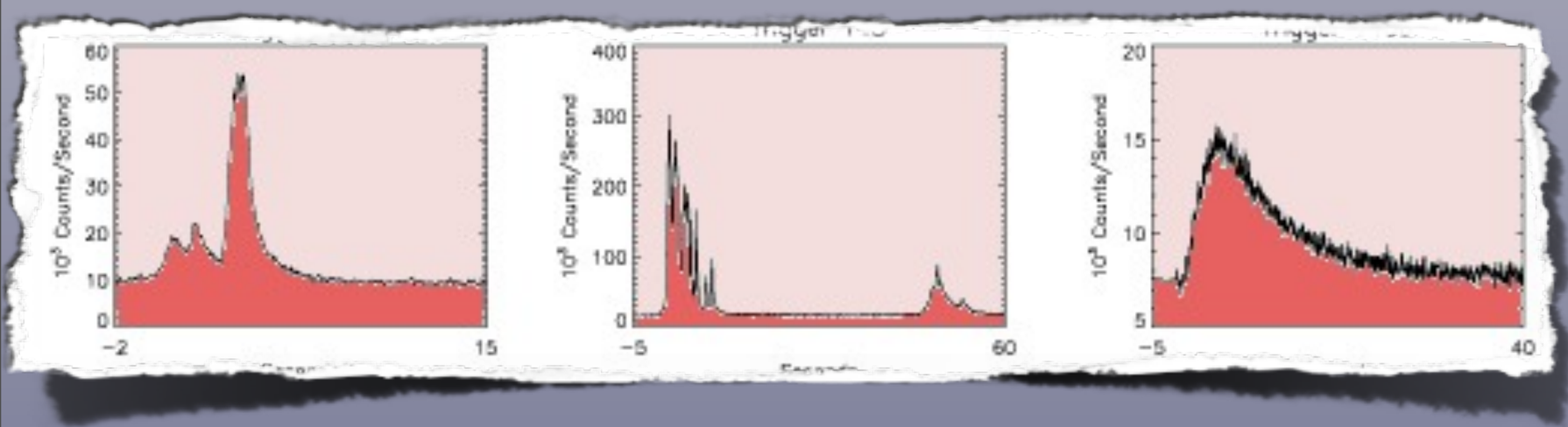
(Introduction to the The ultra-luminous Universe: Gamma-Ray Bursts and Active Galactic Nuclei Session)

Gamma-Ray Bursts: The Brightest Explosions in the Universe

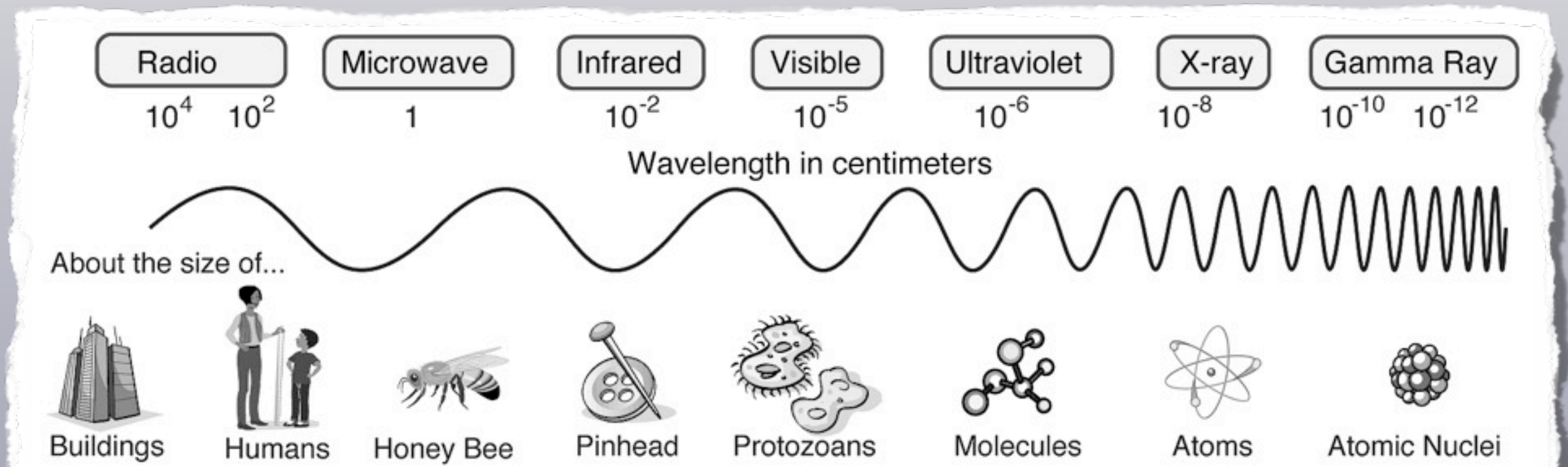
Arne Rau (MPE Garching)



(credit: NASA/Dana Berry)

(The Electromagnetic Spectrum)

- RADIATION FROM MASSLESS PARTICLES (PHOTONS) TRAVELING IN WAVE-LIKE PATTERN WITH SPEED OF LIGHT
- HIGHER ENERGY -> SHORTER WAVELENGTHS



(3rd Sino-German Frontiers of Science Symposium 2010)

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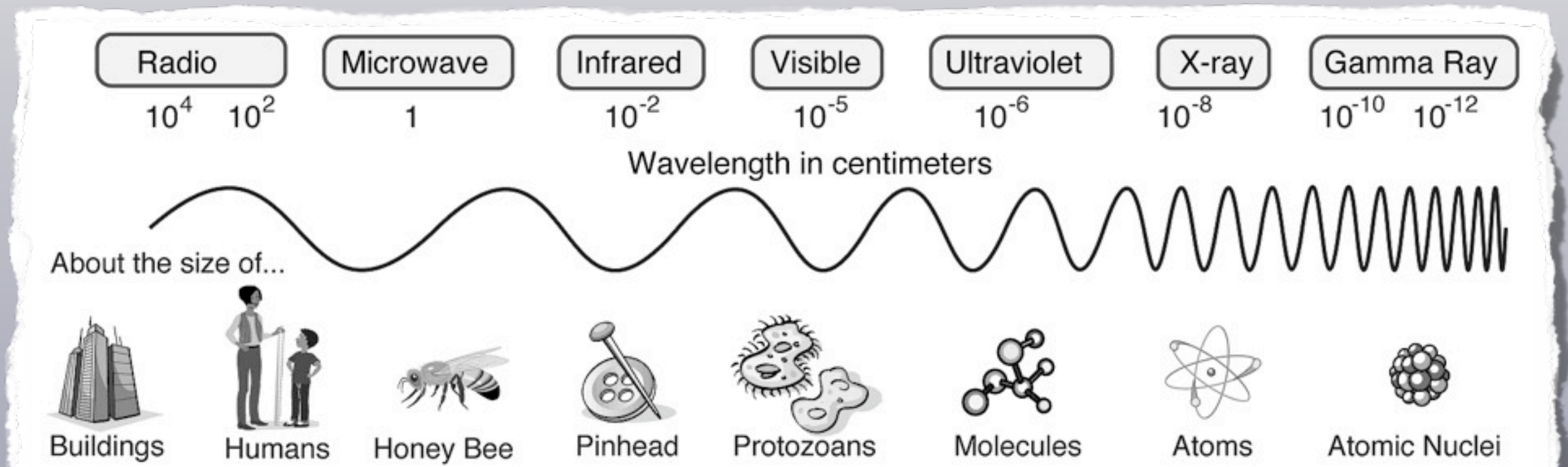

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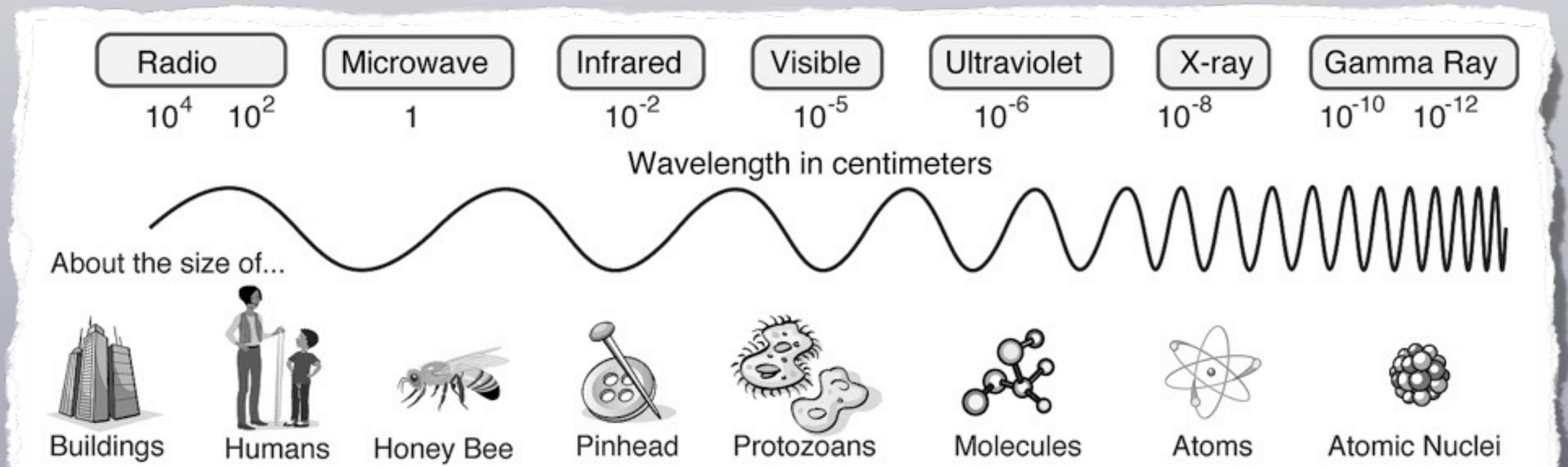

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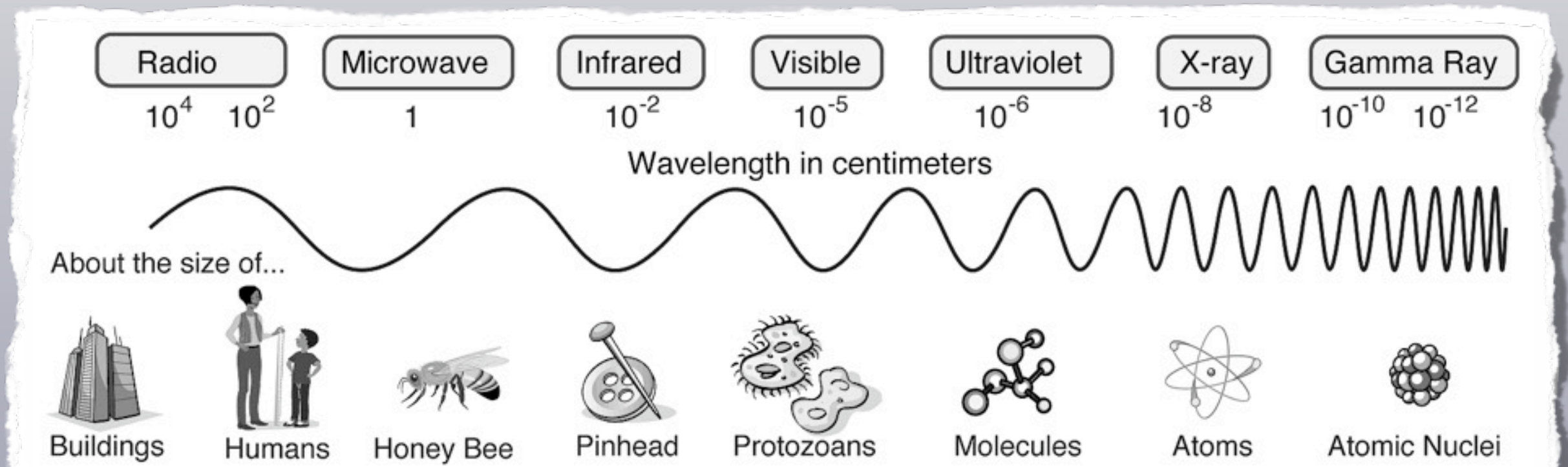

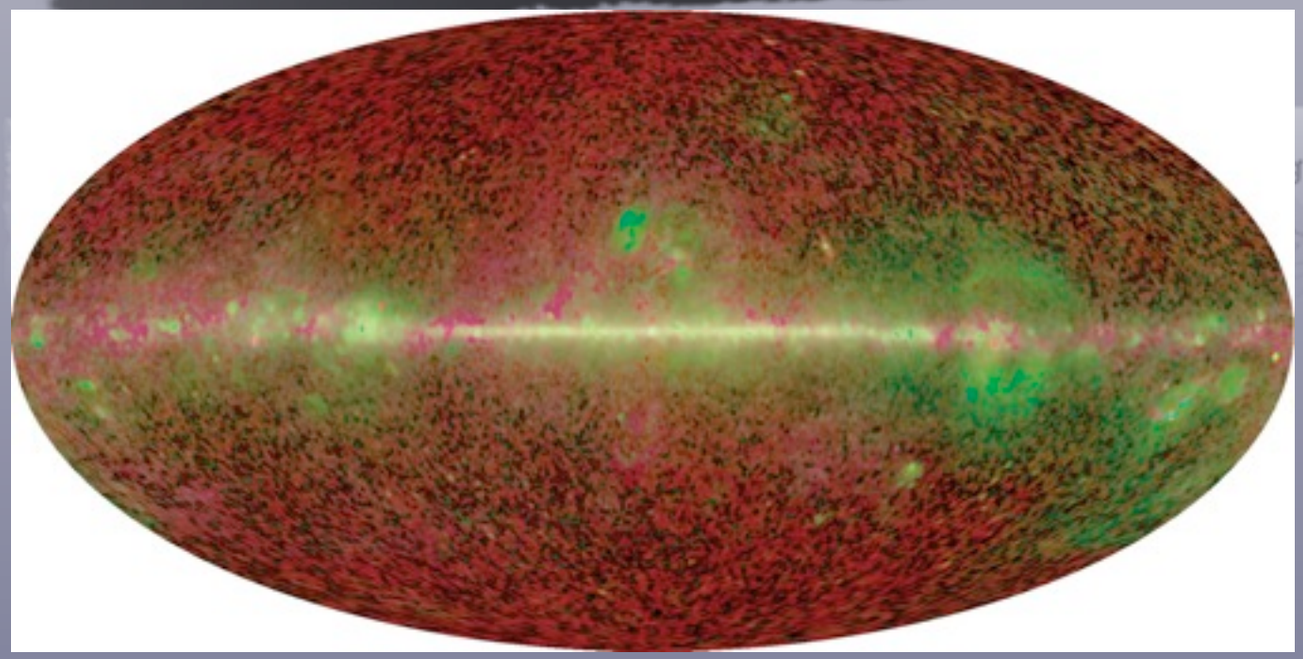

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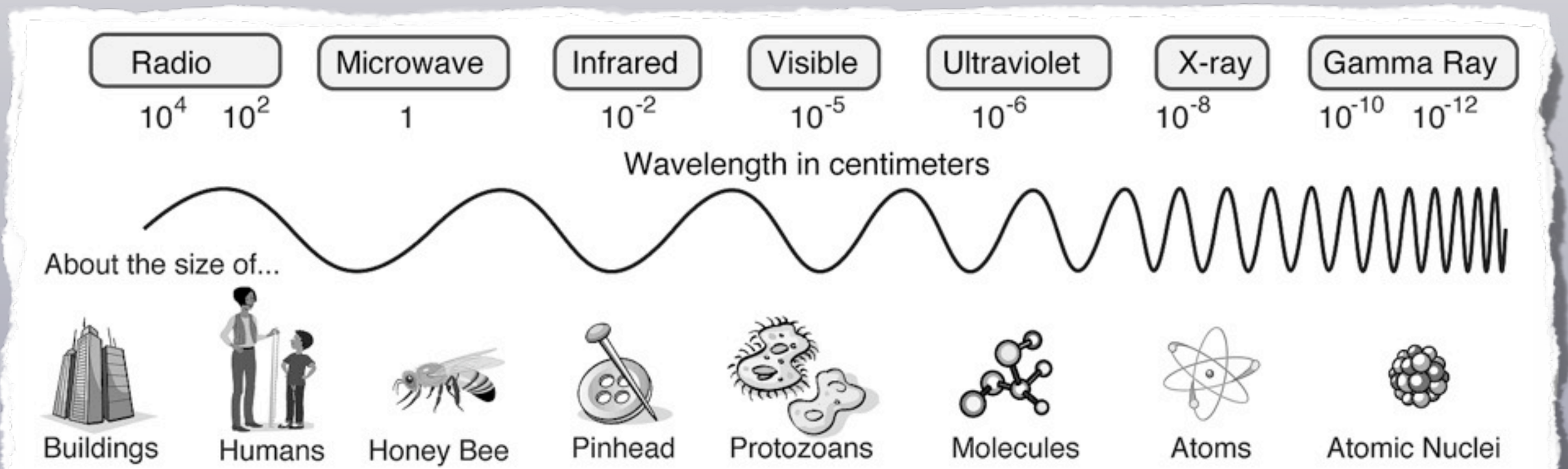

