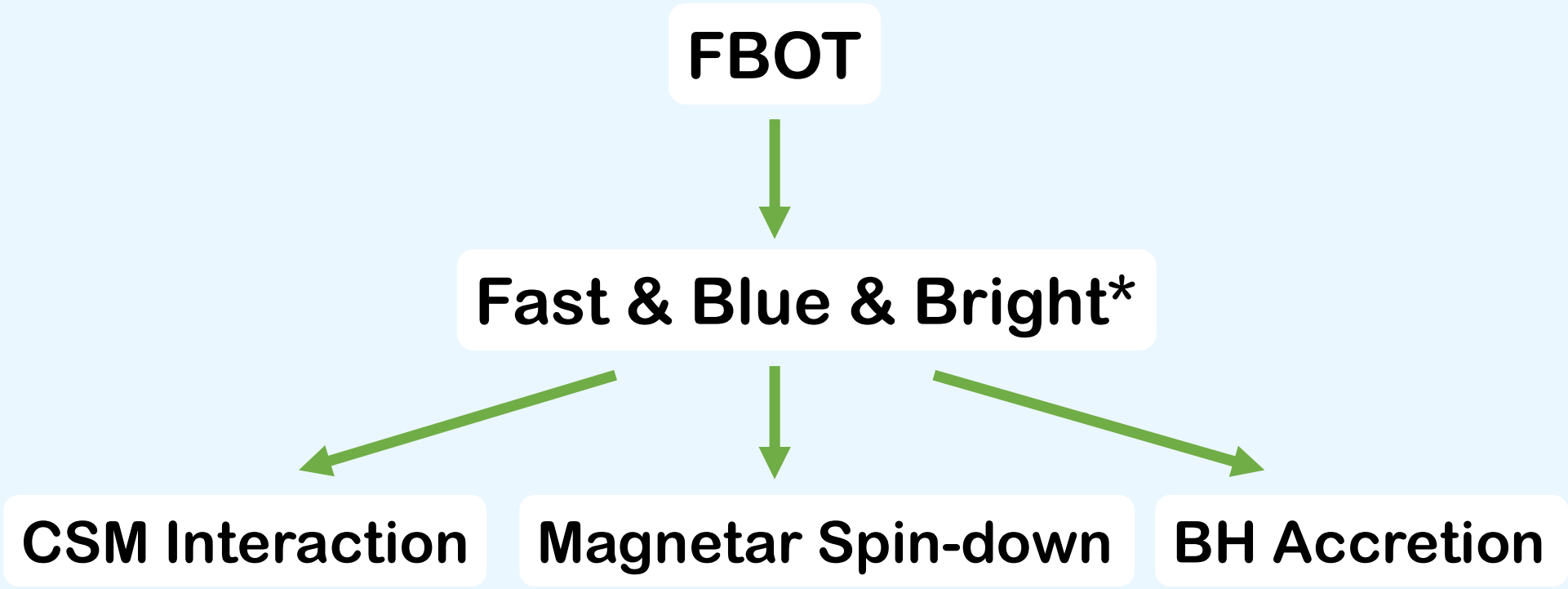
FEET24 (Feb. 26, 2024)

Possible Progenitors and Models for FBOTs

Yuyang Chen
PhD Student
Co-supervisors: Maria Drout & Bryan Gaensler
University of Toronto

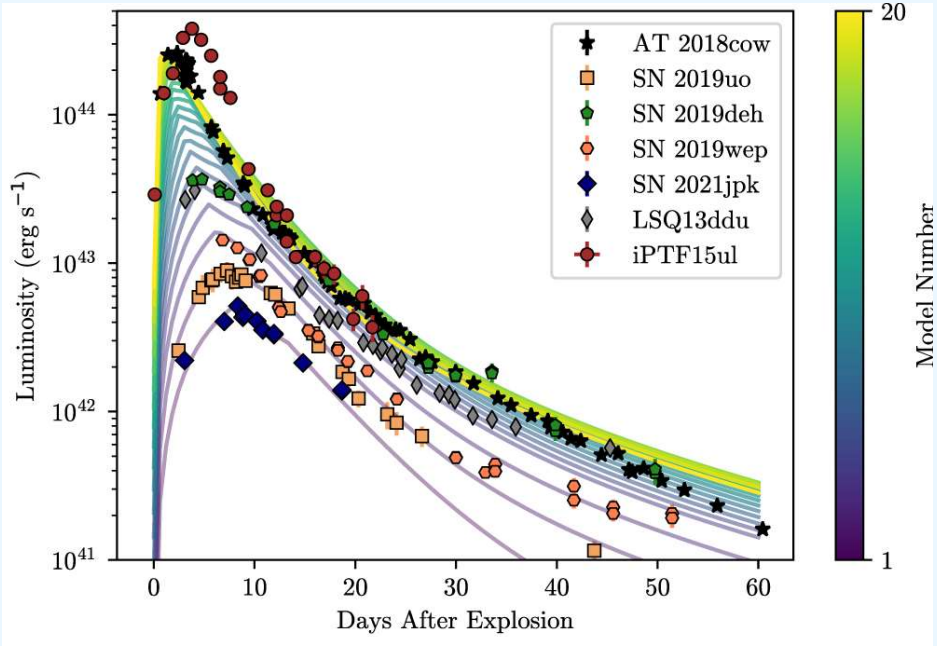
DUNLAP INSTITUTE
for ASTRONOMY & ASTROPHYSICS


FBOT
Fast & Blue & Bright*
CSM Interaction
Magnetar Spin-down
BH Accretion

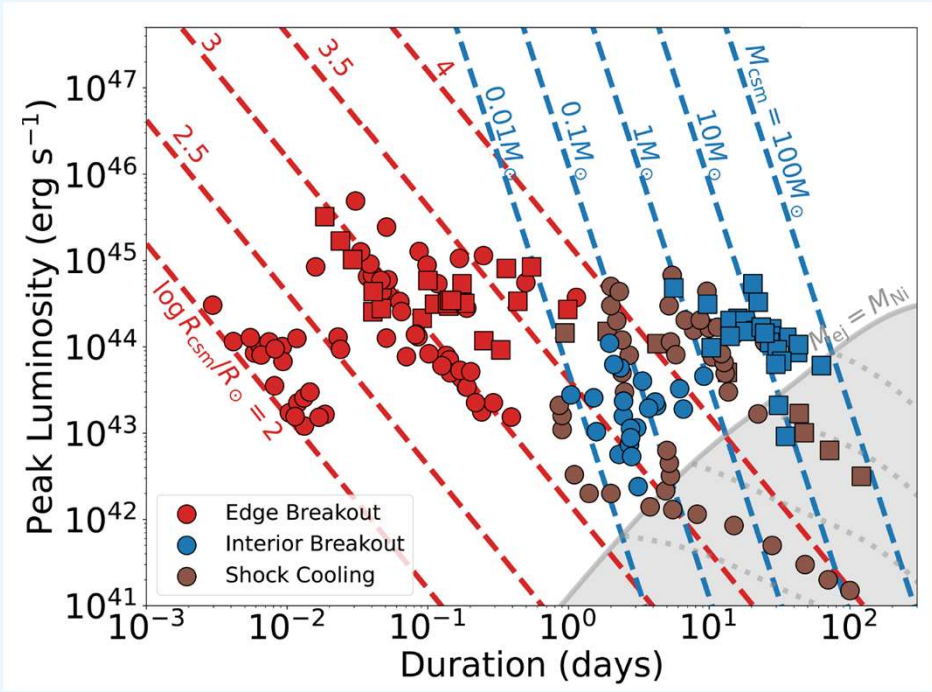
CSM Interaction

$$L_{sh} \sim P_{sh} A v_{sh}$$

Pellegrino et al. (2022)



