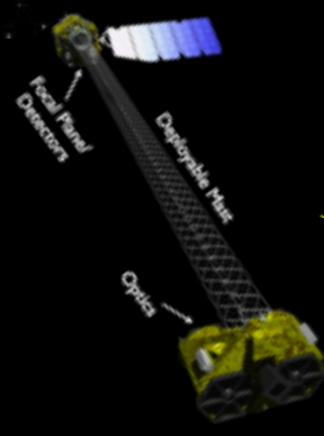
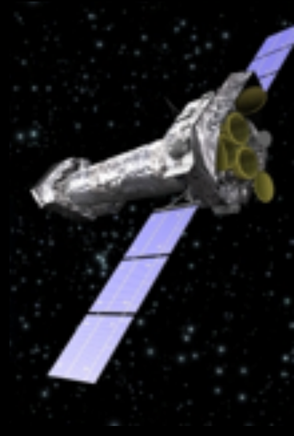
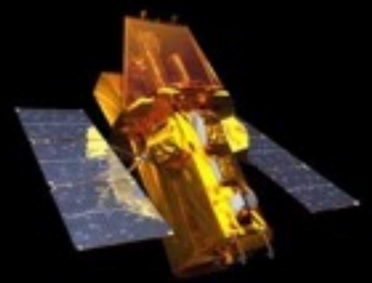




Soft and Hard X-rays from YOUNG Stellar Explosions



Raffaella Margutti

Dan Milisavljevic, Jerod Parrent, Atish Kamble, Wen-Fai Fong, Ryan Chornock, Ashley Zauderer

“We always find something, eh Didi, to give us the impression We exist?”   S. Beckett

Envelope-Stripped SNe

Deepest Limits to Type Ia SNe

Margutti et al,.2014ApJ…790…52M
Margutti et al., 2012ApJ…751..134M

First solid detection of X-rays from a SuperLuminous SN

Chandra is observing right now!!!

Margutti et al., in prep

The weakest Engine-driven SNe

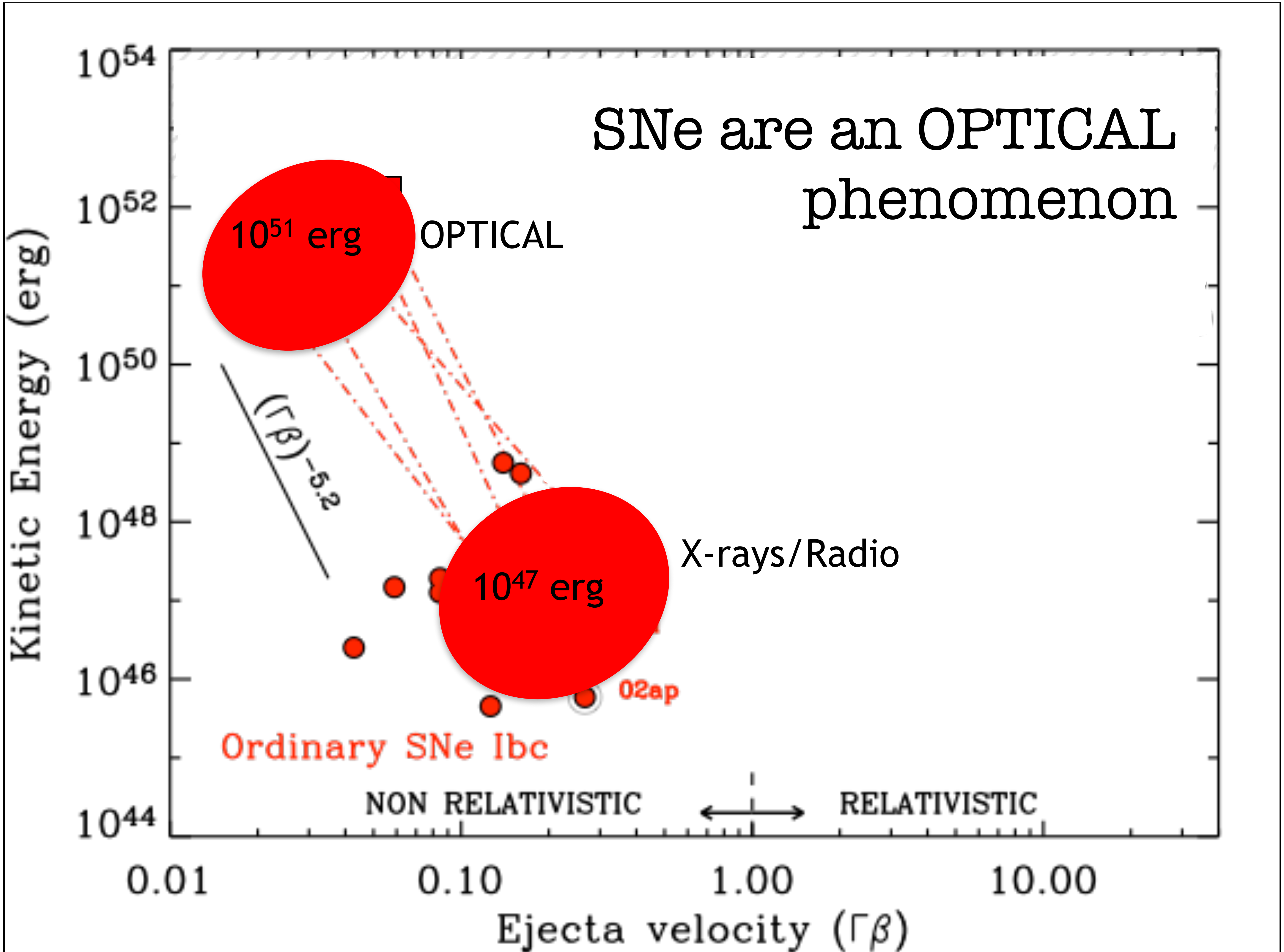
Margutti et al., 2014ApJ…797..107M
Margutti et al., 2013ApJ…778…18M

Massive Envelope Ejection timed with Core-Collapse

(The SN chameleon 2014C)

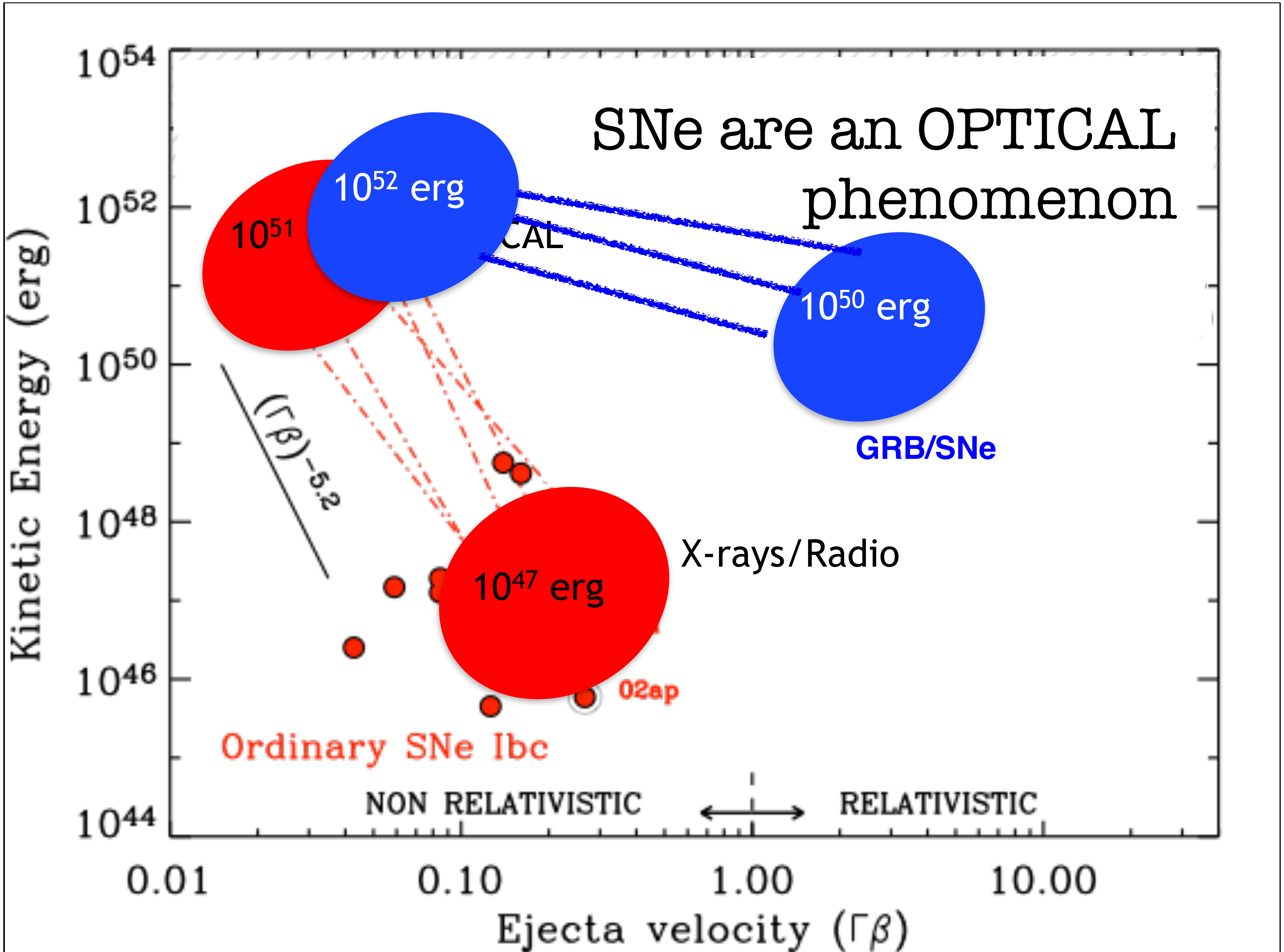
Margutti et al., ApJ Submitted, 2016arXiv160106806M
Milisavljevic, Margutti et al., 2015ApJ…815..120M

Energy partitioning



Margutti +13, +14, +15, +16; Kamble +13

Energy partitioning



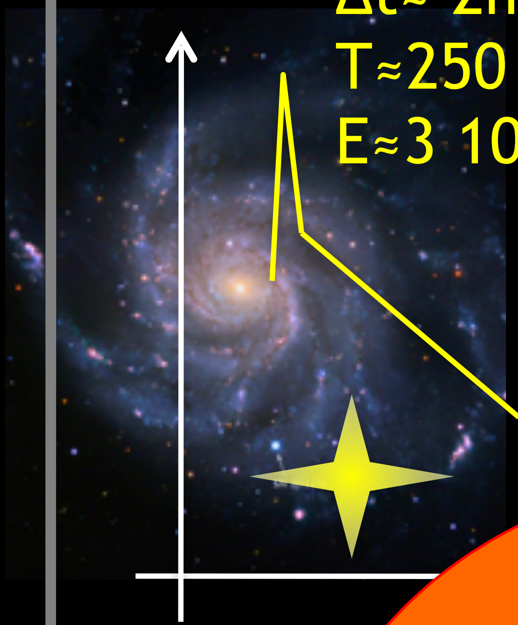
Margutti +13, +14, +15, +16; Kamble +13

"It sort of makes you stop and think, doesn't it."

X-rays from Supernovae

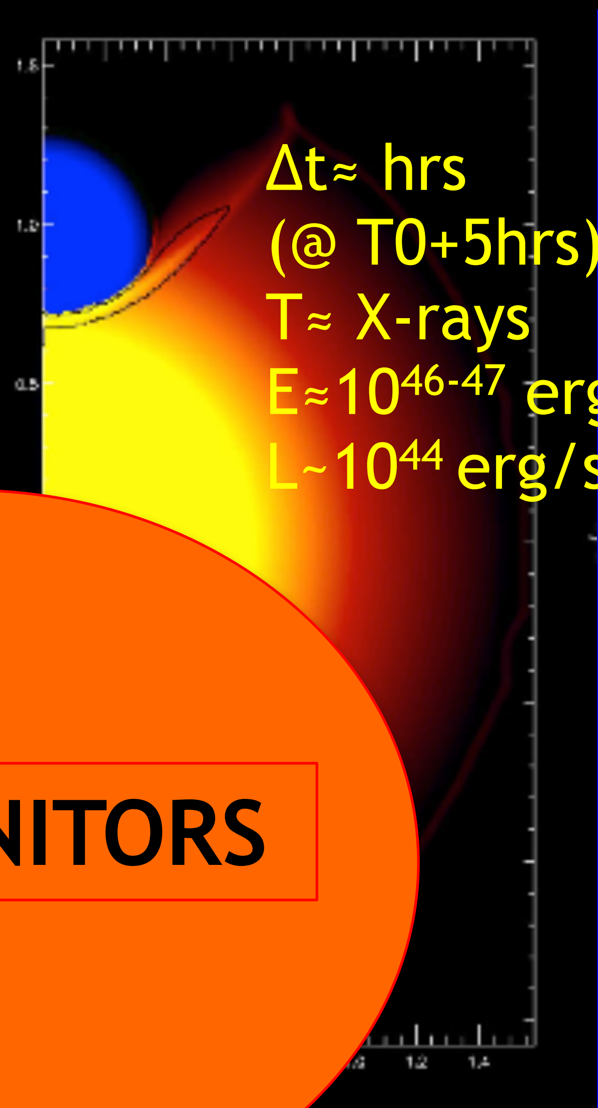
Log Lx

SHOCK BREAK OUT
(R exploding star)



Δt≈ 2ms
T≈250 keV
E≈3 10^{41} erg

SHOCK INTERACTION w. COMPANION
(R and distance of the companion



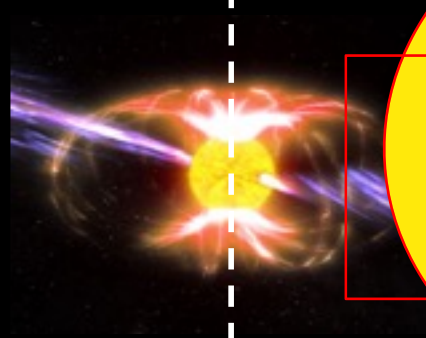
Δt≈ hrs
(@ T0+5hrs)
T≈ X-rays
E≈10^{46-47} erg
L~10^{44} erg/s

< several hrs

SHOCK/JET INTERACTION w. the MEDIUM
(mass-loss of the progenitor)

MASS-LOSS

RADIATION from the REMNANT



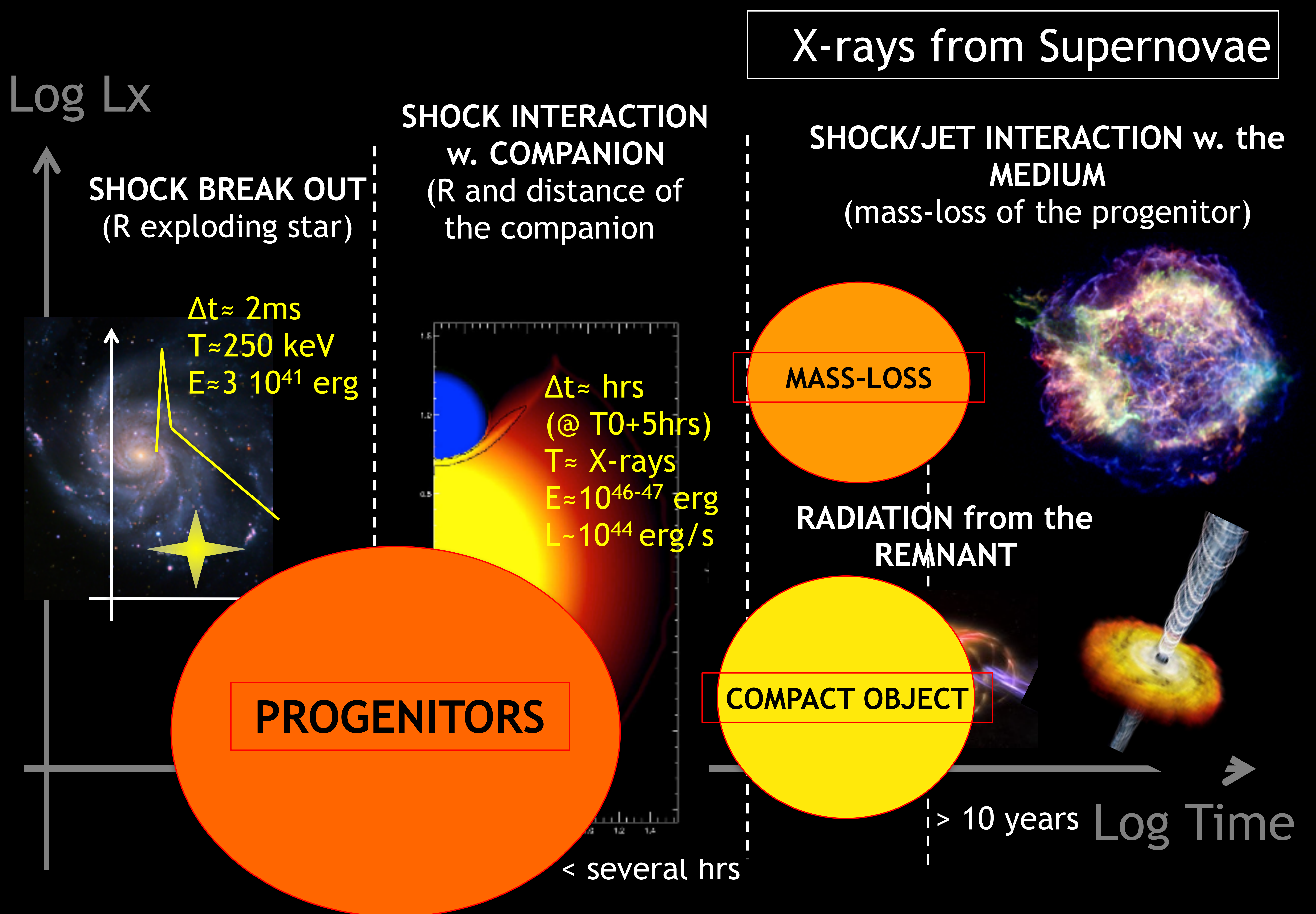
COMPACT OBJECT

PROGENITORS

> 10 years

Log Time

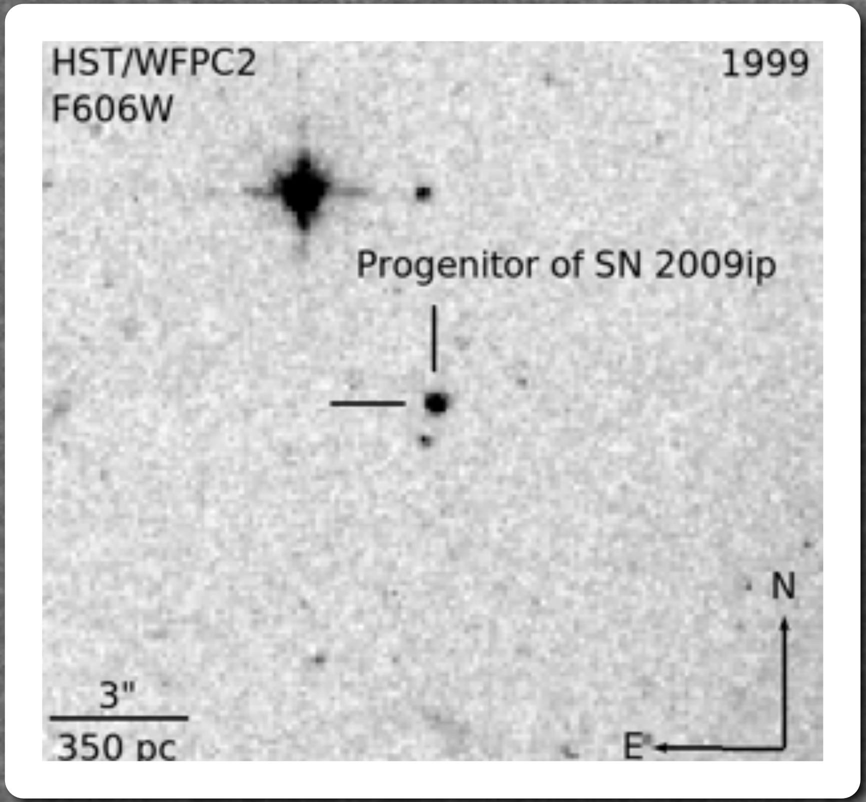
...BUT...


X-rays from Supernovae
Log Lx
SHOCK BREAK OUT
(R exploding star)
Δt≈ 2ms
T≈250 keV
E≈3 10^41 erg
SHOCK INTERACTION
w. COMPANION
(R and distance of
the companion
Δt≈ hrs
(@ T0+5hrs)
T≈ X-rays
E≈10^46-47 erg
L~10^44 erg/s
SHOCK/JET INTERACTION w. the
MEDIUM
(mass-loss of the progenitor)
MASS-LOSS
RADIATION from the
REMNANT
COMPACT OBJECT
PROGENITORS
< several hrs
> 10 years
Log Time

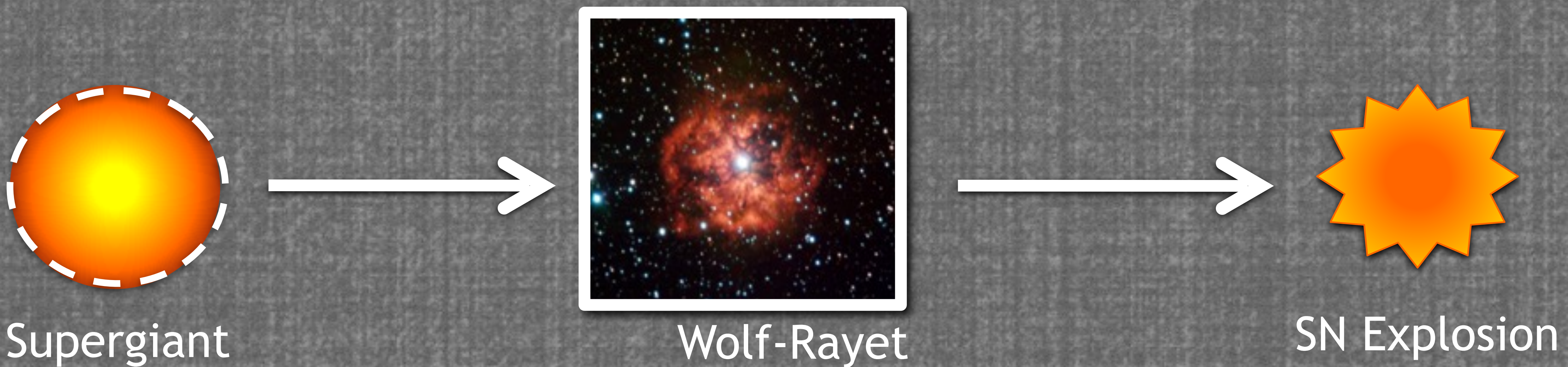
The BIG questions

(current Areas of Ignorance)

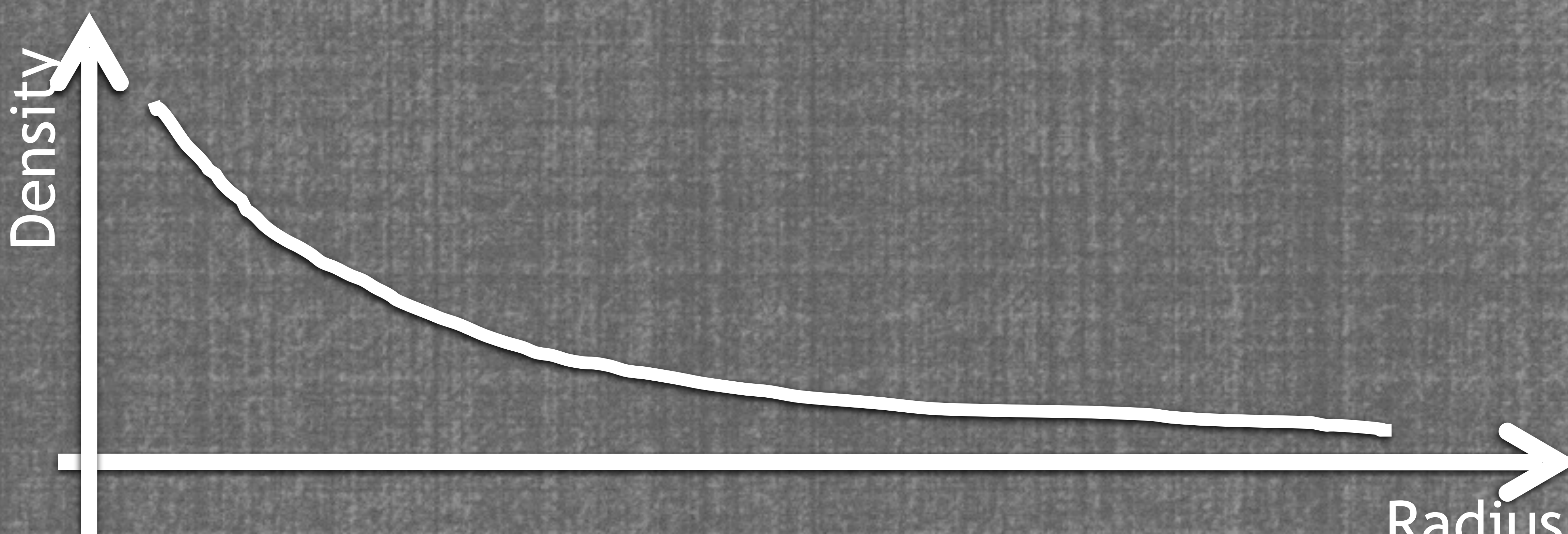
- Stellar Progenitors
  and their pre-explosion structure
- Mass Loss
- Explosion Mechanism/ Source of Energy



Expected Evolution from Stellar tracks:



~10^4-10^5 yrs



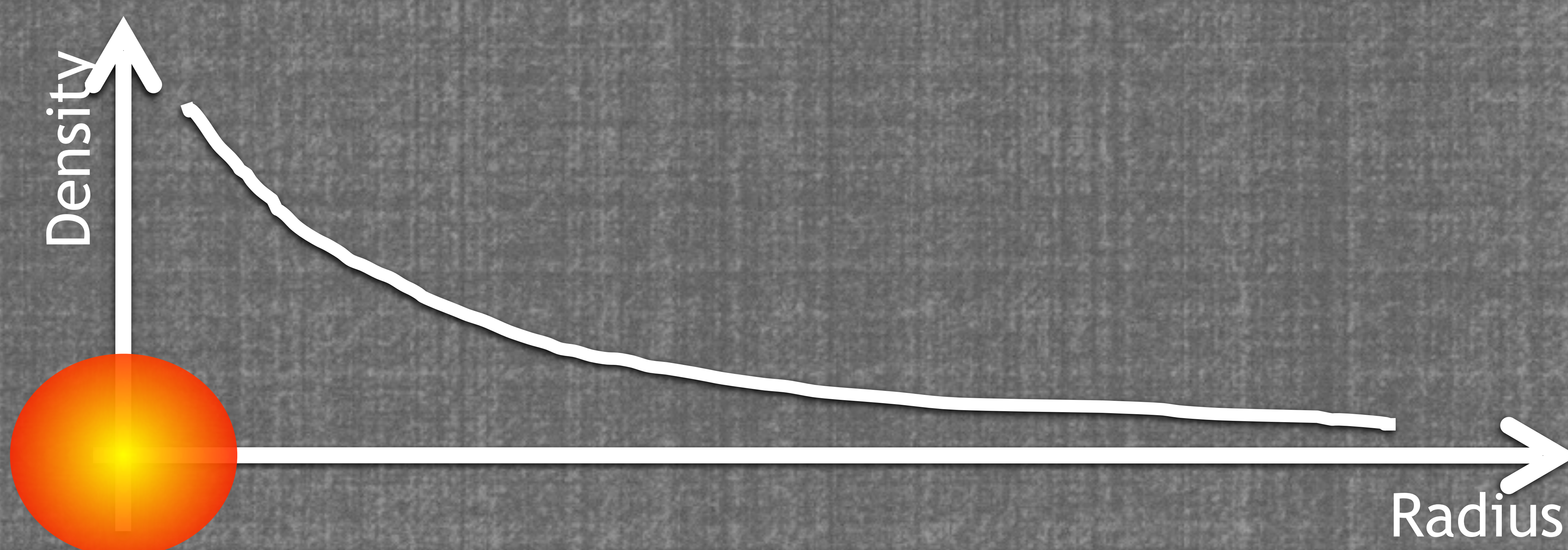
Expected Evolution from Stellar tracks:

Supergiant

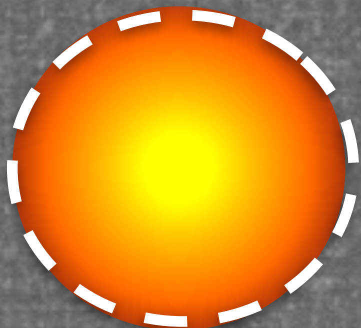
Wolf-Rayet

~10^4-10^5 yrs

SN Explosion



Expected Evolution from Stellar tracks:

