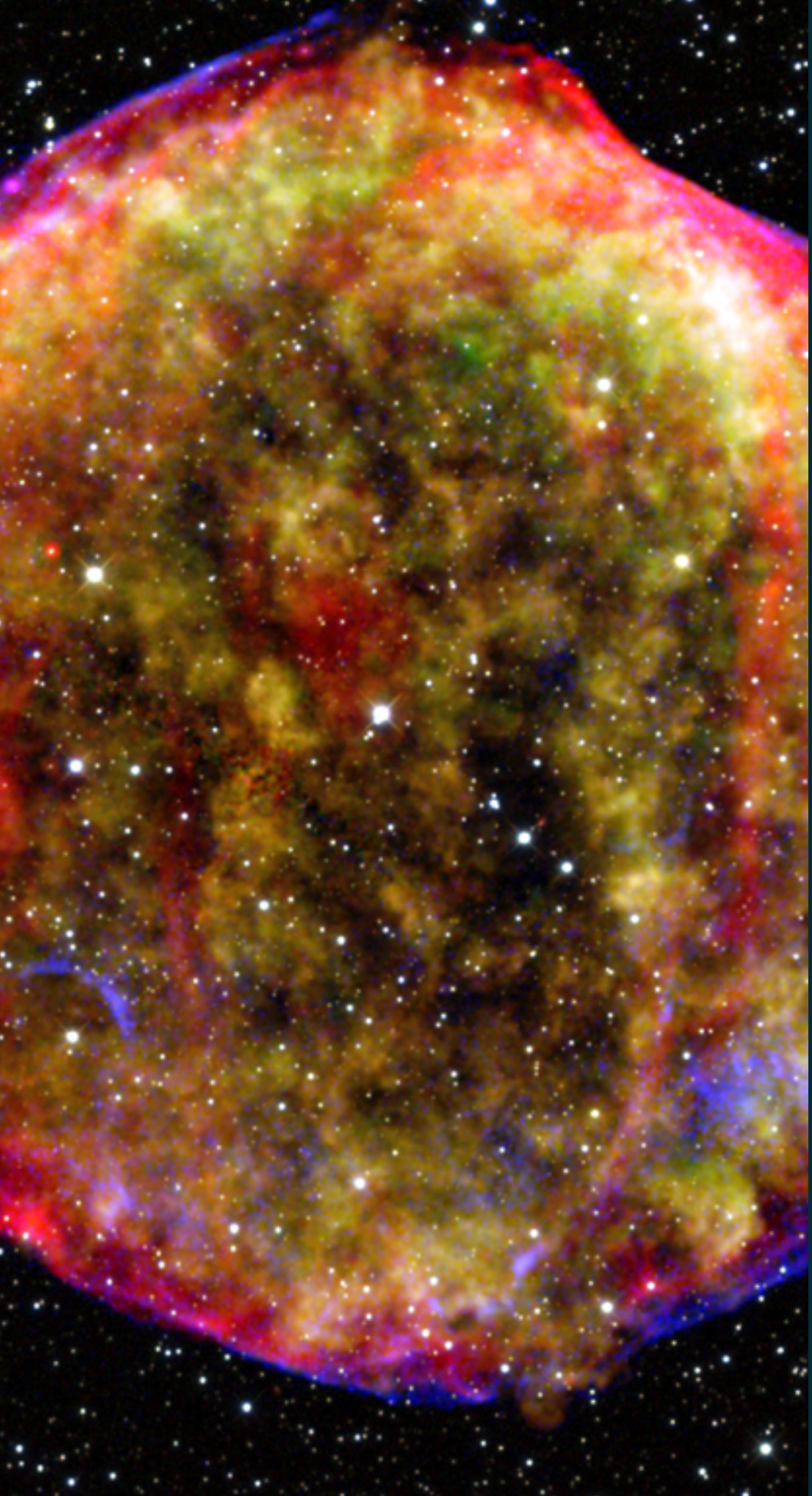
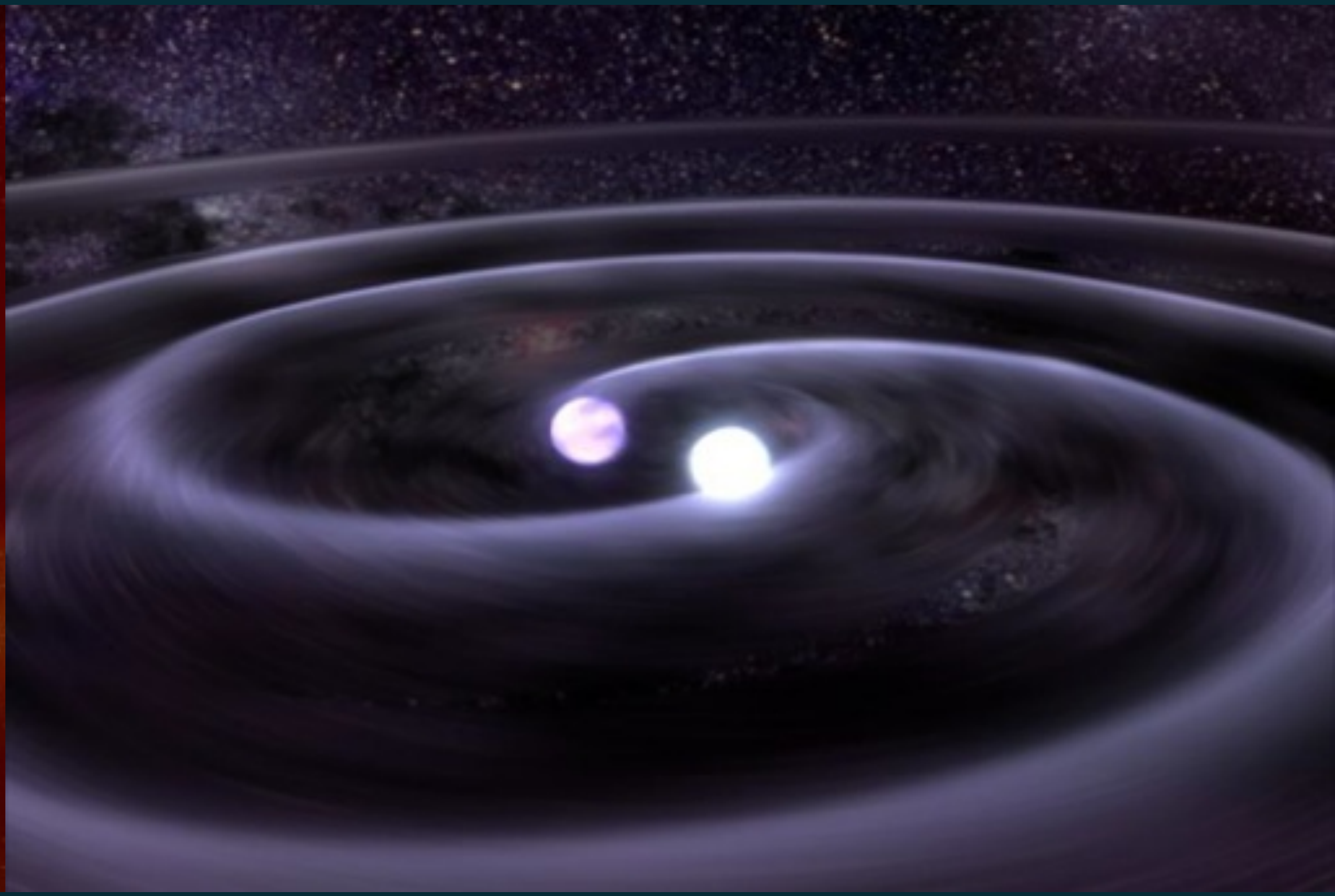


theory and modeling

summary

Edward Brown
Michigan State University

required for admission



Importance [Livio]

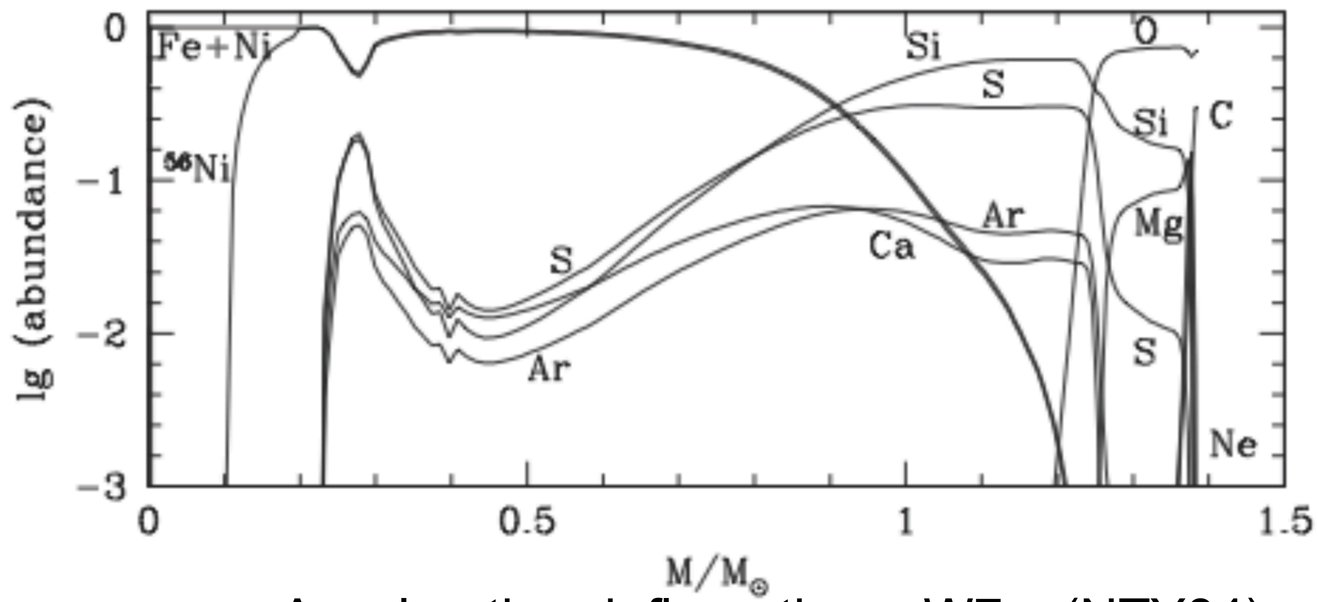
- Understanding the progenitors and explosion models are essential for understanding systematics and galactic chemical evolution

the problem | shift in view

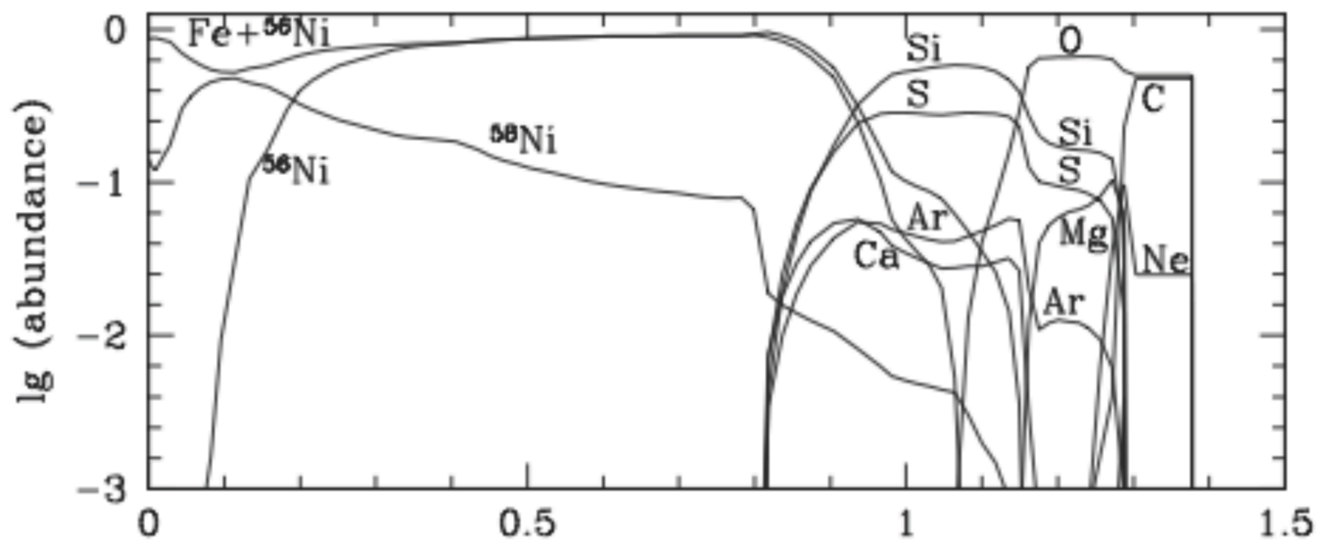
- “I thought I knew what the progenitors are. I don’t know anymore.”—Livio

- We used to ask, “What is a type Ia supernova?”; we now ask, “What are type Ia supernovae?”—Woosley

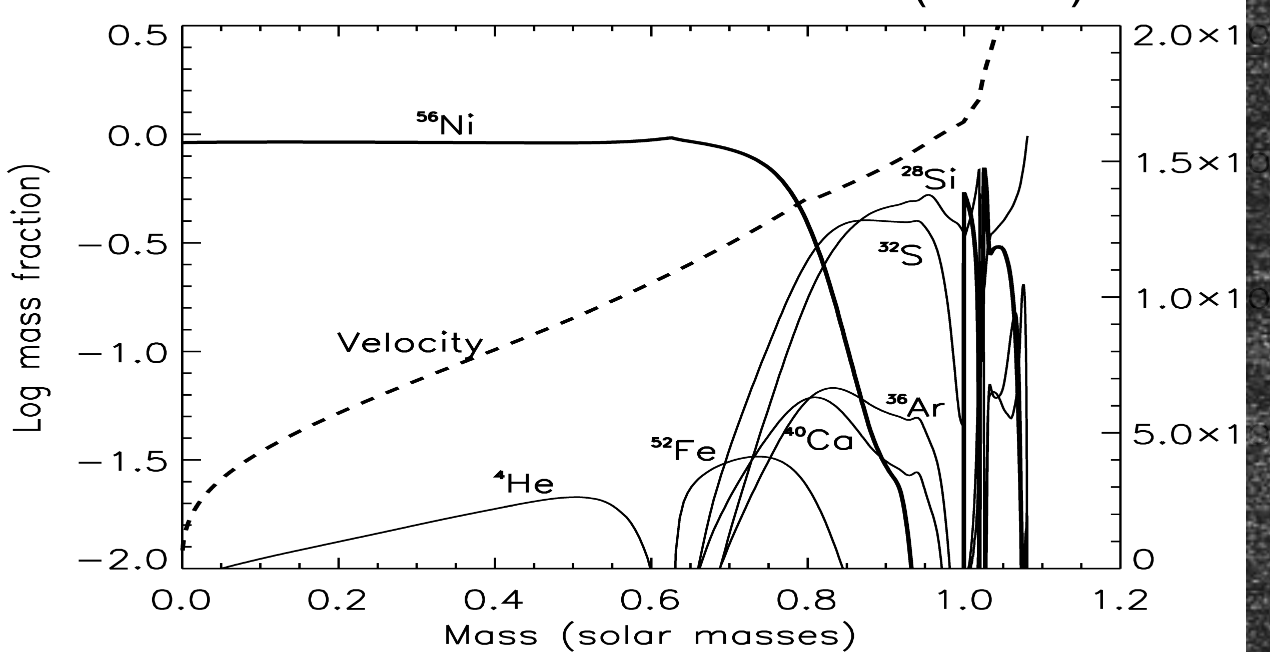
Delayed Detonation – DD4 - (WW90)



Accelerating deflagration – W7 – (NTY84)



sub-Chandrasekhar – 10H – (WK11)



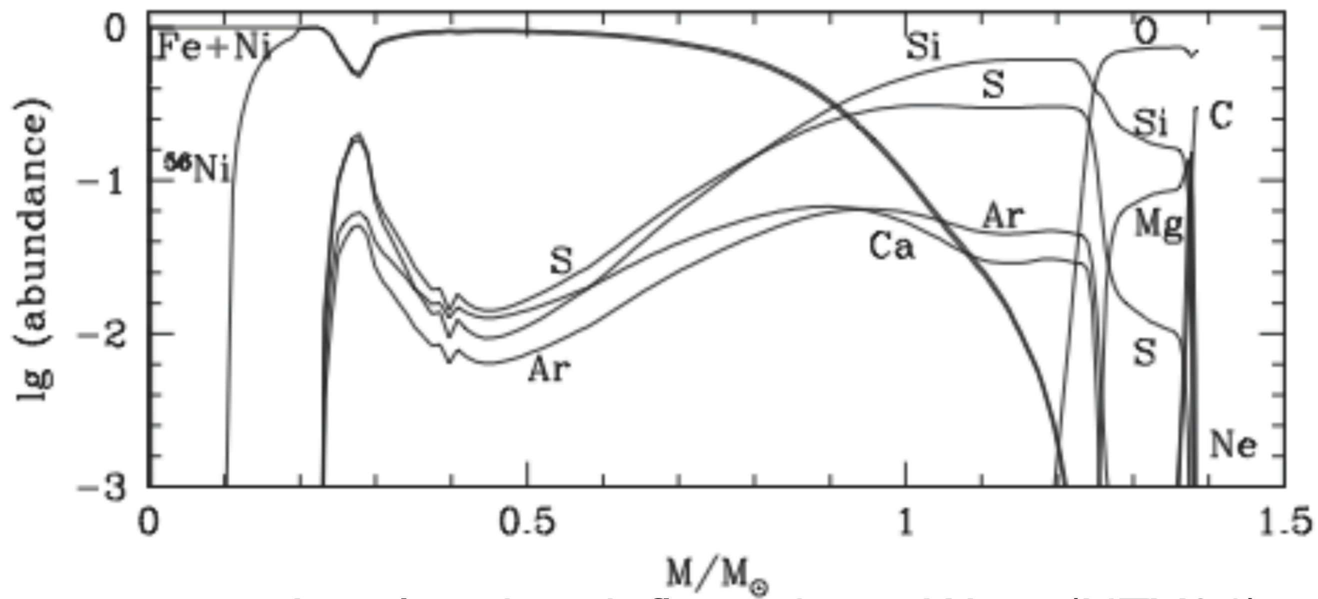
The Answer
(You already knew it)

Model	^{56}Ni	Si+S	KE/gm
	Msun	Msun	10^{17}
DD4	0.63	0.42	4.5
W7	0.63	0.23	4.7
10H	0.62	0.29	5.3*

