10 August 2021

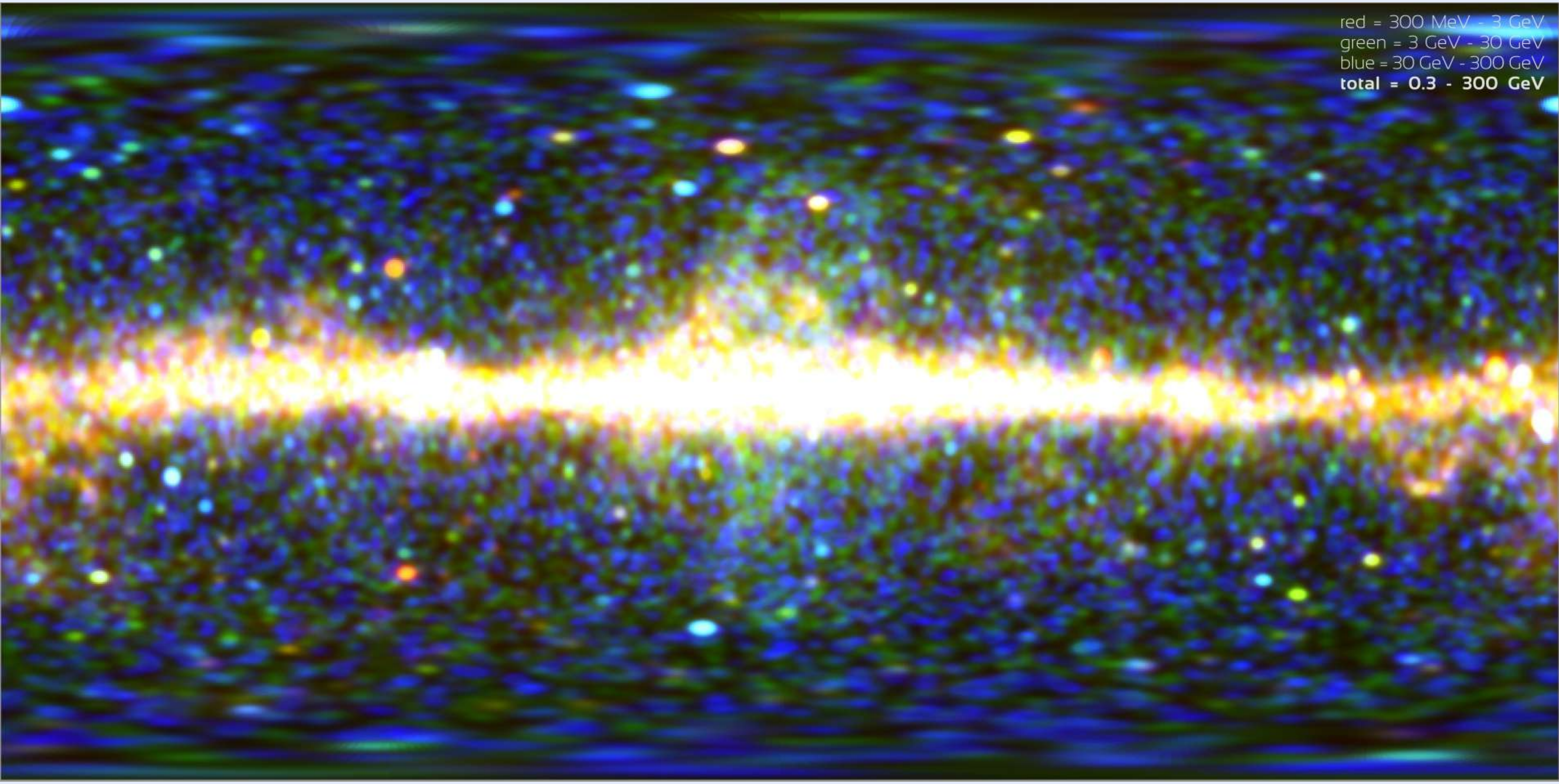
Observation of GRBs in mm wavelengths

Antonio de Ugarte Postigo
HETH / IAA-CSIC (Spain)
DARK/NBI (Denmark)

CMB-S4 Summer Meeting 2021

Greetings from Tusheti (Georgia)

Gamma Ray Bursts



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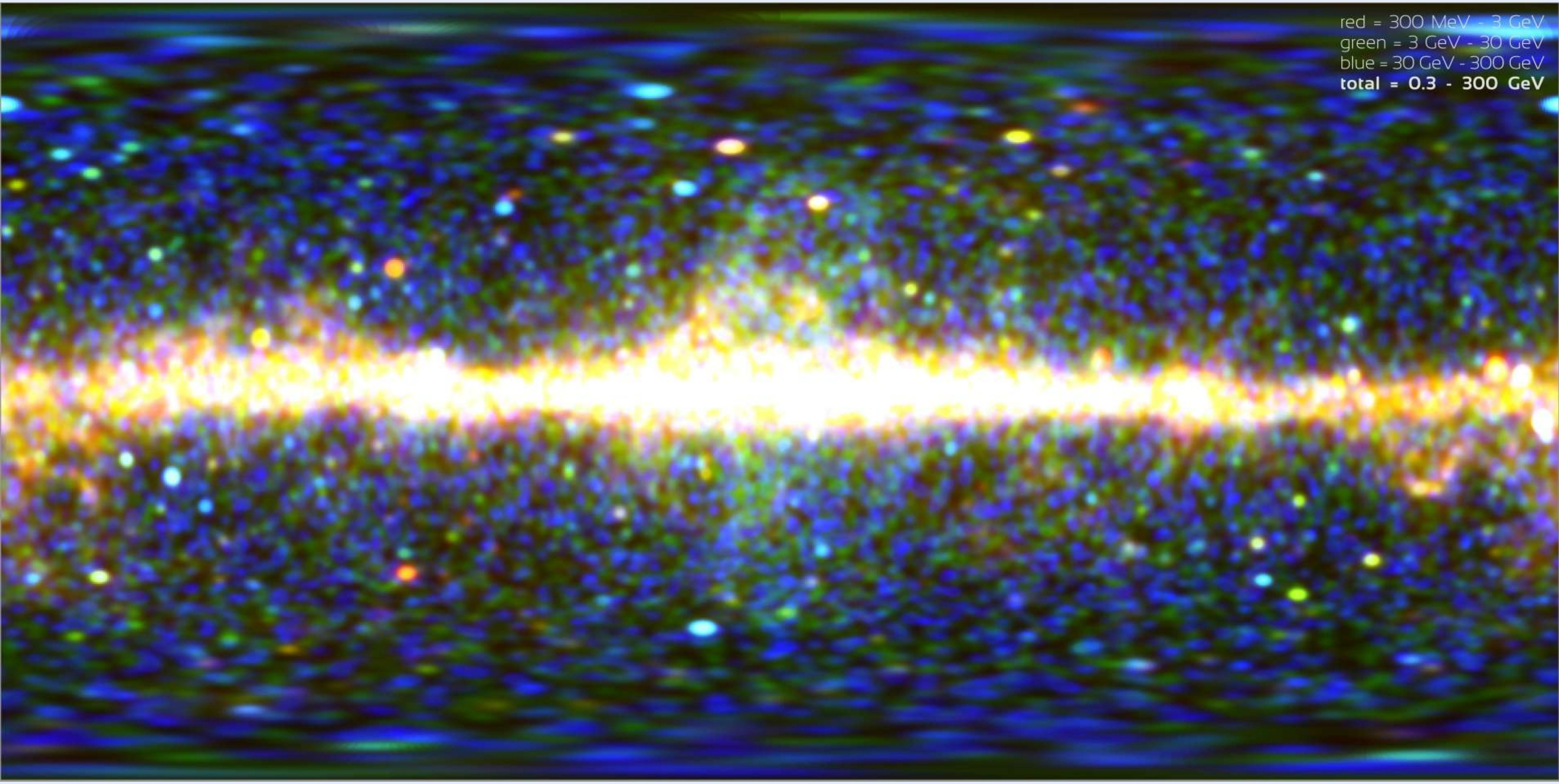

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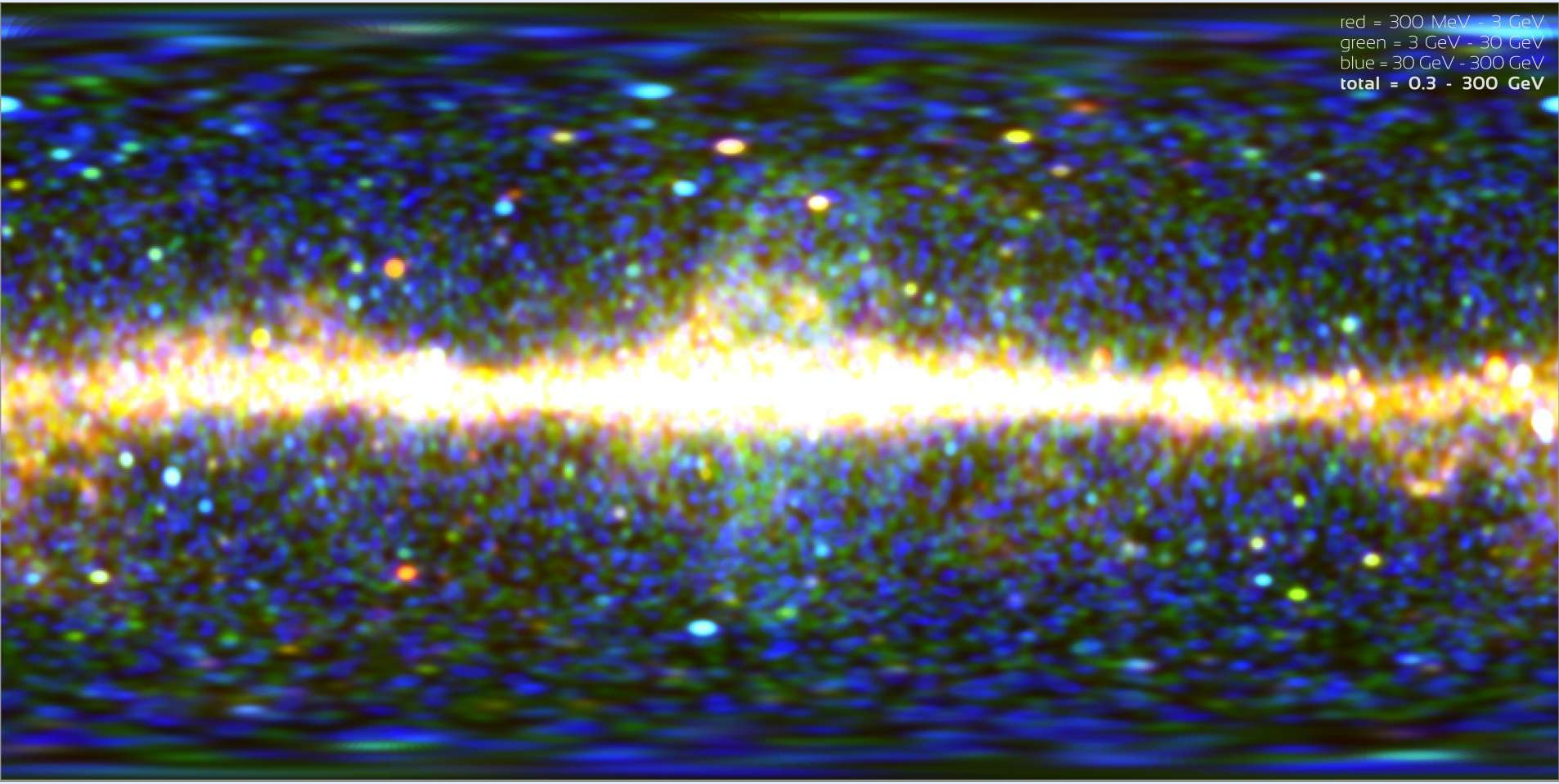

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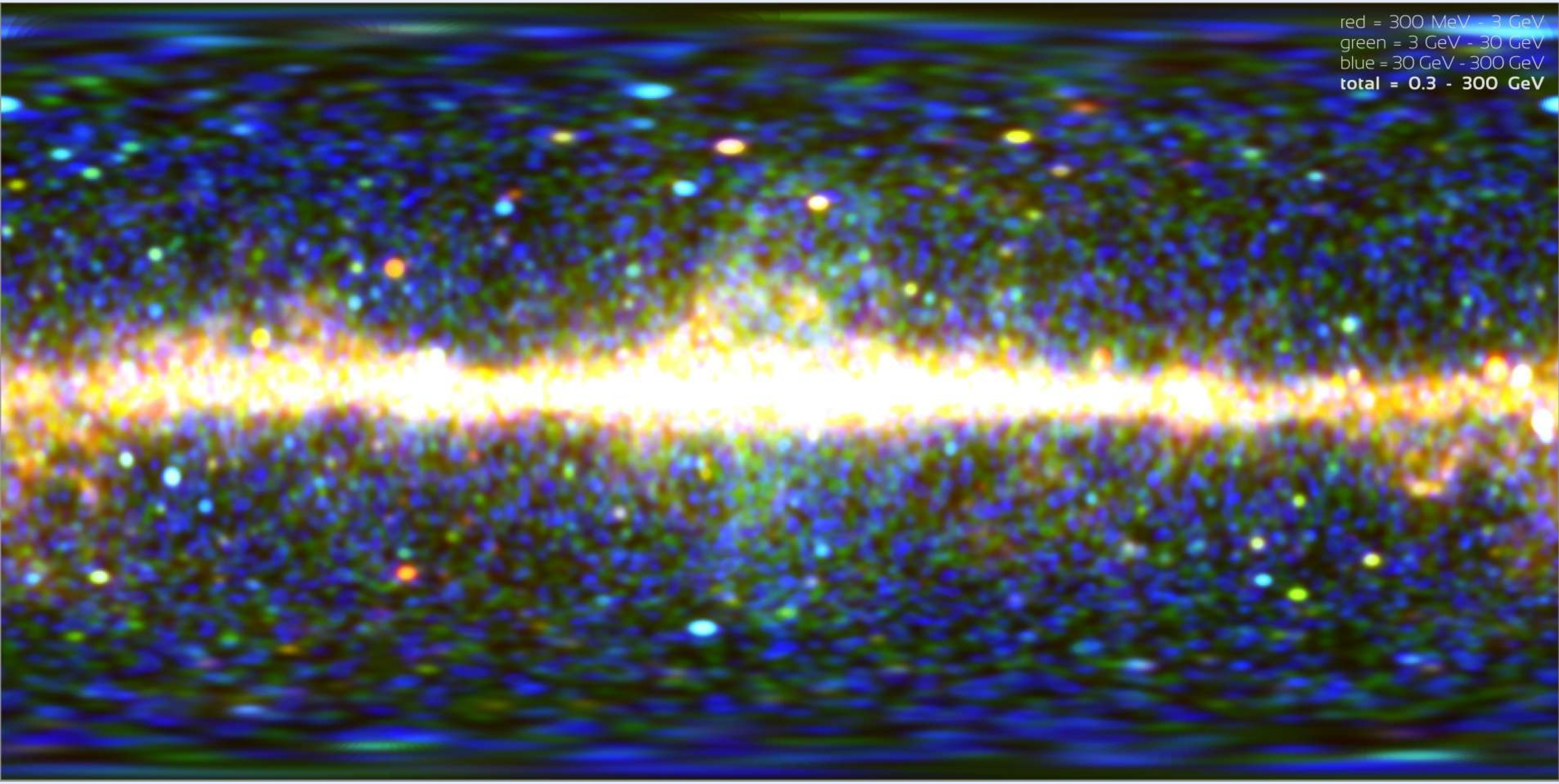

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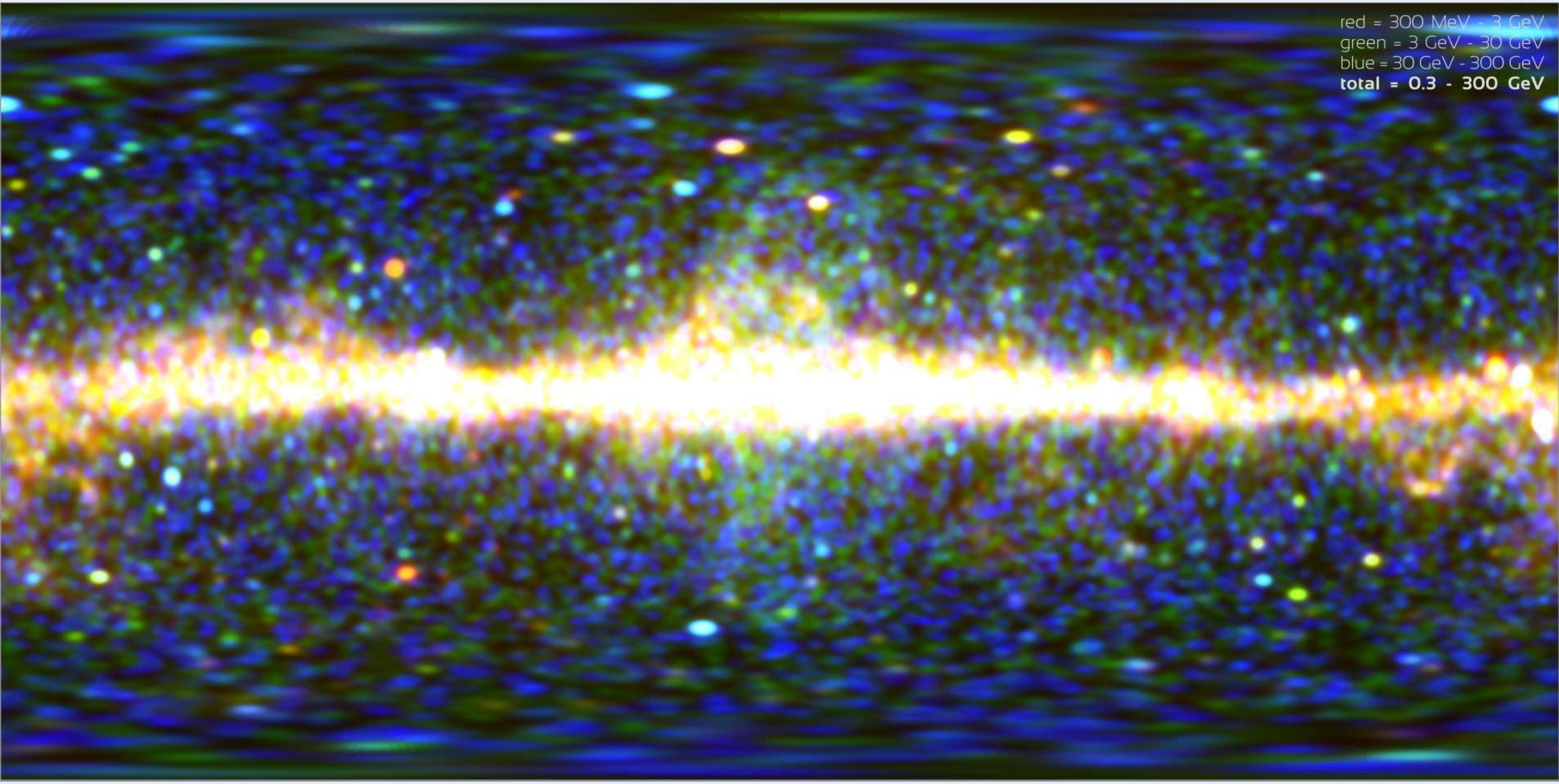
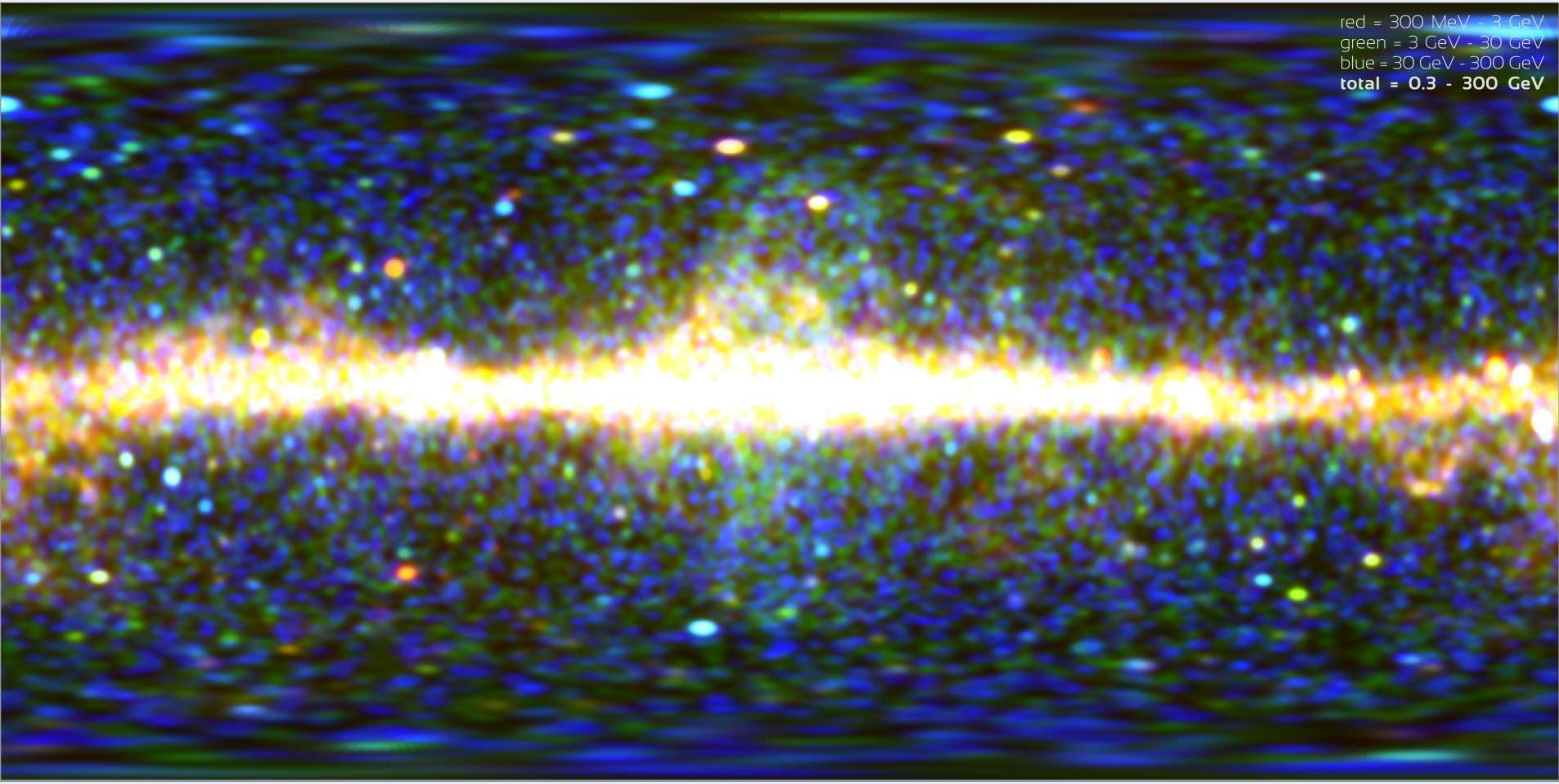