Khatami et al. (2023)



CSM Interaction

High mass-loss rates
- Radiation-driven wind
- Wave-driven mass-loss
- Binary interaction

Proposed Progenitors

Compact single massive star
- Helium star
- WR star
- LBV star

Intermediate-mass star

Massive star in binary

CSM Interaction

High mass-loss rates
- Radiation-driven wind
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Proposed Progenitors

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Intermediate-mass star
Massive star in binary

Extended Envelope:
- Shell burning
- PPI

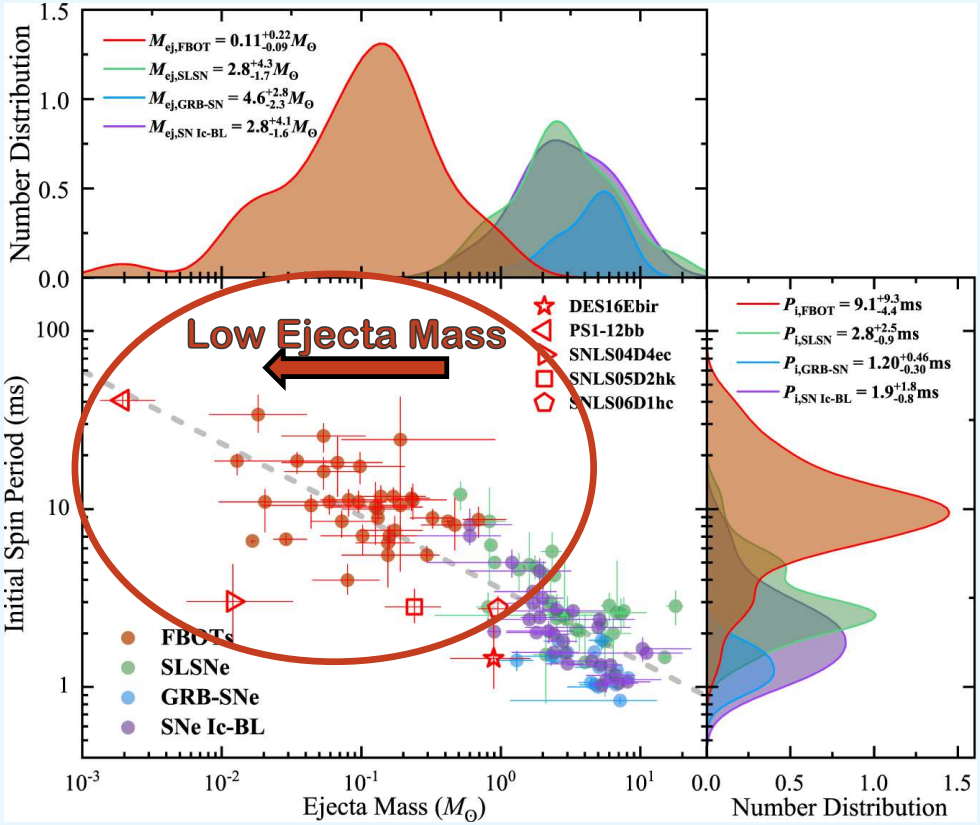
WD + WD
(Massive Remnant with Extended Envelope)
Very Massive Stars

Magnetar Spin-down

$$L_{sd} = L_{sd,0}\left(1+\frac{t}{t_{sd}}\right)^{-2}$$

$$L_{sd,0} \propto P^{-4}B^{2}$$
$$t_{sd} \propto P^{2}B^{-2}$$

Liu et al. (2022)



