Stripped-Envelope SN Progenitors

Massive Stars and Supernovae

Bariloche – November 6th 2018

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Massive stars and mass loss

What is the origin of H-poor/free SNe (Types IIb, Ib, Ic)?

How do massive stars lose their envelopes?

Can we map SN Types back onto their progenitors' properties?

What is the role of binarity?

Progenitor characterization

Direct detections

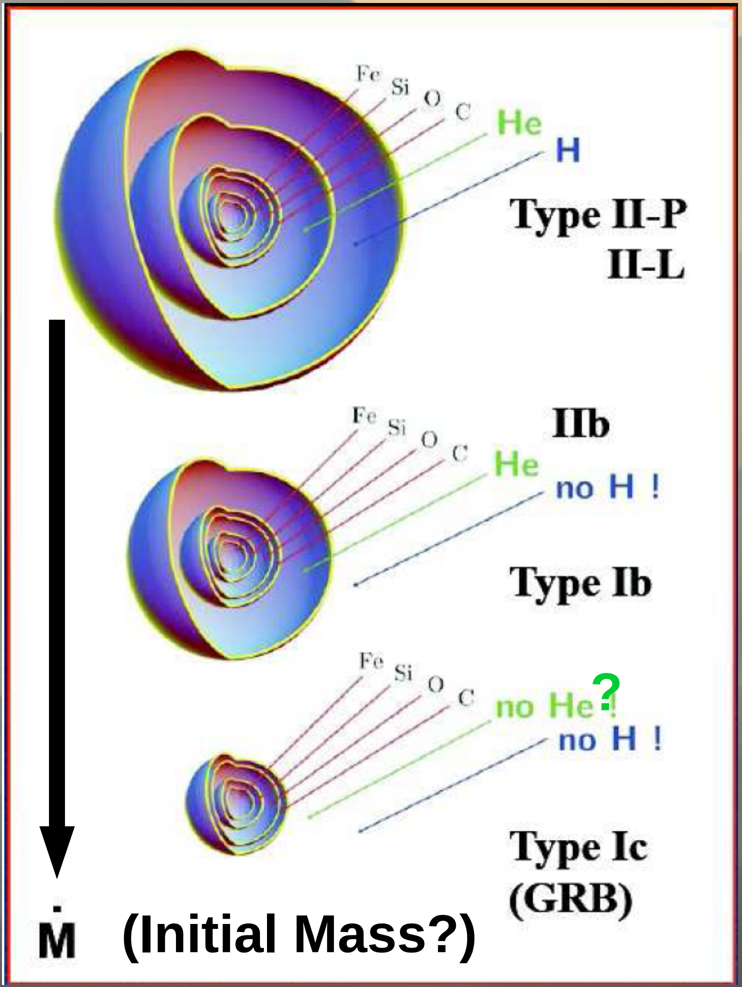
Fractions and rates of each SN Type

Associated stellar populations

Hydrodynamical light-curve modeling

Spectral modeling

Very early observations



Schematic stellar structures (M. Modjaz)

Direct identifications

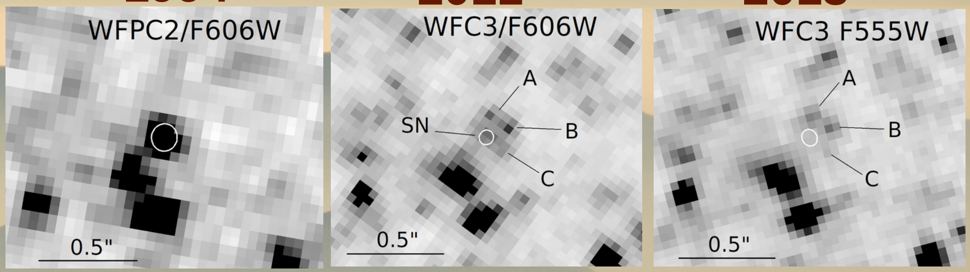
High-resolution, deep imaging (HST)

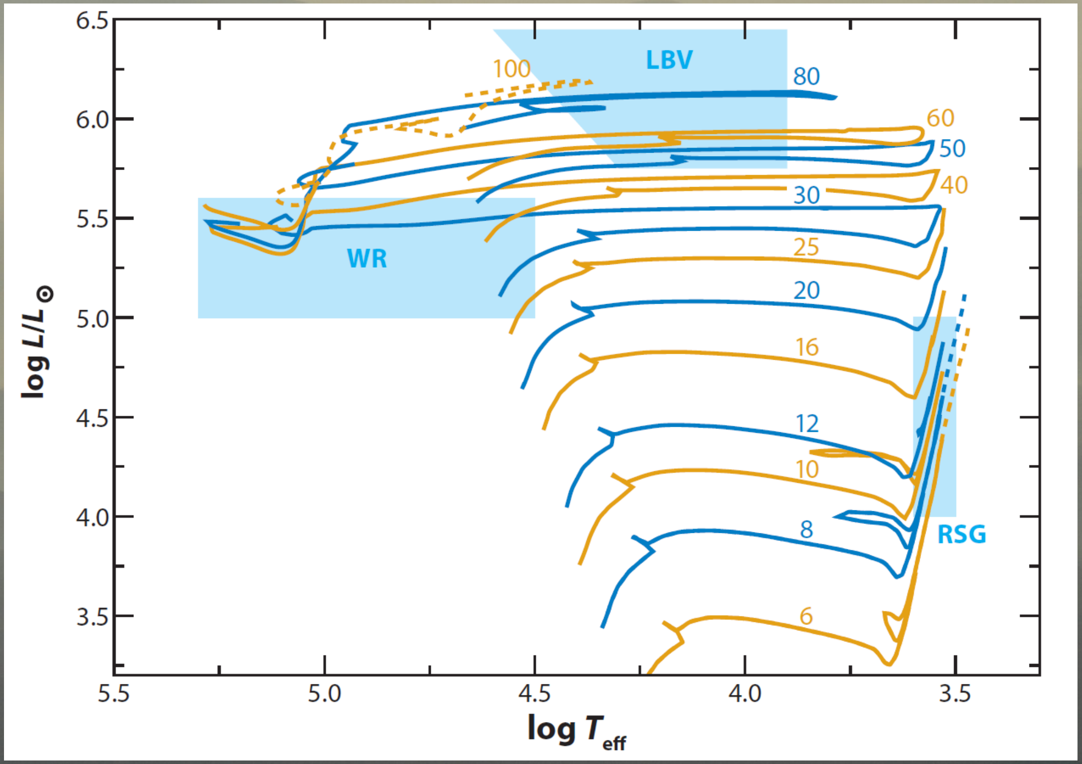
Combined with evolutionary tracks

Feasible out to d ~ 30 Mpc

Type IIb SN 2008ax (Crockett+08, GF+15)

1994 **2011** **2013**





Single-star evolutionary model predictions – Smartt'09

Direct identifications

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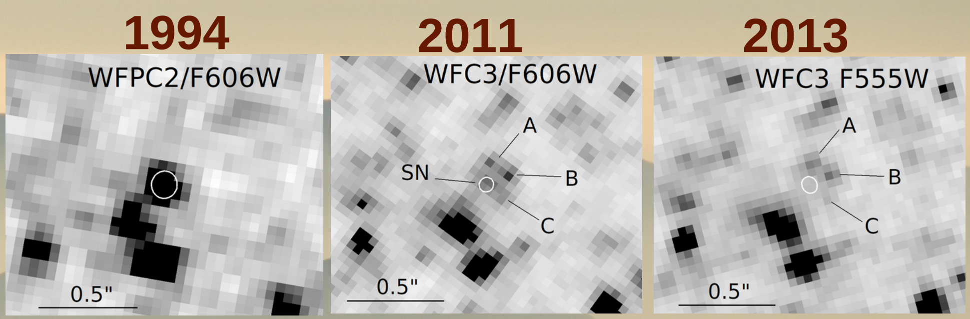
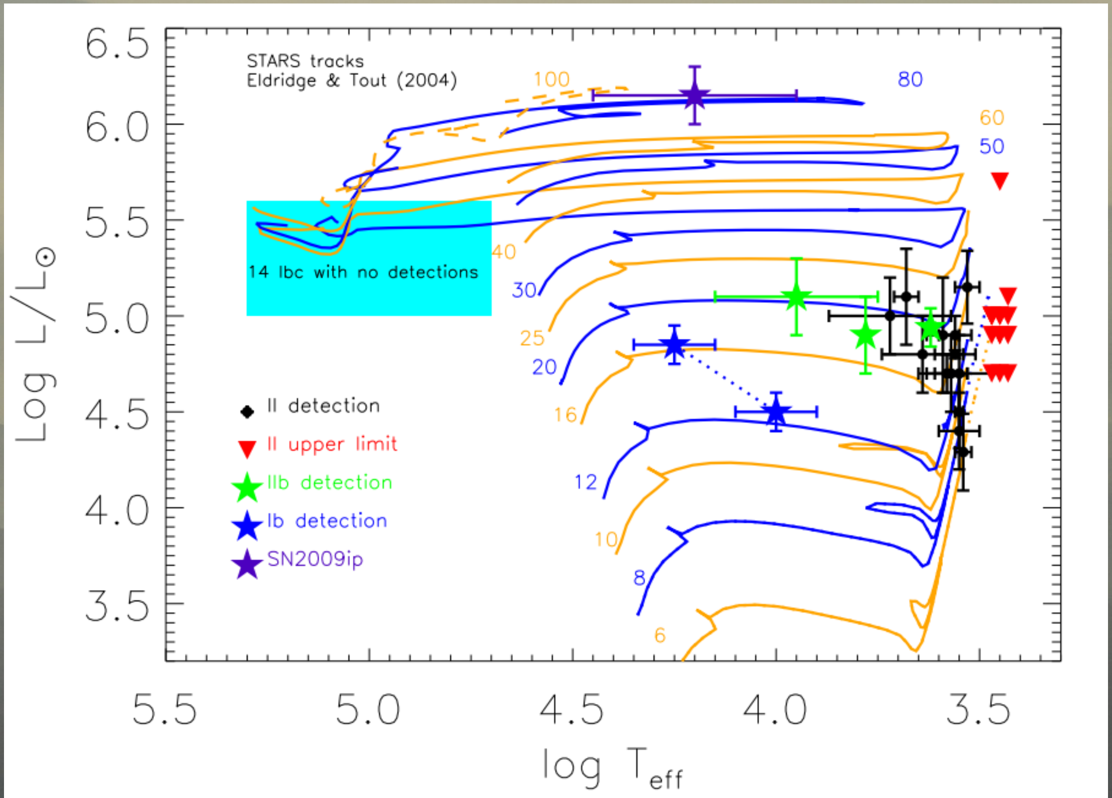


Over a dozen SN II progenitor detections (S. Van Dyk's talk)

SNe Ib: only iPTF13bvn (confirmed) Blue progenitor likely in a binary system

SNe Ic: SN2017ein (to be confirmed) Compatible with very massive star

SNe IIb: four confirmed Luminous YSG progenitors Three possible companion detections



