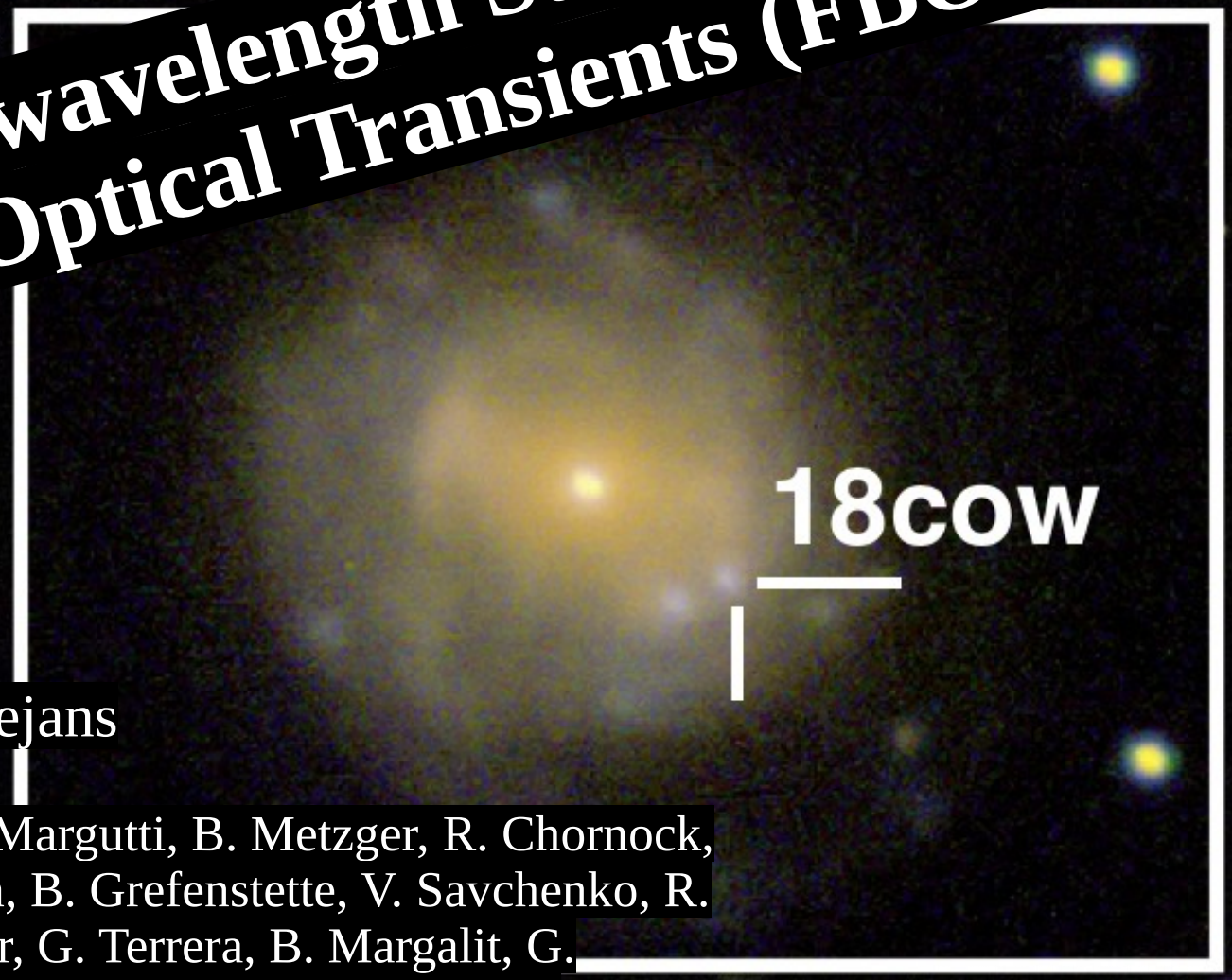
NORTHWESTERN UNIVERSITY

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

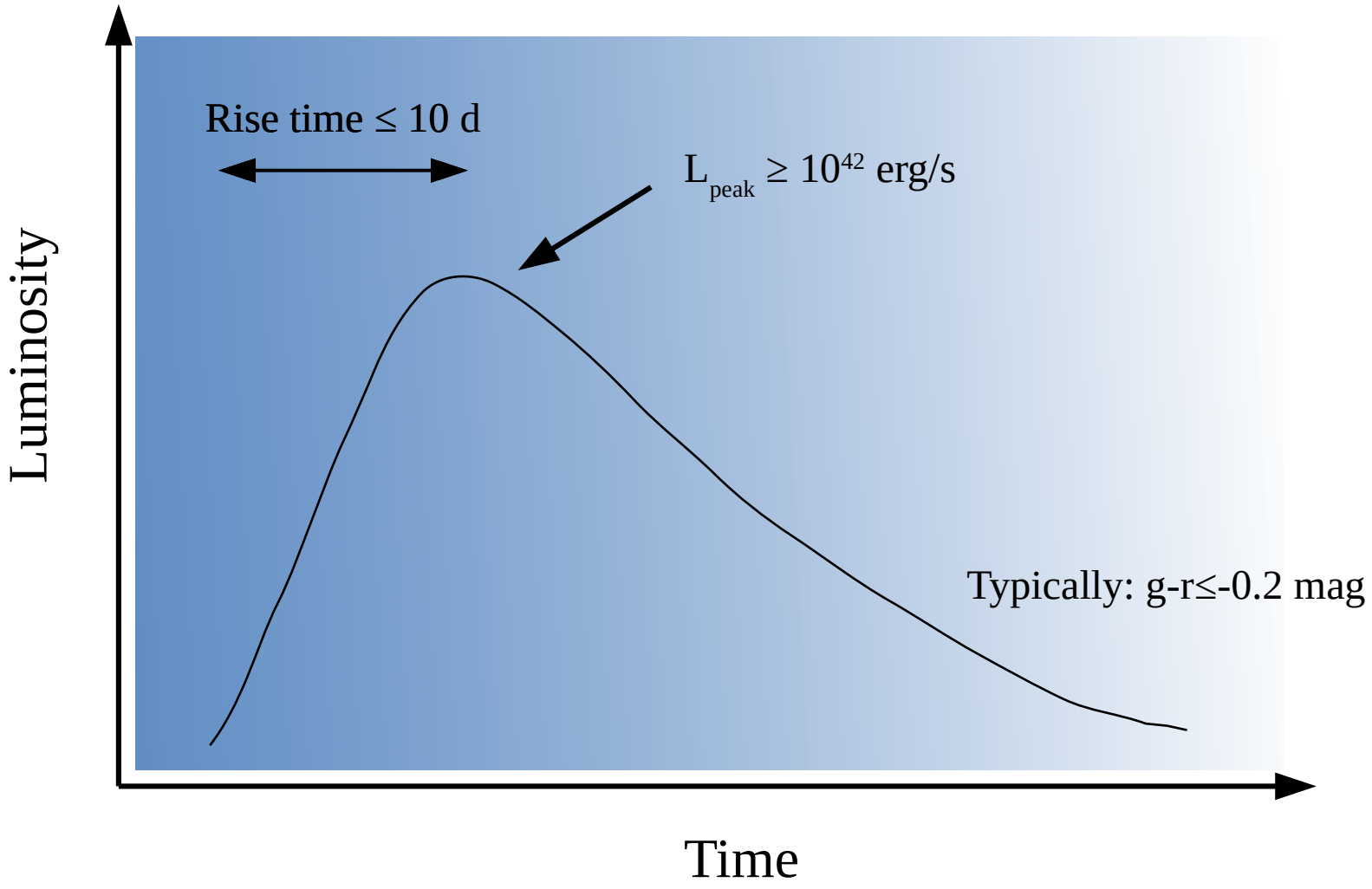


Deanne Coppejans

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...

CIERA
CENTER FOR INTERDISCIPLINARY EXPLORATION AND RESEARCH IN ASTROPHYSICS

