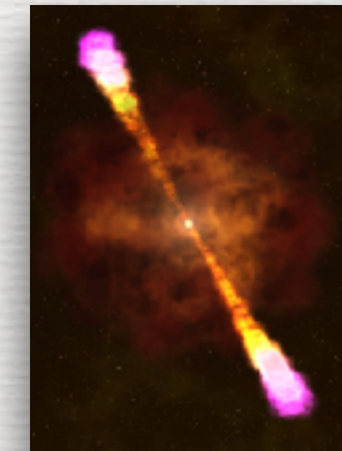
Rythme 1039 by Sonia Delaunay

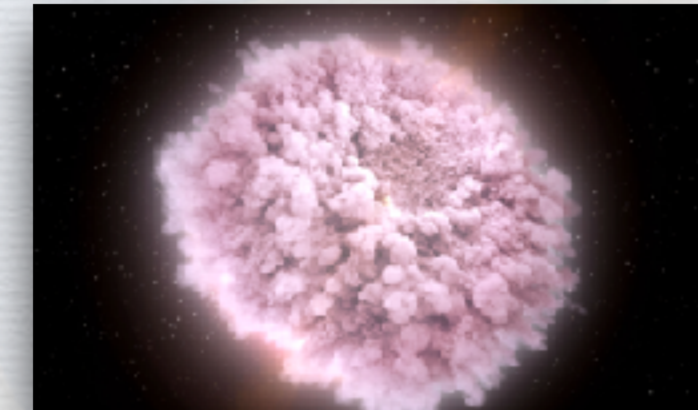
S.D.Vergani

Multi-messenger astrophysics

Relativistic astrophysics



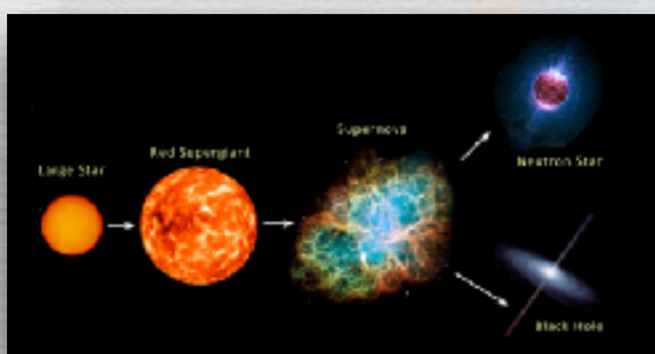
Radioactively powered transients



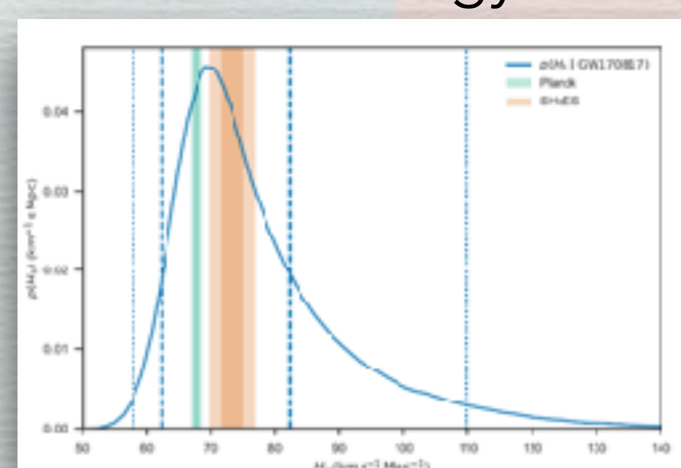
Nucleosynthesis and enrichment of the Universe

GW170817
Multi-messenger studies

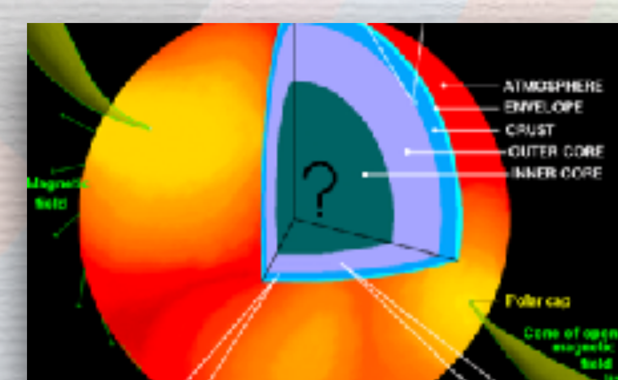
Compact object formation and evolution



Cosmology



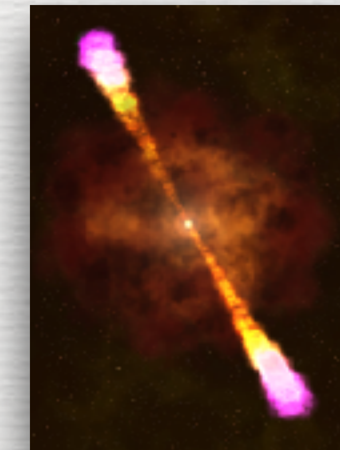
Nuclear matter physics



Courtesy of M. Branchesi

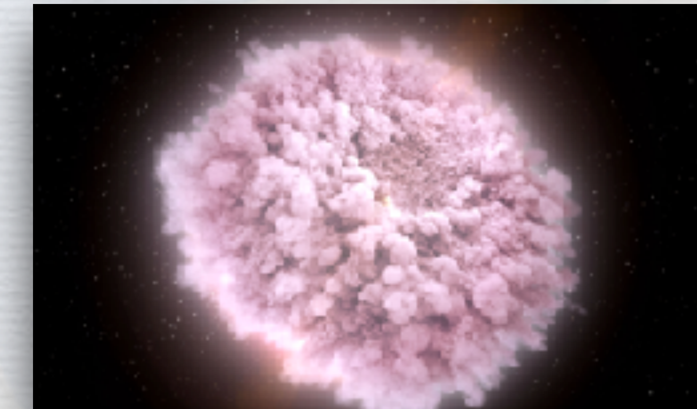
Gamma-ray bursts

Relativistic astrophysics



Kilonova

Radioactively powered transients



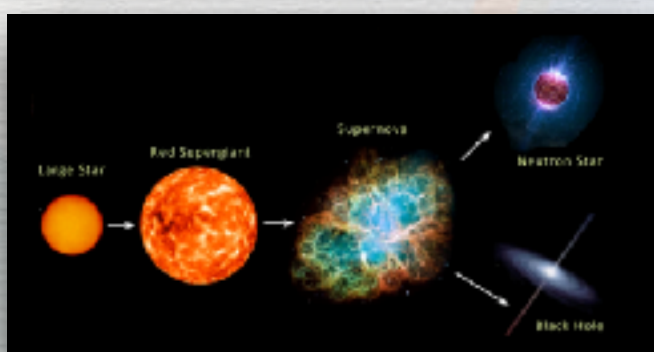
R-process

Nucleosynthesis and enrichment of the Universe

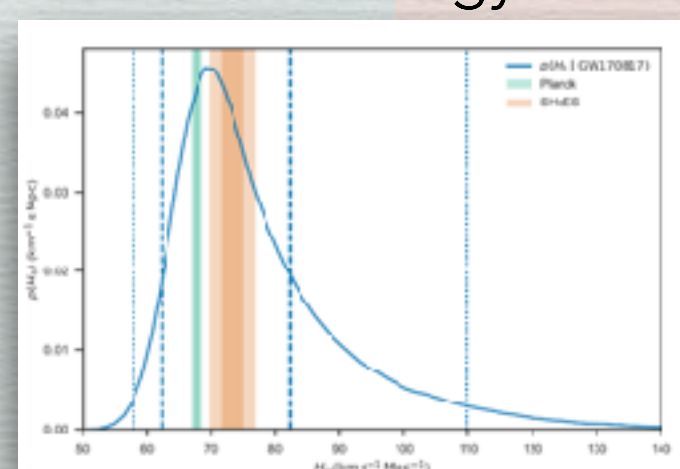
GW170817

Multi-messenger studies

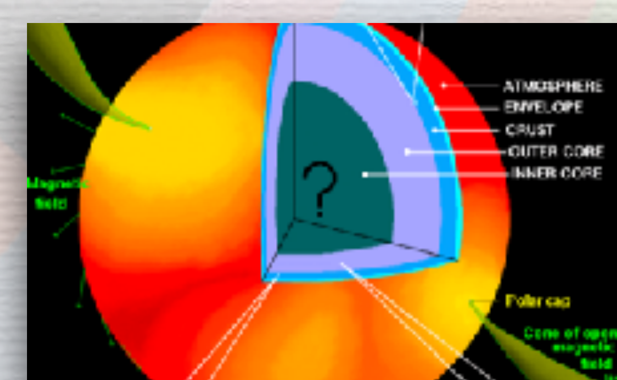
Compact object formation and evolution

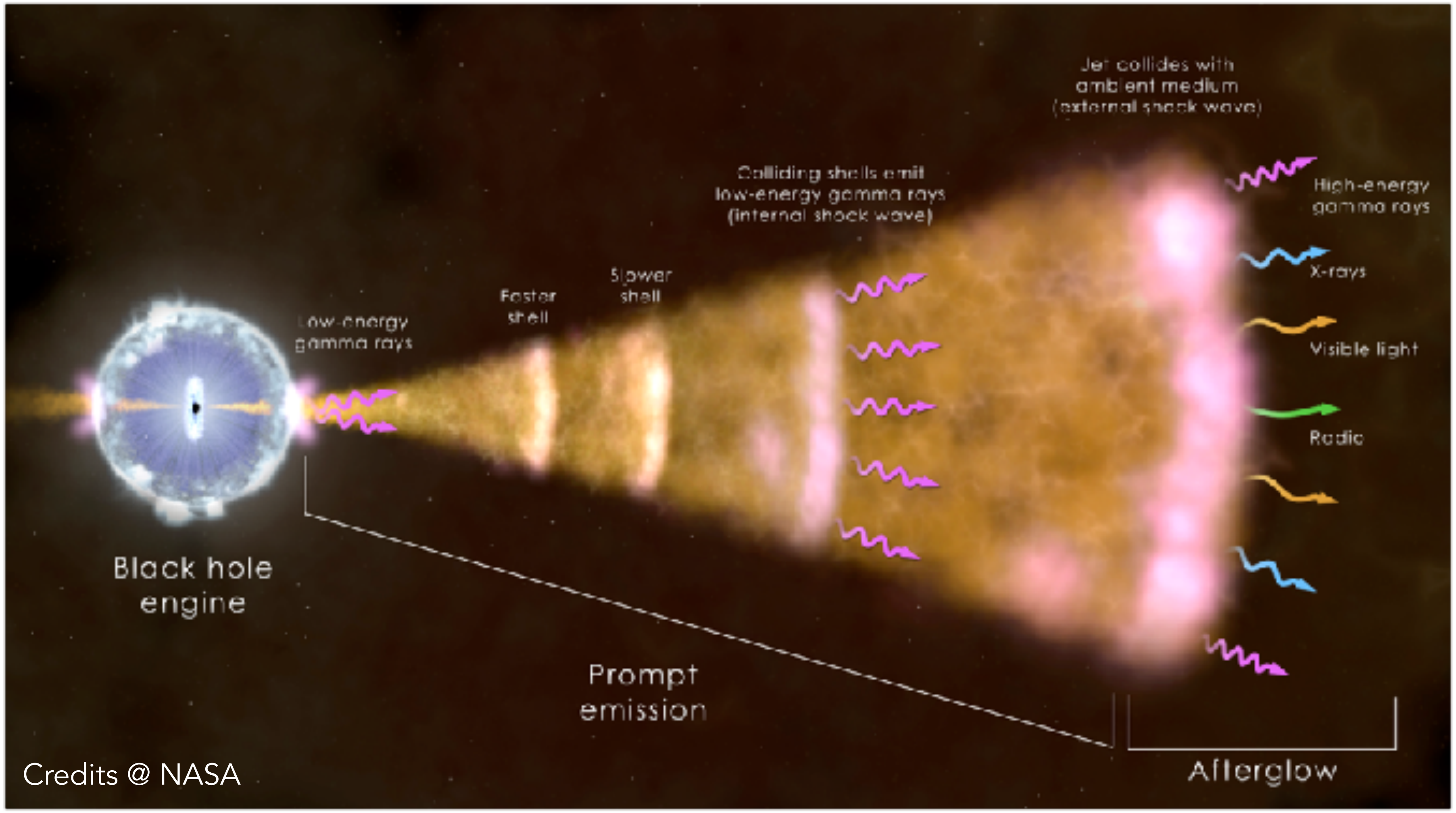


Cosmology



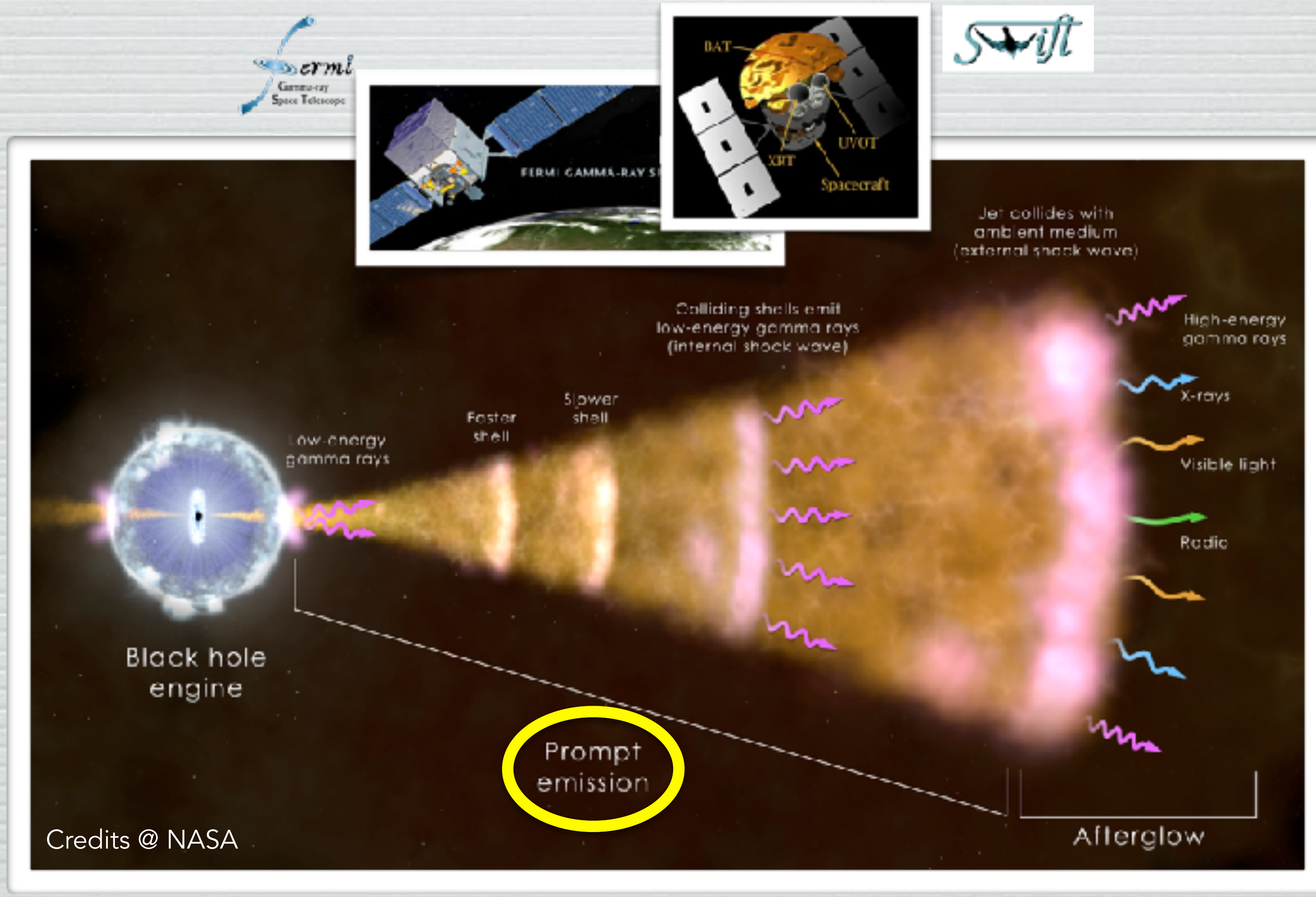
Nuclear matter physics





Gamma-ray bursts

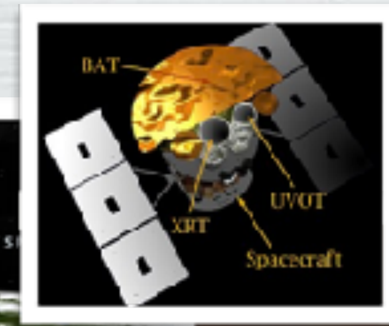
Ultra-relativistic jets
Stellar mass black-hole formation



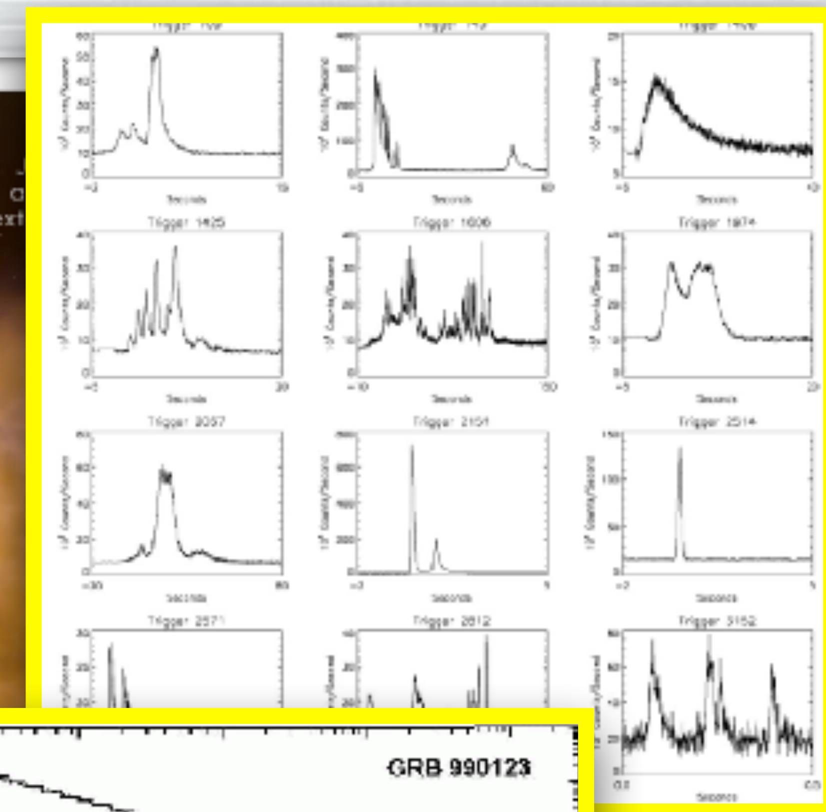
Credits @ NASA

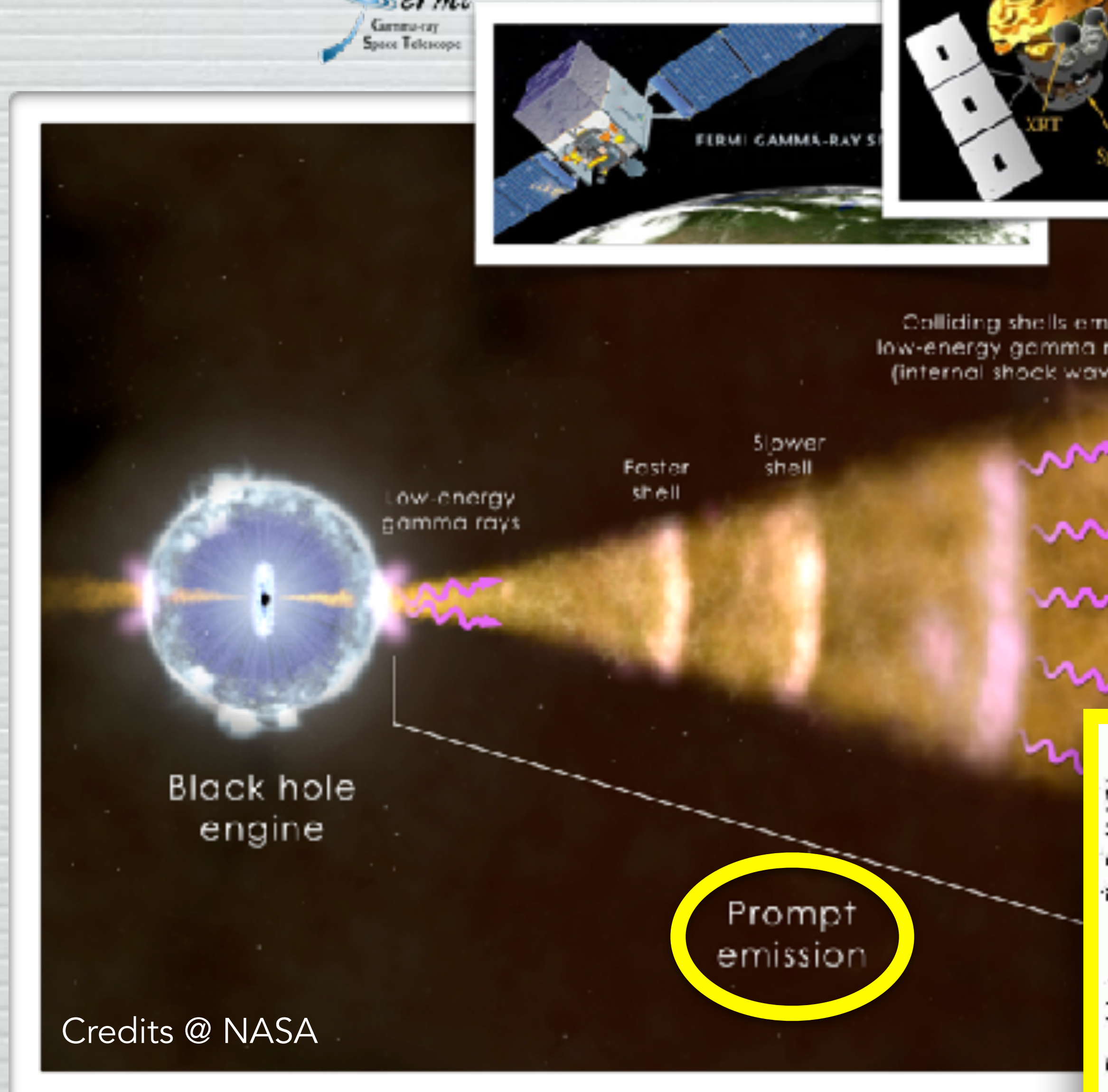
Gamma-ray bursts

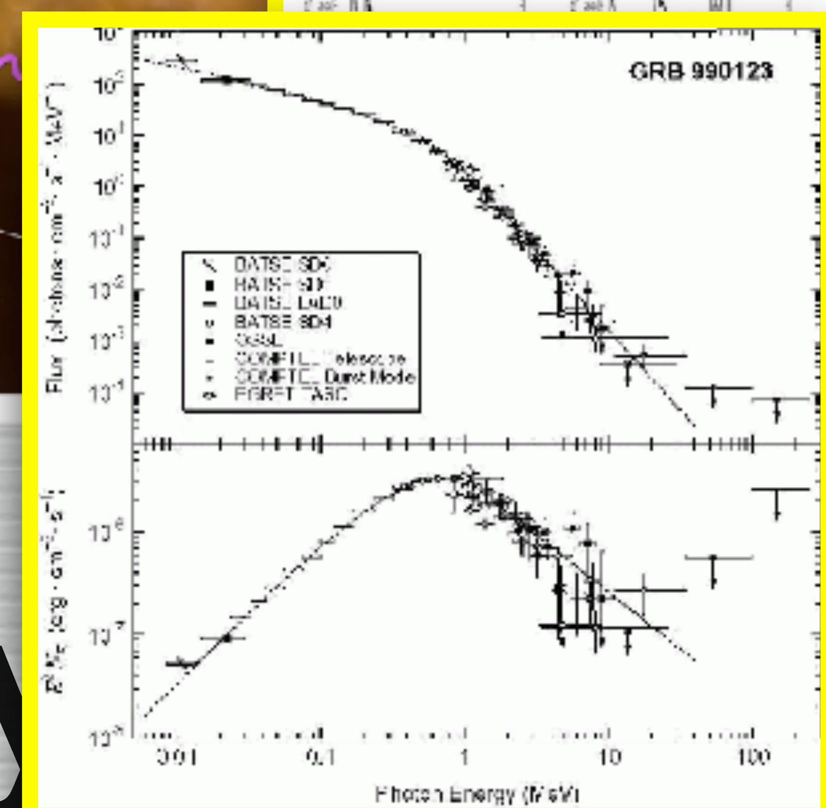
Ultra-relativistic jets
Stellar mass black-hole formation



