The Status of SN Ia Models

and how to distinguish between them

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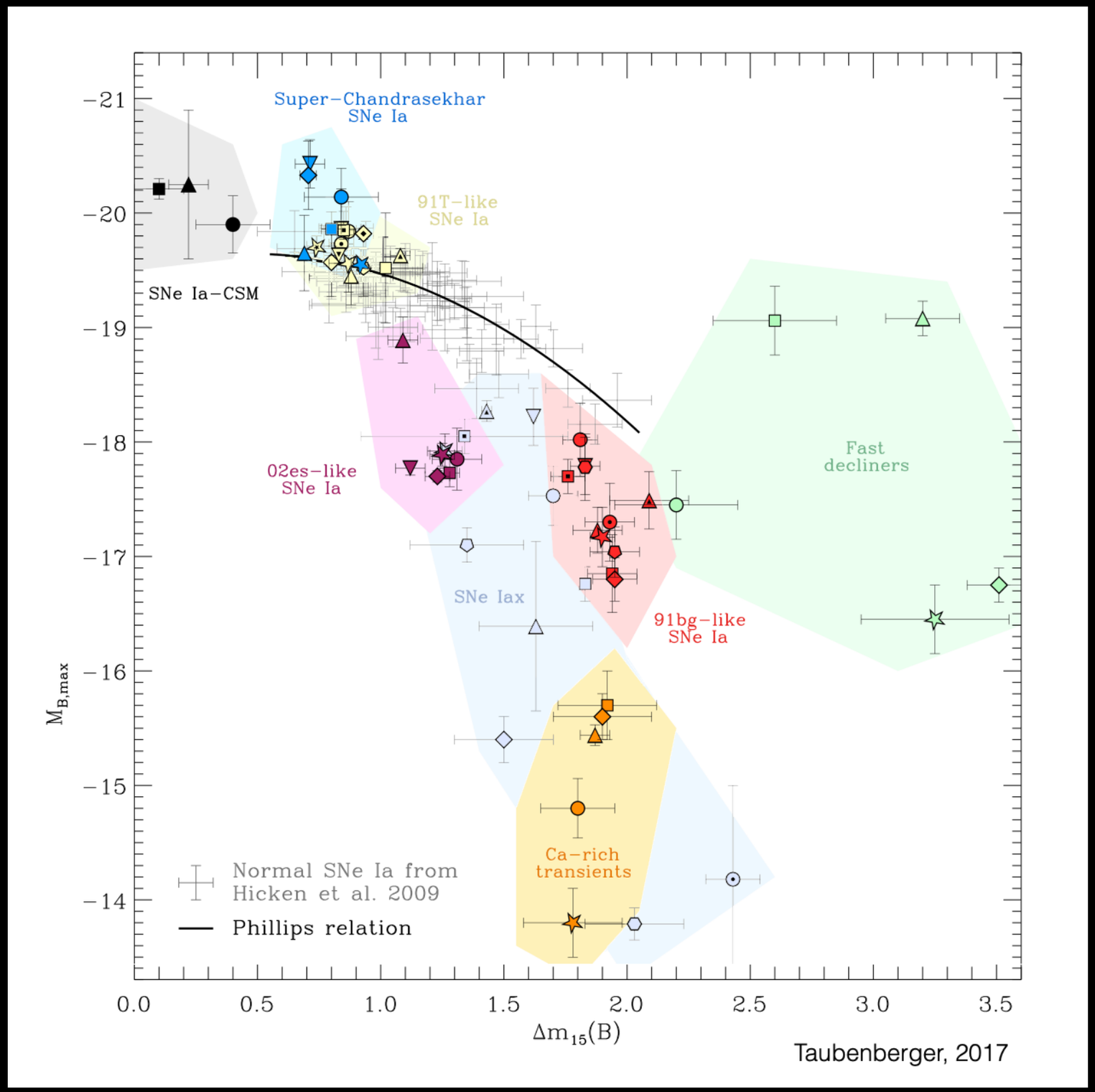
Diverse Landscape of Type Ia SNe



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The Chandrasekhar Mass Model

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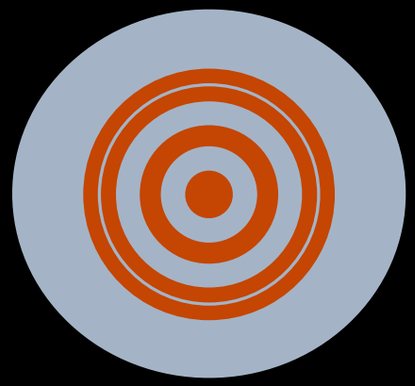
The Chandrasekhar Mass Model



Detonation:

Too Much Ni (too bright)

No IMES

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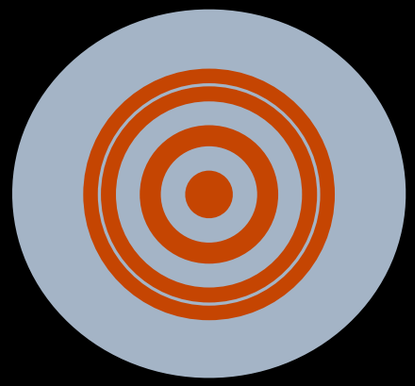
The Chandrasekhar Mass Model



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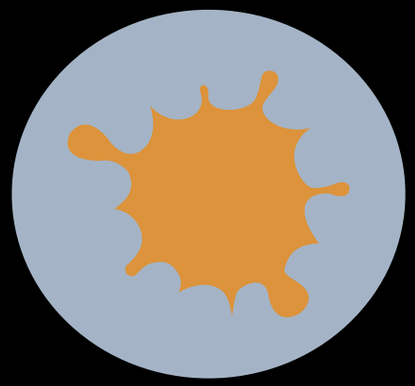

Deflagration:

Not enough Ni

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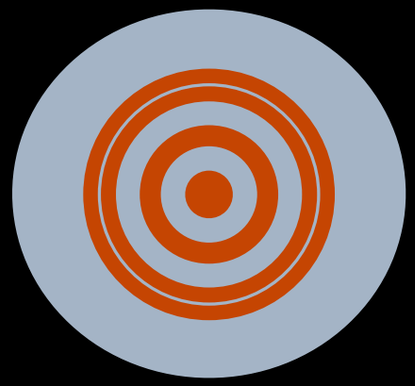
The Chandrasekhar Mass Model



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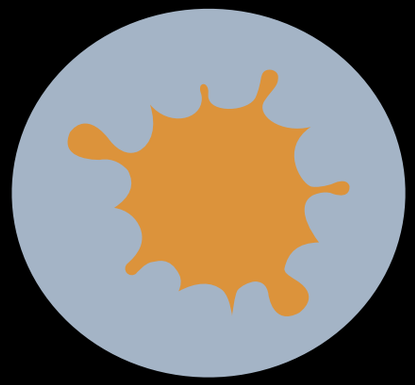
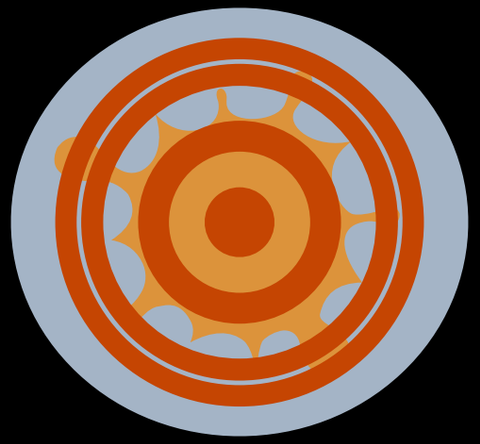


Deflagration:

Not enough Ni



Delayed Detonation:

Deflagration to Detonation Transition

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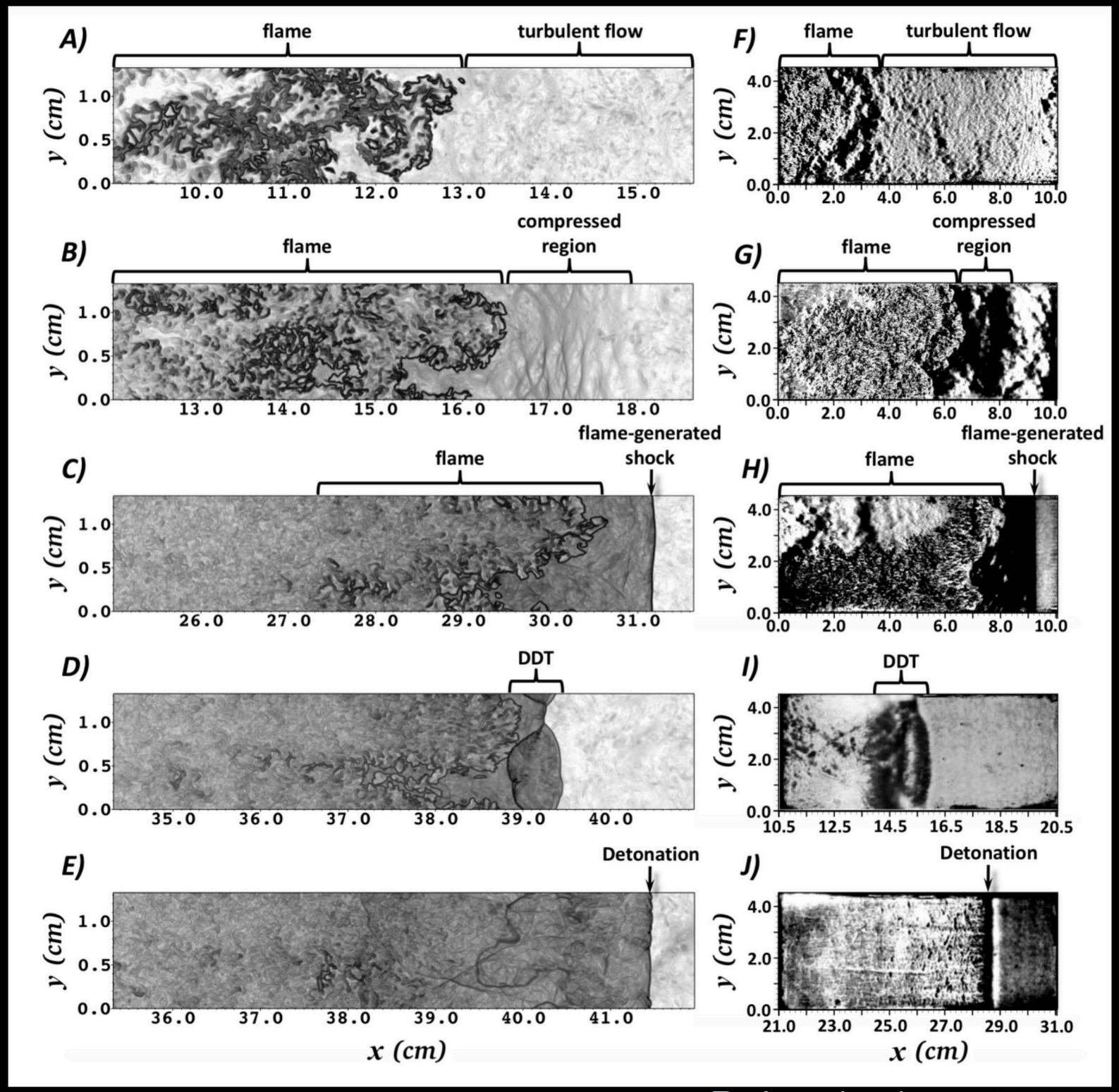
Deflagration to Detonation Transition

Simulation



Lab

Polundneko+ 2019

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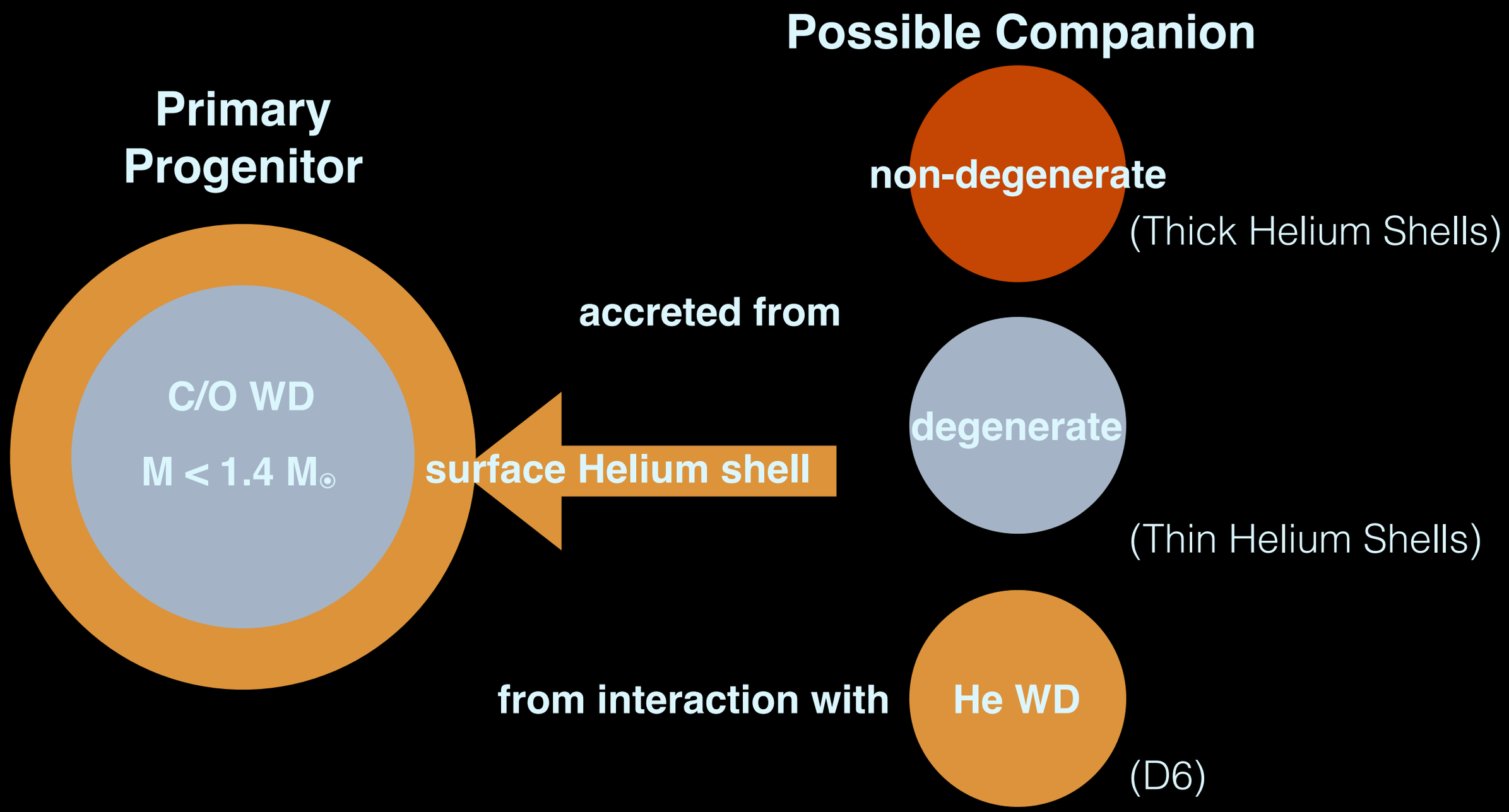
The Sub-Chandrasekhar Model



Double Detonation Scenario: detonation of the surface helium leads to a detonation of the carbon-oxygen core

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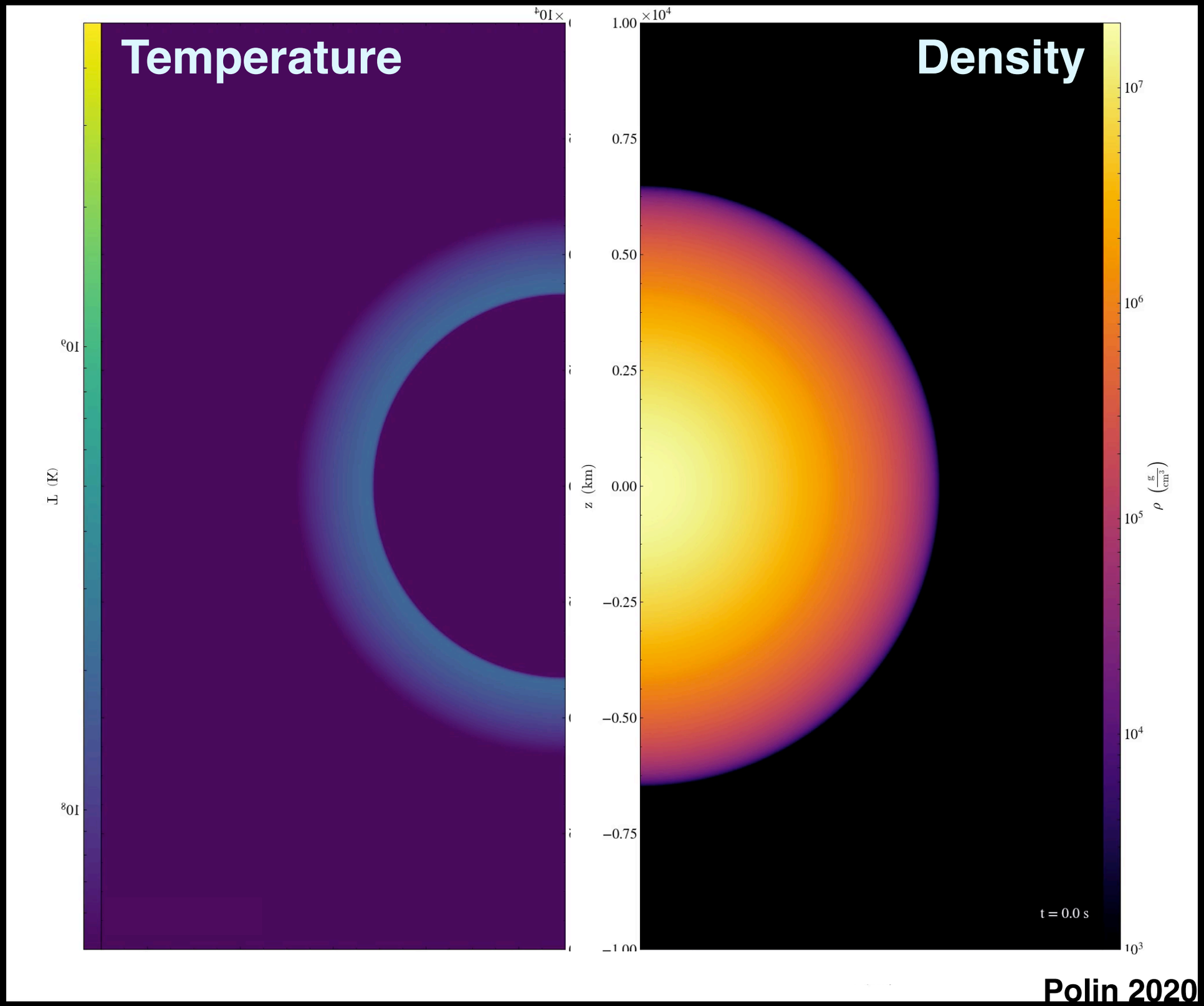
Double Detonation - 0.76 $M_\odot$ WD w/ 0.15 $M_\odot$ He