Short GRB

Gamma Ray Bursts

Long GRB GRB



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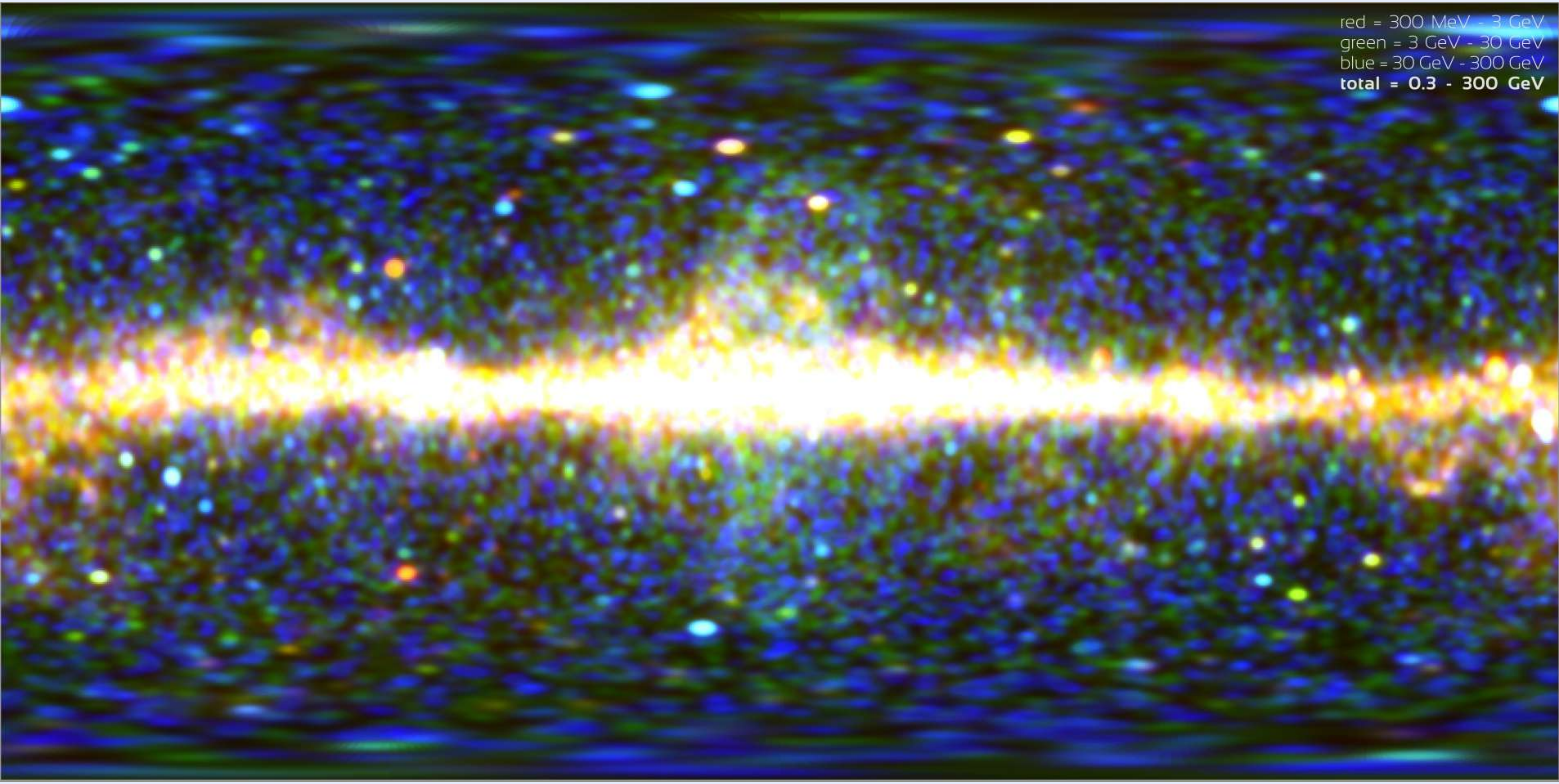
Gamma Ray Bursts

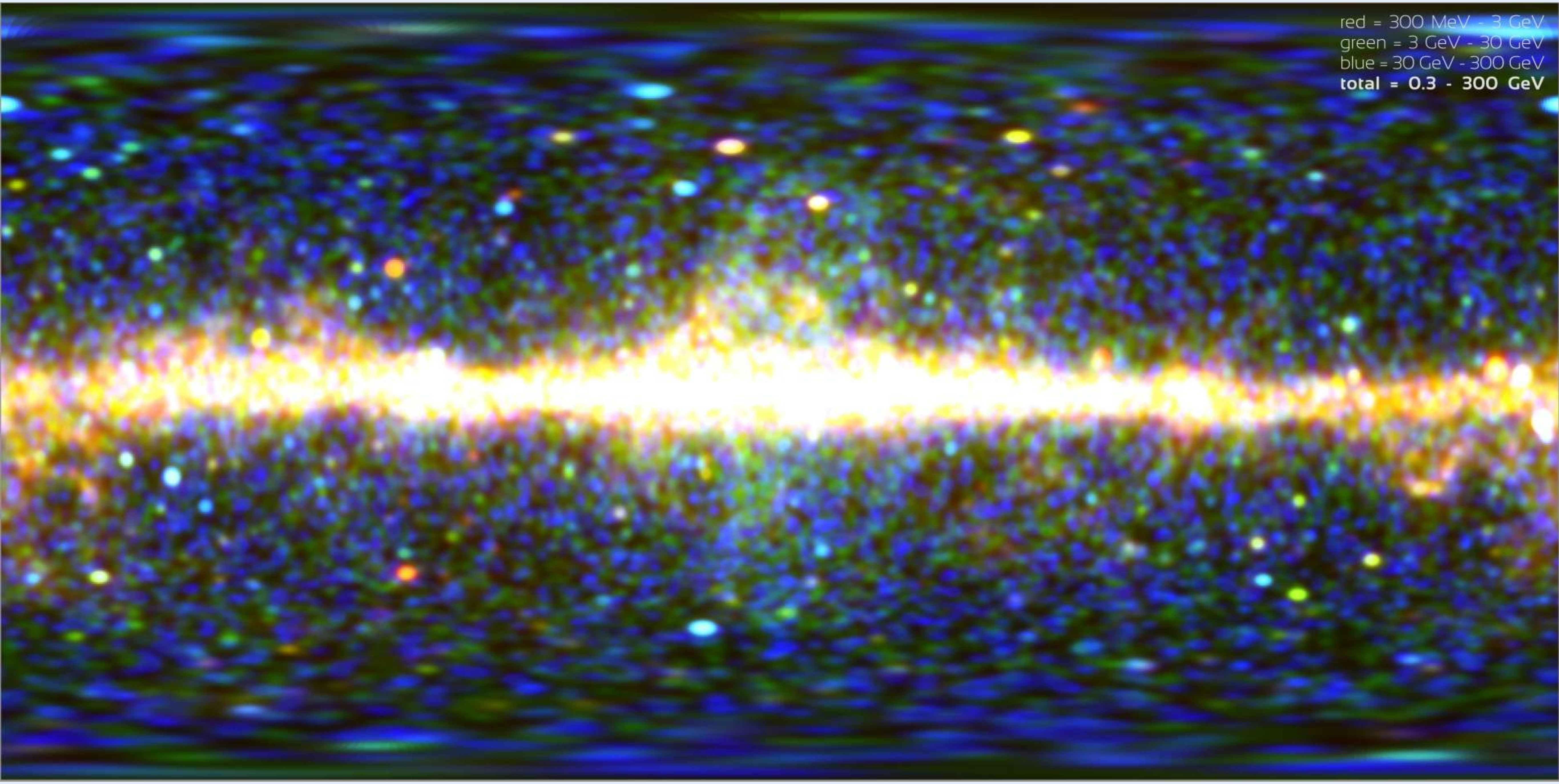
Long GRB   GRB21



Short GRB

Gamma Ray Bursts

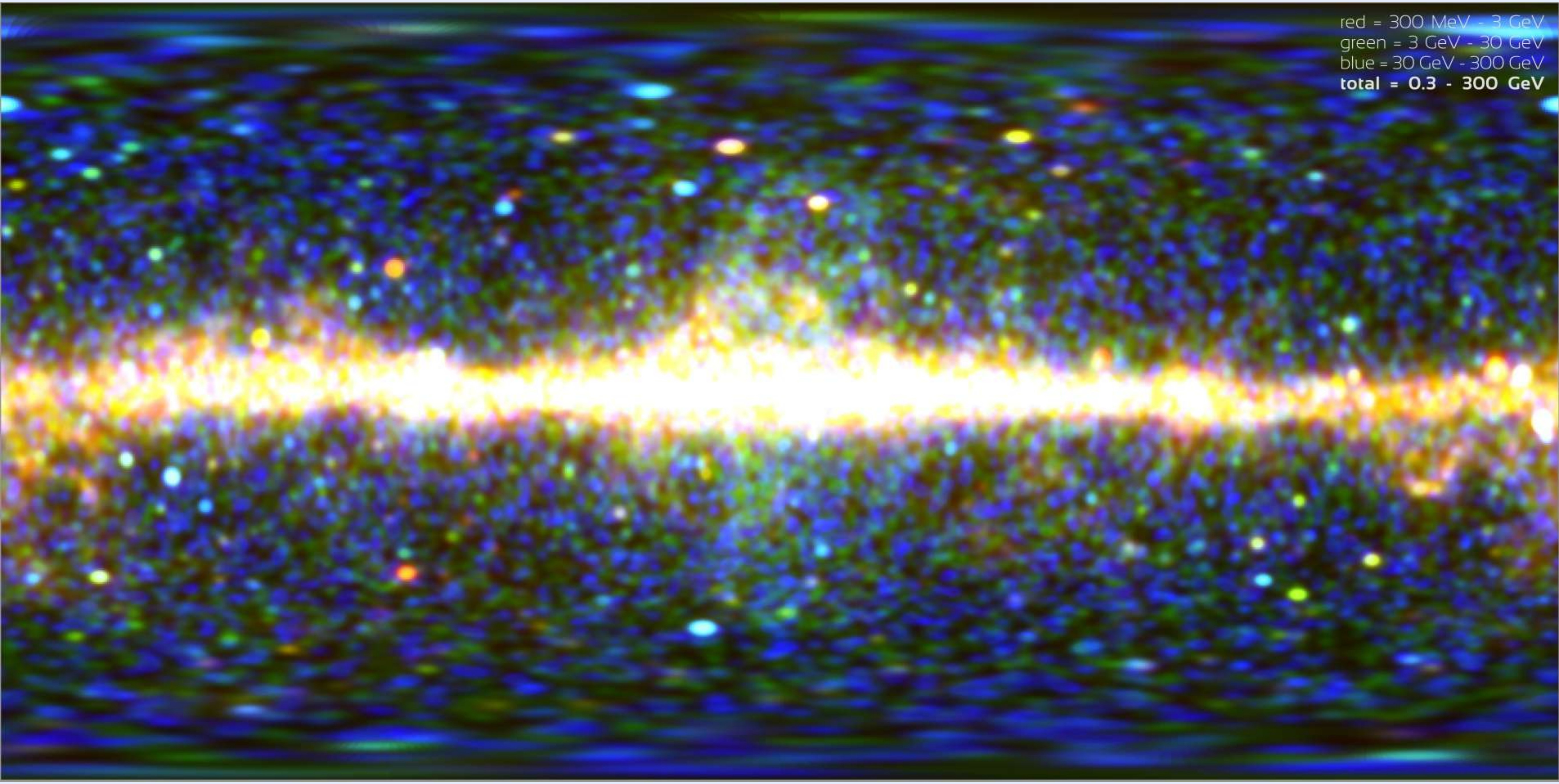
Long GRB   GRB2108



Short GRB

Gamma Ray Bursts

Long GRB   GRB210810



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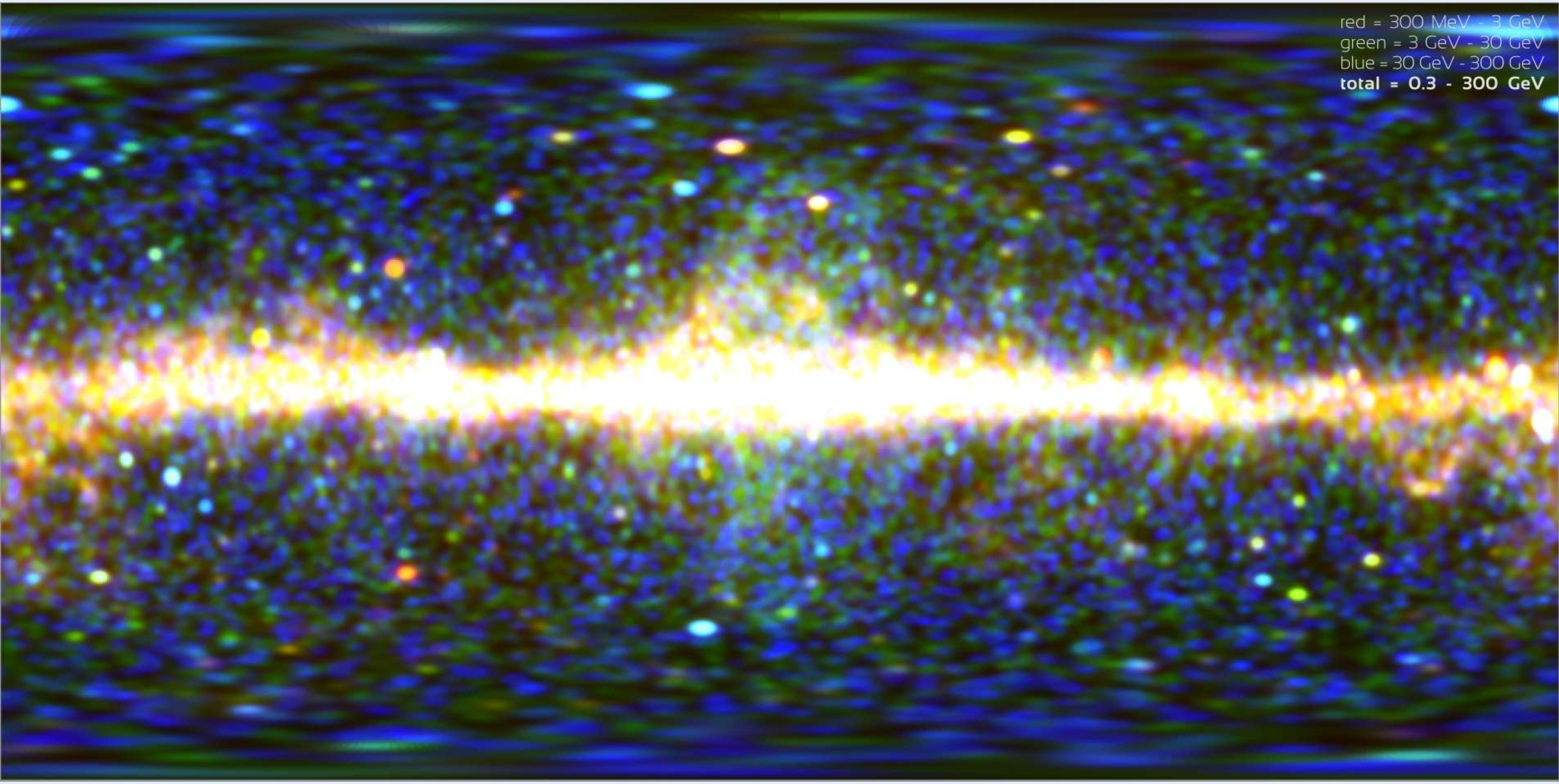
Gamma Ray Bursts

Long GRB   GRB210810A



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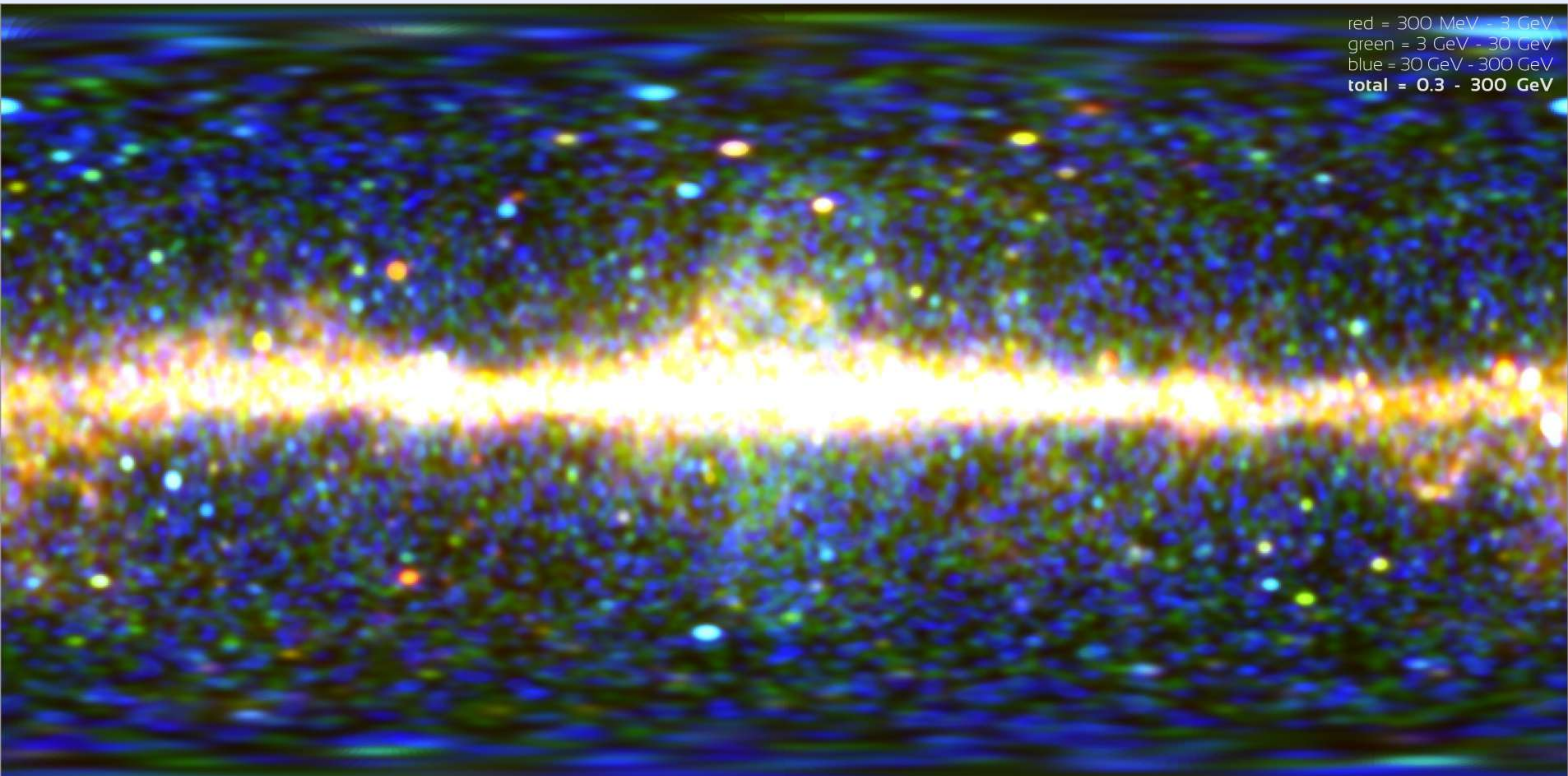
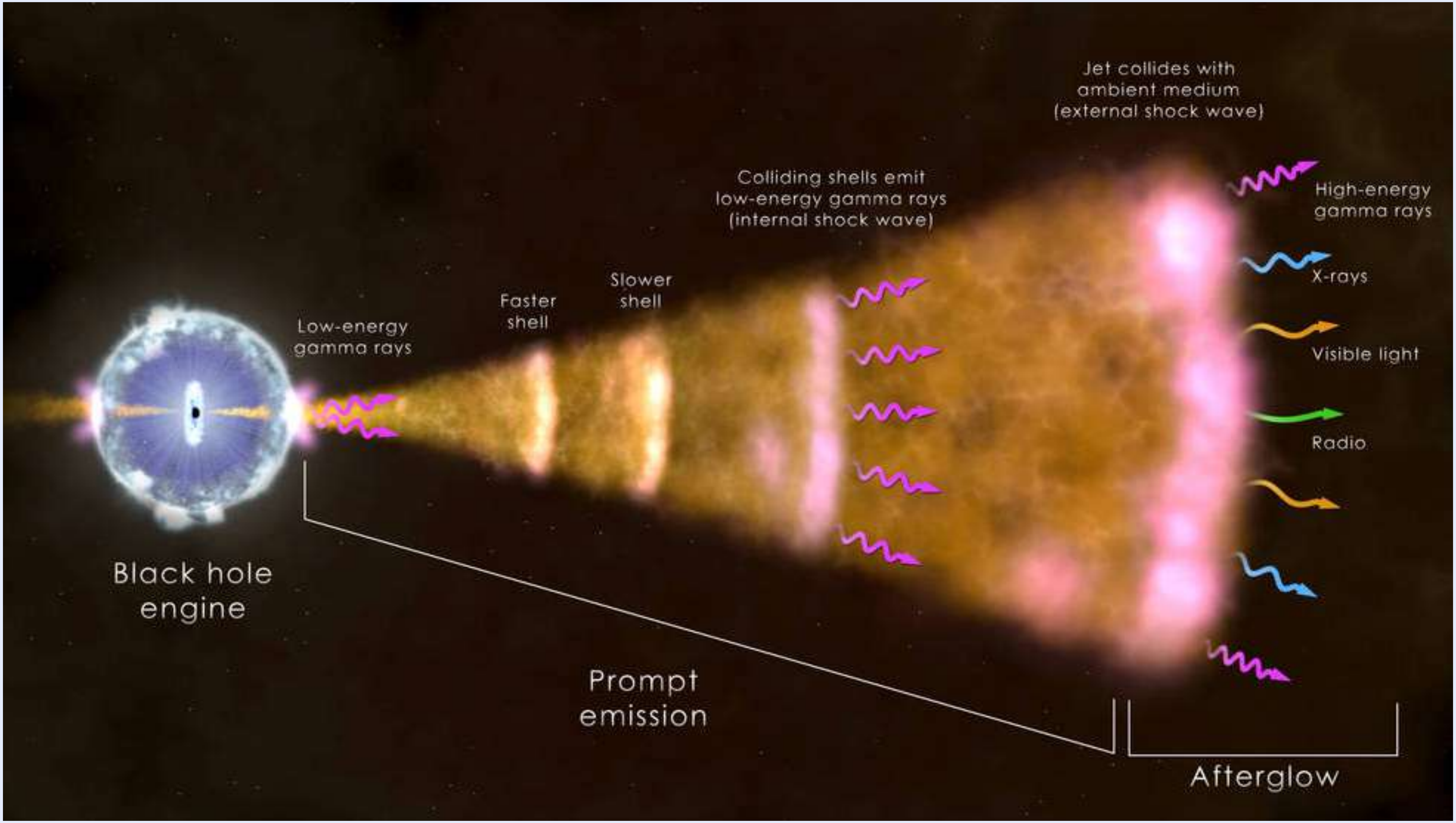