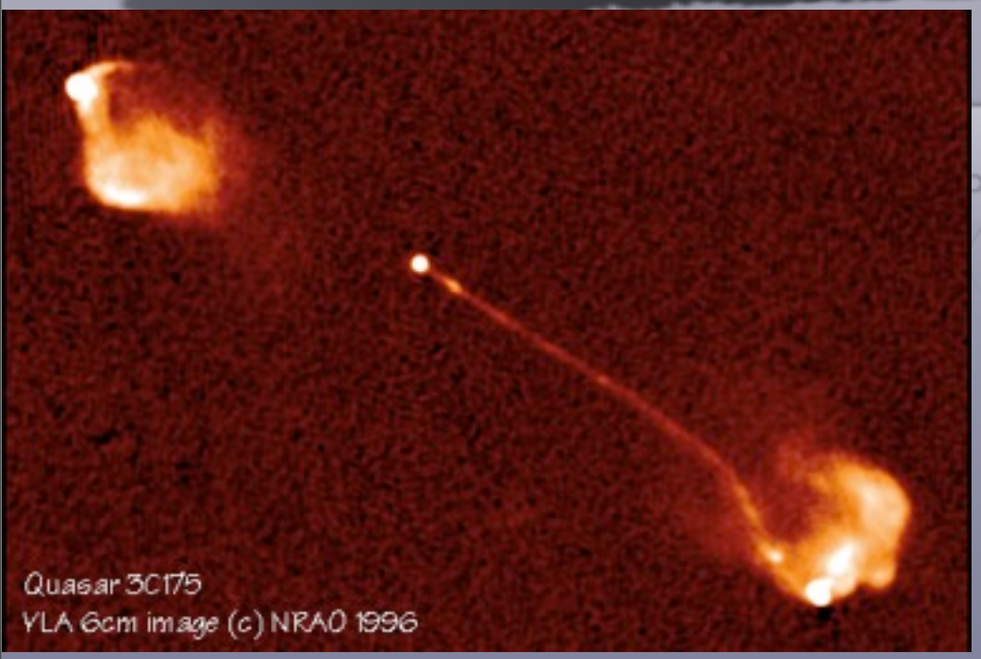

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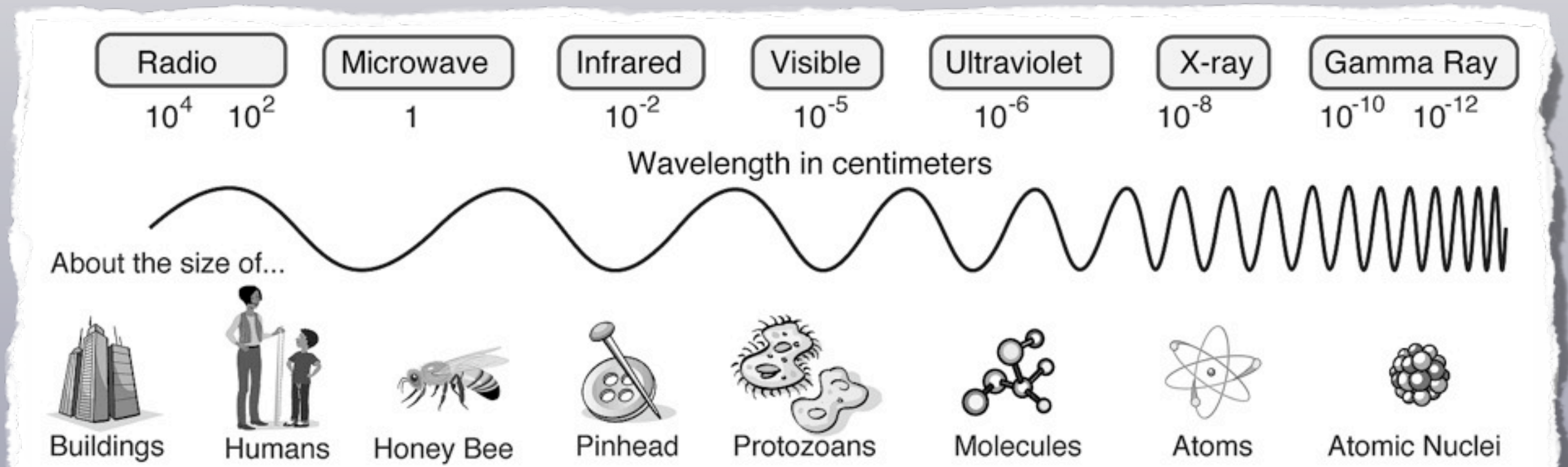

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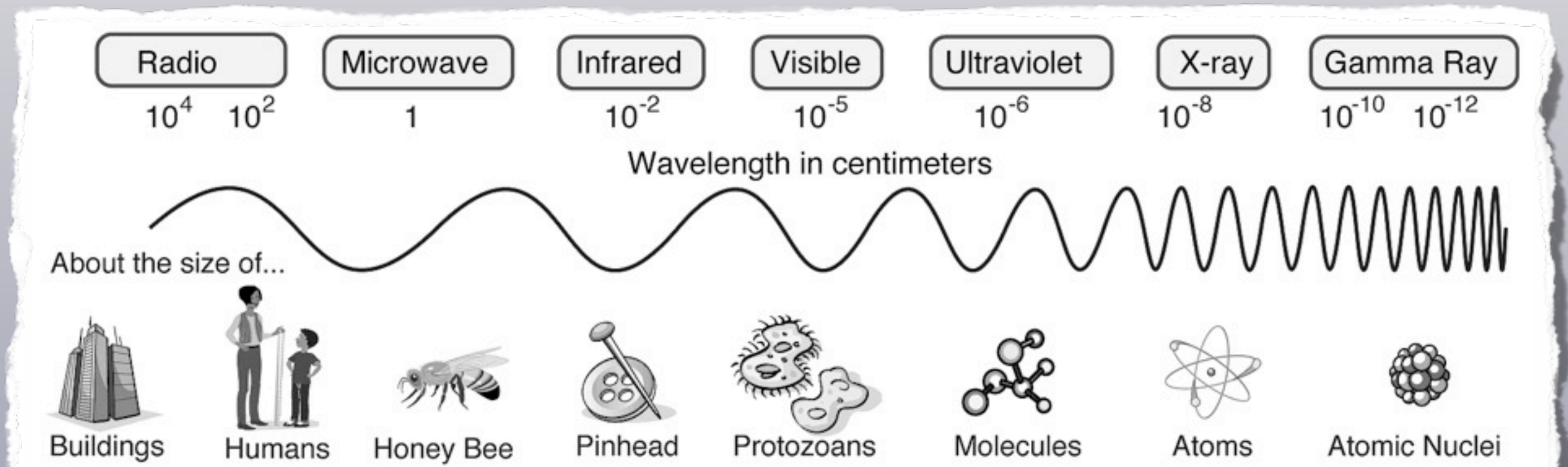

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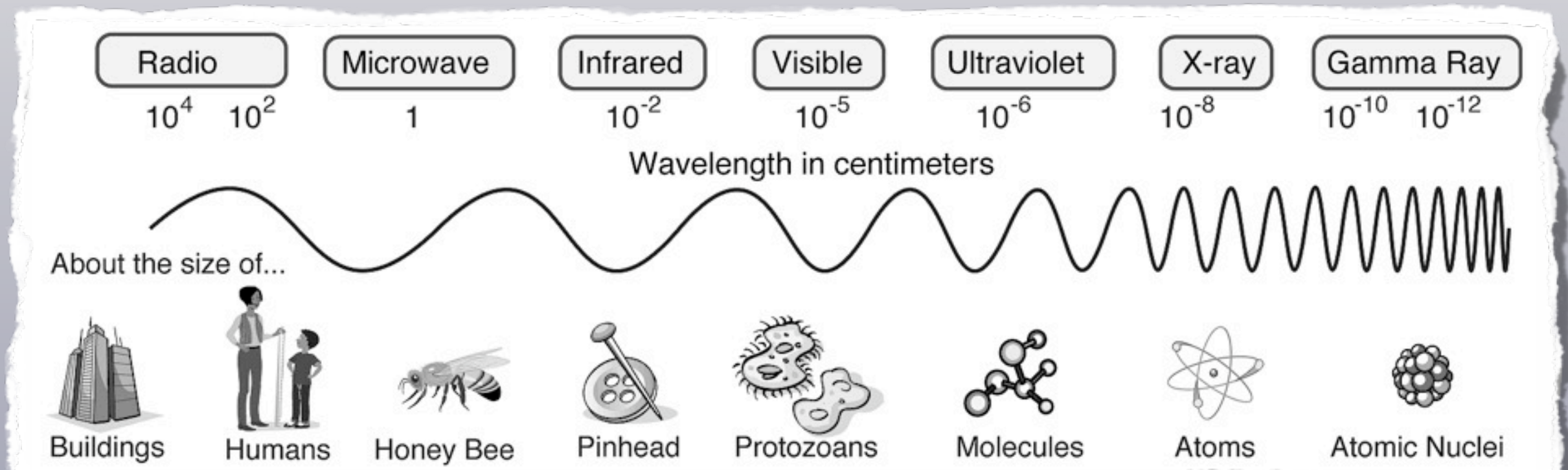
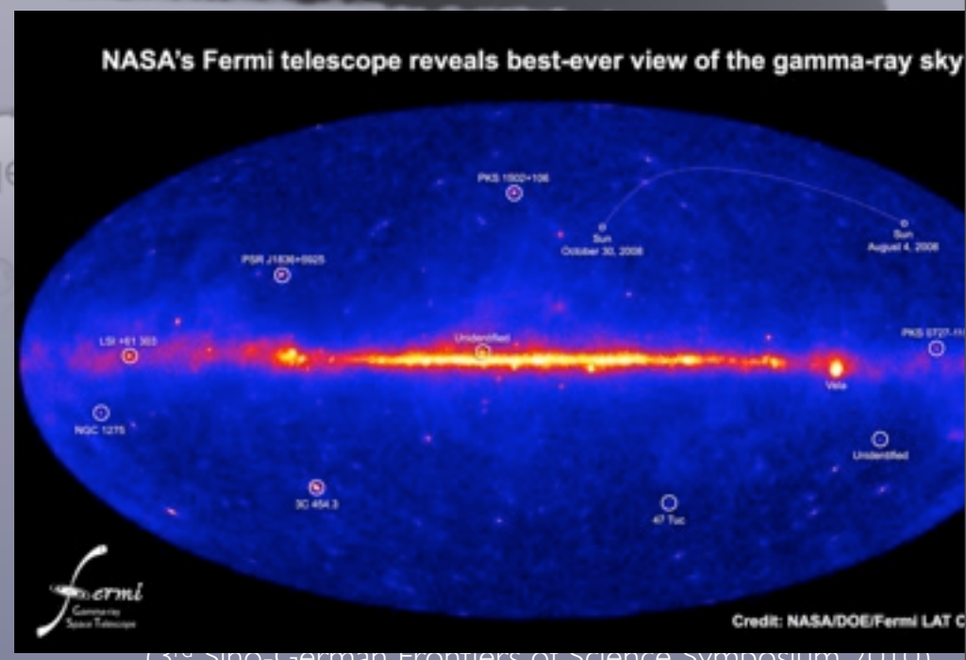
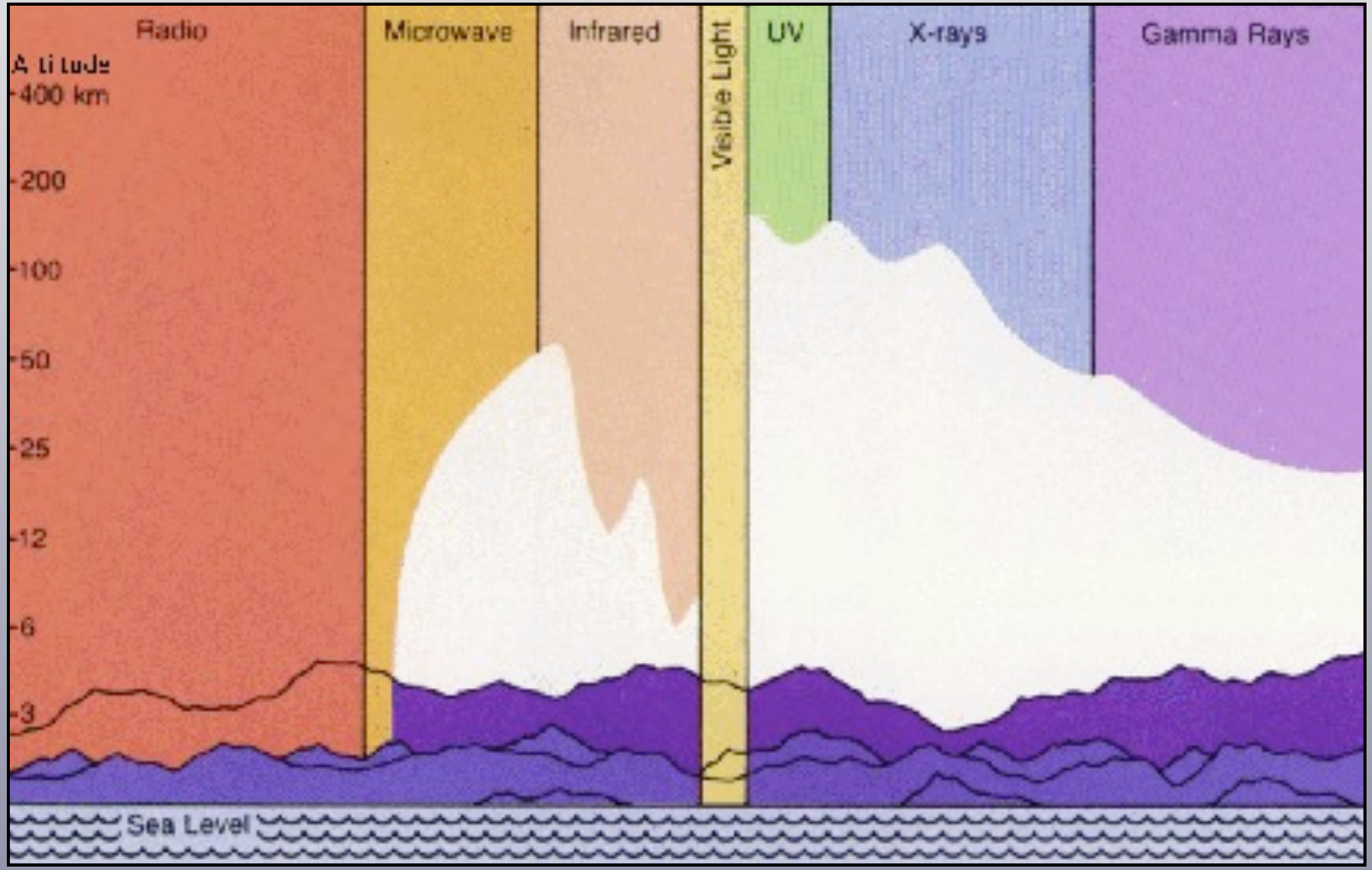




(The [bad] impact of the Earth Atmosphere)



- RADIO AND VISIBLE ASTRONOMY POSSIBLE FROM GROUND
- REST (INCL. GAMMA-RAYS) (NEARLY) EXCLUSIVELY FROM SPACE

(3rd Sino-German Frontiers of Science Symposium 2010)

(The Sky in Gamma-Ray Light)

- GAMMA-RAY BURSTS DETECTIONS WITH NASA'S SWIFT SATELLITE (2004-2010)

(credit: NASA/Goddard Space Flight Center)

(The Sky in Gamma-Ray Light)