Polin 2020

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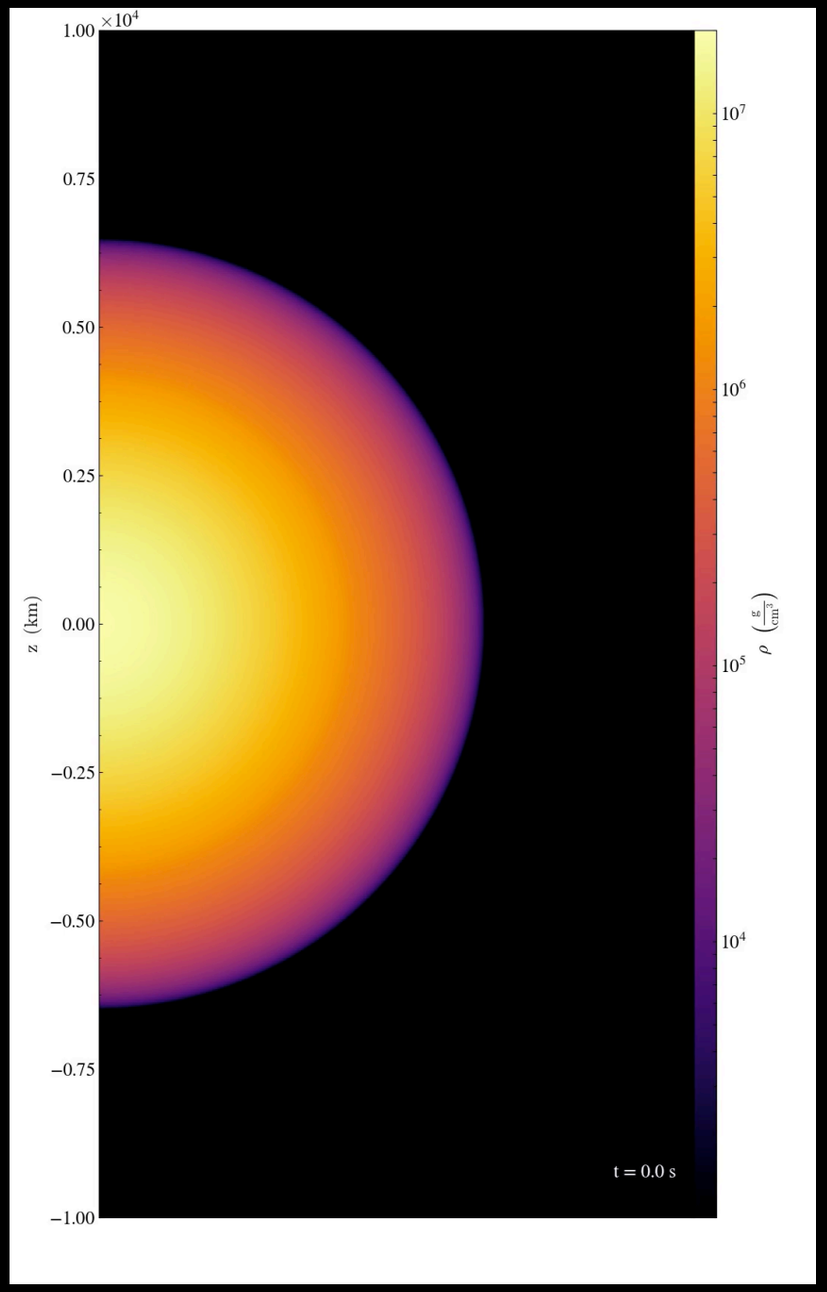
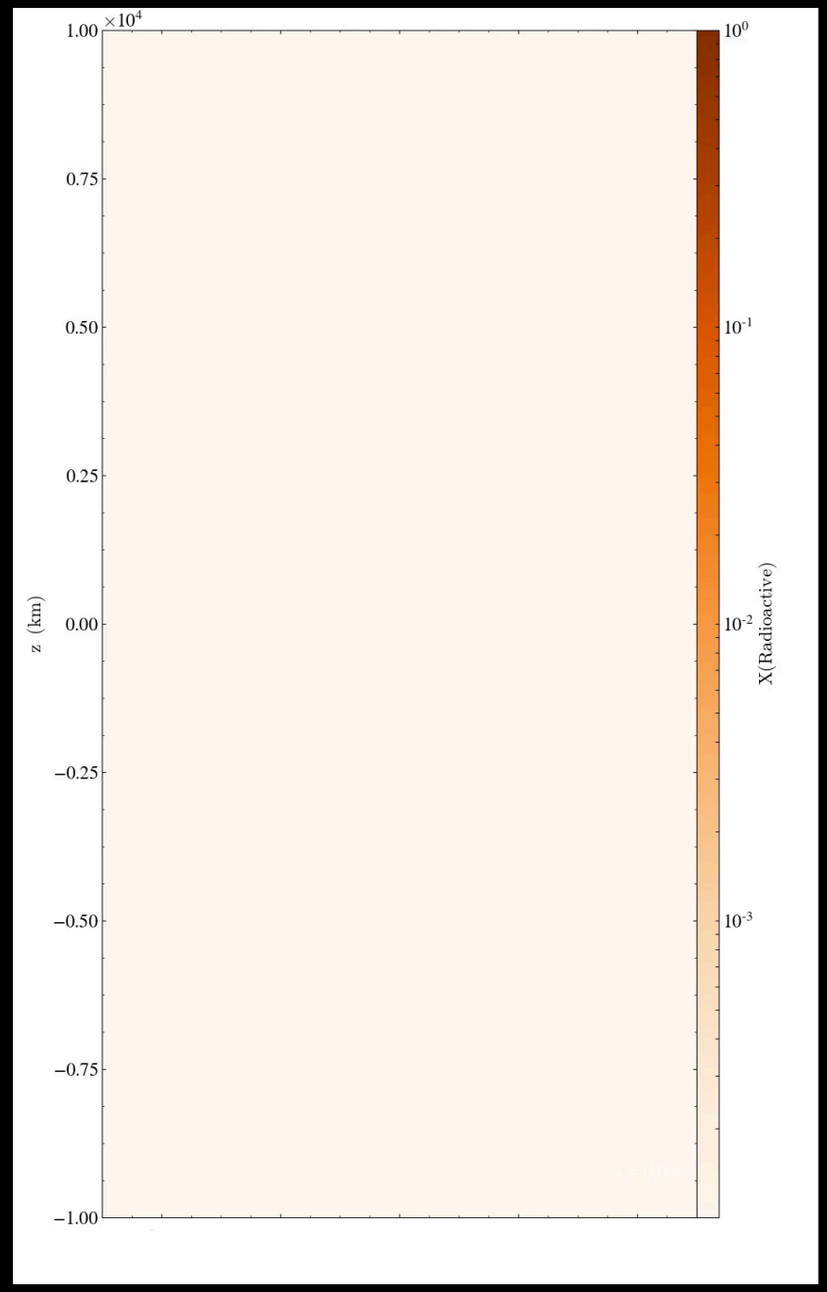
Double Detonation - 0.76 $M_\odot$ WD w/ 0.15 $M_\odot$ He

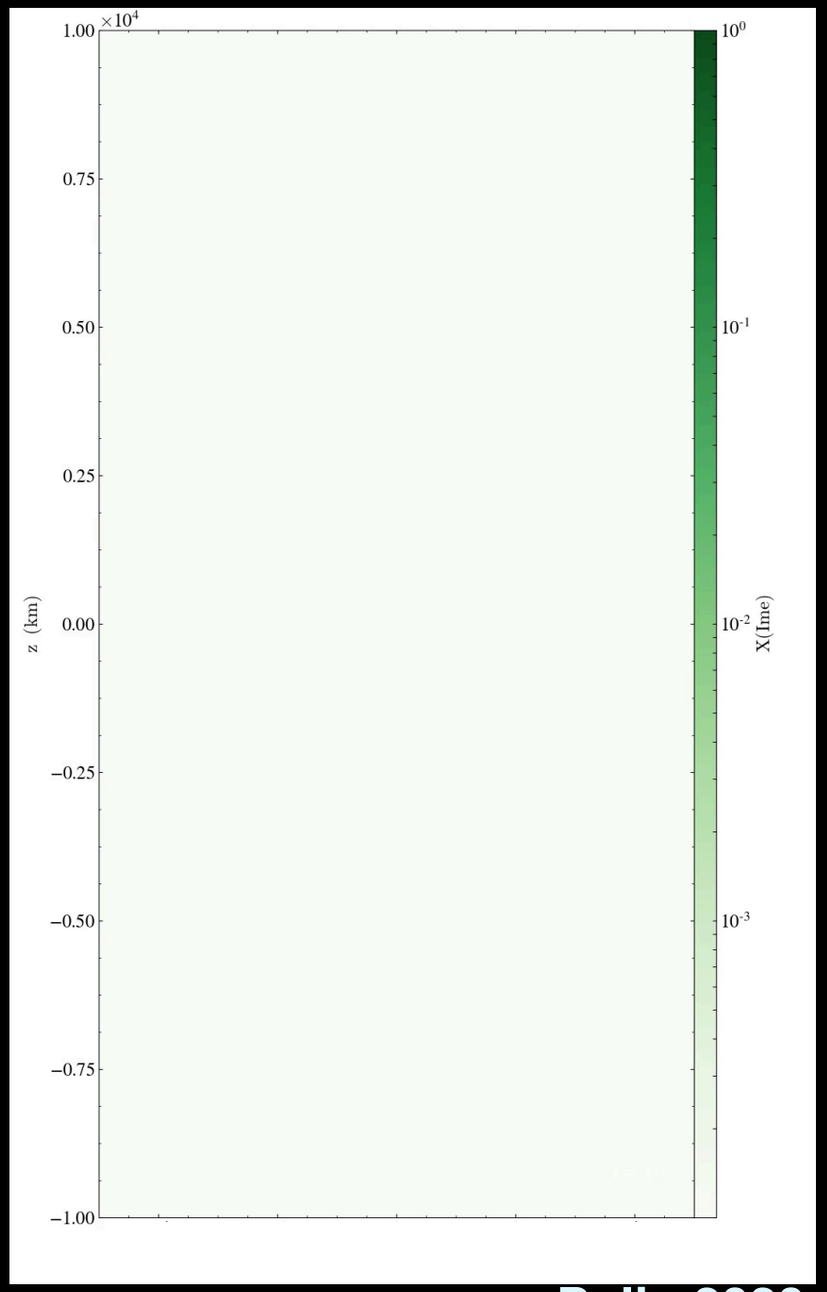
Density



radioactive elements



IMEs (10<Z<20)



Polin 2020

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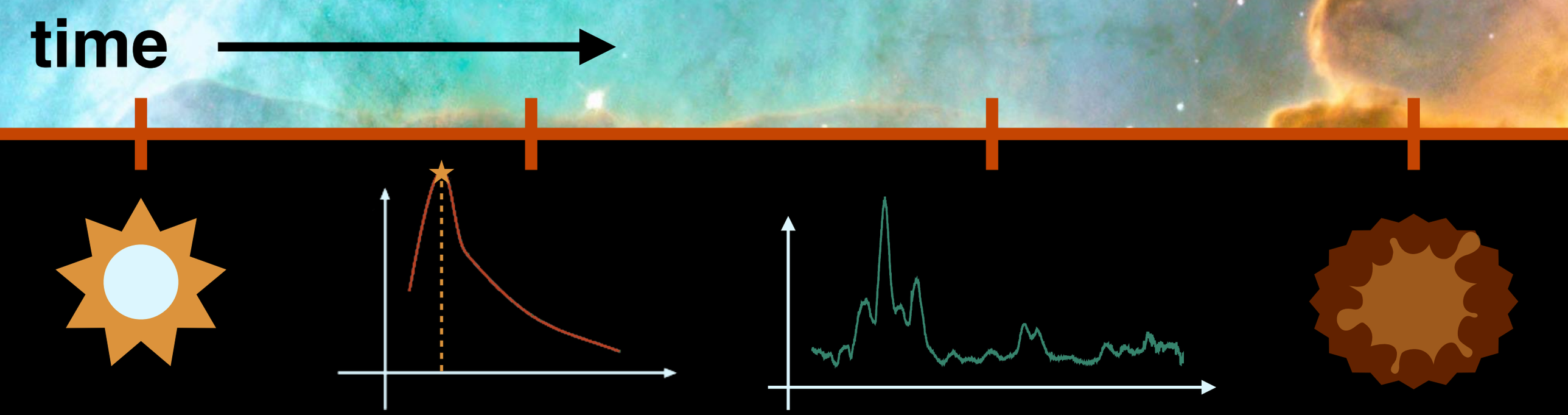

Lifetime of a Supernova

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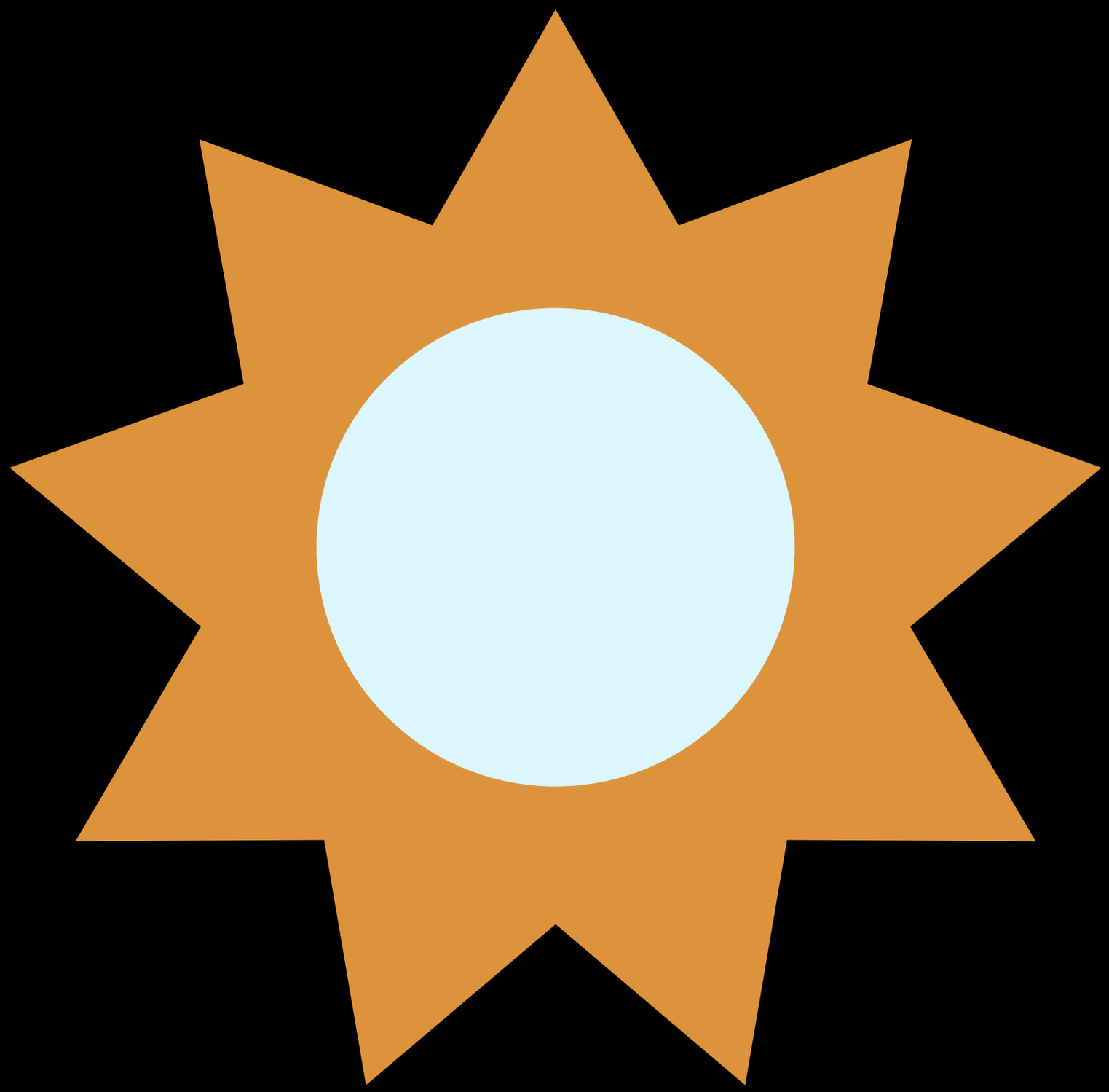
Infancy



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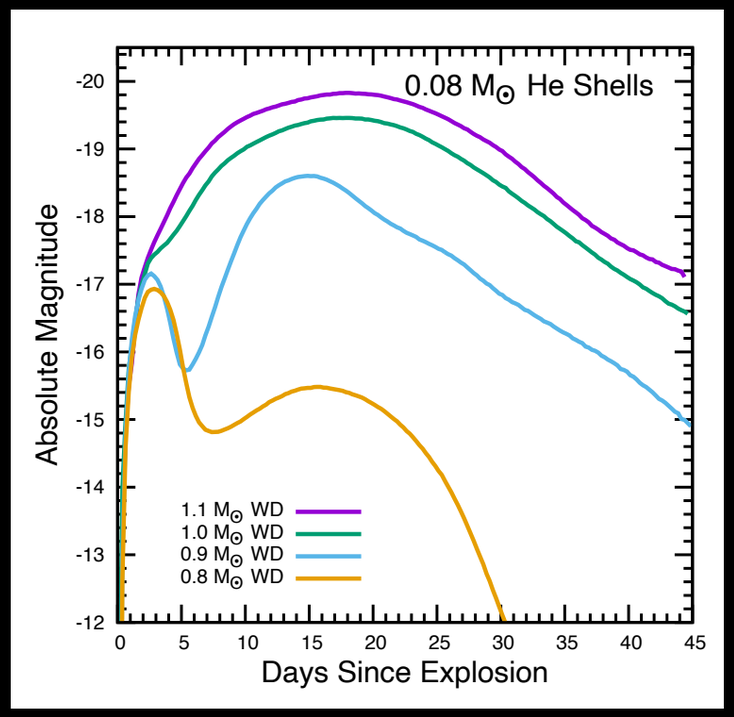
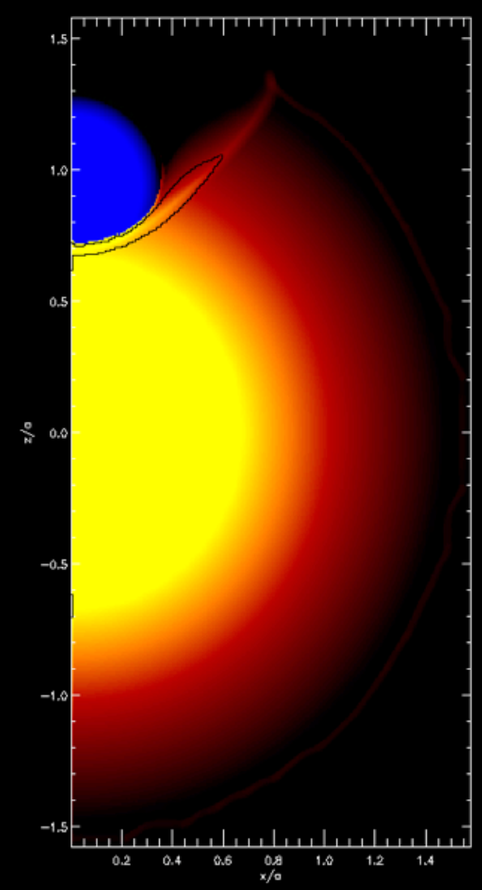
Early Light Curve Bumps