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…)

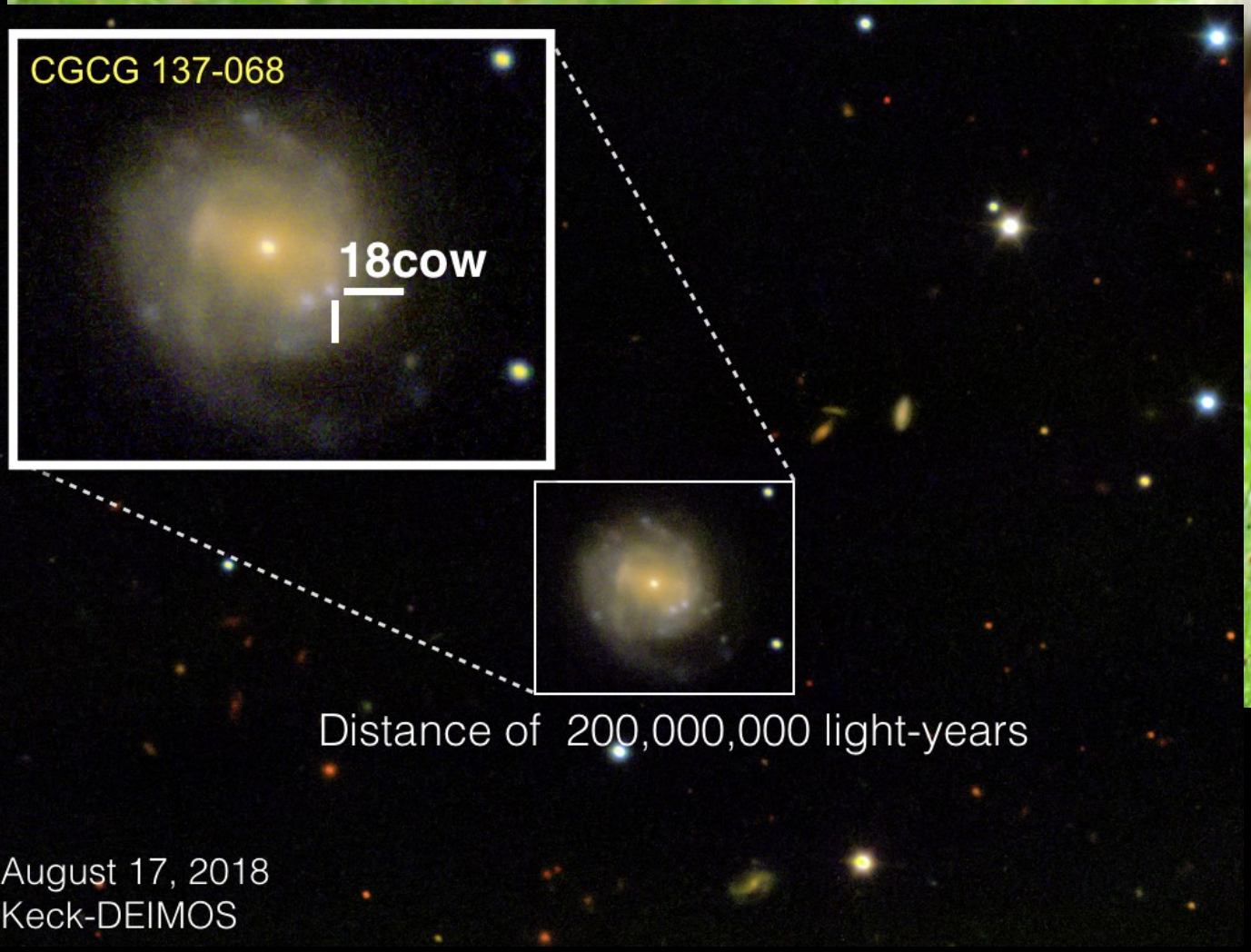
- Breakout of a SN shock from a dense wind or extended progenitor (e.g. Ofek+ 2010, Drout+ 2014, Pastorello+ 2015, Shivvers+ 2016, Arcavi+ 2017, Tanaka+ 2016, Rest+ 2018)

