PHY 7097 | Modern Astrophysics

Lecture XXV.

Gamma-ray Bursts & Afterglows

UF | UNIVERSITY of FLORIDA

Imre Bartos | Spring 2018

MARCH 29-31, 2018

GUENAKHFEST

HOME ABOUT COLLOQUIUM TRAVEL & STAY REGISTRATION

Colloquium

Einstein, Gravitational Waves and a New Science

Physics Building NPB-1002 (streamed into the lobby)

Barry Barish

Barry Barish, Linde Professor of Physics emeritus at the California Institute of Technology, has made important contributions in particle physics, gravitational physics, and astrophysics. He worked in neutrino physics at Fermilab, directed a magnetic monopole search at Grand Sasso, and was the spokesperson for the GEM detector at the SSC. (Guenakh Mitslemaker was also part of the GEM collaboration.)

In 1994 he took charge of the Laser Interferometer Gravitational-Wave Observatory (LIGO) project as principal investigator/director (1994–2005) and saw the project through construction, commissioning and the first science runs. As director he expanded the LIGO collaboration; the Florida LIGO group, led by Guenakh Mitselmakher, was the first new

Thursday, March 29, 4:05 pm
Room 1002, New Physics Building

https://www.phys.ufl.edu/events/guenakhfest/program.html

Friday, March 30 (afternoon)

Chairperson: David Tanner

Time	Location	Event	Speaker
1: 45 pm	NPB-2205	Tevatron Legacy	Dmitri Denisov
2:10 pm	NPB-2205	True Measurements, False Discoveries	Tiziano Camporesi
2:35 pm	NPB-2205	LIGO Then and Now: UF's role in LIGO Over the Past Two Decades and LIGO's Plans for the Near Future	David Reitze
3:00 pm	NPB-2205	Searches for Continuous Gravitational Waves	Keith Riles
3:25 pm		Break	
3:45 pm	NPB-2205	Searches for gravitational wave bursts with LIGO	Sergey Klimenko
4:10 pm	NPB-2205	Comprehensive Multisensory Multimodal Integration in Astrophysics	Szabi Marka
4:35 pm	NPB-2205	Beyond Advanced LIGO: the third generation detectors	Rana Adhikari
5:00 pm		End	
6:30 pm	Thomas Center	Dinner Venue	

Saturday, March 31 (morning)

Chairperson: Andrey Korytov

Time	Location	Event	Speaker

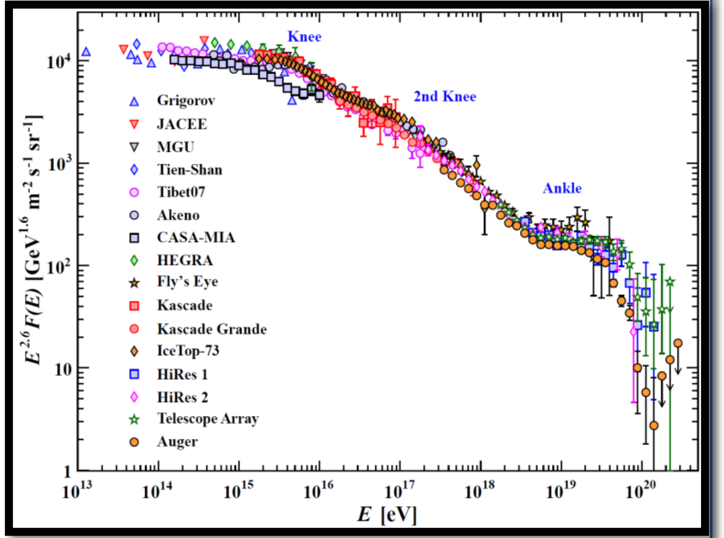
HW: Neutrino spectrum from starburst galaxies

Distribution of galaxy luminosities (Schechter function):

$$\Phi(L)dL = (\frac{\Phi^*}{L^*})(\frac{L}{L^*})^{\alpha} \exp(-\frac{L}{L^*})dL$$

$L_{MW} \sim 1\ \mathrm{M_{\odot} yr^{-1}}$

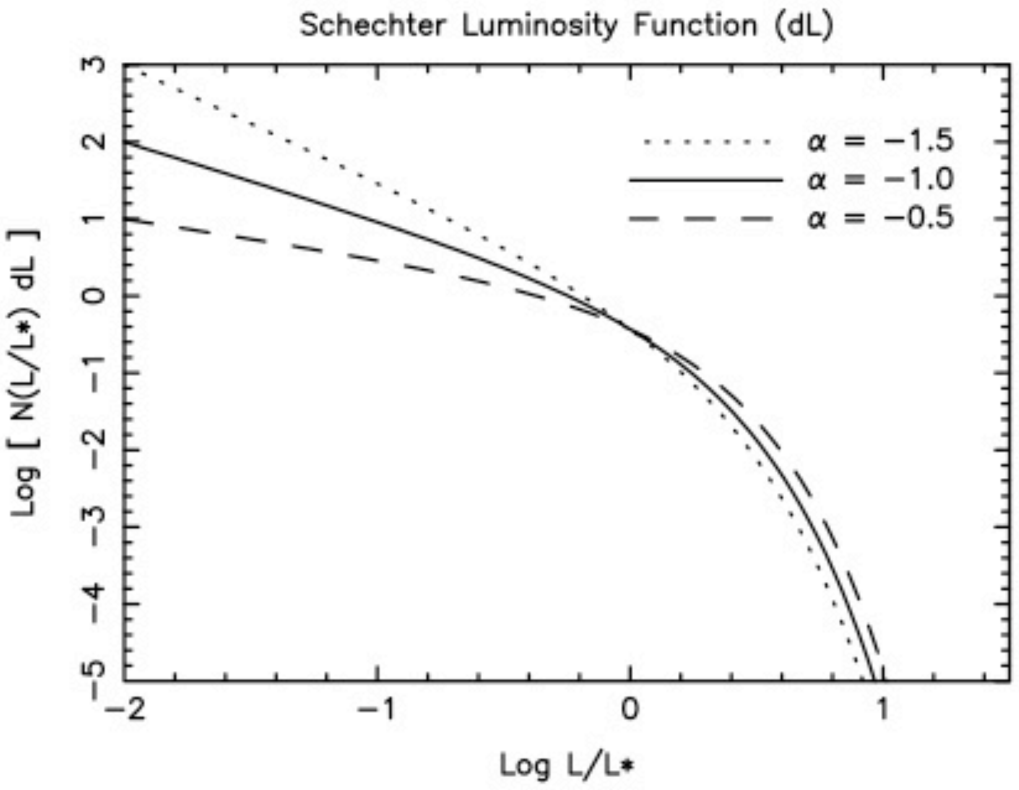
Cosmic rays above 10^{15} eV escape from the Milky Way.