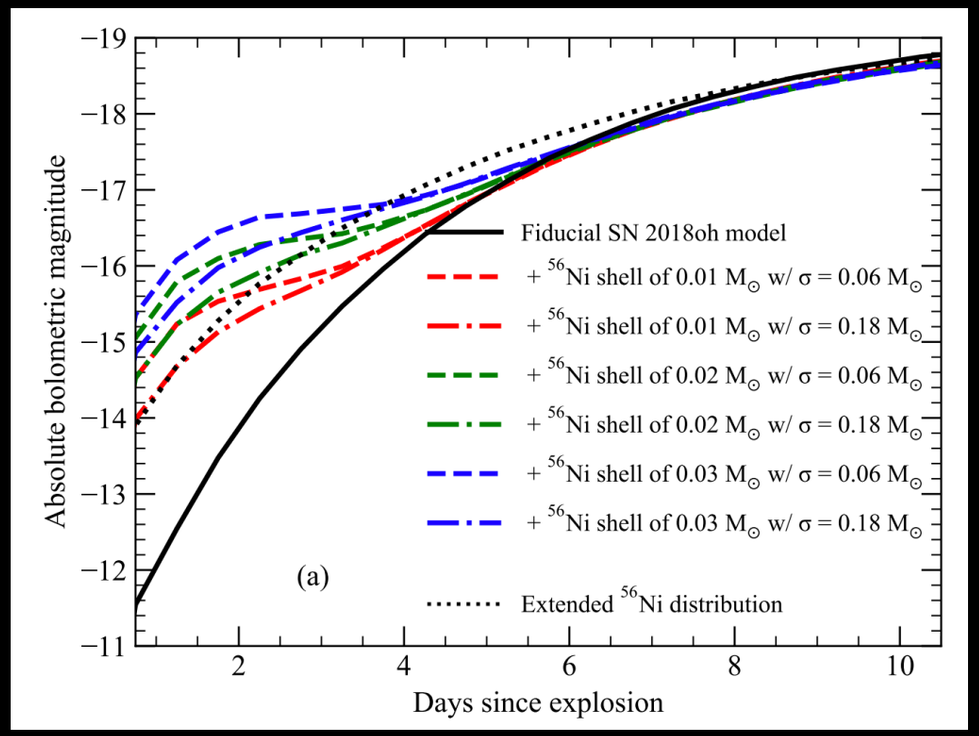
Double Detonations

(e.g Polin 2019)



Companion Interaction

(Kasen 2010)



Extended Ni Distributions

(e.g. Magee & Maguire 2020)

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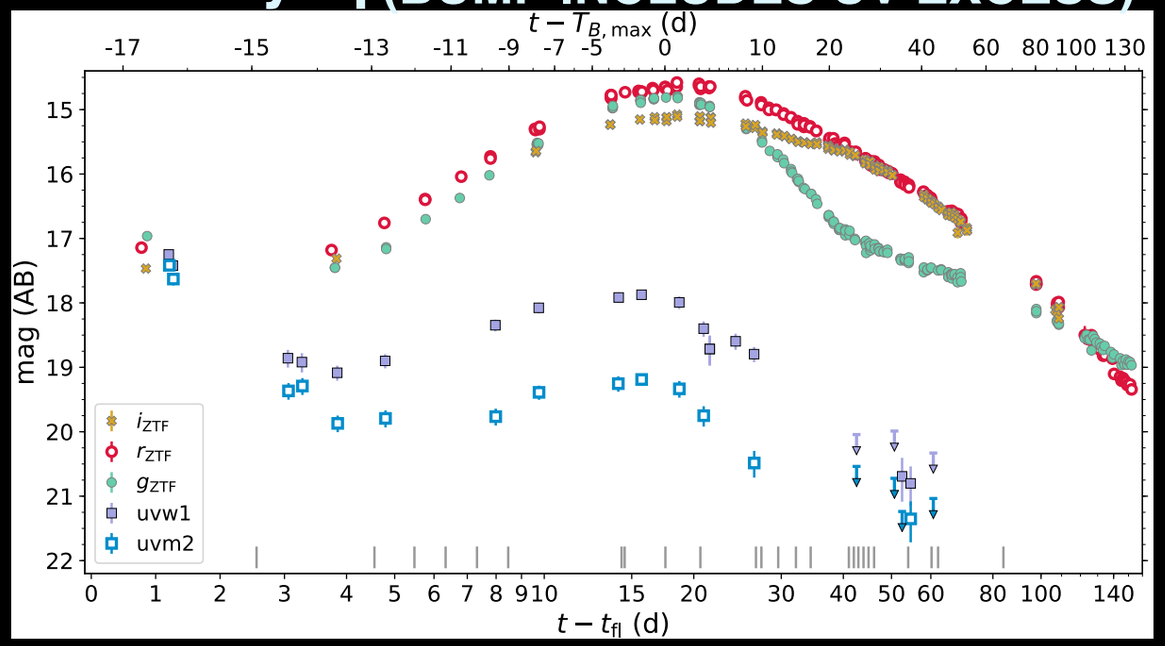
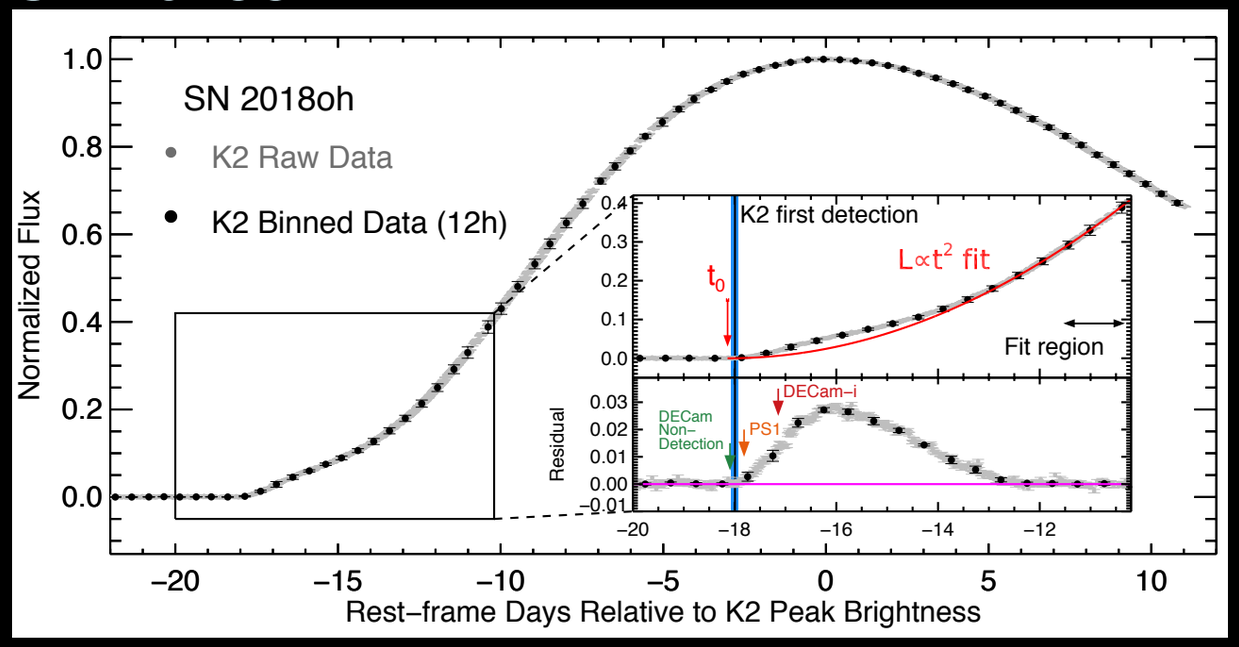
Bumpy SNe Ia

SN 2019yvq (BUMP INCLUDES UV EXCESS)



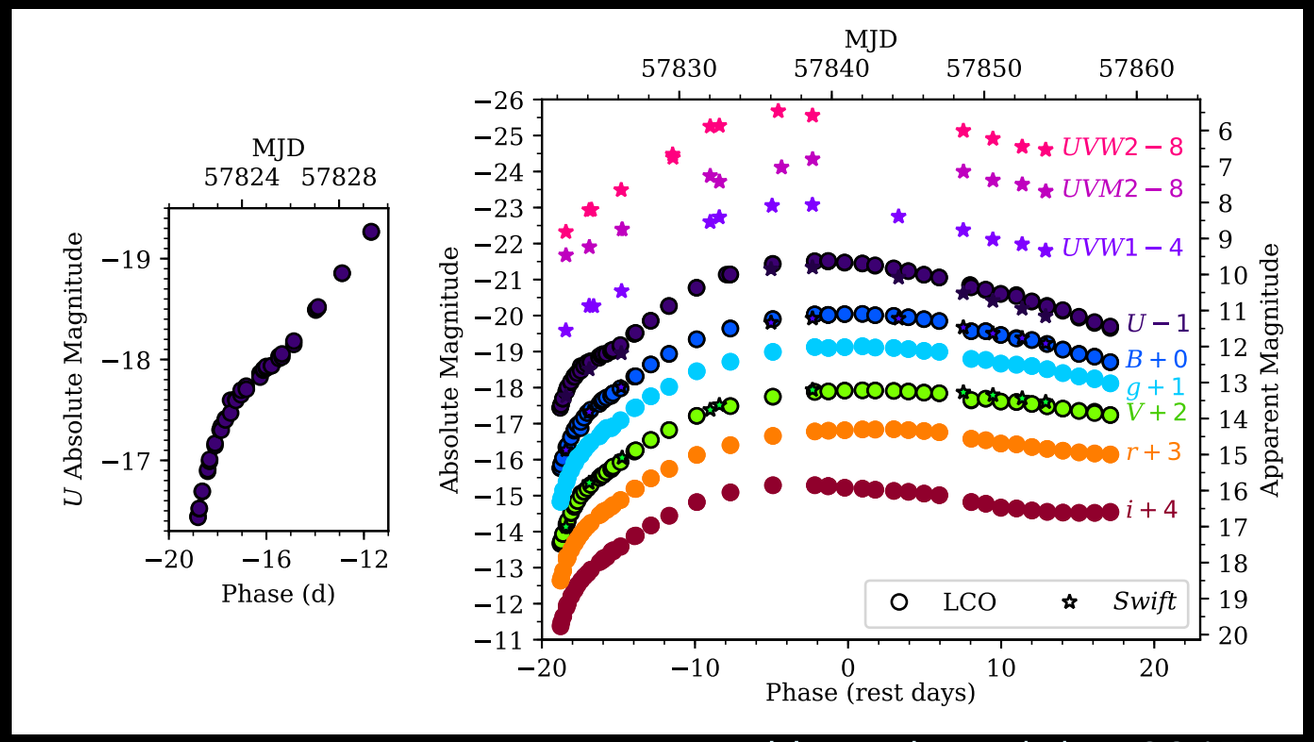
Miller+ 2020

SN 2018oh



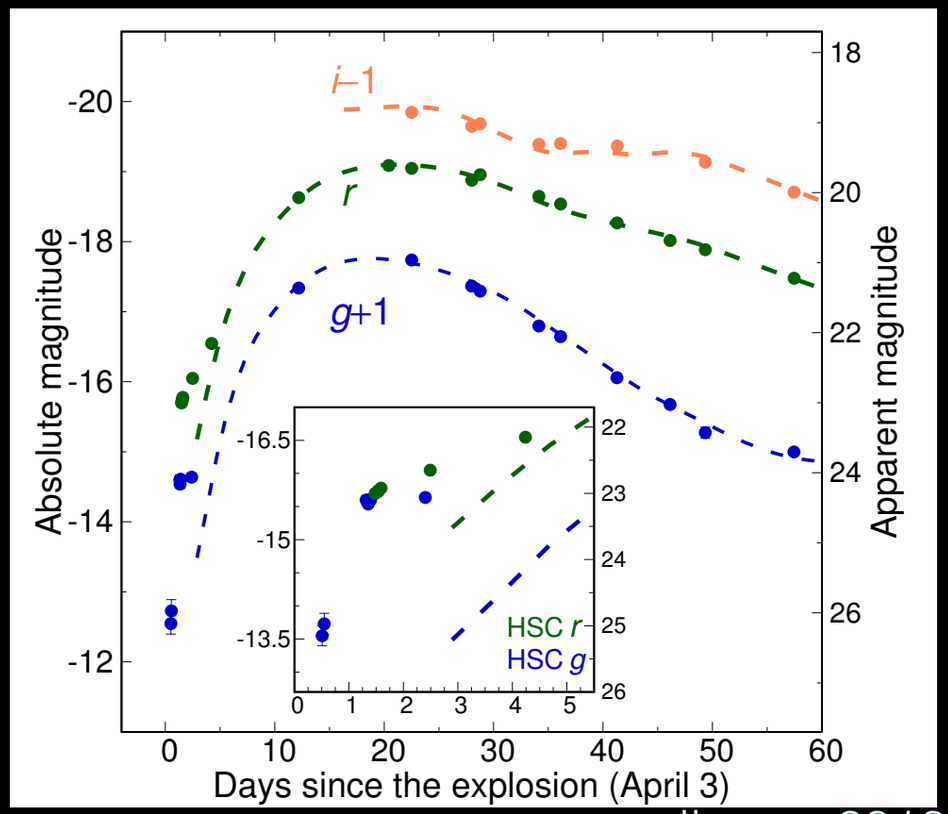
Dimitriadis+ 2019

SN 2017cbv



Hosseinzadeh+ 2017

MUSSES1604D



Jiang+ 2018

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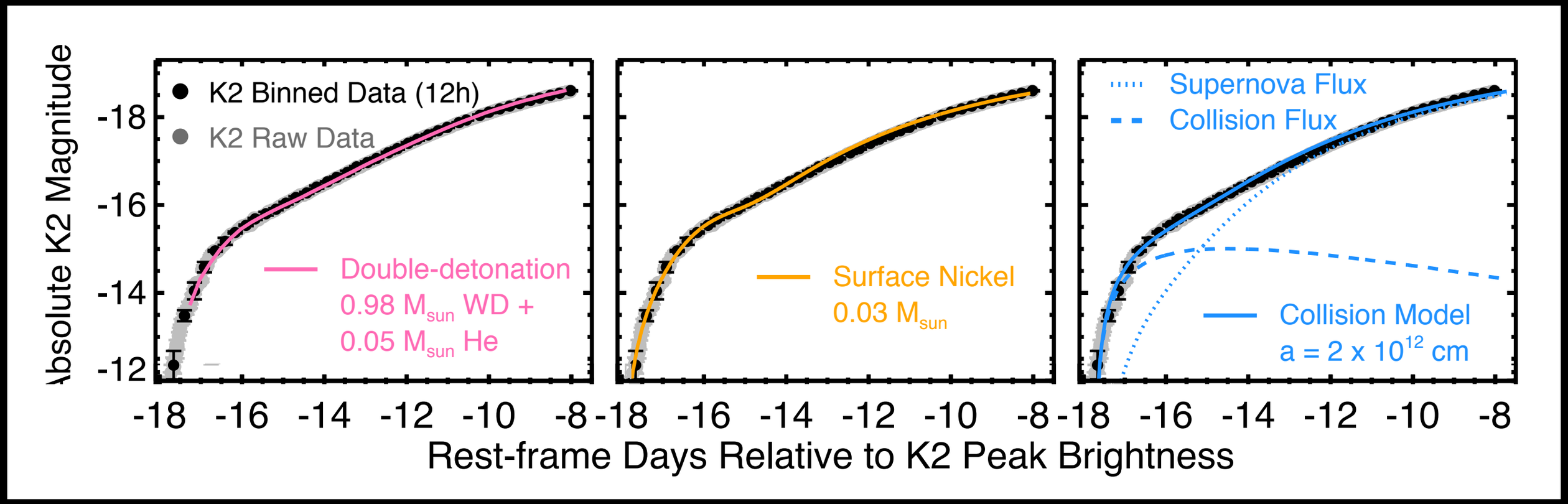
Bumpy SNe Ia — Degeneracies