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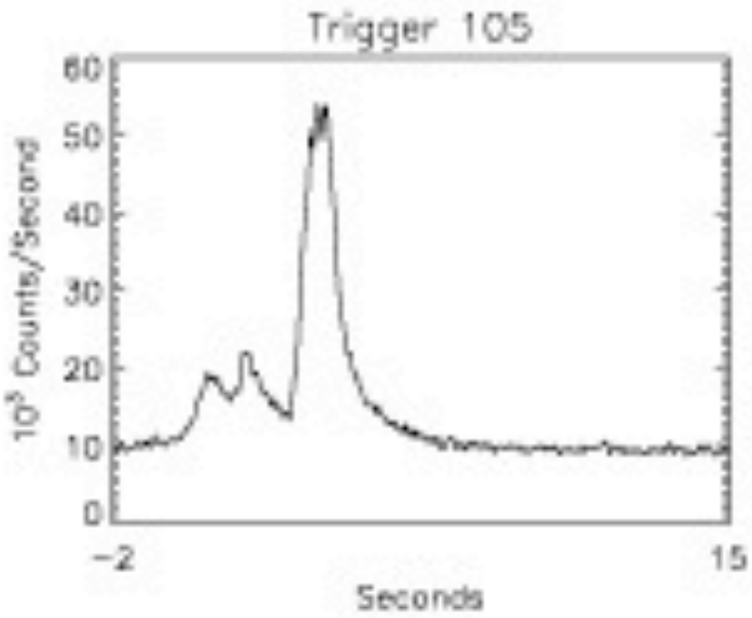
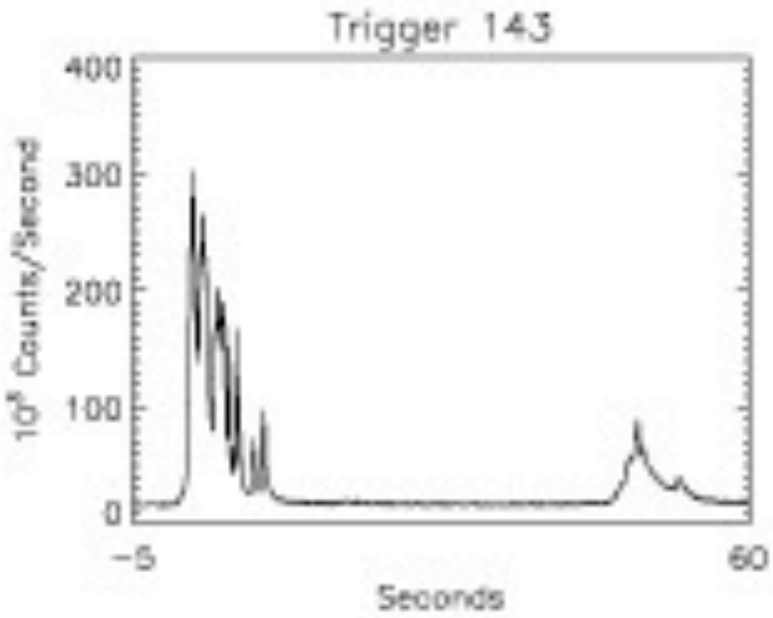
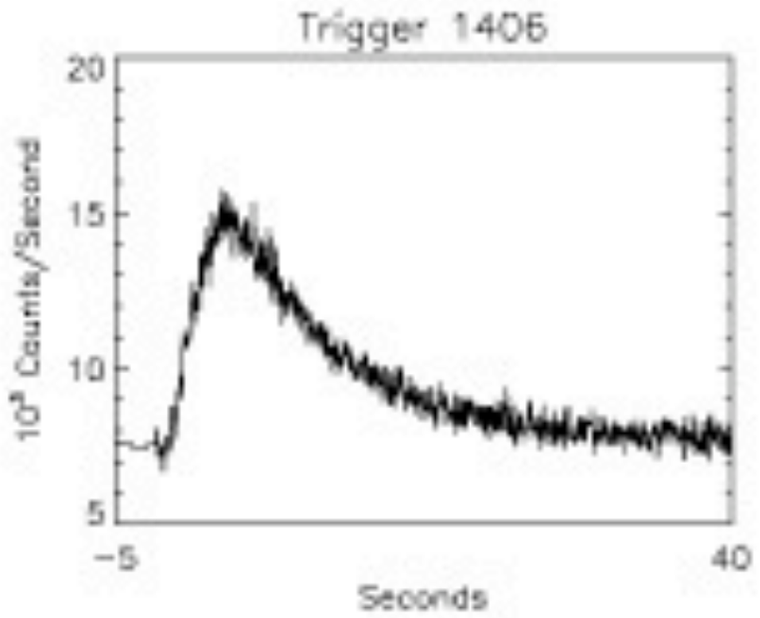
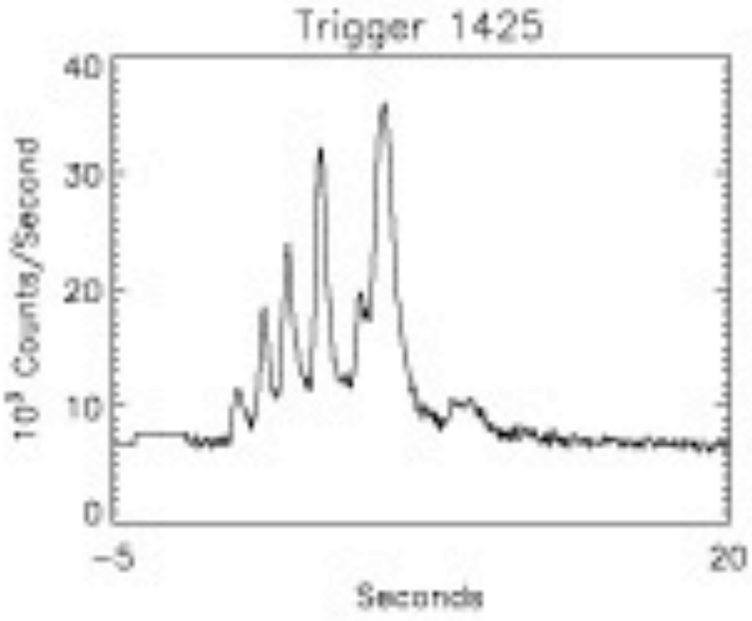
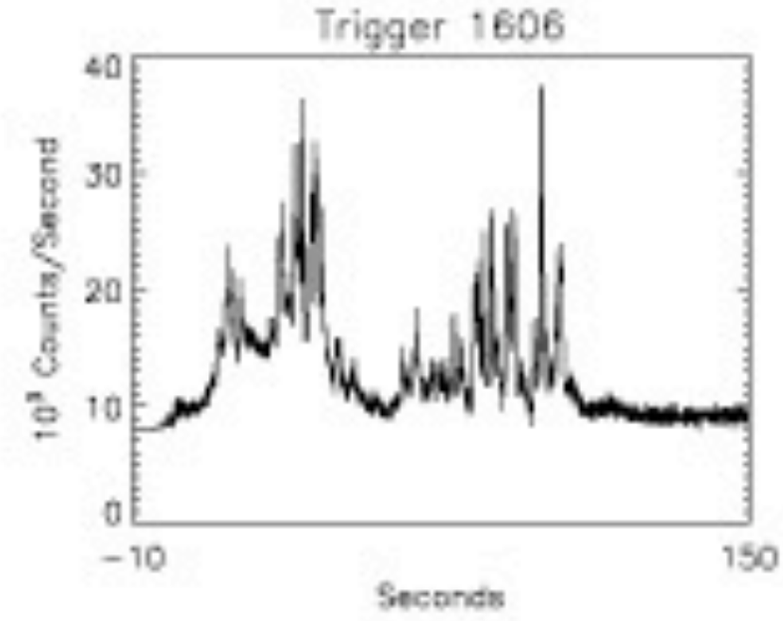
(Gamma-ray Lightcurves)

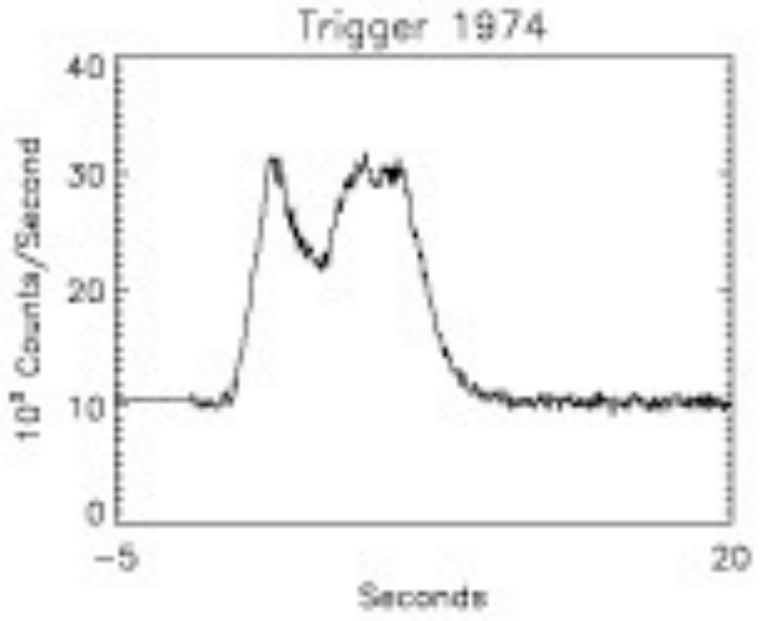












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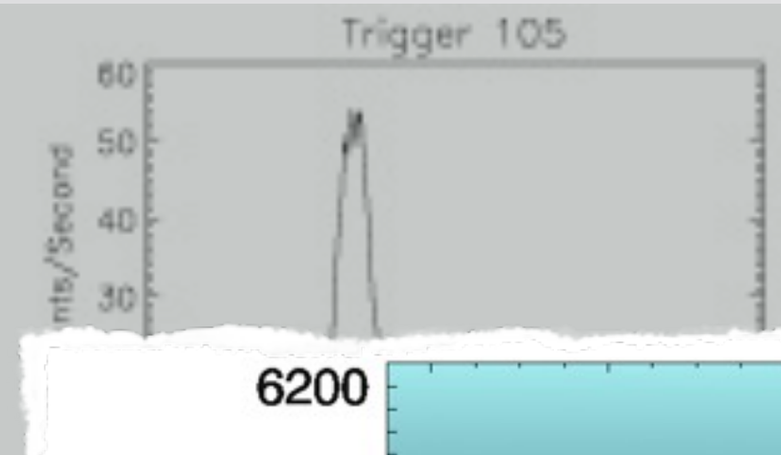
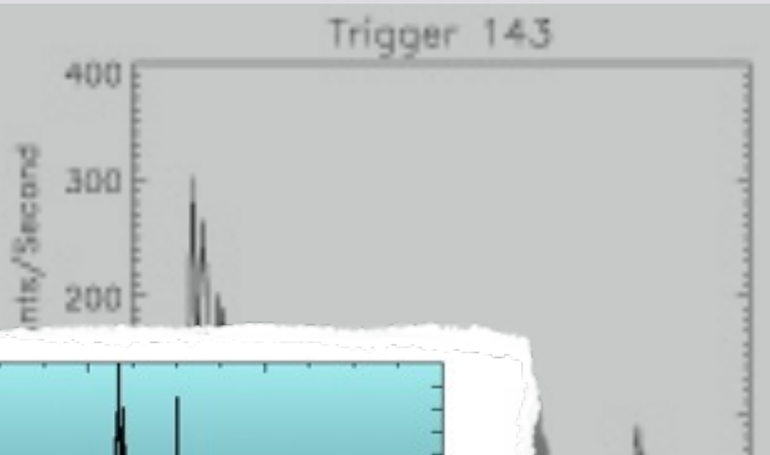
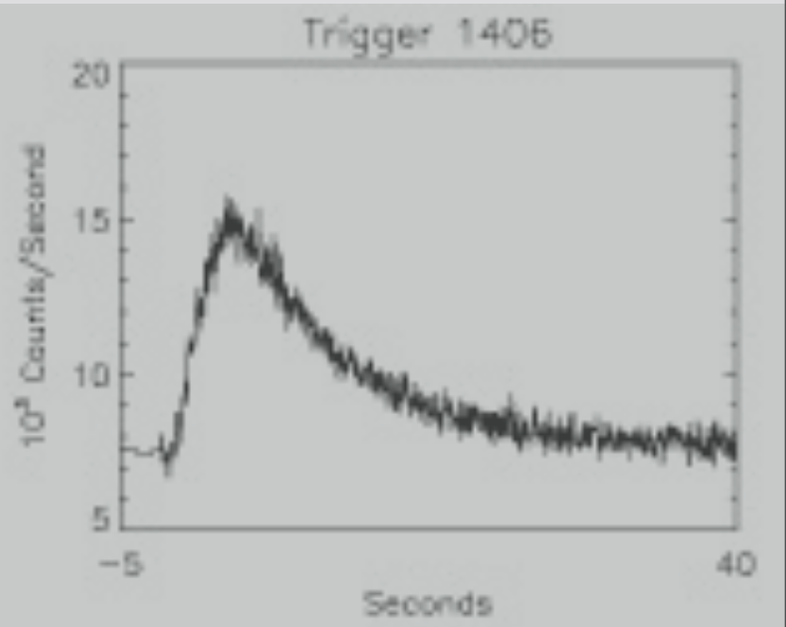
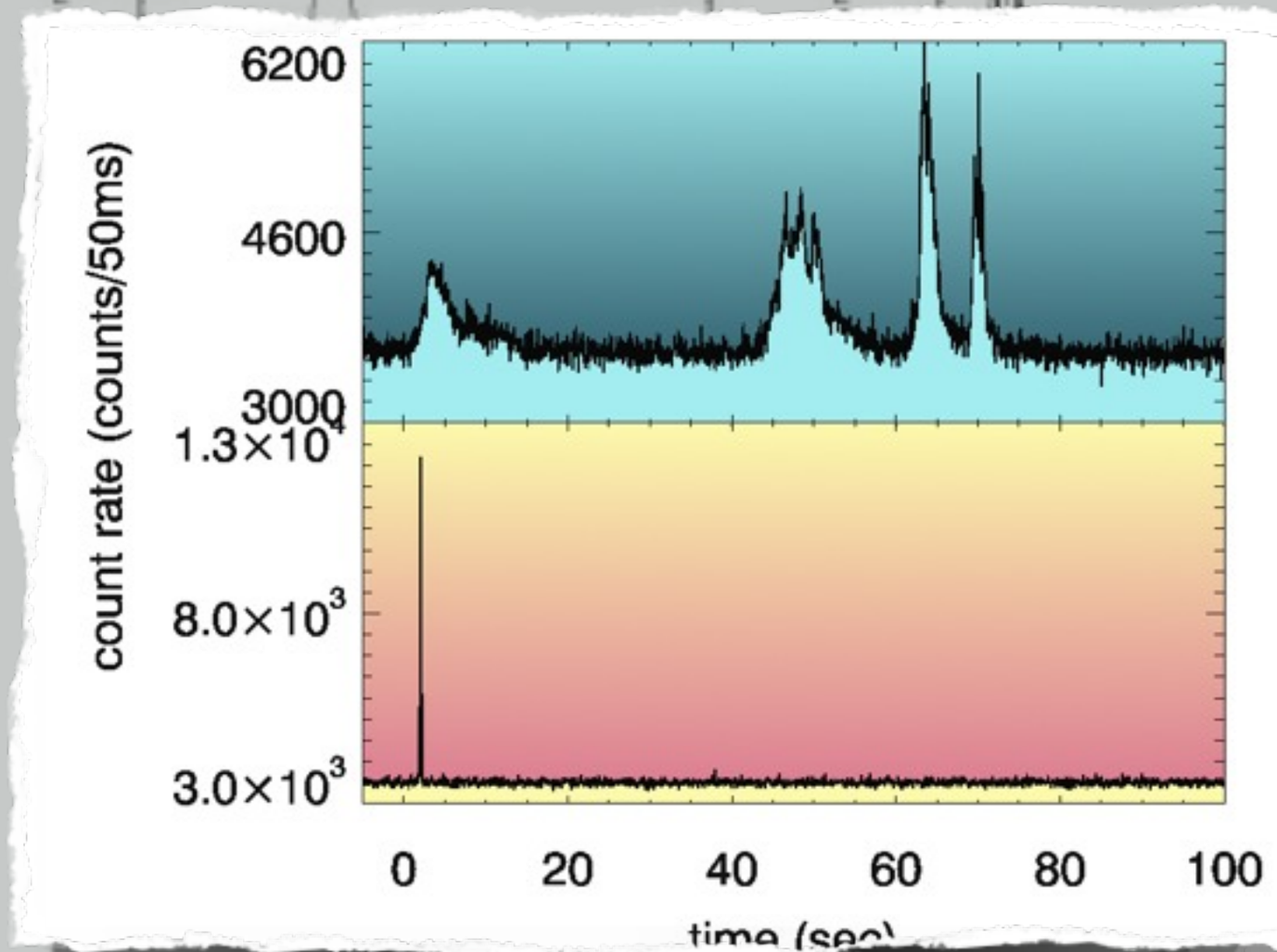
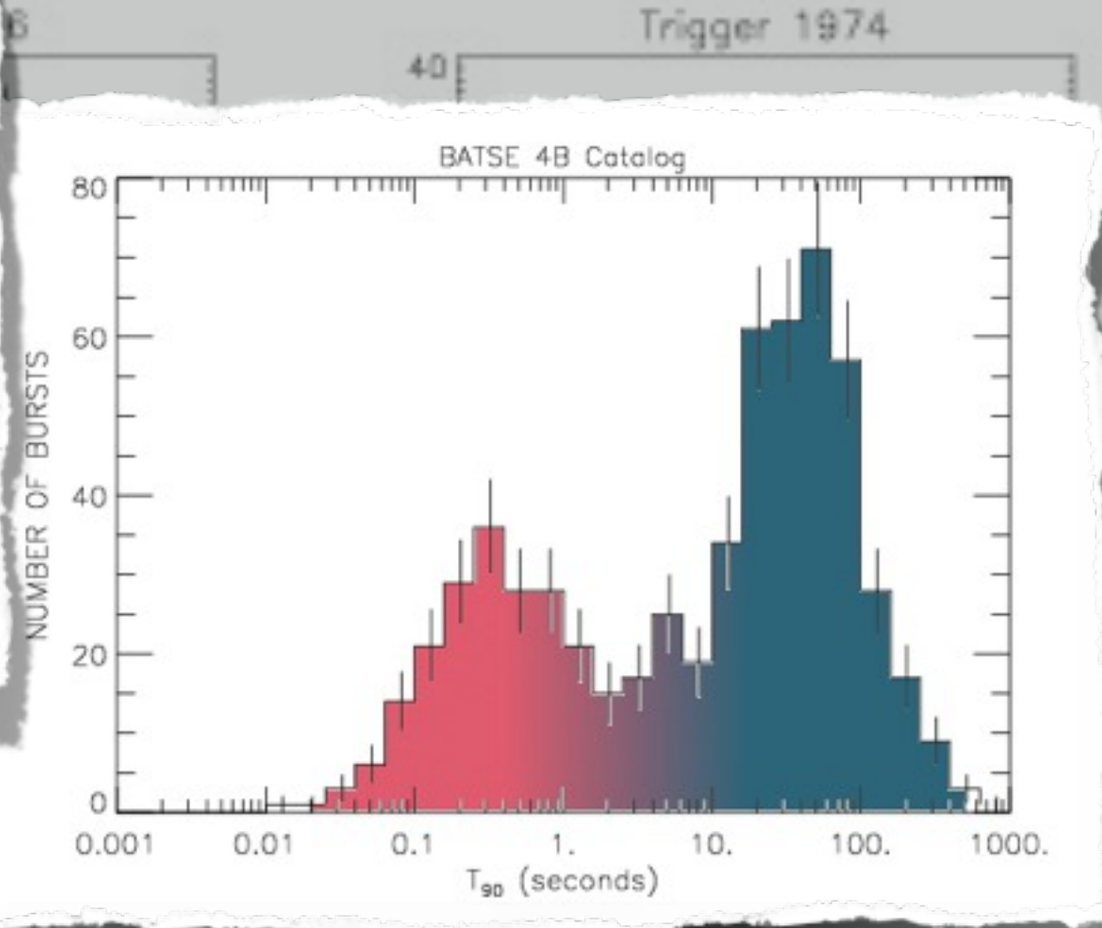
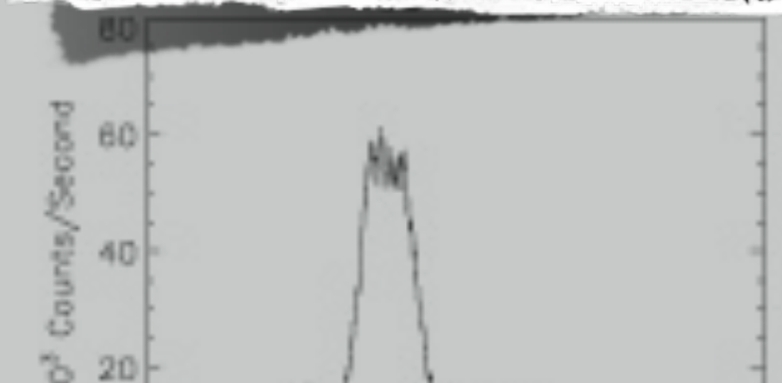