Progenitor detections – Smartt+15

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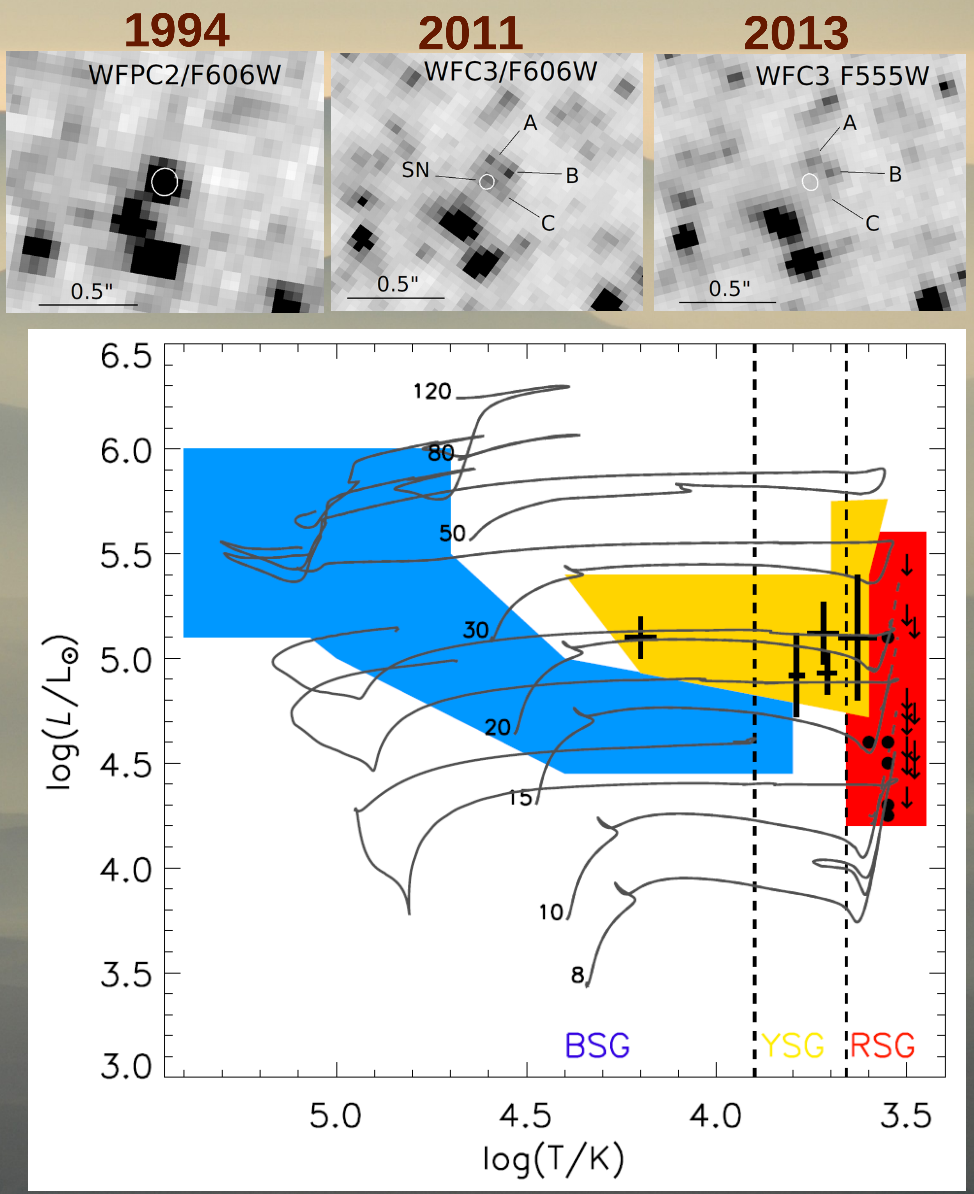


Binary progenitor models – Eldridge+13

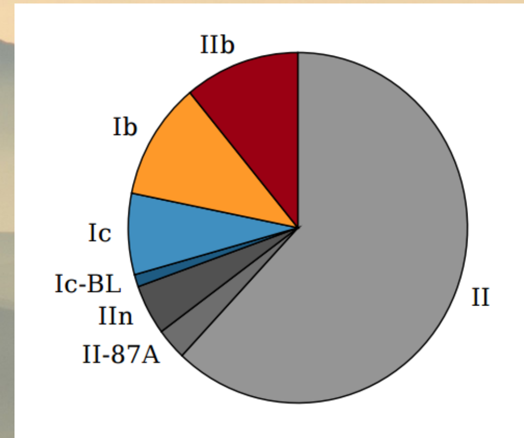
SN Type fractions

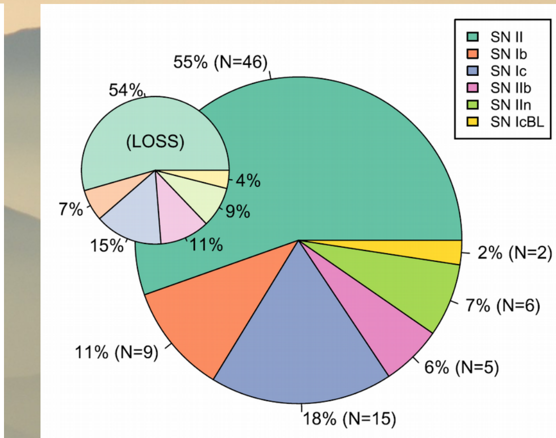
Relative number of core-collpase SNe

Compared with predictions from evolutionary models and IMF

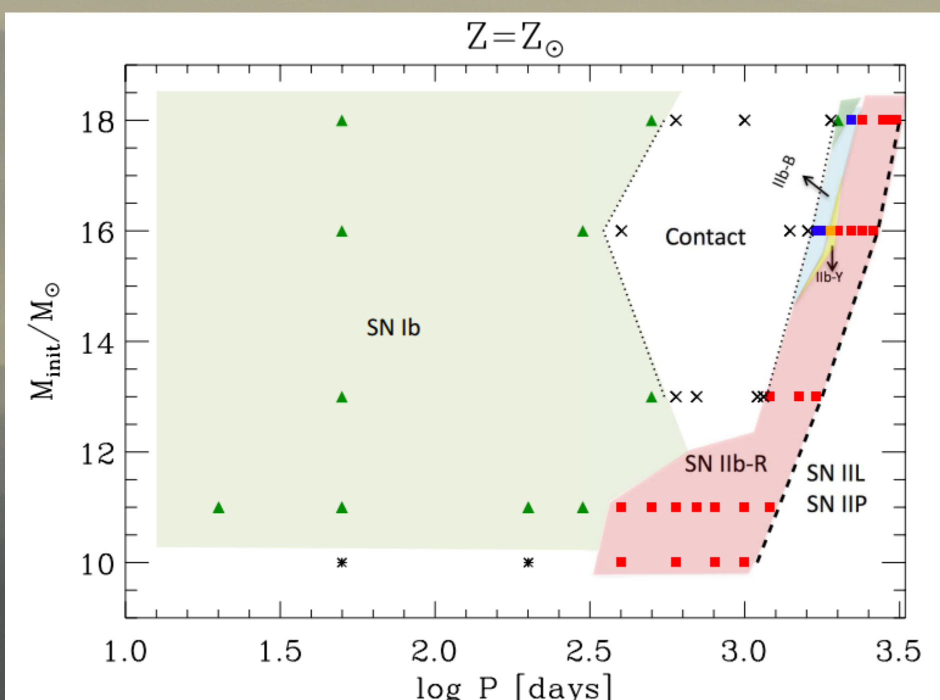
Requires a definition of SN Types for the evolutionary models

Observations (Shivvers+17,Kuncarayakti+18)

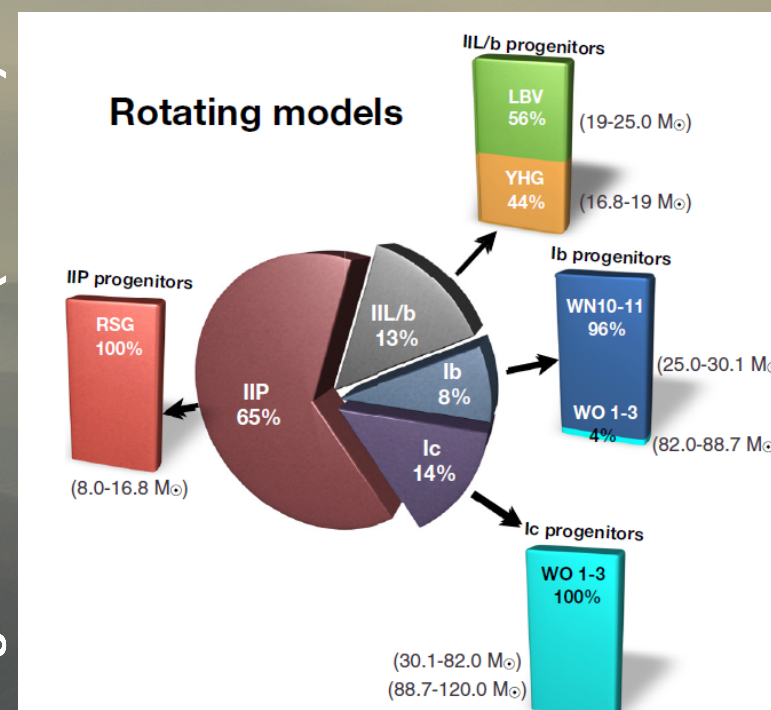




Binary models (Yoon+17)



Single-star models (Groh+13)

