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

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ARTICLES

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

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Takashi Moriya
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Millennium Institute of Astrophysics

Image credit: NAOJ

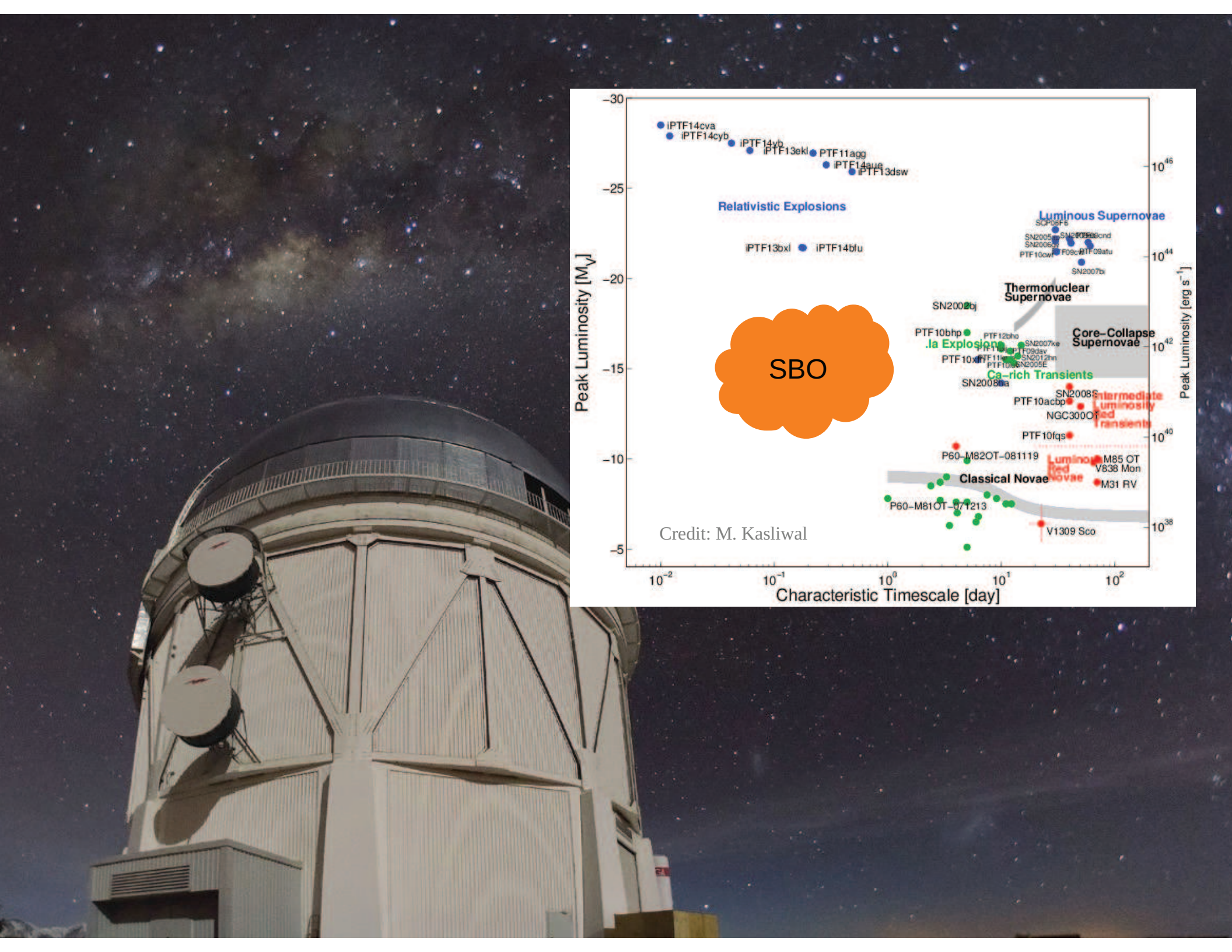
CMM Center for Mathematical Modeling

NLHPC National Laboratory for High Performance Computing Chile

MILLENNIUM INSTITUTE OF ASTROPHYSICS

CONICYT

ALeRCE Automatic Learning for the Rapid Classification of Events


Peak Luminosity [M_V]
Peak Luminosity [erg s^{-1}]
Characteristic Timescale [day]
−30
−25
−20
−15
−10
−5
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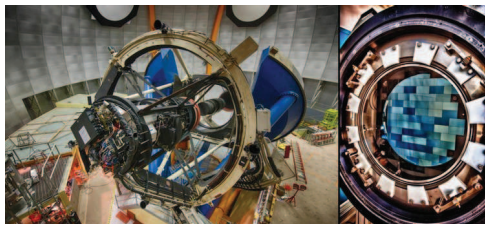
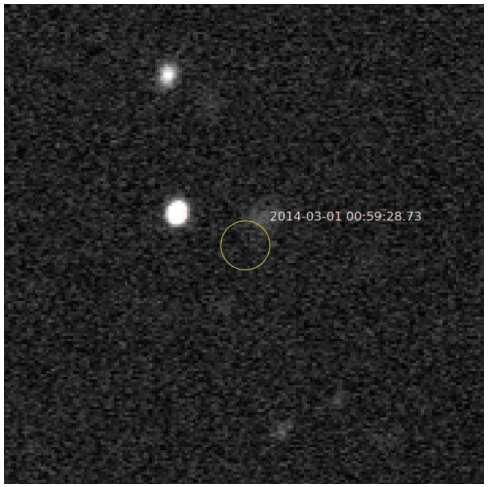
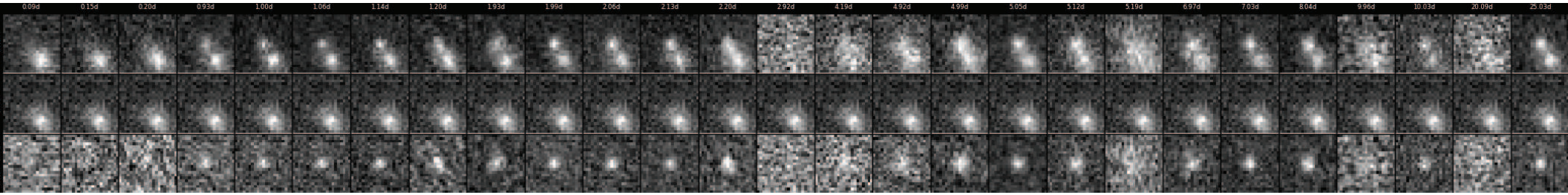
10^{-1}
10^{0}
10^{1}
10^{2}
10^{46}
10^{44}
10^{42}
10^{40}
10^{38}
iPTF14cva
iPTF14cyb
iPTF14yb
iPTF13ekl
PTF11agg
iPTF14aue
iPTF13dsw
Relativistic Explosions
iPTF13bxl
iPTF14bfu
Luminous Supernovae
SCP06F6
SN2006gy
PTF10cwr
PTF09atu
SN2007bi
Thermonuclear Supernovae
SN2002bj
PTF10bhp
PTF12bho
.Ia Explosions
SN2007ke
PTF09dav
PTF10xfh
SN2012hn
SN2005E
Core−Collapse Supernovae
Ca−rich Transients
SN2008ha
SN2008S
PTF10acbp
NGC300OT
Intermediate Luminosity Red Transients
PTF10fqs
P60−M82OT−081119
M85 OT
V838 Mon
M31 RV
Classical Novae
P60−M81OT−071213
V1309 Sco
SBO
Credit: M. Kasliwal

