Search for very-high-energy gamma-ray emission from tidal disruption events with VERITAS

8th Heidelberg International Symposium on High-Energy Gamma-Ray Astronomy

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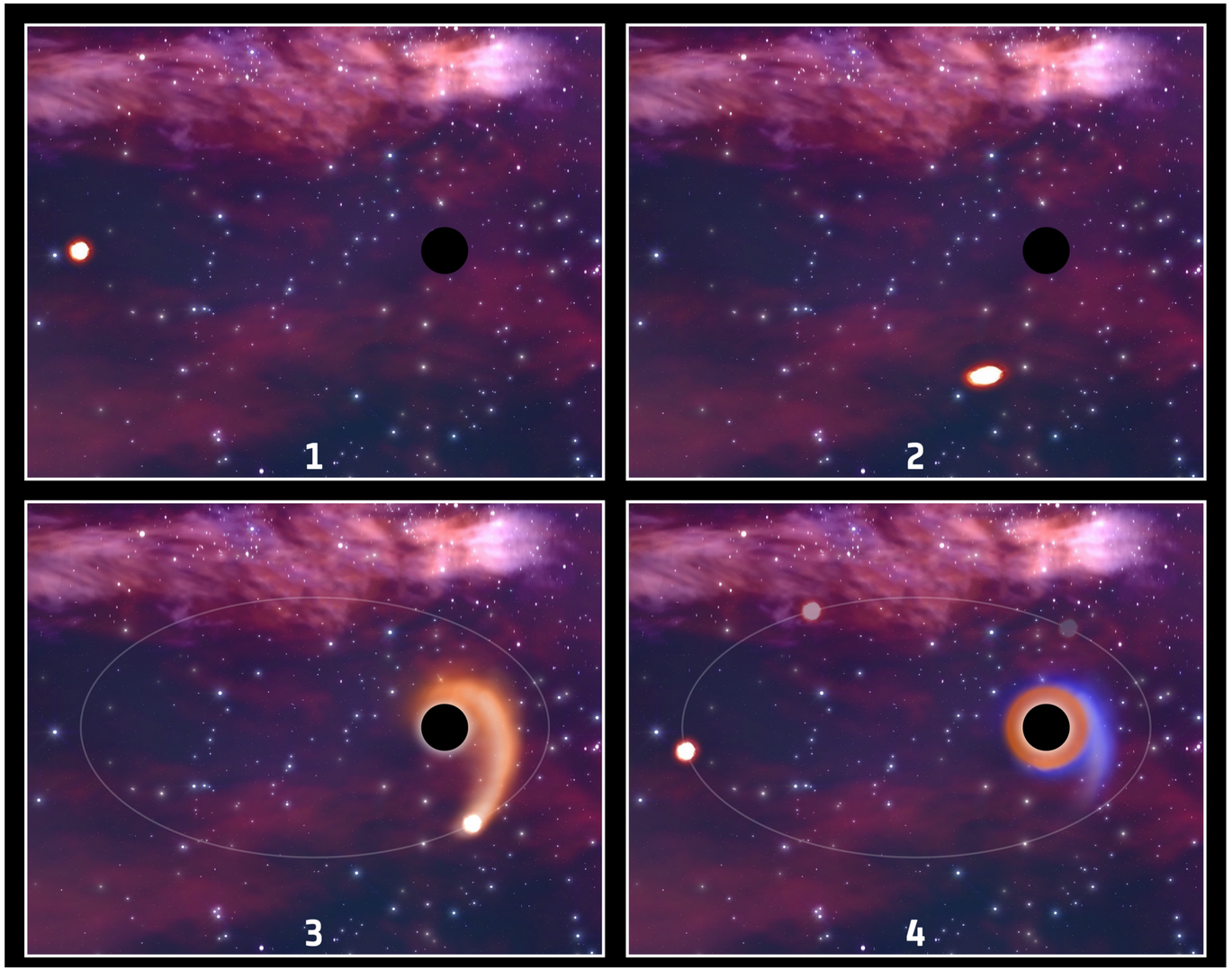
Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum

What are tidal disruption events (TDEs)?



Credit: Adapted from: A black hole eating a star again and again - ESA

Stars that pass within the tidal radius of SMBHs are pulled apart by tidal forces[1]:

$$R_t \simeq 7 \times 10^{12} \left(\frac{M_{\mathrm{BH}}}{10^6 M_\odot} \right)^{\frac{1}{3}} \left(\frac{M_*}{M_\odot} \right)^{-\frac{1}{3}} \frac{r_*}{r_\odot} \,\mathrm{cm}\,.$$

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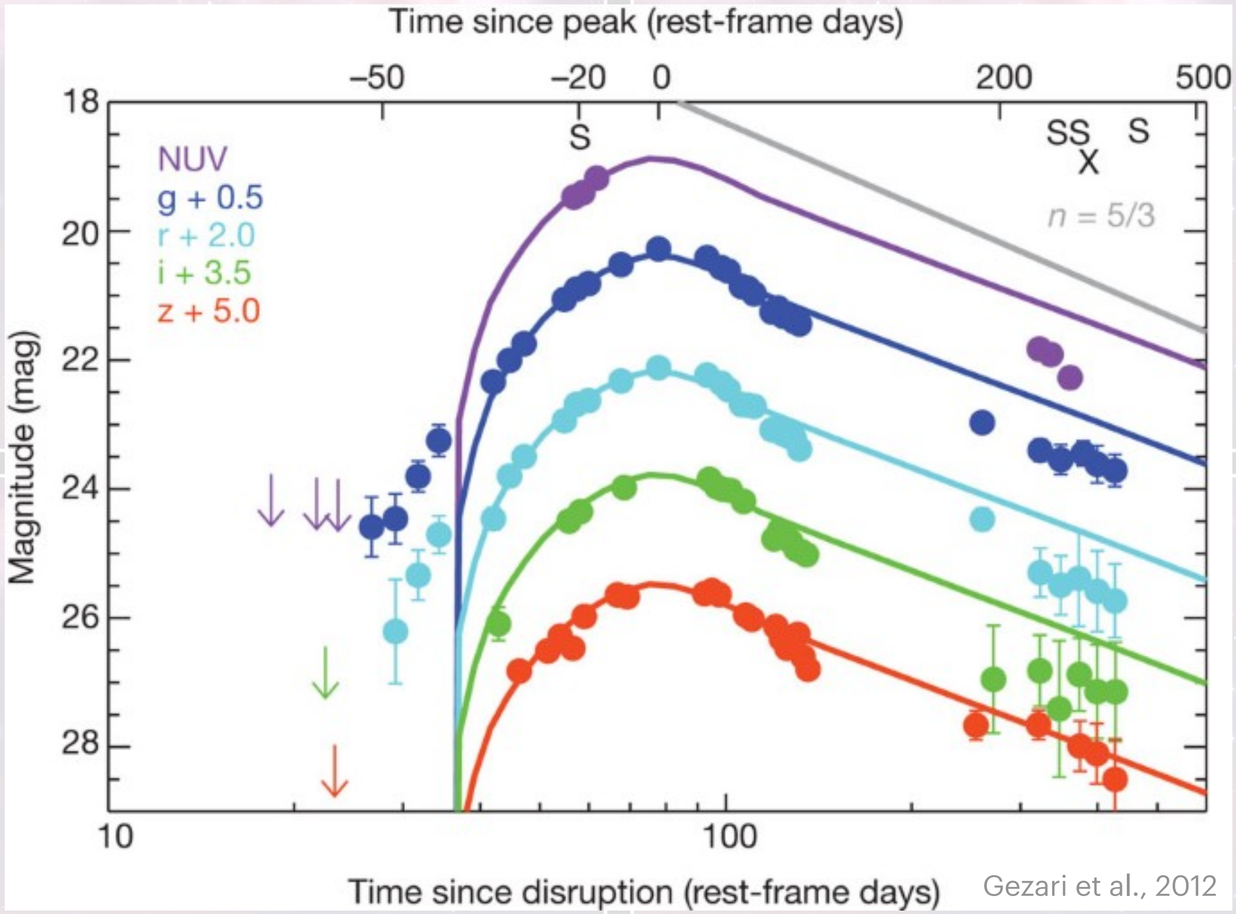

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General light curve properties for events detected in optical surveys :