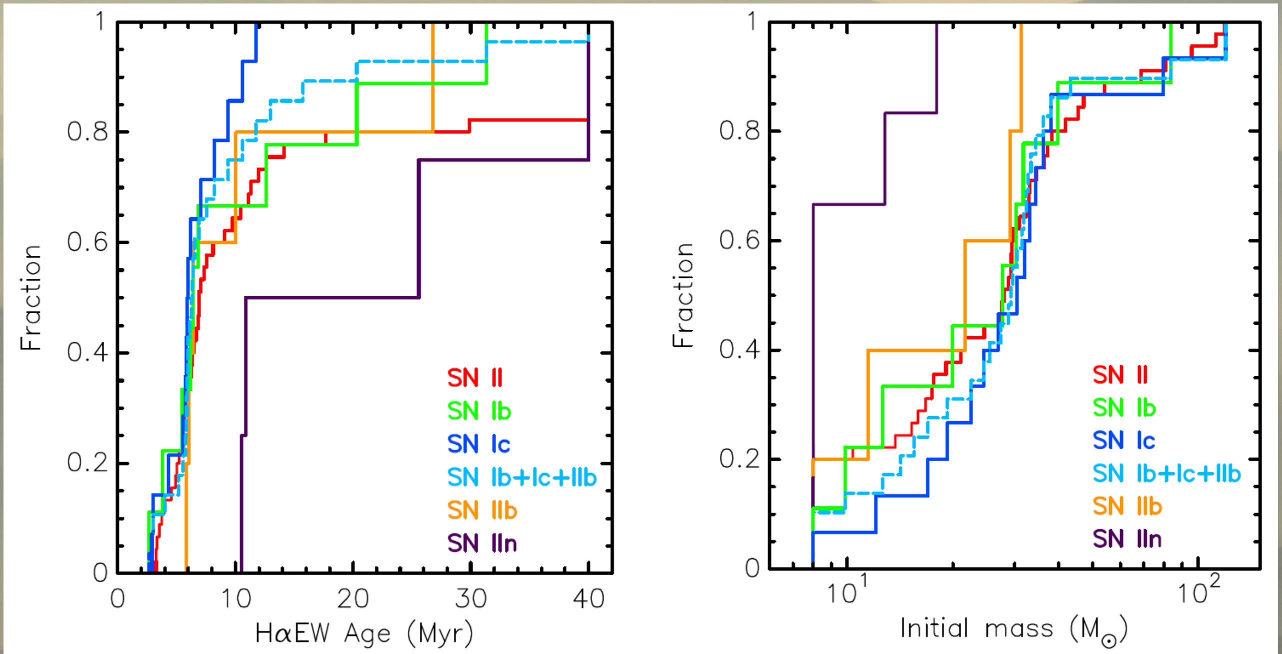


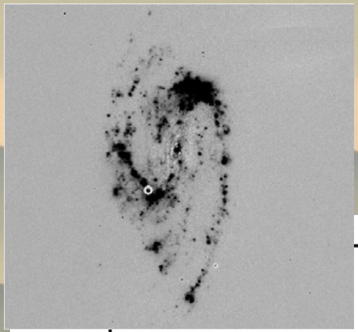
Environments

Associated stellar populations

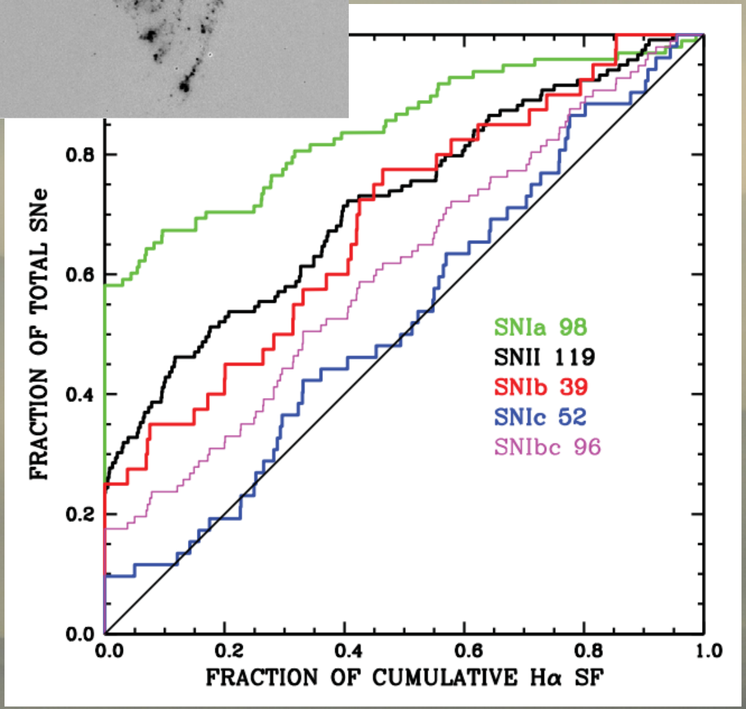
Star-formation history – metallicities

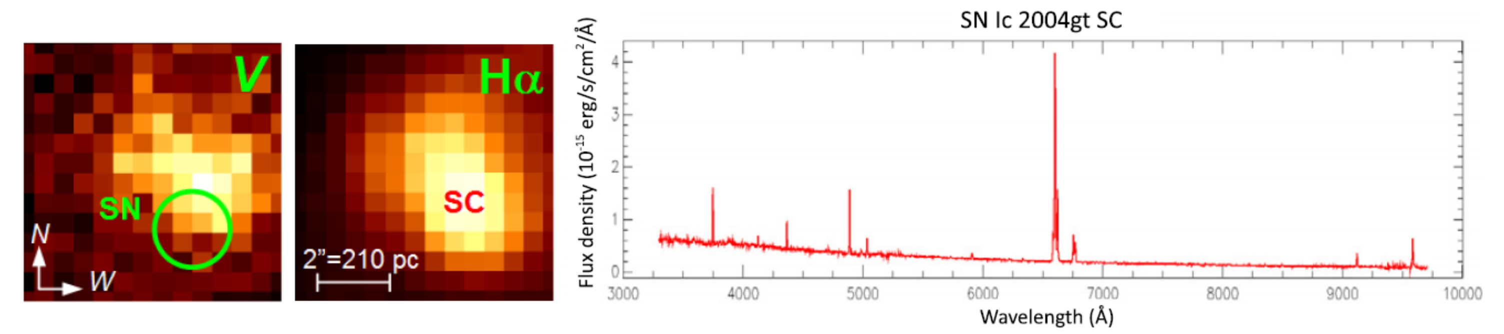
Inferred progenitor masses from models





Hα association
Anderson+'12,'15





IFU spectra of underlying emission Kuncarayakti+13ab,18

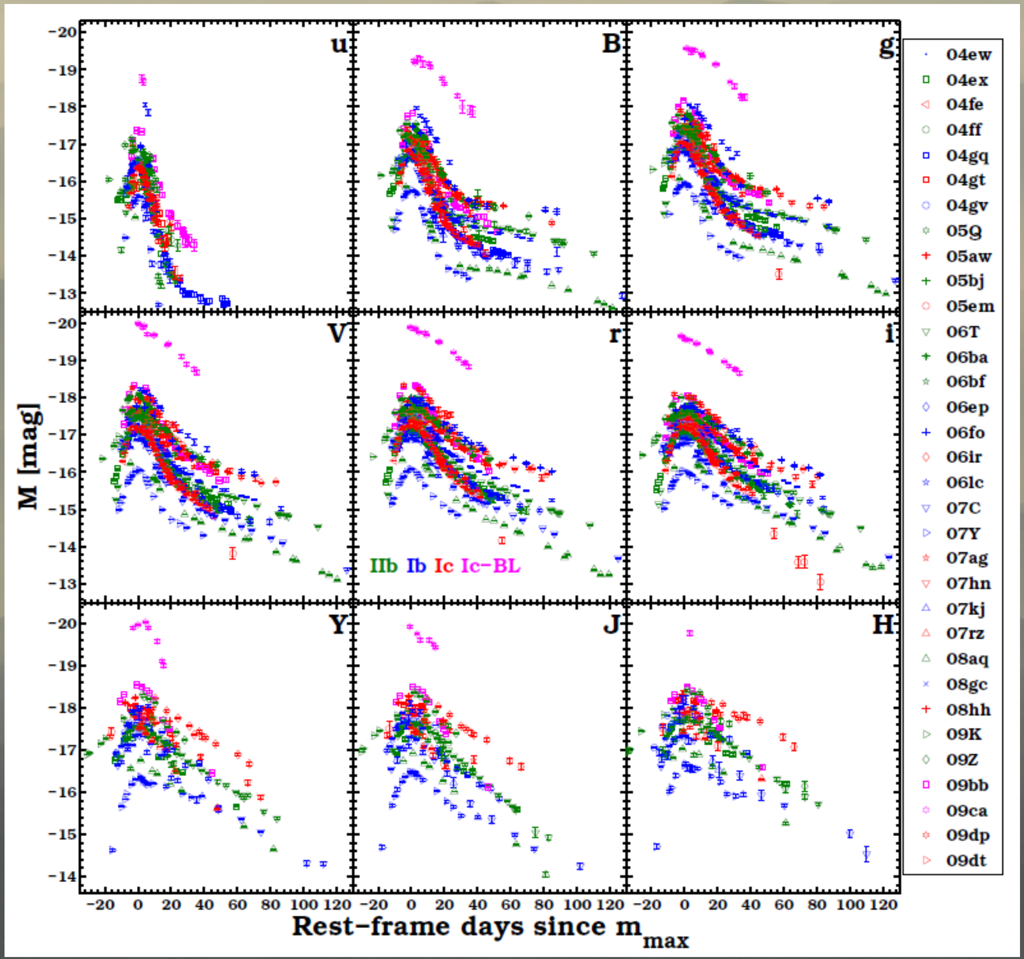
Light-curve shapes

Multi-band photometry – extinction – bolometric flux

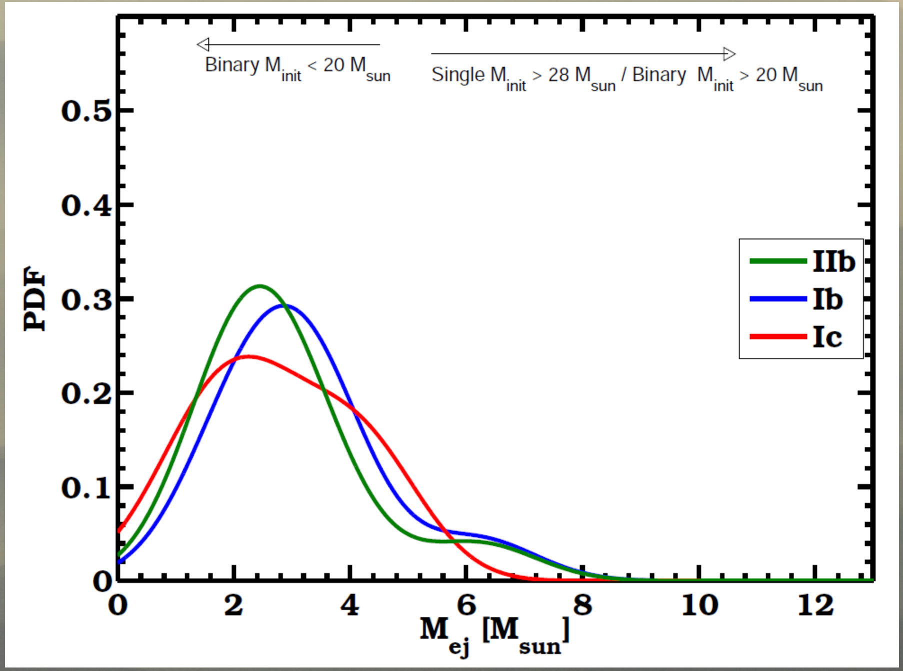
Inferred ejecta masses

Binary vs. single star progenitors

Talk by Priscila Pessi on Thursday



Inferred ejecta mass distributions (also Drout+11, Cano+13, Lyman+16)



Absolute optical + NIR light curves
CSP SE SNe sample
Taddia+18

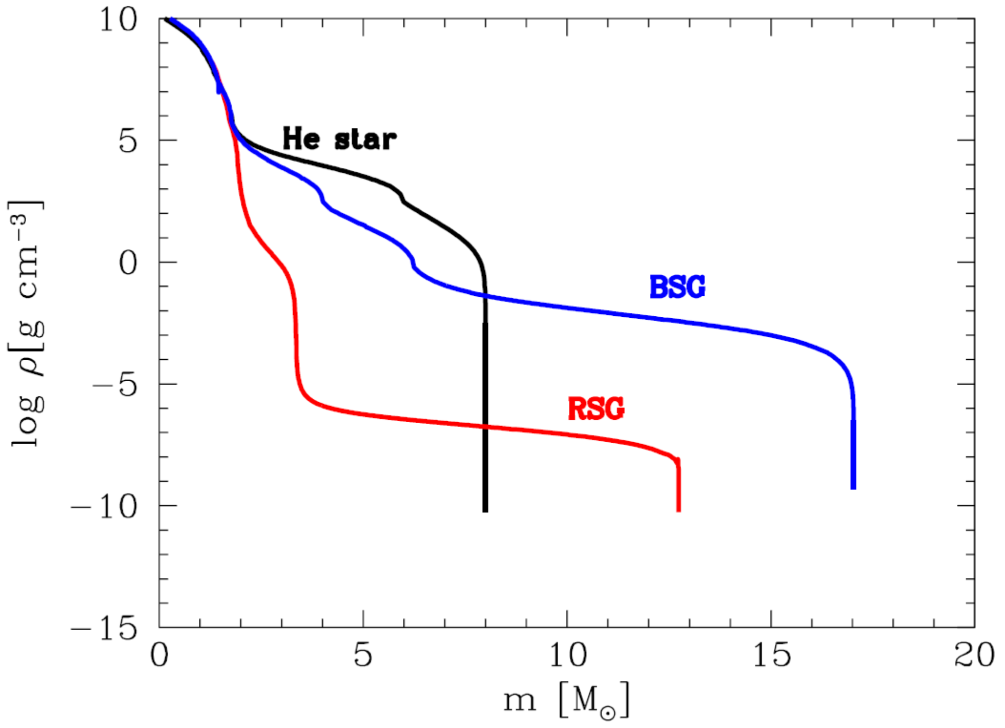
Hydrodynamical models

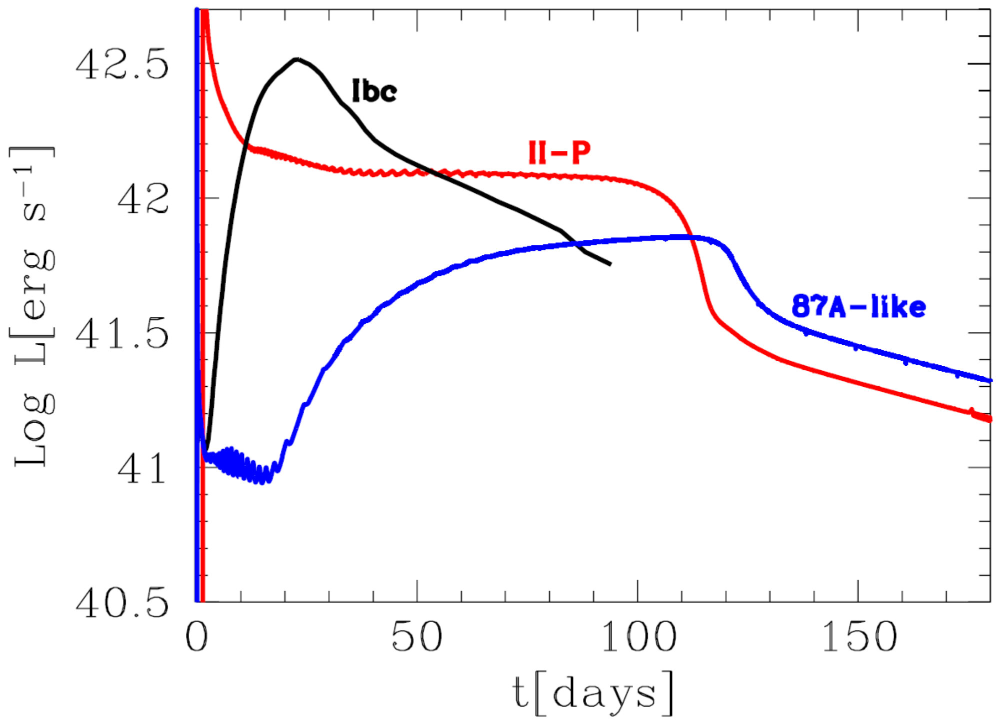
LC and expansion velocities modeled to infer progenitor and explosion properties

