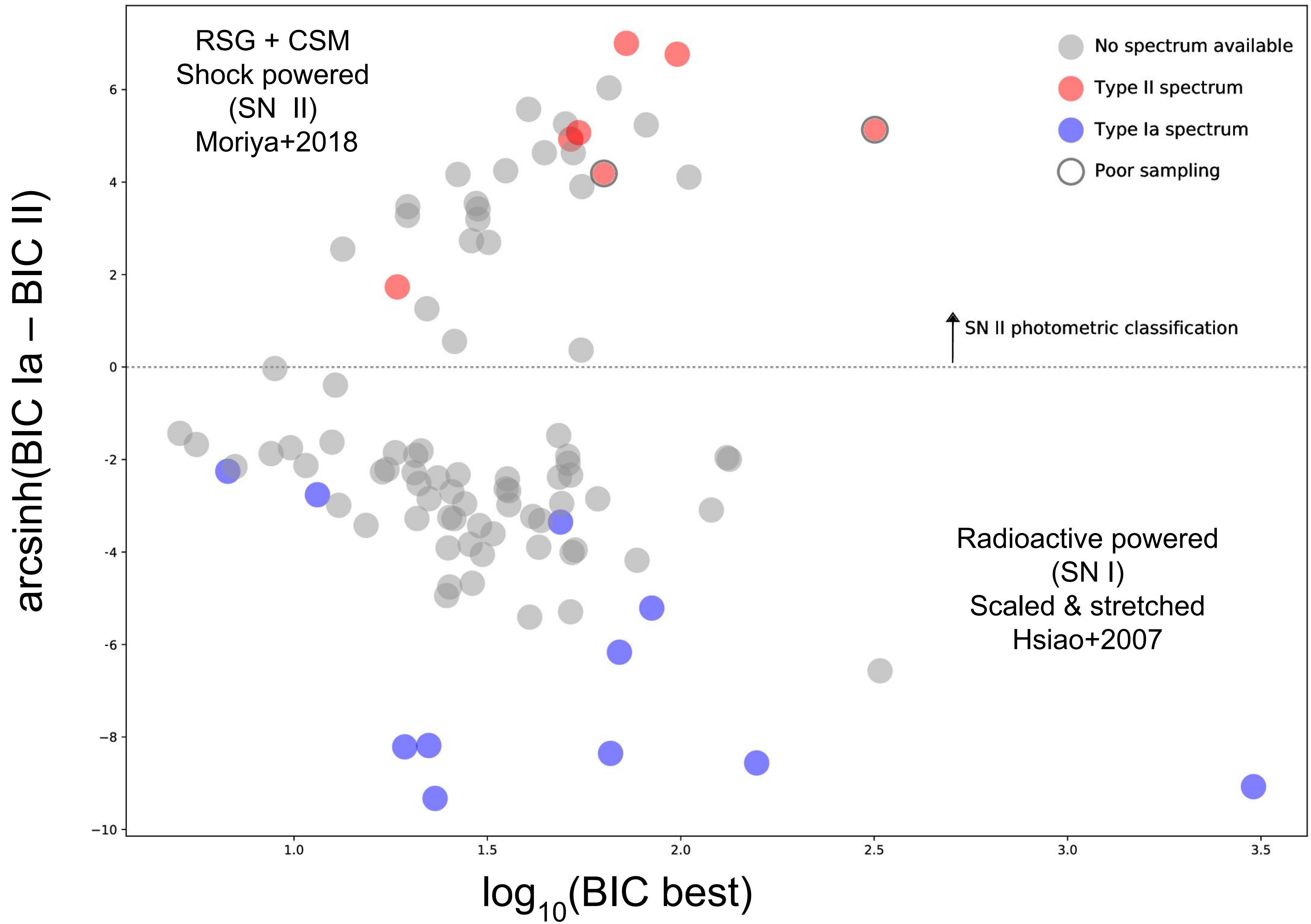


1692 models (time series of spectra) & 150 M synthetic photometric points

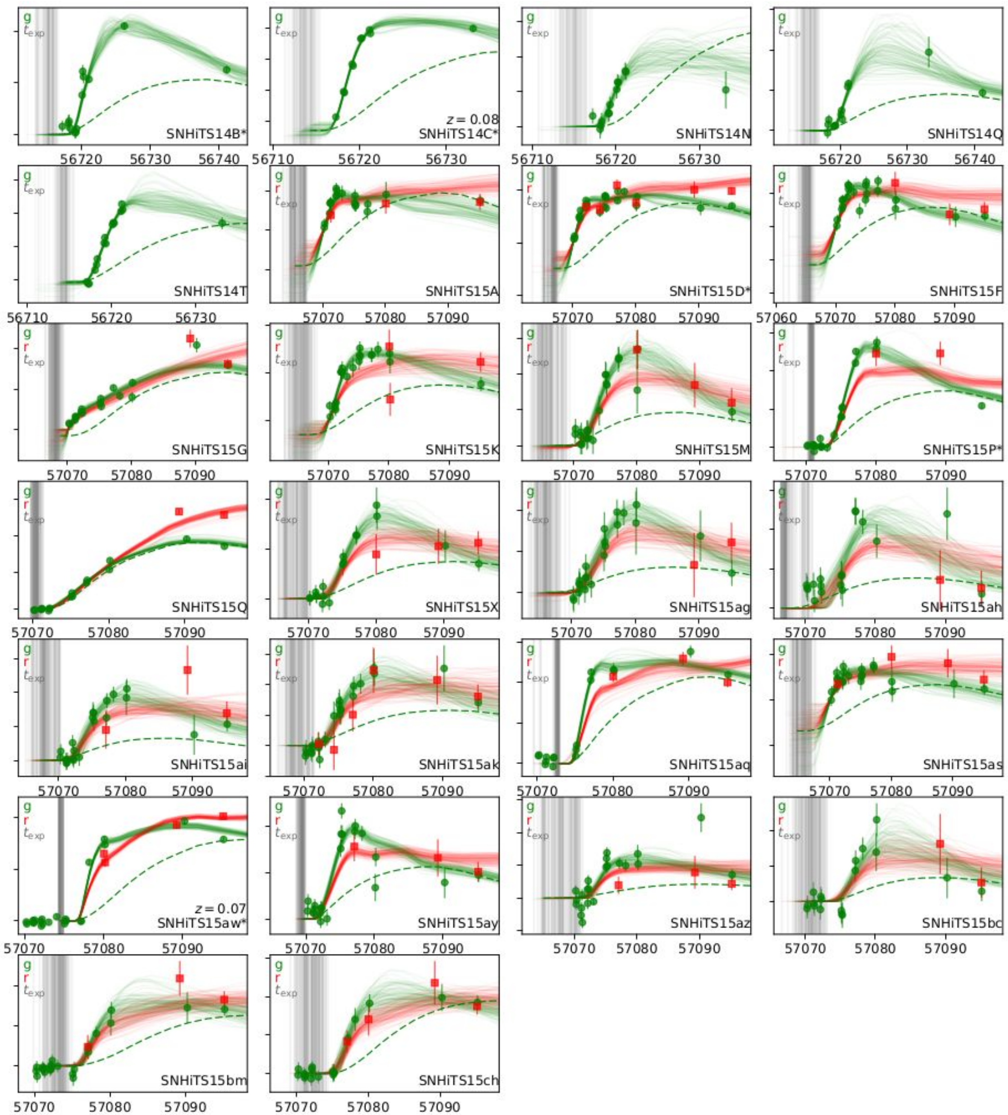
Light curve based classification

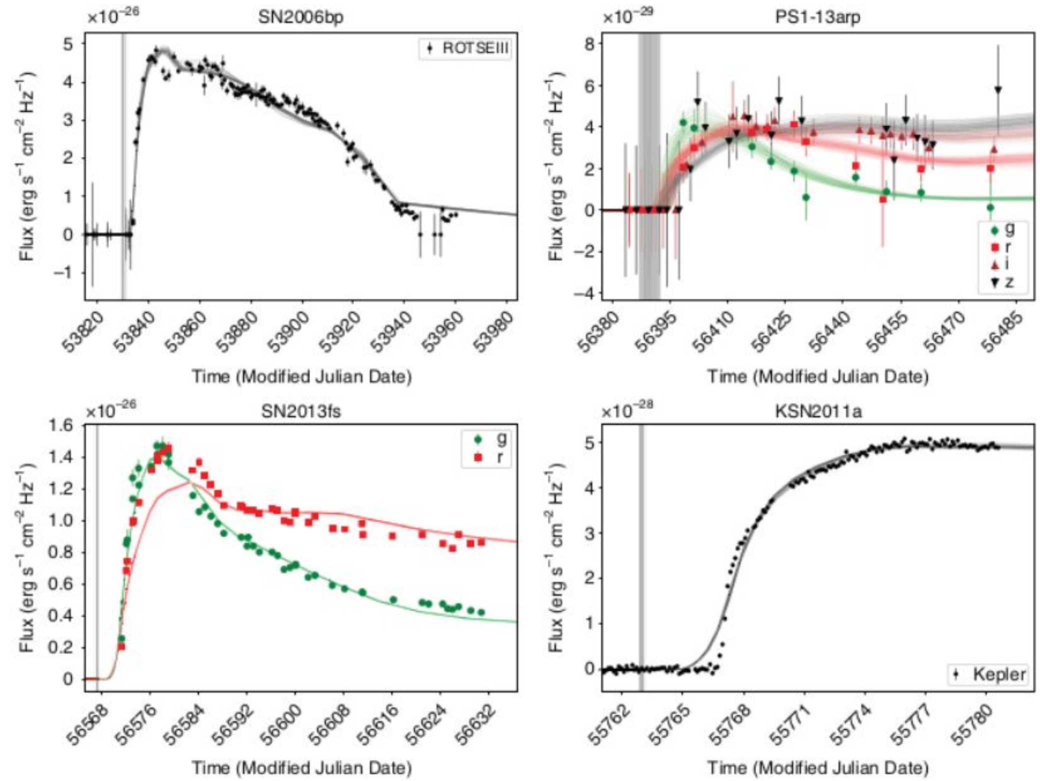


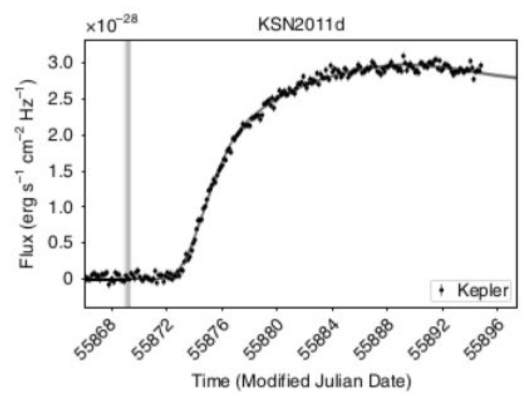