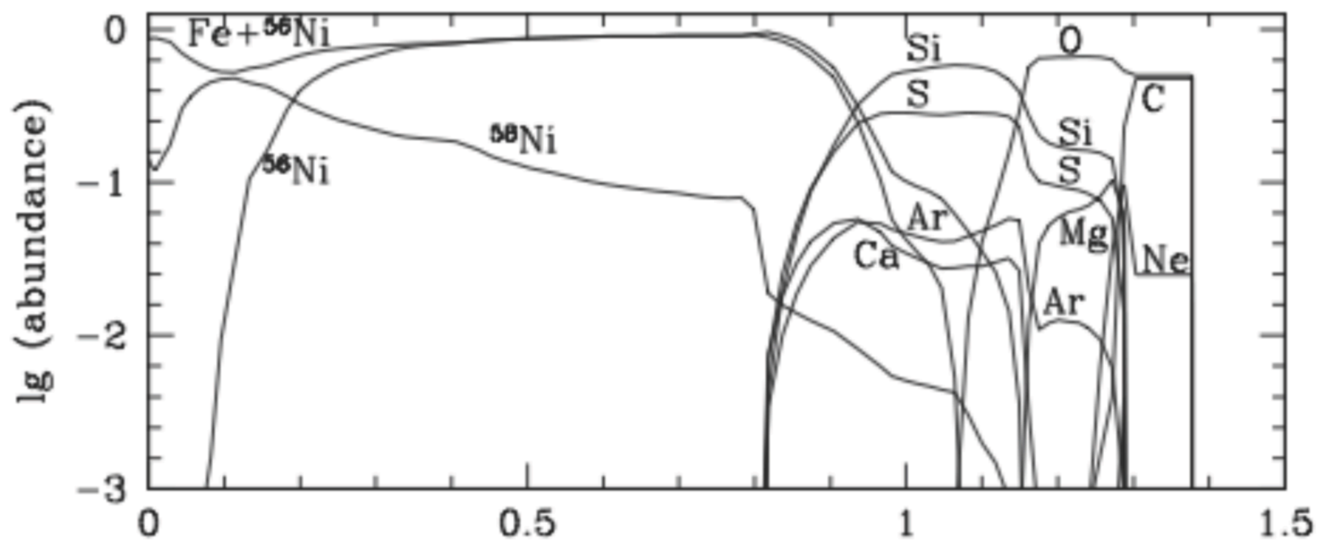
*6.0 if include outer 0.045 solar masses of hi-v helium

A SN Ia is the outcome of detonating 1 solar mass of carbon and oxygen with $\rho_{max} \approx 0.5 - 2 \times 10^8$ g cm^{-3}

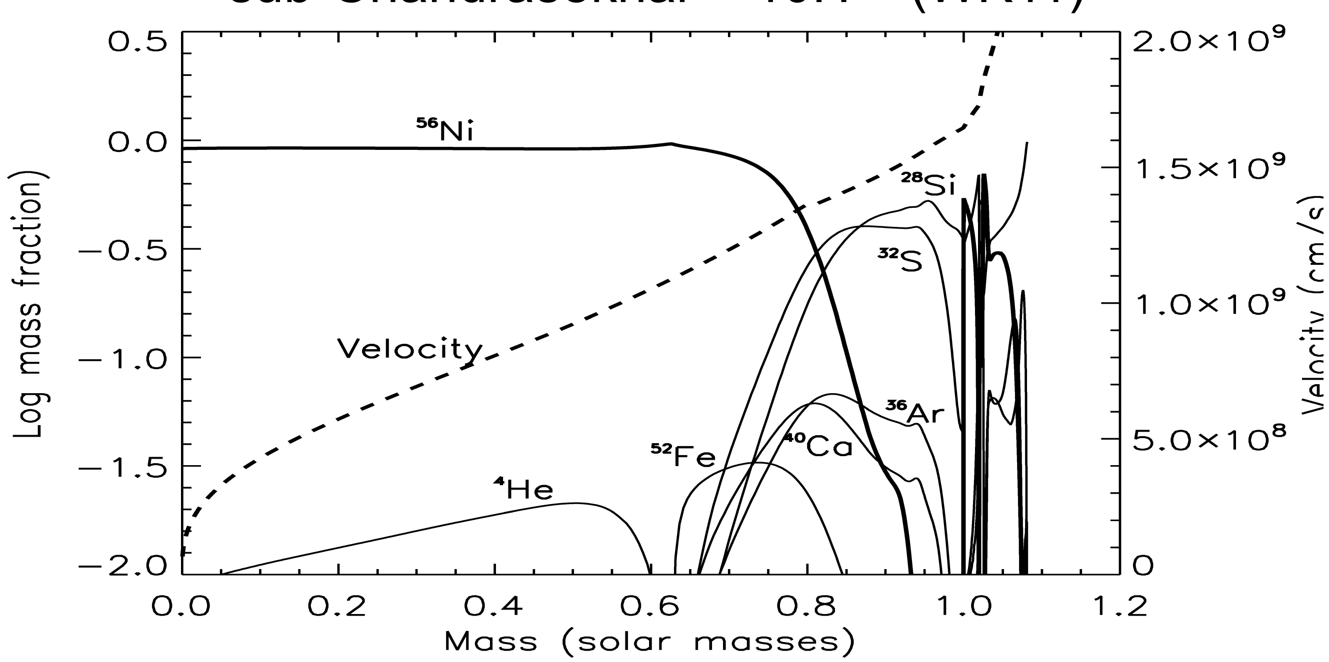
Delayed Detonation – DD4 - (WW90)



Accelerating deflagration – W7 – (NTY84)



sub-Chandrasekhar – 10H – (WK11)



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A SN Ia is the outcome of detonating 1 solar mass of carbon and oxygen with $\rho_{max} \approx 0.5 - 2 \times 10^8$ g cm^{-3}

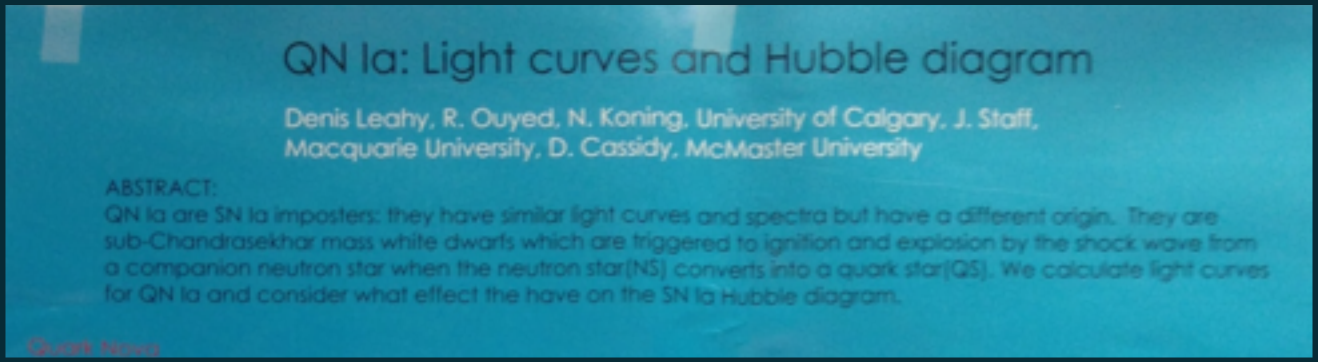
zeroth order

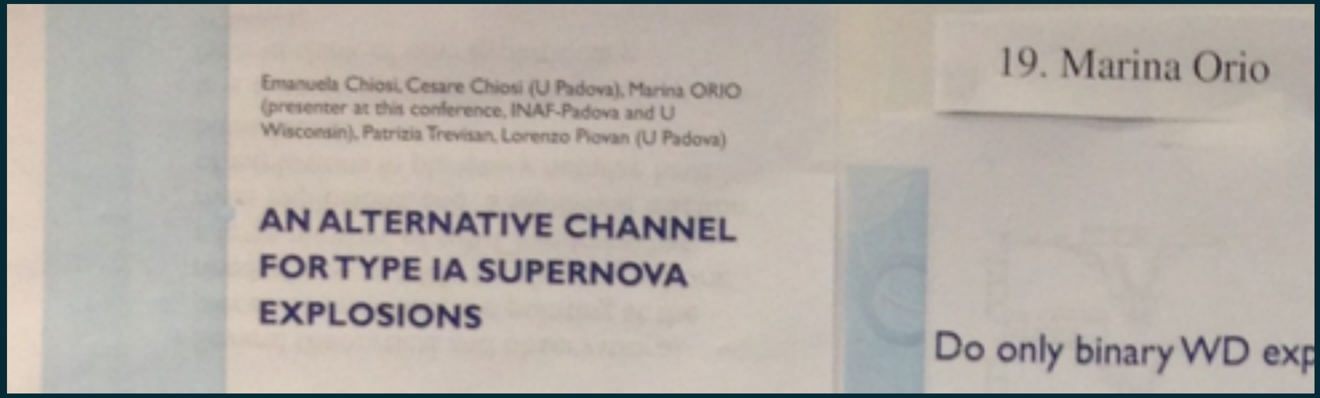
- Detonation of ≈ 1 M_{sun} C/O is sufficient to produce something that is broadly consistent in appearance with bulk of observed Ia's

- We must do more

alternatives

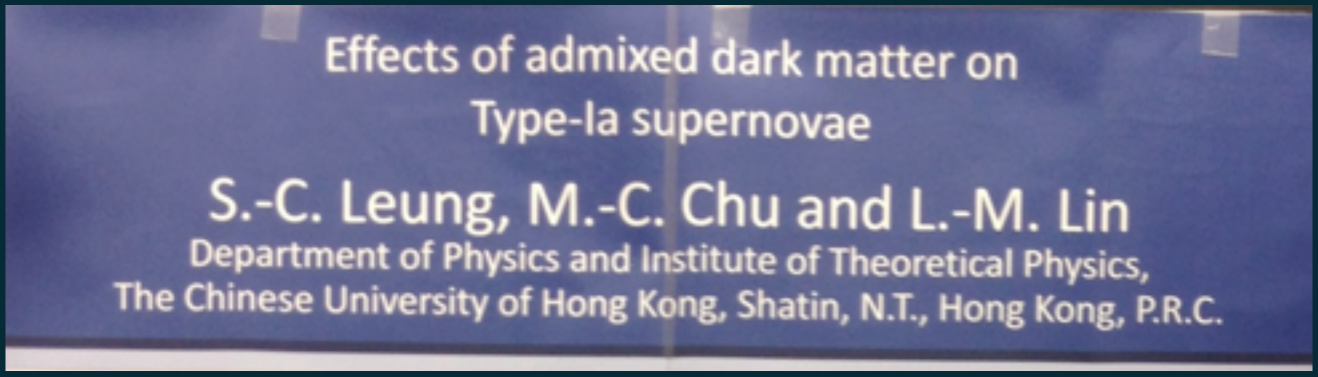
ignition triggered by conversion of neutron star to quark star





ignition in a solo white dwarf triggered by pycnonuclear reactions

admixture of DM (~ few%) into WD lowers Chandrasekhar mass



single-degenerate

- formation of white dwarf, evolution to thermal instability (implicit lagrangian code, e.g., MESA)
- simmering (or is it smoldering?): early stages with stellar evolution code (but important to treat electron captures—convective Urca—carefully)
- just prior to explosion: low mach number code (MAESTRO)
- explosion: explicit hydro (FLASH)
- post-explosion, light curve: radiative transfer

Hybrid C-O-Ne White Dwarfs as Progenitors of Diverse SNe Ia

\. Denissenkov[1,4,9], J. W. Truran[2,4,9], F. Herwig[1,4,9], S. Jones[1,5,9], B. Paxton[3], K. Nomoto[6,10], T. Suzuki[7] and H. Toki[8]

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[2]Department of Astronomy and Astrophysics, and Enrico Fermi Institute, University of Chicago, Chicago, IL 60637 USA
[3]Kavli Institute for Theoretical Physics and Department of Physics, Kohn Hall, University of California, Santa Barbara, CA 93106, USA
[4]The Joint Institute for Nuclear Astrophysics, Notre Dame, IN 46556, USA
[5]Astrophysics Group, Research Institute for the Environment, Physical Sciences and Applied Mathematics, Keele University, Keele, Staffordshire ST5 5BG
[6]Kavli Institute for Physics and Mathematics of the Universe (WPI), The University of Tokyo, Kashiwa, Chiba 277-8583, Japan
[7]Department of Physics, College of Humanities and Sciences, Nihon University, Sakurajosui 3-25-40, Setagaya-ku, Tokyo 156-8550, Japan
[8]Research Center for Nuclear Physics, (RCNP), Osaka University, Ibaraki, Osaka 567-0047, Japan
[9]NuGrid collaboration
[10]Hamamatsu Professor

ABSTRACT

When ... bon is ignited off-centre in a CO core of a super-AGB star, its burning in a convective shell tends to propa... to the center. Whether the C flame will actually be able to reach the center depends on the efficiency of extra ...g beneath the C convective shell. Whereas thermohaline mixing is too inefficient to interfere with the C-flame ...agation, convective boundary mixing can prevent the C burning from reaching the center. As a result, a C-O-N... ...te dwarf (WD) is formed, after the star has lost its envelope. Such a "hybrid" WD has a small CO core surroun... by a thick ONe zone. In our 1D stellar evolution computations the hybrid WD is allowed to accrete C-rich ma...l, as if it were in a close binary system and accreted H-rich material from its companion with a sufficie... high rate at which the accreted H would be processed into He under stationary conditions, assuming that He ...ld then be transformed into C. When the mass of the accreting WD approaches the Chandrasekhar limit, we find ...eries of convective Urca shell flashes associated with high abundances of ^{23}Na and ^{25}Mg. They are followed b... off-center C ignition leading to convection that occupies almost the entire star. To model the Urca processes ...e use the most recent well-resolved data for their reaction and neutrino-energy loss rates. Because of the emphasized uncertainty of the convective Urca process in our hybrid WD models of SN Ia progenitors, we consider a number of their potentially possible alternative instances for different mixing assumptions, all of which reach a phase of explosive C ignition, either off or in the center. Our hybrid SN Ia progenitor models have much lower C to O abundance ratios at the moment of the explosive C ignition than their pure CO counterparts, which may explain the ...served diversity of the SNe Ia.

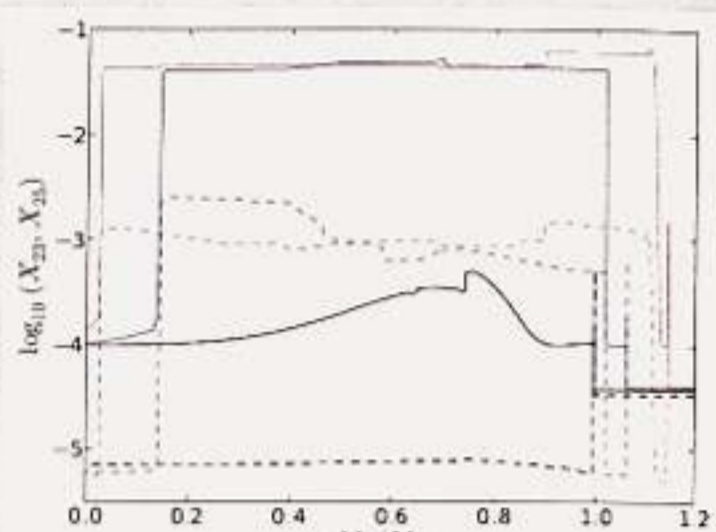


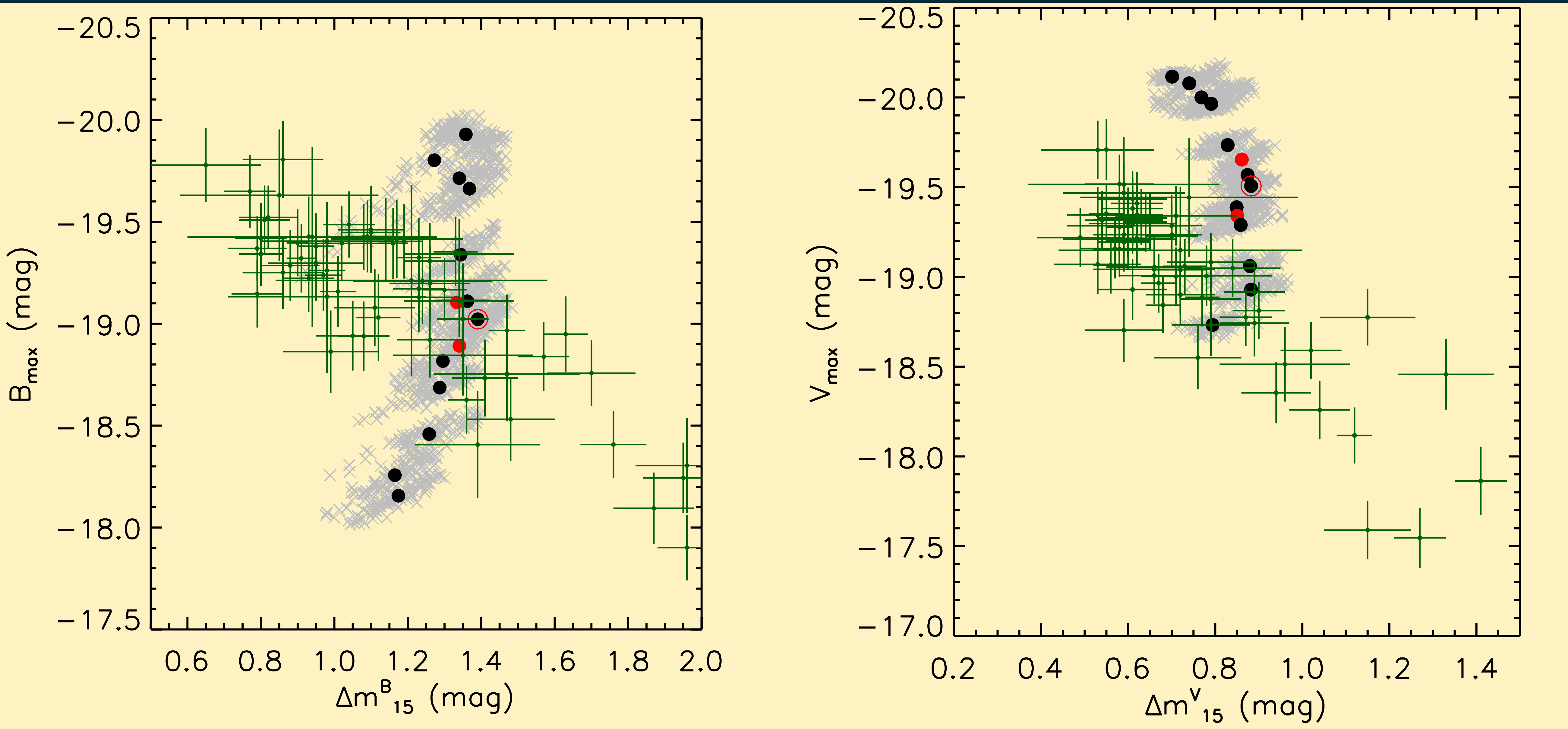
Figure 3. Mass fraction profiles of ^{23}Na (solid curves) and ^{25}Mg (dashed curves) in the CO core of the AGB star with ... curves) after the first He-shell thermal pulse, and in the hybrid C-O-Ne cores of the super-AGB stars with the initial mass ... curves) and 7.3$M_\odot$ (red curves) at the end of C burning.