High cadence Transient Survey (HiTS) in a nutshell

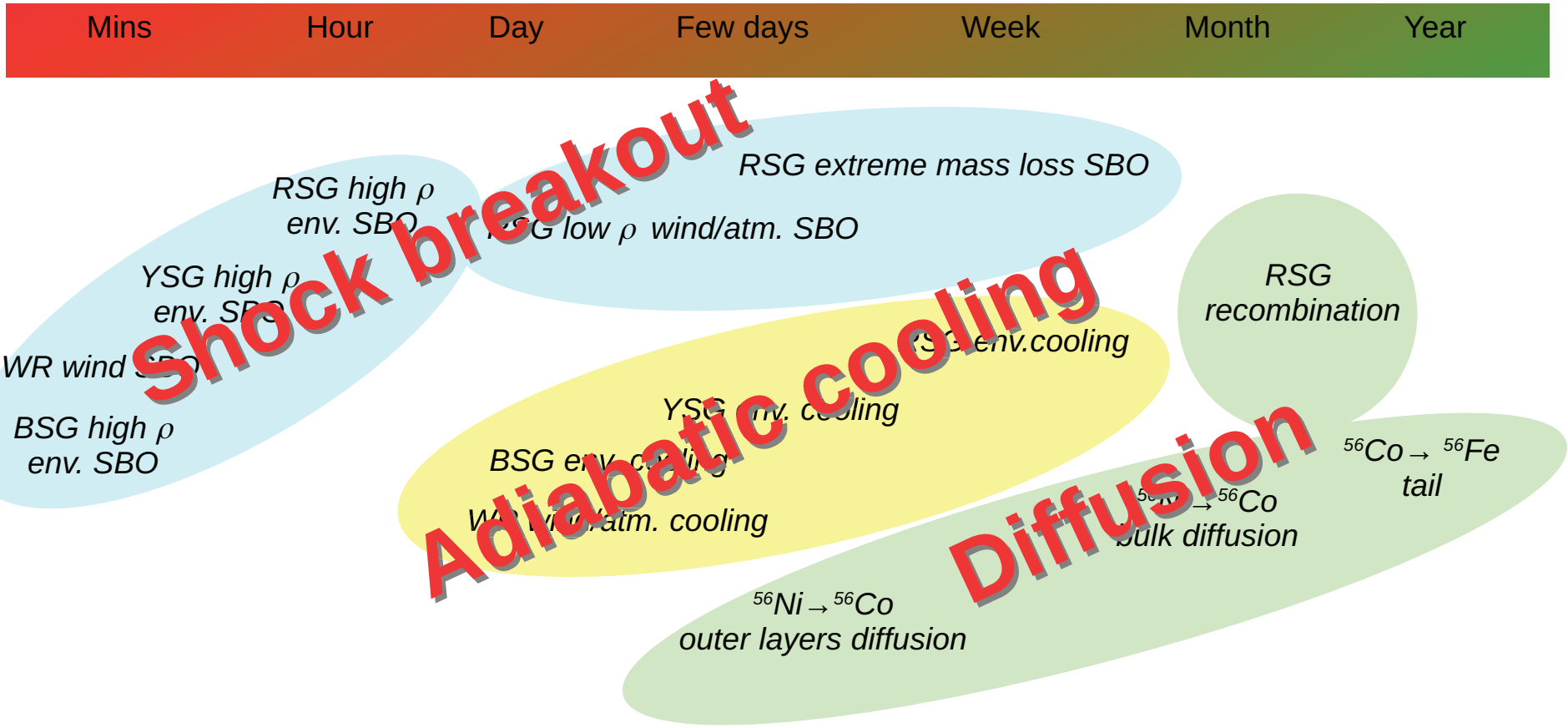




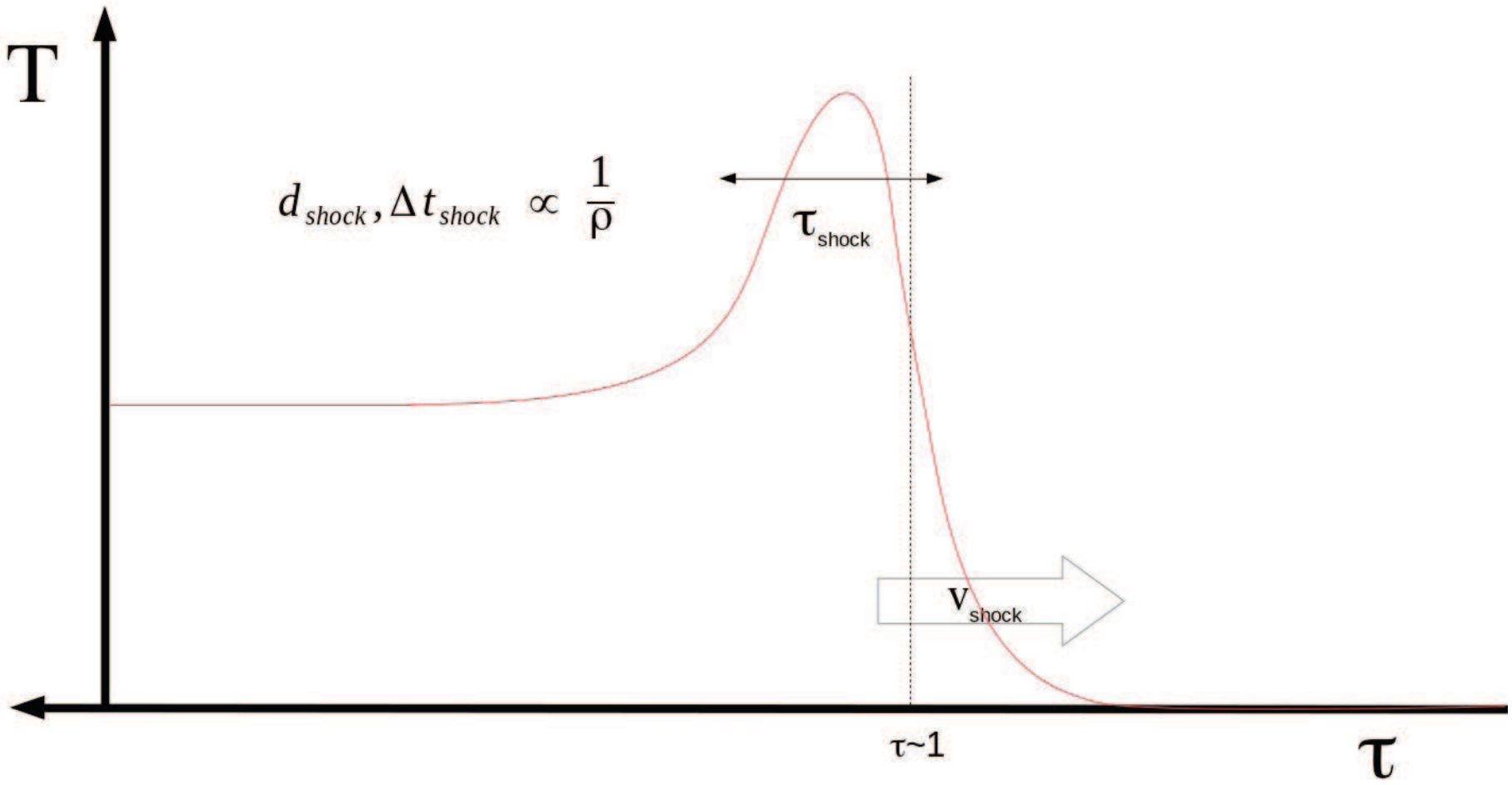
- 320 deg^2 deep & high cadence survey
- 1st real time analysis of DECam data (Feb 2014)
- 125 supernova detected (ATELs)
- **SBO models ruled out (Förster+16, ApJ)**
- 1st CNN real/bogus filter (Cabrera-Vives+17, ApJ)
- 18 distant RR Lyrae (Medina+17,18, ApJ)
- ~10k new asteroids (Peña+18, AJ)
- ~22M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