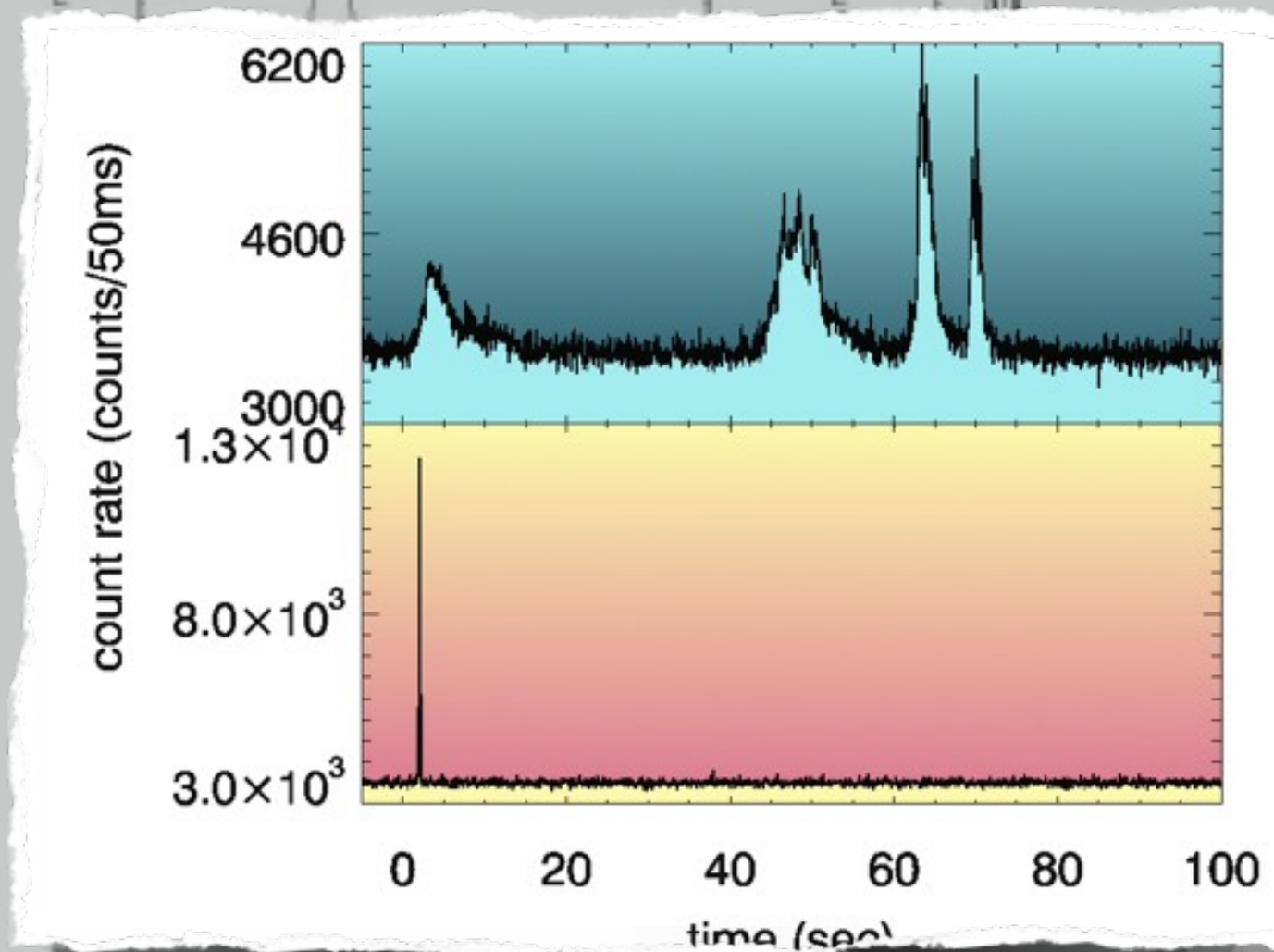


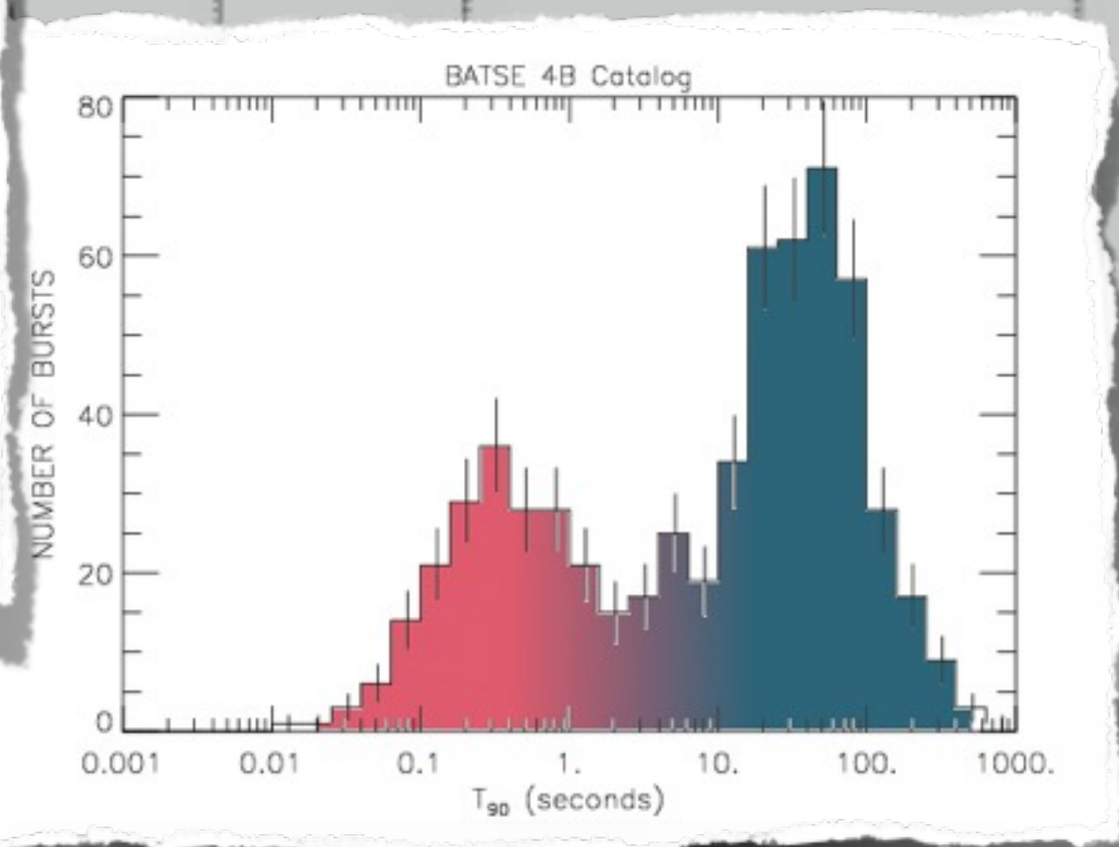




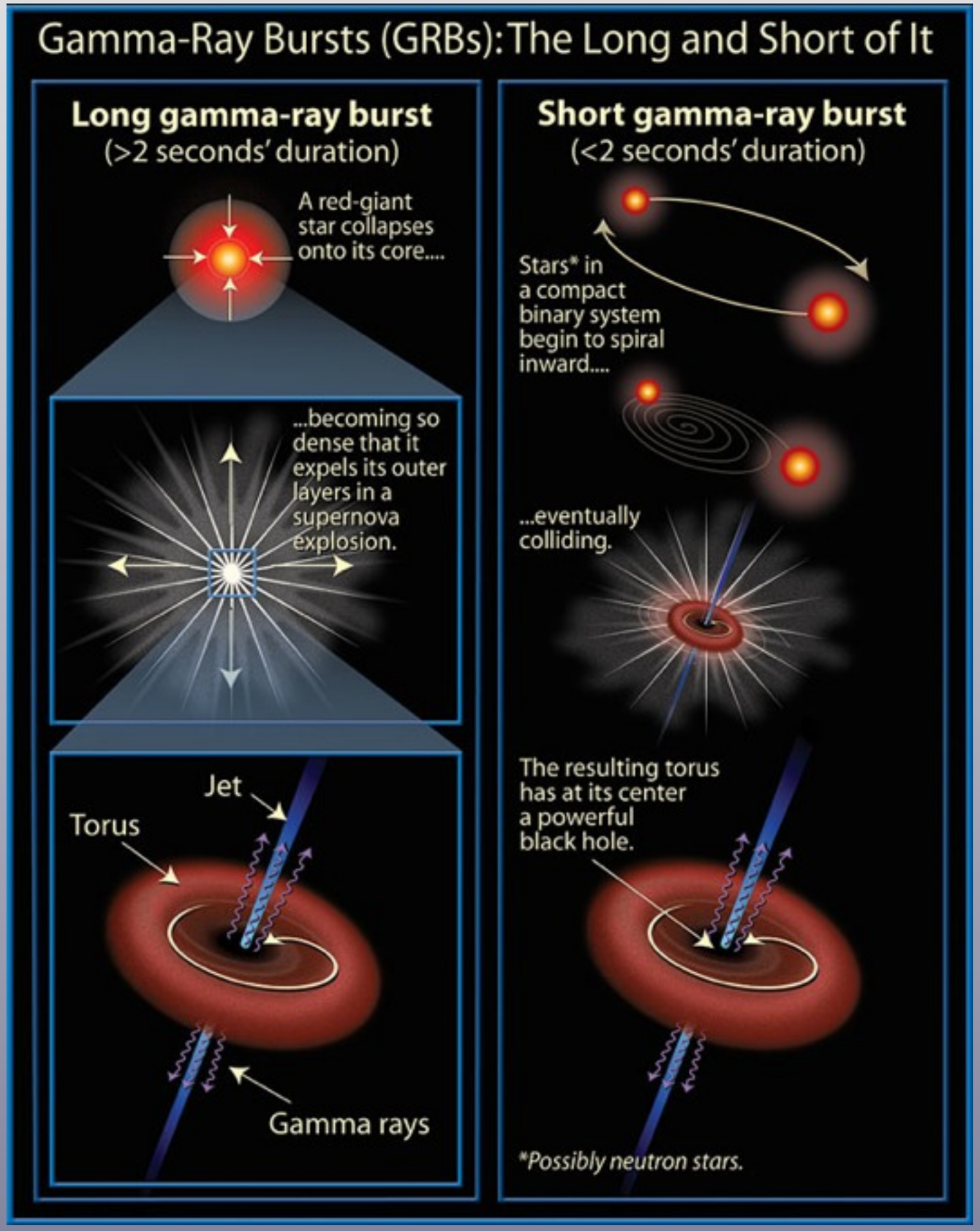
(Gamma-ray Lightcurves)

- GAMMA-RAY EMISSION LASTS FROM MILLISECONDS TO TENS OF MINUTES
- TWO DISTINCT CLASSES (T < 2 SEC = SHORT, T > 2 SEC = LONG)





(Formation Scenarios)



(credit: NASA/Dana Berry)

- LONG BURST -> COLLAPSE OF MASSIVE STAR

- SHORT BURST -> MERGER OF TWO COMPACT STARS

- ALWAYS BLACK HOLE AND ACCRETION DISK

(3rd Sino-German Frontiers of Science Symposium 2010)

