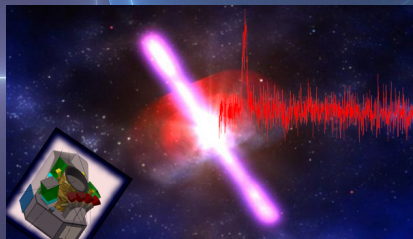


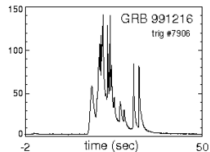
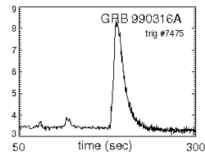
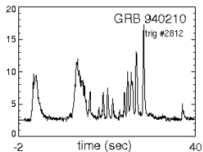
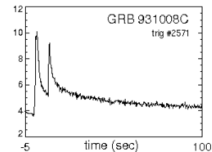
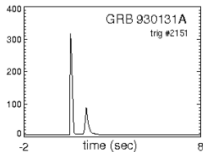
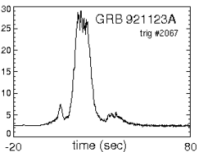
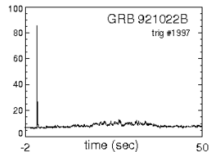
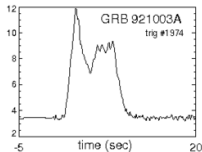
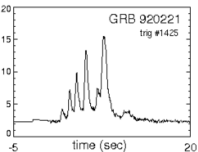
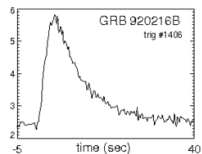
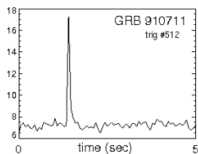
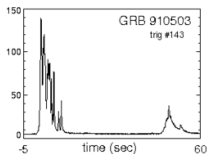
Gamma-ray bursts

Dorottya Szécsi

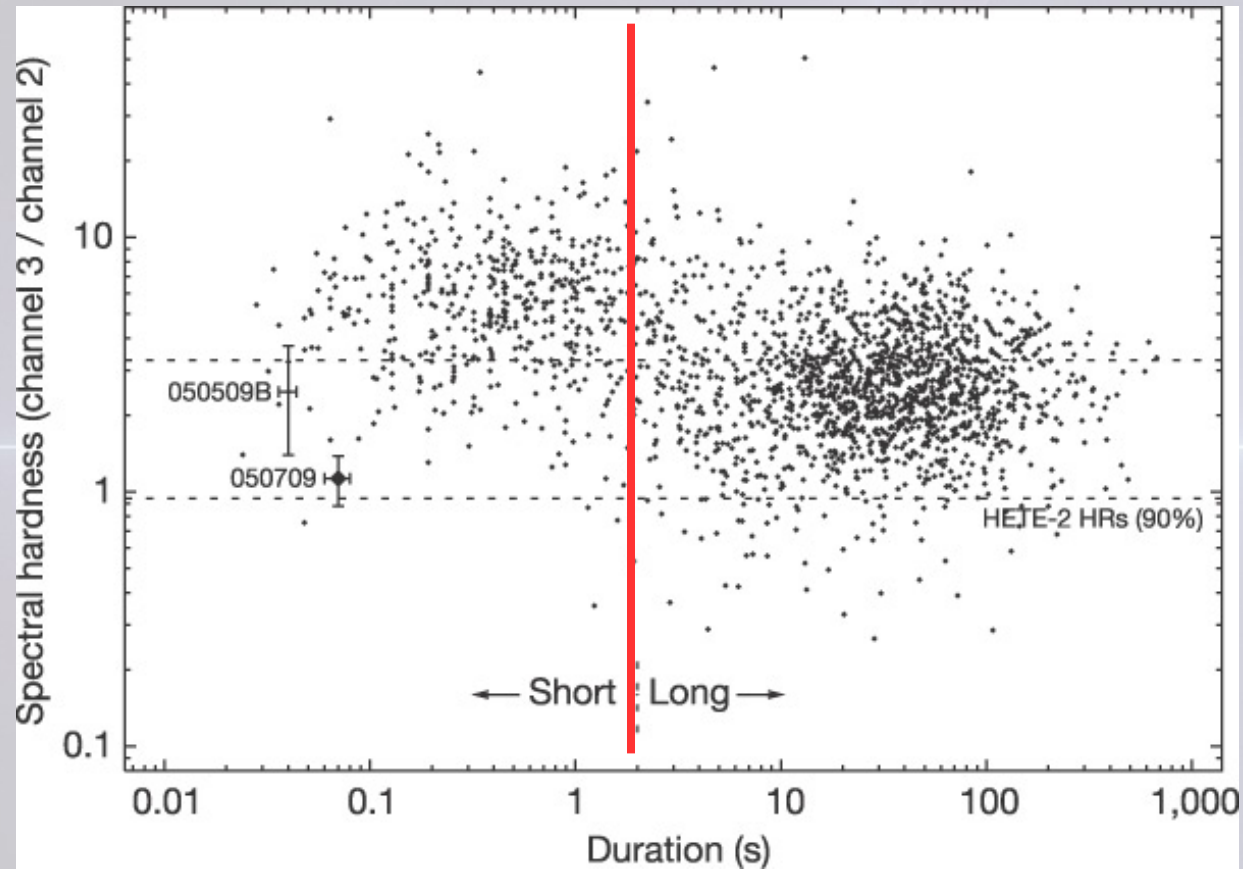


SILCC group meeting
University of Cologne, 30th June 2020

During the cold war...

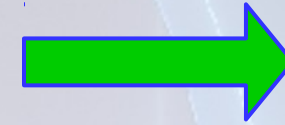
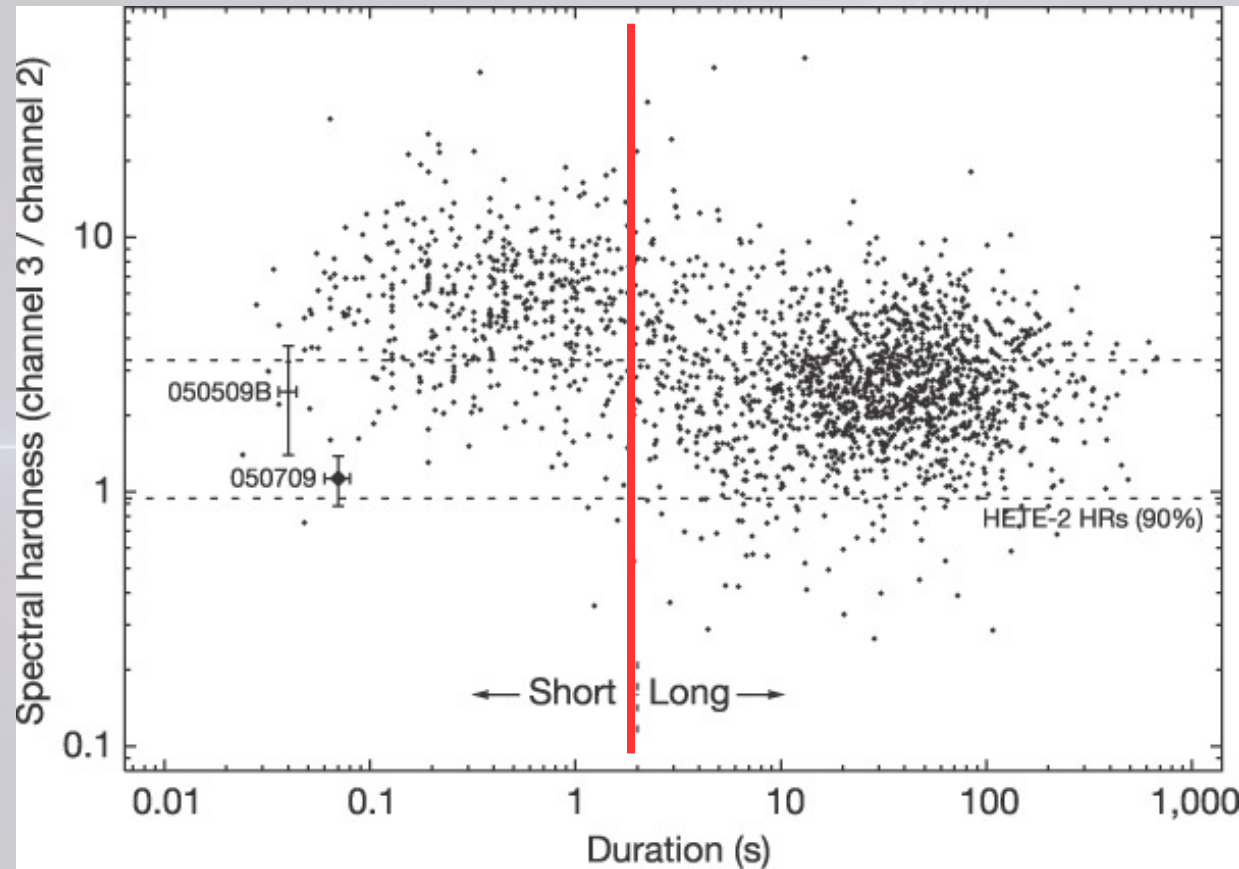


