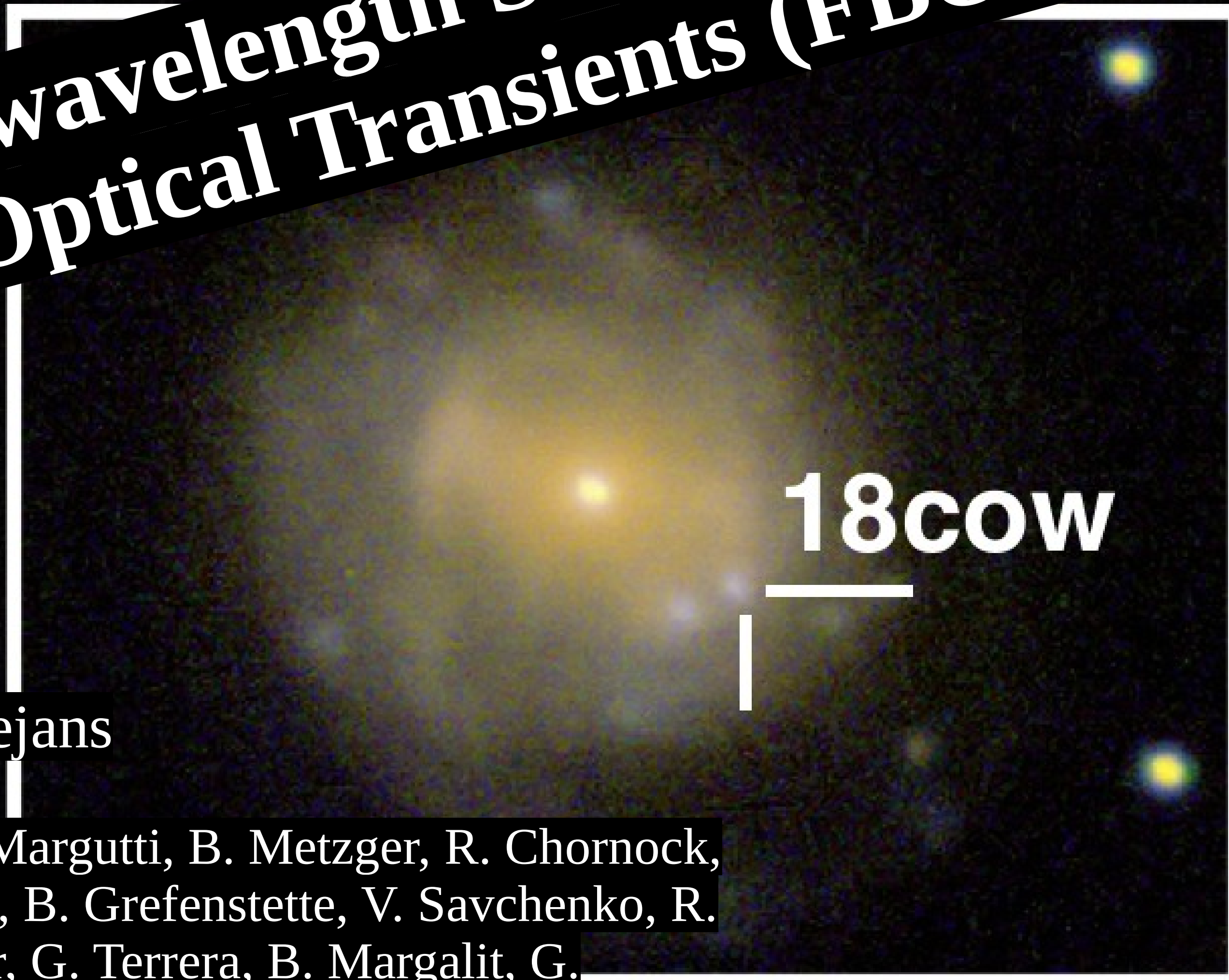
Multi-wavelength Studies of Fast Blue Optical Transients (FBOTs)



Deanne Coppejans

On behalf of R. Margutti, B. Metzger, R. Chornock, I. Vurm, N. Roth, B. Grefenstette, V. Savchenko, R. Cartier, J. Steiner, G. Terrera, B. Margalit, G. Migliori, D. Milisavljevic, K. Alexander, M. Bietenholz, P. Blanchard, E. Bozzo, D. Brethauer, I. Chilingarian, L. Ducci, C. Ferrigno, W. Fong, D. Gotz, C. Guidorzi, A. Hajela, K. Hurley and more...

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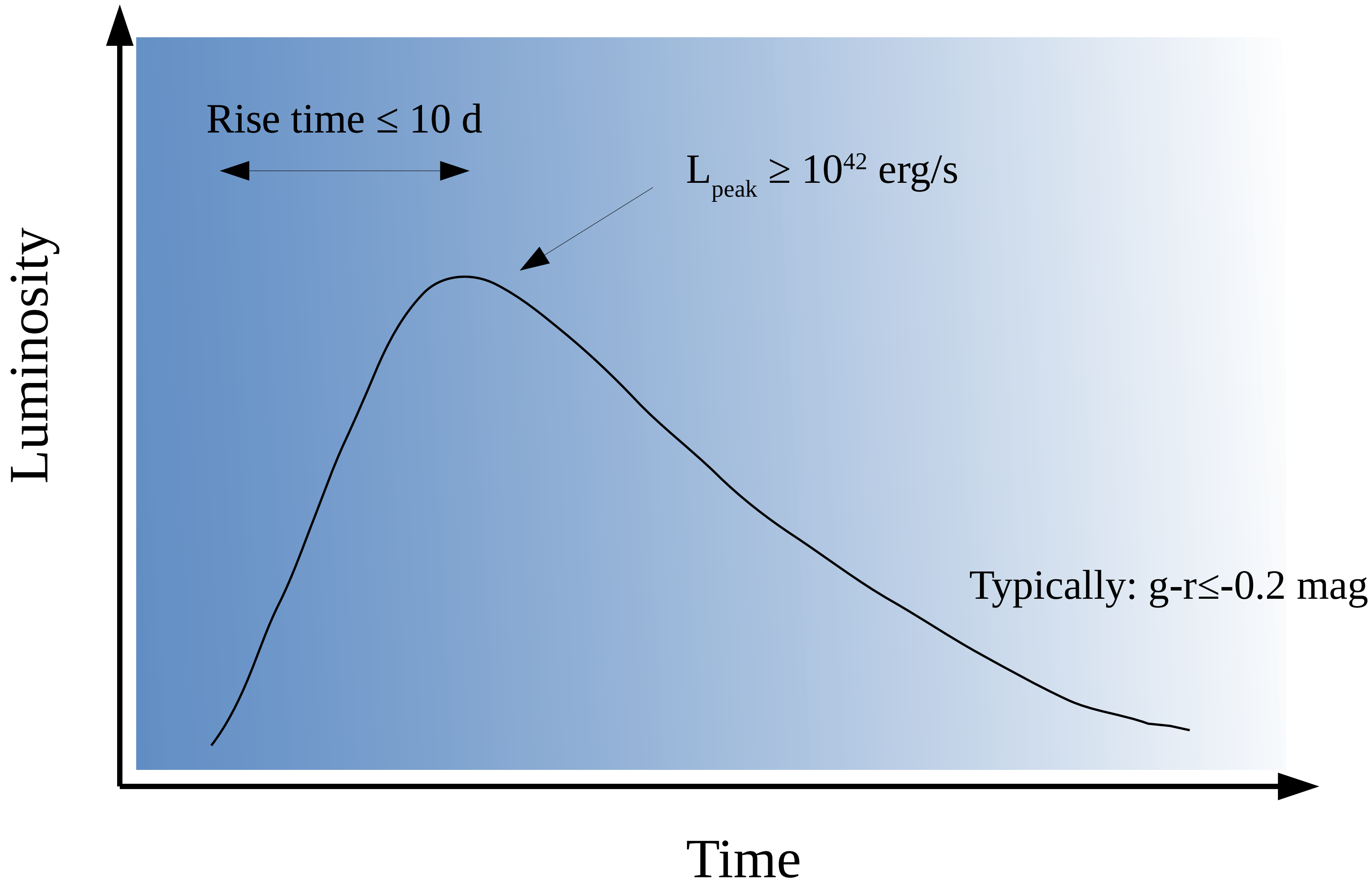
Fast Blue Optical Transients (FBOTs)
Alternatively: Fast Evolving Luminous Transients (FELTS)