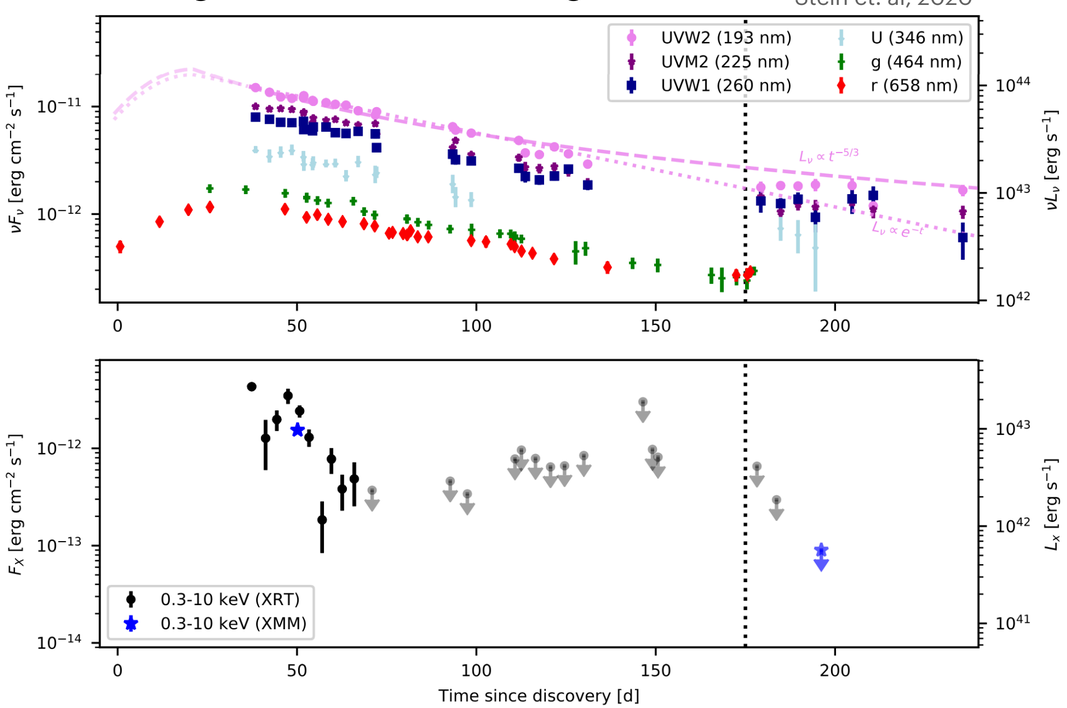
- OUV emission detected for ~ months,
- Peak OUV ~ 10^{42} — 10^{44} erg/s,
- Decline with a PL; -5/3 Rees, 1998,

Why are TDEs interesting for VHE searches?

Associations with astrophysical neutrinos:

MW light curve for AT2019dsg:

Stein et. al, 2020



- AT2019dsg - IC191001A: E_ν = 217 TeV (59% sig.)
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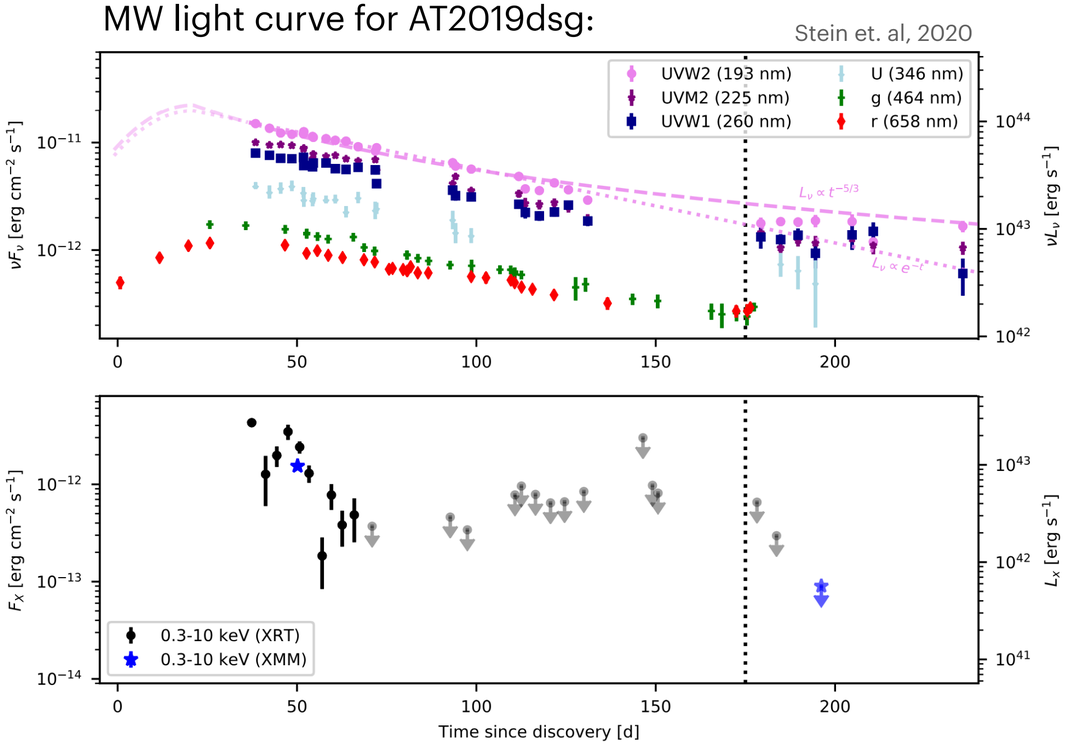

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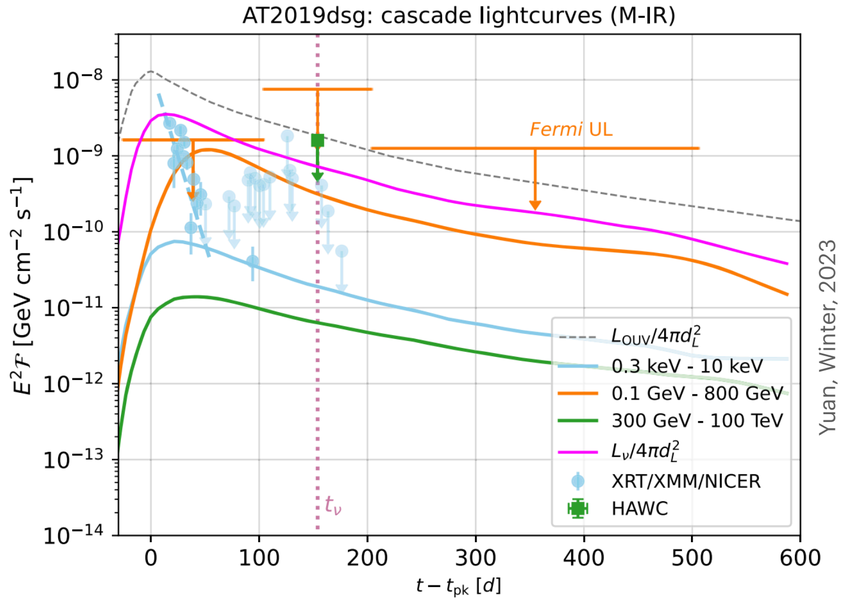

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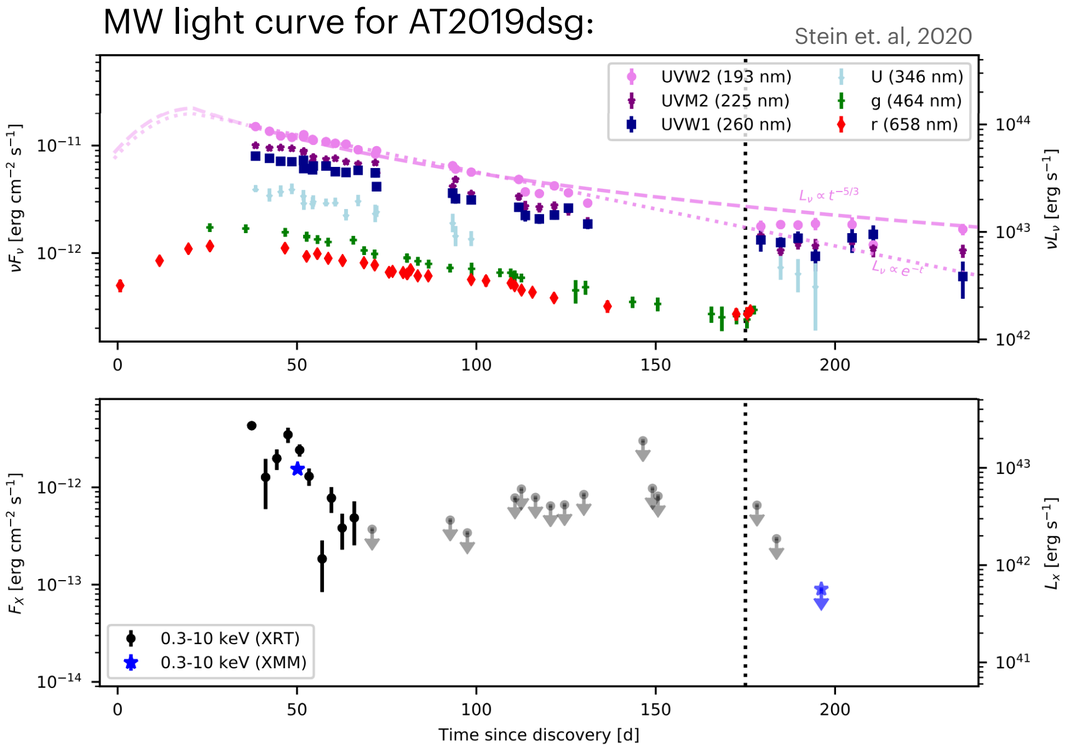