At least two, physically distinct types of objects



Credit: Hjorth+2005

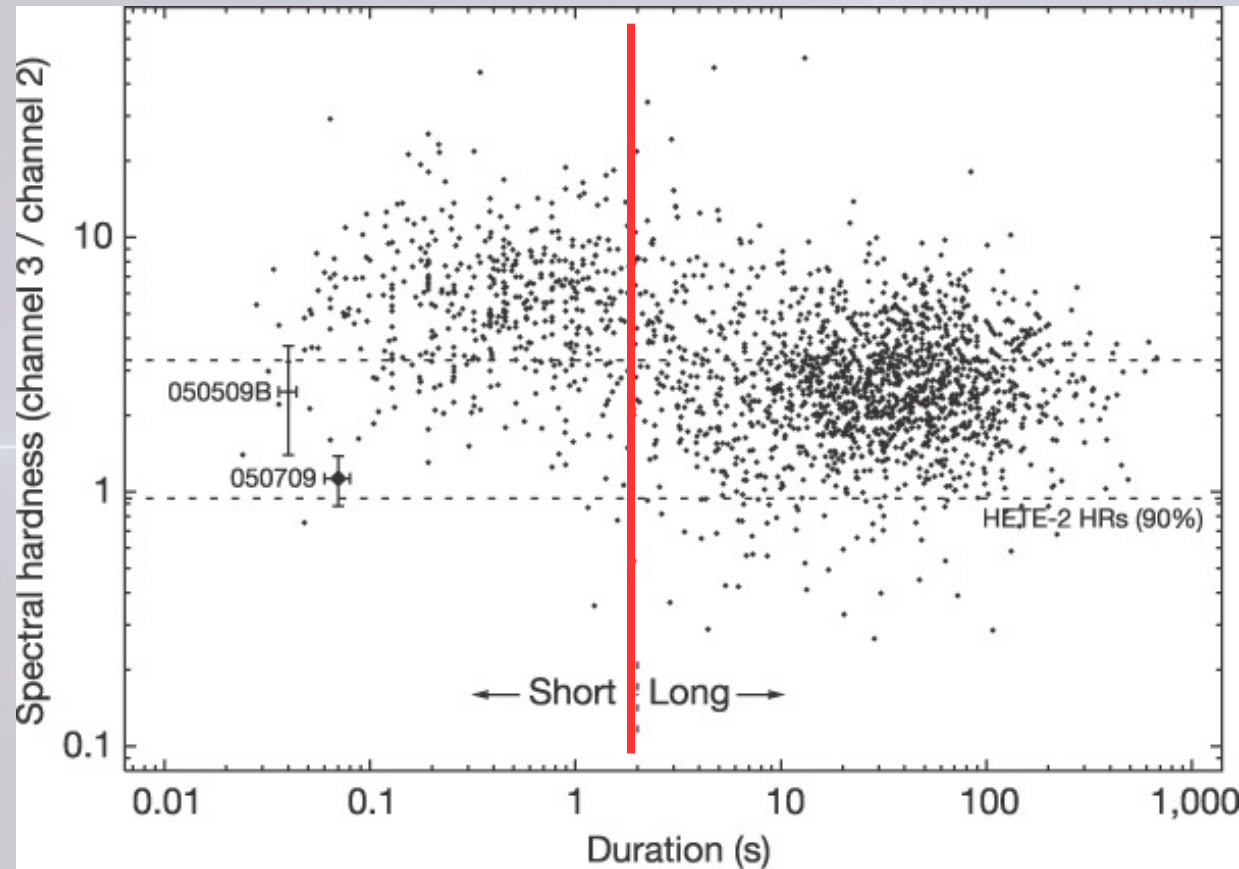
At least two, physically distinct types of objects



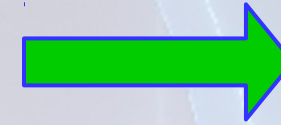
Long/soft:
Massive Stars
at
collapse

Credit: Hjorth+2005

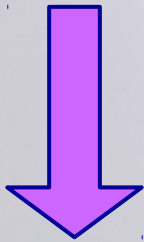
At least two, physically distinct types of objects



Credit: Hjorth+2005



**Long/soft:
Massive
Stars
at
collapse**



Short/hard: two Compact Objects at merger



Short/hard GRBs:

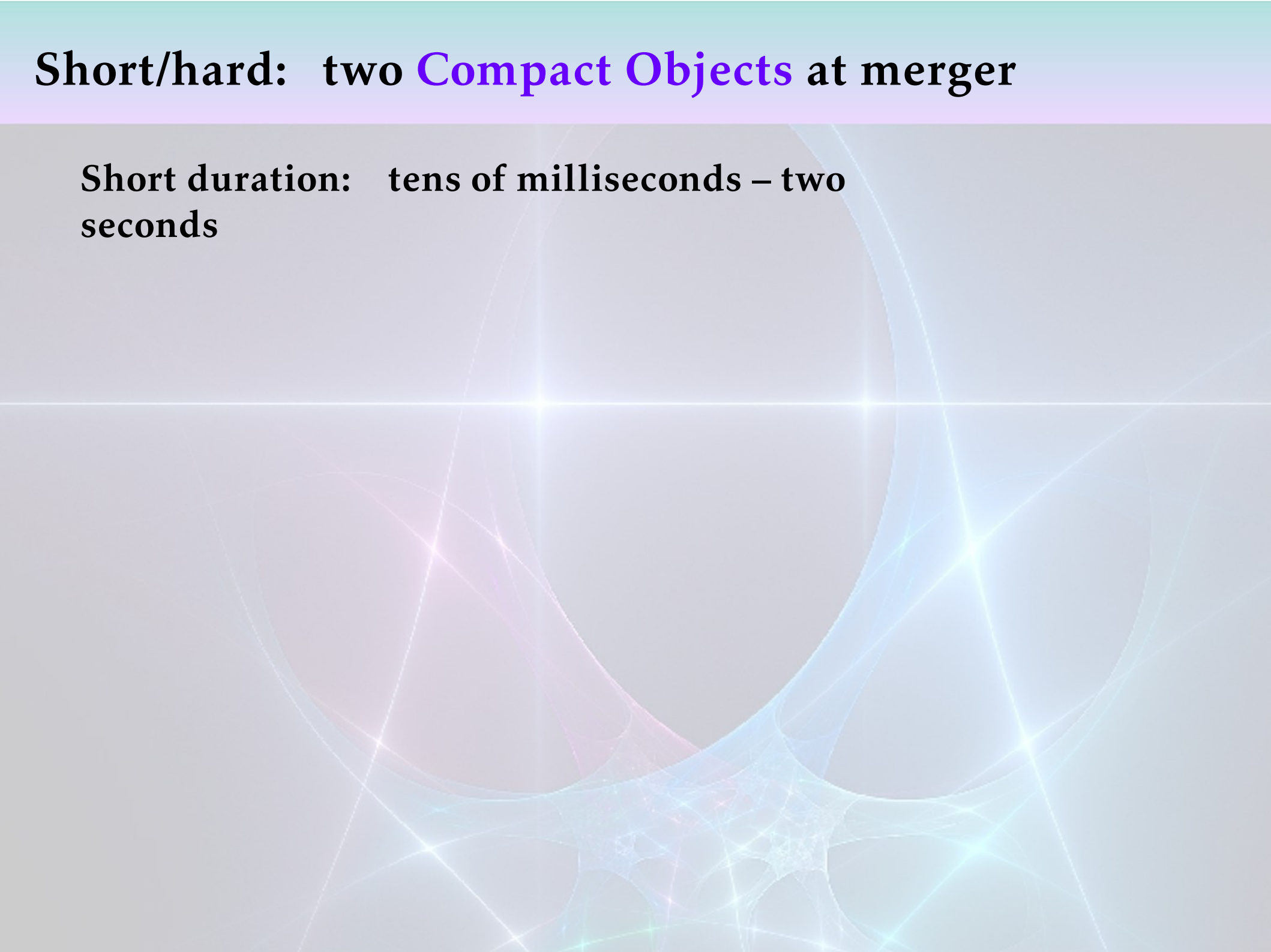
**two Compact Objects
at merger**

Short/hard: two Compact Objects at merger



Short/hard: two **Compact Objects** at merger

Short duration: tens of milliseconds – two seconds

The background of the slide is an abstract, artistic representation of a gravitational well or spacetime curvature. It features a large, dark, circular shape in the upper center, surrounded by a complex network of glowing, translucent lines in shades of blue, purple, and pink. These lines form a web-like structure that suggests the merging of two objects, with bright points of light at the intersections and along the lines, creating a sense of dynamic energy and light emission.

Short/hard: two **Compact Objects** at merger

Short duration: tens of milliseconds – two seconds

→ progenitor systems with a dynamical timescale of milliseconds

Short/hard: two **Compact Objects** at merger

Short duration: tens of milliseconds – two seconds

→ progenitor systems with a dynamical timescale of milliseconds

NS-NS:

Short/hard: two **Compact Objects** at merger

Short duration: tens of milliseconds – two seconds
See the review of Berger+14

→ progenitor systems with a dynamical timescale of milliseconds

NS-NS:

Short/hard: two **Compact Objects** at merger

Short duration: tens of milliseconds – two seconds
See the review of Berger+14

→ progenitor systems with a dynamical timescale of milliseconds

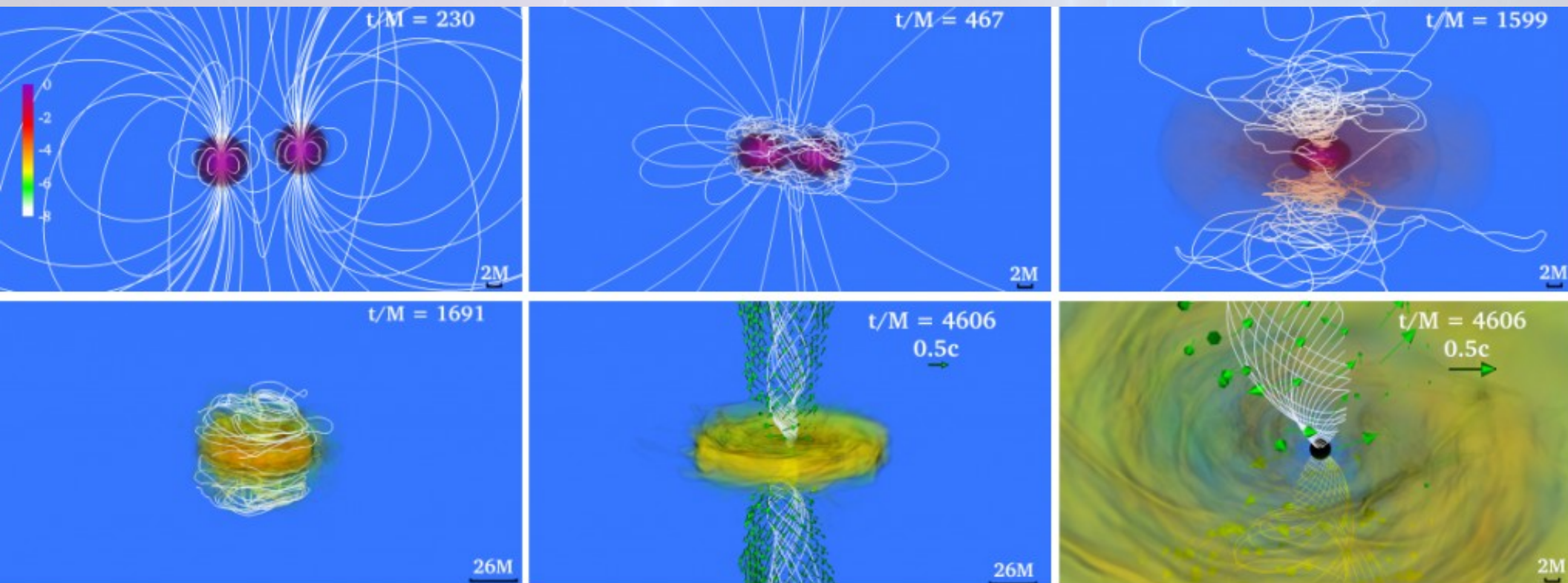
NS-NS: *First: Eichler+89*

Short/hard: two Compact Objects at merger

Short duration: tens of milliseconds – two seconds
See the review of Berger+14

→ progenitor systems with a dynamical timescale of milliseconds

NS-NS: *First: Eichler+89*



Credit: Ruiz+2016

Short/hard: two Compact Objects at merger

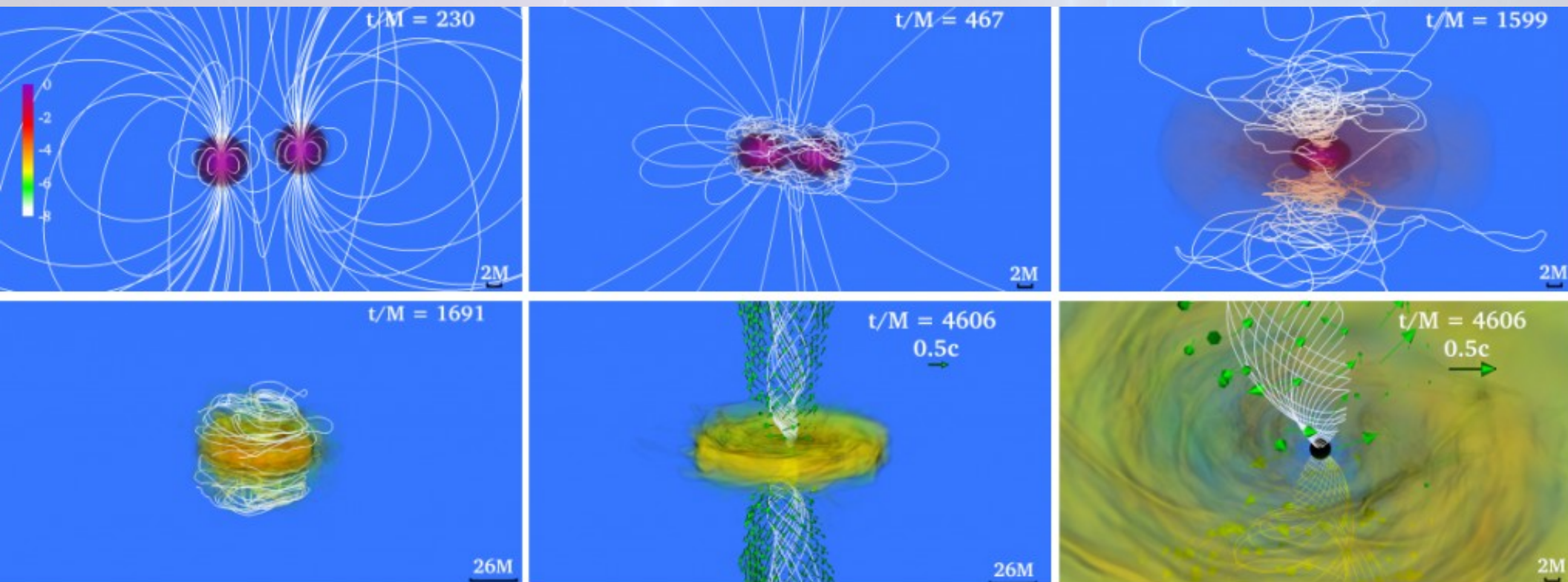
Short duration: tens of milliseconds – two seconds
See the review of Berger+14

→ progenitor systems with a dynamical timescale of milliseconds

NS-NS: *First: Eichler+89*

NS-BH

First: Narayan+92



Credit: Ruiz+2016

Short/hard: two Compact Objects at merger

Short duration: tens of milliseconds – two seconds
See the review of Berger+14

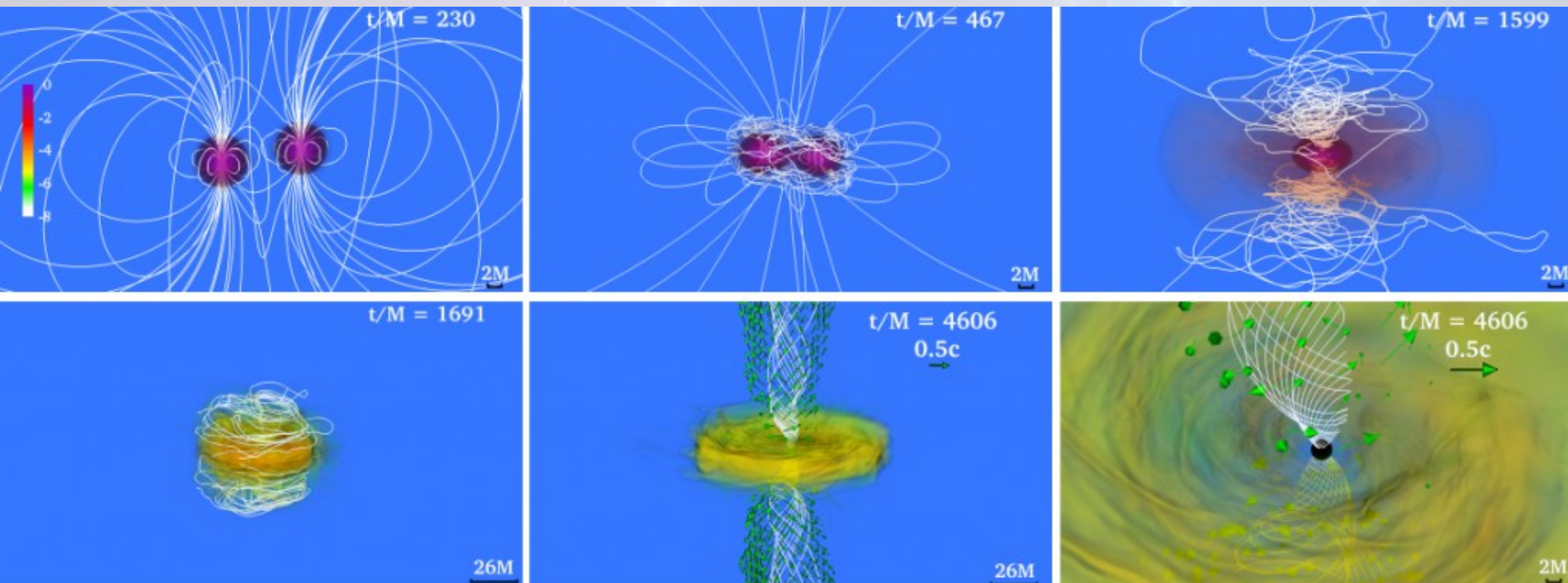
→ progenitor systems with a dynamical timescale of milliseconds

NS-NS: *First: Eichler+89*

NS-BH

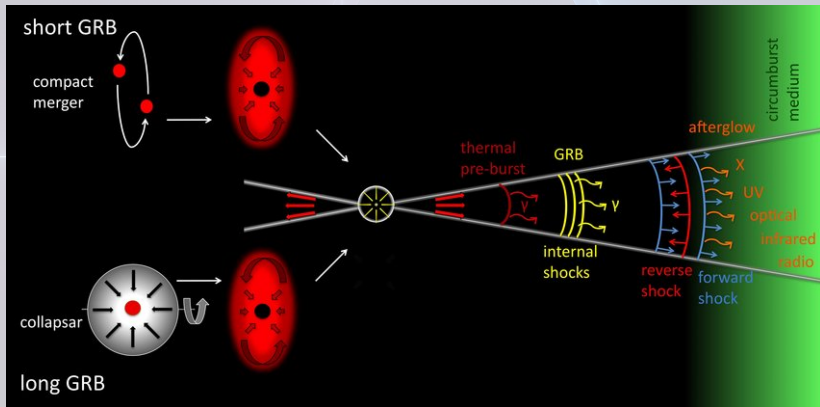
First: Narayan+92

BH-BH (?!)



Credit: Ruiz+2016

The gamma-ray++ emission



Gomboc'12

The background features a large, faint, light-colored circle centered in the upper half. Overlaid on this are several glowing, ethereal lines in shades of blue and pink, which appear to be part of a complex, web-like structure or a stylized representation of a star's internal processes. The lines are thin and have a soft, glowing aura around them.

Long/soft GRBs:

**Massive Stars
at collapse**

Long/soft GRBs: **Massive Stars** at collapse



Long/soft GRBs: **Massive Stars** at collapse

Massive Stars – *more precisely?*



Long/soft GRBs: **Massive Stars** at collapse

Massive Stars – *more precisely?*

$\sim 9 M_{\odot}$ – $\sim 300 M_{\odot}$

Long/soft GRBs: **Massive Stars** at collapse

Massive Stars – *more precisely?*

$\sim 9 M_{\odot} - \sim 300 M_{\odot}$

Z_{\odot} – low-Z – metal free

Long/soft GRBs: **Massive Stars** at collapse

Massive Stars – *more precisely?*

$\sim 9 M_{\odot} - \sim 300 M_{\odot}$

Z_{\odot} – low-Z – metal free

rotation...

Long/soft GRBs: **Massive Stars** at collapse

Massive Stars – *more precisely?*

$\sim 9 M_{\odot} - \sim 300 M_{\odot}$

Z_{\odot} – low-Z – metal free

rotation...

**binary systems:
orbit, mass ratio,
mass transfer...**

Long/soft GRBs: **Massive Stars** at collapse

Massive Stars – *more precisely?*

$\sim 9 M_{\odot} - \sim 300 M_{\odot}$

Z_{\odot} – low-Z – metal free

rotation...

binary systems:
orbit, mass ratio,
mass transfer...