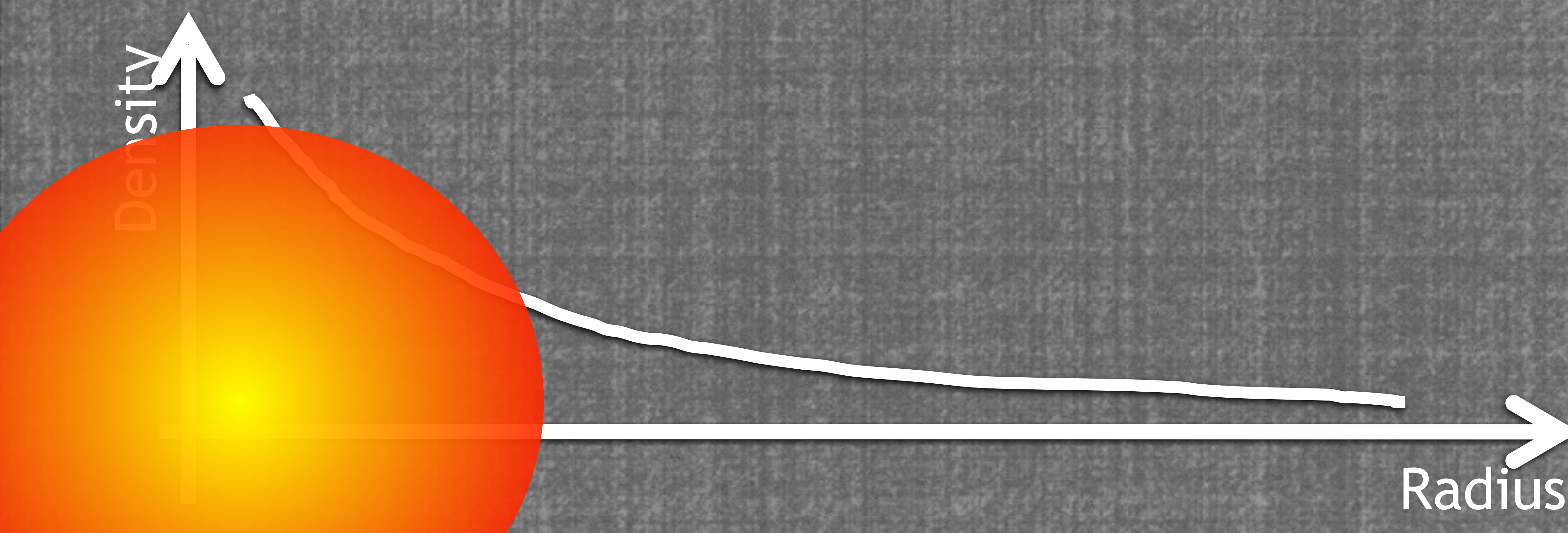


Supergiant

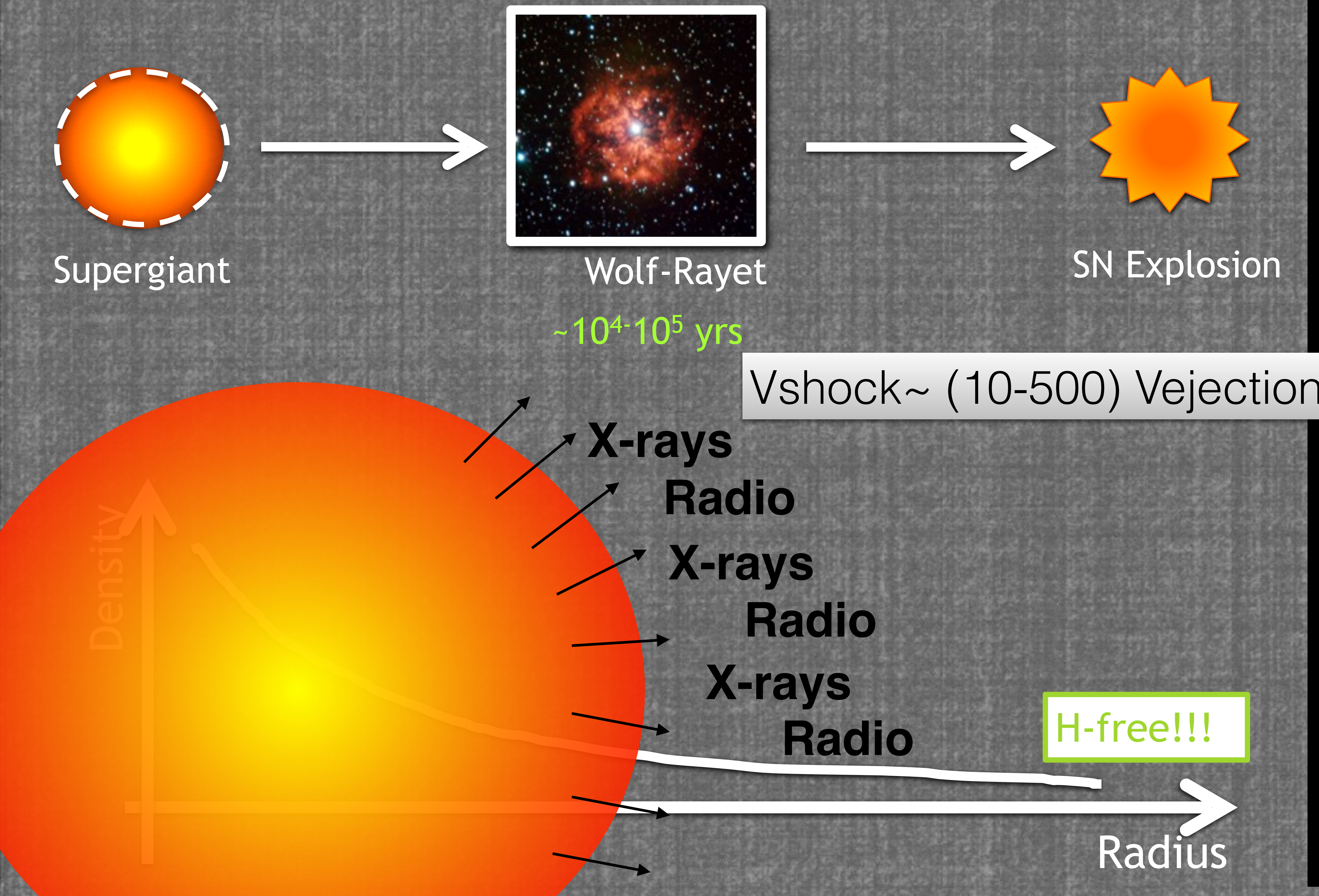
Wolf-Rayet

~10^4-10^5 yrs

SN Explosion



Expected Evolution from Stellar tracks:



Vshock~ (10-500) Vejection

(10-500)t

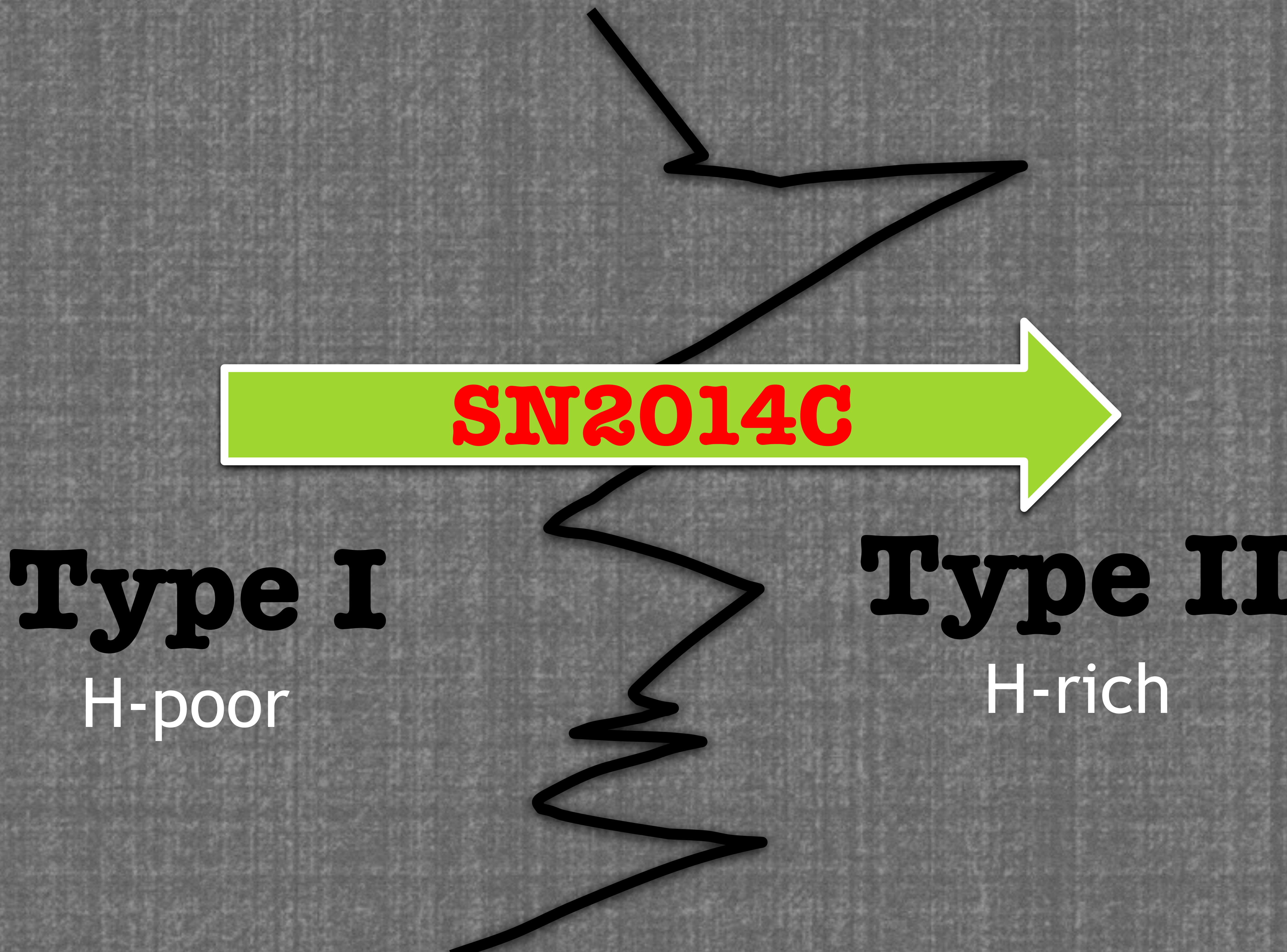
Core-Collapse SN

Type I

H-poor

Type II

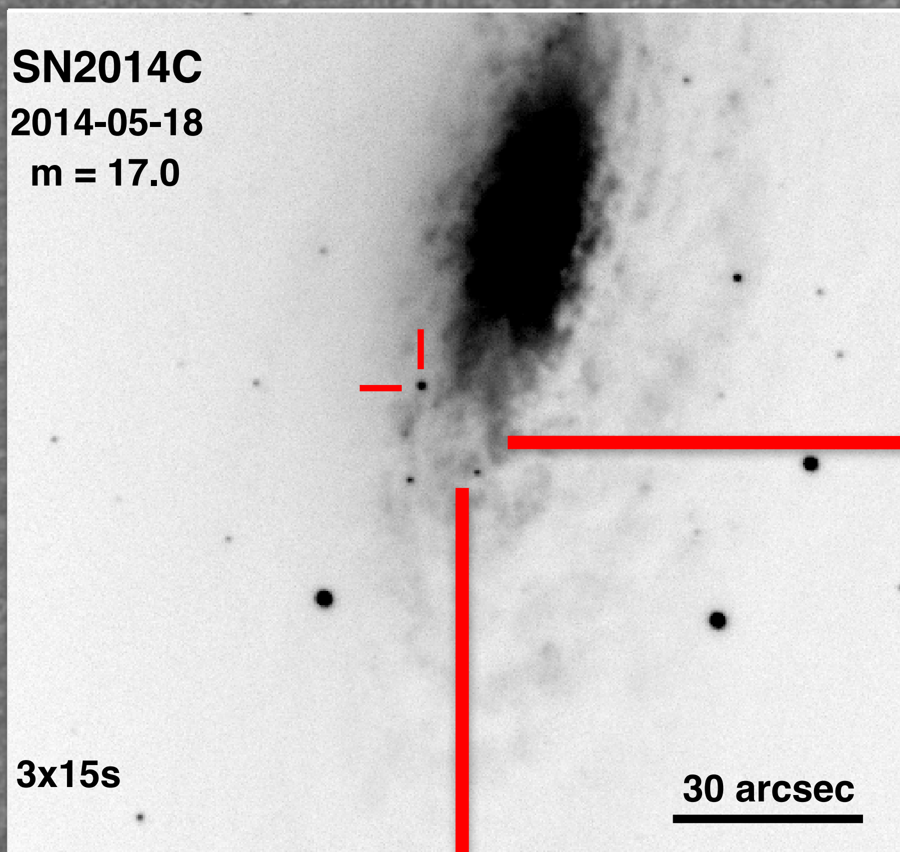
H-rich



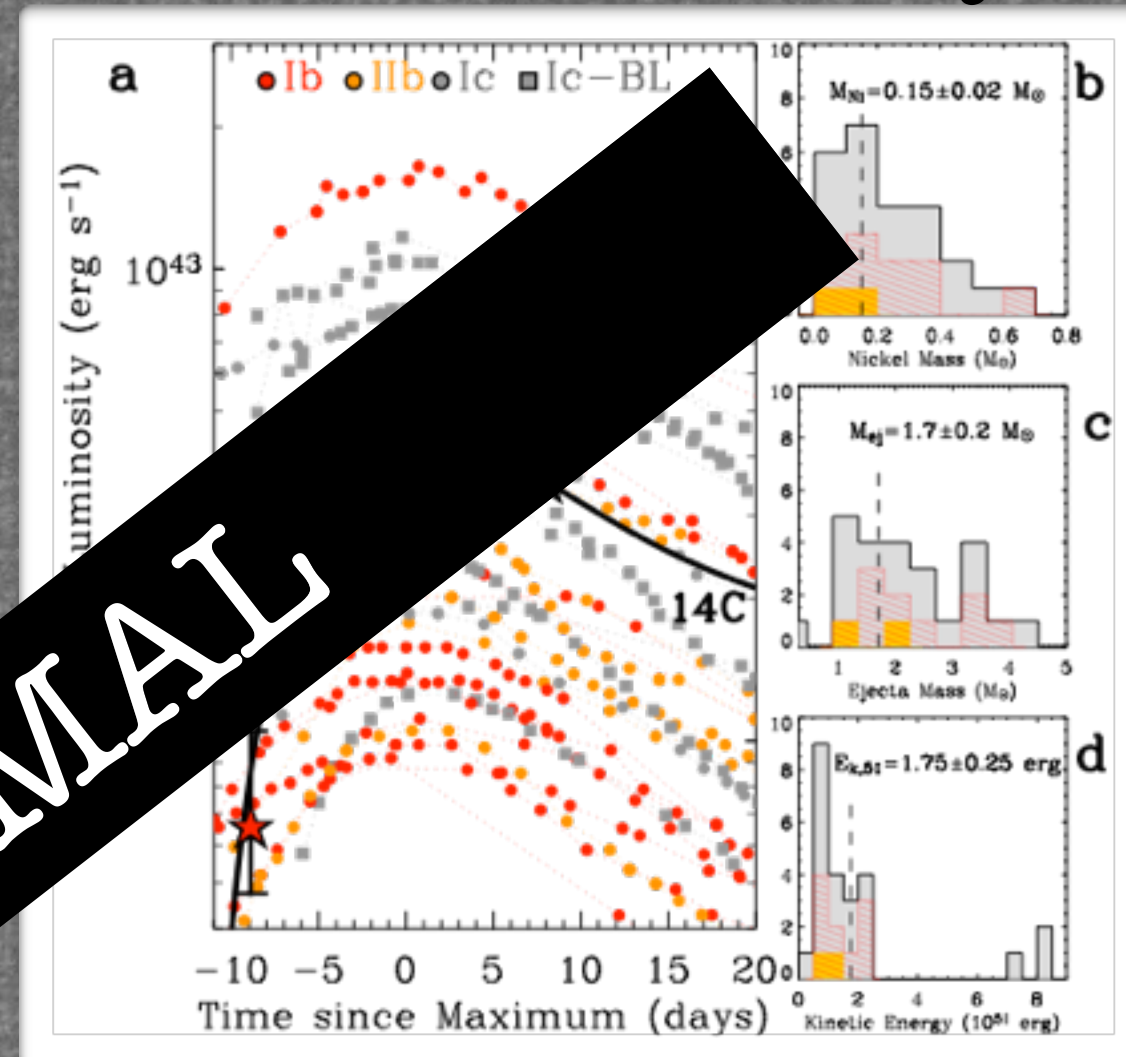
Margutti et al., 2016, Submitted, arXiv: 1601.06806

SN2014C: a normal Ib SN

dist=15.7 Mpc



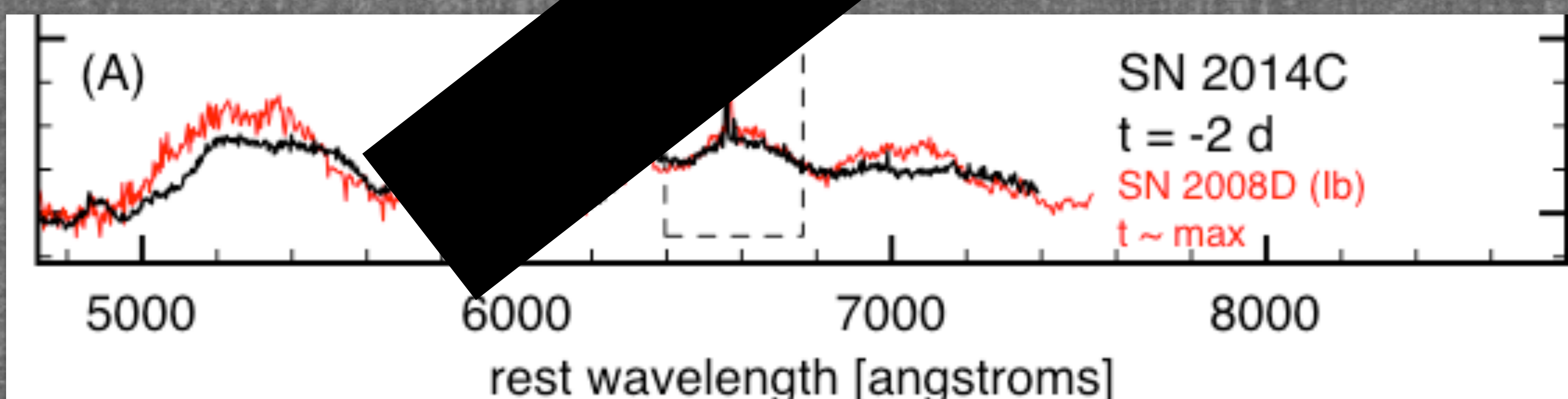
Bolometric Luminosity



RM+16

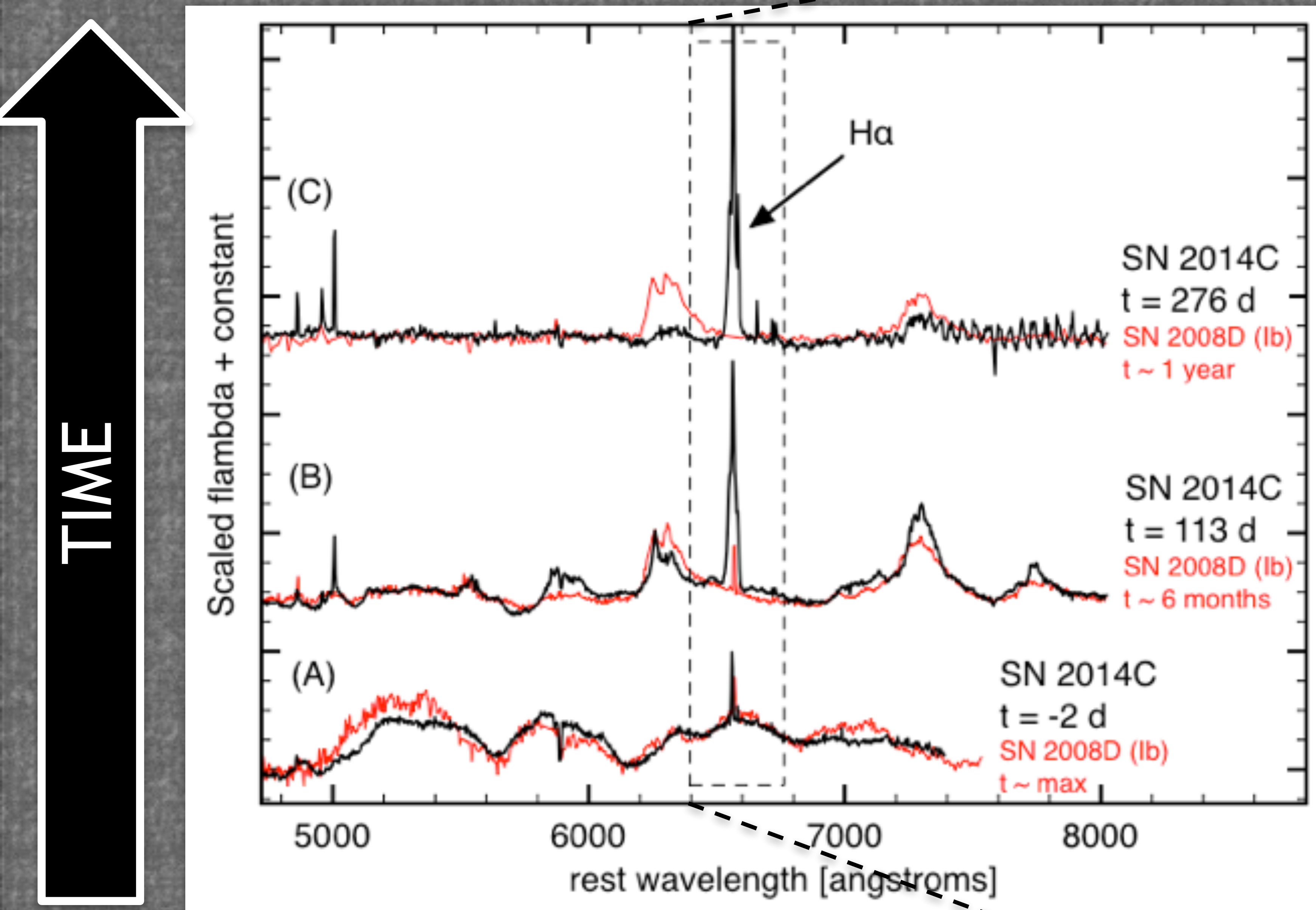
NORMAL

Optical Spectrum at

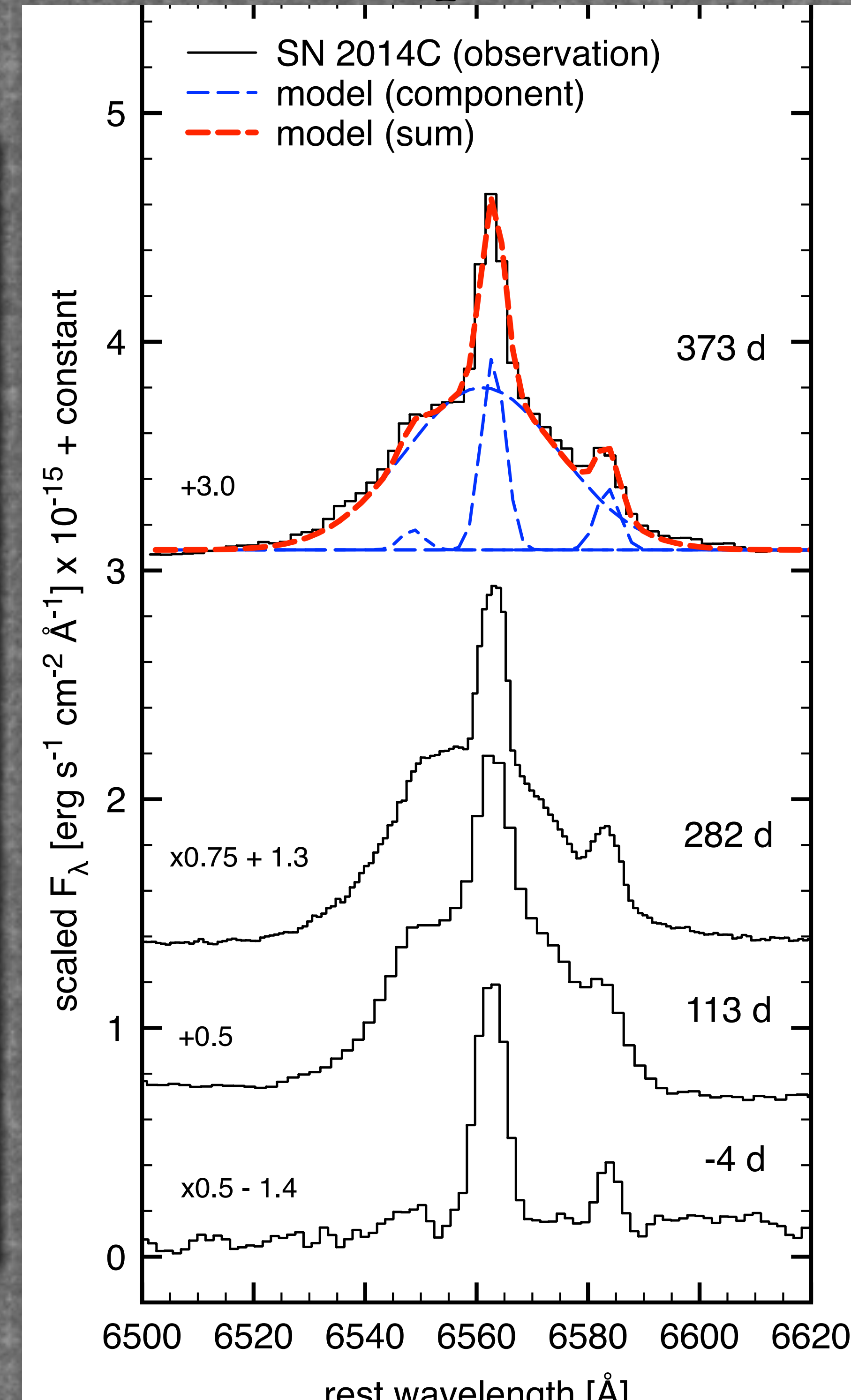


Milisavljevic, RM+15

SN2014C-Optical



Halpha

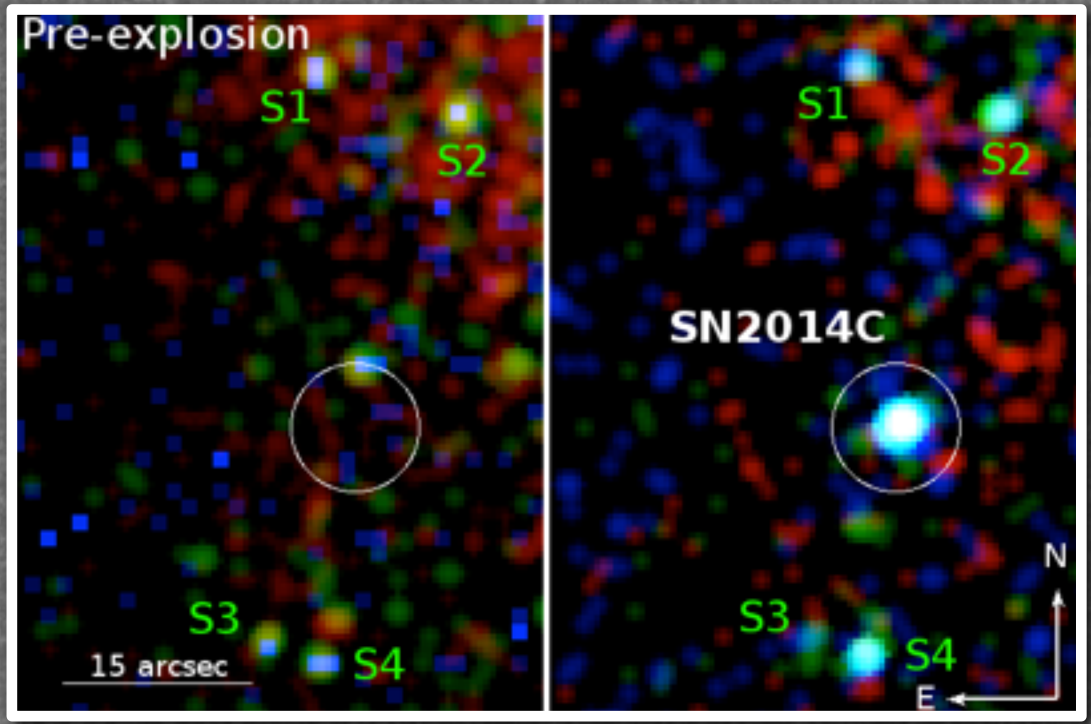


Milisavljevic, RM+15

Development of H-features with time

SN2014C-X-rays (soft+hard)

