Multi-Messenger Astrophysics Workshop (MMAW)

EGO, 11 October 2022

Multi-messenger astrophysics at the Moon

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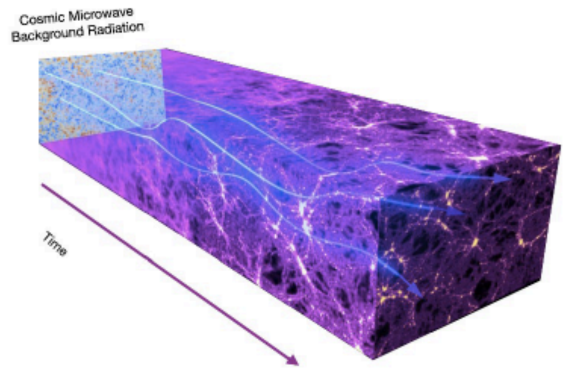
Decadal Survey on Astronomy and Astrophysics 2020 (Astro2020)

Science Theme: New Messengers and New Physics

New Messengers and New Physics captures the scientific questions associated with inquiries ranging from astronomical constraints on the nature of dark matter and dark energy, to the new astrophysics enabled by combined observations with particles, neutrinos, gravitational waves, and light

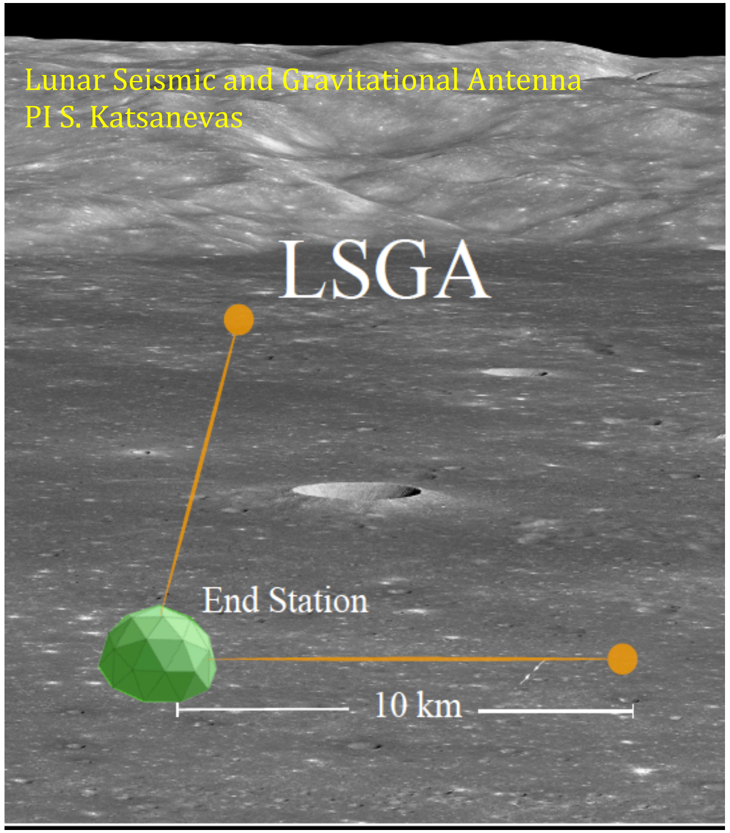


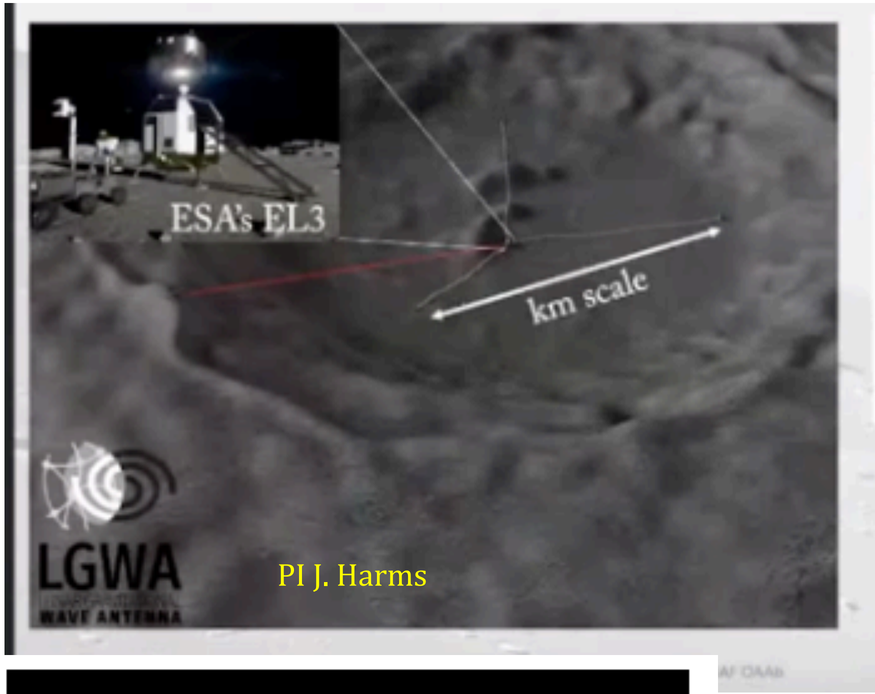
This theme is forefront this decade because of:

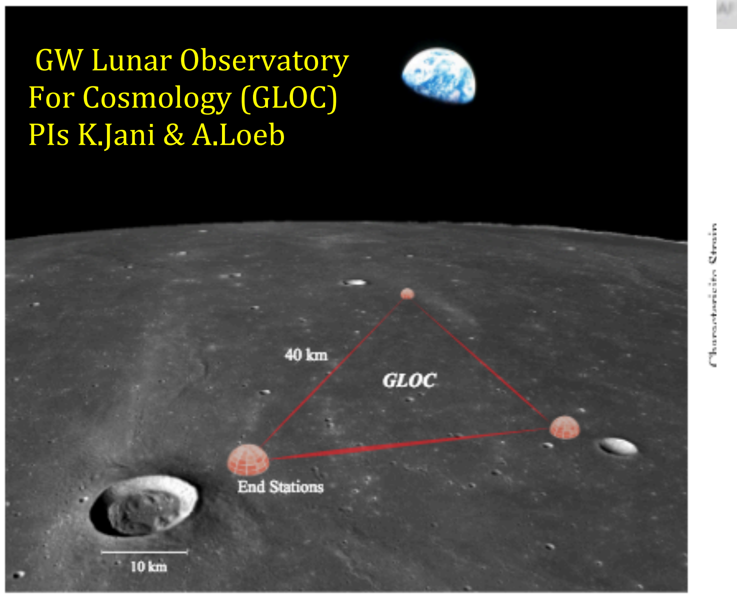
- Tremendous progress in observations of the Cosmic Microwave Background
- Time domain surveys that have uncovered an astounding array of transient phenomena
- The discovery of compact object mergers with LIGO, and the detection of electromagnetic counterparts
- Ice Cube's detection of high energy neutrinos of astrophysical origin

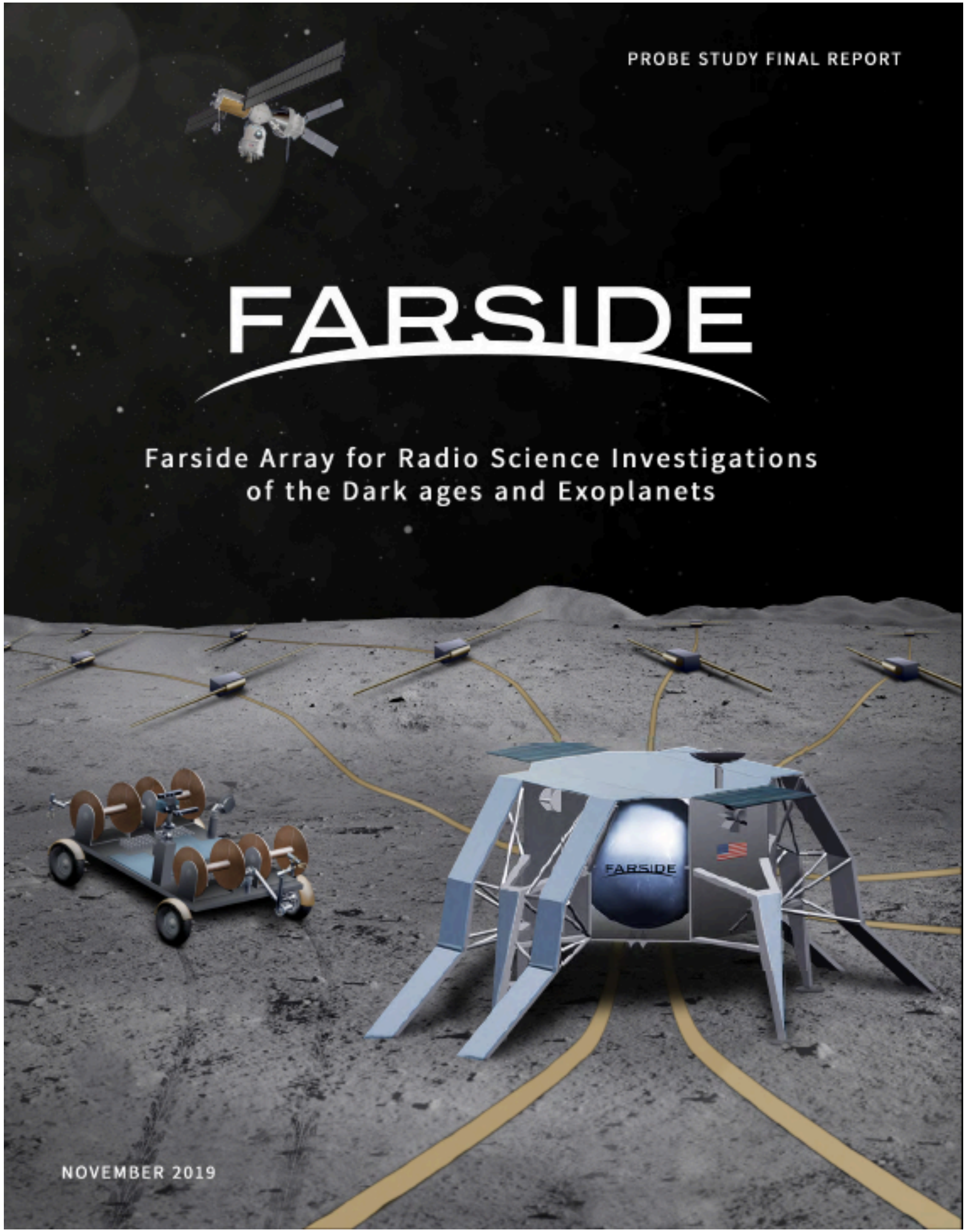
Nap.edu/astro2020

Gravitational wave detection experiments on the Moon aim at catching low-frequency (0.1-1 Hz) signals