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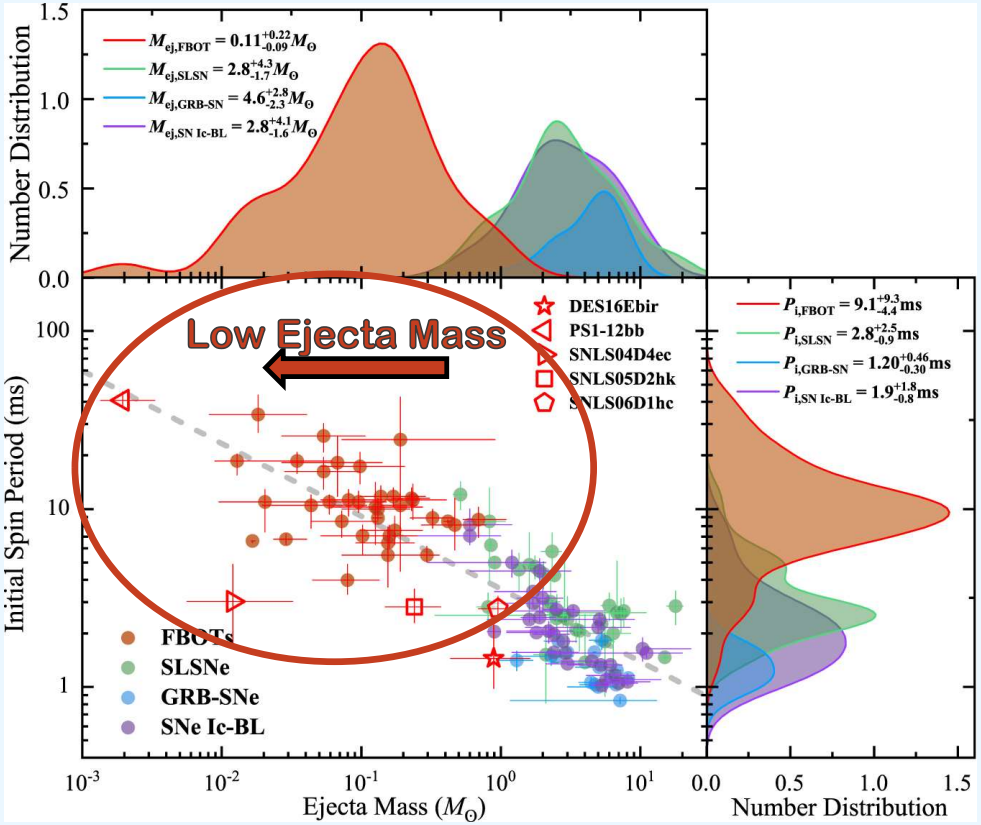
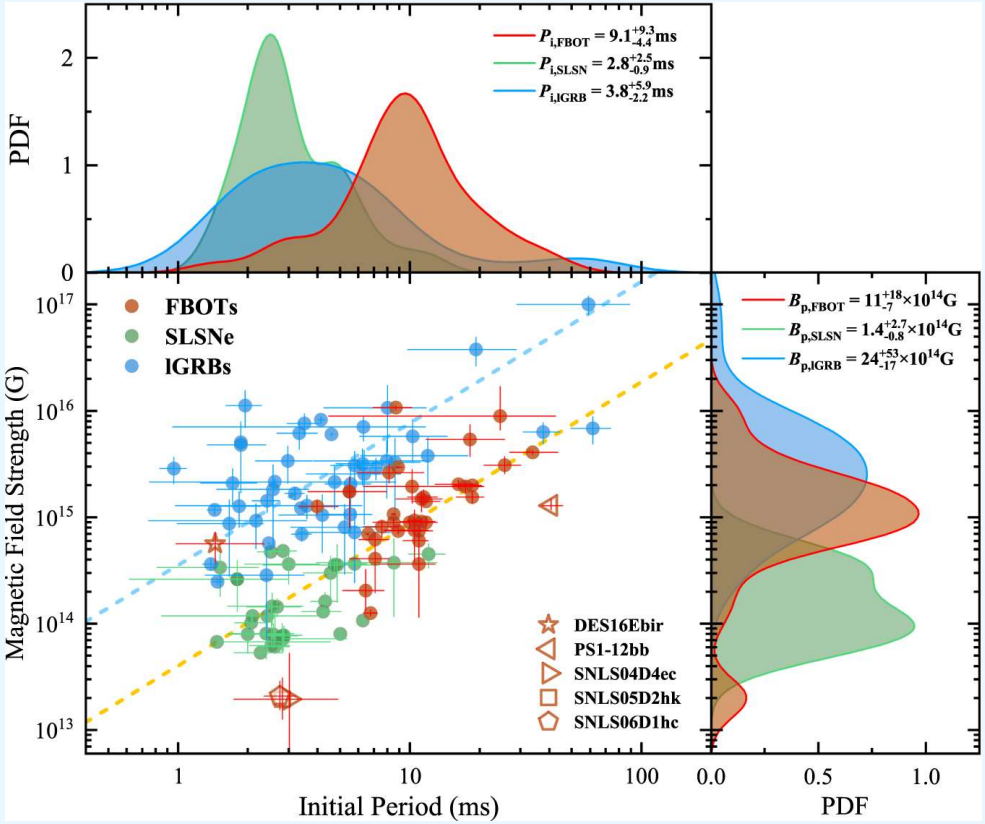




Magnetar Spin-down

Proposed Progenitors

Small ejecta mass 

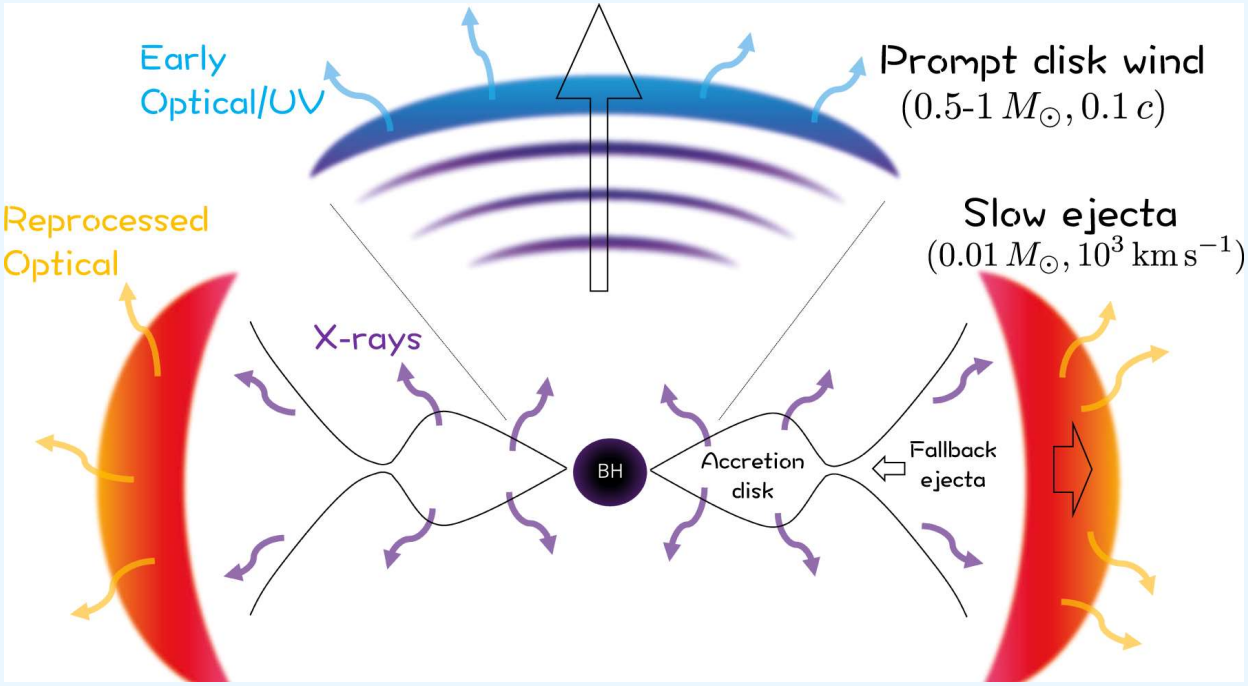
Compact binary (merger)
- NS + NS
- NS + WD
- WD + WD/Star

Ultra-stripped star (SN)

