

# Progenitors of GRBs

**Dorottya Szécsi**

post-doctoral researcher at the  
Astronomical Institute of the  
Czech Academy of Sciences



AKADEMIE VĚD  
ČESKÉ REPUBLIKY

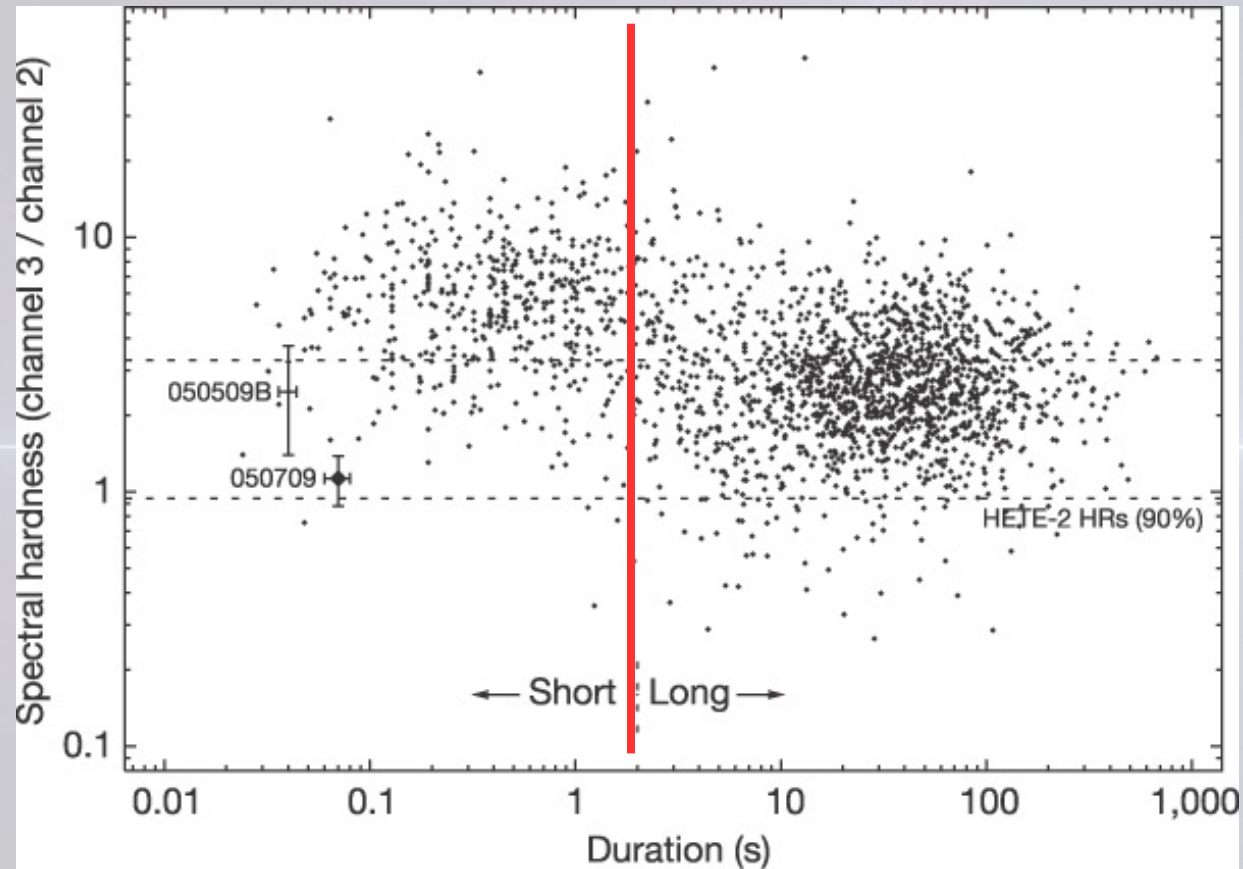


Astronomický  
ústav  
AV ČR

*Grant: 13-10589S GA ČR*

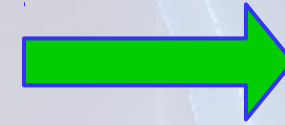
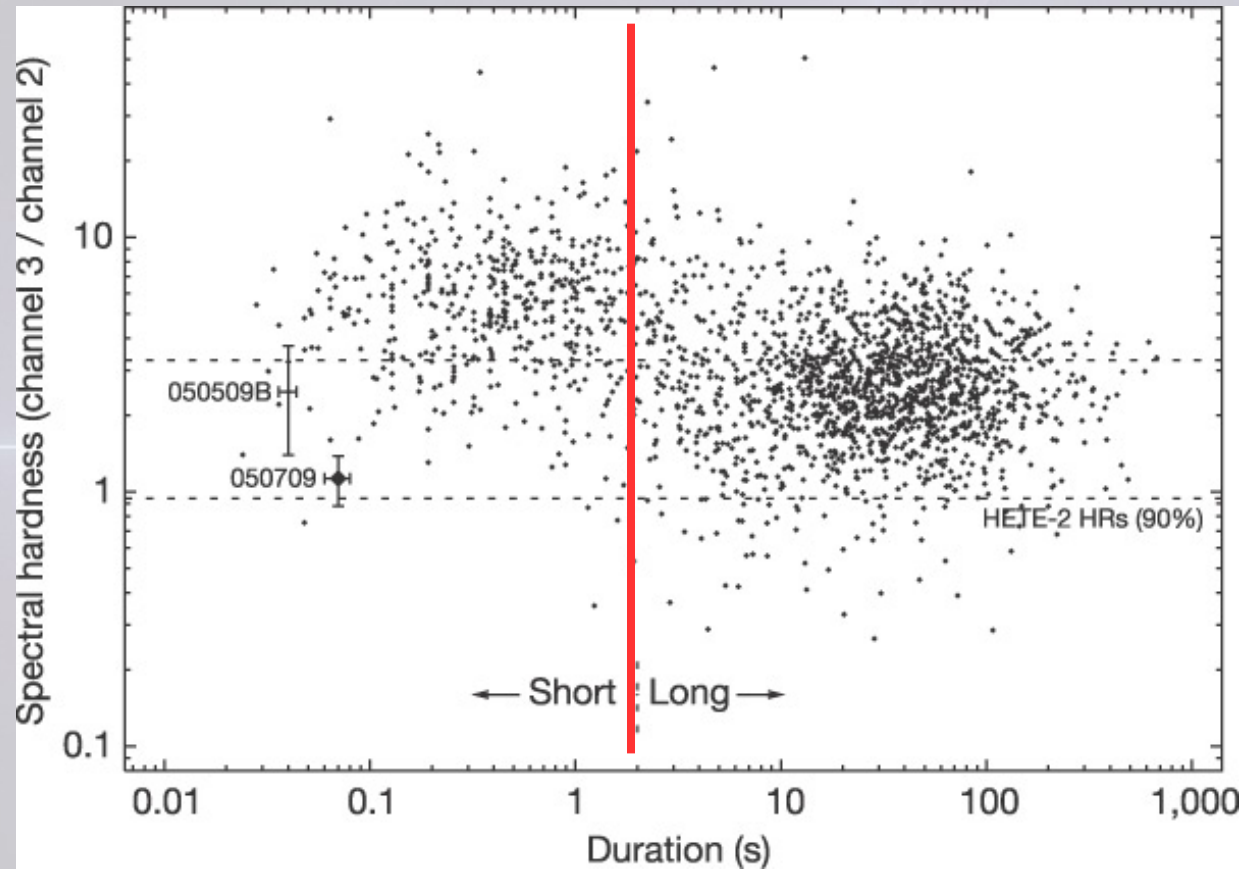
Multifrequency Behaviour of High Energy Cosmic Sources XII  
Palermo, 16th June 2017

# At least two, physically distinct types of objects



*Credit: Hjorth+2005*

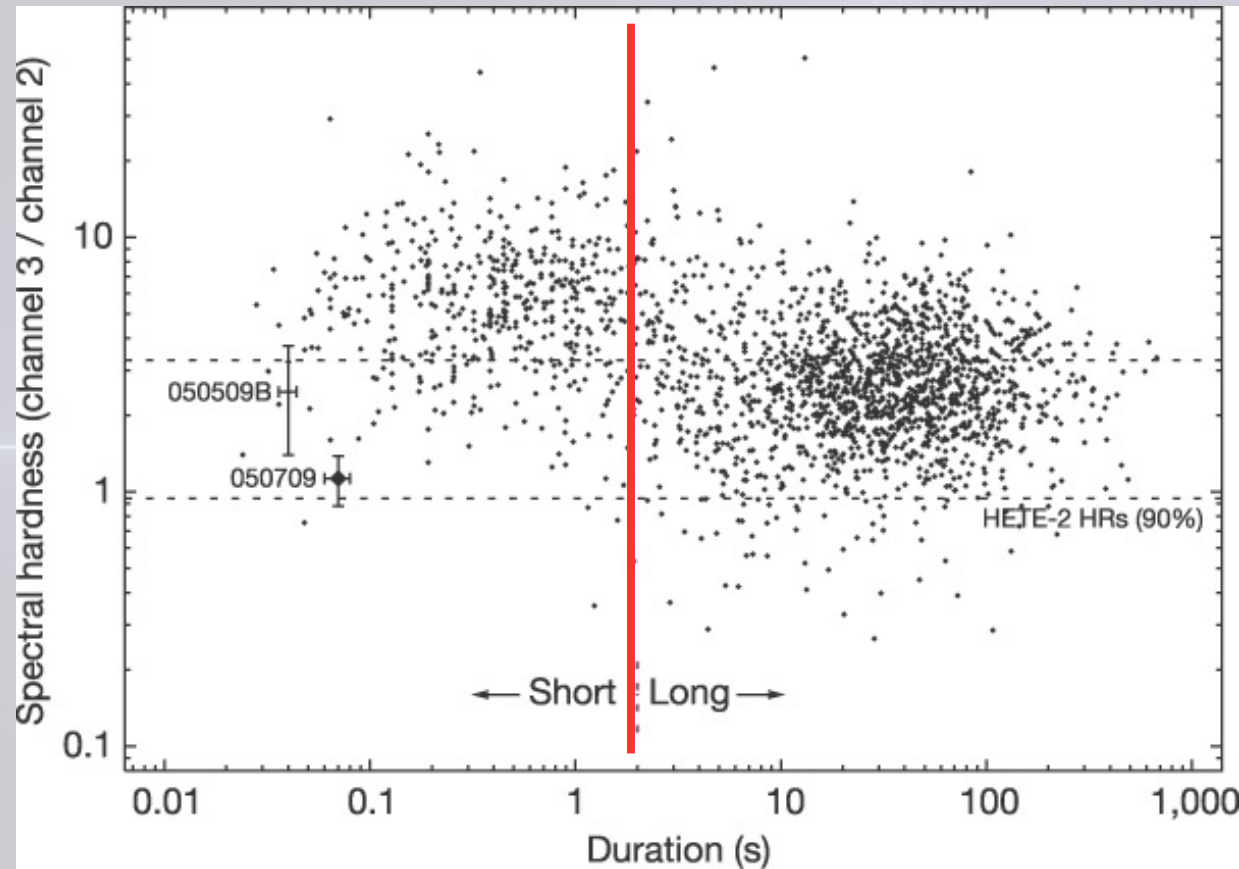
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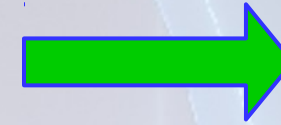
**Long/soft:**  
**Massive Stars**  
**at**  
**collapse**

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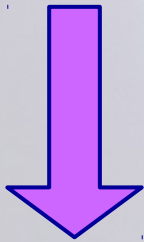
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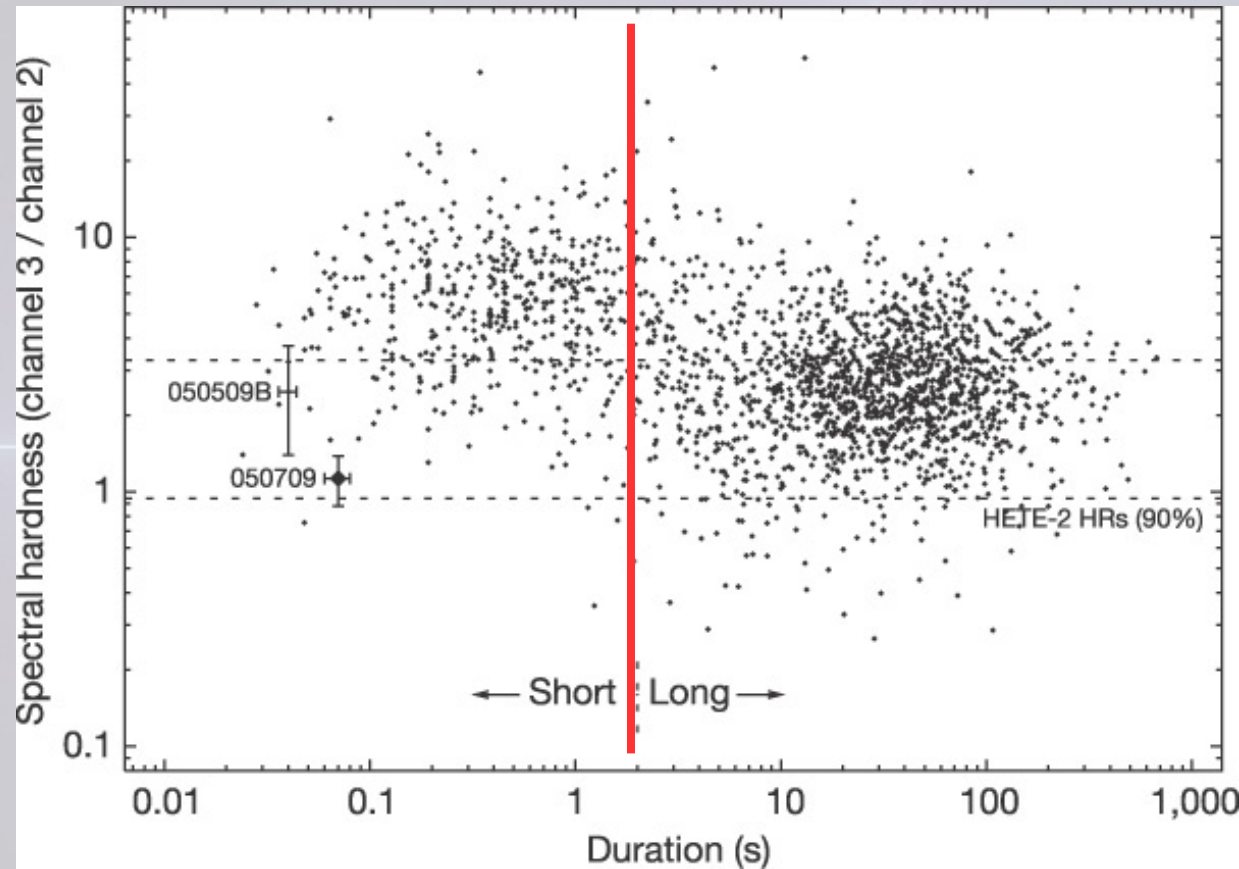


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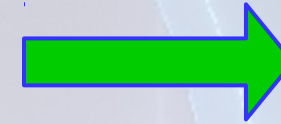


**Short/hard: two Compact Objects at merger**

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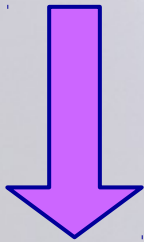


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Long/soft:  
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Progenitor  
models...