GRB210810B   Short GRB

Processes during a GRB



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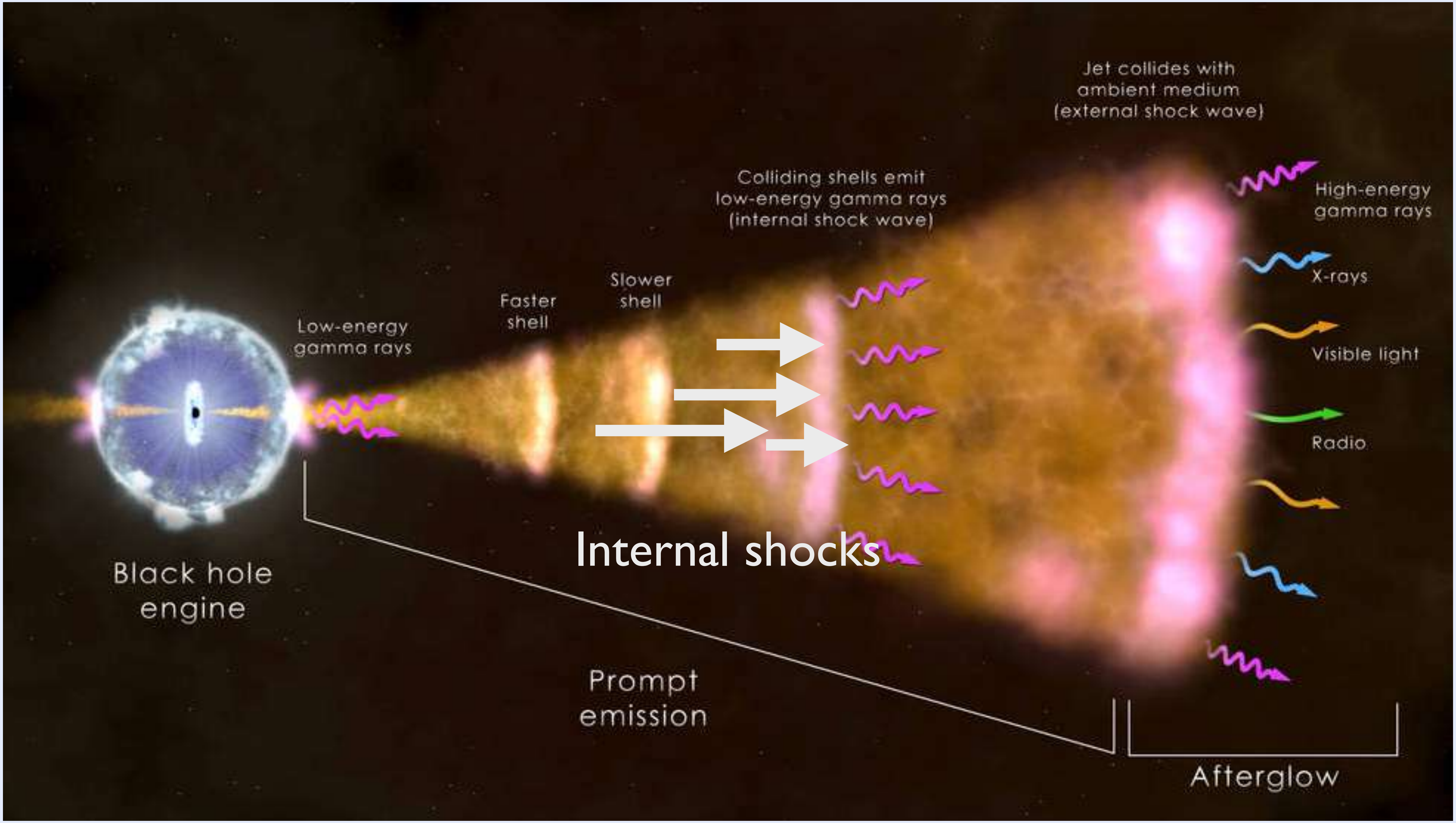

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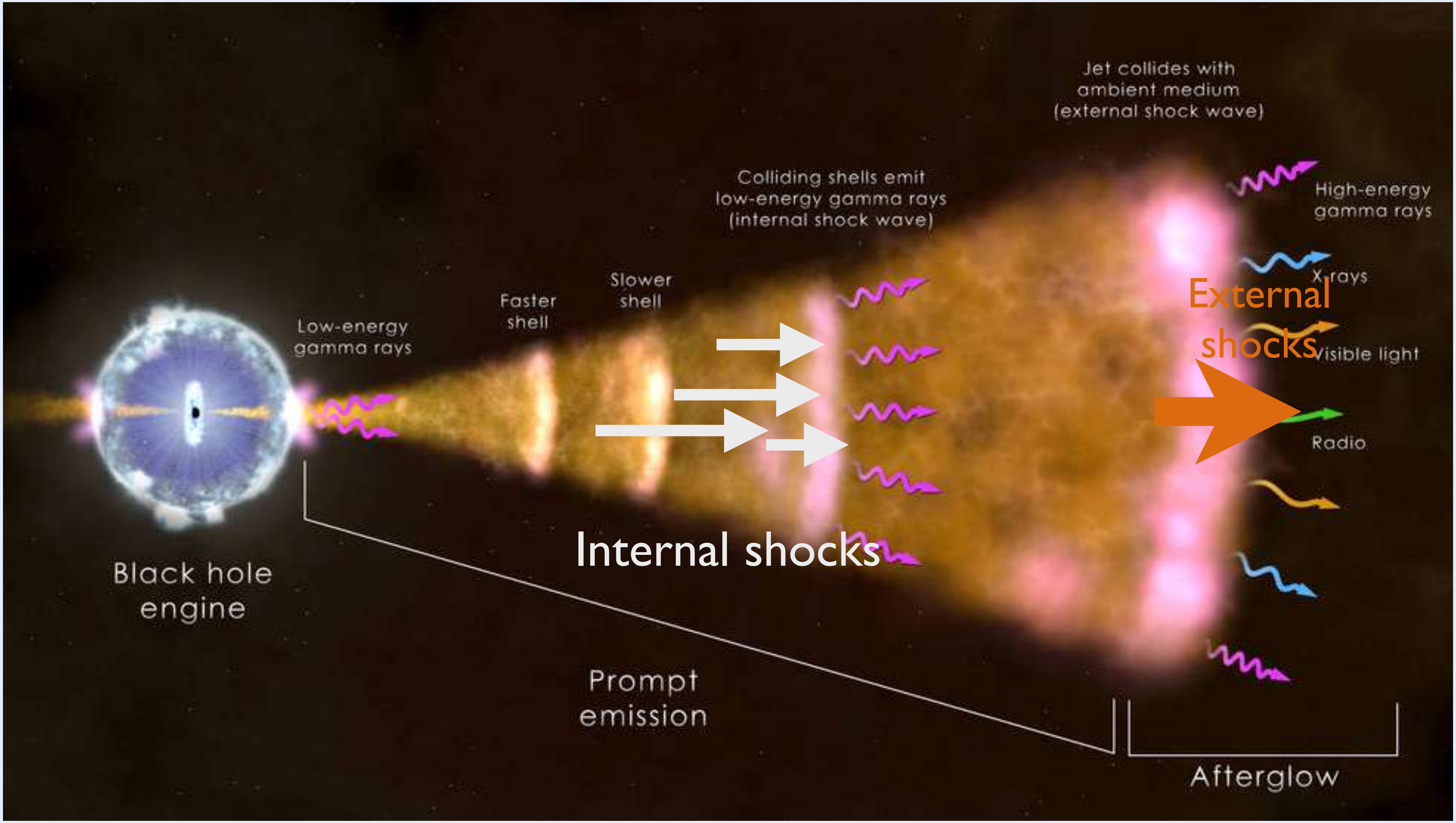

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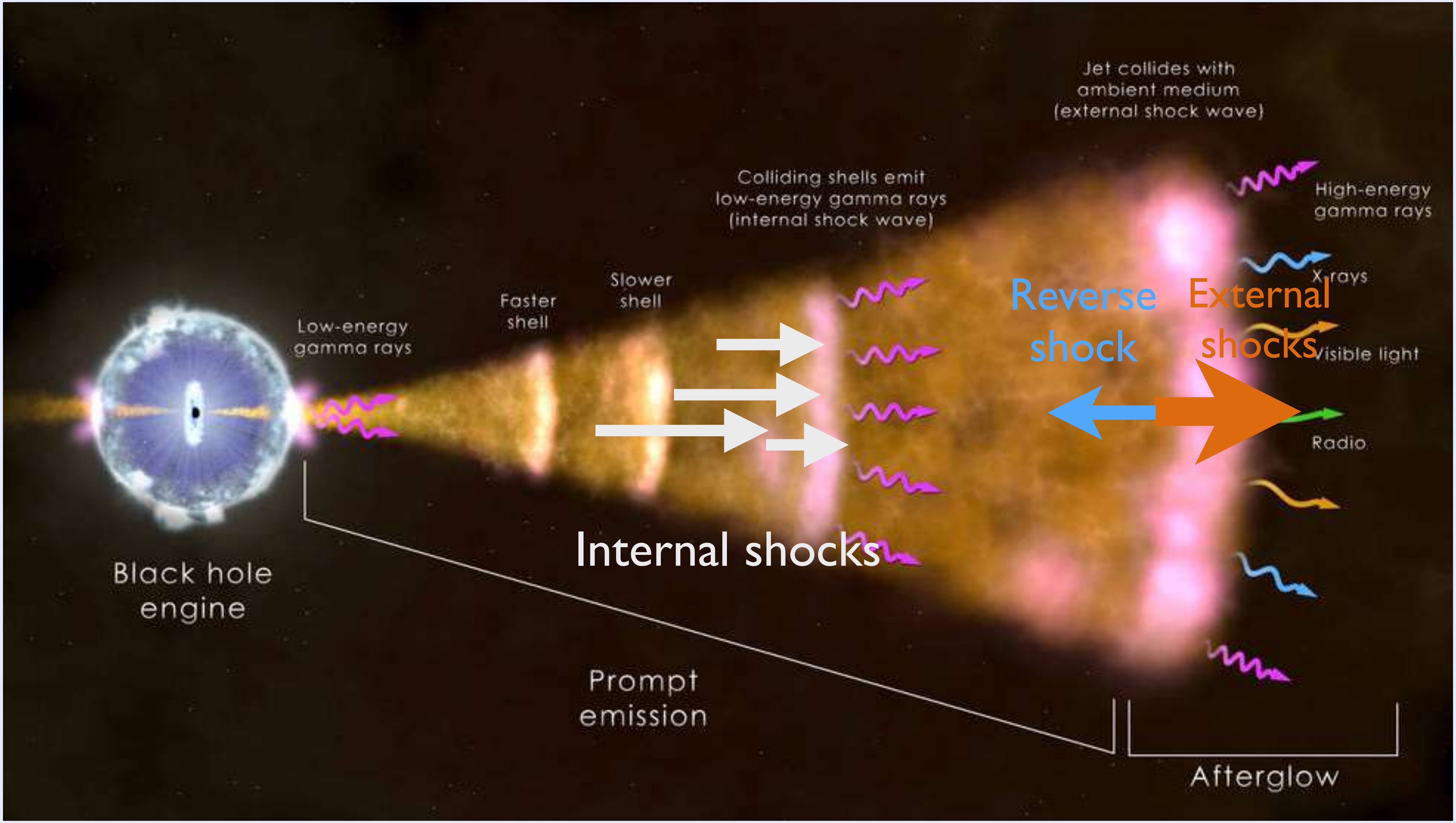

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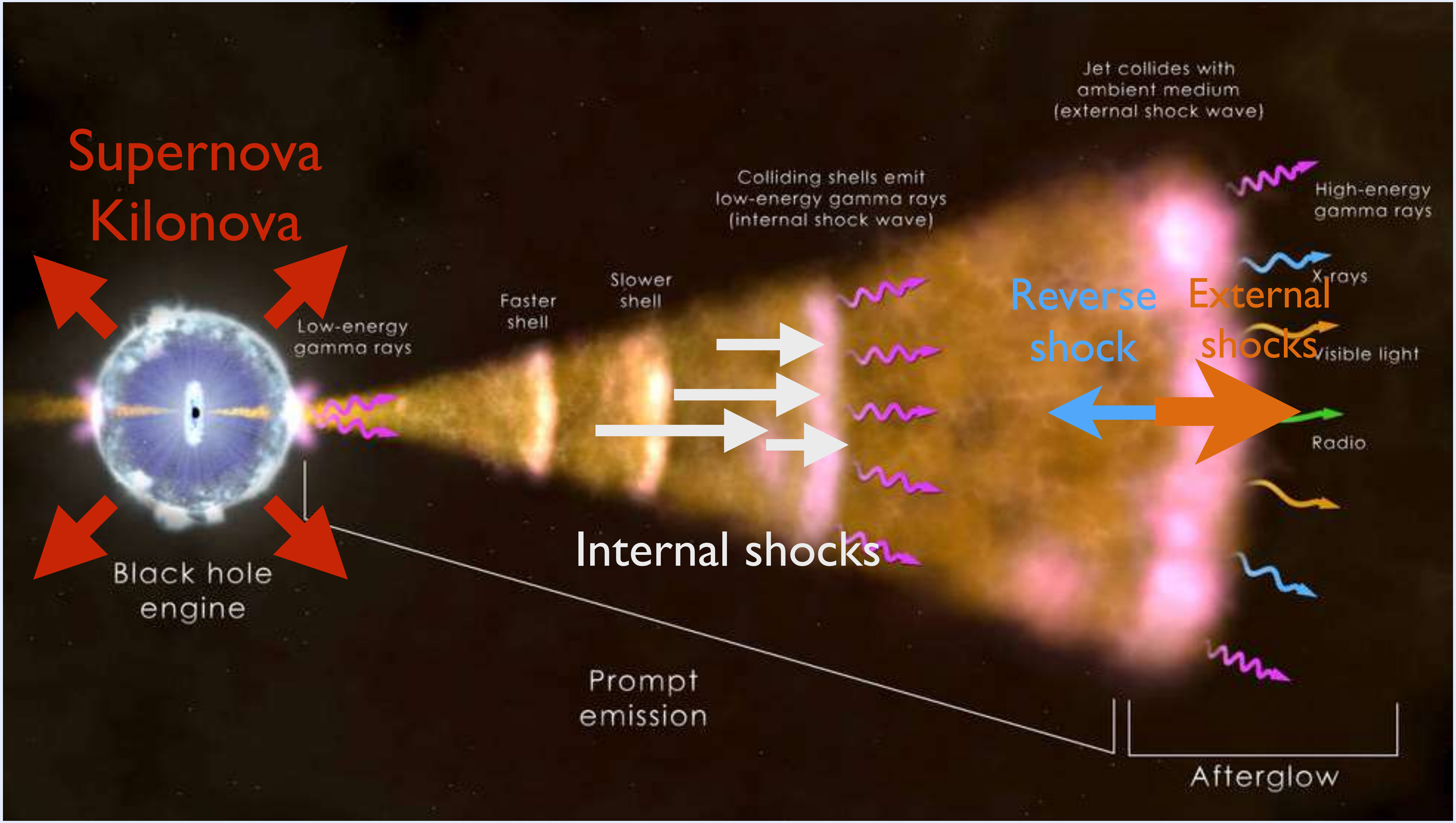

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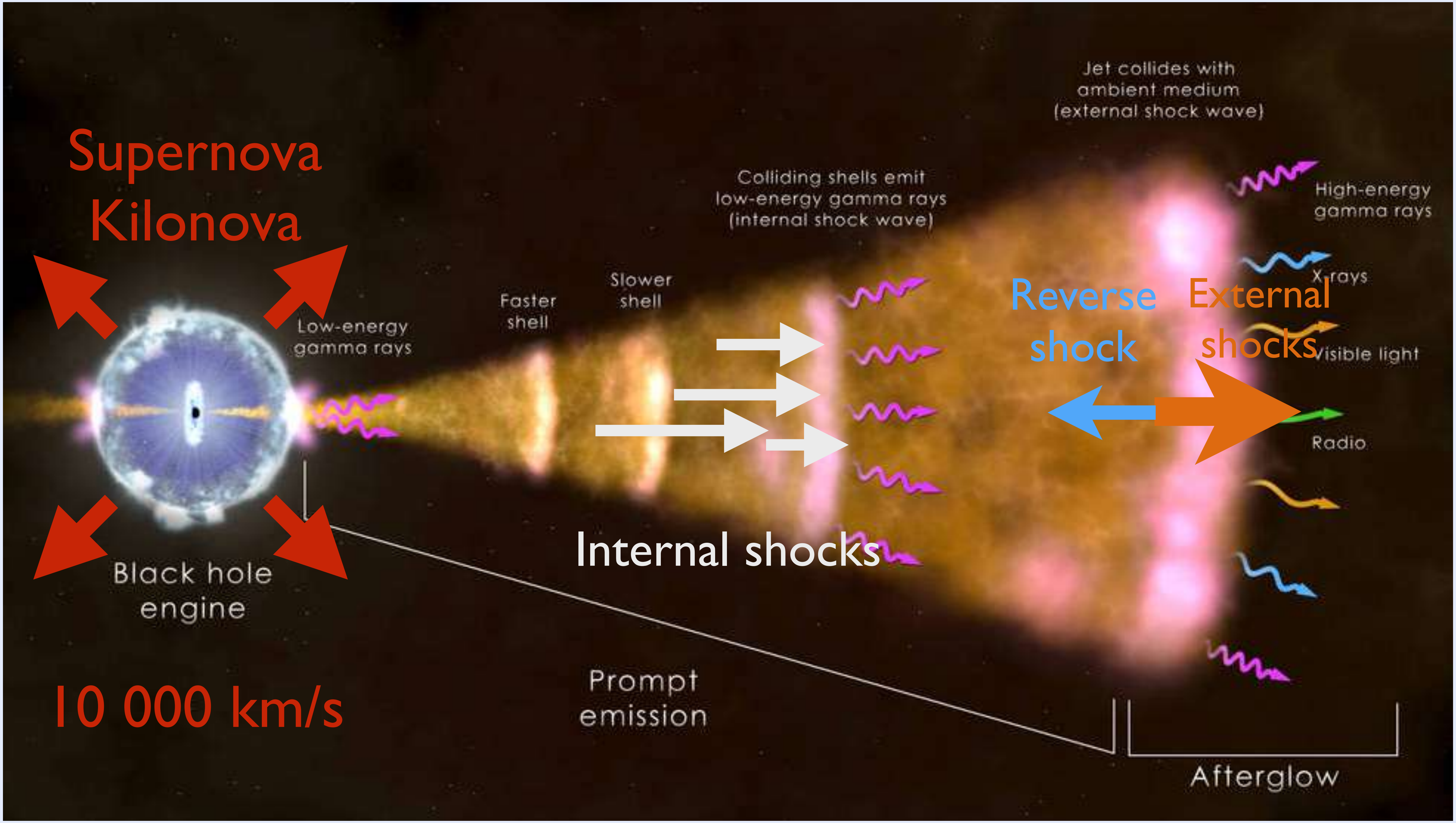