FARSIDE

1) Minimal anthropogenic radio interference
2) Unencumbered by ionosphere

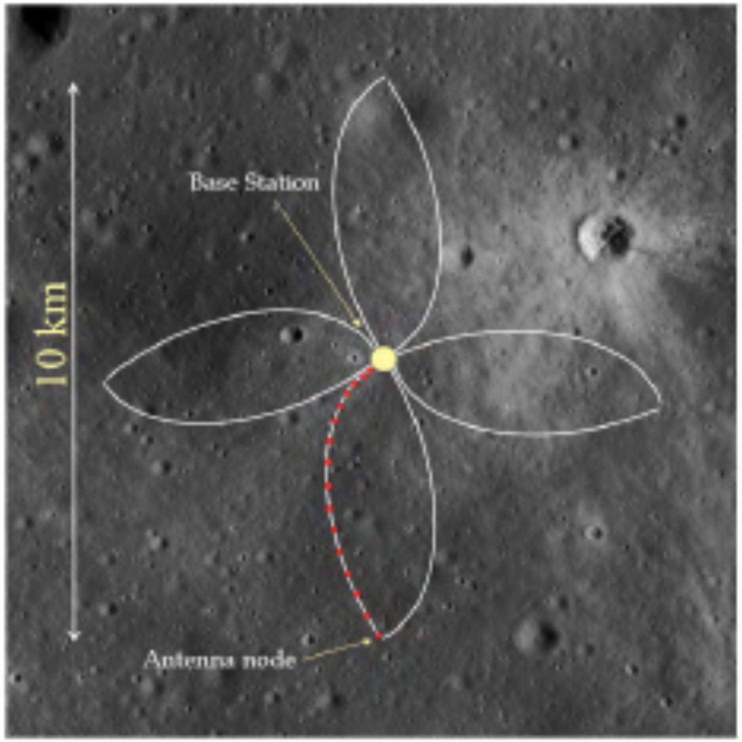


Figure 3.1-1. FARSIDE will consist of 128 antenna nodes deployed by a rover from a central base station, arranged in a petal configuration.

Burns et al. 2019 (arXiv:1911.08649)

Future ultraviolet missions (apertures of 8-30 cm):

ULTRASAT (PIs: E.Waxman & S.Kulkarni)

https://www.weizmann.ac.il/ultrasat

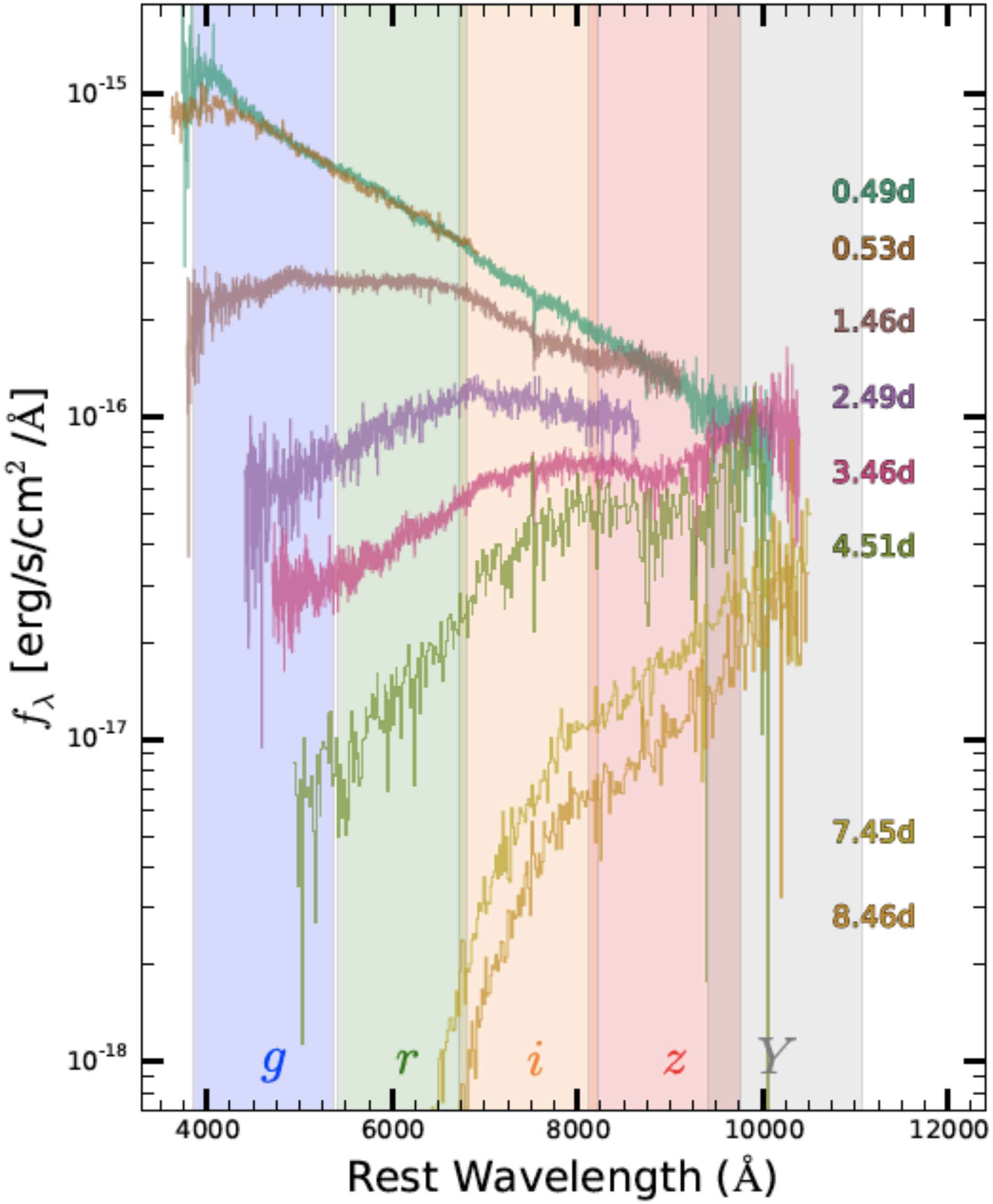
GUCI/Dorado (PI: B. Cenko)