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)

AT2018cow/ATLAS18qqn/ZTF18abcfcoo

The Astrophysical Journal Letters, 865:L3 (8pp), 2018 September 20 https://doi.org/10.3847/2041-8213/aadd90

The Cow: Discovery of a Luminous, Hot, and Rapidly Evolving Transient

S. J. Prentice[1], K. Maguire[1], S. J. Smartt[1], M. R. Magee[1], P. Schady[2], S. Sim[1], T.-W. Chen[2], P. Clark[1], C. Colin[1,3], M. Fulton[1], O. McBrien[1], D. O'Neill[1], K. W. Smith[1], C. Ashall[4], K. C. Chambers[5], L. Denneau[5], H. A. Flewelling[5], A. Heinze[5], T. W.-S. Holoien[6], M. E. Huber[5], C. S. Kochanek[7,8], P. A. Mazzali[9,10], J. L. Prieto[11,12], A. Rest[13,14], B. J. Shappee[5], B. Stalder[15], K. Z. Stanek[7], M. D. Stritzinger[16], T. A. Thompson[7,8], and J. L. Tonry[5]

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birth of a neutron star c

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Democracy Dies in Darkness

Speaking of Science

'I've never seen anything like this': Astronomers dazzled by brilliant supernova

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https://doi.org/10.3847/1538-4357/aaf473

AT2018cow: A Luminous Millimeter Transient

Anna Y. Q. Ho[1], E. Sterl Phinney[2], Vikram Ravi[1,3], S. R. Kulkarni[1], Glen Petitpas[3], Bjorn Emonts[4], V. Bhalerao[5], Ray Blundell[3], S. Bradley Cenko[6,7], Dougal Dobie[8,9], Ryan Howie[3], Nikita Kamraj[1], Mansi M. Kasliwal[1], Tara Murphy[8], Daniel A. Perley[10], T. K. Sridharan[3], and Ilsang Yoon[4]

Monthly Notices of the Royal Astronomical Society
MNRAS 484, 1031–1049 (2019)
Advance Access publication 2018 December 22

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

Daniel A. Perley,[1★] Paolo A. Mazzali,[1,2] Lin Yan,[3] S. Bradley Cenko,[4,5] Suvi Gezari,[5]

Swift spectra of AT2018cow: A White Dwarf Tidal Disruption Event?

N. Paul M. Kuin,[1★] Kinwah Wu,[1] Samantha Oates,[2] Amy Lien,[3,13] Sam Emery,[1]

Diversity of common envelope jets supernovae and the fast transient AT2018cow

Noam Soker ✉, Aldana Grichener, Avishai Gilkis

Monthly Notices of the Royal Astronomical Society, Volume 484, Is
Pages 4972–4979, https://doi.org/10.1093/mnras/stz364

FBOTs and AT2018cow following electron-capture collapse of merged white dwarfs

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Multimessenger Implications of AT2018cow: High-Energy Cosmic Ray and Neutrino Emissions from Magnetar-Powered Super-Luminous Transients

Ke Fang,[1] Brian D. Metzger,[2] Kohta Murase,[3,4,5,6] Imre Bartos,[7,2] and Kumiko Kotera[8,9]

The Astrophysical Journal Letters, 865:L3 (8pp), 2018 September 20 https://doi.org/10.3847/2041-8213/aadd90

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https://doi.org/10.3847/1538-4357/aaf473

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Focus in this talk:

The Astrophysical Journal, 872:18 (32pp), 2019 February 10 https://doi.org/10.3847/1538-4357/aafa01

An Embedded X-Ray Source Shines through the Aspherical AT 2018cow: Revealing the Inner Workings of the Most Luminous Fast-evolving Optical Transients

R. Margutti[1], B. D. Metzger[2], R. Chornock[3], I. Vurm[4], N. Roth[5,6], B. W. Grefenstette[7], V. Savchenko[8], R. Cartier[9], J. F. Steiner[10,33], G. Terreran[1], B. Margalit[11], G. Migliori[12,13], D. Milisavljevic[14], K. D. Alexander[1,33], M. Bietenholz[15,16], P. K. Blanchard[17], E. Bozzo[8], D. Brethauer[1], I. V. Chilingarian[17,18], D. L. Coppejans[1], L. Ducci[8,19], C. Ferrigno[8], W. Fong[1], D. Götz[20], C. Guidorzi[21], A. Hajela[1], K. Hurley[22], E. Kuulkers[23], P. Laurent[20], S. Mereghetti[24], M. Nicholl[17,25], D. Patnaude[17], P. Ubertini[26], J. Banovetz[15], N. Bartel[16], E. Berger[17], E. R. Coughlin[2,33], T. Eftekhari[17], D. D. Frederiks[27], A. V. Kozlova[27], T. Laskar[28,29], D. S. Svinkin[29], M. R. Drout[30,31], A. MacFadyen[32], and K. Paterson[1]