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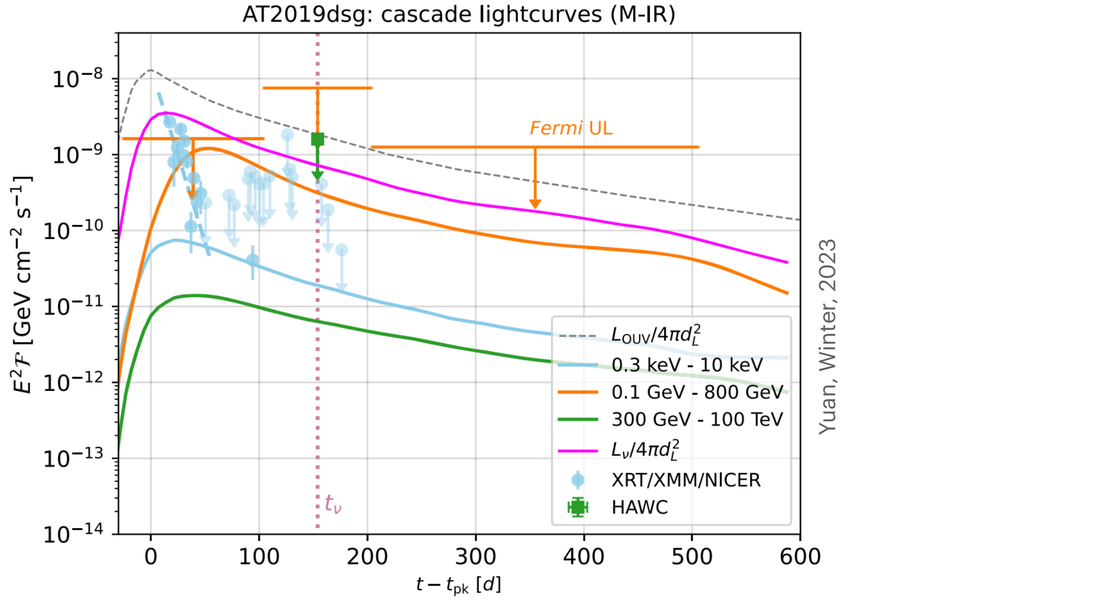
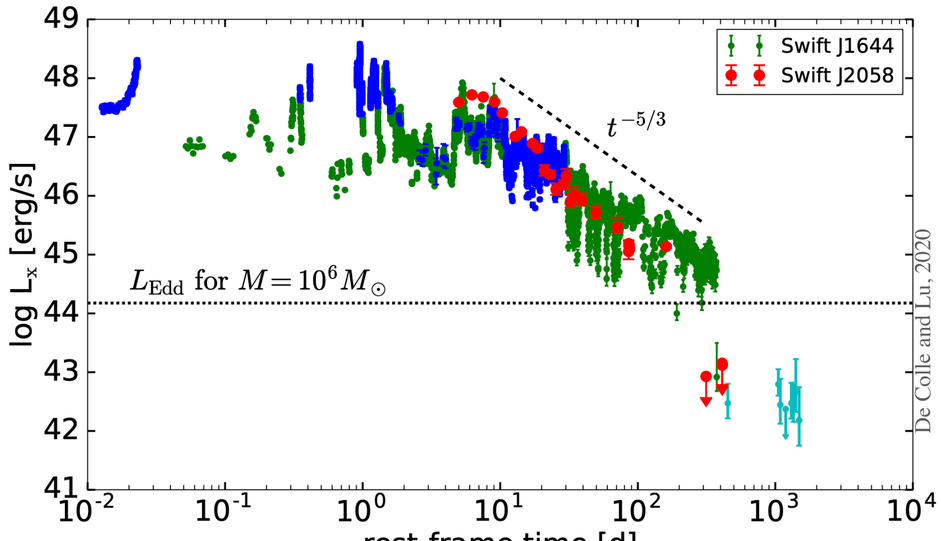


Non-thermal emission from extraordinary events



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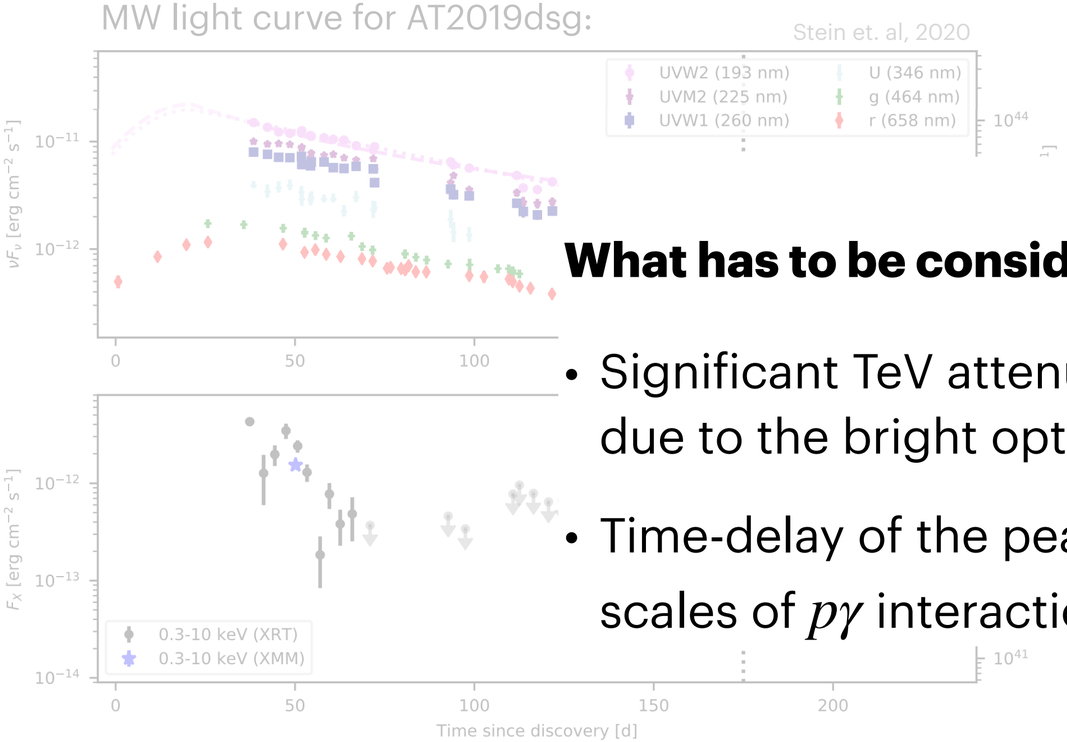

What has to be consider in VHE follow-up campaigns:

- Significant TeV attenuation via $\gamma\gamma$ for ~ 50 - 90 days [2] due to the bright optical background,
- Time-delay of the peak of the EM emission in the time-scales of $p\gamma$ interactions [3].

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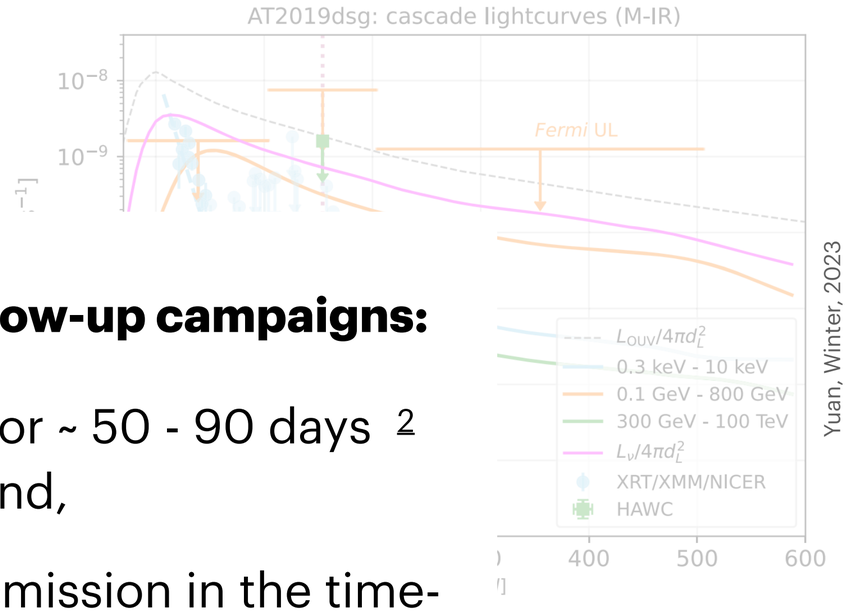

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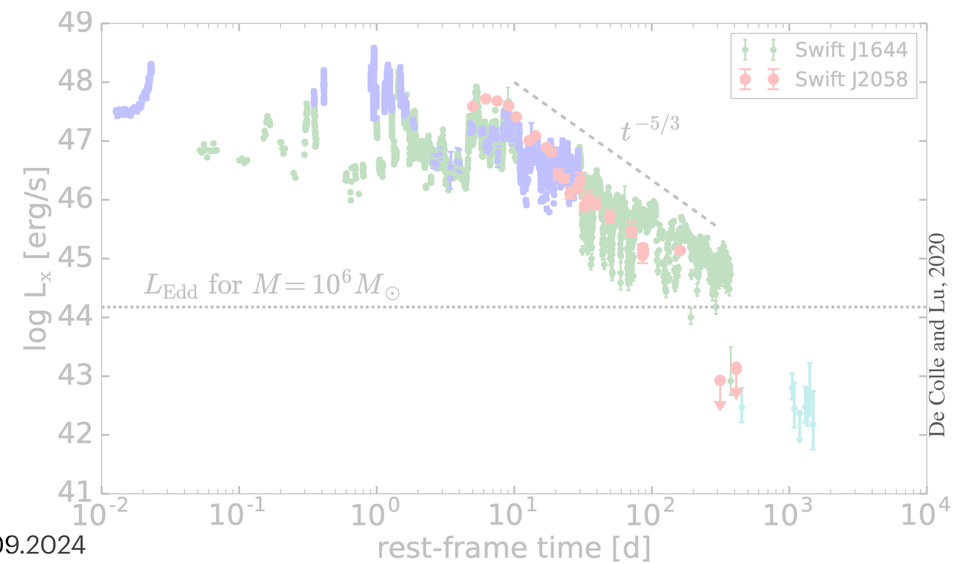