Short/hard: two Compact Objects at merger



**Short/hard GRBs:**

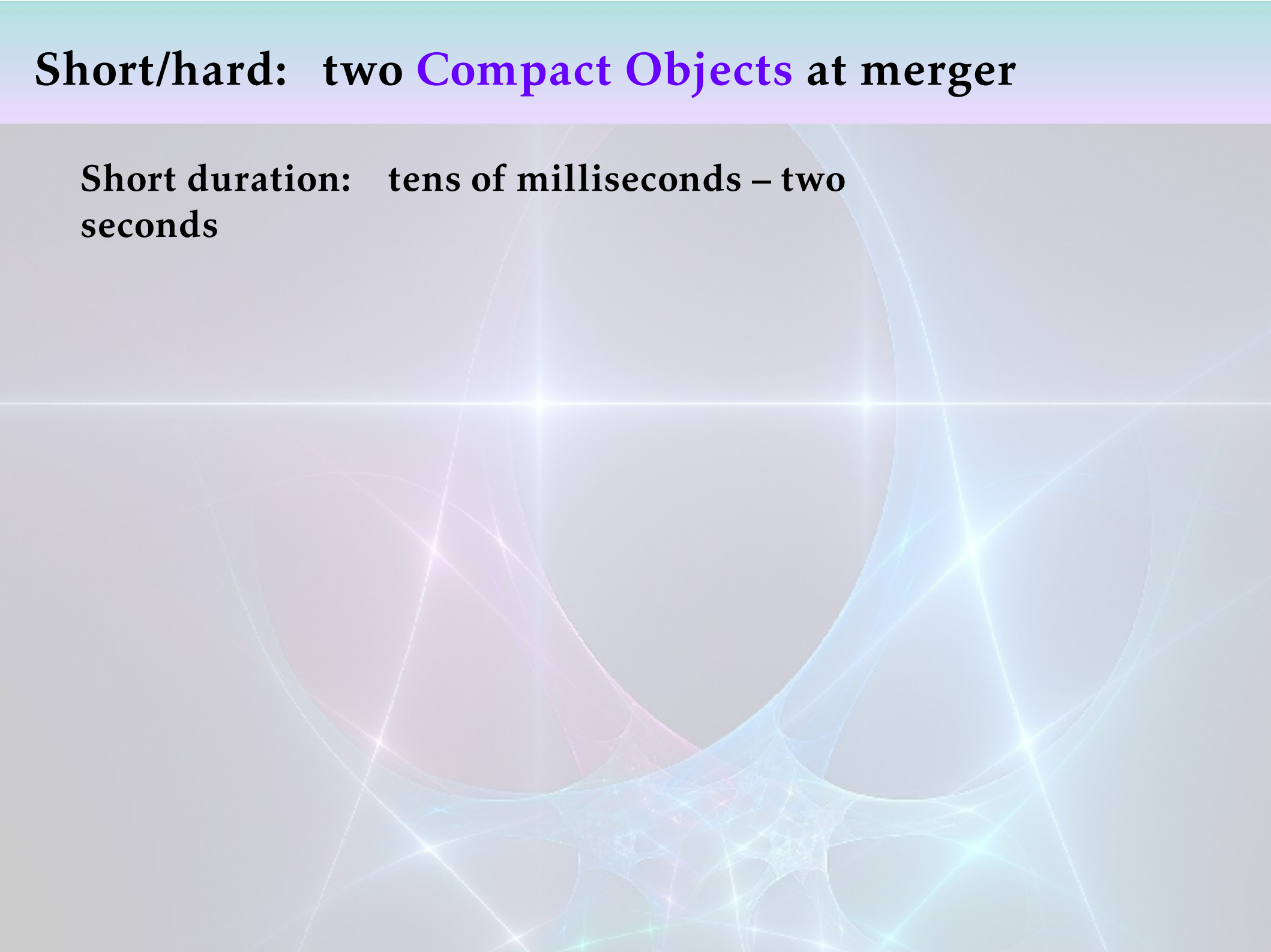
**two Compact Objects  
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**Short/hard: two Compact Objects at merger**



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

Short duration: tens of milliseconds – two seconds

The background of the slide features a complex, abstract pattern of glowing, overlapping lines and shapes. The colors are primarily light blue, cyan, and magenta, with some white highlights. The lines appear to be part of a larger, intricate structure that resembles a network or a series of interconnected paths. The overall effect is that of a futuristic or scientific visualization, possibly related to the 'Compact Objects' mentioned in the text.



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→ progenitor systems with a dynamical timescale of milliseconds

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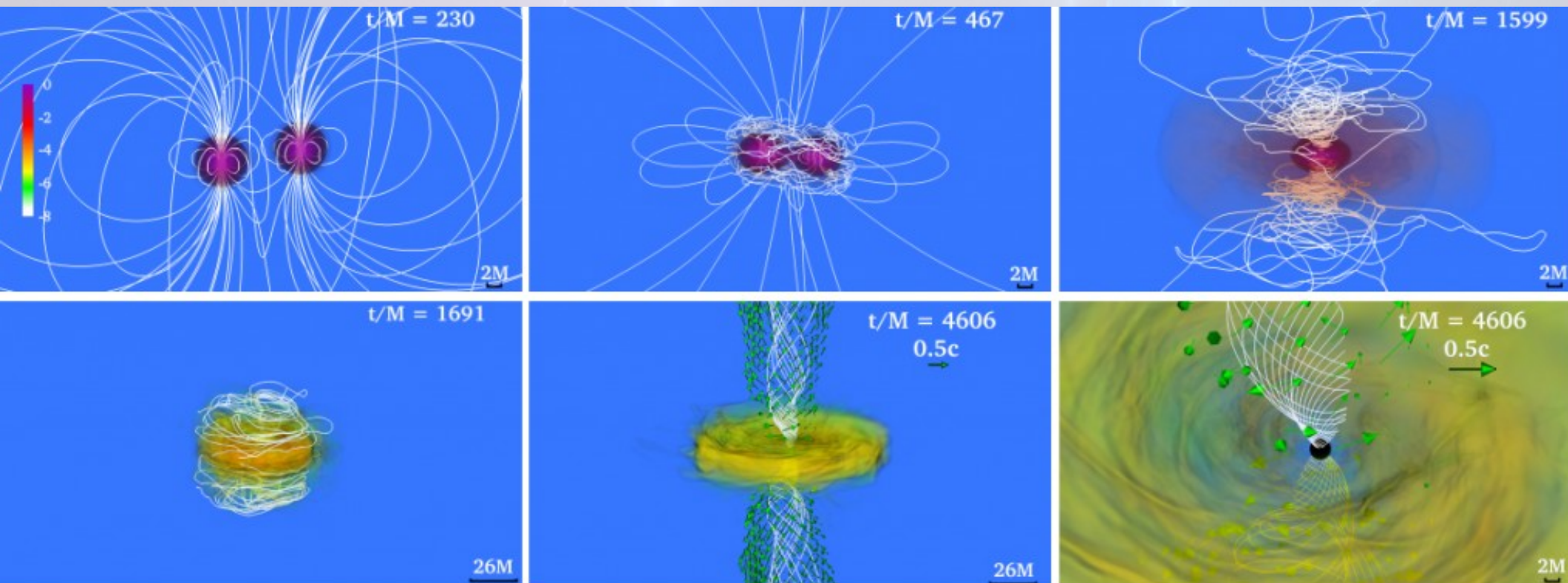
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*Credit: Ruiz+2016*

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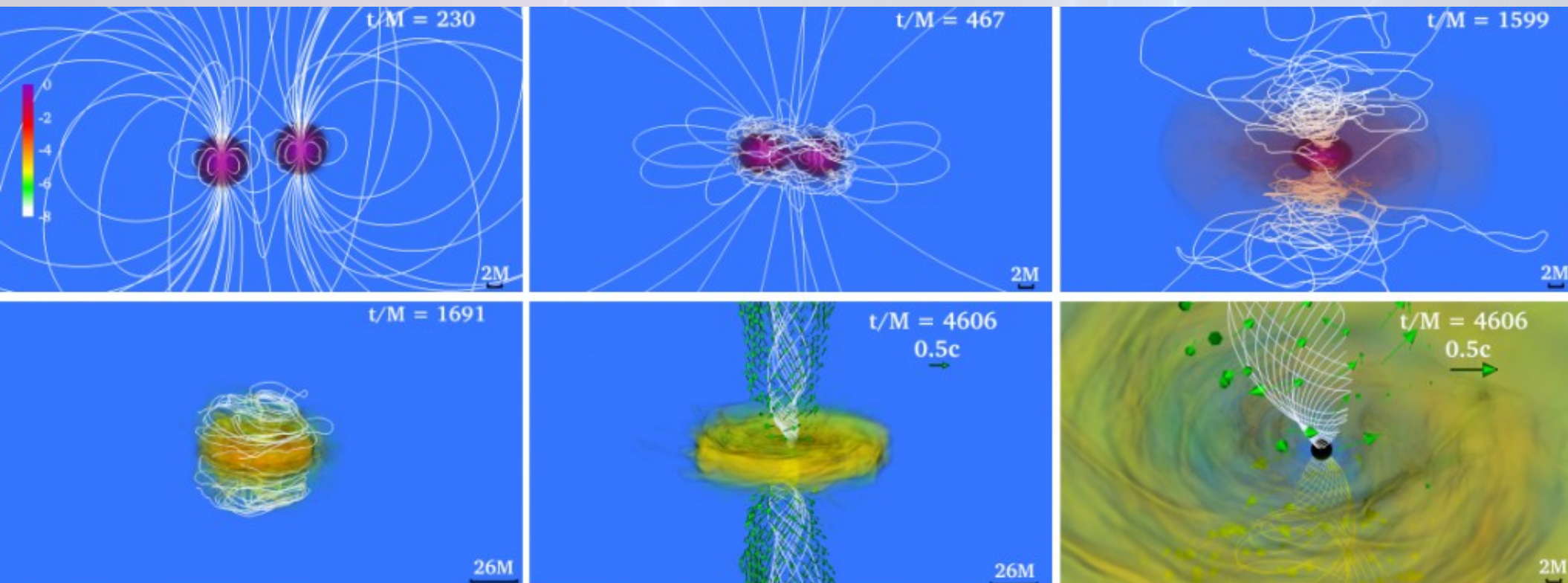
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**NS-NS:** *First: Eichler+89*

**NS-BH**

*First: Narayan+92*



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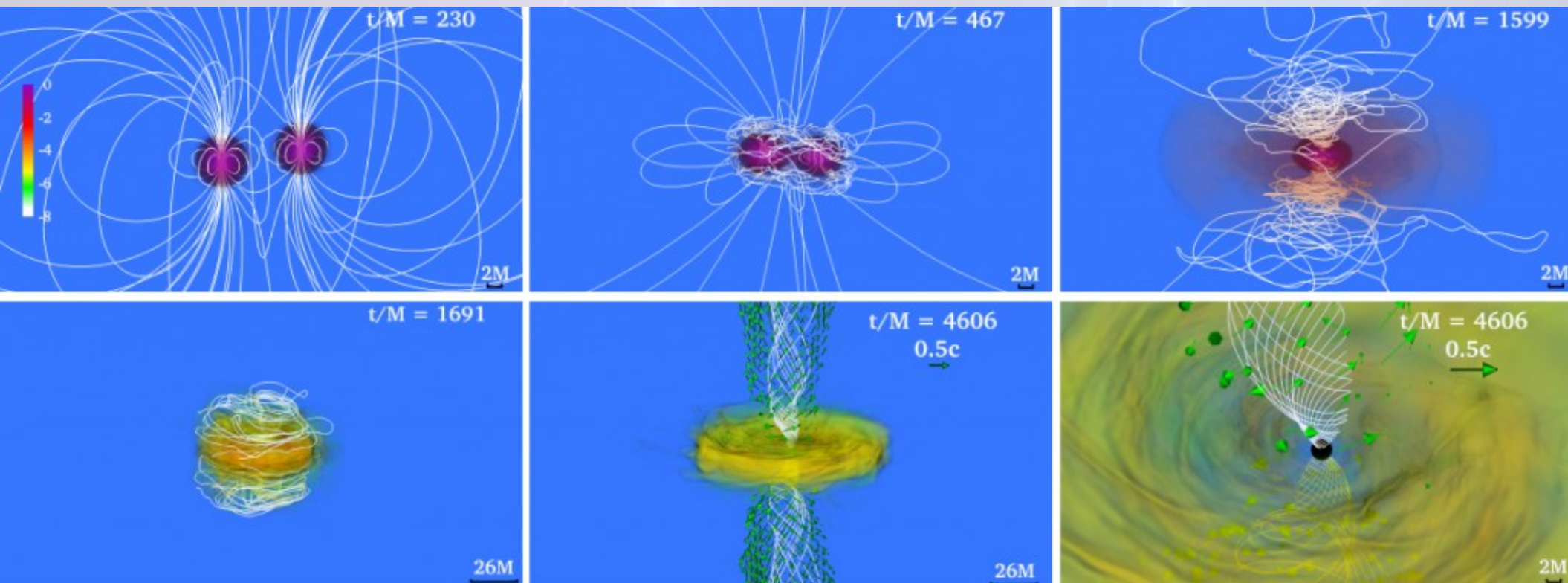
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**BH-BH (?!)**



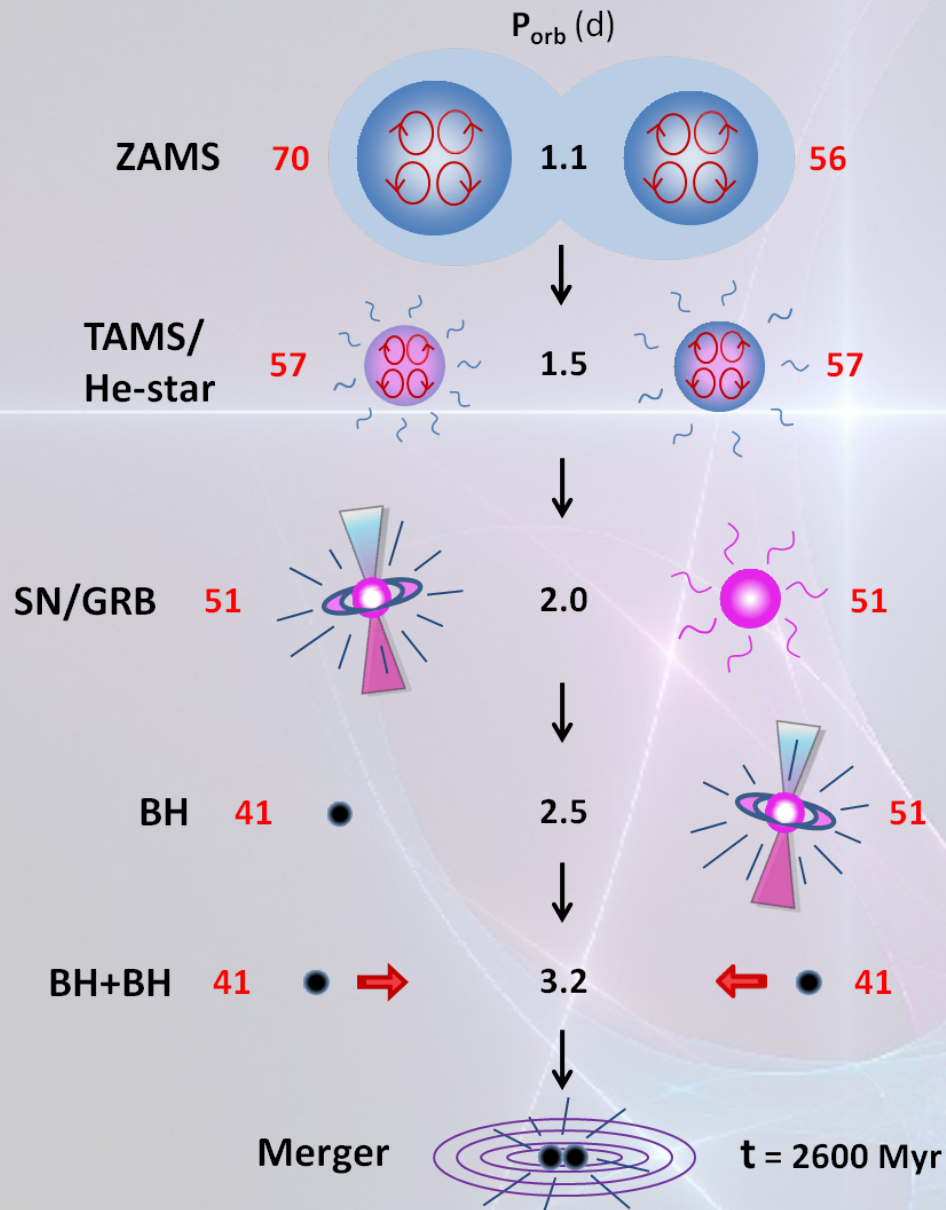
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# BH-BH merger $\rightarrow$ Gravitational Wave detection + SGRB