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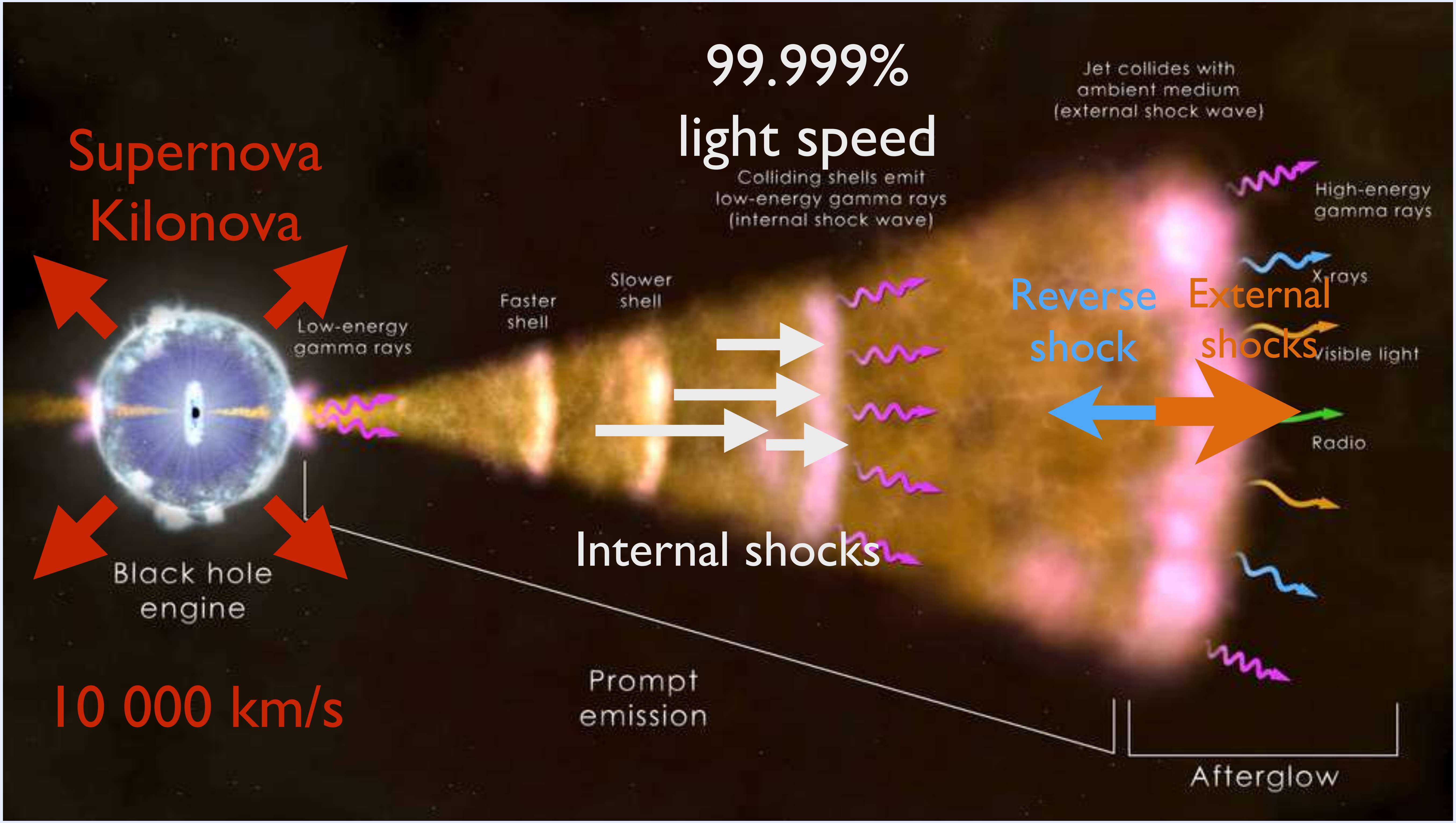
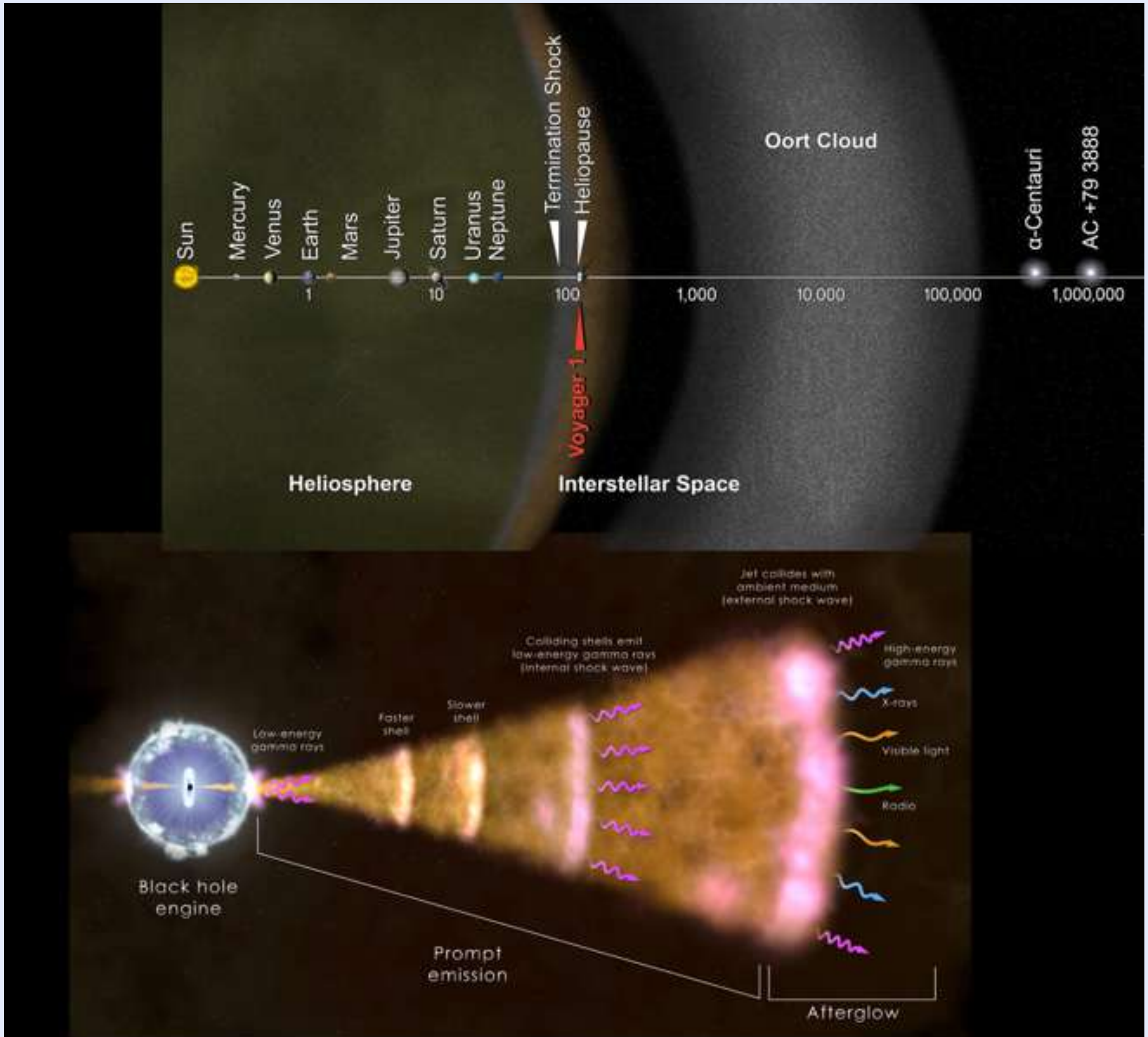
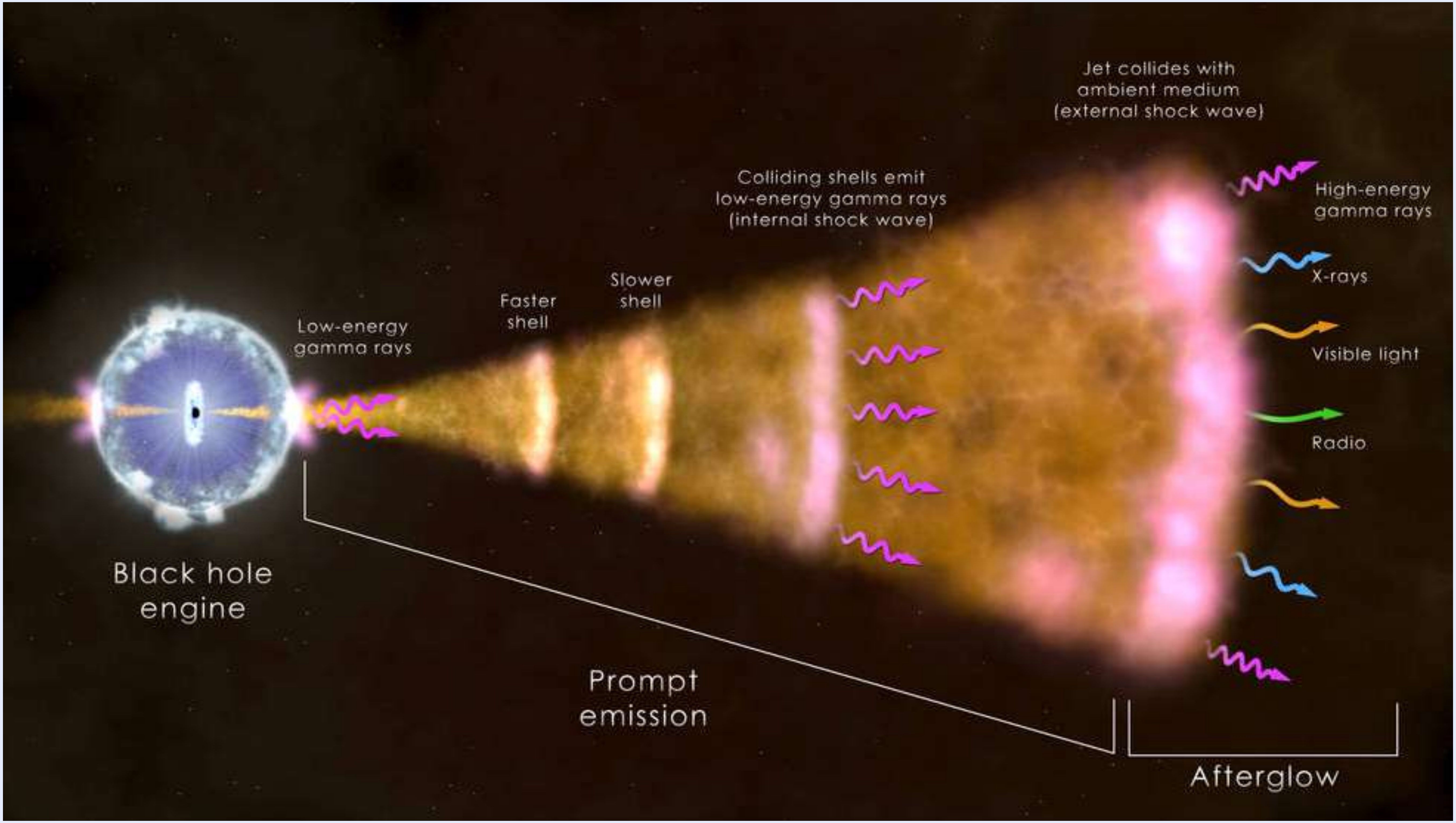


Physical scales

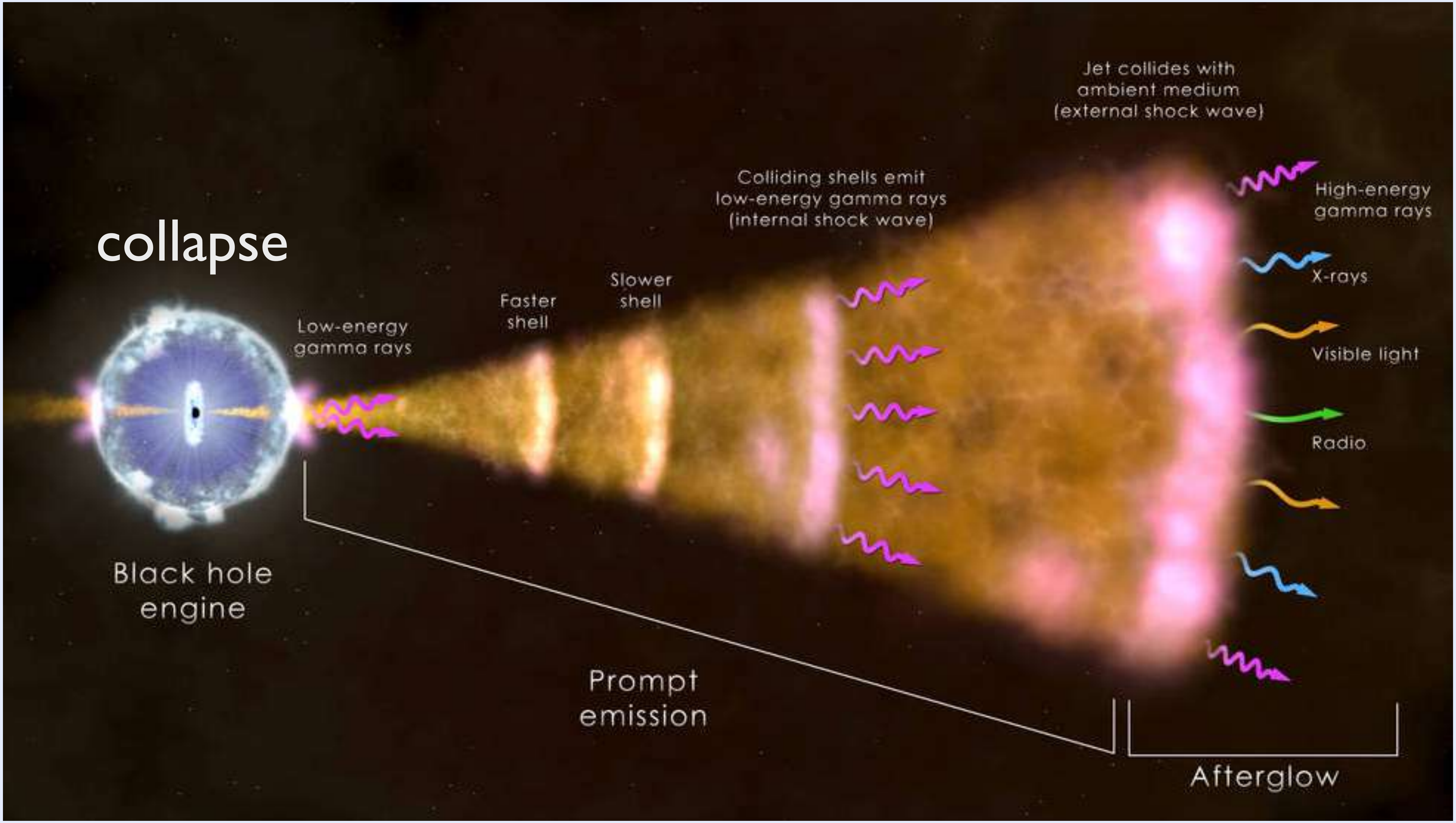


Time scale



Jet collides with
ambient medium
(external shock wave)
Colliding shells emit
low-energy gamma rays
(internal shock wave)
High-energy
gamma rays
X-rays
Visible light
Radio
Slower
shell
Faster
shell
Low-energy
gamma rays
Black hole
engine
Prompt
emission
Afterglow

Time scale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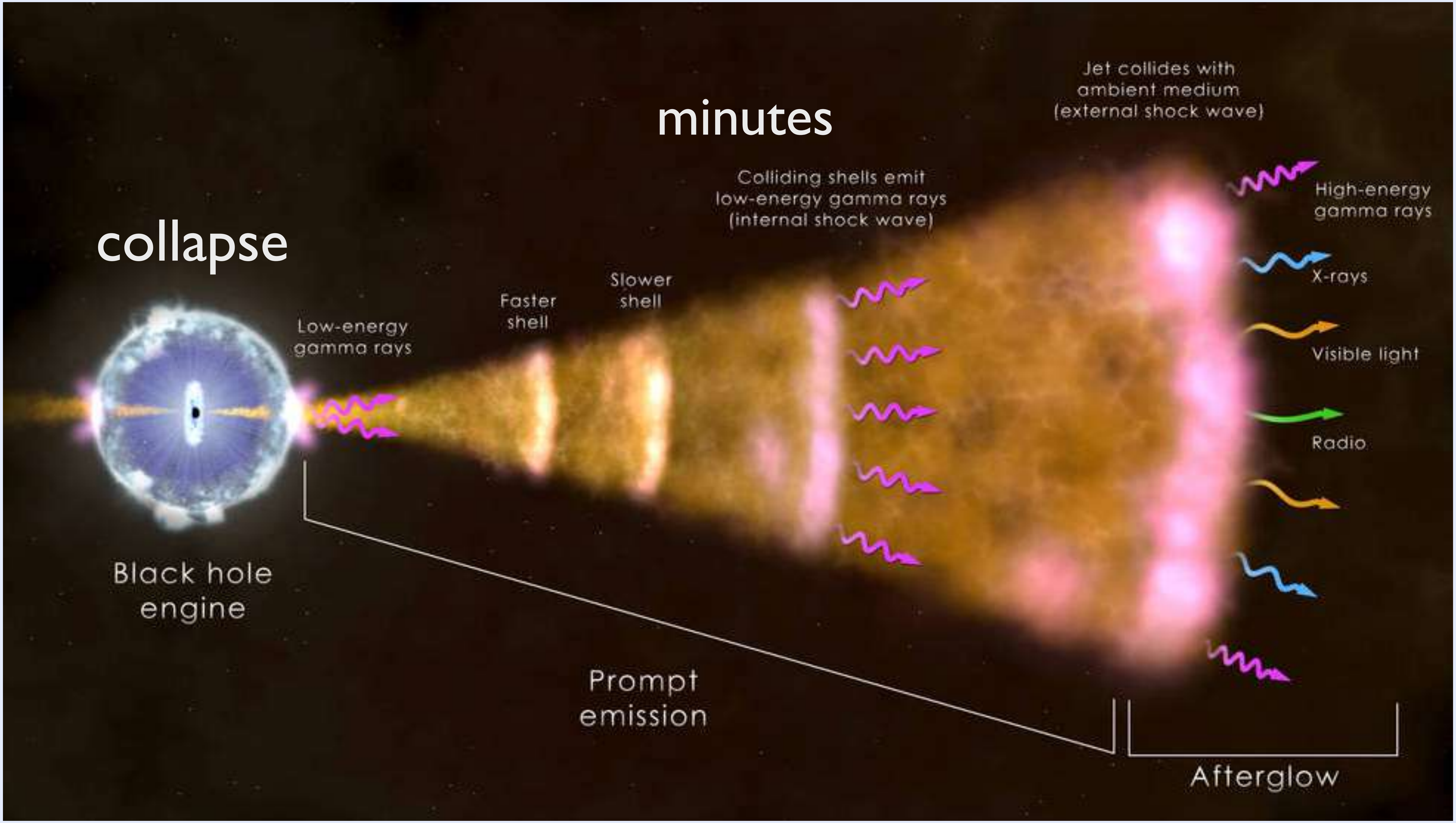
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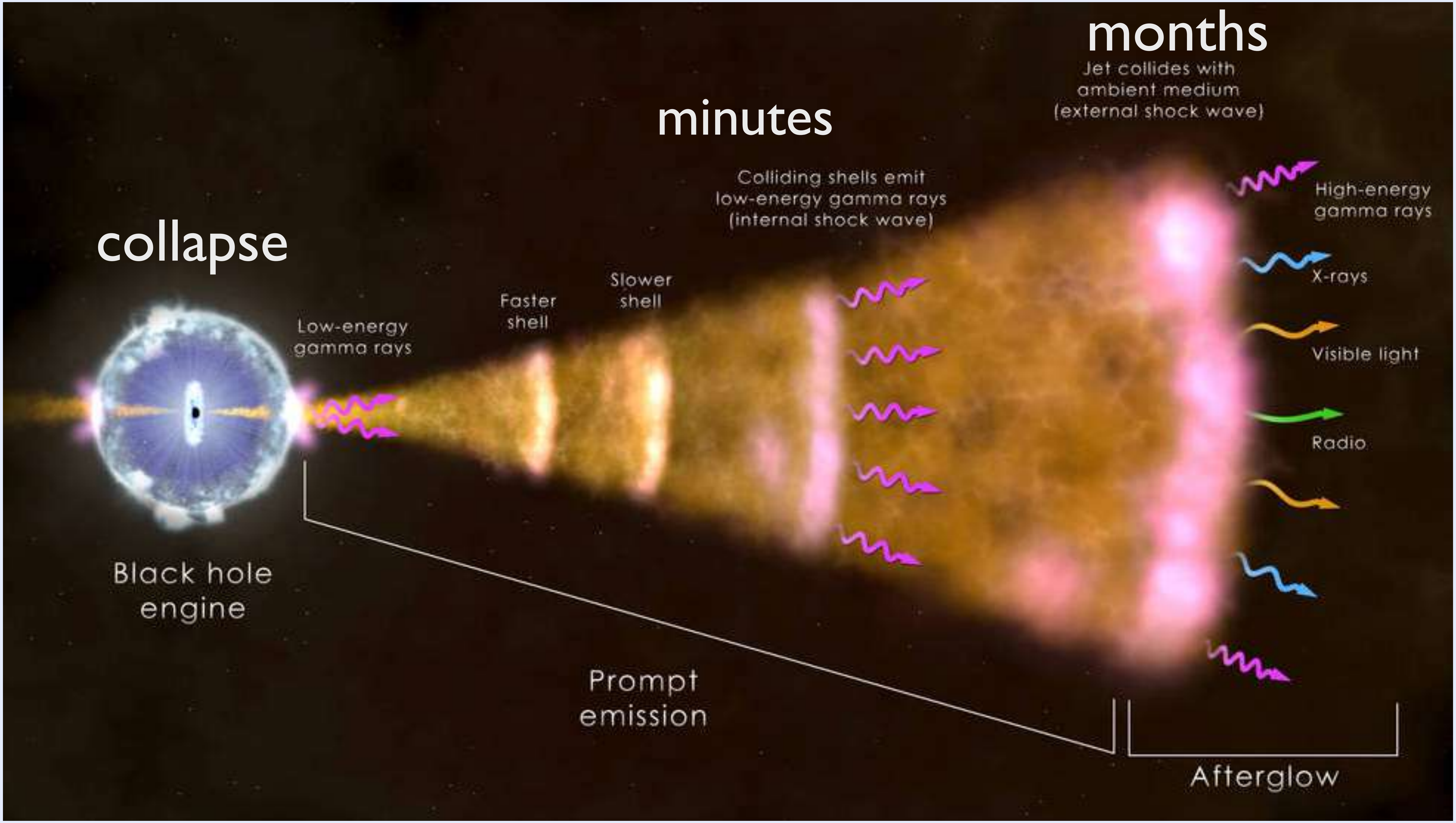
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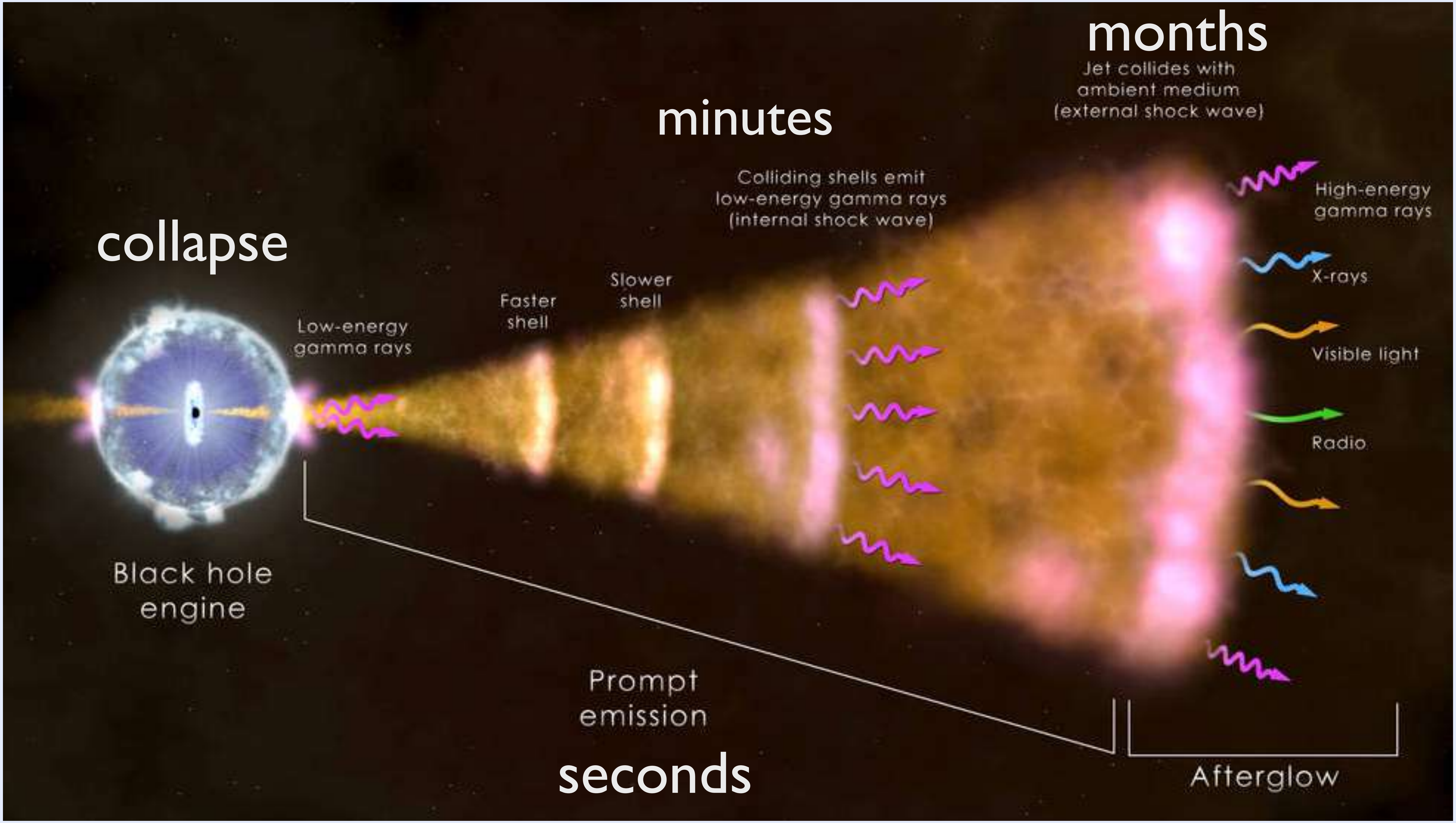