1. The C flame quenching by convective boundary mixing in super AGB stars

single-degenerate

- formation of white dwarf, evolution to thermal instability (implicit lagrangian code, e.g., MESA)
- simmering (or is it smoldering?): early stages with stellar evolution code (but important to treat electron captures—convective Urca—carefully)
- just prior to explosion: low mach number code (e.g., MAESTRO); birth of flame (e.g., CASTRO)
- explosion: explicit hydro (e.g., FLASH)
- post-explosion, light curve: radiative transfer

DDT models (Sim et al.)



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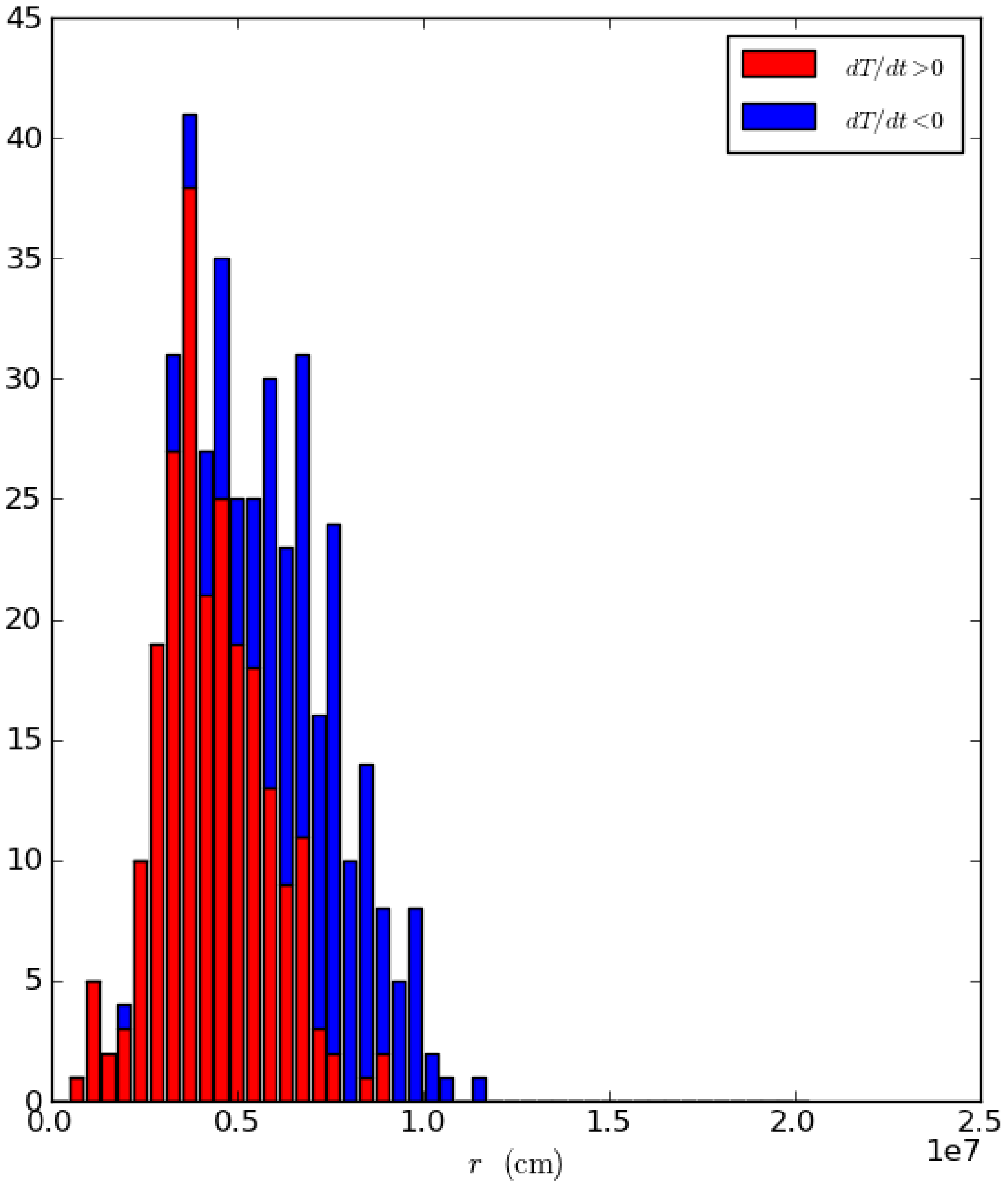
Ignition Radius Likelihood

- Distribution of likely ignition locations
  - Average hotspot radius over 1 s intervals
  - Consider final 200 s of evolution
- Vast majority of hotspots are moving outward from the center
- Off-center ignition likely



► Histogram of likely ignition radii from 576^3 non-rotating model. Hotspot radii are averaged into 1 s intervals and colored by sign of temperature change

Stony Brook University

Pulsation in Spherical Premixed Flames with Large Lewis Numbers

Center for Combustion Energy

Tsinghua University

Yang Gao[1,2,*], Yibo Zhao[1,3], Guangzheng Xing[1,3], Chung K. Law[1,4,*]

1 Center for Combustion Energy, Tsinghua University

2 Department of Thermal Engineering, Tsinghua University

3 Department of Engineering Physics, Tsinghua University

4 Department of Mechanical and Aerospace Engineering, Princeton University

I. Introduction

The thermal-diffusional pulsating instability of a premixed expanding spherical flame with Lewis number much greater than unity is considered. The positive flame curvature affects the critical value of the Zel'dovich number (dimensionless activation energy), hence facilitating the onset of the instability as well as increasing the amplitude of the resulting pulsating flame speed. This work is of particular relevance to the study of flame propagation in condensed matters and supernova flames whose Lewis numbers are much greater than unity.

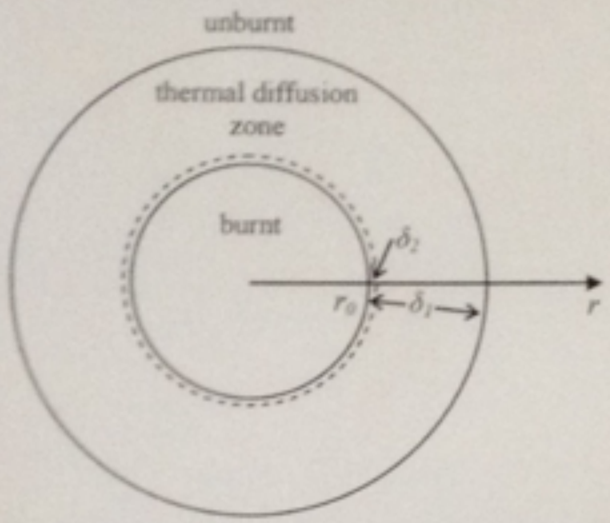


Fig. 1 Schematic of an expanding spherical flame with Lewis number much greater than unity. The thickness of the thermal diffusion zone δ_1 is much greater than the thickness of the mass diffusion zone, δ_2. A secondary hot flame can be generated in the boundary of the mass diffusion (dash line) where unburnt fuel dominates and the temperature is much higher than the reaction induction temperature.

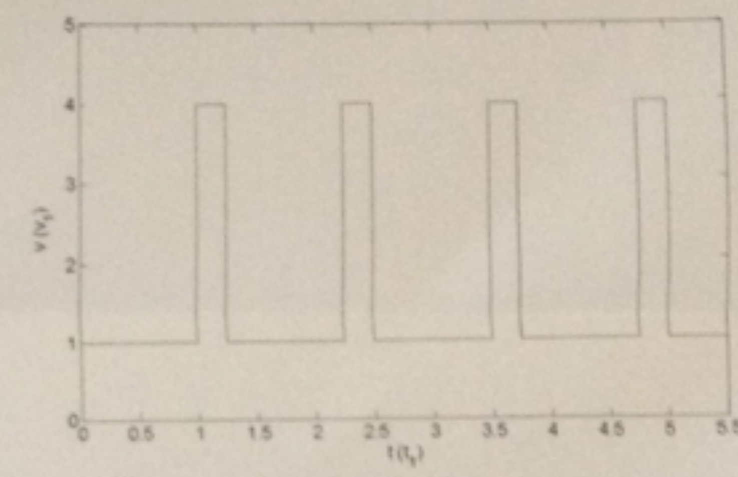


Fig. 2 A schematic illustrating flame speed pulsation under the condition $r_0=\delta_1$ and $\delta_2 << \delta_1$. The assumption of $Y_{1,0}=1$ is also made so that the pure curvature effect is shown. In a $Ze>1$ flame, the ratio between higher and lower speeds can be much greater than that illustrated here.

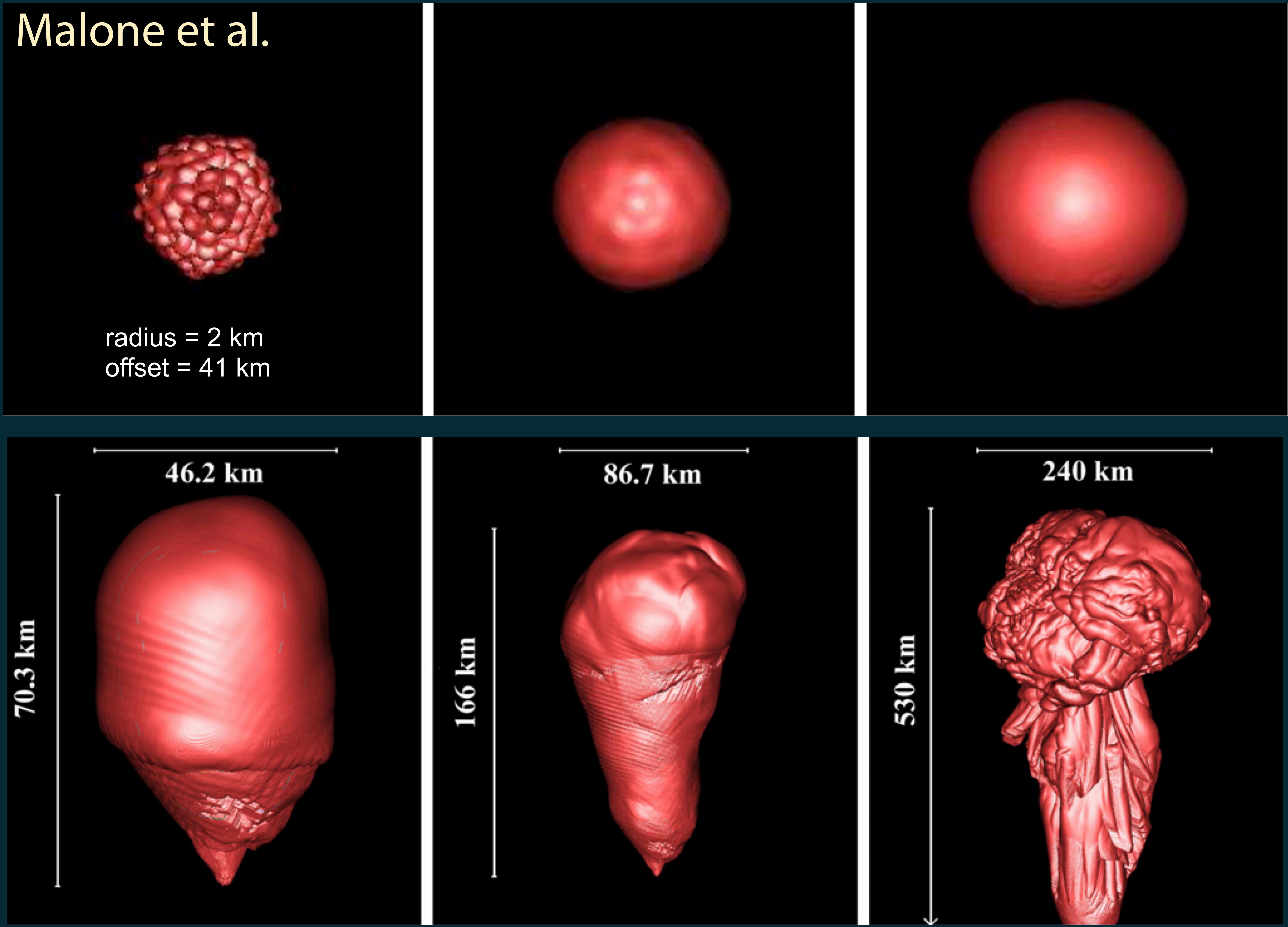
It is expected that flame pulsation may serve as an additional mechanism for the flame to speed up to a value close to or greater than the speed of sound, which in turn could lead to the transition to detonation.

IV. Physical conditions in supernova explosion

- Lewis number: $Le = \frac{\kappa}{\rho C_p D} \sim 10^7$

  represents the comparison between thermal diffusion and mass diffusion. In type Ia supernova, thermal diffusion is effected by the relativistic

Malone et al.



The Center for Astrophysical Thermonuclear Flashes

Simulation of the Deflagration and Detonation Phases of a Type Ia Supernovae

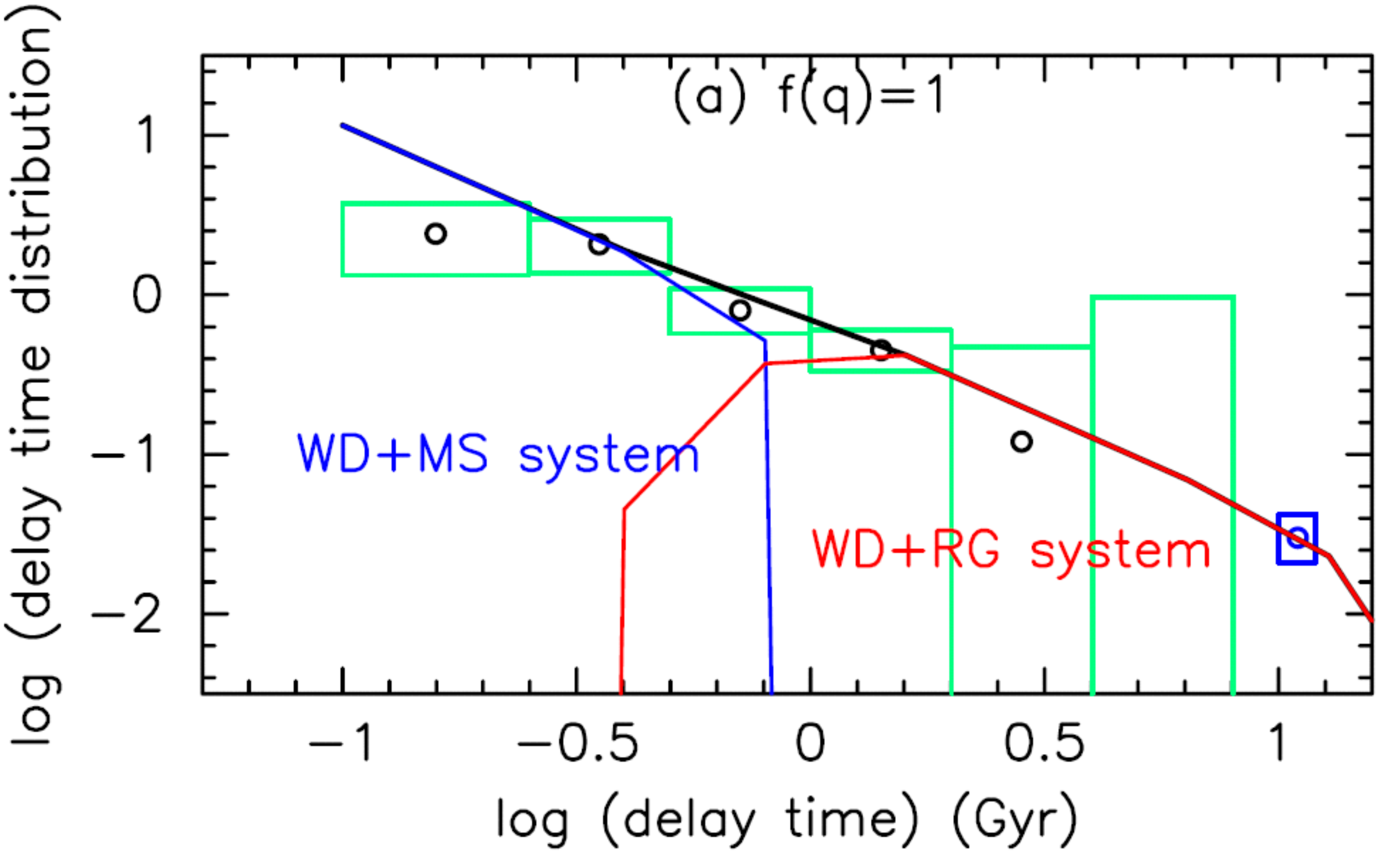
Ignition occurs 40 km from the center of the star.
Hot material is shown in color and stellar surface in green.

This work was supported in part at the University of Chicago by the DOE NNSA ASC ASAP and by the NSF. This work also used computational resources at LBNL NERSC awarded under the INCITE program, which is supported by the DOE Office of Science.