BH Accretion – Failed SN

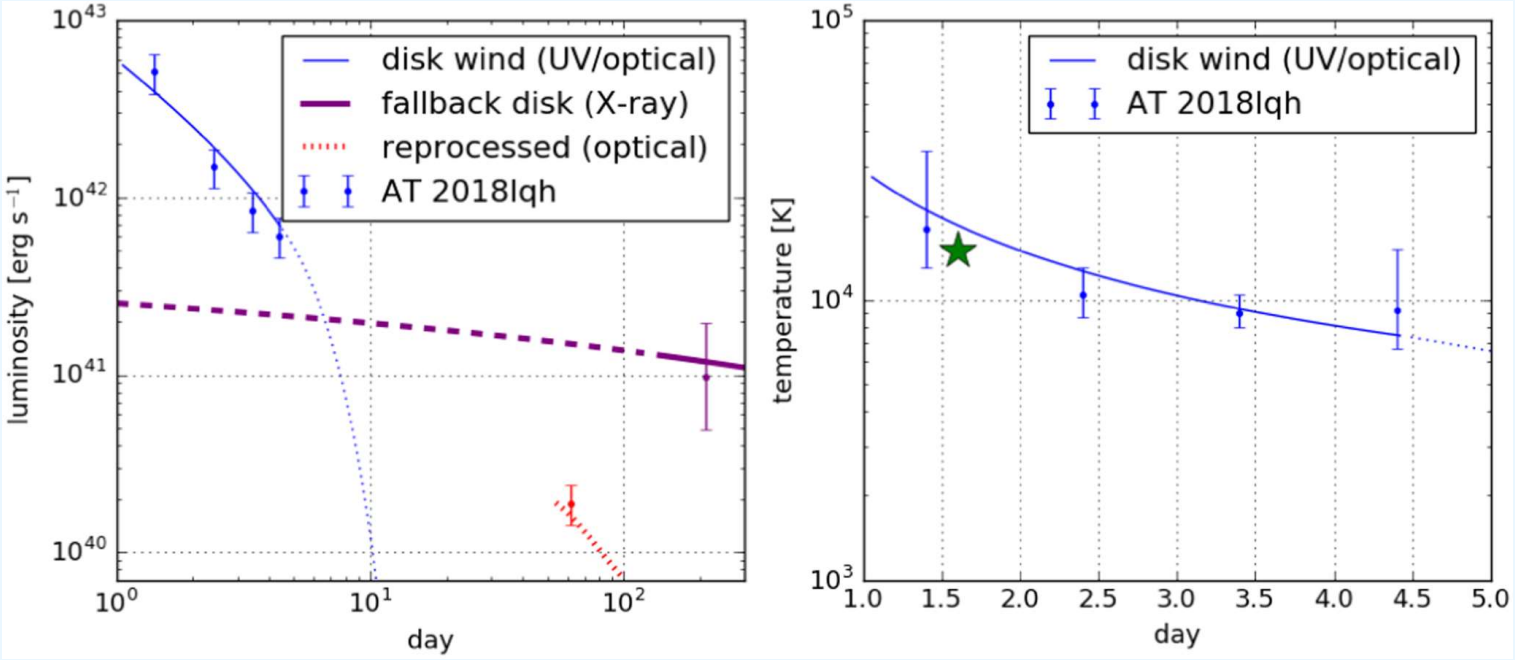
$$L_{acc} \sim \eta \frac{M_{acc}}{t_{acc}} \left(\frac{t}{t_{acc}} \right)^{-\frac{5}{3}}$$

Outflow launched & L_{fb} injected



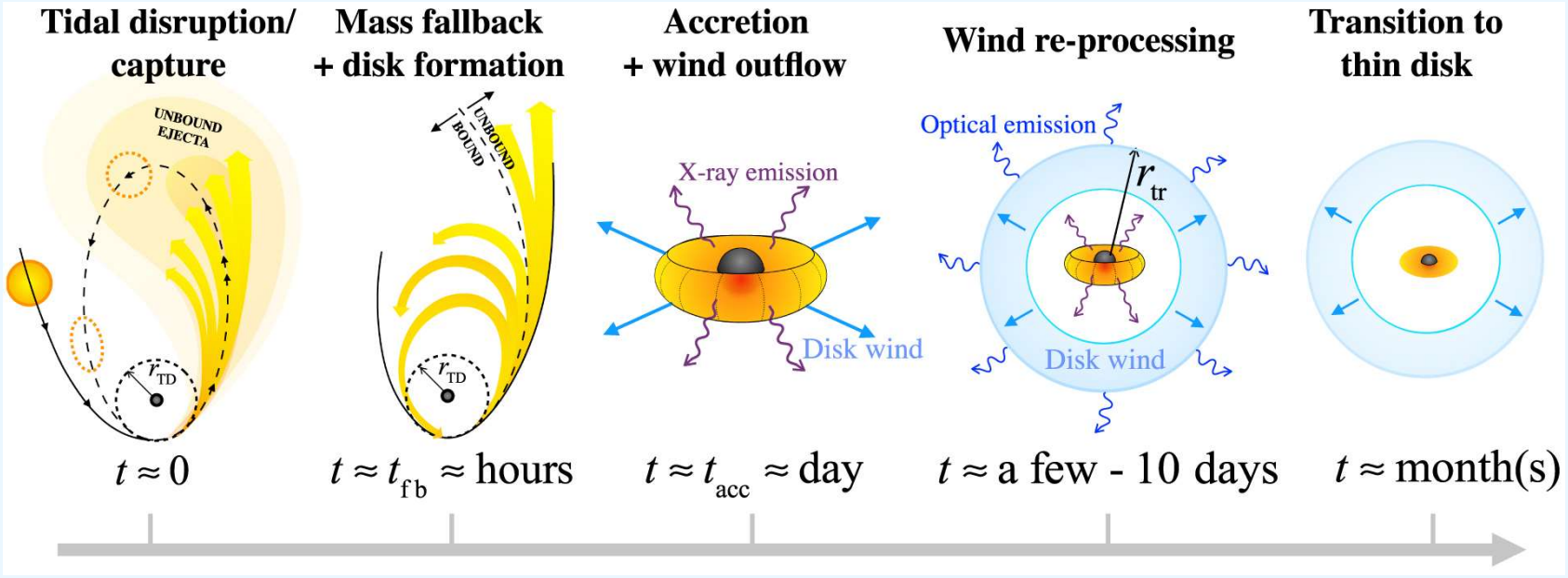
Tsuna et al. (2022)

BH Accretion – Failed SN



Tsuna et al. (2022)

BH Accretion - TDE

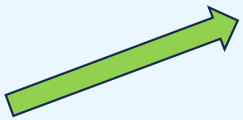


Kremer et al. (2022)