Light curve based classification



RSG wind constraints from early SN light curves



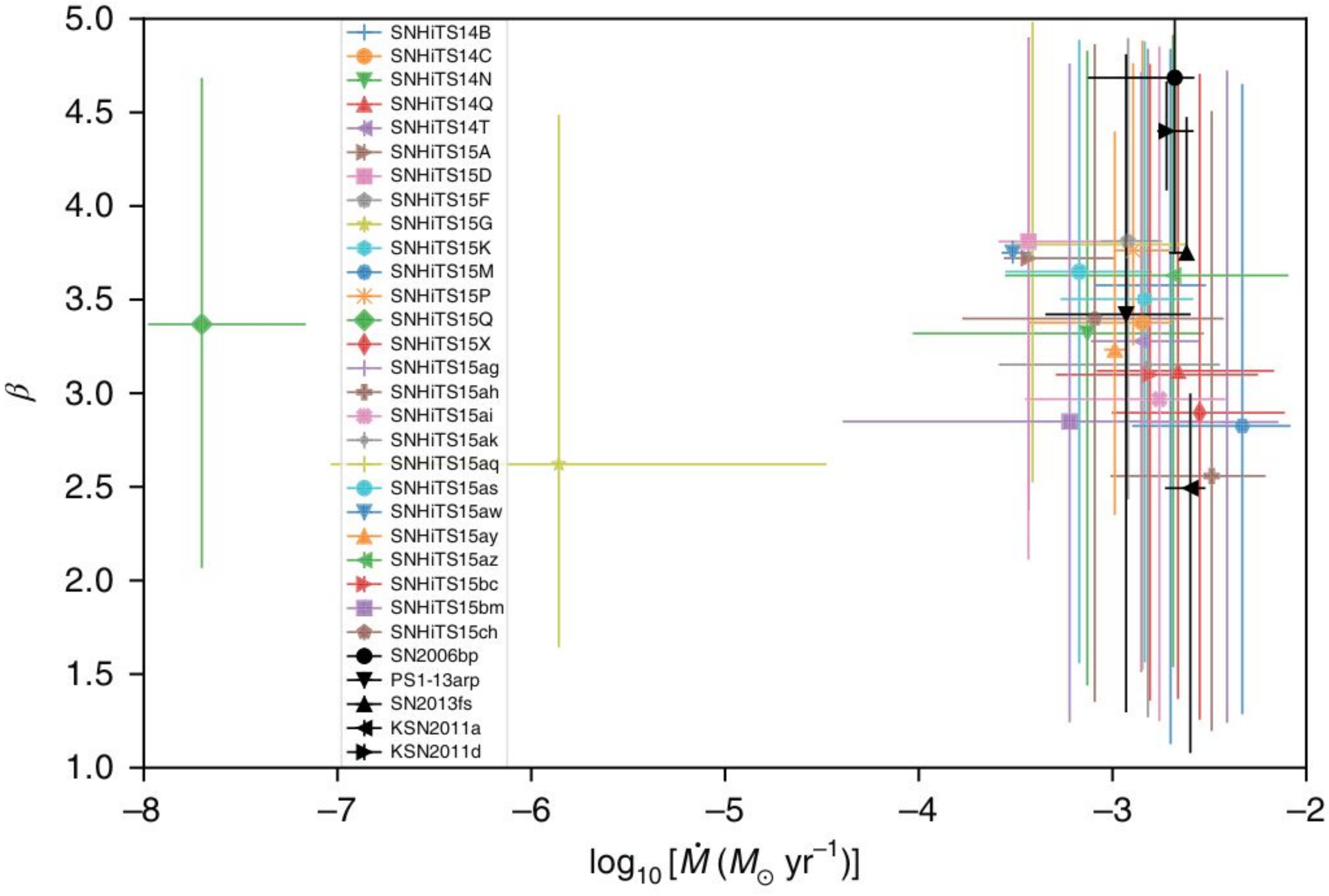




Literature
SN20016bp: Quimby+2007
PS1-13arp: Gezari+2015
SN2013fs: Yaron+2017
KSN2011a/d: Garnavich+2016

Förster et al. 2018, Nature Astronomy

RSG wind constraints from early SN light curves



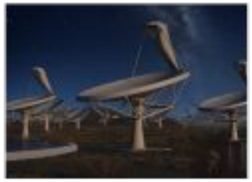
Förster et al. 2018, Nature Astronomy

Can we derive physical parameters for large samples of supernova from ZTF, LSST and other large etendue telescopes?

Future time domain astronomy ecosystem

Survey telescopes






Alert brokers

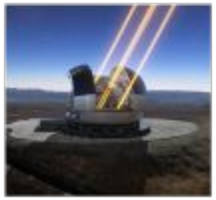
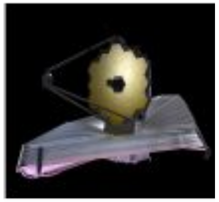
ALeRCE
Automatic Learning for the Rapid Classification of Events

ANTARES

Lasair

Follow up telescopes

Prime Focus Spectrograph
SuMIRe

Background: from HiTS to LSST

HiTS

2013-2015 (~3 weeks)