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Monthly Notices of the Royal Astronomical Society, Volume 484, Is
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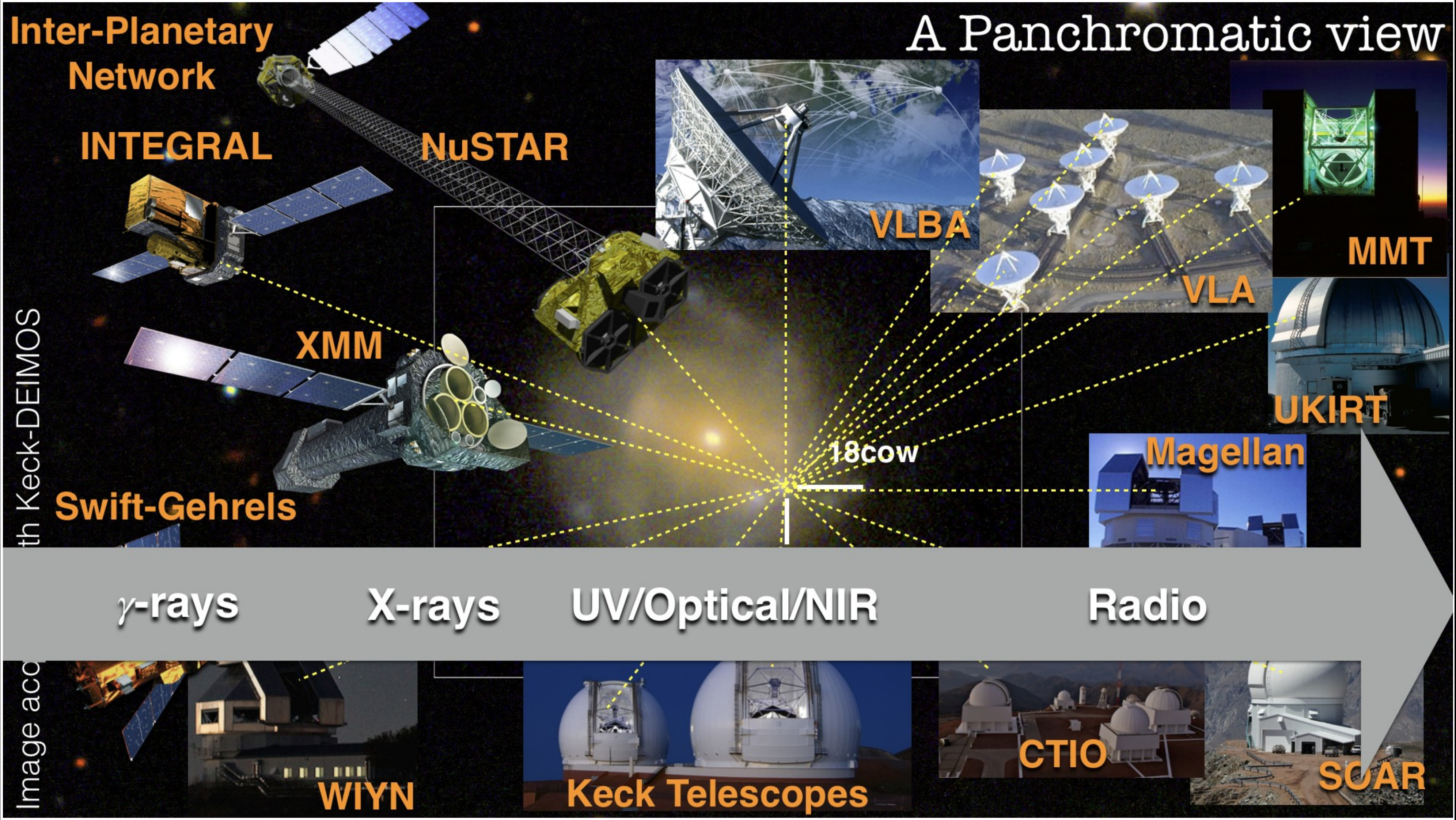
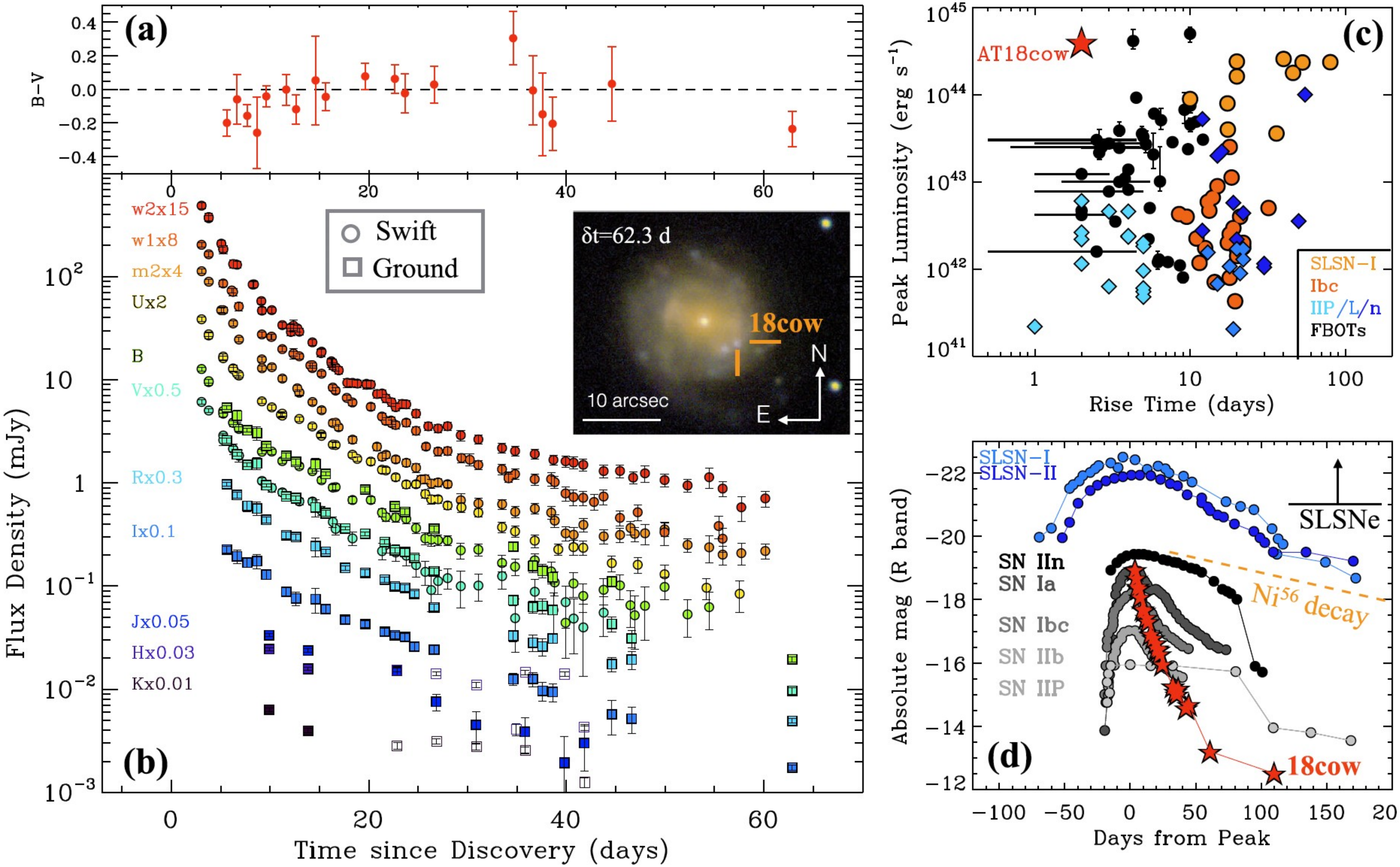

A Panchromatic view
Inter-Planetary Network
INTEGRAL
NuSTAR
VLBA
MMT
VLA
XMM
UKIRT
18cow
Magellan
Swift-Gehrels
Image acq… with Keck-DEIMOS
γ-rays
X-rays
UV/Optical/NIR
Radio
WIYN
Keck Telescopes
CTIO
SOAR

