Multi-wavelength Studies of Fast Blue Optical Transients (FBOTs)

Deanne Coppejans

Fast Blue Optical Transients (FBOTs)
Alternatively: Fast Evolving Luminous Transients (FELTS)

\[ L_{\text{peak}} \geq 10^{42} \text{ erg/s} \]

Rise time \( \leq 10 \text{ d} \)

Typically: \( g-r \leq -0.2 \text{ mag} \)

e.g. Drout+ 2014, Arcavi+ 2016, Tanaka+ 2016, Pursiainen+ 2018
What are they?

- SNe (or failed SNe) of massive stripped stars
  (e.g. Drout+ 2013, Tauris+ 2013, 2015, Kleiser & Kasen 2014, Kazumi & Quataert 2015, Suwa+ 2015…)

- Breakout of a SN shock from a dense wind or extended progenitor
  (e.g. Ofek+ 2010, Drout+ 2014, Pastorello+ 2015, Shivvers+ 2016, Arcavi+ 2017, Tanaka+ 2016, Rest+ 2018)

- Cooling envelope emission from radially extended red supergiants
  (e.g. Drout+ 2014, Tanaka+ 2016)

- Prolonged energy injection from:
  - Millisecond magnetar (e.g. Gao+ 2013, Yu+ 2013, Metzger & Piro 2014, Hotokezaka+ 2017)
  - Accreting neutron star (e.g. Margalit & Metzger 2016)
  - Accreting black hole (e.g. Kashiyama & Quataert 2015, Strubbe & Quataert 2009, Cenko+ 2012)

- Detonation of a helium shell on a white dwarf (e.g. Shen+ 2010, Perets+ 2010)

- Shockwave afterglows from GRBs (Cenko+ 2013, 2015, Stalder+ 2017; Bhalerao+ 2017)
The Cow: Discovery of a Luminous, Hot, and Rapidly Evolving Transient


Holy Cow! Astronomers agog at mysterious new supernova

An event known as ‘Cow’ may have heralded the birth of a neutron star

Speaking of Science

‘I’ve never seen anything like this’: Astronomers dazzled by brilliant supernova
The Cow: Discovery of a Luminous, Hot, and Rapidly Evolving Transient

AT2018cow: A Luminous Millimeter Transient

The fast, luminous ultraviolet transient AT2018cow: extreme supernova, or disruption of a star by an intermediate-mass black hole?

Diversity of common envelope jets supernovae and the fast transient AT2018cow

An Embedded X-Ray Source Shines through the Aspherical AT2018cow: Revealing the Inner Workings of the Most Luminous Fast-evolving Optical Transients


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Optical

(a)

(b)

(c)

(d)

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X-ray

(a) $F_\nu \propto \nu^{-0.62 \pm 0.03}$ at $t = 7.7$ days

(b) $F_\nu \propto \nu^{-0.49 \pm 0.05}$ at $t = 10.1$ days

(c) $F_\nu \propto \nu^{-0.43 \pm 0.08}$ at $t = 16.5$ days

(d) $F_\nu \propto \nu^{-0.58 \pm 0.04}$ at $t = 28.2$ days

(e) $F_\nu \propto \nu^{-0.67 \pm 0.02}$ at $t = 36.5$ days
Radio

Shock velocity $\sim 0.1c$

Progenitor mass-loss rate $\sim 10^{-4}-10^{-3} \, M_{\odot} \, yr^{-1}$

Internal Energy $\sim 2 \times 10^{48} \, \text{erg}$
Combined model
Combined model

\[ F_v \propto \nu^{-0.62 \pm 0.03} \]

\( t = 7.7 \text{ days} \)

Margutti+ 2019
Conclusion and Future work

First radio to gamma-ray study of an FBOT

AT2018cow is aspherical powered by a central engine

Continued observations will probe the late-time x-ray emission and help to diagnose the central engine

Future multi-wavelength campaigns on FBOTs will uncover the physical nature of this diverse class of objects
**Extra slides**