Fishman et al. 1995



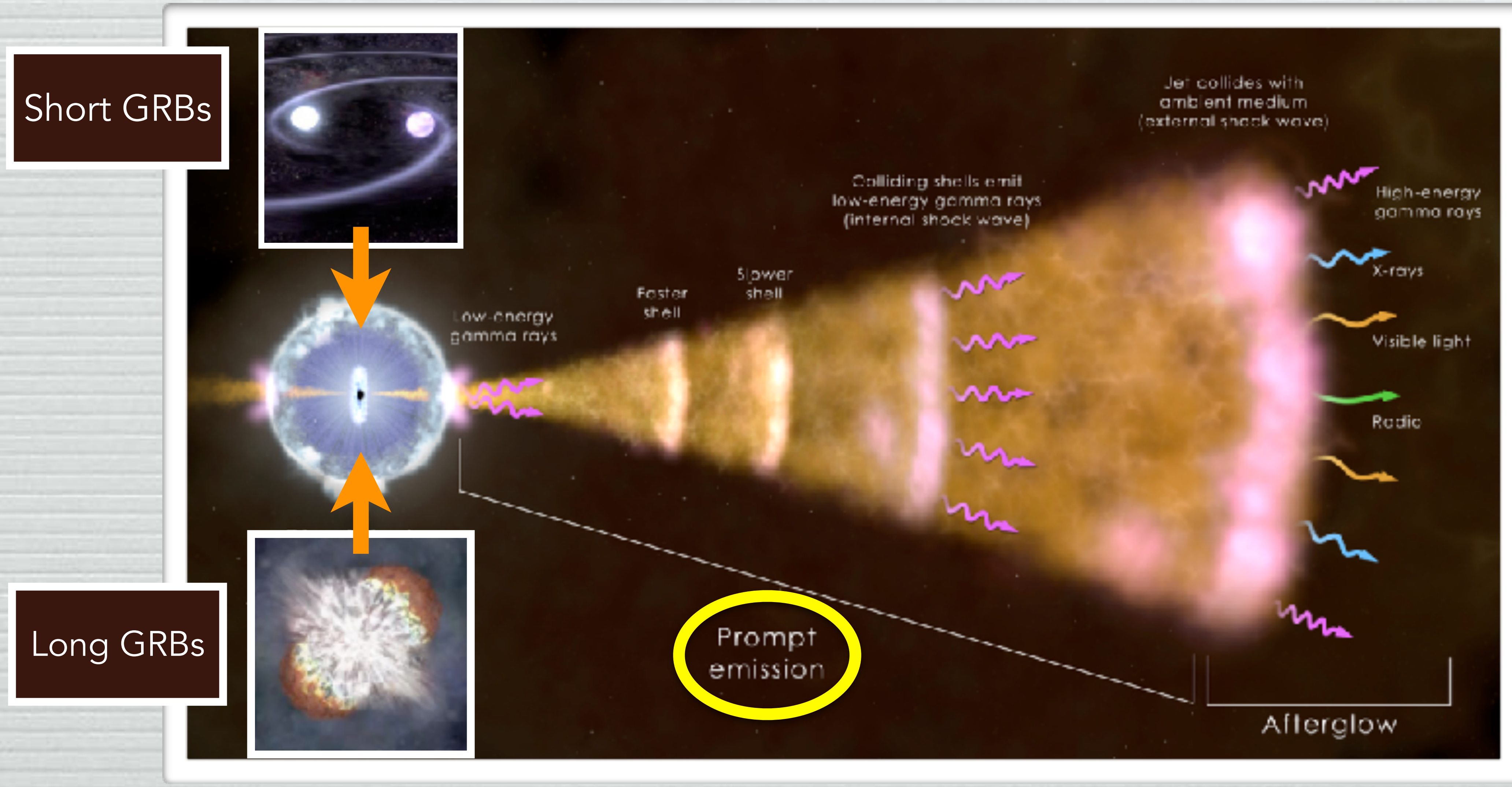




Gomboc+2012

Gamma-ray s

Ultra-relativistic jets
Stellar mass black-hole formation



Gamma-ray bursts

Ultra-relativistic jets
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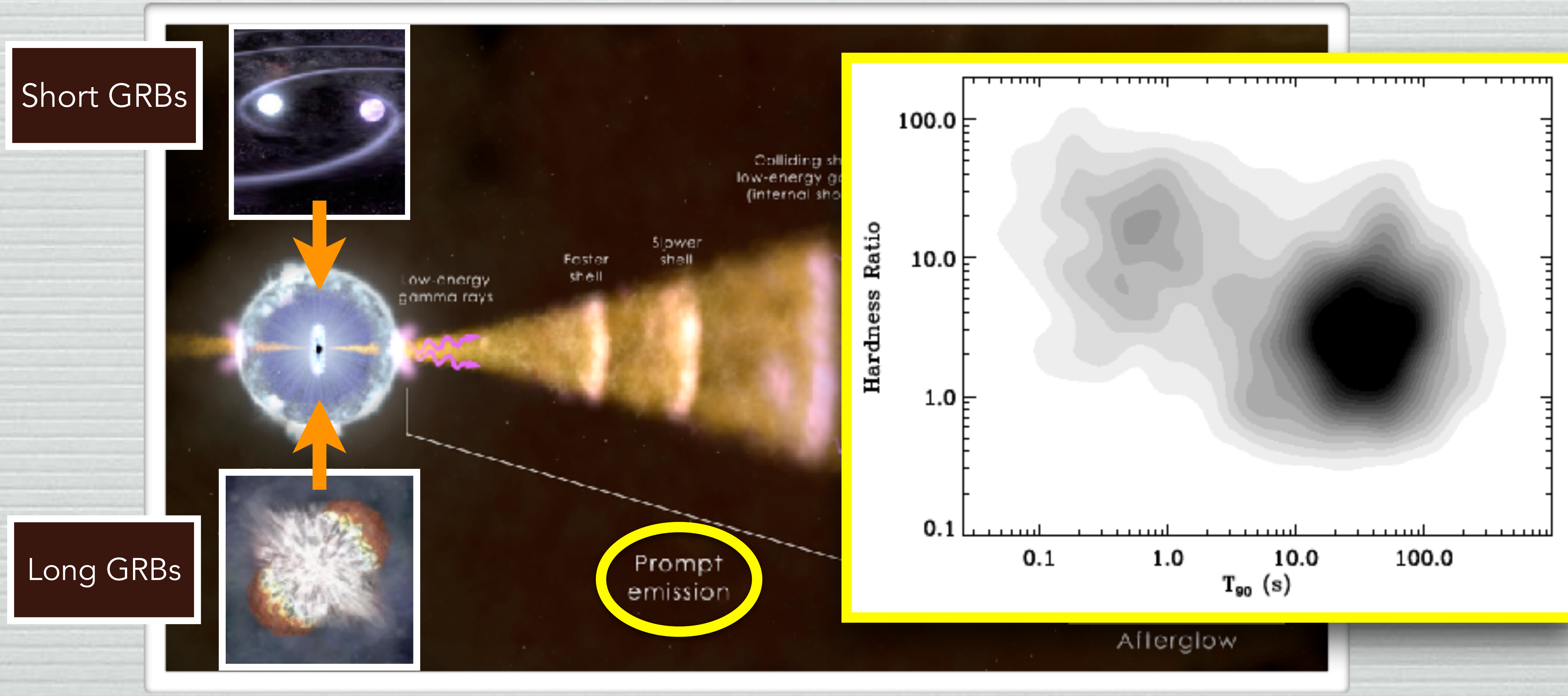

Gamma-ray bursts

Ultra-relativistic jets
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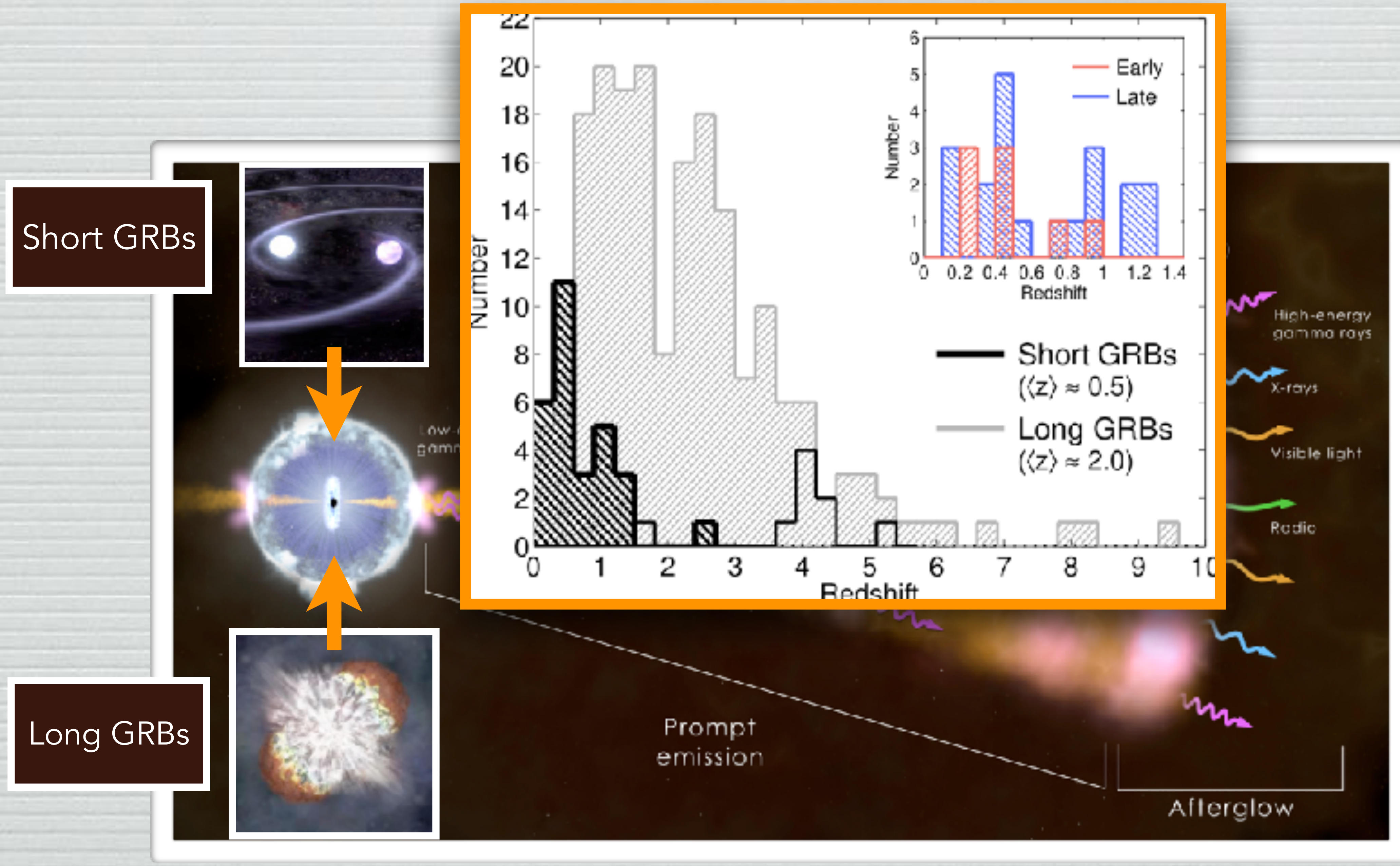


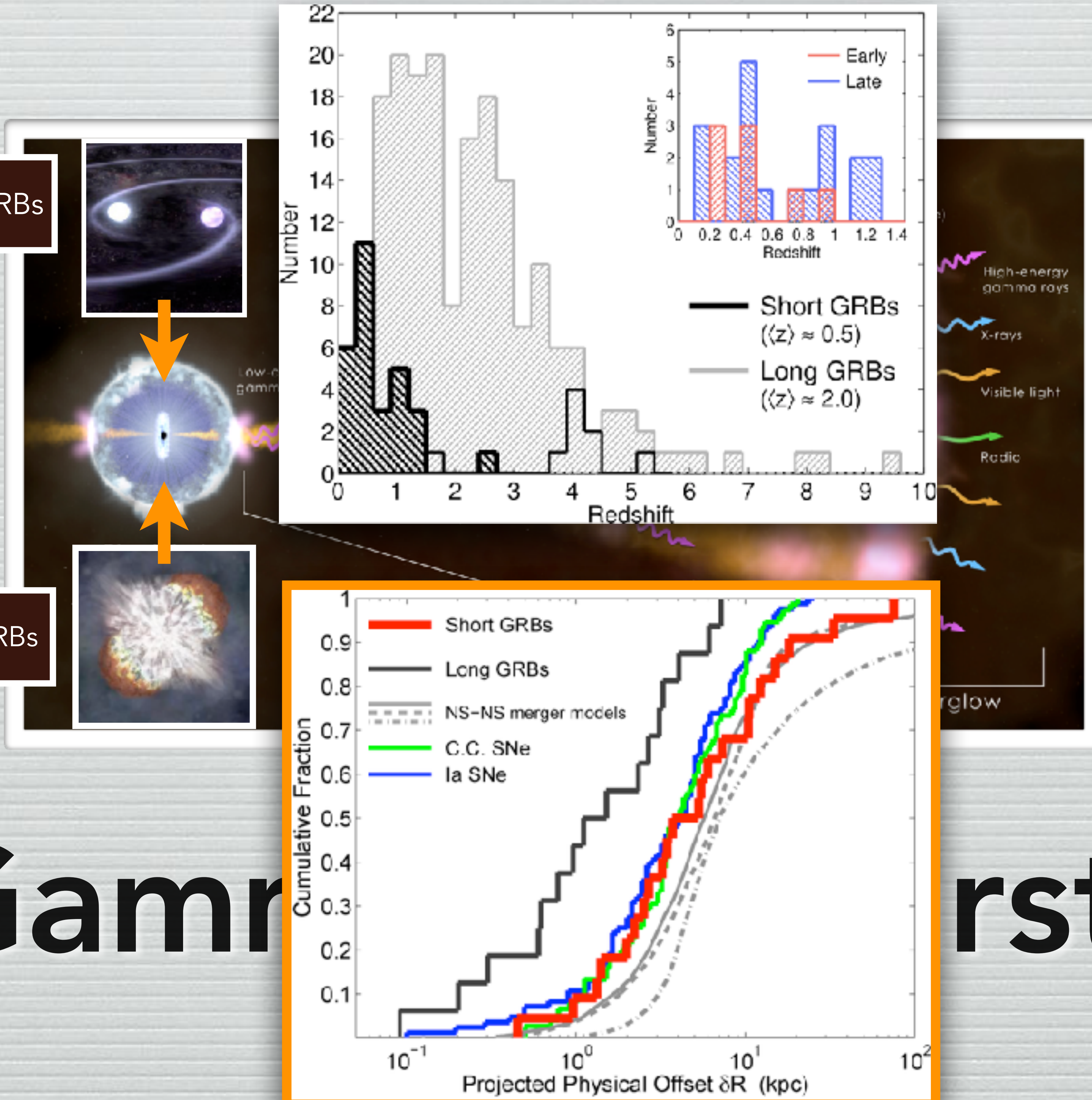
Gamma-ray bursts

Ultra-relativistic jets
Stellar mass black-hole formation

Berger+2014

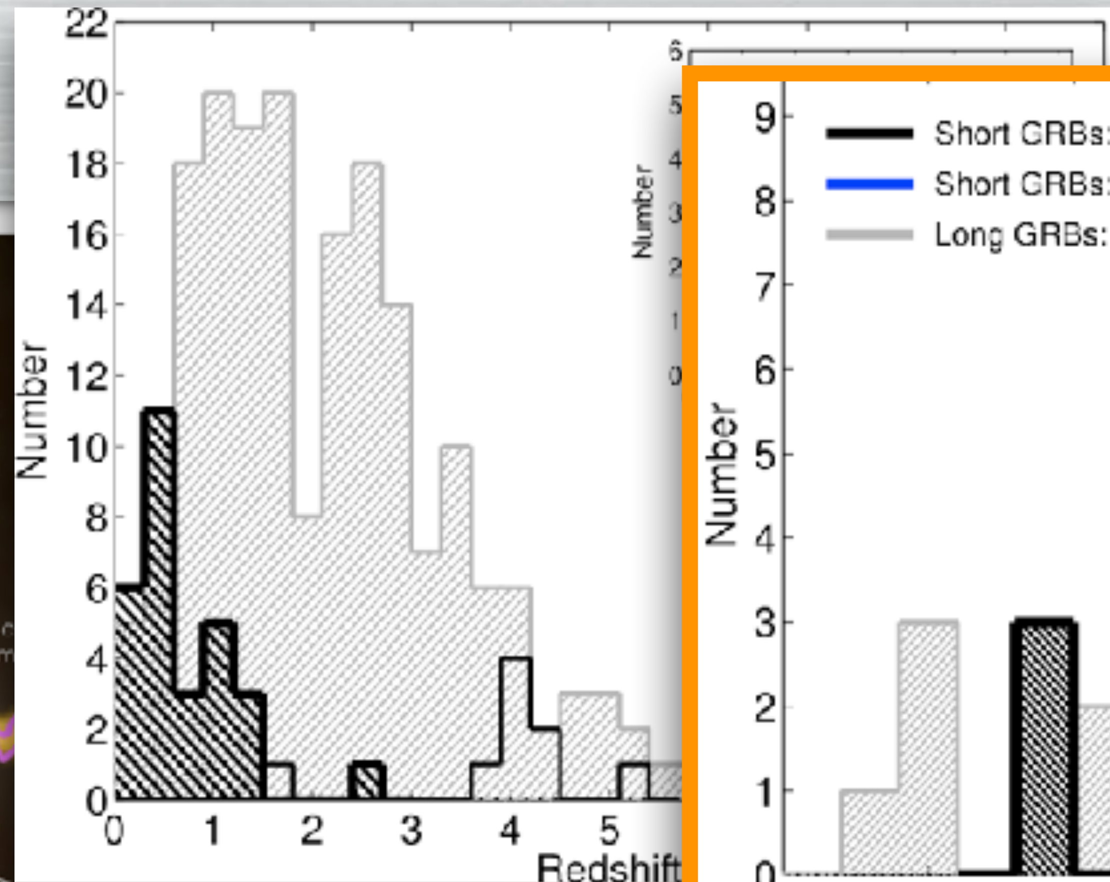
Short GRBs

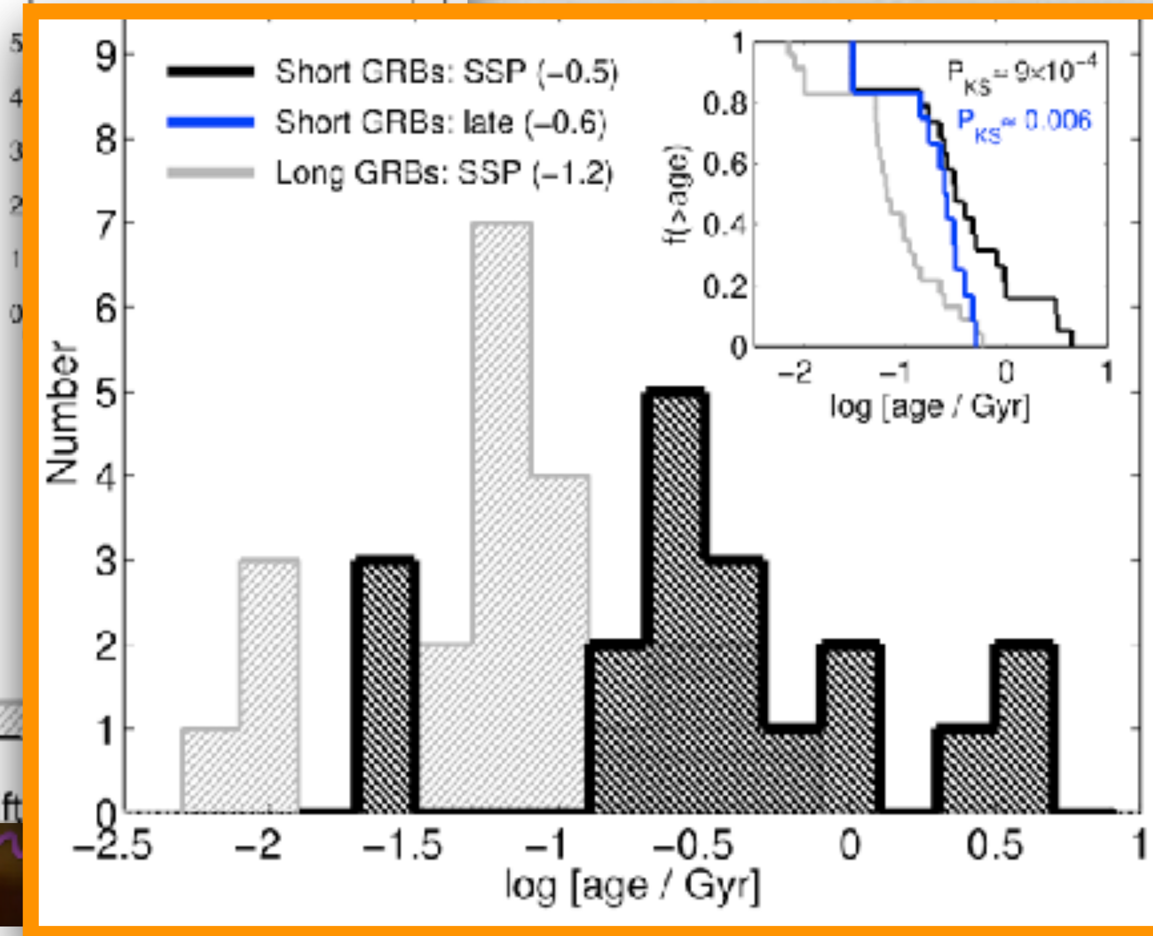
Long GRBs

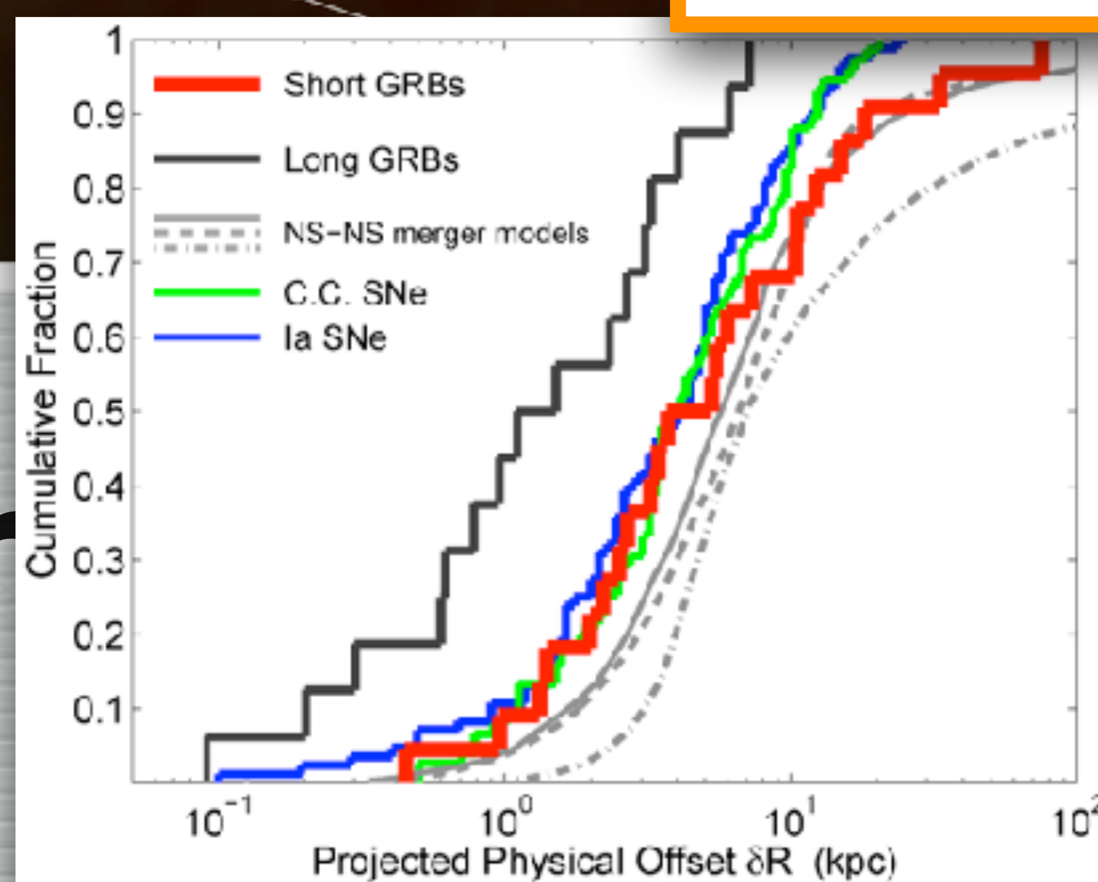


Gamr rsts

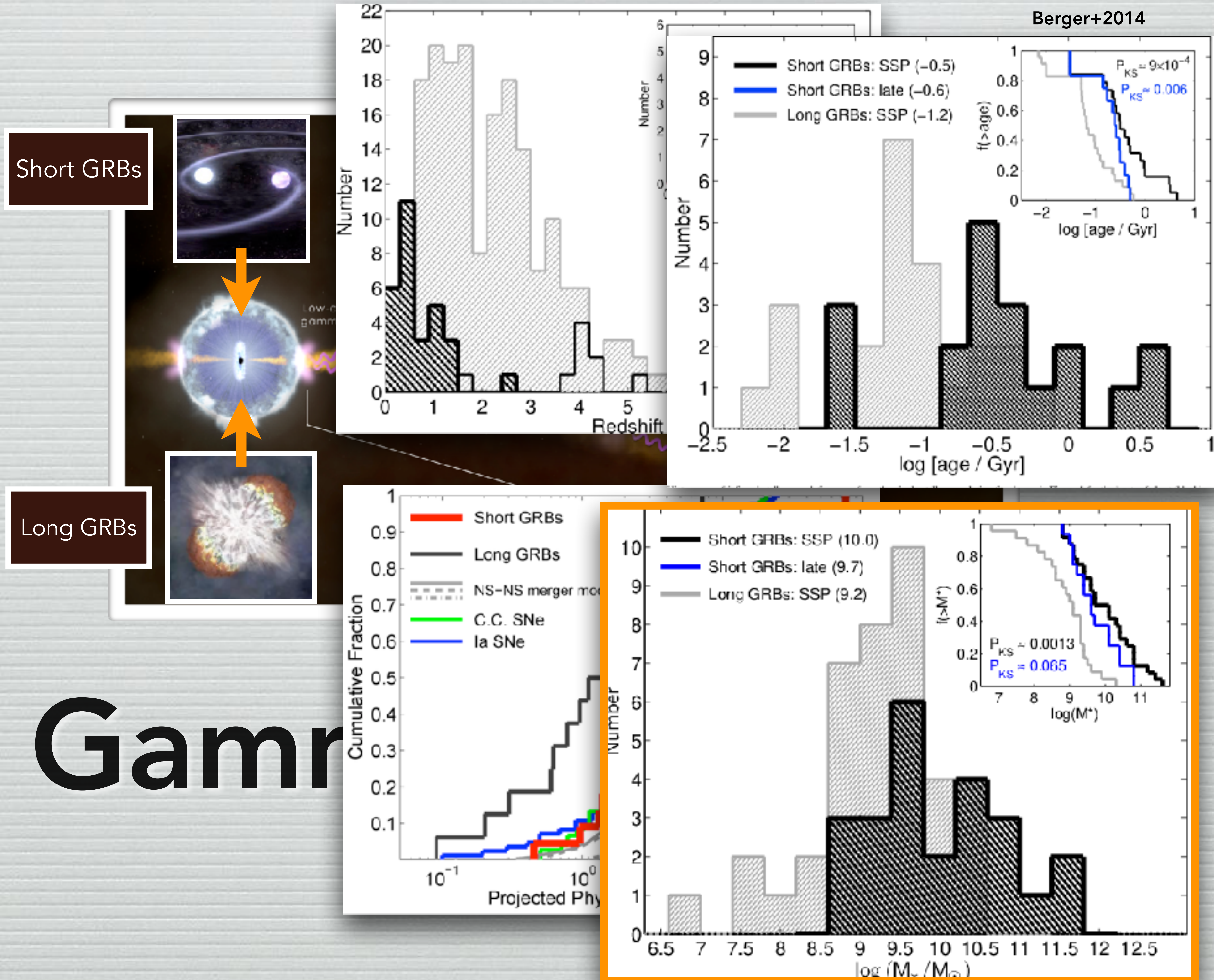
Berger+2014





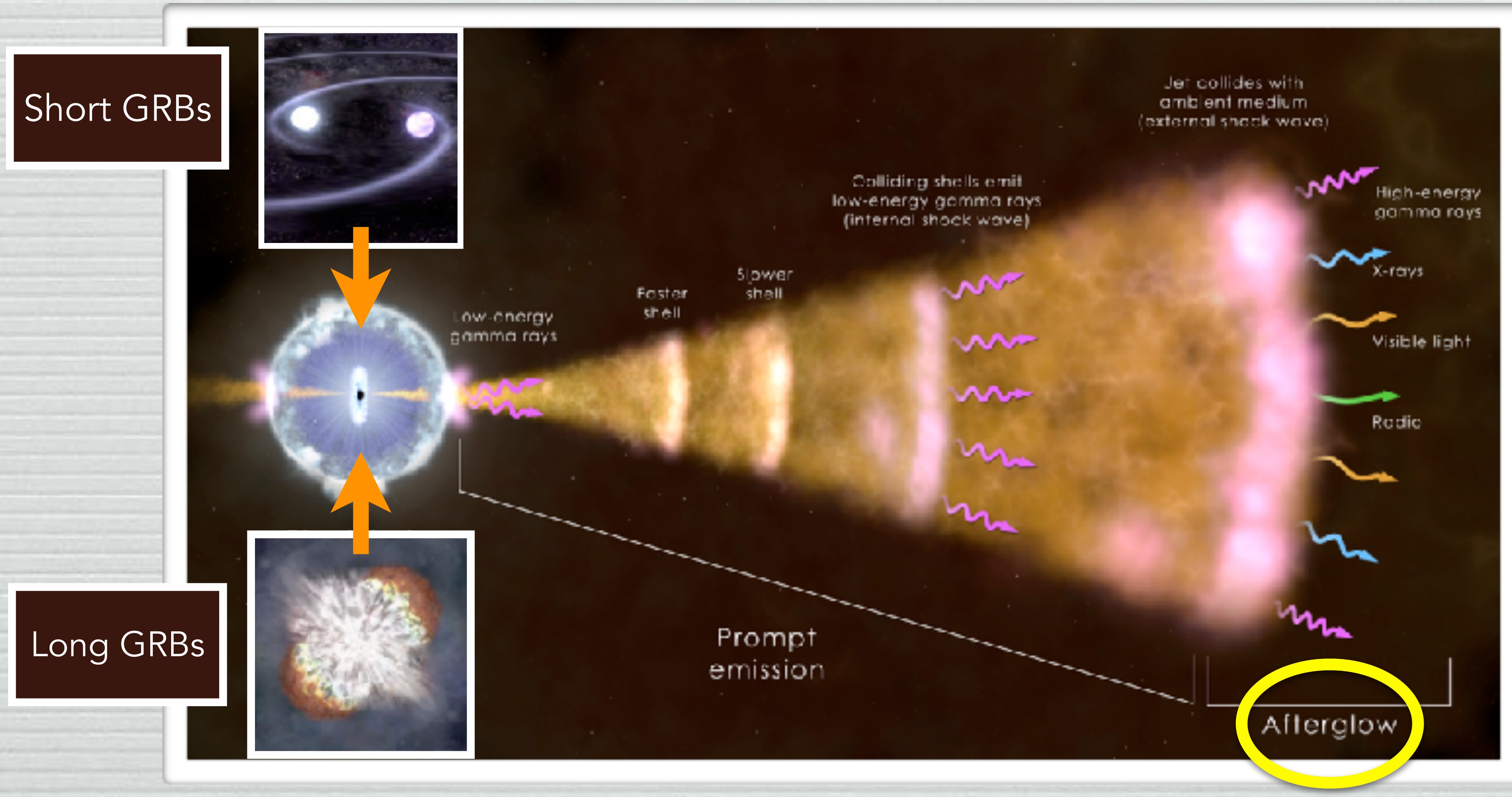


Gamr rsts



Berger+2014
Short GRBs
Long GRBs
Number
Redshift
Short GRBs: SSP (−0.5)
Short GRBs: late (−0.6)
Long GRBs: SSP (−1.2)
log [age / Gyr]
f(>age)
$P_{KS} = 9\times10^{-4}$
$P_{KS} = 0.006$
Cumulative Fraction
Short GRBs
Long GRBs
NS−NS merger mo
C.C. SNe
Ia SNe
Projected Phy
Short GRBs: SSP (10.0)
Short GRBs: late (9.7)
Long GRBs: SSP (9.2)
f(>M*)
$P_{KS} = 0.0013$
$P_{KS} = 0.065$
log(M*)
log (M_*/$M_\odot$)

Gamm

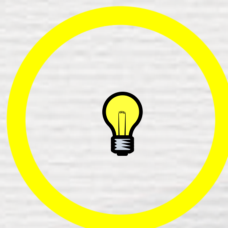


Gamma-ray bursts

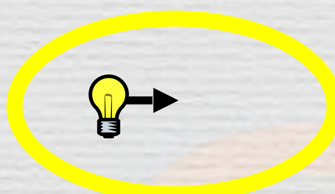
Ultra-relativistic jets
Stellar mass black-hole formation

An emitter moving at $v \sim c$, even if emitting isotropically in its rest frame, will strongly beam its radiation as seen by the observer.