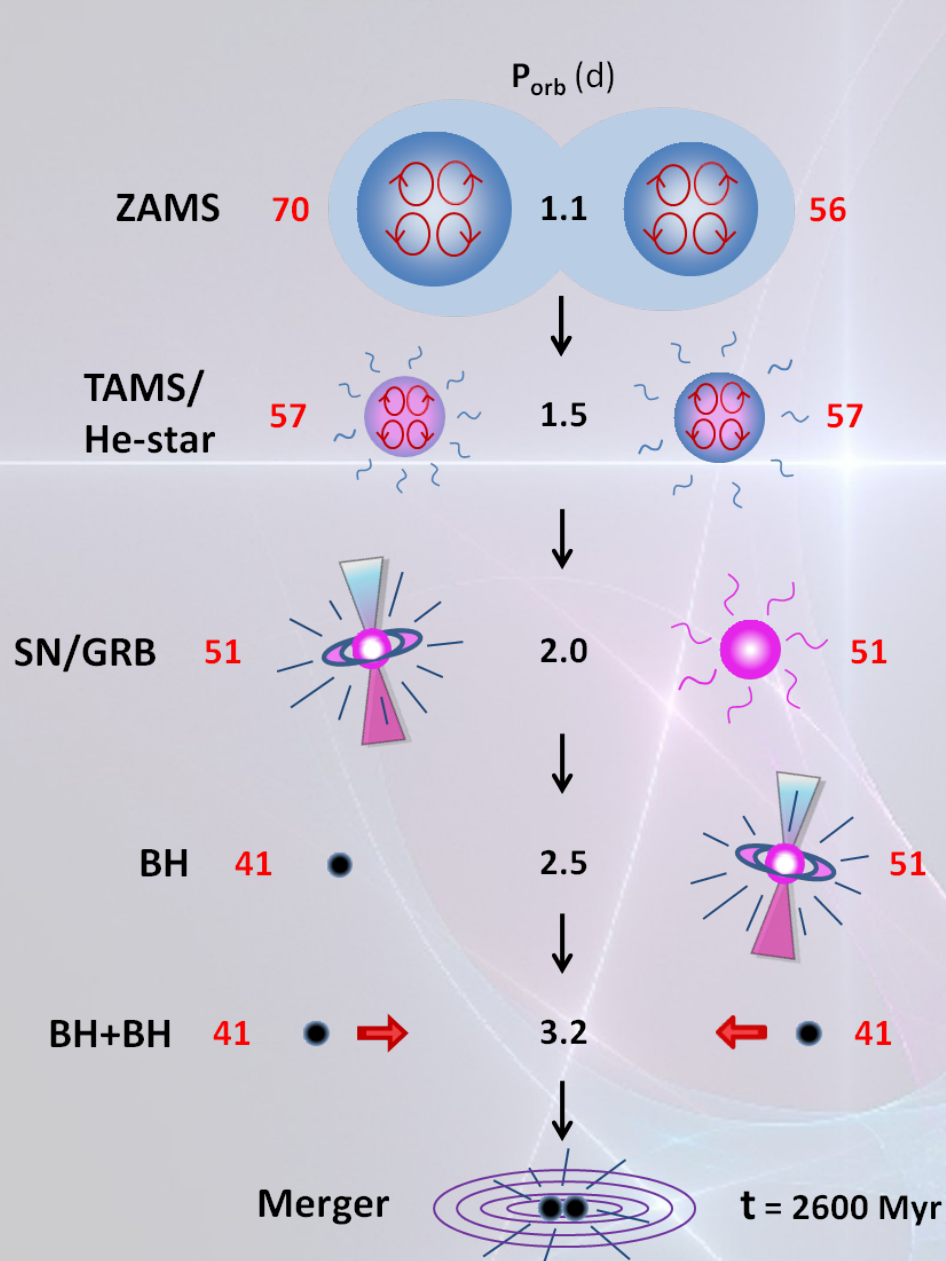


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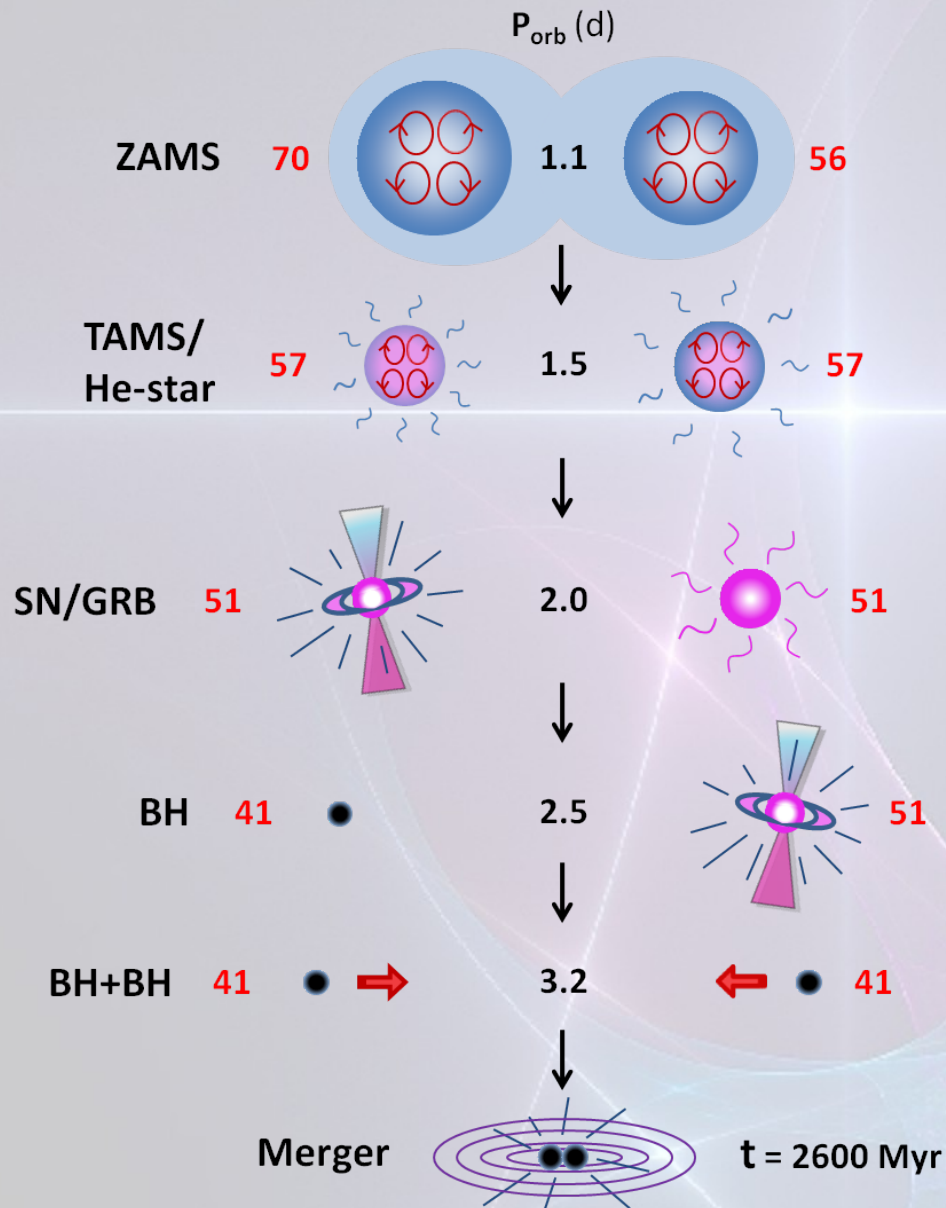
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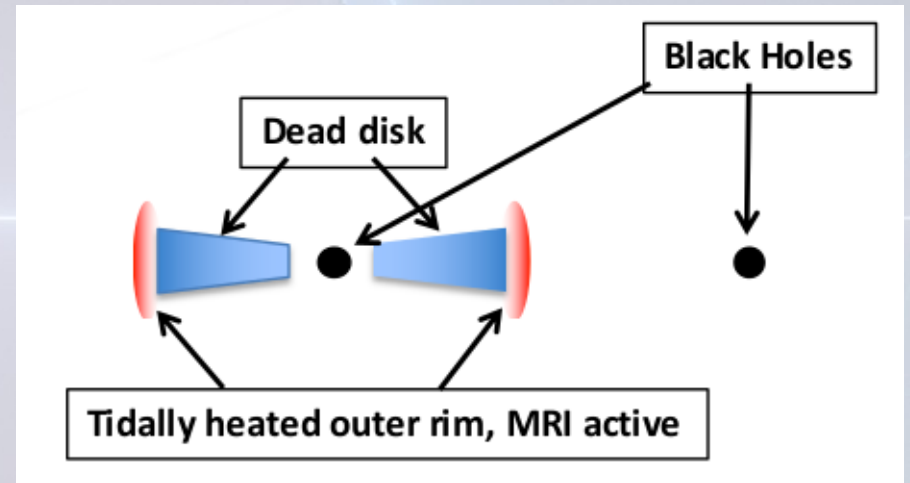
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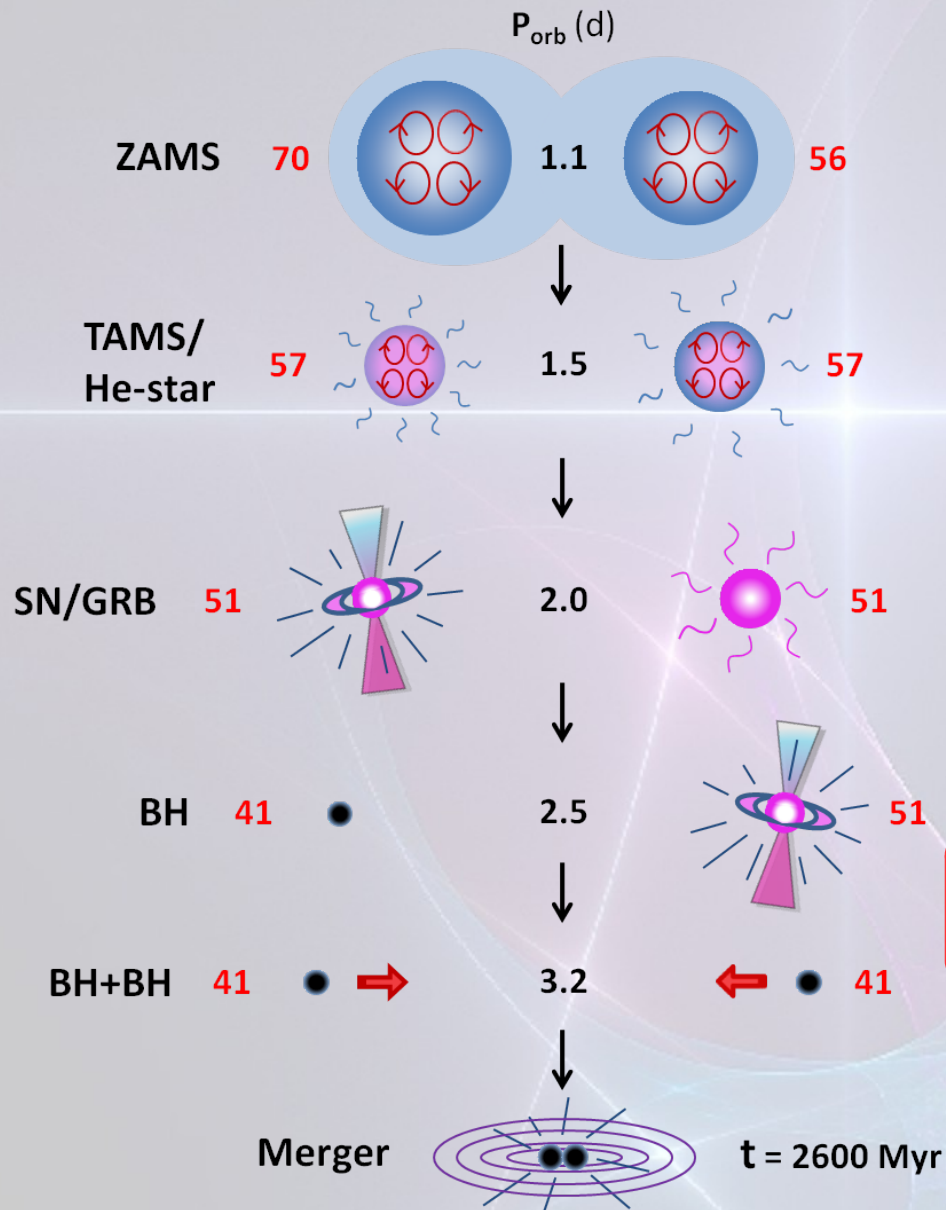
*Perna+16:*