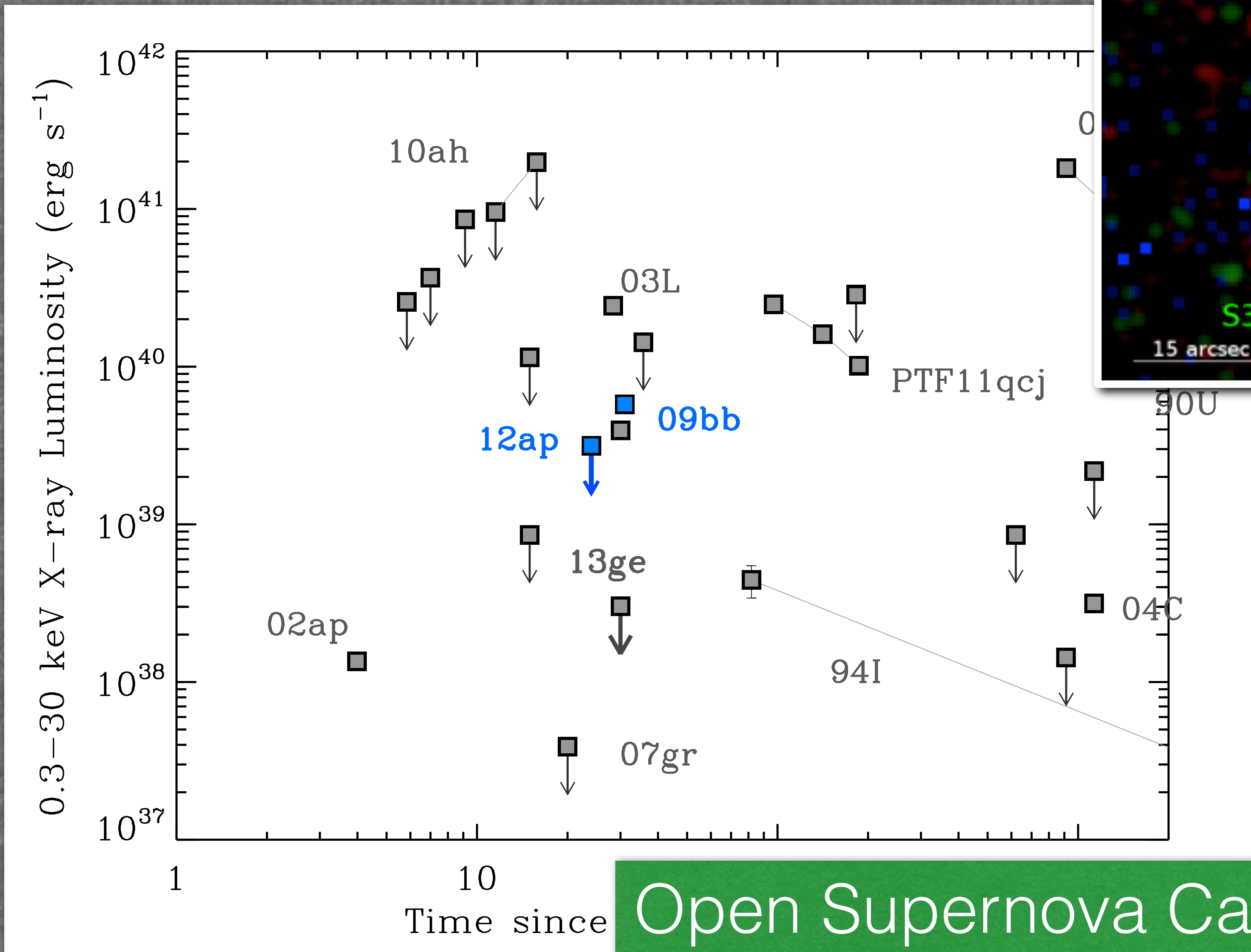
Chandra

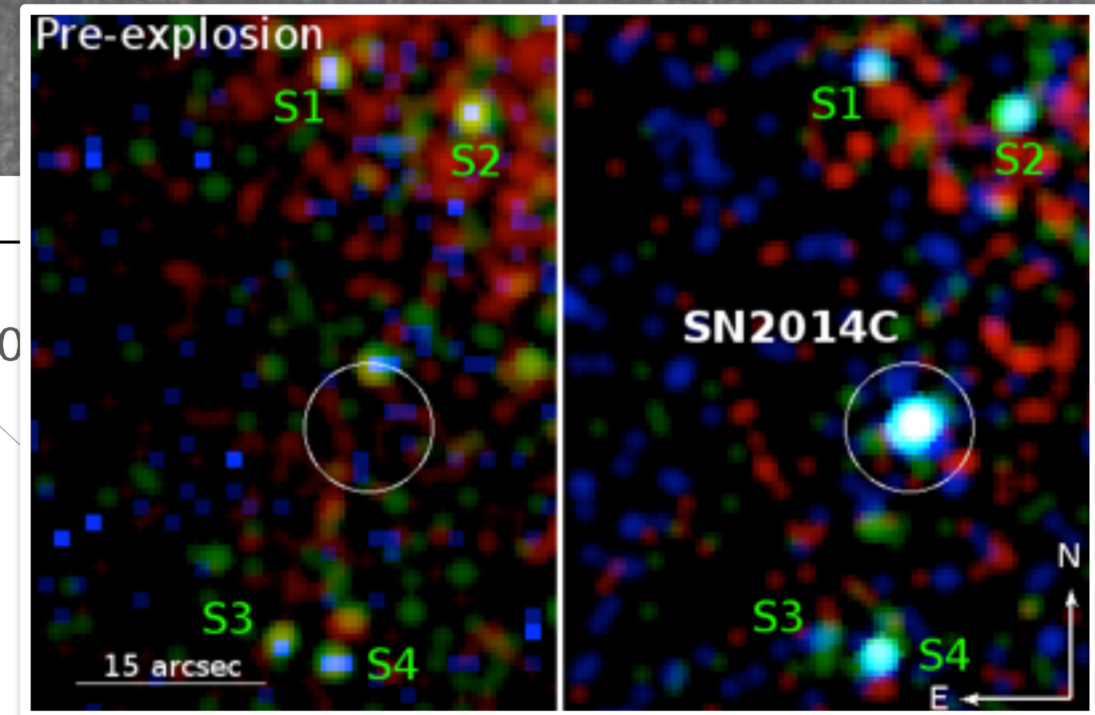


RM+16

FIRST Hstripped-SN ever detected at hard X-rays!

SN2014C-X-rays (soft+hard)



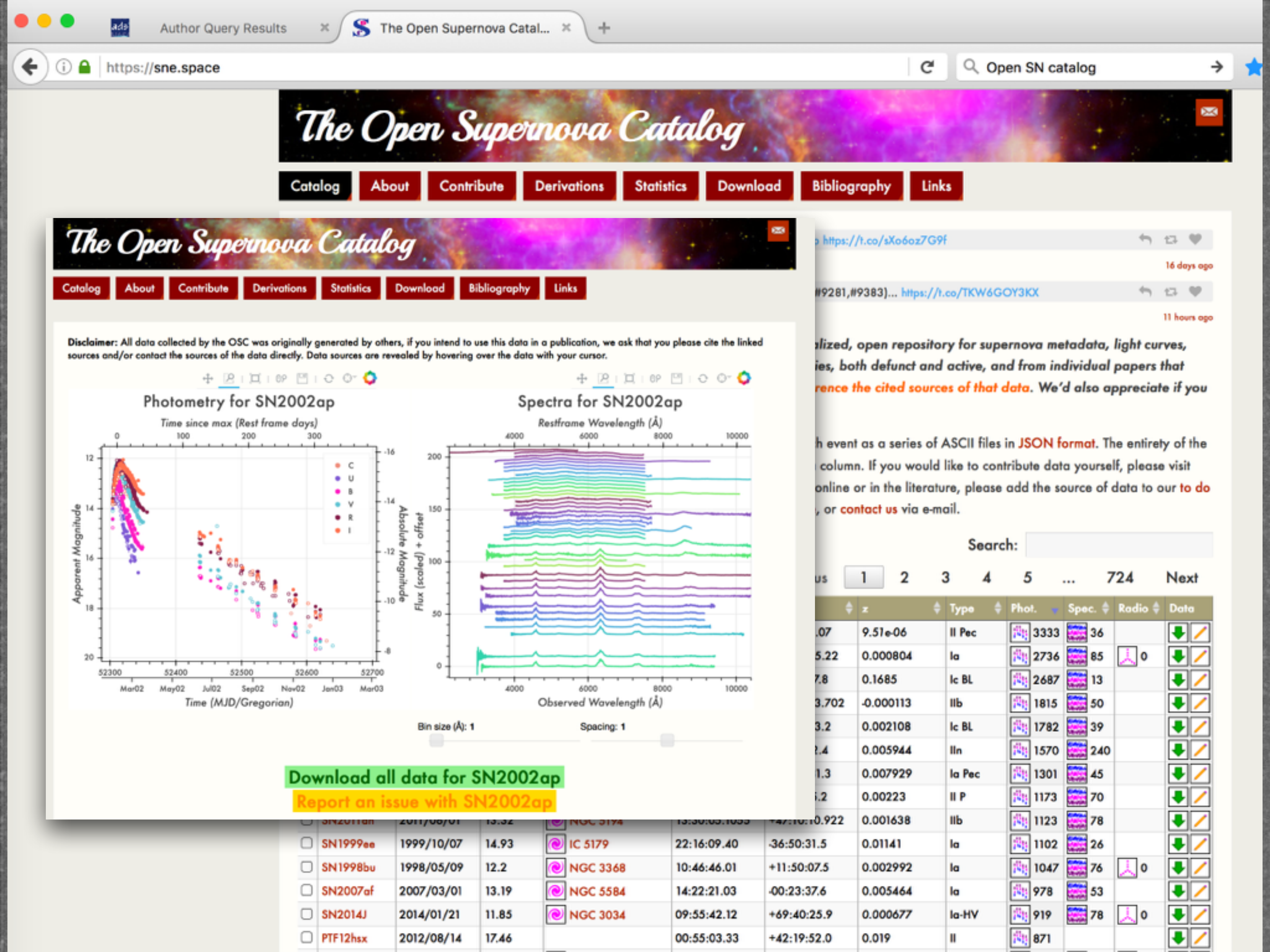


RM+16

Rising X-ray Luminosity!

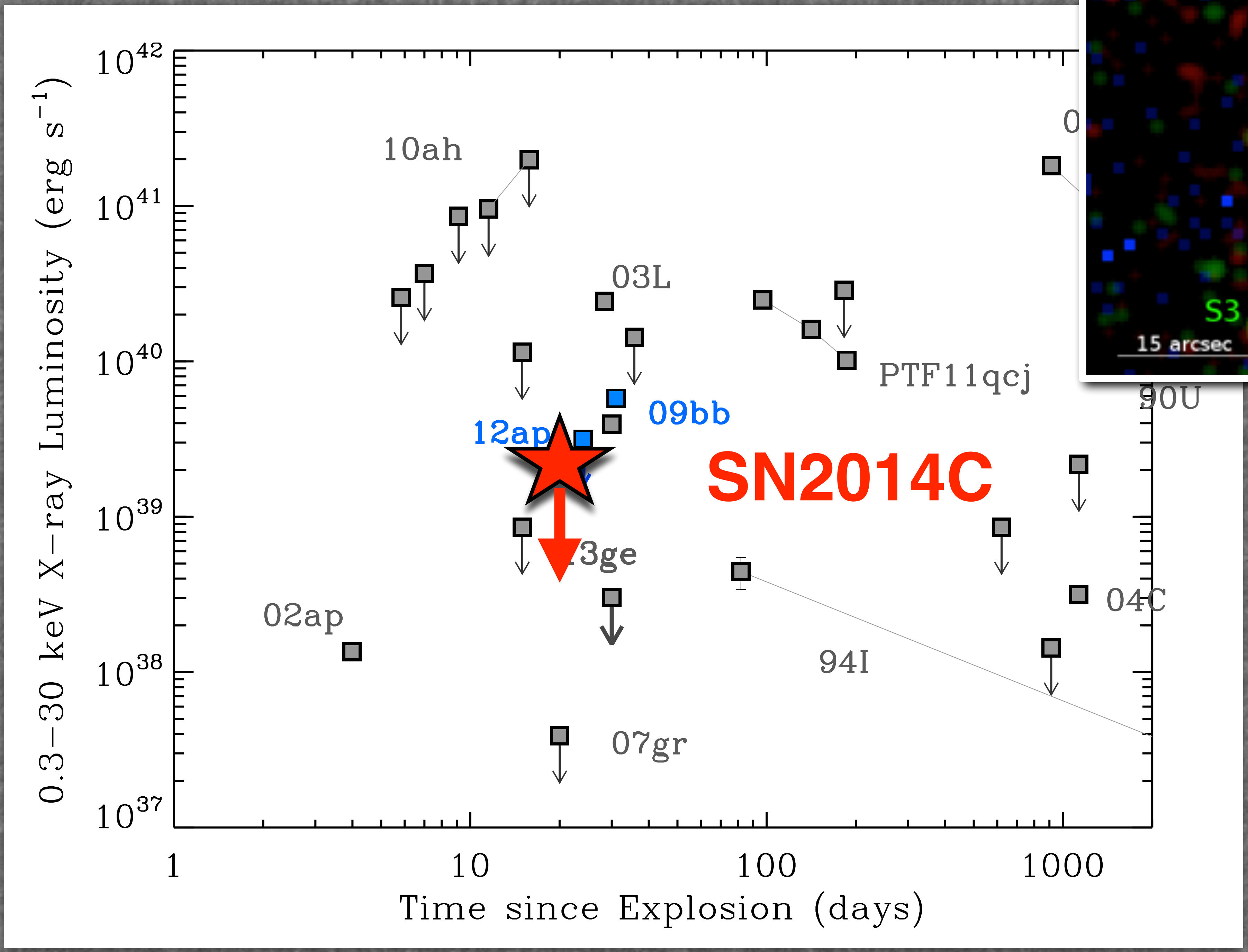
Open Supernova Catalog (~36000 SNe)
https://sne.space/

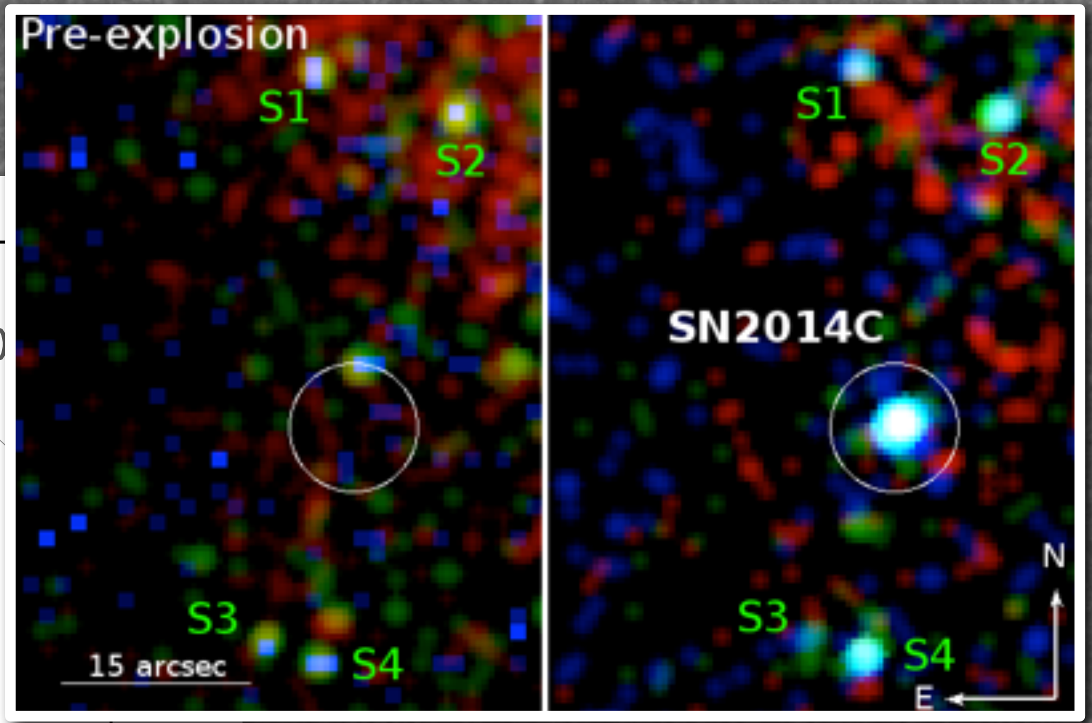
FIRST Hstripped-SN ever detected at hard X-rays!



Author Query Results
The Open Supernova Catal...
https://sne.space
Open SN catalog
The Open Supernova Catalog
Catalog
About
Contribute
Derivations
Statistics
Download
Bibliography
Links
https://t.co/sXo6oz7G9f
16 days ago
#9281,#9383)... https://t.co/TKW6GOY3KX
11 hours ago
alized, open repository for supernova metadata, light curves,
ies, both defunct and active, and from individual papers that
rence the cited sources of that data. We'd also appreciate if you
h event as a series of ASCII files in JSON format. The entirety of the
column. If you would like to contribute data yourself, please visit
online or in the literature, please add the source of data to our to do
, or contact us via e-mail.
Search:
1 2 3 4 5 ... 724 Next
Type
Phot.
Spec.
Radio
Data
Disclaimer: All data collected by the OSC was originally generated by others, if you intend to use this data in a publication, we ask that you please cite the linked sources and/or contact the sources of the data directly. Data sources are revealed by hovering over the data with your cursor.
Photometry for SN2002ap
Time since max (Rest frame days)
Apparent Magnitude
Absolute Magnitude
Time (MJD/Gregorian)
Spectra for SN2002ap
Restframe Wavelength (Å)
Flux (scaled) + offset
Observed Wavelength (Å)
Bin size (Å): 1
Spacing: 1
Download all data for SN2002ap
Report an issue with SN2002ap
SN1999ee 1999/10/07 14.93 IC 5179 22:16:09.40 -36:50:31.5 0.01141 Ia 1102 26
SN1998bu 1998/05/09 12.2 NGC 3368 10:46:46.01 +11:50:07.5 0.002992 Ia 1047 76 0
SN2007af 2007/03/01 13.19 NGC 5584 14:22:21.03 -00:23:37.6 0.005464 Ia 978 53
SN2014J 2014/01/21 11.85 NGC 3034 09:55:42.12 +69:40:25.9 0.000677 Ia-HV 919 78 0
PTF12hsx 2012/08/14 17.46 00:55:03.33 +42:19:52.0 0.019 II 871

SN2014C-X-rays (soft+hard)



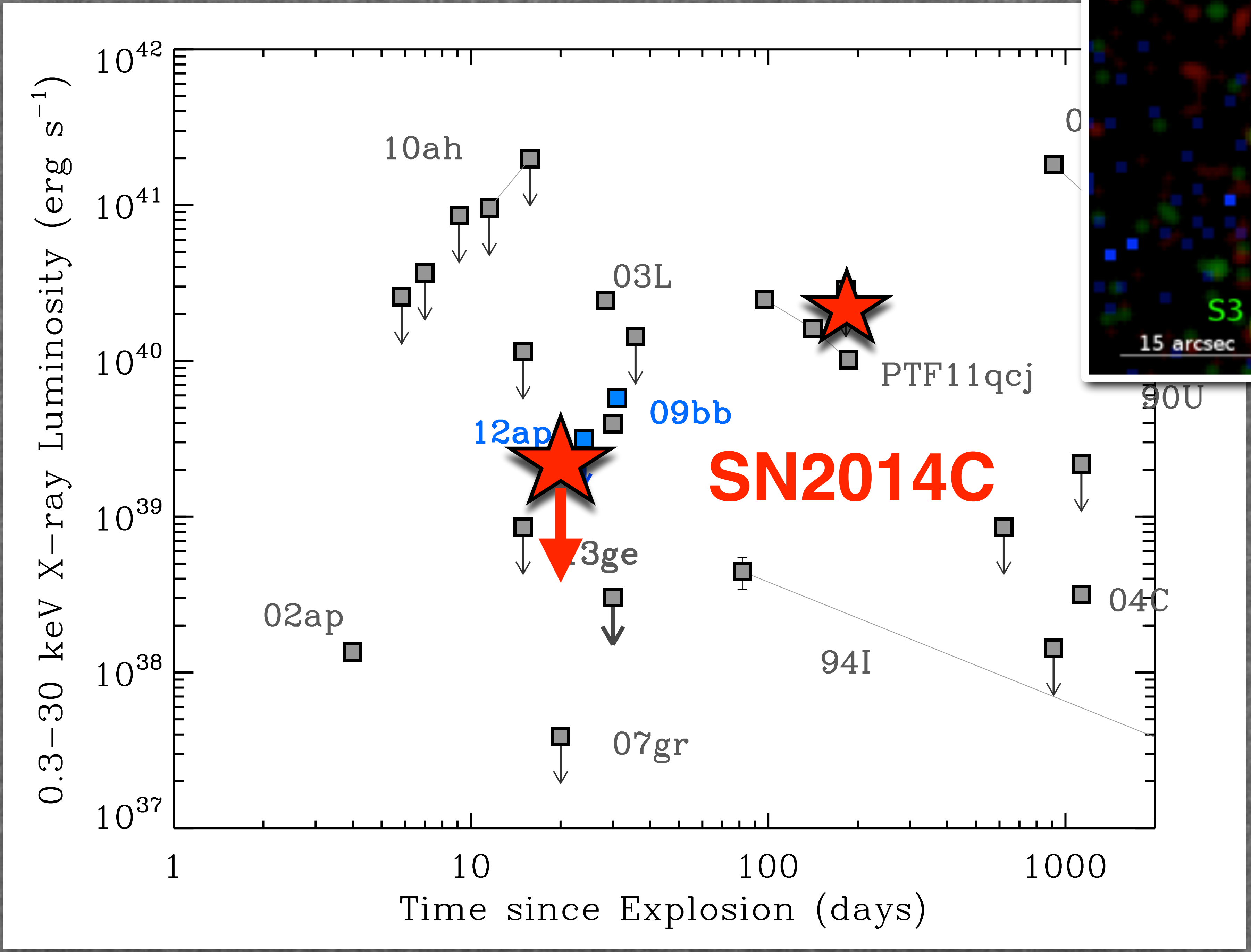


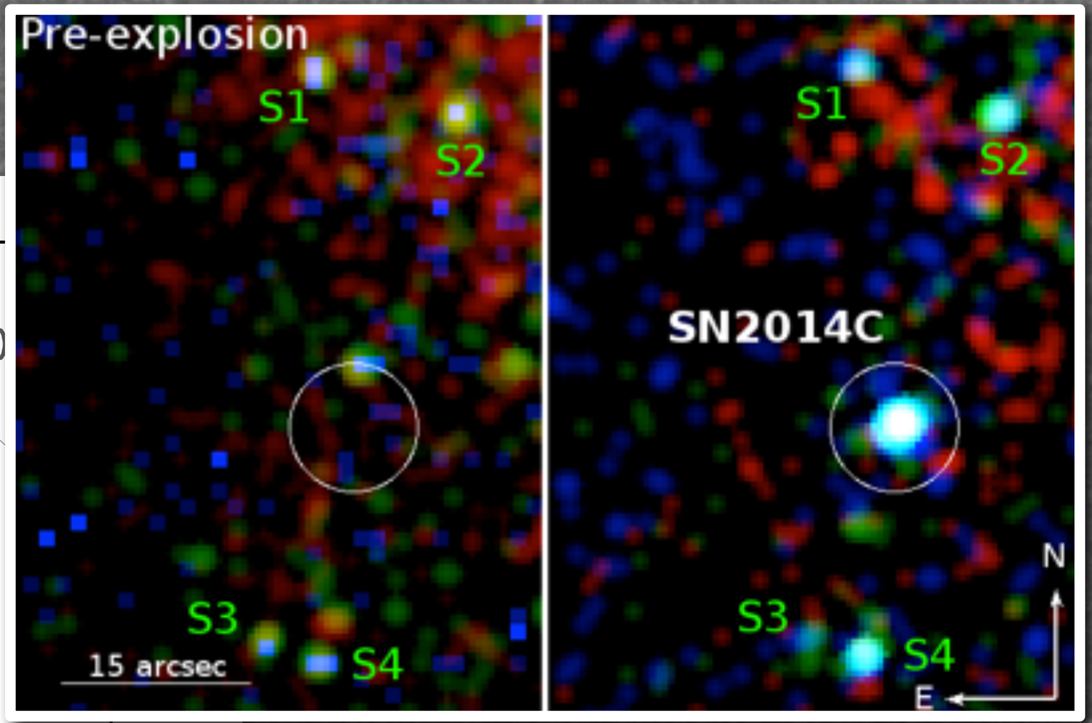
RM+16

Rising X-ray Luminosity!

FIRST Hstripped-SN ever detected at hard X-rays!

SN2014C-X-rays (soft+hard)



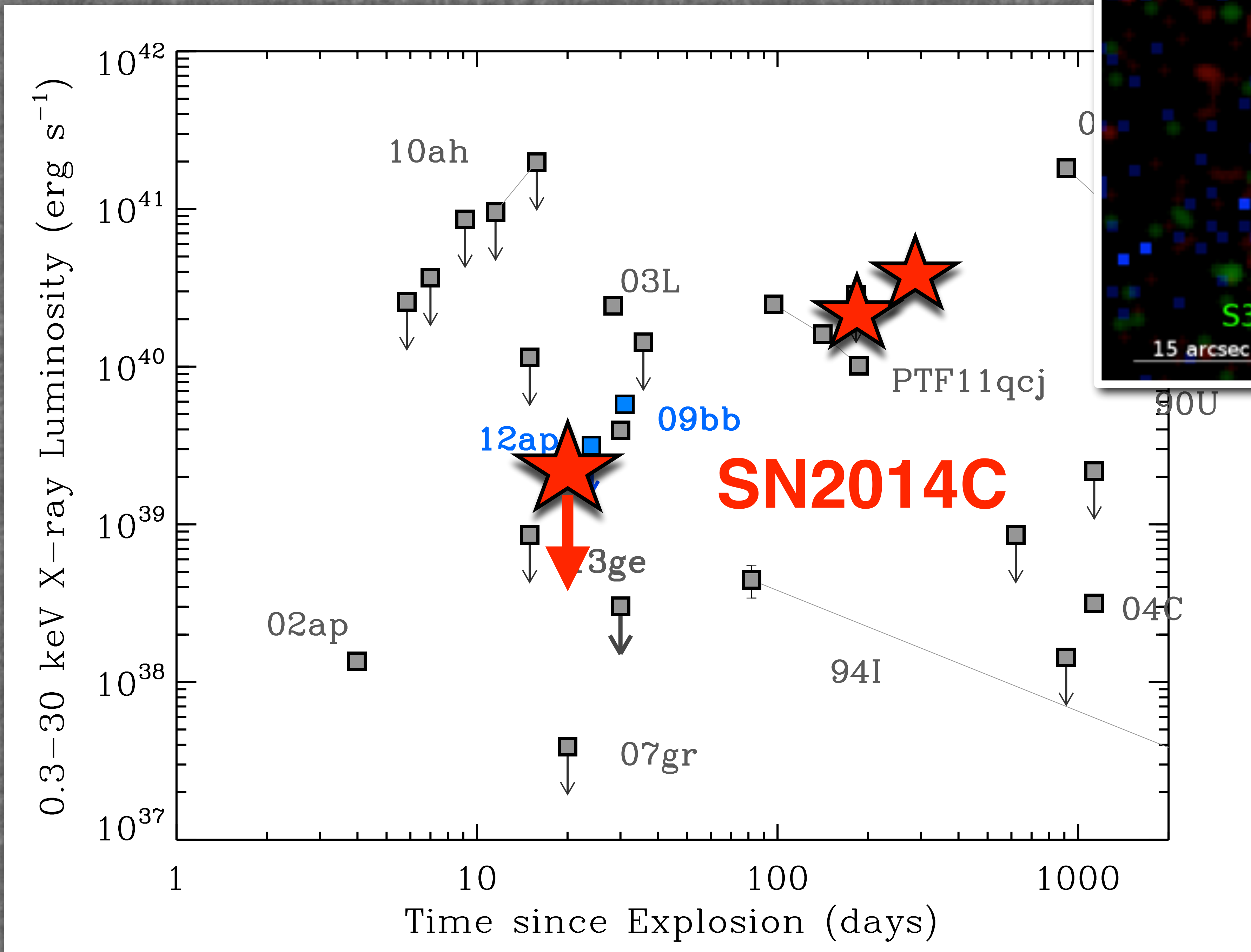


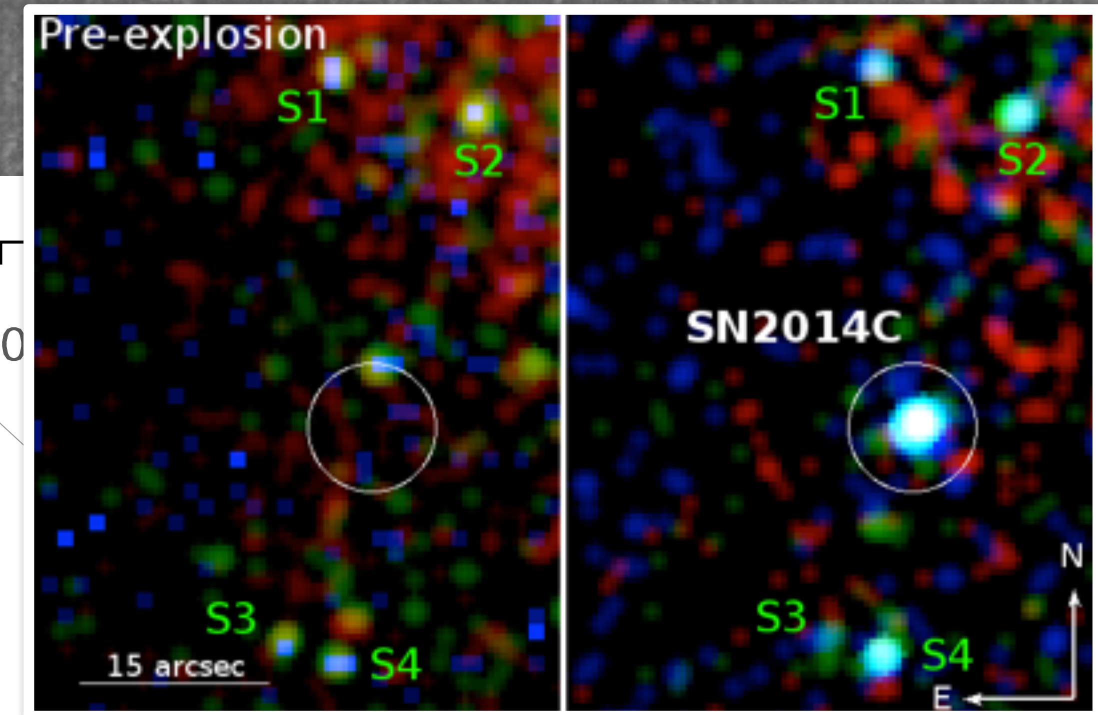
RM+16

Rising X-ray Luminosity!