$v = 0$
$\Gamma = 1$

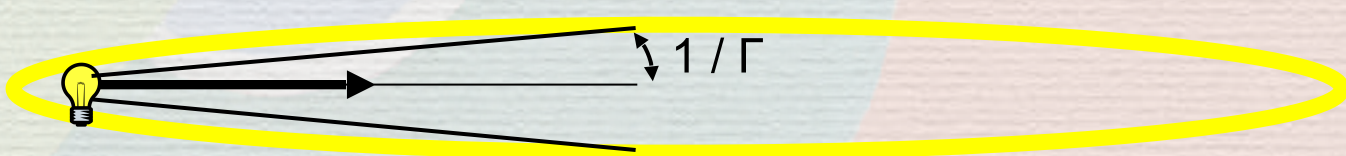


Beaming angle : $\Omega = 4\pi$



Beaming angle : $\Omega = \pi\,\theta^2$
$\theta_{beam} \sim 1 / \Gamma$

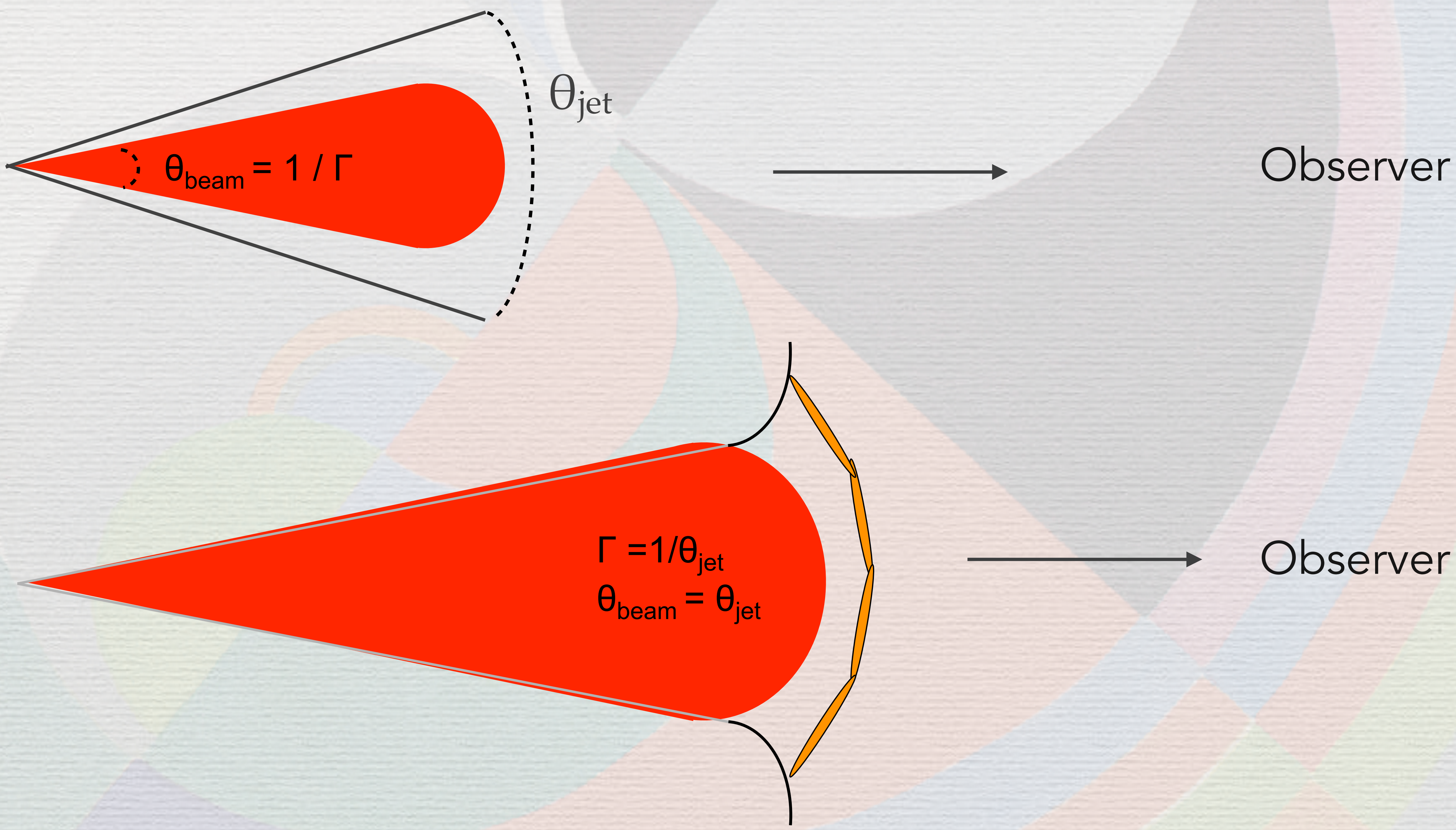
$v \sim c$
$\Gamma >> 1$



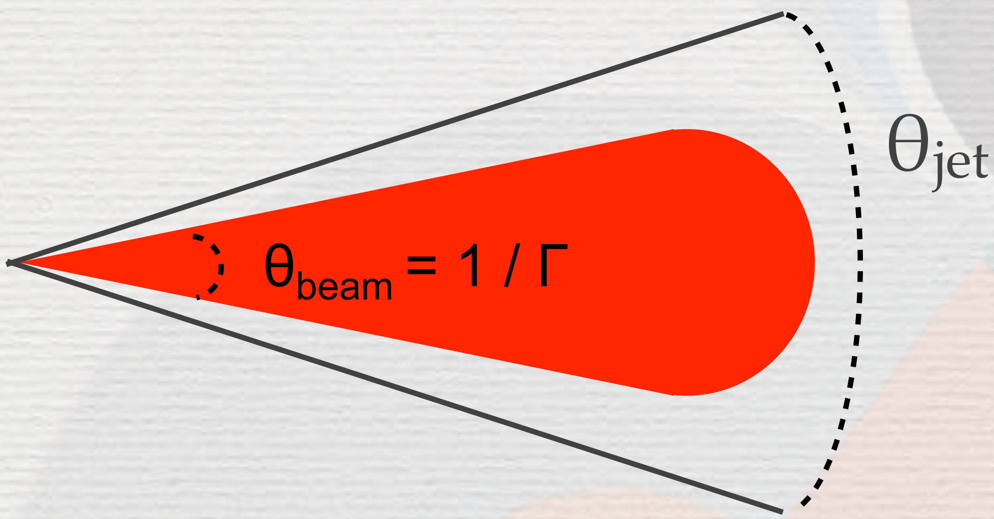
Credits @ D. Perley

On-axis observer

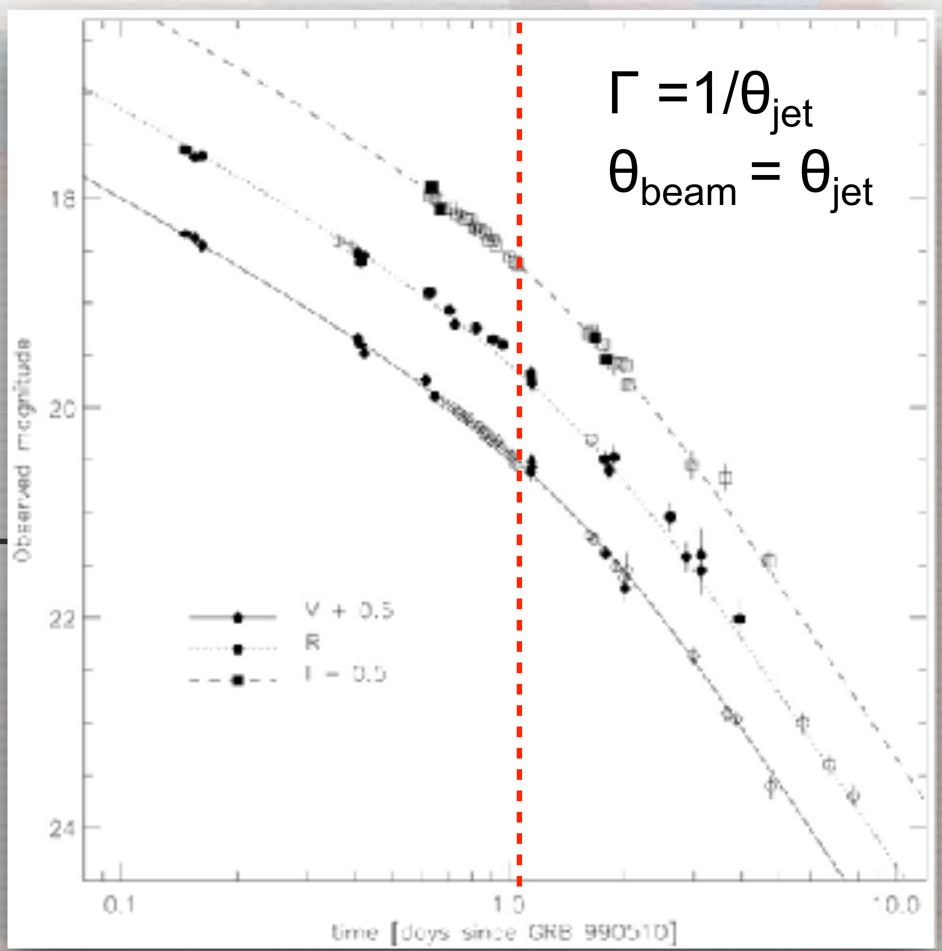
On-axis observer

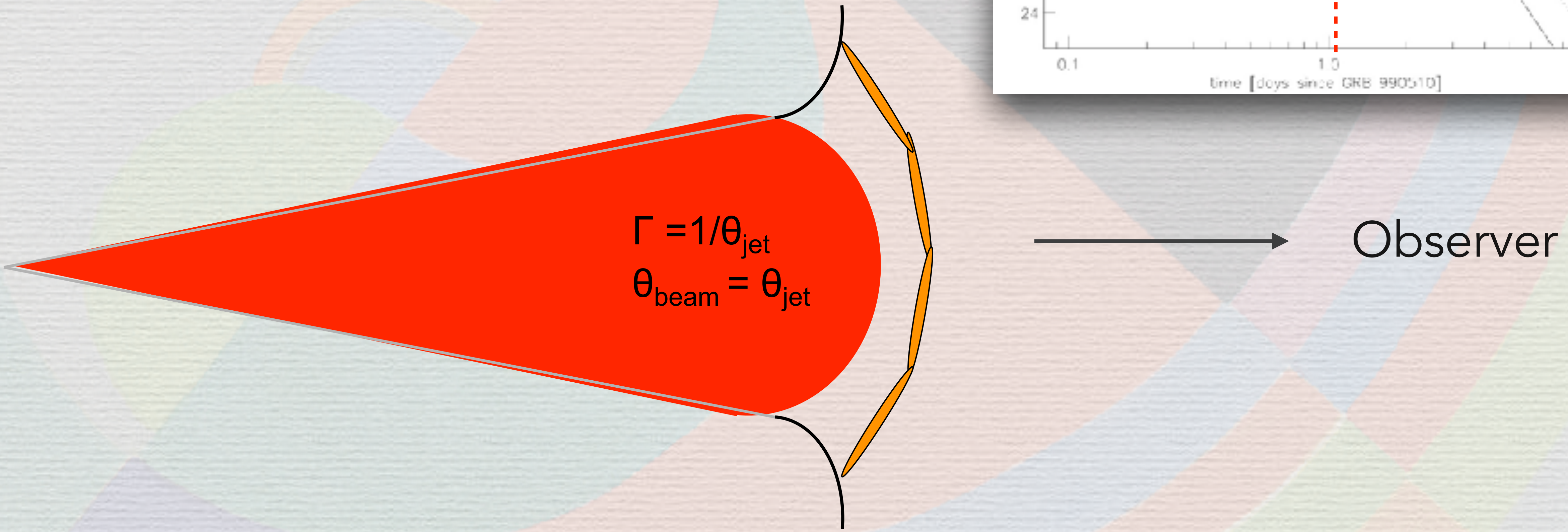


On-axis observer



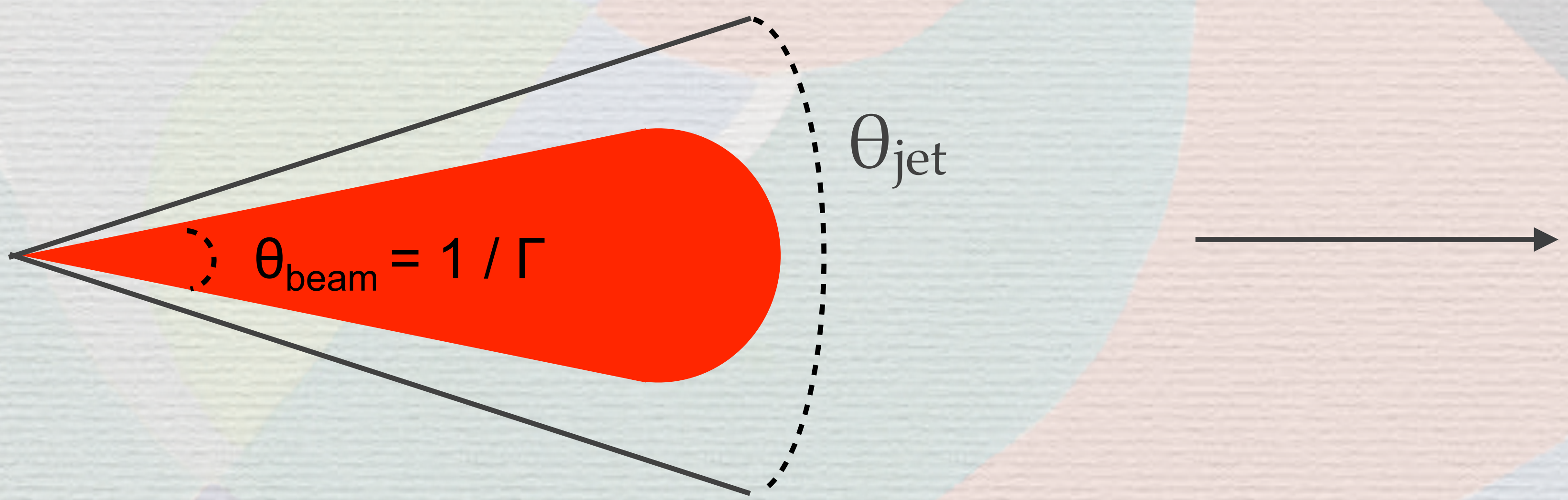
Achromatic break



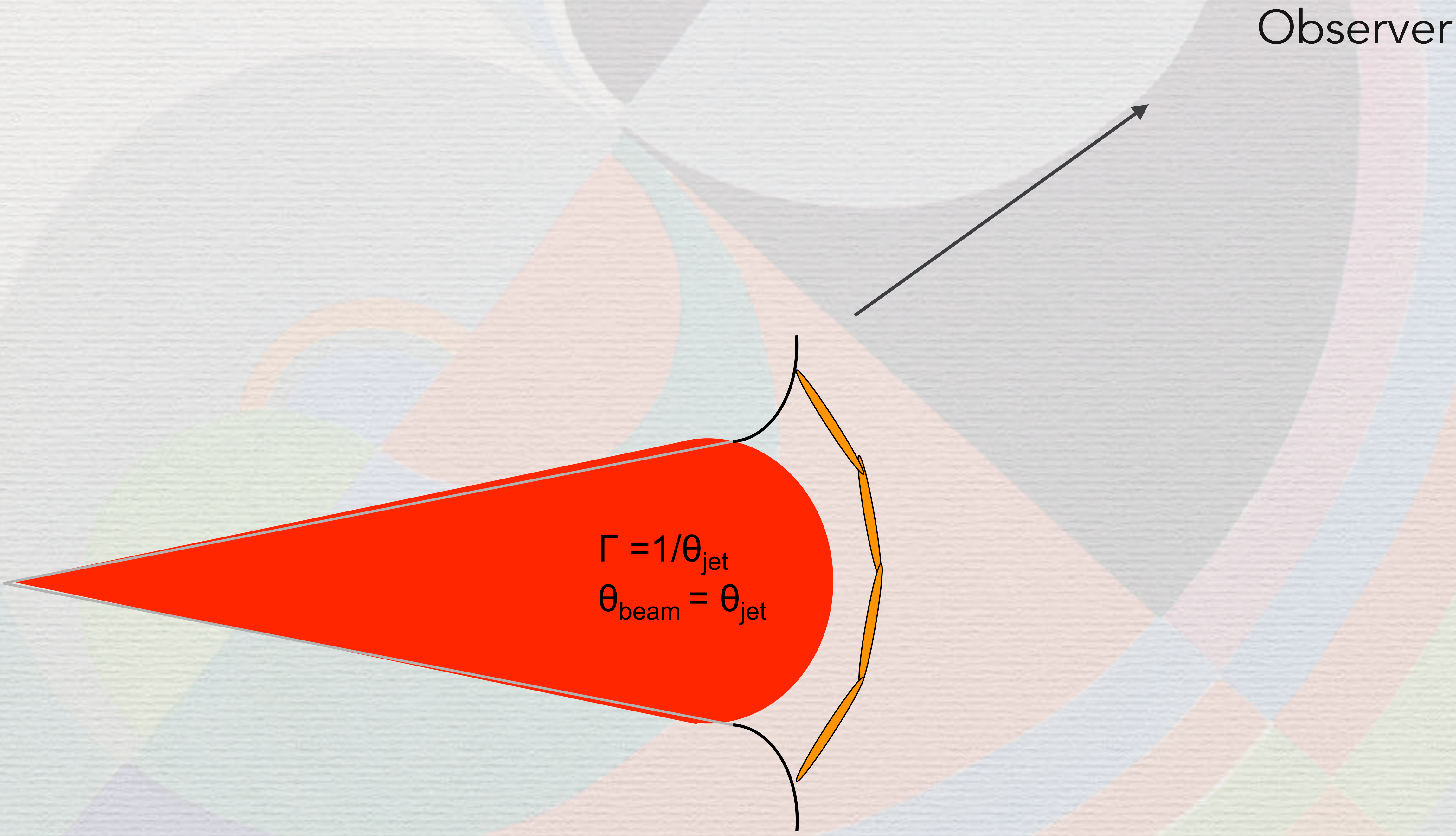


Off-axis observer

Observer

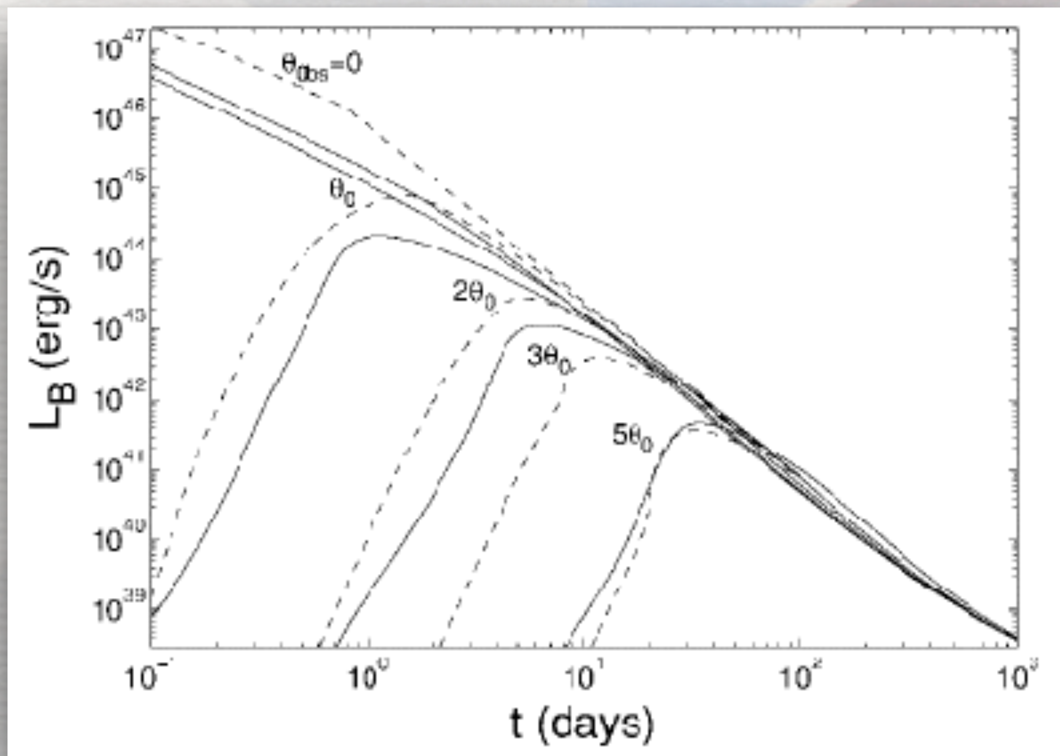


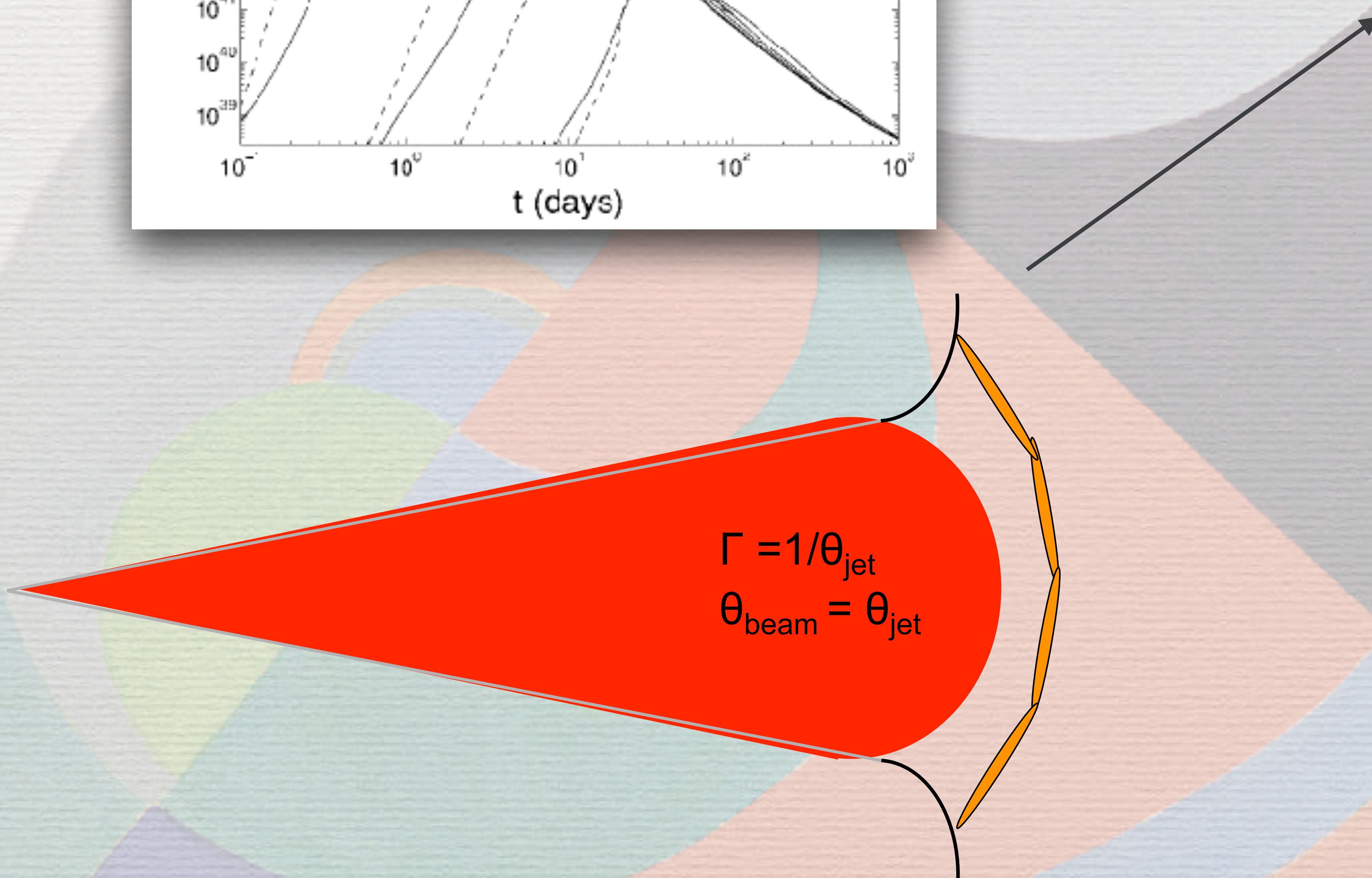
Off-axis observer



Off-axis observer

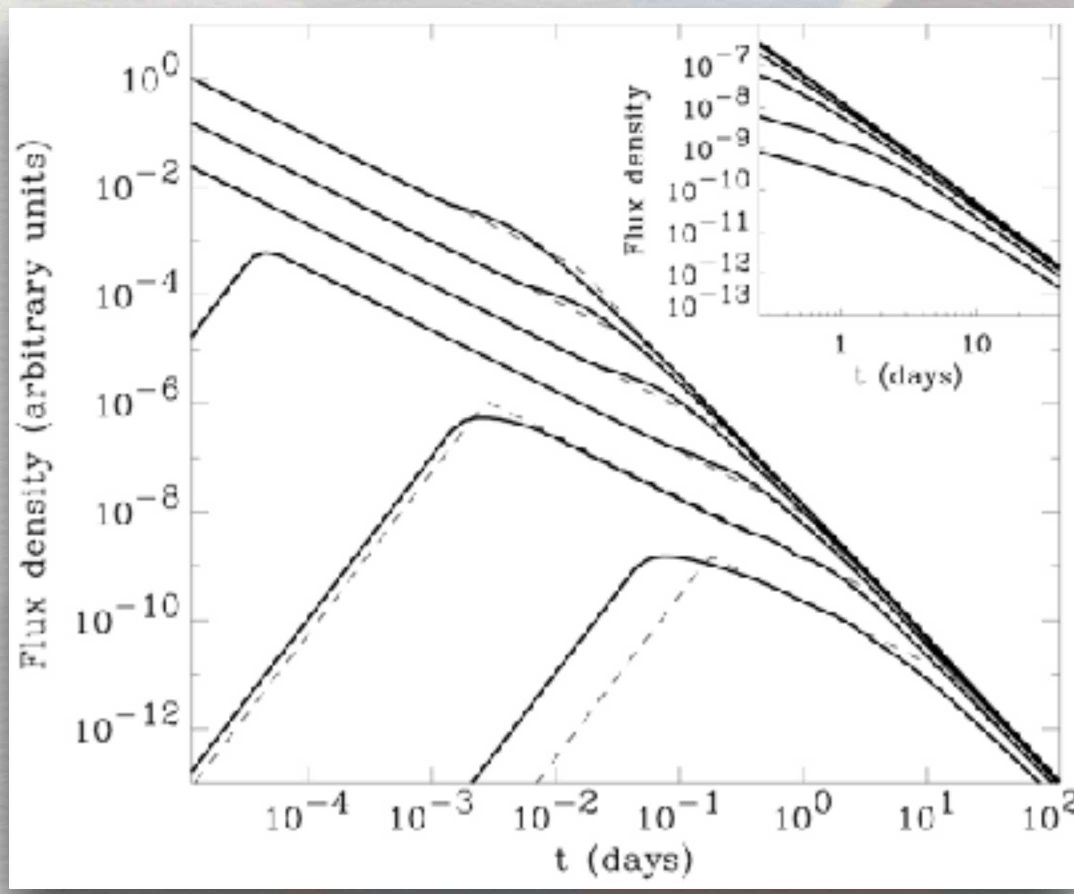
Granot+2002