Optical



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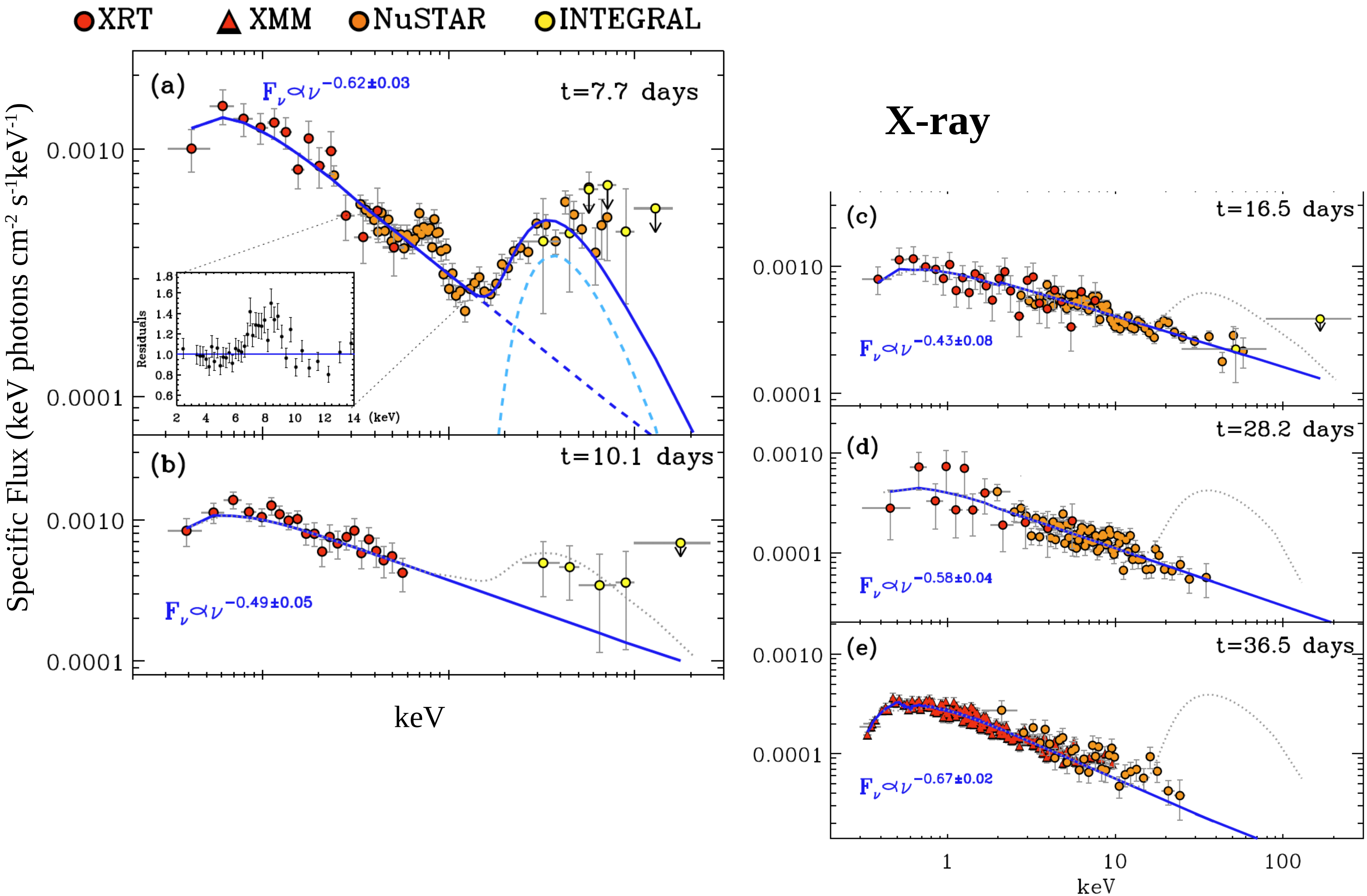
X-ray



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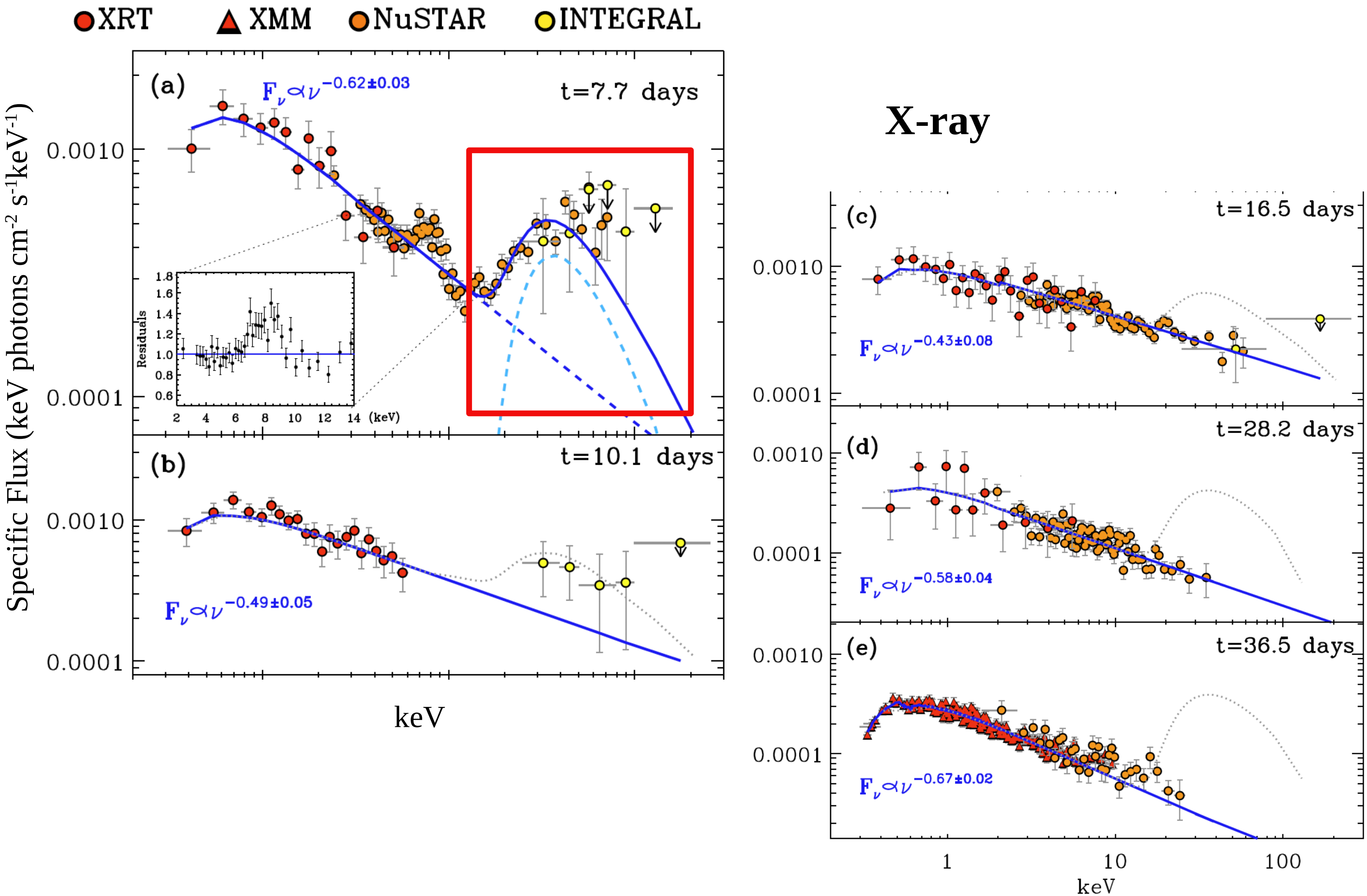
X-ray