Special requirements
depend on
astrophysical
scenario

Collapsar scenario

Magnetar scenario

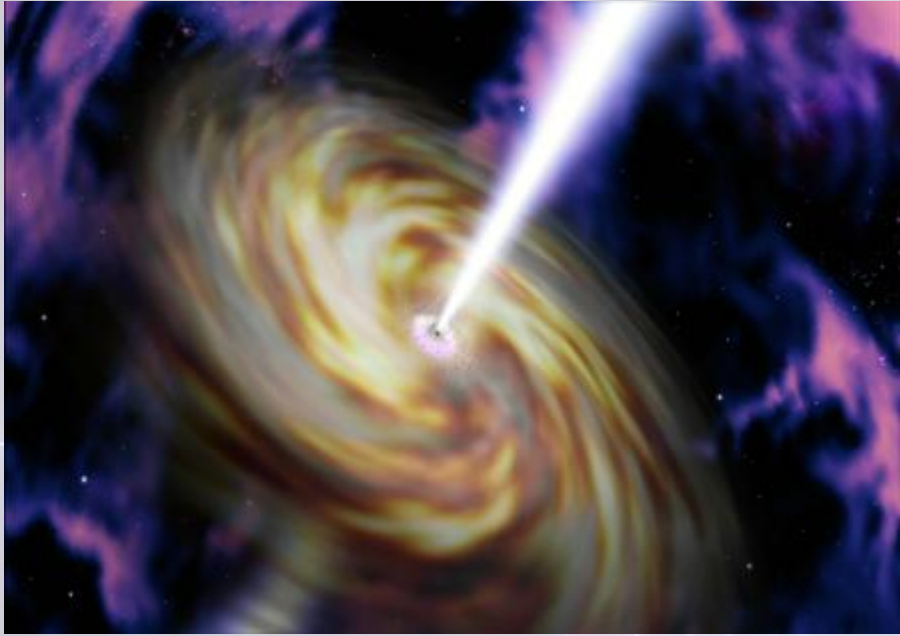
Collapsar scenario

Magnetar scenario

*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

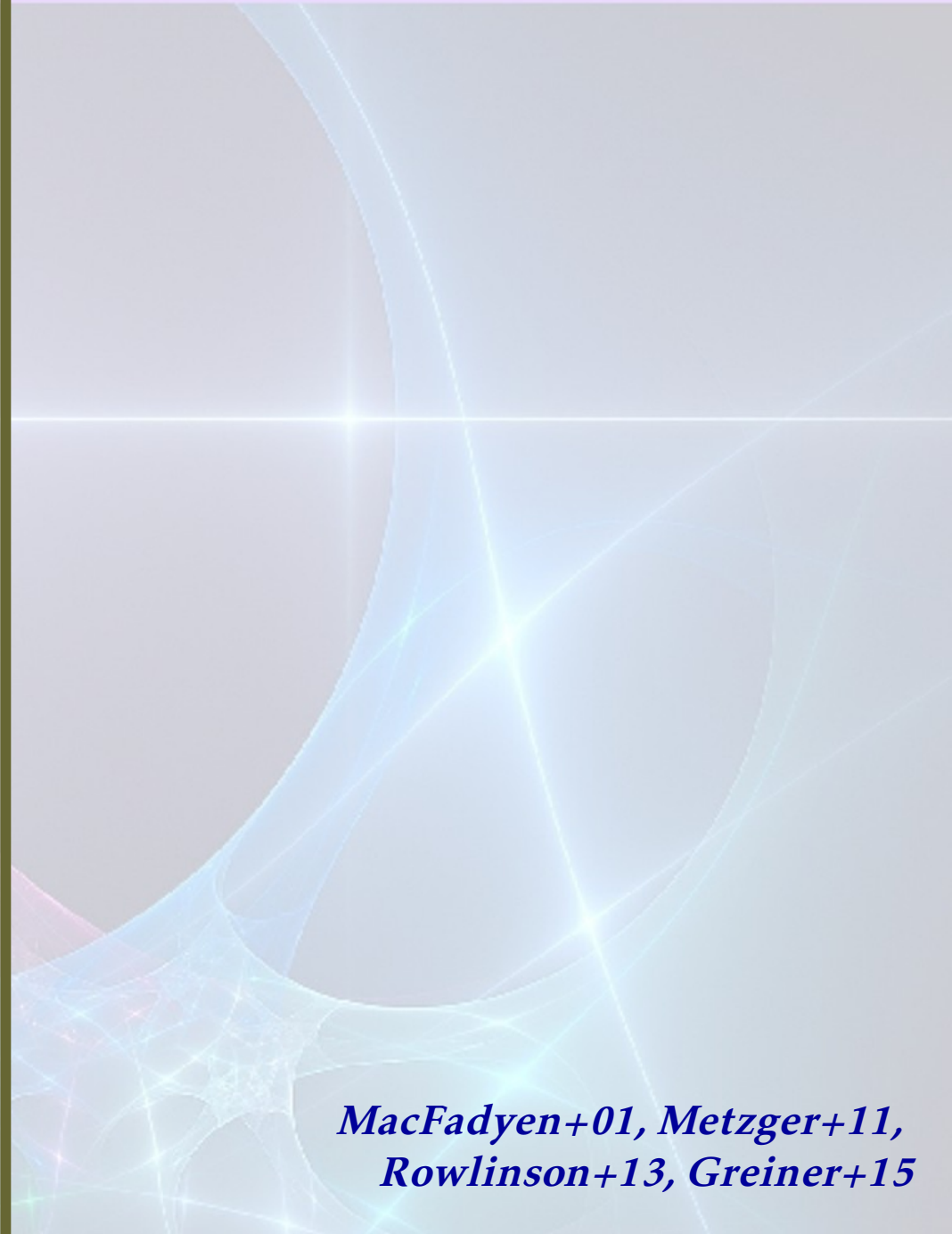
*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

Collapsar scenario



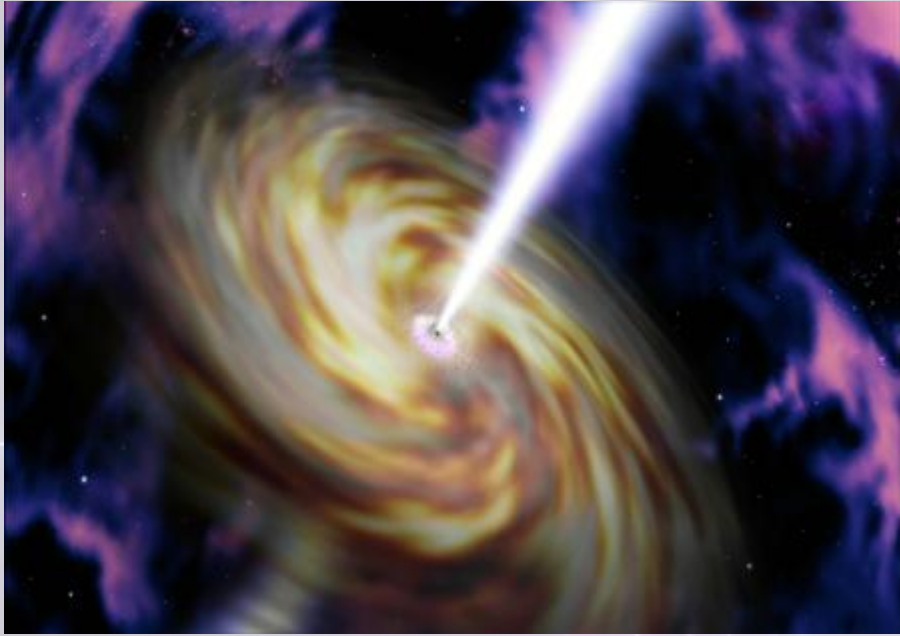
*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

Magnetar scenario



*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

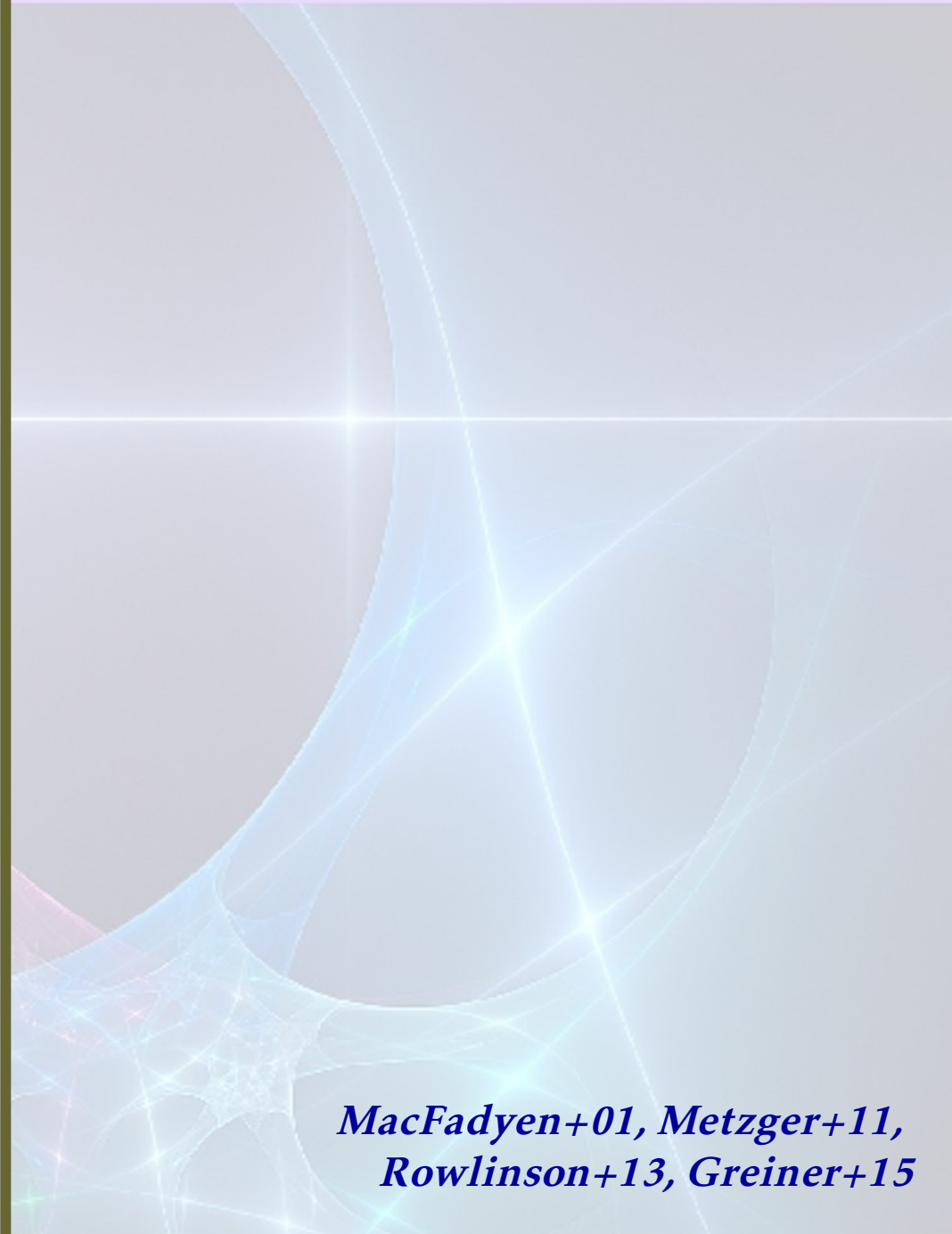
Collapsar scenario



– iron core → collapse

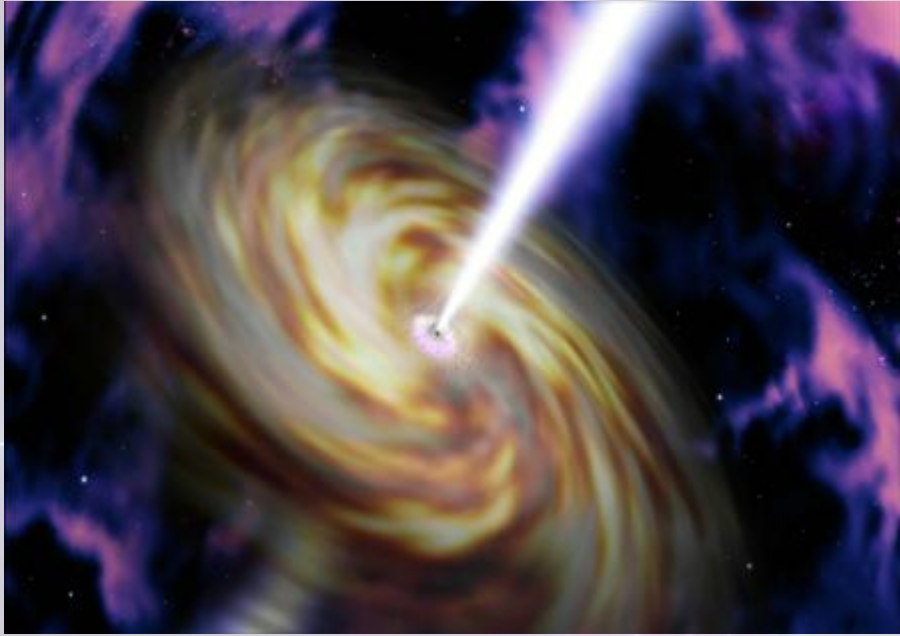
*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