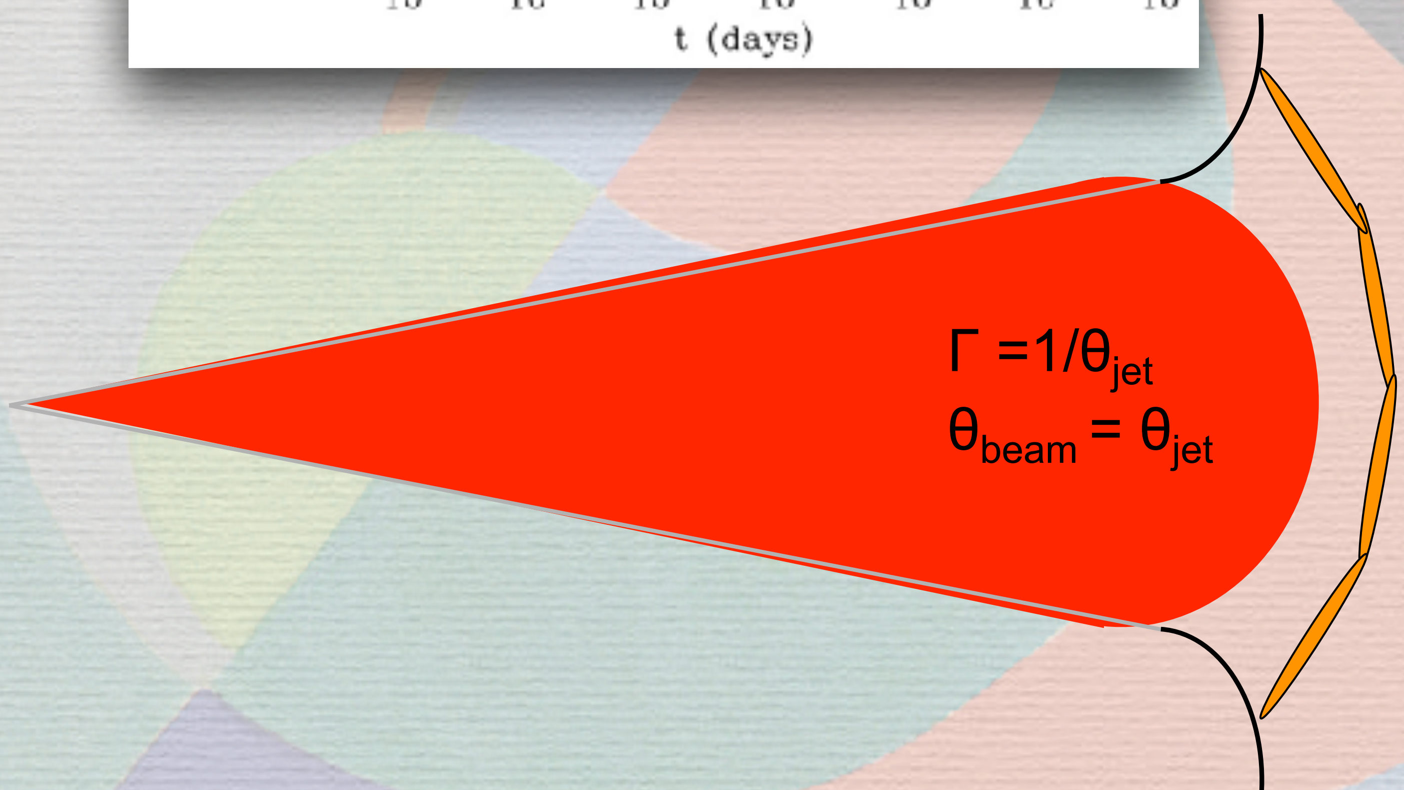




Off-axis observer

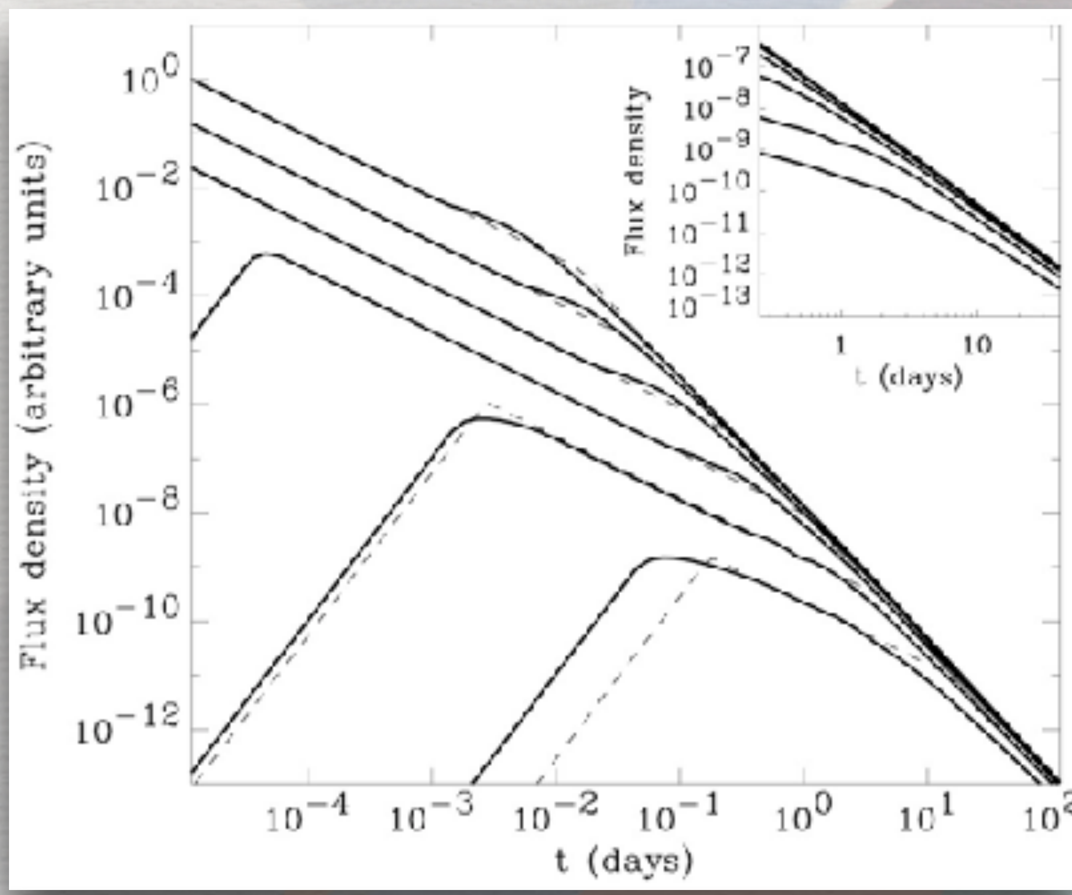
Rossi+2002



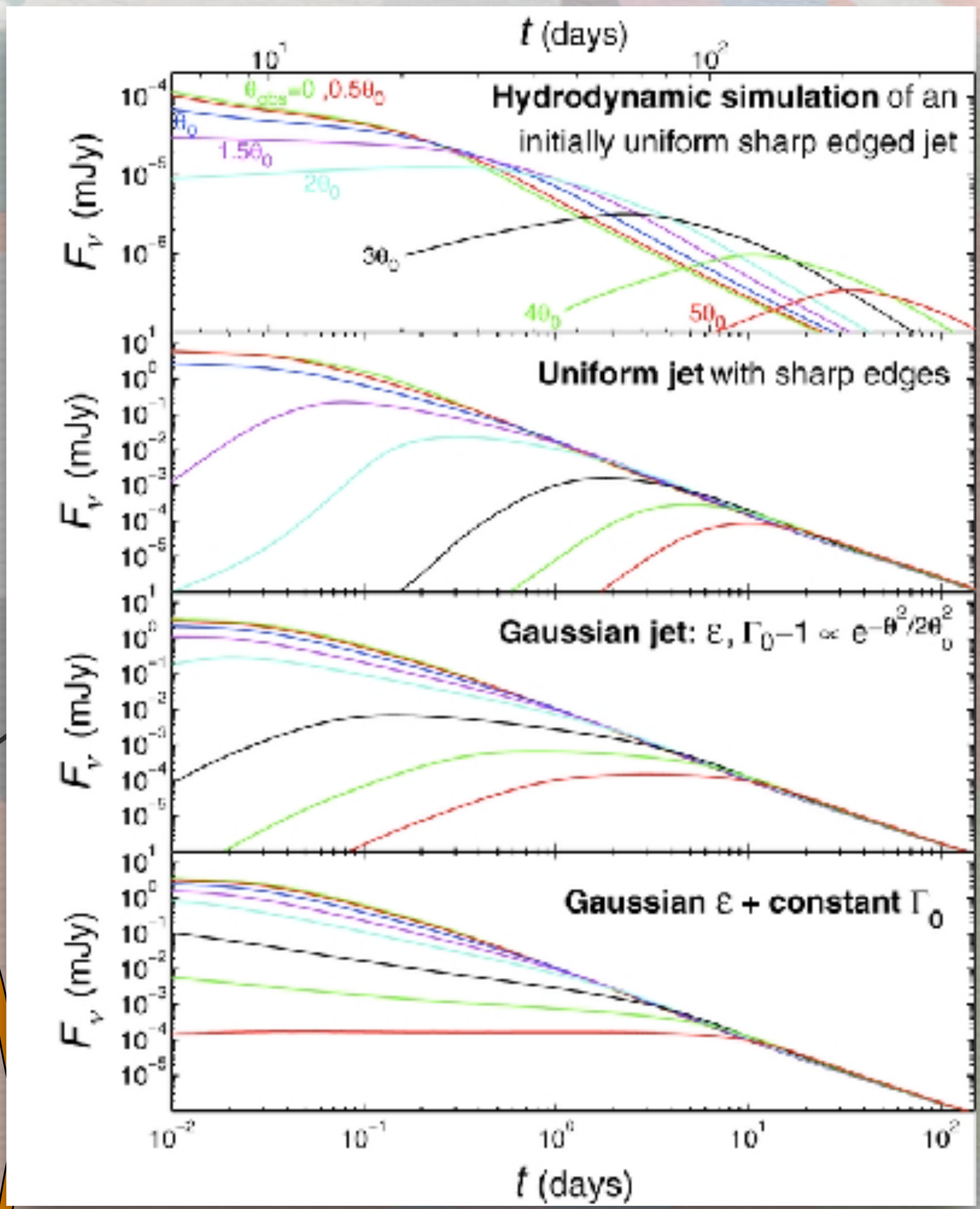


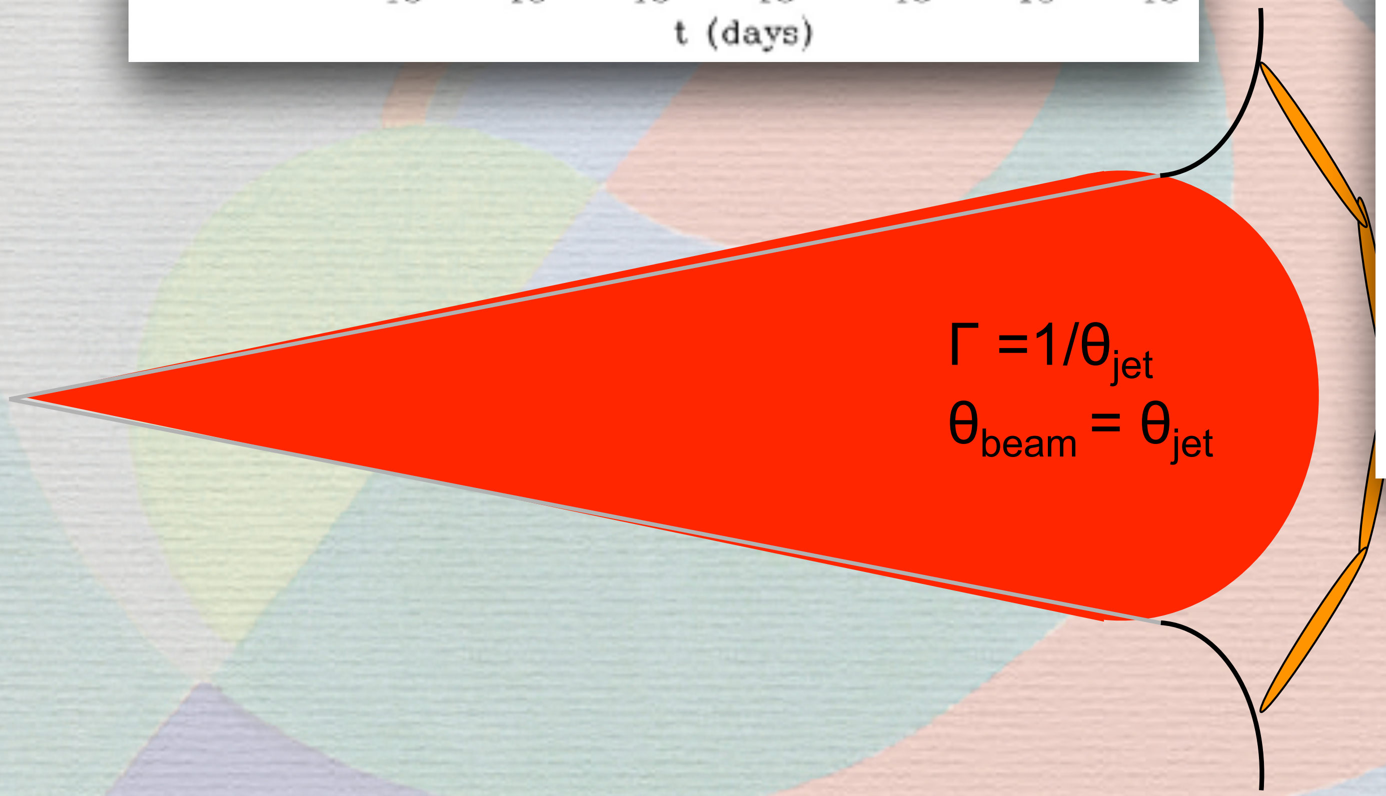
Off-axis observer

Rossi+2002



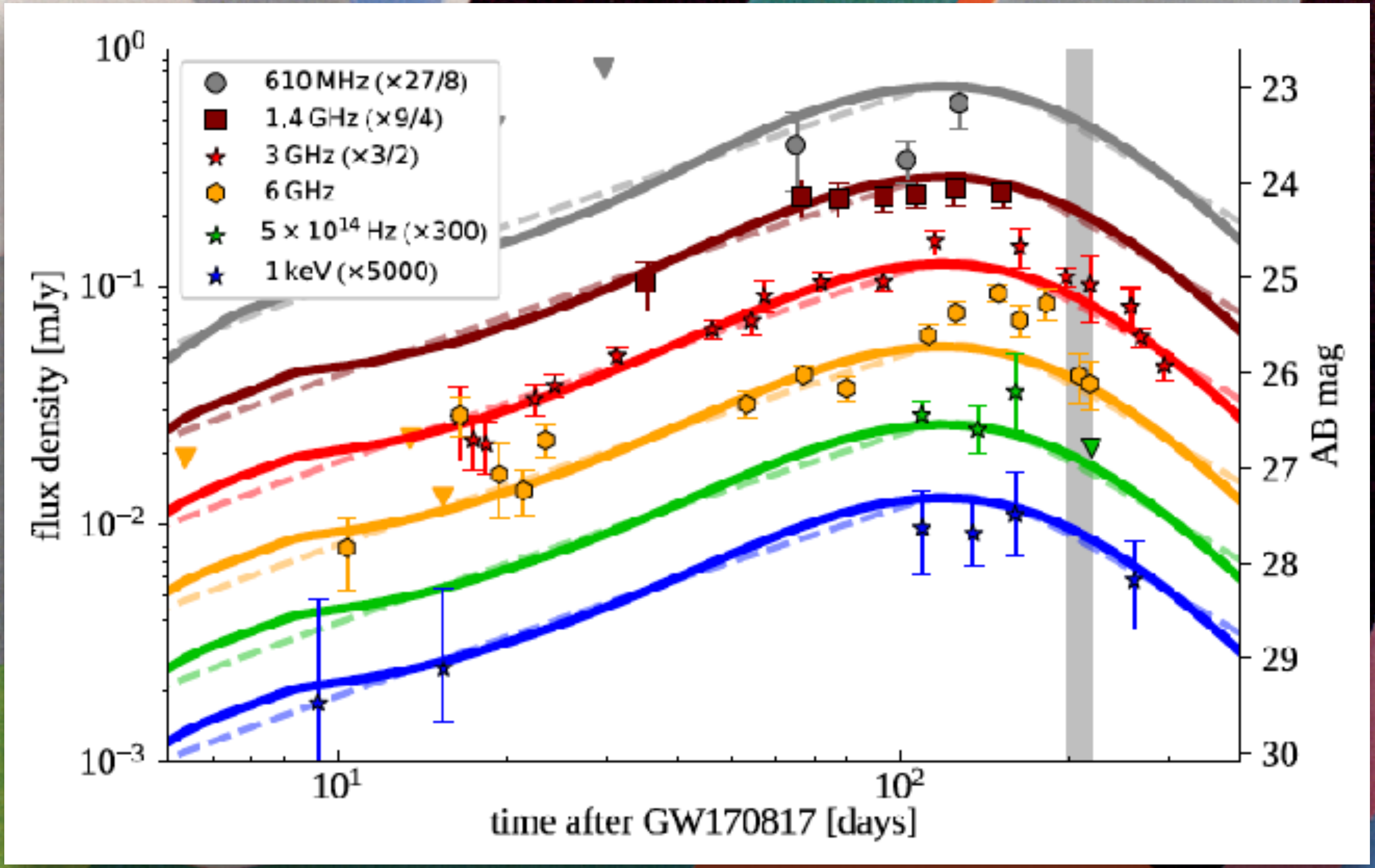
Granot+2014



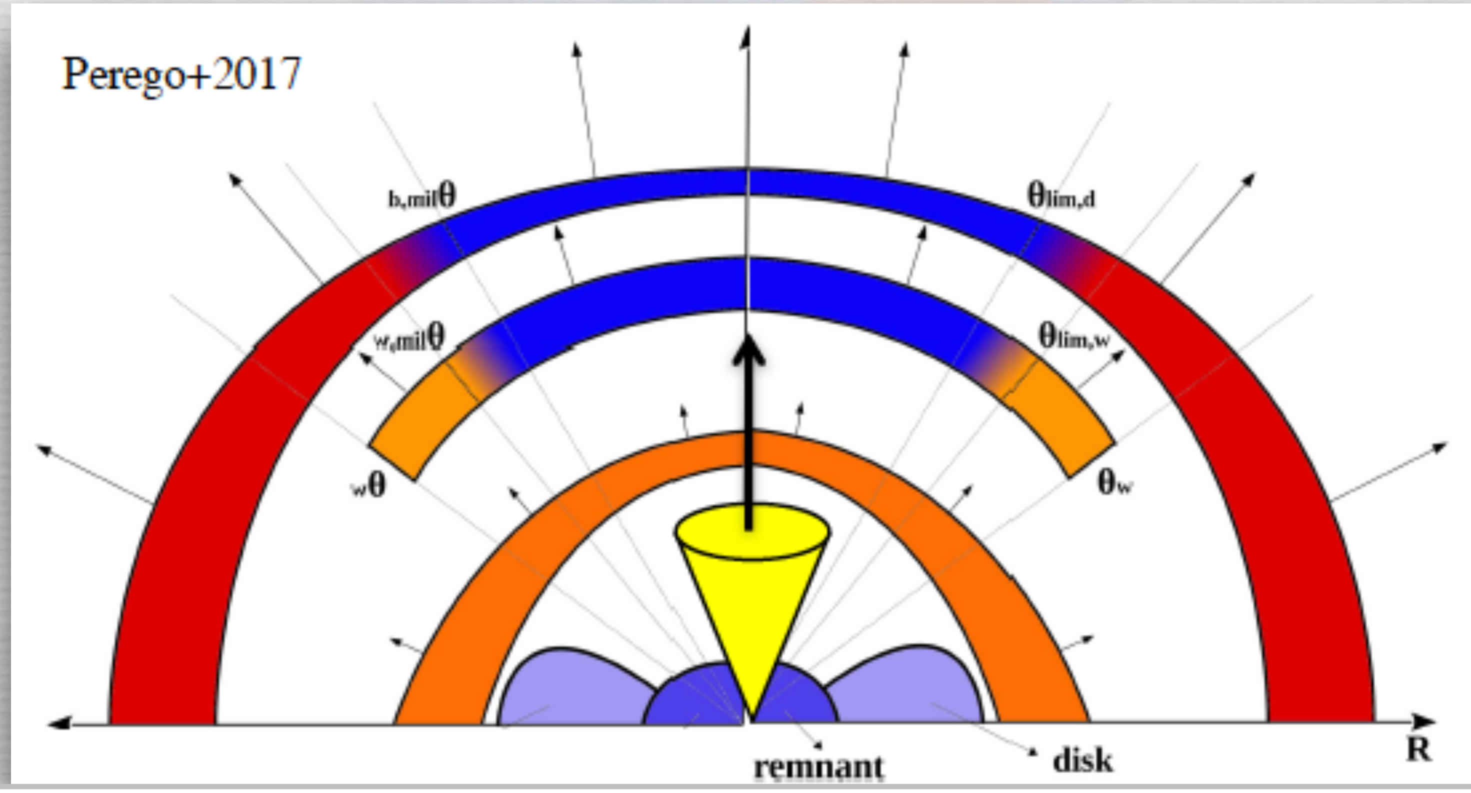


GRB170817 / GW170817

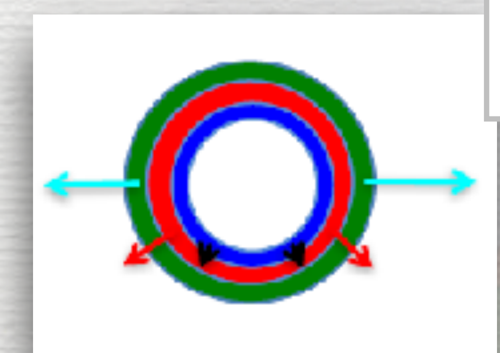
Ghirlanda+2019

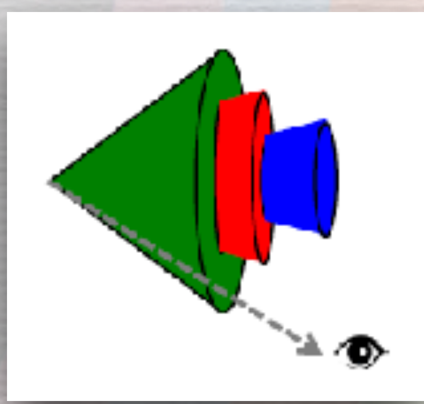


Rejected



radial or angular structure due to the interaction of the jet head with the merger ejecta

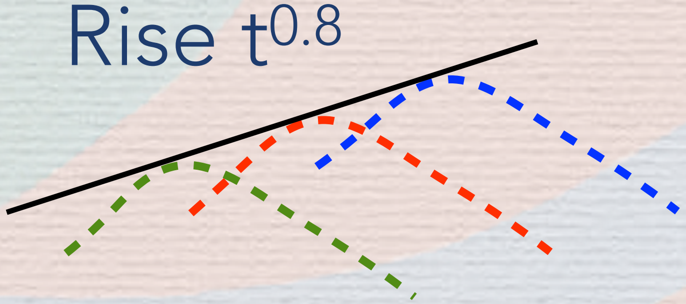




Choked jet (not successful)
radial structure
some degree of anisotropy
$\Gamma_1 < \Gamma_2 < \Gamma_3$
$E_1 > E_2 > E_3$
$E_{jet} < E_{ejecta}$