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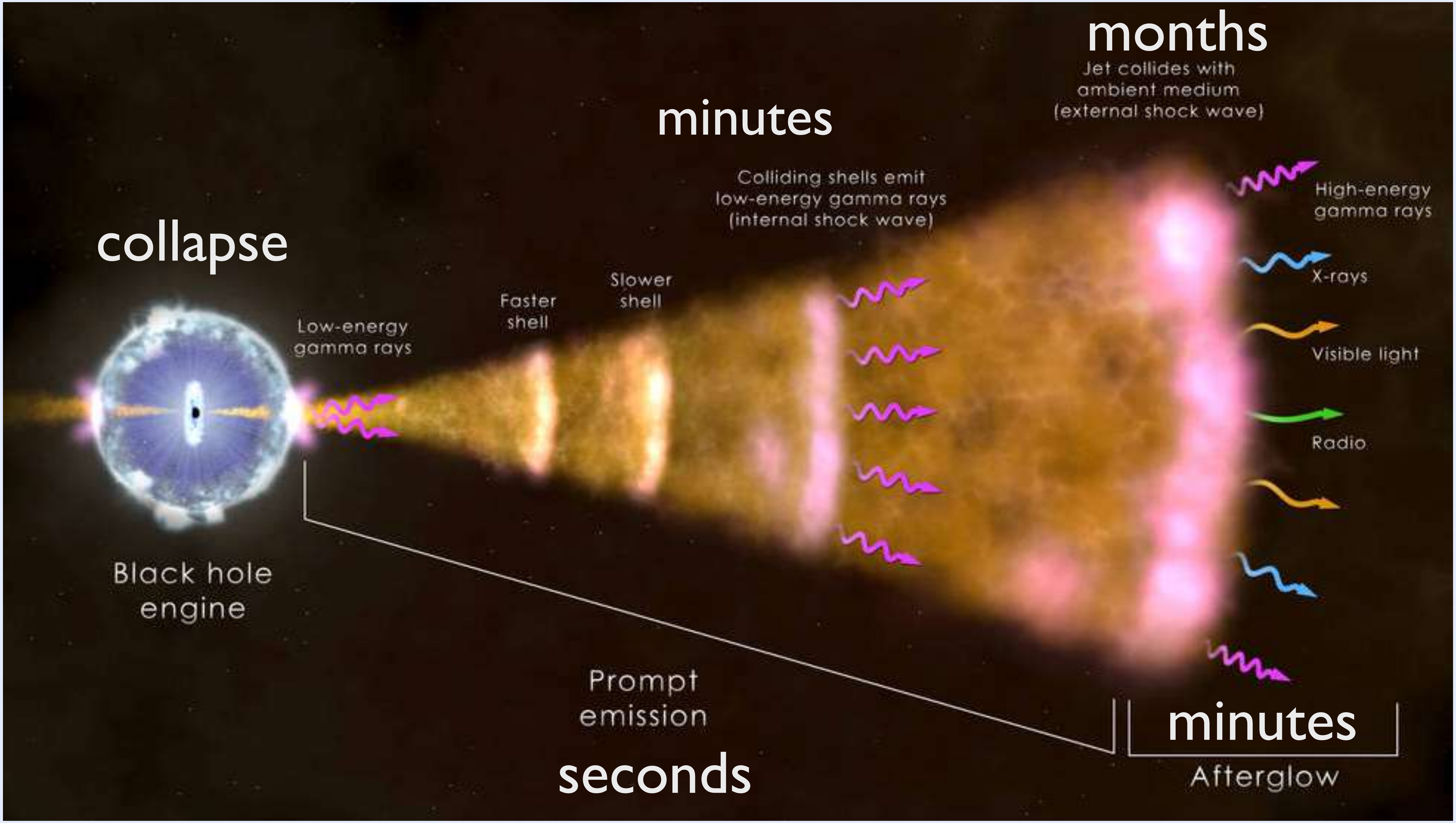
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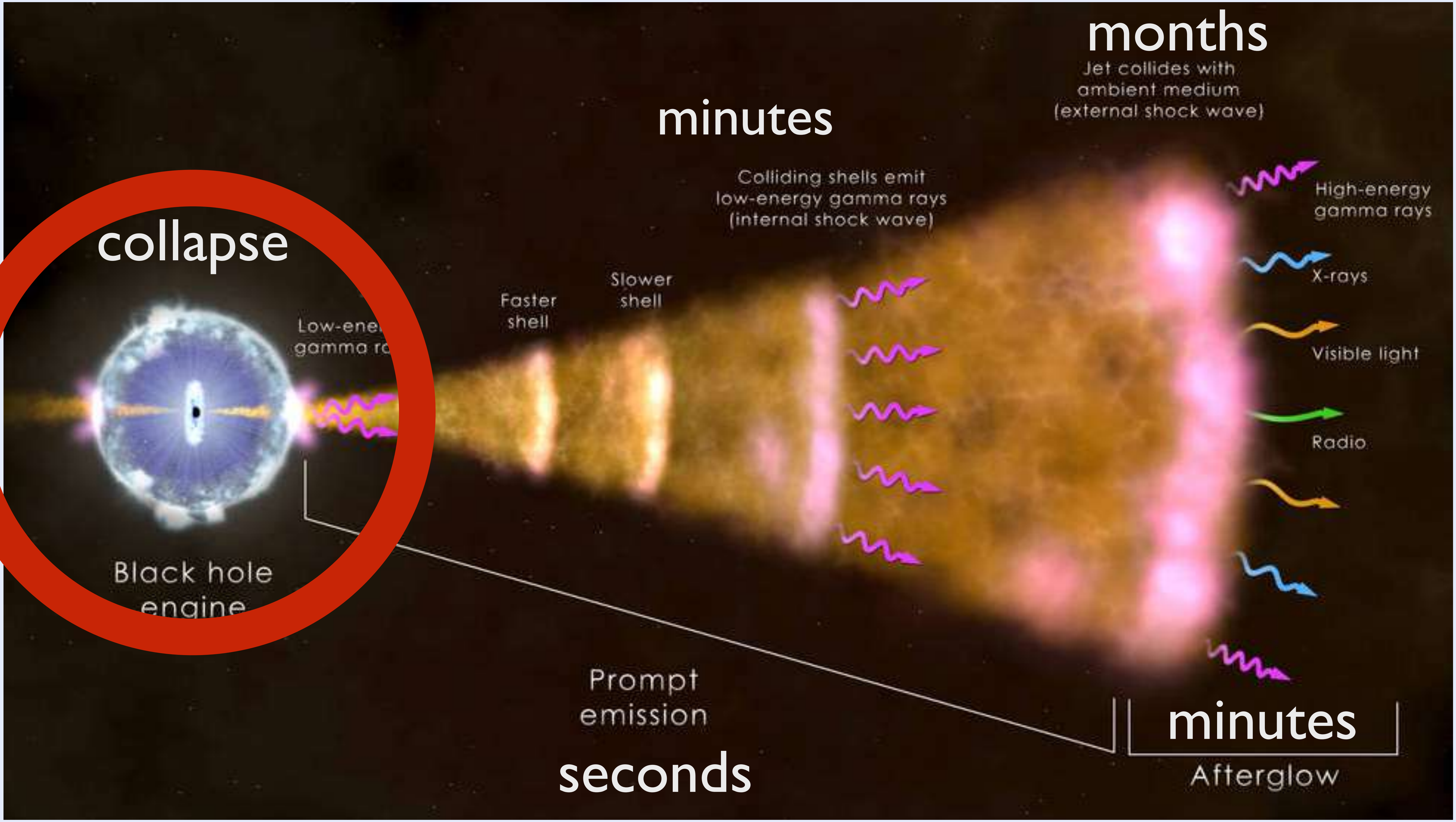
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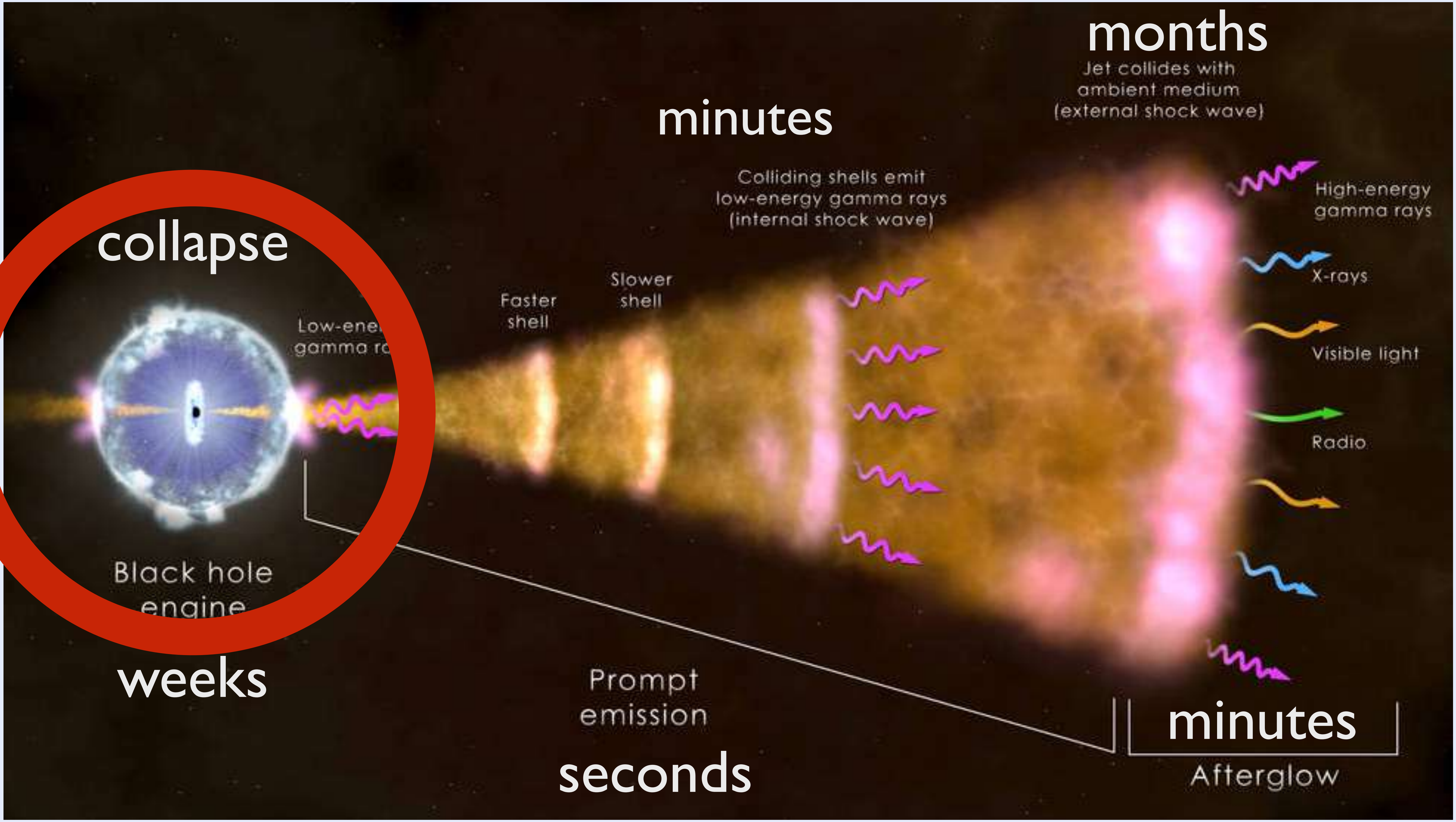
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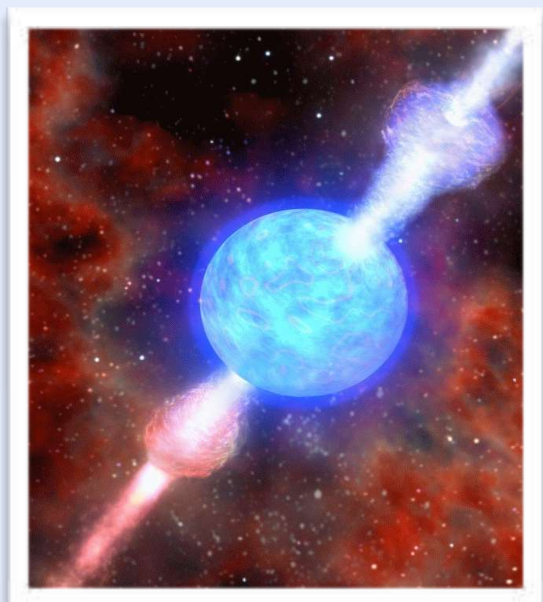
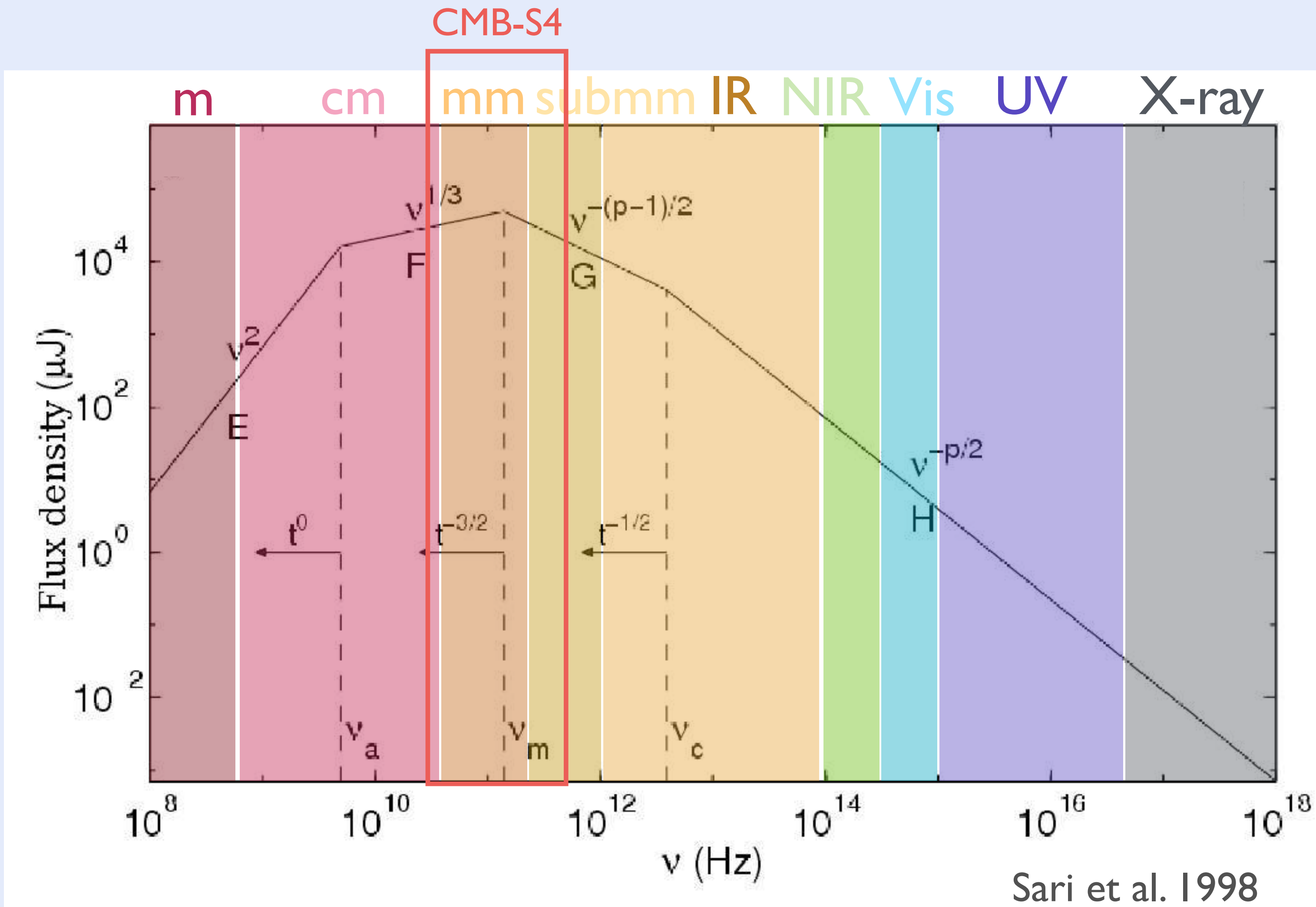
Synchrotron spectrum



Long GRBs



Short GRBs

Value and evolution of:

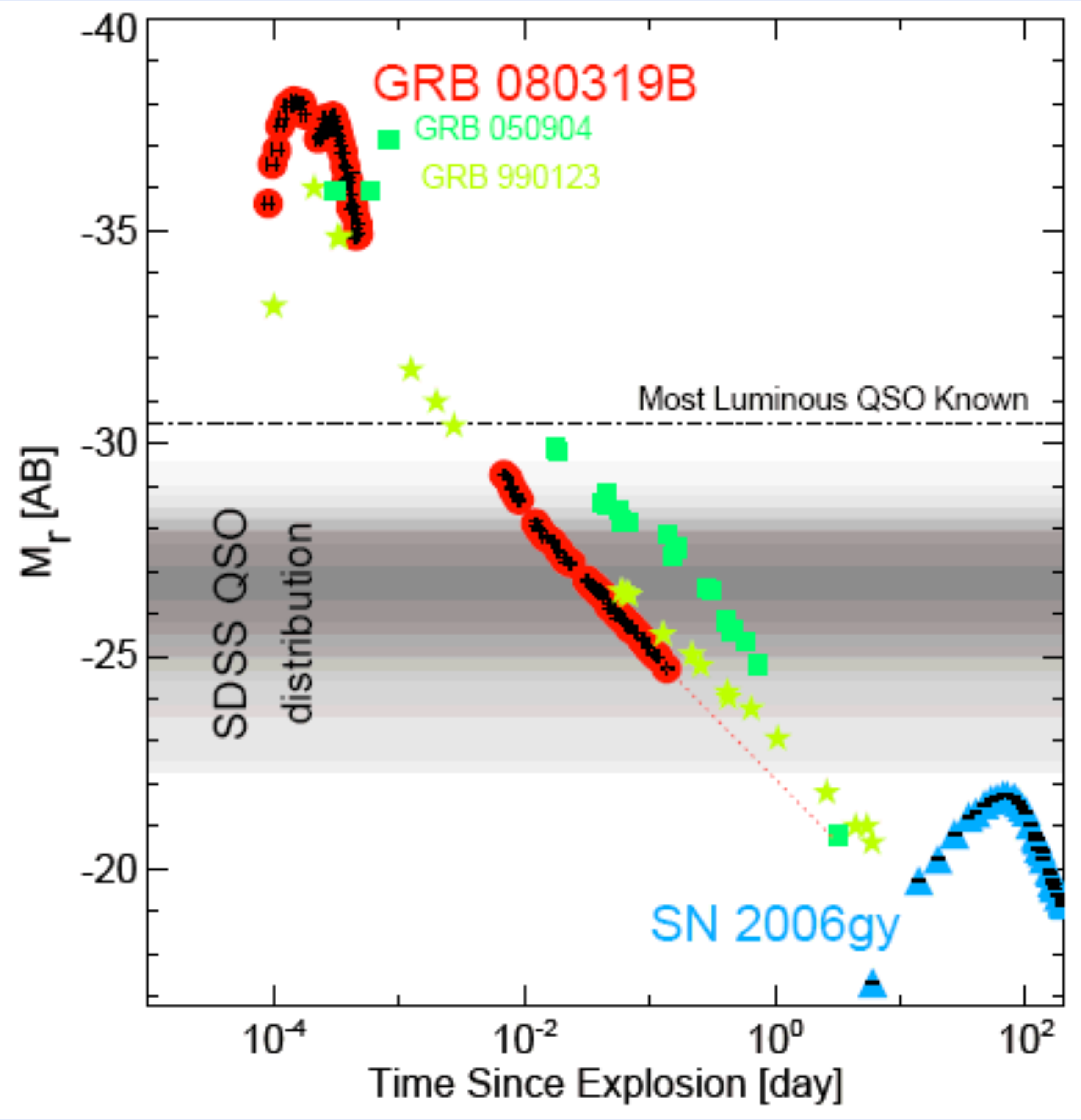
- Characteristic frequencies
- Slopes

Determines:

- Acceleration
- Density
- Geometry
- Microphysical parameters

Long GRBs

- Most luminous explosions in the Universe ($E_{iso} = 10^{51-54}$ erg)
- Detected at all redshifts $0.008 < z < 9.4$, 99% of the Universe's history (Tanvir et al. 2009, Cucchiara et al. 2011)
- Average $z \sim 2$ (Jakobsson et al. 2006)
- Associated with broad-line SN Ic (Galama et al. 1998)
- Located in star forming galaxies (Christensen et al. 2004)
- Produced by collapsars



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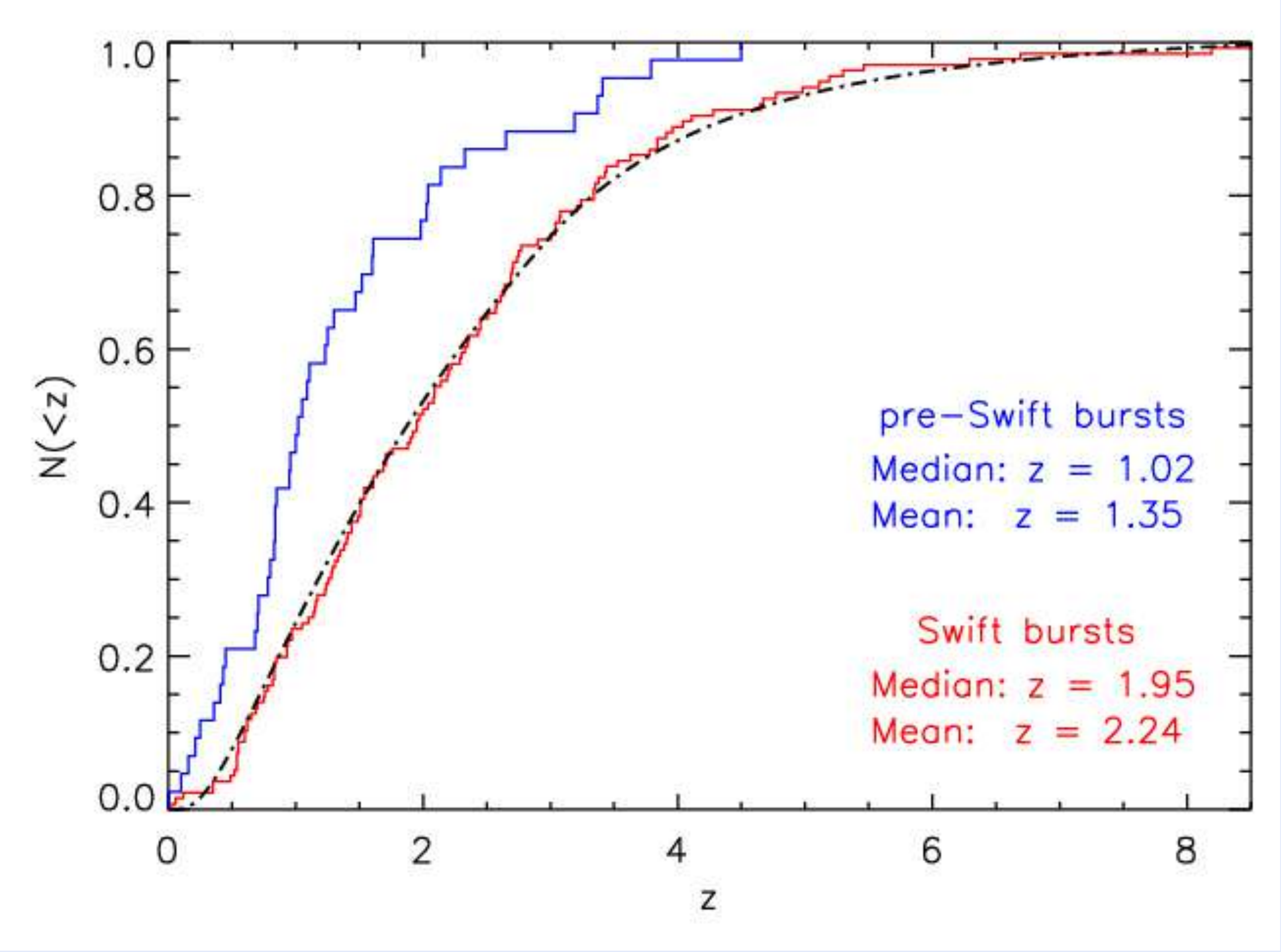