- 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)

The enigmatic supernova AT2018cow (aka “The Cow”)



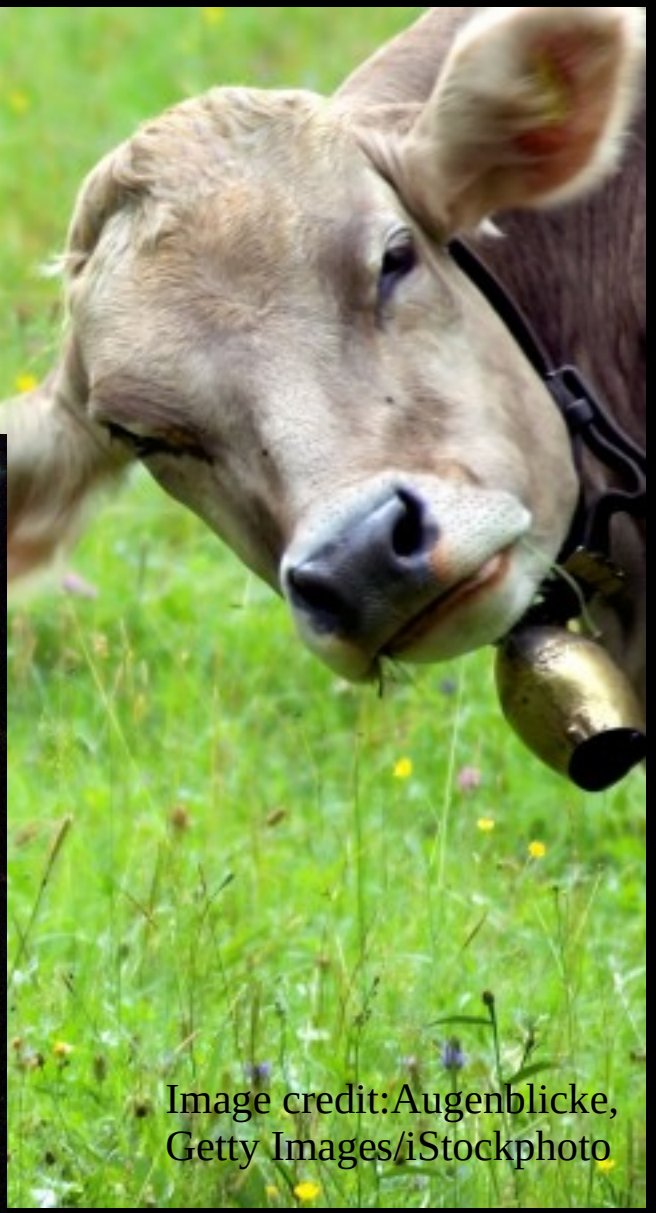
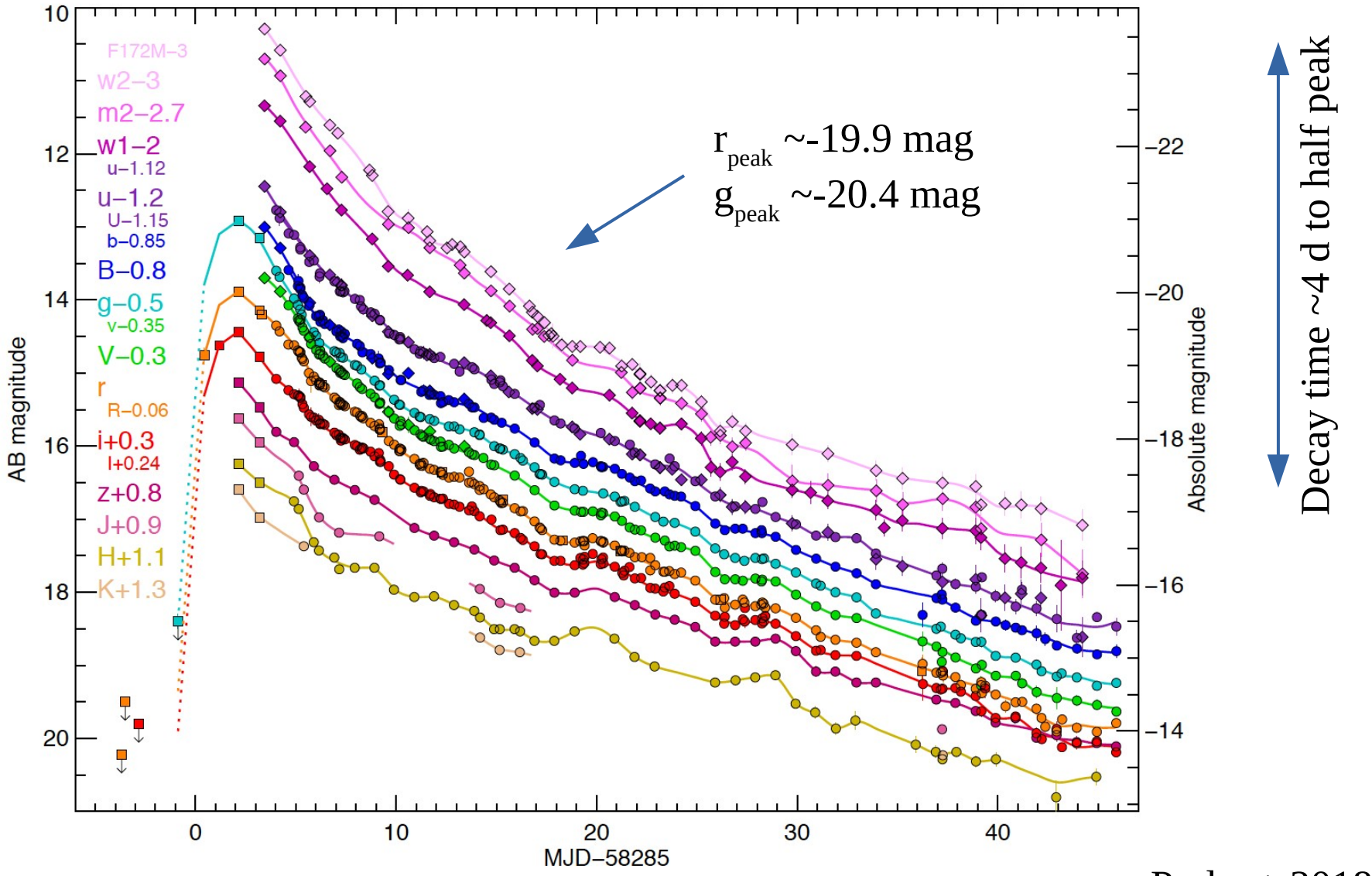