$\alpha = 1.4$

$L^* = 625\,\mathrm{M_{\odot} yr^{-1}}$

$\Phi^* = 2.2 \times 10^5\ \mathrm{Mpc^{-3}}$



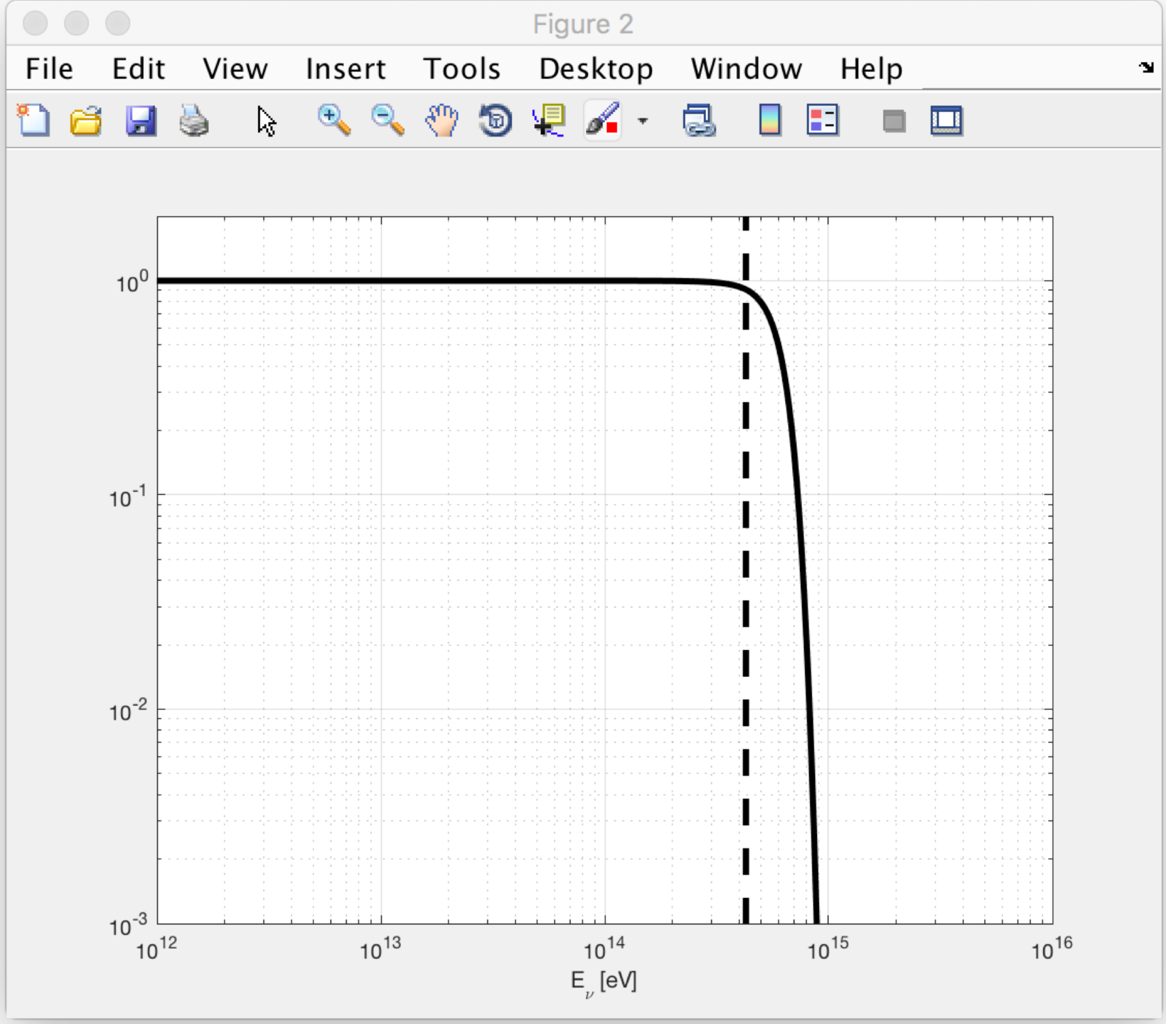
- Cosmic rays are emitted by sources (e.g. GRB/supernovae) within galaxies with dN/dE~E-2 spectrum.
- Neutrinos are produced with energy ~5% of the interacting cosmic ray's energy.

HW: What will be the power spectral density of neutrinos observed from the Universe?