SN 2018oh



Dimitriadis+ 2019

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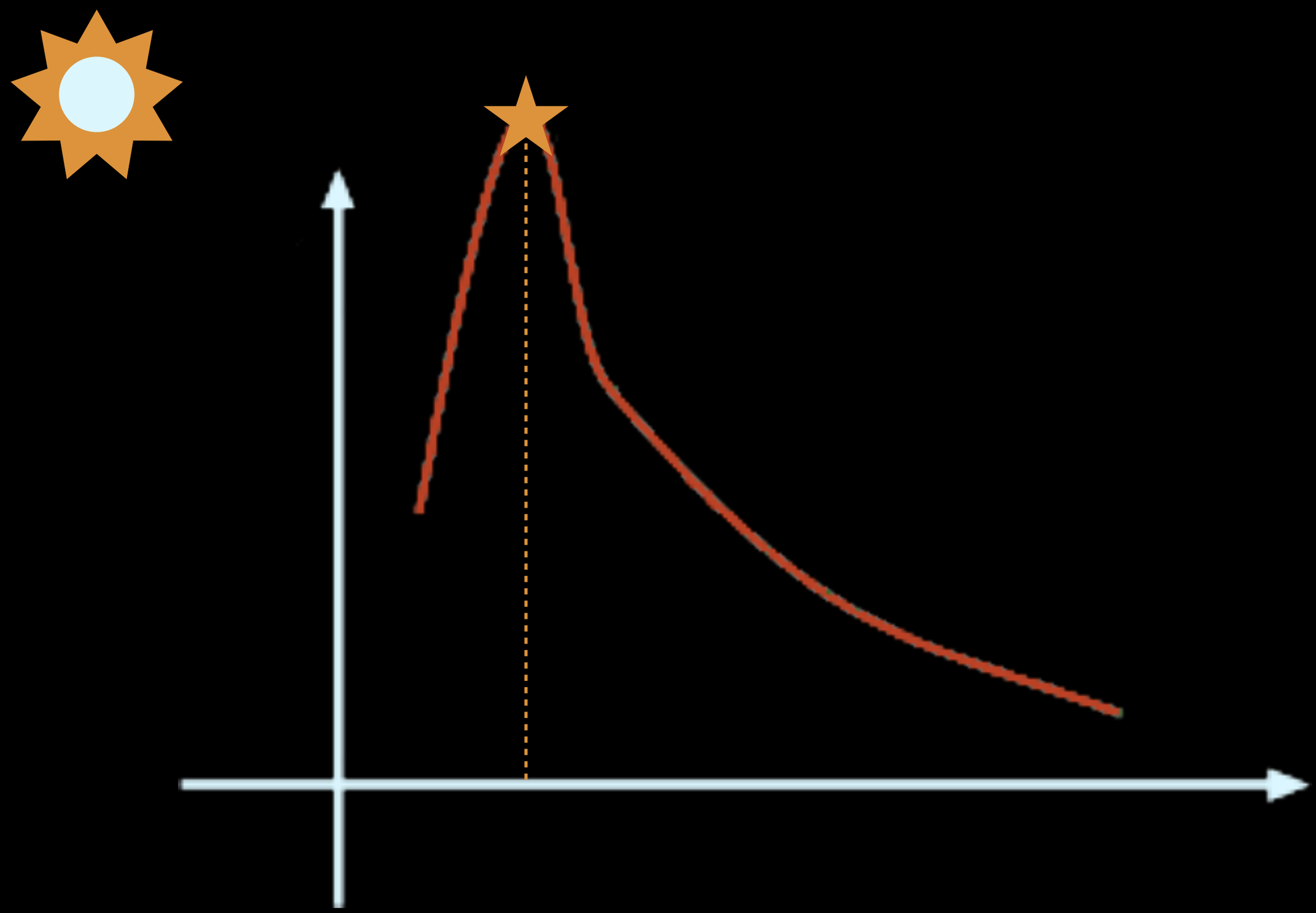
Infancy

Peak Times



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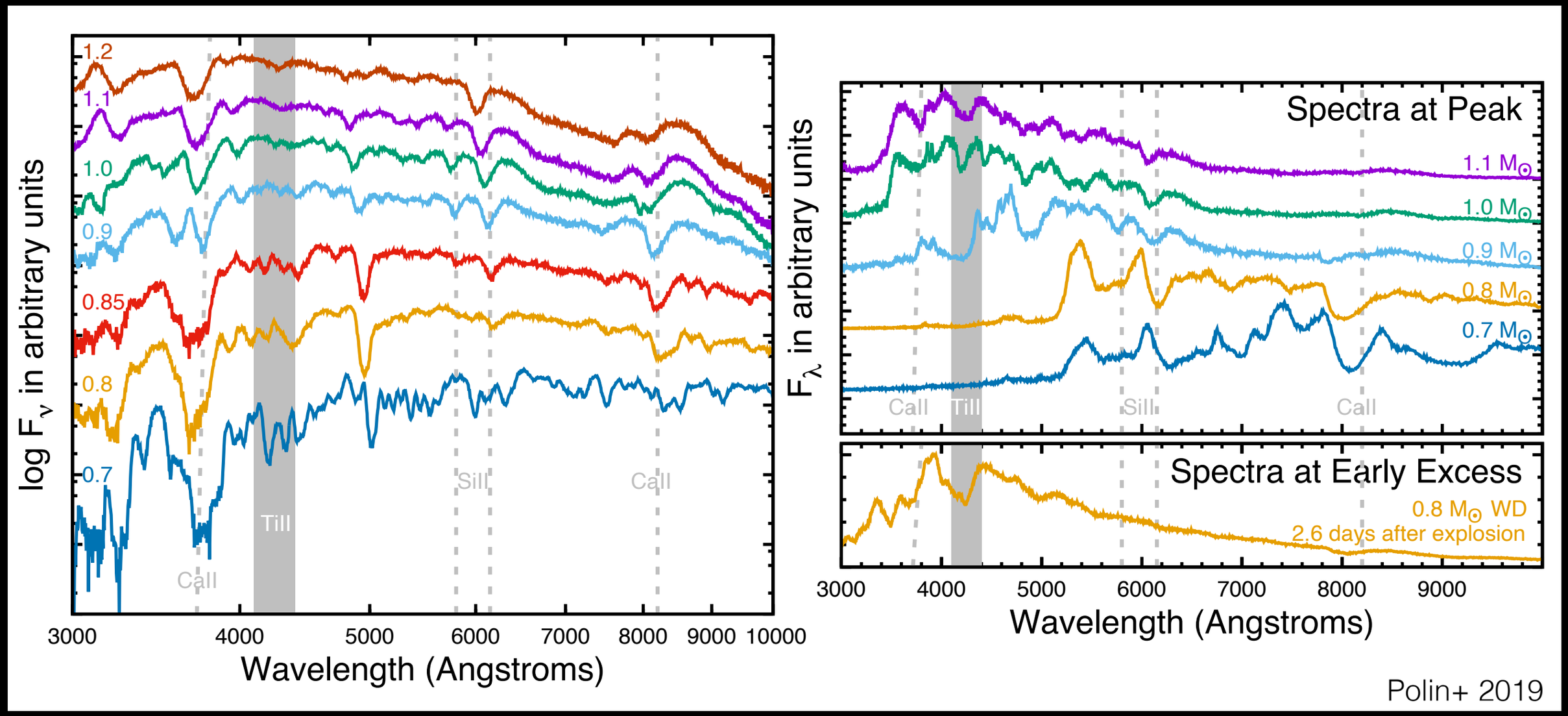
Double Detonation Spectra - (at peak)

Thin Helium Shells | **Thick Helium Shells**



normal & 91bg-like las | extreme line blanketing

Caveat: detonations are very efficient at C burning

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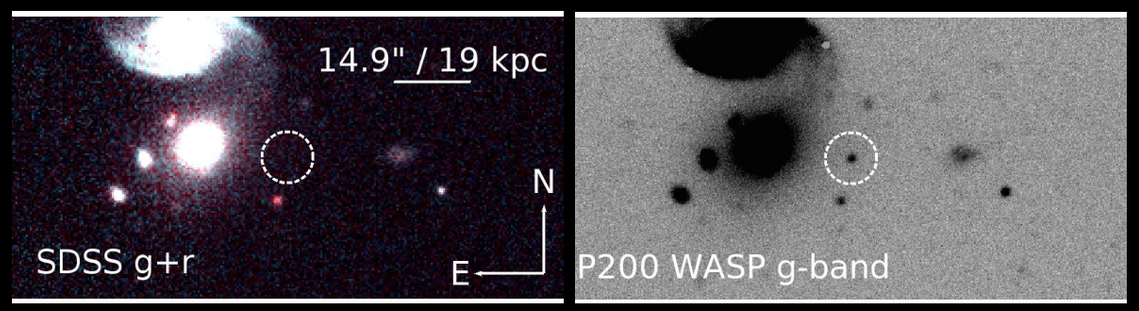
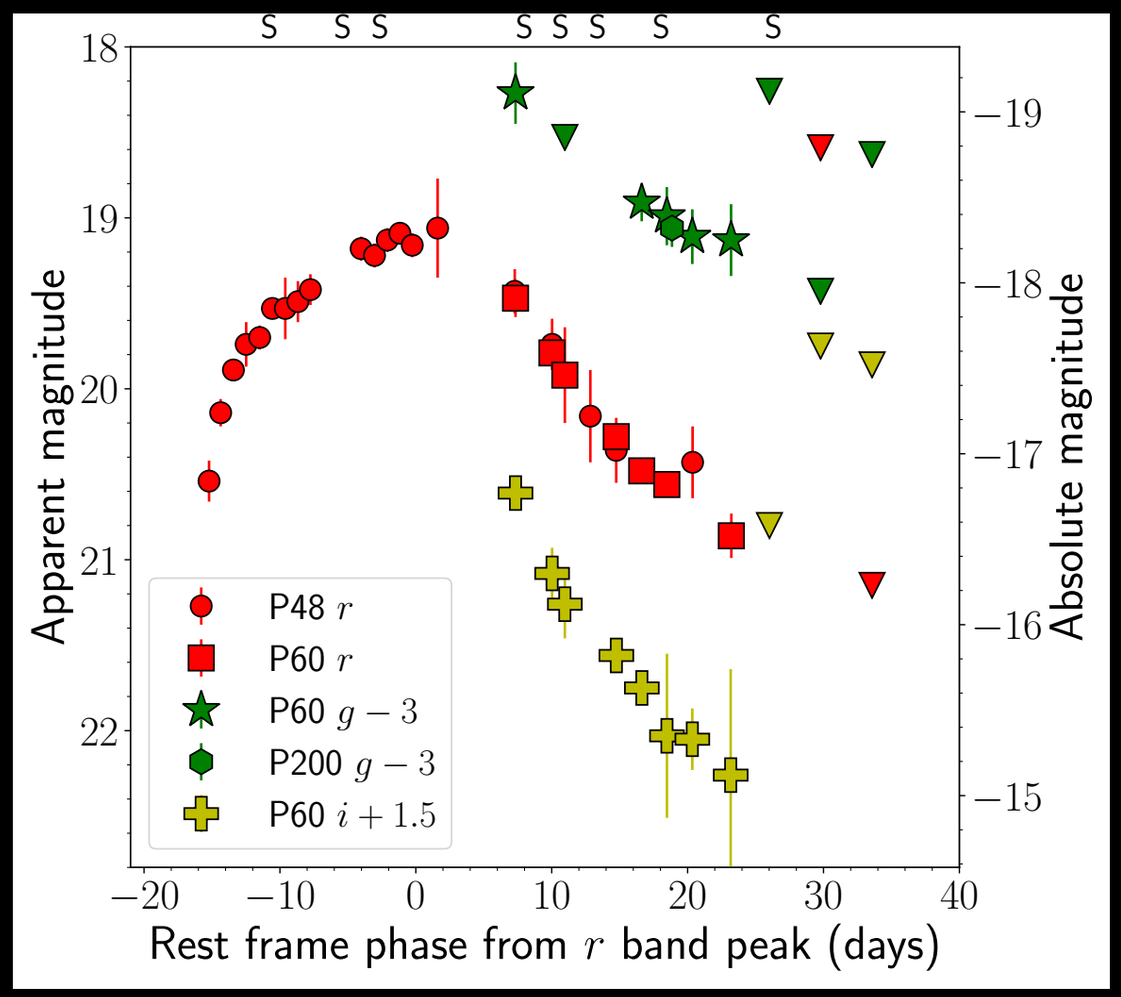
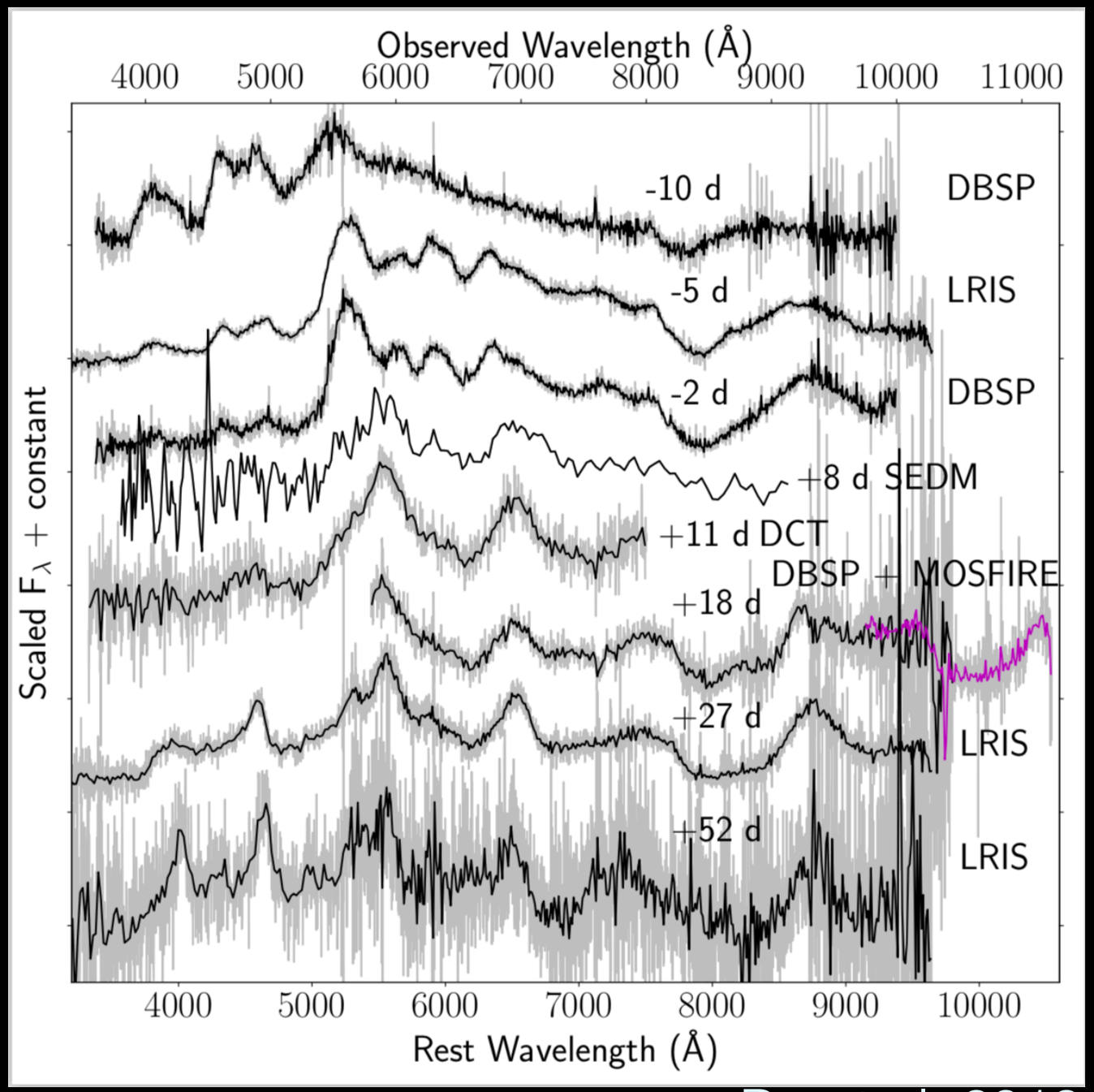
Thick Shells are Extreme & Recognizable

SN 2018byg

A Massive Helium-shell Double Detonation on a Sub-Chandrasekhar Mass White Dwarf







De et al. 2019

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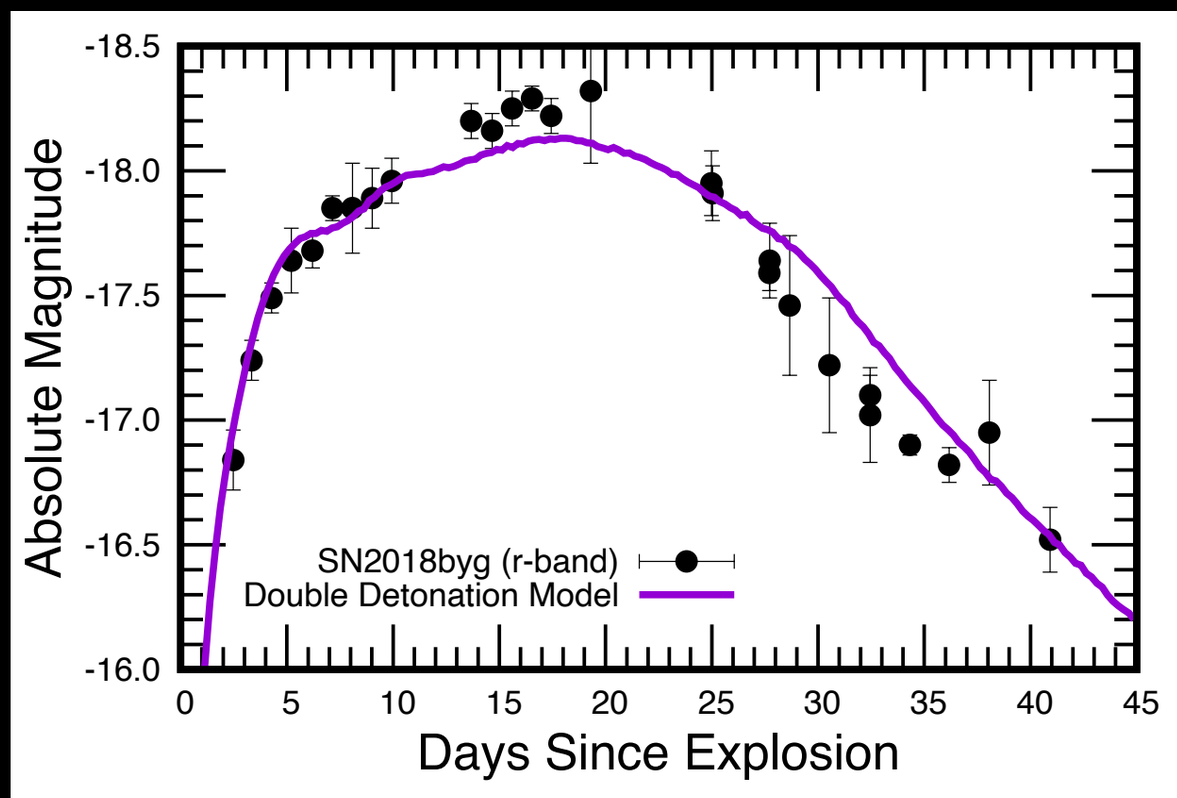
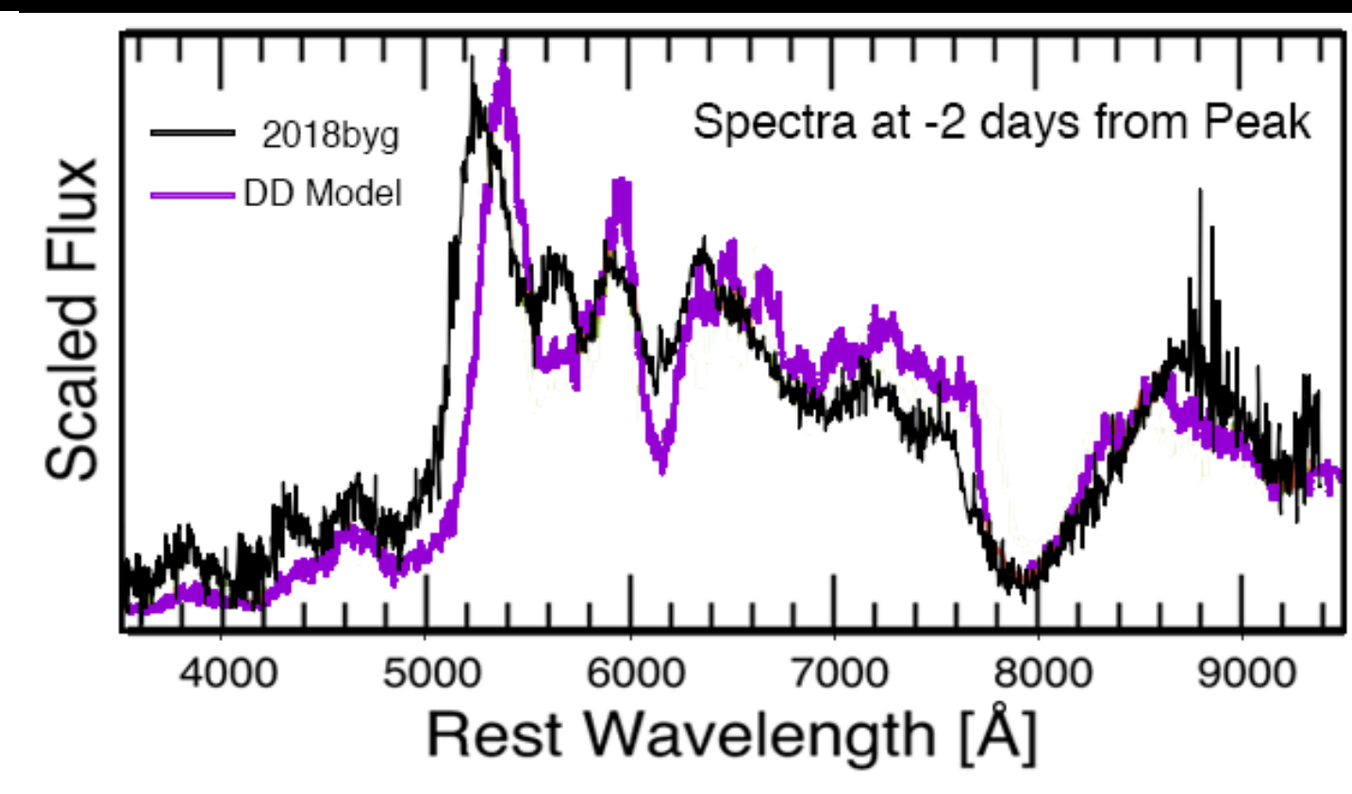
Double Detonations CAN Explode a WD

