Long gamma-ray bursts from interacting binaries

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Long gamma-ray bursts - model

Core collapse of rapidly-rotating massive star

High specific angular momentum: some material falls back into a disc

Accretion of the disc produces relativistic jets at the poles

Problem: strong stellar winds should spin the star down

In a close binary, one star will raise tidal motions on the surface of the other.

Orbital angular frequency $\Omega$

Spin angular frequency $\omega$
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Orbital angular frequency $\Omega$

Spin angular frequency $\omega$

If $\omega < \Omega$
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If $\omega < \Omega$
Close binaries

In a close binary, one star will raise tidal motions on the surface of the other.

Orbital angular frequency \( \Omega \)

Spin angular frequency \( \omega \)

If \( \omega < \Omega \)

Tidal torque transfers angular momentum and can spin the star up
The view from above

Newly-formed black hole
The view from above

Newly-formed black hole
Material falling back into disc around new black hole (as in single star case)
Newly-formed black hole
The view from above

Long fall-back time material lands outside either star’s Roche Lobe

Material falling back into disc around new black hole (as in single star case)

Newly-formed black hole
The view from above

Long fall-back time material lands outside either star’s Roche Lobe

Some gas sufficiently deflected to form a disc around the companion black hole

Material falling back into disc around new black hole (as in single star case)

Newly-formed black hole

$r_0 = 1601 \text{ km}$, $a = 3.359 \text{ R}_\odot$, $v_{\text{rot}} = 6145 \text{ km}$

$M_1 = 15.61 \text{ M}_\odot$, $M_2 = 5.694 \text{ M}_\odot$, $\Delta M_2 = 2.709 \text{ M}_\odot$
Typical accretion curve

- Single-star case
- Newly-formed BH (star 2)
- Companion BH (star 1)
Typical accretion curve

Early times the same as single star case
Typical accretion curve

Early times the same as single star case

Sharp break from Roche Lobe truncation
Typical accretion curve

Early times the same as single star case

Late-time flaring activity

Sharp break from Roche Lobe truncation
Flare properties

- $t_{\text{flare}}$ in seconds
- $M_{\text{flare}}/M_\odot$
- $E_{\text{flare}}$/erg

Observed GRB flares:
- GRB 050502B
- GRB 070107
- GRB 070318

Legend:
- No kick
- Kick $-x$
- Kick $+x$
- Kick $-y$
- Kick $+y$
- Observed GRB flares
Summary

A black hole companion can spin a star up sufficiently to make a gamma-ray burst.
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Such a companion will affect the material that falls back on to the black hole.
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Such a companion will affect the material that falls back on to the black hole.

This interference produces sharp light curve breaks and late-time flares.