second SN may be weak → long-lived disk from stellar envelope



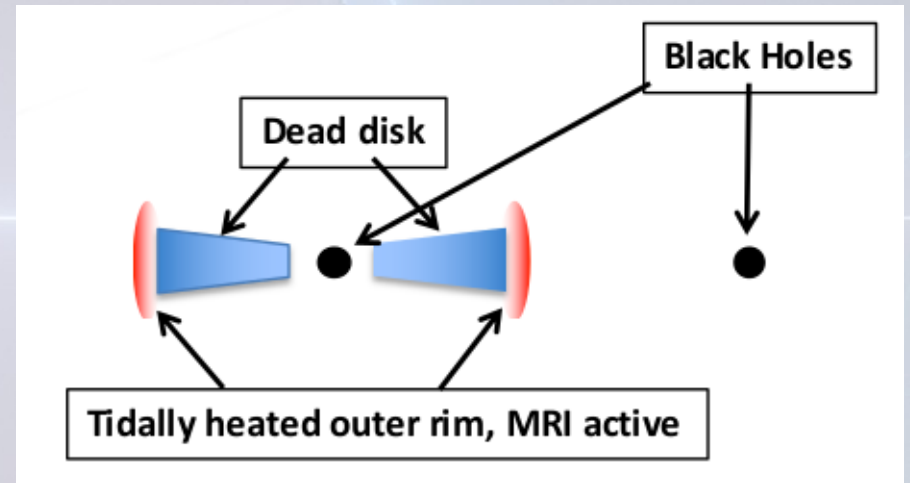
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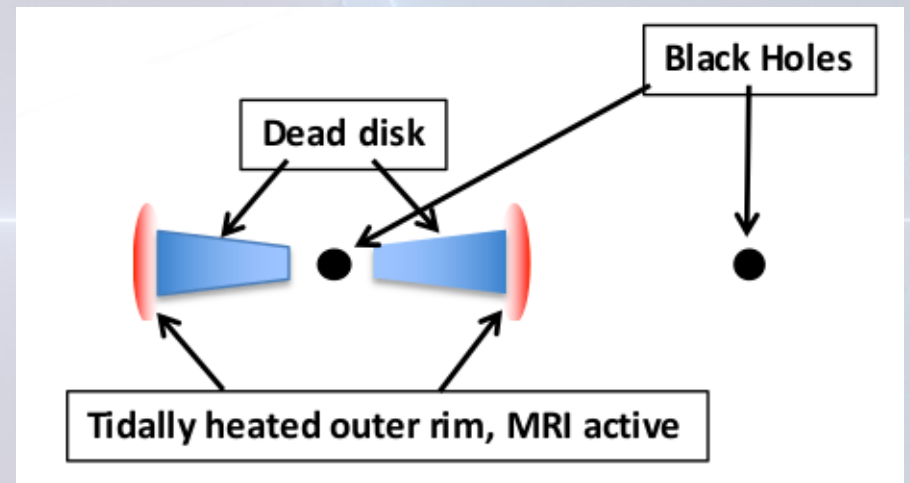
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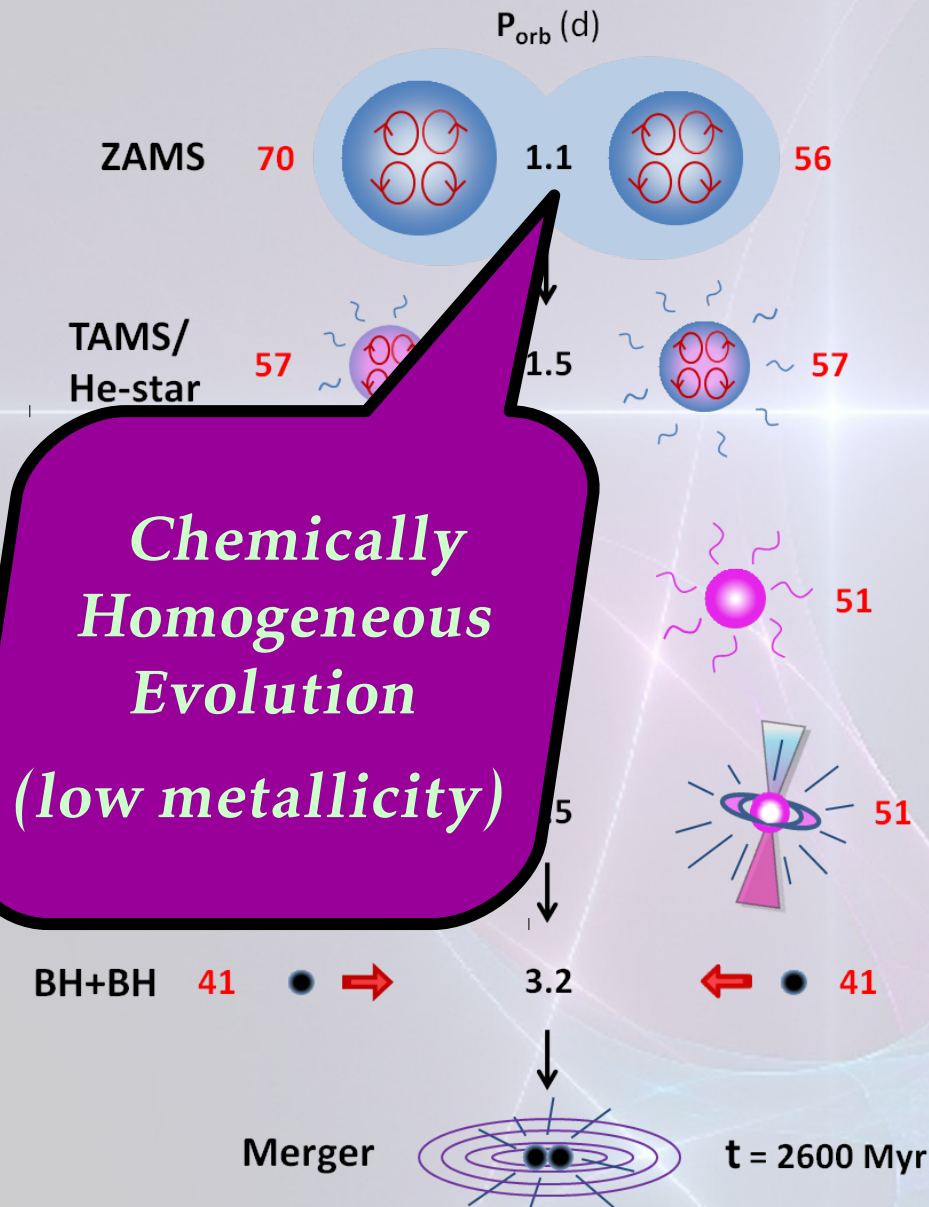
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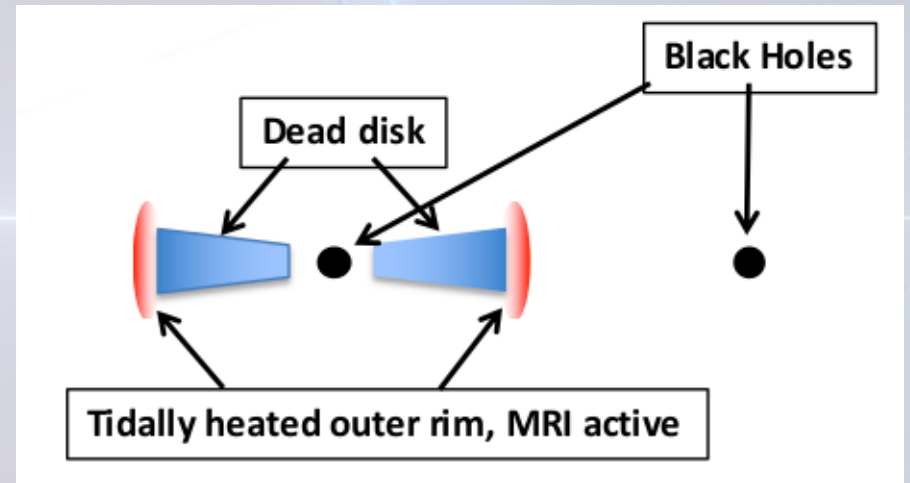


**Chemically Homogeneous Evolution (low metallicity)**

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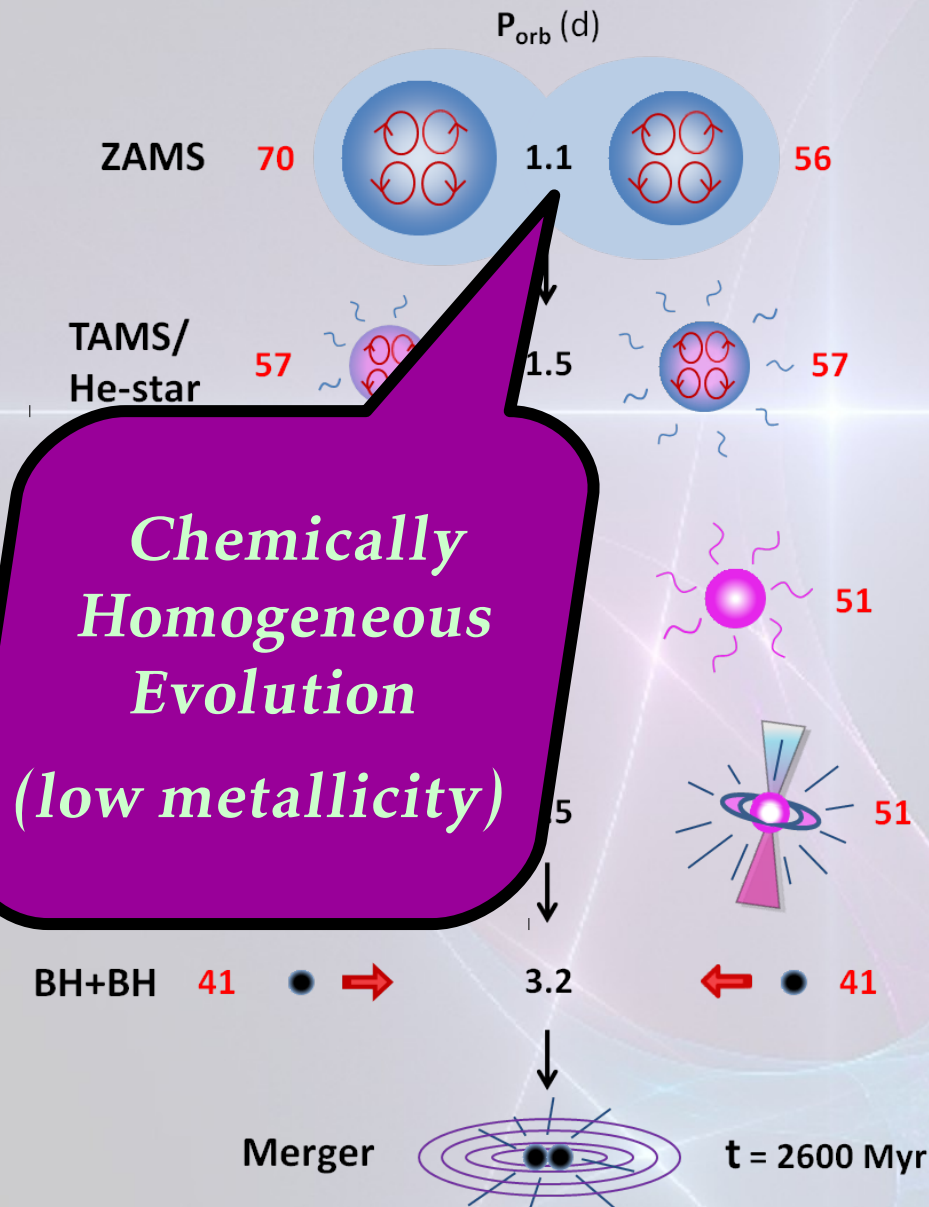
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*Other models:*

*Zhang'16* – one of the BHs is charged

*Belczynski+16, Kruckow+16*  
– common envelope evolution



**Chemically Homogeneous Evolution (low metallicity)**

Credit: Marchant+2016



**Long/soft GRBs:**

**Massive Stars  
at collapse**

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**Massive Stars** – *more precisely?*



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**rotation...**

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**rotation...**

**binary systems:  
orbit, mass ratio,  
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Special requirements  
depend on  
astrophysical  
scenario

**Collapsar** scenario

**Magnetar** scenario

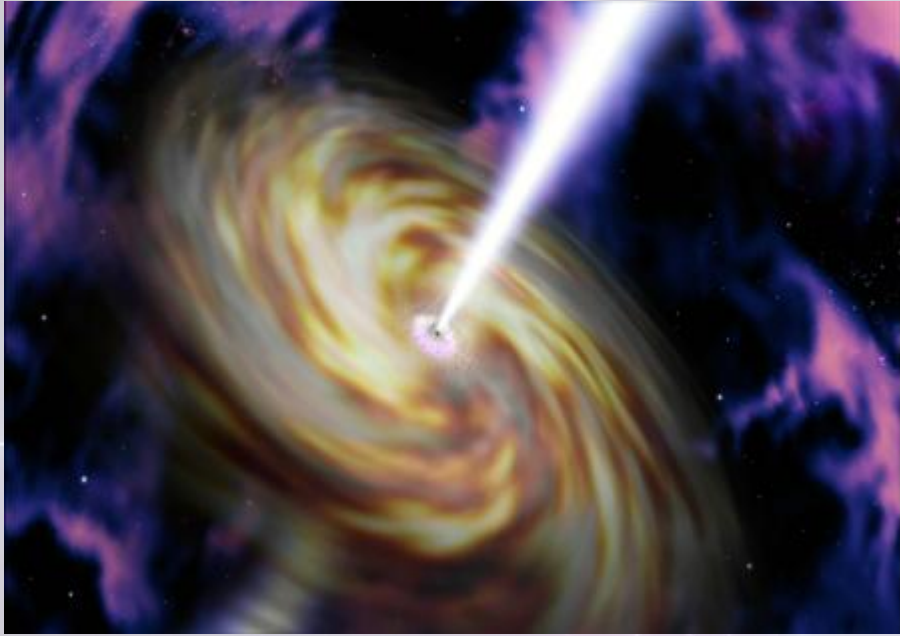
# Collapsar scenario

# Magnetar scenario

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

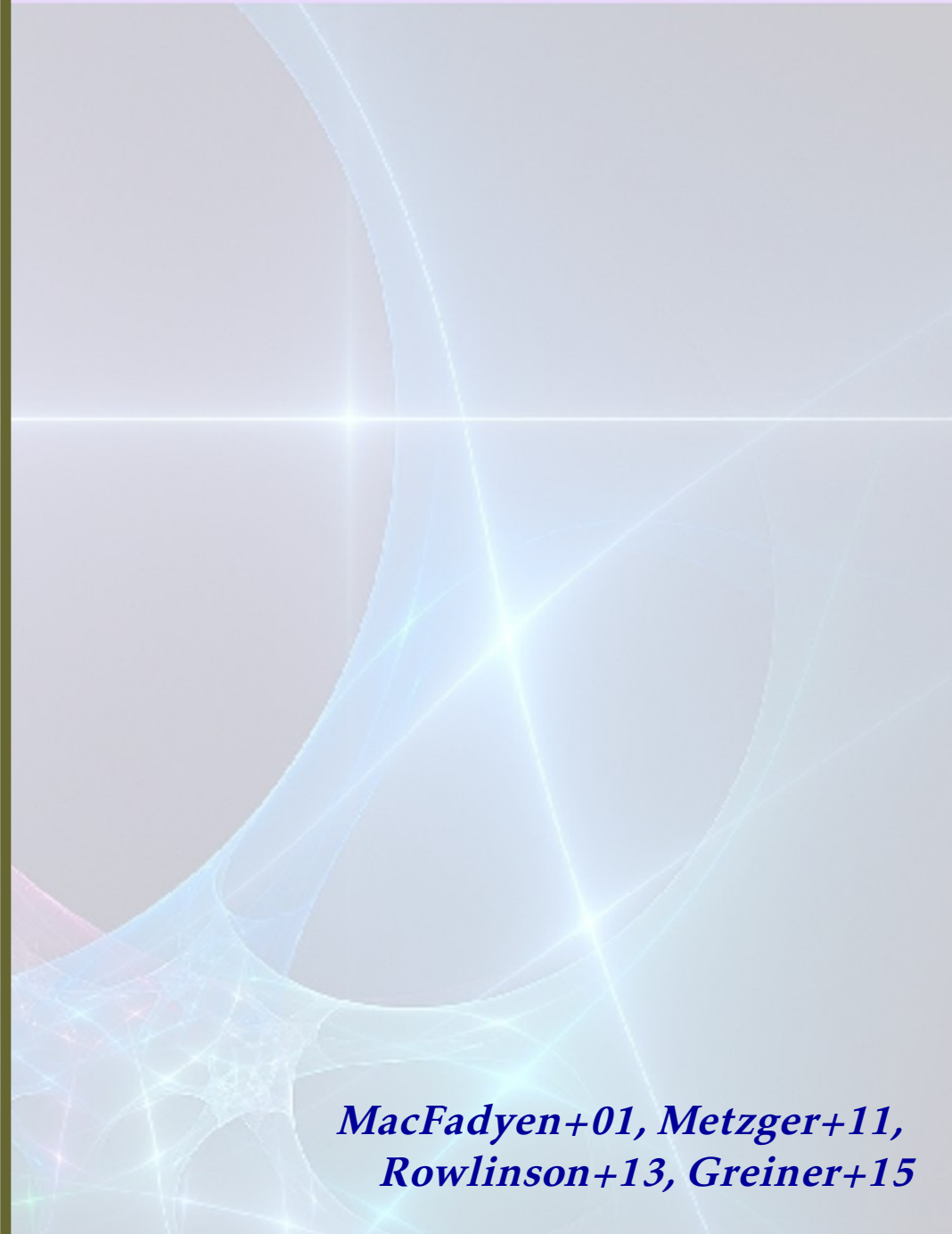
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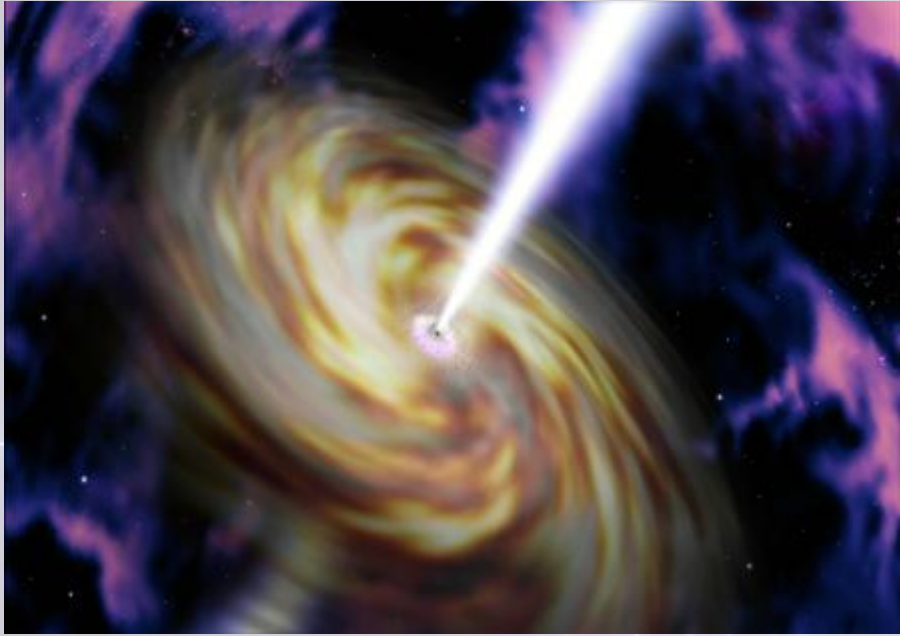
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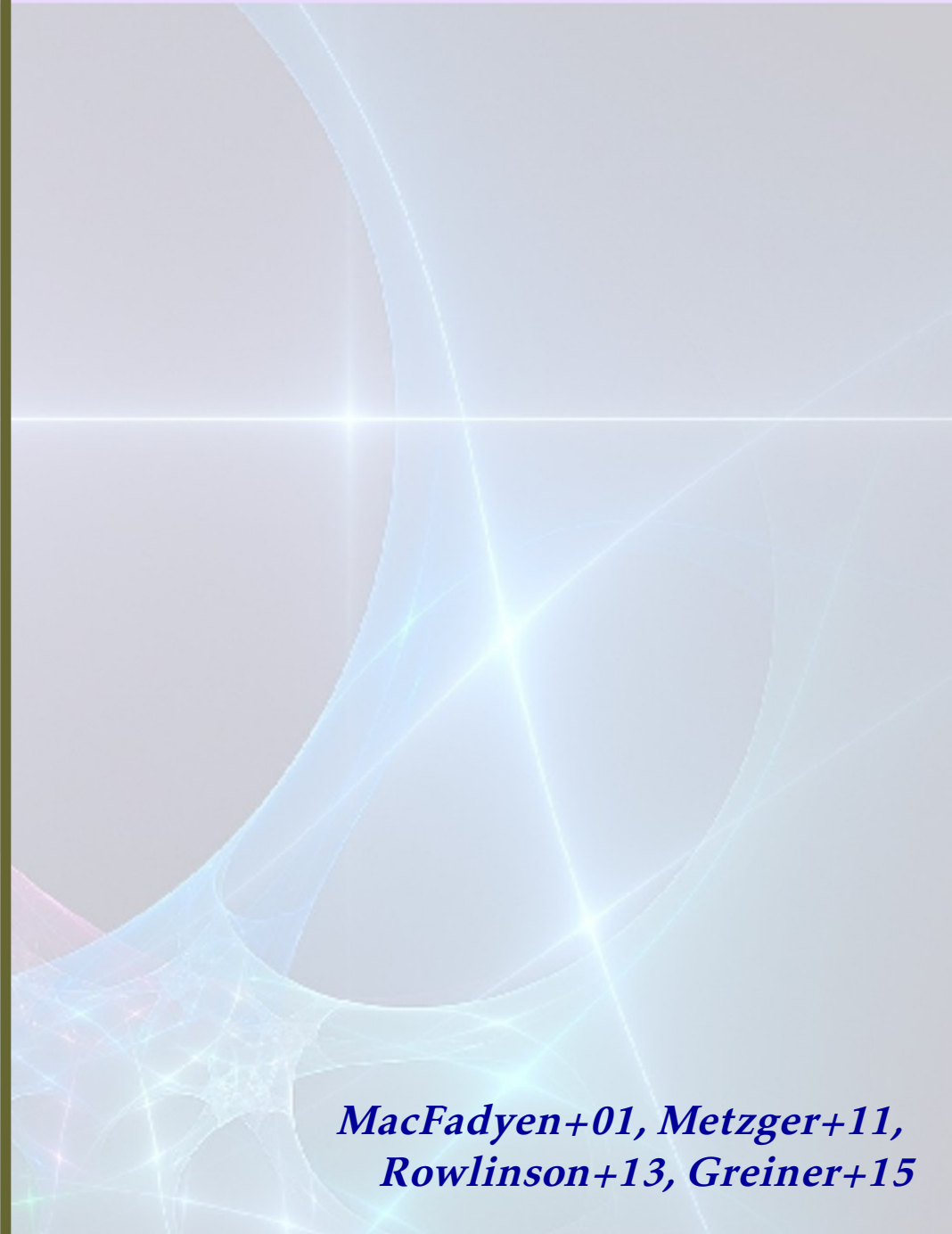
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– iron core → collapse