0.2 TB per night

~20 million objects

~100 million measurements

~0.1 million alerts per night

→ **10x**

ZTF

2018-2020

1.4 TB per night

~1 billion objects

~1 trillion measurements

~1 million alerts per night

→ **10x**

LSST

2022-2032

15 TB per night

~37 billion objects

~7 trillion measurements

~10 million alerts per night

ALeRCE

Automatic Learning for the Rapid Classification of Events

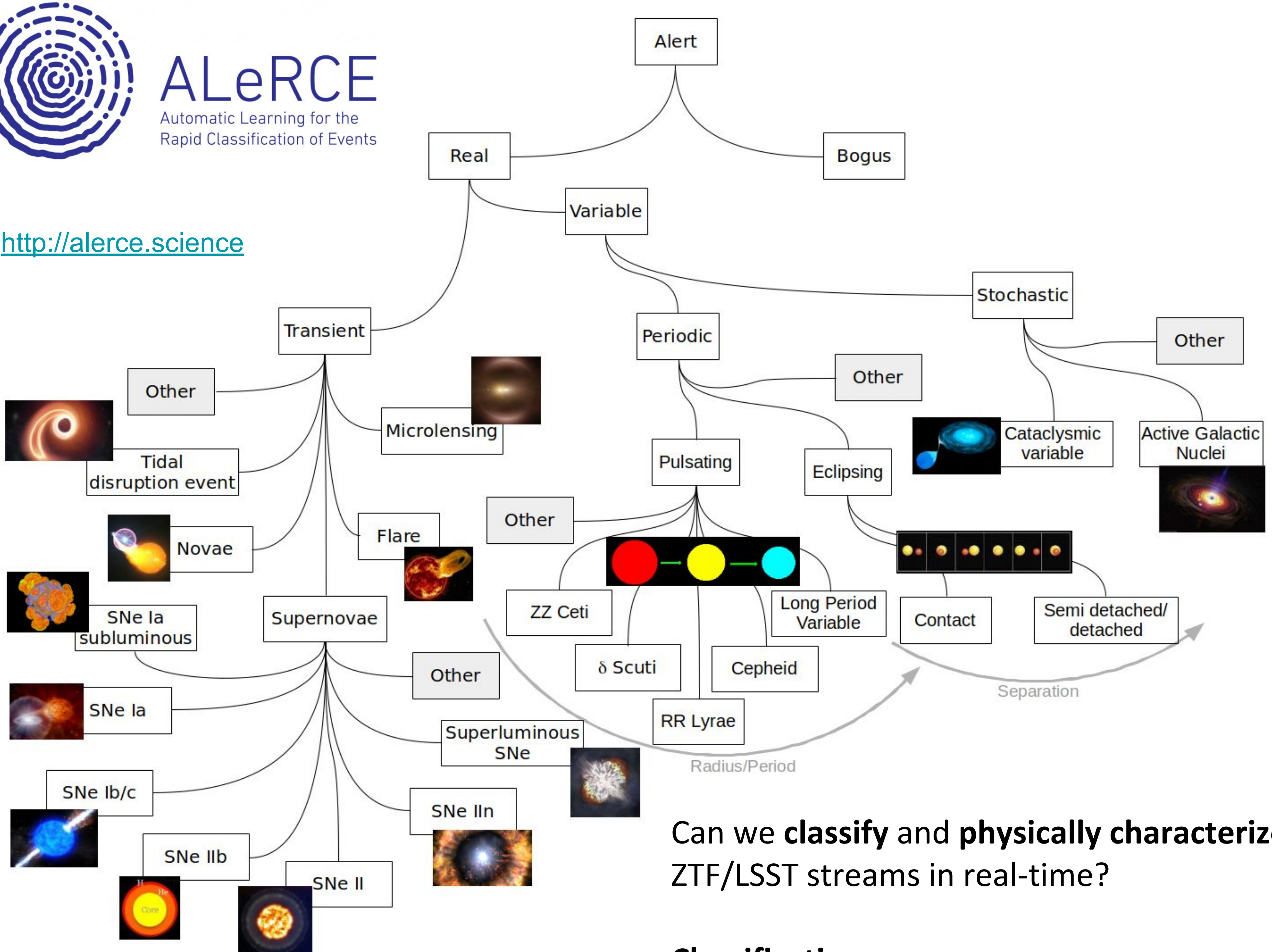
Goals

Facilitate the study of non-moving, variable and transients objects:

- **Fast classification** of **transients**, **variable stars** and **AGNs** (Cabrera-Vives+16 ApJ, Elorrieta+16, Huijse+18 ApJ, Förster+18 Nat Ast, Carrasco-Davis+18 PASP)
- **Filtered streams** of aggregated, annotated and classified alerts
- **Alert exploration** tools (API + frontend, domain dashboards, jupyter hub)
- Connect with **follow up** resources
- Distributed and scalable system for **batch processing**

ALeRCE
Automatic Learning for the Rapid Classification of Events

http://alerce.science



Can we **classify** and **physically characterize** the ZTF/LSST streams in real-time?

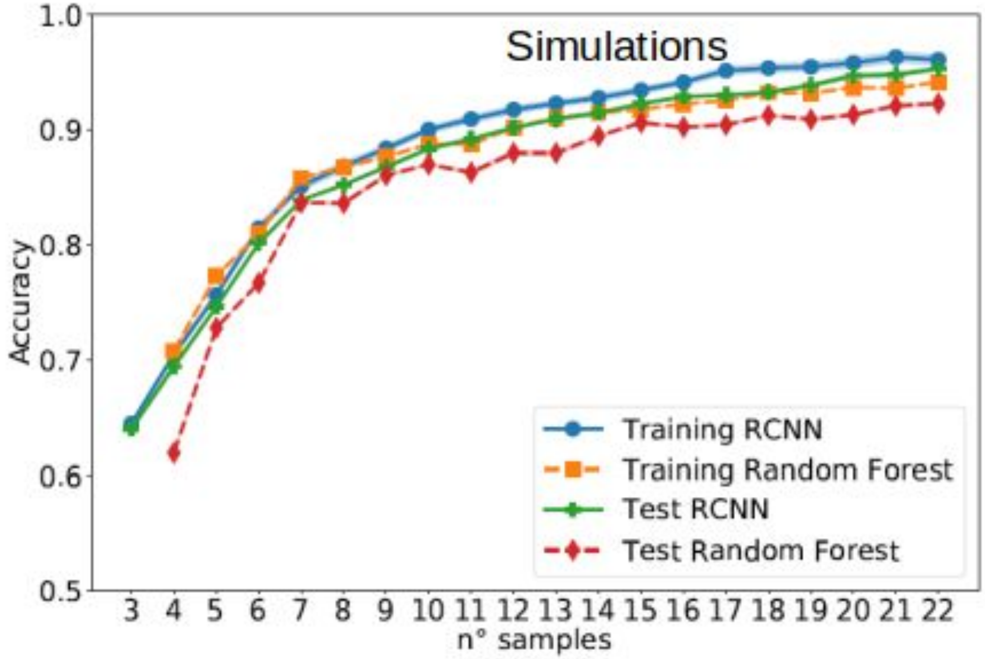
Classification:

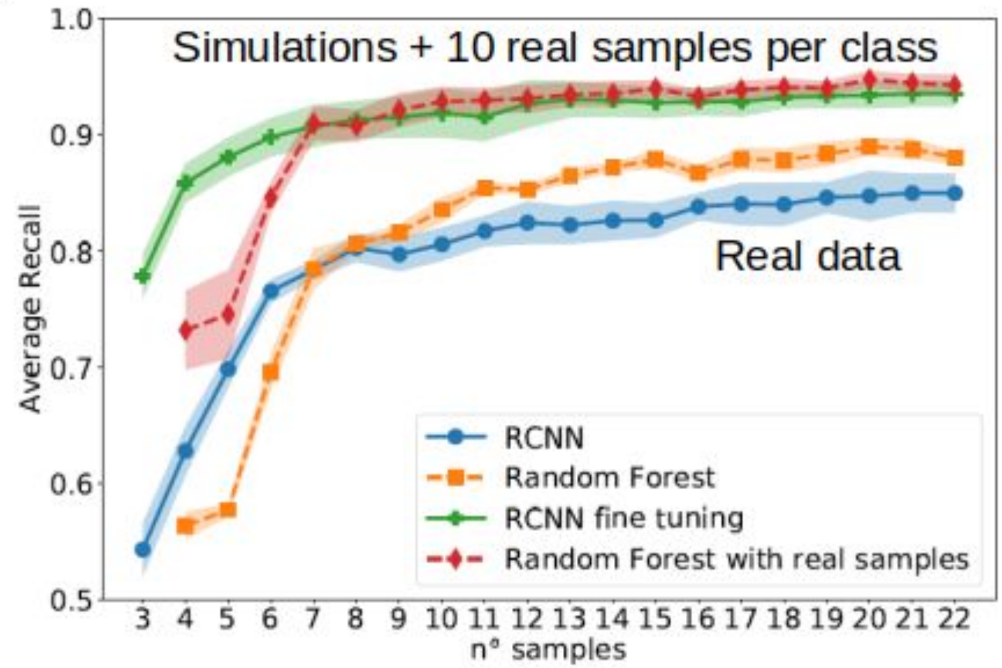
Need spectroscopically confirmed SNe

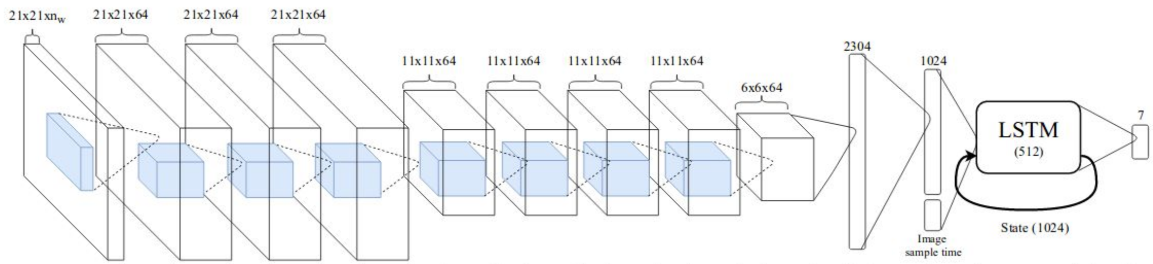
Physical characterization:

Need models ([low res.] spectral time series)