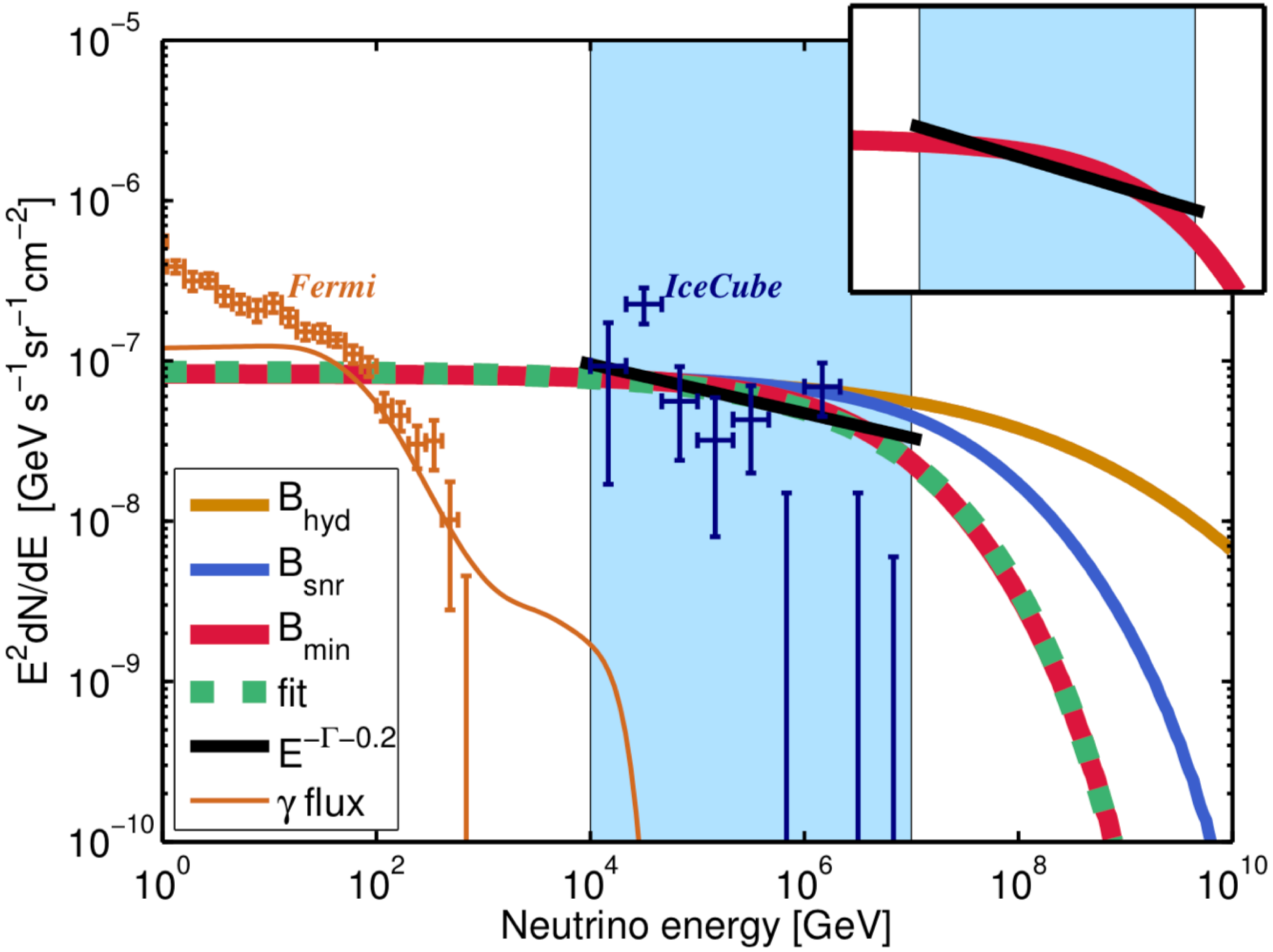
MATLAB R2016a - academic u

Dropbox/DOCUMENTS/Multimessenger_Astrophysics_Course/NeutrinoSpectrum.m

```
function NeutrinoSpectrum()
% Modern Astrophysics PHY7097 HW #3 solution

% neutrino spectral range over which we want results
  E_nu = logspace(9, 20, 1000);

% parameters
  alpha = 1.4;
  Lstar = 625; % [Mstar yr^-1]
  E_cut_MW = 5*10^13; % [eV]
  L_MW = 1; % [Msun yr^-1]


% calculate result
  for i=1:length(E_nu)
    Phi_nu(i) = gammainc(1+alpha, L_MW * (E_nu(i)/E_cut_MW)^3/Lstar);
  end;

% plot
  figure(2)
  loglog(E_nu,Phi_nu, 'k', 'LineWidth', 3);
  xlabel('E_{\nu} [eV]');
  grid on;
  ylim([10^-3 2])
  xlim([10^12 10^16])
  % also plot cutoff for Lstar
    E_Lstar_cut = E_cut_MW * (Lstar / L_MW)^(1/3);
    hold on;
    plot([1 1]*E_Lstar_cut, [10^-3 2], 'k--', 'LineWidth', 3);
    hold off;

return
```



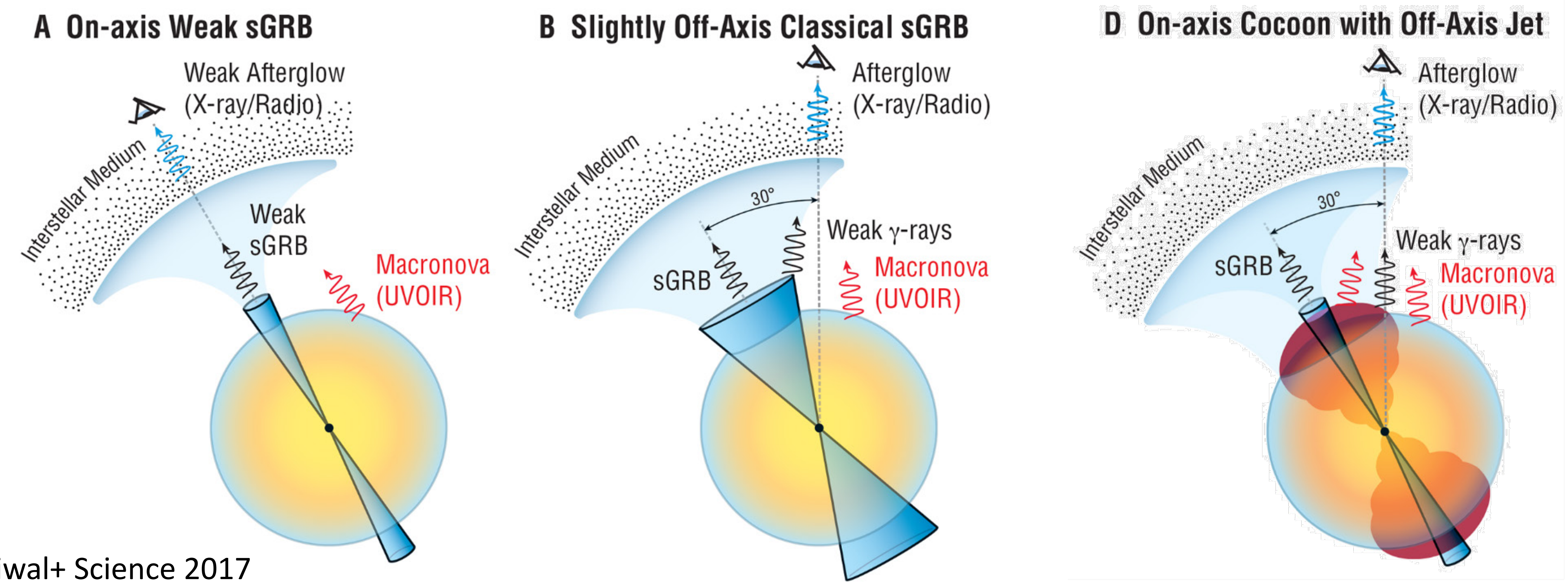
Homework



Bartos & Marka 2015

Gamma-ray burst

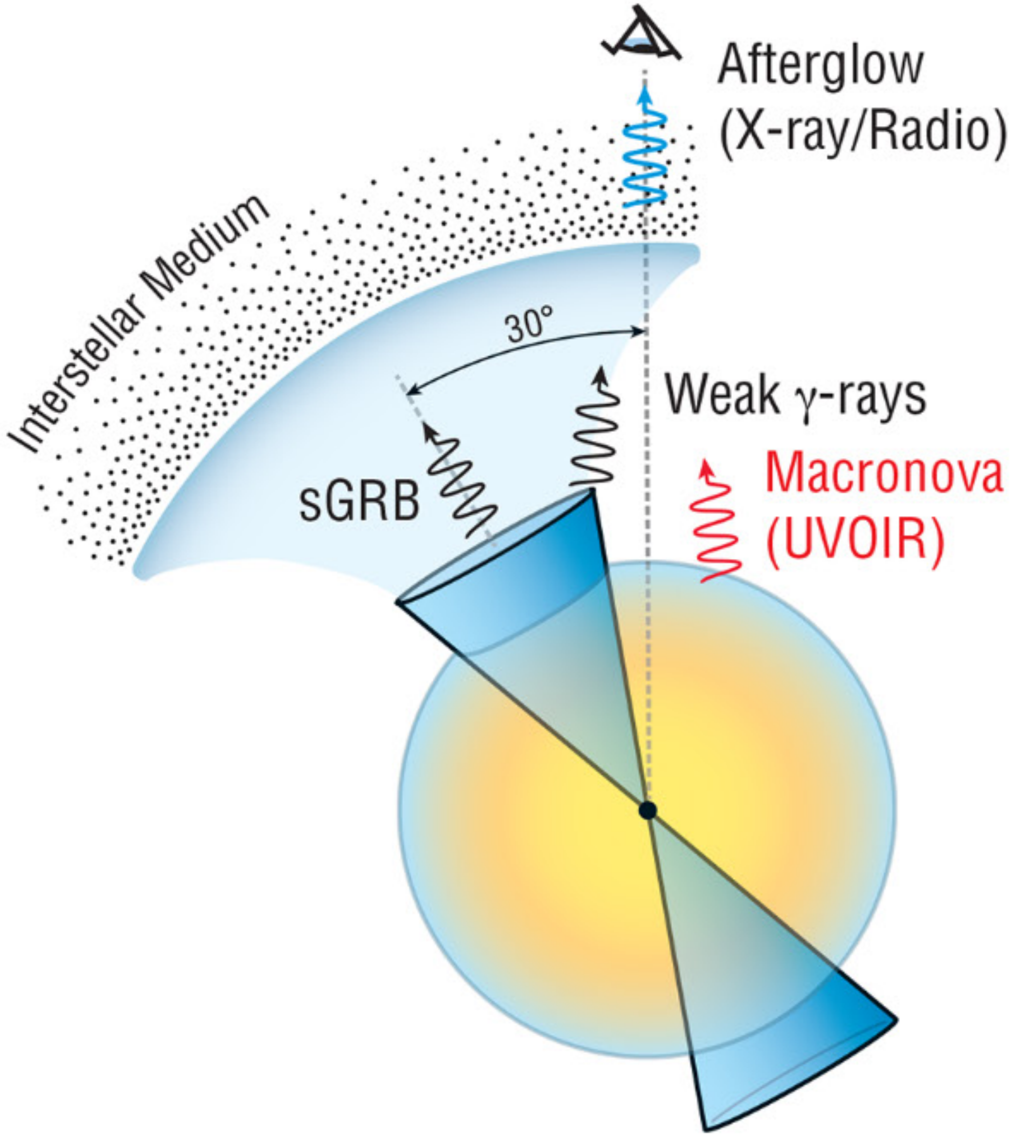
- Very weak --- energy orders of magnitude below weakest GRB detected
- Short-hard --- consistent with binary neutron star picture
- Host galaxy --- low star formation, probably very old NSs (Blanchard+ 2017)
- X-ray/Radio delay (9 and 15 days) --- unusual, consistent with off-axis scenario
- There was a GRB → merger remnant collapsed to a black hole
- 1.7 s delay --- e.g. jet propagation before shock
- Fundamental limits: Constraint on speed of gravity: ~10^{-15}c | rules out DM emulators | etc.