The Very Energetic Radiation Imaging Telescope Array System

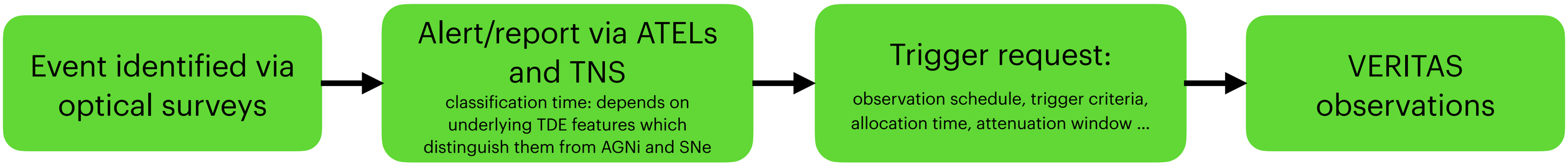
- Array of 4 IACTs at the Fred Lawrence Whipple Observatory,
- Sensitive to gamma rays in the energy range of 100 GeV to > 30 TeV,
- A source with 1% of the Crab Nebula strength is detected in ~25h,
- Angular resolution of < 0.1 deg at 1 TeV.

Follow-up observations of TDEs with VERITAS

Trigger criteria:

Redshift	< 0.5
Elevation	> 30 degrees
Time period	< 3 months post-optical peak
Request	20 hours

Timeline for trigger decision:

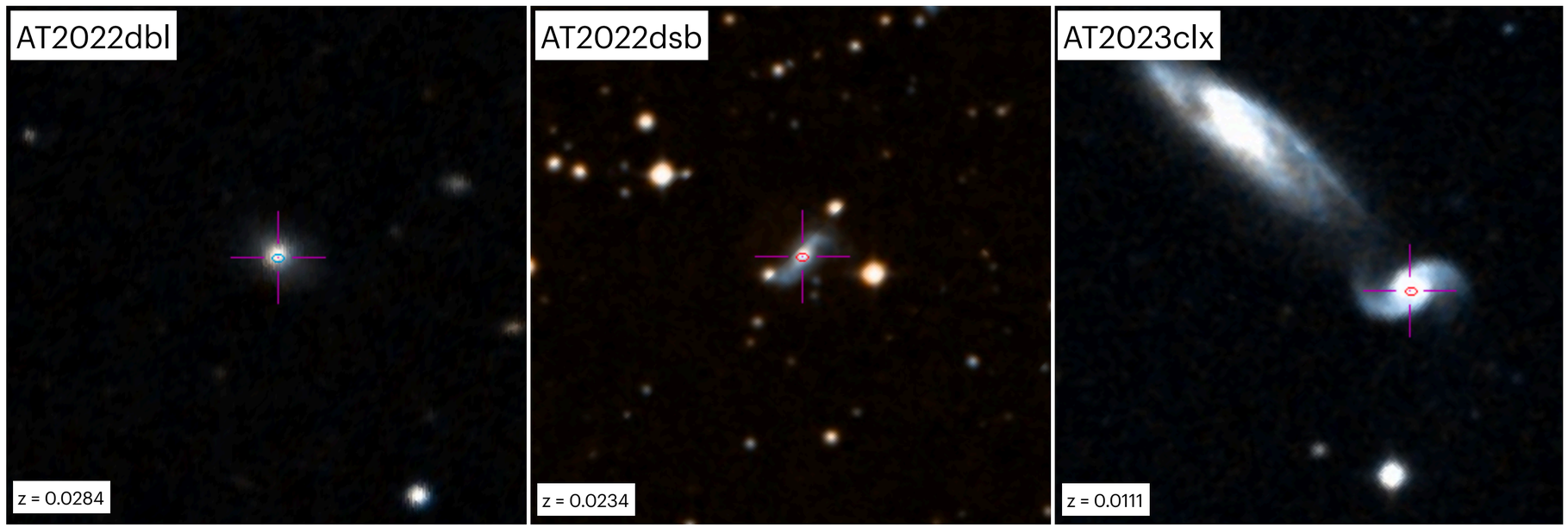


Follow-up observations of TDEs with VERITAS

Three events triggered via a target of opportunity proposal:

AT2022dbl, AT2022dsb and AT2023clx

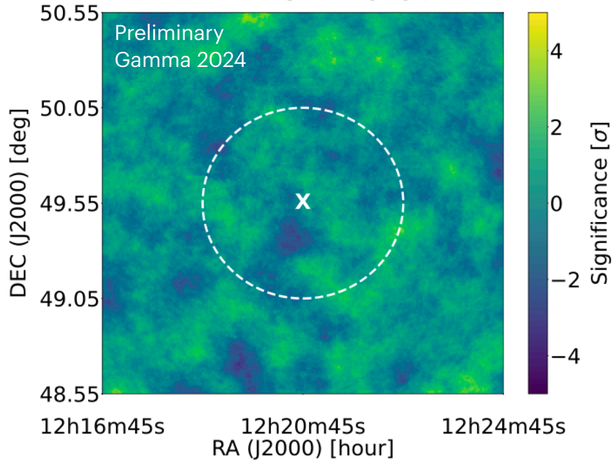
Optical images of TDEs hosts - SDSS



- Peak OUV emission ~ 10^{44} erg/s for AT2022dsb and AT2022dbl,
- AT2022dsb: X-ray detection (SRG/eROSITA (0.2 - 8 keV) - Temperature ~ 47 eV (blackbody)
- No reports of neutrino association.

VERITAS analysis results

AT2022dbl



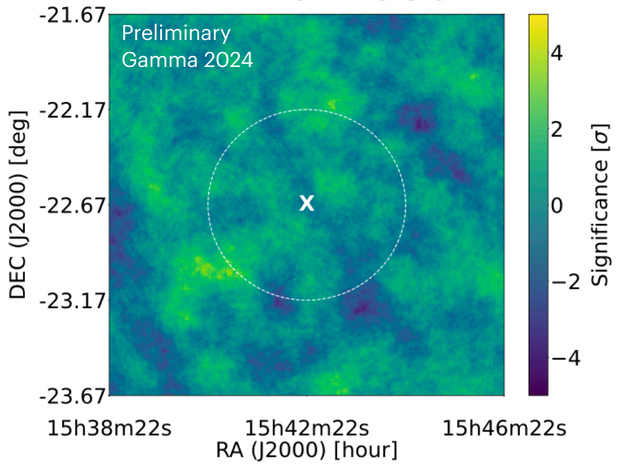
Live-time: 20.91 hours

Significance: 0.1

Flux UL (95% C. L., 0.1 - 10 TeV)

$7.81 \cdot 10^{-13}$ erg/cm^2/s

AT2022dsb



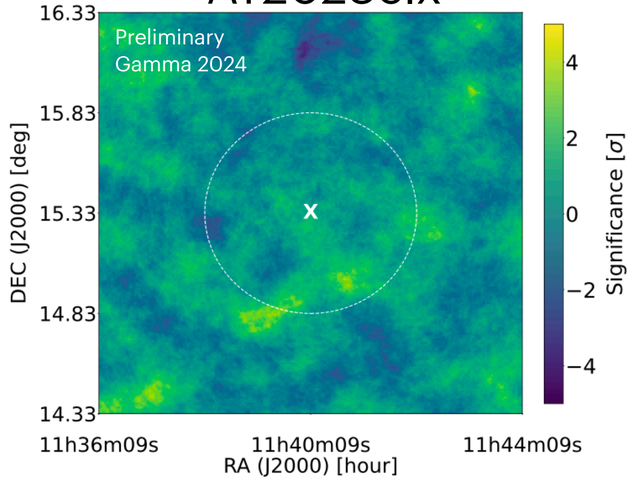
Live-time: 14.61 hours

Significance: -1.2

Flux UL (95% C. L., 0.1 - 10 TeV)

$4.76 \cdot 10^{-13}$ erg/cm^2/s

AT2023clx



Live-time: 12.13 hours

Significance: 1.5

Flux UL (95% C. L., 0.1 - 10 TeV)

$1.71 \cdot 10^{-12}$ erg/cm^2/s

Estimating the internal gamma-ray annihilation for AT2022dsb and AT2022dbl

Target photon field: OUV and X-ray emission modelled as two independent blackbodies:

Goal: estimate the internal annihilation via two-photon annihilation: $\gamma + \gamma \rightarrow e^- + e^+$.