Image credit:Augenblicke, Getty Images/iStockphoto

Optical

Rise time 2-3 d (Perley+ 2018, Prentice+ 2018)

Remained blue

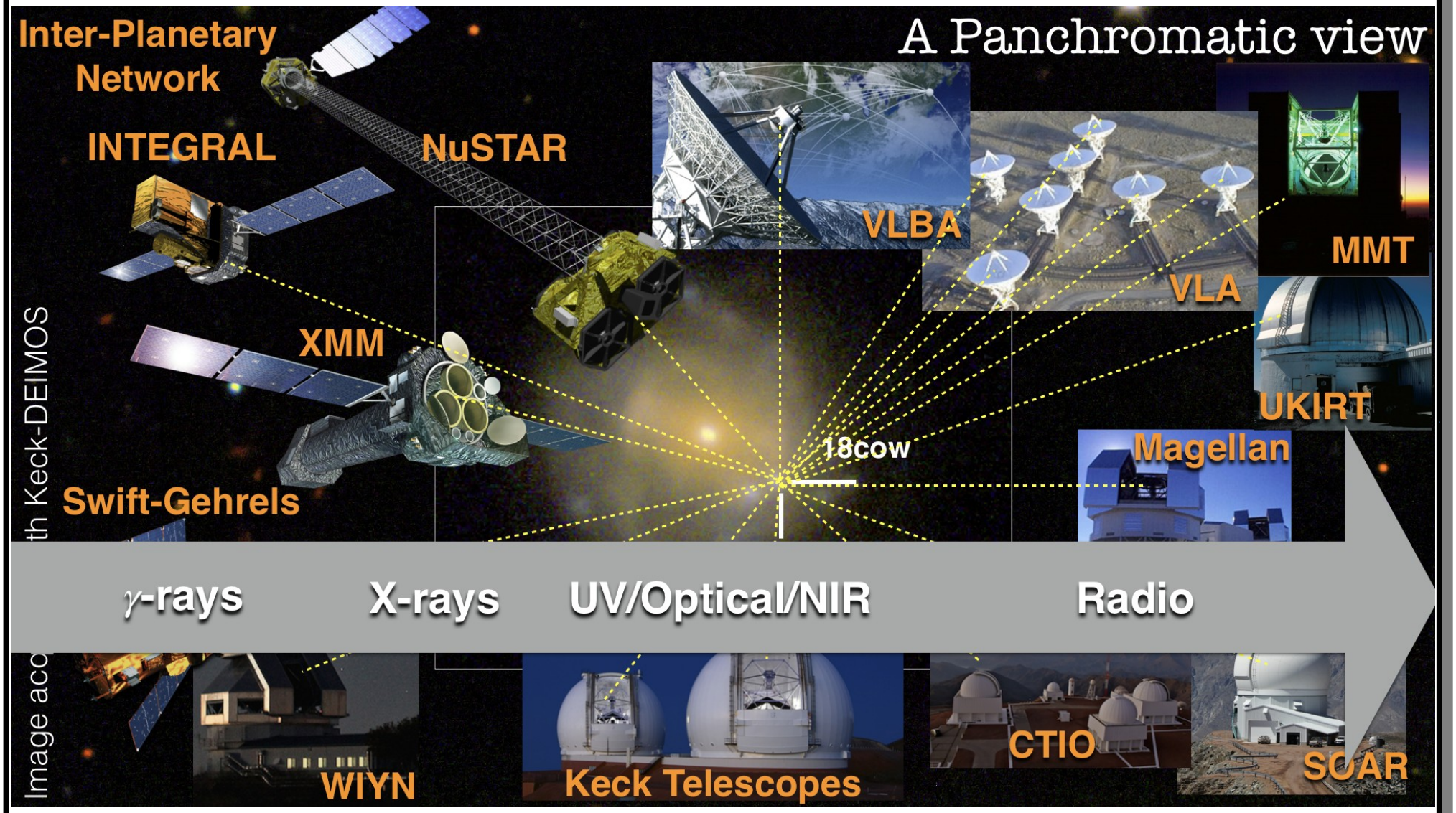


r_{peak} ~-19.9 mag

g_{peak} ~-20.4 mag

Decay time ~4 d to half peak

Perley+ 2018


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

What is the nature of the Cow?