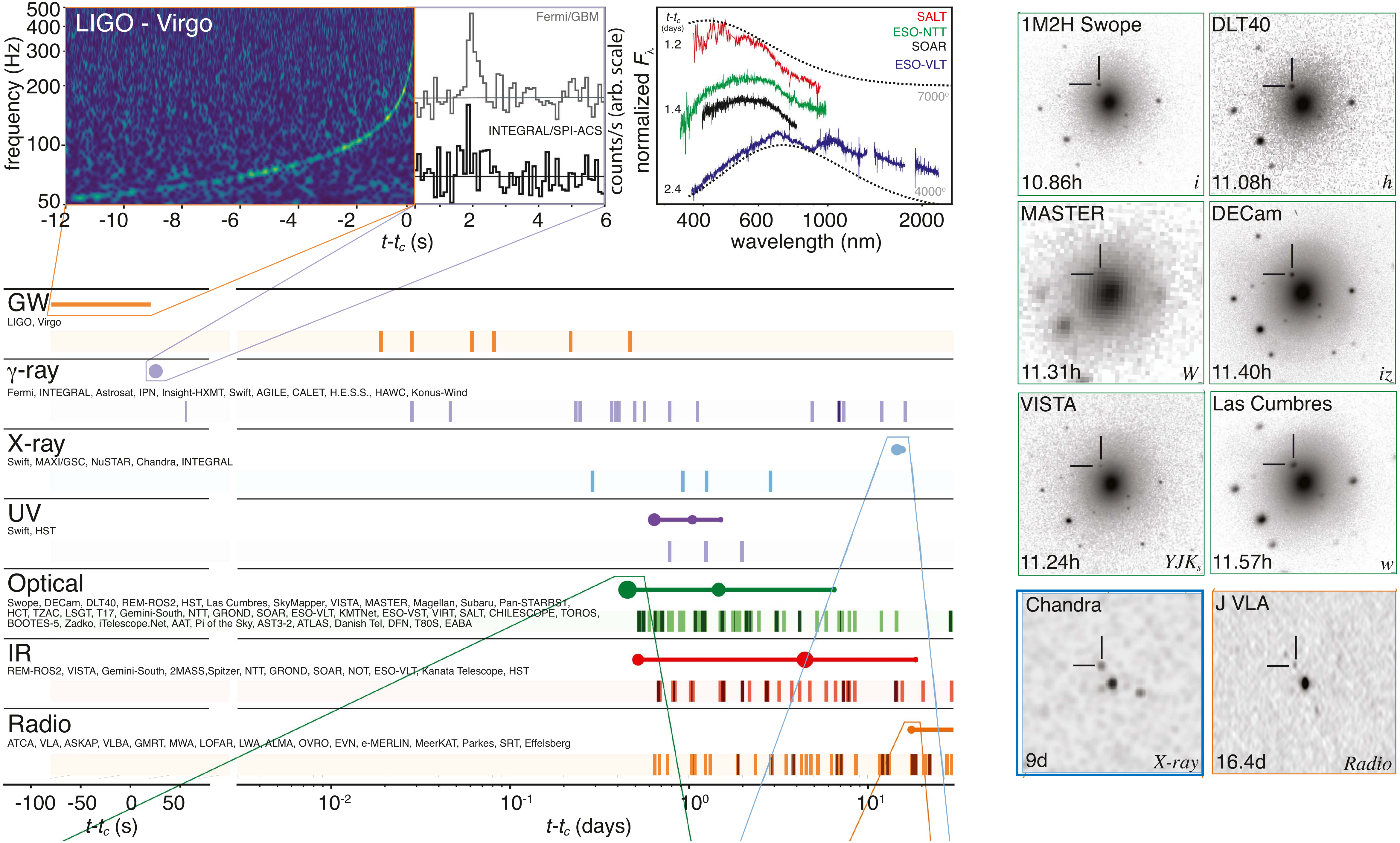


Kasliwal+ Science 2017

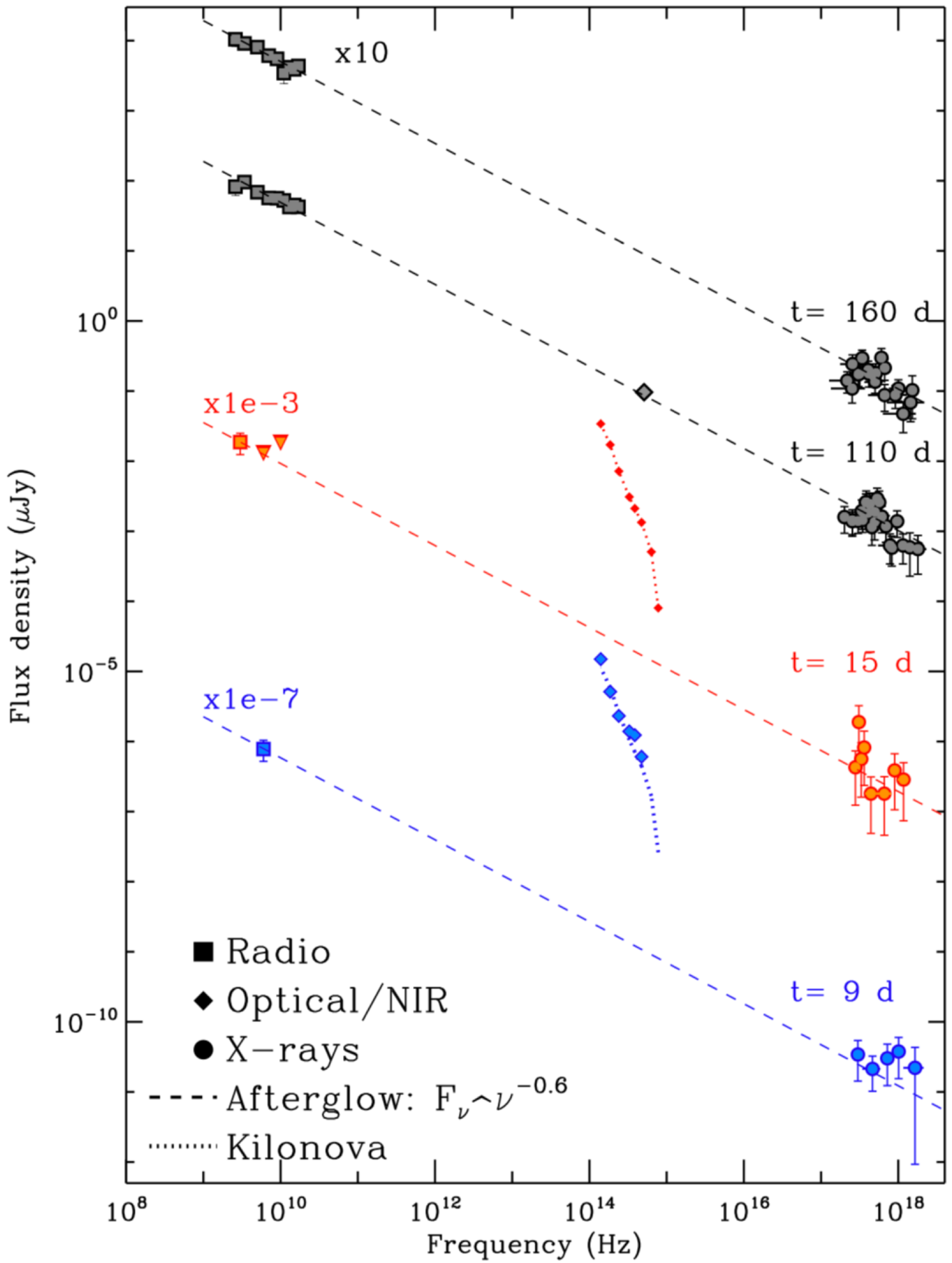
Off-axis?