**Table 4.** Key properties of AT 2018cow

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$z$</td>
<td>0.0140</td>
<td>Redshift (from host emission)</td>
</tr>
<tr>
<td>$t_{\text{rise}}$</td>
<td>$\sim 2.5$ d</td>
<td>Rise time to peak (g)</td>
</tr>
<tr>
<td>$t_{\text{rise,1/2}}$</td>
<td>$\sim 1.5$ d</td>
<td>Time to rise from half-max (r)</td>
</tr>
<tr>
<td>$t_{\text{decline,1/2}}$</td>
<td>$\sim 3$ d</td>
<td>Time to decay to half-max (r)</td>
</tr>
<tr>
<td>$M_{g,\text{peak}}$</td>
<td>-20.4</td>
<td>Peak $g$ absolute magnitude</td>
</tr>
<tr>
<td>$M_{r,\text{peak}}$</td>
<td>-19.9</td>
<td>Peak $r$ absolute magnitude</td>
</tr>
<tr>
<td>$L_{\text{bol,peak}}$</td>
<td>$4 \times 10^{44}$ erg s$^{-1}$</td>
<td>UVOIR luminosity at optical peak</td>
</tr>
<tr>
<td>$E_{\text{rad}}$</td>
<td>$5 \times 10^{49}$ erg</td>
<td>Total UVOIR radiative output</td>
</tr>
<tr>
<td>$v_{\text{spec}}$</td>
<td>6000 km s$^{-1}$</td>
<td>Velocity width of late emission lines</td>
</tr>
<tr>
<td>$M_{*,\text{host}}$</td>
<td>$1.4 \times 10^9$ $M_{\odot}$</td>
<td>Host stellar mass</td>
</tr>
<tr>
<td>$\text{SFR}_{\text{host}}$</td>
<td>$0.22$ $M_{\odot}$ yr$^{-1}$</td>
<td>Host star-formation rate</td>
</tr>
</tbody>
</table>

Perley+ 2018
## Extra slides

### Table 1
Energy Radiated by AT 2018cow at $3 < \delta t < 60$ days

<table>
<thead>
<tr>
<th>Component</th>
<th>Band</th>
<th>Radiated Energy (erg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power law</td>
<td>0.3–10 keV</td>
<td>$9.8_{-0.1}^{+0.2} \times 10^{48}$</td>
</tr>
<tr>
<td>Power law</td>
<td>0.3–50 keV</td>
<td>$2.5_{-0.3}^{+0.4} \times 10^{49}$</td>
</tr>
<tr>
<td>Hard X-ray bump</td>
<td>20–200 keV</td>
<td>$\sim 10^{49}$</td>
</tr>
<tr>
<td>Blackbody</td>
<td>UVOIR</td>
<td>$1.0_{-0.2}^{+0.2} \times 10^{50}$</td>
</tr>
<tr>
<td>Non-thermal(^a)</td>
<td>UVOIR</td>
<td>$\sim 5 \times 10^{48}$</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>$\sim 1.4 \times 10^{50}$ erg</td>
</tr>
</tbody>
</table>

**Note.**
\(^a\) Based on the analysis from Perley et al. (2019).

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Extra slides

Graph showing luminosity over time since discovery with different spectral features and time exponents.
### Table 2
Central X-Ray “Engine” Models for AT 2018cow

<table>
<thead>
<tr>
<th>Model</th>
<th>Ejecta Mass/Velocity</th>
<th>Engine Timescale</th>
<th>CSM?</th>
<th>He?</th>
<th>H?</th>
<th>References</th>
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</thead>
<tbody>
<tr>
<td>NS–NS Merger Magnetar</td>
<td>×</td>
<td>✓</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>1</td>
</tr>
<tr>
<td>WD–NS Merger</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>2</td>
</tr>
<tr>
<td>IMBH TDE</td>
<td>✓</td>
<td>Maybe&lt;sup&gt;a&lt;/sup&gt;</td>
<td>×</td>
<td>✓</td>
<td>✓</td>
<td>3</td>
</tr>
<tr>
<td>Stripped-Envelope SN + Magnetar/BH</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>×</td>
<td>✓</td>
<td>4</td>
</tr>
<tr>
<td>Electron Capture SN + Magnetar</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>5</td>
</tr>
<tr>
<td>Blue Supergiant Failed SN + BH</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>6</td>
</tr>
<tr>
<td>SN + Embedded CSM Interaction</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>7</td>
</tr>
</tbody>
</table>

<sup>a</sup> If circularization is efficient.