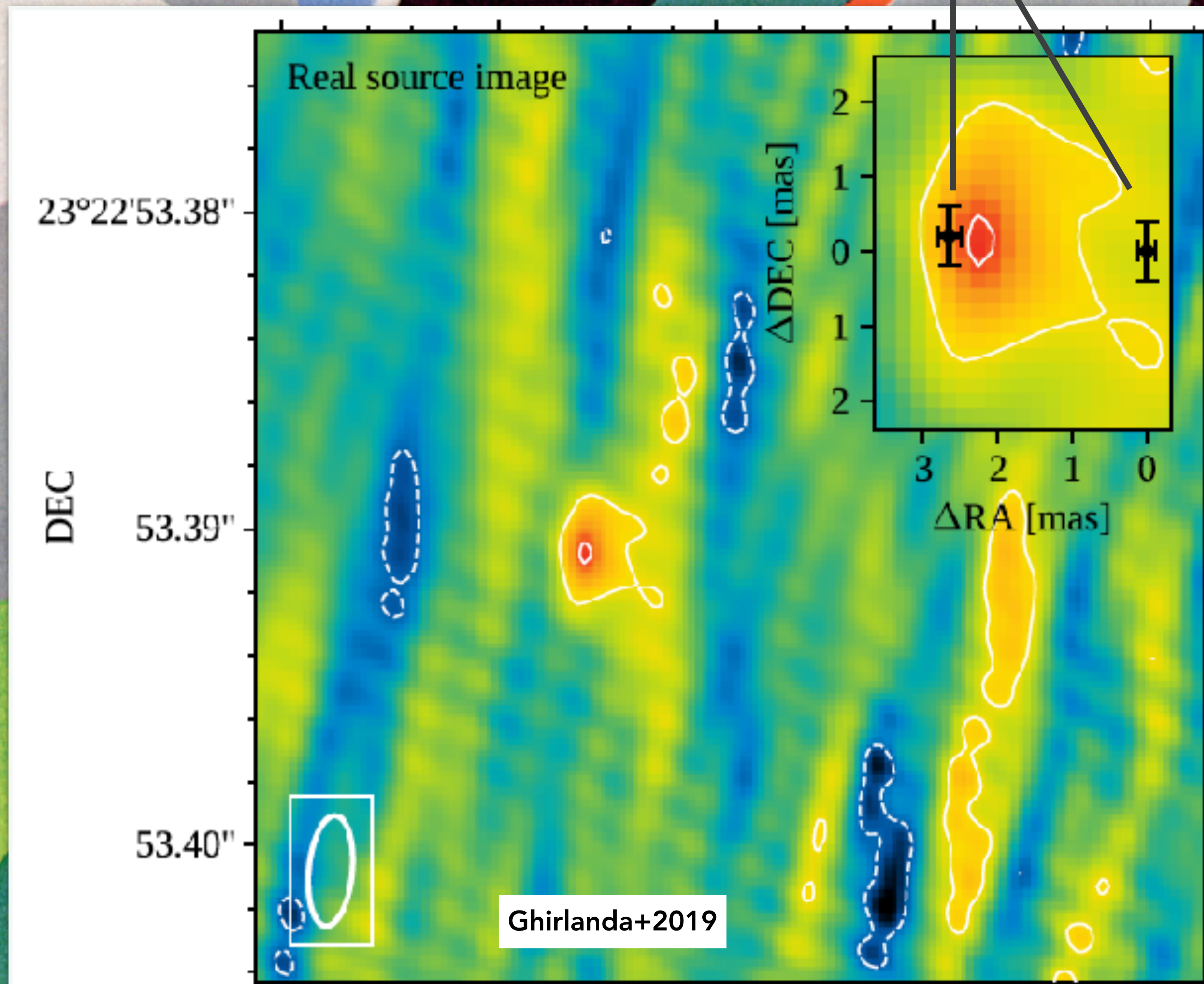
Structured Jet (successful)
off-axis jet
+ angular structure
$\Gamma_1 > \Gamma_2 > \Gamma_3$
$E_1 > E_2 > E_3$
$E_{jet} < E_{ejecta}$

Rise $t^{0.8}$



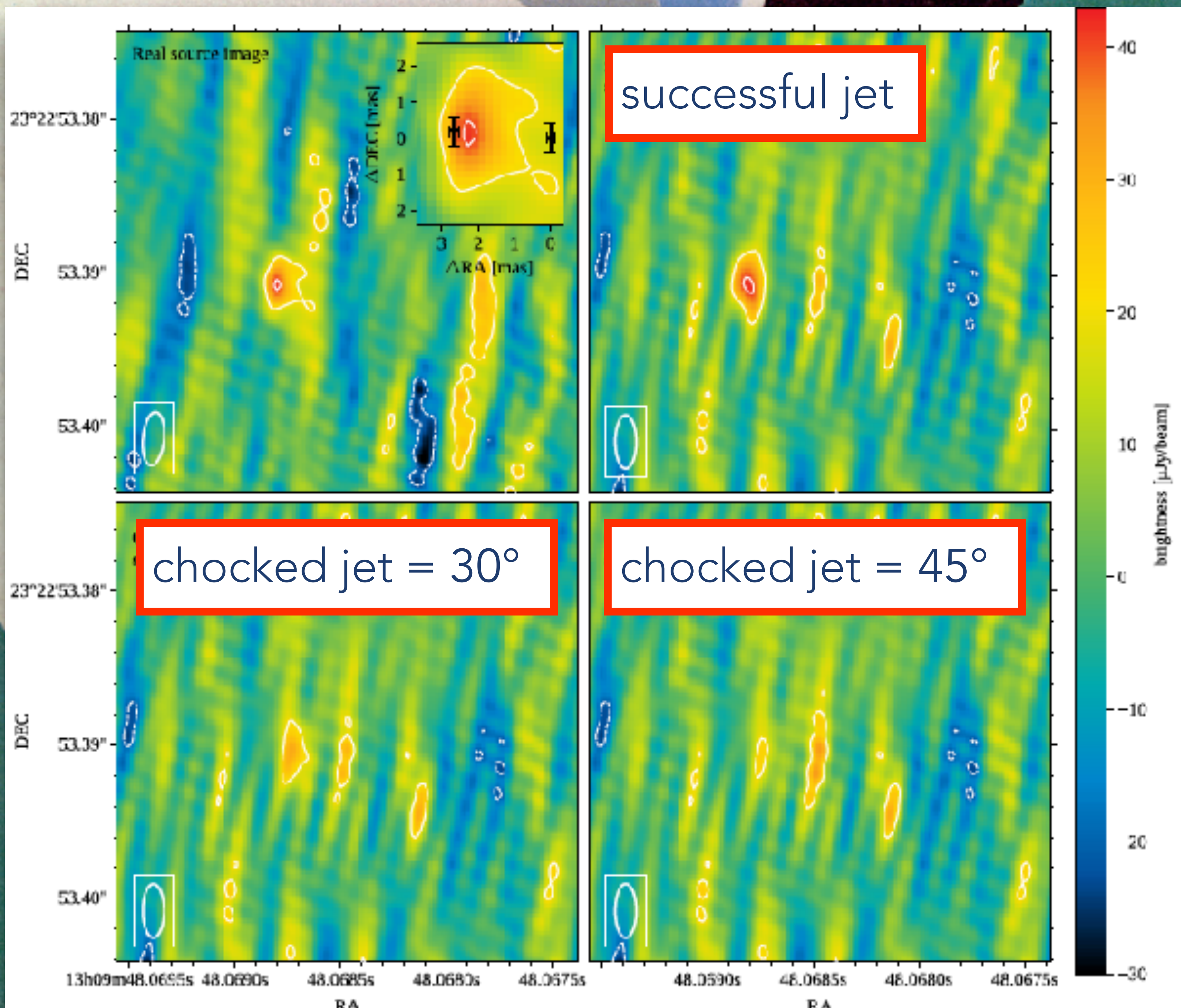
GRB170817 / GW170817

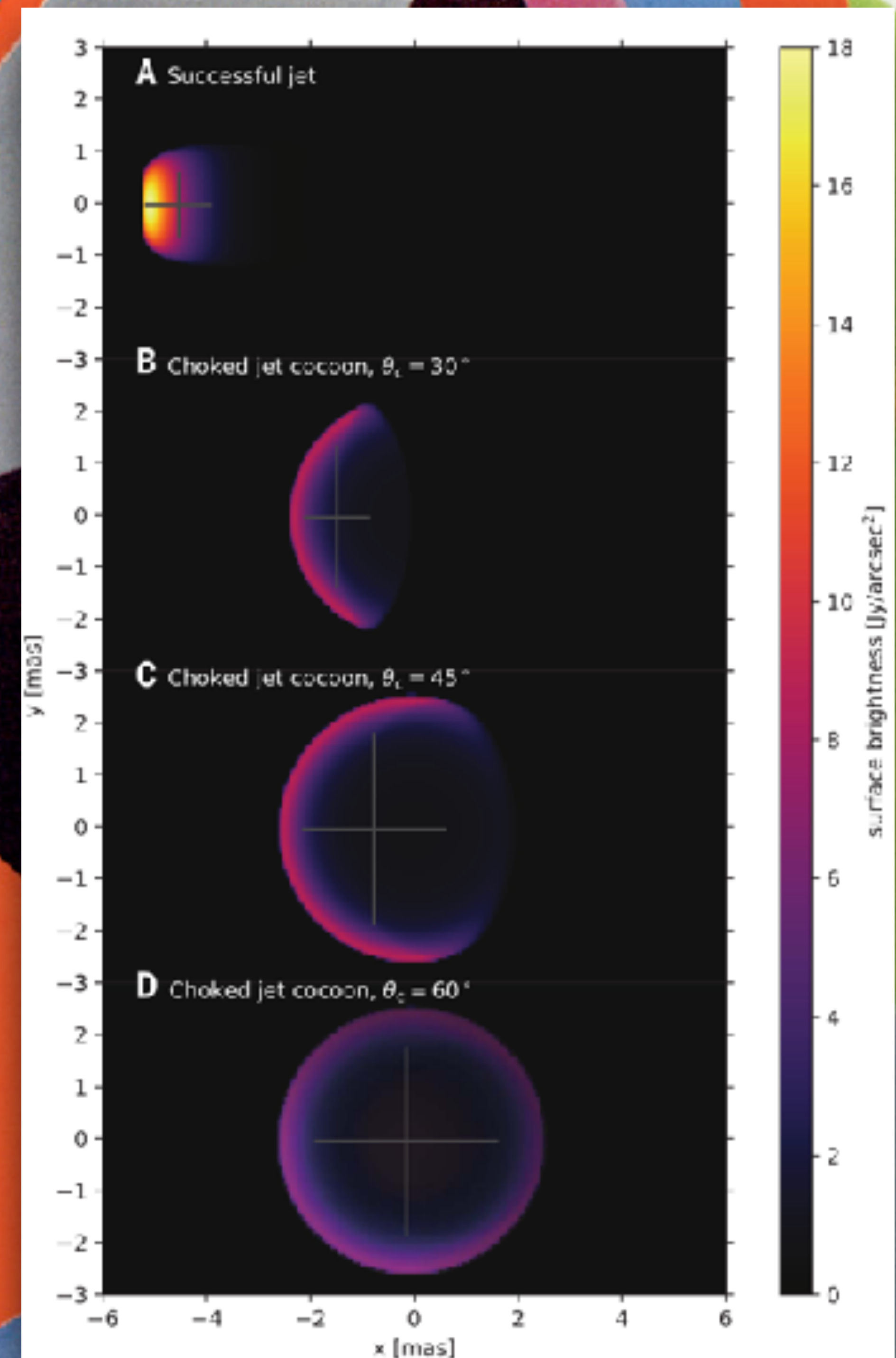
Mooley+18: displacement of 2.7mas in 155 days



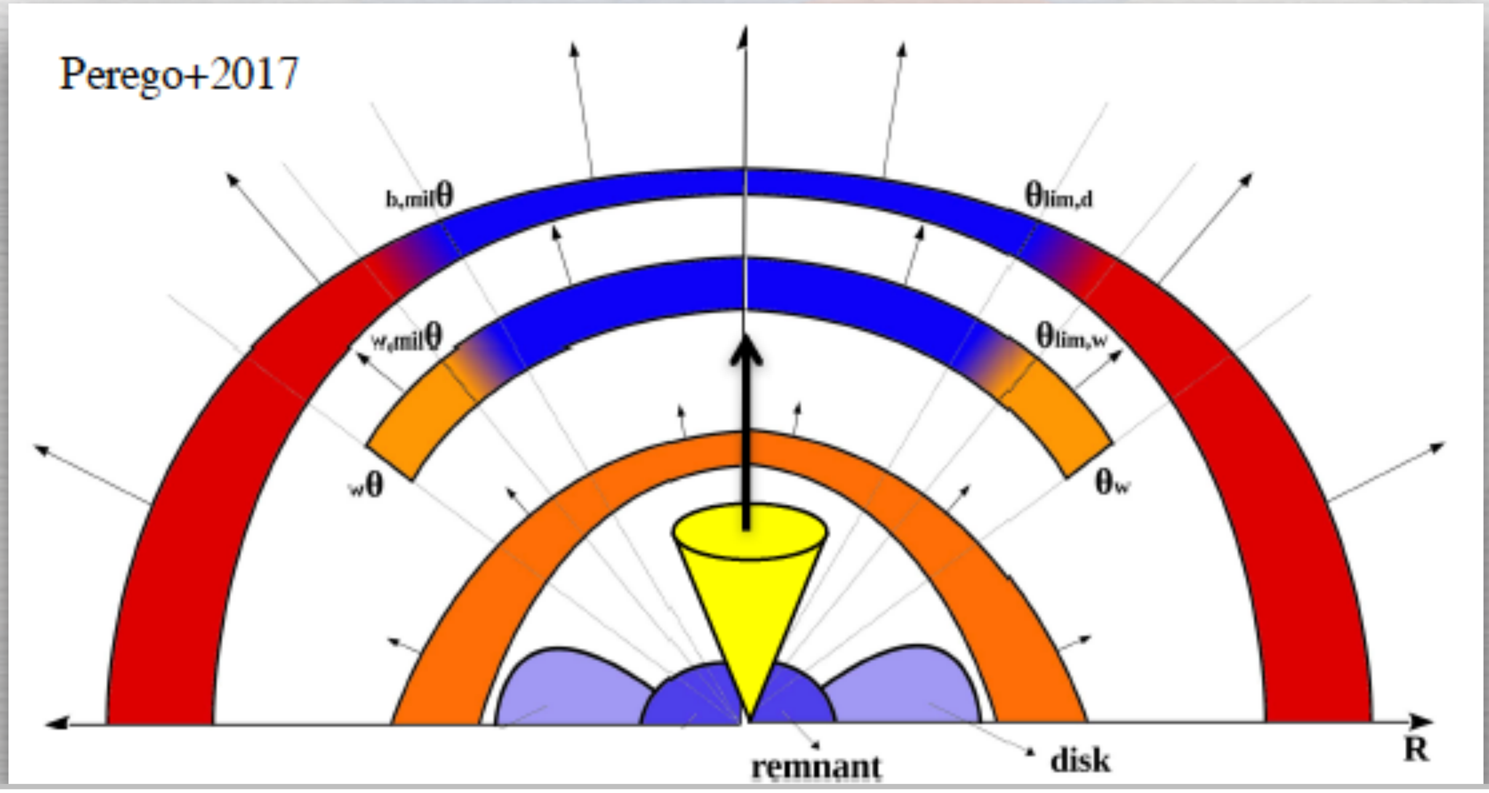
VLBI images

GRB170817 / GW170817

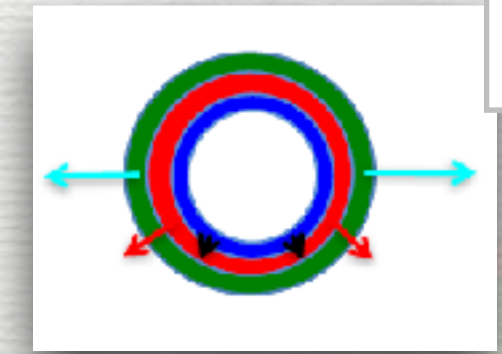


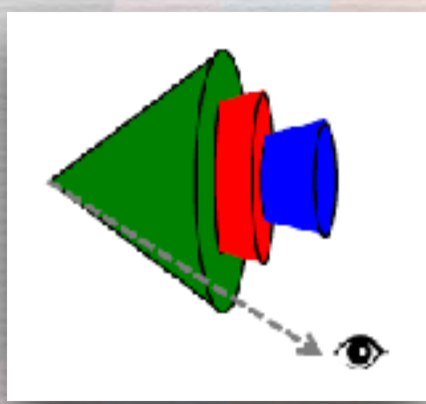


Ghirlanda+2019



radial or angular structure due to the interaction of the jet head with the merger ejecta





Choked jet (not successful)
radial structure
some degree of anisotropy
$\Gamma_1 < \Gamma_2 < \Gamma_3$
$E_1 > E_2 > E_3$
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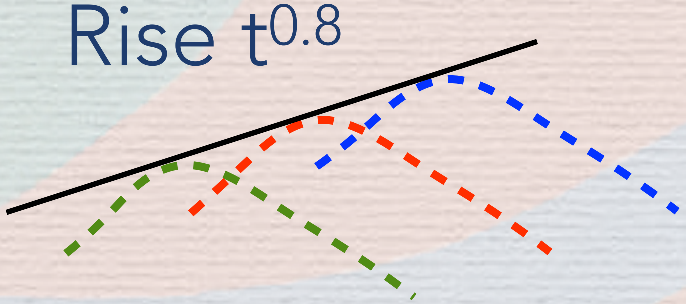
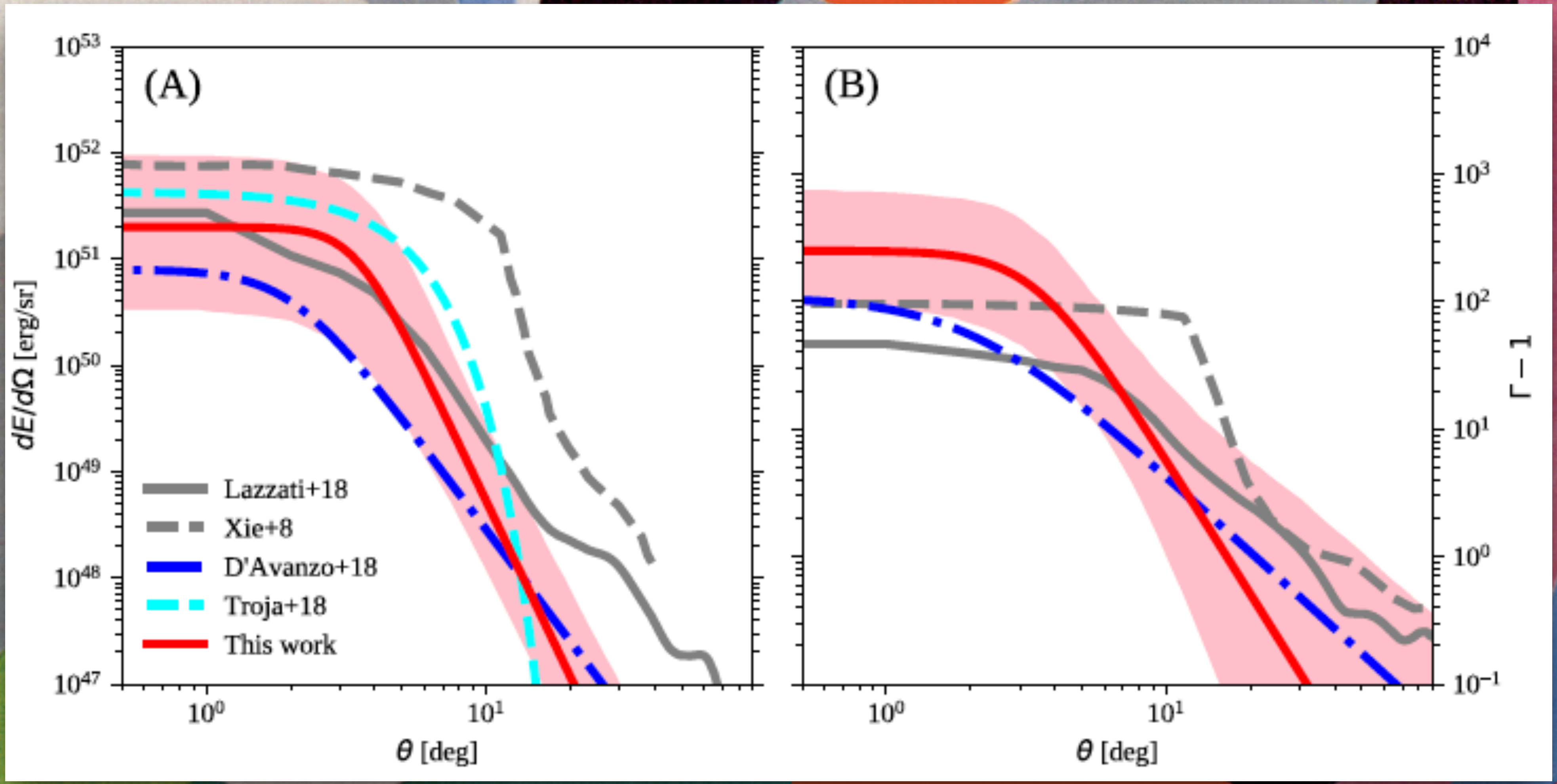


Structured Jet (successful)
off-axis jet
+ angular structure
$\Gamma_1 > \Gamma_2 > \Gamma_3$
$E_1 > E_2 > E_3$
$E_{jet} < E_{ejecta}$

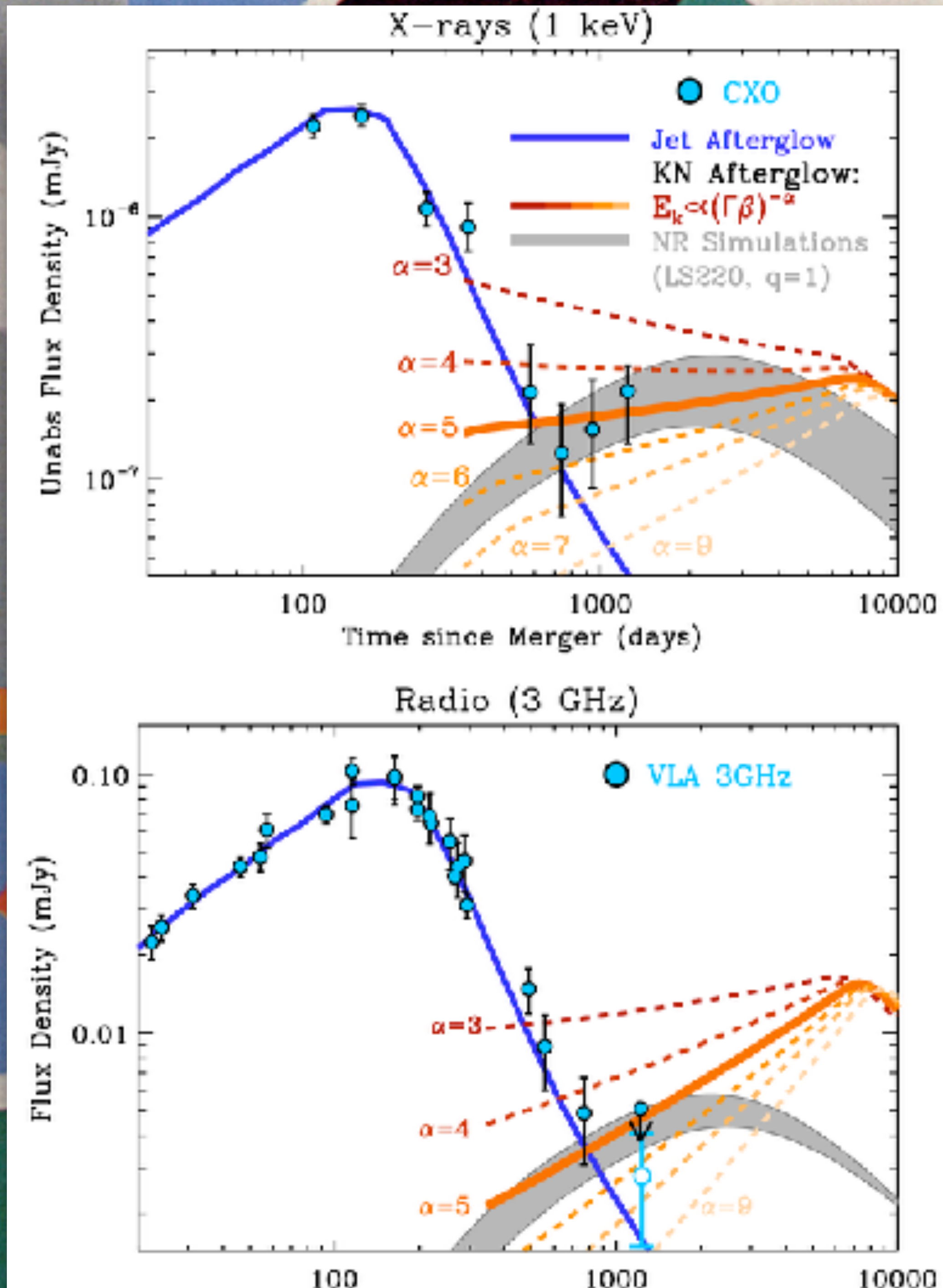
GRB170817 / GW170817

successful structured jet



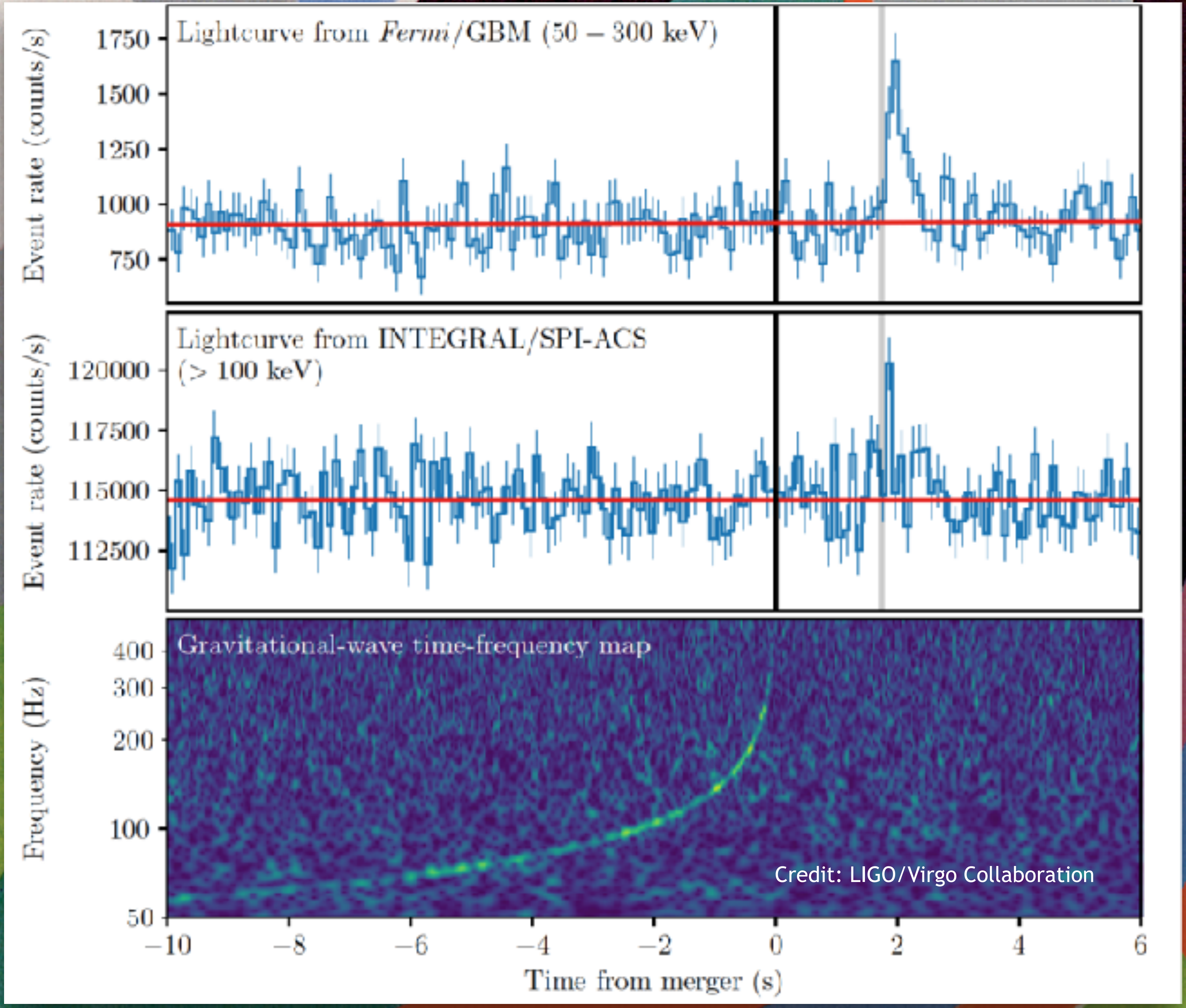
Ghirlanda+2019

GRB170817 / GW170817 / KN afterglow?