Very early observations provide unique information of stellar structure

Talk by Laureano Martínez

Progenitor structures and light curves – M. Bersten





Hydrodynamical models

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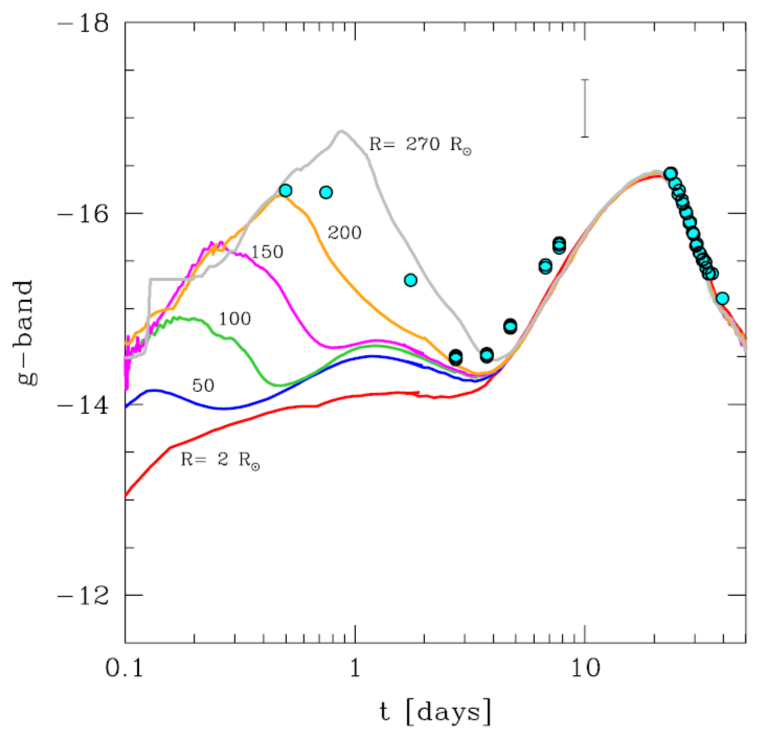
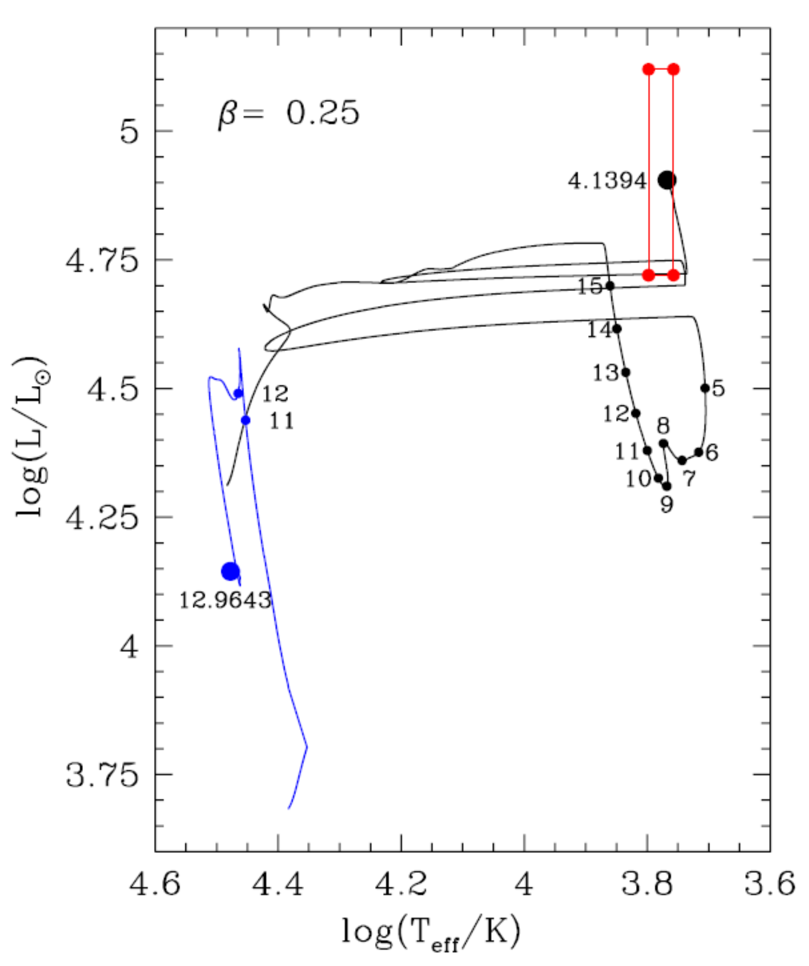
Type IIb SN 2011dh:
Radius from early-time light-curve model
Plus interacting binary progenitor model



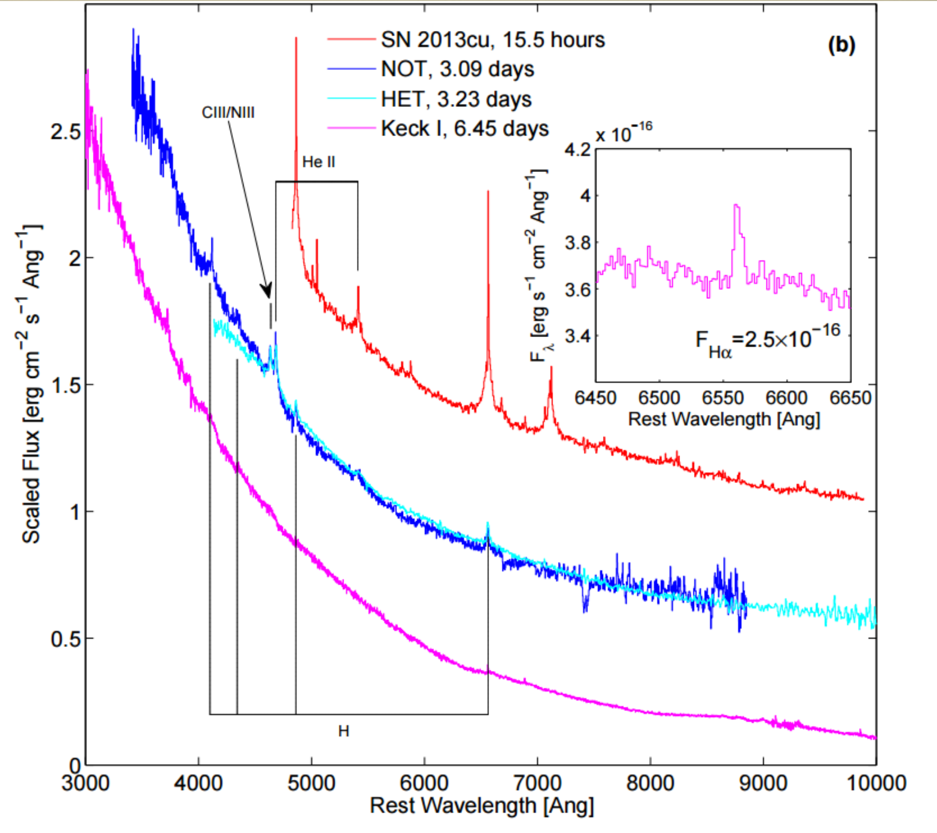


Bersten+12, Benvenuto+13

Very early/late spectra

Highly-ionized emissions seen hours after the explosion

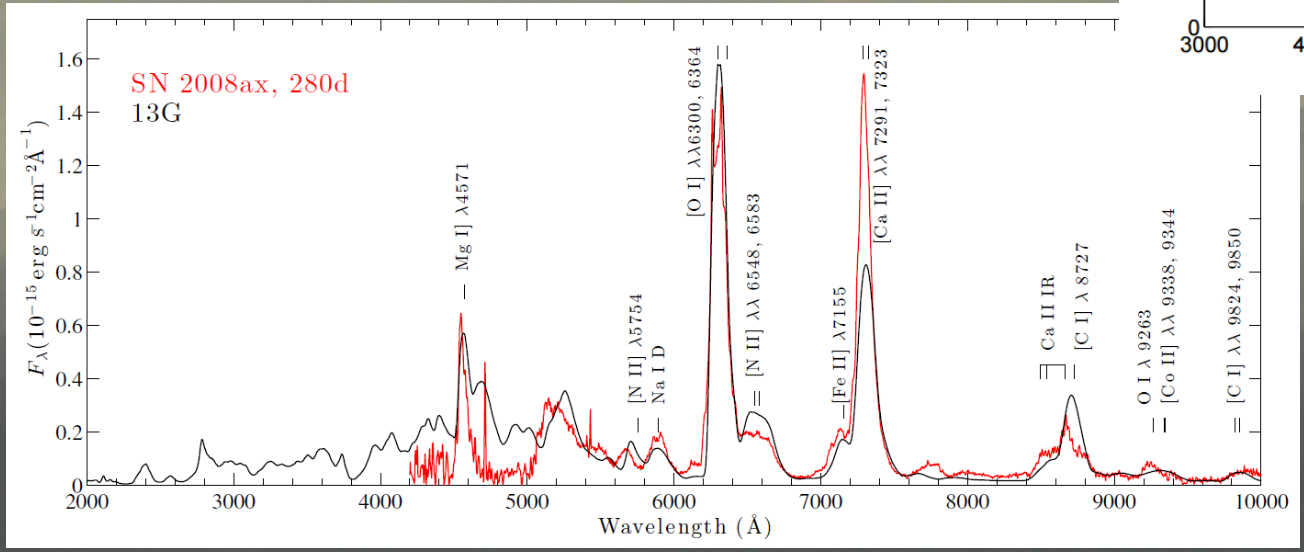
Probes outer progenitor structure



Year-old spectra show emission from core

Progenitor core masses inferred

Nebular spectrum model of Type IIb SN 2008ax Jerkstrand+15



"Flash spectroscopy" of Type IIb SN 2013cu Gal-Yam+14

First electromagnetic signal

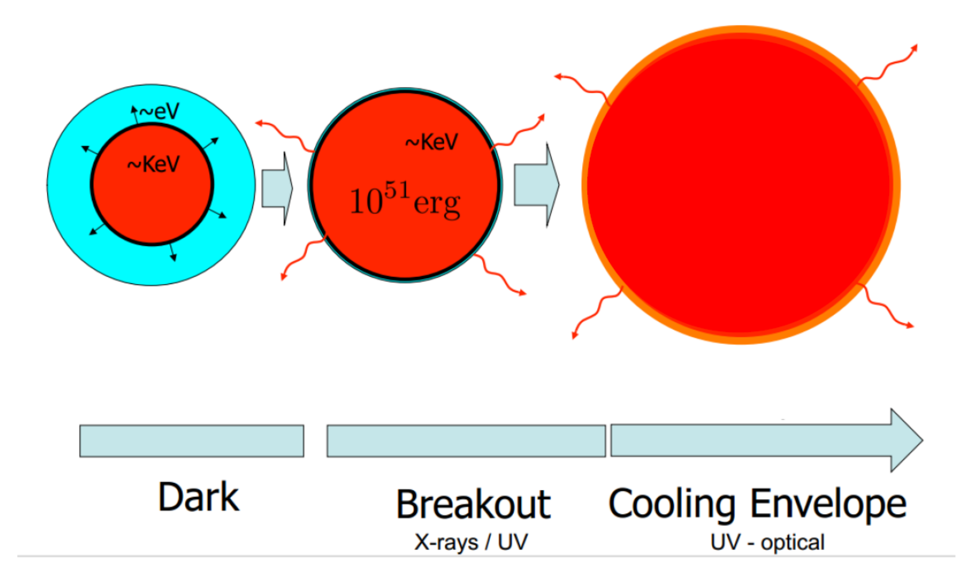
Shock breakout (SBO) emission:

A luminous burst of UV / X-ray radiation occurs when $\tau < v_{shock} / c$

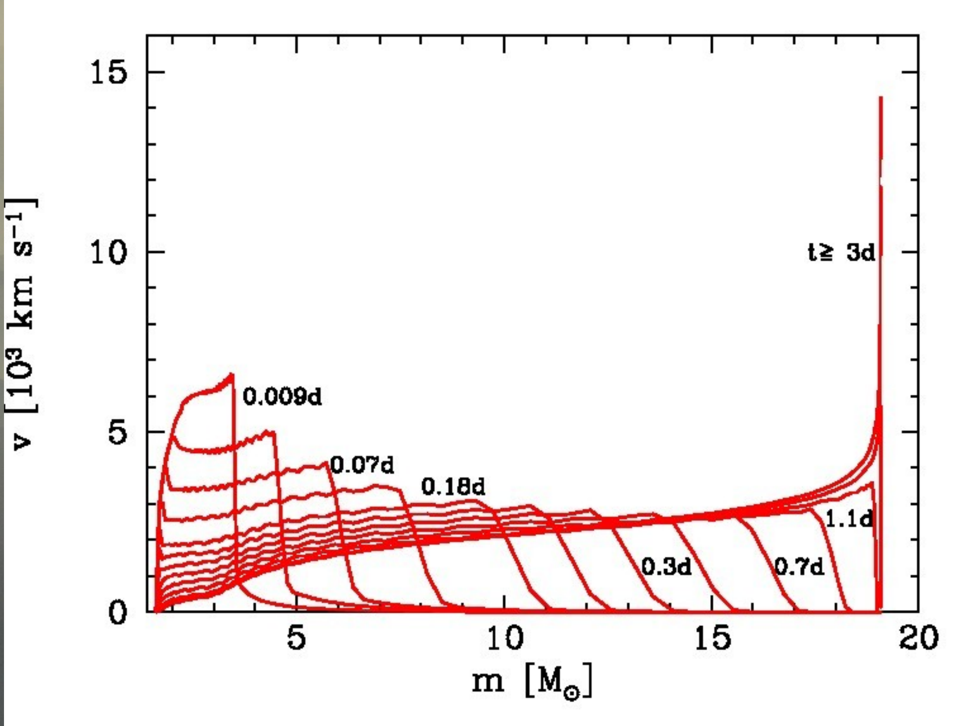
Produces an emission peak in the optical – long predicted by models

Provides information about the external structure of the star

Shock breakout – B. Katz



Shock propagation – Bersten+11



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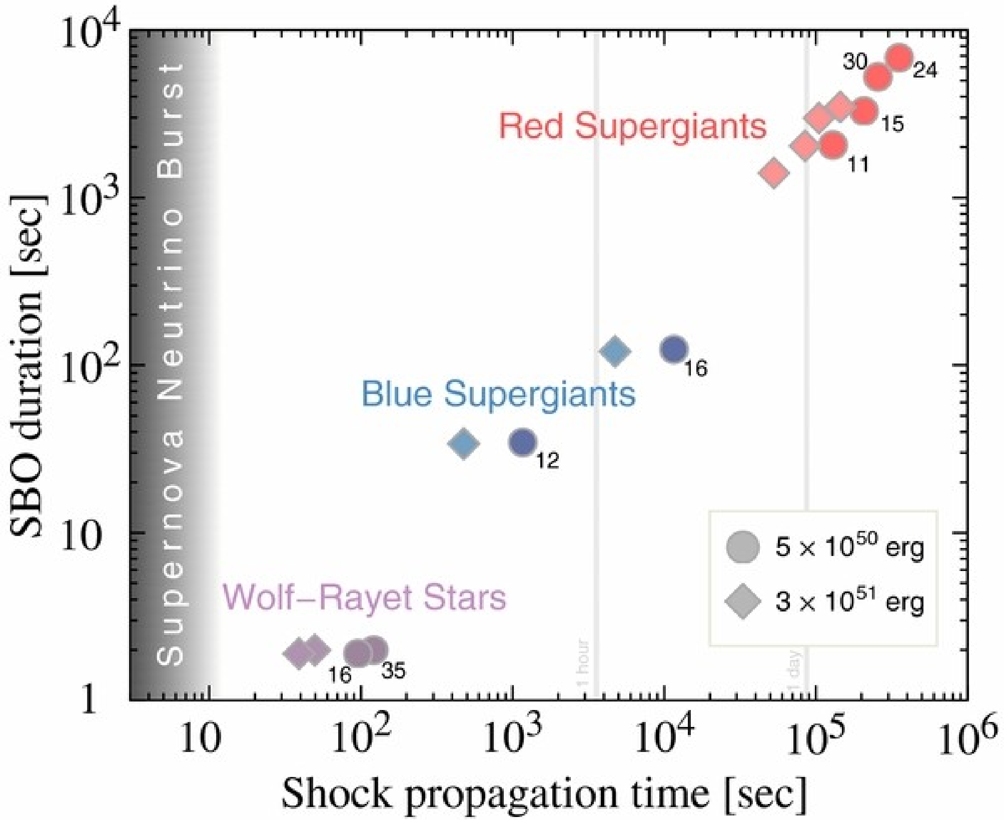
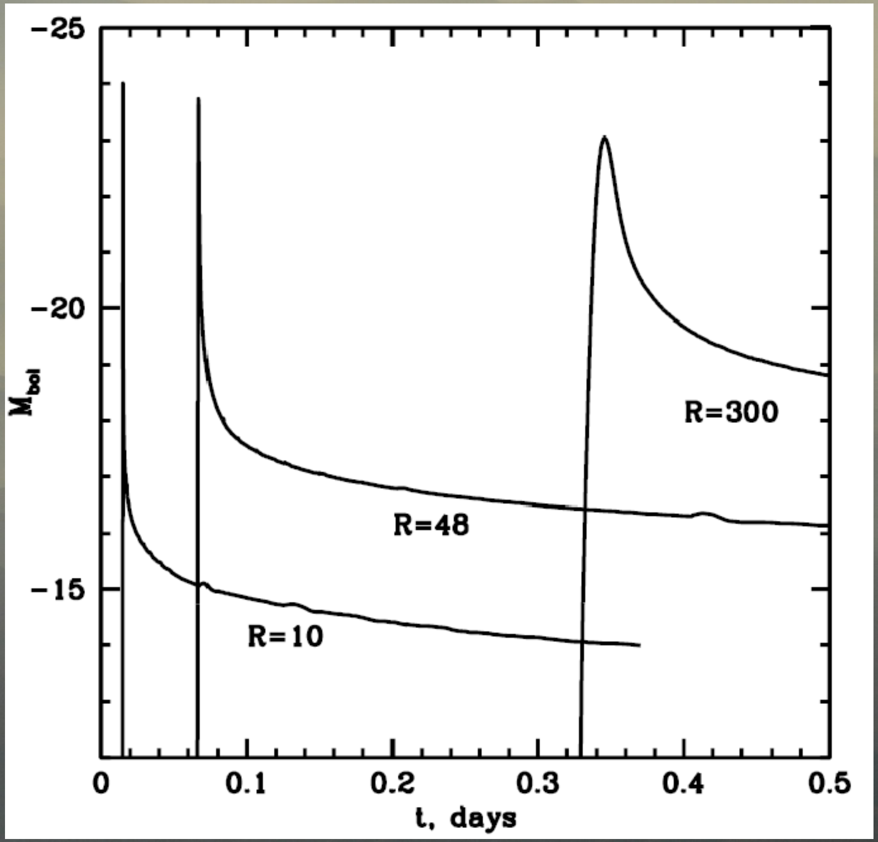


Kistler+14

SBO emission – S. Blinnikov



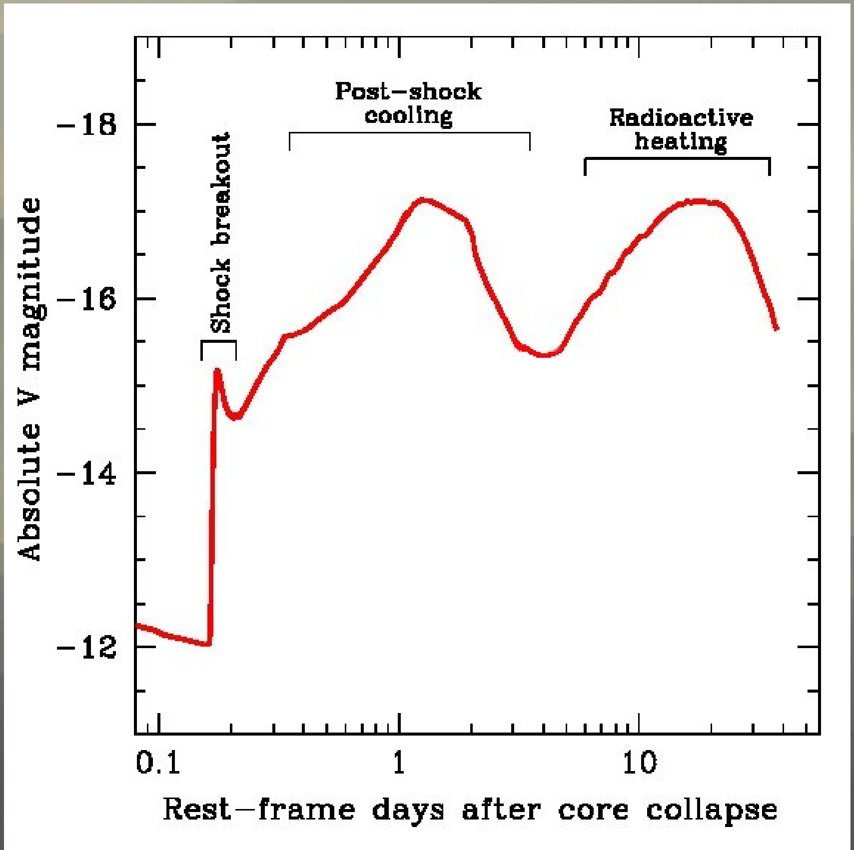
First signal in optical

Characteristic SBO emission in optical bands

Weak, short-duration peak – hours for stripped progenitors

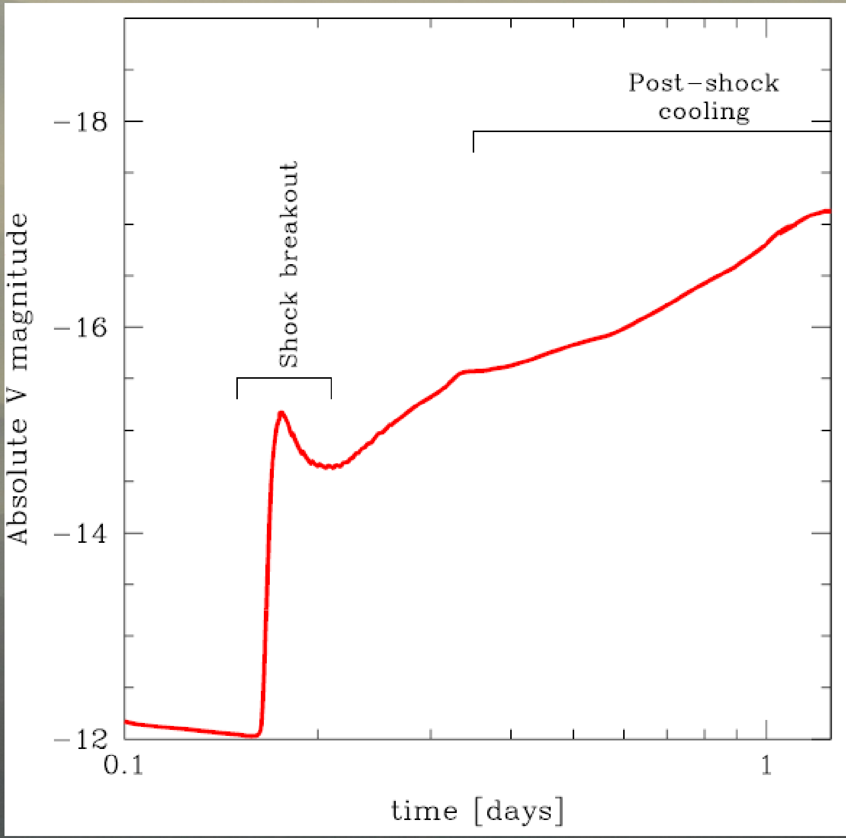
Different physical process to those that regulate the rest of the evolution