FIRST Hstripped-SN ever detected at hard X-rays!

SN2014C-X-rays (soft+hard)



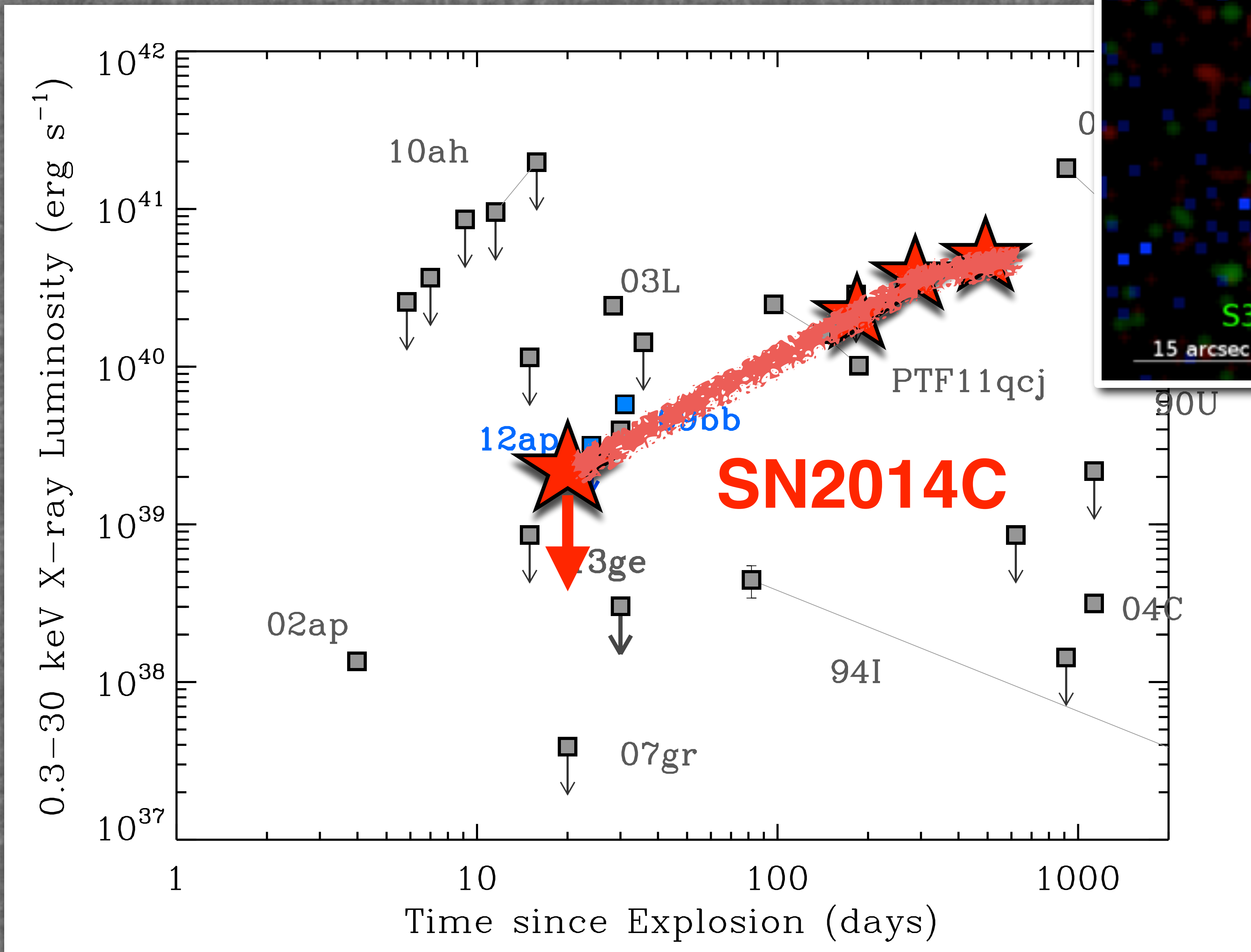


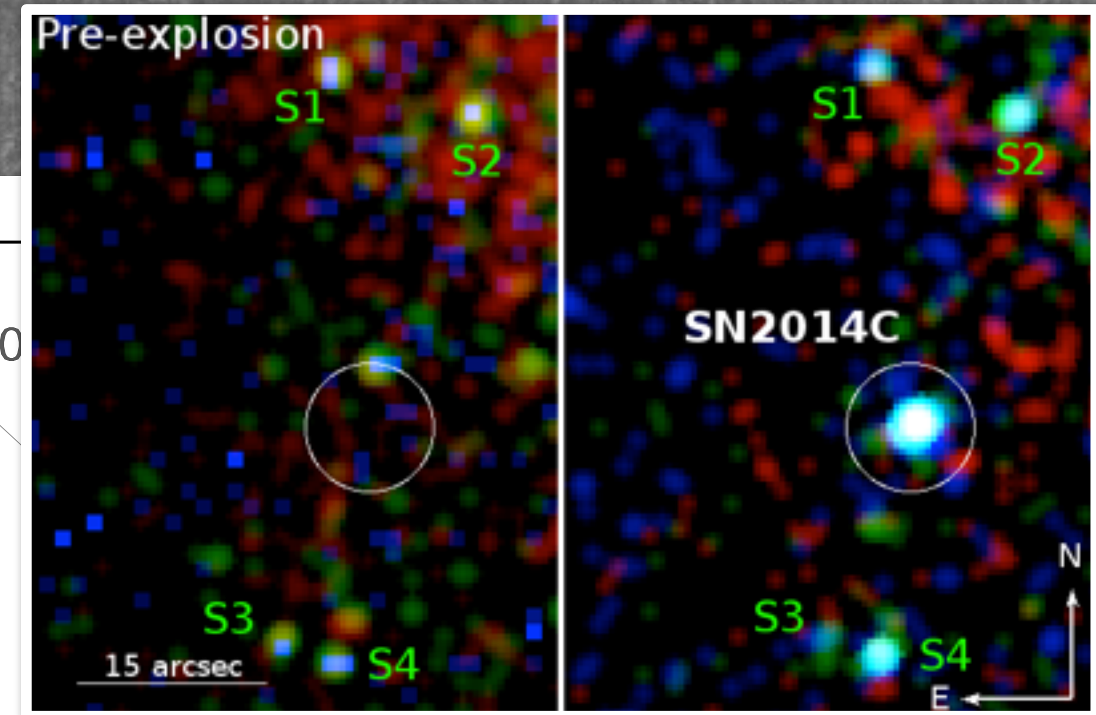
RM+16

Rising X-ray Luminosity!

FIRST Hstripped-SN ever detected at hard X-rays!

SN2014C-X-rays (soft+hard)





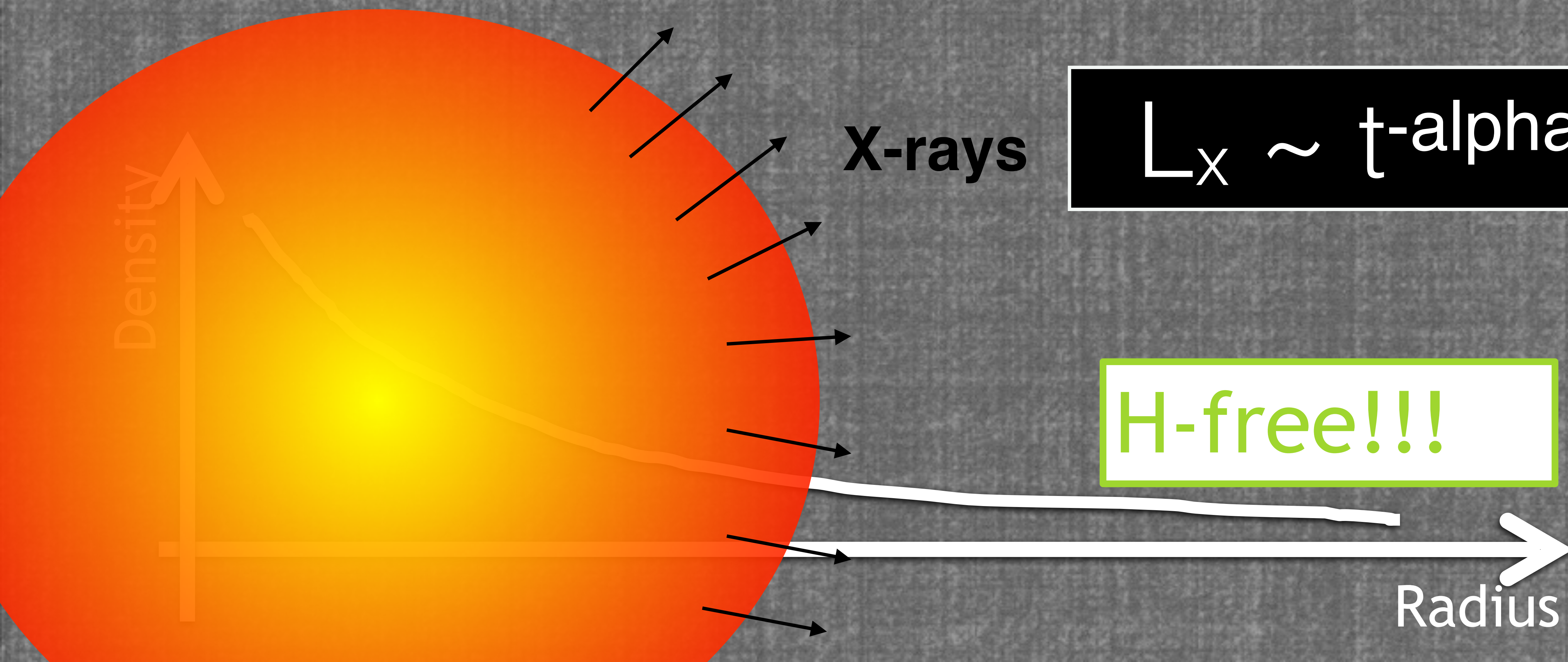
RM+16

Rising X-ray Luminosity!

FIRST Hstripped-SN ever detected at hard X-rays!

Expected Evolution from Stellar tracks:

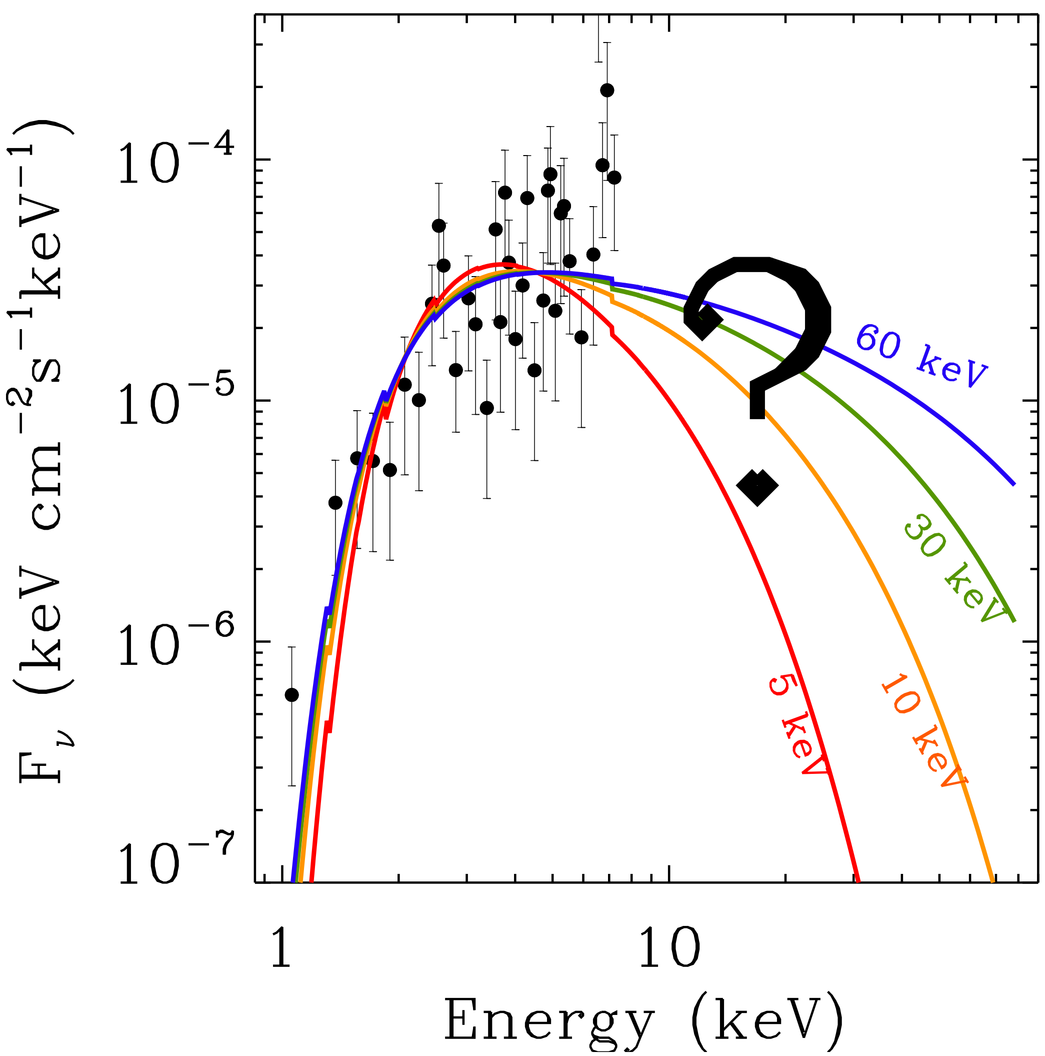
~10^4-10^5 yrs



$L_X \sim t^{-alpha}$

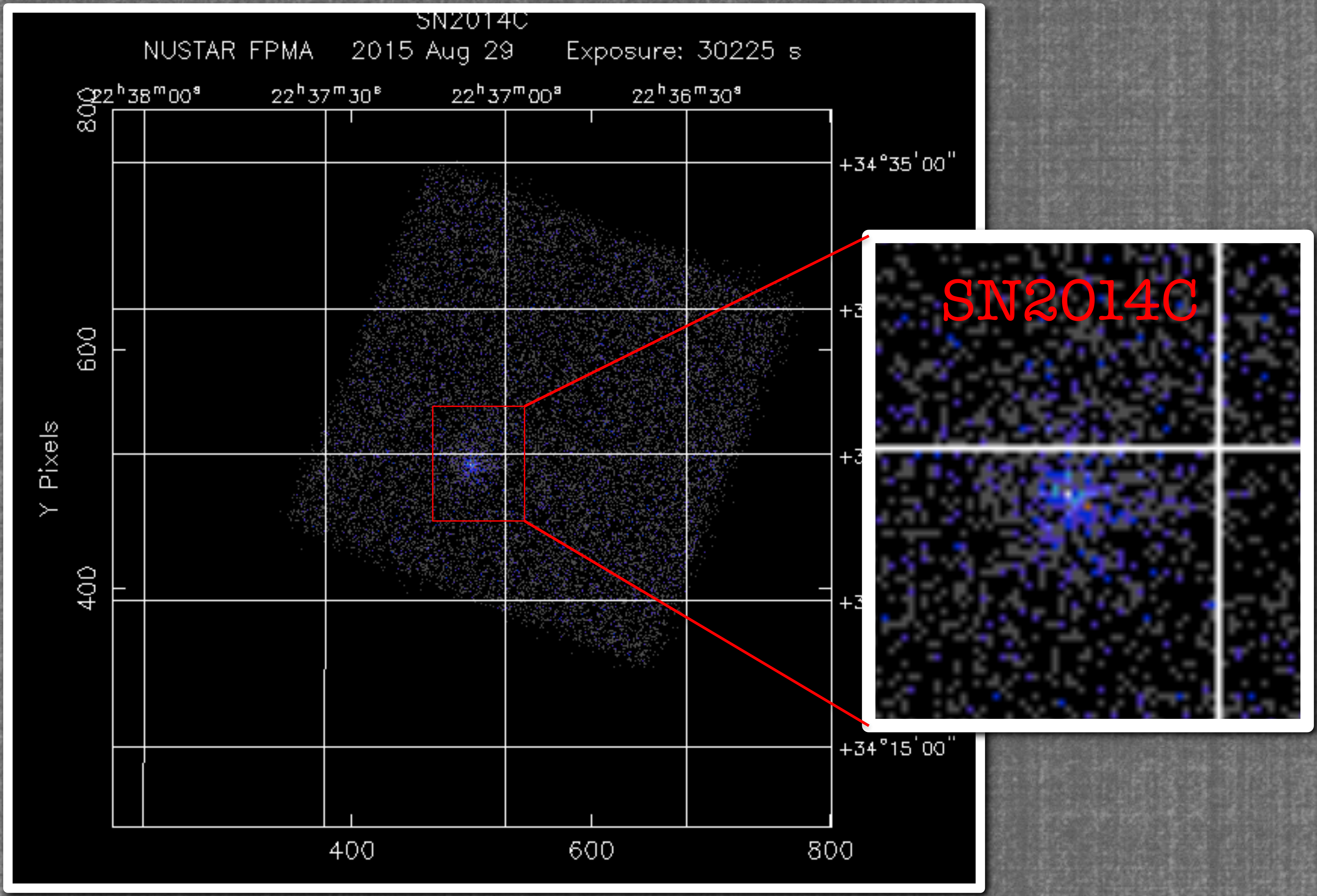
H-free!!!

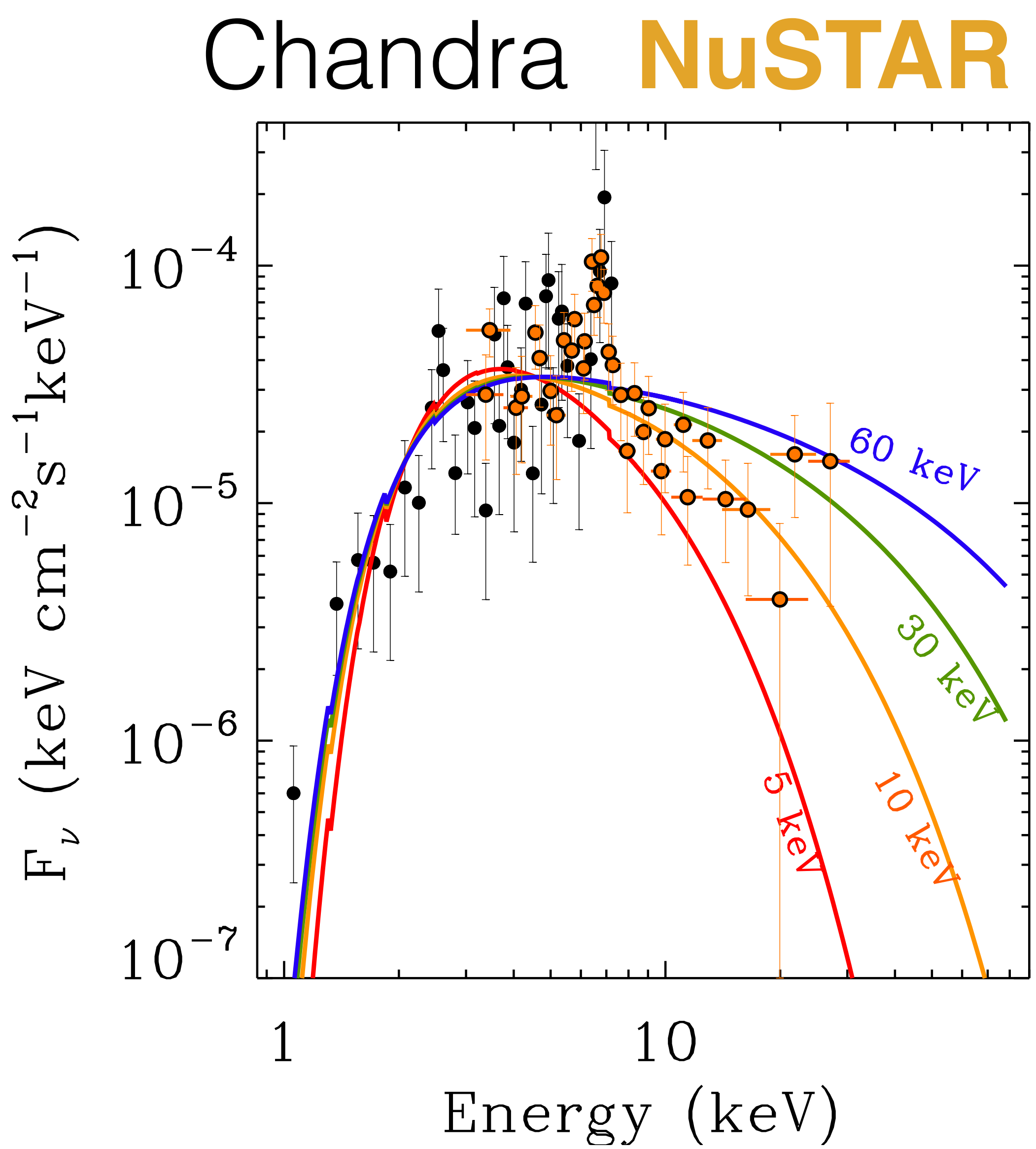
Chandra

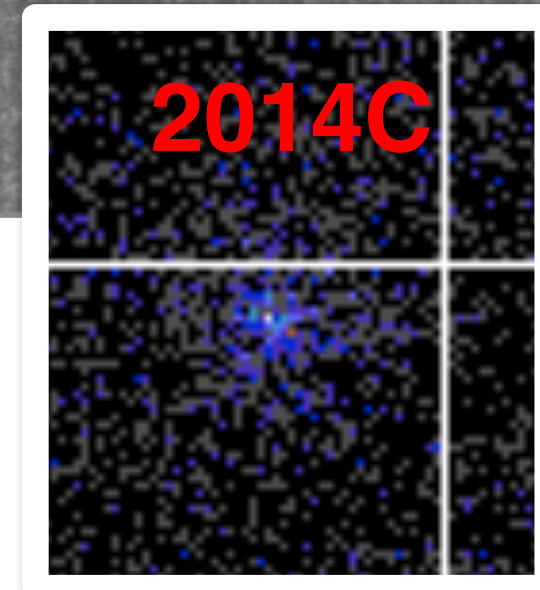


10^{-4}
10^{-5}
10^{-6}
10^{-7}
1
10
Energy (keV)
F_ν (keV cm^{-2}s^{-1}keV^{-1})
60 keV
30 keV
10 keV
5 keV
?