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Set of assumptions:

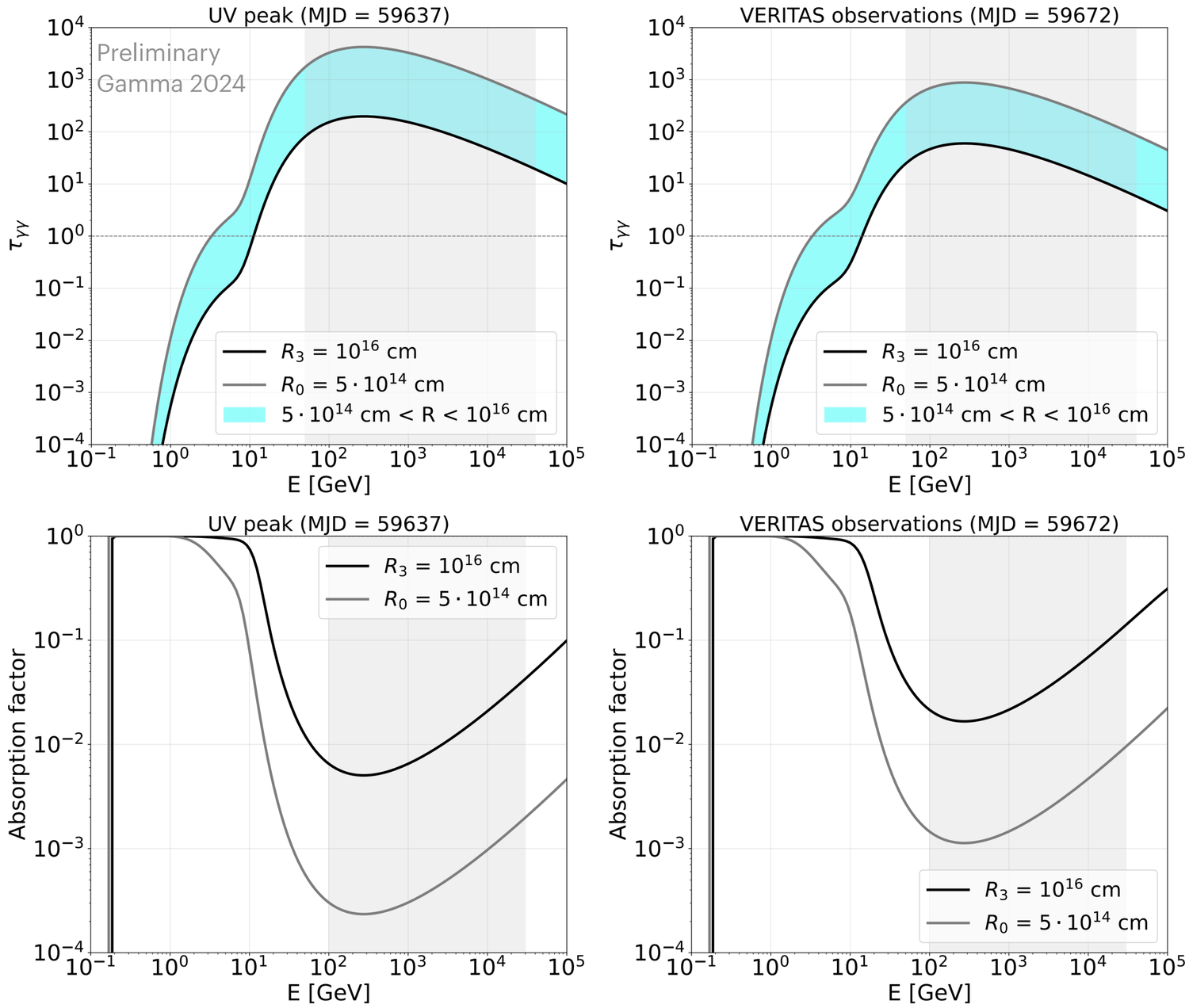
✦ Assumption 1: homogenous target field - bolometric correction of OUV from source,

✦ Assumption 2: blackbody radii: $5 \cdot 10^{14}$ cm - 10^{16} cm (ZTF TDEs - van Velzen et al., 2020).

- Annihilation rates are calculated with AM3: Astrophysical Multi-Messenger Modeling code [4].

Estimation of the internal γ-ray annihilation

AT2022dbl



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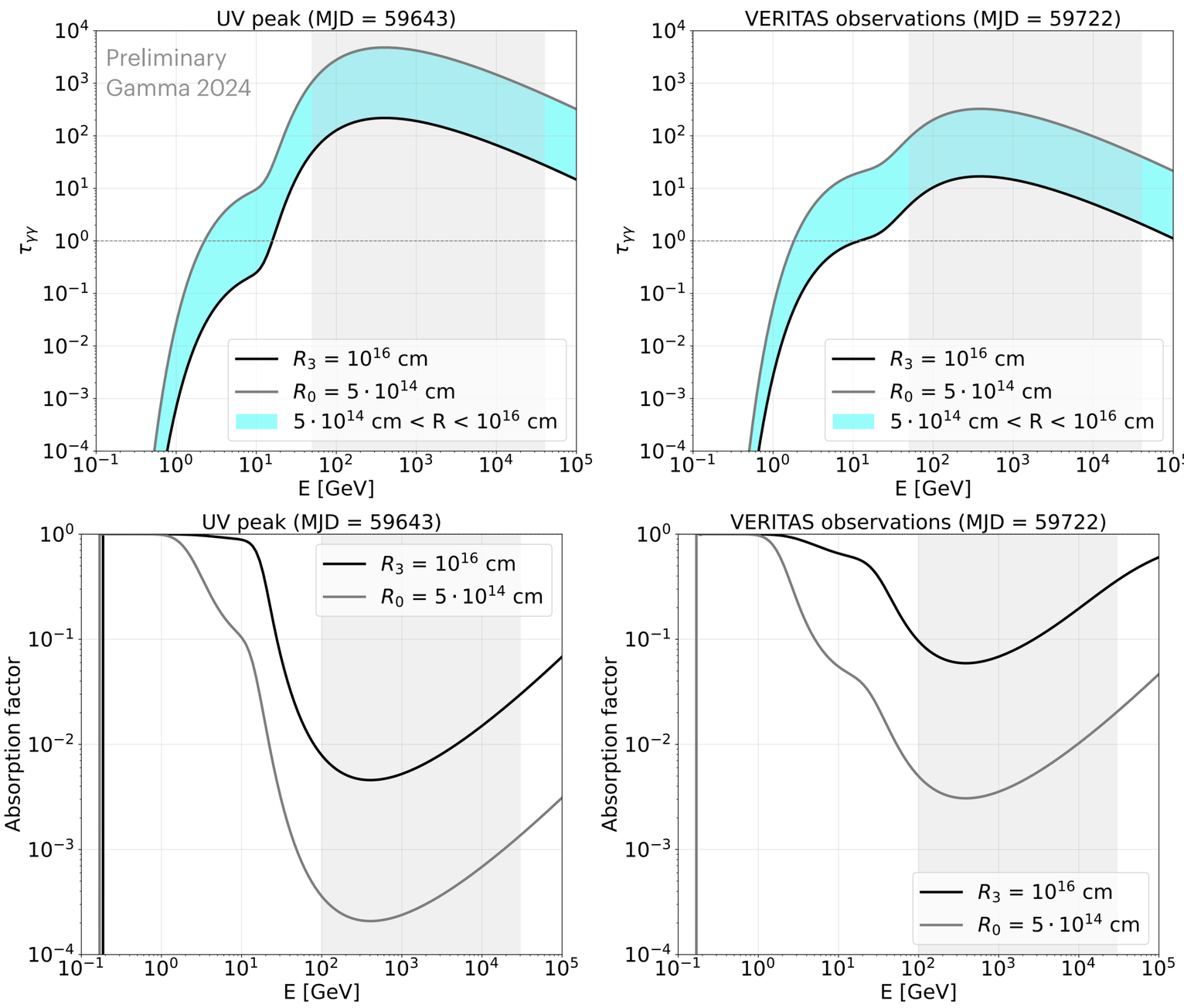

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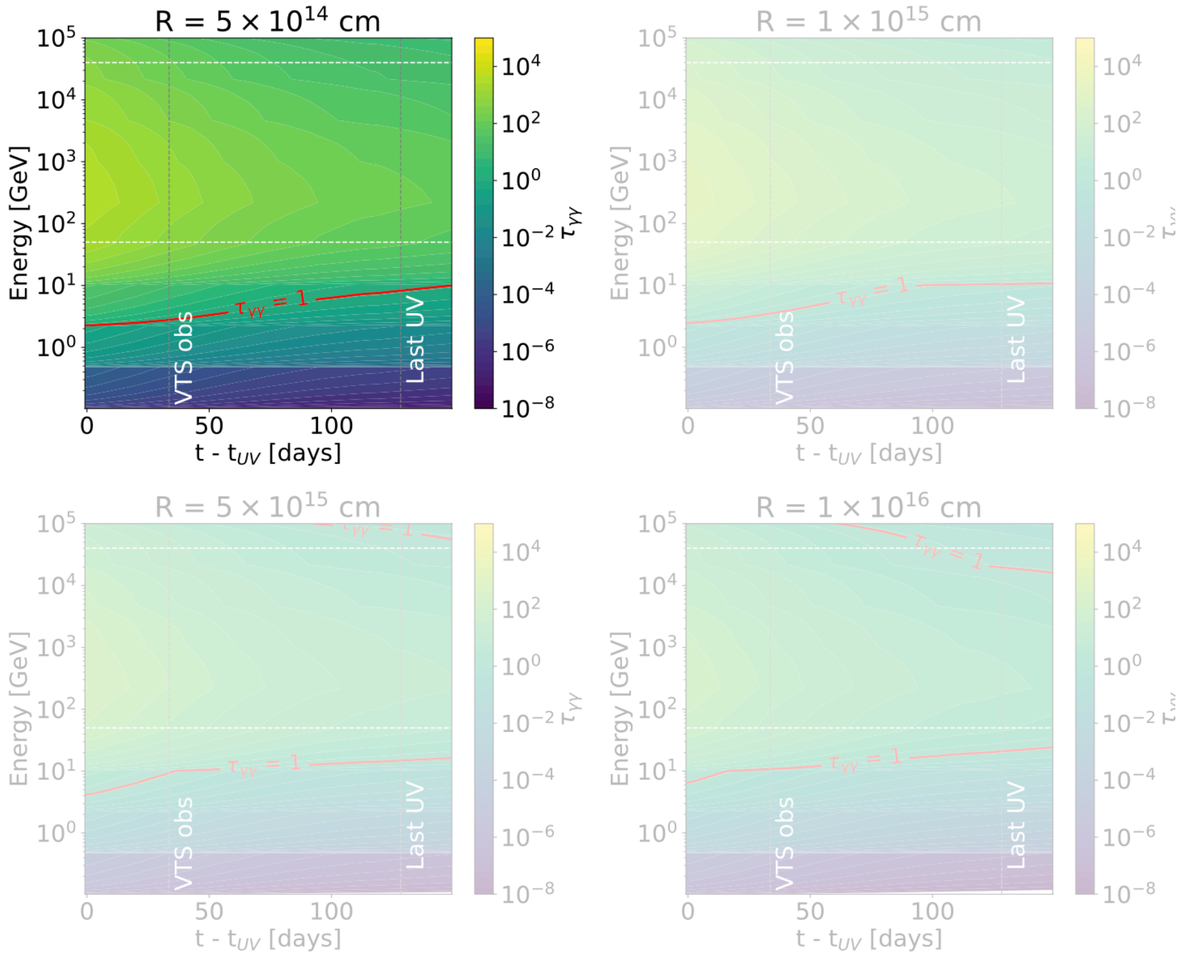
Time evolution of the optical depth