We approximated the observed off-axis spectral fluence, $F_{\rm off}(E)$, for these models using $F_{\rm off}(E) = \eta F_{\rm on}(E/\eta)$, where the scaling factor $\eta = \delta(\theta_{\rm obs})/\delta(0)$ accounts for different Doppler factors $\delta(\theta_{\rm obs}) = [\Gamma(1 - \beta\cos(\theta_{\rm obs} - \theta_j))]^{-1}$ (Granot et al. 2002).



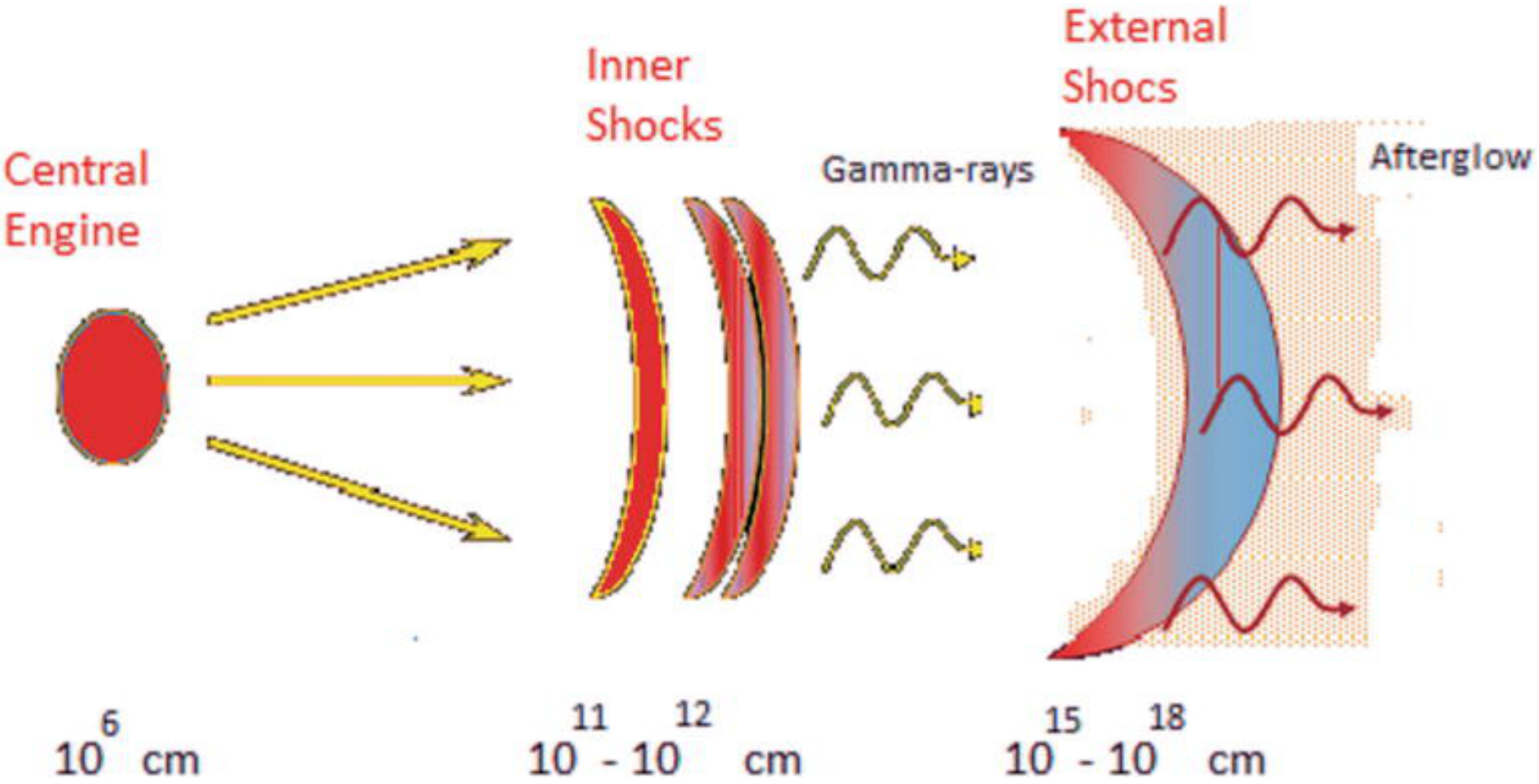

LIGO - Virgo
frequency (Hz)
500
400
300
200
100
50
-12
-10
-8
-6
-4
-2
0
2
4
6
t-t$_c$ (s)
Fermi/GBM
INTEGRAL/SPI-ACS
counts/s (arb. scale)
normalized F_λ
t-t$_c$ (days)
1.2
1.4
2.4
SALT
ESO-NTT
SOAR
ESO-VLT
7000°
4000°
400
600
1000
2000
wavelength (nm)
1M2H Swope
10.86h
i
DLT40
11.08h
h
MASTER
11.31h
W
DECam
11.40h
iz
VISTA
11.24h
YJK_s
Las Cumbres
11.57h
w
Chandra
9d
X-ray
J VLA
16.4d
Radio
GW
LIGO, Virgo
γ-ray
Fermi, INTEGRAL, Astrosat, IPN, Insight-HXMT, Swift, AGILE, CALET, H.E.S.S., HAWC, Konus-Wind
X-ray
Swift, MAXI/GSC, NuSTAR, Chandra, INTEGRAL
UV
Swift, HST
Optical
Swope, DECam, DLT40, REM-ROS2, HST, Las Cumbres, SkyMapper, VISTA, MASTER, Magellan, Subaru, Pan-STARRS1,
HCT, TZAC, LSGT, T17, Gemini-South, NTT, GROND, SOAR, ESO-VLT, KMTNet, ESO-VST, VIRT, SALT, CHILESCOPE, TOROS,
BOOTES-5, Zadko, iTelescope.Net, AAT, Pi of the Sky, AST3-2, ATLAS, Danish Tel, DFN, T80S, EABA
IR
REM-ROS2, VISTA, Gemini-South, 2MASS,Spitzer, NTT, GROND, SOAR, NOT, ESO-VLT, Kanata Telescope, HST
Radio
ATCA, VLA, ASKAP, VLBA, GMRT, MWA, LOFAR, LWA, ALMA, OVRO, EVN, e-MERLIN, MeerKAT, Parkes, SRT, Effelsberg
-100
-50
0
50
t-t$_c$ (s)
10^{-2}
10^{-1}
10^{0}
10^{1}
t-t$_c$ (days)