Magnetar scenario



*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

Collapsar scenario



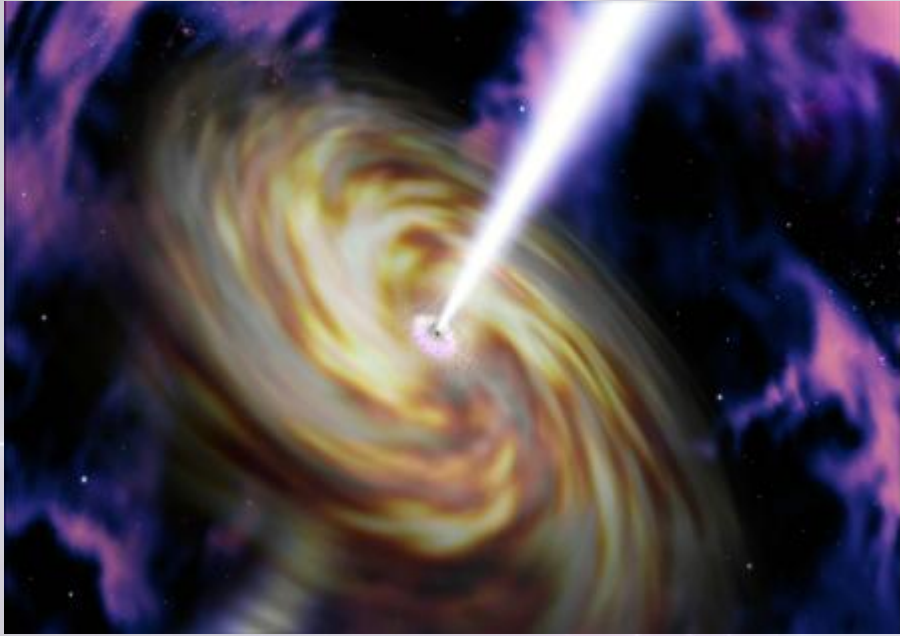
- iron core → collapse
- supernova is weak ('failed')
i.e. compactness parameter ξ is large

*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

Magnetar scenario

*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

Collapsar scenario



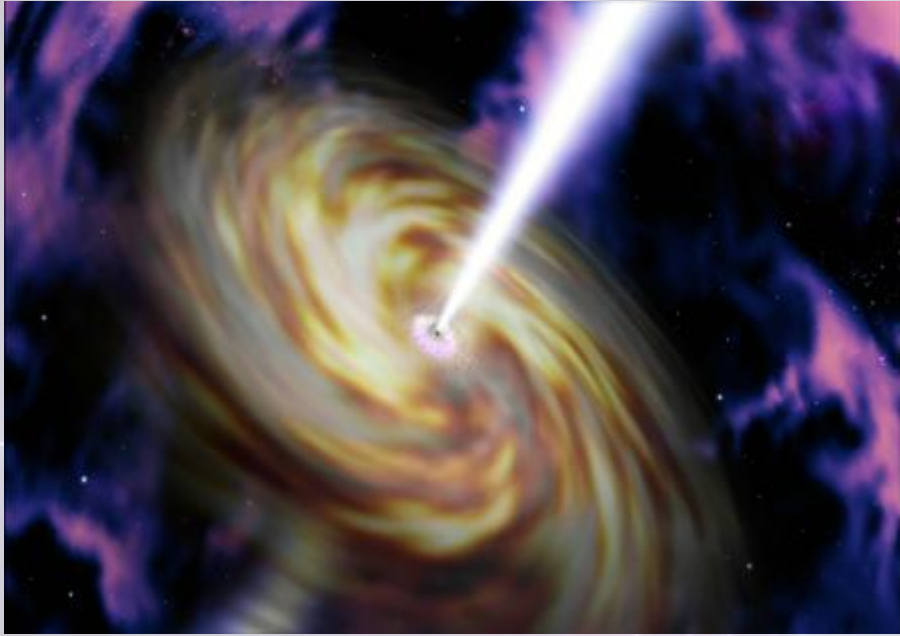
- iron core → collapse
- supernova is weak ('failed')
i.e. compactness parameter ξ is large
- material falls in → BH

*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

Magnetar scenario

*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

Collapsar scenario



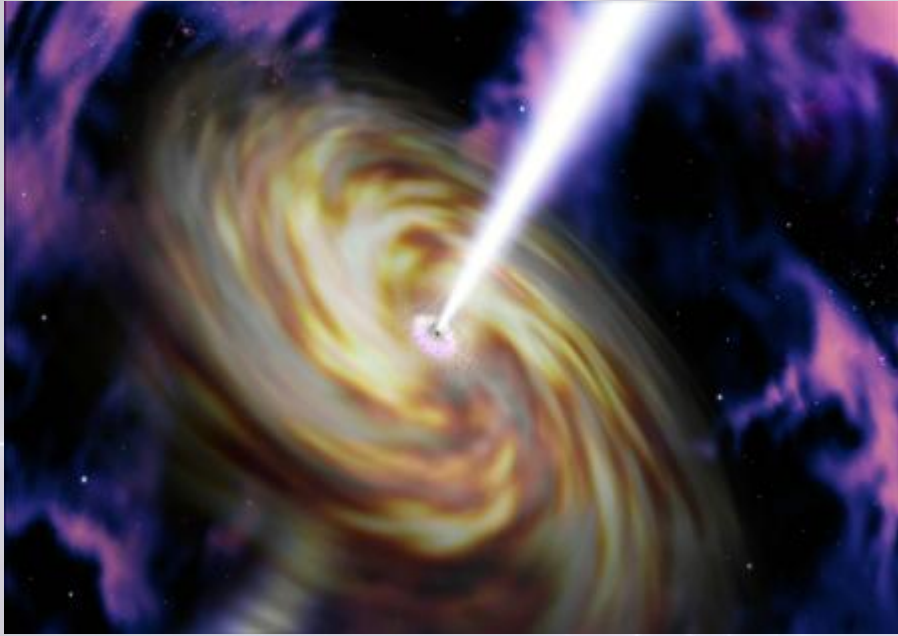
- iron core → collapse
- supernova is weak ('failed')
i.e. compactness parameter ξ is large
- material falls in → BH
- fast rotation → accretion disc
→ jet → LGRB

*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

Magnetar scenario

*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

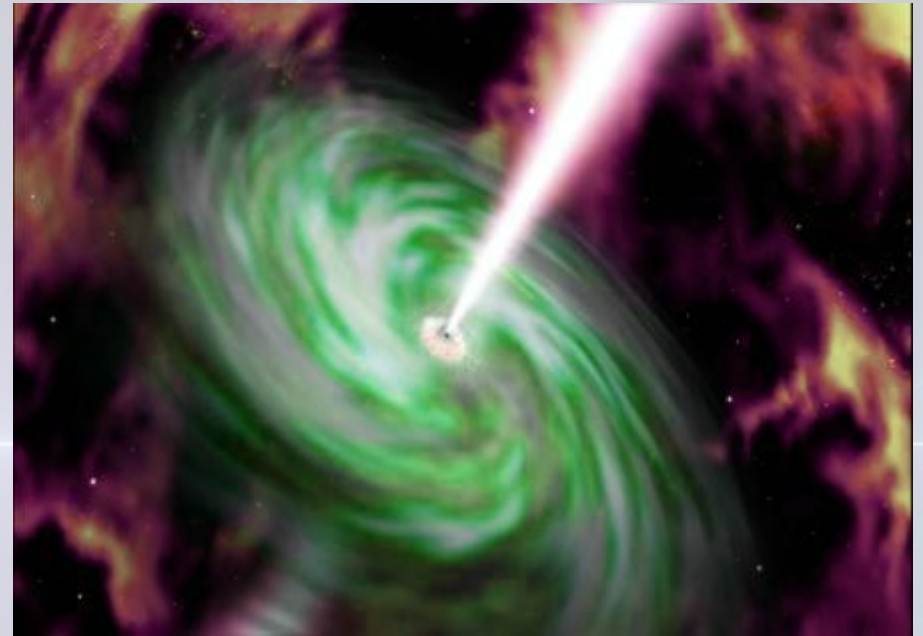
Collapsar scenario



- iron core → collapse
- supernova is weak ('failed')
i.e. compactness parameter ξ is large
- material falls in → BH
- fast rotation → accretion disc
→ jet → LGRB

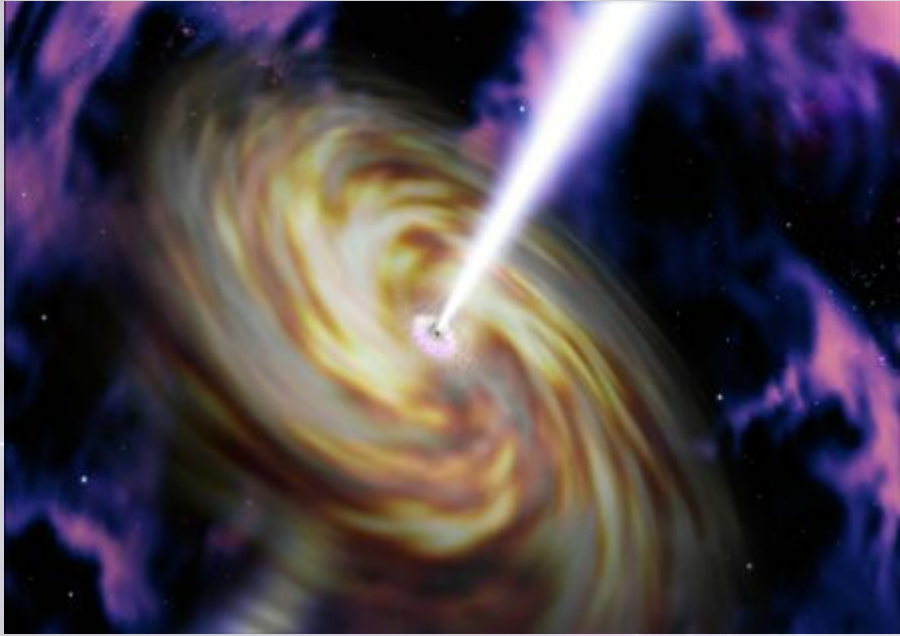
*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