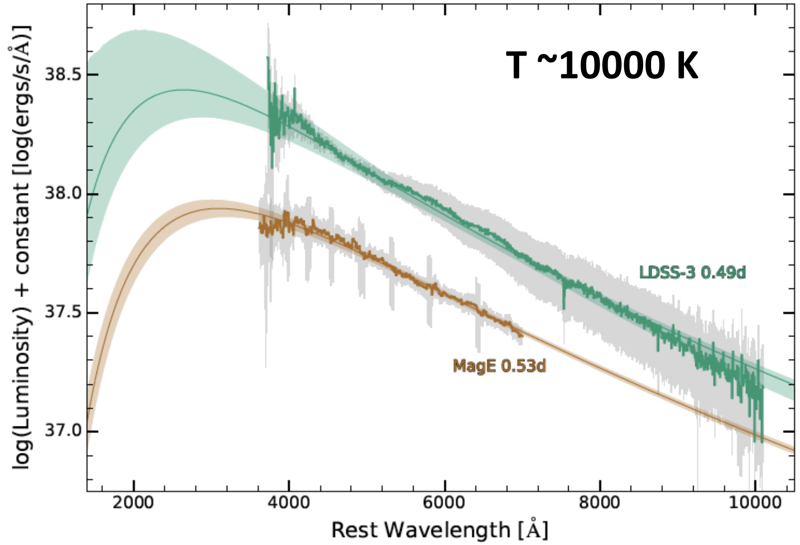
https://www.nasa.gov/sites/default/files/atoms/files/guci.pdf;
https://cor.gsfc.nasa.gov/copag/AAS_Jan2021/presentations/uvvis/Dorado_AAS.pdf

LUCI (pathfinder for the Moon)

Mathew et al. 2016, arXiv:1610.02220

Magellan spectral sequence of kilonova AT2017gfo (40 Mpc)