AT2022dbl



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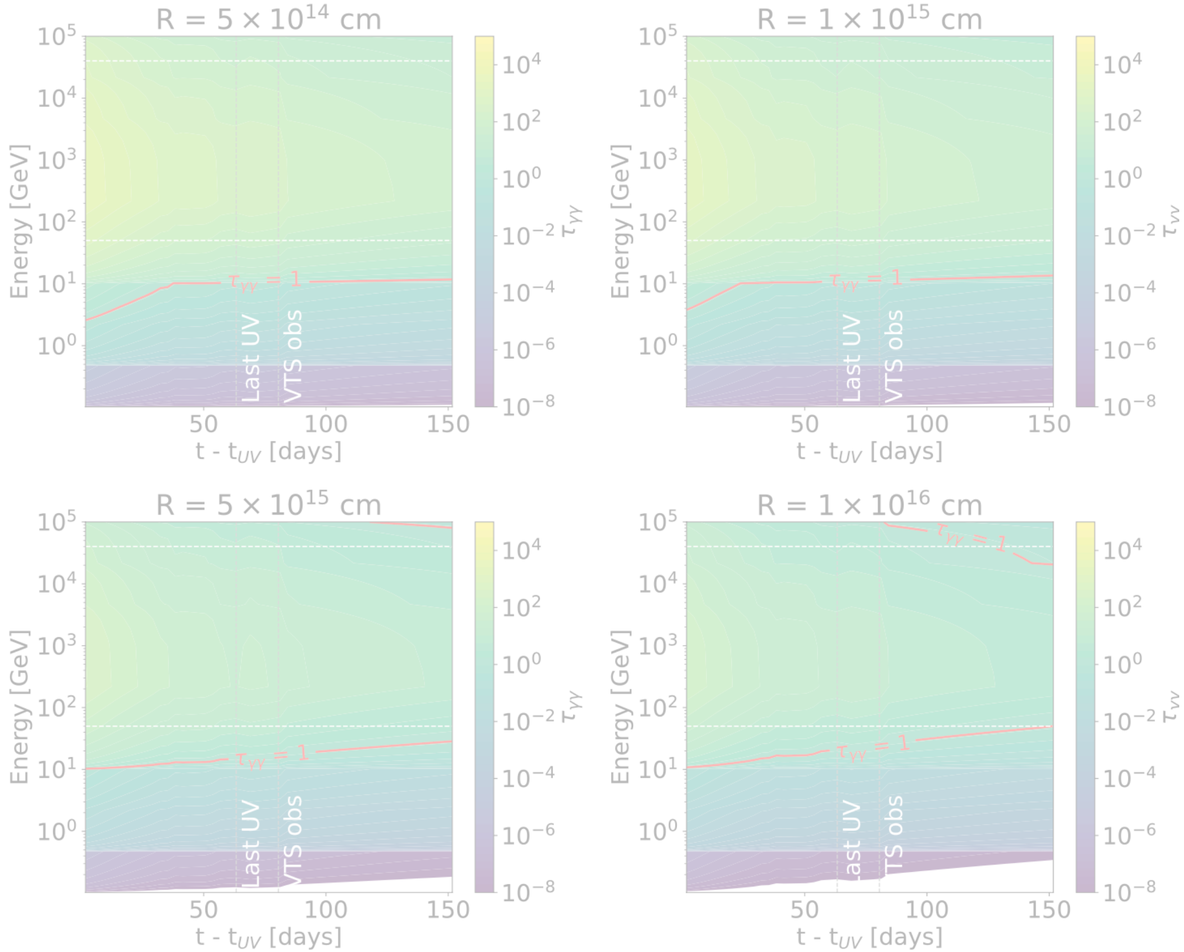

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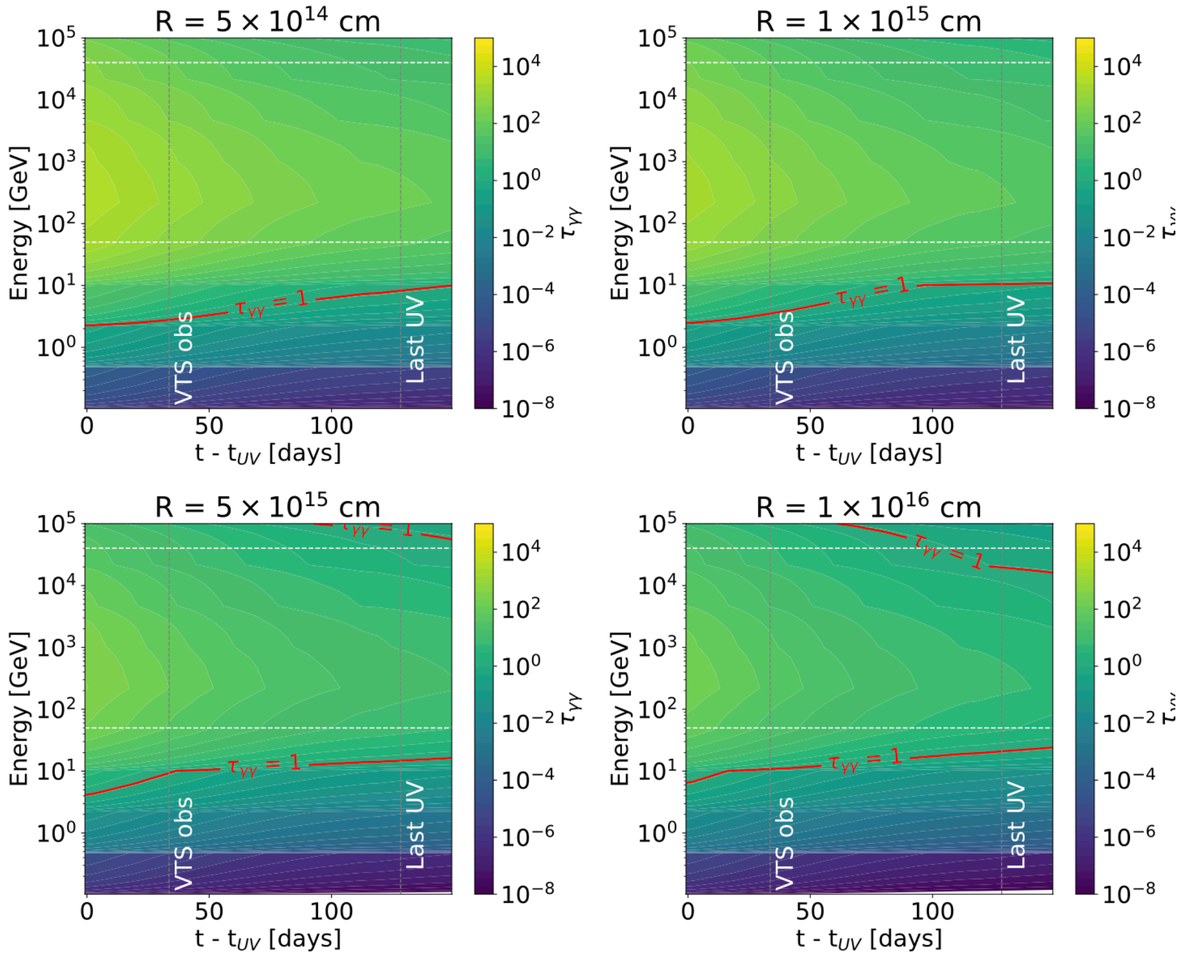