Ni-powered

Perley+ 2018, Prentice+ 2018, Margutti+ 2018, Kuin+ 2018

Shock-breakout of a star

Perley+ 2018, Prentice+ 2018, Margutti+ 2018, Kuin+ 2018

Shock-breakout of a star with a larger effective radius

Perley+ 2018, Prentice+ 2018, Margutti+ 2018, Kuin+ 2018

Pure Interaction

Rivera Sandoval+ 2018, Fox+ 2019

Perley+ 2018, Prentice+ 2018, Margutti+ 2018, Kuin+ 2018, Ho+ 2018

Engine powered

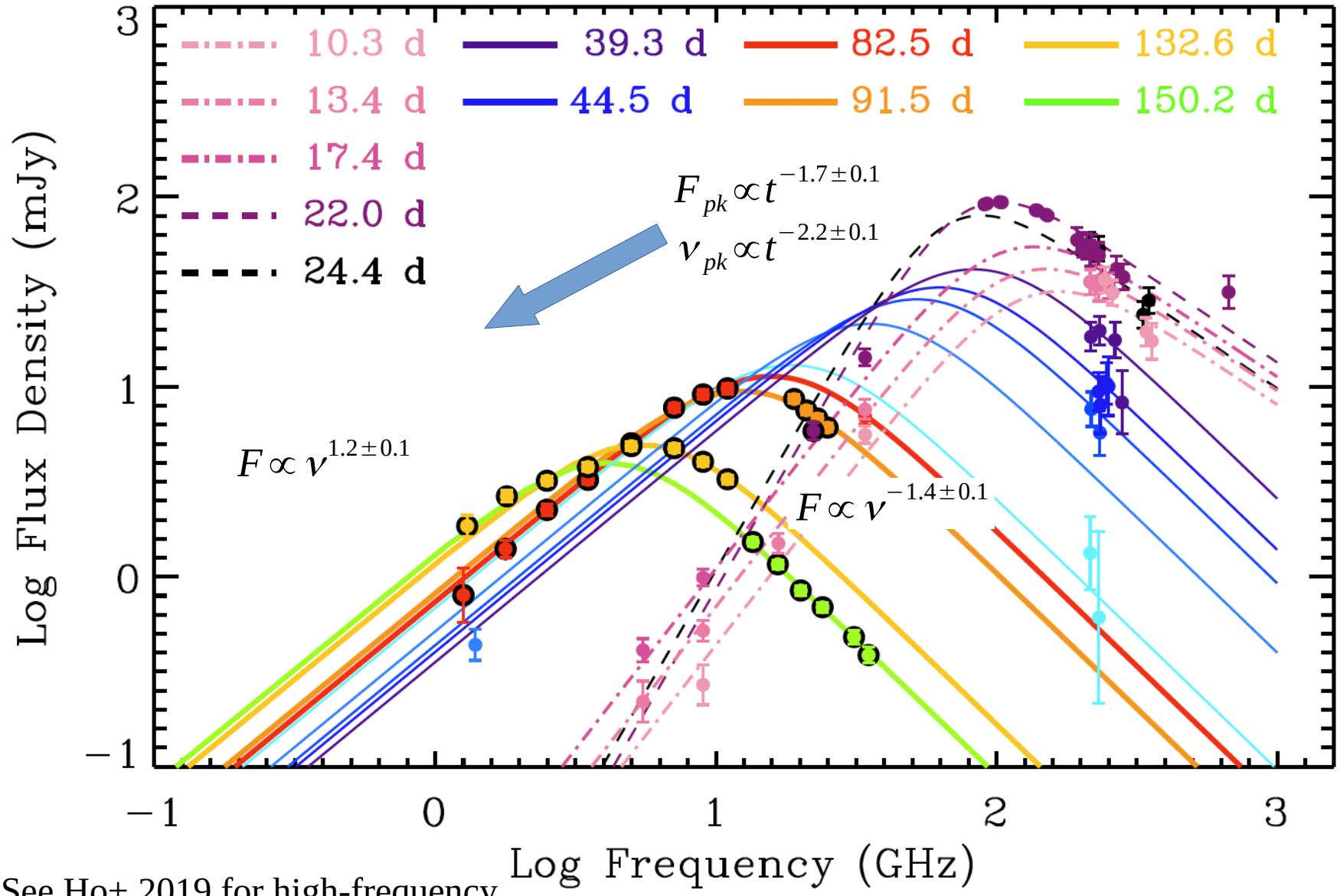
Perley+ 2018, Prentice+ 2018, Kuin+ 2018, Margutti+ 2018, Ho+ 2018, Lyutikov & Toonen+ 2018