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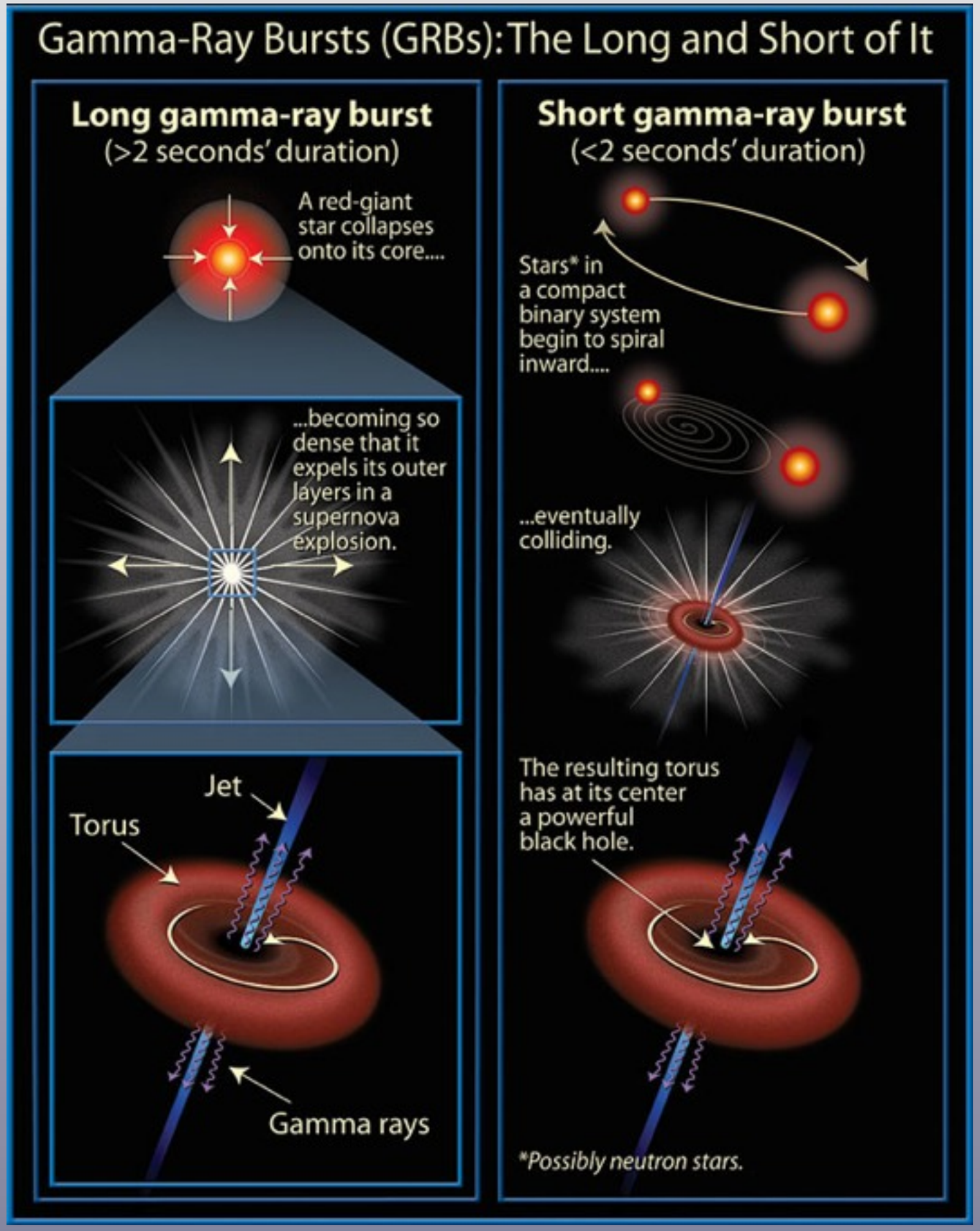

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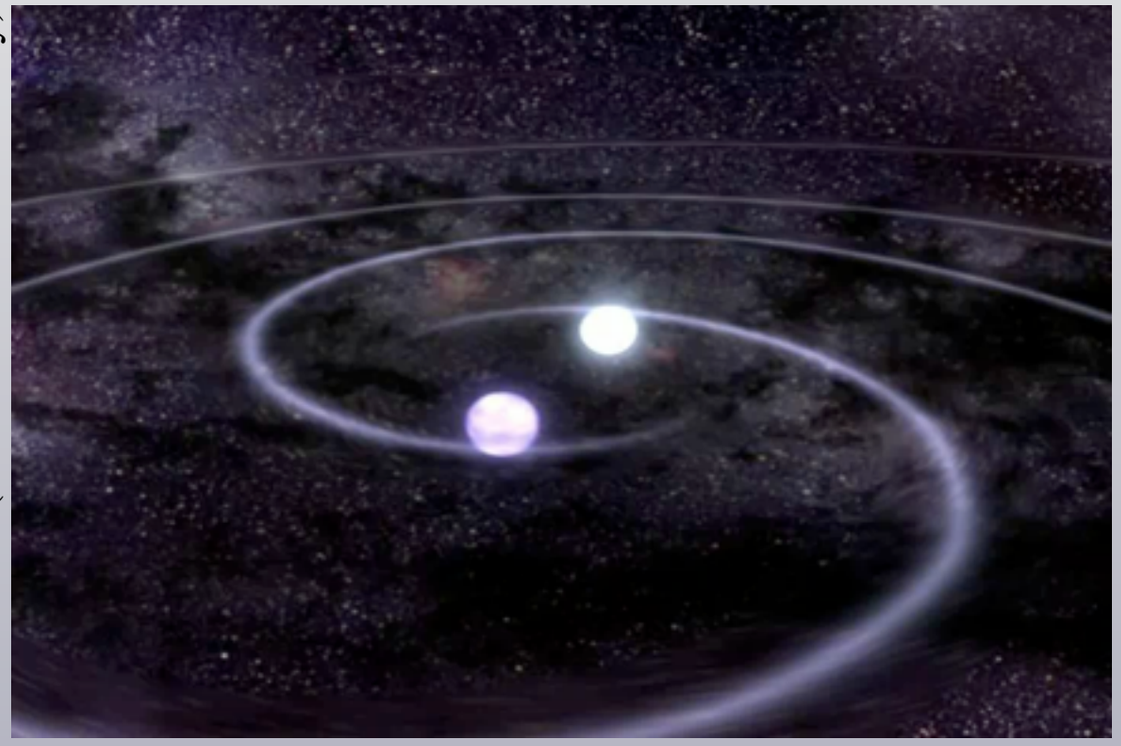

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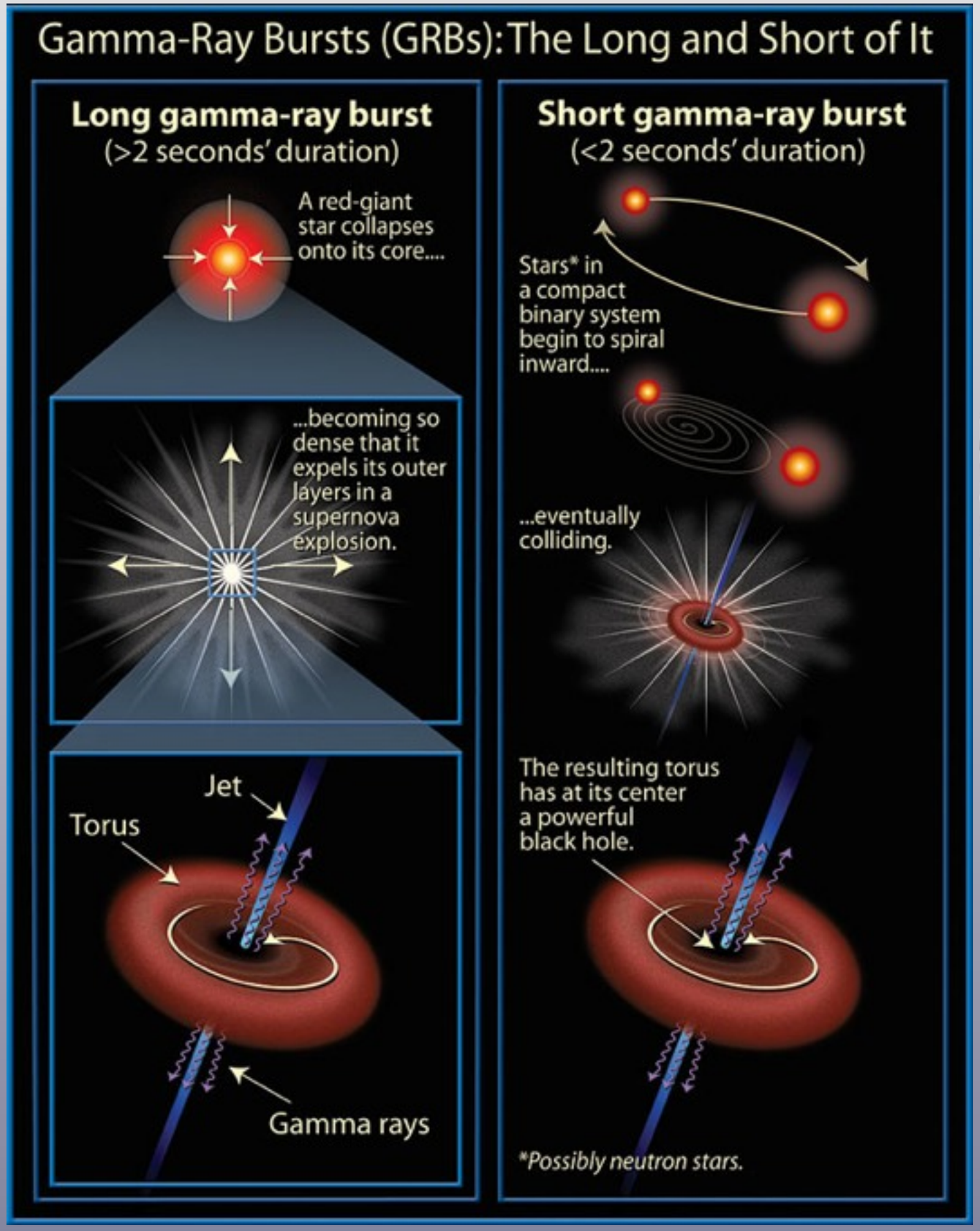