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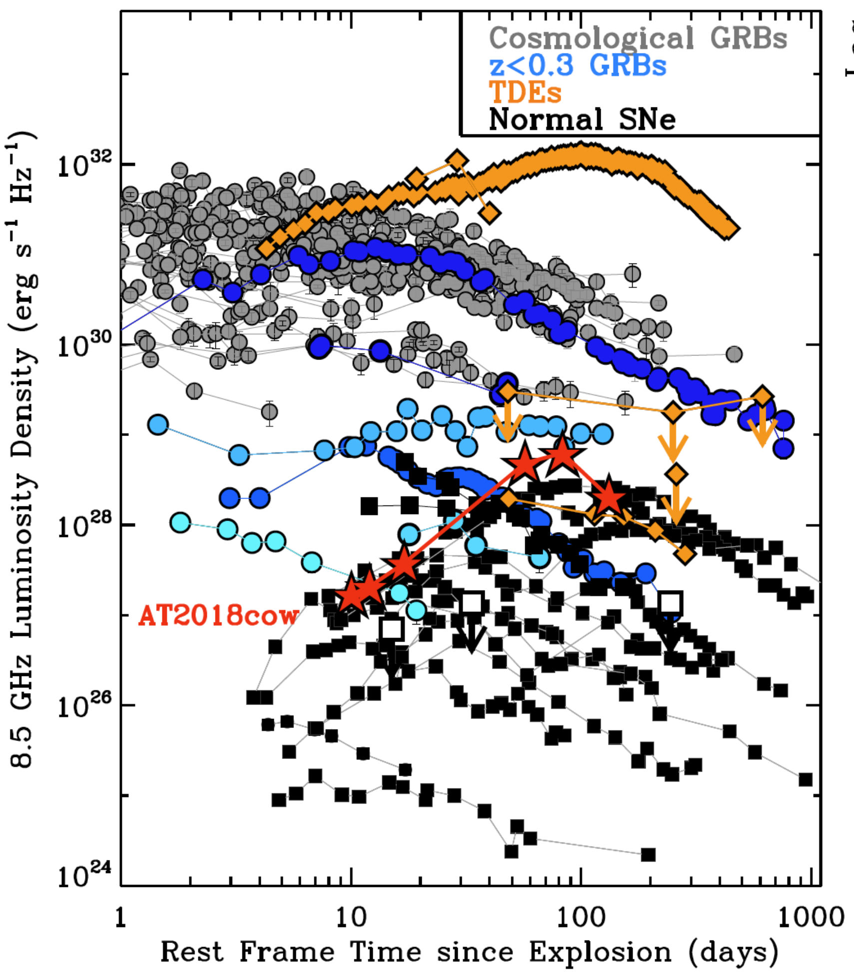
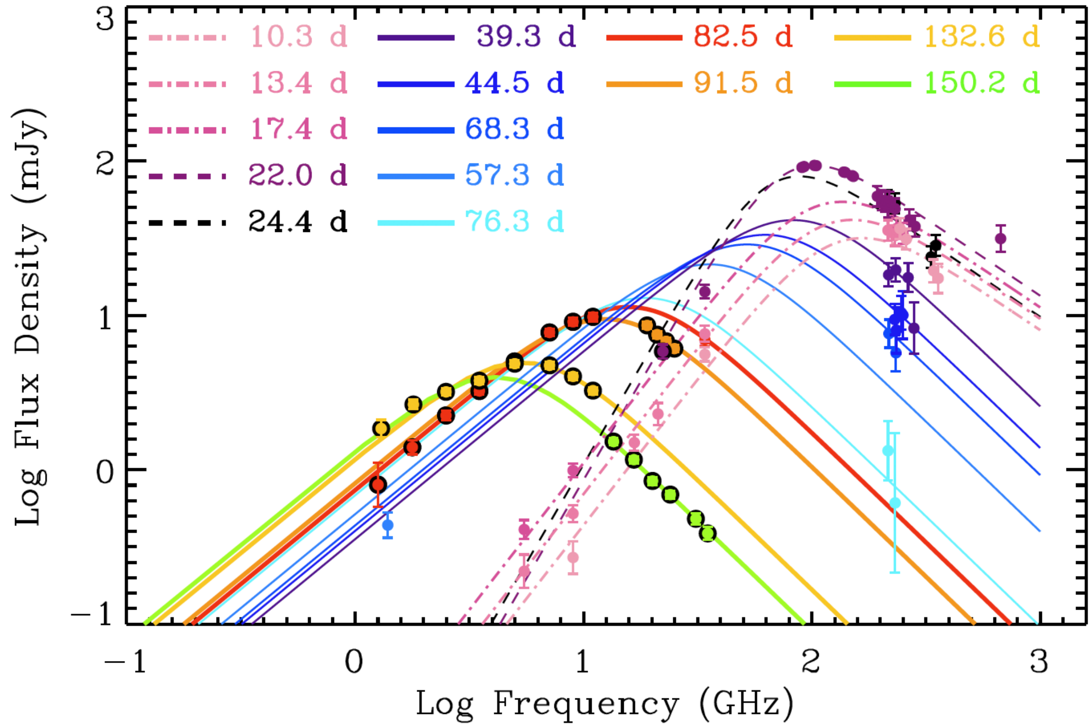
Radio





Shock velocity ~ 0.1c

Progenitor mass-loss rate ~ 10^{-4}-10^{-3} $M_{sol}y^{-1}$

Internal Energy >~ $2x10^{48}$ erg

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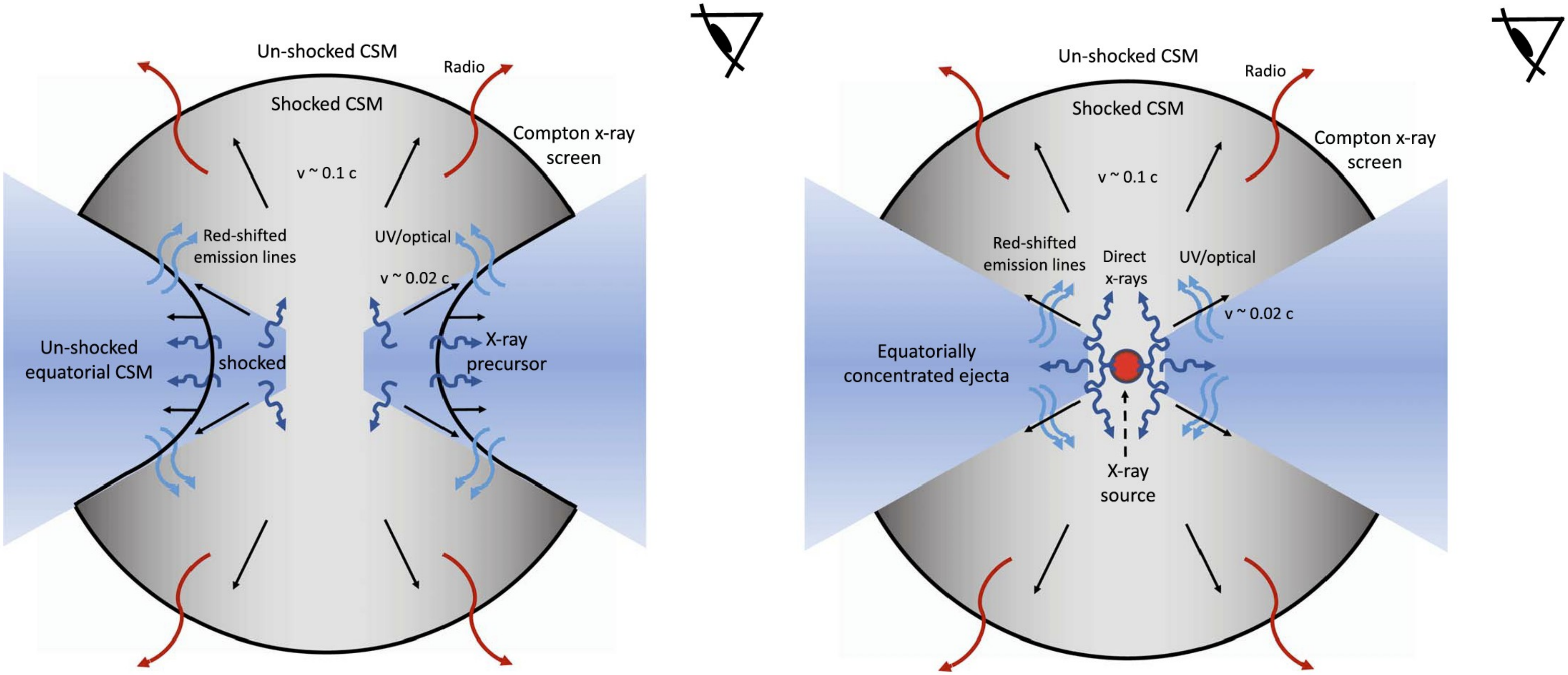
Combined model