Fox+ 2019

Ruled out/disfavoured by these authors

Suggested or ruled plausible by these authors

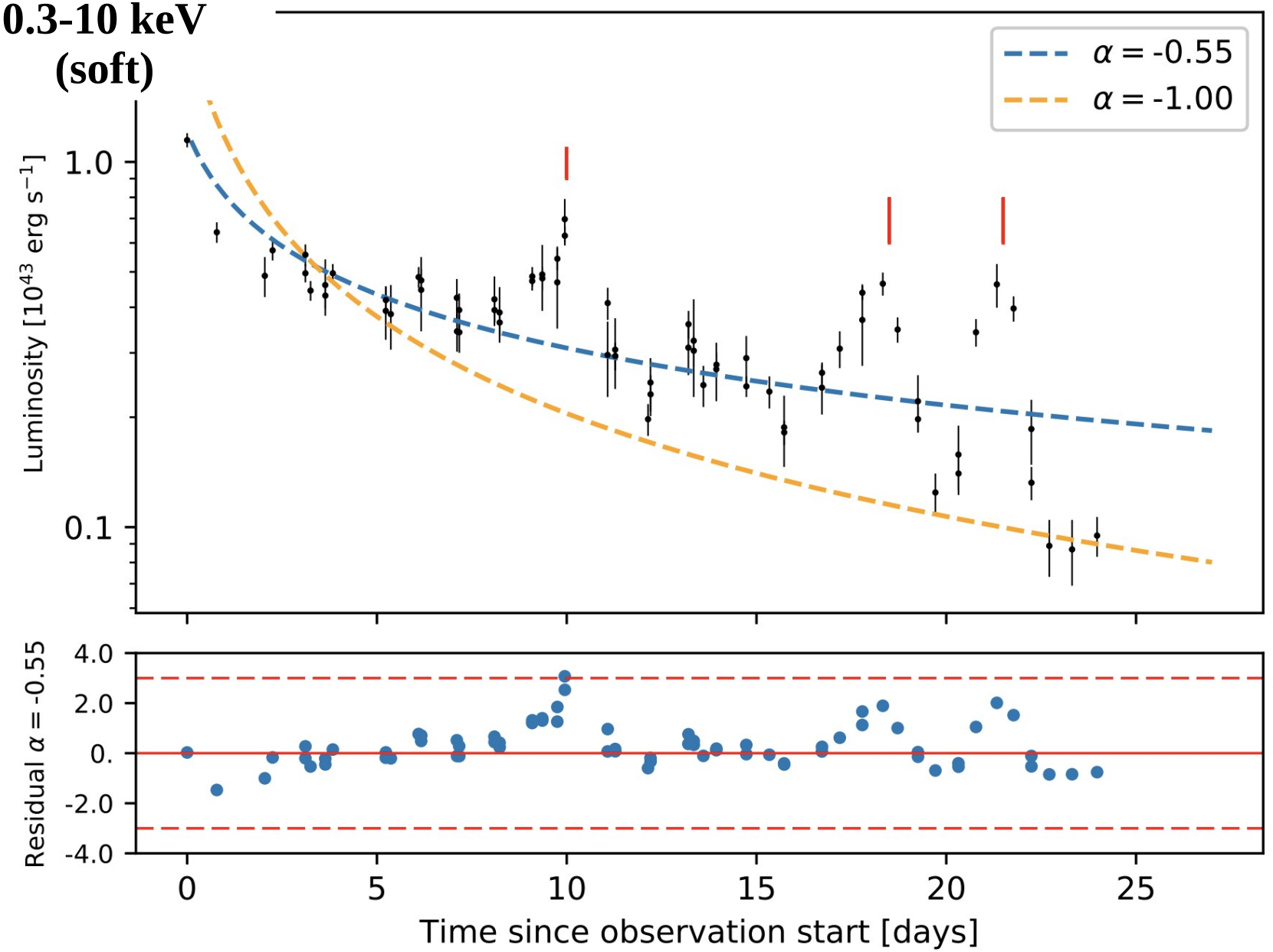
Radio



See Ho+ 2019 for high-frequency early observations

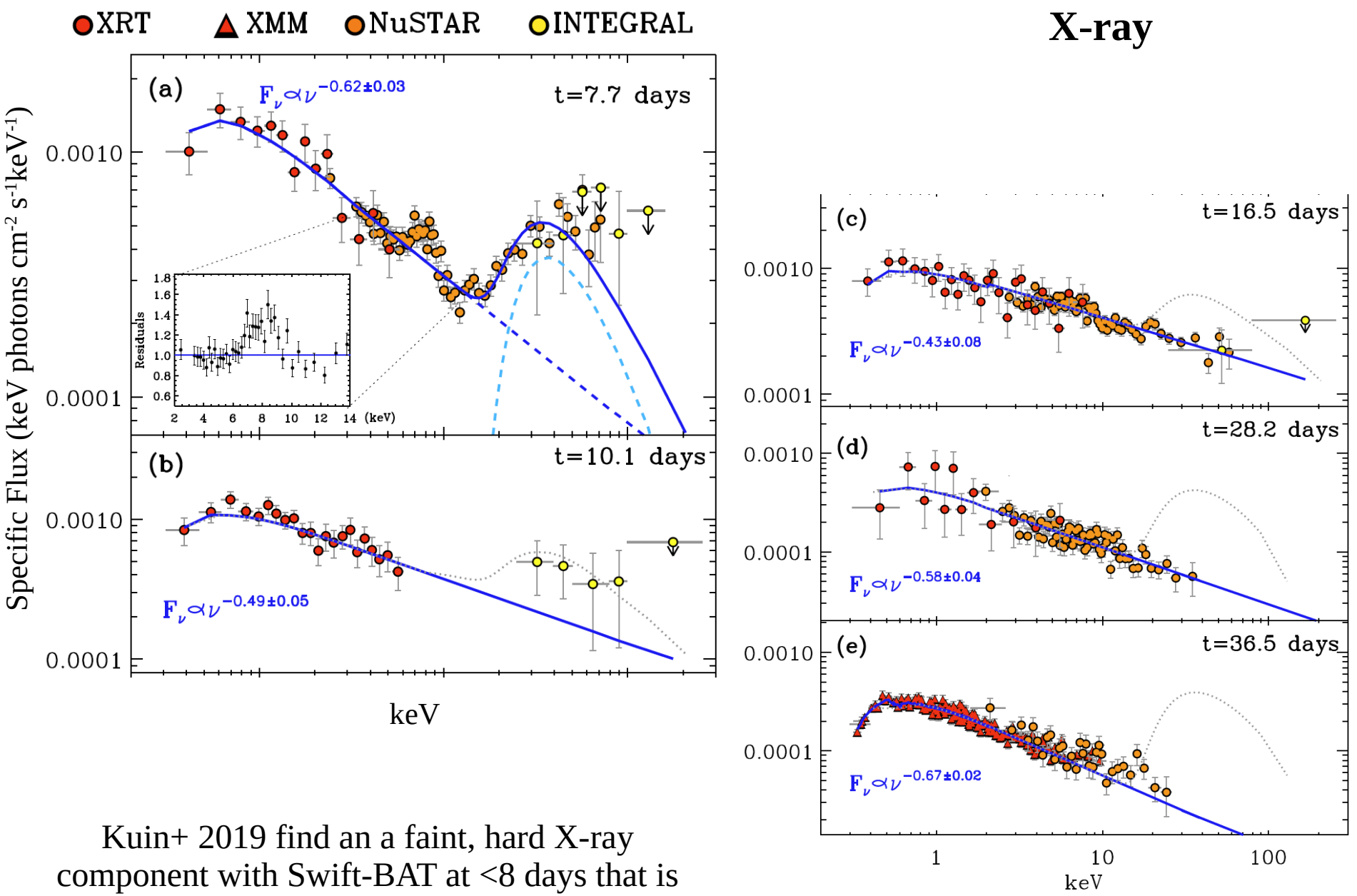
Margutti+ 2019

X-rays
0.3-10 keV
(soft)