Magnetar scenario



*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

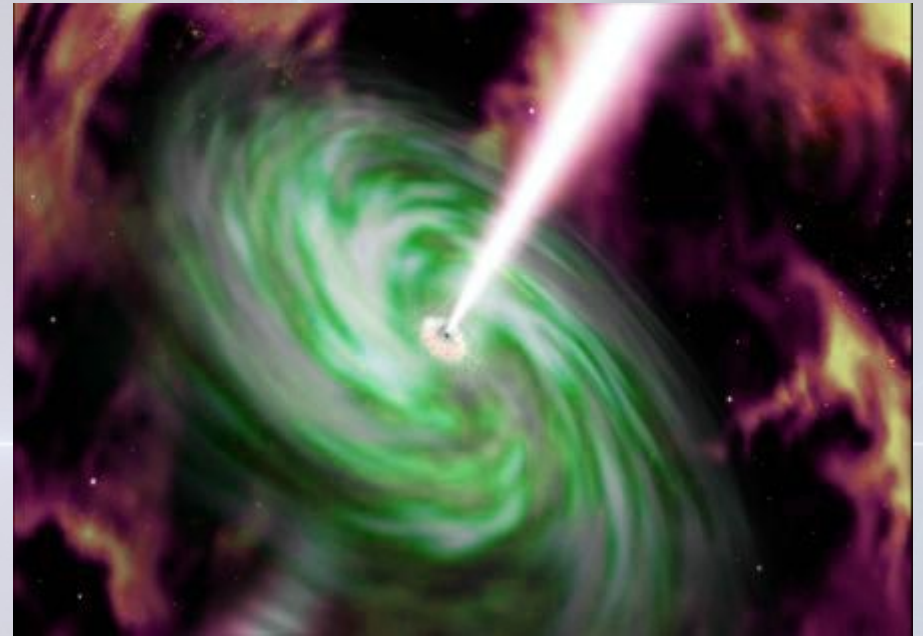
Collapsar scenario



- iron core → collapse
- supernova is weak ('failed')
i.e. compactness parameter ξ is large
- material falls in → BH
- fast rotation → accretion disc
→ jet → LGRB

*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

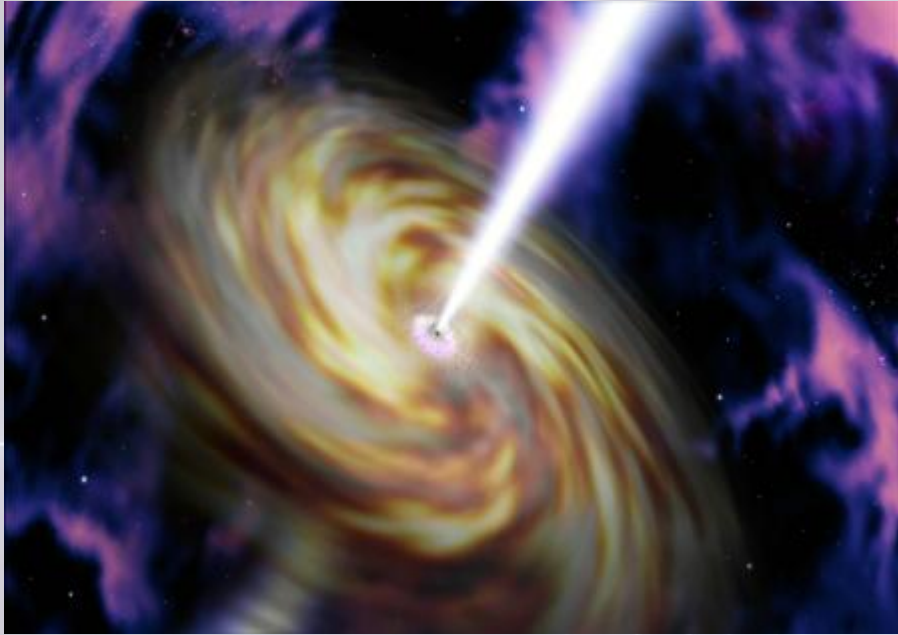
Magnetar scenario



- iron core → collapse

*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

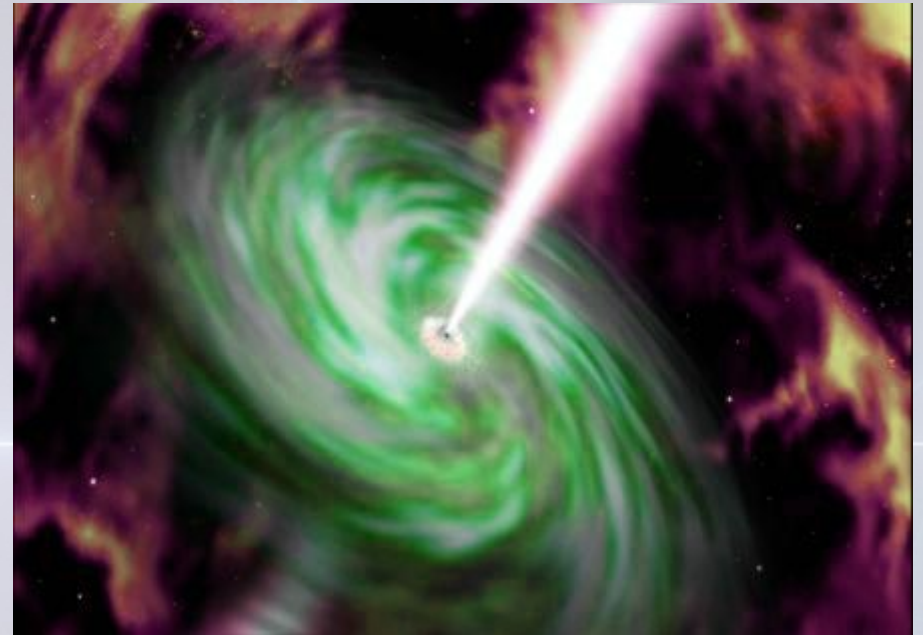
Collapsar scenario



- iron core → collapse
- supernova is weak ('failed')
i.e. compactness parameter ξ is large
- material falls in → BH
- fast rotation → accretion disc
→ jet → LGRB

*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

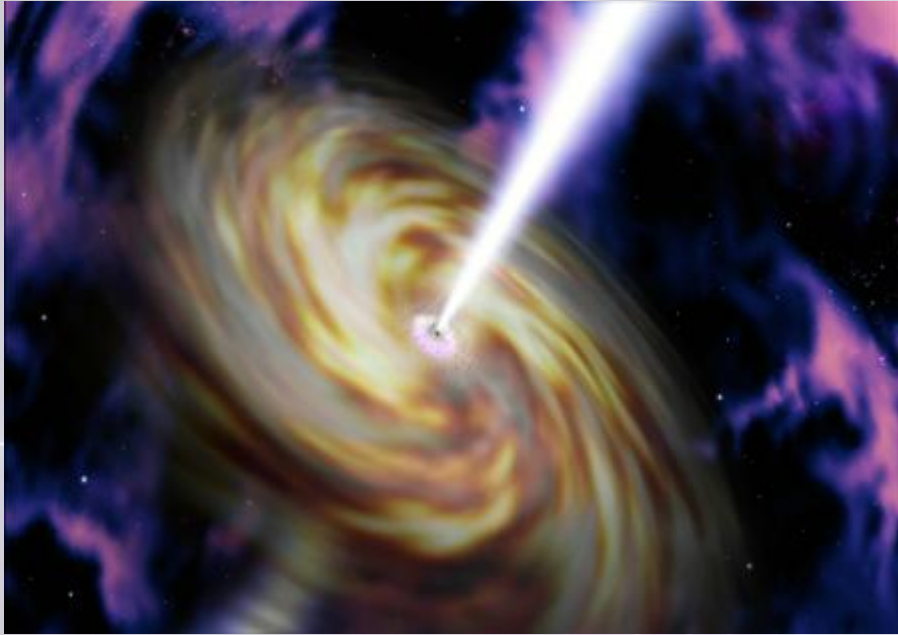
Magnetar scenario



- iron core → collapse
- supernova is successful
i.e. compactness parameter ξ is small

*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

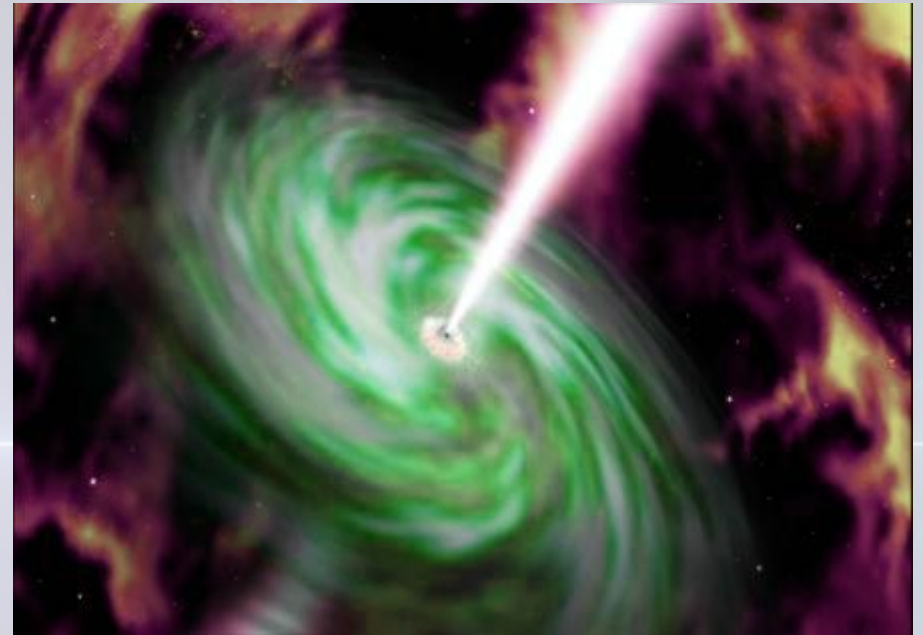
Collapsar scenario



- iron core → collapse
- supernova is weak ('failed')
i.e. compactness parameter ξ is large
- material falls in → BH
- fast rotation → accretion disc
→ jet → LGRB