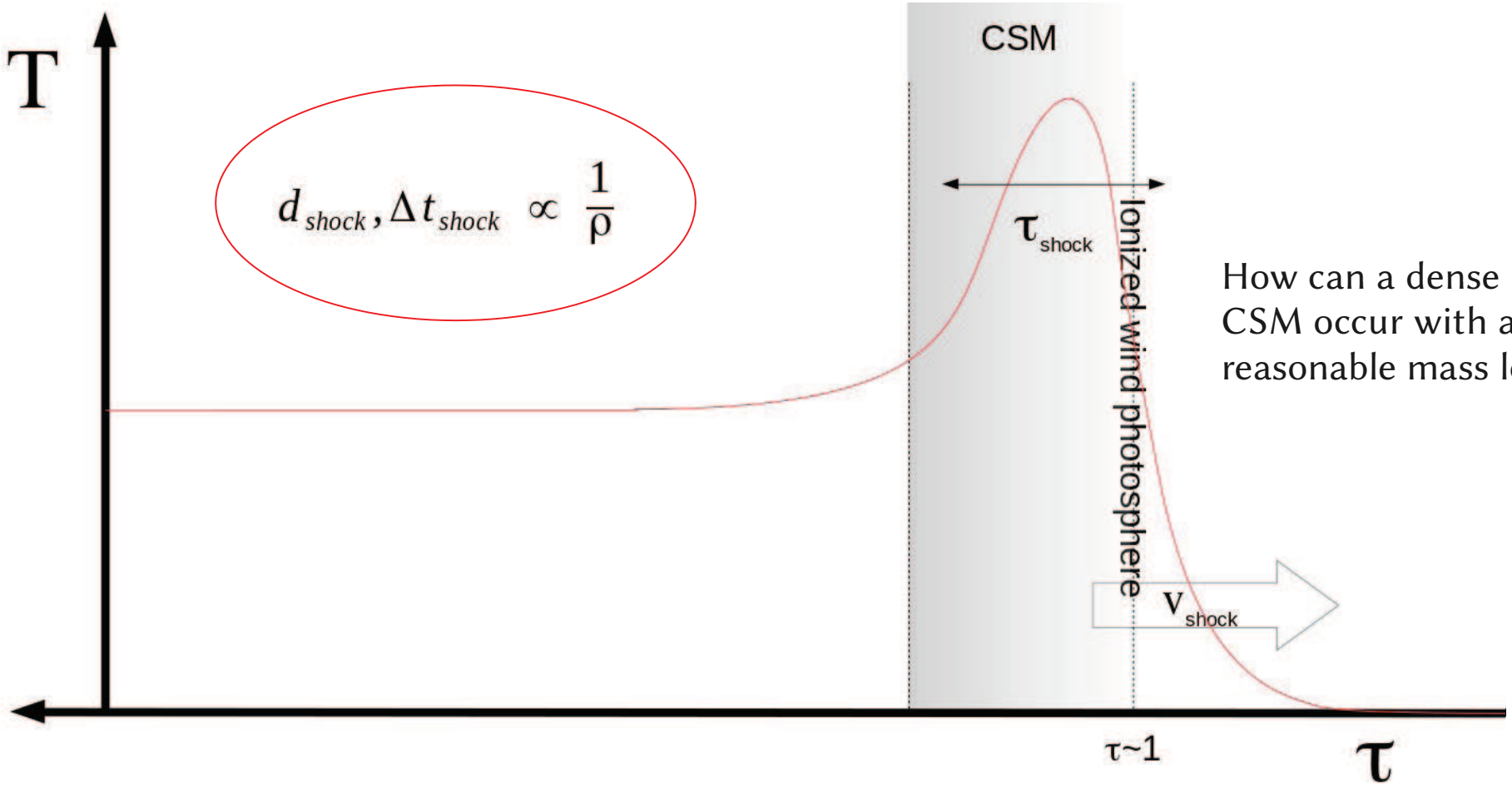
Physical processes and timescales in supernovae