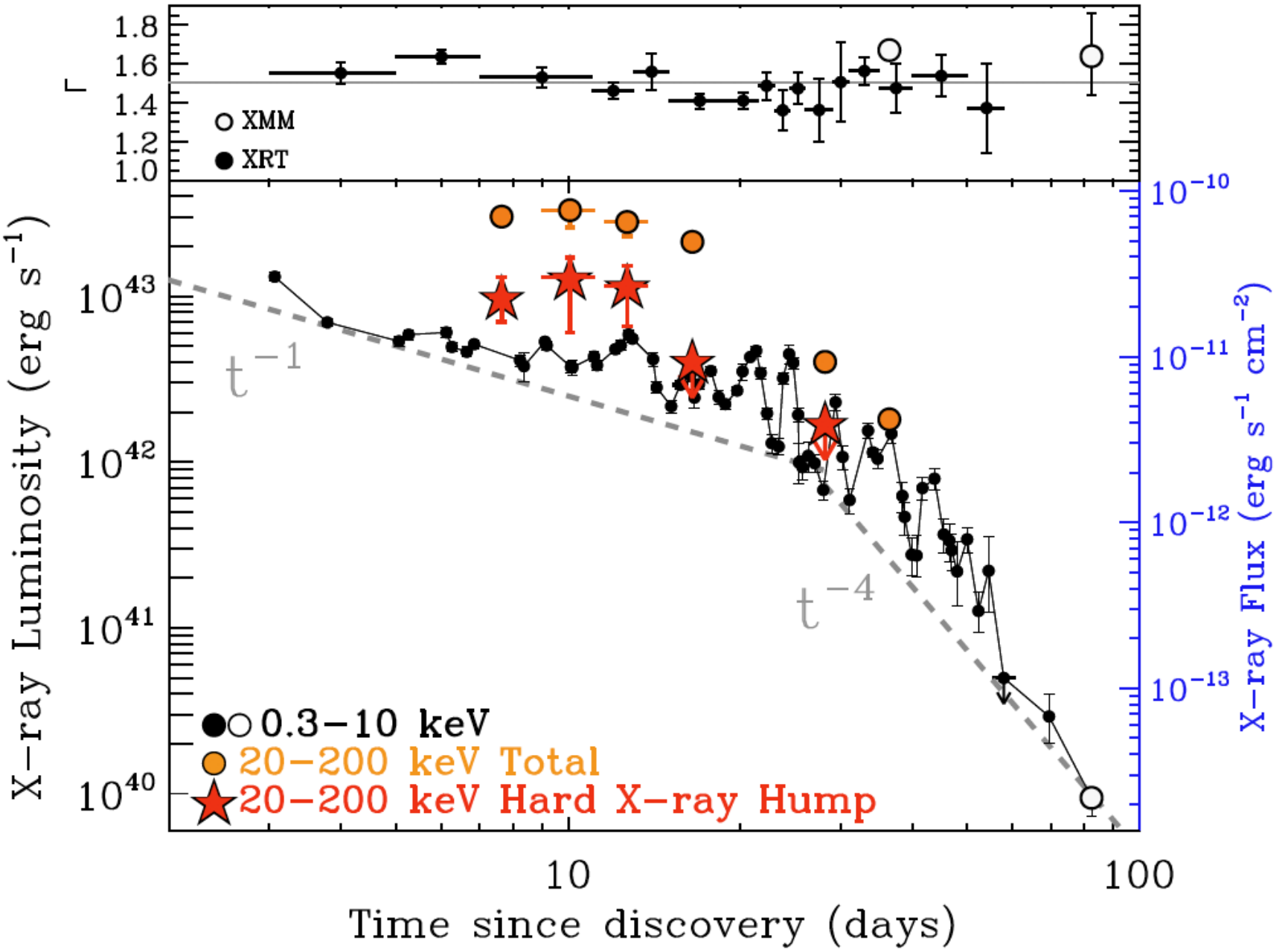
Rivera Sandoval+ 2018

X-ray



Kuin+ 2019 find an a faint, hard X-ray component with Swift-BAT at <8 days that is consistent with the flux of the hard X-ray bump

Margutti+ 2019



Margutti+ 2019

Does a pure interaction scenario account for all the X-ray properties?