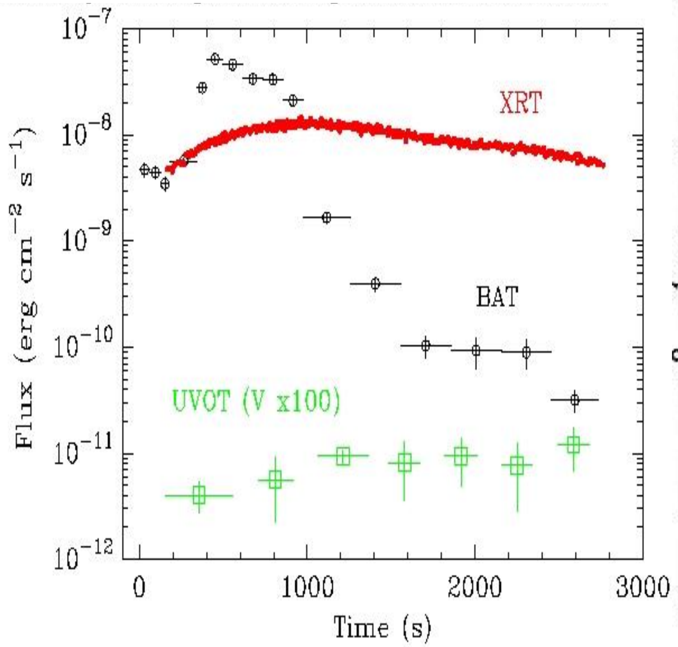


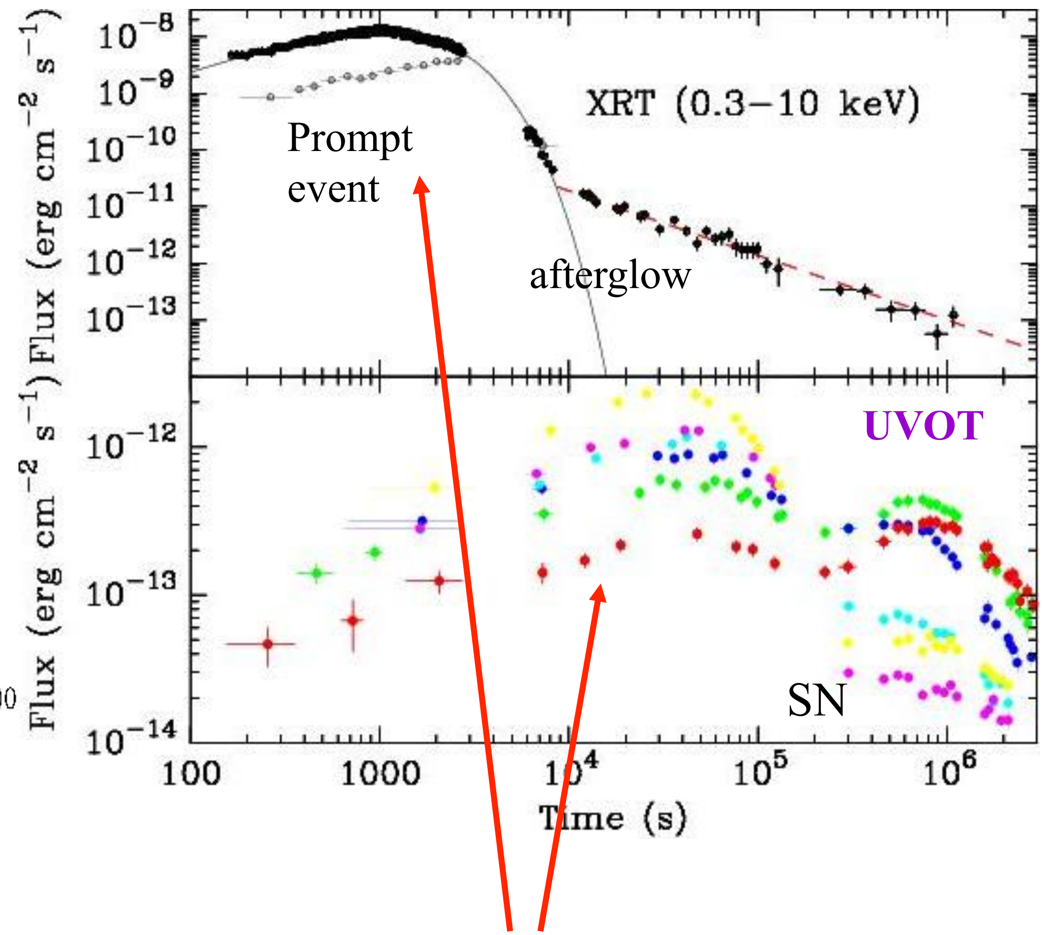


Early UV detection sets strong constraint on initial photospheric speed

Shappee et al. 2017

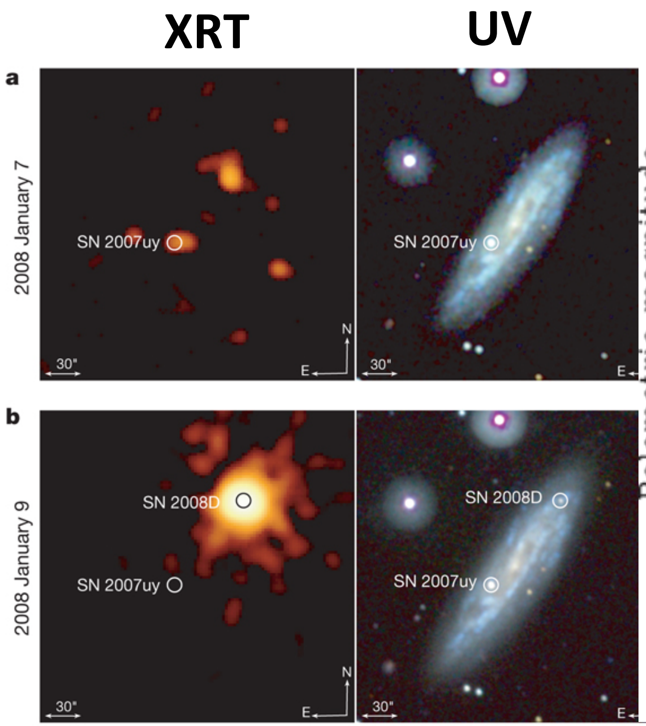
XRF060218/SN2006aj (z = 0.33)