Shock breakout

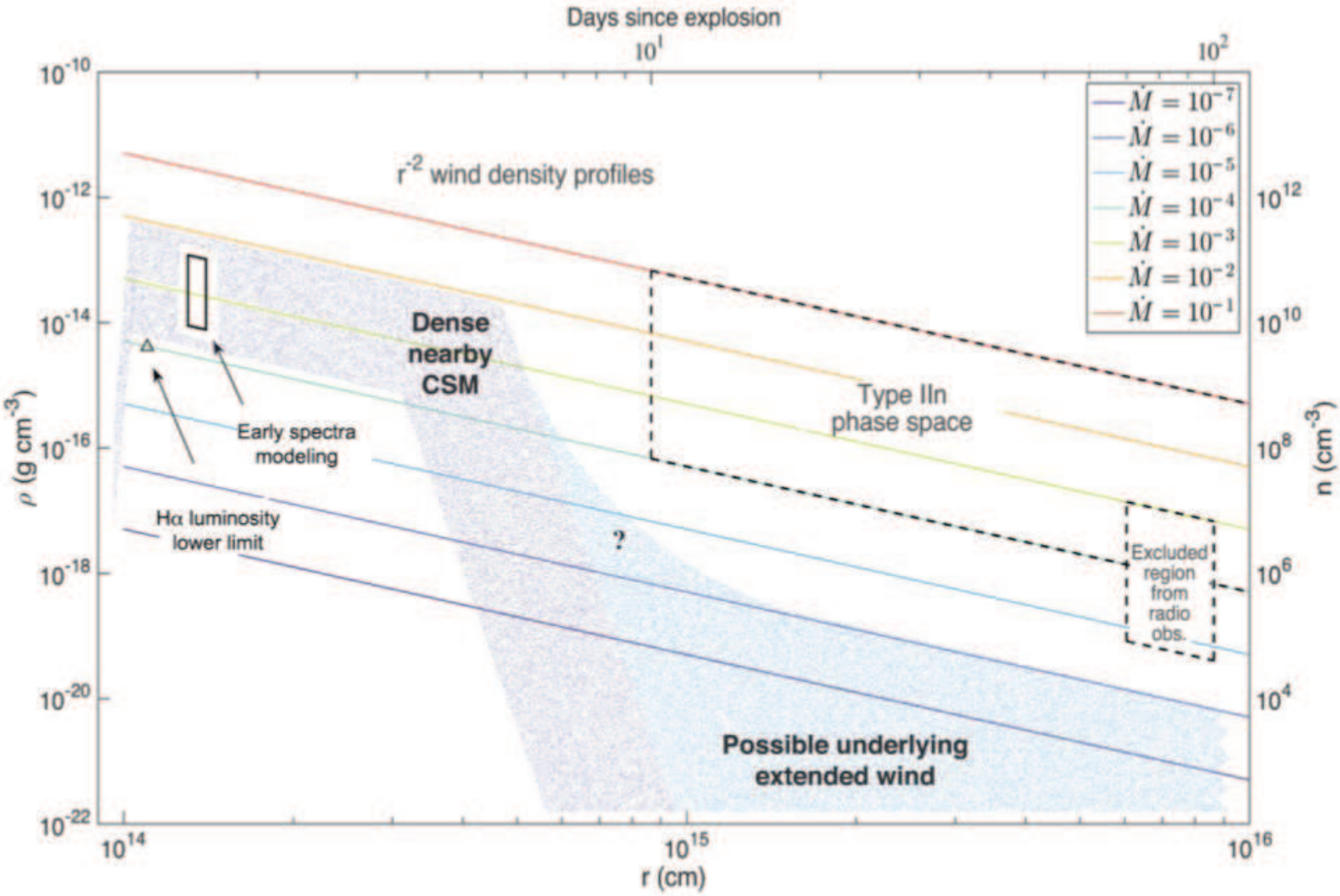


Shock breakout in dense CSM



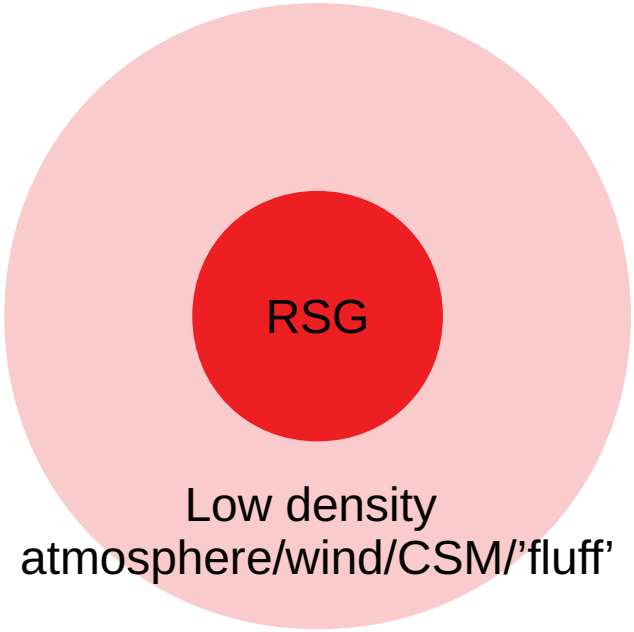
How can a dense CSM occur with a reasonable mass loss?