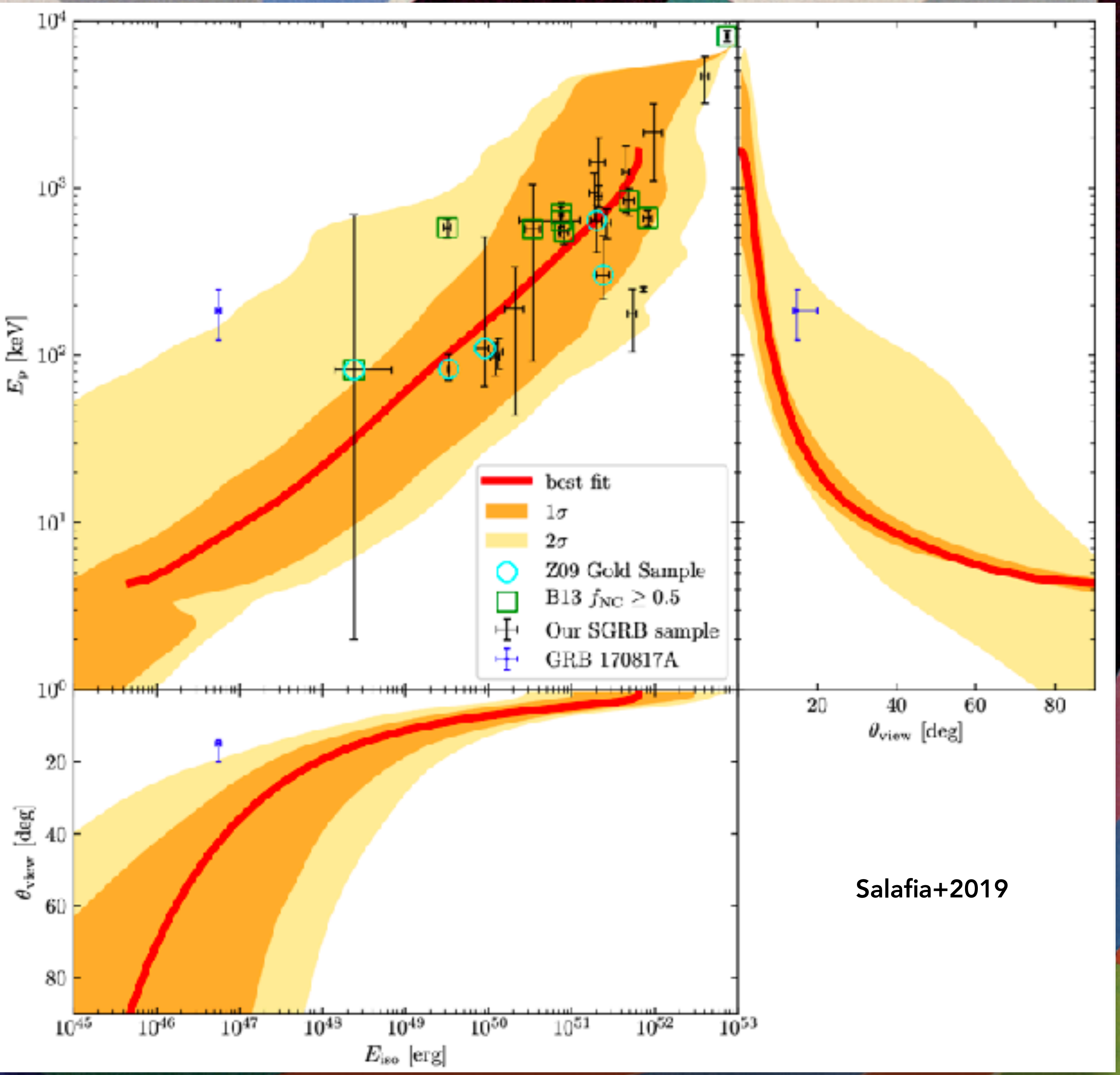


Hajela+2021

GRB170817 / GW170817



GRB170817 / GW170817



Salafia+2019

GRB170817 / GW170817

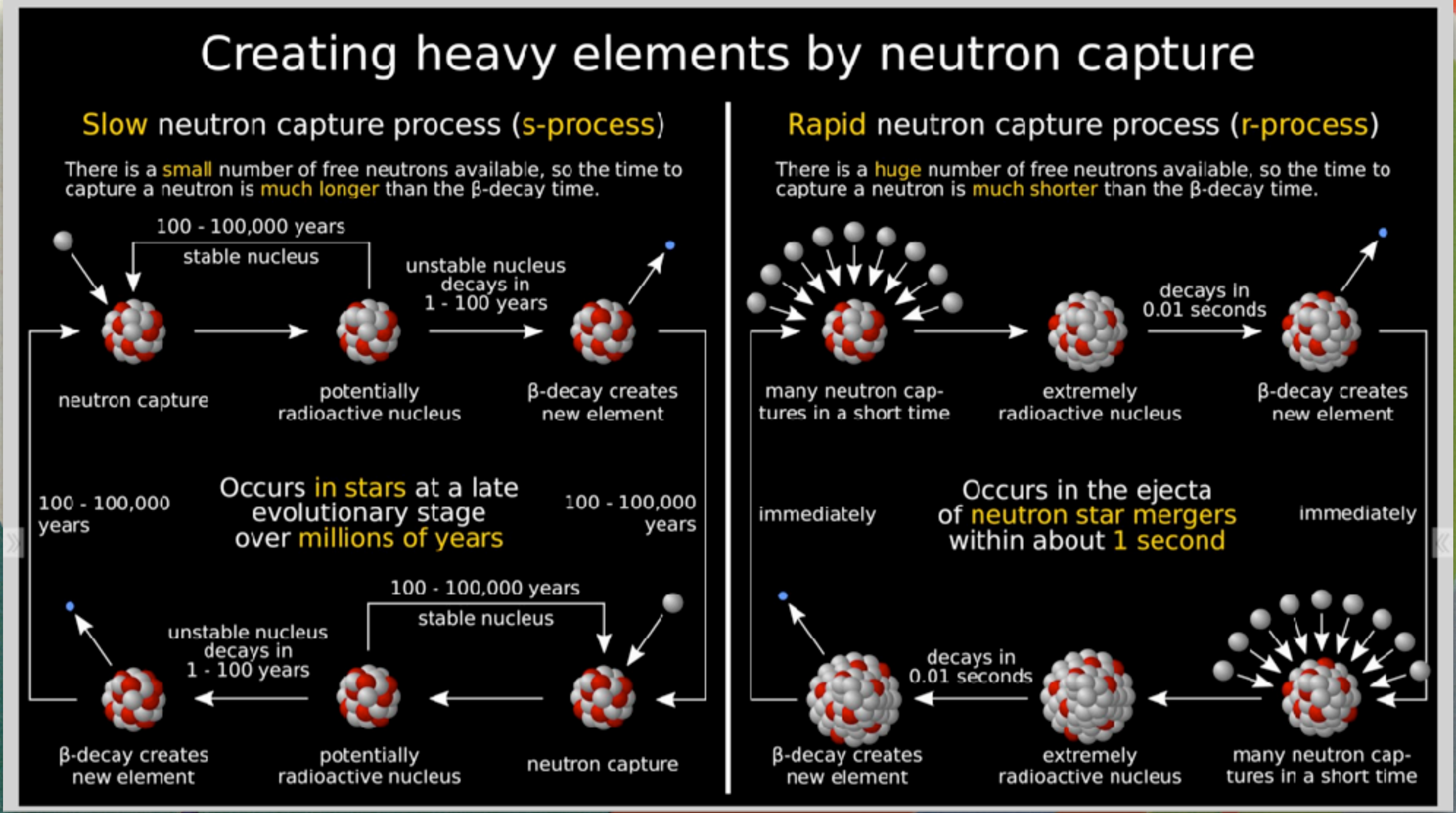
- Are all BNS associated with SGRB?
- Are all SGRB associated with BNS?
- Are all SGRB associated with BNS similar to GRB170817?
- Is the jet structure universal?
- Are SGRB associated also with NSBH ?

Kilonova (KN)

- Burbridge+1957, Cameron+1957 : heavy elements produced by r-process
- Where?
- Core-collapse SNe? Compact binary mergers (Lattimer & Schramm 1974)?
- Rosswog+1999,2000 :
  dynamical ejecta in compact binary mergers producing heavy elements
- Li & Paczynski 1998 :
  radioactive decay of the neutron-rich nuclei in dynamic ejecta
  produce a macronova (also referred to as kilonova)
  a short lived optical - IR weak supernova-like signal.

- Eichler+1989 : SGRB - BNS

Kilonova (KN)



Credits @ Los Alamos

Kilonova (KN)

A schematic representation of the s- and r-processes

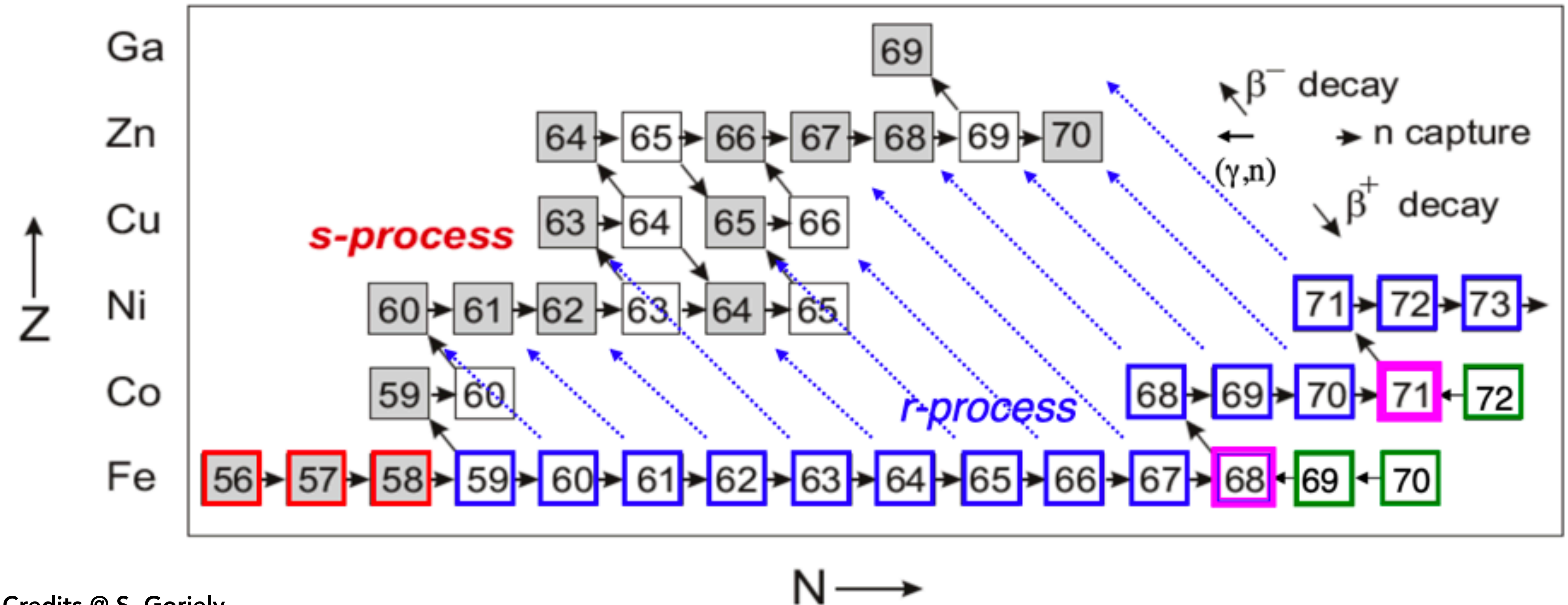
Slow neutron-capture process: $\tau_\beta \ll \tau_n$

$N_n \sim 10^7\text{-}10^{11}\ \mathrm{cm}^{-3}$ $\quad T \sim 1\text{-}3\ 10^8\mathrm{K}$ $\quad t_{irr} \sim 10\text{-}10^4\mathrm{yr}$

Rapid neutron-capture process: $\tau_\beta \gg \tau_n$

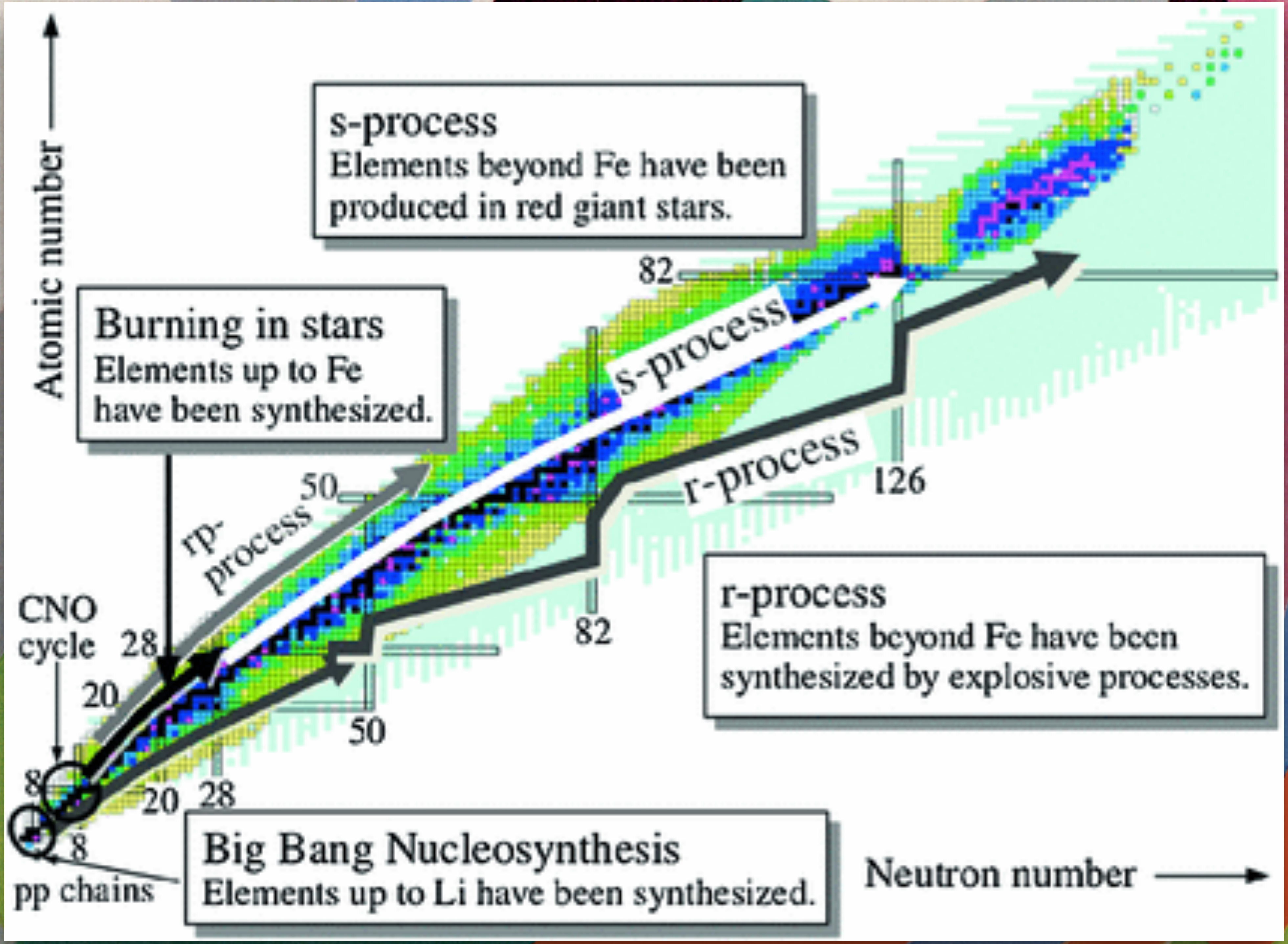
$N_n \gg 10^{20}\ \mathrm{cm}^{-3}$ $\quad T \sim 1\text{-}2\ 10^9\mathrm{K}$ $\quad t_{irr} \sim 1\mathrm{s}$

τ_n = lifetime against neutron capture
τ_β = lifetime against β^- decay



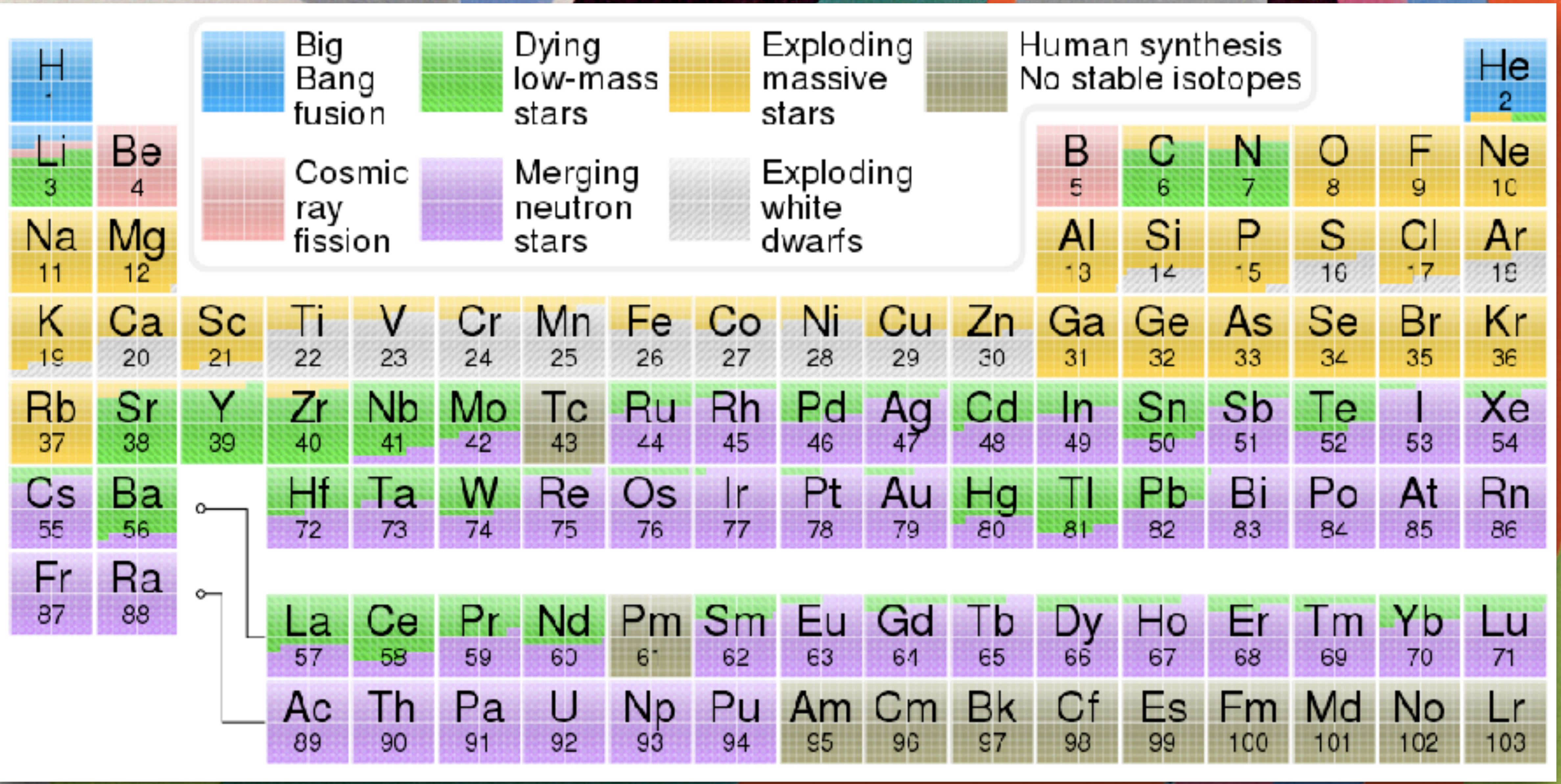
Credits @ S. Goriely

Kilonova (KN)



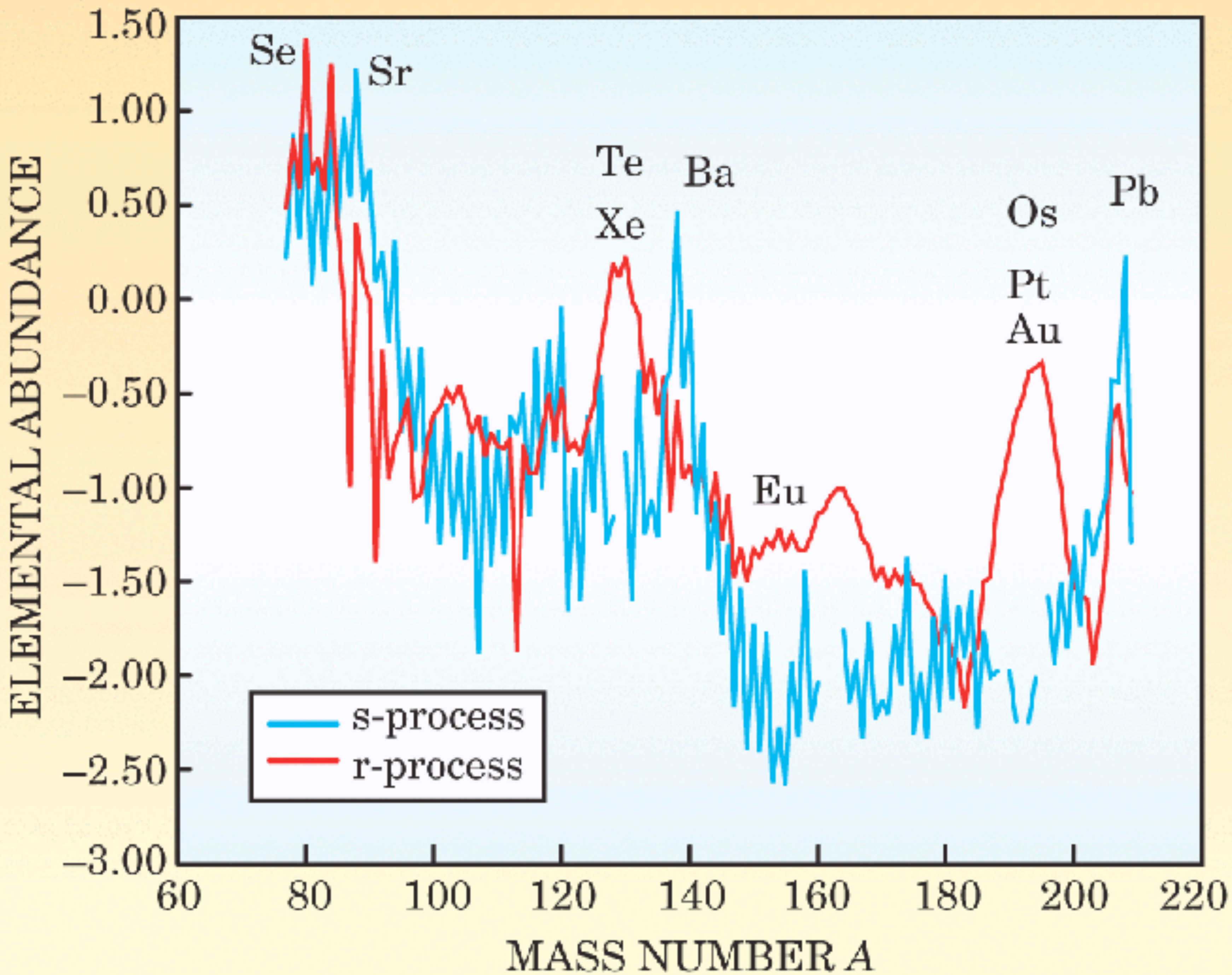
Takigawa+2017

Kilonova (KN)



Big Bang fusion
Dying low-mass stars
Exploding massive stars
Human synthesis No stable isotopes
Cosmic ray fission
Merging neutron stars
Exploding white dwarfs
H 1
He 2
Li 3
Be 4
B 5
C 6
N 7
O 8
F 9
Ne 10
Na 11
Mg 12
Al 13
Si 14
P 15
S 16
Cl 17
Ar 18
K 19
Ca 20
Sc 21
Ti 22
V 23
Cr 24
Mn 25
Fe 26
Co 27
Ni 28
Cu 29
Zn 30
Ga 31
Ge 32
As 33
Se 34
Br 35
Kr 36
Rb 37
Sr 38
Y 39
Zr 40
Nb 41
Mo 42
Tc 43
Ru 44
Rh 45
Pd 46
Ag 47
Cd 48
In 49
Sn 50
Sb 51
Te 52
I 53
Xe 54
Cs 55
Ba 56
Hf 72
Ta 73
W 74
Re 75
Os 76
Ir 77
Pt 78
Au 79
Hg 80
Tl 81
Pb 82
Bi 83
Po 84
At 85
Rn 86
Fr 87
Ra 88
La 57
Ce 58
Pr 59
Nd 60
Pm 61
Sm 62
Eu 63
Gd 64
Tb 65
Dy 66
Ho 67
Er 68
Tm 69
Yb 70
Lu 71
Ac 89
Th 90
Pa 91
U 92
Np 93
Pu 94
Am 95
Cm 96
Bk 97
Cf 98
Es 99
Fm 100
Md 101
No 102
Lr 103