NuSTAR (3-80 keV)





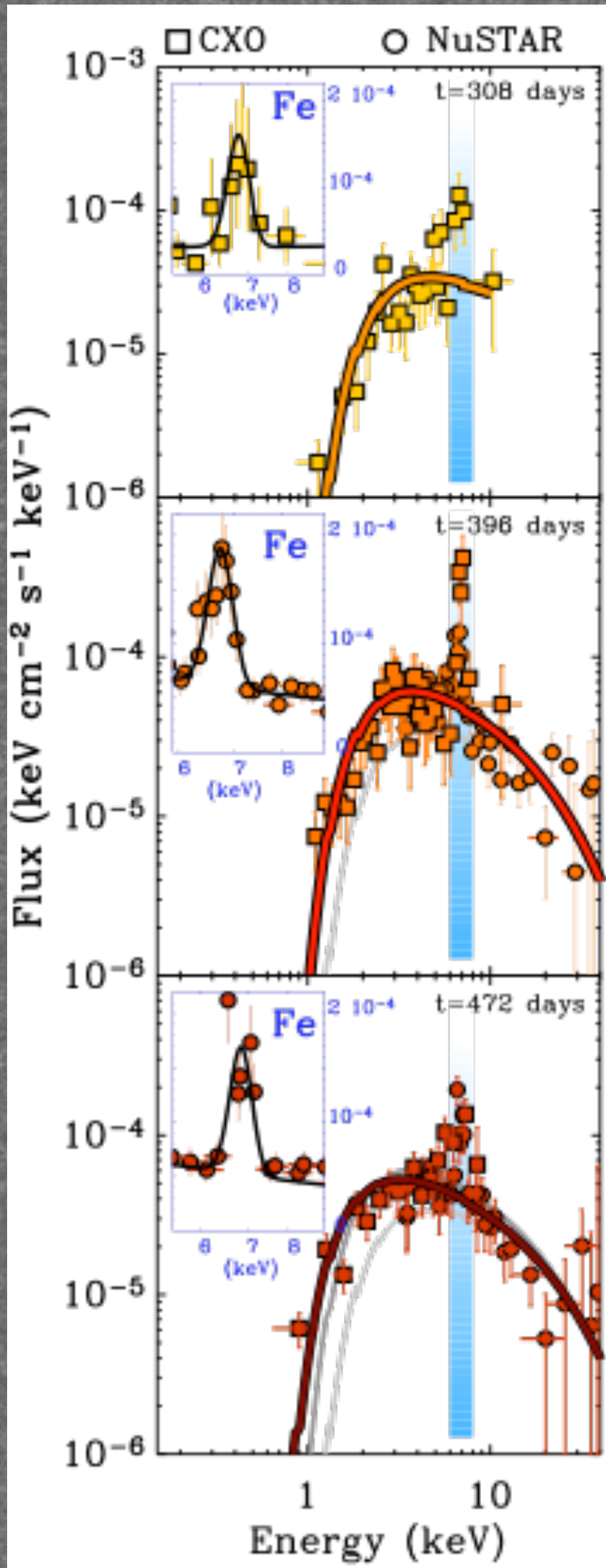


T~20 keV

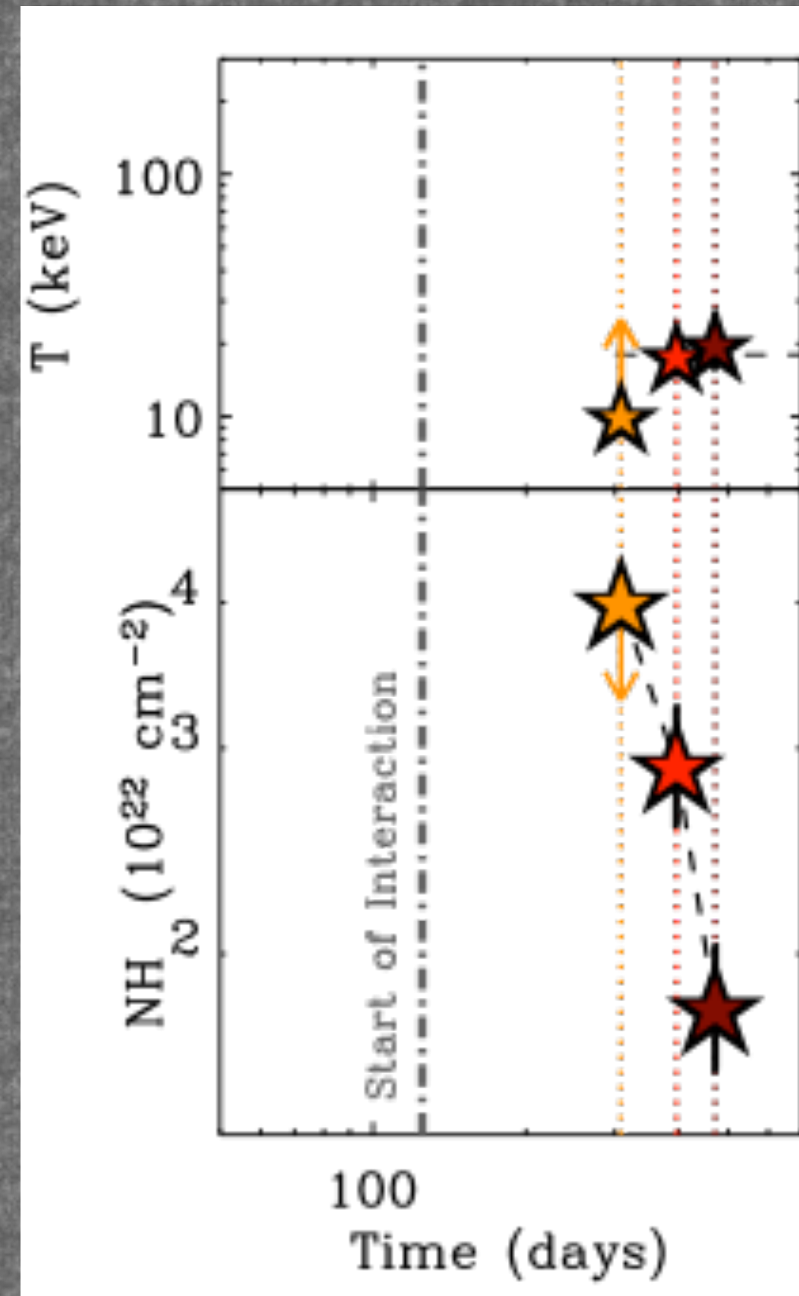
NH~4d22 cm-2

Chandra+NuSTAR

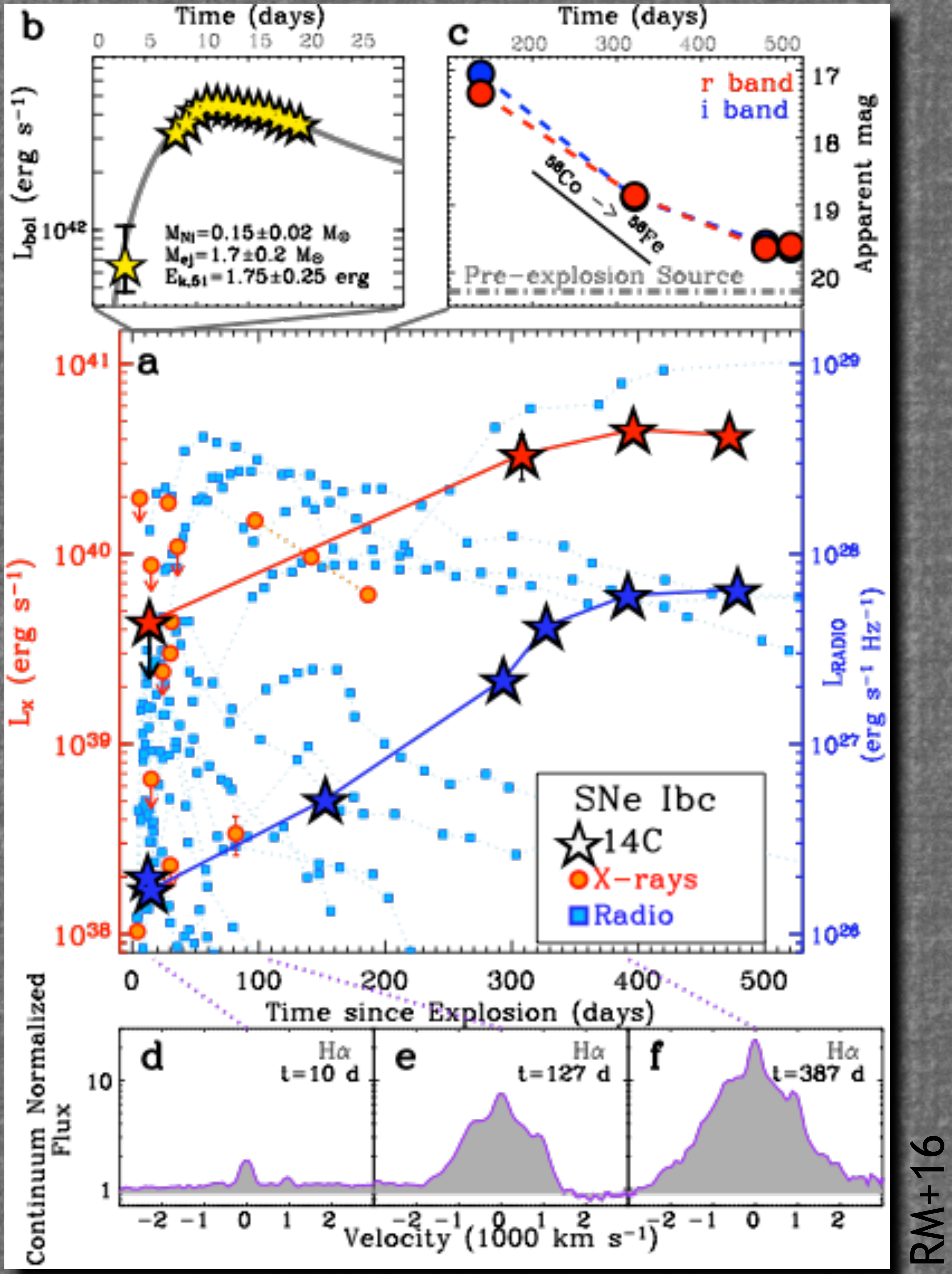
RM+16



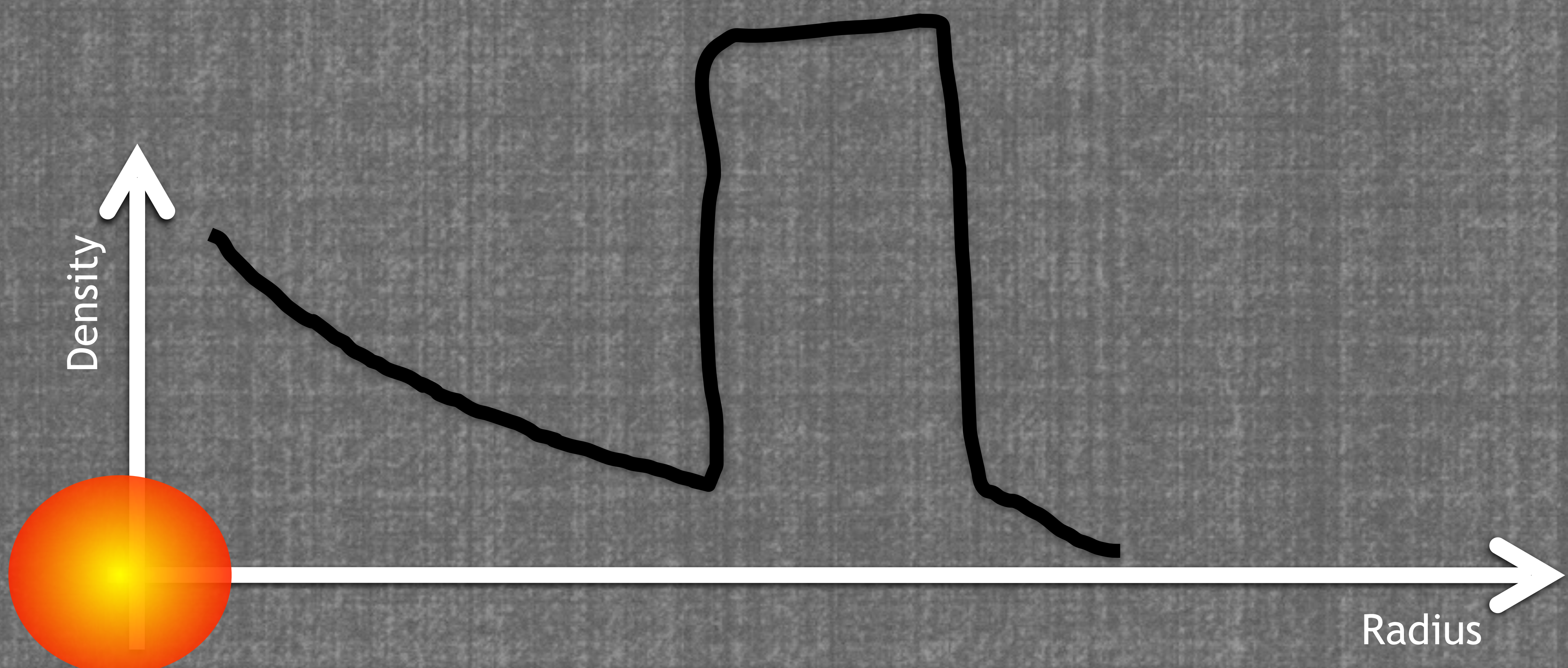
=

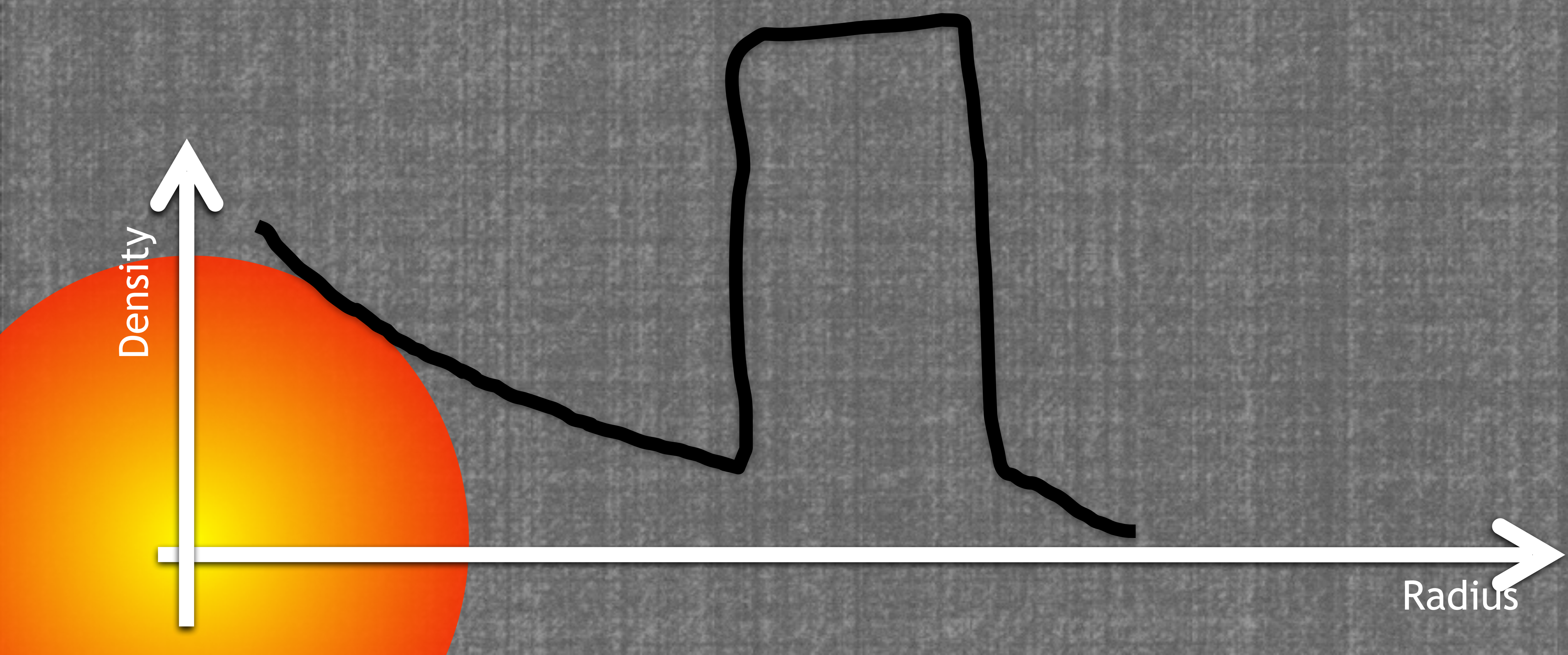


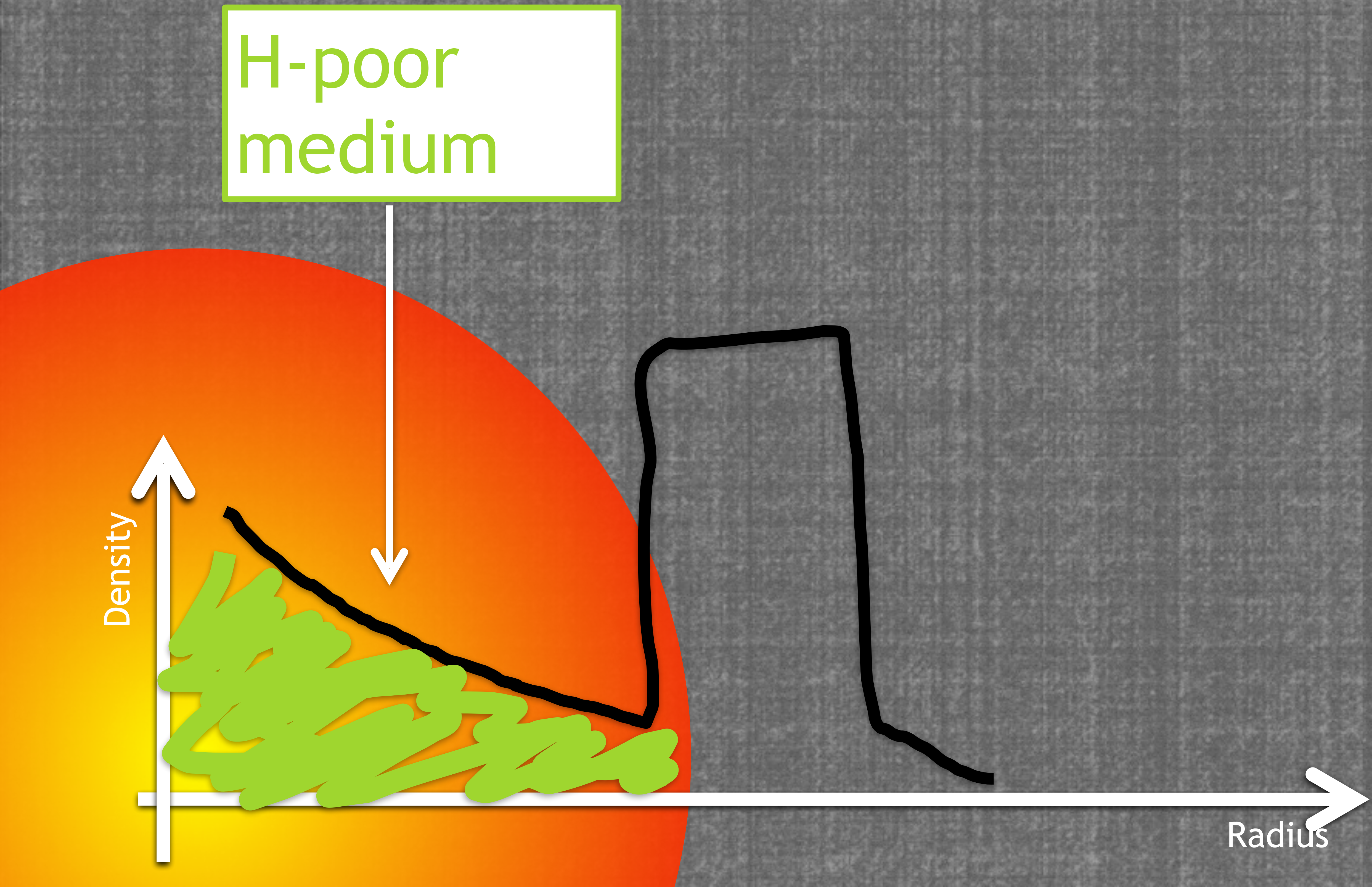
Direct Constraints on the shock dynamics!



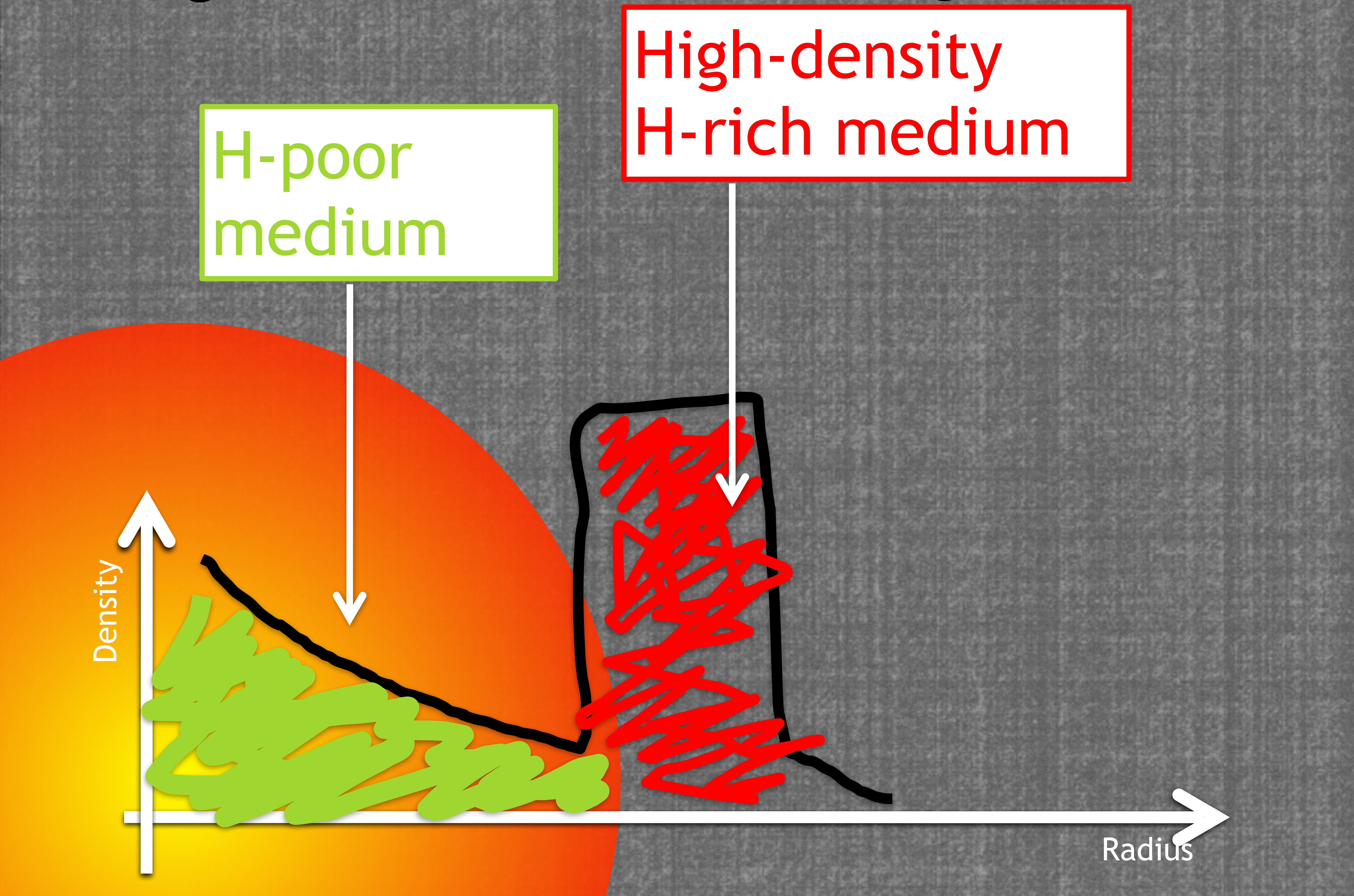
Type I SN → Type II SN


Density
Radius

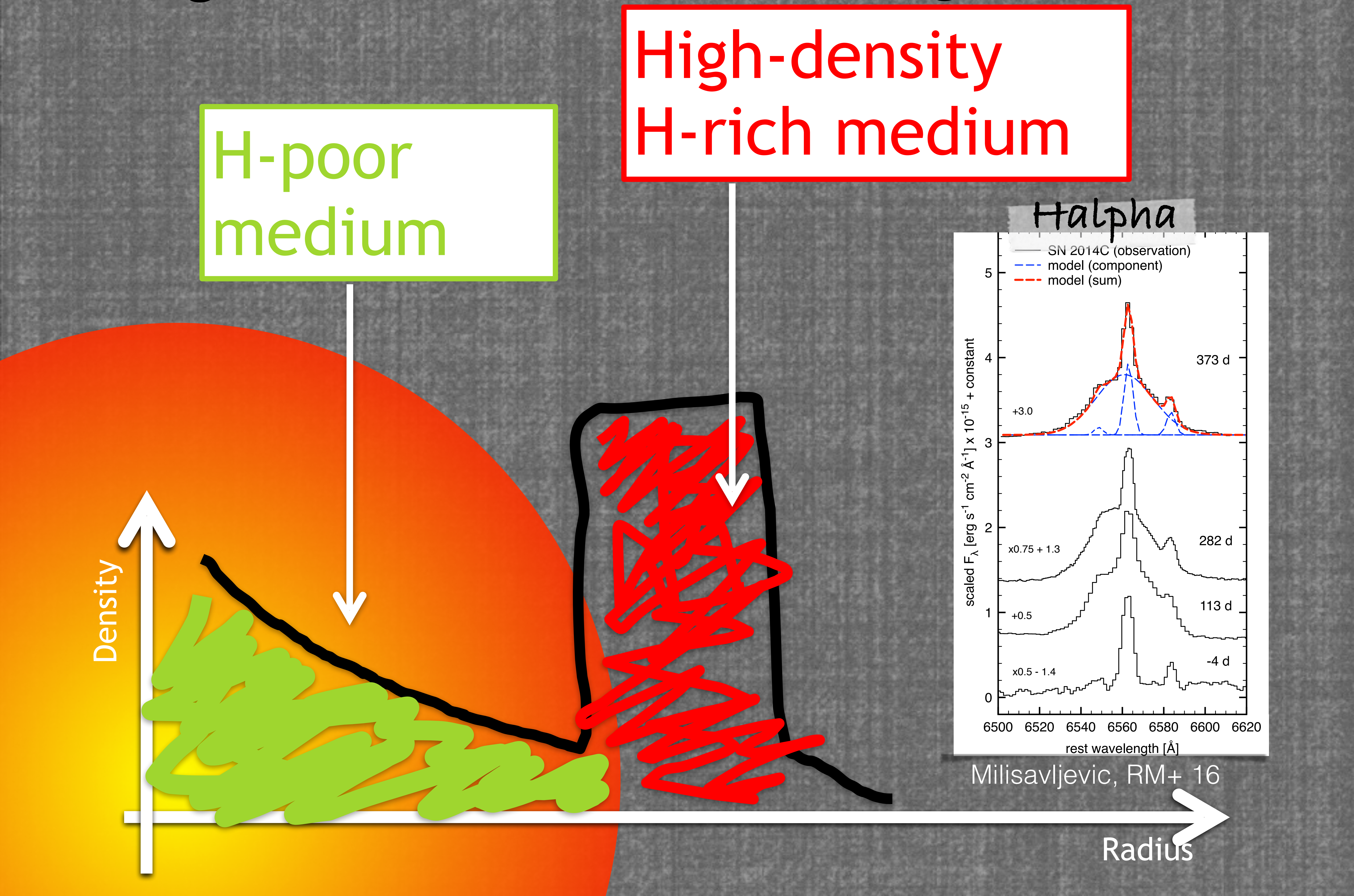

Density
Radius


H-poor
medium
Density
Radius

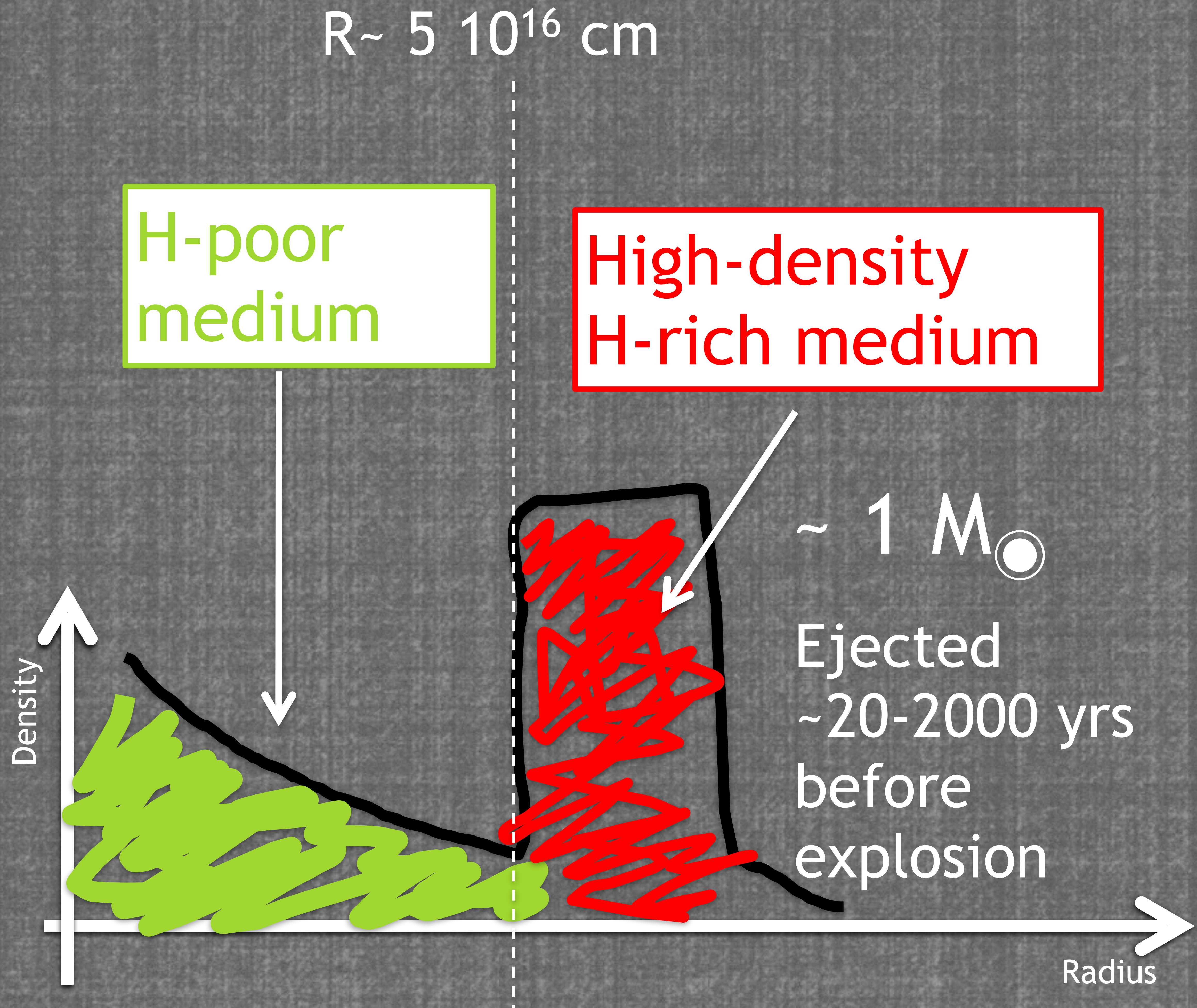
Type I → Type II



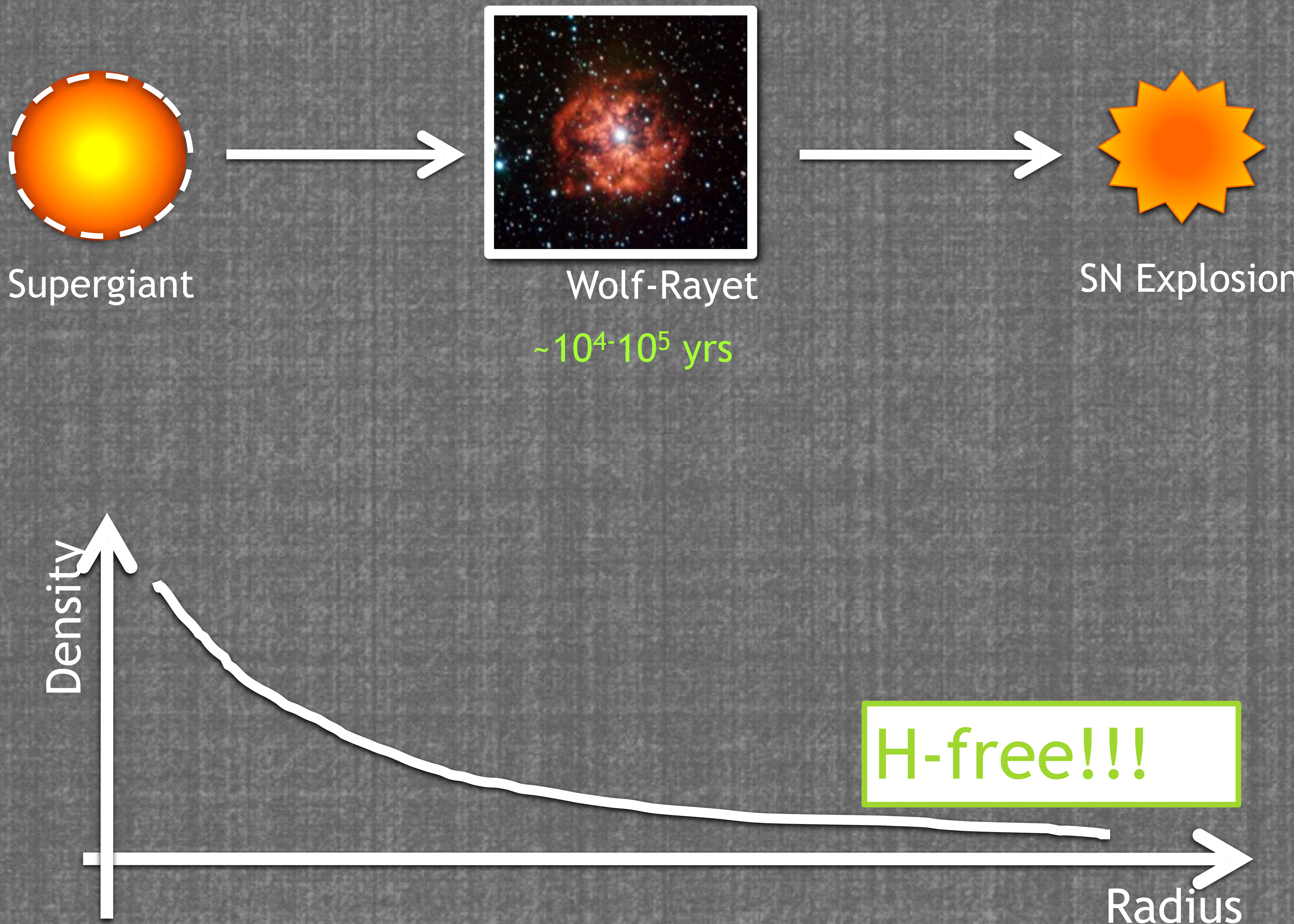
Type I → Type II



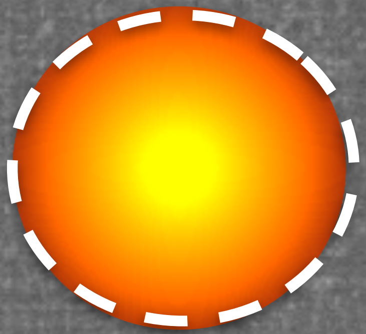
Milisavljevic, RM+ 16


R~ 5 10^16 cm
H-poor medium
High-density H-rich medium
~ 1 M☉
Ejected ~20-2000 yrs before explosion
Density
Radius