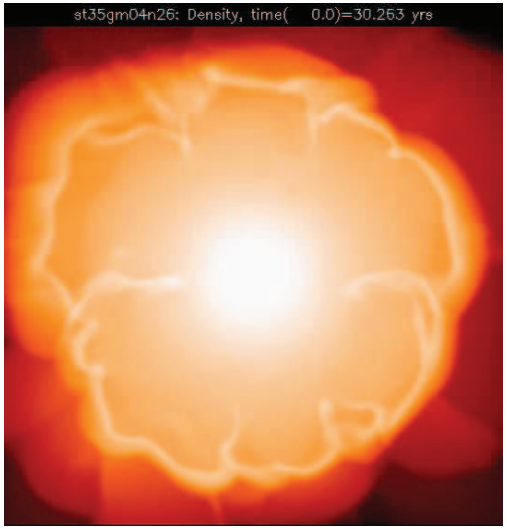
RSG circumstellar density



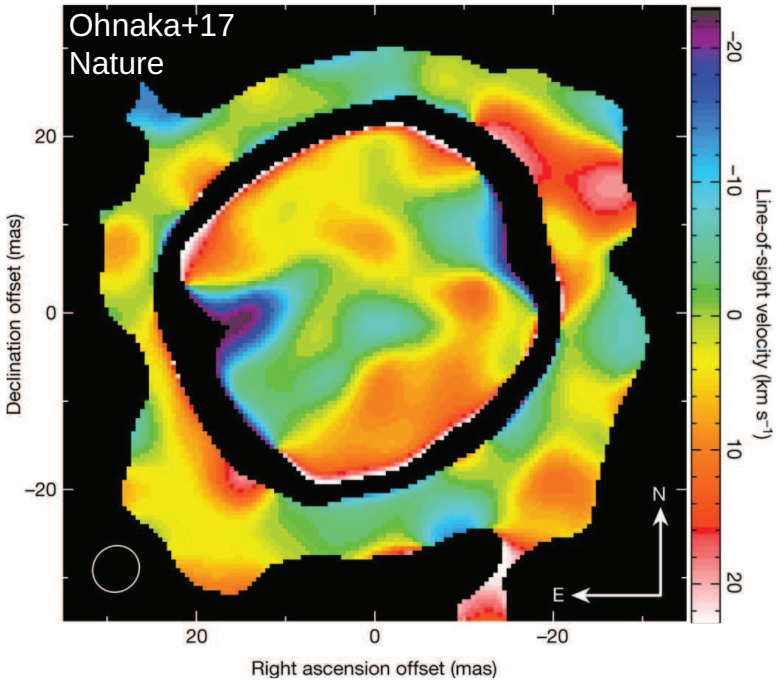
Yaron+2017, SN2013fs

RSG circumstellar material



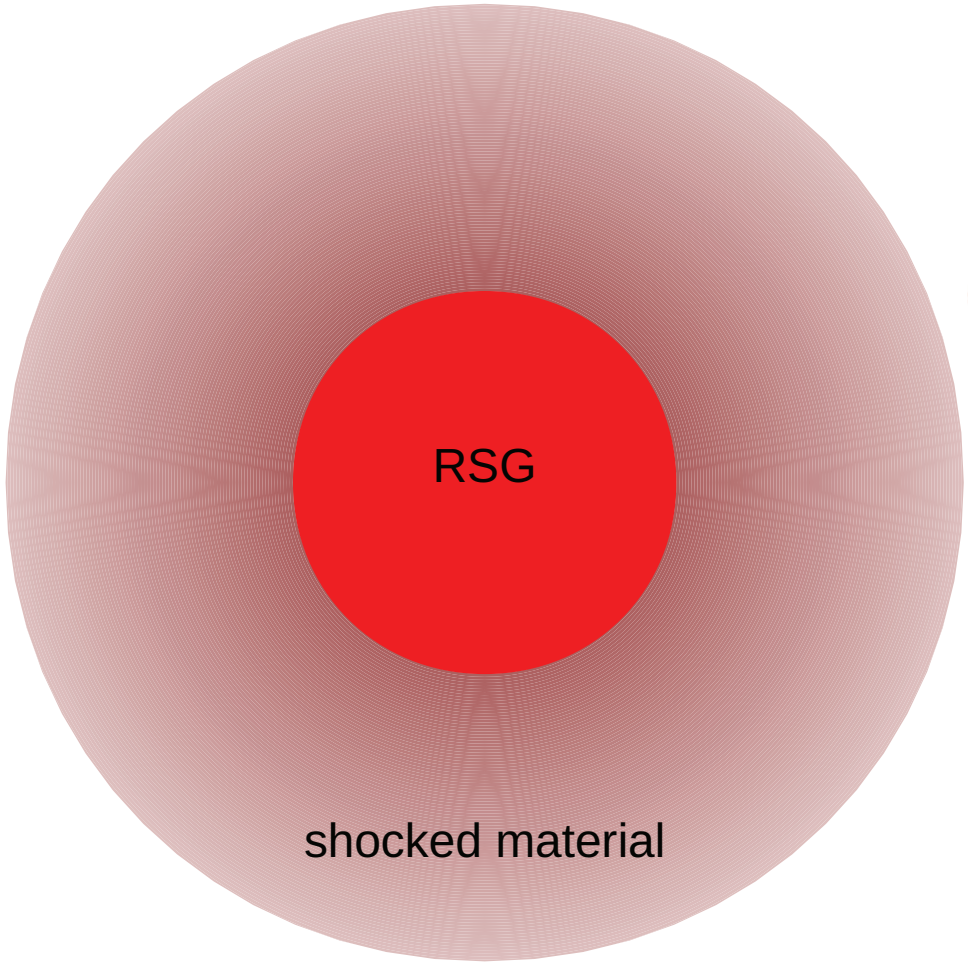


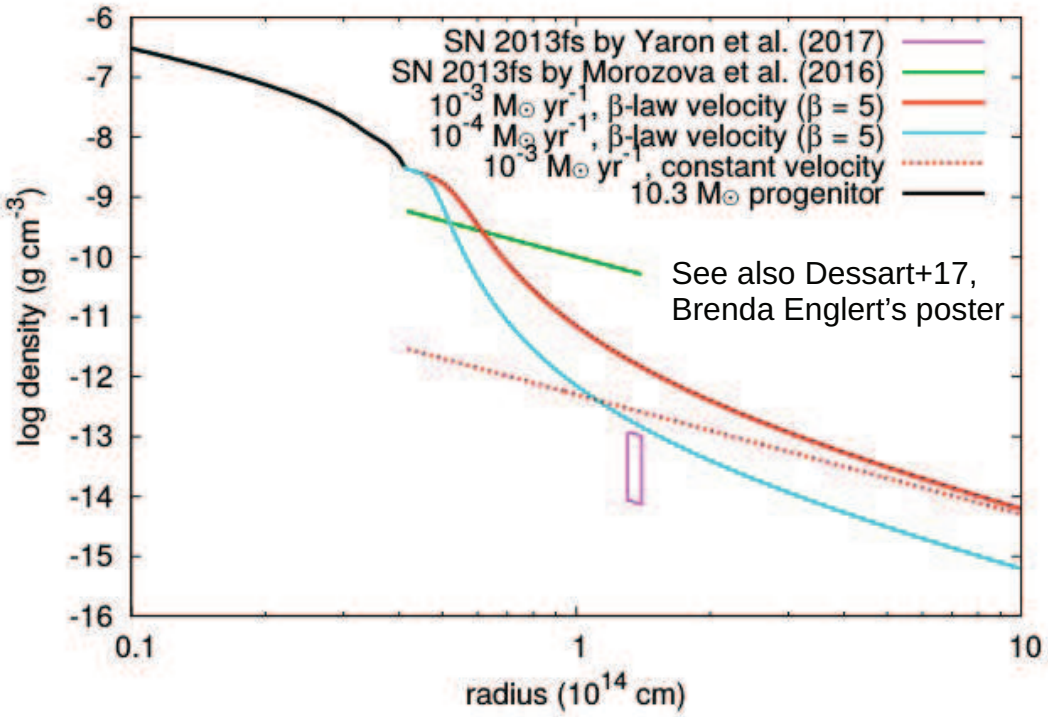
Bernd
Freytag



RSG winds including acceleration

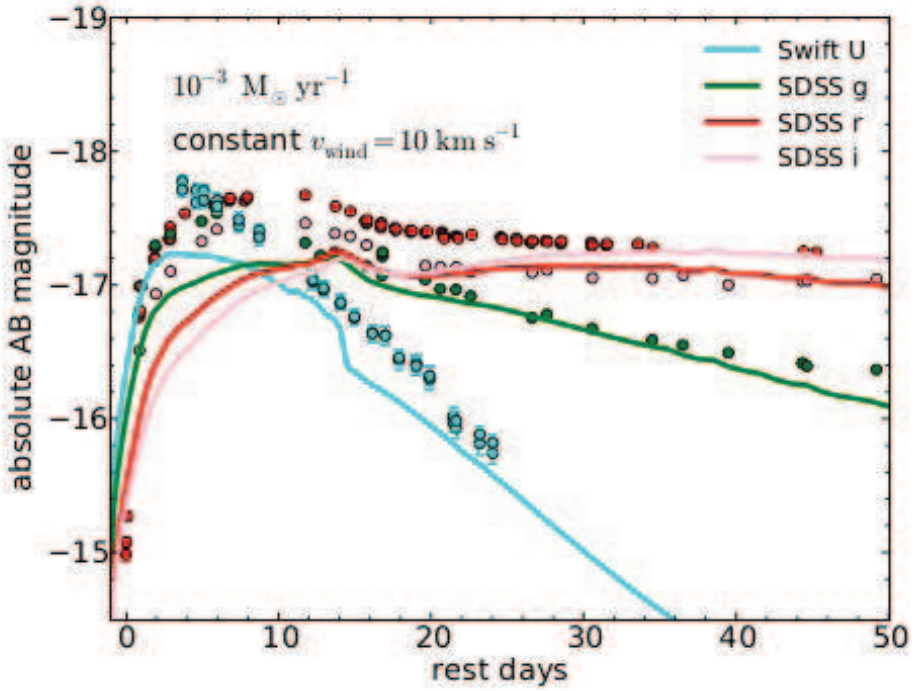
$$v_{\rm wind}(r) = v_0 + (v_\infty - v_0)\left(1 - \frac{R_0}{r}\right)^\beta$$