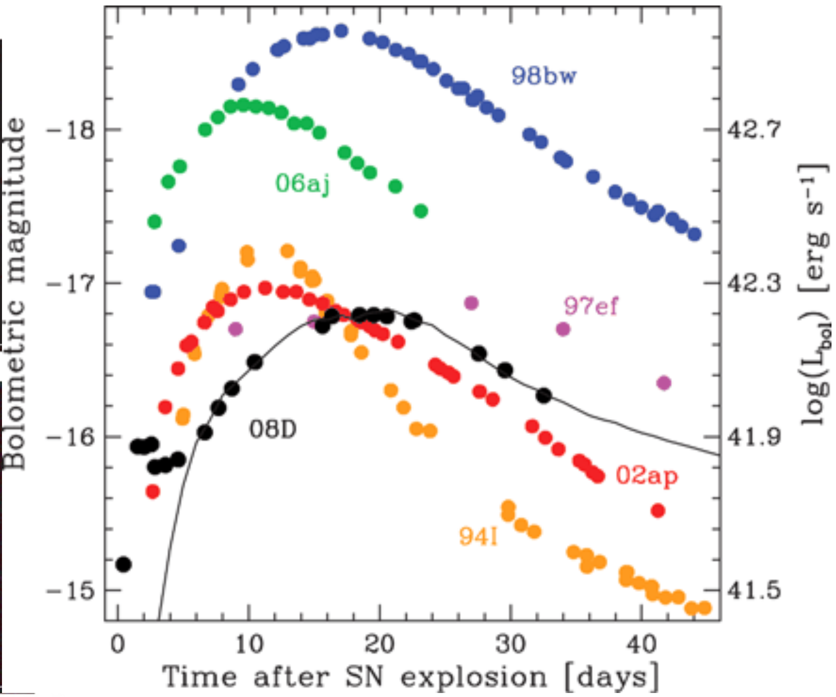


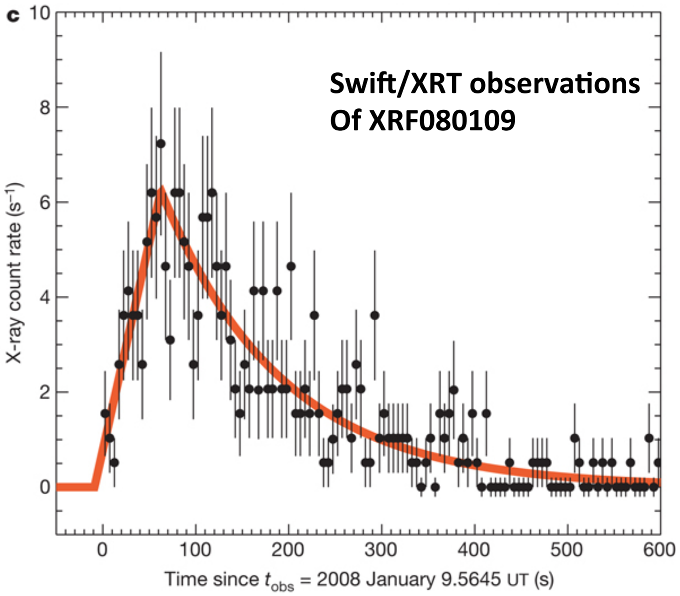


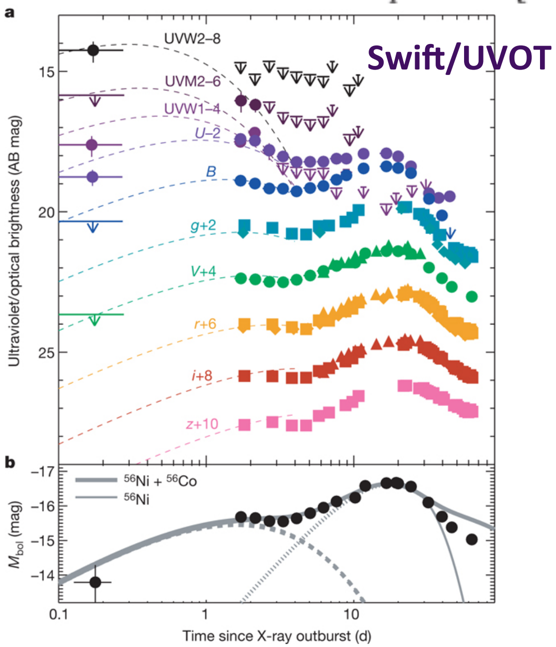
Shock breakout or jet cocoon interaction with CSM,
Or central engine, or synchrotron + inverse Compton ?

Campana et al. 2006





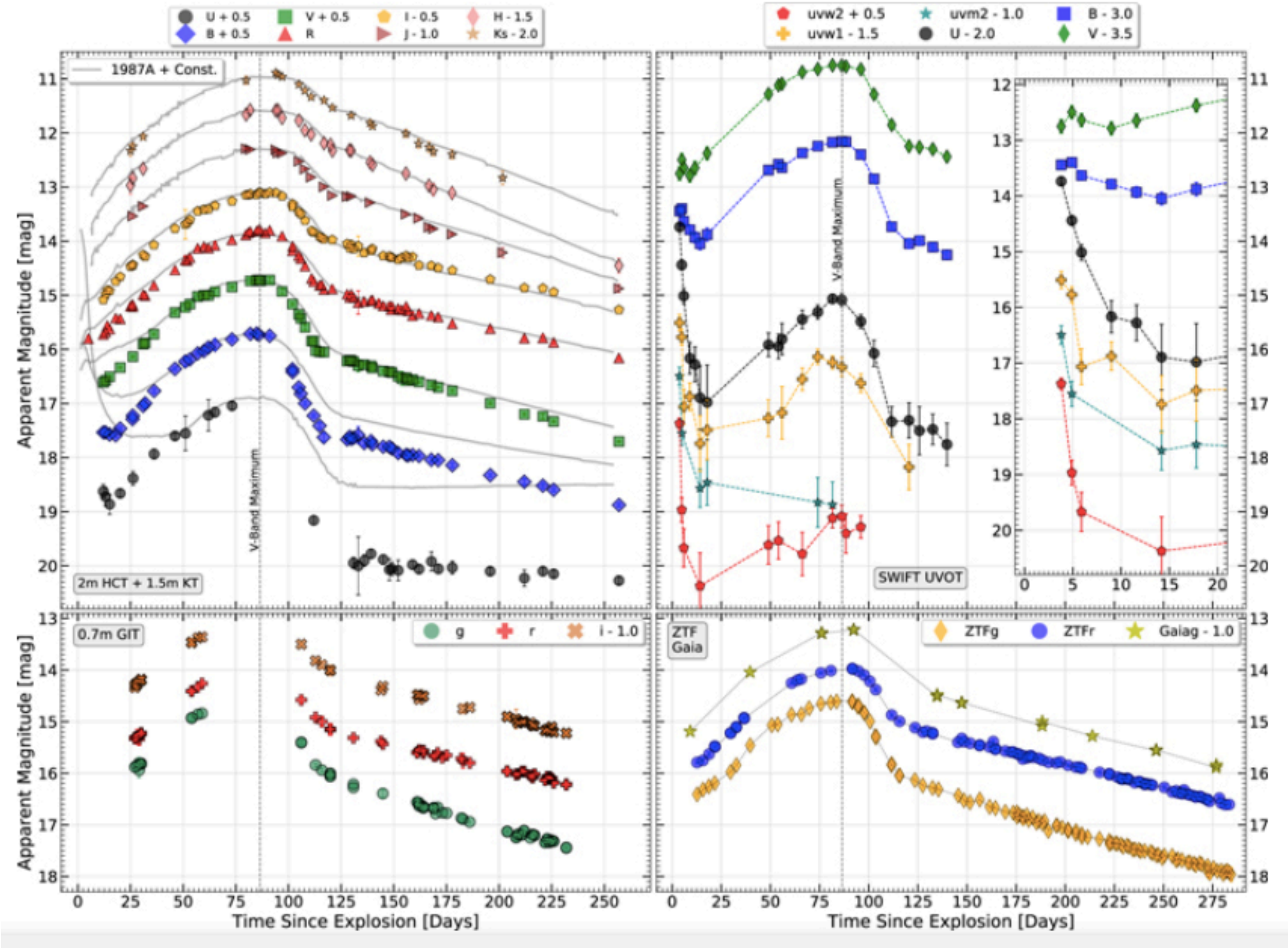




XRF080109/
SN2008D (25 Mpc)