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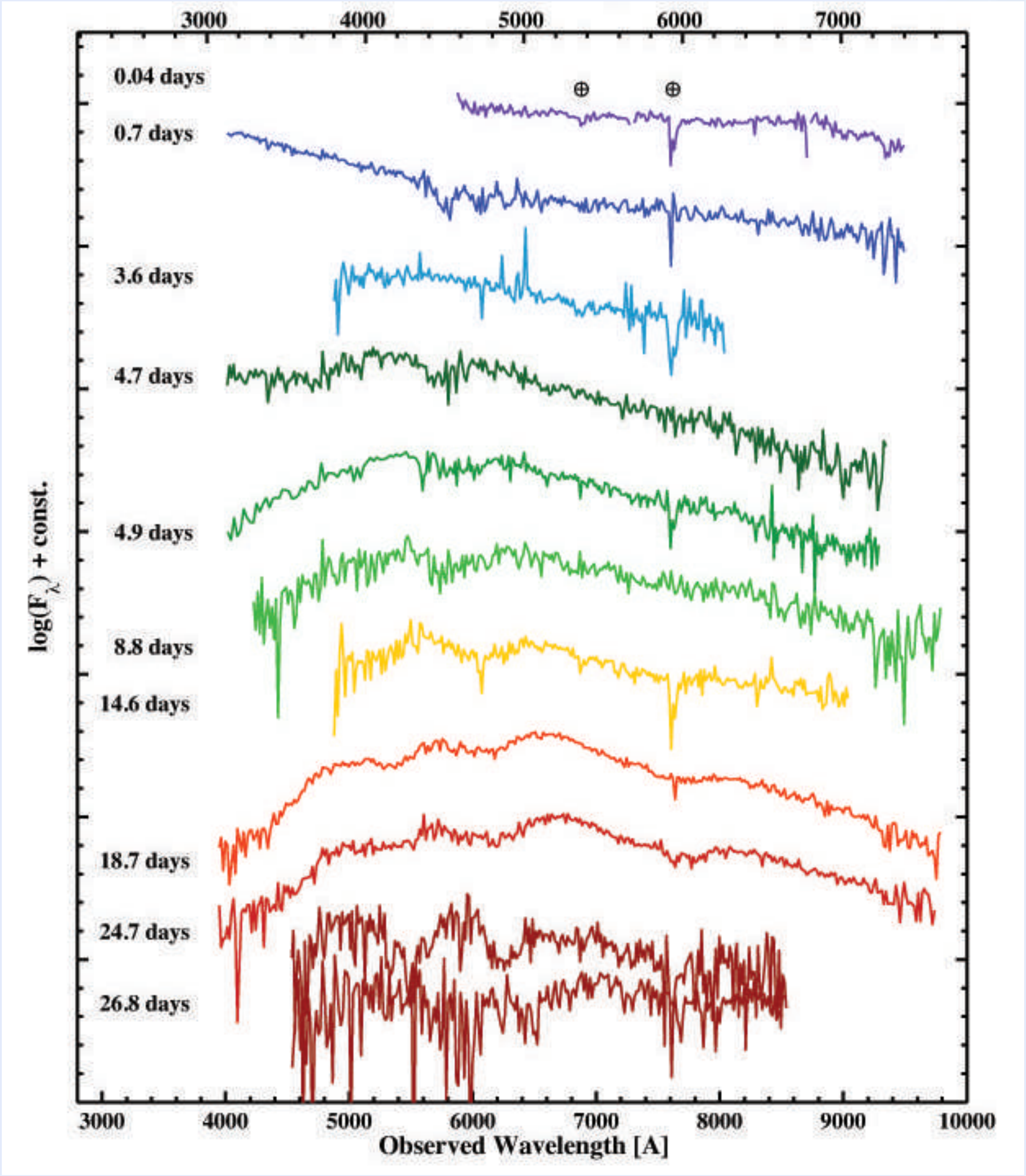

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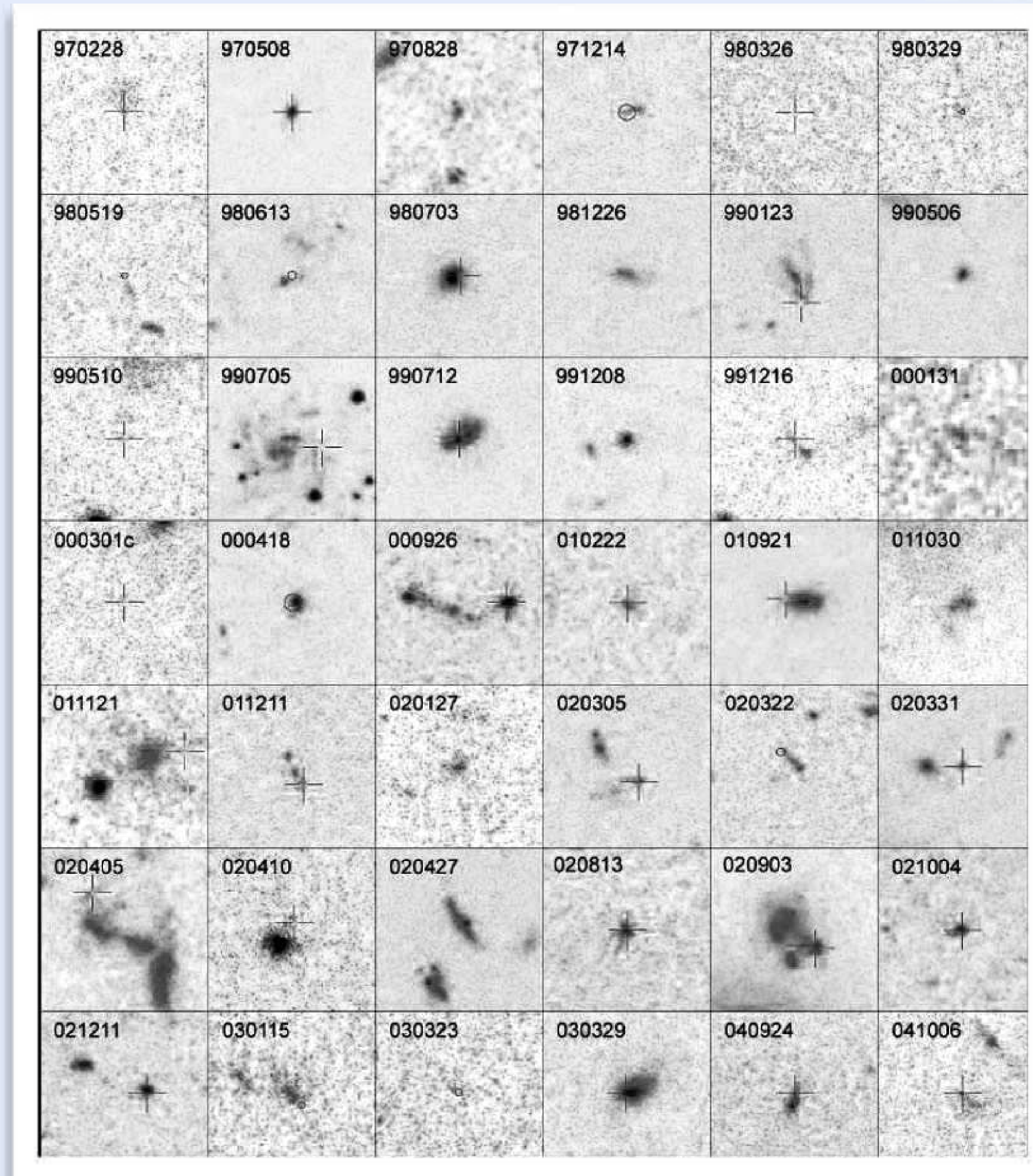

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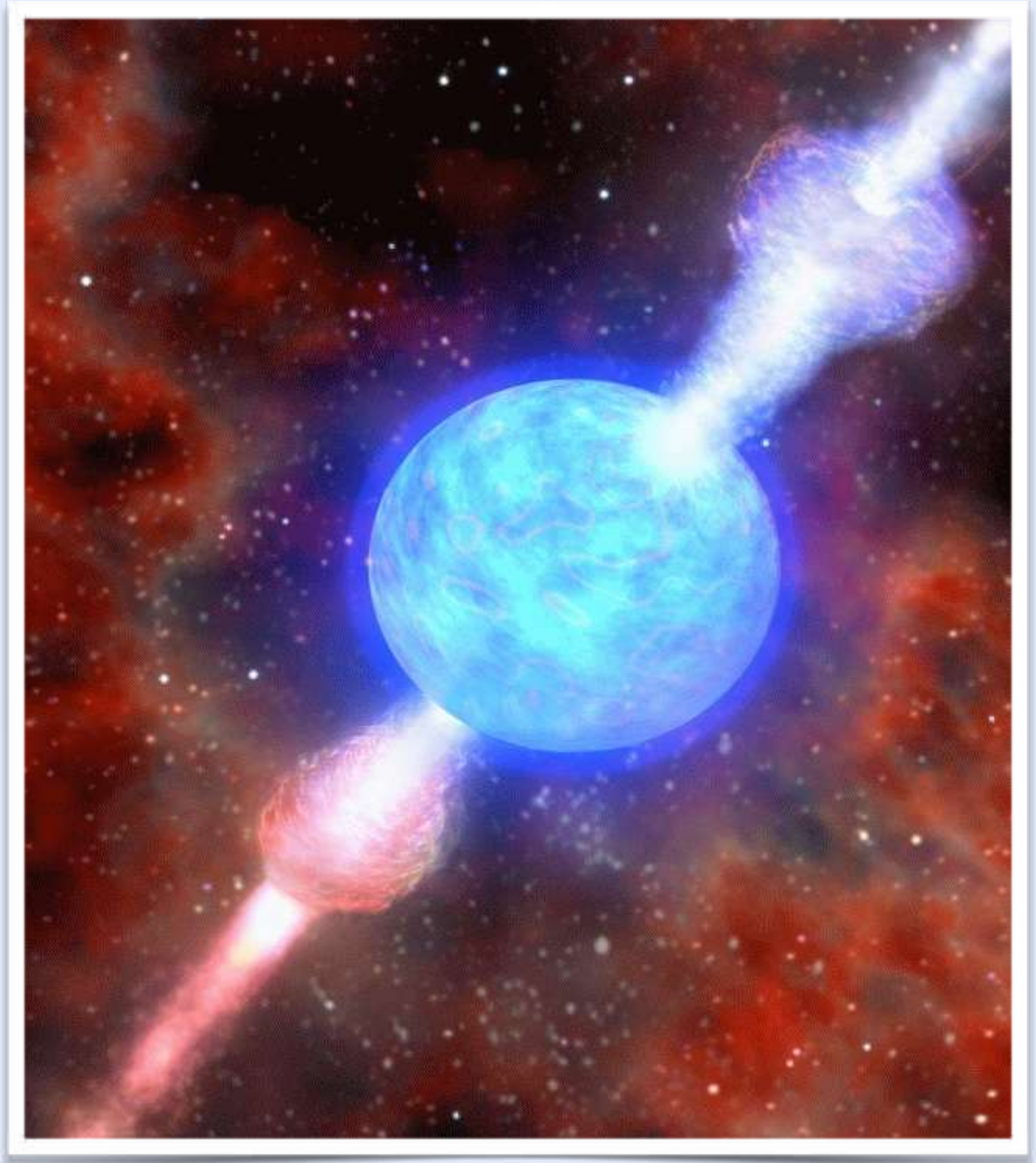
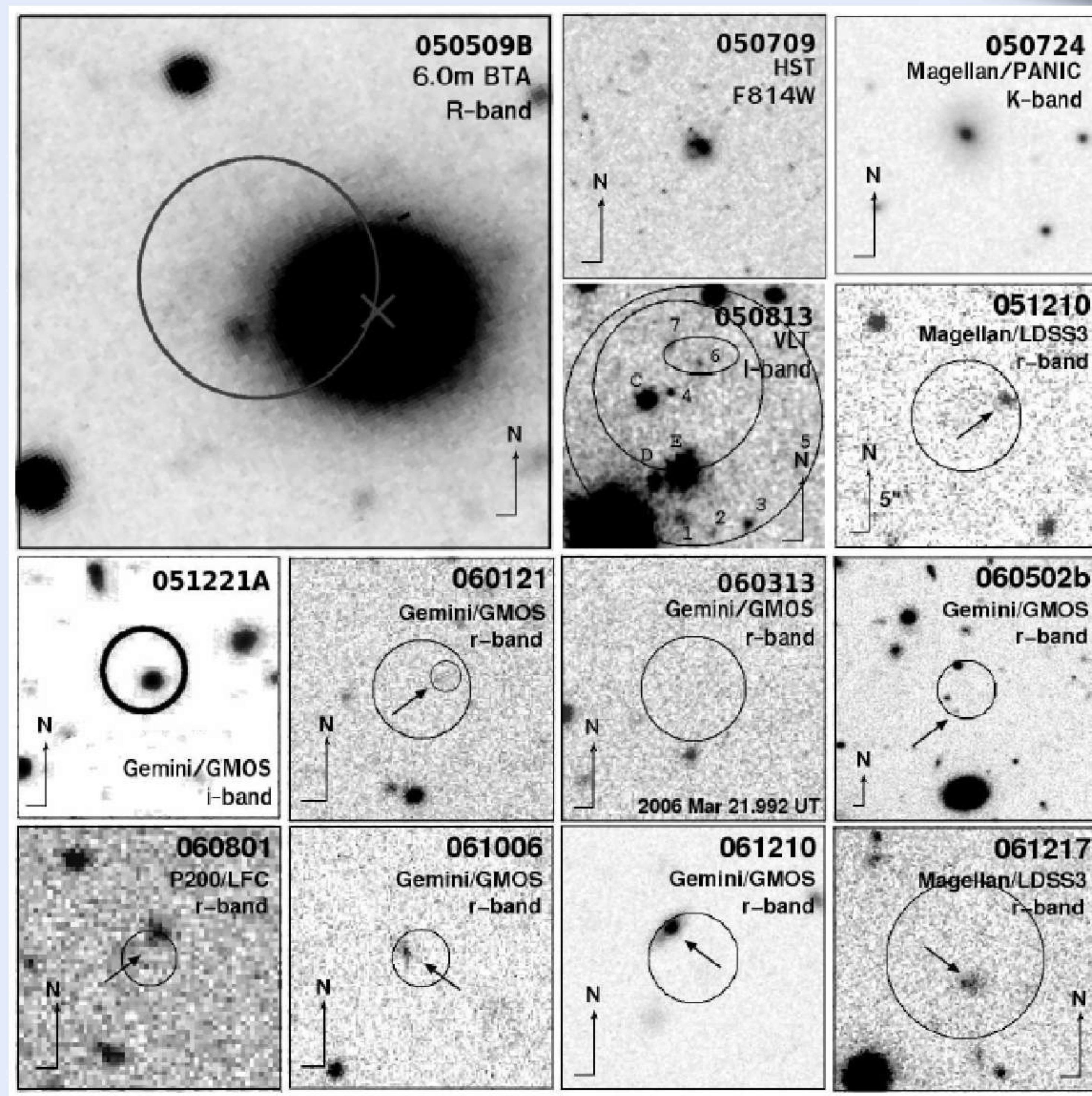


Short GRBs

- Fainter and very elusive!
- Varied types of host galaxies
- Only spectroscopy of 1 SGRB afterglow published until now (GRB130603B, de Ugarte Postigo et al. 2013)
- No SN, but an associated kilonova (Tanvir et al. 2013, Berger et al. 2013)
- Associated to GW signals (GRB170817A)
- Produced by the merger of compact objects



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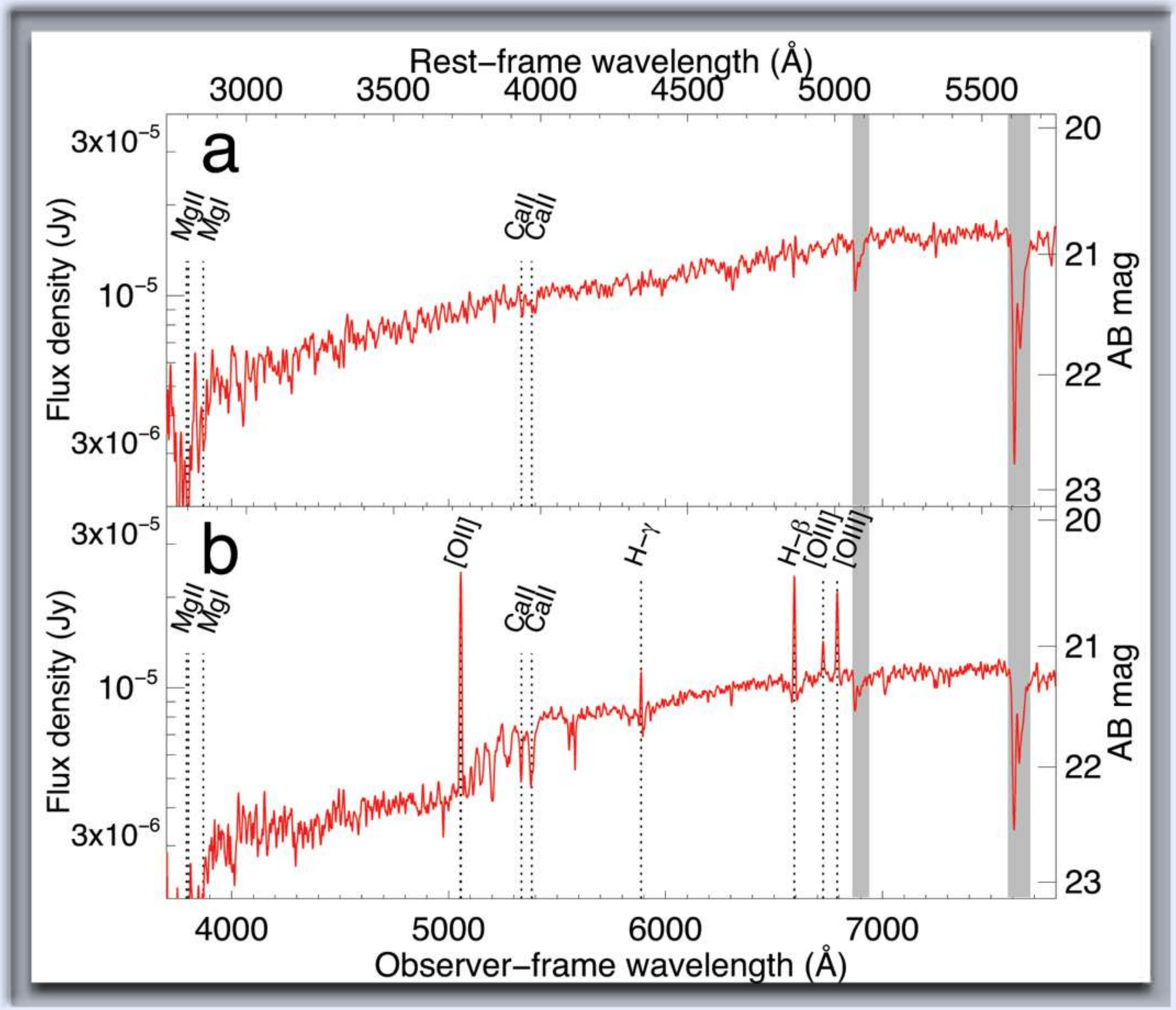

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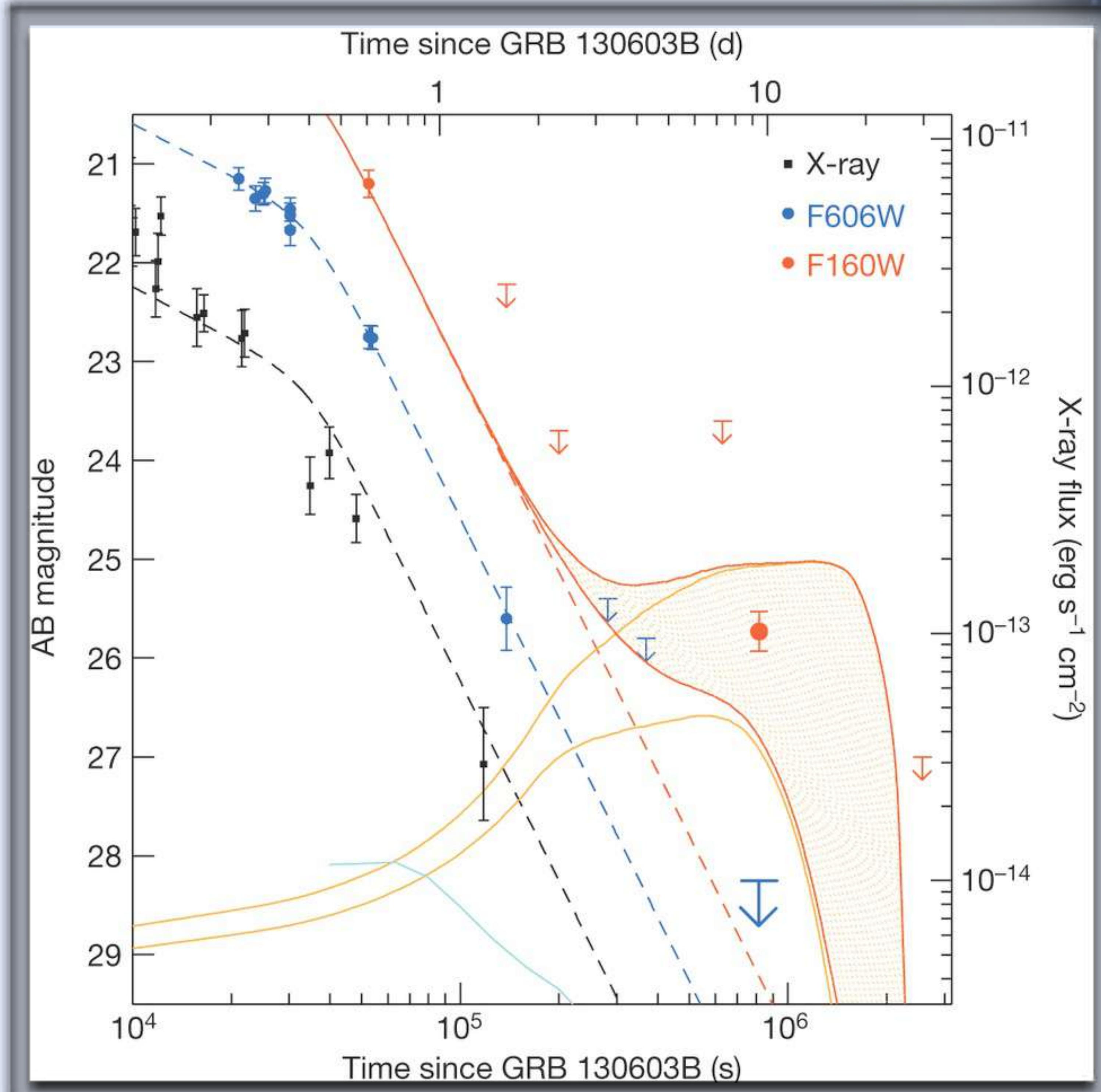