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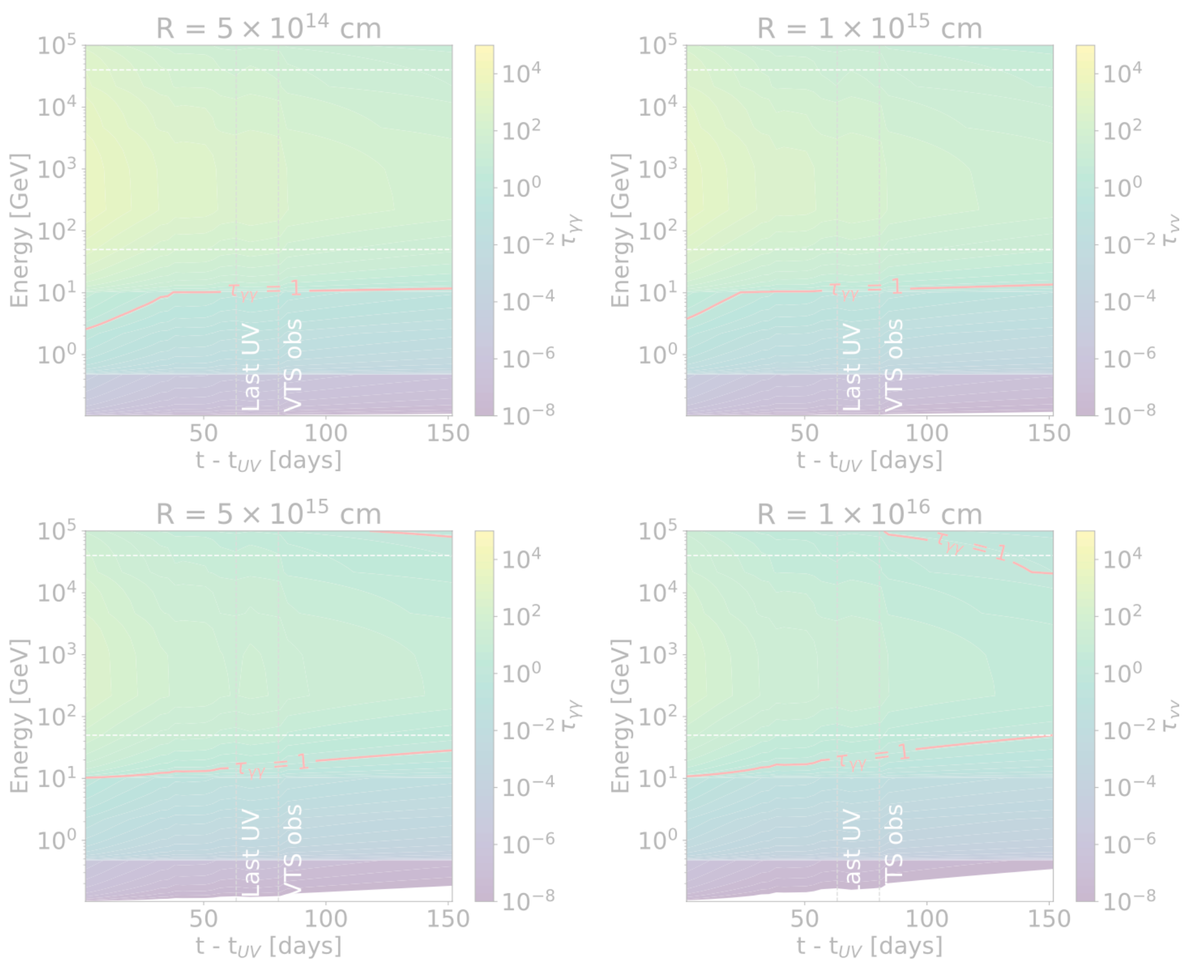

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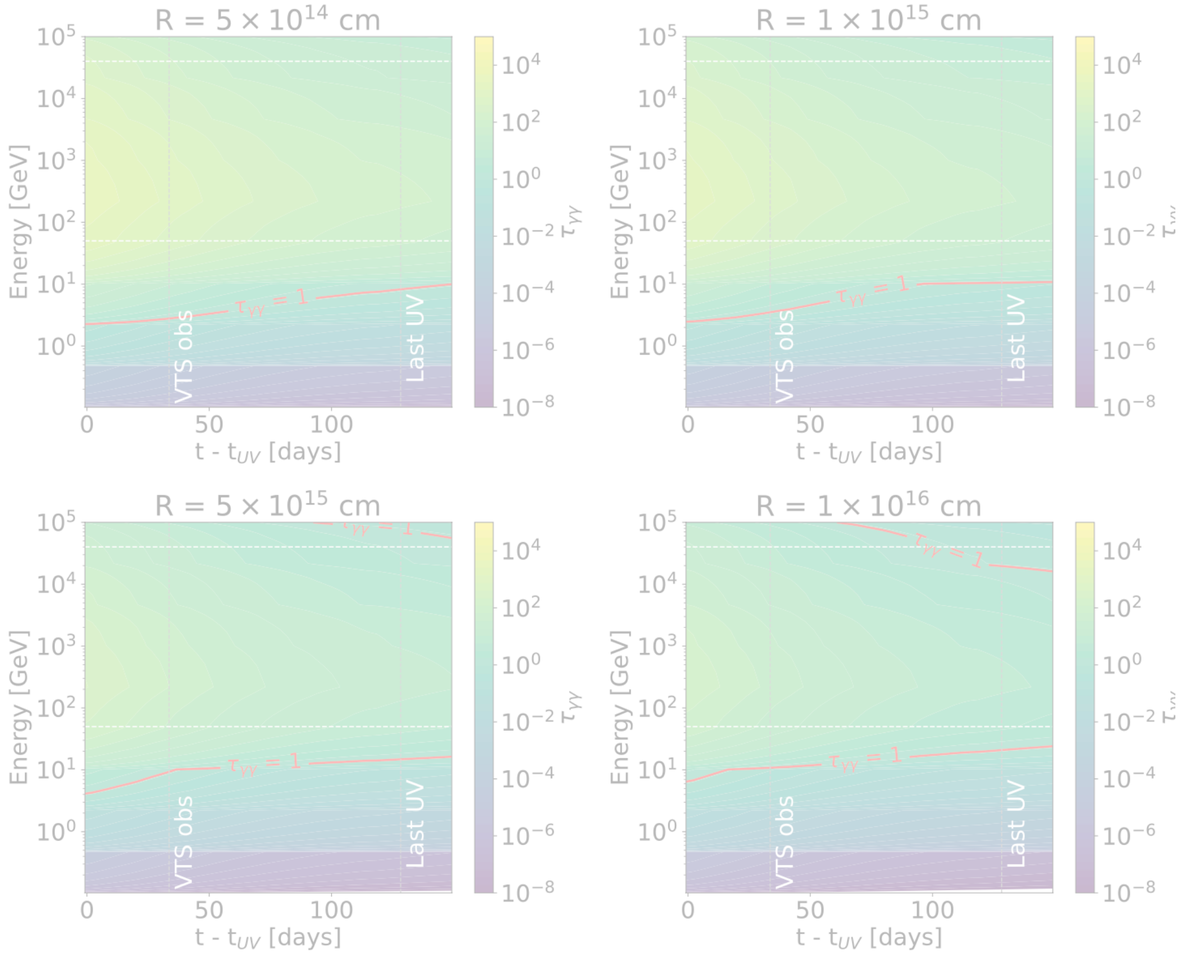

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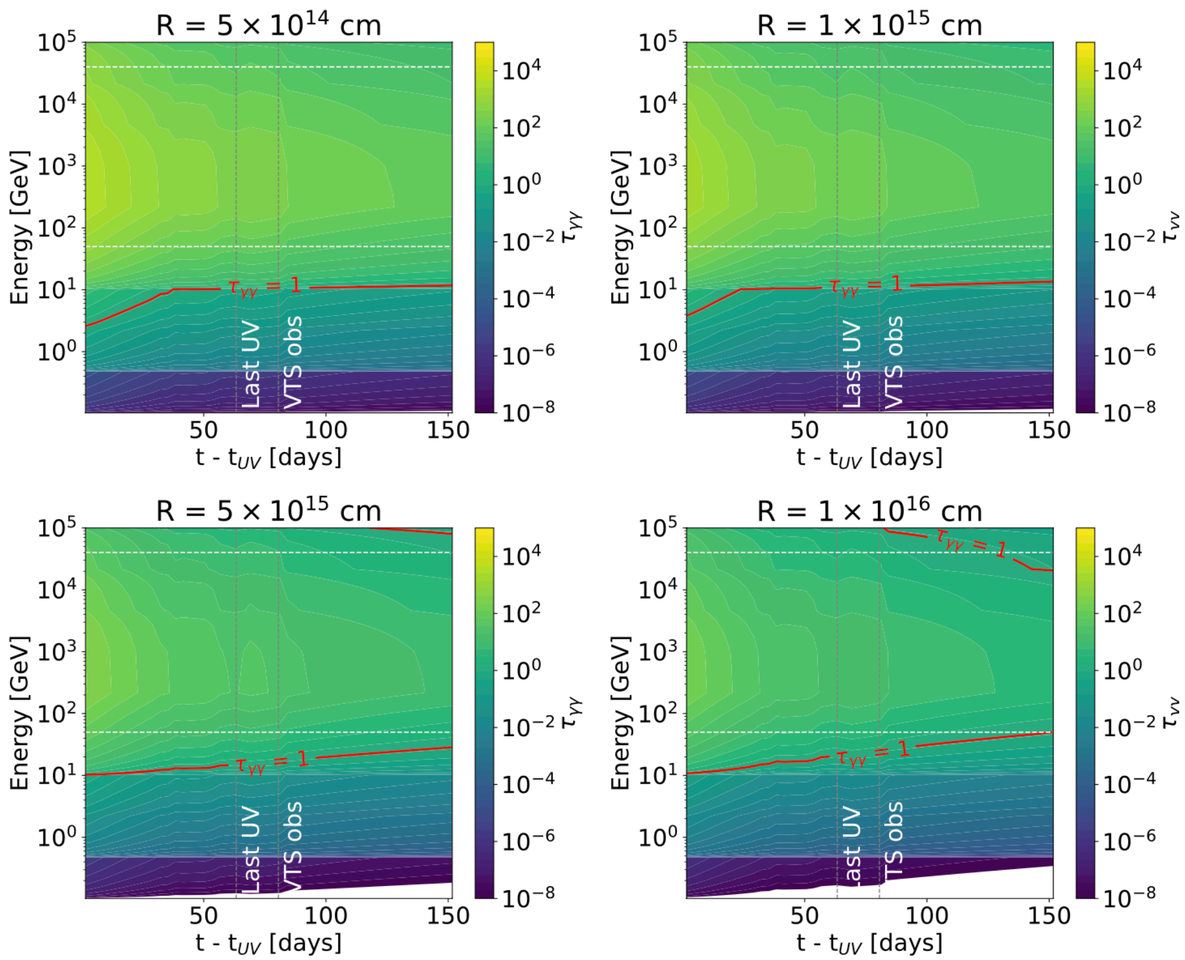