Expected Evolution from Stellar tracks:



Expected Evolution from Stellar tracks:

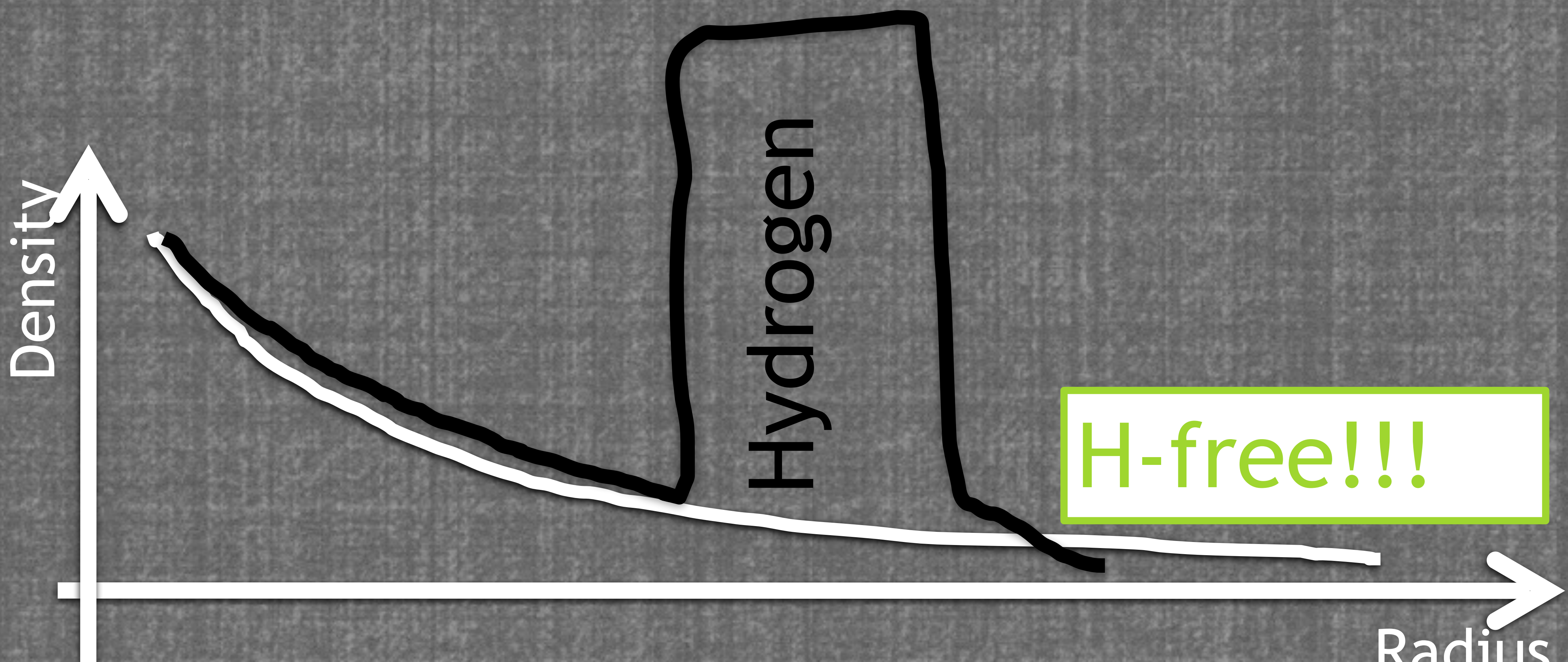


Supergiant

Wolf-Rayet

~10^4-10^5 yrs

SN Explosion



Why so important?

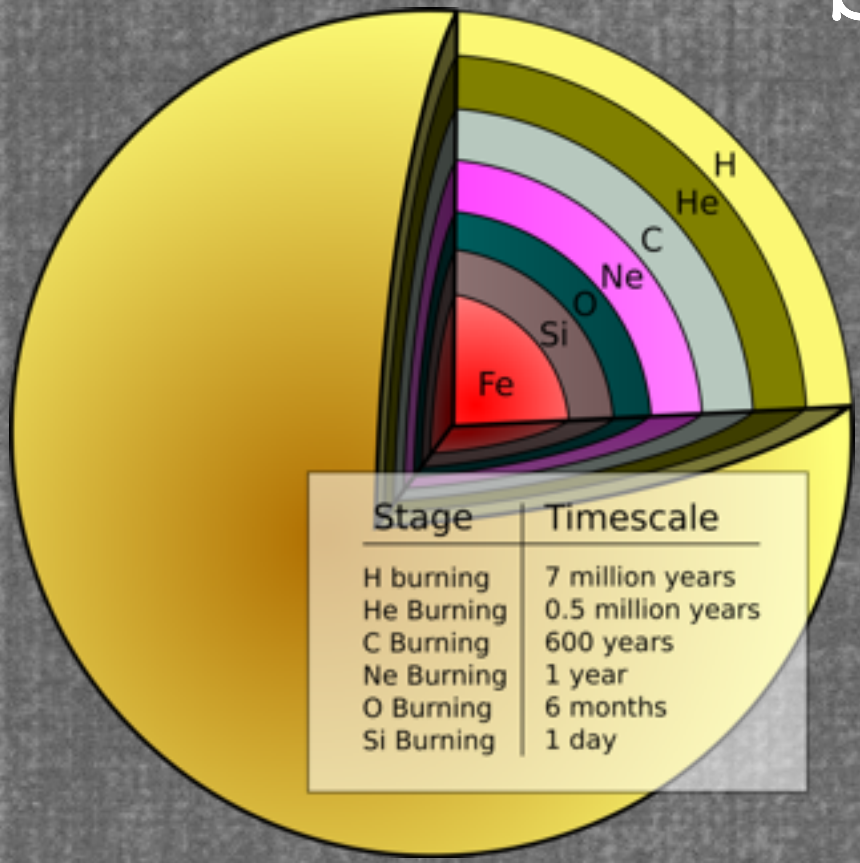
Mass - Loss

↓

Stellar Structure
at Collapse

↓

"Explodability" of
a Star



Why so important?

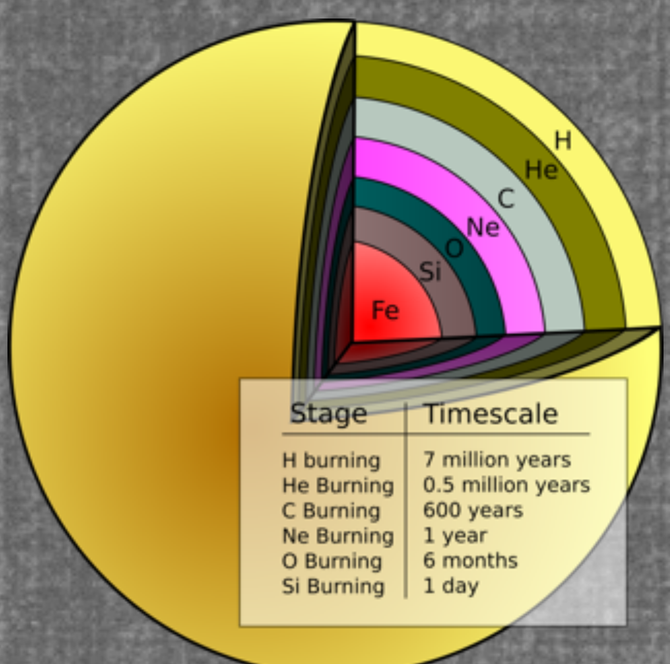
Mass - Loss

Chemical Enrichment of the Universe

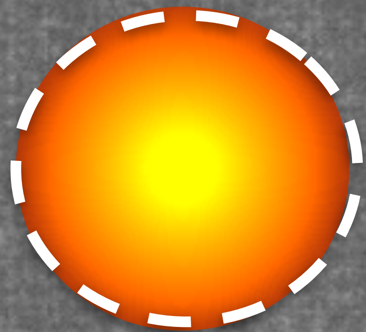
Stellar Structure at Collapse

"Explodability" of a Star

Impact our understanding of the **Star Formation History** of the Universe.



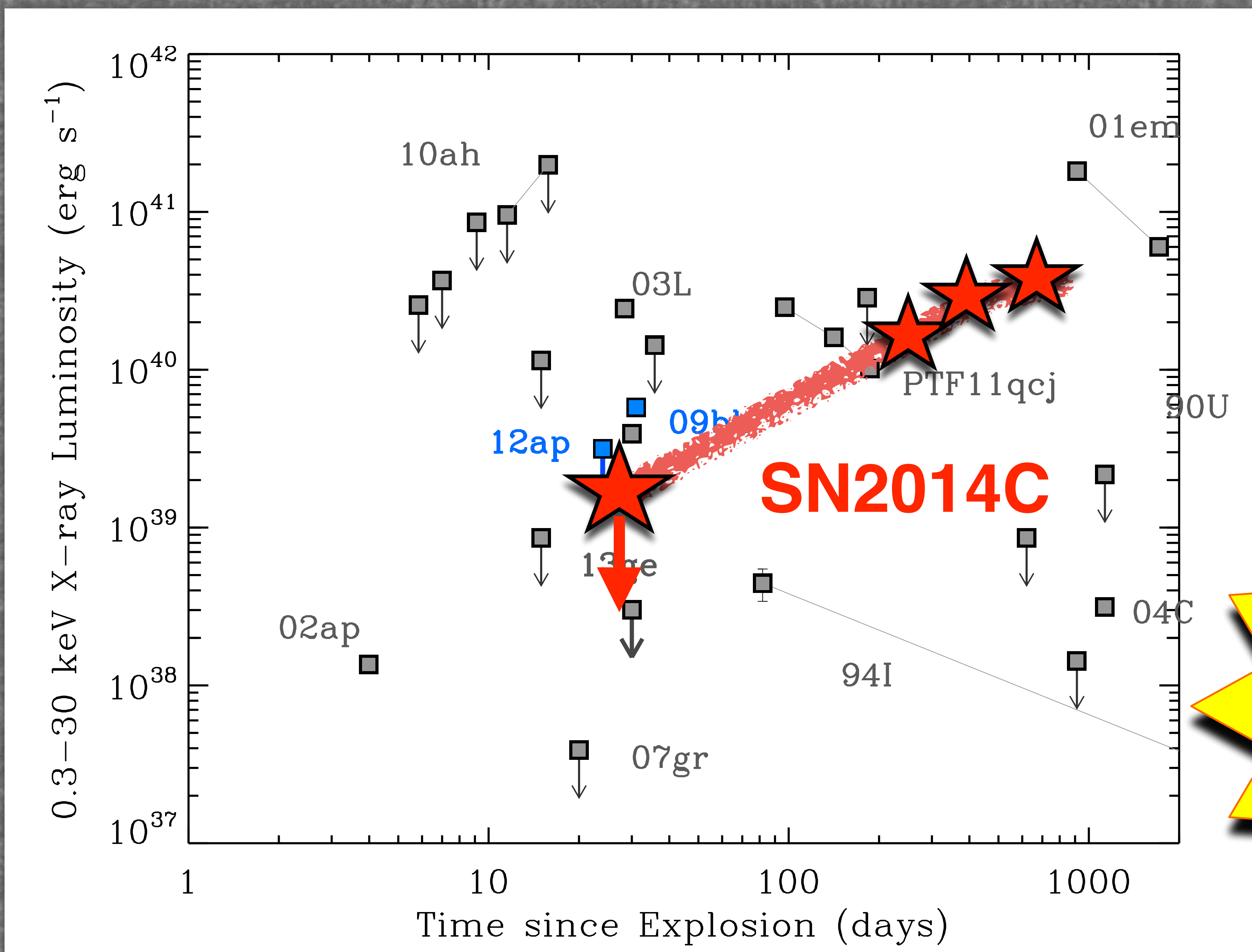
Expected Evolution from Stellar tracks:

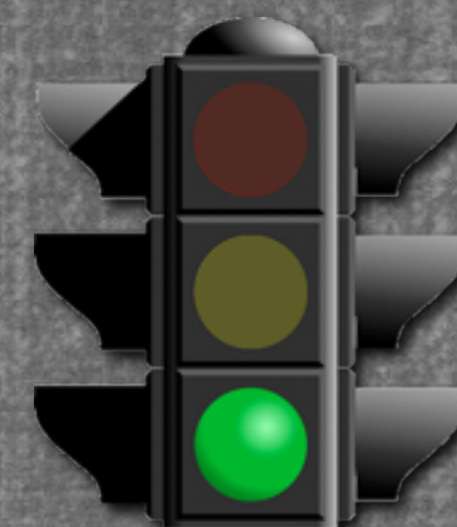


Supergiant

Wolf-Rayet

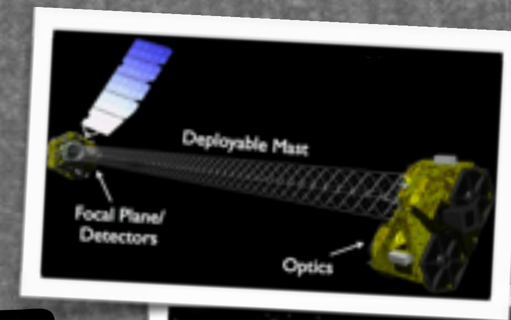
SN Explosion

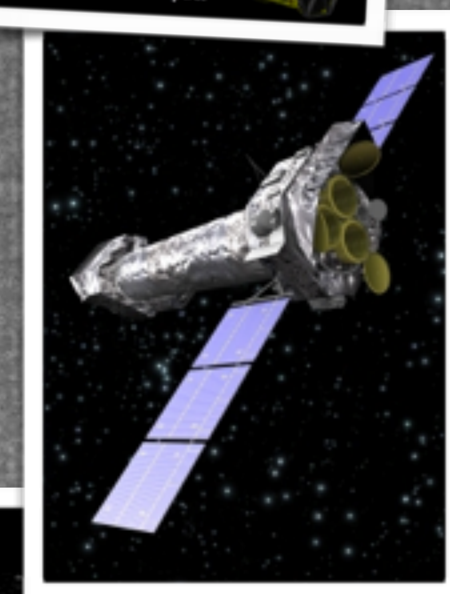




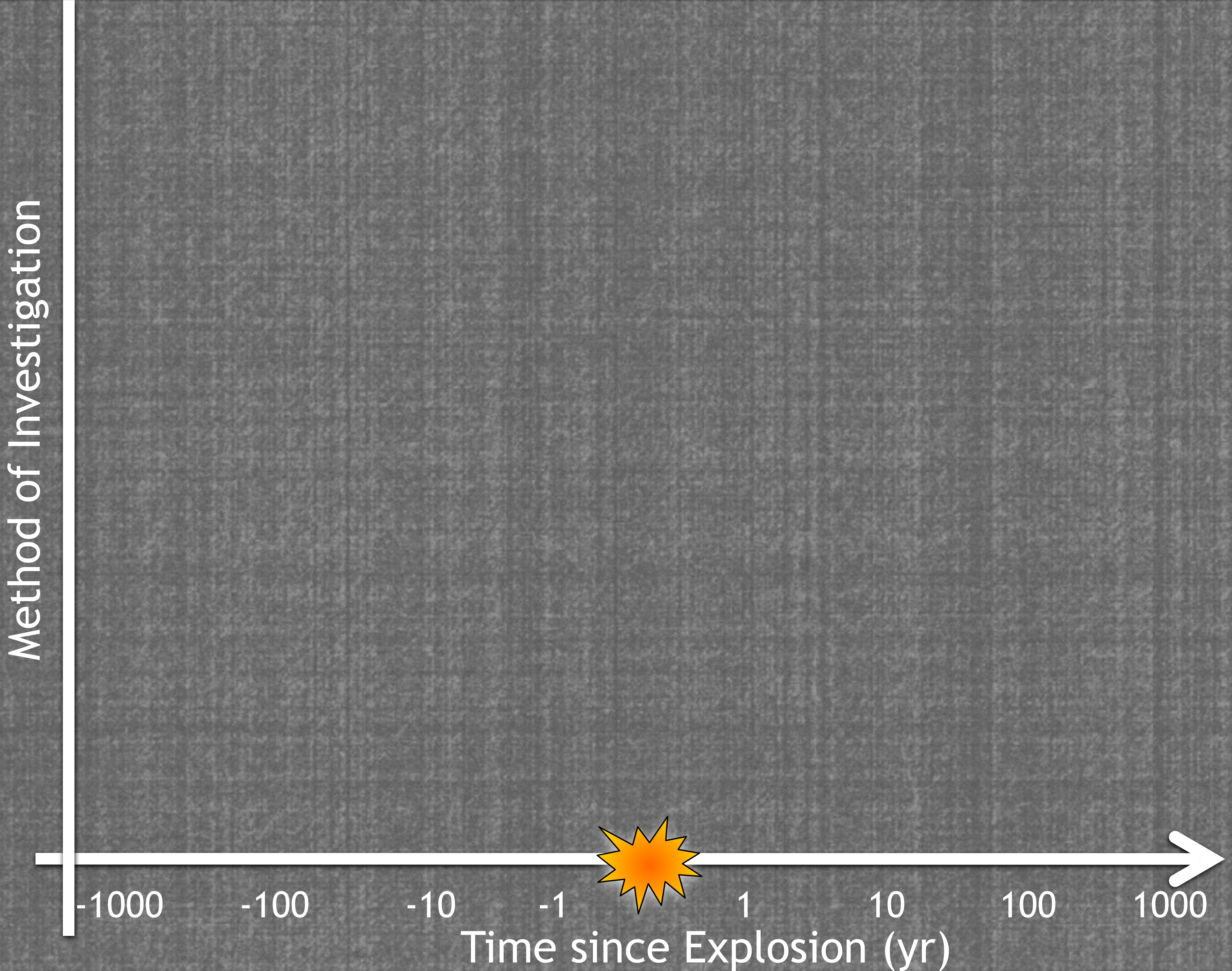
MASS LOSS- Massive Stars

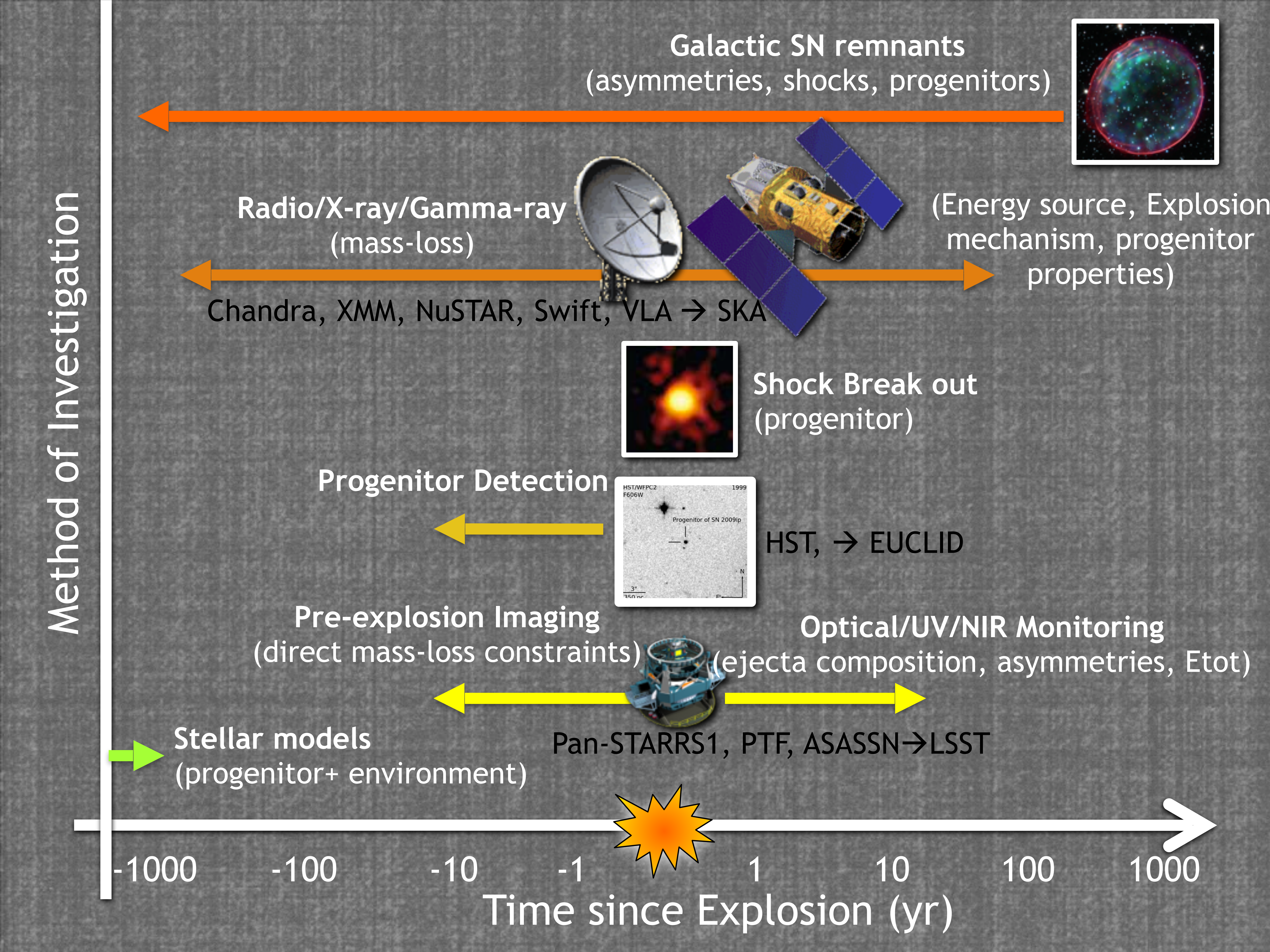
The
KNOWLE DGE
GA P

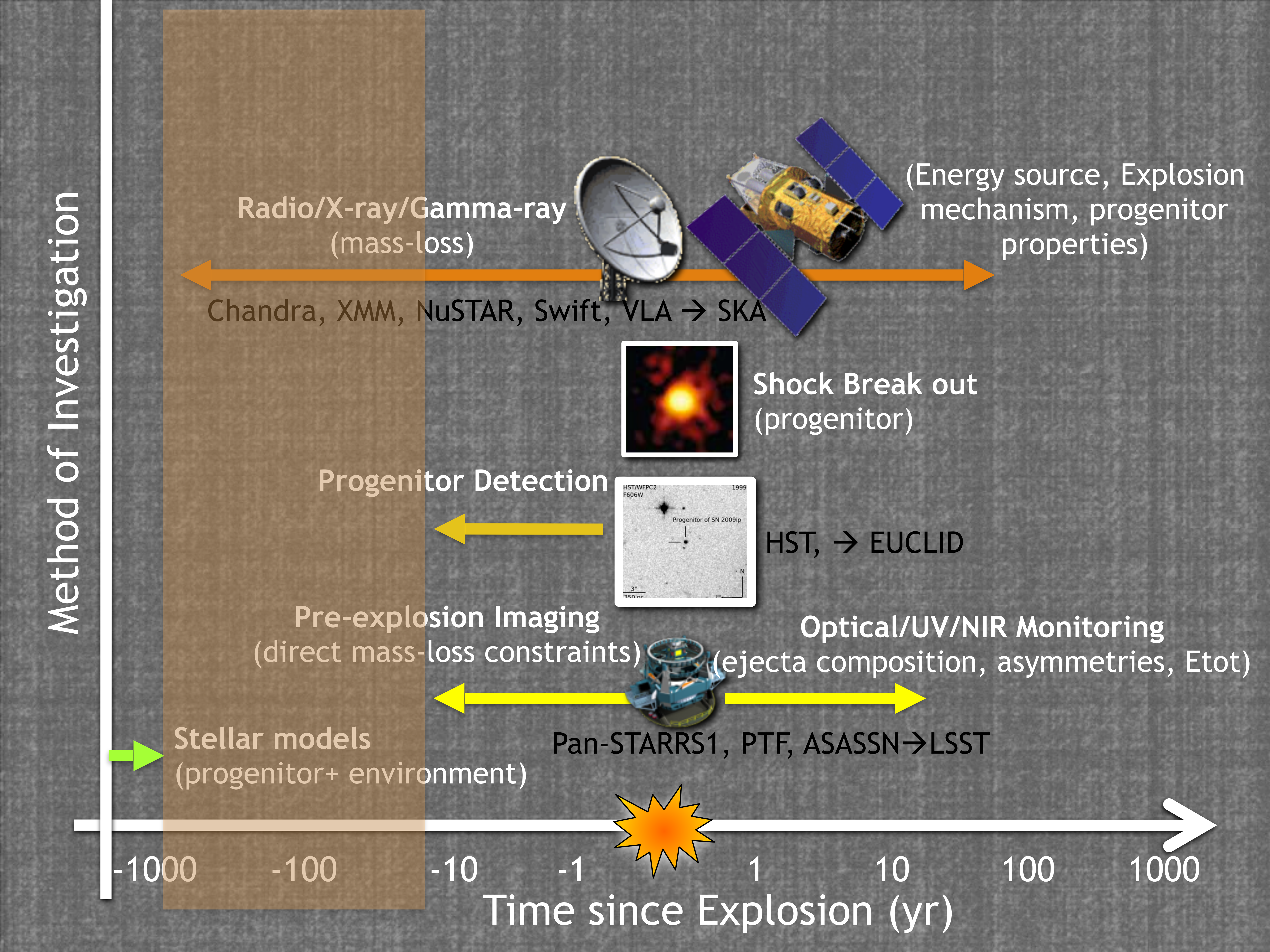




All H-stripped CC-SNe d<40 Mpc —> 300 ks/yr

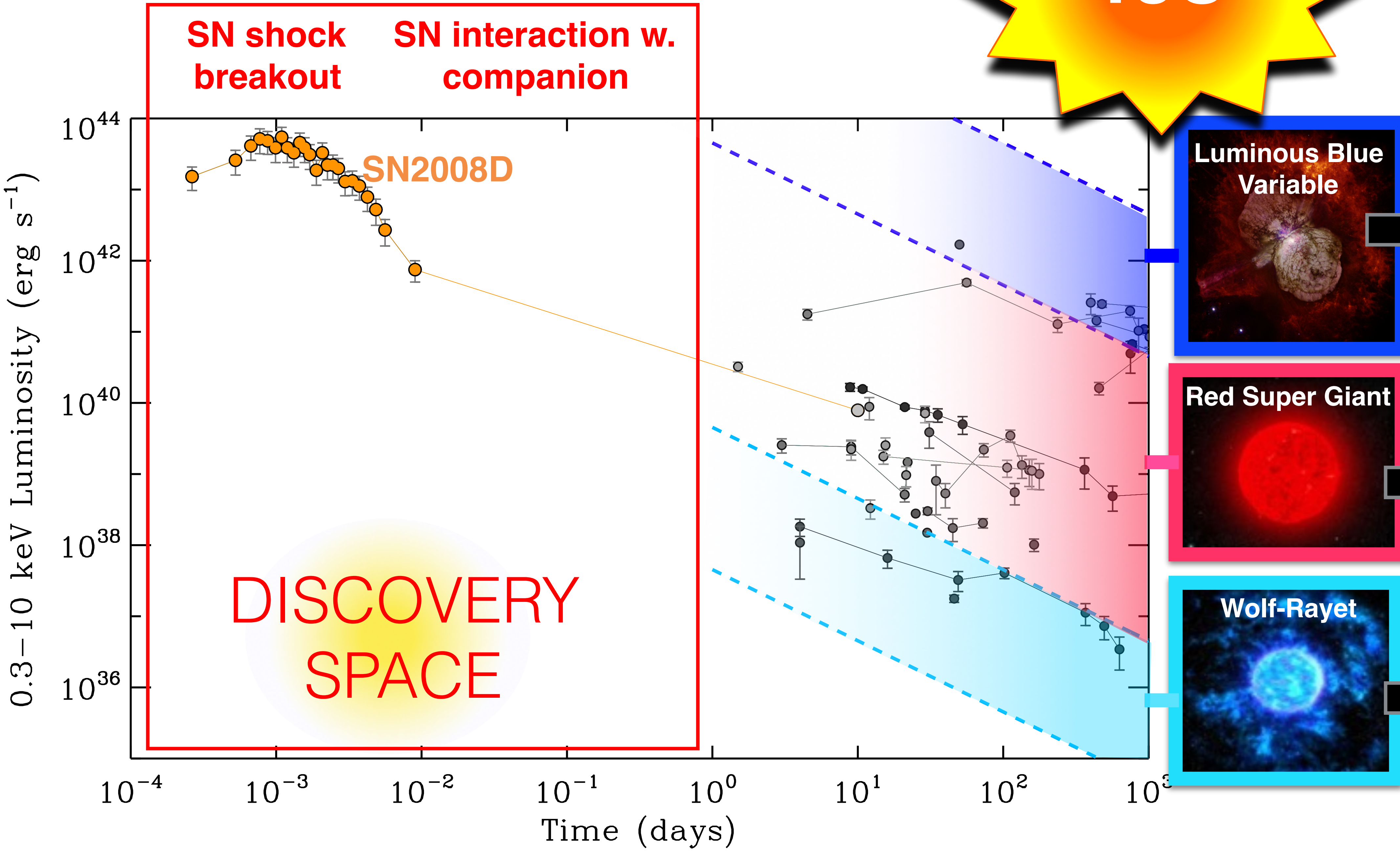

Method of Investigation
-1000
-100
-10
-1
1
10
100
1000
Time since Explosion (yr)