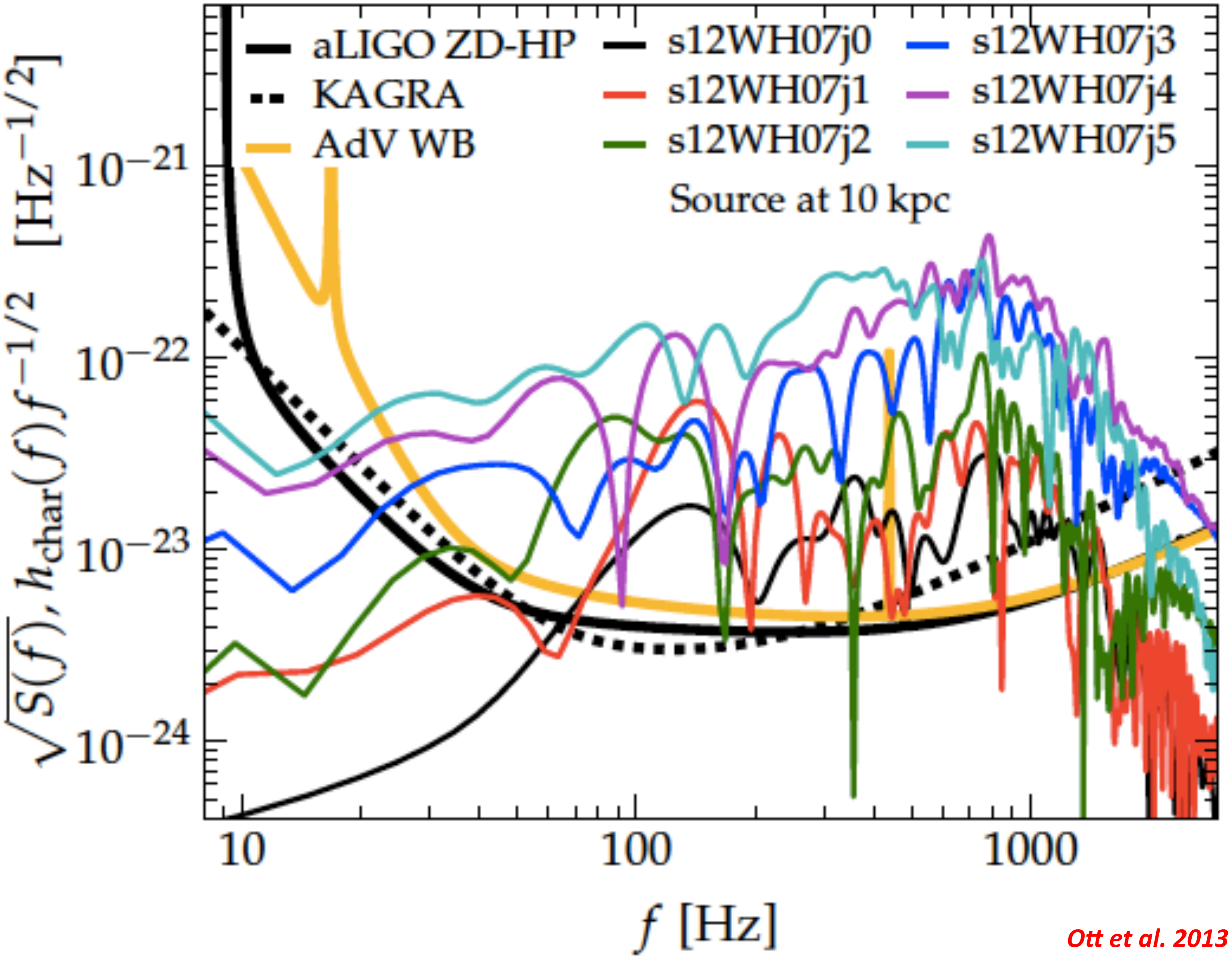
Soderberg et al. 2008
Mazzali et al. 2008

Core-Collapse (Type II) SN2018hna (10 Mpc)