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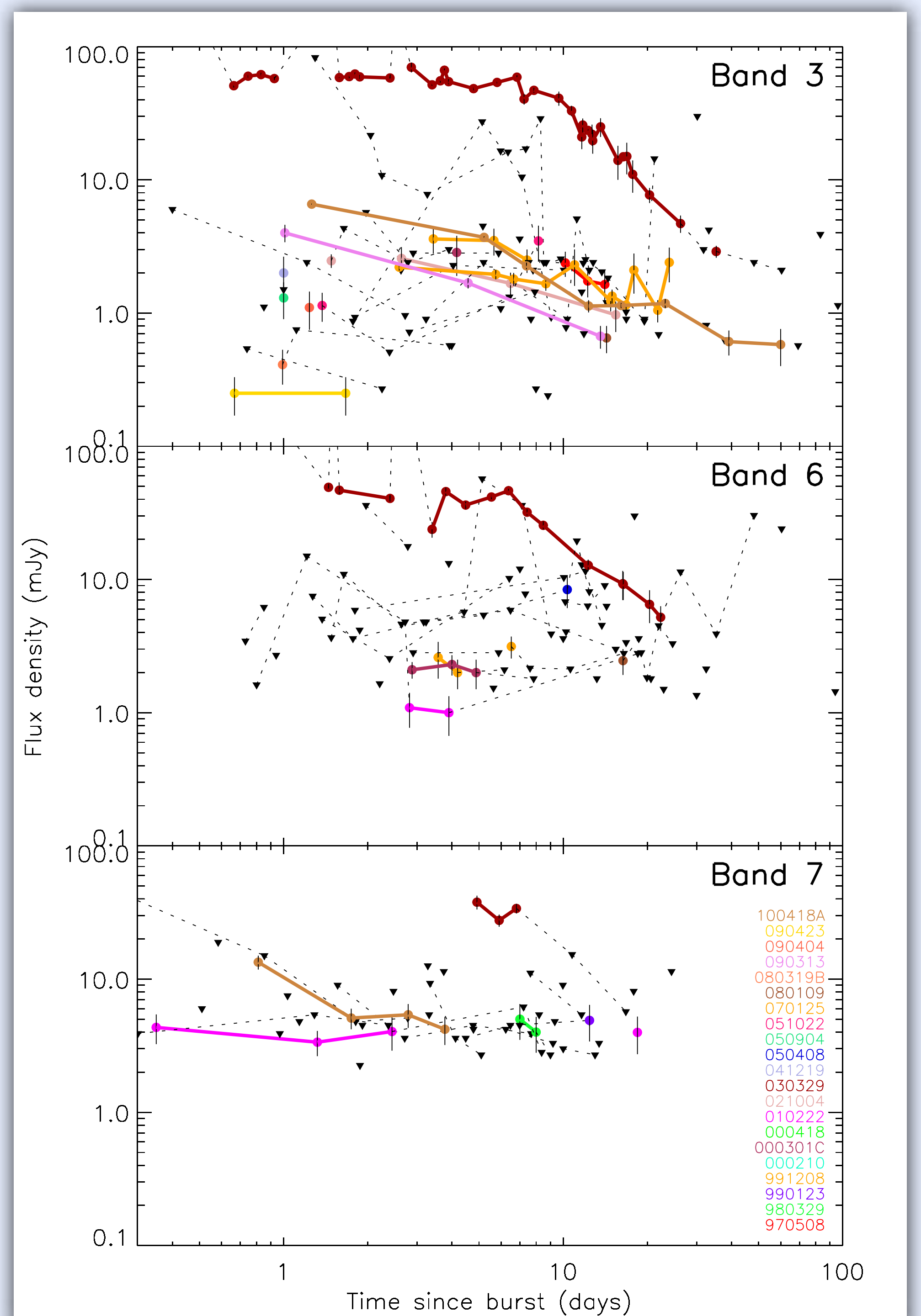
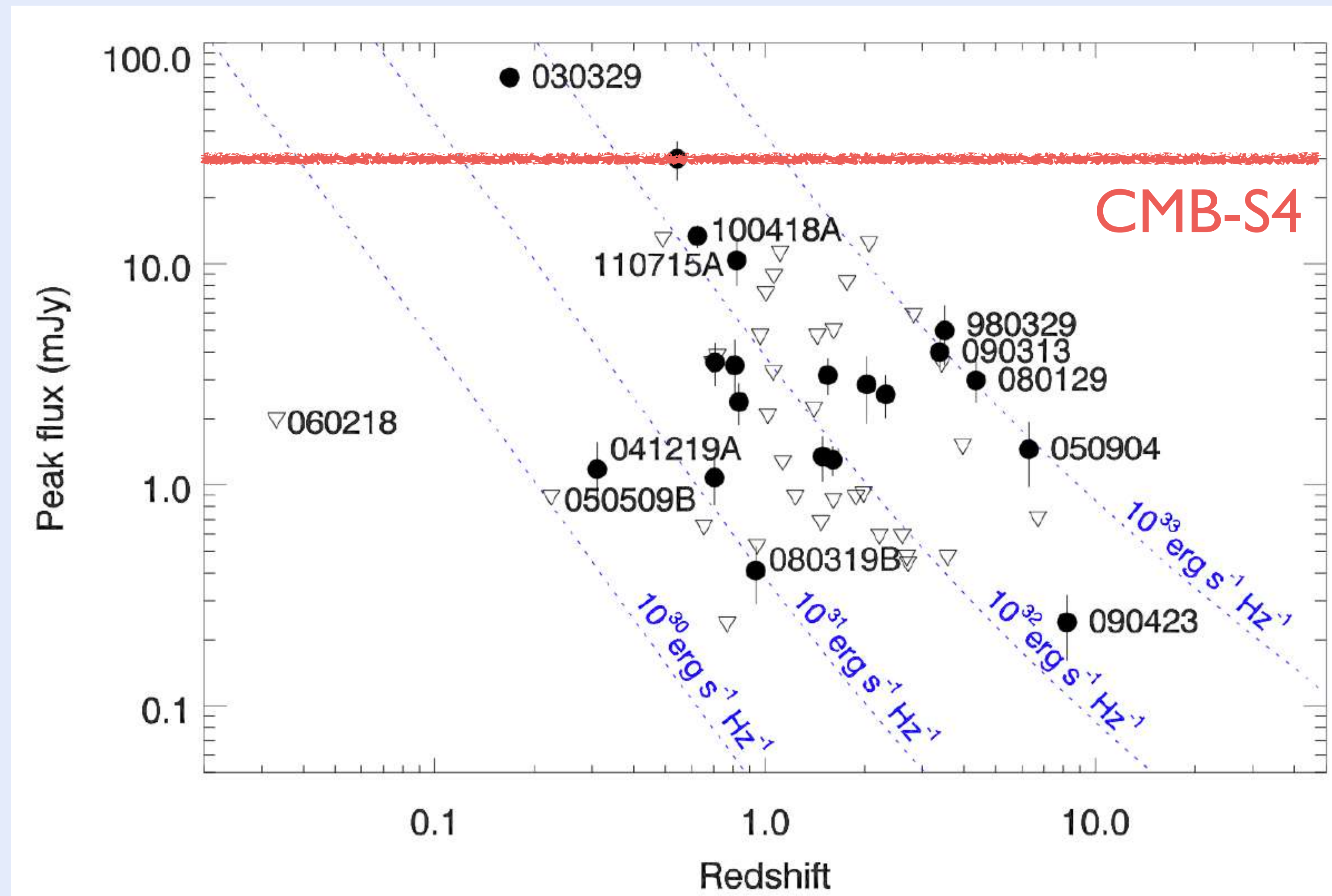
Why the mm/submm range?

- Peak of synchrotron spectrum
- No absorption effects (as in optical or X-rays)
- Negligible scintillation
- Reverse shock at early time
- Host galaxy dust bump
- Molecules at all redshifts
- ALMA in the South
  NOEMA in the North
  (SMA, JCMT, etc…)

de Ugarte Postigo et al. 2012

mm/submm GRB sample



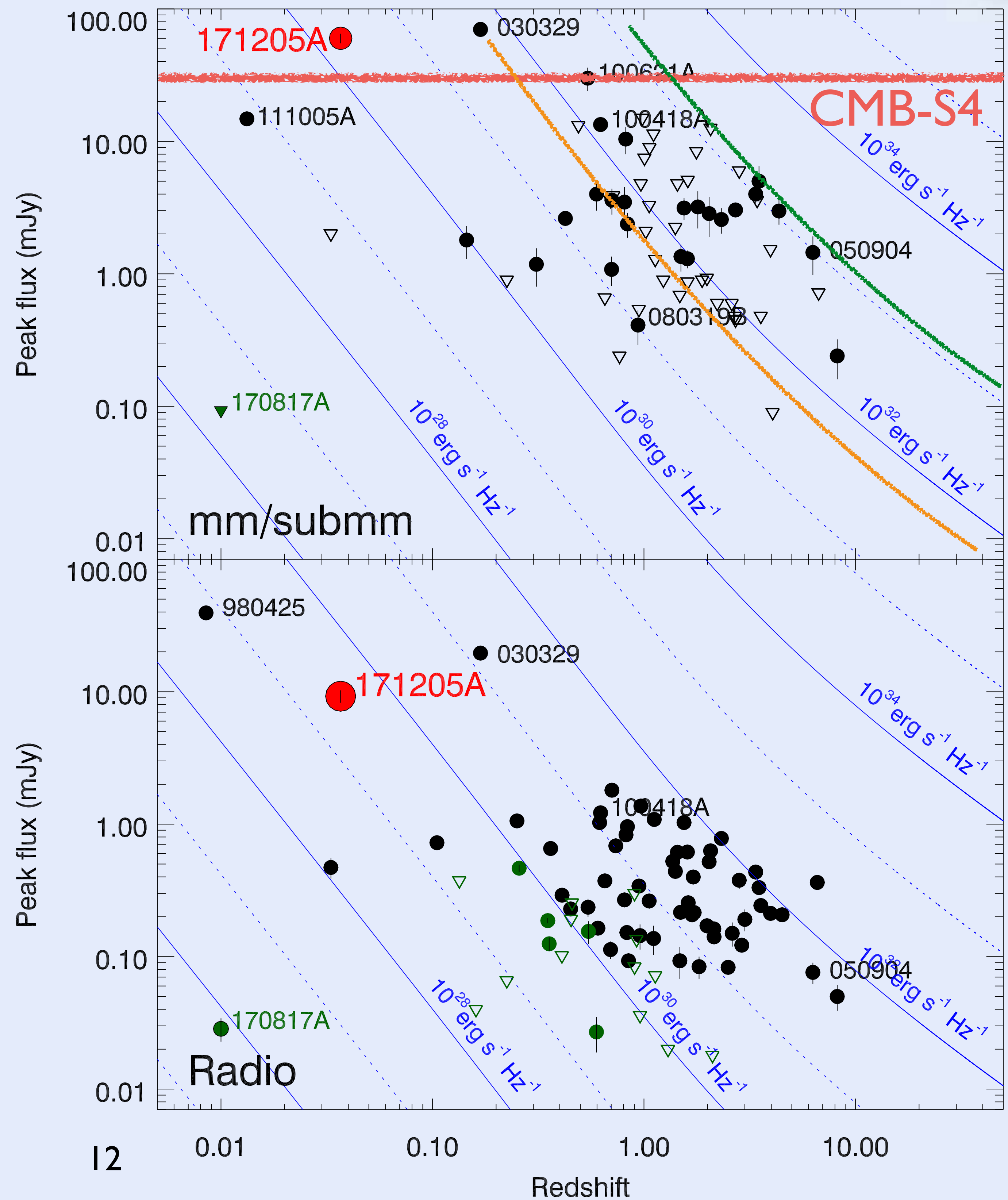


Study of the luminosity distribution of GRBs

First paper of the ALMA observatory

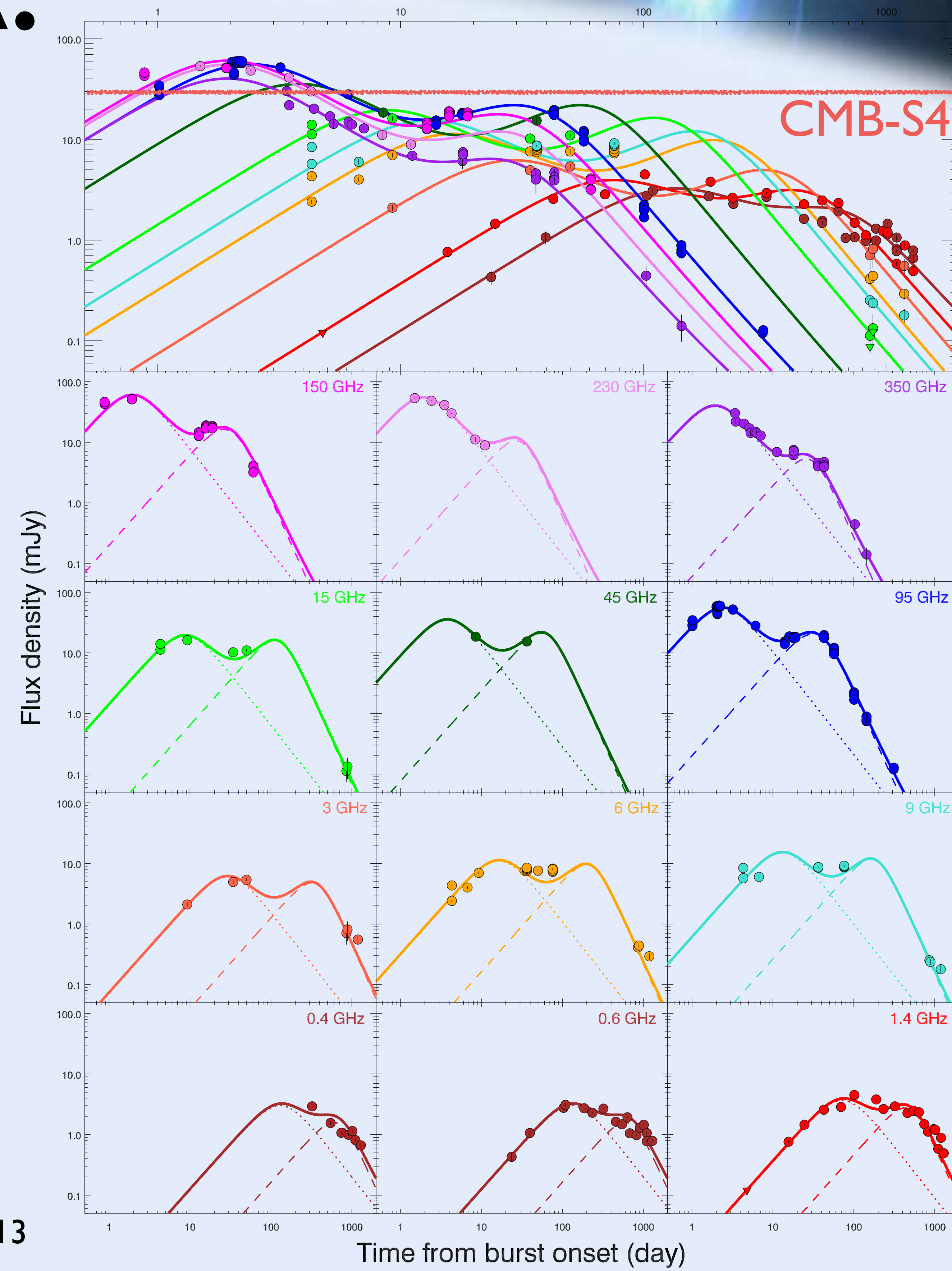
GRB 171205A

- Amongst the brightest ever (~60 mJy)
- But less luminous than average GRBs
- z = 0.0368
- CMB-S4 would have detected it



GRB171205A: Light curves

- Observable by GBM-S4 for ~1 week
- Multiwavelength observations are important for modelling
- Rapid detection alerts (within a day) to triggering further observations



GRB171205A: SEDs

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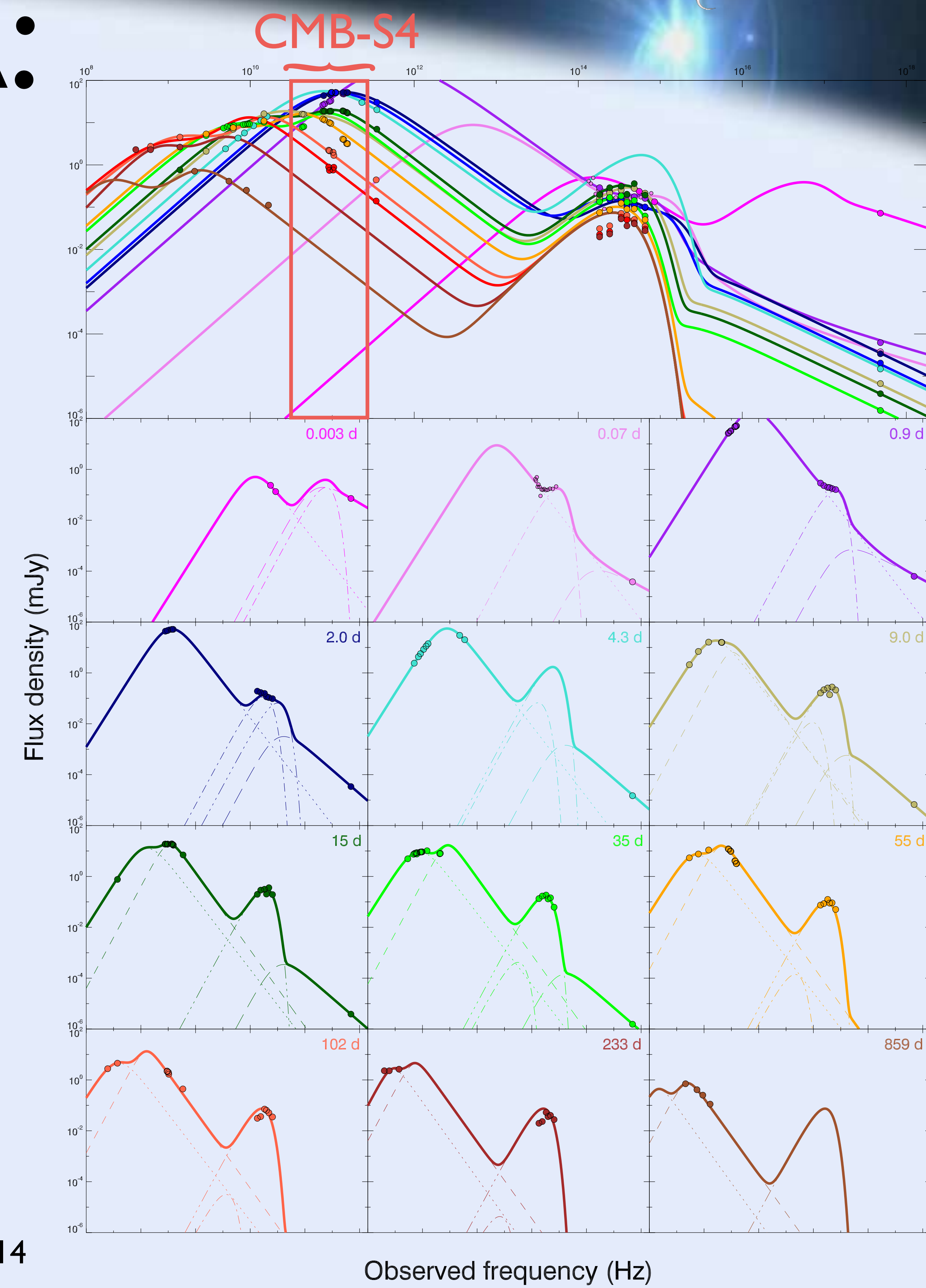

Millimetre spectroscopy

- Search for molecular absorption
- Performed during the peak emission of the GRB
- SNR ~ 200
- No absorption detected

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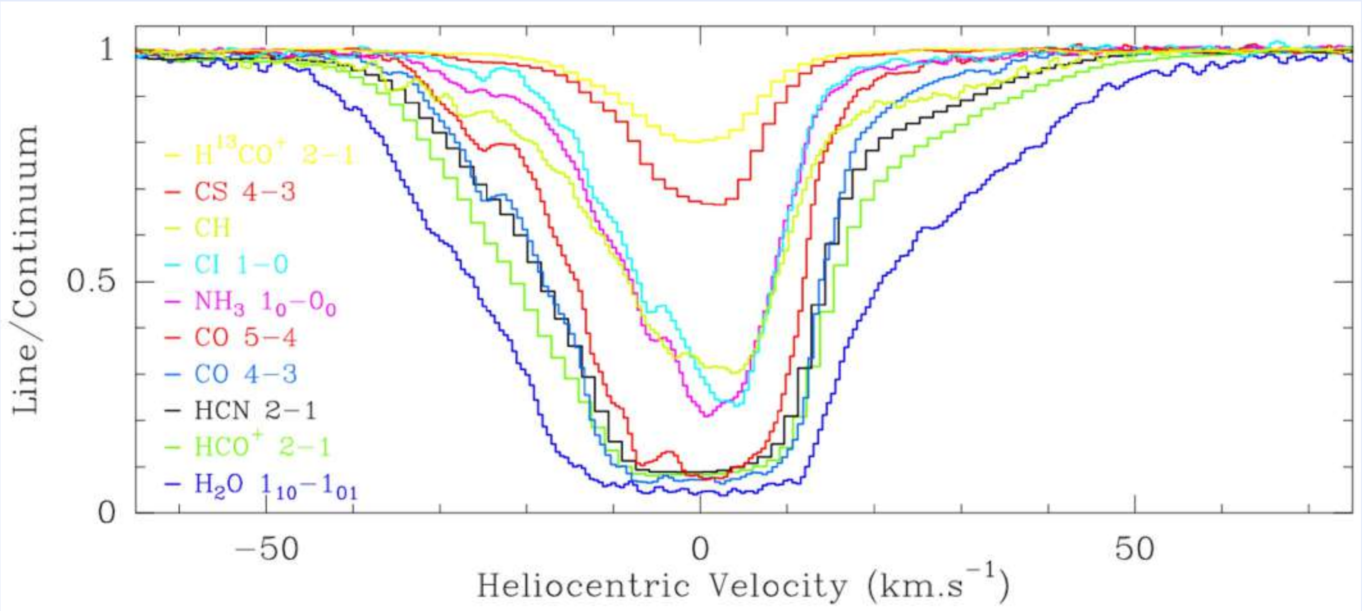