Galactic SN remnants
(asymmetries, shocks, progenitors)
Radio/X-ray/Gamma-ray
(mass-loss)
(Energy source, Explosion
mechanism, progenitor
properties)
Chandra, XMM, NuSTAR, Swift, VLA → SKA
Shock Break out
(progenitor)
Progenitor Detection
HST/WFPC2
F606W
1999
Progenitor of SN 2009ip
HST, → EUCLID
Pre-explosion Imaging
(direct mass-loss constraints)
Optical/UV/NIR Monitoring
(ejecta composition, asymmetries, Etot)
Pan-STARRS1, PTF, ASASSN→LSST
Stellar models
(progenitor+ environment)
Method of Investigation
-1000
-100
-10
-1
1
10
100
1000
Time since Explosion (yr)

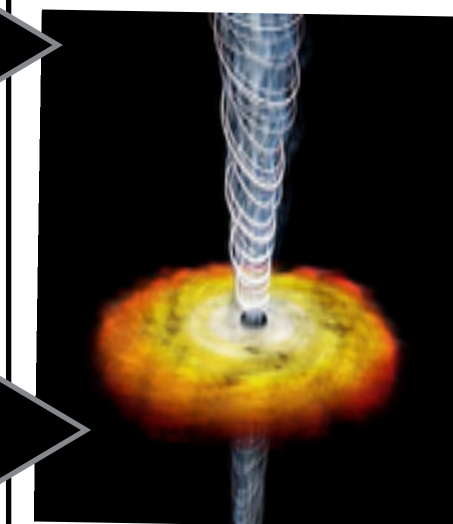

Radio/X-ray/Gamma-ray
(mass-loss)
(Energy source, Explosion mechanism, progenitor properties)
Chandra, XMM, NuSTAR, Swift, VLA → SKA
Shock Break out
(progenitor)
Progenitor Detection
HST/WFPC2
F606W
1999
Progenitor of SN 2009ip
HST, → EUCLID
Pre-explosion Imaging
(direct mass-loss constraints)
Optical/UV/NIR Monitoring
(ejecta composition, asymmetries, Etot)
Pan-STARRS1, PTF, ASASSN→LSST
Stellar models
(progenitor+ environment)
Method of Investigation
-1000
-100
-10
-1
1
10
100
1000
Time since Explosion (yr)

WIDE FIELD

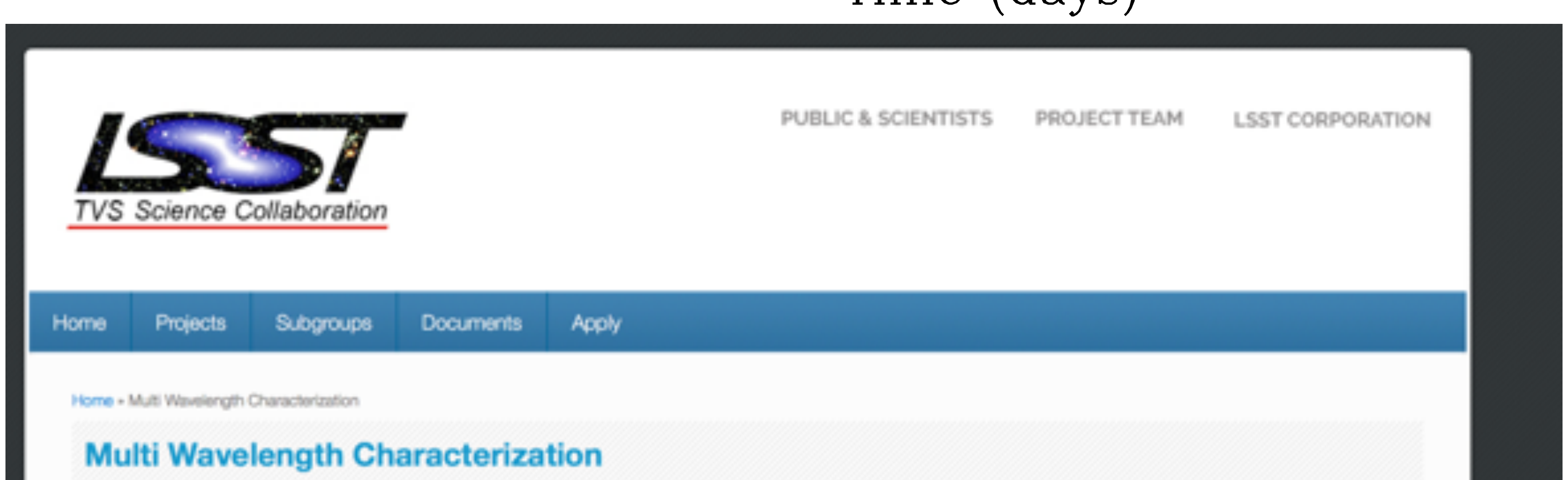
ToO



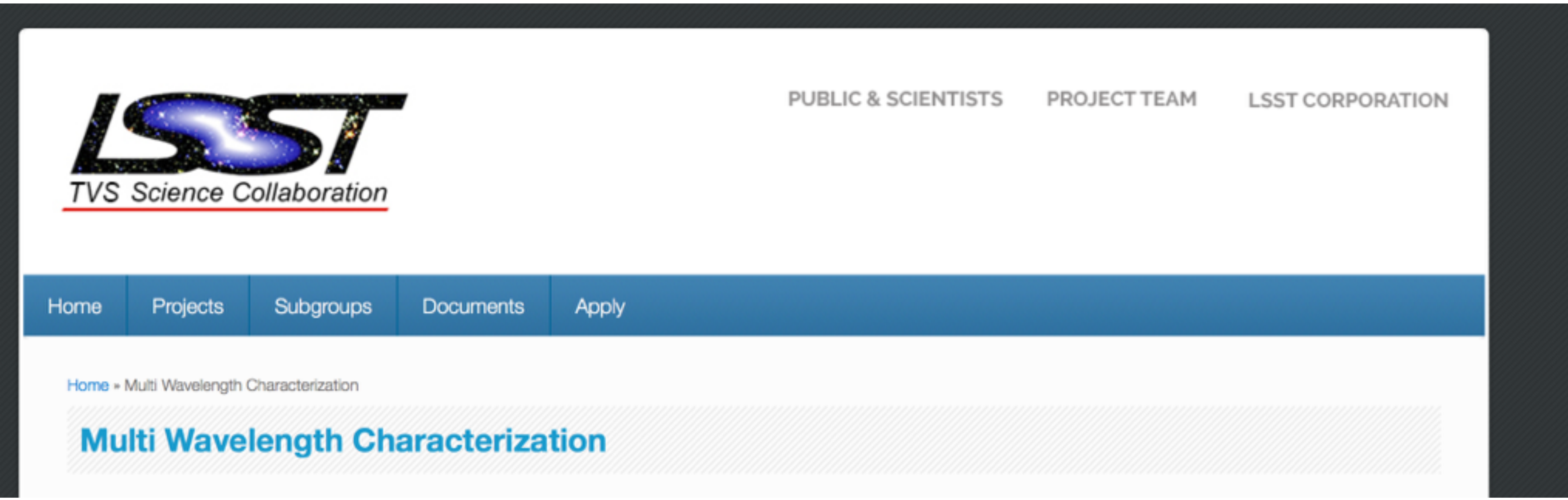
BH

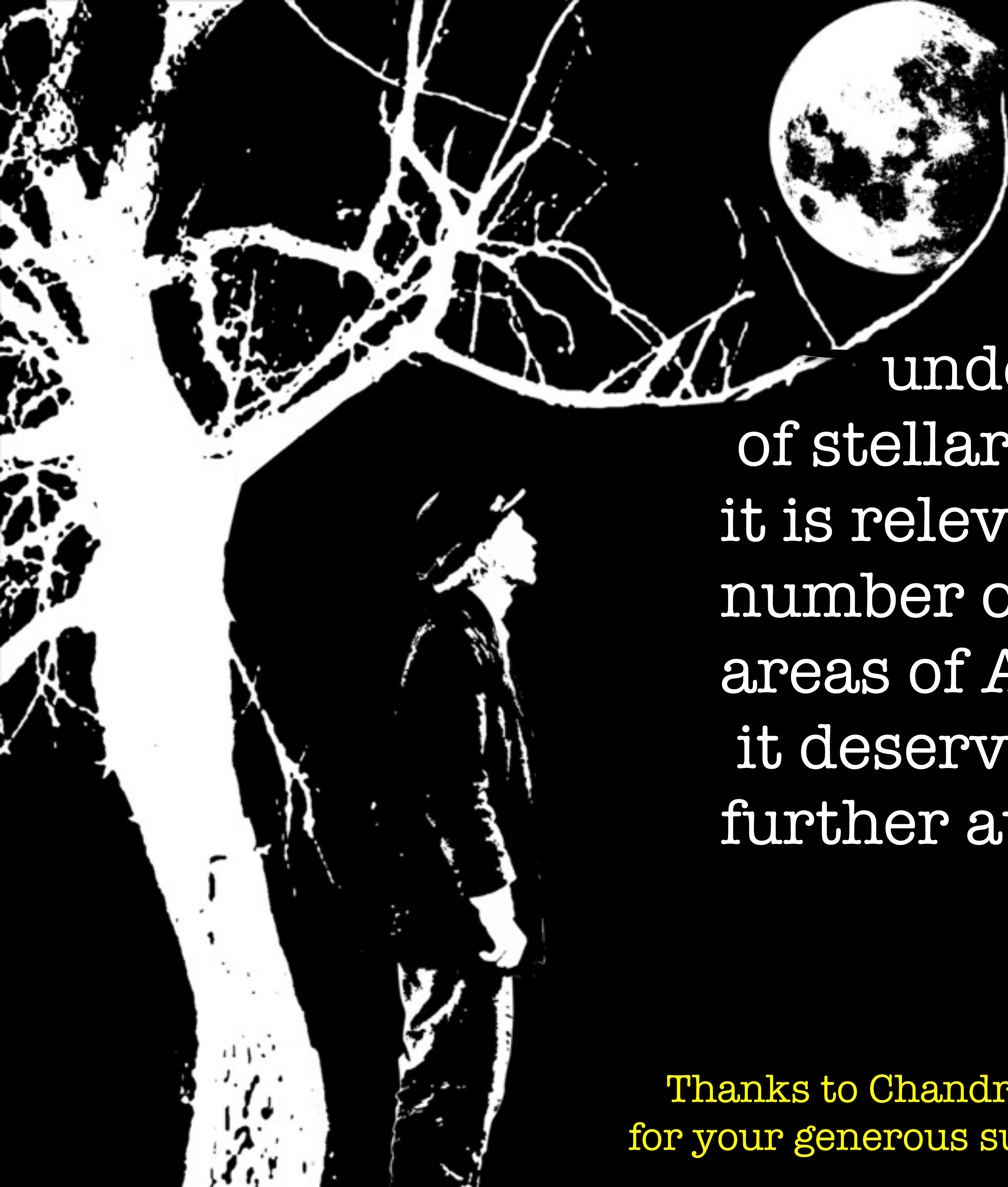


NS



Poster by
Dan Milisavljevic!


TVS Science Collaboration
PUBLIC & SCIENTISTS
PROJECT TEAM
LSST CORPORATION
Home
Projects
Subgroups
Documents
Apply
Home » Multi Wavelength Characterization
Multi Wavelength Characterization



Mass-loss in evolved massive stars is one of the least understood aspects of stellar evolution, it is relevant to a number of different areas of Astrophysics, it deserves further attention.

Thanks to Chandra, XMM, Swift, NuSTAR
for your generous support to our investigation

“…The END

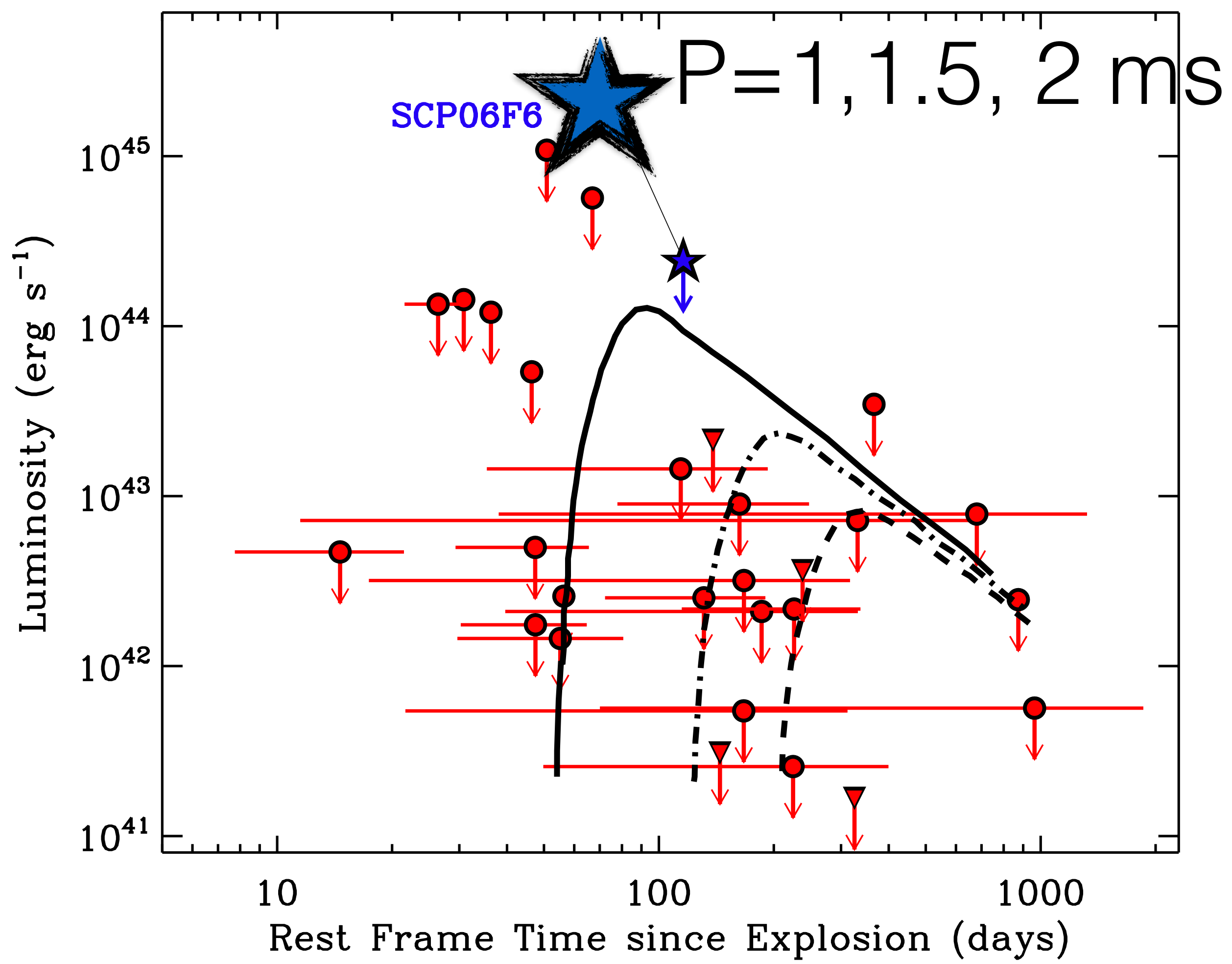
is where we start from…”

The Little Gidding by T.S. Eliot

Thanks to Chandra, XMM, Swift, NuSTAR
for your generous support to our investigation

Back up

Super-Luminous X-rays are not for everybody...

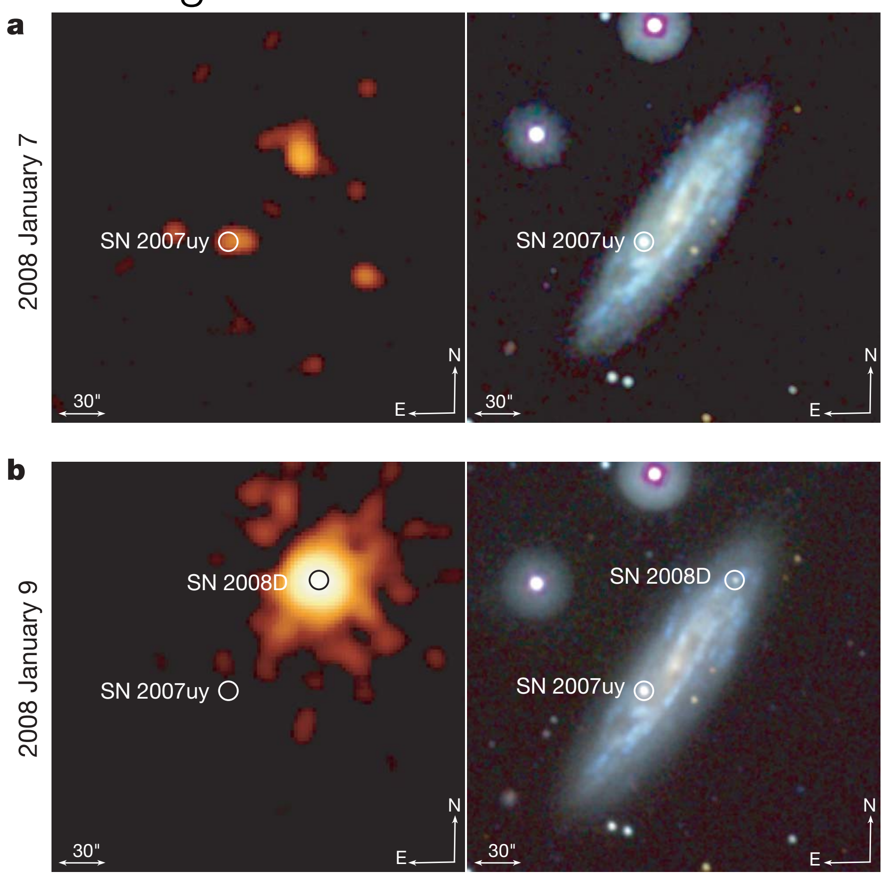


Margutti in prep.

SN2008D/XRF080109

Serendipitous Detection by Swift/XRT

Soderberg + 2008



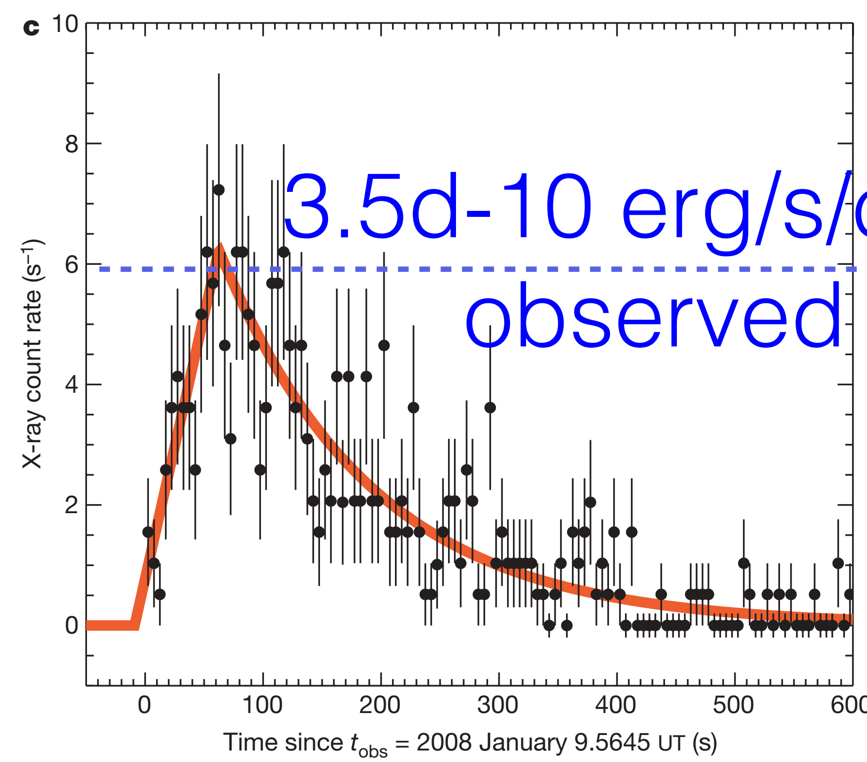
NGC2770, d=27 Mpc

Swift horizon = 200 Mpc

Duration of ~400 sec

Gamma=2.3 +\- 0.3

NHint=6e21 cm-2



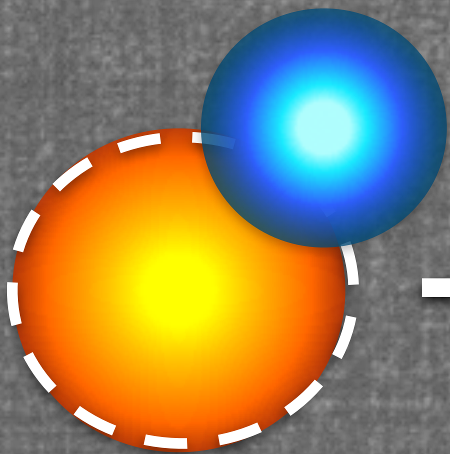
3.5d-10 erg/s/cm2

observed

Ex=2d46 erg

Lpeak=6d43 erg/s

Expected Evolution from Stellar tracks:

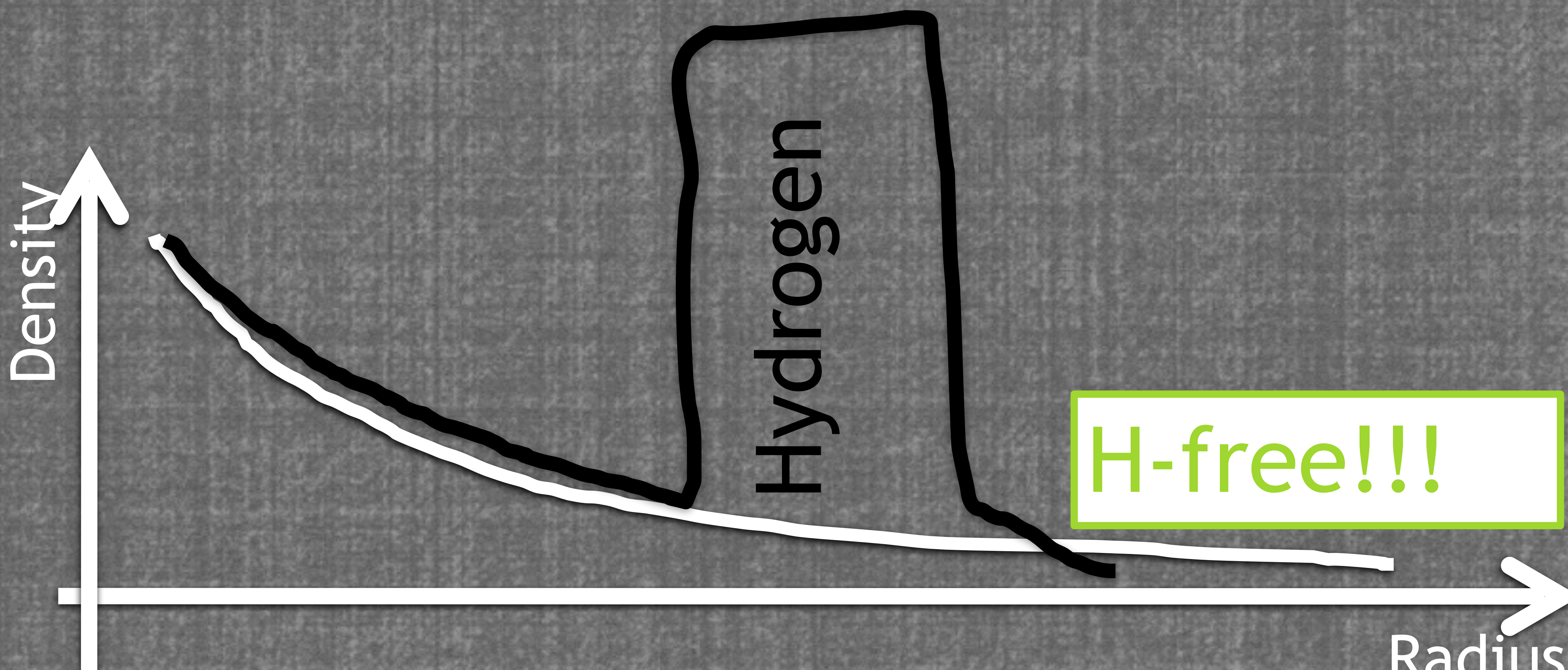


Supergiant

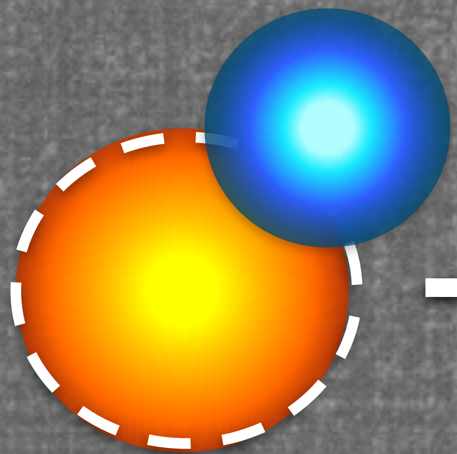
Wolf-Rayet

~10^4-10^5 yrs

SN Explosion



Expected Evolution from Stellar tracks:



Supergiant

Wolf-Rayet

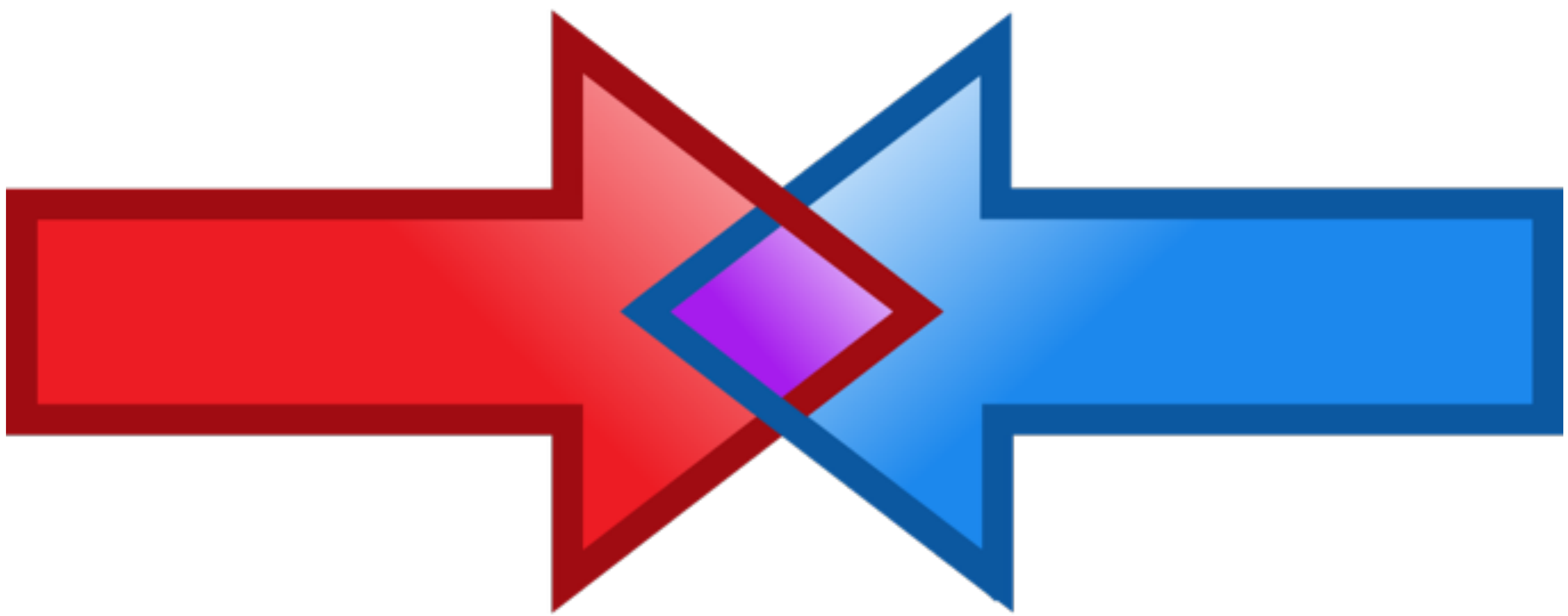
~10^4-10^5 yrs

1000 yrs

SN Explosion

Nuclear Burning Instabilities

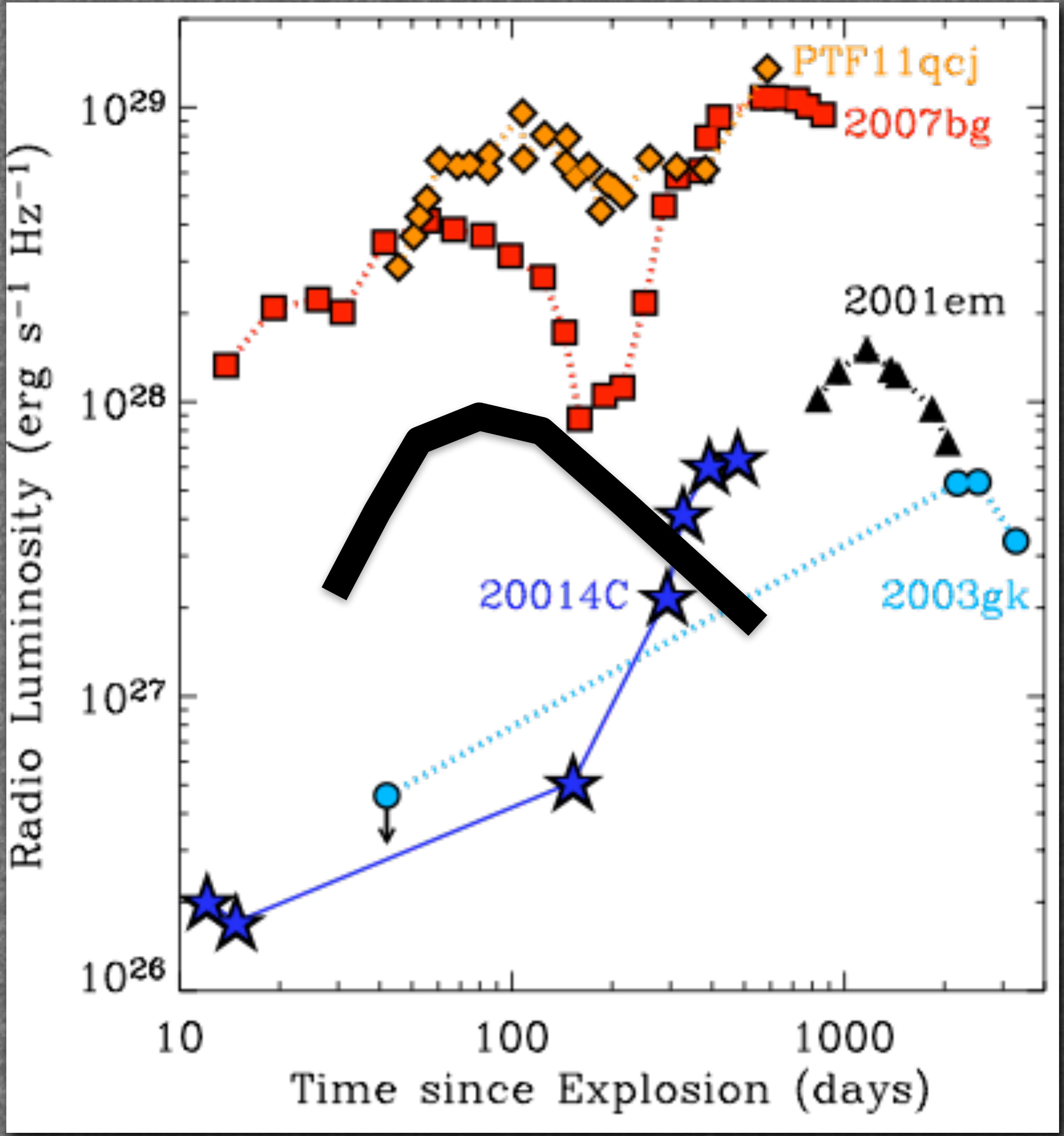
Binary Evolution
Burning Instabilities



MASS LOSS

Nathan's Review Paper

Non thermal Radio emission Ibc

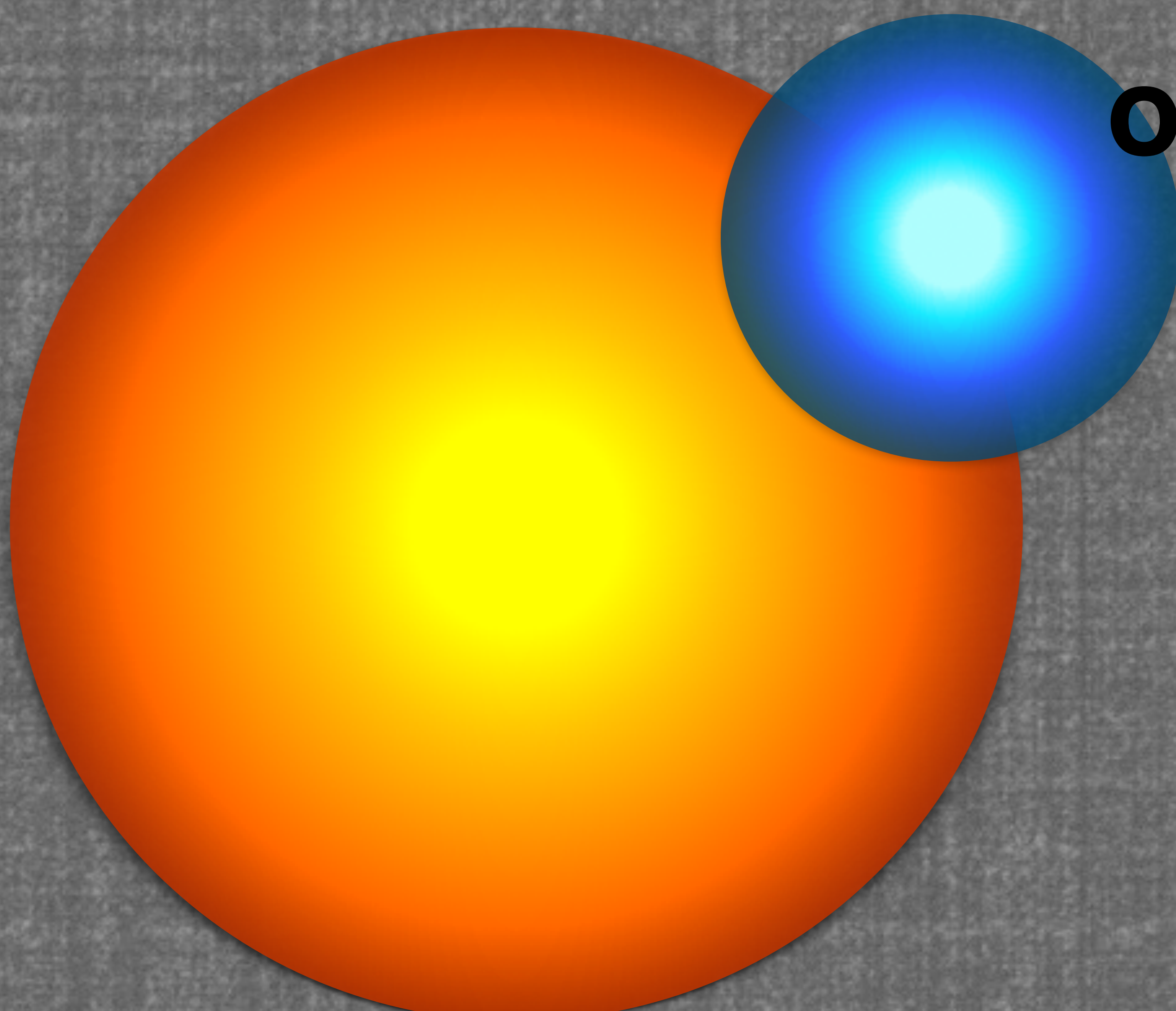


10%

RM+16

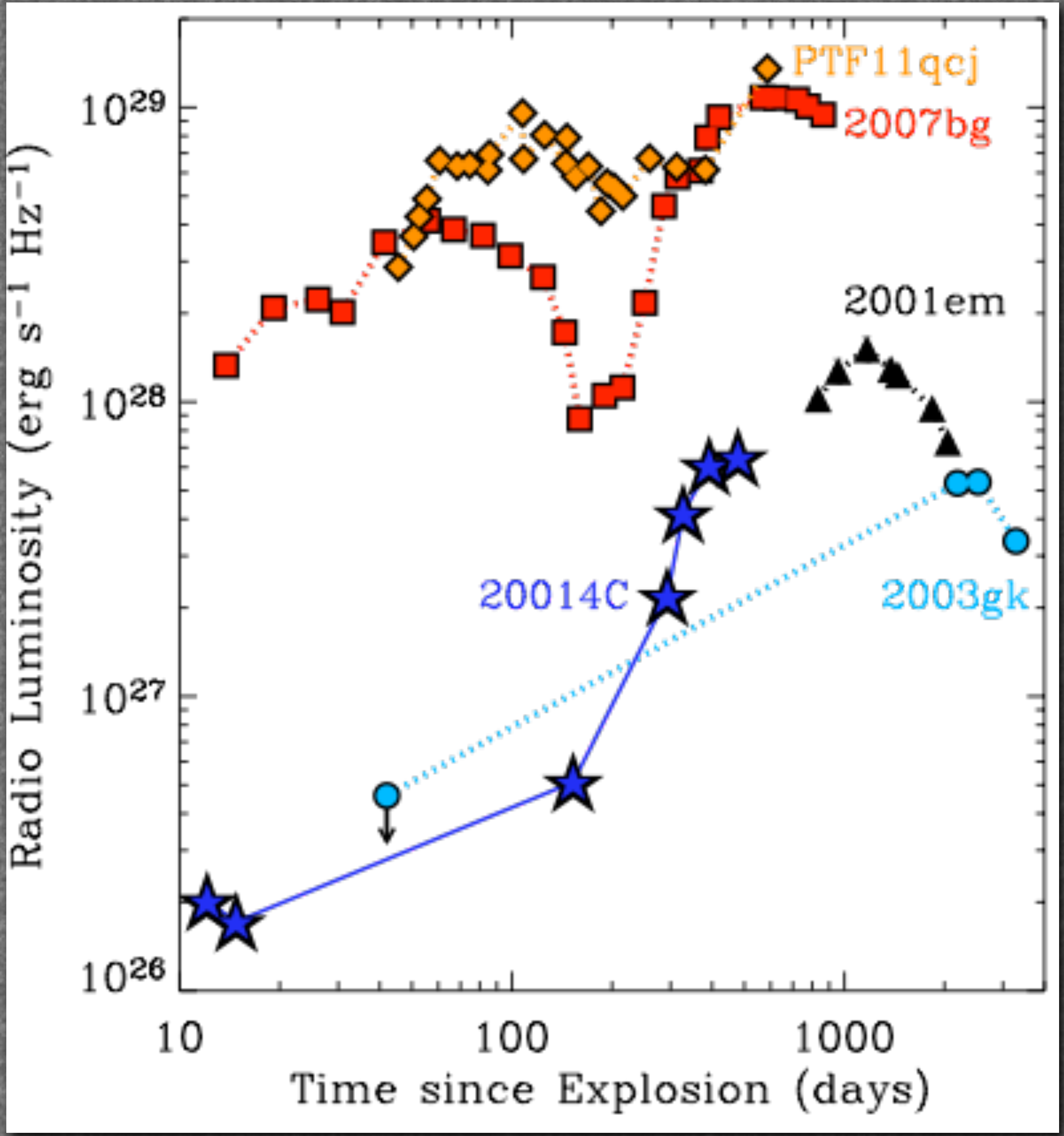
Binary Population Synthesis

S. de Mink, M. Zapartas



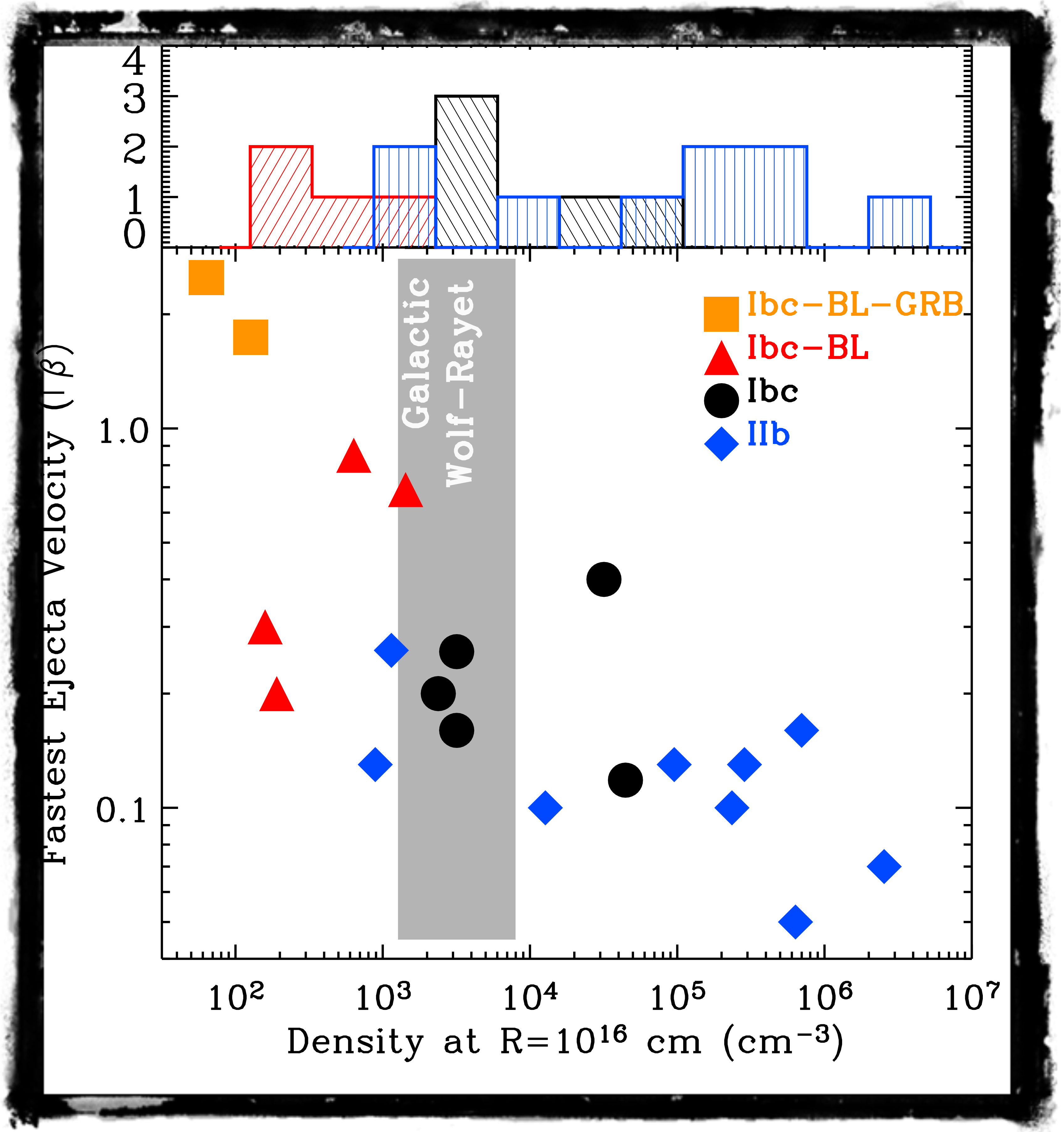
~6.5% [3.5-10%] of Ib/c progenitors go through CE evolution within ~ few 1000 yr before collapse

Non thermal Radio emission Ibc



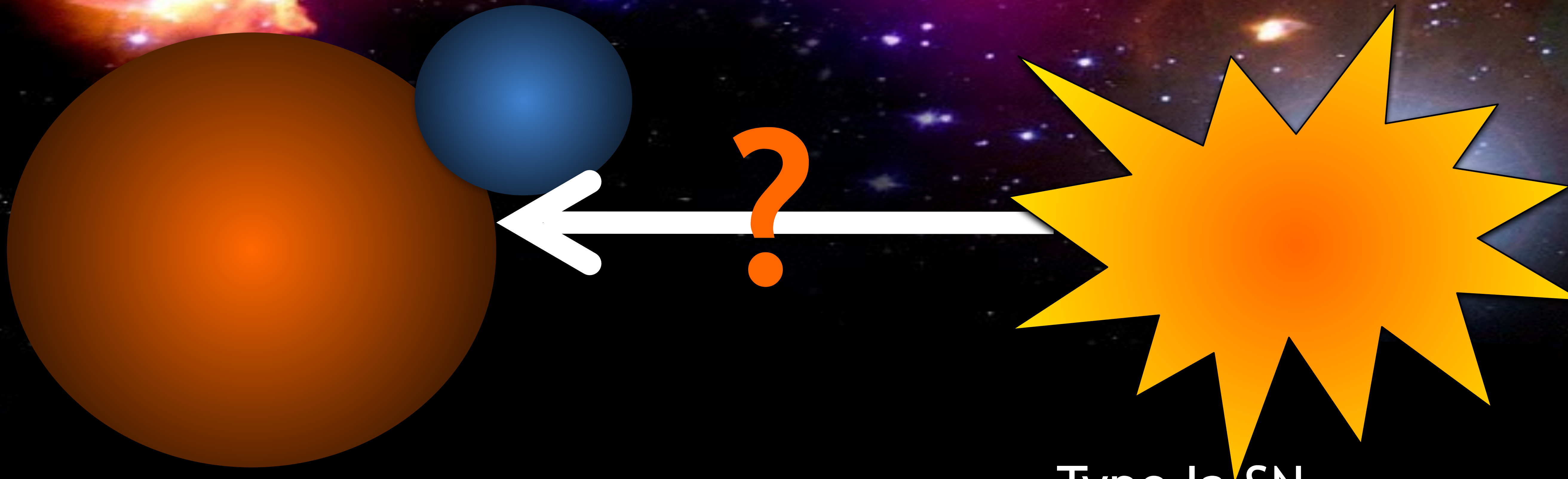
RM+16

} 10%



Margutti et al., in prep

The PROBLEM

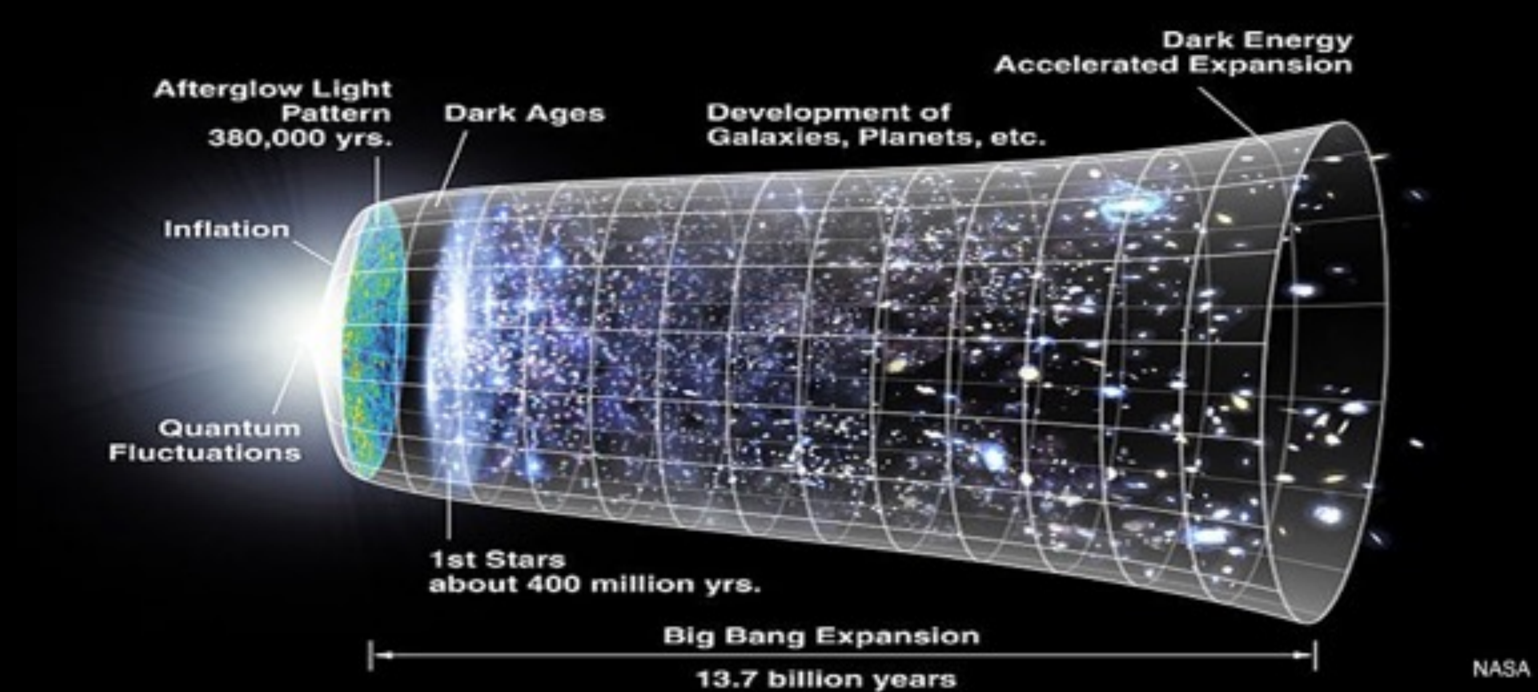


Progenitor System

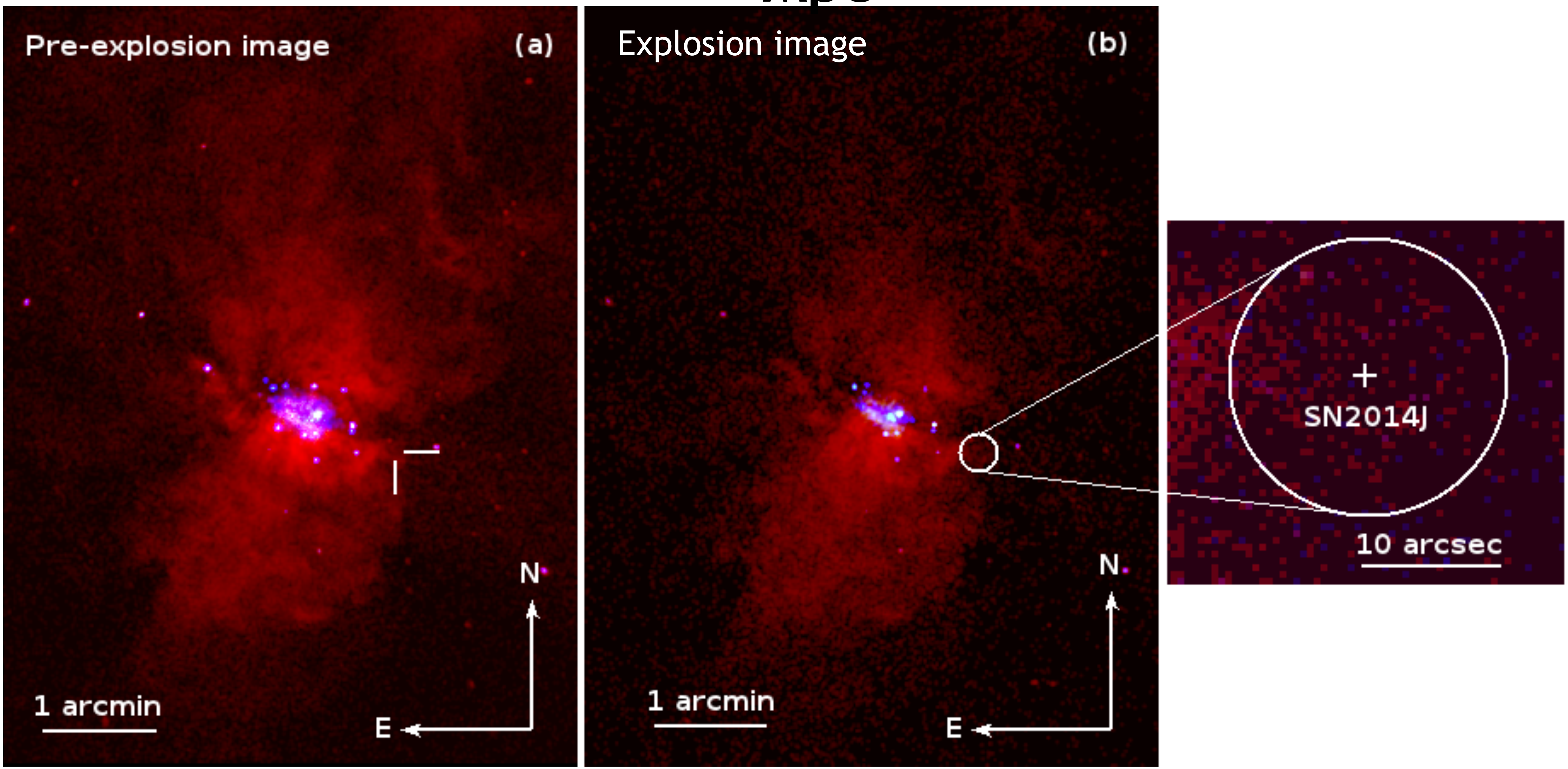
Type Ia SN explosion

"...The end is where we start from..."

The Little Gidding by T. S. Eliot



Type Ia SN2014J
Host Galaxy: M82, D=3.5 Mpc



Margutti +14

Chandra X-ray images

Thanks to the Chandra Team!!