*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

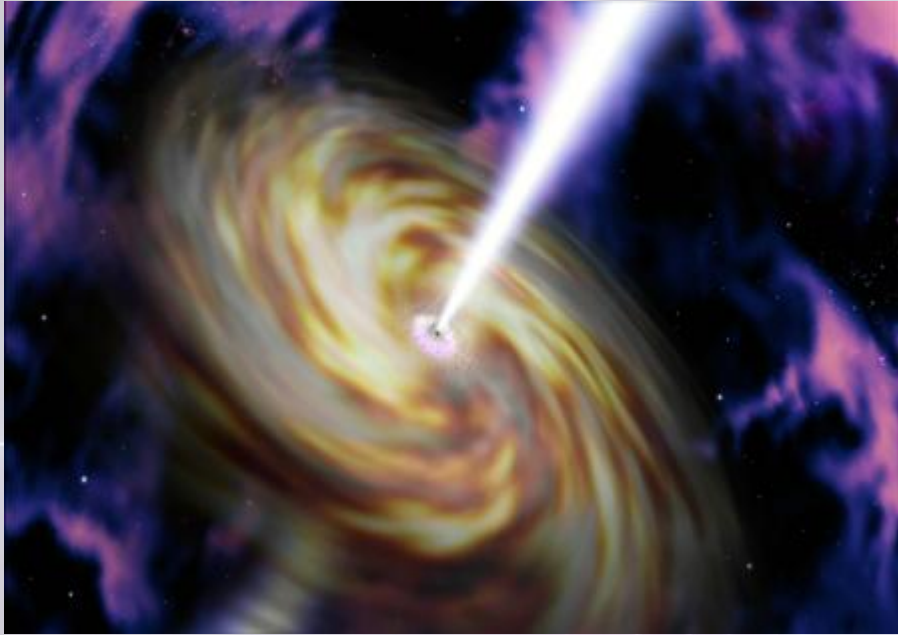
Magnetar scenario



- iron core → collapse
- supernova is successful
i.e. compactness parameter ξ is small
- material expelled → NS

*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

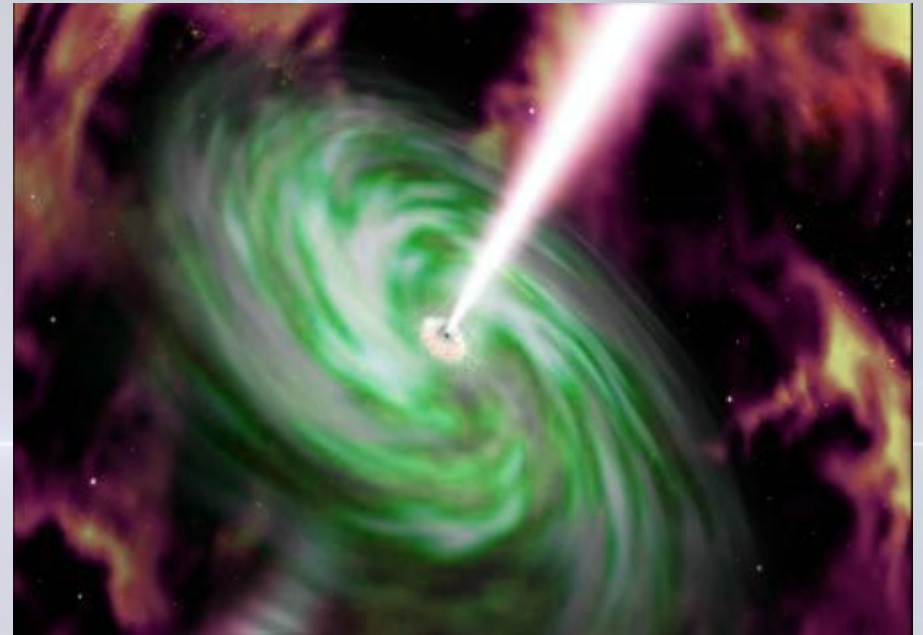
Collapsar scenario



- iron core → collapse
- supernova is weak ('failed')
i.e. compactness parameter ξ is large
- material falls in → BH
- fast rotation → accretion disc
→ jet → LGRB

*Woosley'93, Macfadyen+99,
Yoon+05, Woosley+06*

Magnetar scenario



- iron core → collapse
- supernova is successful
i.e. compactness parameter ξ is small
- material expelled → NS
- fast rotating, magnetized NS
powers the jet → LGRB

*MacFadyen+01, Metzger+11,
Rowlinson+13, Greiner+15*

Question:

What kind of star would die this way?

Question:

What kind of star would die this way?

...task for stellar physicists!

Question:

What kind of star would die this way?

...task for stellar physicists!

- **fast rotation at the
moment of collapse
(low metallicity)**

Question:

What kind of star would die this way?

...task for stellar physicists!

- **fast rotation at the moment of collapse (low metallicity)**
- **iron core... massive star (but less than $40 M_{\odot}$ core – pair instability)**
- **no large envelope – jet should be able to penetrate through!**

Question:

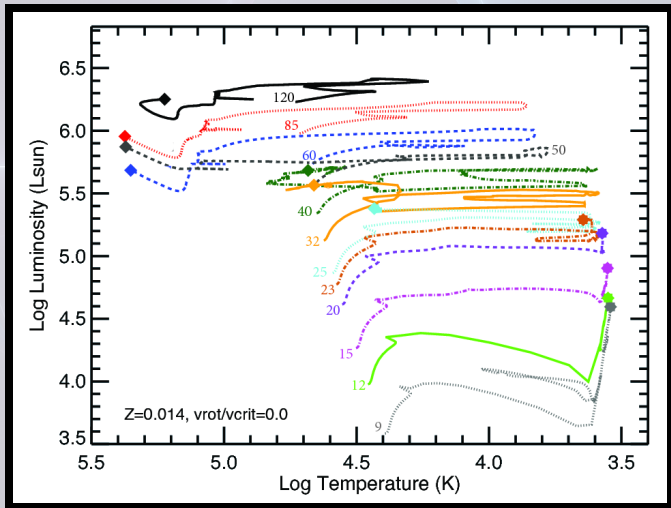
What kind of star would die this way?

...task for stellar physicists!

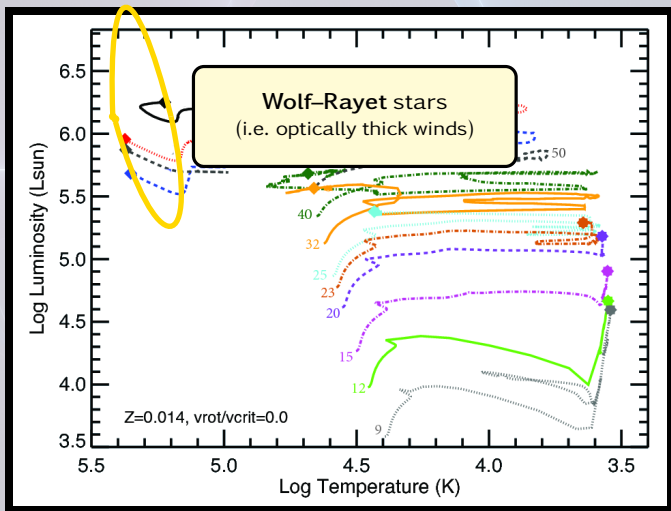
- fast rotation at the moment of collapse (low metallicity)
- iron core... massive star (but less than $40 M_{\odot}$ core – pair instability)
- no large envelope – jet should be able to penetrate through!

classical Wolf–Rayet stars?

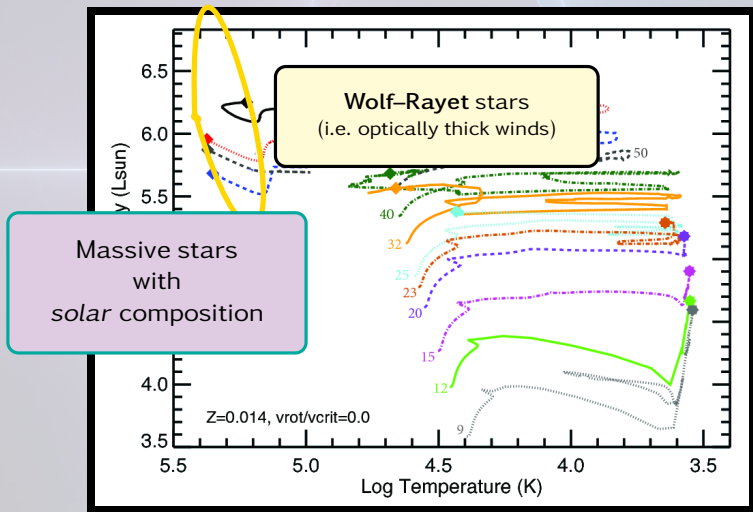
Hertzprung–Russell diagram



Hertzprung–Russell diagram



Hertzprung–Russell diagram



Question:

What kind of star would die this way?

...task for stellar physicists!

- **no large envelope**
– jet should be able to penetrate through!
- **fast rotation at the moment of collapse**
- **iron core... massive star**

classical Wolf–Rayet stars?
... spin down due to strong mass loss
NO.

Question:

What kind of star would die this way?

...task for stellar physicists!

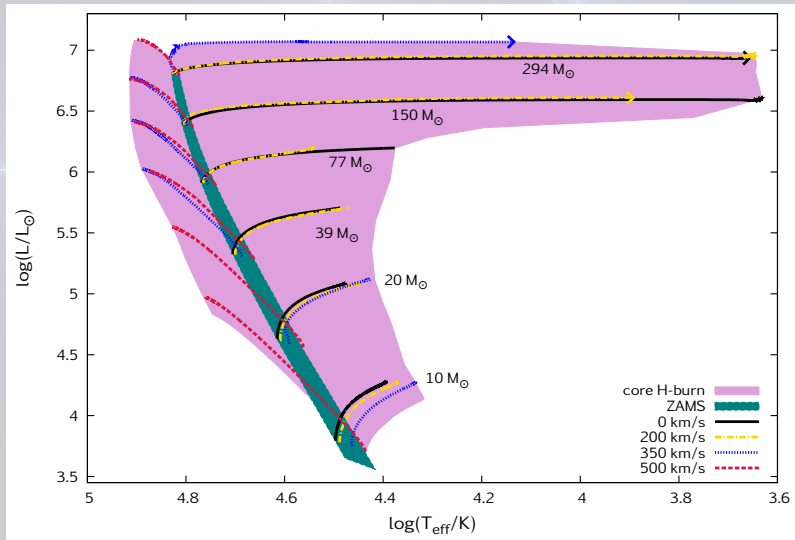
- no large envelope
– jet should be able to penetrate through!
- fast rotation at the moment of collapse
- iron core... massive star

classical Wolf–Rayet stars?
... spin down due to strong mass loss
NO.