Singh et al. 2019

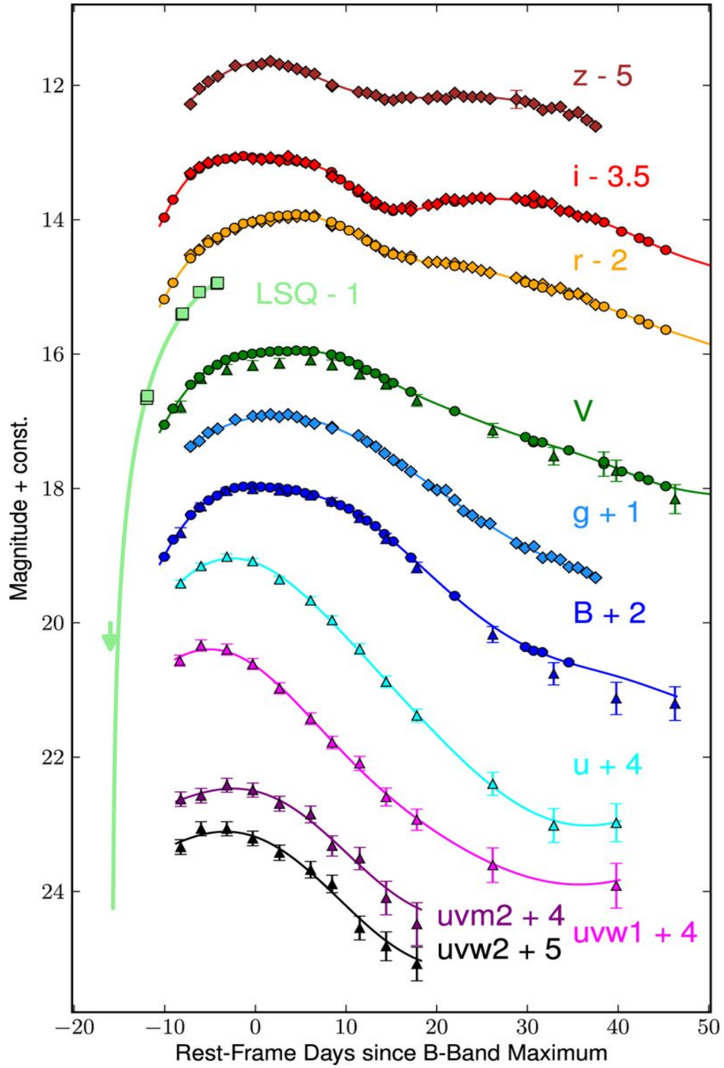
GWs from rapidly rotating core collapse



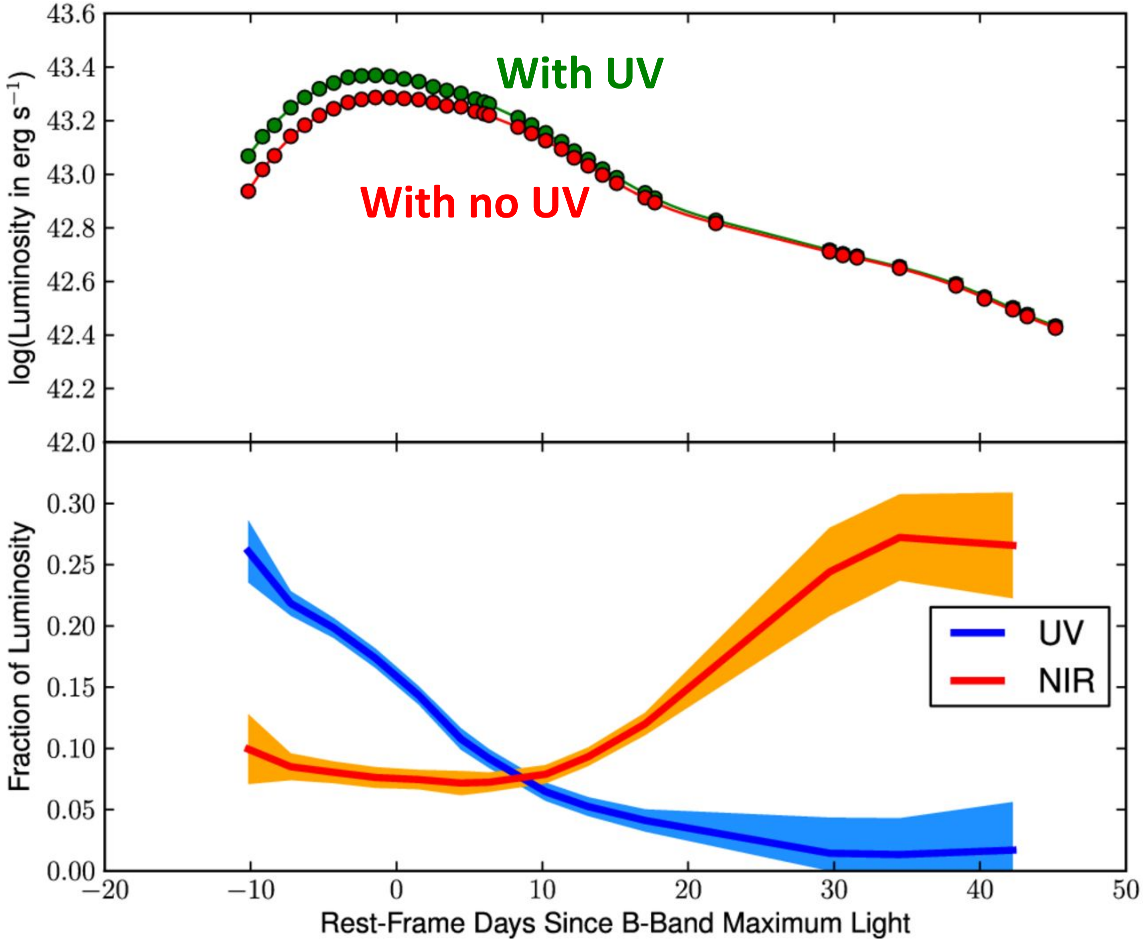
Ott et al. 2013

Thermonuclear supernova LSQ12gdj

Multiband light curves



Rest-frame bolometric light curves



Scalzo et al. 2014

A ~1m aperture UV telescope on the Moon with wide-field camera and rapid (seconds) turnaround would be an asset for time-domain astrophysics:

Rapid stellar transients

Supernova shock breakout

GRB early counterparts (a.k.a. optical/UV flashes)

Early kilonova phases

Tidal disruption events, blazar outbursts (HE neutrinos)

CONCLUSIONS

Multi-messenger approach is critical for time-domain astrophysics

ARTEMIS colonization of the Moon brings opportunities for high-energy astrophysics and opens up new portions of parameter space

One example is the potential detection of 0.1-1 Hz GW signals, that bridge the gap between currently “audible” GWs (1-1000 Hz) and LISA mHz range.

Electromagnetic detectors on the Moon will benefit from vacuum conditions, lower noise and servicing opportunity. Radio array FARSIDE already represents a fully-fledged concept.

Optical/NIR/UV small telescopes may play a crucial role; we support medium apertures (>50cm) and large-field cameras for rapid wide-angle searches.

The absence of atmosphere at the Moon gives the possibility to detect UHECR through the acoustic signal produced by the UHE particles on the lunar surface (Katsanevas et al. 2022).