Intensively sought for – with no success

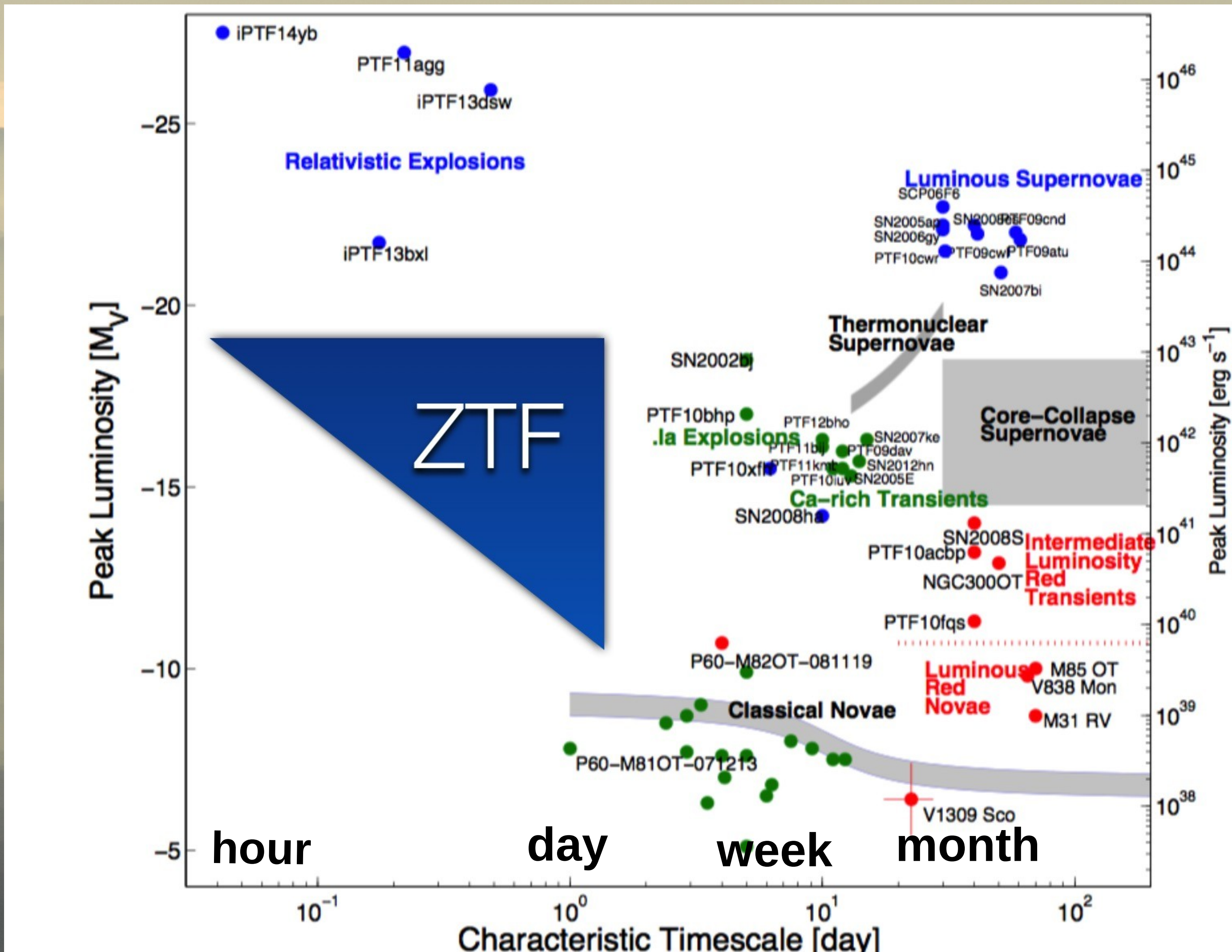


Stripped-envelope SN hydro LC model

SBO optical emission – M. Bersten



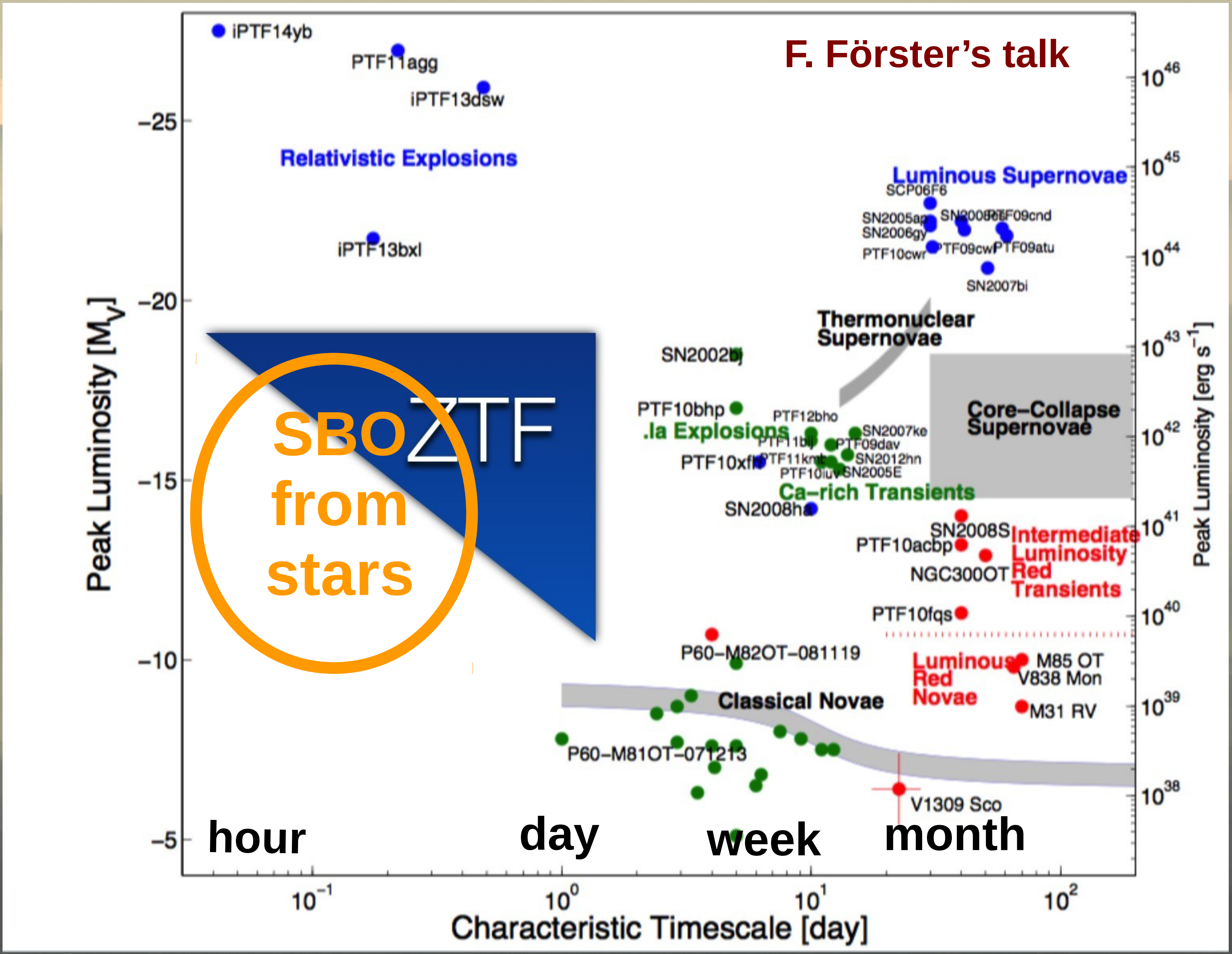
Early discovery



M. Kasliwal / ZTF

Projects: iPTF, KISS, HiTS, HSC-SHOOT, ZTF, LSST, ULTRASAT

Early discovery



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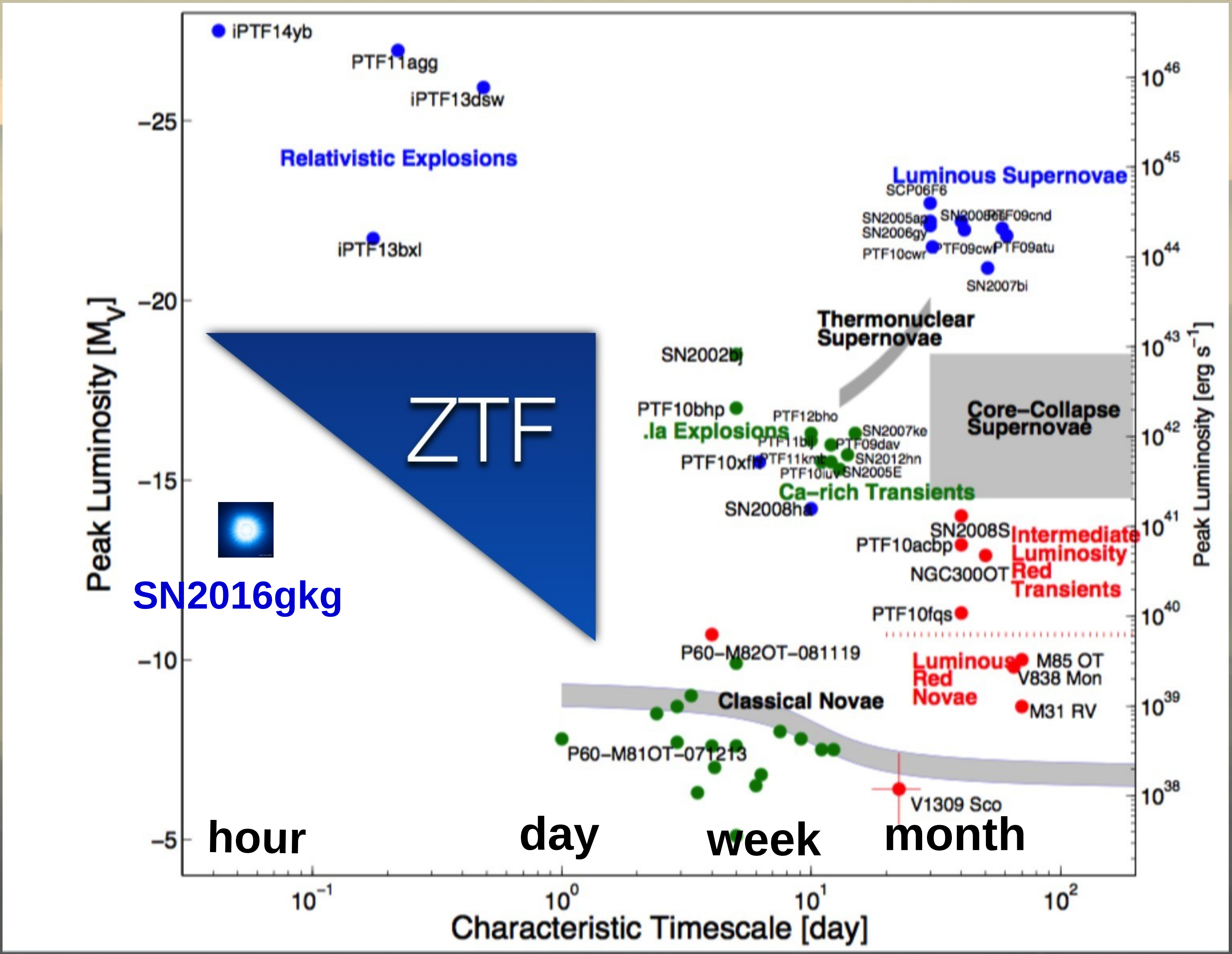