Soft X-ray Spectrum (α~-0.5)

Transient hard X-ray component

Variability timescales

Fast fall-off in X-rays

Does a pure interaction scenario account for all the X-ray properties?

Soft X-ray Spectrum (α~-0.5)

No: Electrons are in the fast cooling regime, so $F \sim \nu^{-p/2}$

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Transient hard X-ray component

Can't be produced by IC from a relativistic Maxwellian distribution of electrons as the spectral energy peak is a factor <100 times larger than expected

Variability timescales

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CSM

Fast fall-off in X

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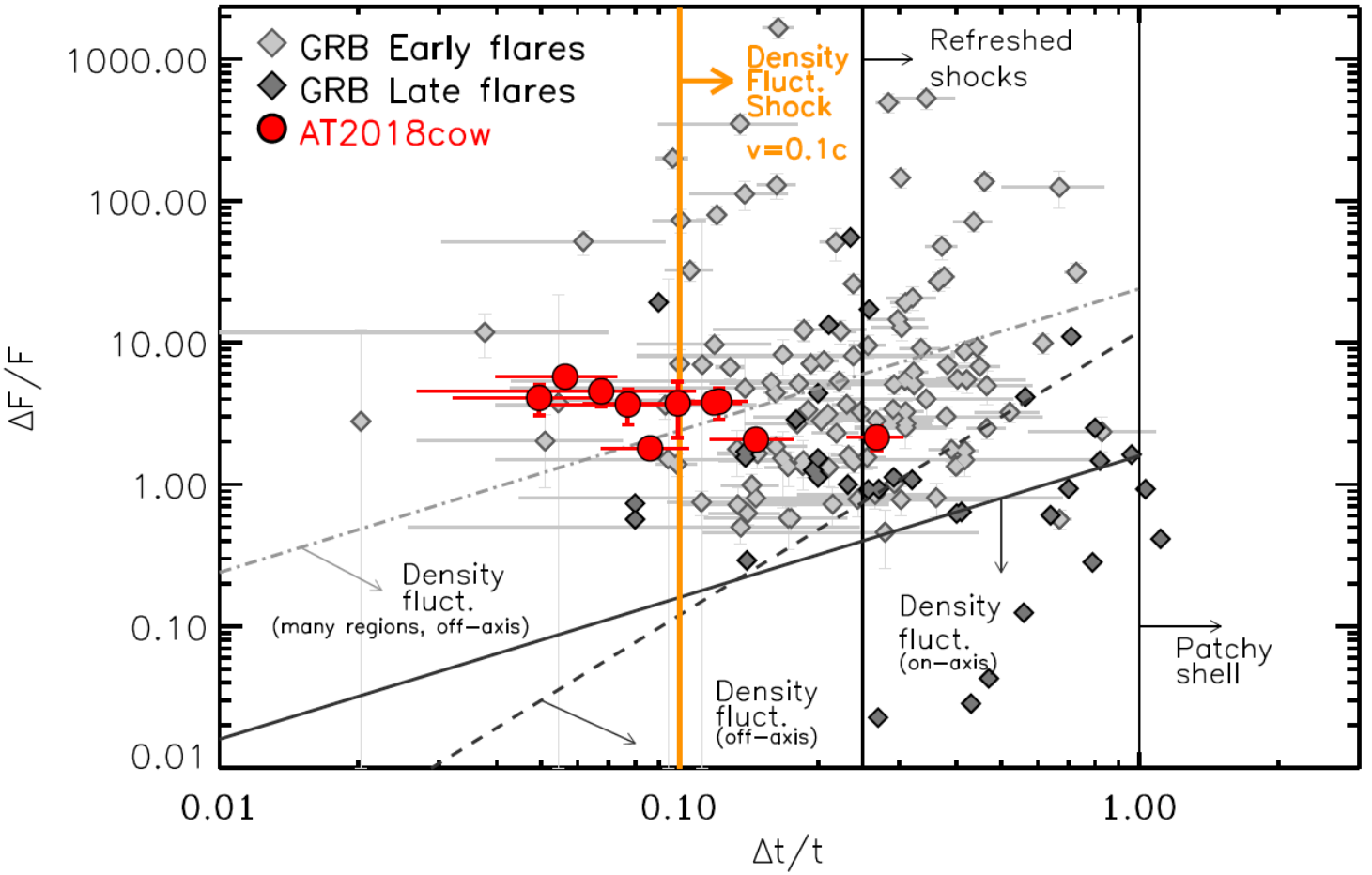

Margutti+ 2018, see Ioka+ 2005 for constraints

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Variability timescales

If the overdensity regions occupy a large fraction of the solid angle:

Violate the light-crossing time if the ejecta cover a large fraction of the viewing angle (we need $\Delta t/t > 0.1\text{-}0.2c$) AND No linear increase in duration

If we instead have a clumpy medium:

Duration and amplitude of flares are not consistent with density fluctuations in the CSM

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Fast fall-off in X-rays

We would expect a fall off of $L_x \sim t^{-1}$ for a spherical blastwave and $L_x \sim t^{-2}$ for a jet

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Ni-powered
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Conclusion and Future work

First radio to gamma-ray study of an FBOT

X-ray properties (in particular) imply the presence of a central engine

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

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