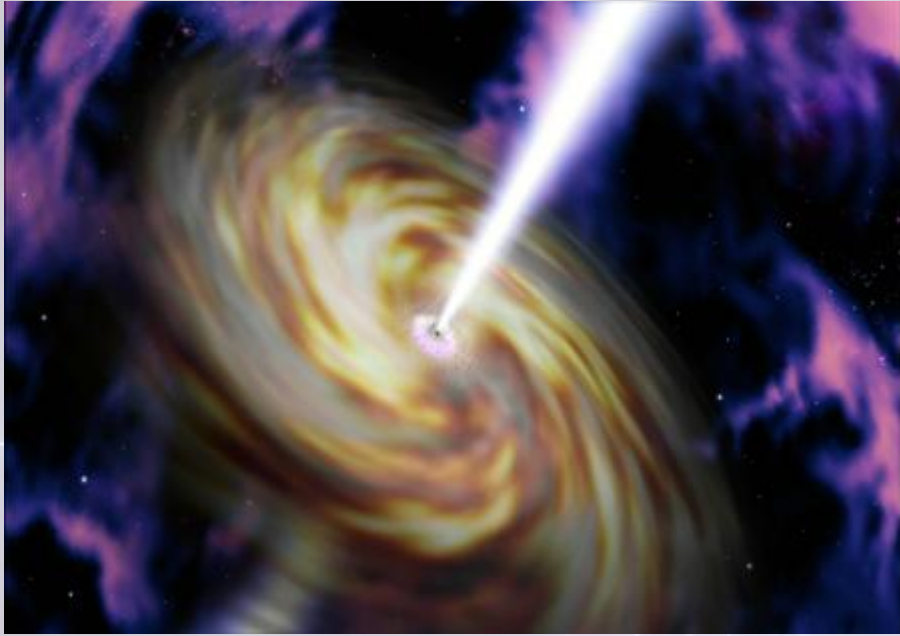
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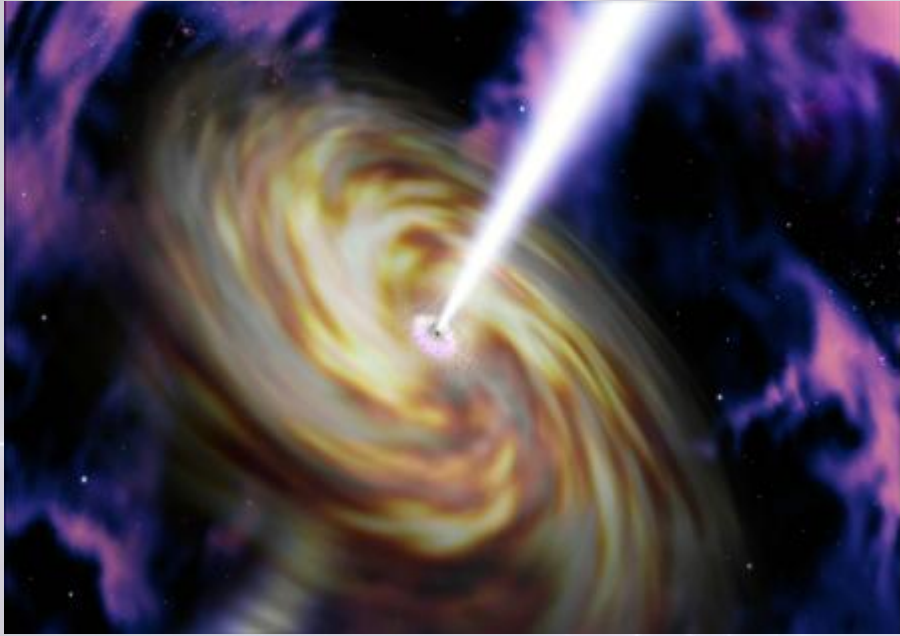
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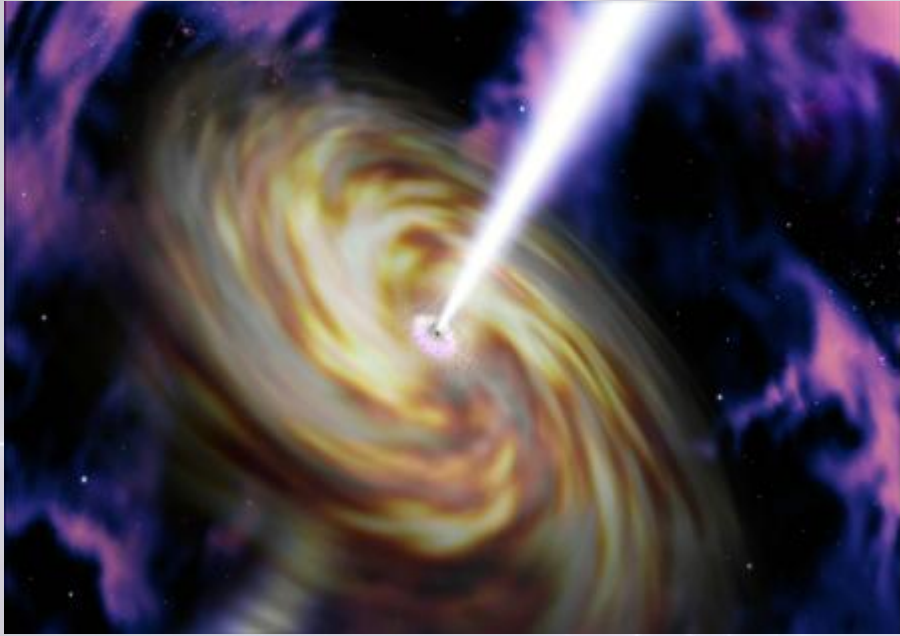
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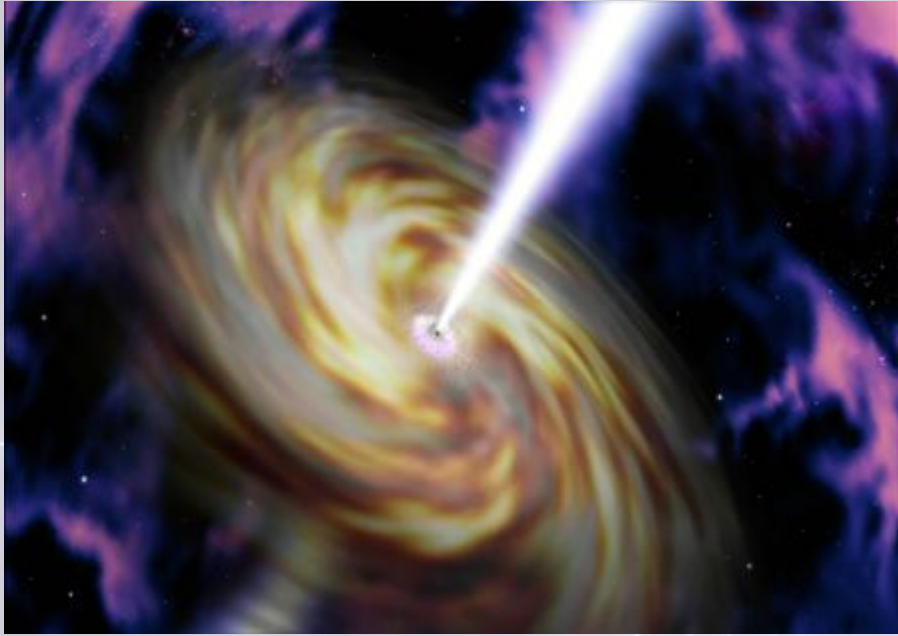
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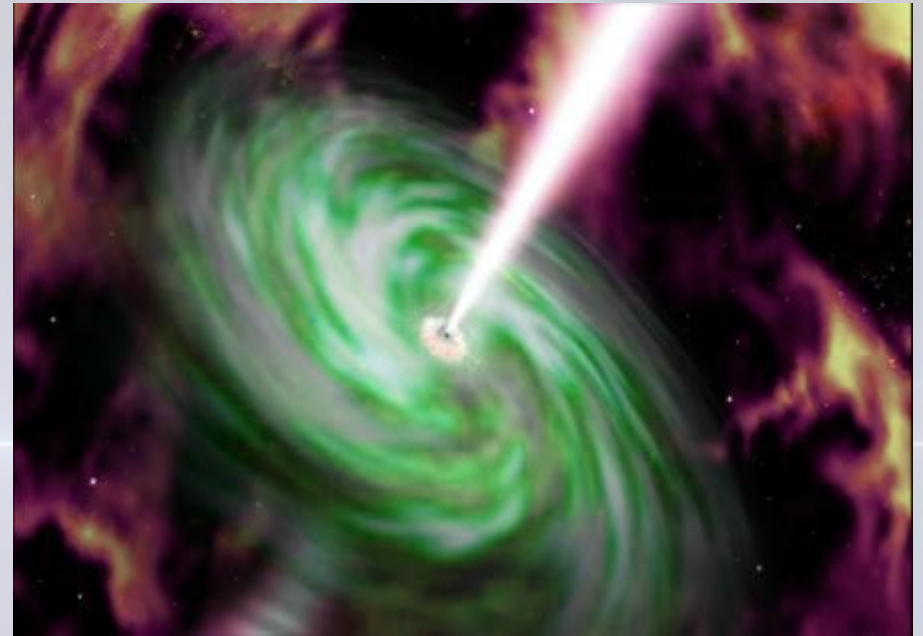
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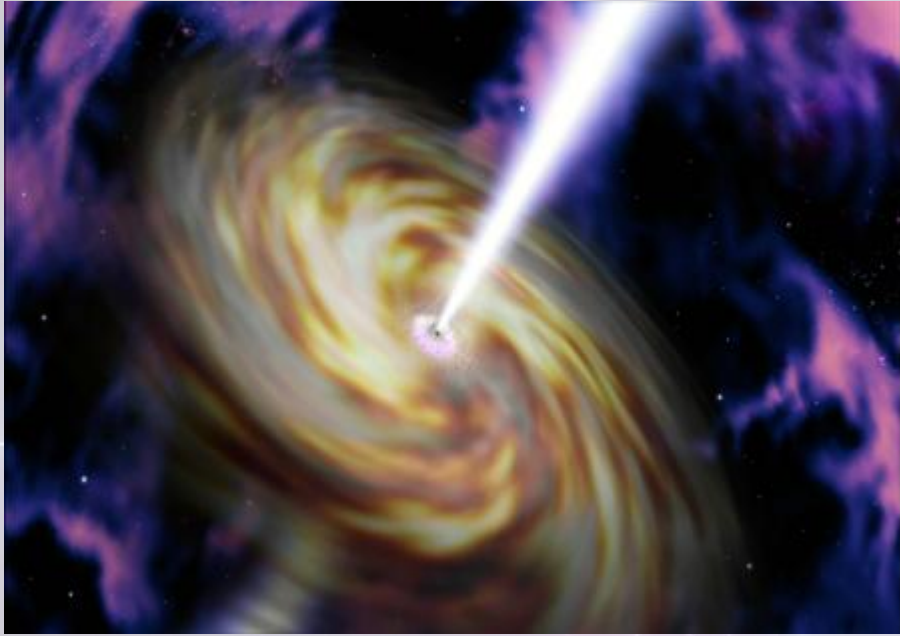
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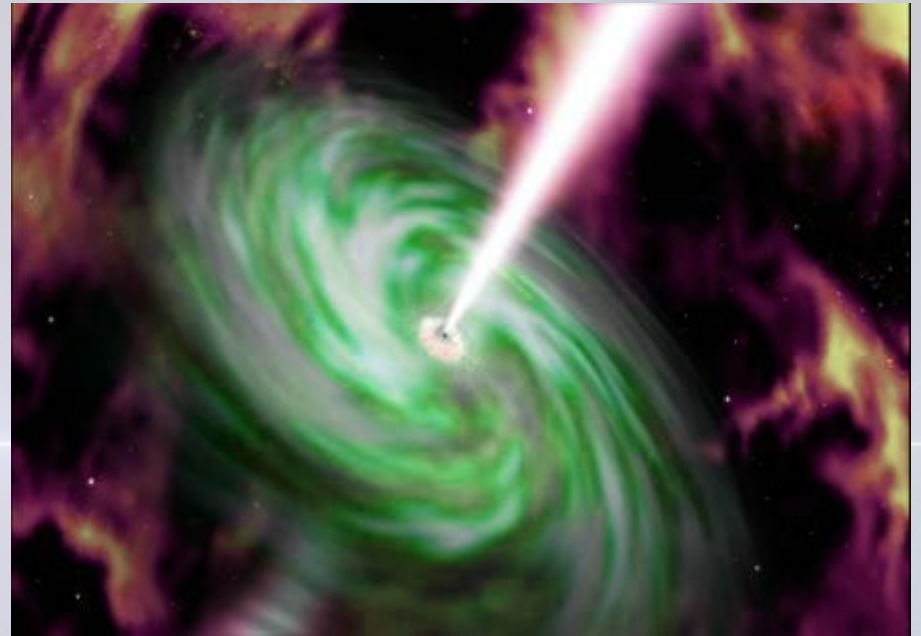
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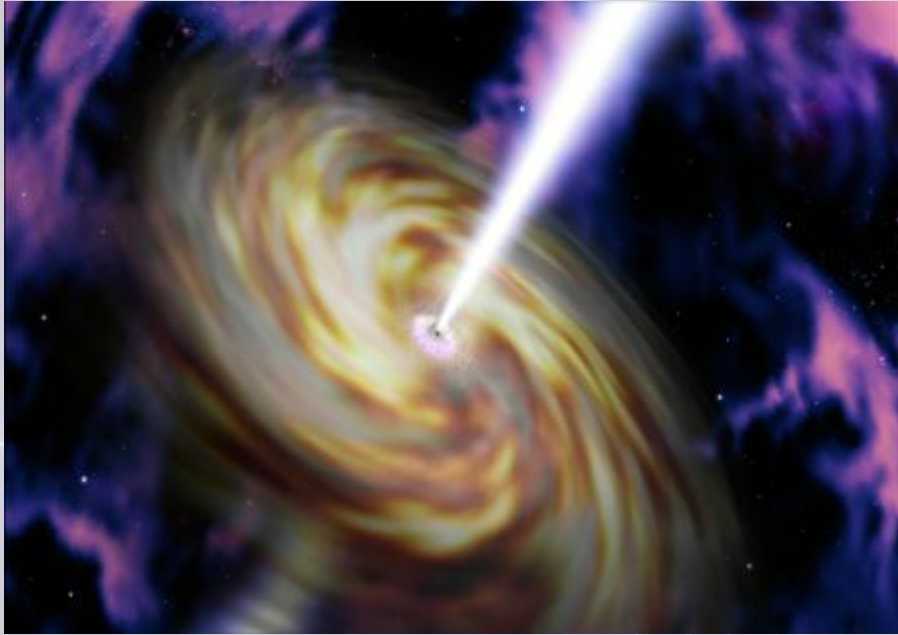
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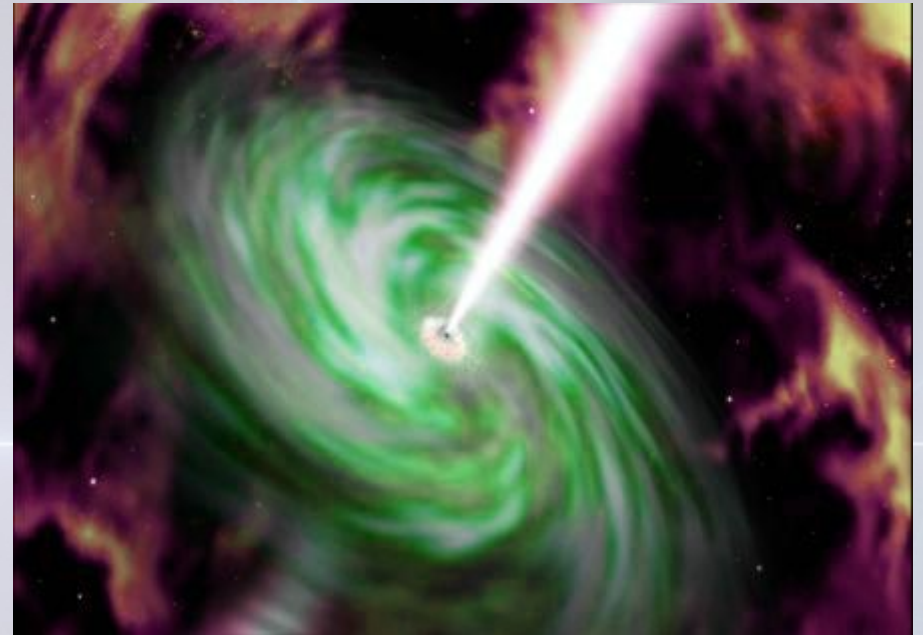
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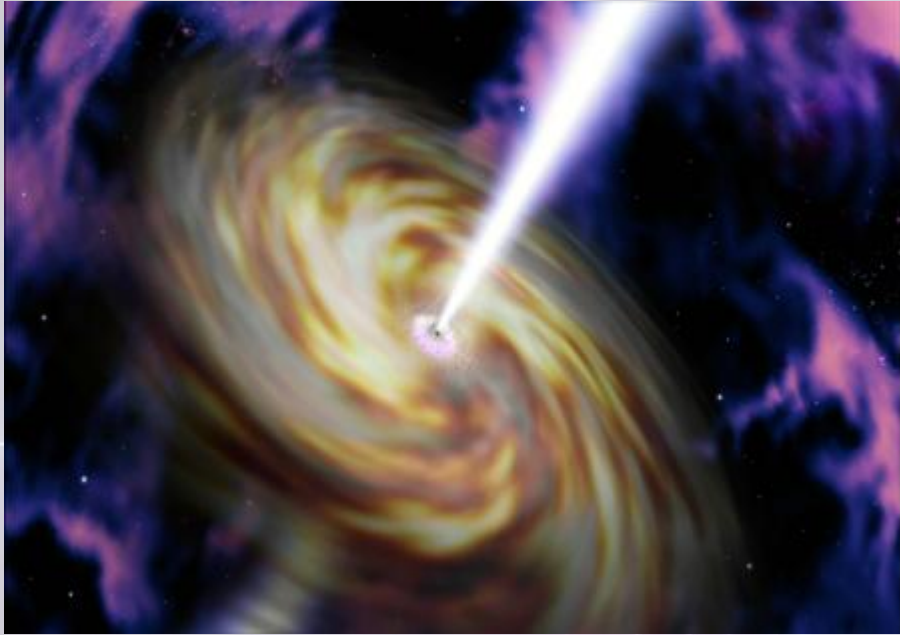
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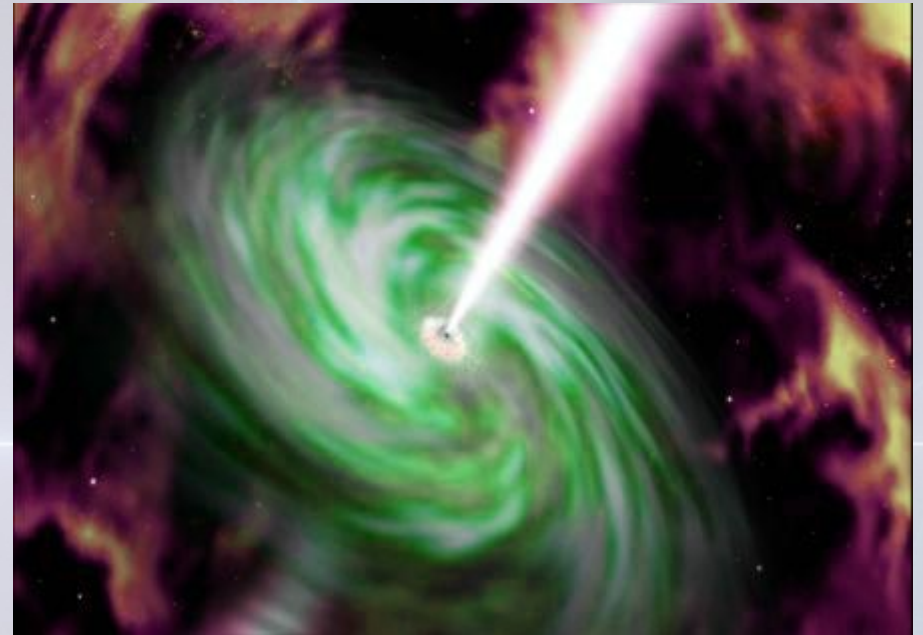
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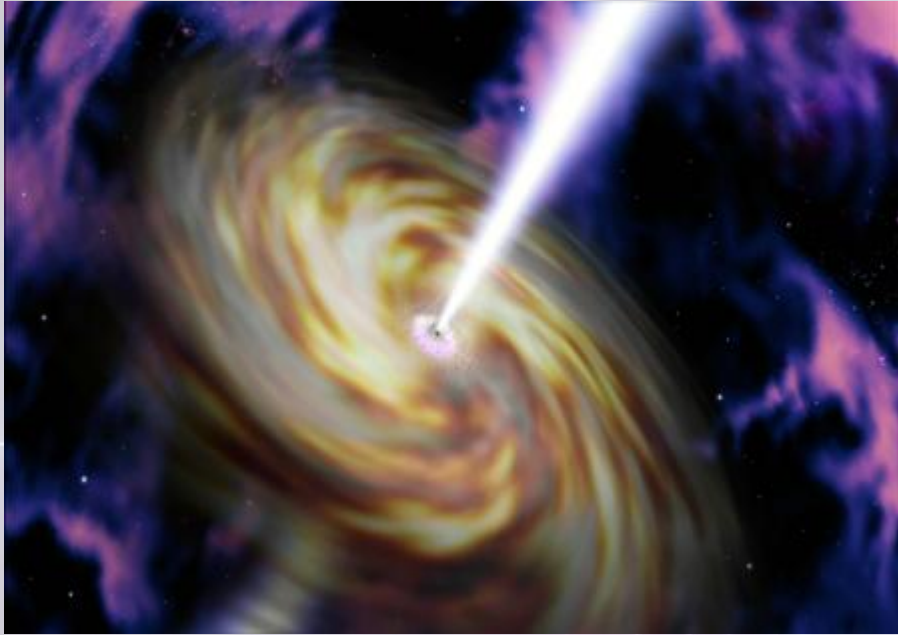