Kilonova (KN)



Cowan+2004

Kilonova (KN)

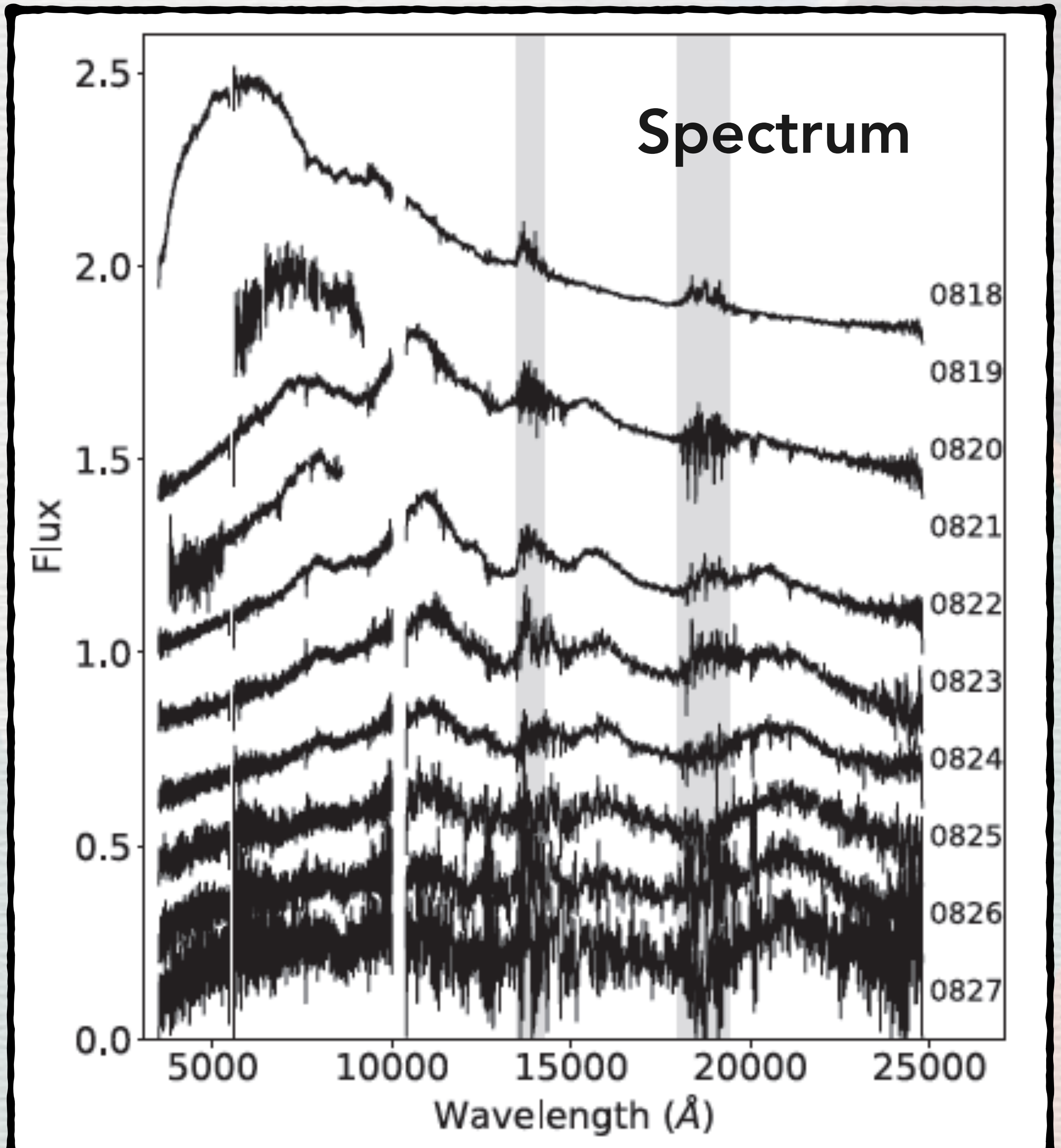
- Burbridge+1957, Cameron+1957 : heavy elements produced by r-process
- Where?
- Core-collapse SNe? Compact binary mergers (Lattimer & Schramm 1974)?
- Rosswog+1999,2000 :
  dynamical ejecta in compact binary mergers producing heavy elements
- Li & Paczynski 1998 :
  radioactive decay of the neutron-rich nuclei in dynamic ejecta
  produce a macronova (also re-ferred to as kilonova)
  a short lived optical - IR weak supernova-like signal.

- Eichler+1989 : SGRB - BNS

Kilonova (KN) : AT2017gfo

ESO-VLT/X-Shooter

Pian et al. 2017, Nature

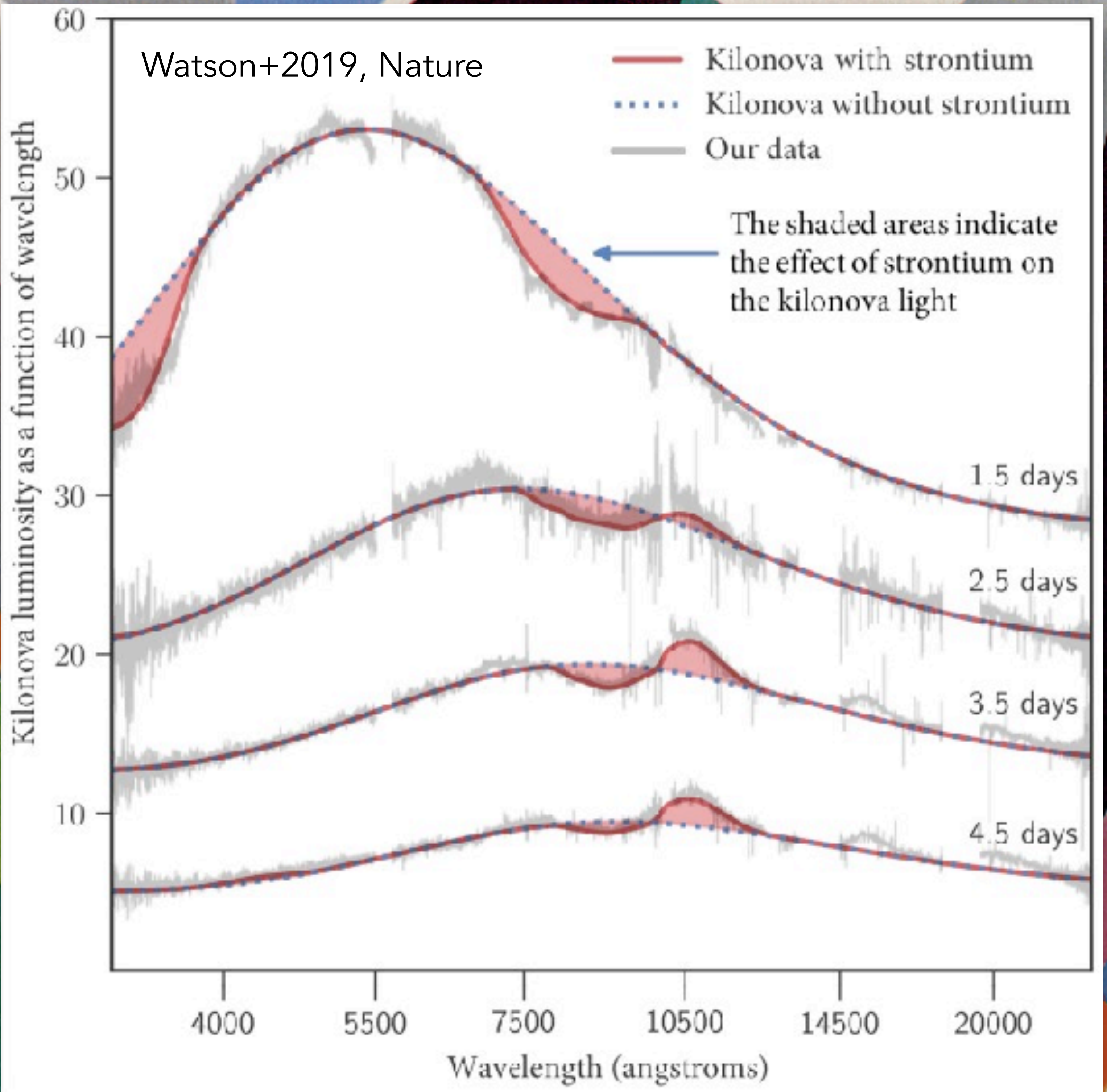


First spectral identification of a KN

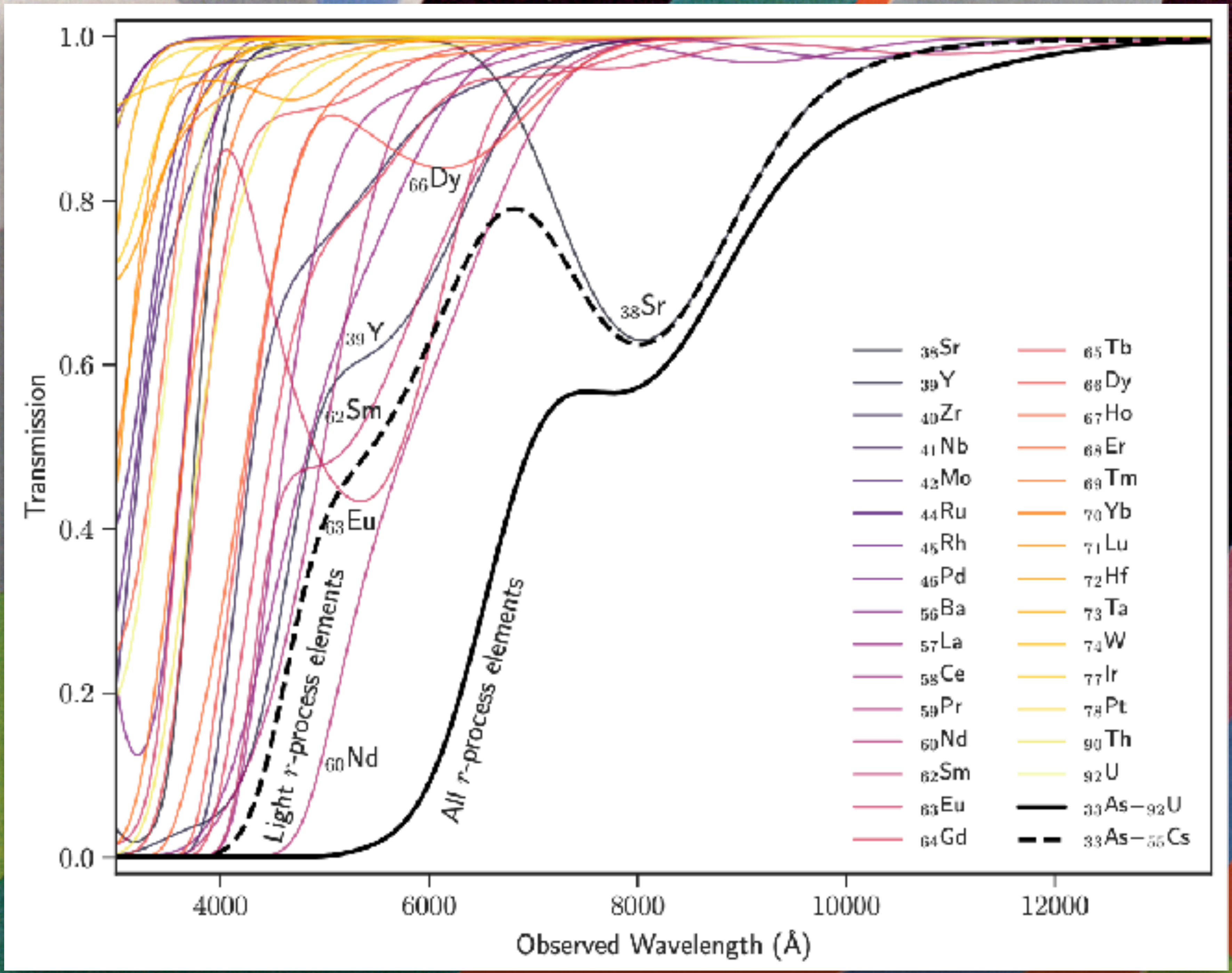
- radioactive decay of **r-process nucleosynthesis**
- BNS merger **site for heavy element production in the Universe**

Which heavy elements?
Very difficult!

Kilonova (KN) : AT2017gfo

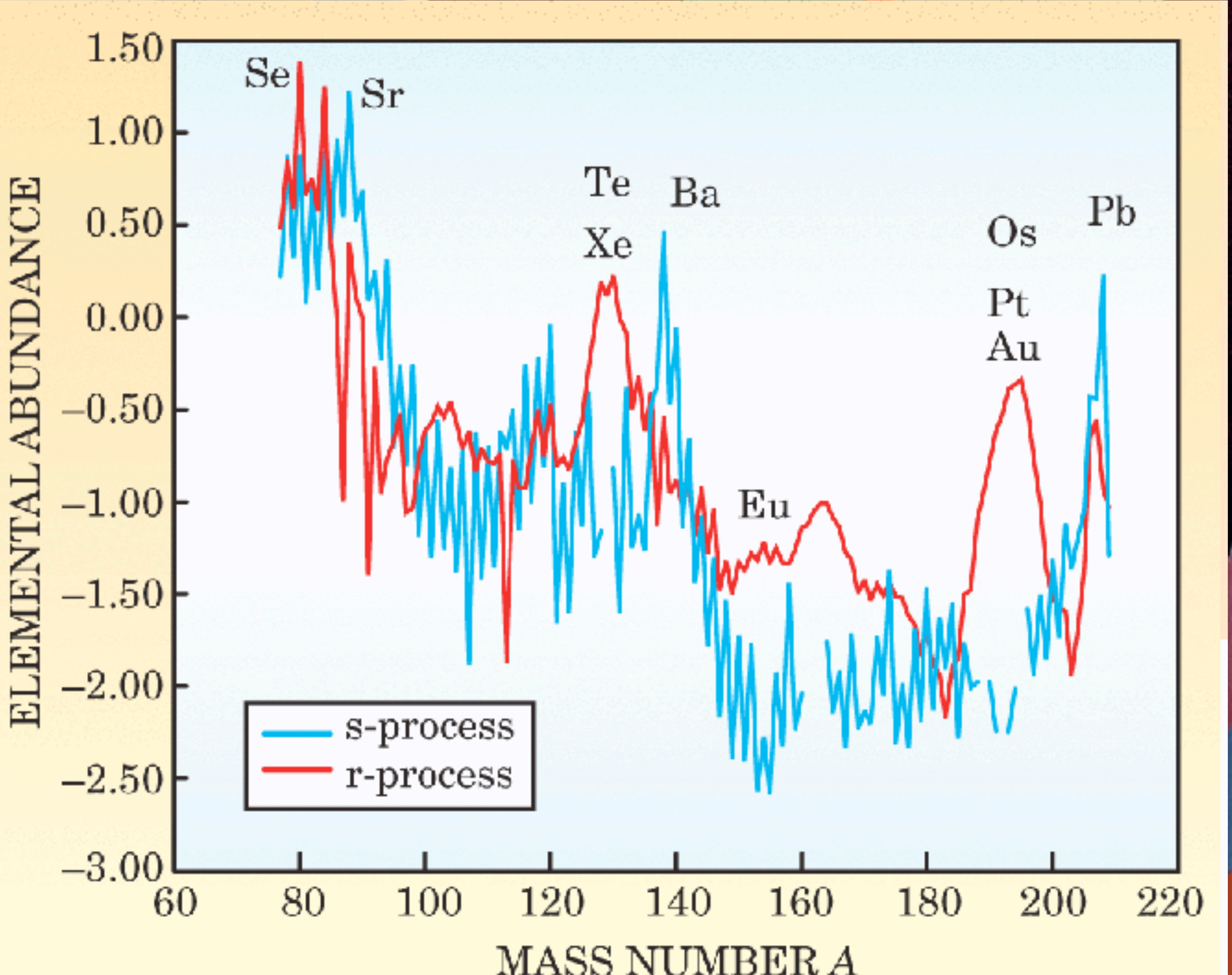


Kilonova (KN)



Watson+2019

Kilonova (KN)

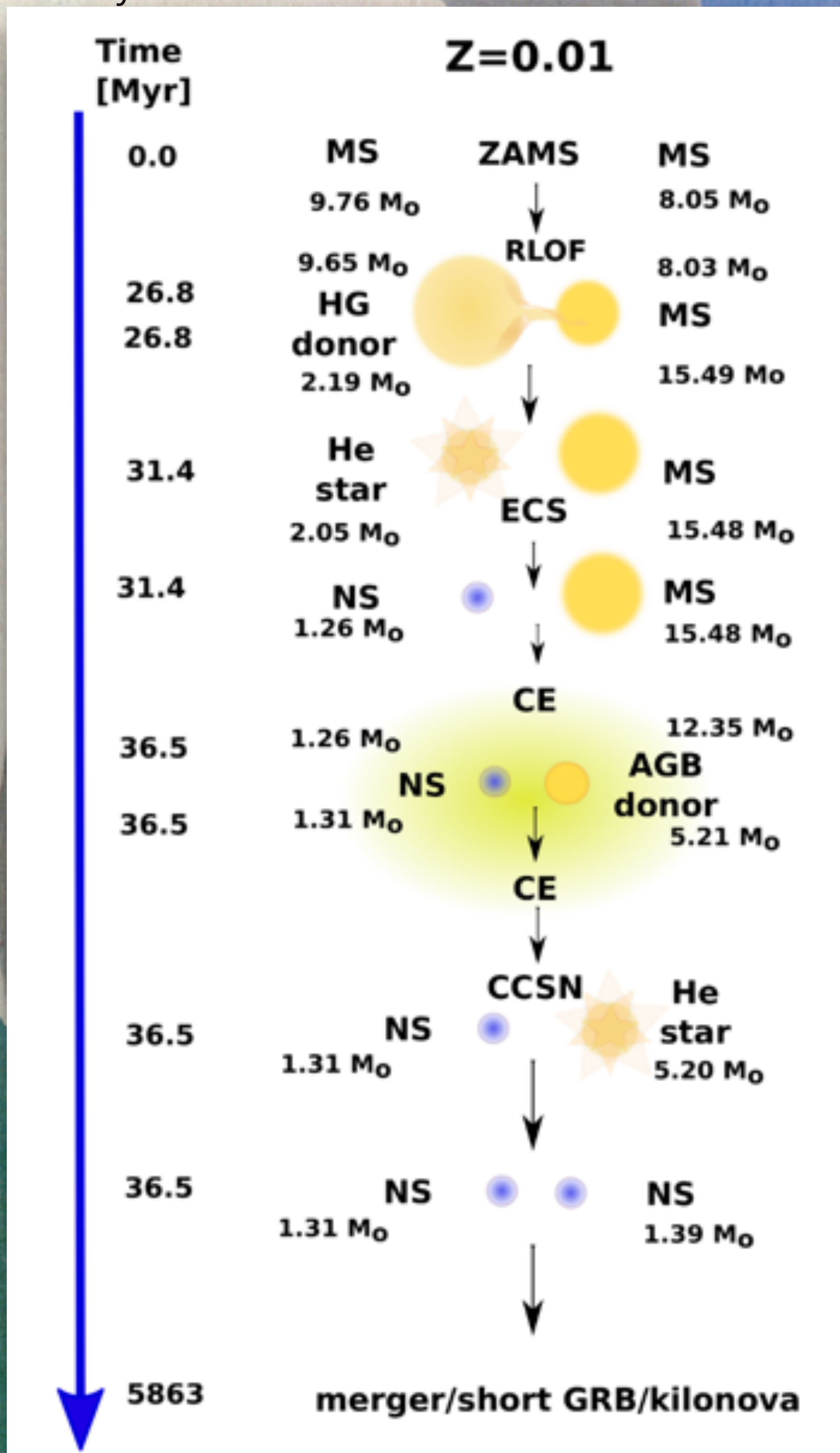


Cowan+2004

- Are all KN like AT2017gfo?
- Will we be able to identify heavy elements?
- What is the mass produced?