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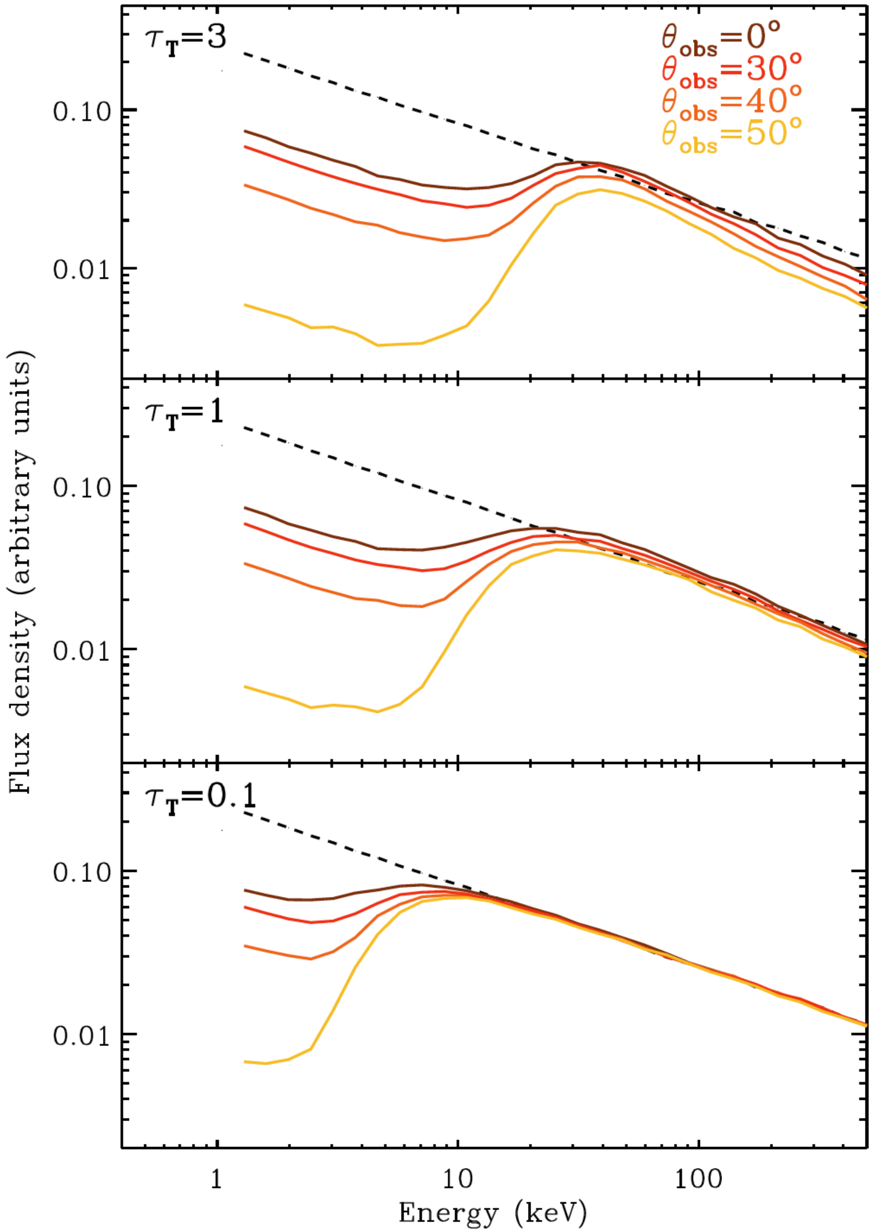

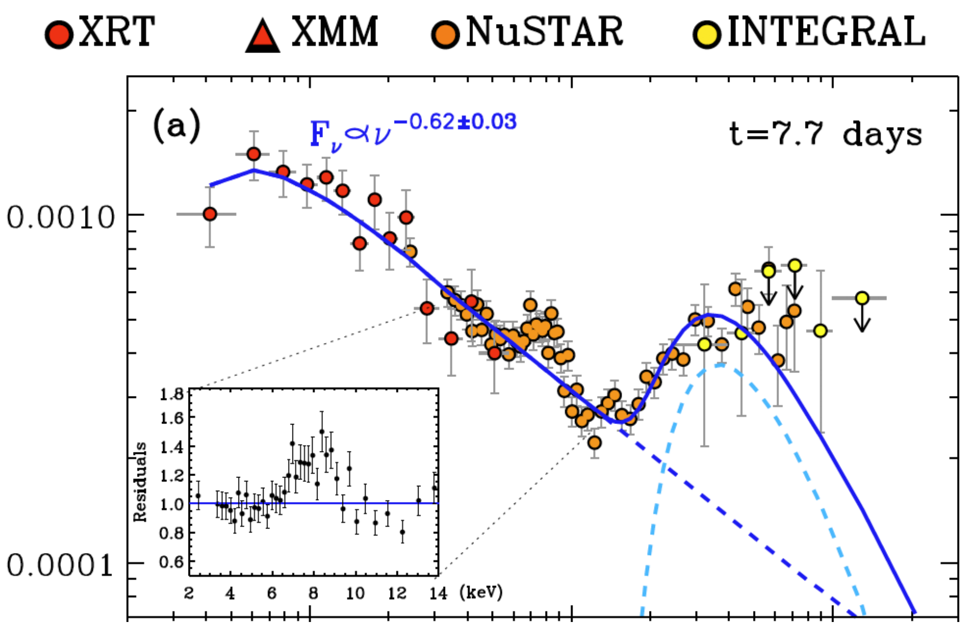

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Conclusion and Future work

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

z	0.0140	Redshift (from host emission)
t_{rise}	$\sim$2.5 d	Rise time to peak (g)
$t_{\mathrm{rise},1/2}$	$\sim$1.5 d	Time to rise from half-max (r)
$t_{\mathrm{decline},1/2}$	$\sim$3 d	Time to decay to half-max (r)
$M_{g,\mathrm{peak}}$	-20.4	Peak g absolute magnitude
$M_{r,\mathrm{peak}}$	-19.9	Peak r absolute magnitude
$L_{\mathrm{bol,peak}}$	4×10^{44} erg s^{-1}	UVOIR luminosity at optical peak
E_{rad}	5×10^{49} erg	Total UVOIR radiative output
v_{spec}	6000 km s^{-1}	Velocity width of late emission lines
$M_{*,\mathrm{host}}$	$1.4\times10^{9}\ M_{\odot}$	Host stellar mass
$\mathrm{SFR_{host}}$	0.22 $M_{\odot}\mathrm{yr}^{-1}$	Host star-formation rate

Perley+ 2018

Extra slides

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

Component	Band	Radiated Energy (erg)
Power law	0.3–10 keV	$9.8^{+0.2}_{-0.1} \times 10^{48}$
Power law	0.3–50 keV	$2.5^{+0.4}_{-0.3} \times 10^{49}$
Hard X-ray bump	20–200 keV	$\sim 10^{49}$
Blackbody	UVOIR	$1.0^{+0.2}_{-0.2} \times 10^{50}$
Non-thermal[a]	UVOIR	$\sim 5 \times 10^{48}$
Total		$\sim 1.4 \times 10^{50}$ erg

Note.
[a] Based on the analysis from Perley et al. (2019).