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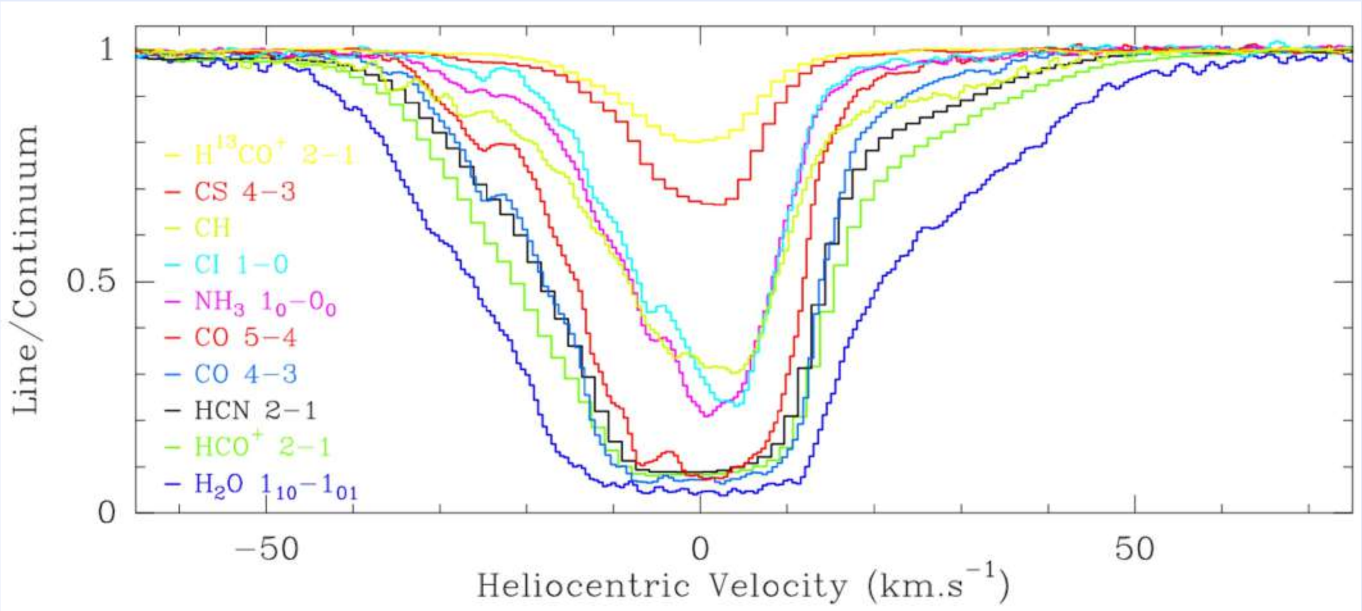

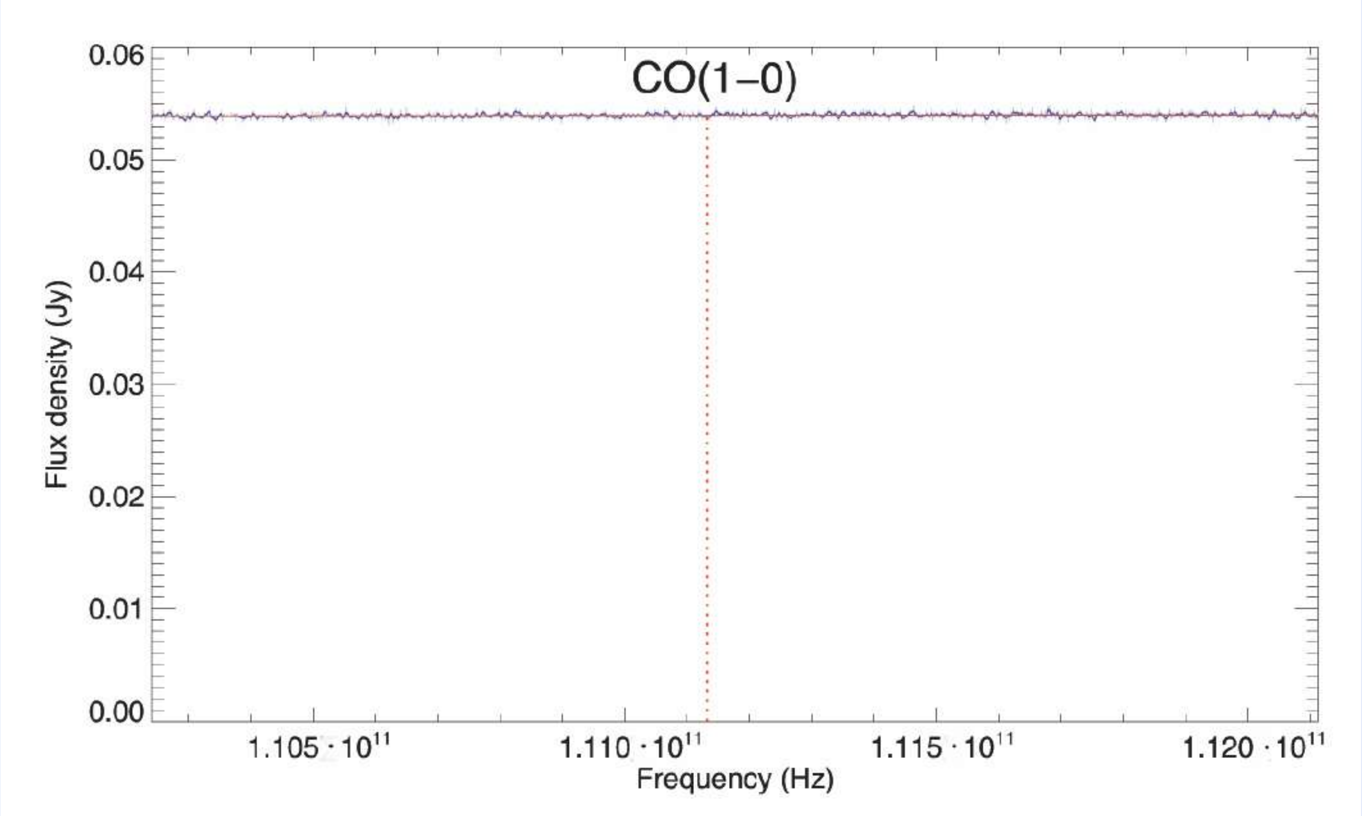

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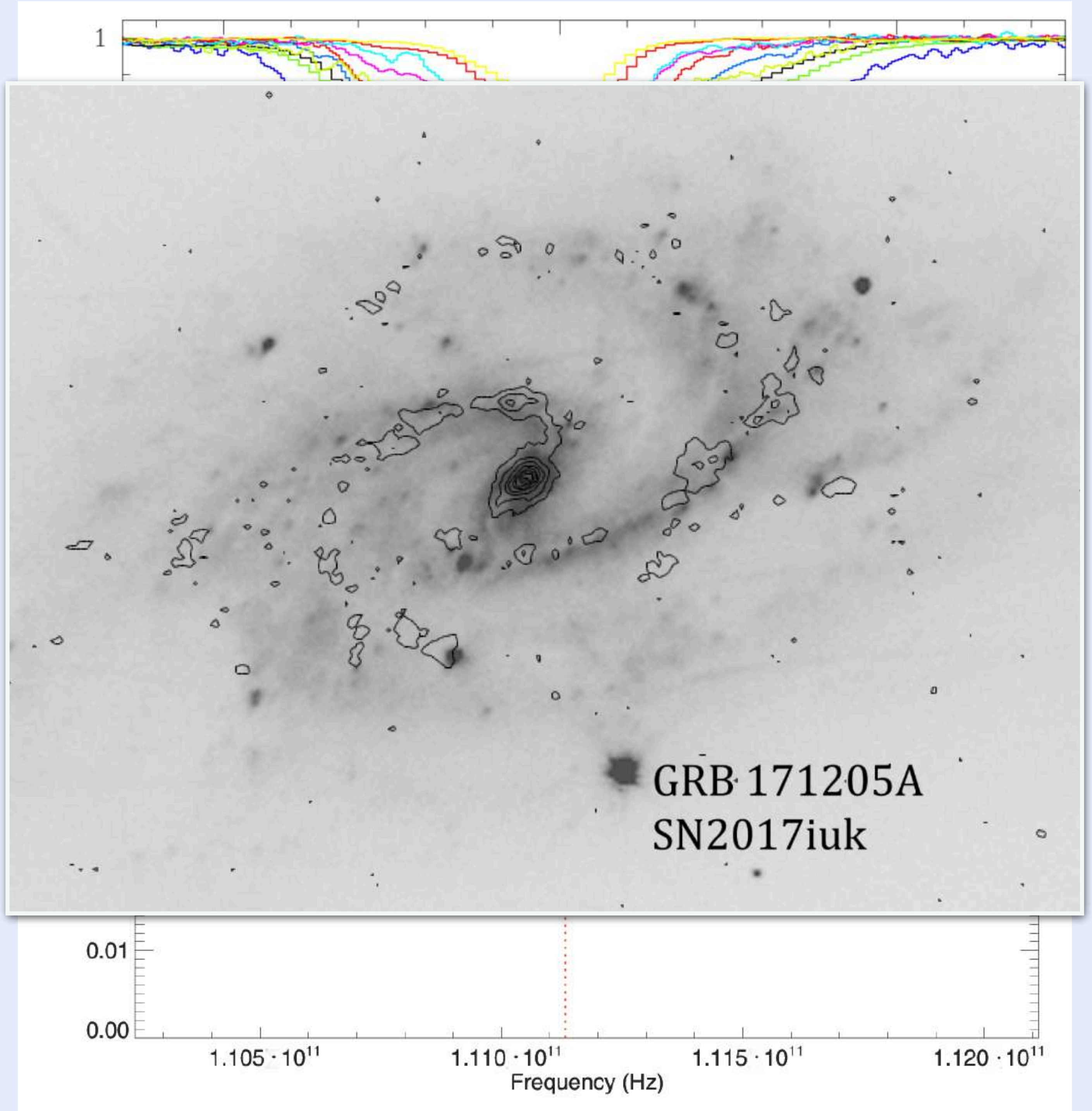

Millimetre polarimetry

- Study the geometry and magnetic fields of the ejecta
- Yuji Urata 2019, ApJ 884, L58
    - Linear polarisation in Band 3
    - P = 0.27+/-0.04 %
    - Varying angle within the different side bands
- Laskar et al. 2020: systematics limits the detection limit to P < 0.30%

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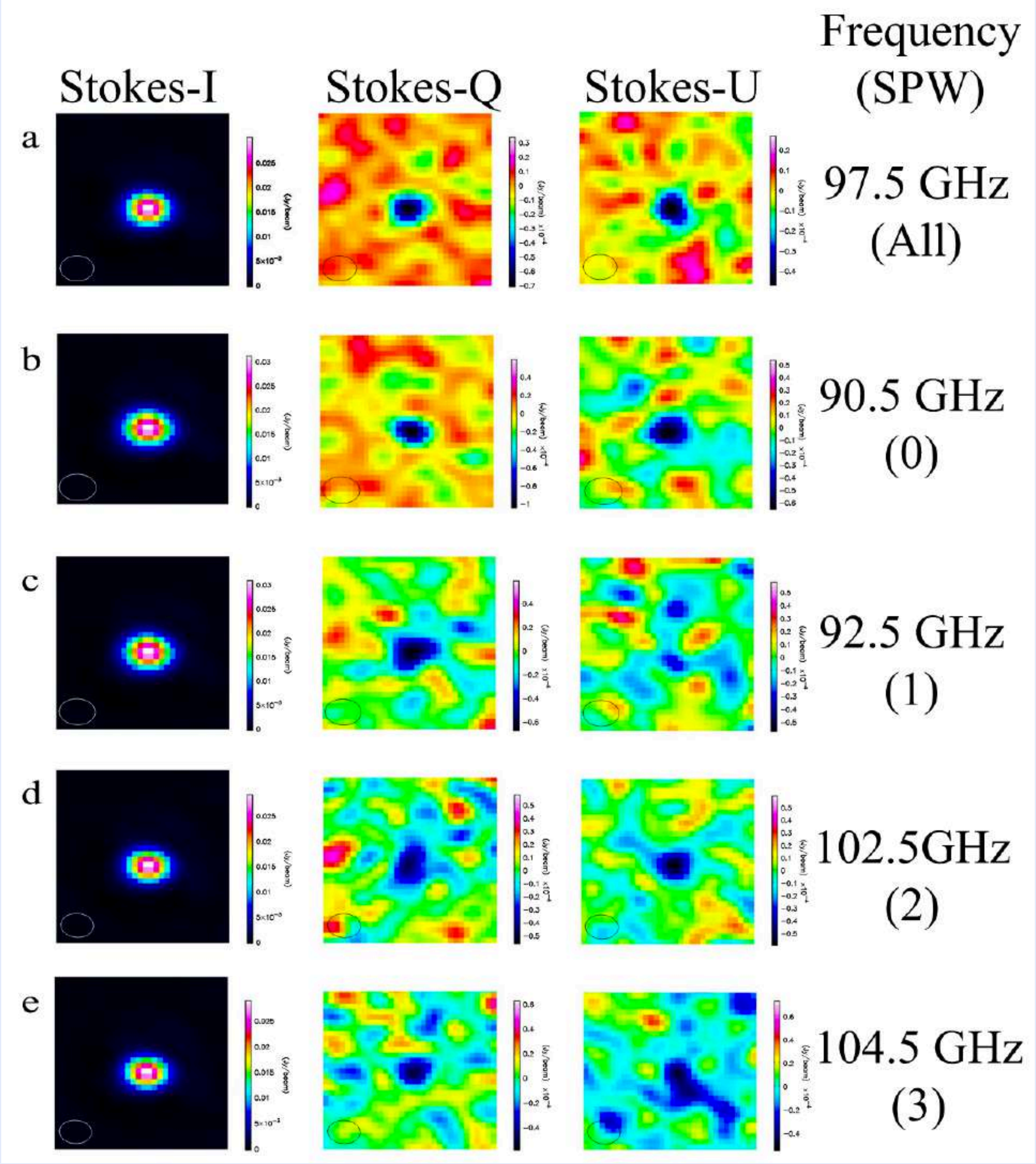

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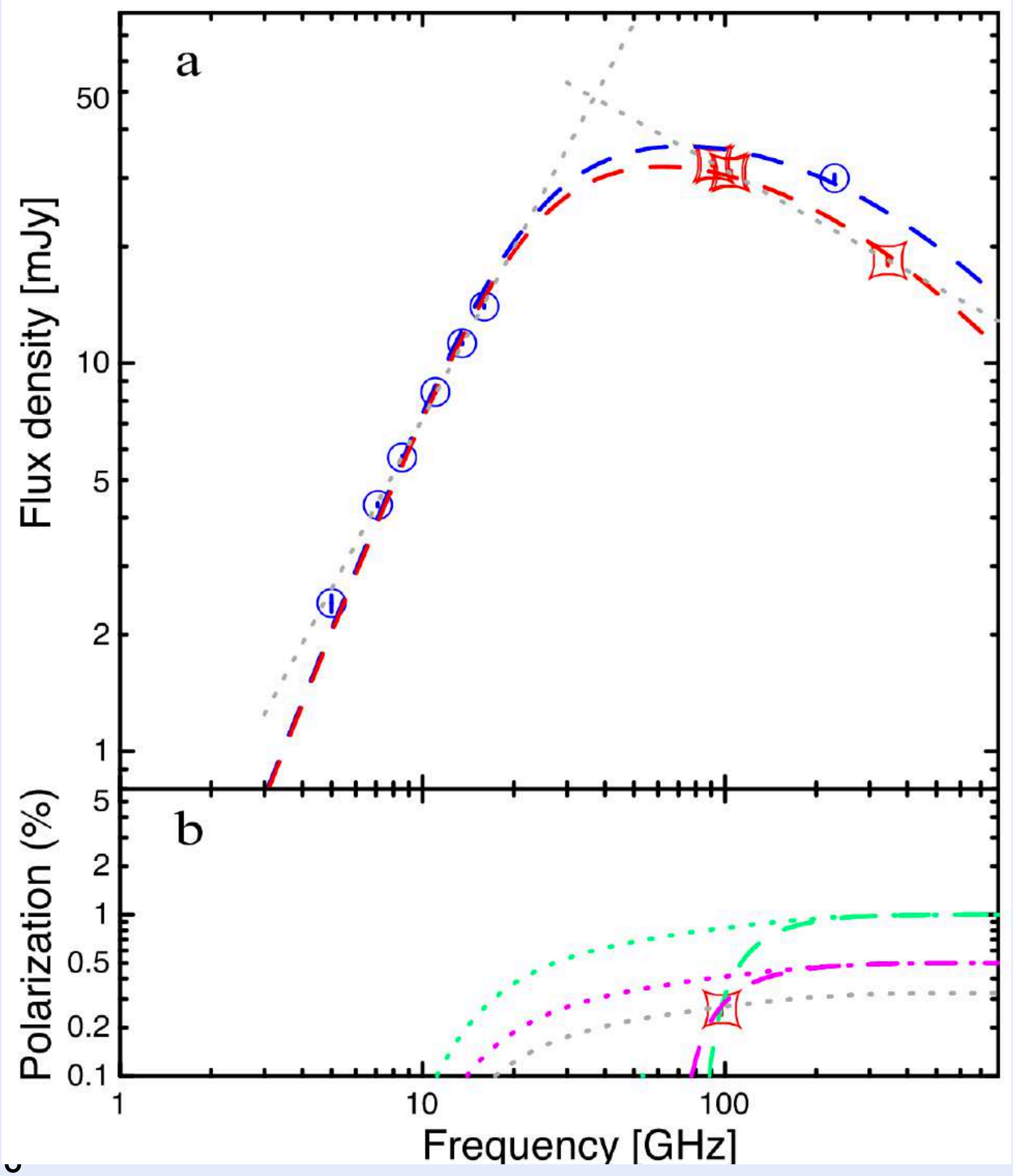

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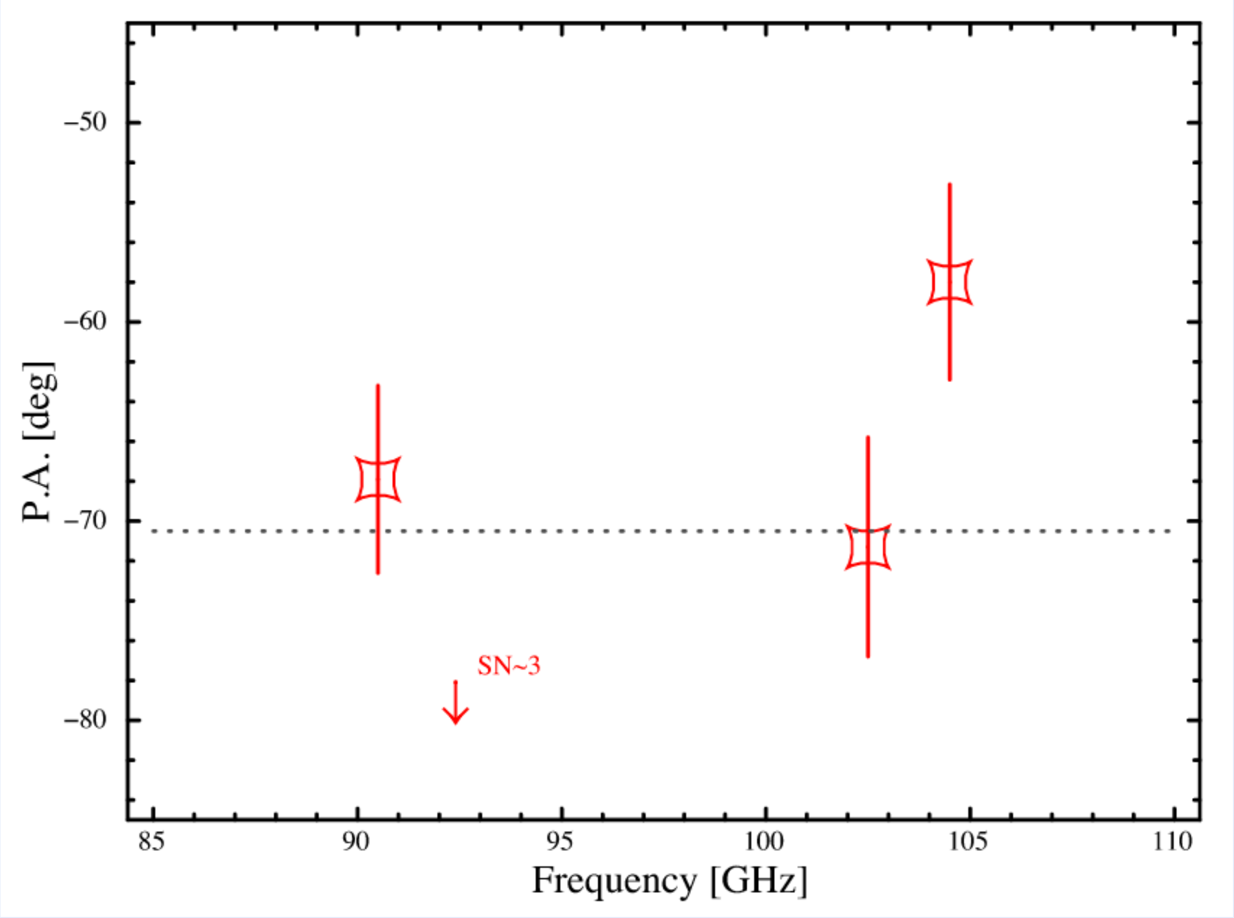
- Laskar et al. 2020: systematics limits the detection limit to P < 0.30%



Conclusions

- CMB-S4 will cover the synchrotron peak during the first days
- Powerful tool to detect untriggered or orphan afterglows
- Able to detect GRBs:
  - Normal events at $z \sim 0.2$
  - Luminous events up to $z \sim 1$
- Deliver alerts within ~ 1 day to other observatories
- Coordinate follow-up with other observatories

Thank you!