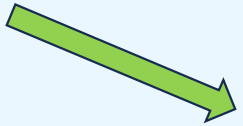
BH Accretion

Proposed Progenitors

Need BH
Need accretion



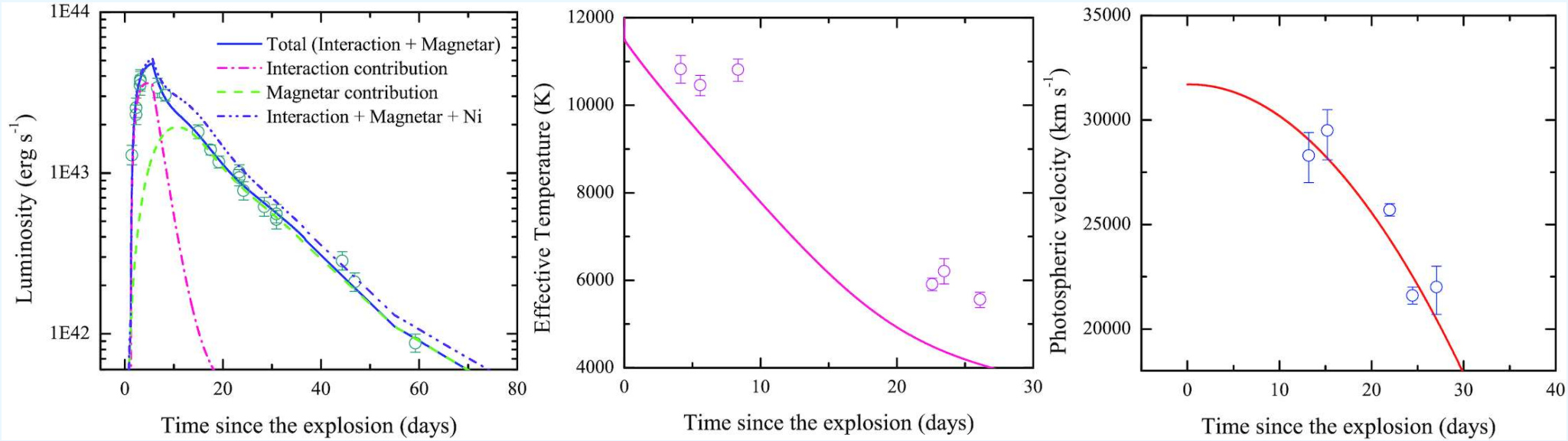
Massive star
(Failed SN)
- BSG
- WR



BH TDE
- Stellar-mass BH + MS
  (Young stellar cluster)
- (?) IMBH + WD

Mix It Up

Wang et al. (2019) iPTF16asu (SN Ic-BL)



FBOT

CSM Interaction

(Single or Binary)
Helium star
WR star
LBV star
Intermediate mass star

WD+WD
Very Massive Star

Magnetar Spin-down

NS + NS
NS + WD
WD + WD/star

Ultra-stripped star

BH Accretion

BSG star
WR star

(TDE)
Stellar-mass BH + MS
(?) IMBH + WD

FBOT

Constraints:

Star-forming galaxies

CSM Interaction

(Single or Binary)
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WR star
LBV star
Intermediate mass star

~~WD+WD~~
Very Massive Star

Magnetar Spin-down

NS + NS?
~~NS + WD~~
~~WD + WD/star~~

Ultra-stripped star

BH Accretion

BSG star
WR star

(TDE)
Stellar-mass BH + MS
~~(?) IMBH + WD~~

FBOT

Constraints:

Star-forming galaxies

Type Ibn/IIb SN

CSM Interaction

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Helium star
WR star
LBV star
Intermediate mass star

~~WD+WD~~ ?
Very Massive Star

Magnetar Spin-down

~~NS + NS~~?
~~NS + WD~~
~~WD + WD/star~~

Ultra-stripped star?

BH Accretion

BSG star
WR star

(TDE)
~~Stellar-mass BH + MS~~
~~(?) IMBH + WD~~

LFBOT

CSM Interaction

(Single or Binary)
Helium star
WR star
LBV star

Very Massive Star

Magnetar Spin-down

NS + NS
NS + WD
WD + WD/star

Ultra-stripped star

BH Accretion

BSG star
WR star
New!
WR-BH/NS Binary

(TDE)
Stellar-mass BH + MS
New?
IMBH + MS
IMBH + WD

LFBOT

Constraints:

Star-forming galaxies

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~~NS + WD~~
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(TDE)
Stellar-mass BH + MS
New? ~~IMBH + MS~~
~~IMBH + WD~~

LFBOT

Constraints:

Star-forming galaxies

Extended CSM (Dust)

CSM Interaction

(Single or Binary)
Helium star
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Very Massive Star

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~~NS + NS~~?
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BSG star
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(TDE)
~~Stellar-mass BH + MS~~
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LFBOT

Constraints:

Star-forming galaxies

Extended CSM (Dust)

Lack Ni-56

CSM Interaction

(Single or Binary)
Helium star
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LBV star

~~Very Massive Star~~

Magnetar Spin-down

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LFBOT

Constraints:

Star-forming galaxies

Extended CSM (Dust)

Lack Ni-56

Aspherical

CSM Interaction

(Single or Binary)???

Helium star

WR star

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Ultra-stripped star?

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BSG star

WR star

New! WR-BH/NS Binary

(TDE)

~~Stellar-mass BH + MS~~

New? ~~IMBH + MS~~

~~IMBH + WD~~

LFBOT

Constraints:

Star-forming galaxies
Extended CSM (Dust)
Lack Ni-56

Aspherical
H-deficient

CSM Interaction

(Single or Binary)???
Helium star
WR star
LBV star

Very Massive Star

Magnetar Spin-down

NS + NS?
NS + WD
WD + WD/star?

Ultra-stripped star?

BH Accretion

BSG star
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New! WR-BH/NS Binary

(TDE)
Stellar-mass BH + MS
New? IMBH + MS
IMBH + WD

LFBOT

Constraints:

- Star-forming galaxies
- Extended CSM (Dust)
- Lack Ni-56
- Aspherical
- H-deficient

Engine

CSM Interaction

(Single or Binary)
Helium star
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BSG star
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WR-BH/NS Binary

New!

(TDE)
~~Stellar-mass BH + MS~~
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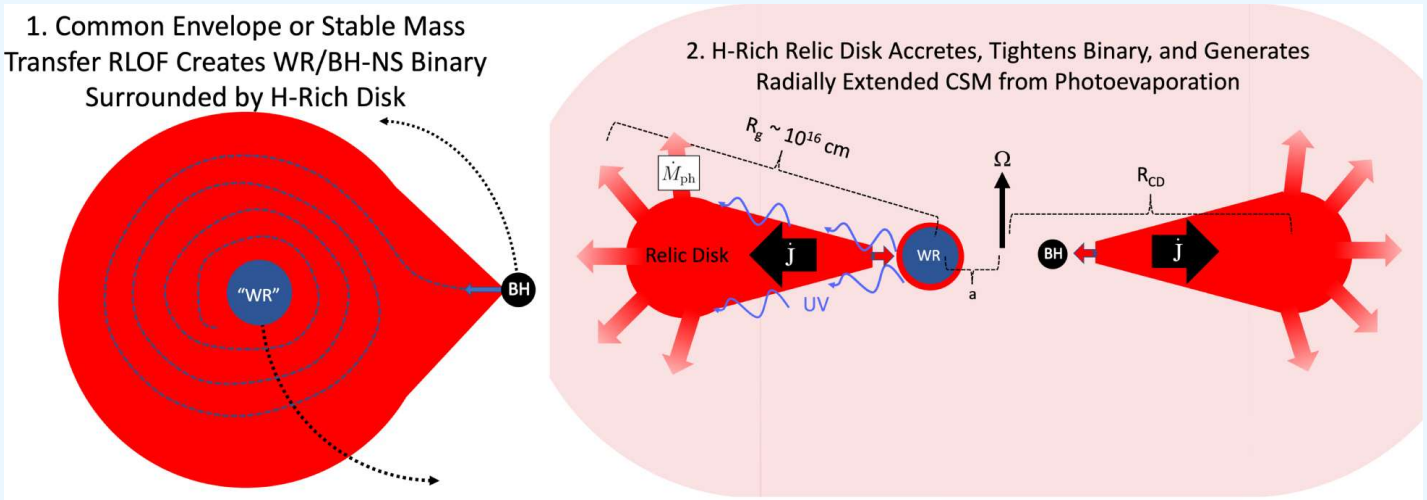
~~IMBH + WD~~

New?