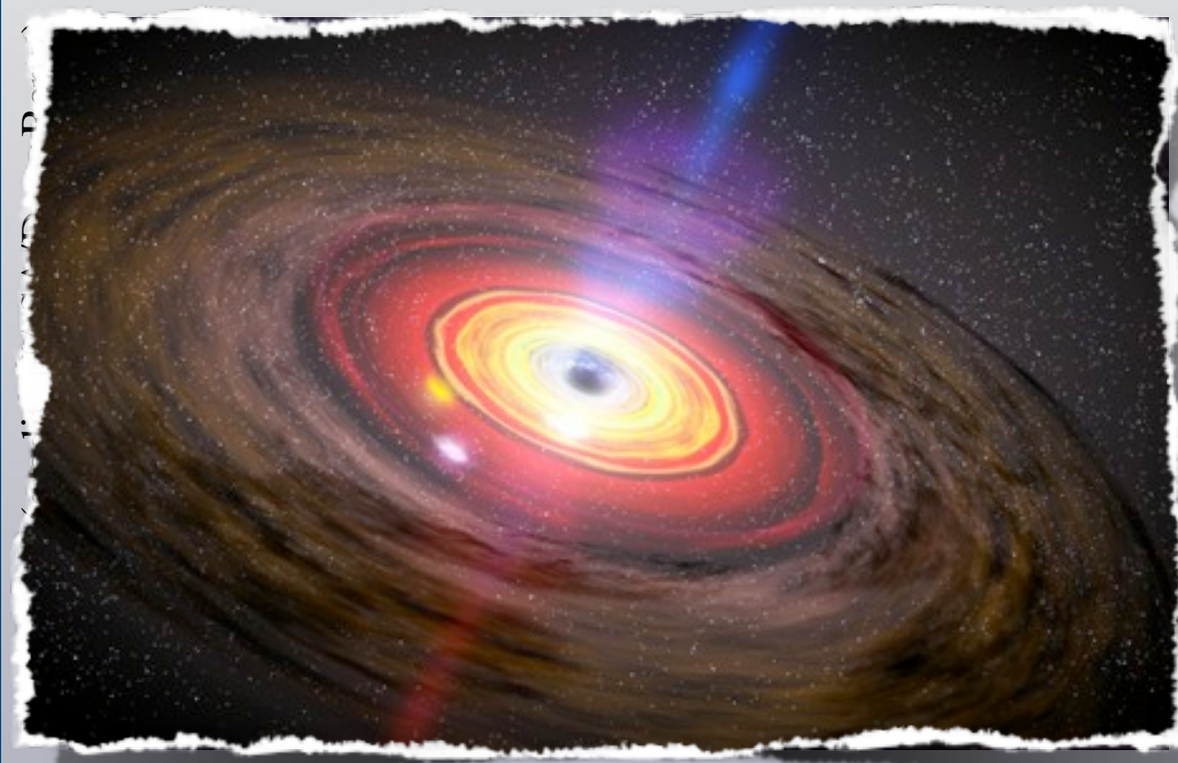

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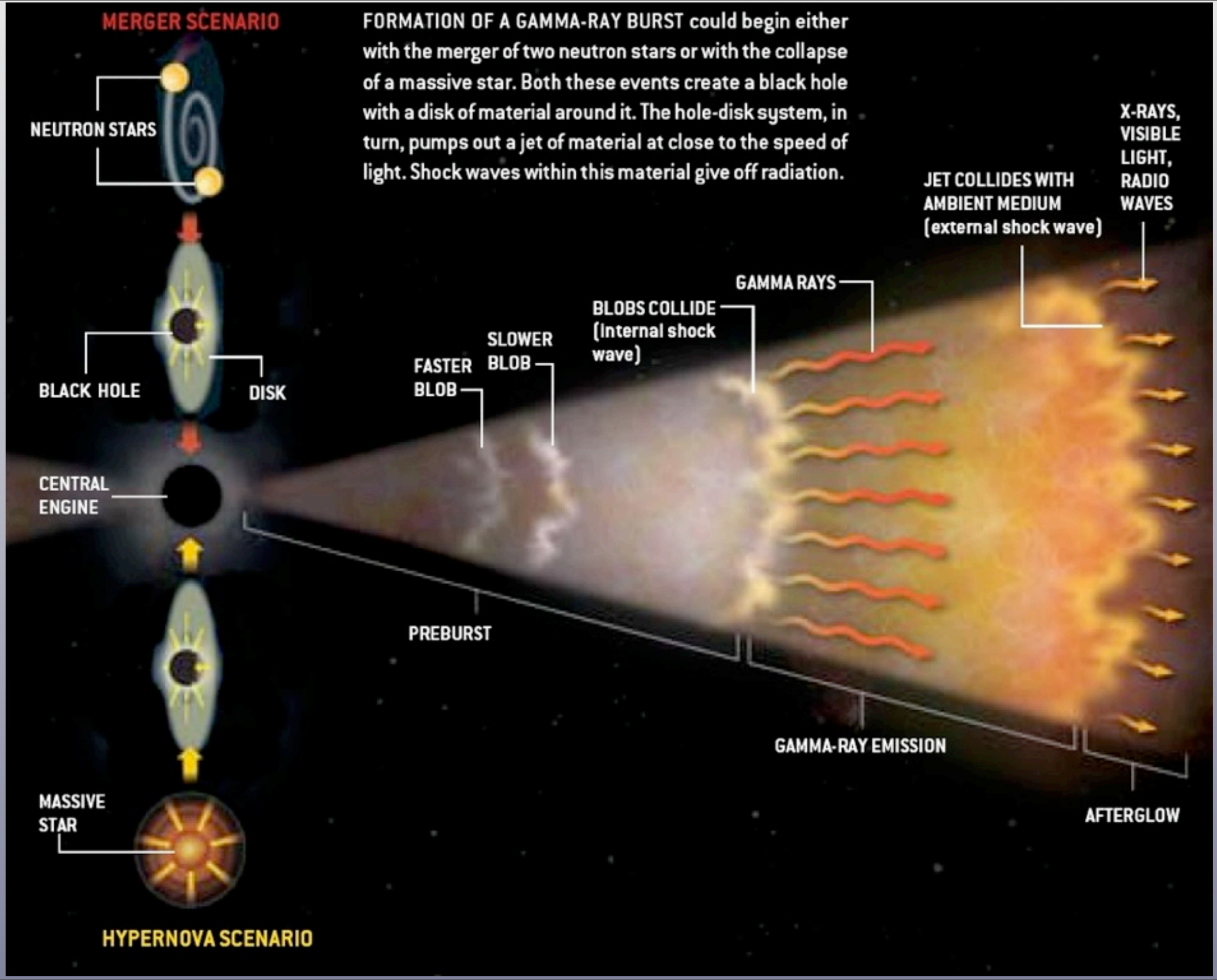
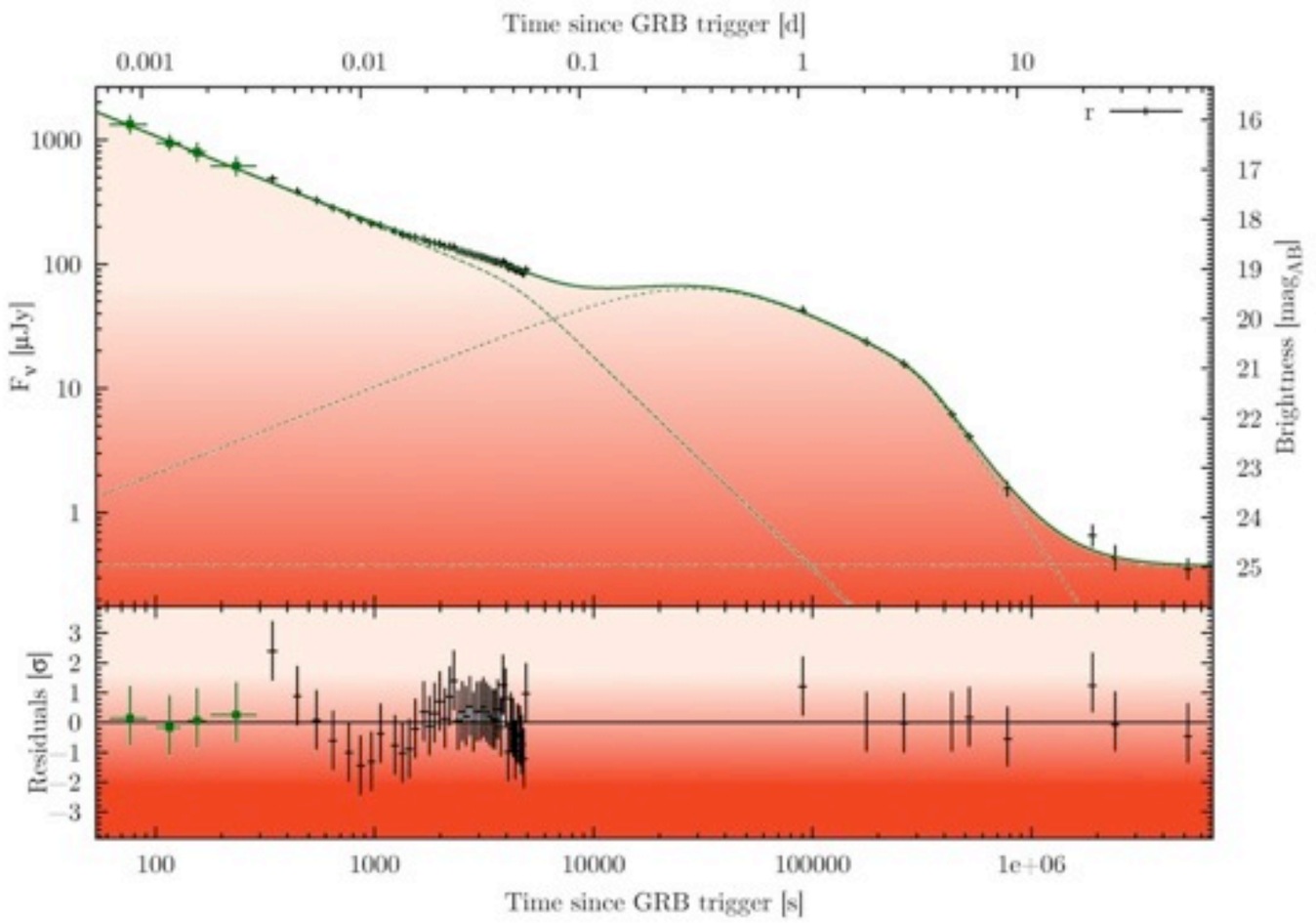

MERGER SCENARIO
FORMATION OF A GAMMA-RAY BURST could begin either with the merger of two neutron stars or with the collapse of a massive star. Both these events create a black hole with a disk of material around it. The hole-disk system, in turn, pumps out a jet of material at close to the speed of light. Shock waves within this material give off radiation.
NEUTRON STARS
BLACK HOLE
DISK
CENTRAL ENGINE
MASSIVE STAR
HYPERNOVA SCENARIO
FASTER BLOB
SLOWER BLOB
BLOBS COLLIDE (Internal shock wave)
GAMMA RAYS
JET COLLIDES WITH AMBIENT MEDIUM (external shock wave)
X-RAYS, VISIBLE LIGHT, RADIO WAVES
PREBURST
GAMMA-RAY EMISSION
AFTERGLOW

2010)

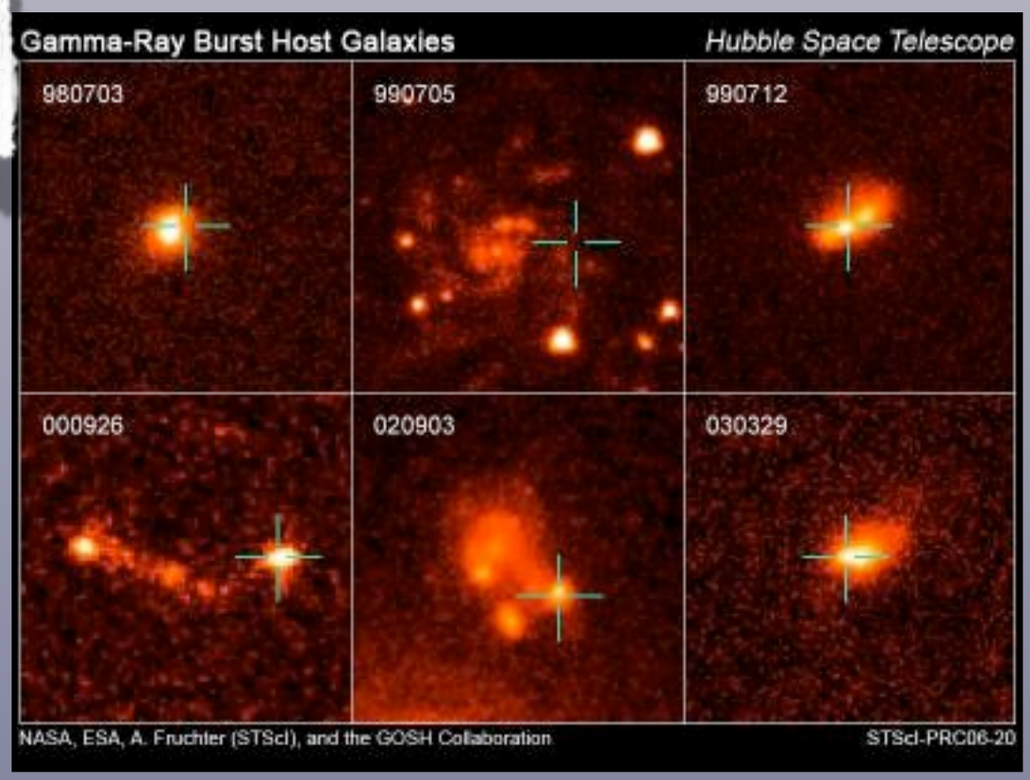
(Beyond the Gamma-rays / Afterglow and Host Galaxy)



(Filgas et al. 2010)

HOST GALAXIES (OPTICAL)

- DISTANCE MEASUREMENT
- YOUNG GALAXIES
- ACTIVELY STARFORMING

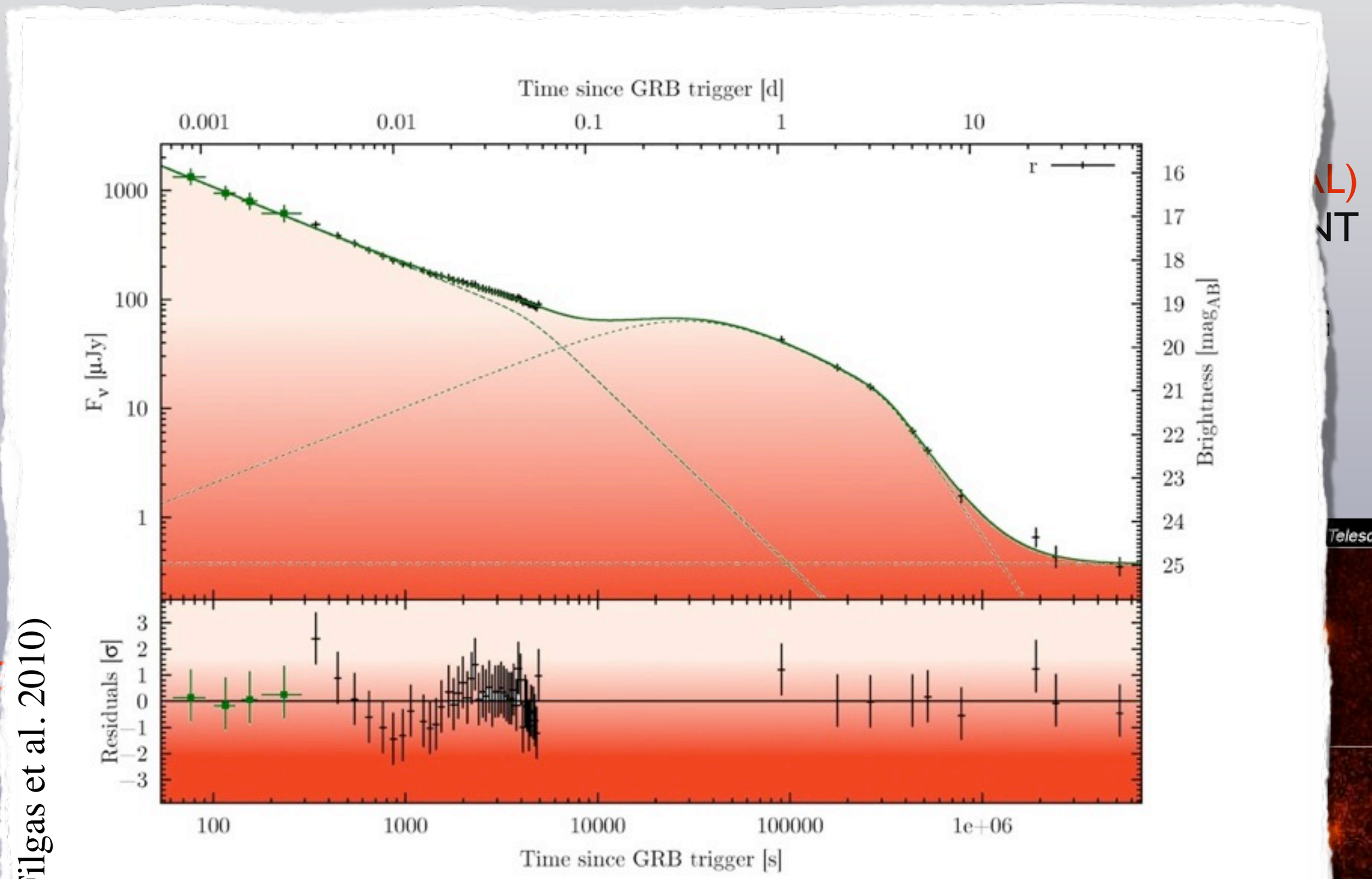


AFTERGLOW (X-RAY TO RADIO)

- $F \sim T^{-1..2}$ + STRUCTURES
- CONSTRAINTS ON JET ANGLE AND TOTAL ENERGY
- PROBE OF ENVIRONMENT
- DISTANCE MEASUREMENT (THROUGH SPECTROSCOPY)

(3rd Sino-German Frontiers of Science Symposium 2010)

(Beyond the Gamma-rays / Afterglow and Host Galaxy)



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(3rd Sino-German Frontiers of Science Symposium 2010)

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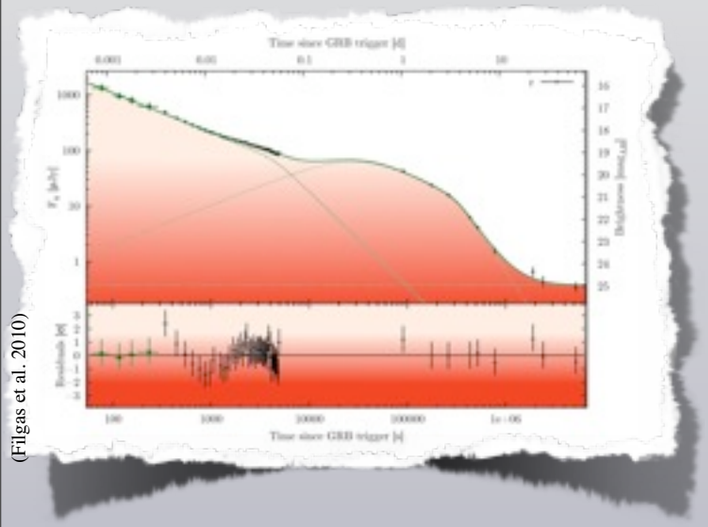

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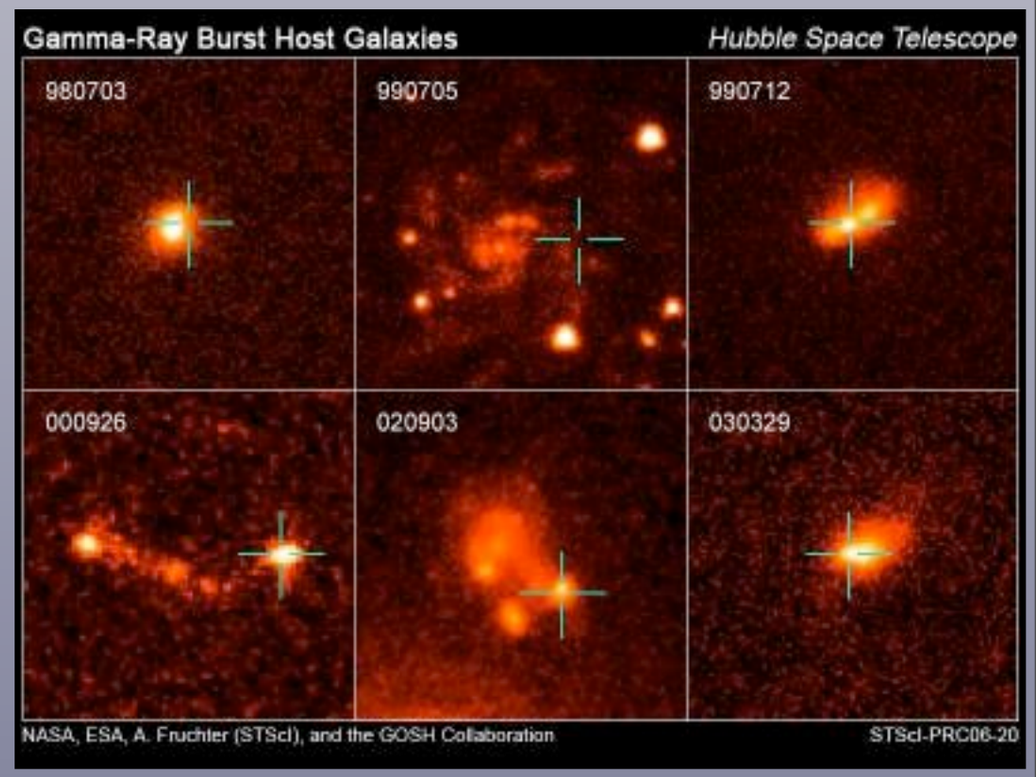
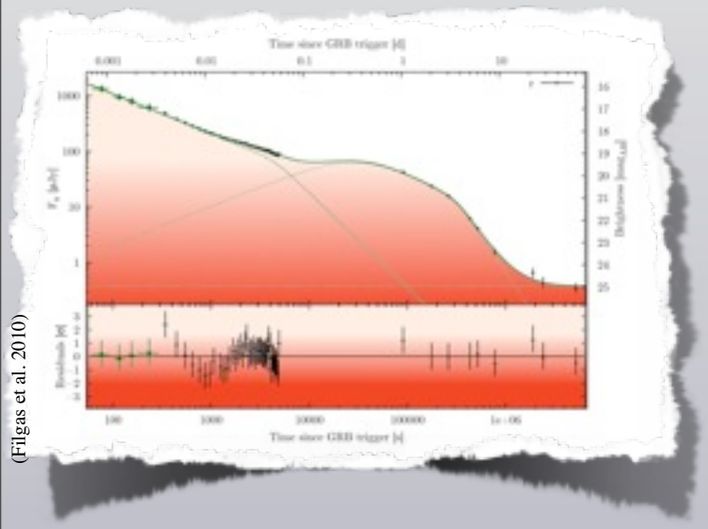