Online image based classification



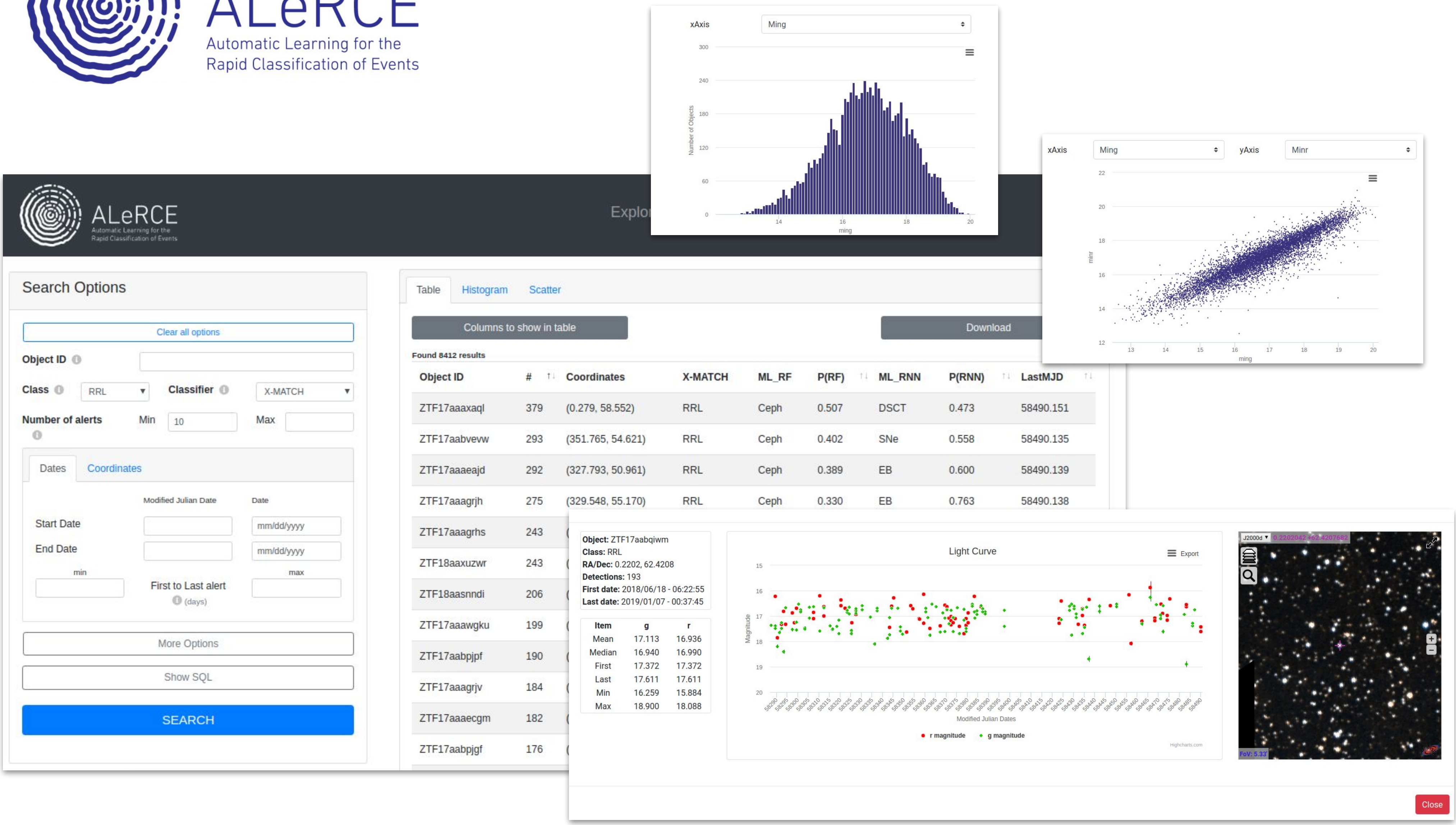




Carrasco-Davis+18
PASP

ALeRCE

Automatic Learning for the Rapid Classification of Events



Summary

HiTS: wide, deep & high cadence survey; 1st real-time survey using DECam → **No signature of RSG envelope optical SBO** (Förster+16, ApJ)

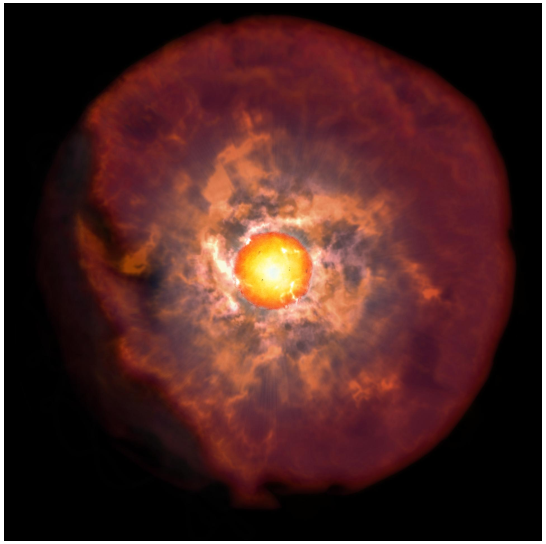
HiTS + wind acceleration models from Moriya+17/18 → **wind shock breakout signature in most SNe II candidates** (Förster+18)

Large grid of models from Moriya+17/18 used to constrain **density profile** around RSG progenitors before explosion.

Wind acceleration models suggest enhanced mass loss rates: typically ~10^{-3} Msun/yr up to ~10^{15}cm (c.f. ~10^{-1} Msun/yr up to ~10^{14}cm).

Markov Chain Monte Carlo + emulation: powerful technique for deriving physical parameters of transients. **Grids of explosion models with different physical parameters needed.**

Open questions: What is the origin of the enhanced density profile: atmosphere/wind/outburst? How would enhanced CSM RSGs look before explosion (see Johnson+2018, Kilpatrick+Foley 2018)? What mechanisms could trigger RSG pre SN wind/outburst (see Fuller+2017, MNRAS)?



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