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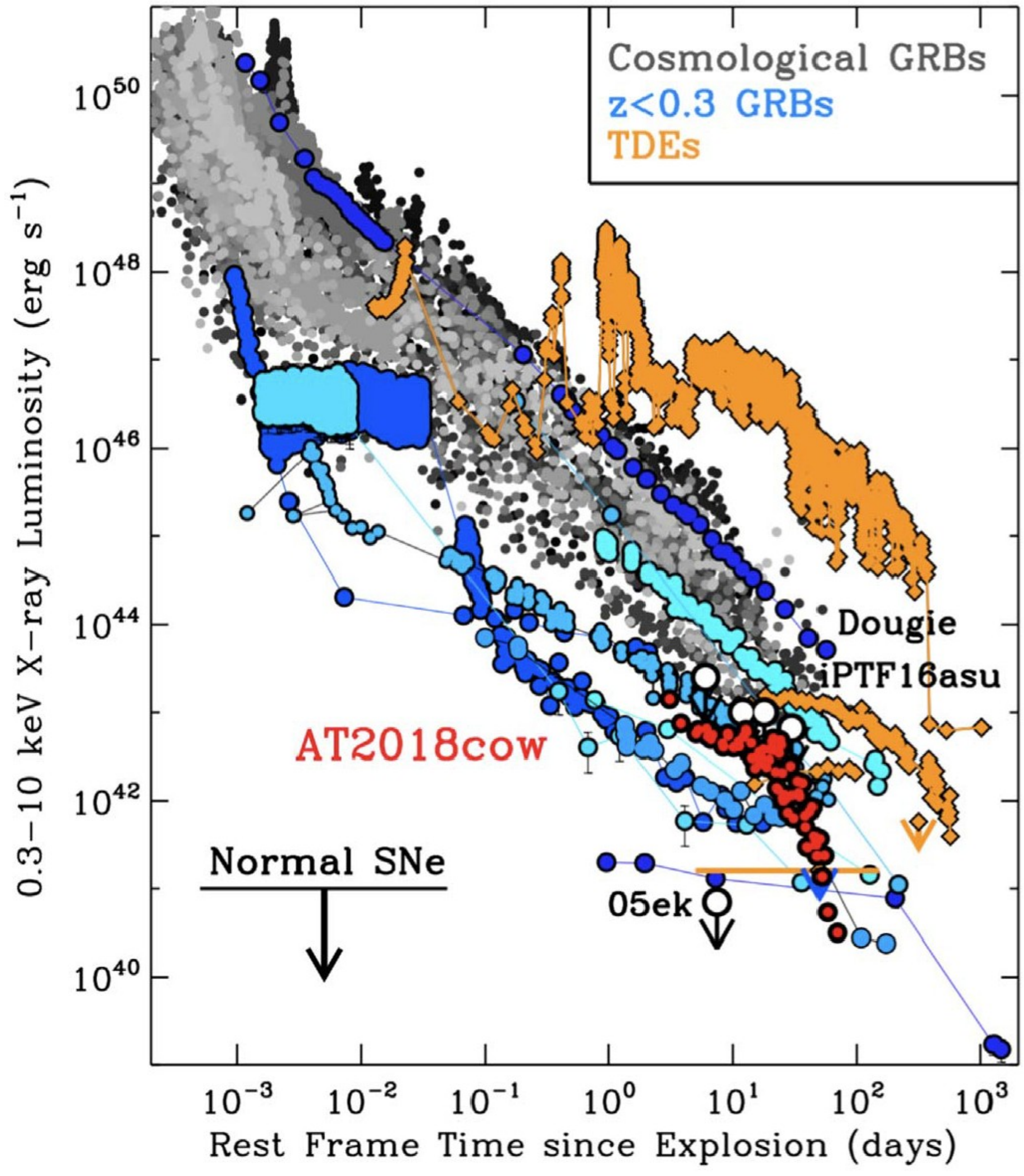
Extra slides



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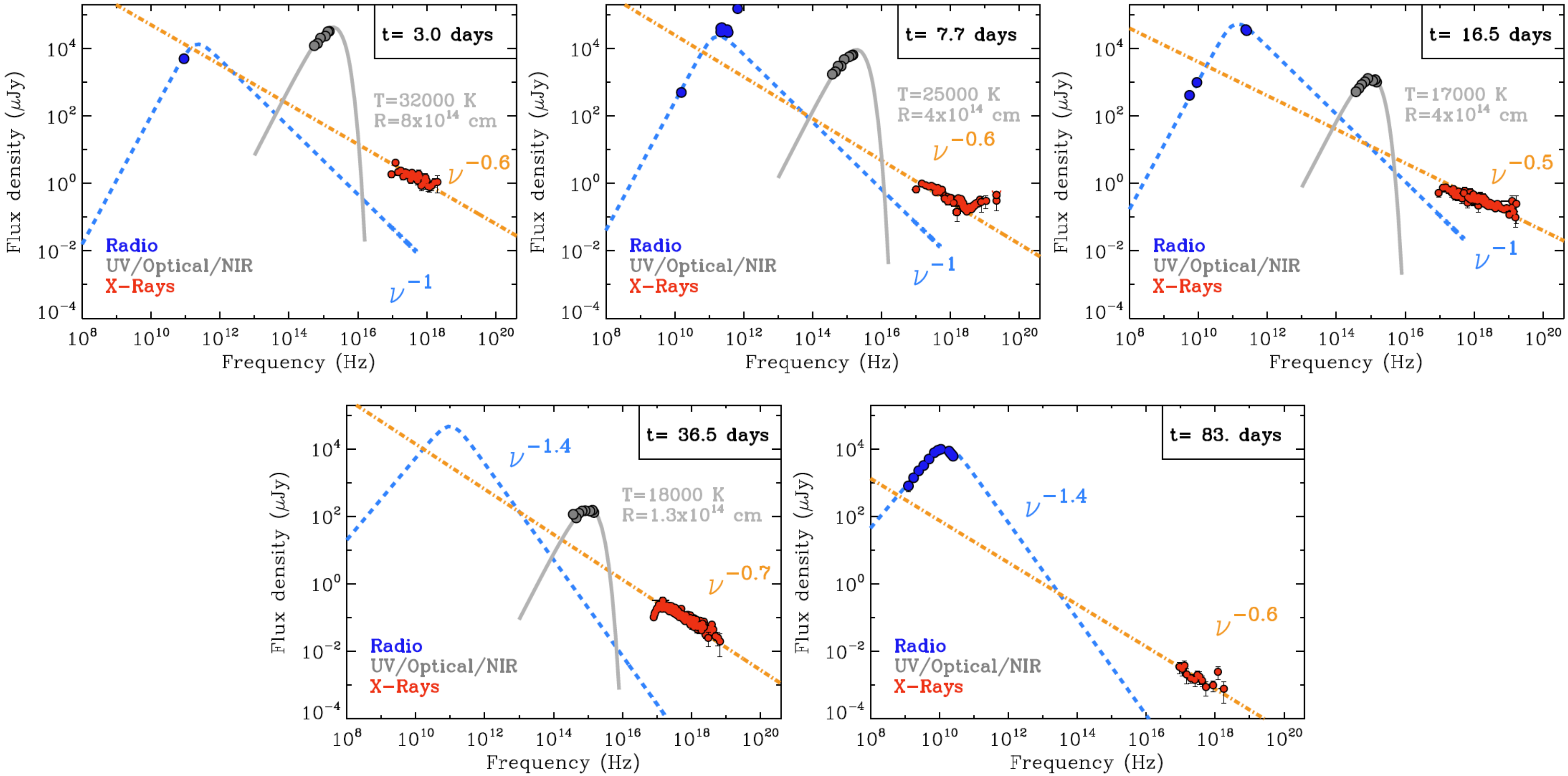