- iron core → collapse
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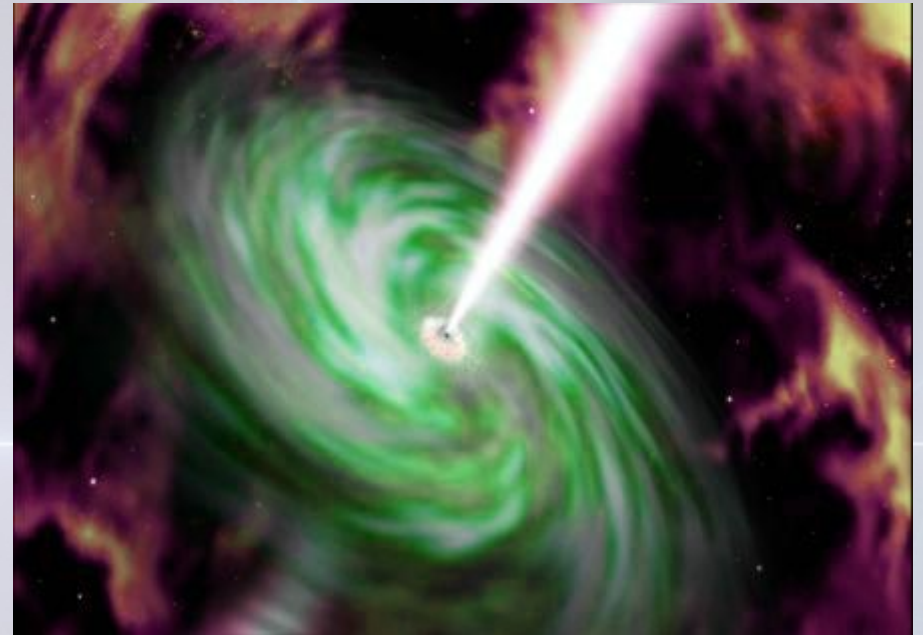
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## Magnetar scenario



- iron core → collapse
- supernova is successful  
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- material expelled → NS
- fast rotating, magnetized NS  
powers the jet → LGRB

*MacFadyen+01, Metzger+11,  
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**Question:**

*What kind of star would die this way?*

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**...task for stellar physicists!**

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- **fast rotation at the moment of collapse (low metallicity)**
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- **no large envelope – jet should be able to penetrate through!**

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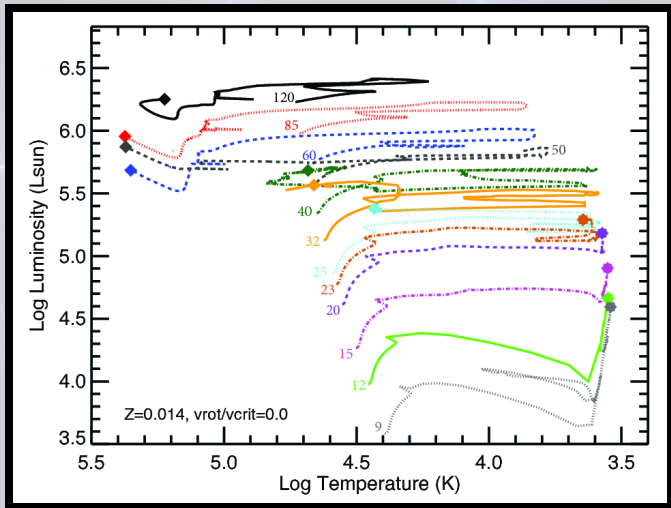
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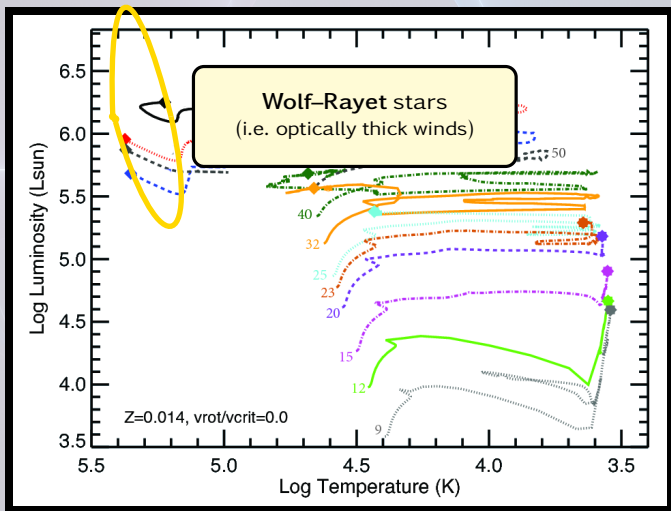
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classical Wolf–Rayet stars?