Early Light Curve Bump + Extreme Peak Line Blanketing





0.76 $M_\odot$ WD with a 0.15 $M_\odot$ Helium Shell

Polin et al. 2019
De et al. 2019

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Double Detonations CAN Explode a WD

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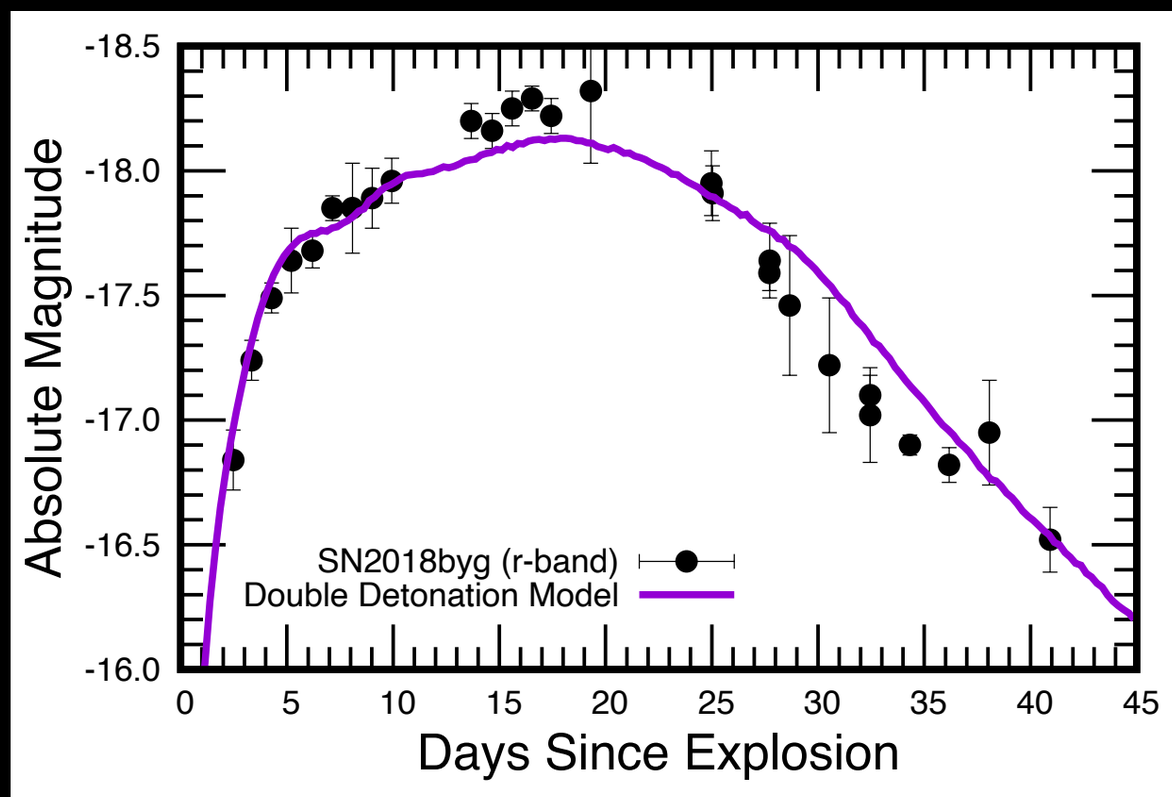

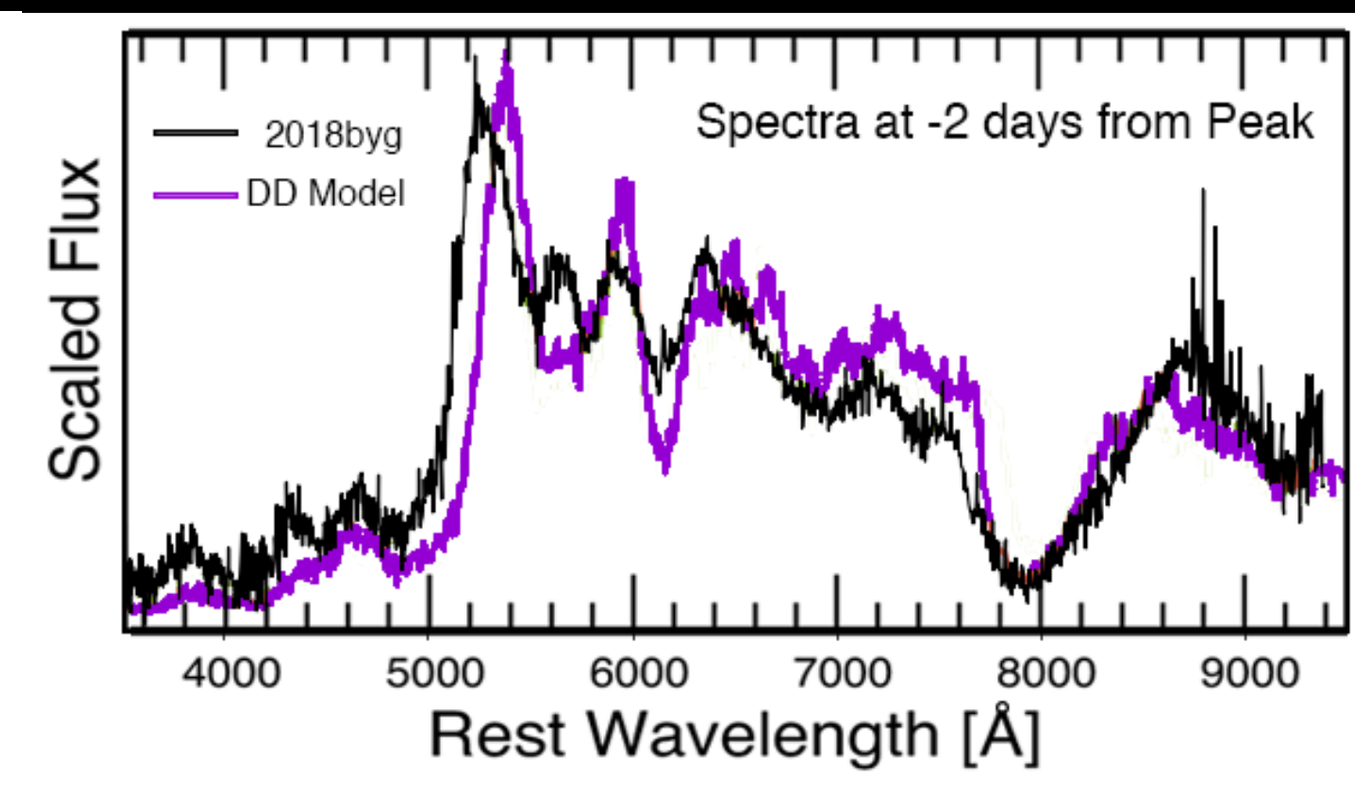

0.76 $M_\odot$ WD with a 0.15 $M_\odot$ Helium Shell

Polin et al. 2019
De et al. 2019

See Also: MUSSES2016D Jiang+ 2018, **SN 2016hnk** Jacobson-Galan+ 2020, **SN 2019yvq** Miller+ 2020, **SN 2016dsg** Dong+ 2022

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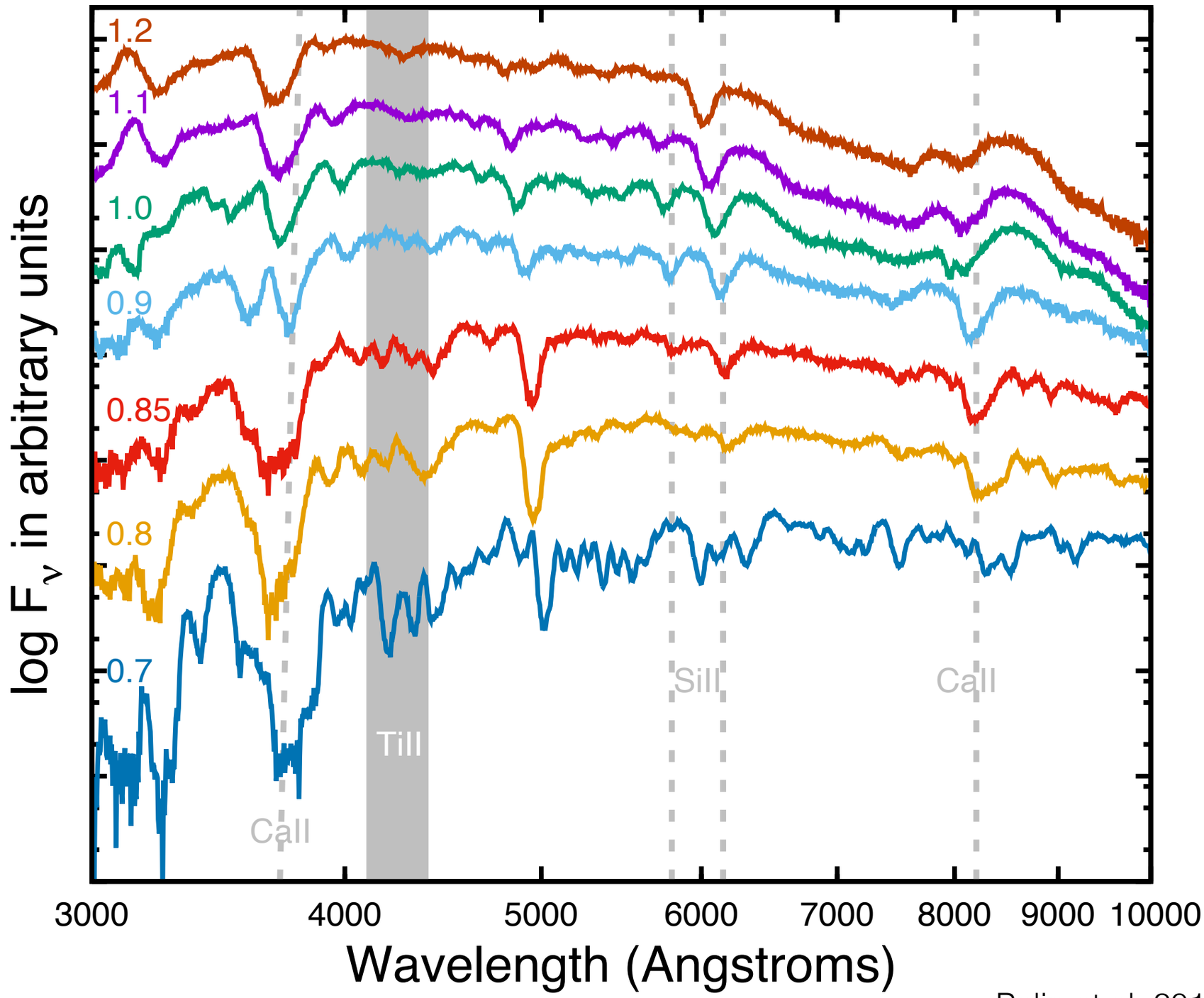
Luminosity - Velocity Relationship



Polin et al. 2019

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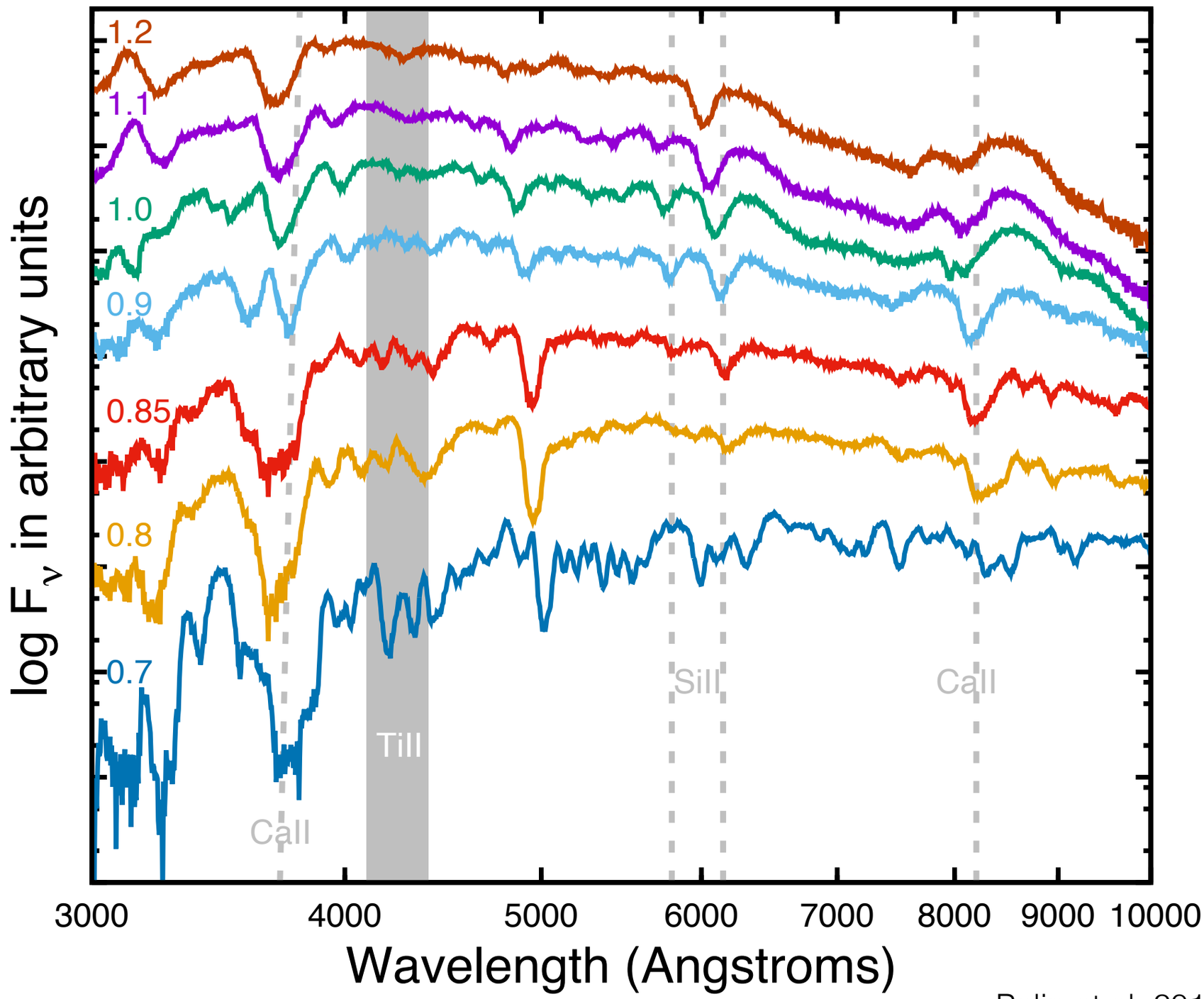
Luminosity - Velocity Relationship