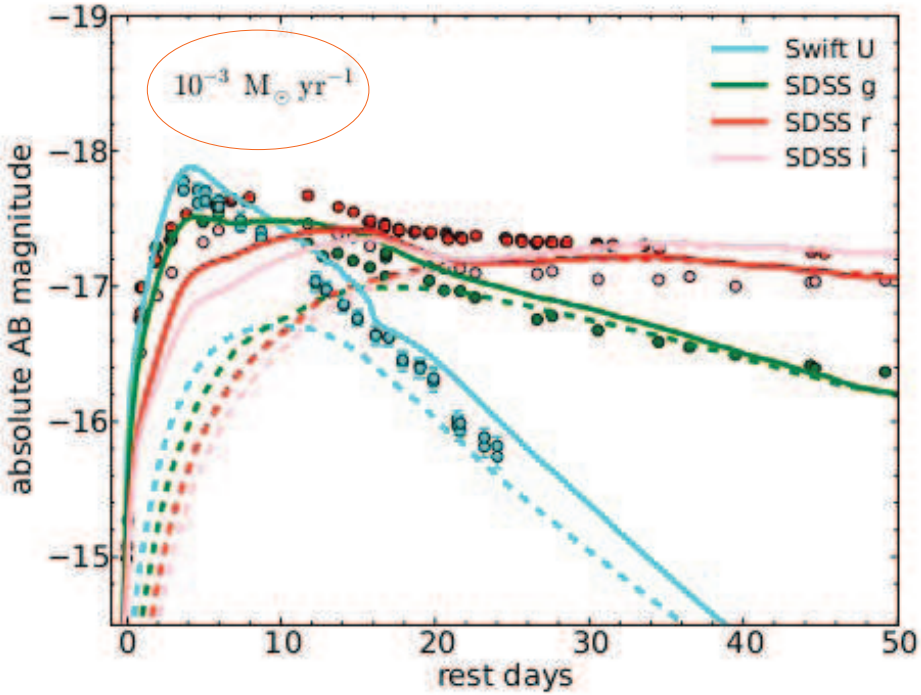


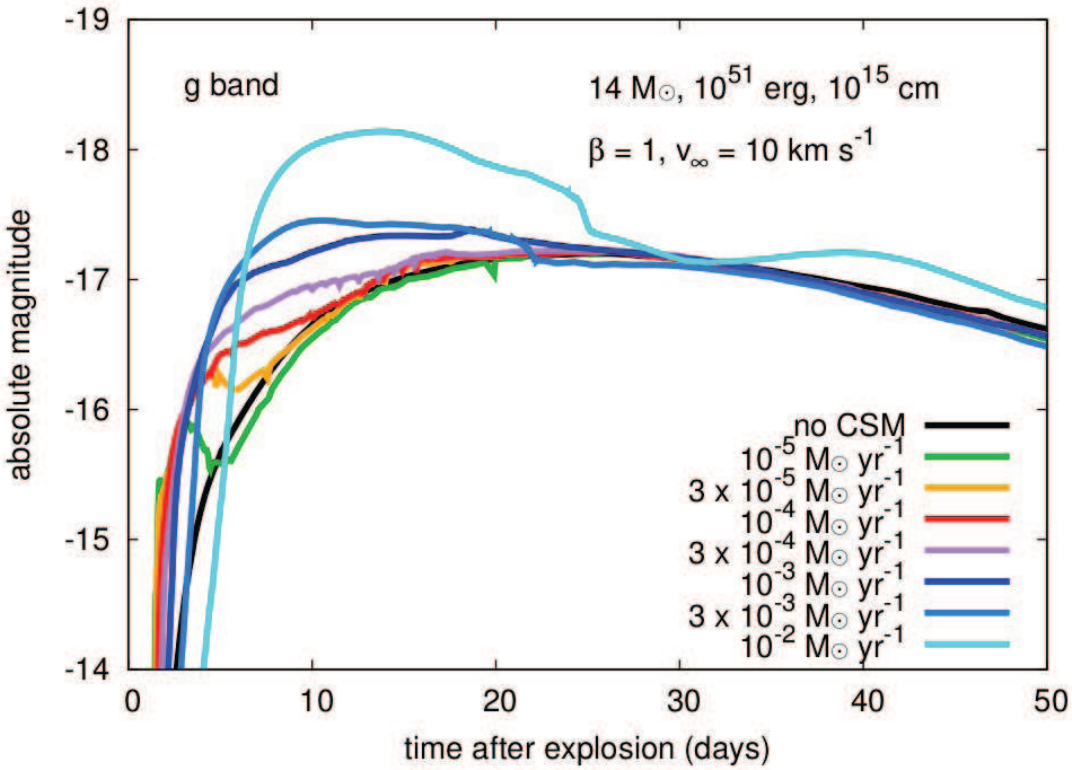


Moriya et al. 2017, 2018

RSG winds including acceleration



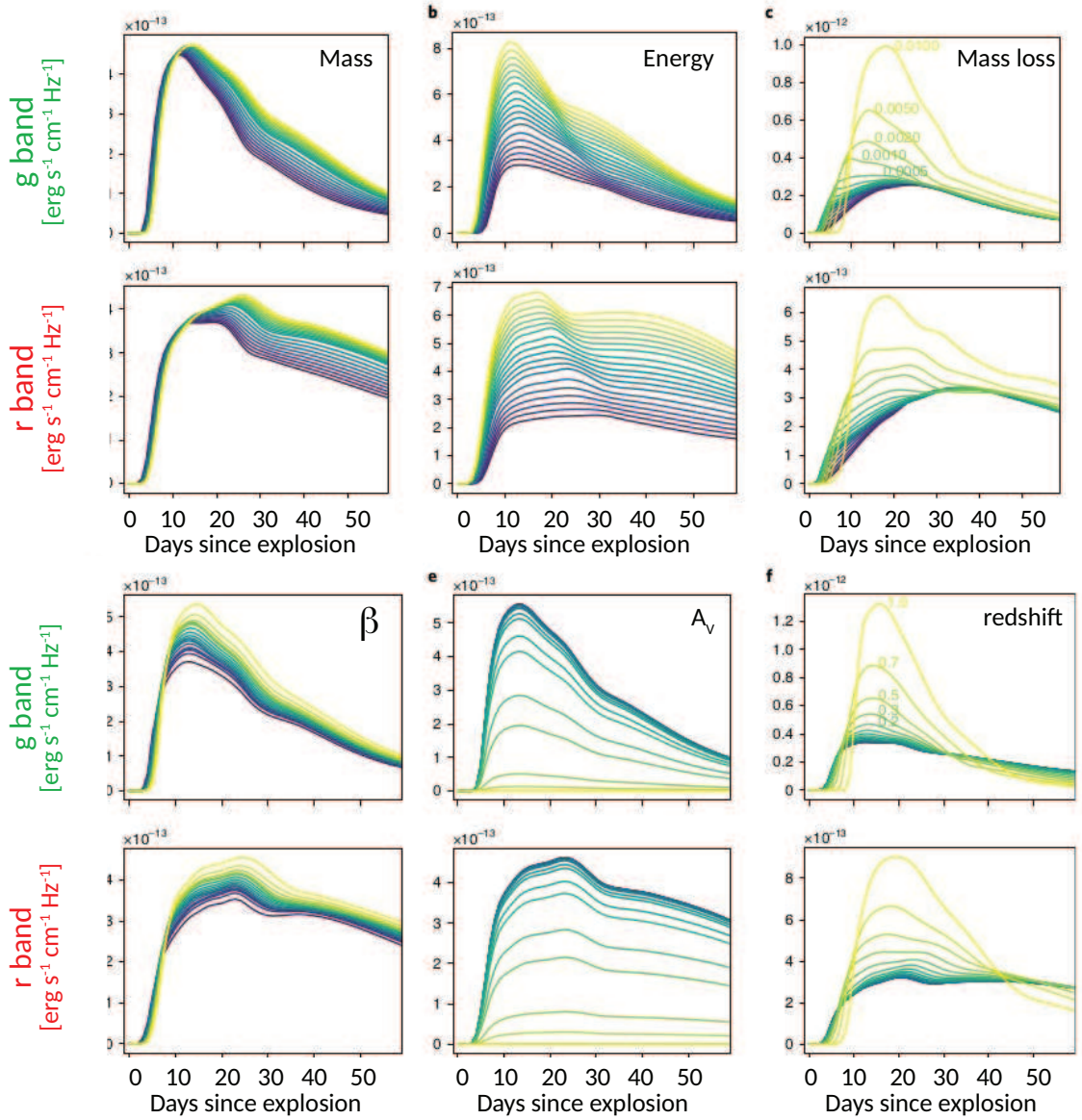


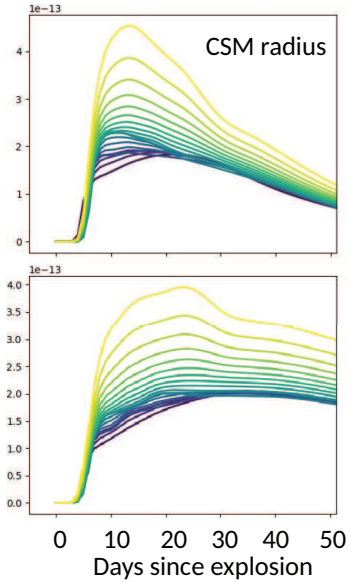


Moriya et al. 2017, 2018

Inferring physical parameters from SN II light curves