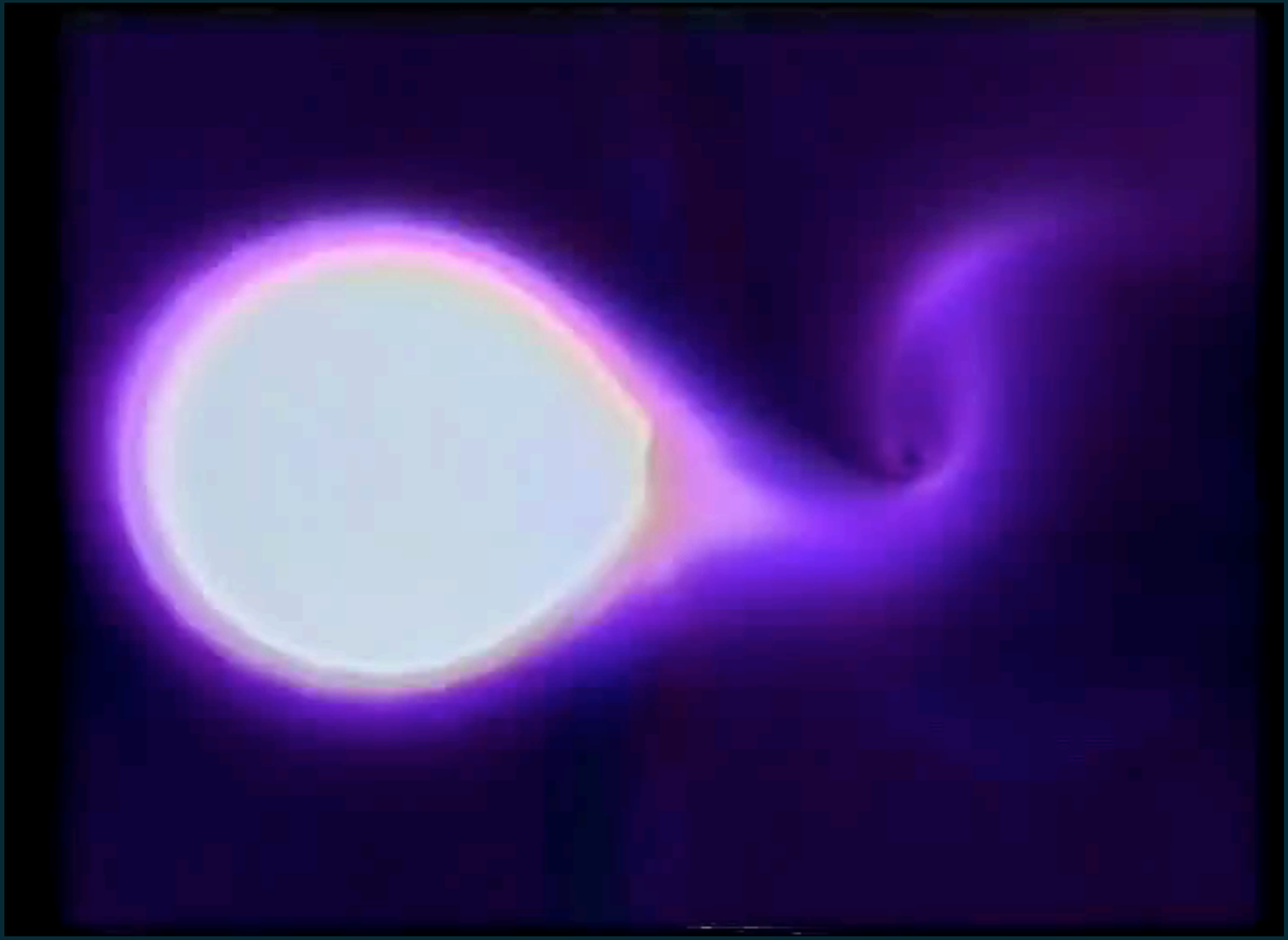
An Advanced Simulation and Computation (ASC)
Academic Strategic Alliances Program (ASAP) Center
at The University of Chicago

ASC

SD: Delay Time Distribution

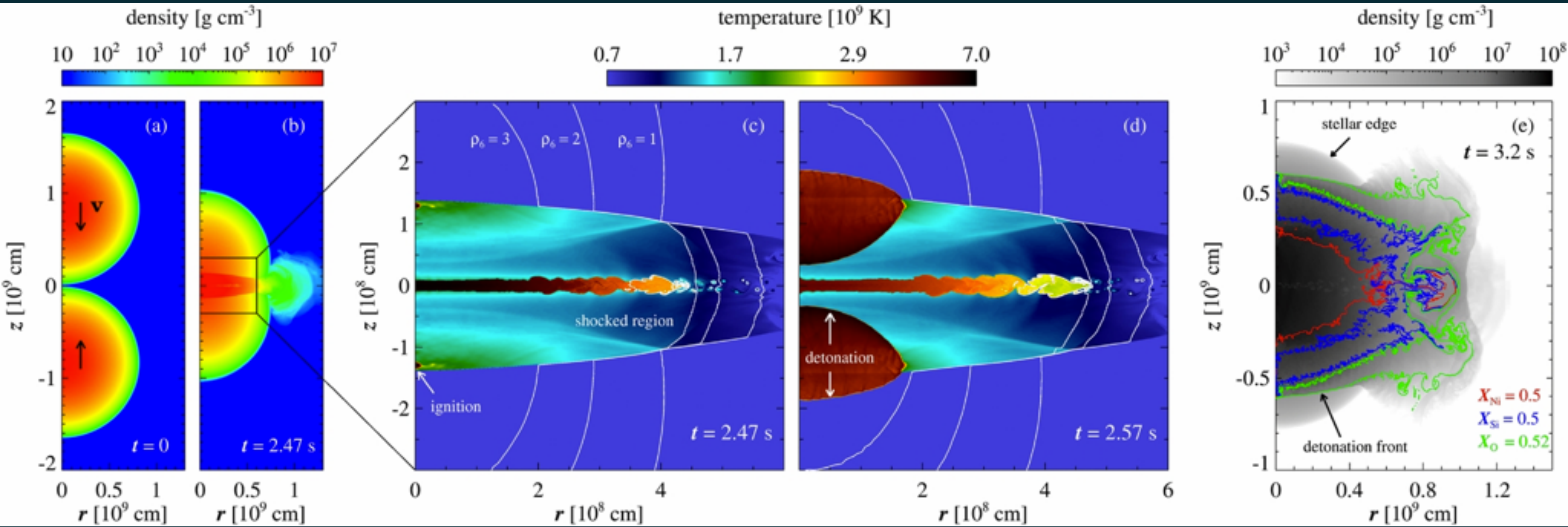


rotation [Nomoto]

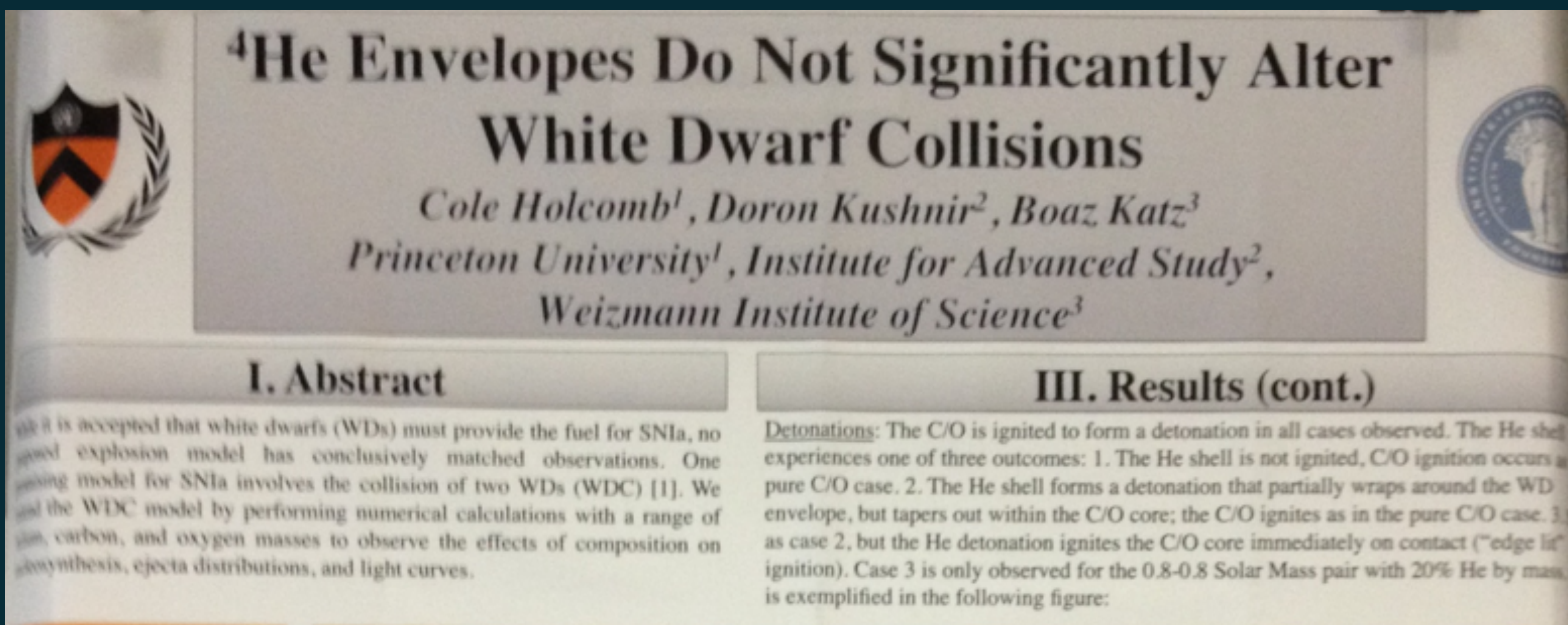


Collisions

- Rosswog et al., Raskin et al., **Kushnir et al.**
- “With triple systems, you can do anything”—F. Rasio



- peak of WD mass distribution at 1.2 $M_{sun}/2$
- but, there is a distribution of impact parameters



^{4}He Envelopes Do Not Significantly Alter White Dwarf Collisions

Cole Holcomb[1], Doron Kushnir[2], Boaz Katz[3]

Princeton University[1], Institute for Advanced Study[2], Weizmann Institute of Science[3]

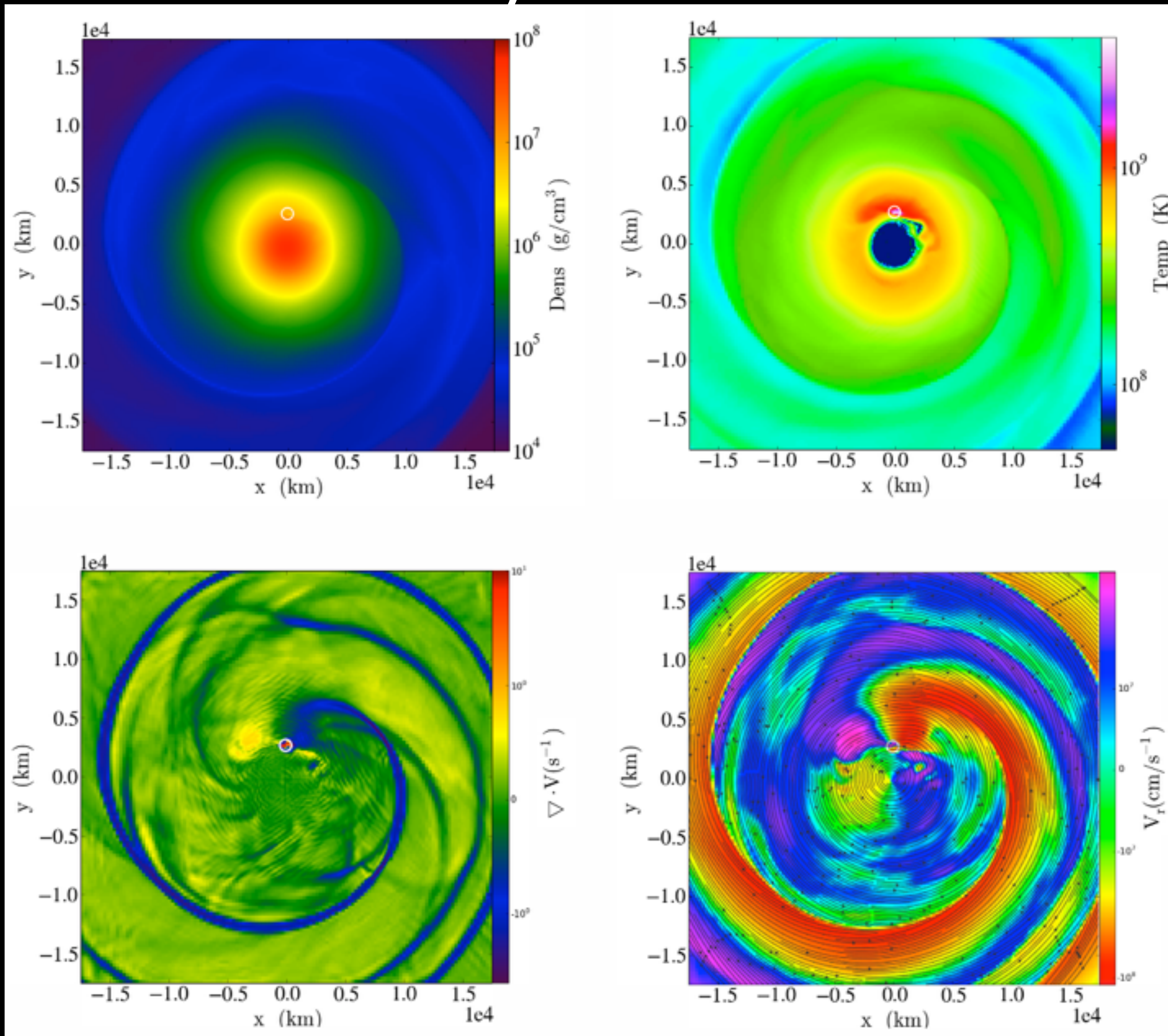
I. Abstract

it is accepted that white dwarfs (WDs) must provide the fuel for SNIa, no
explosion model has conclusively matched observations. One
model for SNIa involves the collision of two WDs (WDC) [1]. We
the WDC model by performing numerical calculations with a range of
carbon, and oxygen masses to observe the effects of composition on
synthesis, ejecta distributions, and light curves.

III. Results (cont.)

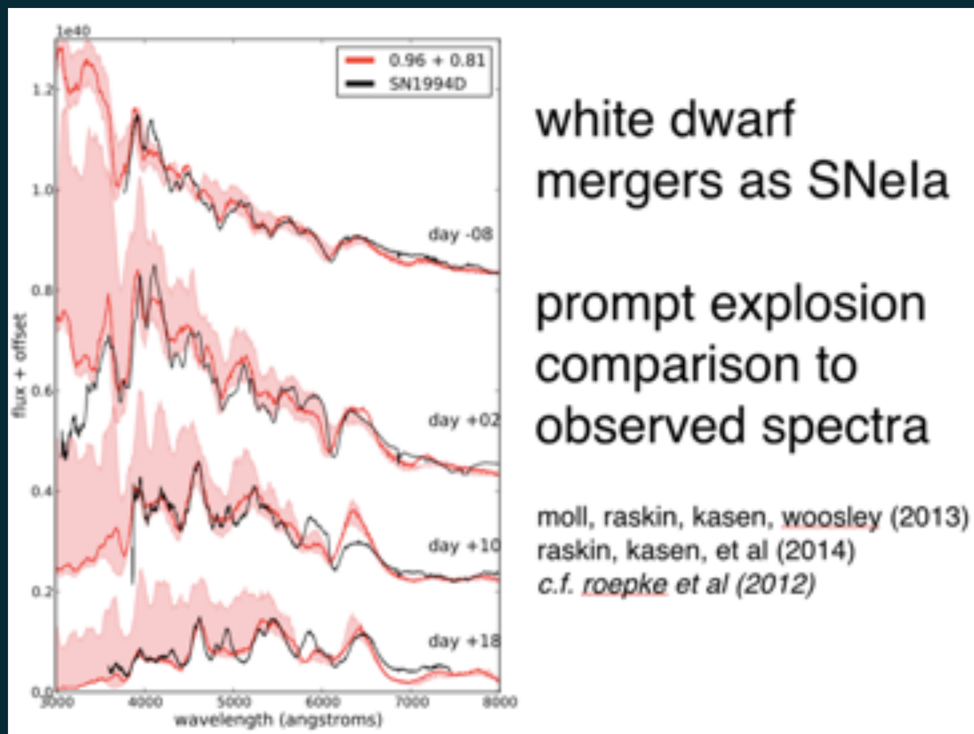
Detonations: The C/O is ignited to form a detonation in all cases observed. The He shel
experiences one of three outcomes: 1. The He shell is not ignited, C/O ignition occurs a
pure C/O case. 2. The He shell forms a detonation that partially wraps around the WD
envelope, but tapers out within the C/O core; the C/O ignites as in the pure C/O case. 3.
as case 2, but the He detonation ignites the C/O core immediately on contact ("edge lit"
ignition). Case 3 is only observed for the 0.8-0.8 Solar Mass pair with 20% He by mass.
is exemplified in the following figure:

Detailed View of 3D Spiral Instability Detonation

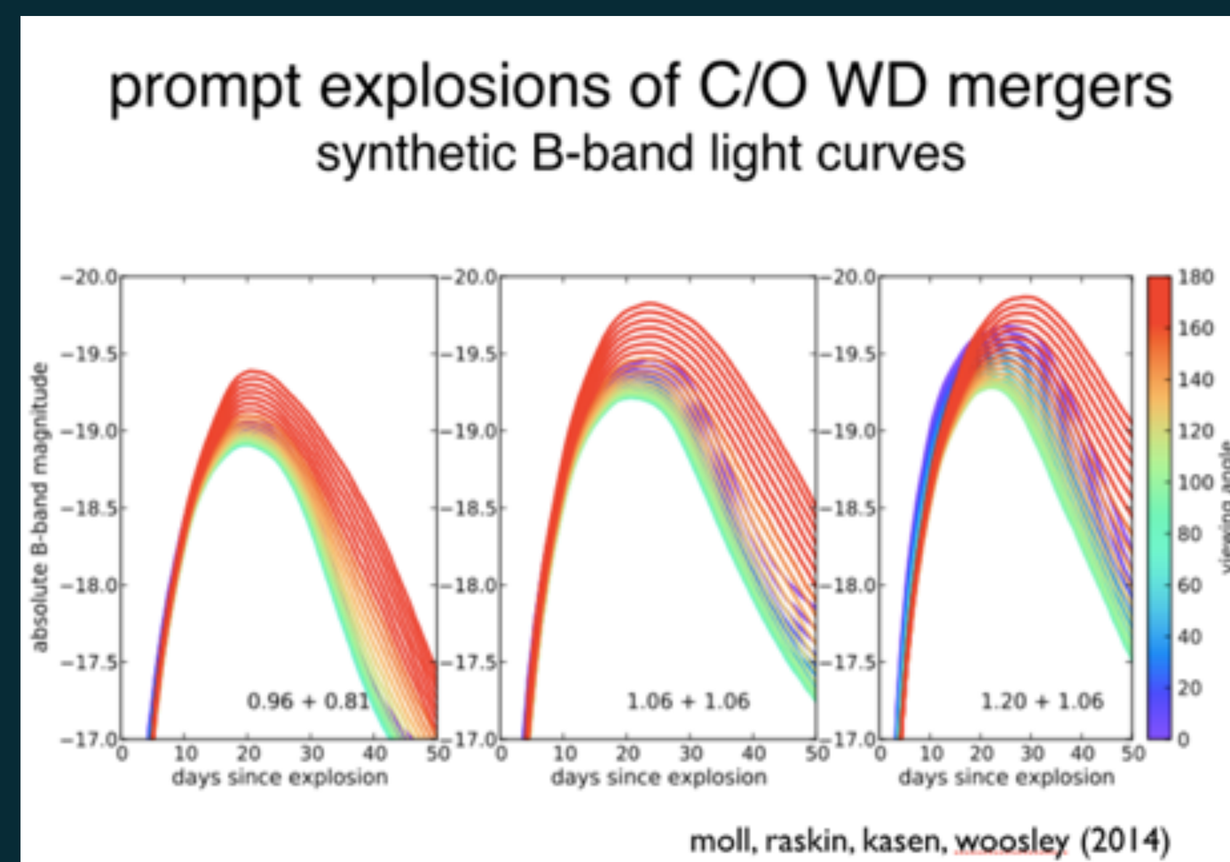


Kashyap et al, 2014, submitted

lightcurves [Kasen]