(3rd Sino-German Frontiers of Science Symposium 2010)

(Beyond the Gamma-rays / Afterglow and Host Galaxy)



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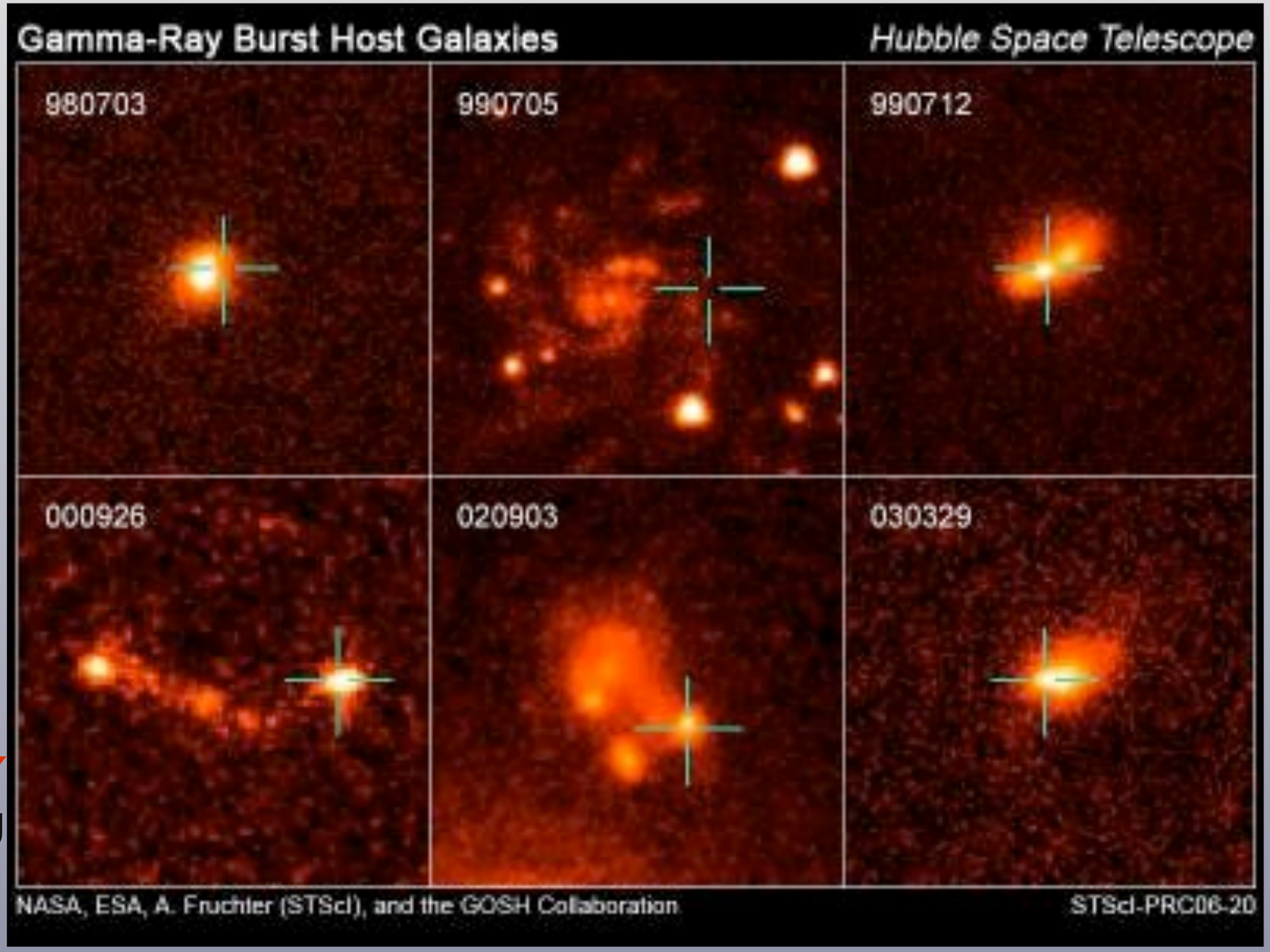

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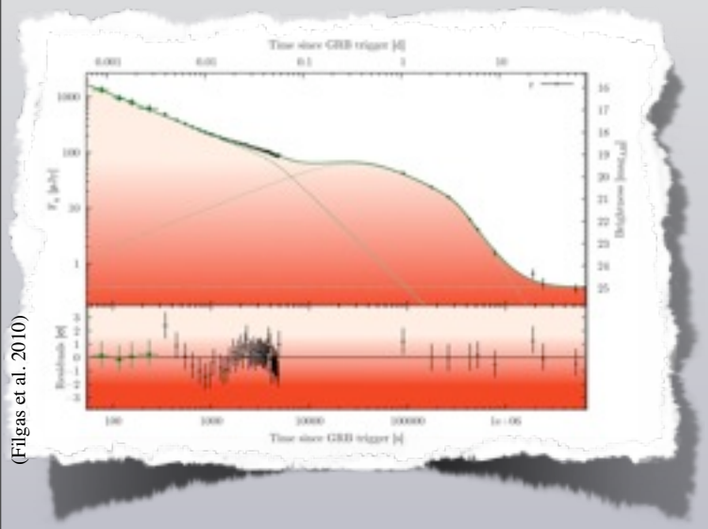

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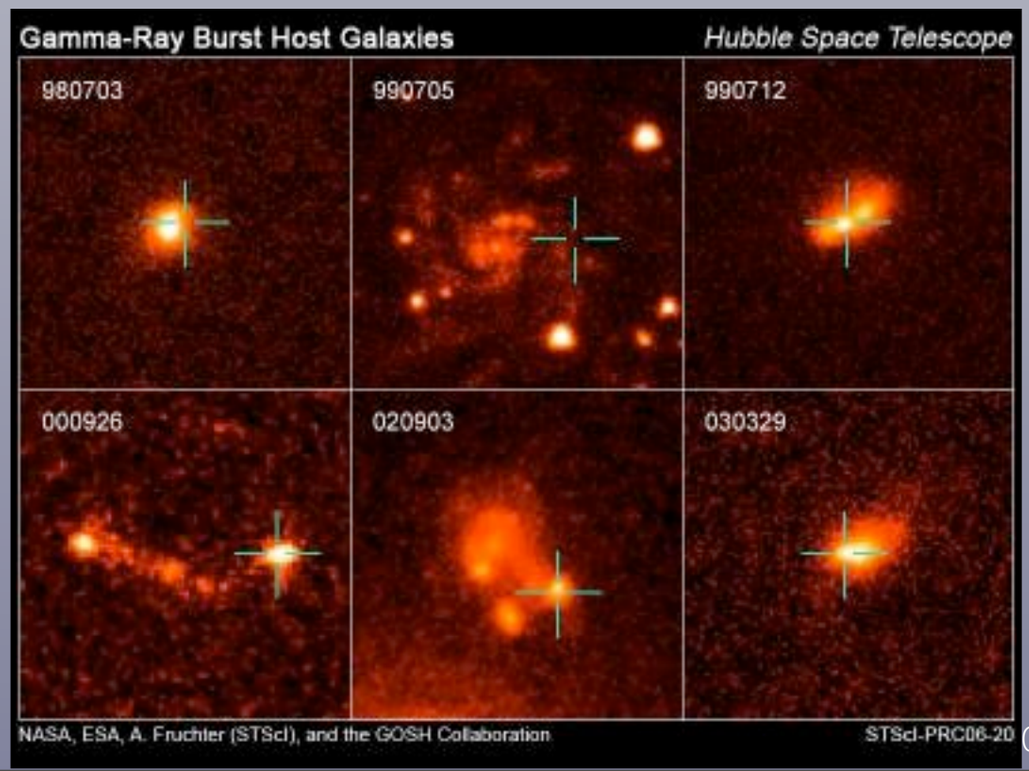
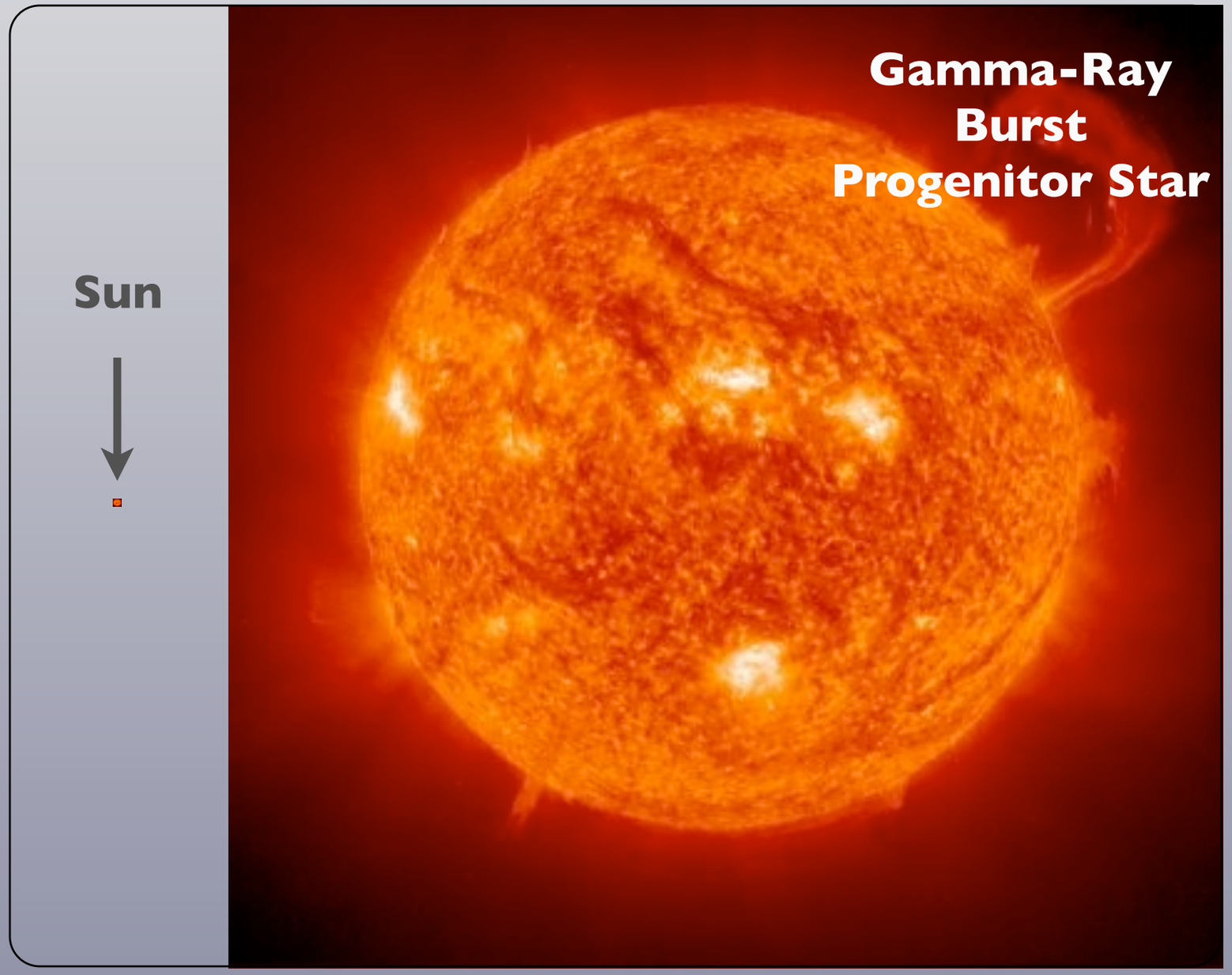


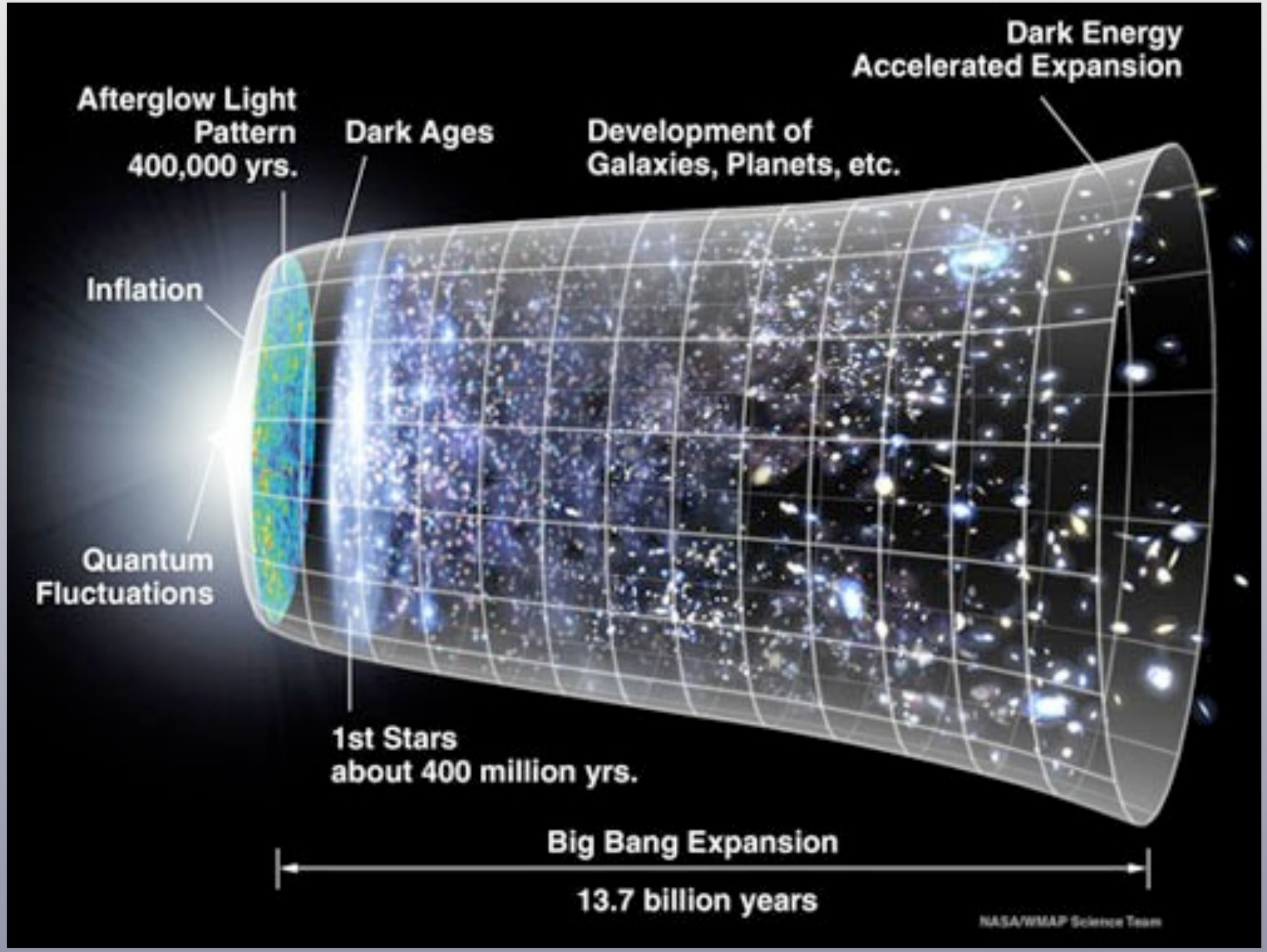
0)

PROGENITOR STARS

- VERY MASSIVE (100 X MASS OF OUR SUN)
- VERY SHORT LIVED (1 MILLION YEARS)