Delayed Merger of WR-BH/NS Binary (Metzger 2022)



- ☑ Engine
- ☑ Extended CSM
- ☑ Prefer Star-forming

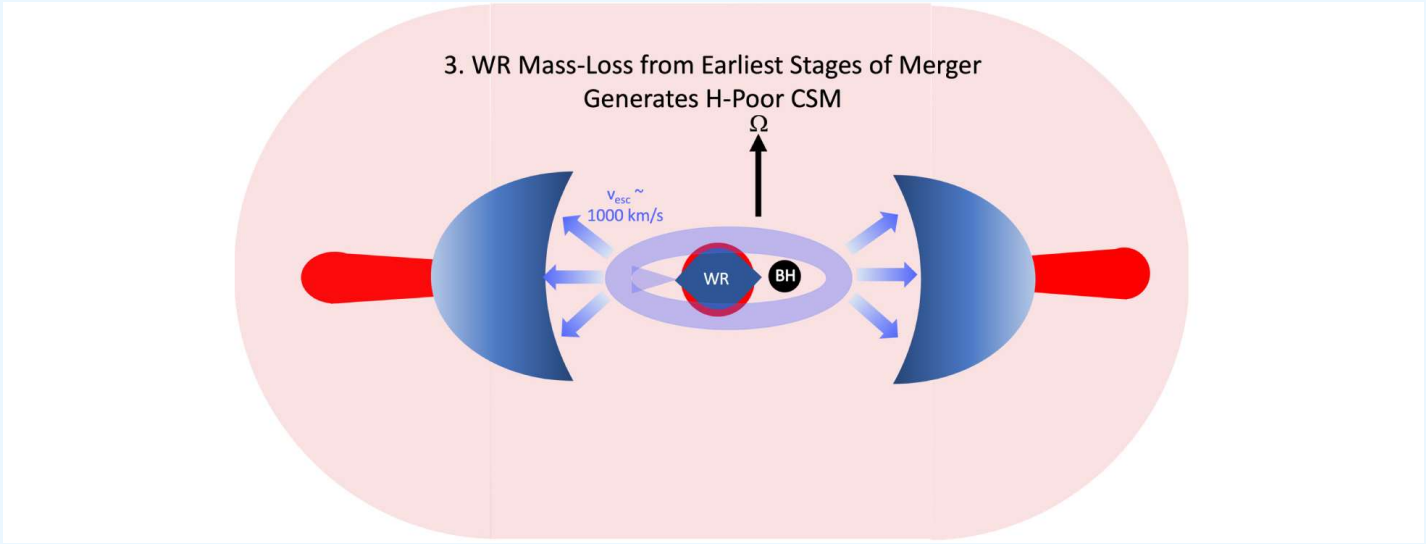
Merger does not immediately happen.

Delayed Merging

$$t_{\rm visc}^{\rm CD} \sim \left.\frac{r^2}{\nu}\right|_{R_{\rm CD}} \sim \frac{1}{\alpha}\frac{1}{\theta^2}\left(\frac{R_{\rm CD}^3}{GM_{\rm bin}}\right)^{1/2}$$

$$\approx 140\ {\rm yr}\ \alpha_{0.1}^{-1}\theta_{0.33}^{-2}\left(\frac{a_0}{30R_\odot}\right)^{3/2}\left(\frac{M_{\rm bin}}{30M_\odot}\right)^{-1/2}\left(\frac{M_{\rm CD}}{0.1M_{\rm bin}}\right)^{-3}$$

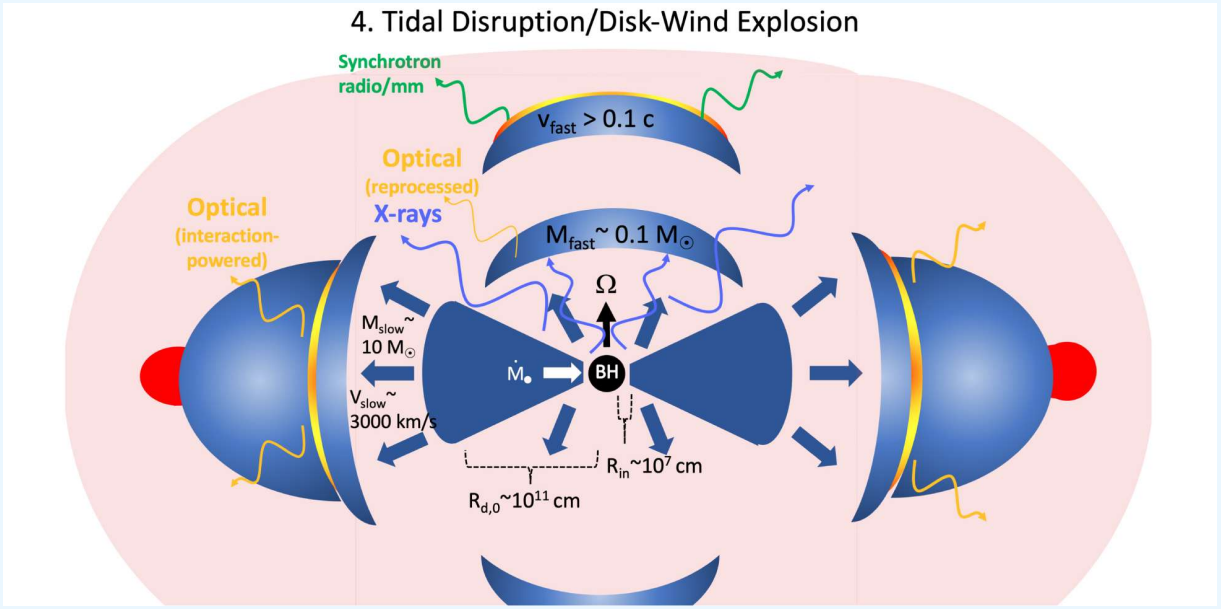
Delayed Merger of WR-BH/NS Binary (Metzger 2022)



☑ H Deficient

Unstable Mass Transfer

Delayed Merger of WR-BH/NS Binary (Metzger 2022)