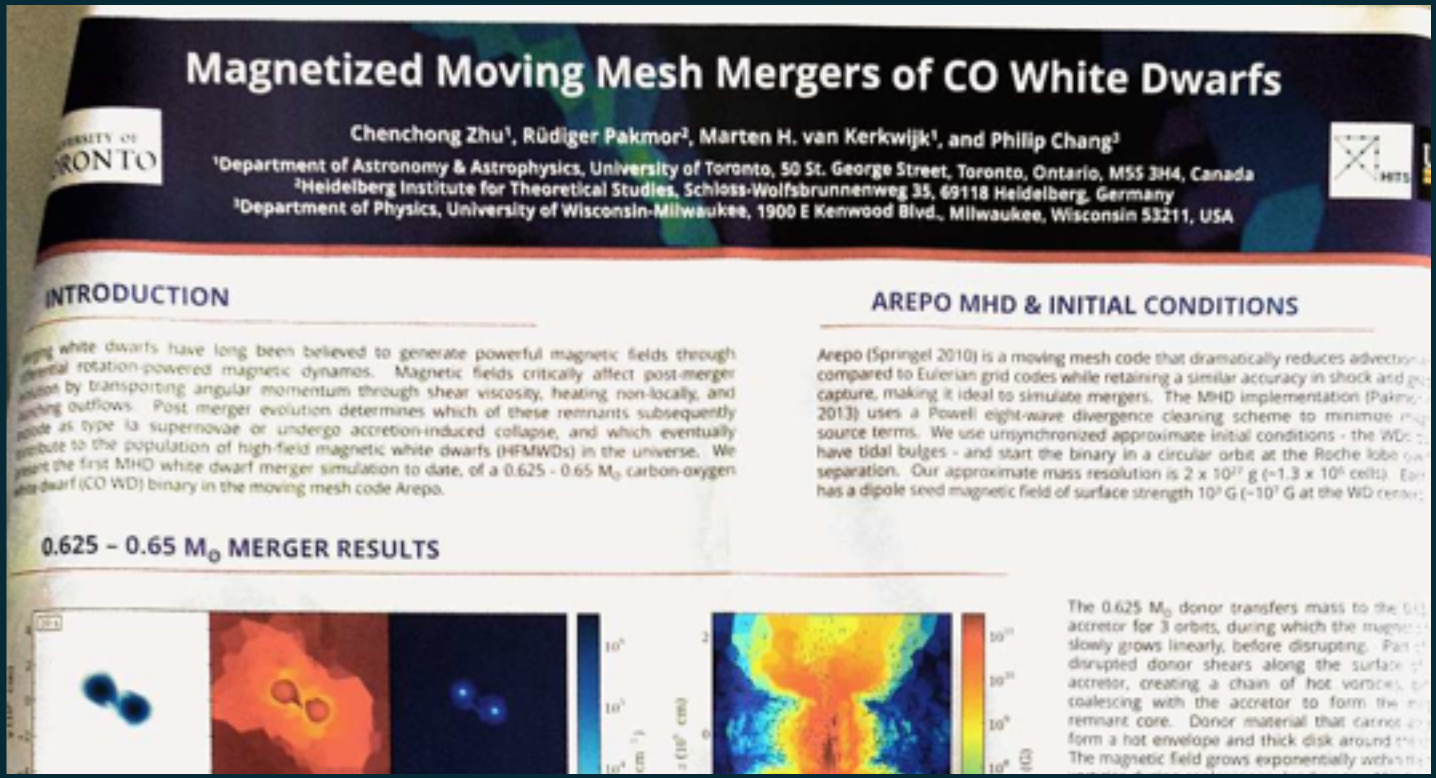


pretty good agreement with observations (black lines) but with wide viewing angle dependence (the light red band)

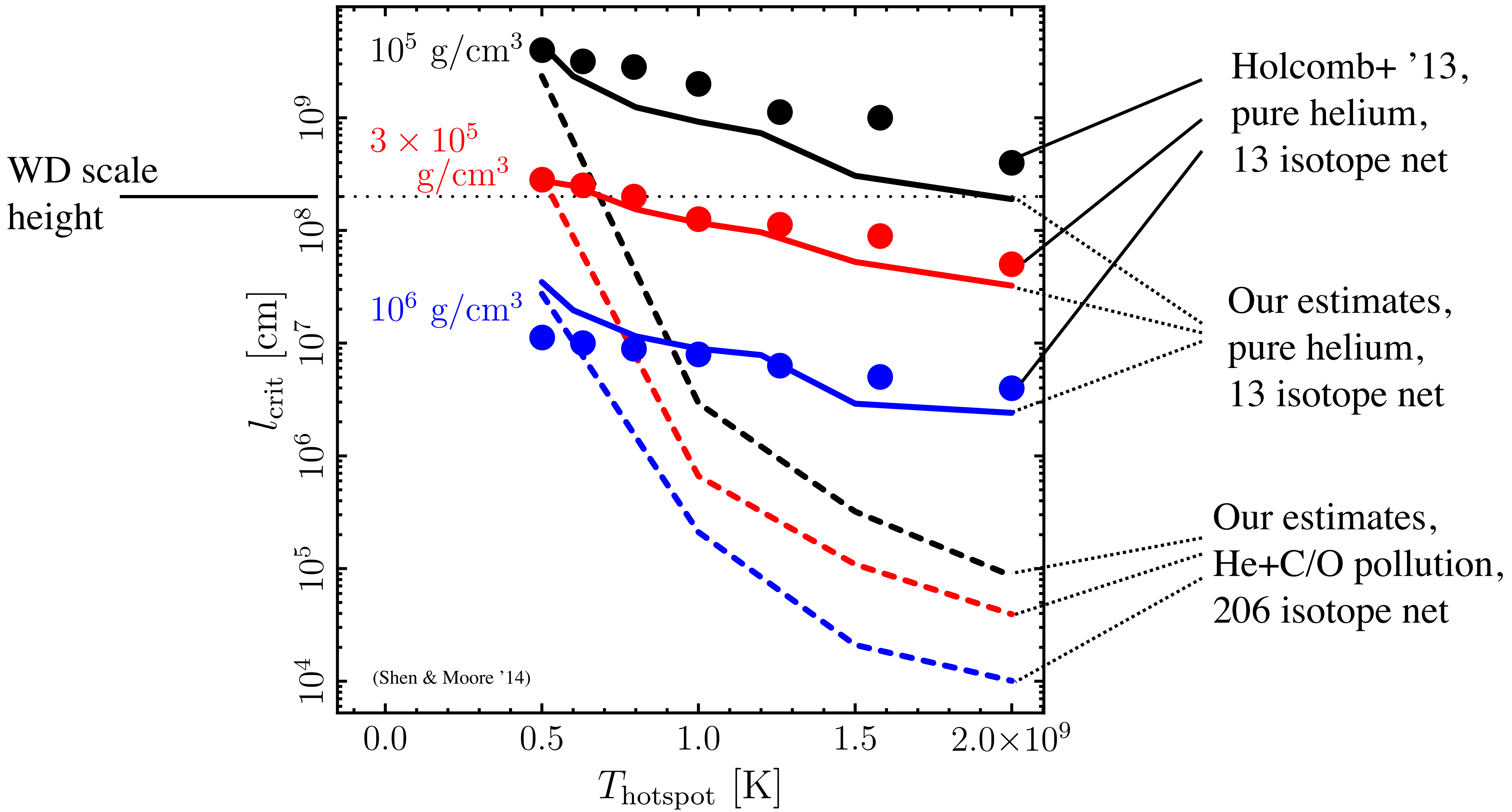


magnetic fields

Naturally get very large magnetic fields ($B \sim 10^{10}$–10^{11} G) during merger



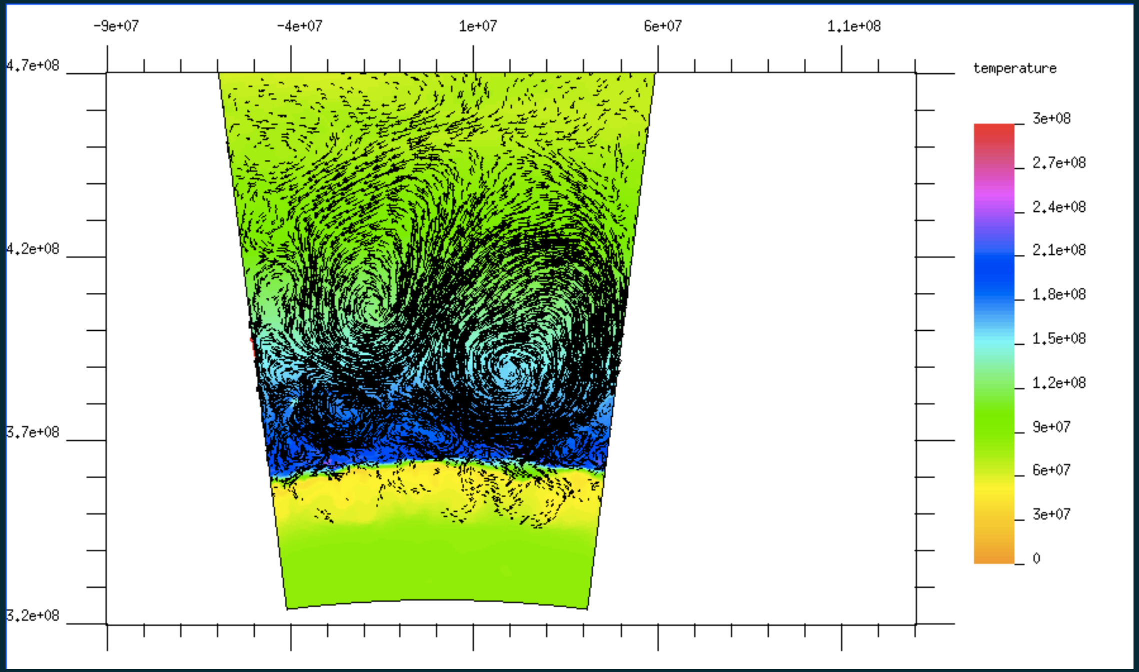
First detonation: Does the helium ignite? Yes!

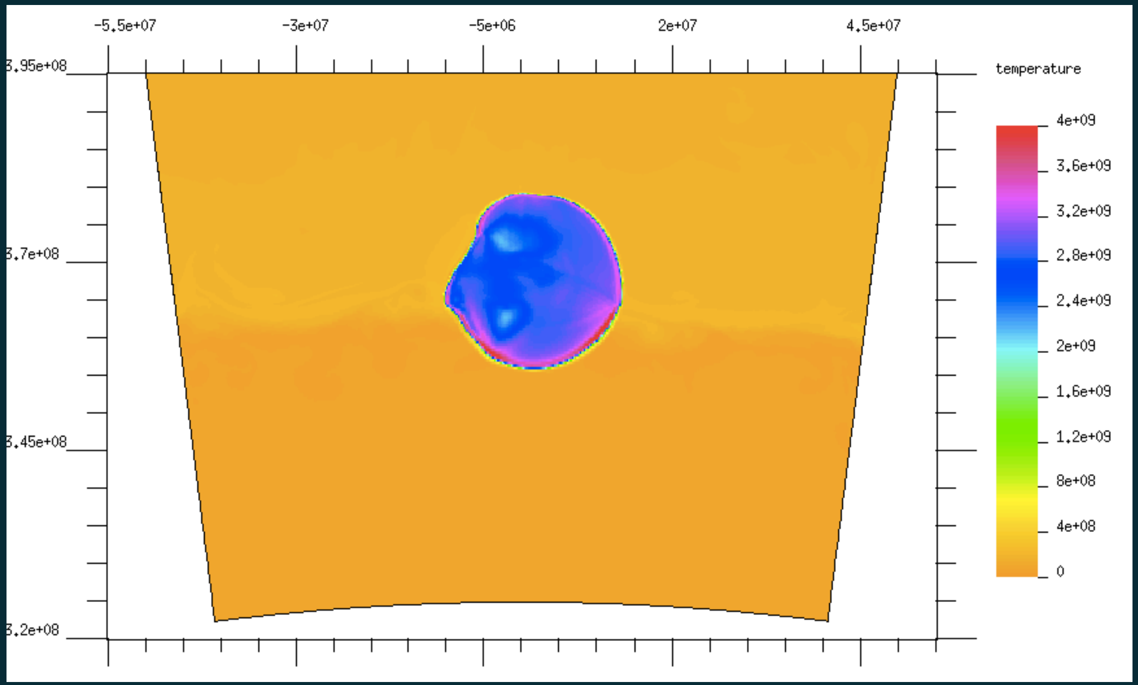


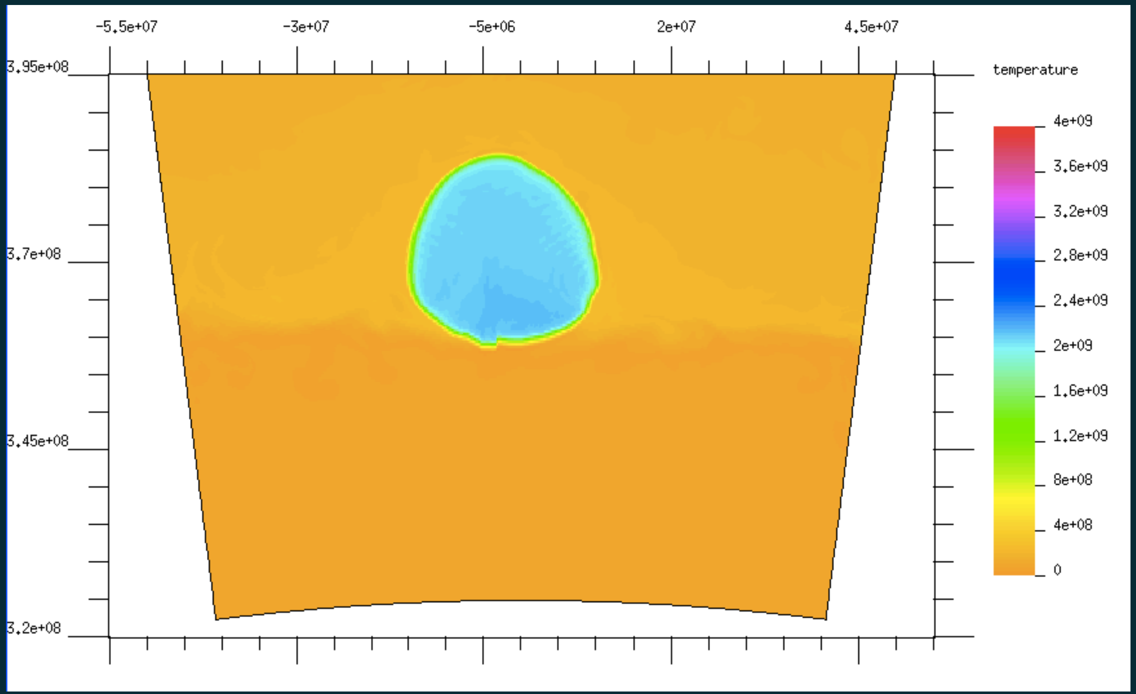
- Small C/O pollution + large nuclear network allows ^{12}C(p, γ)^{13}N(α, p)^{16}O and ^{16}O(α, γ)^{20}Ne, bypass triple-α: **Easy helium detonations!**

sub-Chandra He ignition: pre-mixing of underlying CO into layer [Glasner]

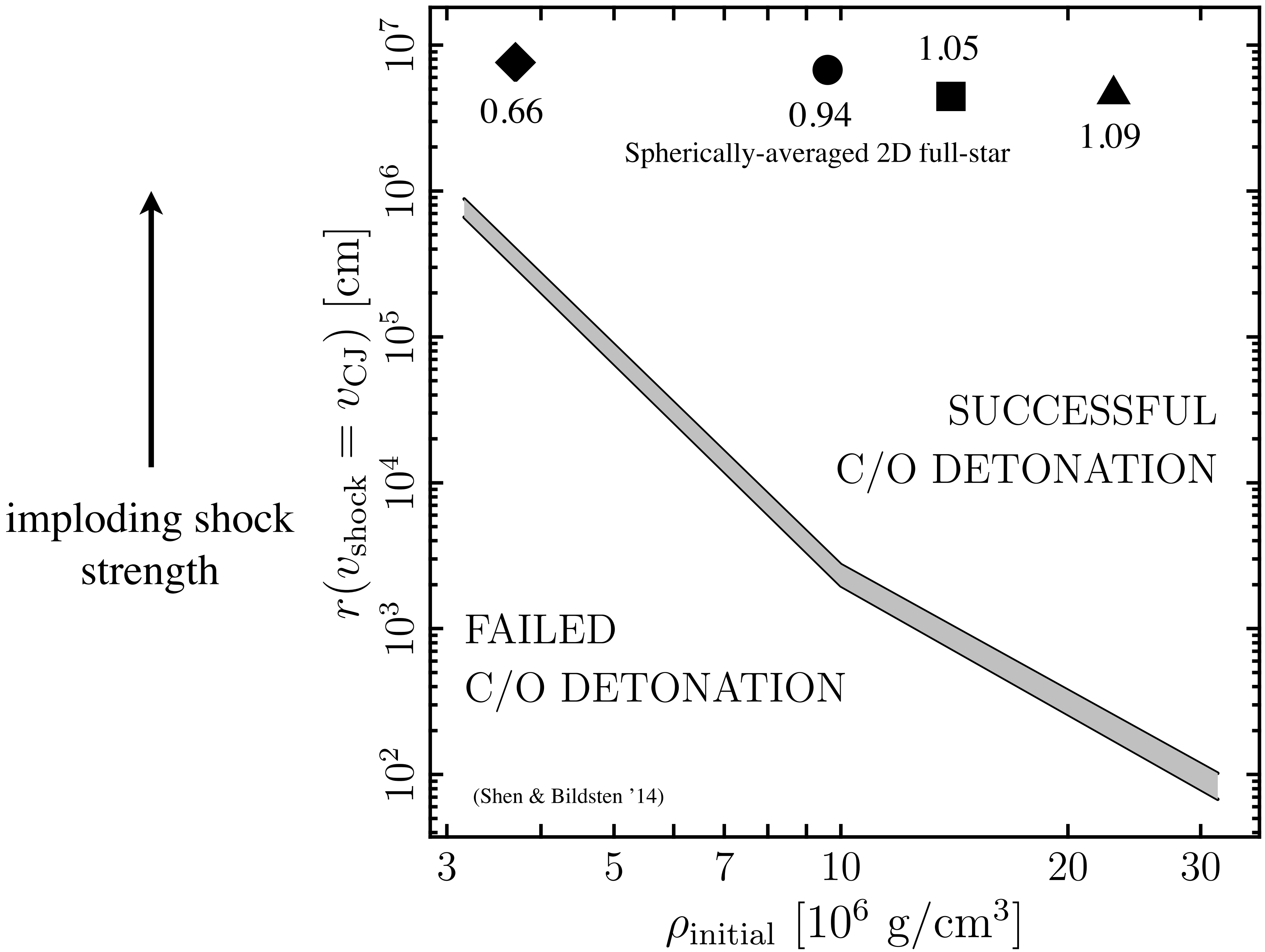
Affects the post-runaway abundances. Helium disappears and the amount of intermediate mass elements increases drastically.