M. Kasliwal / ZTF

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Supernova 2016gkg

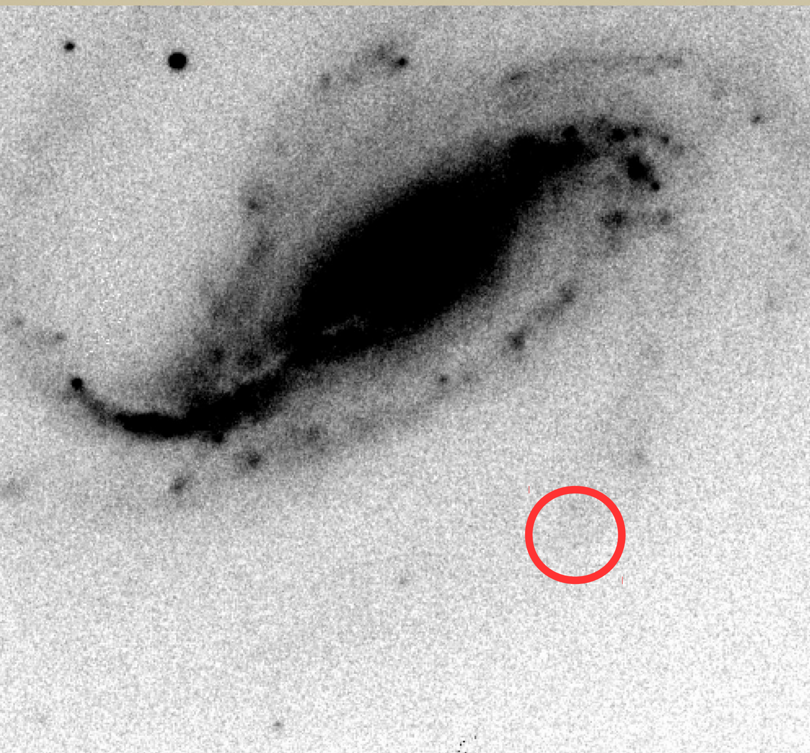
Discovered by Víctor Buso on Sept. 20th 2016

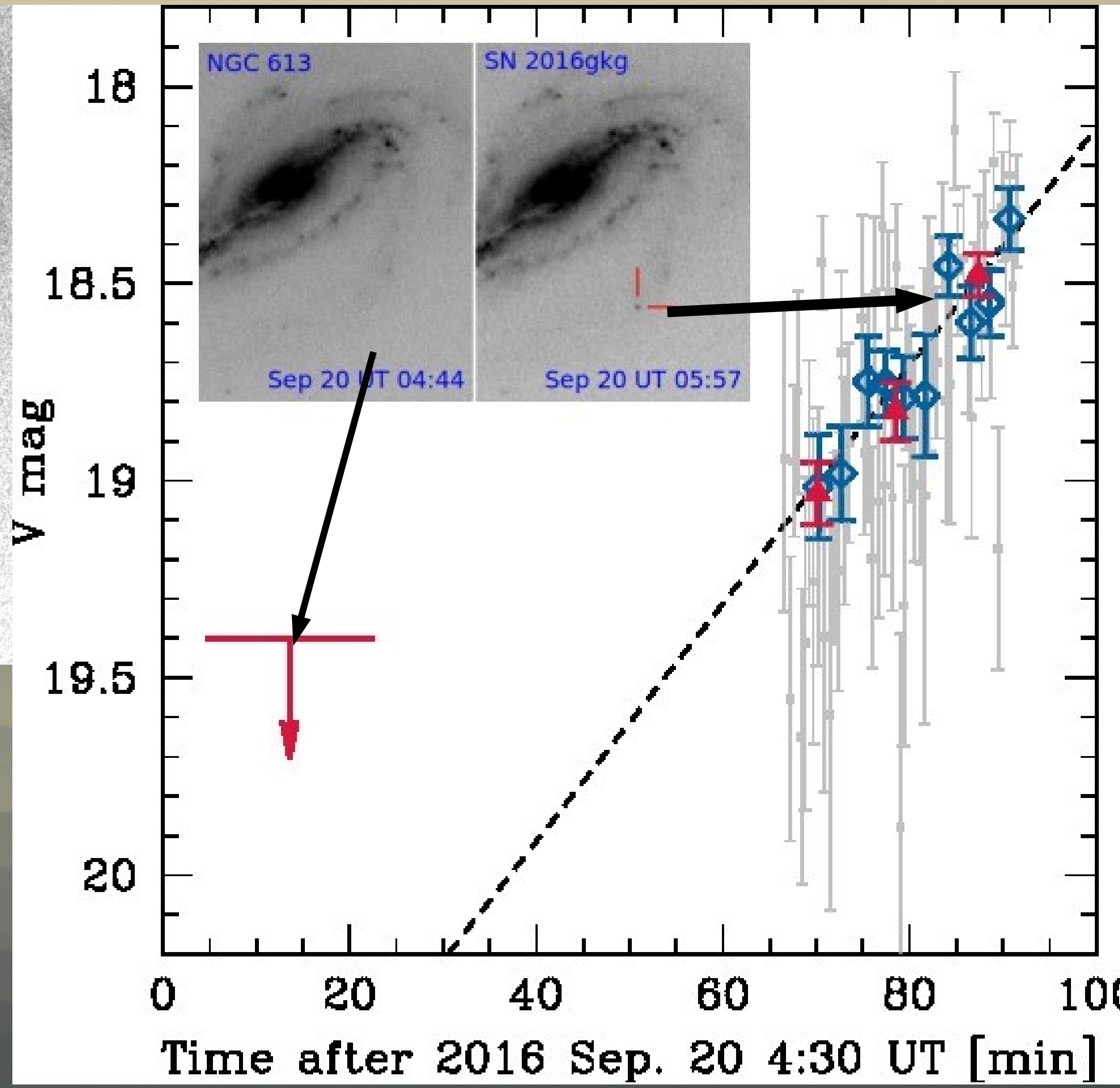
The SN appeared *during* Víctor's observations

The "Observatorio Busoniano" in Rosario

Víctor with his 40 cm Newtonian

A unique observation





1.5 hs imaging NGC 613

Flux doubles in 25 minutes (43 mag/day)

¿Was it the SBO?

Bersten,GF+18

Hydrodynamical model

Stripped SN light curve

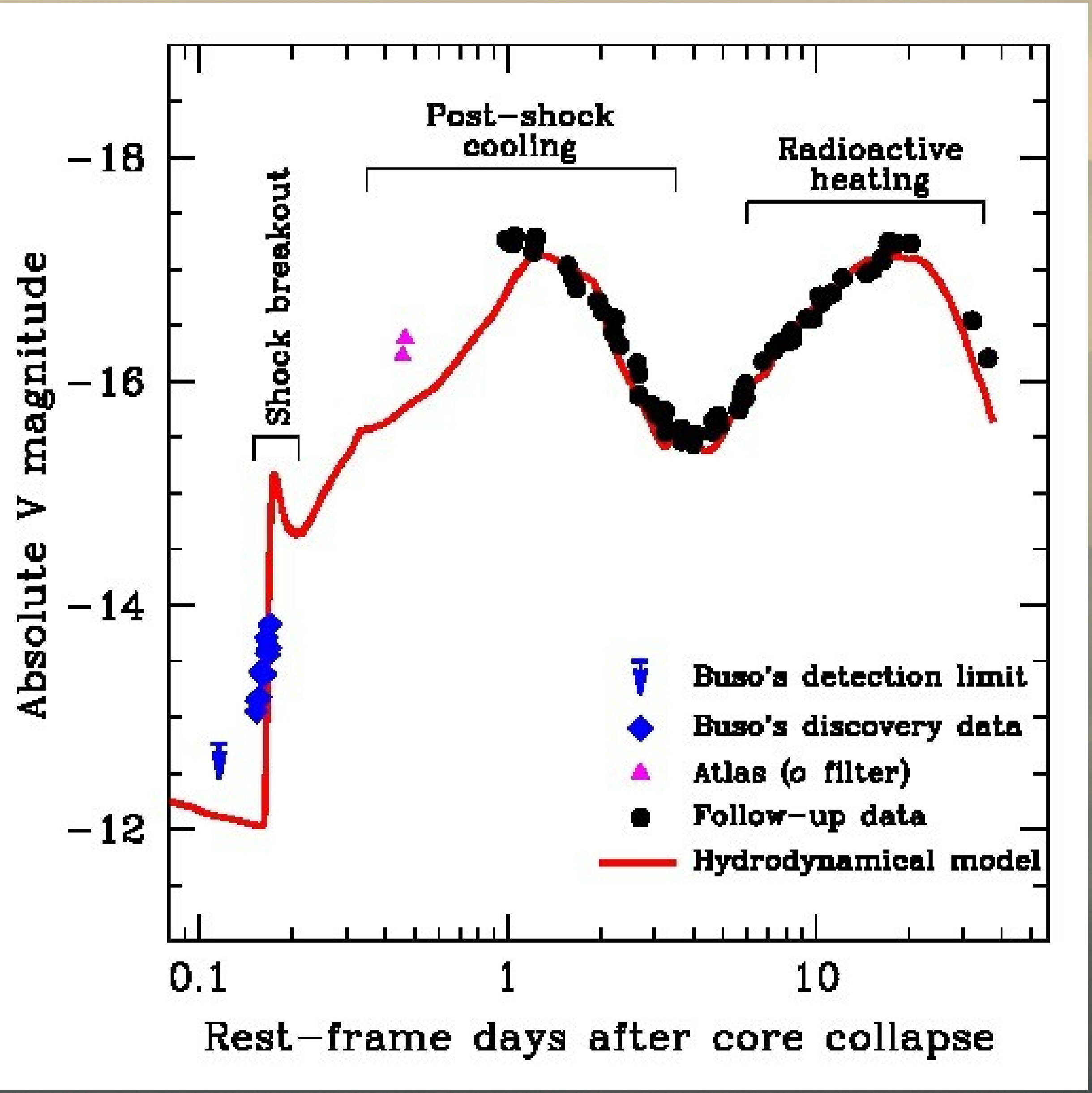
First self-consistent model of a SN during three physically distinct phases

Physical parameters

Ejected mass: 3.5 M☼

Expl. Energy: 1.2 x 10^{51} erg

Progenitor radius: 320 R☼



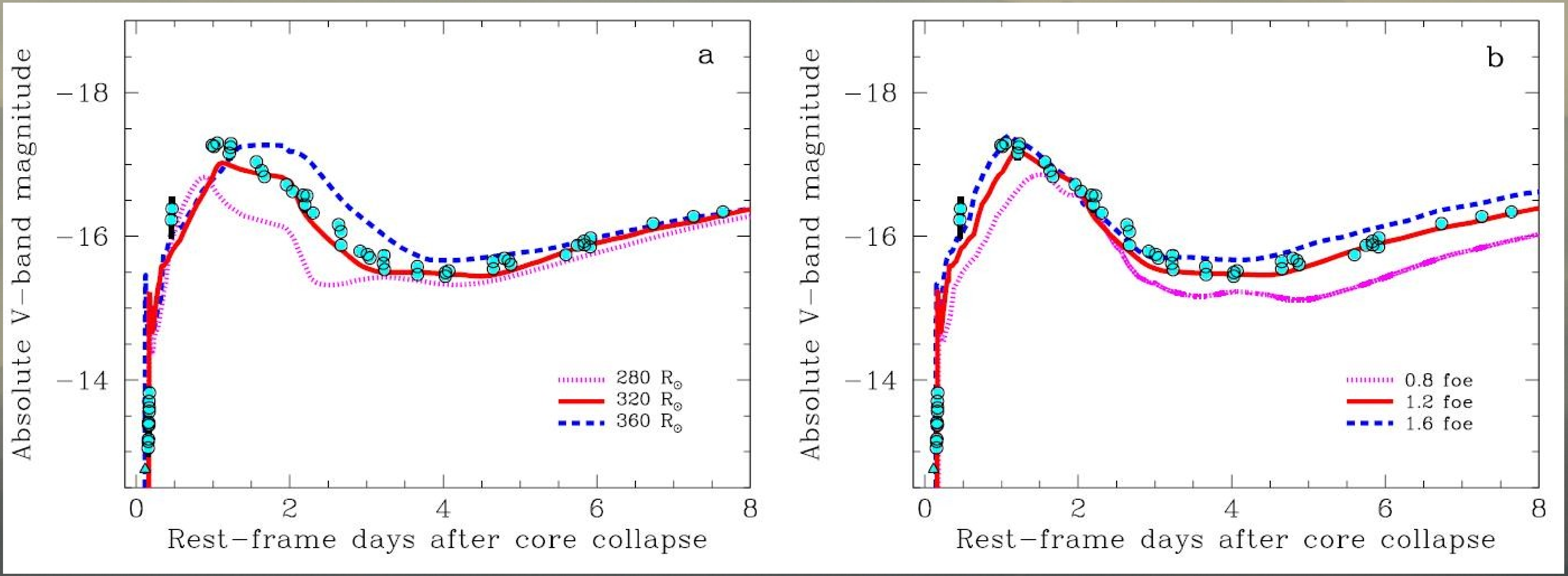
Bersten,GF+18

Hydrodynamical model

Stripped SN light curve

First self-consistent model of a SN during three physically distinct phases

No choice of physical parameters can reconcile the SBO slope with that of the cooling phase