Afterglow…



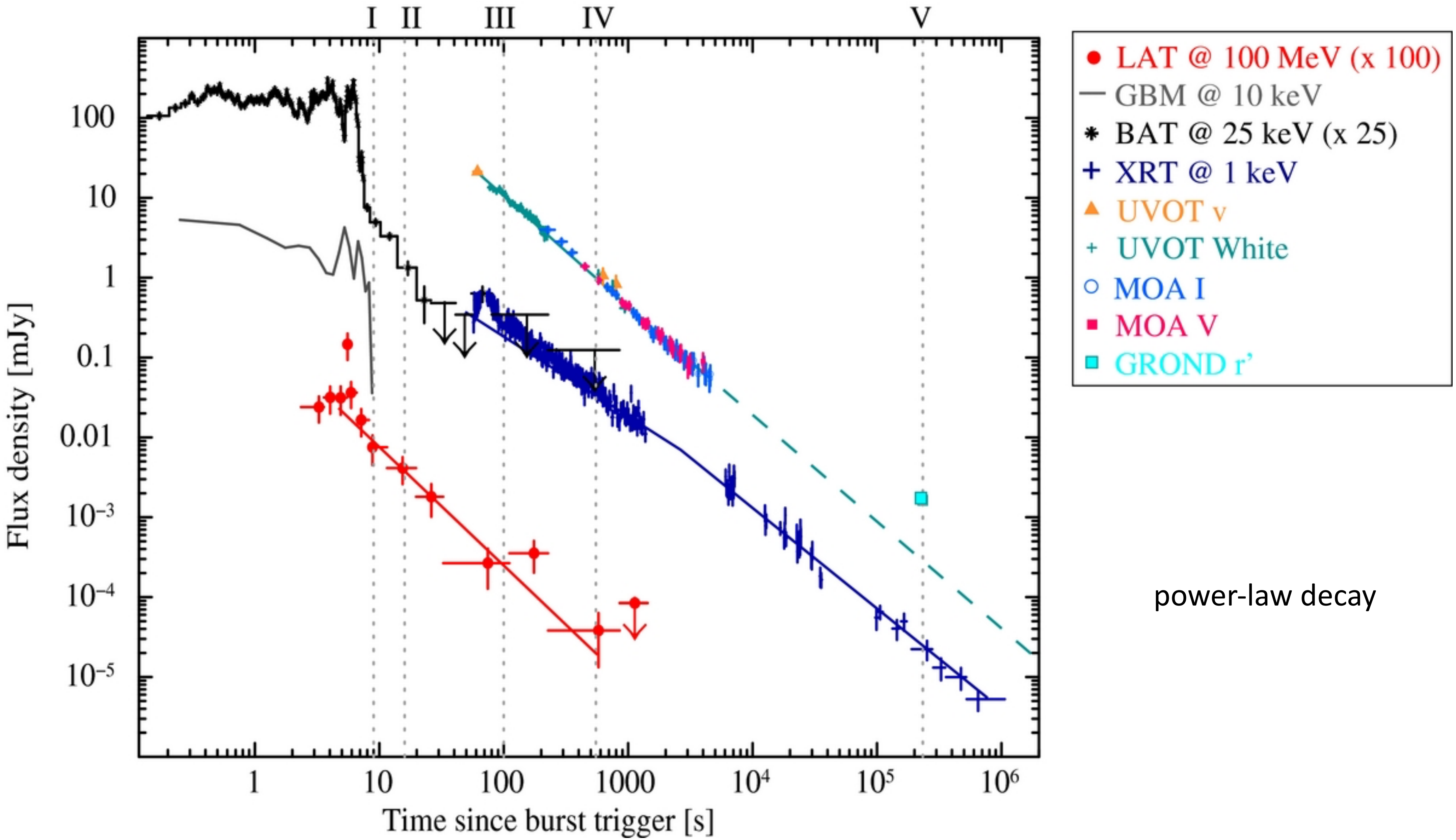
Margutti+ 2018

Afterglow



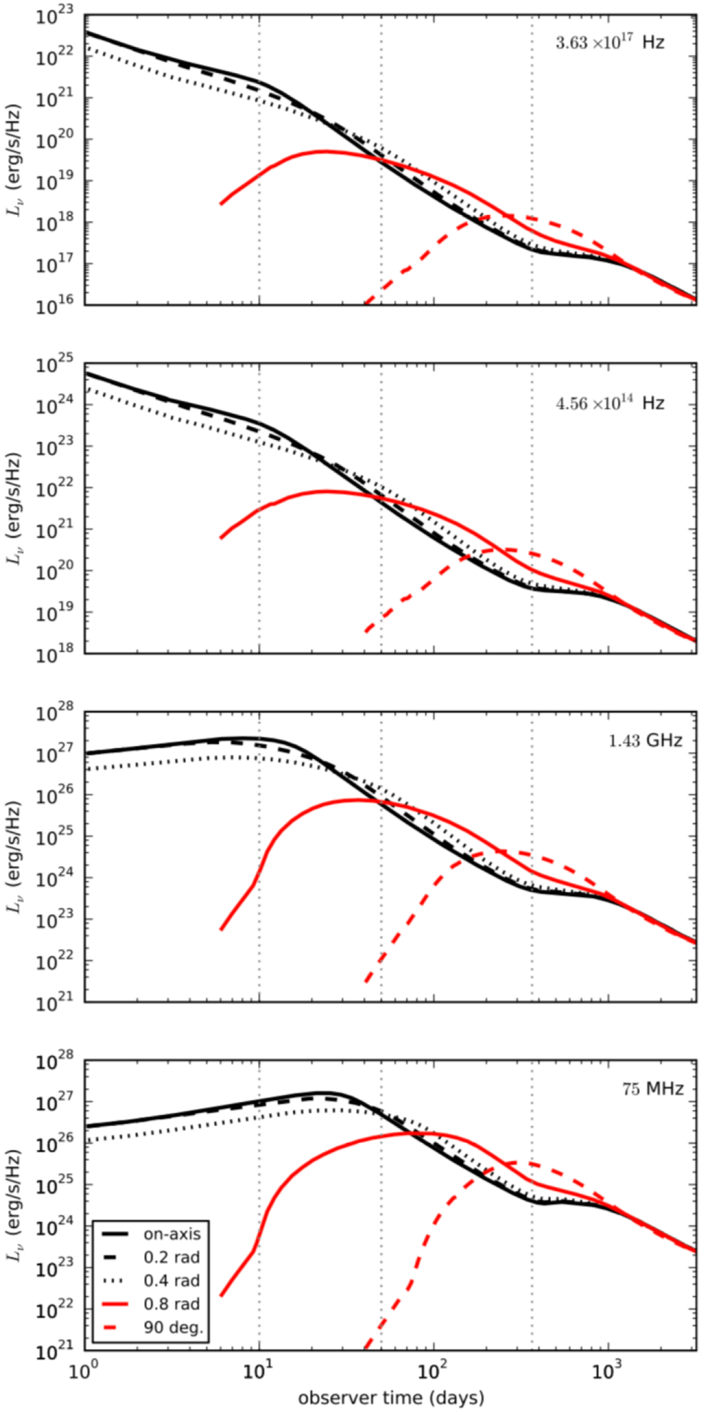
Central Engine
Inner Shocks
Gamma-rays
External Shocs
Afterglow
10^6 cm
10^11 - 10^12 cm
10^15 - 10^18 cm