# Hertzprung–Russell diagram

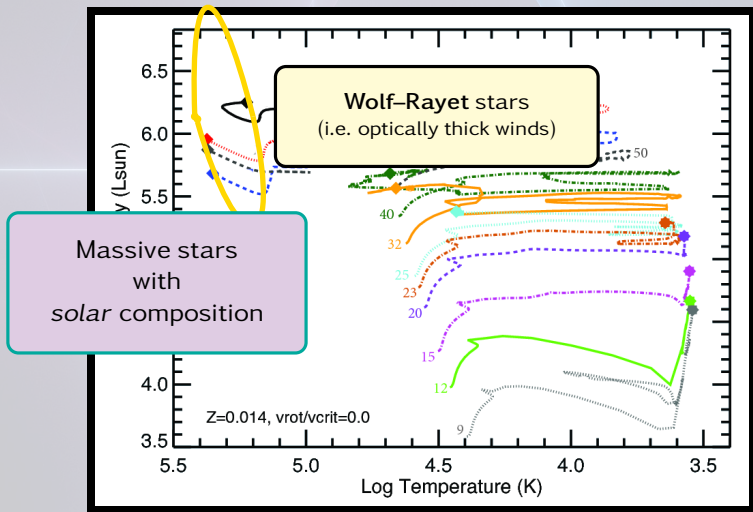


# Hertzprung–Russell diagram





# Hertzprung–Russell diagram



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

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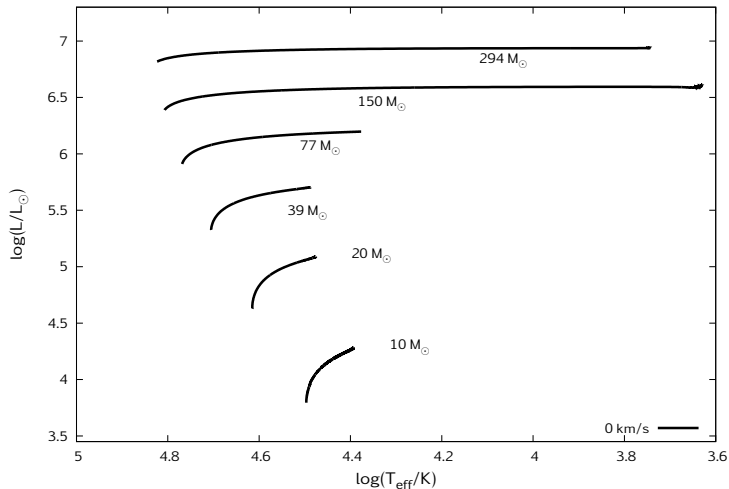
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... spin down due to strong mass loss  
**NO.**

*Chemically  
Homogeneous  
Evolution  
(low metallicity)*

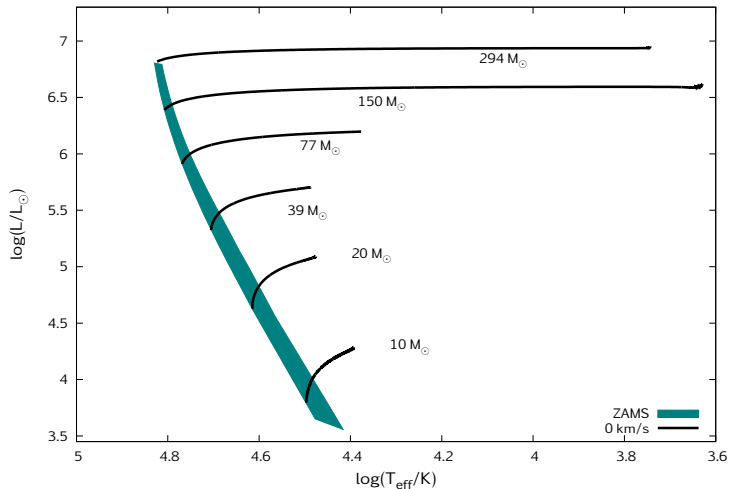
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Szécsi et al. 2015 (*Astronomy & Astrophysics*, v.581, A15)



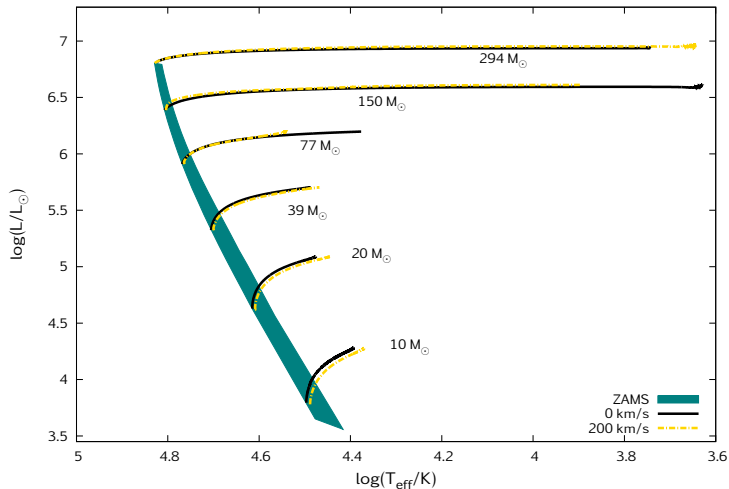
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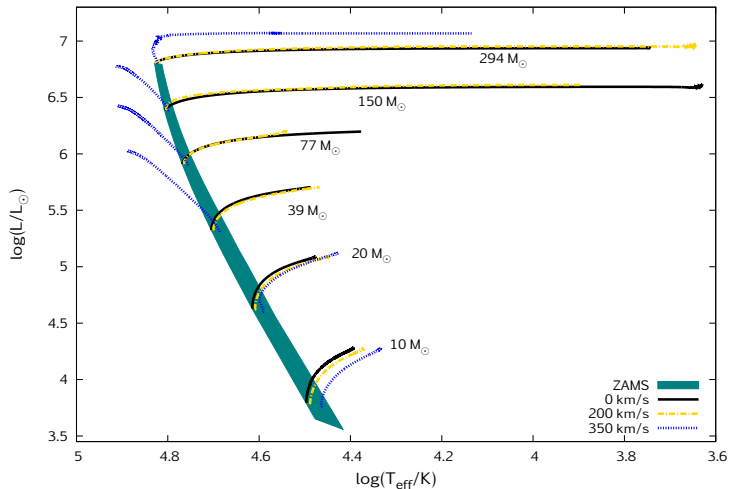
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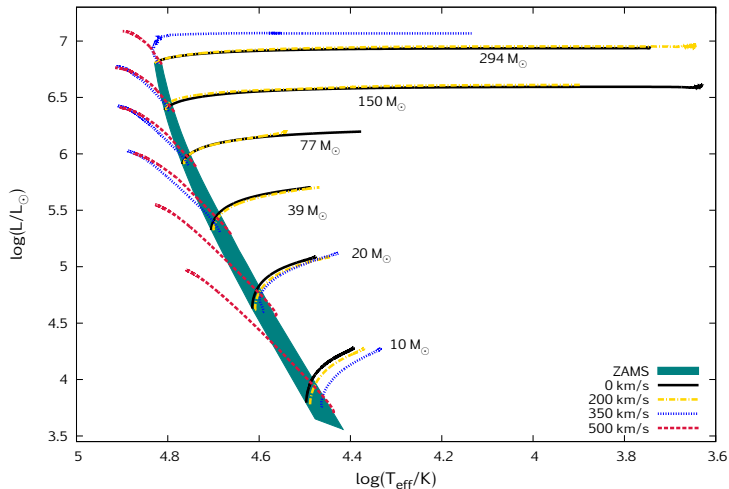
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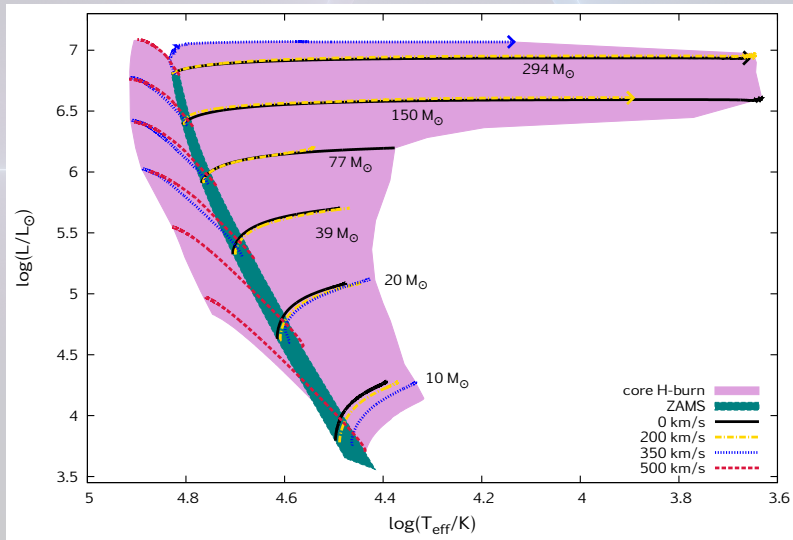
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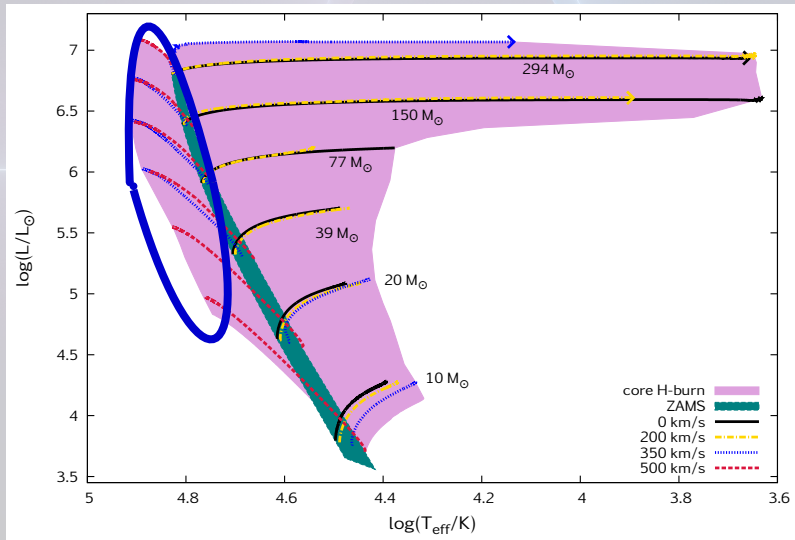
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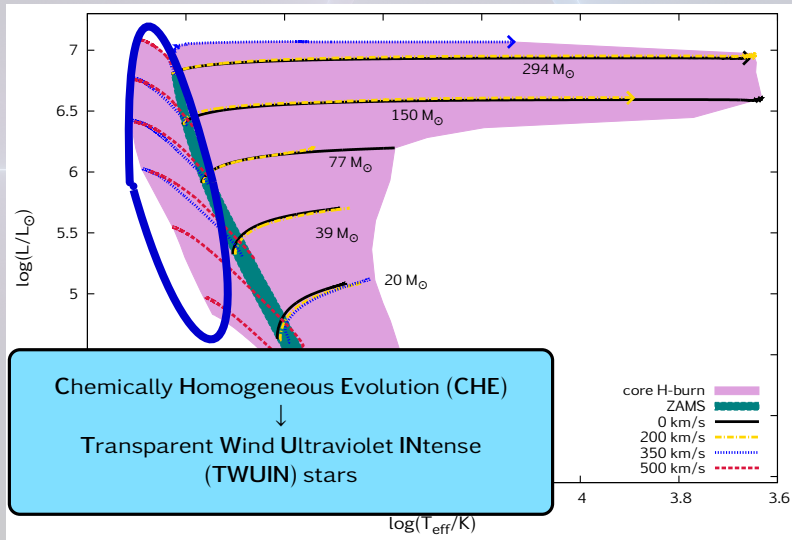
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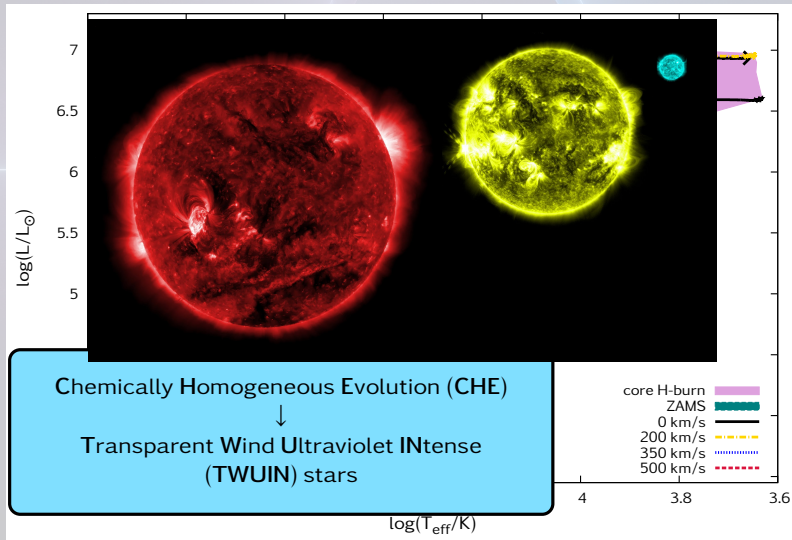
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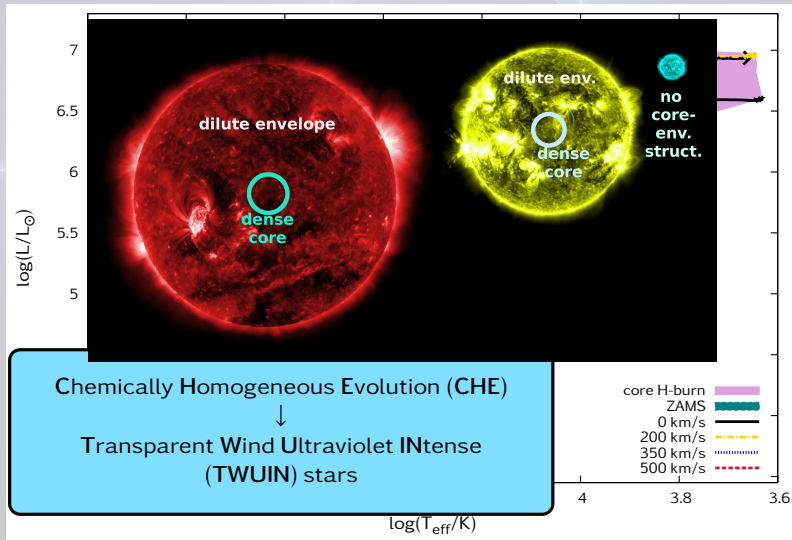
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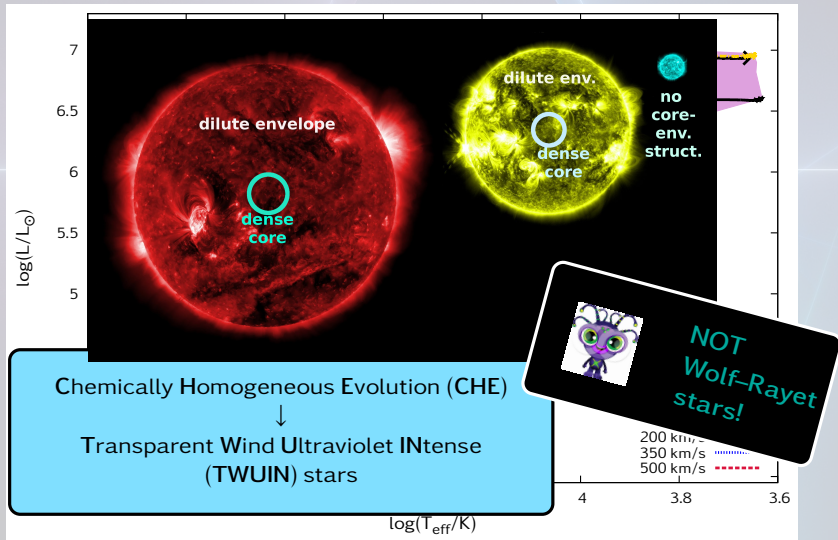
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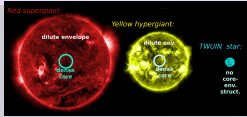
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The background features a large, semi-transparent white circle centered on a light gray background. Overlaid on this are several glowing, ethereal lines in shades of blue, purple, and pink. These lines form a complex, web-like pattern that resembles a network or a stylized molecular structure. The lines are semi-transparent and have a soft, glowing aura around them, creating a sense of depth and movement. The overall aesthetic is clean, modern, and scientific.

**What do we know about TWUIN stars?**

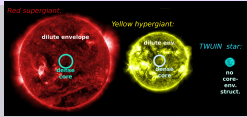
# What do we know about TWUIN stars?