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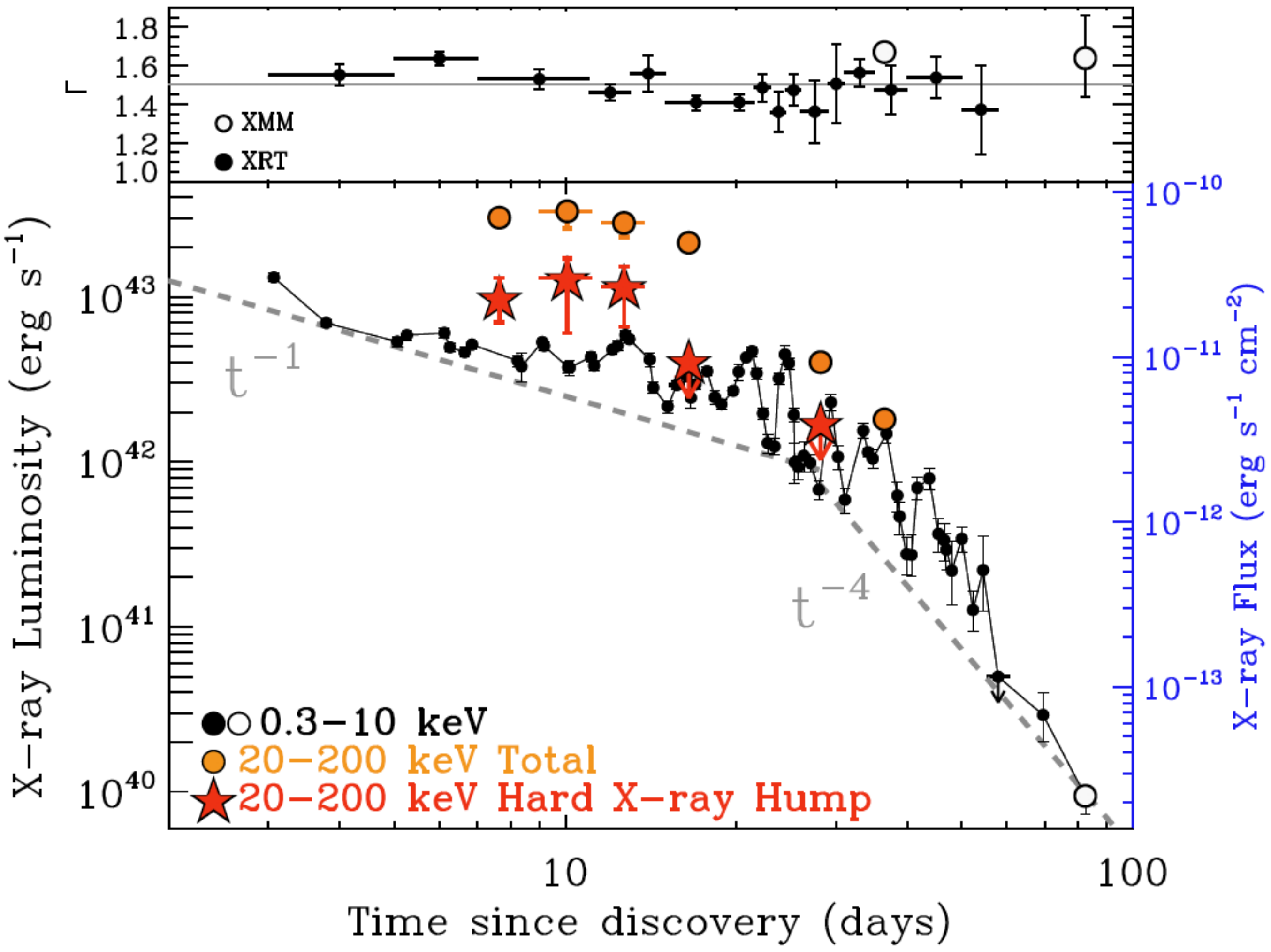

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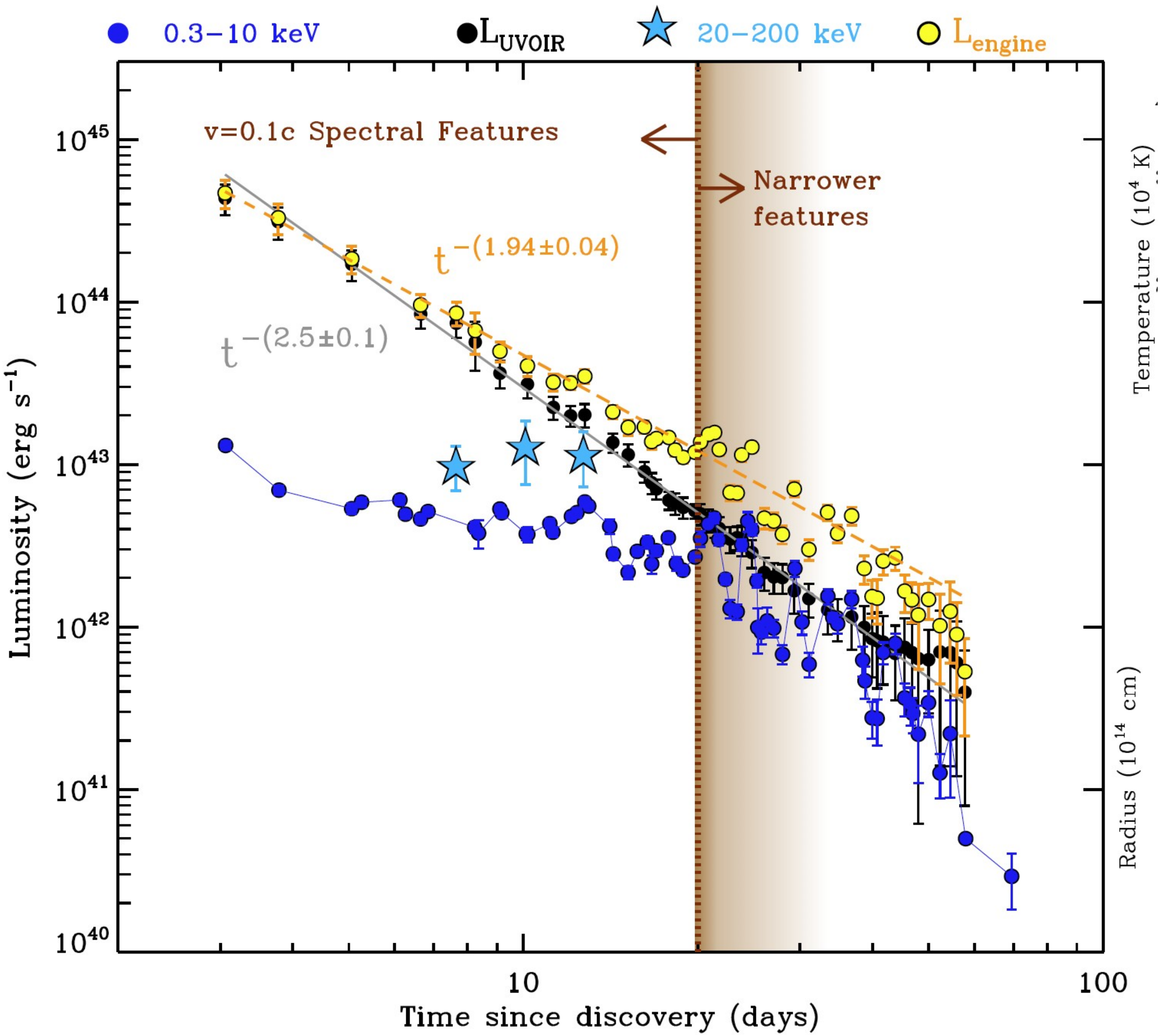

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Table 2
Central X-Ray "Engine" Models for AT 2018cow

Model	Ejecta Mass/Velocity	Engine Timescale	CSM?	He?	H?	References
NS–NS Merger Magnetar	×	✓	×	×	×	1
WD–NS Merger	✓	✓	×	×	×	2
IMBH TDE	✓	Maybe[a]	×	✓	✓	3
Stripped-Envelope SN + Magnetar/BH	✓	✓	✓	Maybe	×	4
Electron Capture SN + Magnetar	✓	✓	✓	✓	✓	5
Blue Supergiant Failed SN + BH	✓	✓	✓	✓	✓	6
SN + Embedded CSM Interaction	✓	✓	✓	✓	✓	7

Note.
[a] If circularization is efficient.

References. (1) Yu et al. (2013), Metzger & Piro (2014), (2) Margalit & Metzger (2016), (3) Chen & Shen (2018), (4) Tauris et al. (2015), (5) e.g., Miyaji et al. (1980), Nomoto et al. (1982), Moriya et al. (2014), and references therein, (6) Fernández et al. (2018); Quataert et al. (2018), (7) Andrews & Smith (2018), Metzger & Pejcha (2017).

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