Second detonation: Does the C/O ignite? Yes!



- $M_{\rm WD} \lesssim 0.8$ Msol: first or second detonation fails (?) → **Long-lived merger remnant, R CrB**
- 0.8 - 1.2 Msol: successful detonation → **SN Ia**
- $\gtrsim$ 1.2 Msol: second detonation fails (O/Ne hard to ignite) → **Long-lived merger remnant, AIC**

Ken Shen (UCB)

DOUBLE DETONATION SN IA FROM A CONFINED HE BELT

THOMAS L. PAPATHEODORE[1,3] AND O. E. BRONSON MESSER[3,2,1]

1. UNIVERSITY OF TENNESSEE, KNOXVILLE, 2. PHYSICS DIVISION, OAK RIDGE NATIONAL LABORATORY, 3. OAK RIDGE LEADERSHIP COMPUTING FACILITY

Introduction

Although there is still no consensus on the explosion mechanism(s) of Type Ia supernovae (SNe Ia), there is general agreement that the progenitor is a white dwarf (WD) in a binary system described by the single-degenerate, double-degenerate, or double-detonation scenario. However, peculiar features of otherwise normal SNe Ia lead to speculative variations of these scenarios. For example, SN2014J was a spectroscopically normal SNe Ia (Marion et al., 2014), but γ-ray observations reveal the presence of low-velocity ^{56}Ni in the outer regions of the ejecta (Diehl et al. 2014). To explain these observations, Diehl et al. (2014) considered a modified version of the double-detonation scenario, where a detonation in an equatorial He *belt* (instead of a He shell) leads to a subsequent explosion of the underlying C/O core. Assuming complete burning of the He, this would leave a belt of ^{56}Ni around the equator when the C/O detonation occurs. This Ni, along with the rest of the outer ejecta would have the characteristically large velocities (~14,000 – 28,000 km s^{-1}) of normal SNe Ia, but viewed from one of the poles, the component of Ni velocity in the direction of the observer would be constrained due to the configuration of the belt. Here we explore the plausibility of this explosion mechanism.

Models

We used the FLASH code (Fryxell et al. 2000) to simulate 2D axisymmetric explosions of sub-Chandrasekhar-mass ($\rho_{c,7}$ = 5, 1.08 $M_\odot$) WDs with an equatorial Ni or He belt. The Ni-belt simulations were used to represent the simplest scenario described by Diehl et al. (2014), where a belt of Ni is posited to already exist from a previous detonation in accreted He. To test the plausibility of this explosion mechanism further we simulated detonations in He belts surrounding WDs.

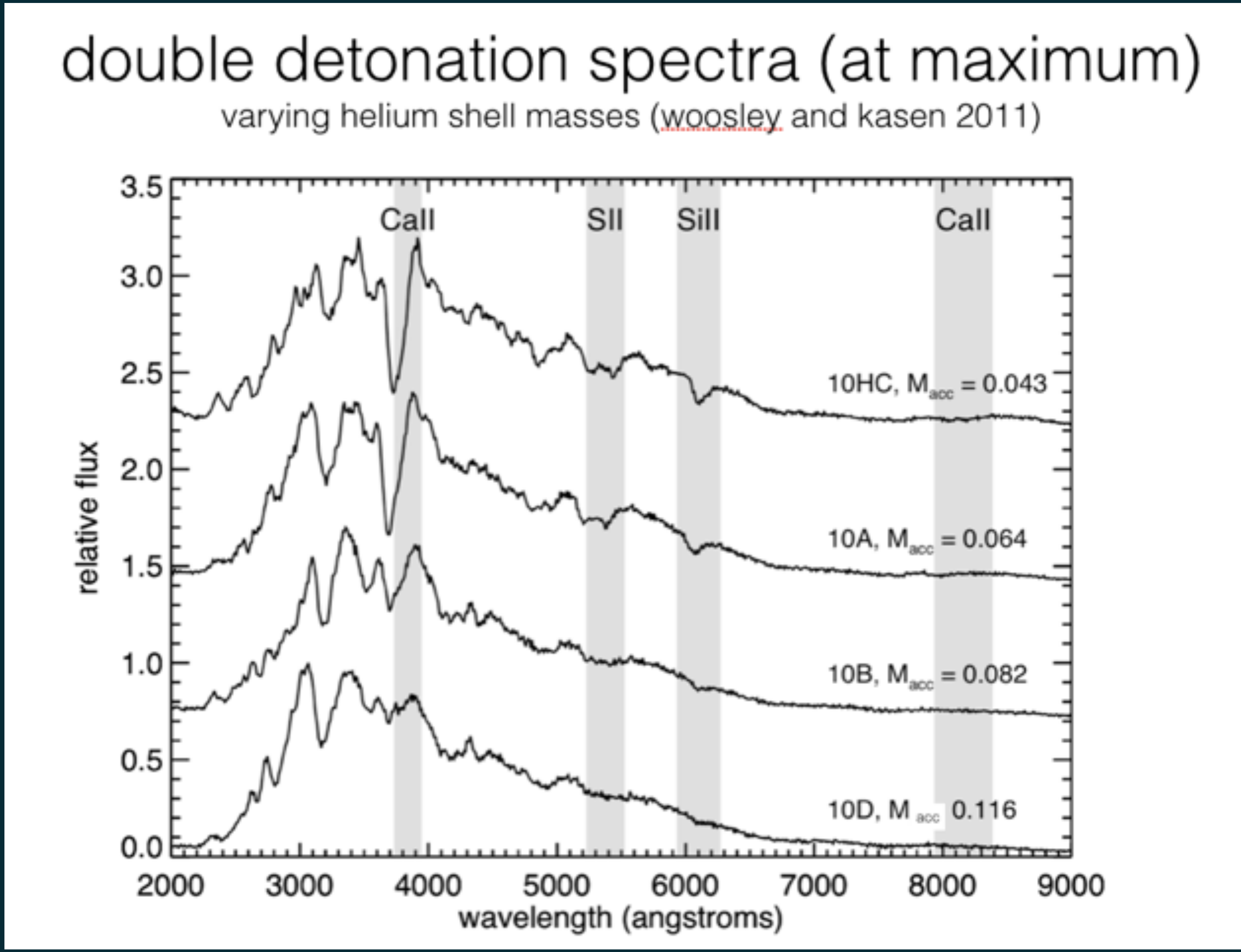
Belt Configurations

The belts of Ni or He used in our simulations were either constant density or stratified as the surrounding WD. The constant density belts were embedded in the WD to a depth where their densities matched the corresponding density contour of the WD. The width of the belt was then calculated based on the total mass desired for the belt. The belts with density gradients were given the same geometry as the corresponding constant density belts (e.g. a belt with density gradient that has a base density of 2×10^6 g cm^{-3} will have the same geometry as the corresponding constant density belt with $\rho = 2\times10^6$ g cm^{-3}), but their densities simply follow the WD density out to the edge. For two of the Ni belts with density gradients, the density was a constant multiple of the WD density. We also considered a crescent shaped belt which followed the density gradient of the WD for three He detonations.

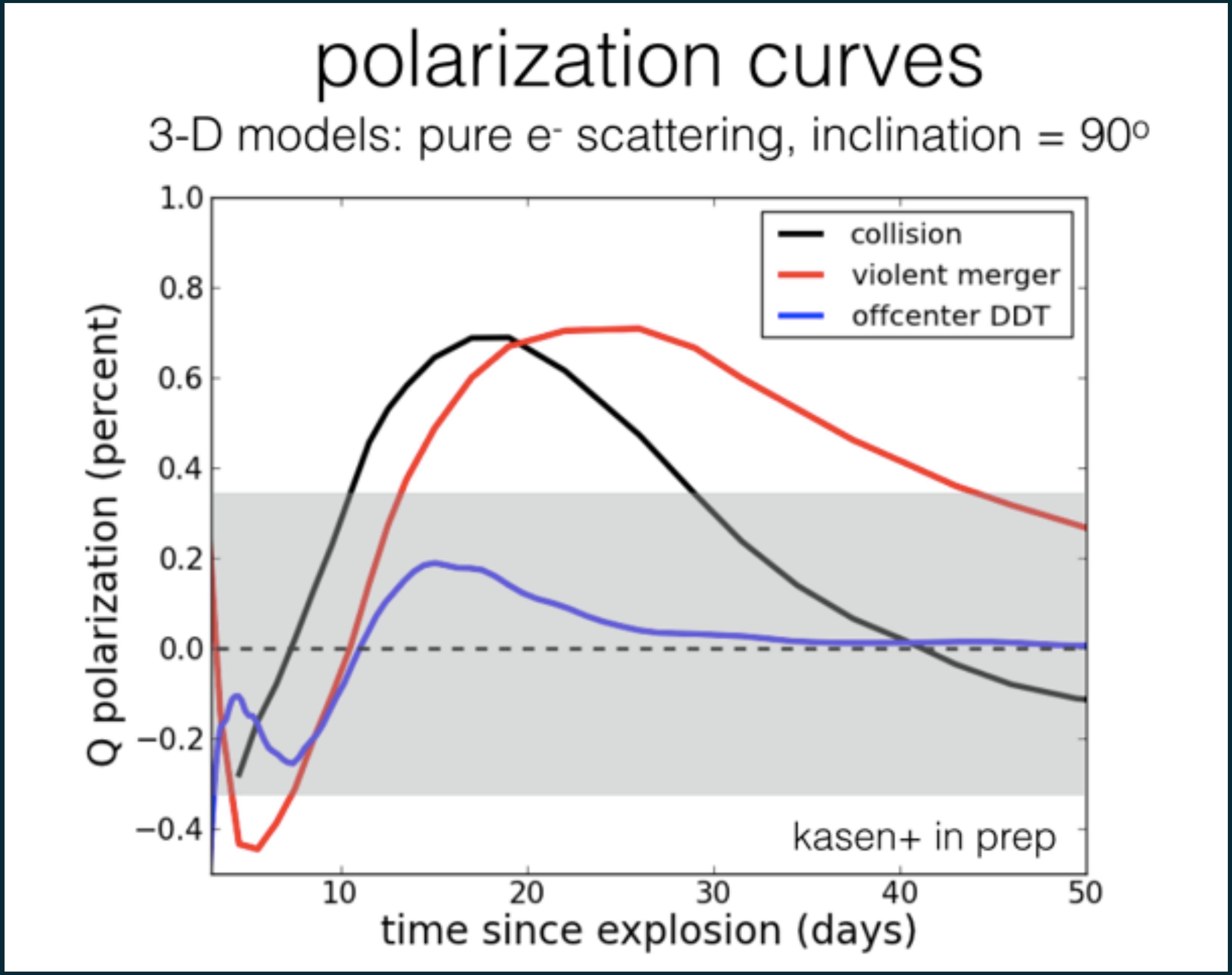
Nuclear Kinetics

For most of our simulations we used the 13-isotope α-chain plus heavy-ion reaction network, Aprox13, included in the public version of FLASH to advance the nuclear kinetics. For two of the He-belt runs we repeated the simulations using a 150-species reaction network (X150) to see how a larger network affects the results. X150 is a specific implementation of the nuclear reaction network, XNet (Hix & Thielemann, 1999), which can handle an arbitrary number of isotopes including thousands of reactions. We have recently installed XNet in FLASH, making it available for future use.

spectra okay if not too much helium

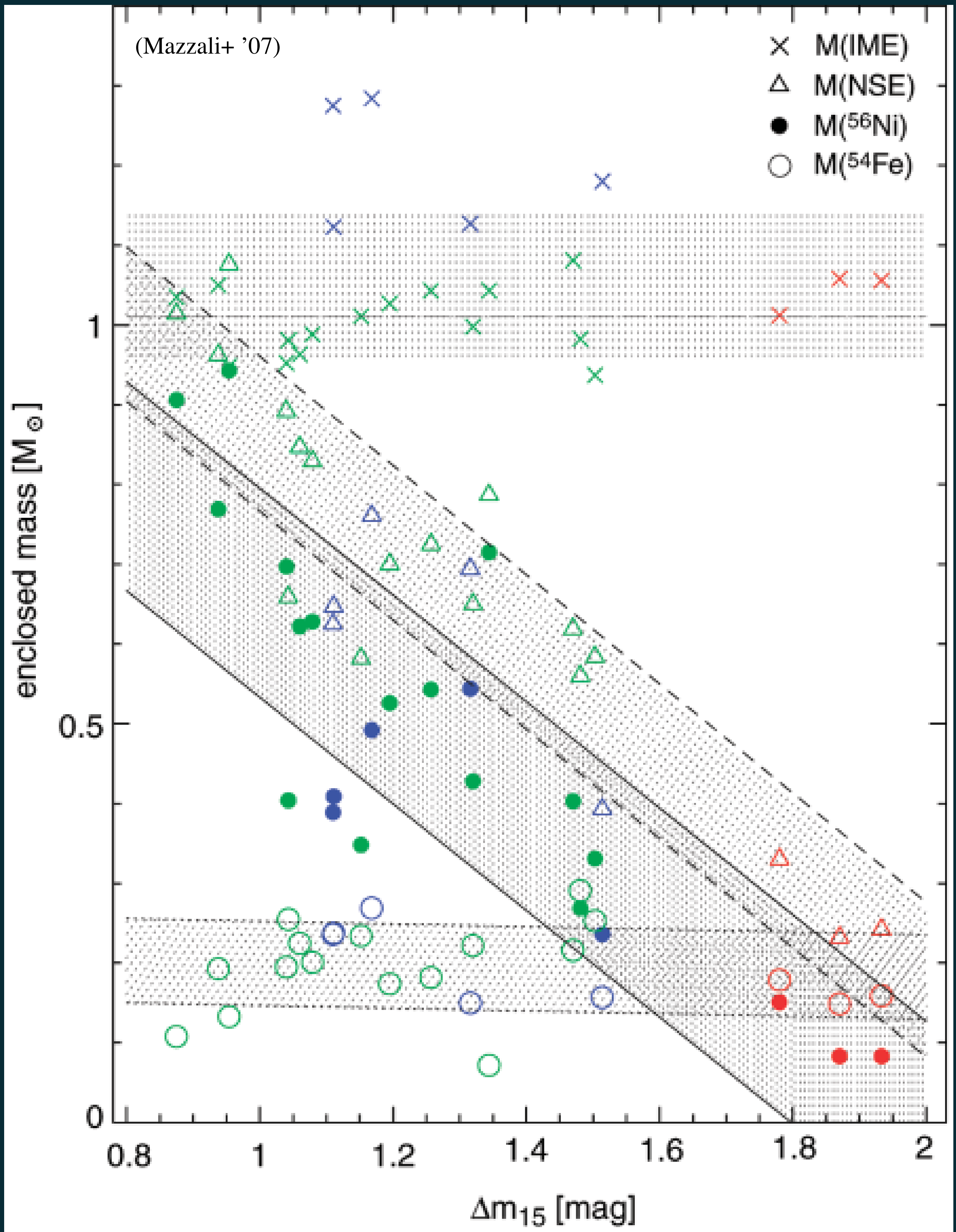


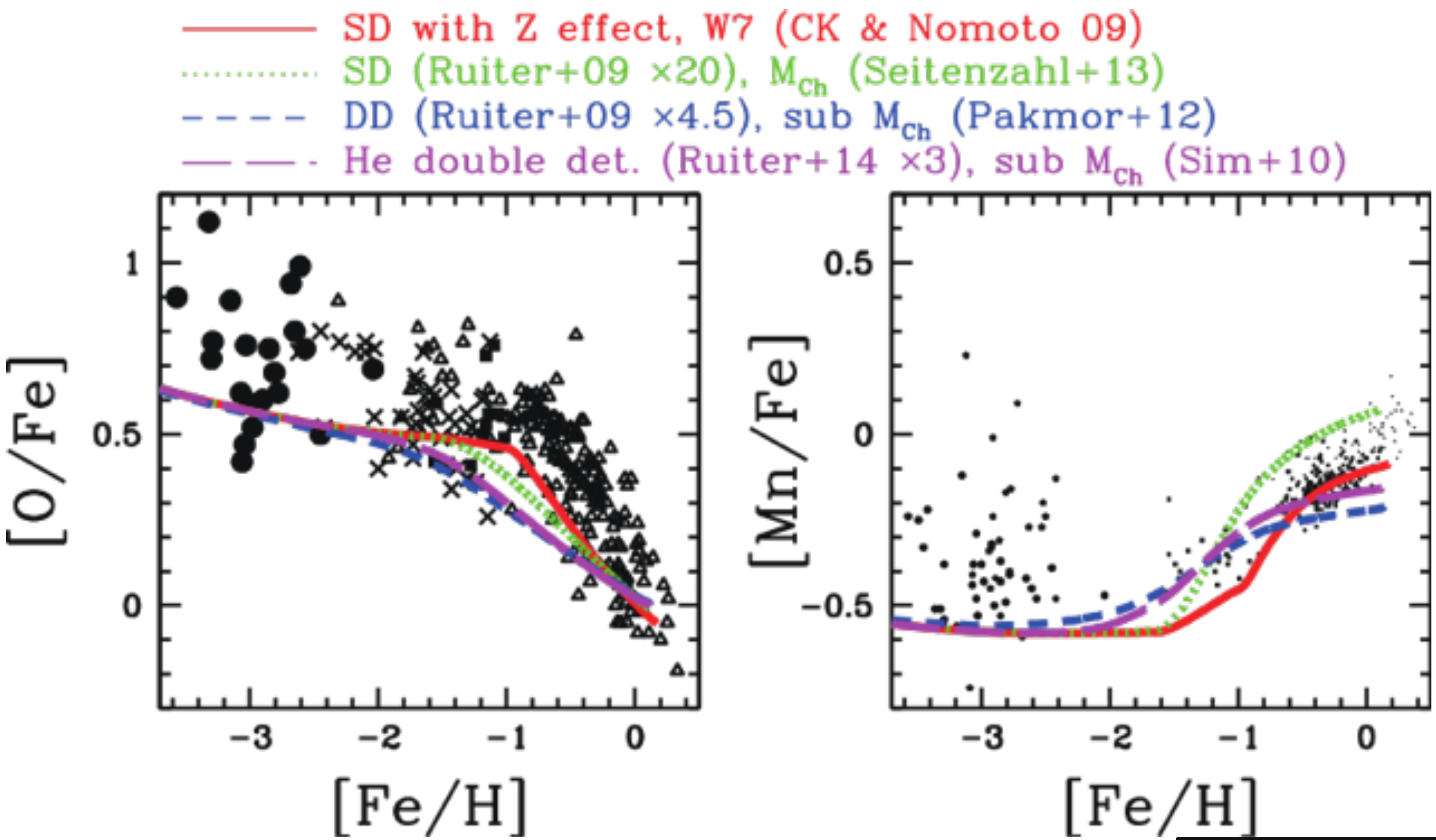
all models are asymmetric



Potentially important discriminant of Chandra, Sub-Chandra: [Wheeler, Maeda]