Typical multi-wavelength light curve



power-law decay

Time and viewing angle dependence



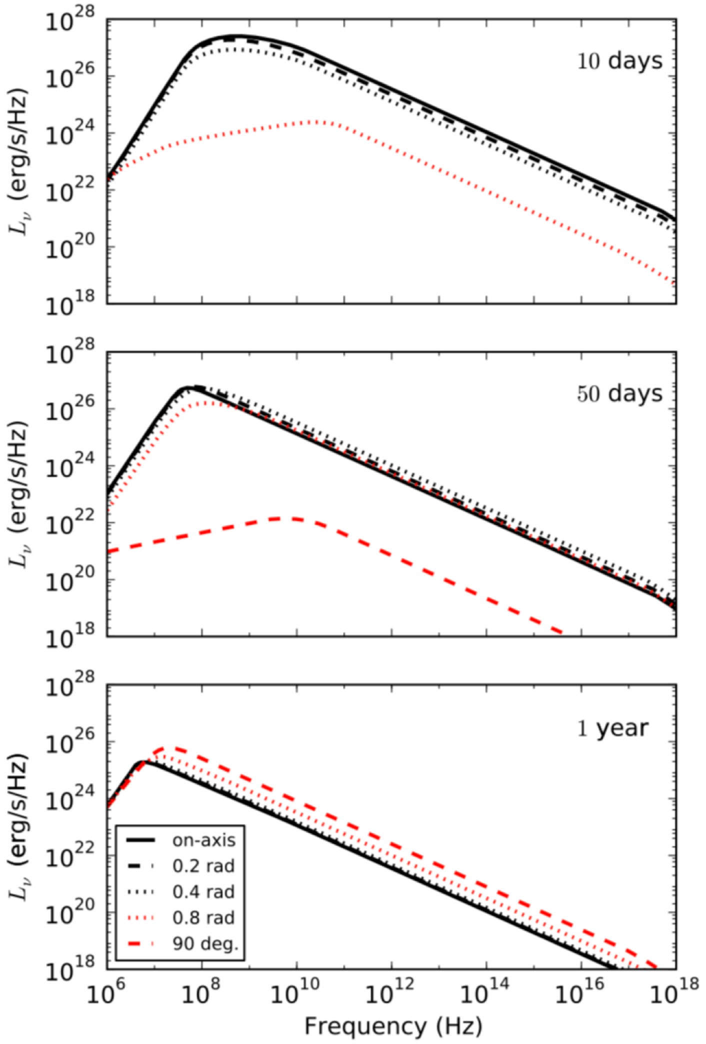


Figure 2. Spectra for $E_j = 10^{48}$ erg, $\theta_j = 0.2$ rad, and $n = 10^{-3}$ cm^{-3} at $t_{\mathrm{obs}} = 10$ days, 50 days, and 1 yr (top to bottom plot), for various observer angles. The legend applies to all plots.

Figure 1. Observed luminosity light curves for $E_j = 10^{48}$ erg, $\theta_j = 0.2$ rad, and $n = 10^{-3}$ cm^{-3} (case B). Observer frequencies from top to bottom: 3.63×10^{17} Hz, 4.56×10^{14} Hz, 1.43 GHz, and 75 MHz. The legend applies to all plots. 10 days, 50 days, and 1 yr have been marked with vertical dotted gray lines. Spectra for these times are provided in Figure 2.

Peak flux:

- Higher for lower angles
- Delayed for greater angles

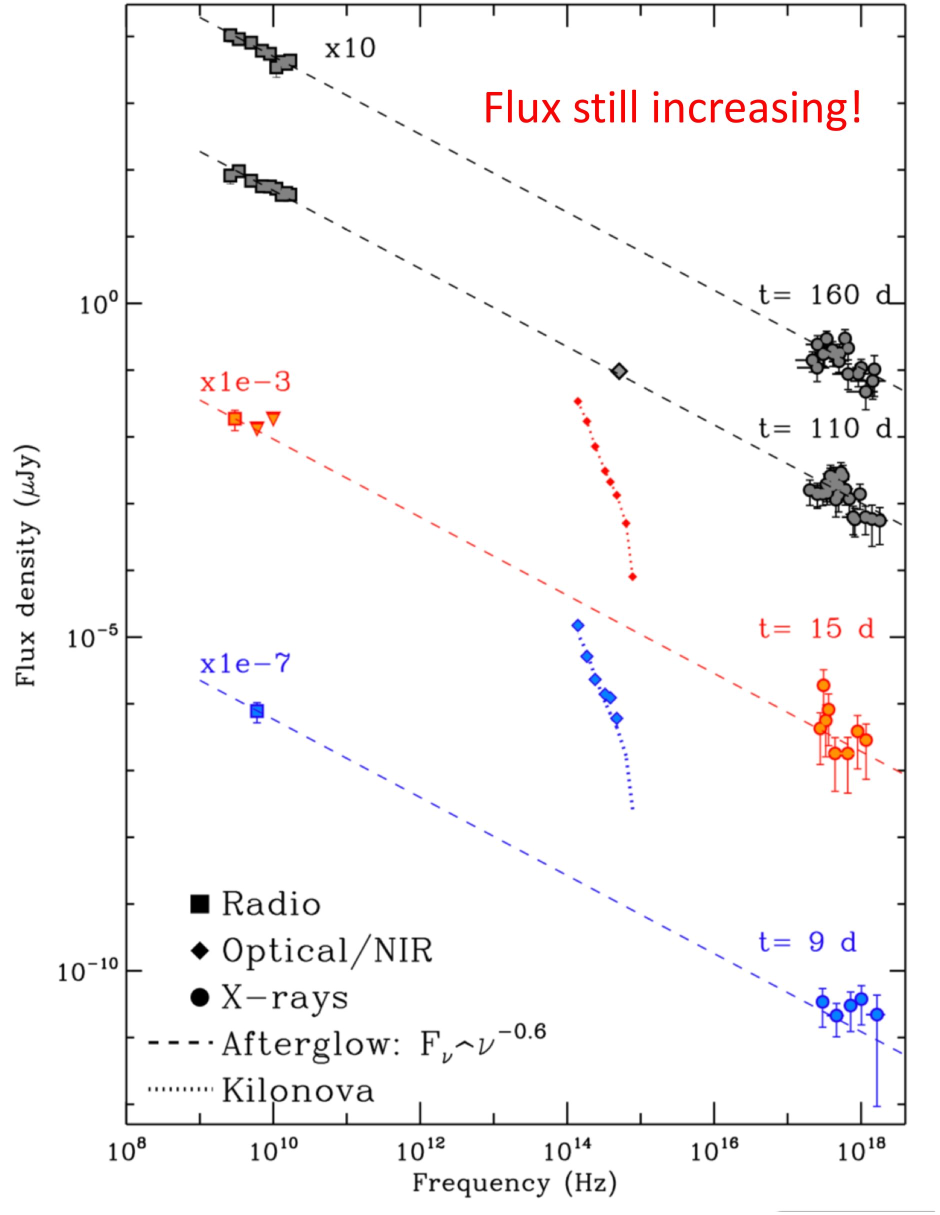
➢ After peak there is ~power law decay

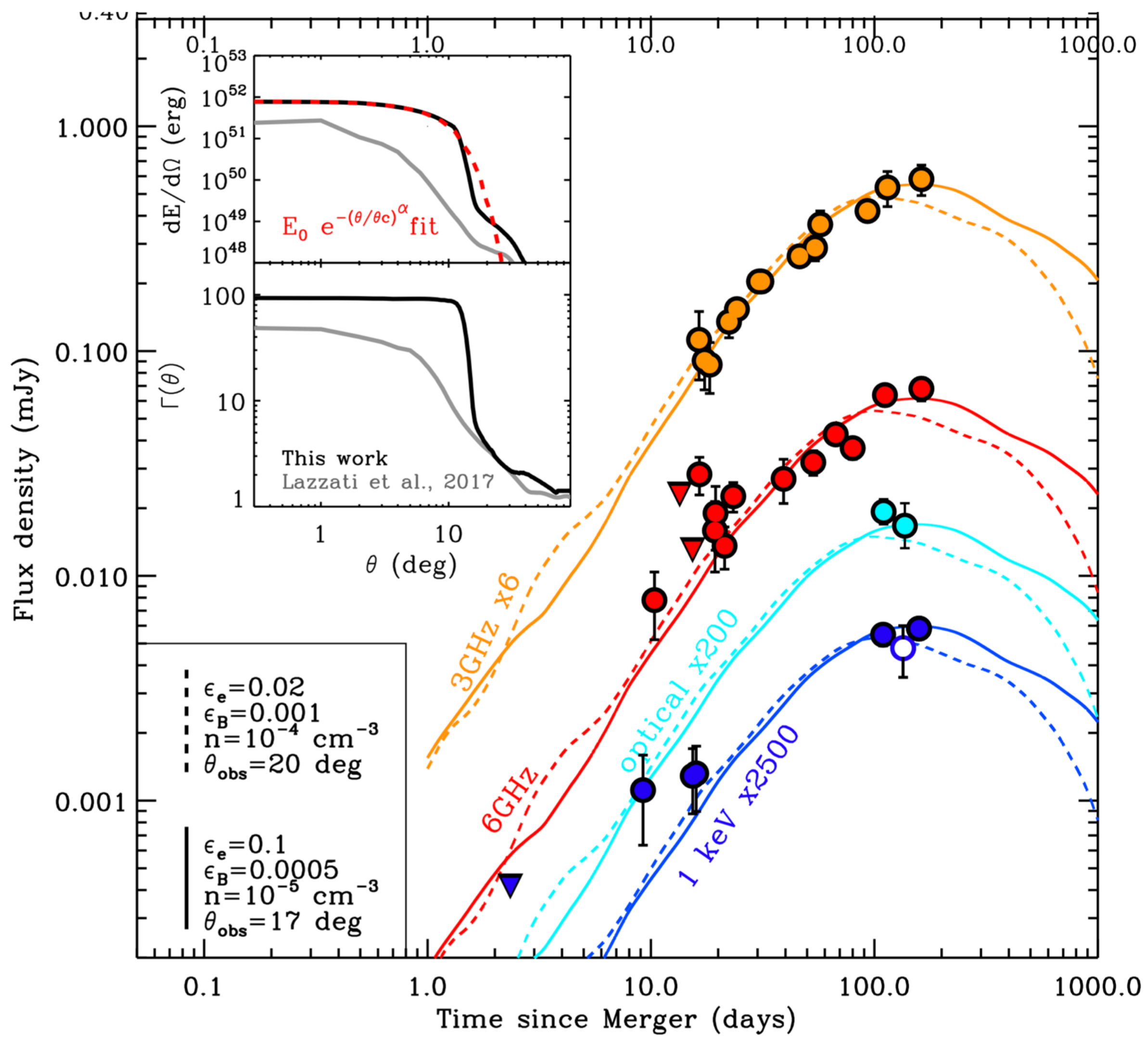
➢ Spectrum is also ~power law above some peak frequency

➢ Spectrum softens with time

Van Eerten+ ApJL 2011

GW170817





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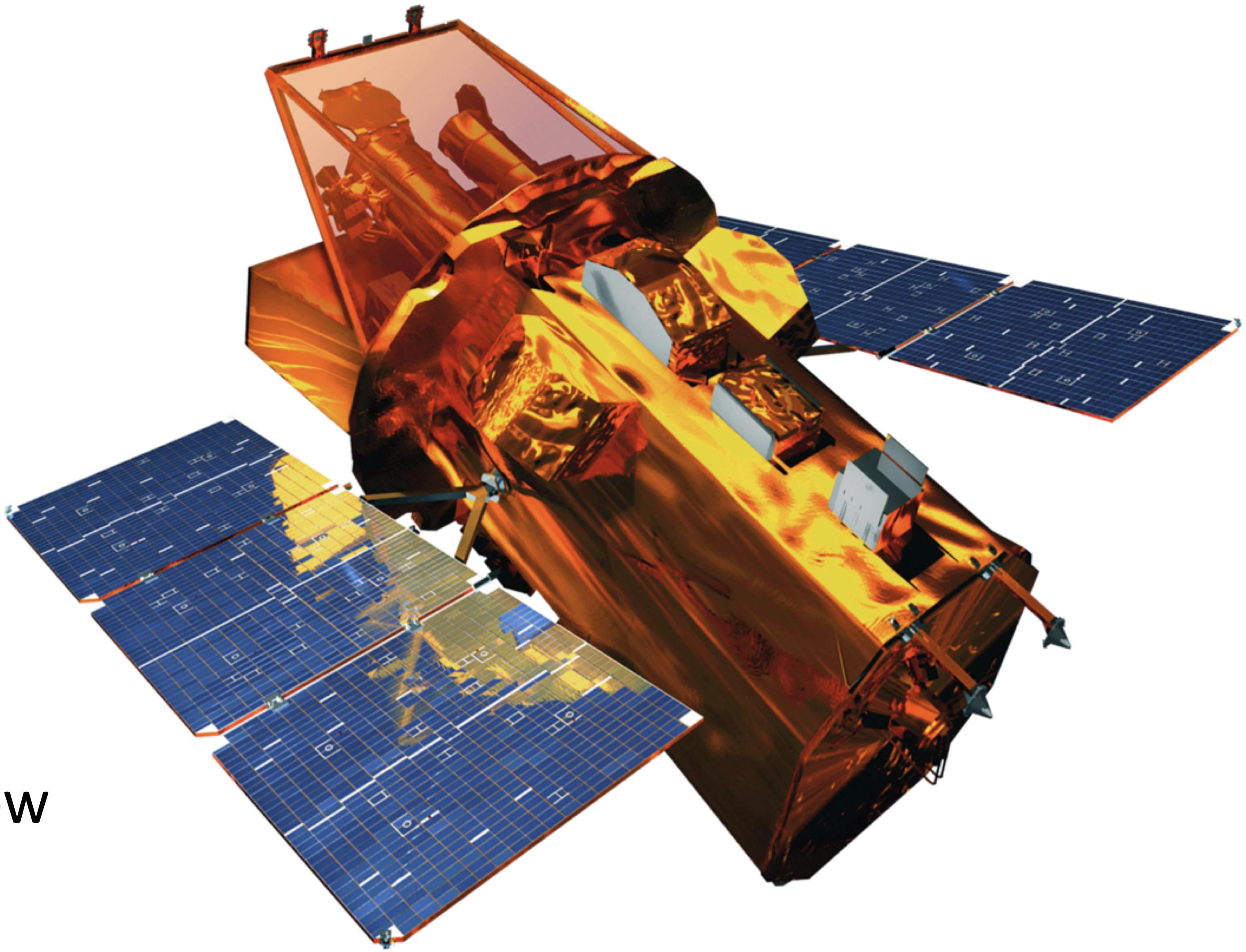
Neil Gehrels Swift Observatory

- Burst Alert Telescope (BAT)
- X-Ray Telescope (XRT)
- Ultraviolet/Optical Telescope (UVOT)



Localization with afterglow