Polin et al. 2019

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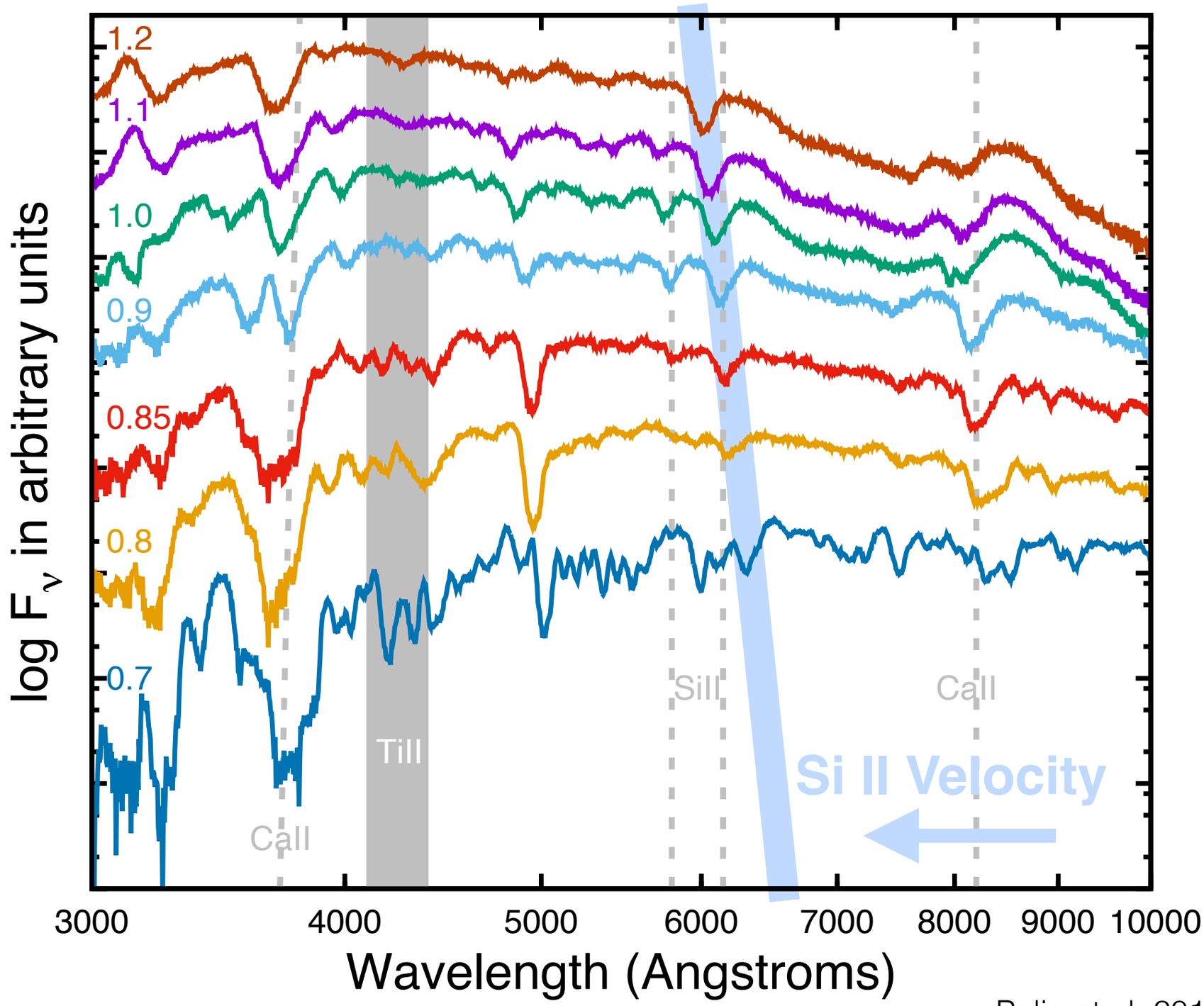
Luminosity - Velocity Relationship



Polin et al. 2019

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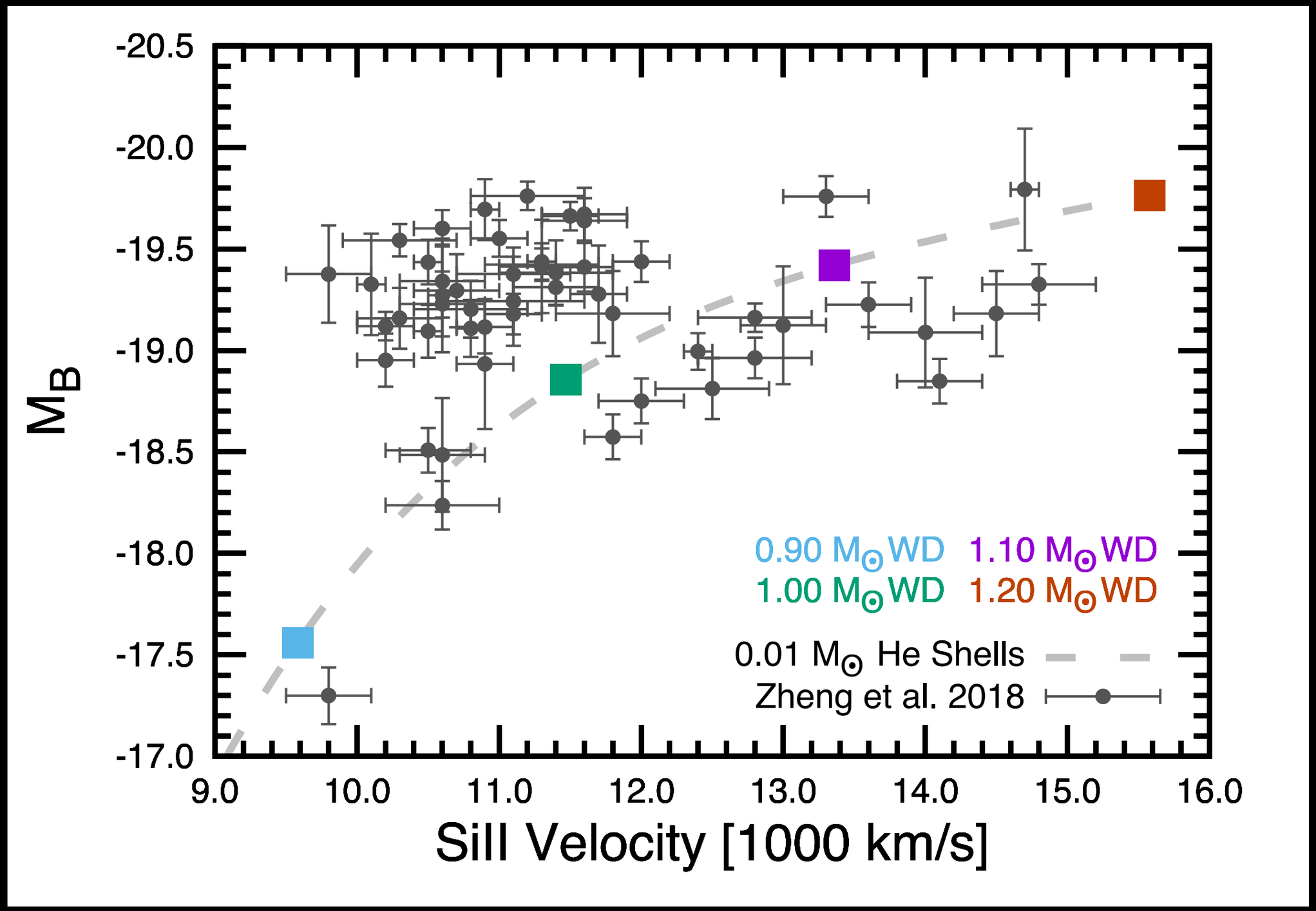
Two Populations of SNe Ia



Polin et al. 2019

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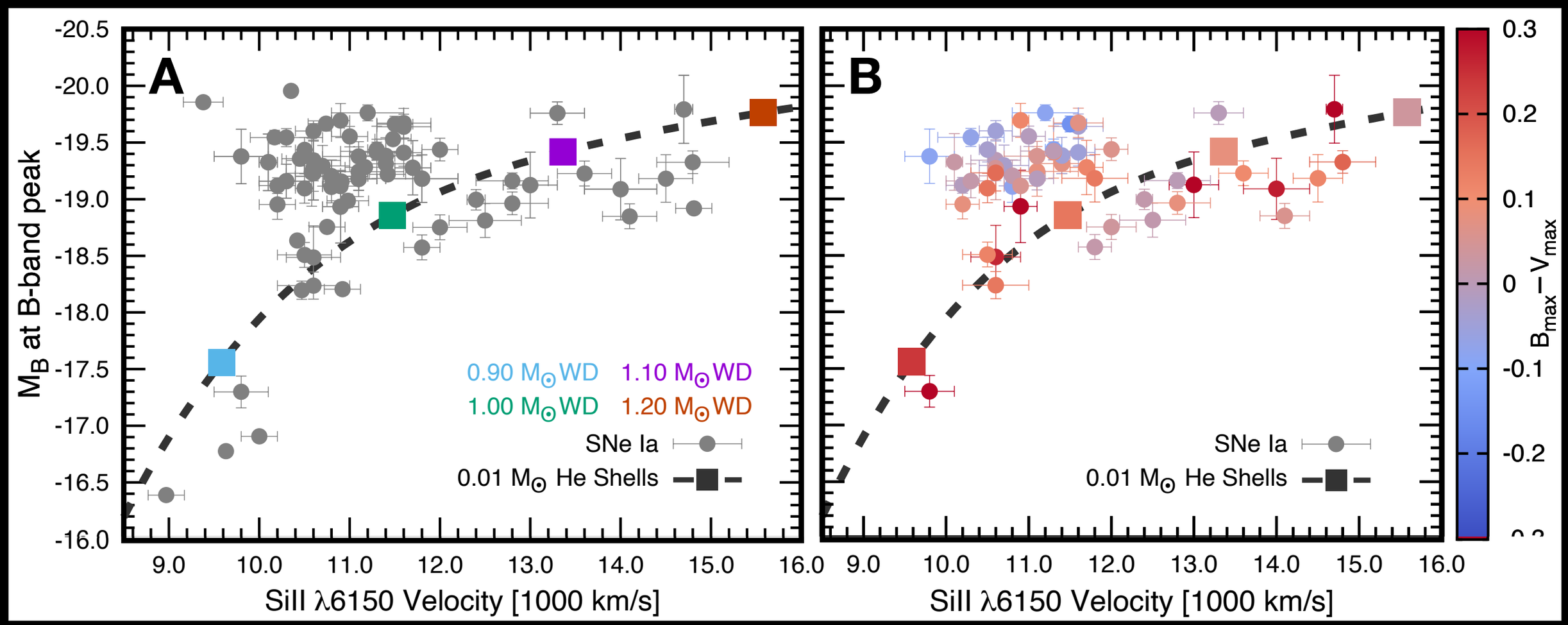
Populations Have Different Colors



Polin et al. 2019

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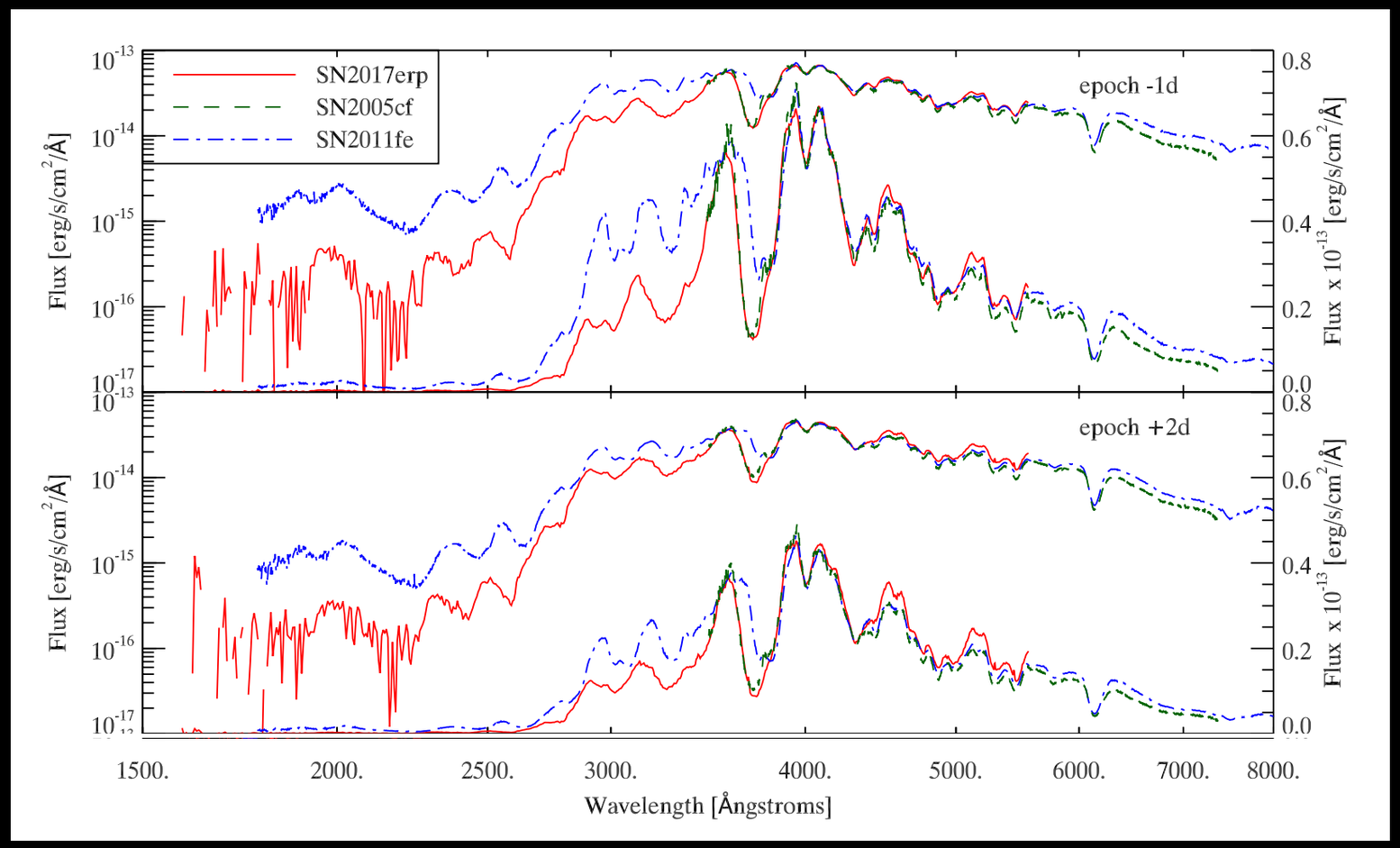
New Landscape for UV Discovery

UVEX
(accepted for NASA Explorer's Program Phase A)

- **deep whole sky survey**
- **two UV bands**
- **broad band spectrometer**

Optical colors may not be good enough:

Even at peak "Twin" Normal SNe Ia can look wildly different in the UV…



Brown+ 2019

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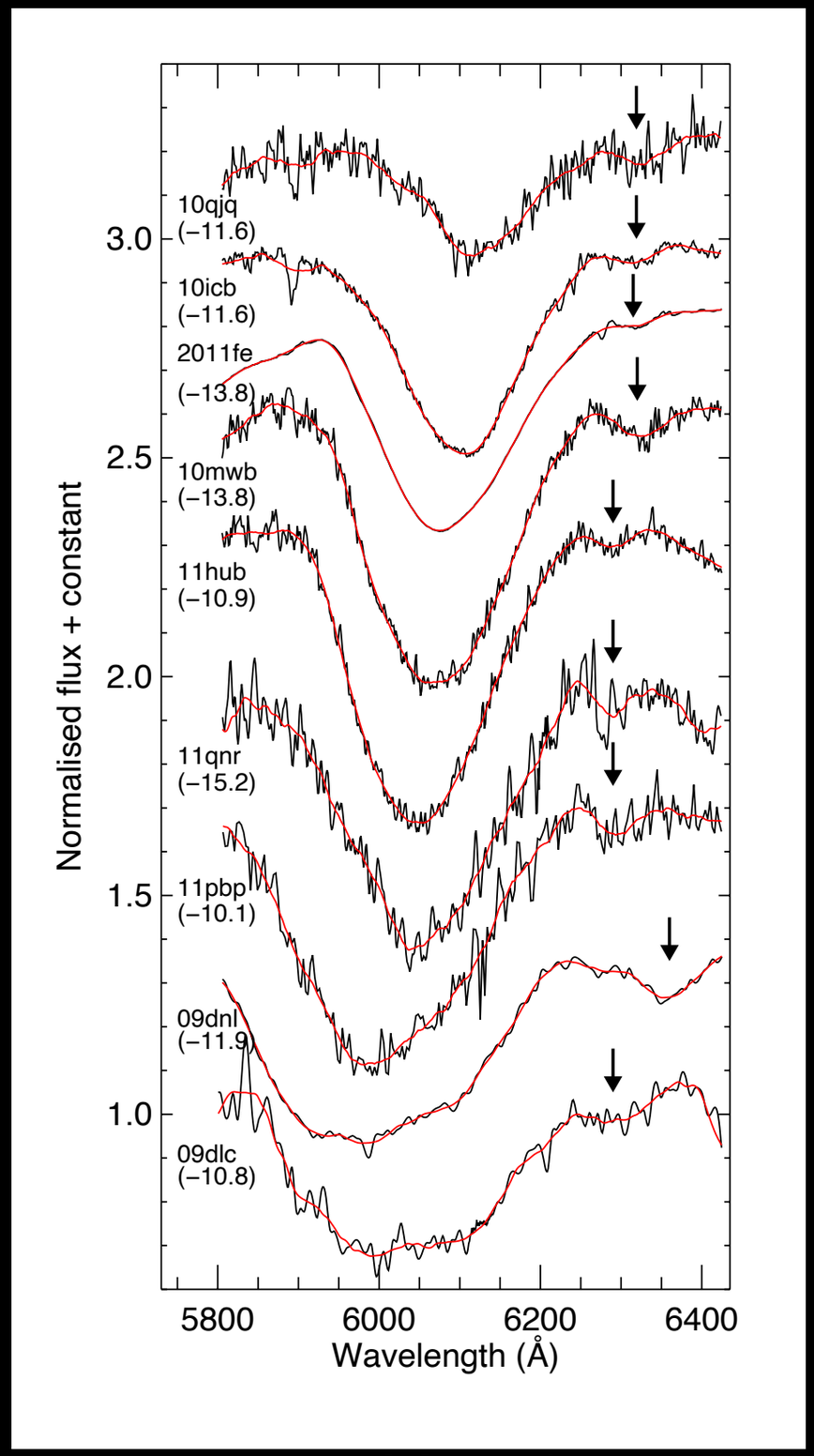
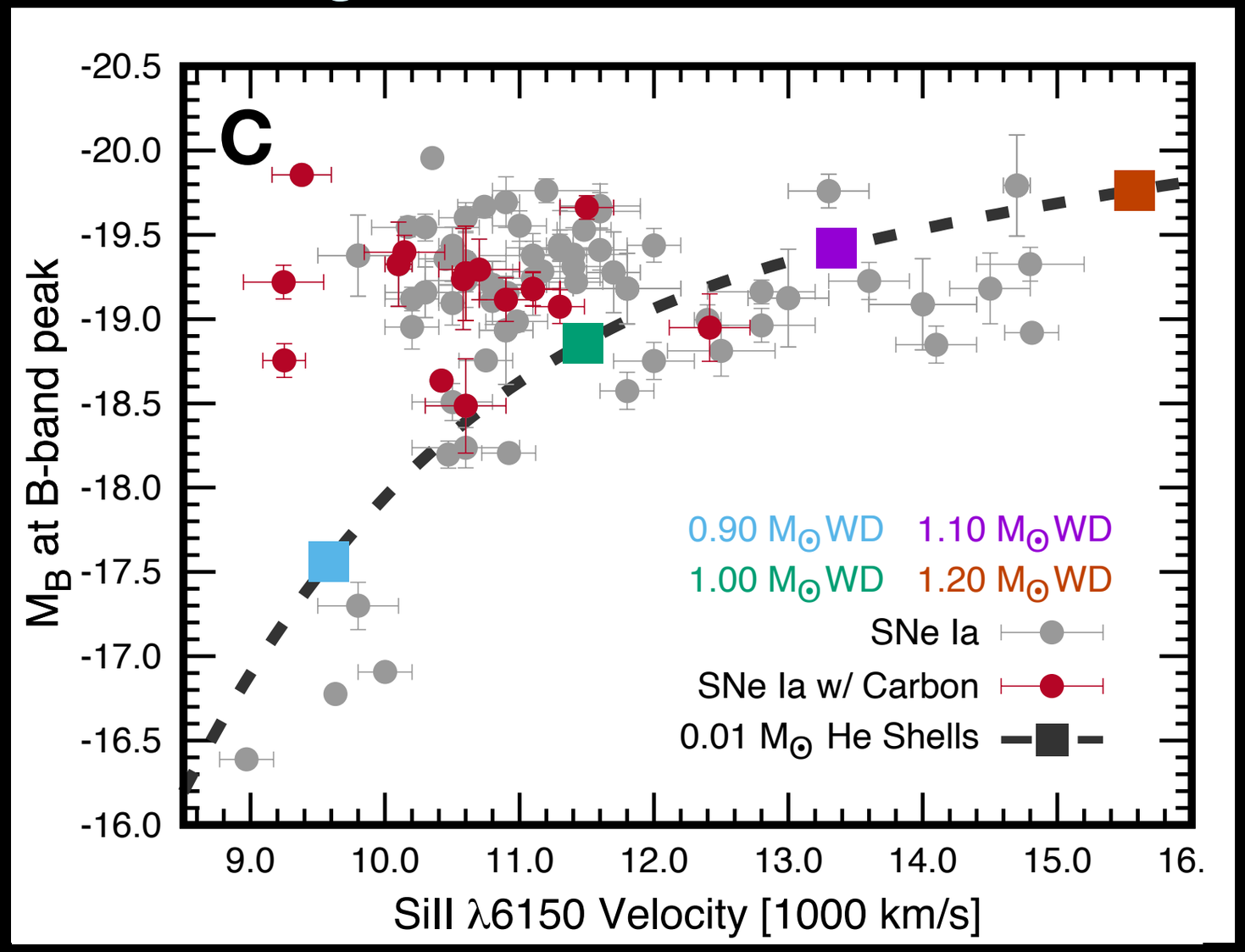
Carbon Features Imply a M_{Ch} Explosion