*TWUIN* stars =  
*Transparent Wind UV Intense* stars



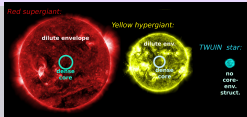
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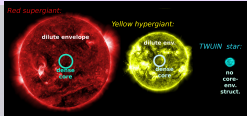
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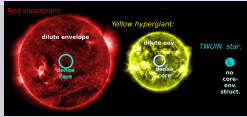
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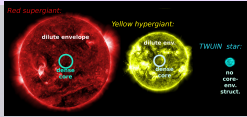
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...computing a grid of synthetic  
TWUIN spectra (in progress 😊)

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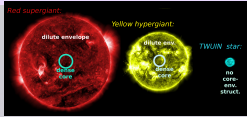
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- but: *IONIZATION!*

# Back to I Zw 18

## I Zwicky 18

- Blue Compact Dwarf Galaxy
- 60 million lightyears  
→ local
- star formation rate:  
 $0.1 M_{\odot}/\text{yr}$
- ionized gas
- low metallicity:  
 $Z=1/50 Z_{\odot}$

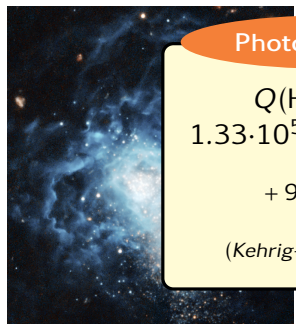


Legrand+07, Aloisi+09, Annibali+13, Kehrig+13, Leboutteiller+13

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## Photoionization

$$Q(\text{H}\alpha)^{\text{obs}} = 1.33 \cdot 10^{50} \text{ photons s}^{-1}$$

+ 9 WC stars

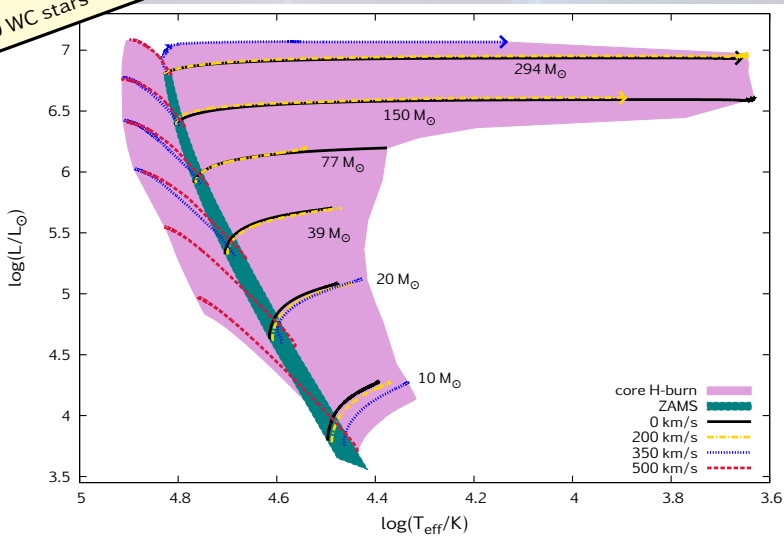
(Kehrig+15, Crowther+06)



# Photoionization in I Zw 18

Photoionization

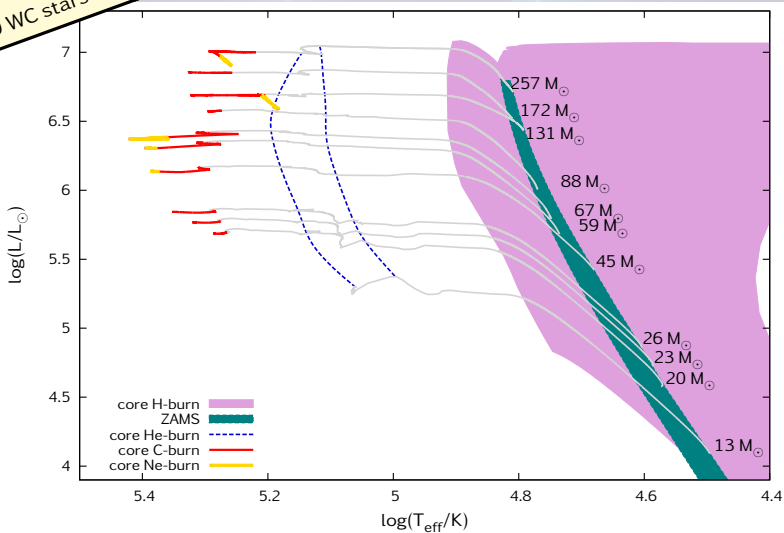
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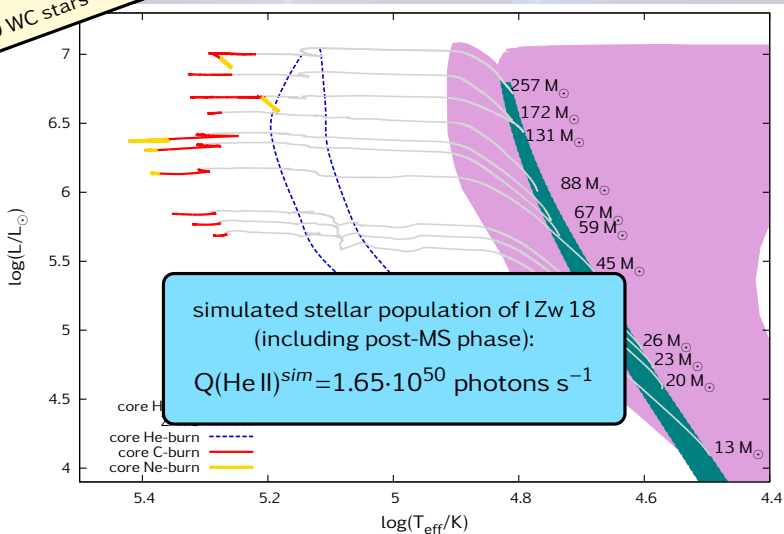
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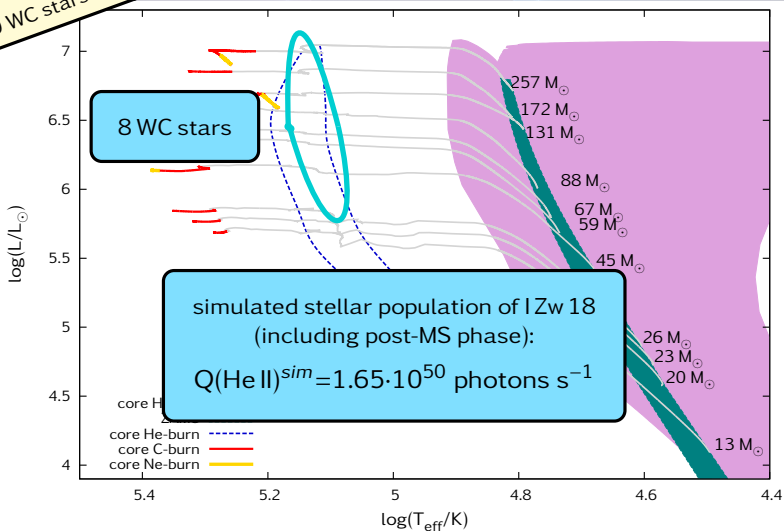
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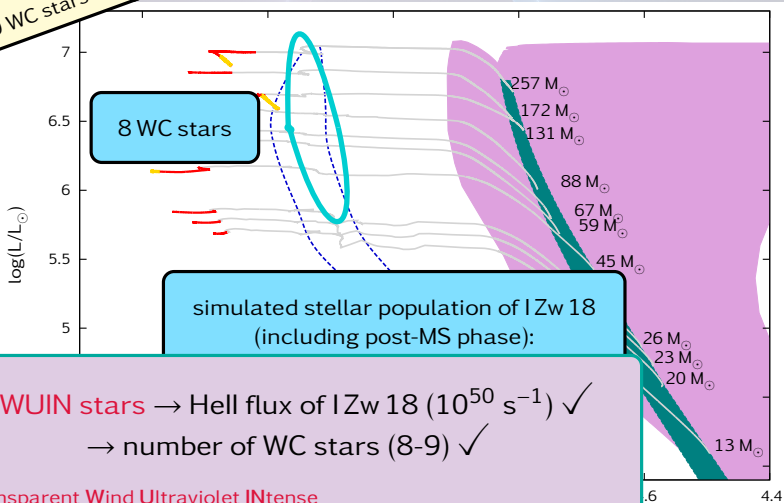
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TWUIN stars  $\rightarrow$  Hell flux of I Zw 18 ( $10^{50} \text{ s}^{-1}$ )  $\checkmark$   
 $\rightarrow$  number of WC stars (8-9)  $\checkmark$

Transparent Wind Ultraviolet INtense

Chemically Homogeneous Evolution  
(low metallicity!)

no Pair Instab.  
core  $< 40 M_{\odot}$

Pair Instability  
core  $> 40 M_{\odot}$

*rotates fast  
at collapse*

`failed` SN  
(collapsar)  
 $\xi$  high  
**IGRB**

successful SN  
(magnetar)  
 $\xi$  low

$B \sim 10^{15} \text{ G}$   
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magnetar scen.

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Pair Instability  
core  $> 40 M_{\odot}$

*spins down  
due to extreme\*  
mass loss*

*rotates fast  
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core collapse  
**SN Ic**

puls. PISN  
 $40 M_{\odot} < \text{core} < 64 M_{\odot}$   
**SLSN I**

'failed' SN  
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PISN  
 $64 M_{\odot} < \text{core} < 133 M_{\odot}$   
**SLSN R**  
**SLSN Ic**

$B \sim 10^{14} \text{ G}$   
magn. powered  
**SLSN type I**

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magnetar scen.

direct collapse to BH  
 $133 M_{\odot} < \text{core}$   
**no explosion**

*Credit: Szécsi et al. (in prep.)*

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magnetar scen.

**Other CHE/TWUIN studies**  
(single stars):

*Woosley+05, Yoon+05, Brott+11,  
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Szécsi+15*



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- Not all massive star.  
See *Yoon+06* for SN/GRB ratio.
- TWUIN stars  $\rightarrow$  photo-ionization
- several 'sister'-explosions:  
SNe, SLSNe
- reason for fast rotation?
  - star-formation ( $\sim 20\%$  CHE)
  - binarity: *Cantiello+07*

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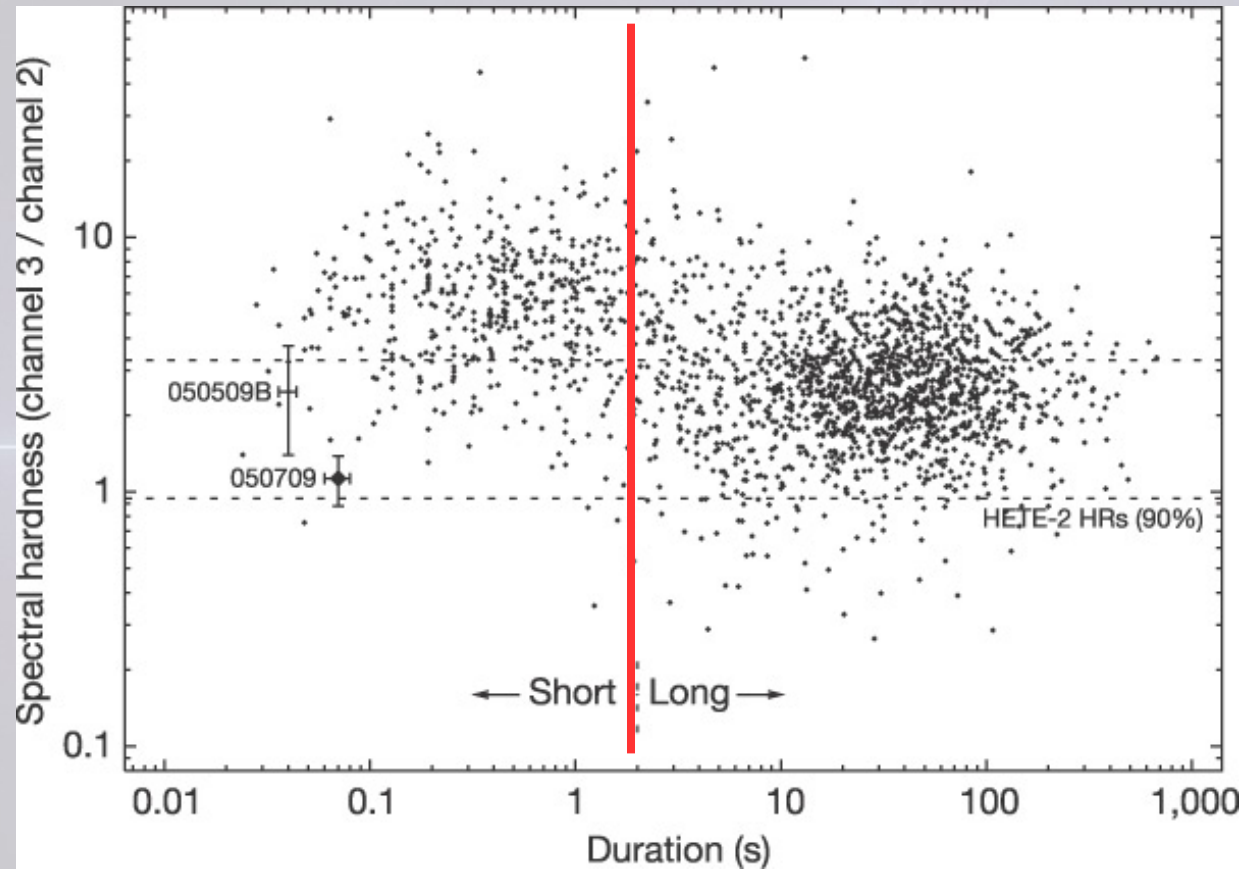
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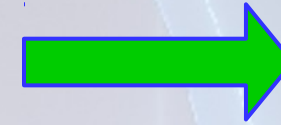
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Alternative way to form a  
stripped, fast rotating He-star:  
*Fryer+05*  
- common envelope evolution  
in a binary system

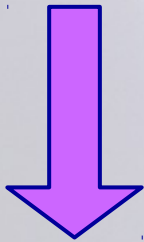
# How may GRBs form? *A review by Dorottya Szécsi*



*Credit: Hjorth+2005*

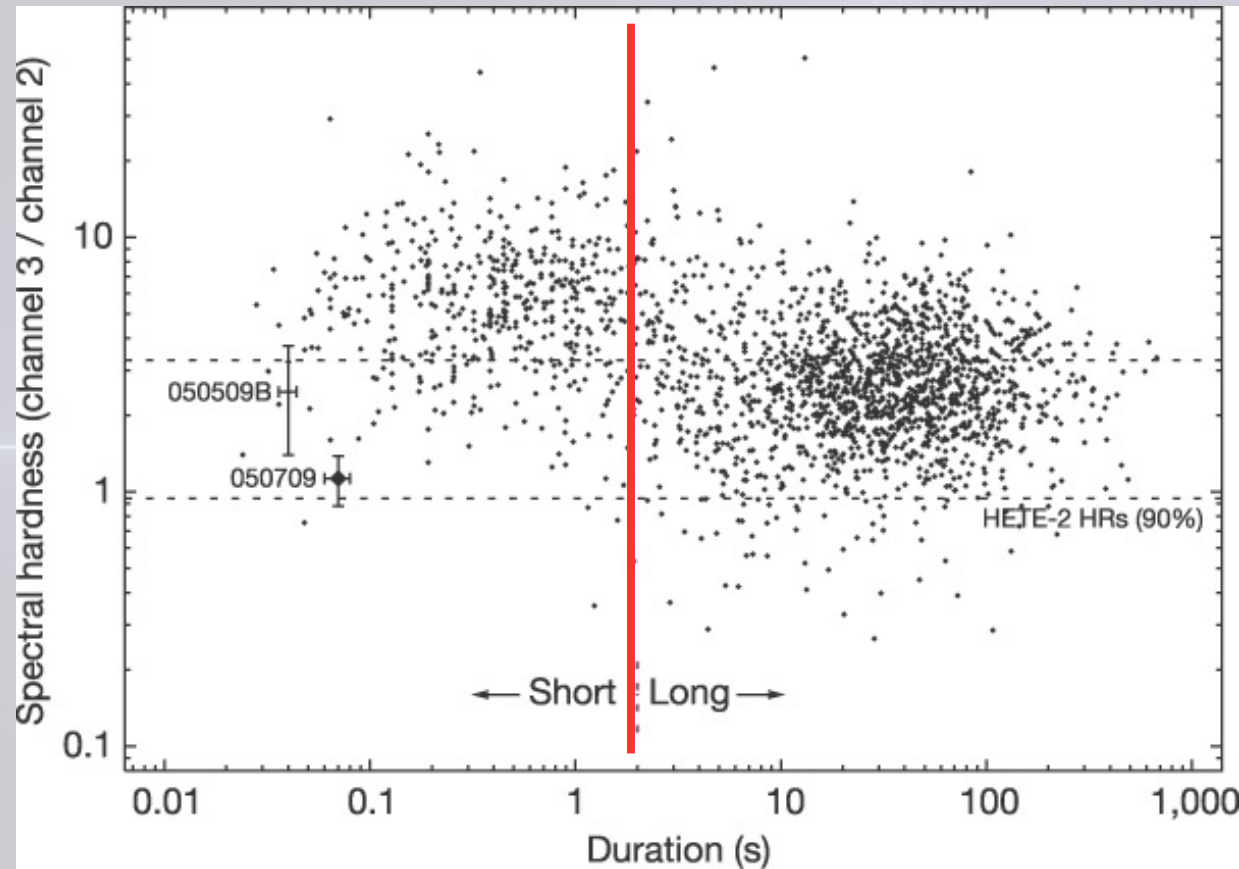


**Long/soft:**  
**Massive Stars**  
**at collapse**



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

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**THANK YOU!**

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