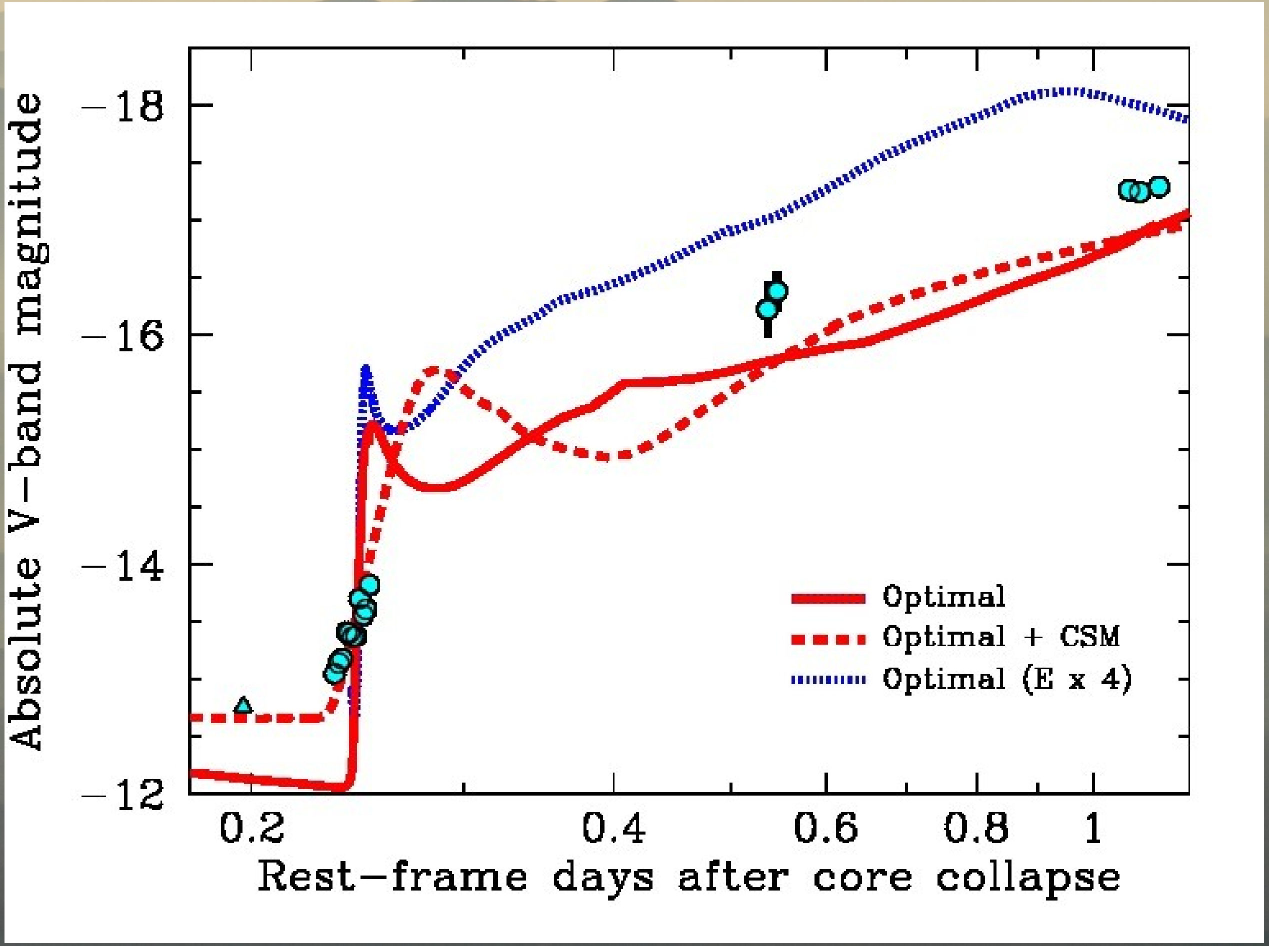


Bersten,GF+18

Hydrodynamical model

Stripped SN light curve
First self-consistent model of a SN during three physically distinct phases

Initial rise rate
Possible presence of circumstellar material that slows down the initial rise



Bersten,GF+18

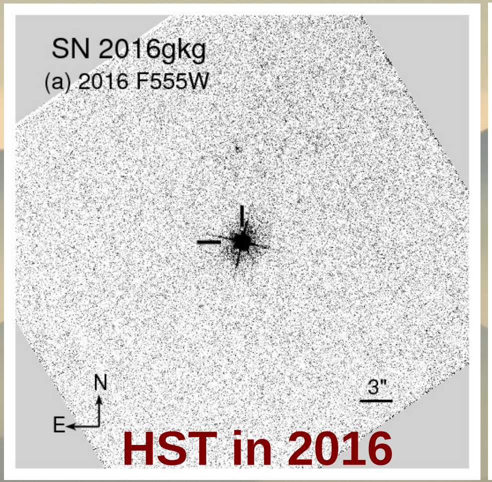
The progenitor of SN 2016gkg

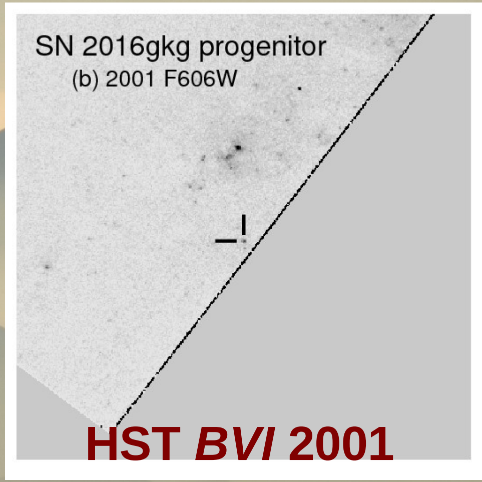
Pre-SN HST imaging

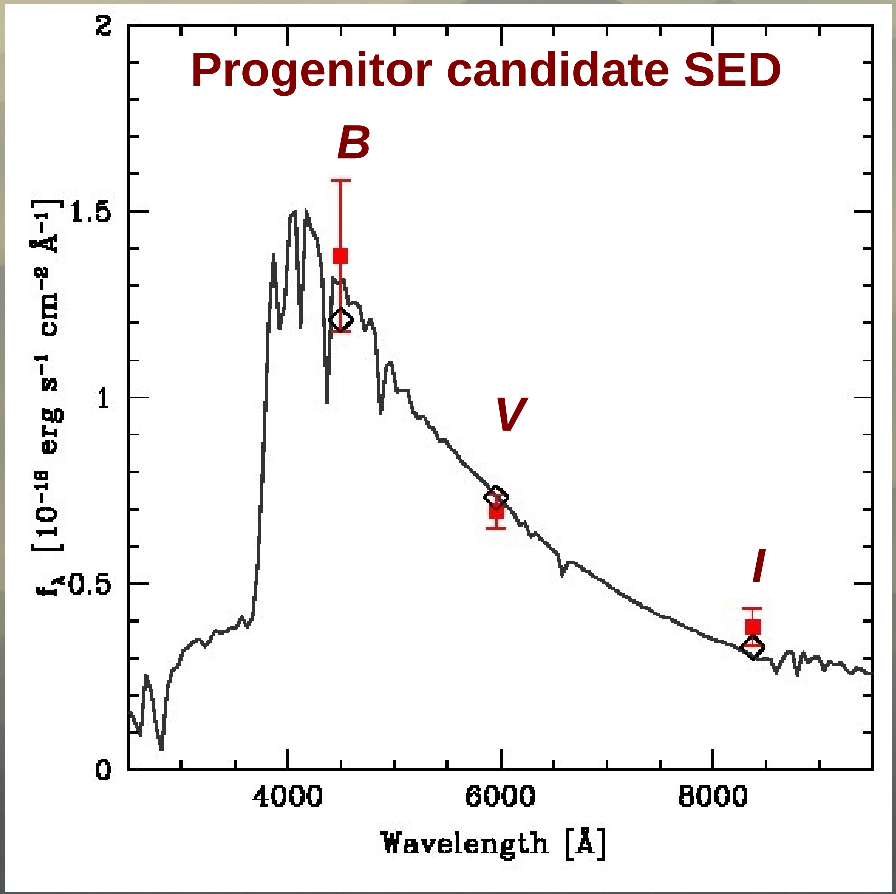
BVI photometry → R ~ 250 R☼

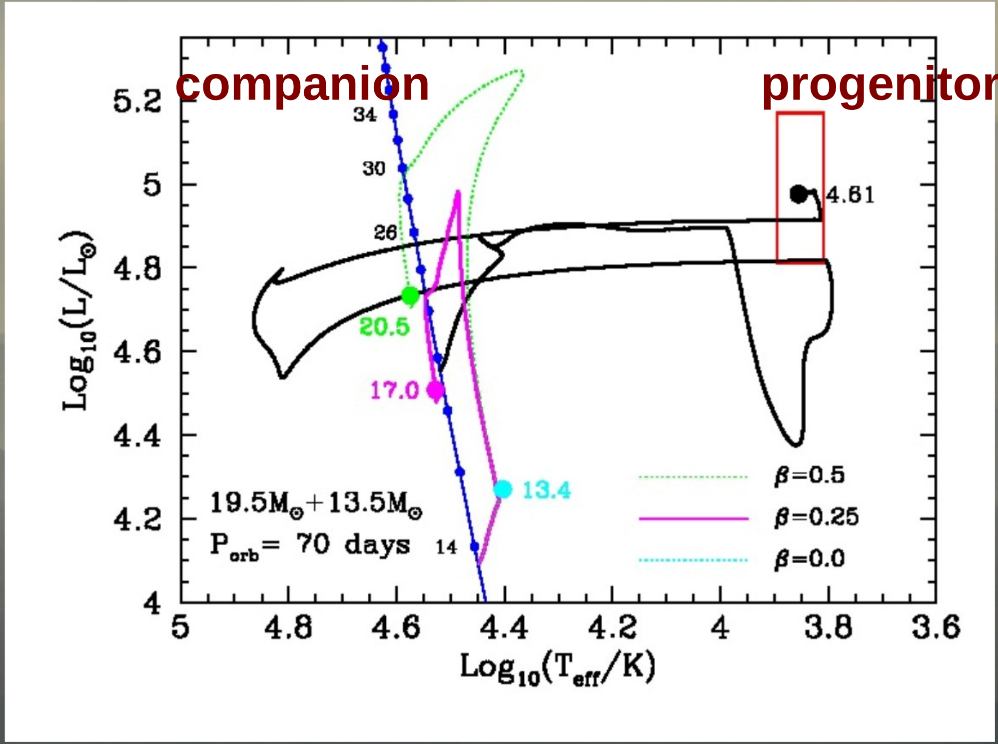
Binary evolution model:

Progenitor with M ~ 4.6 M☼ R ~ 200 R☼









Bersten,GF+18

Conclusions?

How do massive stars evolve before producing a core-collapse supernova?

How do massive stars lose their outer envelopes?

What is the role of interacting binaries in shaping the (outer) structures of SN progenitors?

These questions require improving models, and multi-frequency follow-up from very early till very late

Thank you, Nidia!