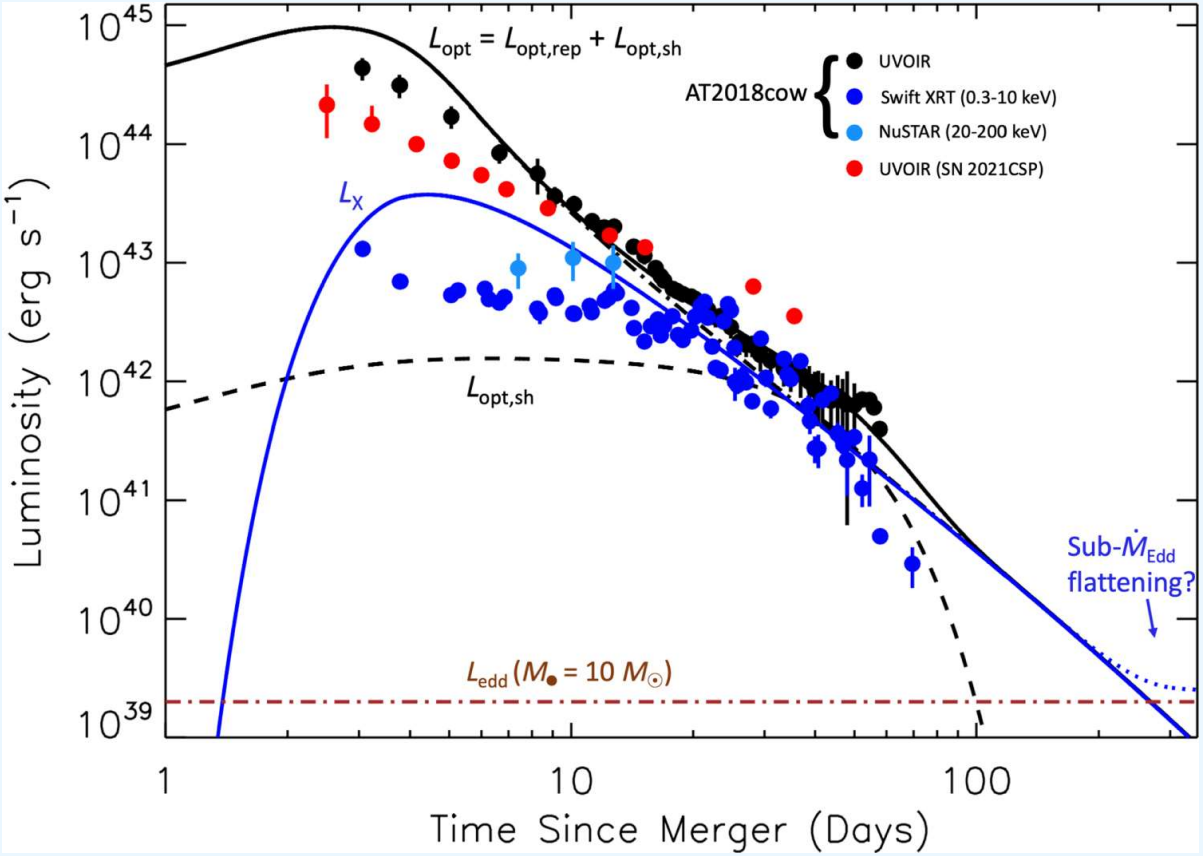


- ☑ Fast + Slow Outflow
- ☑ Lack Ni-56

$$L_{\rm sh} \approx 4\pi f_\Omega R_{\rm sh}^2 \rho_{\rm pre}(R_{\rm sh})(v_{\rm sh}^2/2) v_{\rm sh}$$

$$L_{\rm acc,th} = \phi_0(1 - e^{-\tau_{\rm X}})L_{\rm acc} + \phi_0 L_{\rm acc}$$

Delayed Merger of WR-BH/NS Binary (Metzger 2022)



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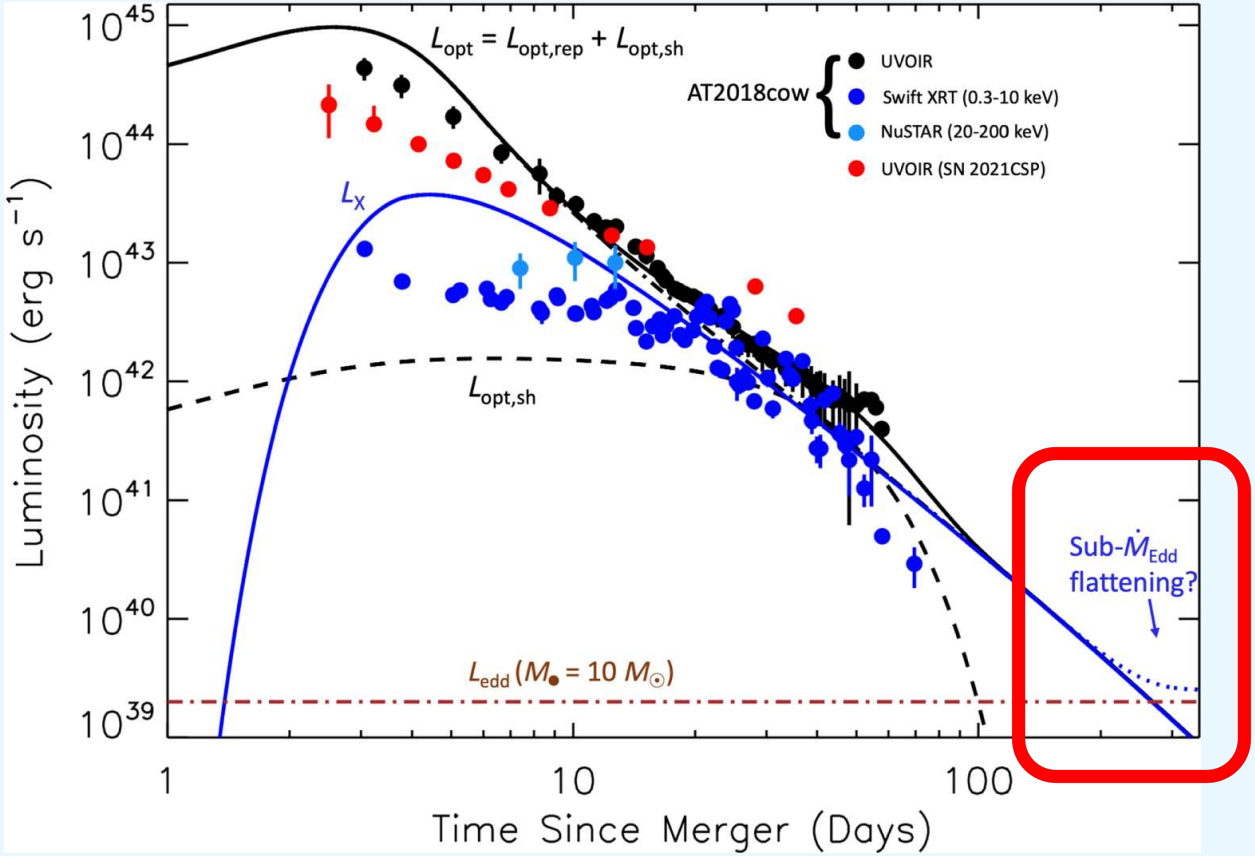