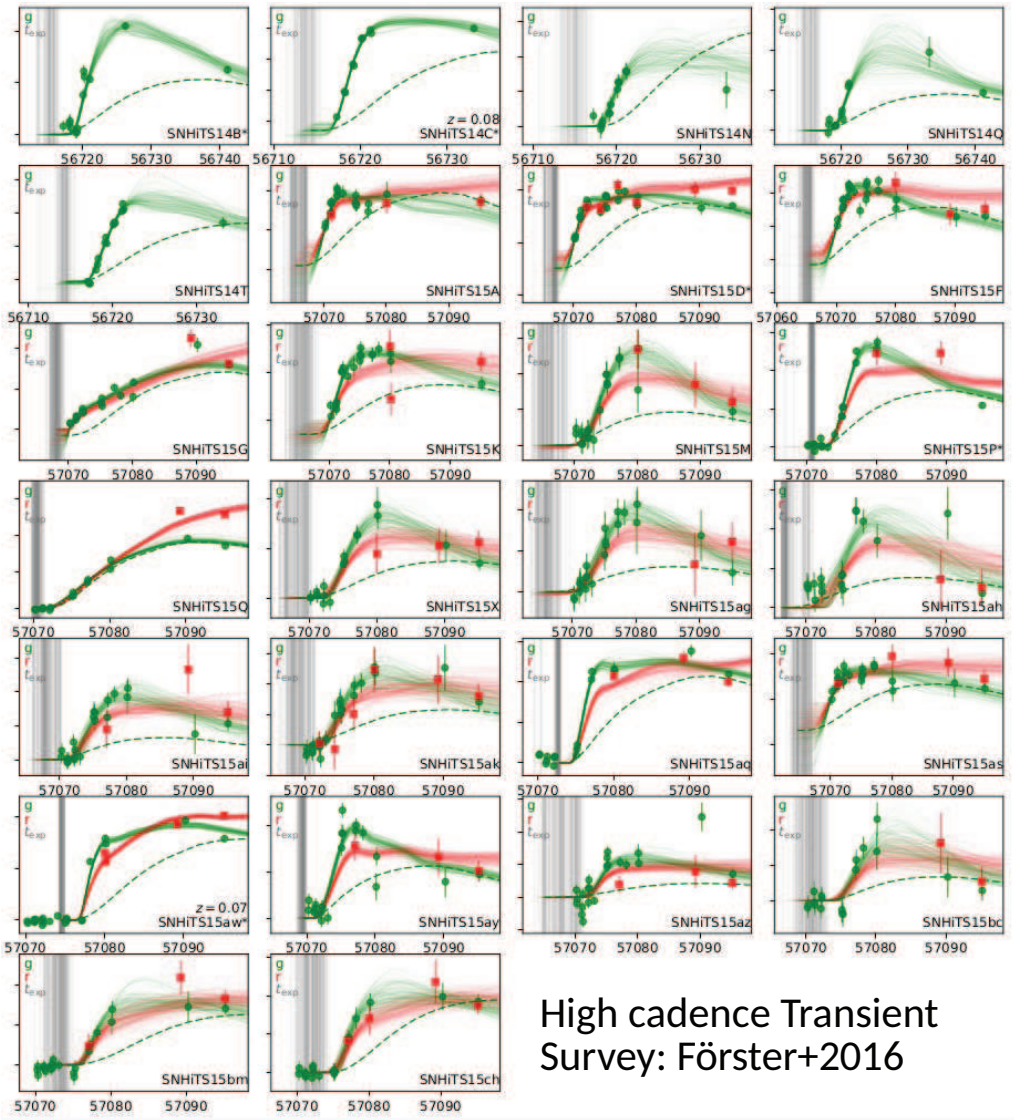
Time series of spectra SNe + CSM (Moriya+17,18) → LCs for progenitor, telescope, redshift, attenuation → Store light curves for fast evaluation → Fast physical parameter interpolation (emulation) → Fast evaluation of model likelihoods → Bayesian inference feasible (MCMC)