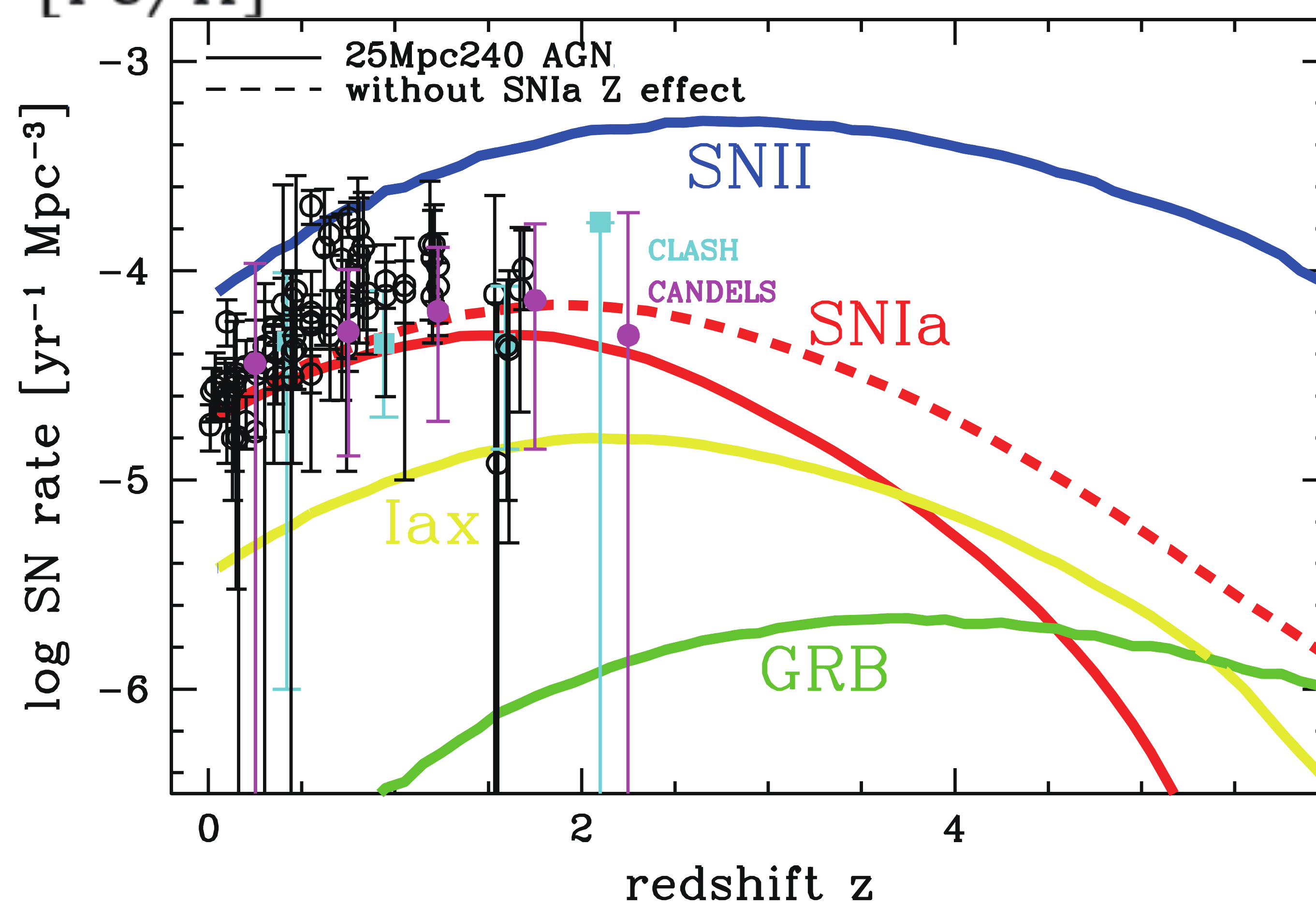
- High density, > 10^9 g/cm^3, electron capture on ^{56}Ni => Stable Ni in center, excitation by ^{56}Ni off-center
- Evidence for high central density
  - Flat-top line profiles of [Fe II], in nebular spectra (Gerardy et al. 2004), truncated lines in Mid-IR spectra (Telesco et al. 2014)
  - Abundance of ^{55}Mn (Seitenzahl et al. 2013)





❖ If the shortest lifetime of majority of SNIa is <1Gyr, I need a metallicity effect; low rate @[Fe/H]<-1.

❖ The metallicity effect should be tested with JWST ☺

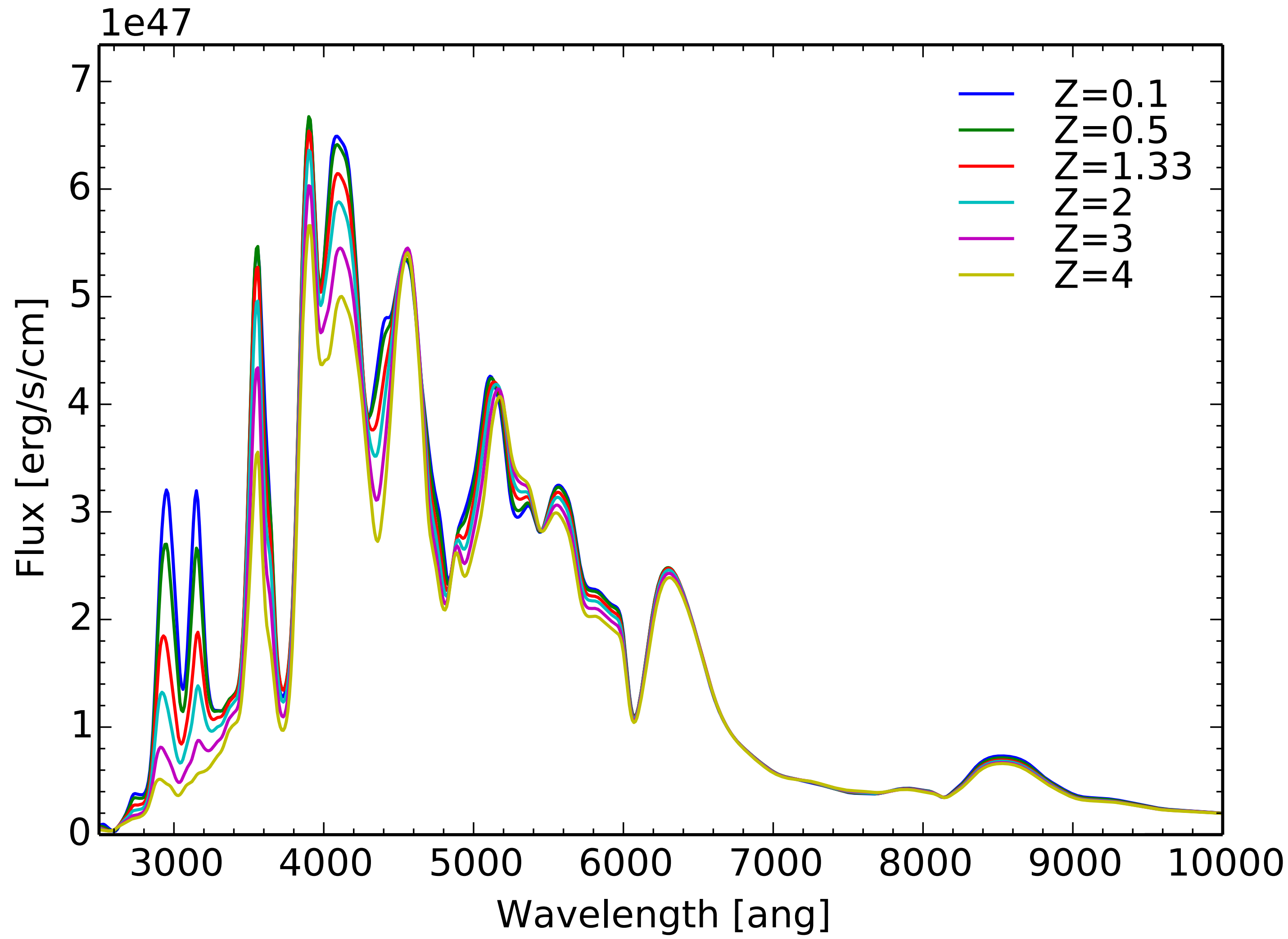


Chiaki Kobayashi

sorry, my flight is at 6:30pm…

Spectral Comparison

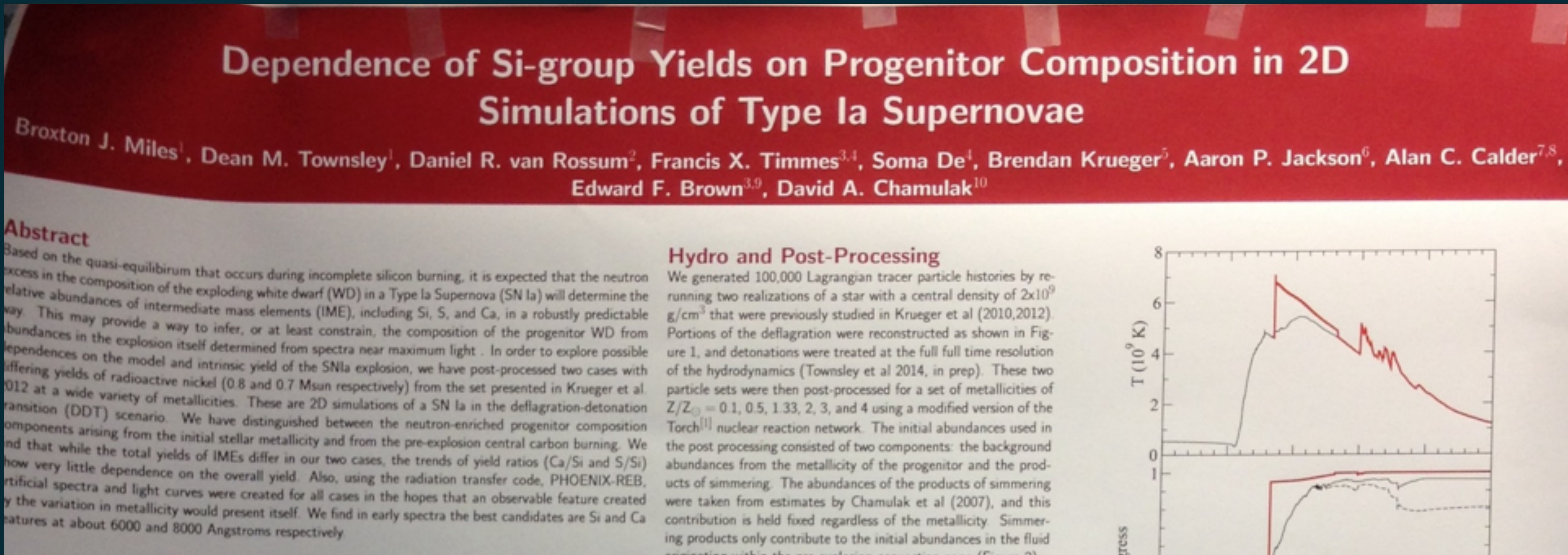
At approximately maximum light:



6100Å P Cygni Si line stable

Variations with metallicity strong at 3000 and 4000-4200 Å

Good to have a mix of invariant and variant features



Dependence of Si-group Yields on Progenitor Composition in 2D Simulations of Type Ia Supernovae

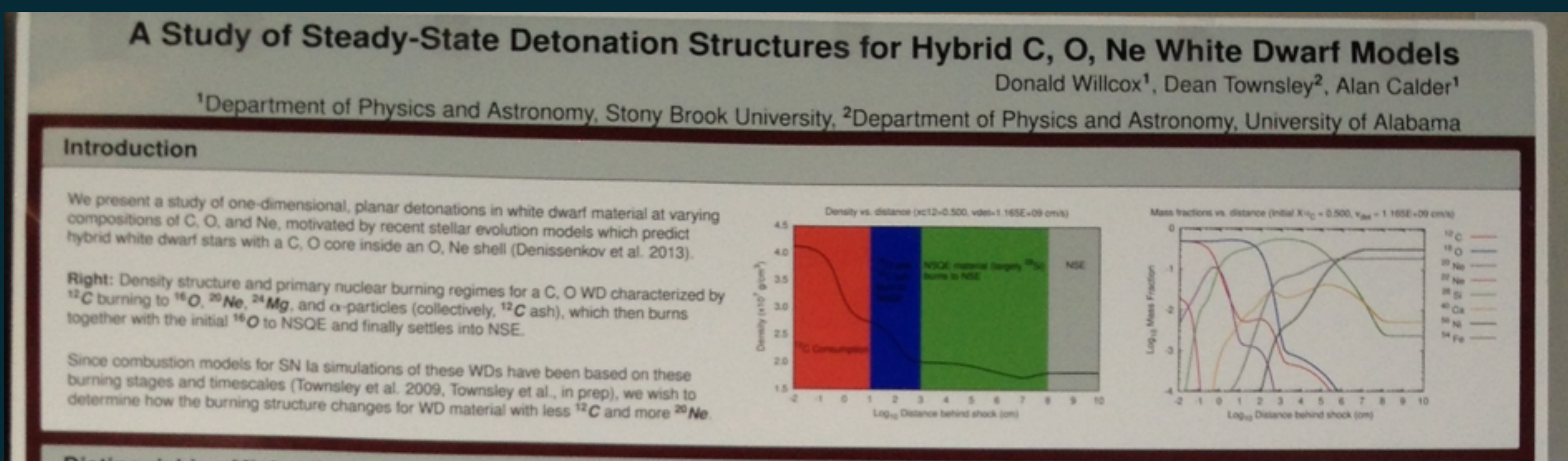
Broxton J. Miles[1], Dean M. Townsley[1], Daniel R. van Rossum[2], Francis X. Timmes[3,4], Soma De[4], Brendan Krueger[5], Aaron P. Jackson[6], Alan C. Calder[7,8], Edward F. Brown[3,9], David A. Chamulak[10]

Abstract

Based on the quasi-equilibirum that occurs during incomplete silicon burning, it is expected that the neutron excess in the composition of the exploding white dwarf (WD) in a Type Ia Supernova (SN Ia) will determine the relative abundances of intermediate mass elements (IME), including Si, S, and Ca, in a robustly predictable way. This may provide a way to infer, or at least constrain, the composition of the progenitor WD from abundances in the explosion itself determined from spectra near maximum light . In order to explore possible dependences on the model and intrinsic yield of the SNIa explosion, we have post-processed two cases with differing yields of radioactive nickel (0.8 and 0.7 Msun respectively) from the set presented in Krueger et al 2012 at a wide variety of metallicities. These are 2D simulations of a SN Ia in the deflagration-detonation transition (DDT) scenario. We have distinguished between the neutron-enriched progenitor composition components arising from the initial stellar metallicity and from the pre-explosion central carbon burning. We find that while the total yields of IMEs differ in our two cases, the trends of yield ratios (Ca/Si and S/Si) show very little dependence on the overall yield. Also, using the radiation transfer code, PHOENIX-REB, artificial spectra and light curves were created for all cases in the hopes that an observable feature created by the variation in metallicity would present itself. We find in early spectra the best candidates are Si and Ca features at about 6000 and 8000 Angstroms respectively.

Hydro and Post-Processing

We generated 100,000 Lagrangian tracer particle histories by re-running two realizations of a star with a central density of 2×10^9 g/cm^3 that were previously studied in Krueger et al (2010,2012). Portions of the deflagration were reconstructed as shown in Figure 1, and detonations were treated at the full full time resolution of the hydrodynamics (Townsley et al 2014, in prep). These two particle sets were then post-processed for a set of metallicities of $Z/Z_\odot$ = 0.1, 0.5, 1.33, 2, 3, and 4 using a modified version of the Torch[1] nuclear reaction network. The initial abundances used in the post processing consisted of two components: the background abundances from the metallicity of the progenitor and the products of simmering. The abundances of the products of simmering were taken from estimates by Chamulak et al (2007), and this contribution is held fixed regardless of the metallicity. Simmering products only contribute to the initial abundances in the fluid originating within the pre-explosion convection zone (Figure 2).



A Study of Steady-State Detonation Structures for Hybrid C, O, Ne White Dwarf Models

Donald Willcox[1], Dean Townsley[2], Alan Calder[1]

[1]Department of Physics and Astronomy, Stony Brook University, [2]Department of Physics and Astronomy, University of Alabama

Introduction

We present a study of one-dimensional, planar detonations in white dwarf material at varying compositions of C, O, and Ne, motivated by recent stellar evolution models which predict hybrid white dwarf stars with a C, O core inside an O, Ne shell (Denissenkov et al. 2013).

Right: Density structure and primary nuclear burning regimes for a C, O WD characterized by ^{12}C burning to ^{16}O, ^{20}Ne, ^{24}Mg, and α-particles (collectively, ^{12}C ash), which then burns together with the initial ^{16}O to NSQE and finally settles into NSE.