*Chemically
Homogeneous
Evolution
(low metallicity)*

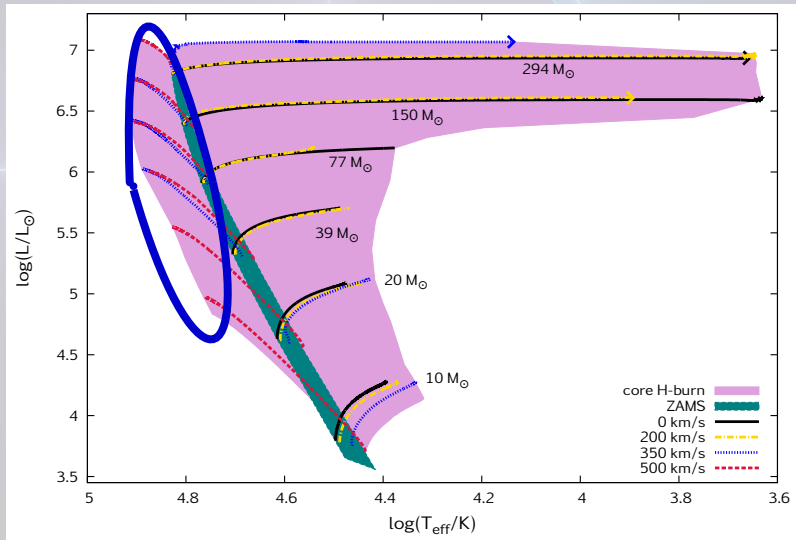
Low Metallicity Massive Stars

Szécsi et al. 2015 (*Astronomy & Astrophysics*, v.581, A15)



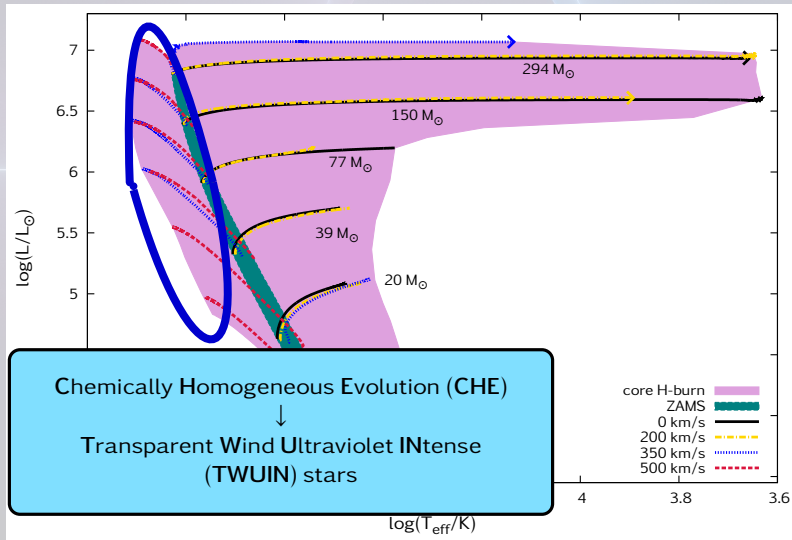
Low Metallicity Massive Stars

Szécsi et al. 2015 (*Astronomy & Astrophysics*, v.581, A15)



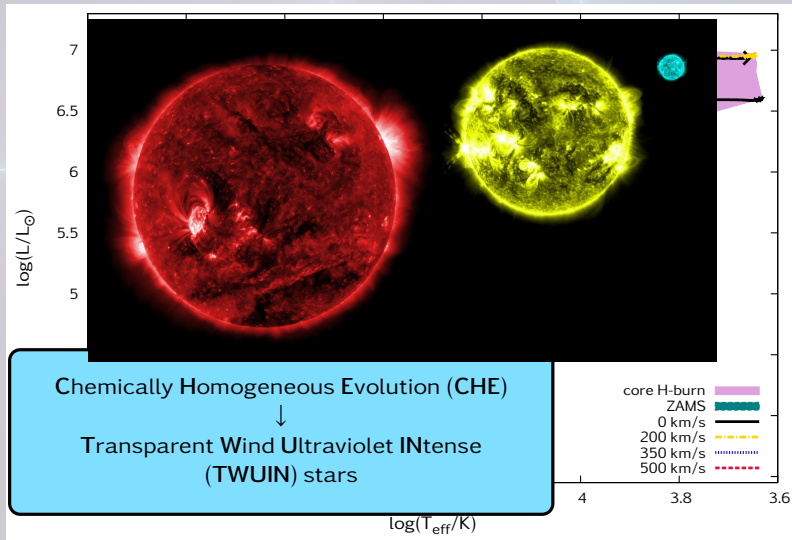
Low Metallicity Massive Stars

Szécsi et al. 2015 (*Astronomy & Astrophysics*, v.581, A15)



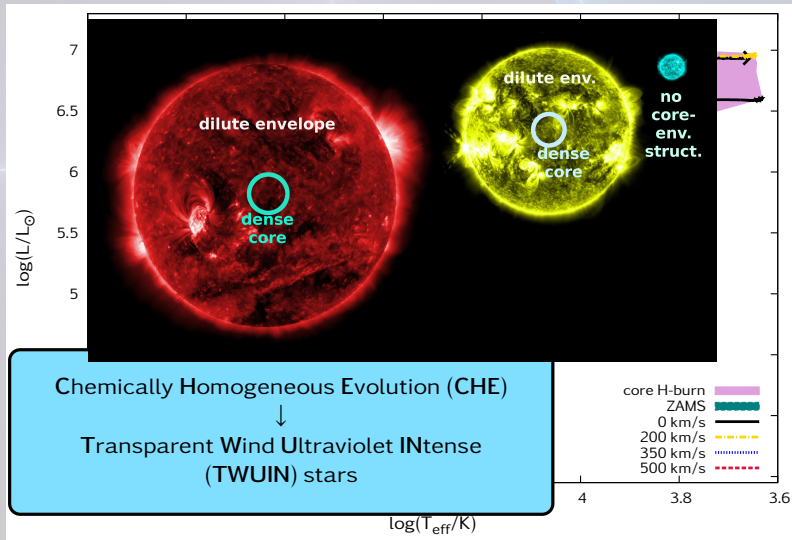
Low Metallicity Massive Stars

Szécsi et al. 2015 (*Astronomy & Astrophysics*, v.581, A15)



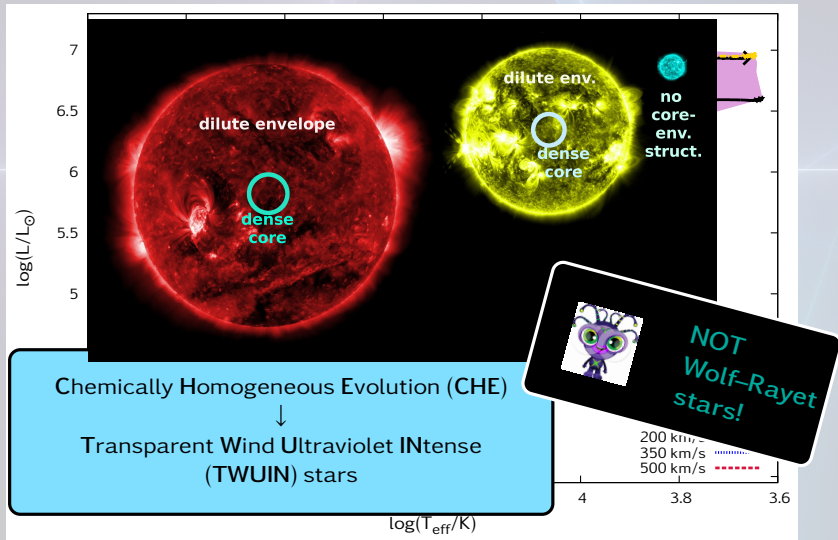
Low Metallicity Massive Stars

Szécsi et al. 2015 (*Astronomy & Astrophysics*, v.581, A15)

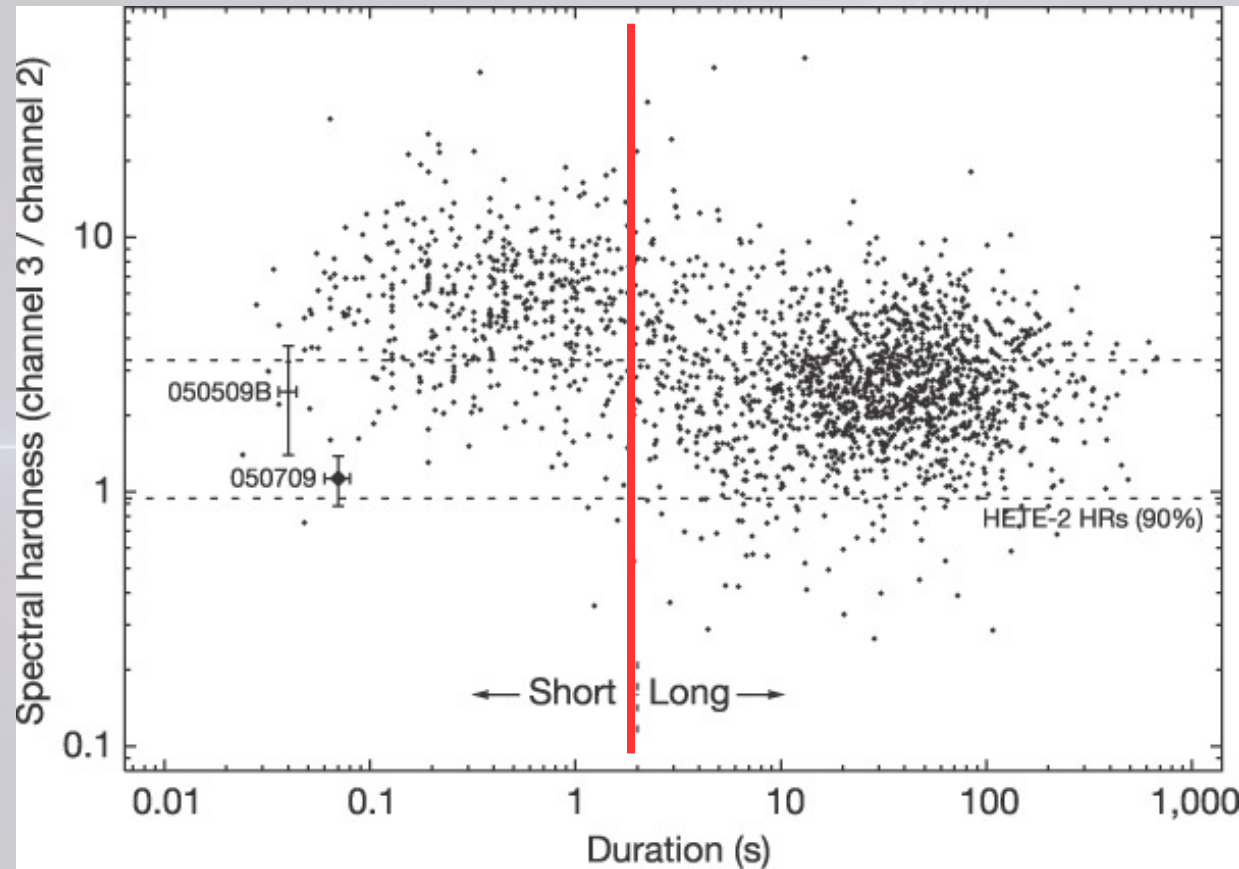


Low Metallicity Massive Stars

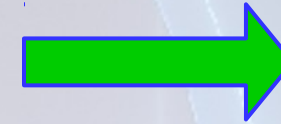
Szécsi et al. 2015 (*Astronomy & Astrophysics*, v.581, A15)



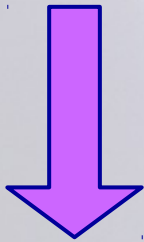
At least two, physically distinct types of objects



Credit: Hjorth+2005



Long/soft:
Massive Stars
at collapse



Short/hard: two Compact Objects at merger