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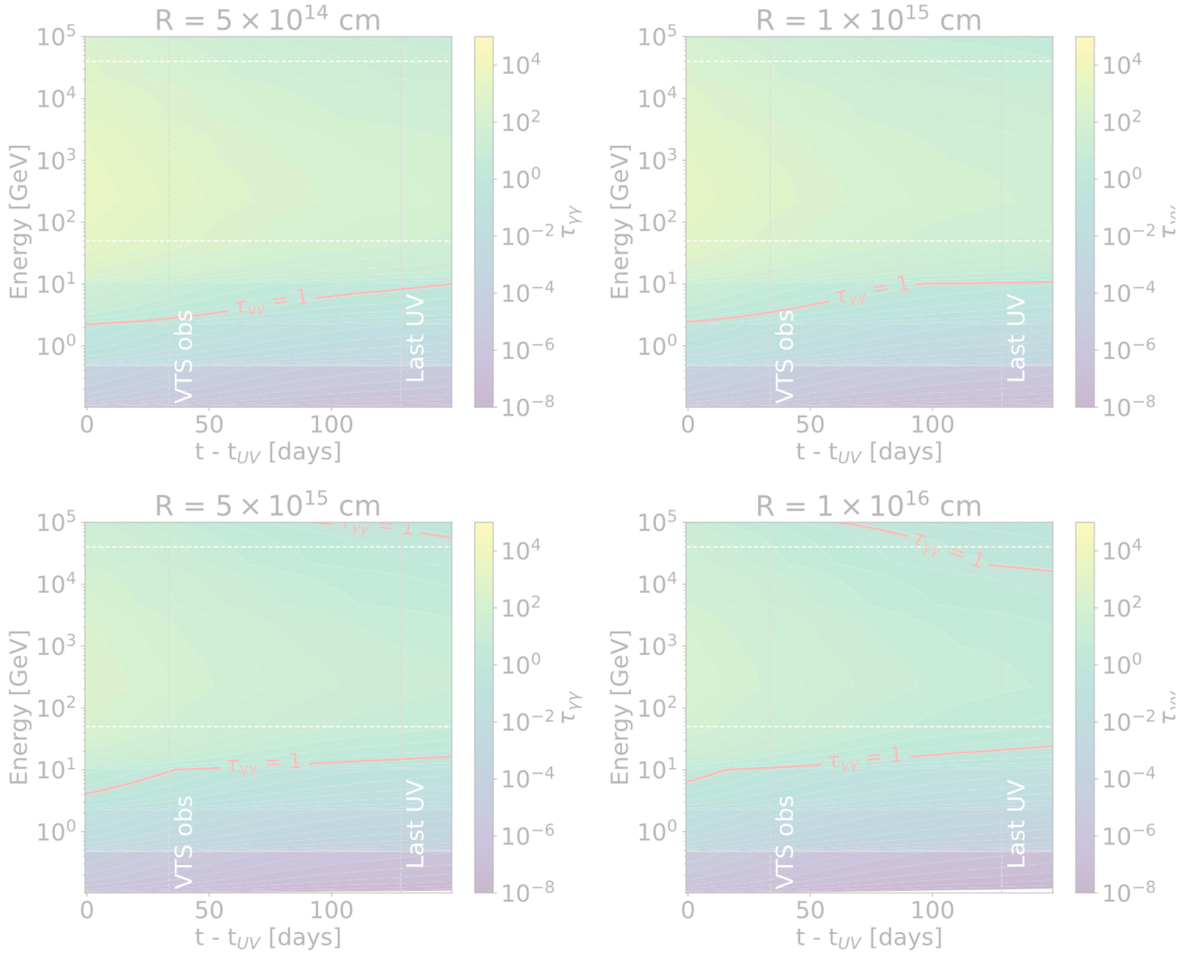

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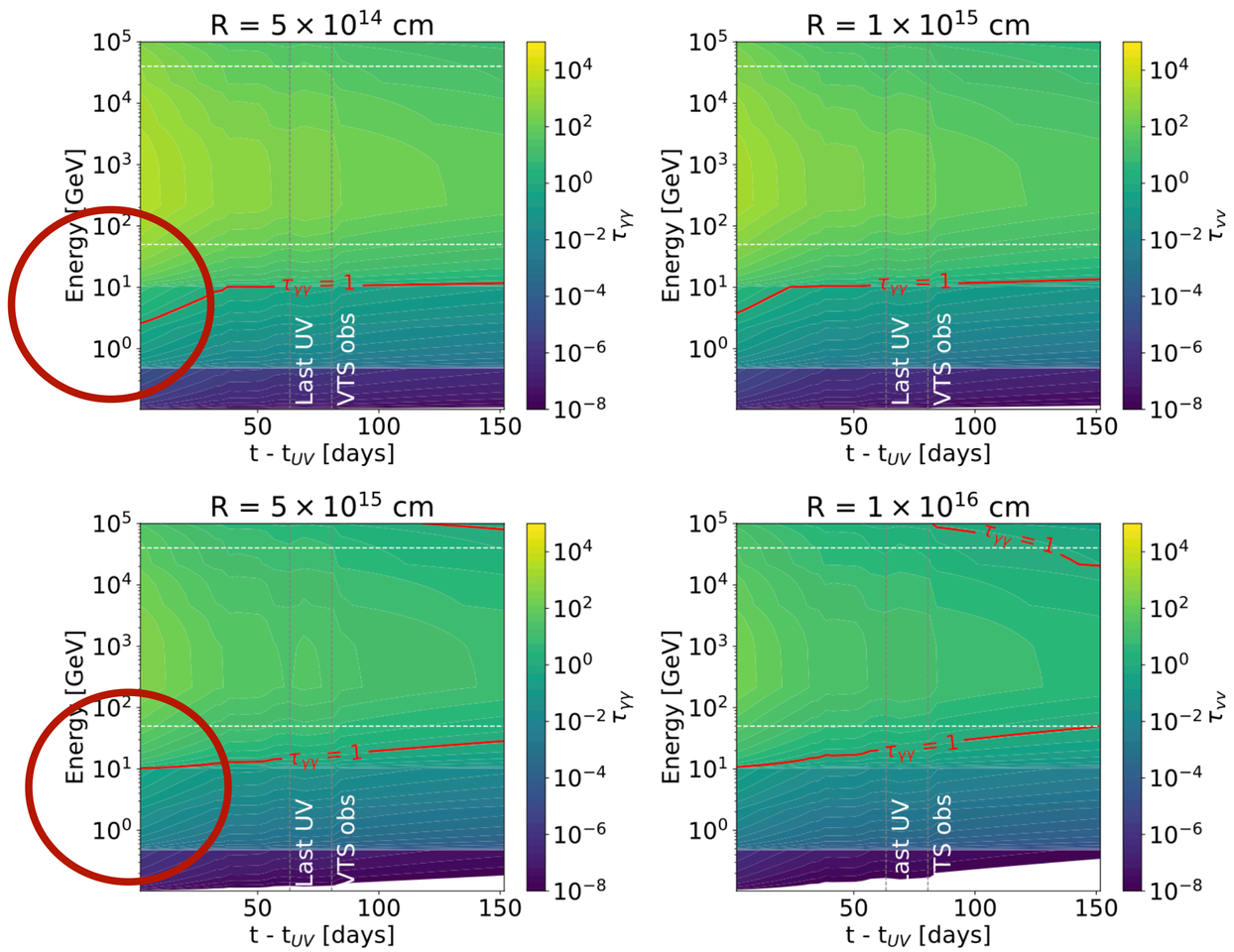

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Thank you! Questions?

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Acknowledgments: https://veritas.sao.arizona.edu/)