Since combustion models for SN Ia simulations of these WDs have been based on these burning stages and timescales (Townsley et al. 2009, Townsley et al., in prep), we wish to determine how the burning structure changes for WD material with less ^{12}C and more ^{20}Ne.

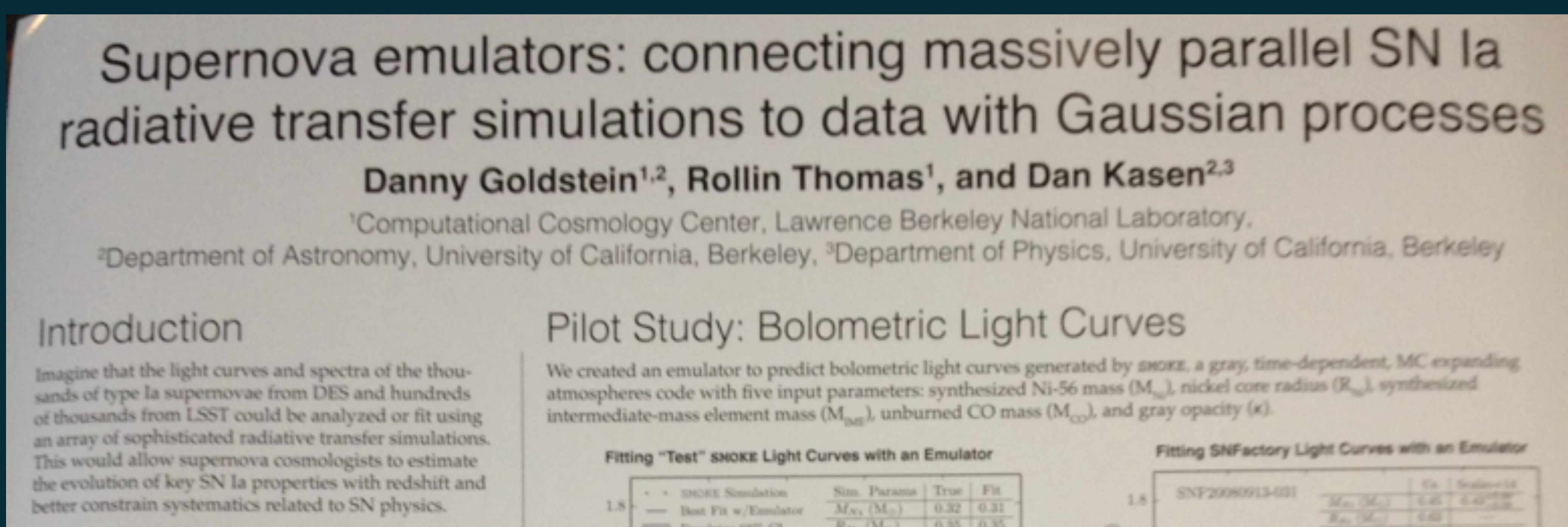
Distinguishing Minimally ...

observables | models should

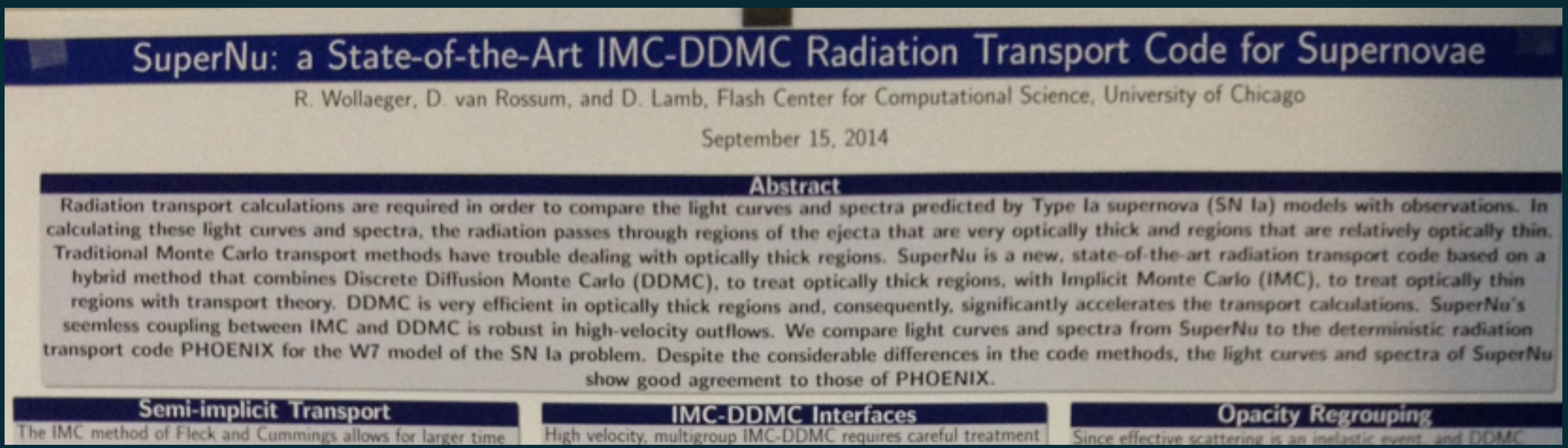
- explode
- produce bolometric and multi-color light curves
- produce multi-wavelength, multi-epoch spectral evolution
- spectropolarimetry

observables | models should

- not run too slowly!
- "[Core-collapse] Supernovae theory has been retarded by the reliance on … codes that run slowly and seldom."—Burrows and Goshy '93, *ApJ*



More codes



SuperNu: a State-of-the-Art IMC-DDMC Radiation Transport Code for Supernovae

R. Wollaeger, D. van Rossum, and D. Lamb, Flash Center for Computational Science, University of Chicago

September 15, 2014

Abstract

Radiation transport calculations are required in order to compare the light curves and spectra predicted by Type Ia supernova (SN Ia) models with observations. In calculating these light curves and spectra, the radiation passes through regions of the ejecta that are very optically thick and regions that are relatively optically thin. Traditional Monte Carlo transport methods have trouble dealing with optically thick regions. SuperNu is a new, state-of-the-art radiation transport code based on a hybrid method that combines Discrete Diffusion Monte Carlo (DDMC), to treat optically thick regions, with Implicit Monte Carlo (IMC), to treat optically thin regions with transport theory. DDMC is very efficient in optically thick regions and, consequently, significantly accelerates the transport calculations. SuperNu's seemless coupling between IMC and DDMC is robust in high-velocity outflows. We compare light curves and spectra from SuperNu to the deterministic radiation transport code PHOENIX for the W7 model of the SN Ia problem. Despite the considerable differences in the code methods, the light curves and spectra of SuperNu show good agreement to those of PHOENIX.

Semi-implicit Transport

The IMC method of Fleck and Cummings allows for larger time

IMC-DDMC Interfaces

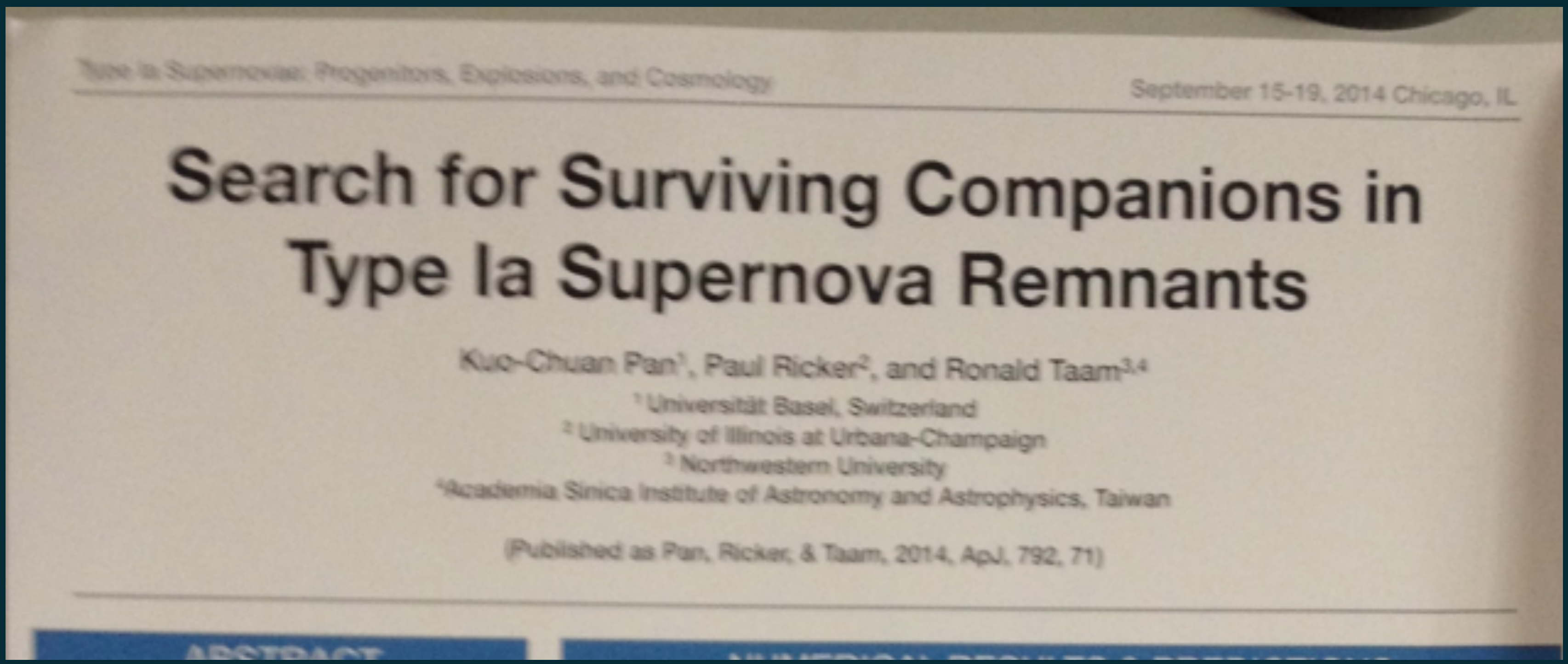
High velocity, multigroup IMC-DDMC requires careful treatment

Opacity Regrouping

Since effective scattering is an inelastic event, and DDMC

TARDIS (Sim)

looking for companions



Type Ia Supernovae: Progenitors, Explosions, and Cosmology — September 15-19, 2014 Chicago, IL

Search for Surviving Companions in Type Ia Supernova Remnants

Kuo-Chuan Pan[1], Paul Ricker[2], and Ronald Taam[3,4]

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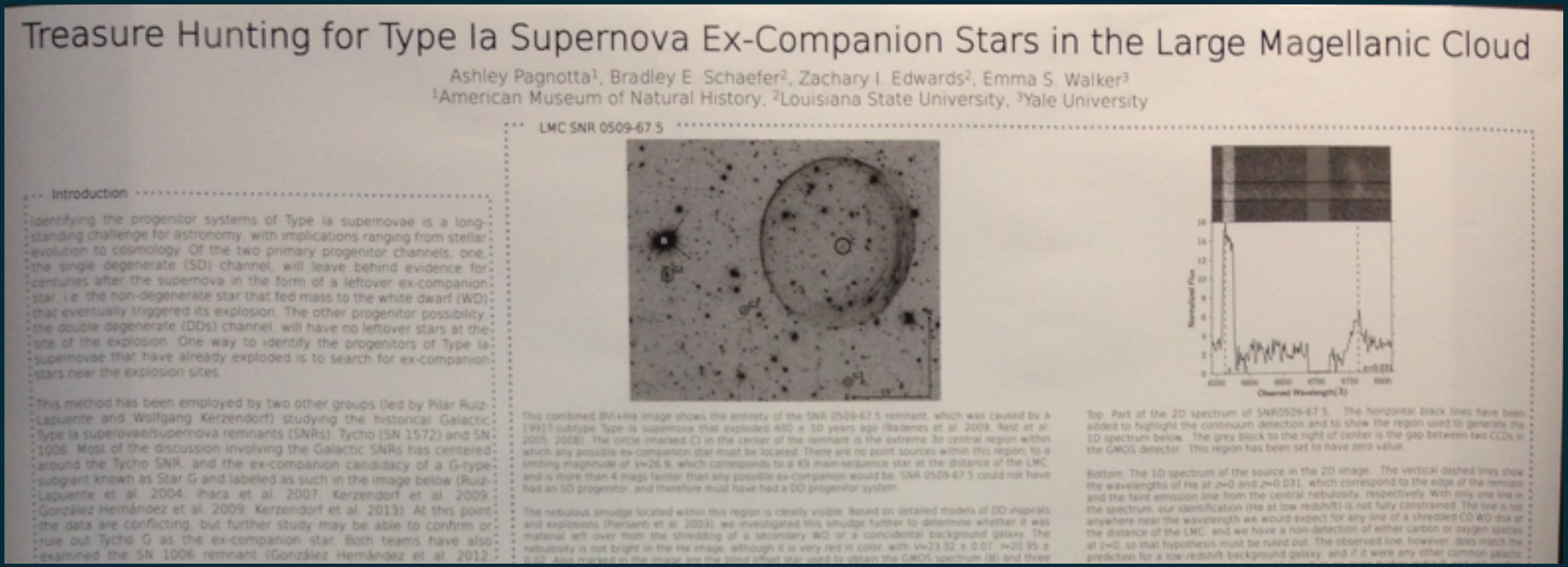
[2] University of Illinois at Urbana-Champaign
[3] Northwestern University
[4] Academia Sinica Institute of Astronomy and Astrophysics, Taiwan

(Published as Pan, Ricker, & Taam, 2014, ApJ, 792, 71)



Treasure Hunting for Type Ia Supernova Ex-Companion Stars in the Large Magellanic Cloud

Ashley Pagnotta[1], Bradley E. Schaefer[2], Zachary I. Edwards[2], Emma S. Walker[3]
[1]American Museum of Natural History, [2]Louisiana State University, [3]Yale University

Introduction

Identifying the progenitor systems of Type Ia supernovae is a long-standing challenge for astronomy, with implications ranging from stellar evolution to cosmology. Of the two primary progenitor channels, one, the single degenerate (SD) channel, will leave behind evidence for centuries after the supernova in the form of a leftover ex-companion star, i.e. the non-degenerate star that fed mass to the white dwarf (WD) that eventually triggered its explosion. The other progenitor possibility, the double degenerate (DDs) channel, will have no leftover stars at the site of the explosion. One way to identify the progenitors of Type Ia supernovae that have already exploded is to search for ex-companion stars near the explosion sites.

This method has been employed by two other groups (led by Pilar Ruiz-Lapuente and Wolfgang Kerzendorf) studying the historical Galactic Type Ia superovae/supernova remnants (SNRs): Tycho (SN 1572) and SN 1006. Most of the discussion involving the Galactic SNRs has centered around the Tycho SNR, and the ex-companion candidacy of a G-type subgiant known as Star G and labeled as such in the image below (Ruiz-Lapuente et al. 2004, Ihara et al. 2007, Kerzendorf et al. 2009, González Hernández et al. 2009, Kerzendorf et al. 2013). At this point the data are conflicting, but further study may be able to confirm or rule out Tycho G as the ex-companion star. Both teams have also examined the SN 1006 remnant (González Hernández et al. 2012,

LMC SNR 0509-67.5

This combined BVI+Hα image shows the entirety of the SNR 0509-67.5 remnant, which was caused by a 1991T-subtype Type Ia supernova that exploded 400 ± 50 years ago (Badenes et al. 2009, Rest et al. 2005, 2008). The circle (marked C) in the center of the remnant is the extreme 3σ central region within which any possible ex-companion star must be located. There are no point sources within this region, to a limiting magnitude of V=26.9, which corresponds to a K9 main-sequence star at the distance of the LMC, and is more than 4 mags fainter than any possible ex-companion would be. SNR 0509-67.5 could not have had an SD progenitor, and therefore must have had a DD progenitor system.

The nebulous smudge located within this region is clearly visible. Based on detailed models of DD inspirals and explosions (Piersanti et al. 2003), we investigated this smudge further to determine whether it was material left over from the shredding of a secondary WD or a coincidental background galaxy. The nebulosity is not bright in the Hα image, although it is very red in color, with V=23.32 ± 0.07, I=20.95 ±

Top: Part of the 2D spectrum of SNR0509-67.5. The horizontal black lines have been added to highlight the continuum detection and to show the region used to generate the 1D spectrum below. The grey block to the right of center is the gap between two CCDs in the GMOS detector. This region has been set to have zero value.

Bottom: The 1D spectrum of the source in the 2D image. The vertical dashed lines show the wavelengths of Hα at z=0 and z=0.031, which correspond to the edge of the remnant and the faint emission line from the central nebulosity, respectively. With only one line in the spectrum, our identification (Hα at low redshift) is not fully constrained. The line is not anywhere near the wavelength we would expect for any line of a shredded CO WD disk at the distance of the LMC, and we have a non-detection of either carbon or oxygen species at z=0, so that hypothesis must be ruled out. The observed line, however, does match the prediction for a low-redshift background galaxy, and if it were any other common galactic

Facility for Rare Isotope Beams | Michigan State

Joint Institute for Nuclear Astrophysics

- NSF Physics Frontier Center
- Lead institution: MSU
- Just renewed! Goal is to understand the origin and evolution of the elements

PHYSICAL REVIEW C **77**, 024307 (2008)

Gamow-Teller strength for the analog transitions to the first $T = 1/2$, $J^{\pi} = 3/2^{-}$ states in ^{13}C and ^{13}N and the implications for type Ia supernovae

R. G. T. Zegers,[1,2,3,*] E. F. Brown,[1,2,3] H. Akimune,[4] Sam M. Austin,[1,3] A. M. van den Berg,[5] B. A. Brown,[1,2,3] D. A. Chamulak,[2,3] Y. Fujita,[6] M. Fujiwara,[7,8] S. Galès,[9] M. N. Harakeh,[5] H. Hashimoto,[8] R. Hayami,[10] G. W. Hitt,[1,2,3] M. Itoh,[11] T. Kawabata,[12] K. Kawase,[8] M. Kinoshita,[4] K. Nakanishi,[8] S. Nakayama,[10] S. Okumura,[8] Y. Shimbara,[1,3] M. Uchida,[13] H. Ueno,[14] T. Yamagata,[4] and M. Yosoi[8]

what do theorists want (from observers)?

- more spectropolarimetry
- more late-time (yr) spectra; determination of line profiles to high precision
- a better gamma-ray telescope
- early-time UV
- data-driven model for spectra
- be ready for serendipity
- good follow-up on the relatively near neighbors
- do we understand the required statistics to solve problems?
- long-term followup—look for companions (esp. He donors)