Maguire+ 2014

Adding PTF SNe w/ Carbon Features



Polin 2020

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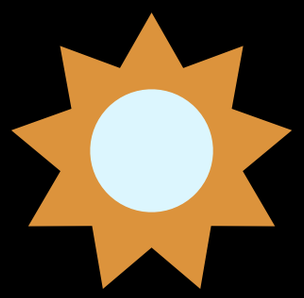
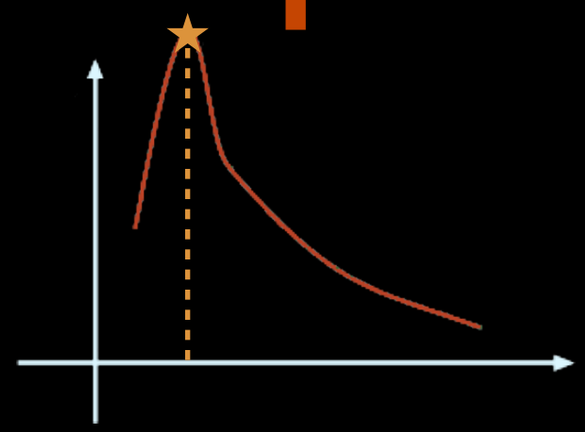
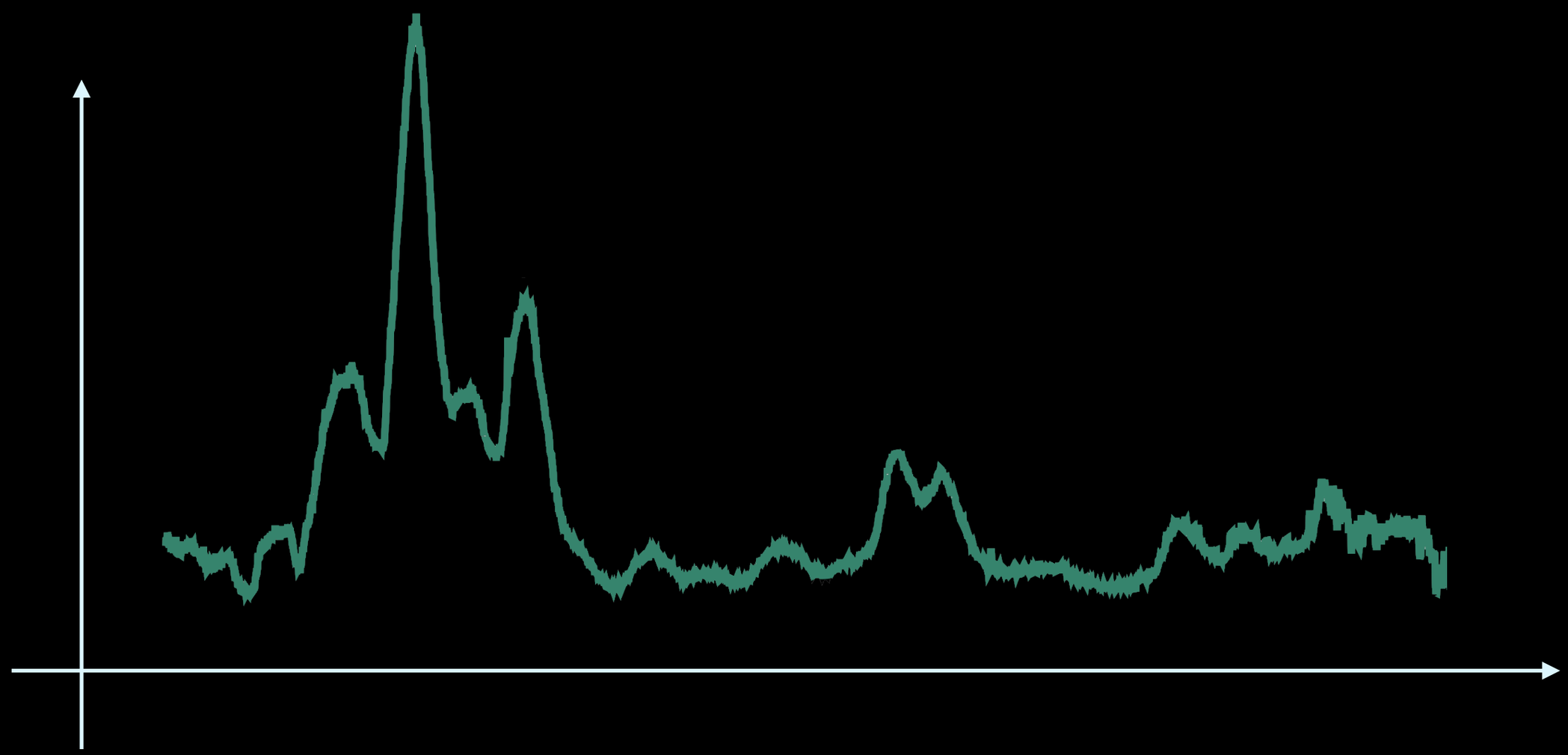
Infancy

Peak Times

Nebular Phase







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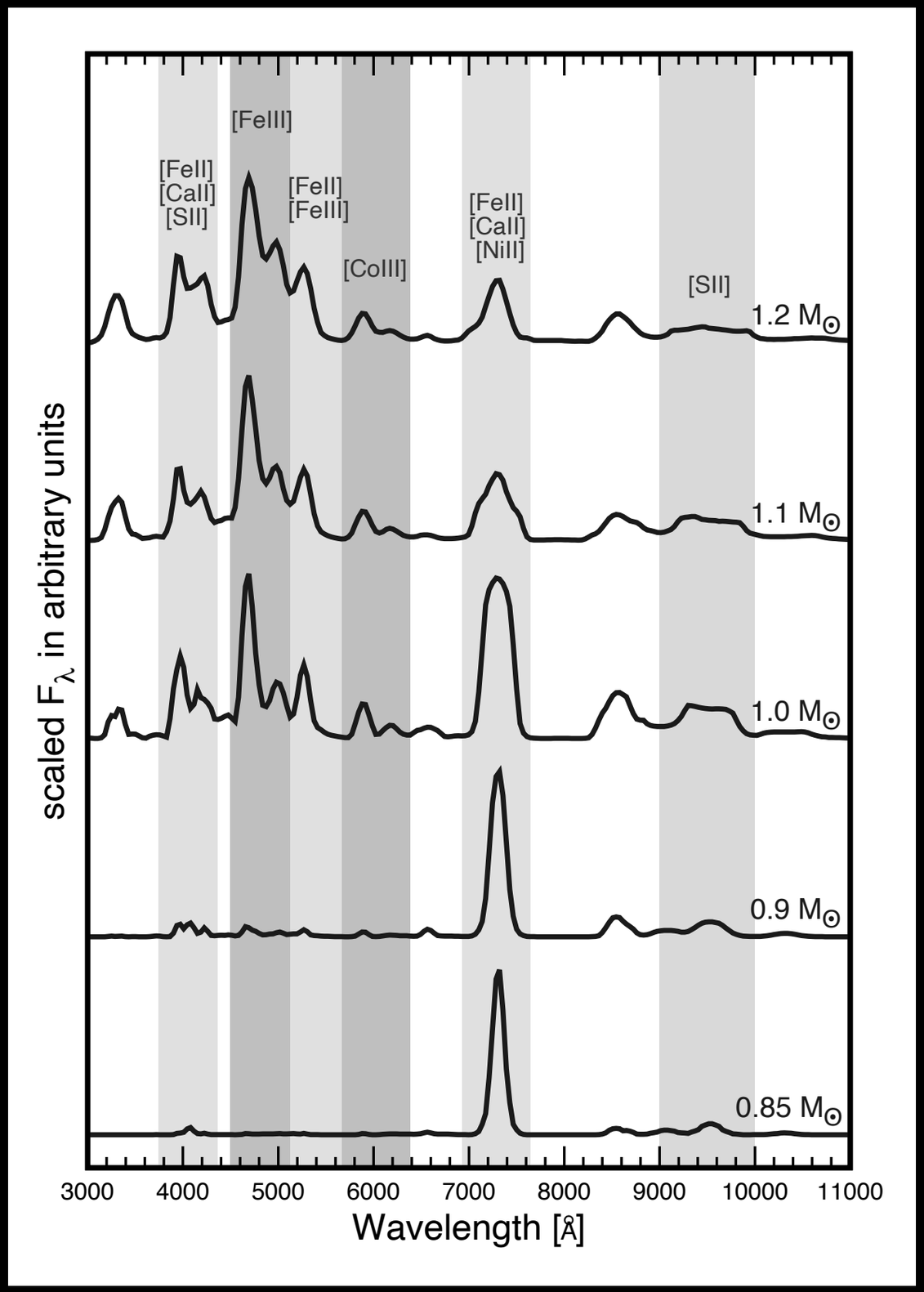
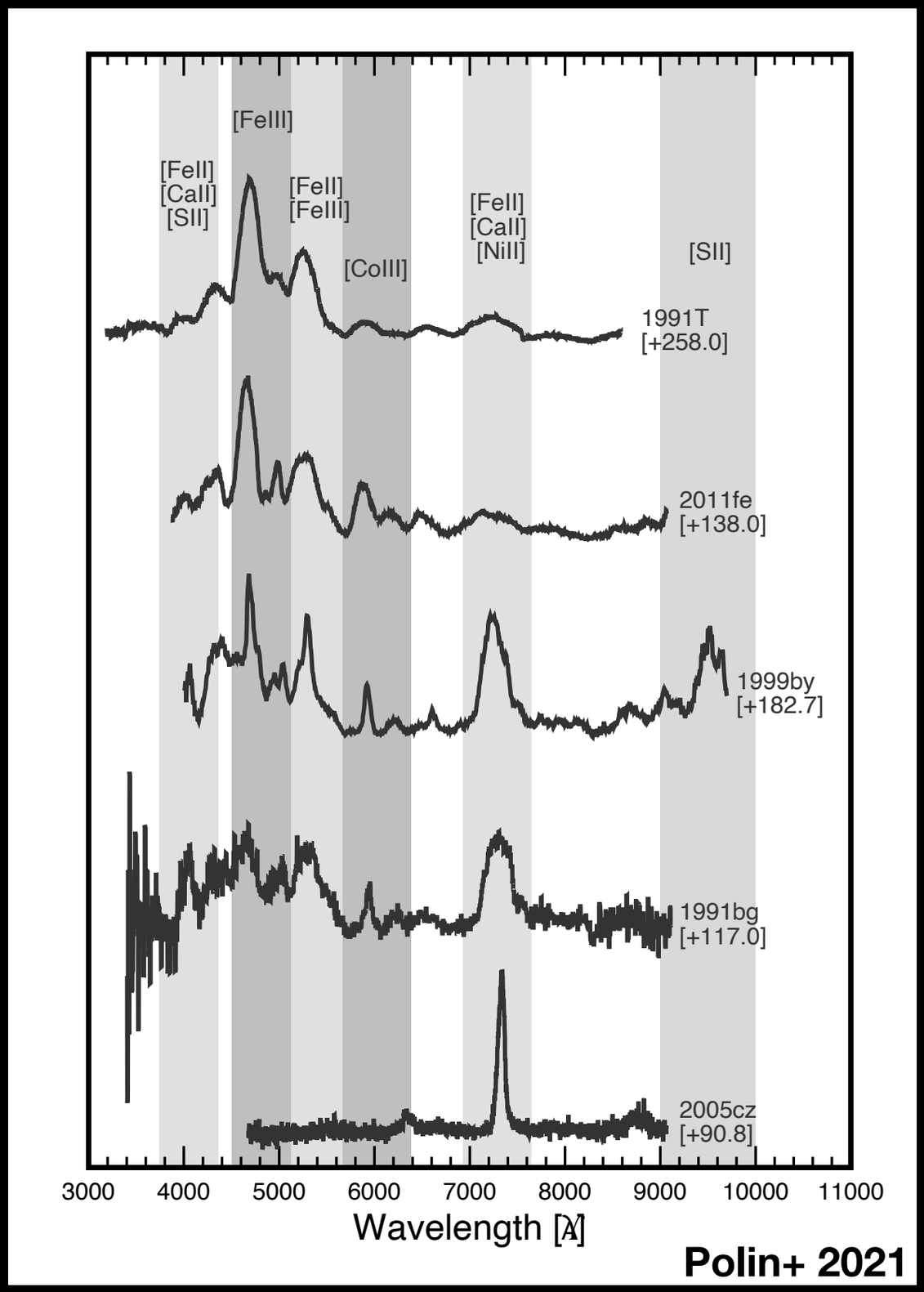
Nebular Double Detonations - [Ca II]





Polin+ 2021

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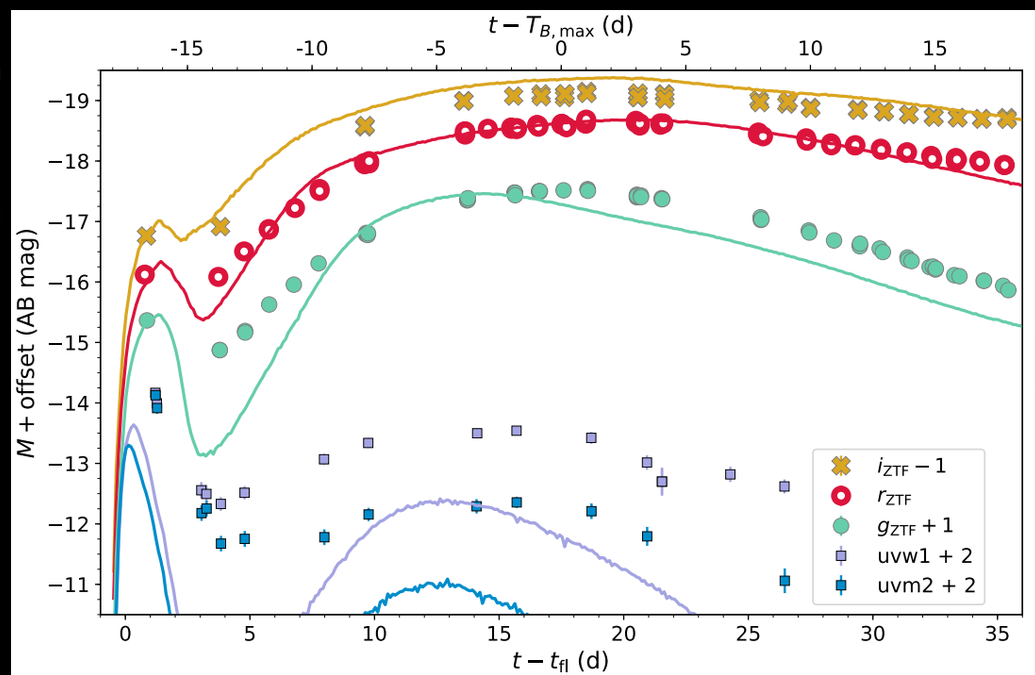
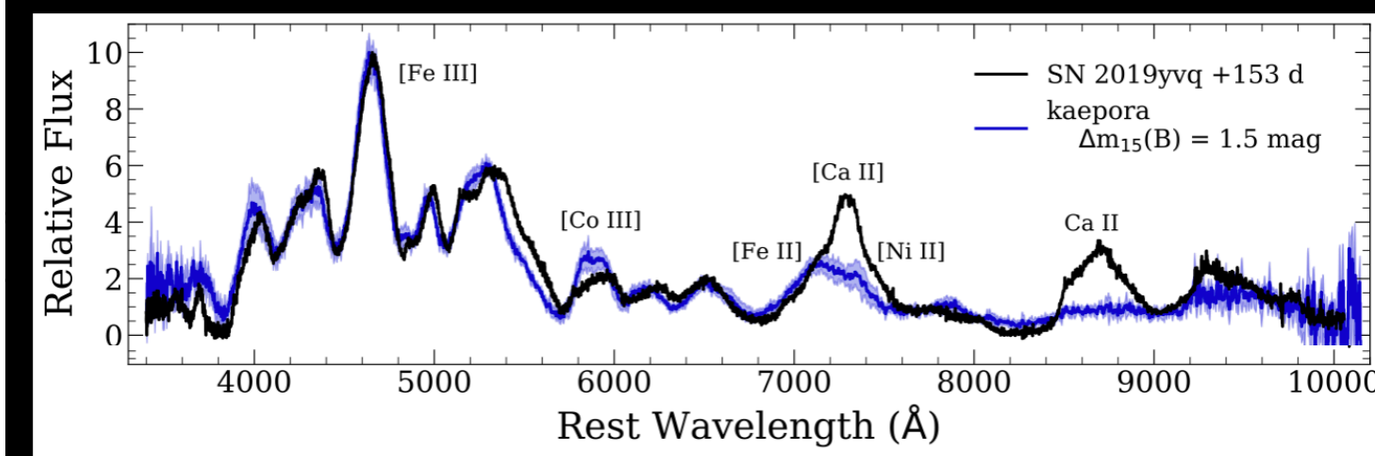
SNe Ia w/ Strong [Ca II] Emission