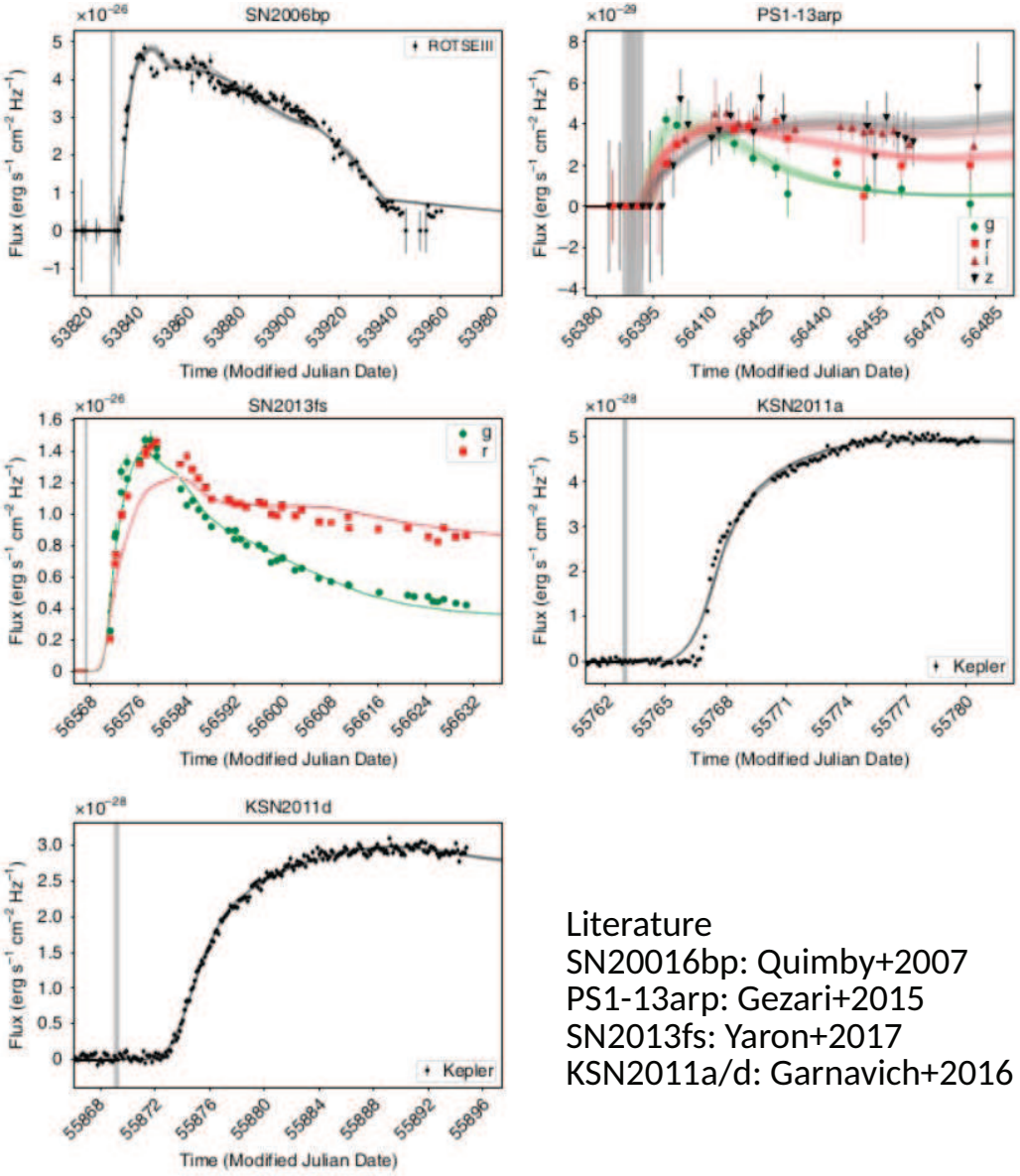


https://github.com/fforster/surveysim

RSG wind constraints from early SN light curves



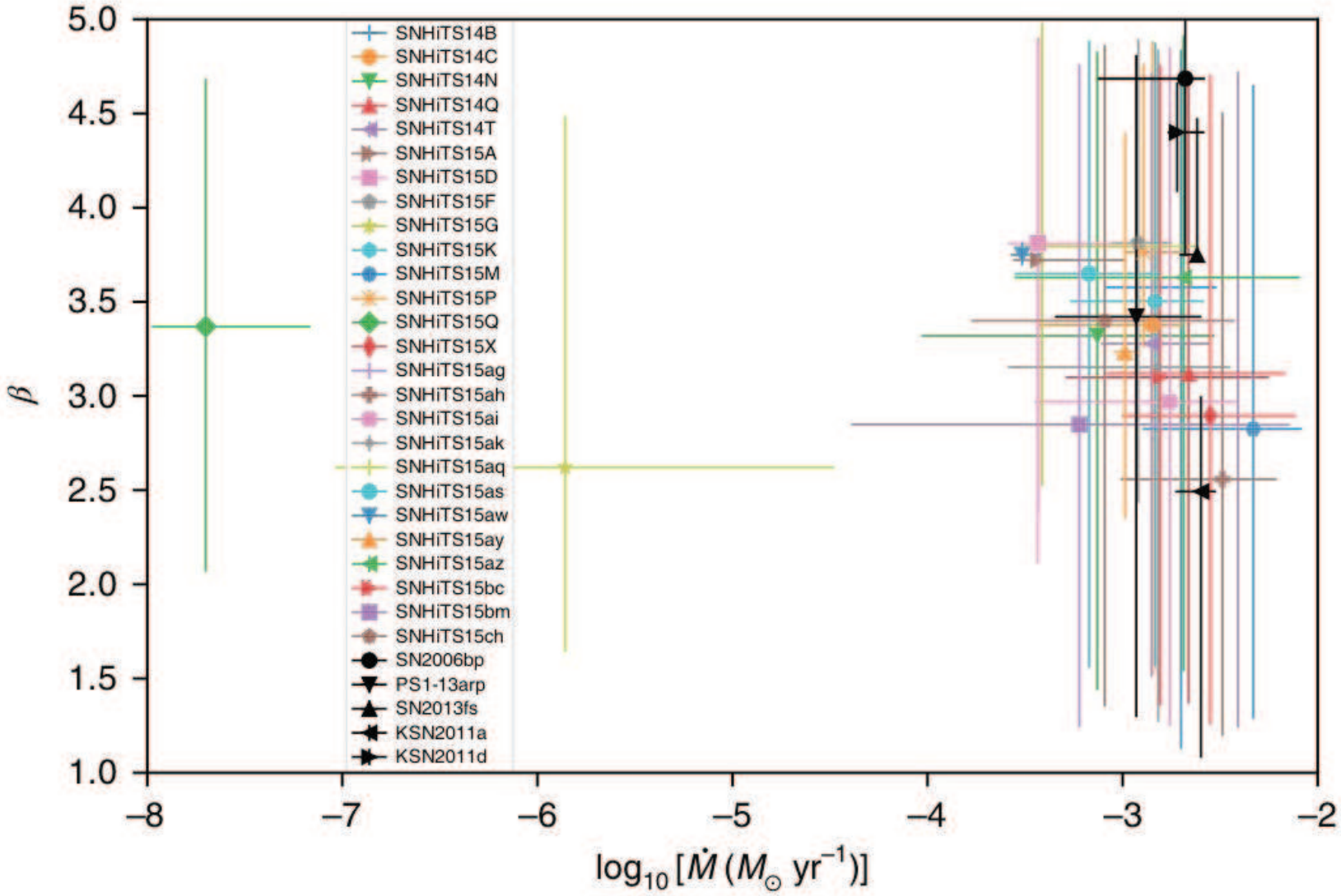
High cadence Transient Survey: Förster+2016



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

Summary

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

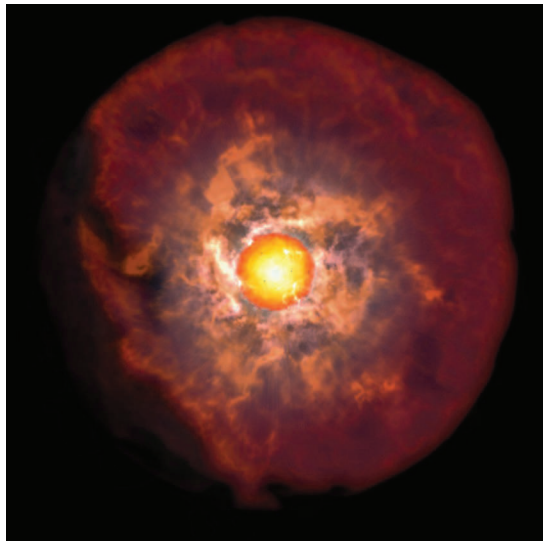
HiTS + wind acceleration models from Moriya+17/18 ⟶ **wind shock breakout signature in most SNe II candidates** (Förster+18)

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 (instead of ~10^{-1} Msun/yr). **Preliminary**: CSM outer radii larger than ~4×10^{14} cm in most SNe II candidates

Markov Chain Monte Carlo + emulation: powerful technique for deriving physical parameters of transients. Use of prior information possible + fast model evaluation (see https://github.com/fforster/surveysim)

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, MNRAS)? What mechanisms could trigger RSG pre SN wind/outburst (see Fuller+2018, MNRAS)?



ALeRCE
Automatic Learning for the Rapid Classification of Events