Late-time UV + X-ray

X-ray plateau
Thermal disk emission
- **5 years?**

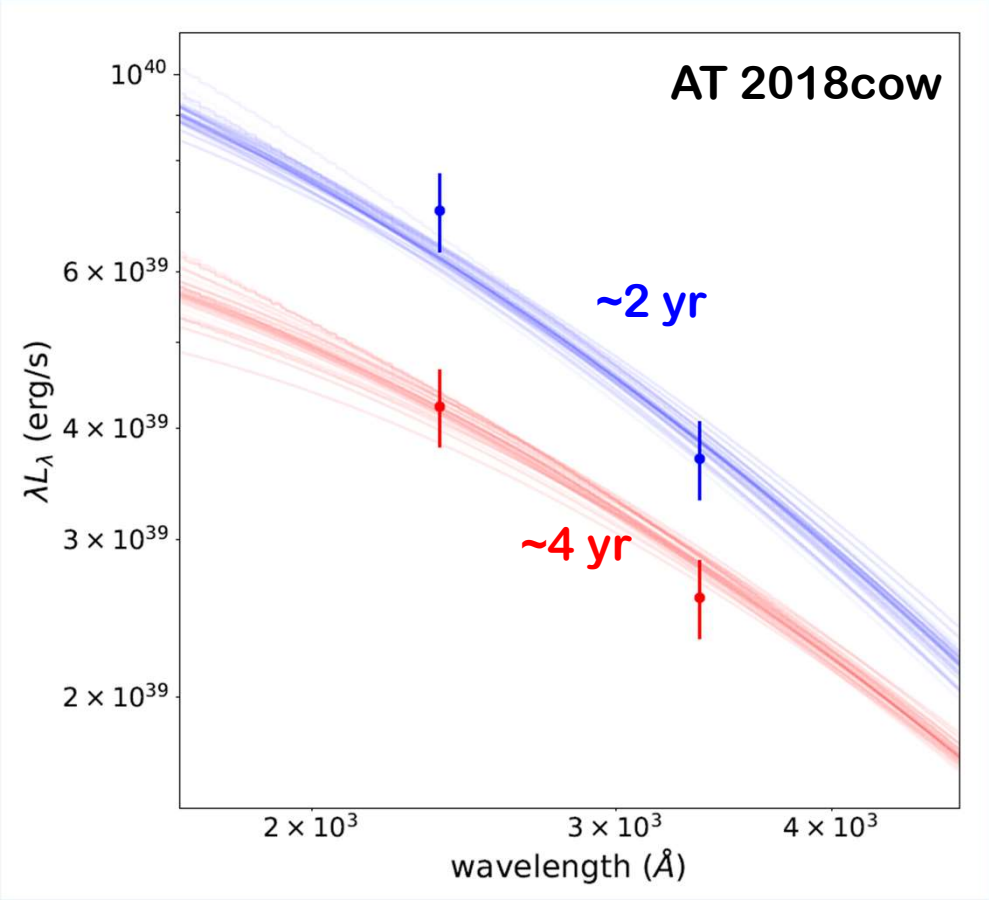
IMBH+MS/WD TDE

 Extended CSM

 Outskirt of star-forming galaxy

 IMBH

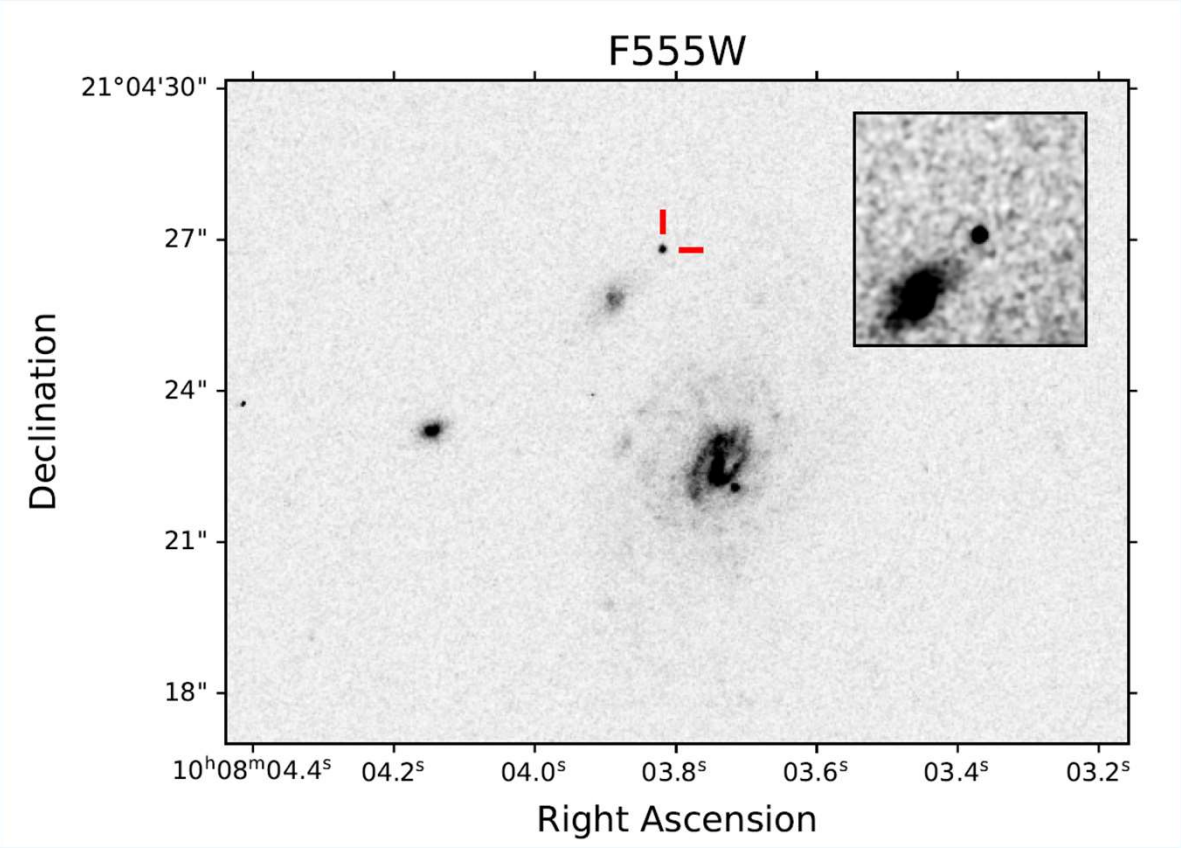
IMBH+MS/WD TDE



Late-time
UV + X-ray

Inkenhaag et al. (2023)

IMBH+MS/WD TDE



Chrimes et al. (2023)

AT 2023fhn:

- **Is massive star more favorable?**

LFBOT

Constraints:

- Star-forming galaxies
- Extended CSM (Dust)
- Lack Ni-56
- Aspherical
- H-deficient

Engine

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