SN 2019yvq

Early Bump + **Nebular [Ca II]**



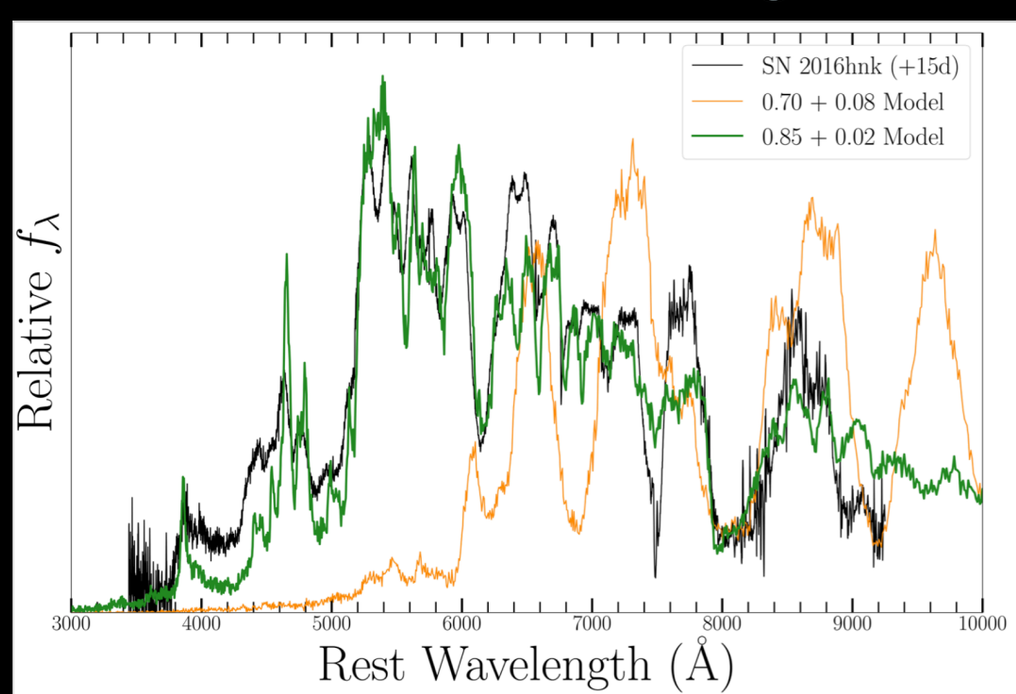


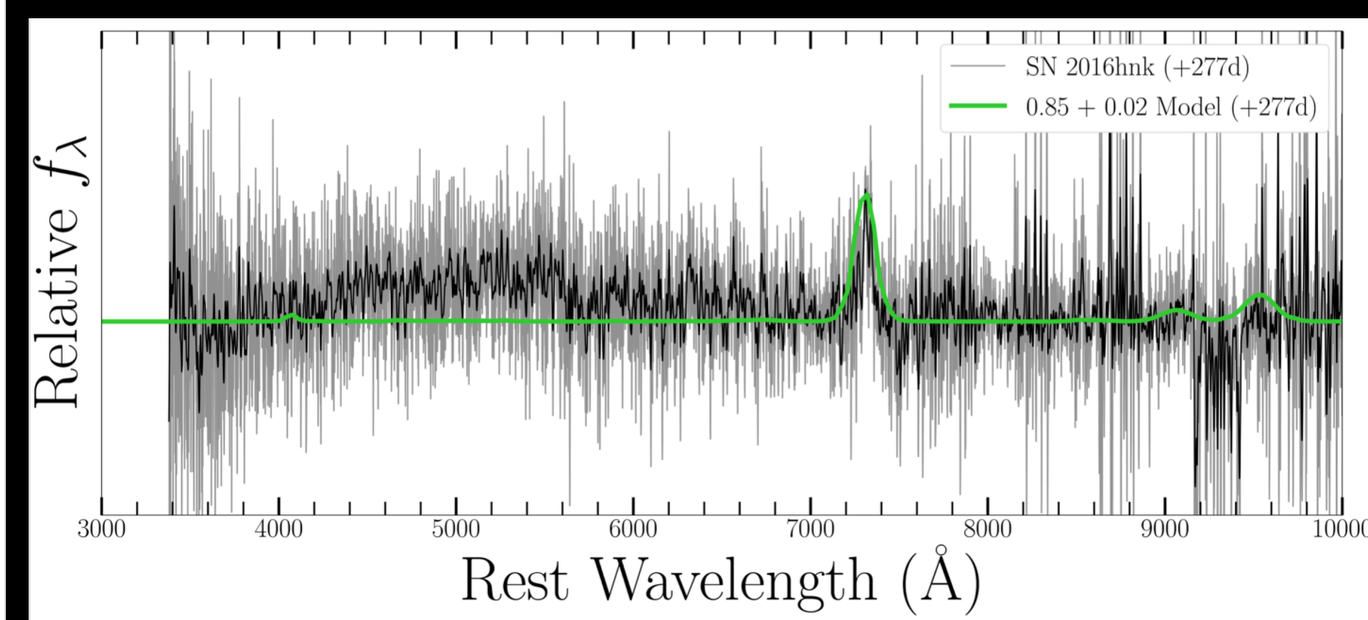
Siebert+ 2020

Miller+ 2020

SN 2016hnk

Peak Line Blanketing + **Nebular [Ca II]**





Jacobson-Galan+ 2019

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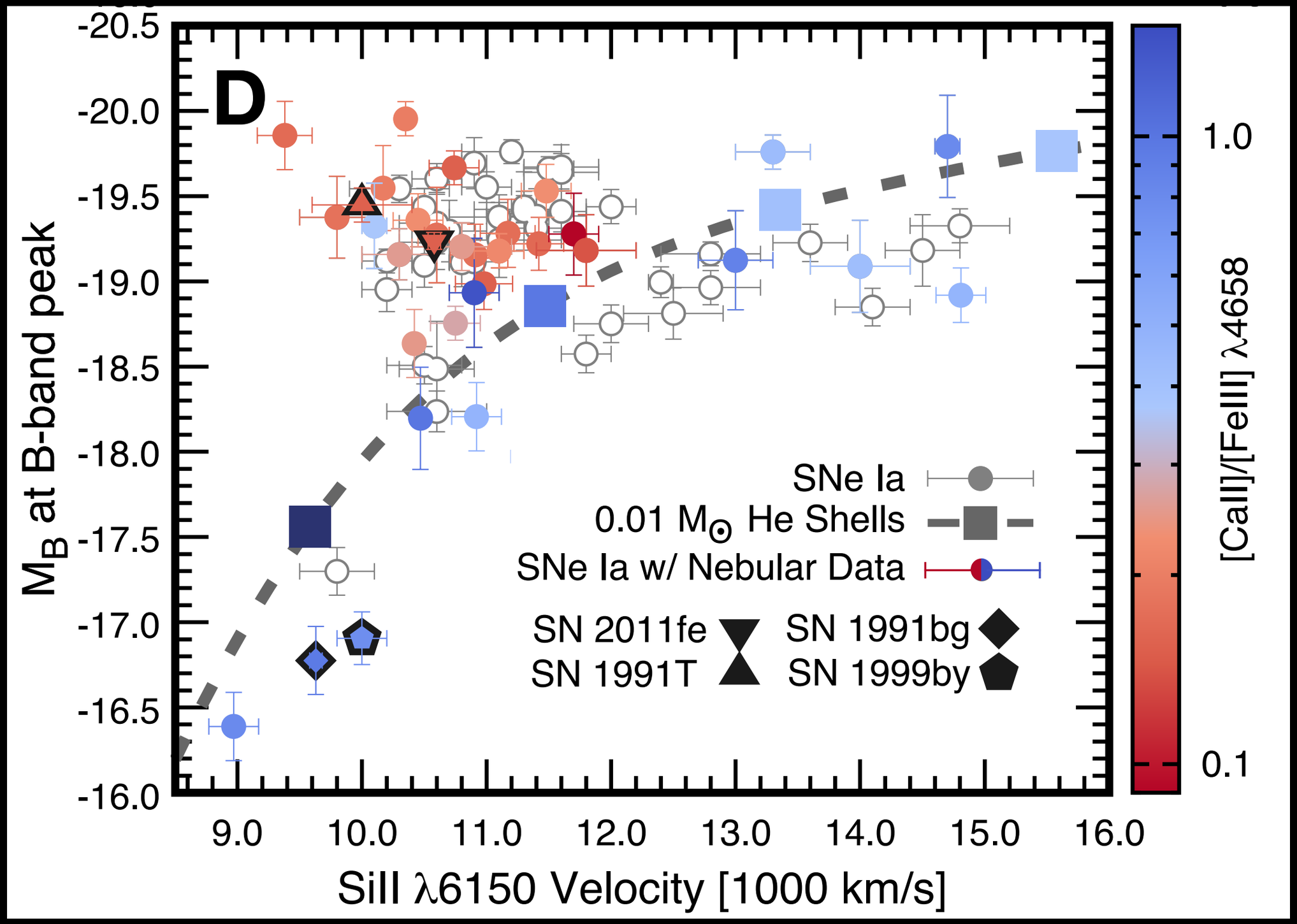
[Ca II] Emission in Ia Populations



Polin + 2020

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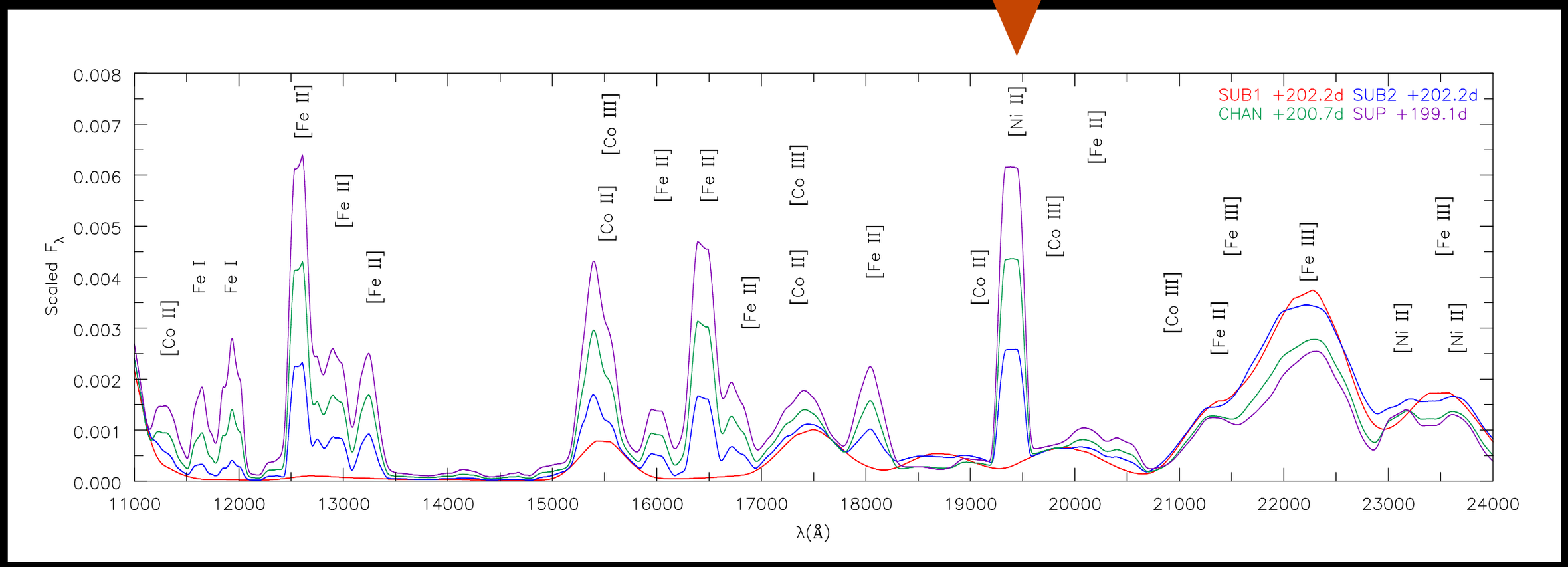
NIR Nebular Features — Stable Ni

Stable Ni Requires High Density Environments: Favors a M_{Ch} Explosion

Uncontaminated [Ni II] in the NIR



Wilk+ 2018

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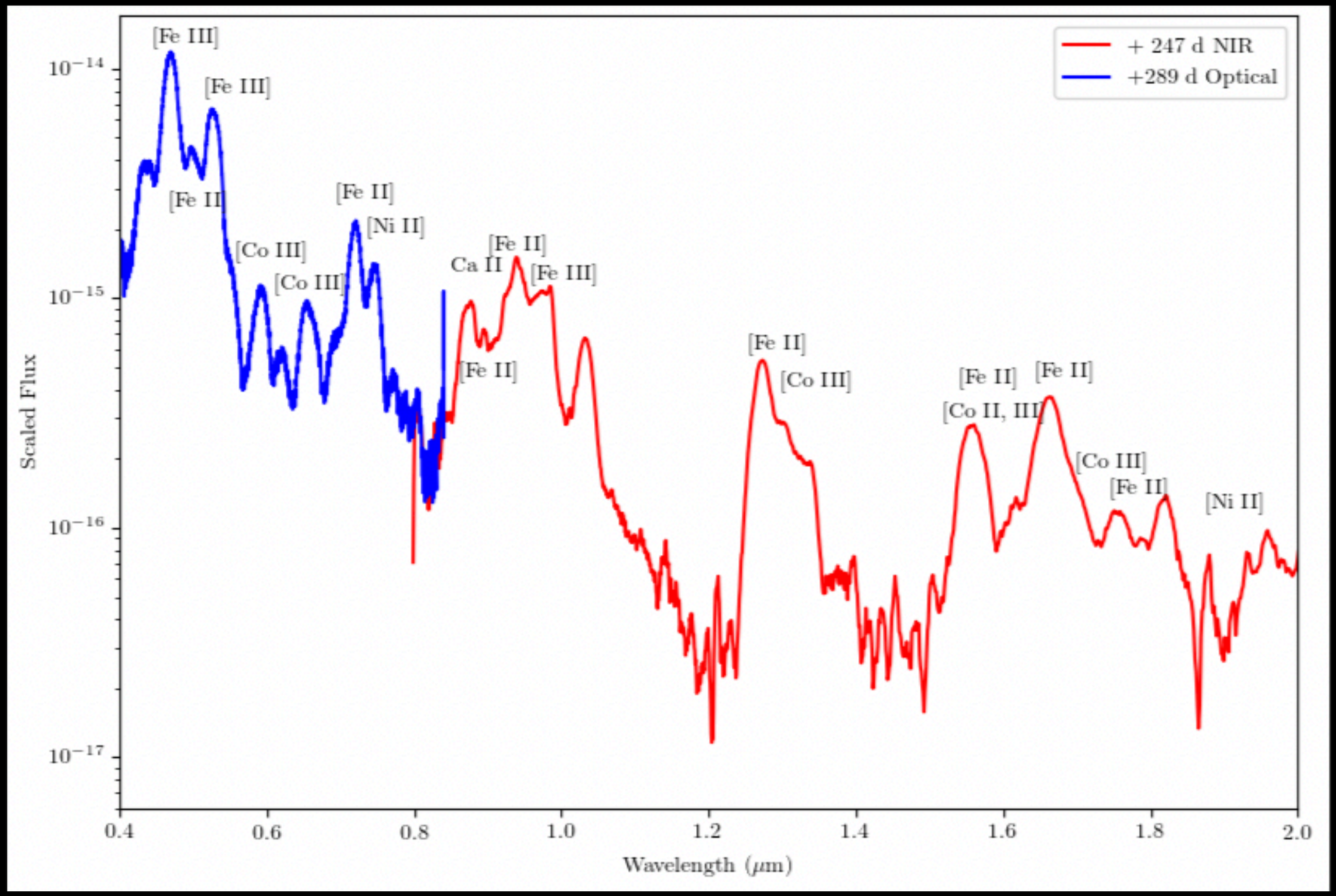
Simultaneous Multiwavelength Nebular Ia

[Ca II] in the Optical OR **[Ni II] in the NIR**



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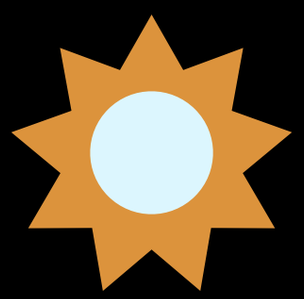
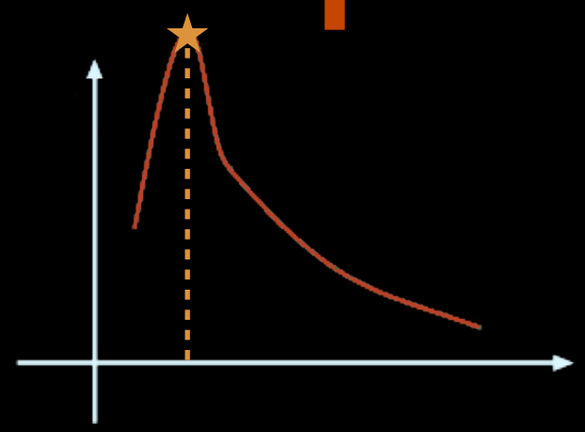
Infancy | **Peak Times** | **Nebular Phase** | **Remnant**



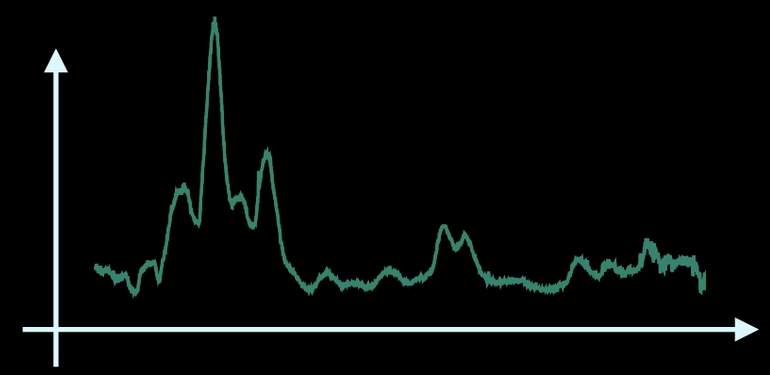
Early Flux Excesses



Velocities

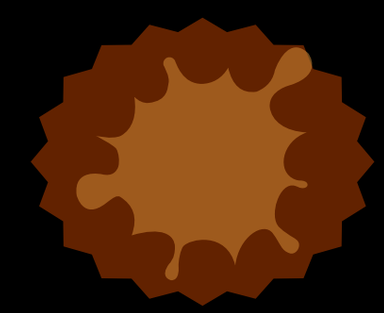
Colors

Carbon Features



[Ca II] Emission

Stable Ni (NIR)



Coming Soon

solving this problem requires a coordination between theory efforts with multi-epoch and multi-wavelength observations

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