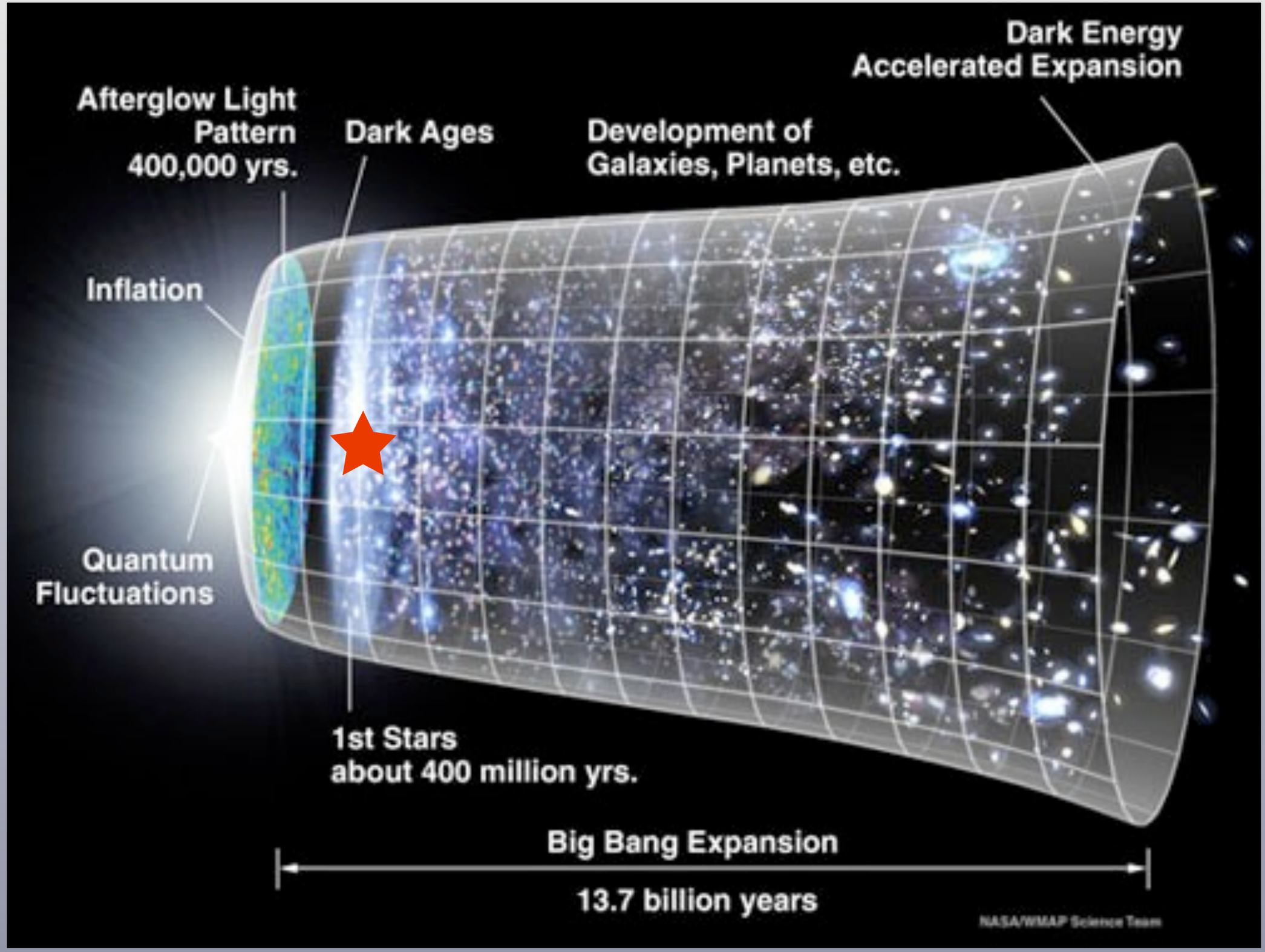


(3rd Sino-German Frontiers of Science Symposium 2010)



- EXCEPTIONAL LUMINOSITY ALLOWS TO DETECT GAMMA-RAY BURSTS FROM THE VERY FIRST STARS IN THE UNIVERSE
- IMPORTANT PROBES OF GALAXY FORMATION AND EVOLUTION

(3rd Sino-German Frontiers of Science Symposium 2010)



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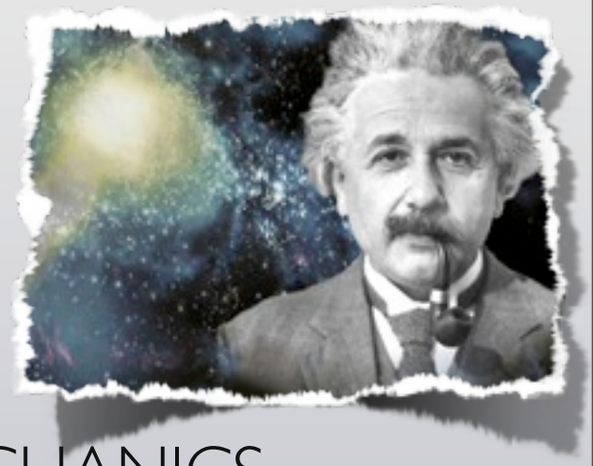
(3rd Sino-German Frontiers of Science Symposium 2010)

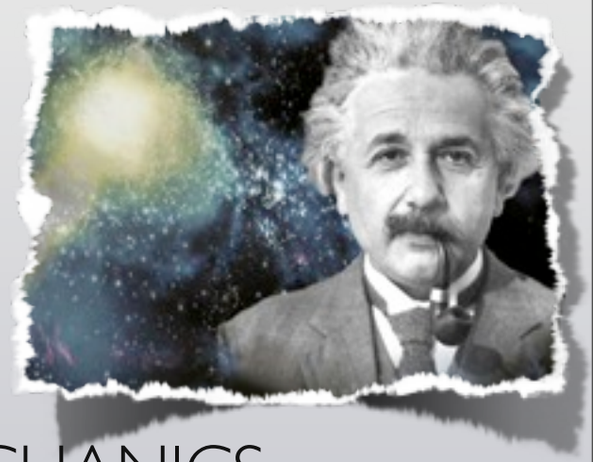
(A Photon Race Ends as a Draw)



- EINSTEIN'S RELATIVITY THEORY PREDICTS A CONSTANT SPEED OF LIGHT
- UNIFICATION THEORIES OF RELATIVITY AND QUANTUM MECHANICS ALLOW THE SPACE TO BE FOAMY -> HIGH-ENERGY GAMMA-RAYS MOVE SLOWER THAN LOW-ENERGY PHOTONS

(3rd Sino-German Frontiers of Science Symposium 2010)

(A Photon Race Ends as a Draw)



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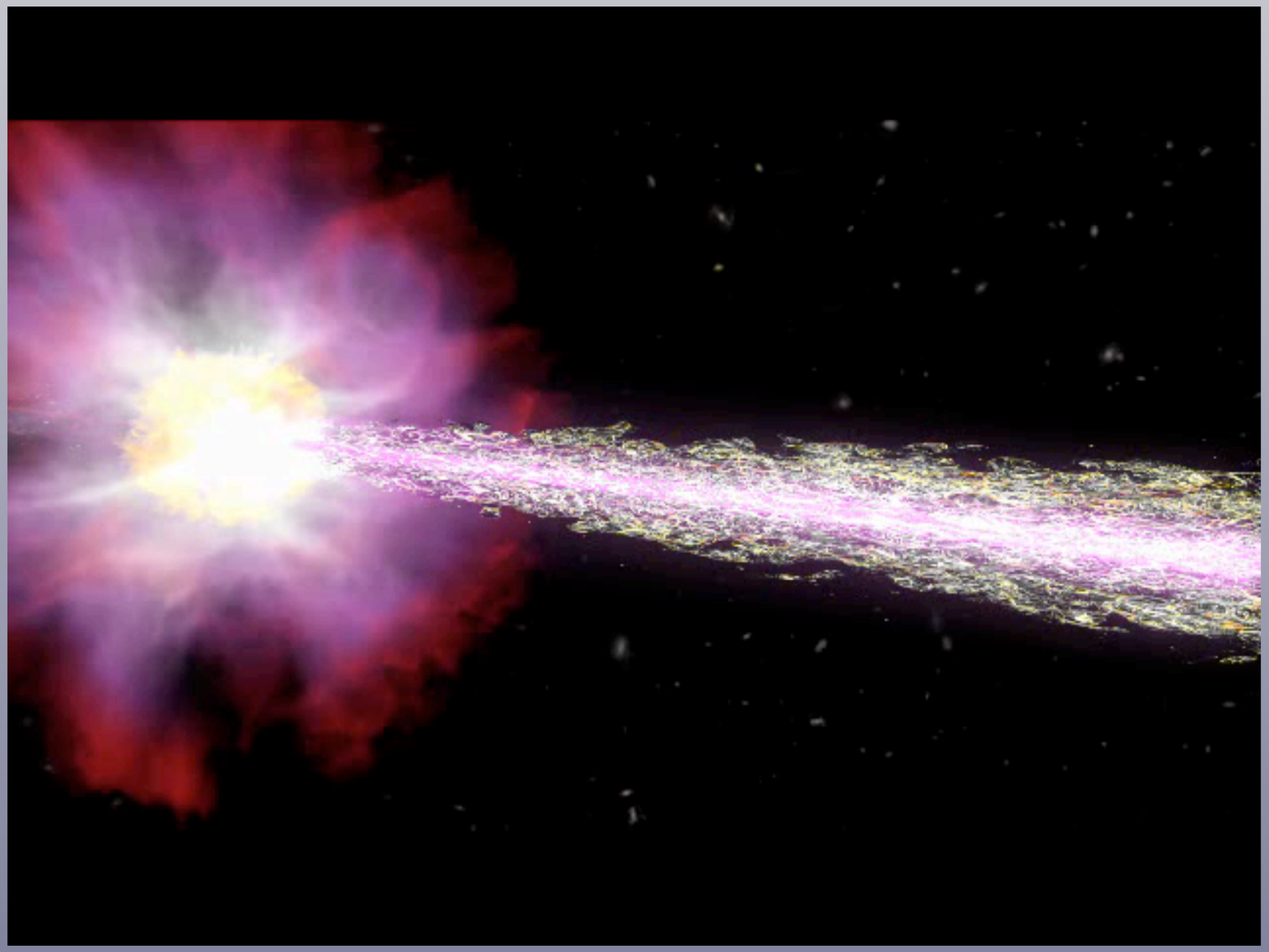

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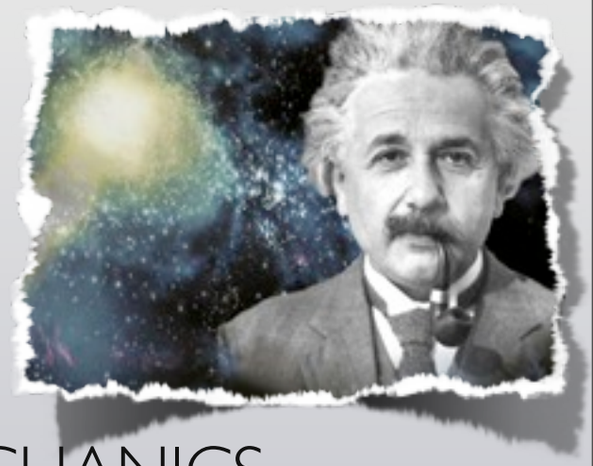

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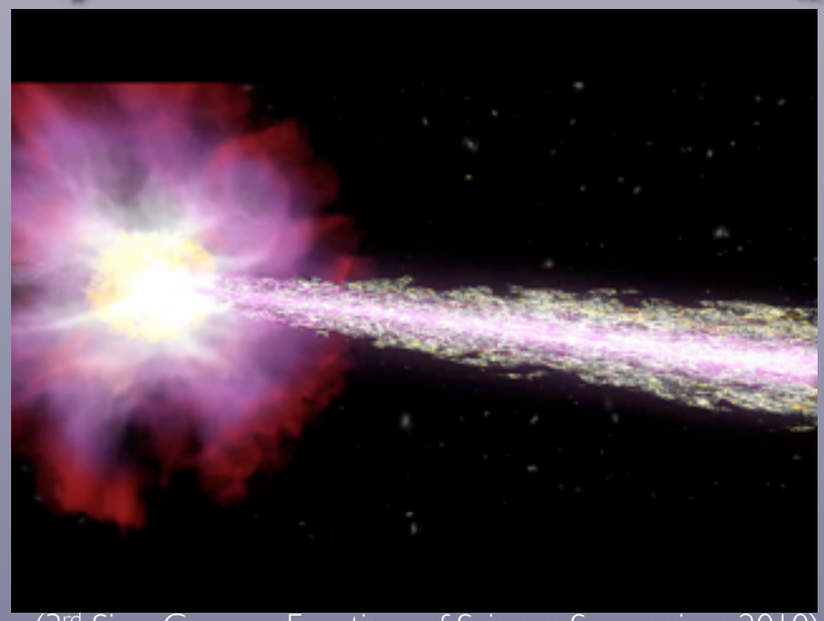
EINSTEIN IS (STILL) CONFIRMED

- AFTER 7 BILLION YEARS LESS THAN 0.9 SEC DELAY OF TWO PHOTONS, ONE 1 MILLION TIMES LESS ENERGETIC THAN THE OTHER
- SAME SPEED TO 1 PART IN 100 MILLION BILLION (10^{18})



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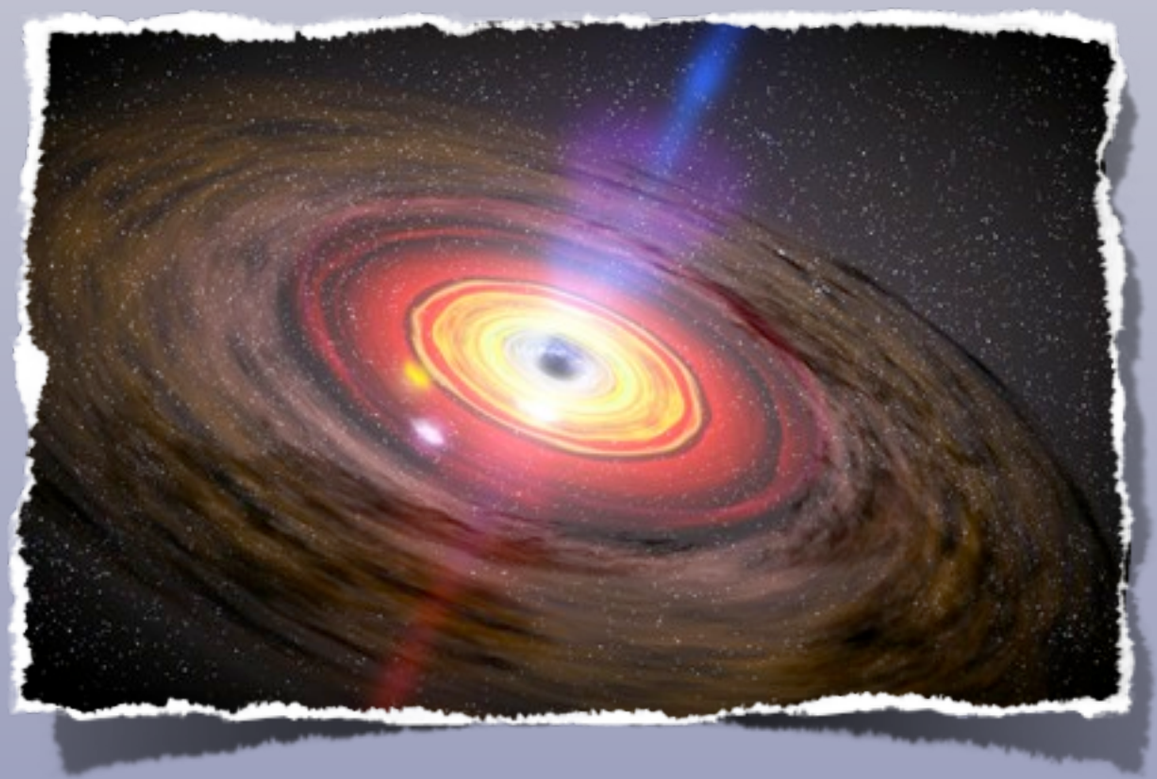
(Summary)

GAMMA-RAY BURSTS ARE:

- SHORT FLASHES OF THE MOST ENERGETIC FORM OF LIGHT
- THE MOST LUMINOUS EXPLOSIONS IN THE UNIVERSE
- SIGNS OF THE DEATHS OF MASSIVE STARS (LONG) OR THE MERGERS OF COMPACT STARS (SHORT)



GAMMA-RAY BURSTS TEACH US ABOUT:

- THE VERY FIRST STARS
- THE FORMATION AND EVOLUTION OF GALAXIES IN THE UNIVERSE
- FUNDAMENTAL PHYSICS

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END