Host Galaxy

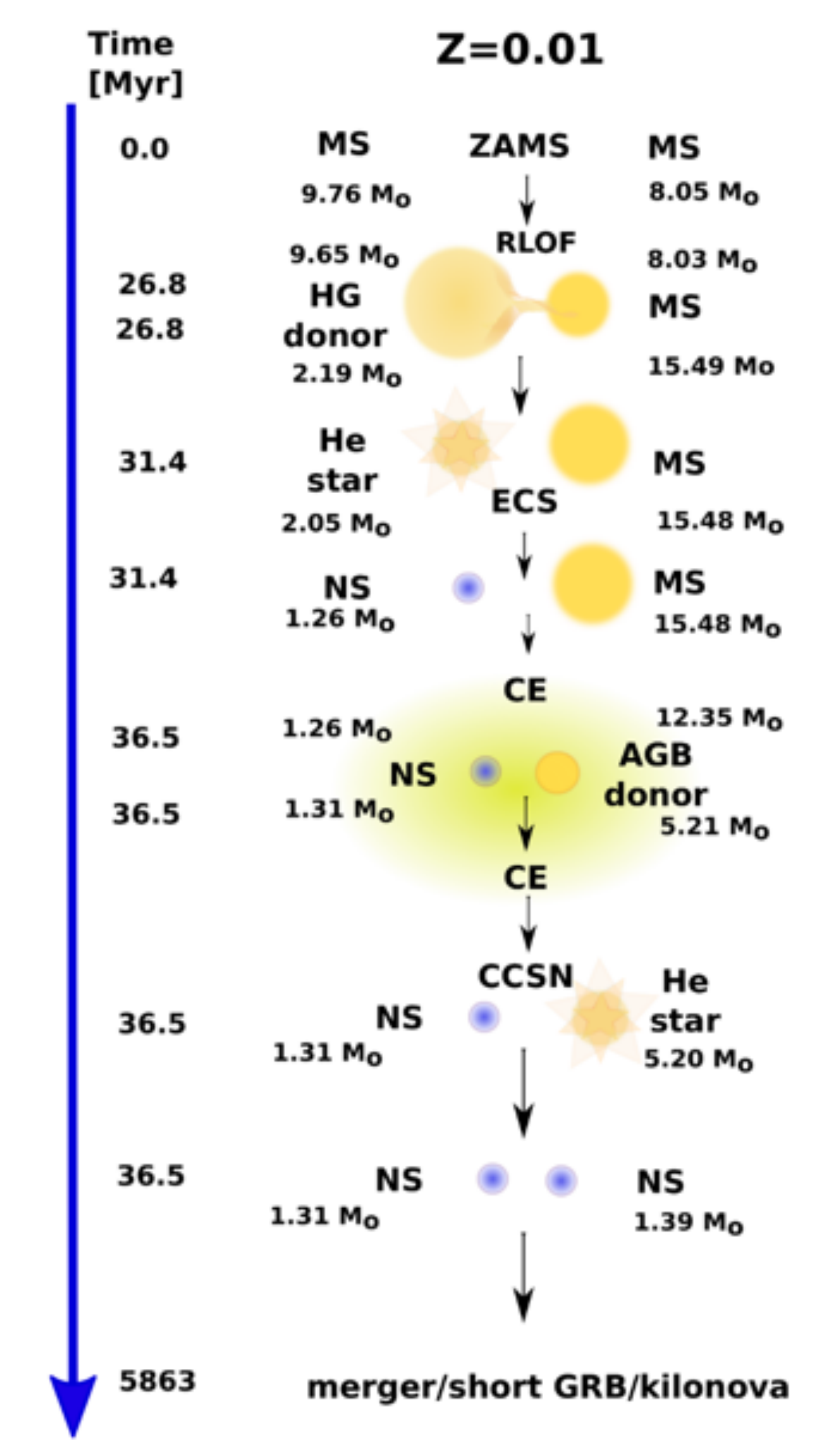
Belczynski+2018

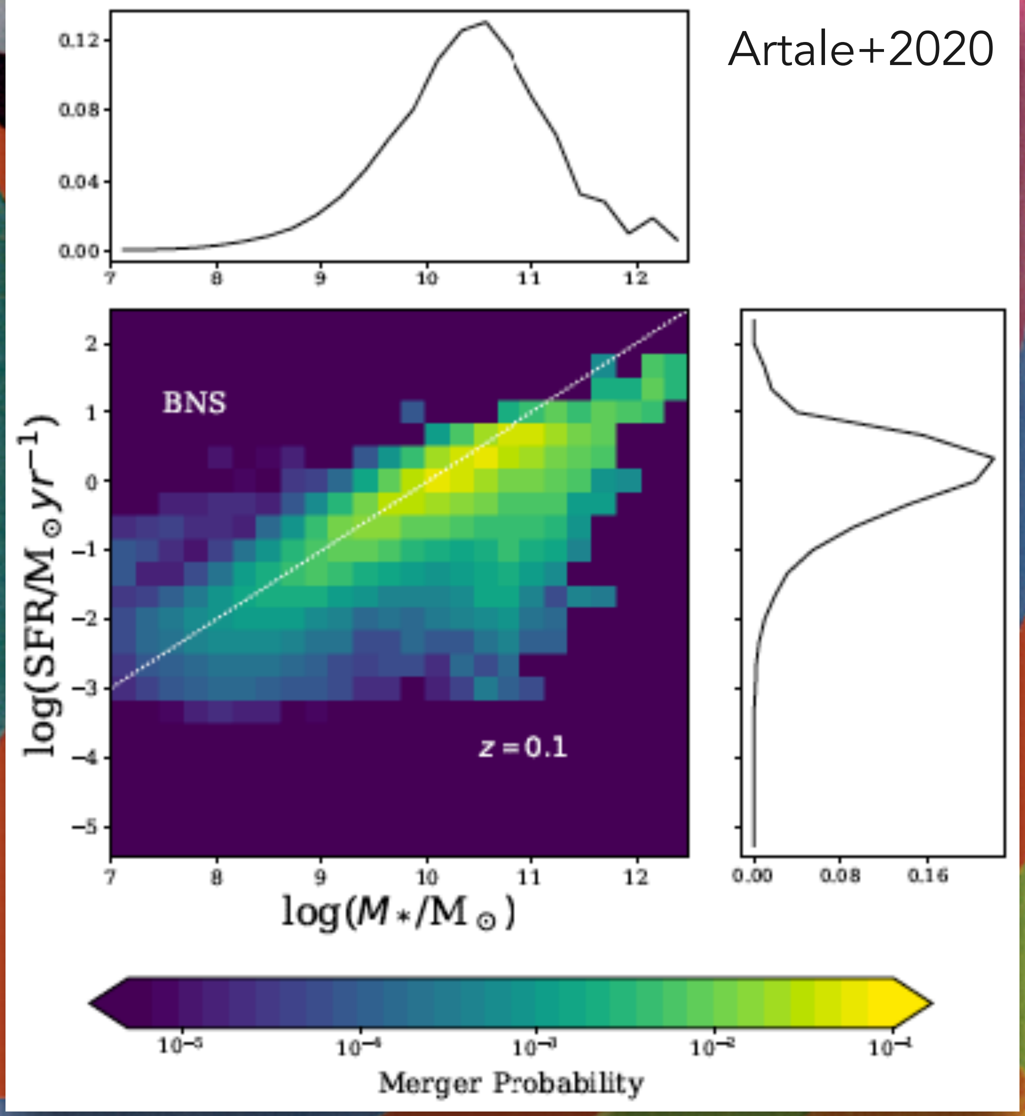


Host Galaxy

- Stellar evolution models
- Galaxy evolution simulations

Belczynski+2018

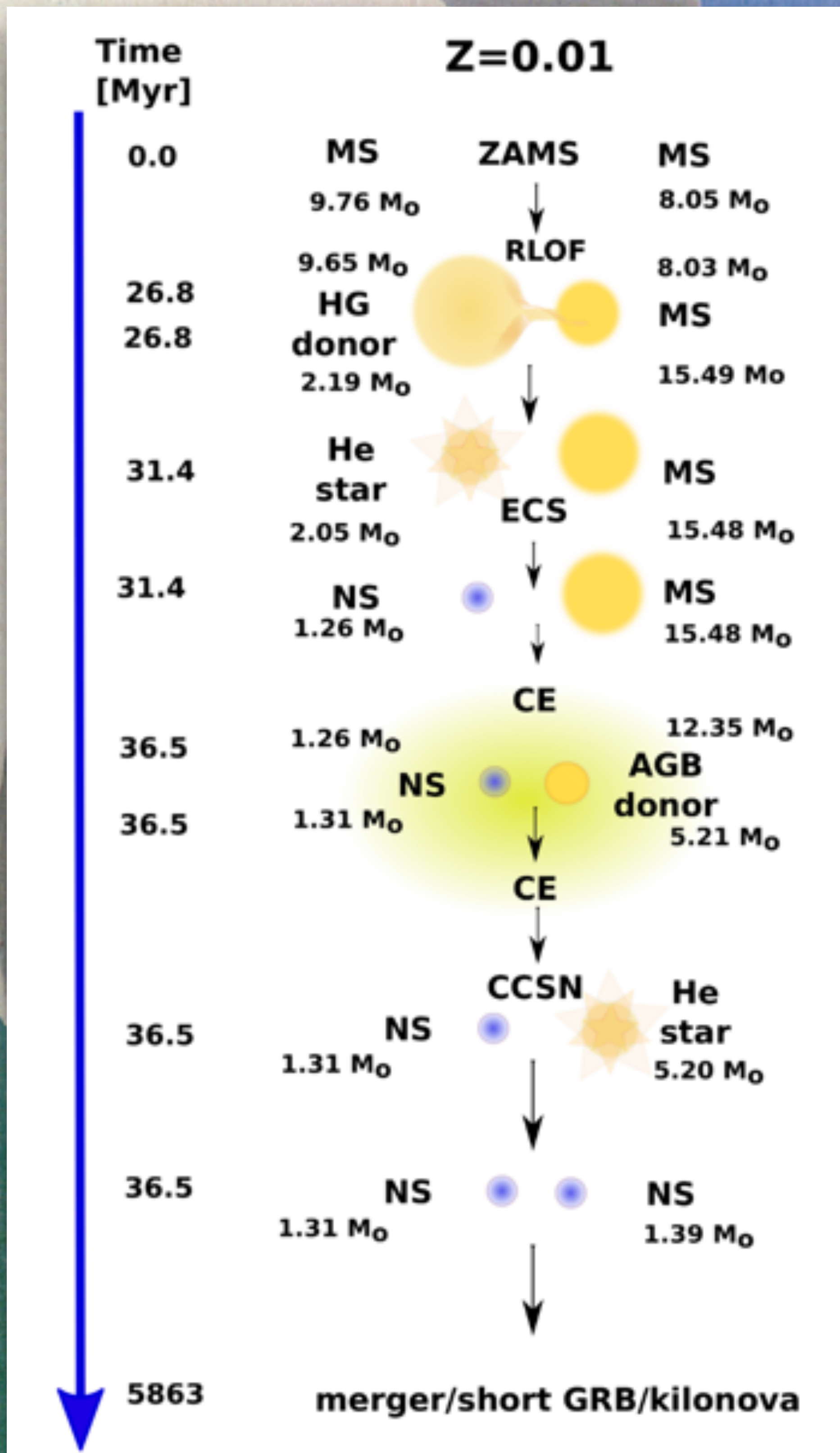


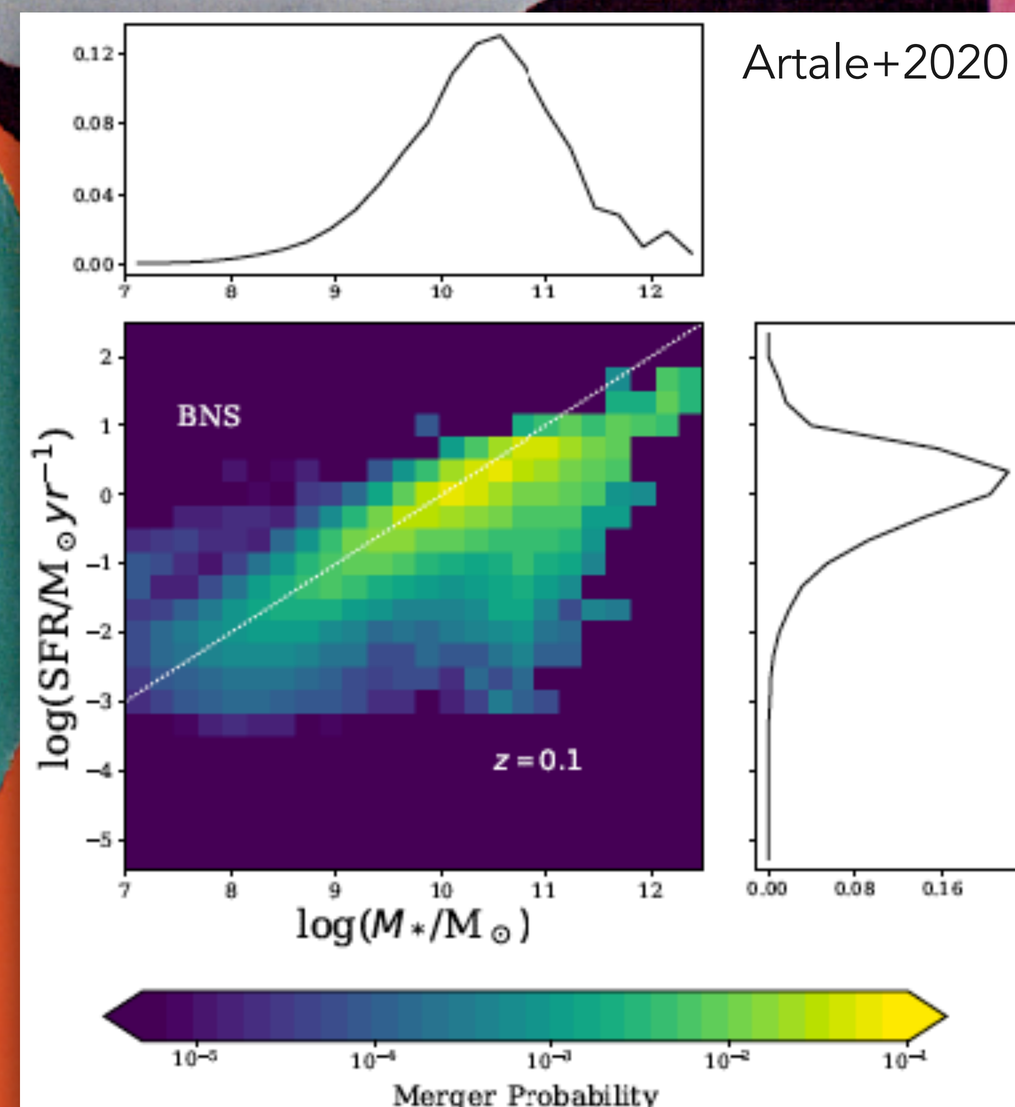


Host Galaxy

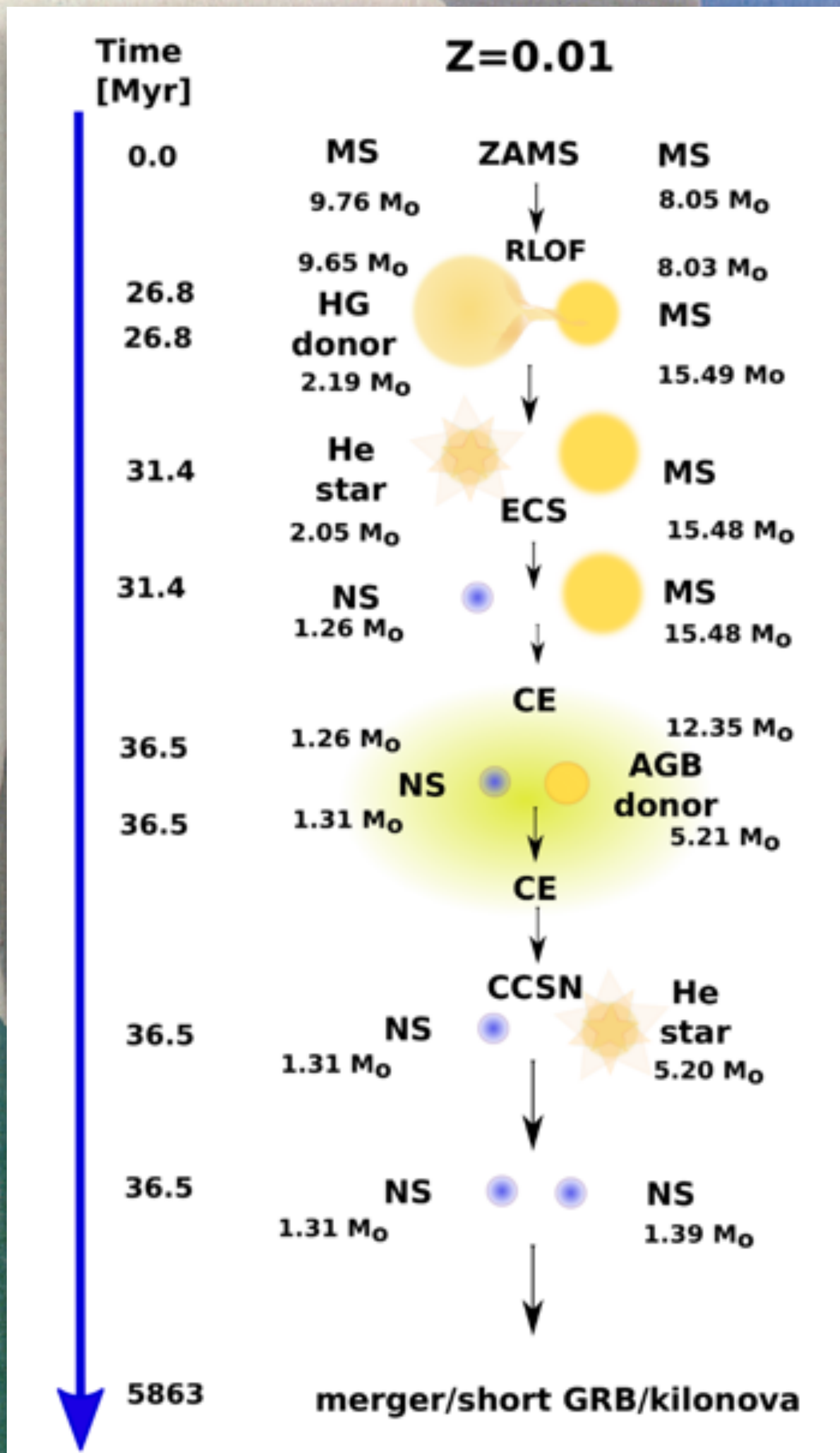
High chance to host a BNS merger

- massive (bright in NIR)
- some SFR (bright in UV-VIS)





Host Galaxy



High chance to host a BNS merger
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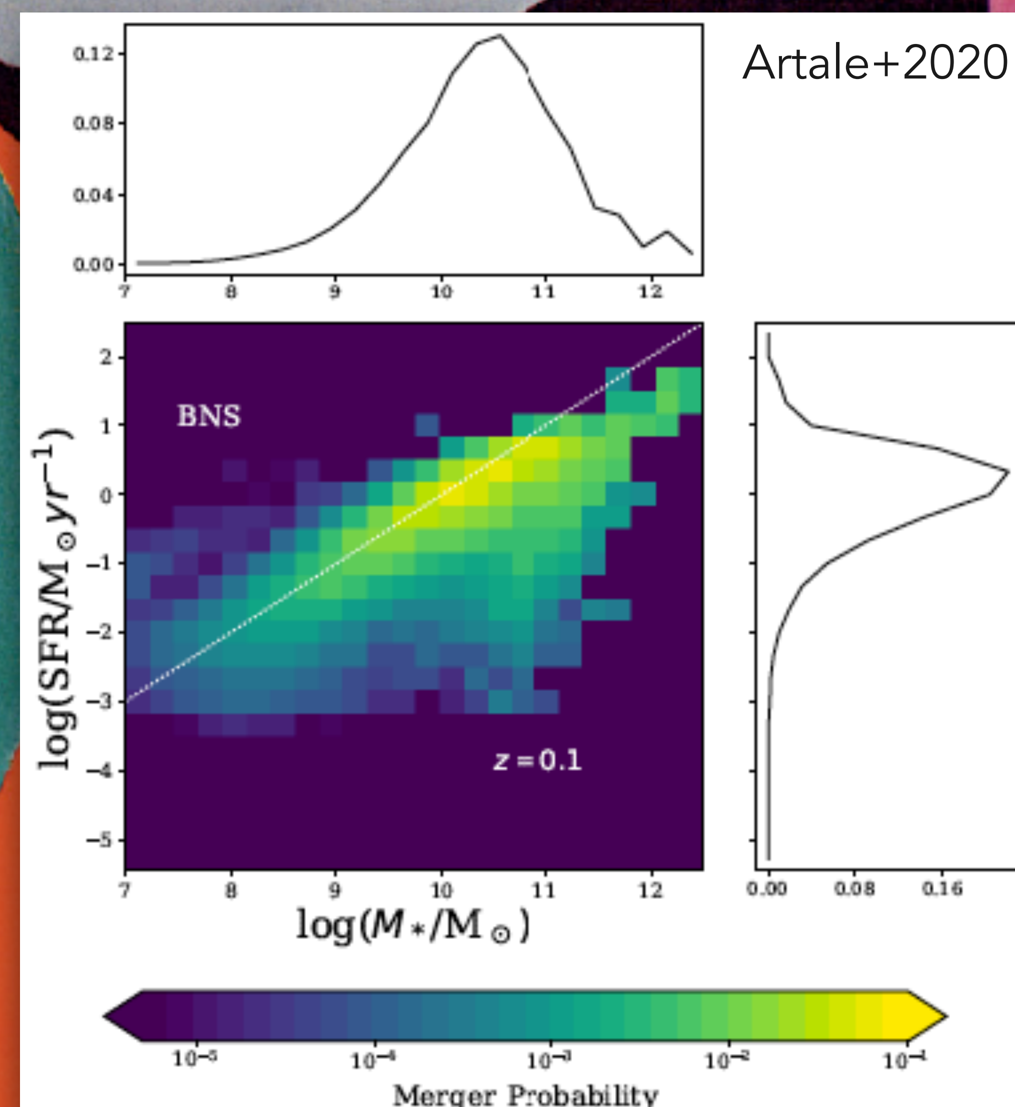
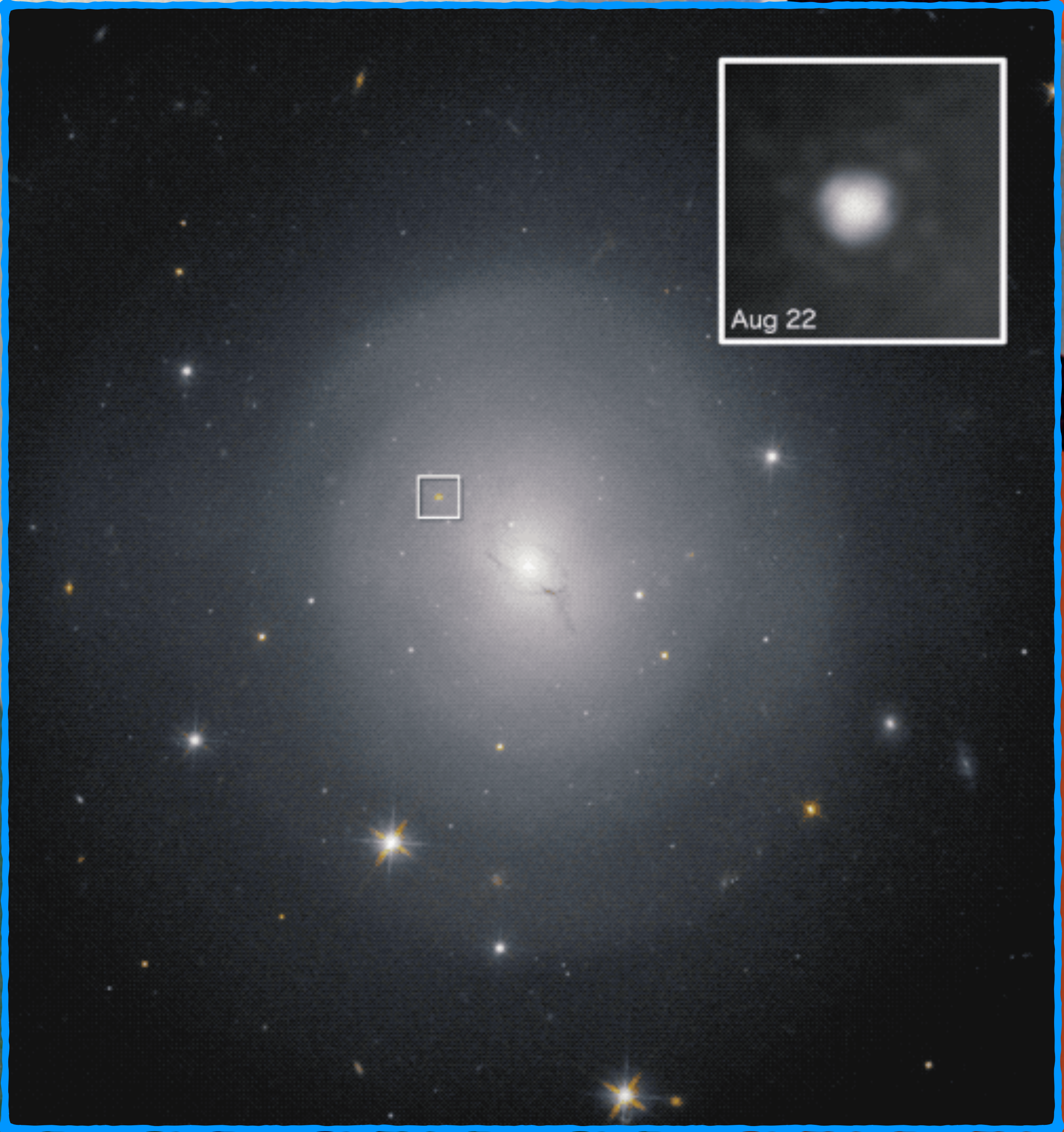


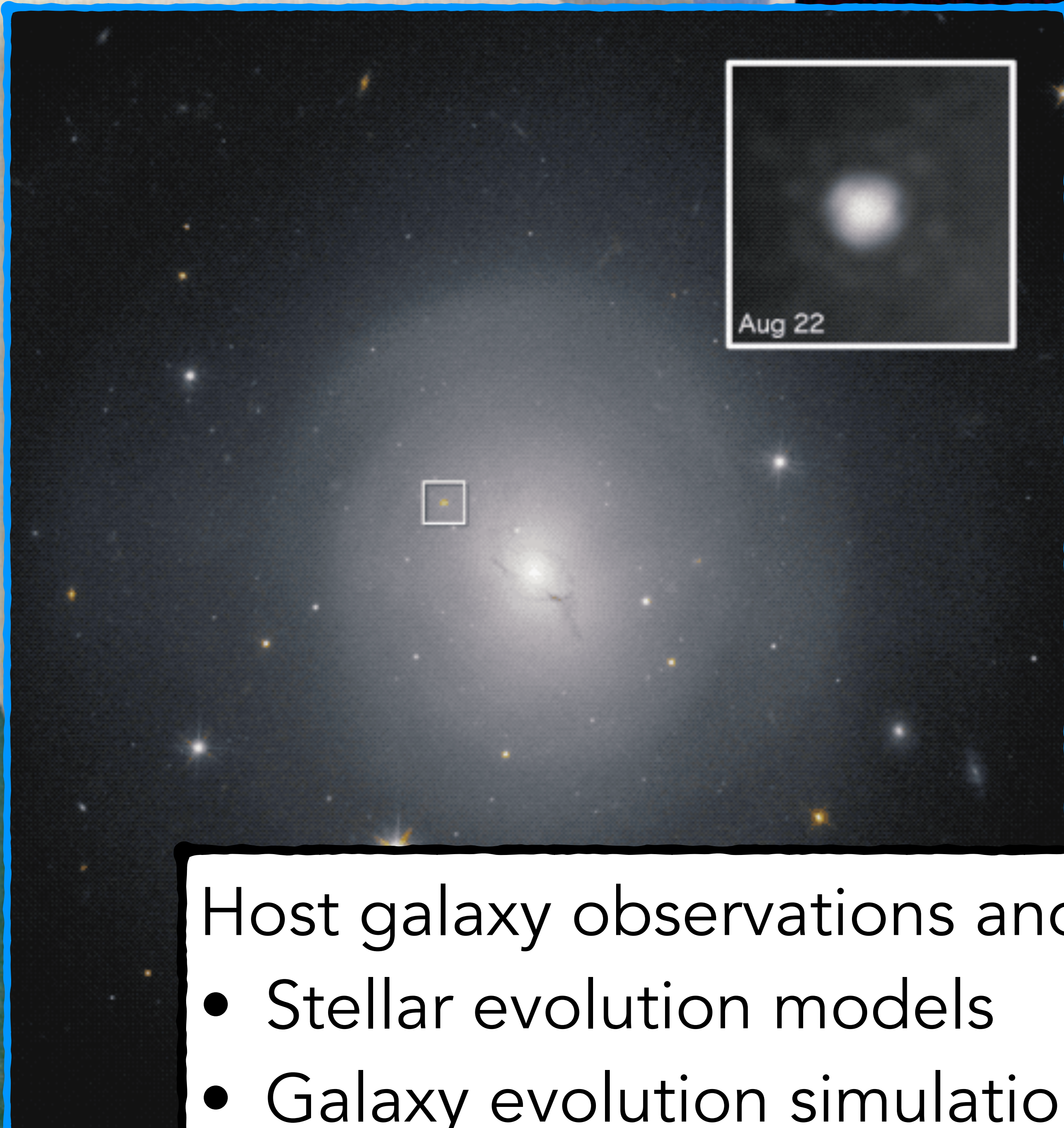
Host Galaxy



Credit: NASA

Credit: Space Telescope Science Institute

Host Galaxy



Credit: NASA

Host galaxy observations and BNS rate

- Stellar evolution models
- Galaxy evolution simulations

Credit: Space Telescope Science Institute

The Electro-Magnetic (EM) counterpart quest

Detection

↓

Identification

↓

Characterization

Detection : necessary …but no astrophysics

Identification : necessary + some astrophysics

Characterization : **Top!**

LIGO-Virgo-Kagra events

Merger of binary system of neutron stars
NS-NS or BNS

Kilonova
(KN)

Relativistic jet
(Gamma-ray burst)

host galaxy
or globular cluster

EM counterparts

LIGO-Virgo-Kagra events

Merger of binary system of neutron stars
NS-NS or BNS

Kilonova
(KN)

Relativistic jet
(Gamma-ray burst)

host galaxy
or globular cluster

Transients!

LIGO-Virgo-Kagra events

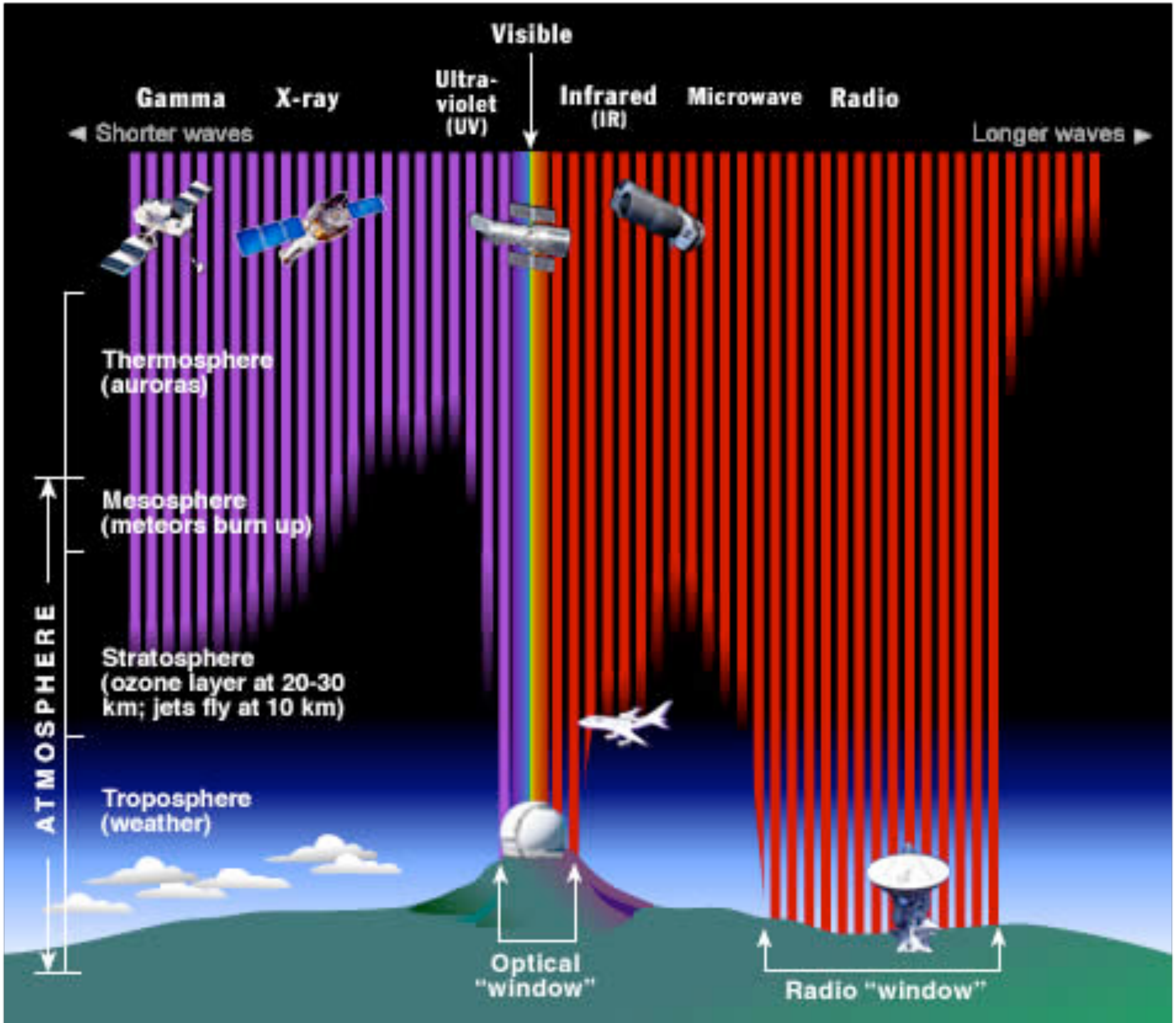
Merger of binary system of neutron stars
NS-NS or BNS

Kilonova
(KN)

Relativistic jet
(Gamma-ray burst)

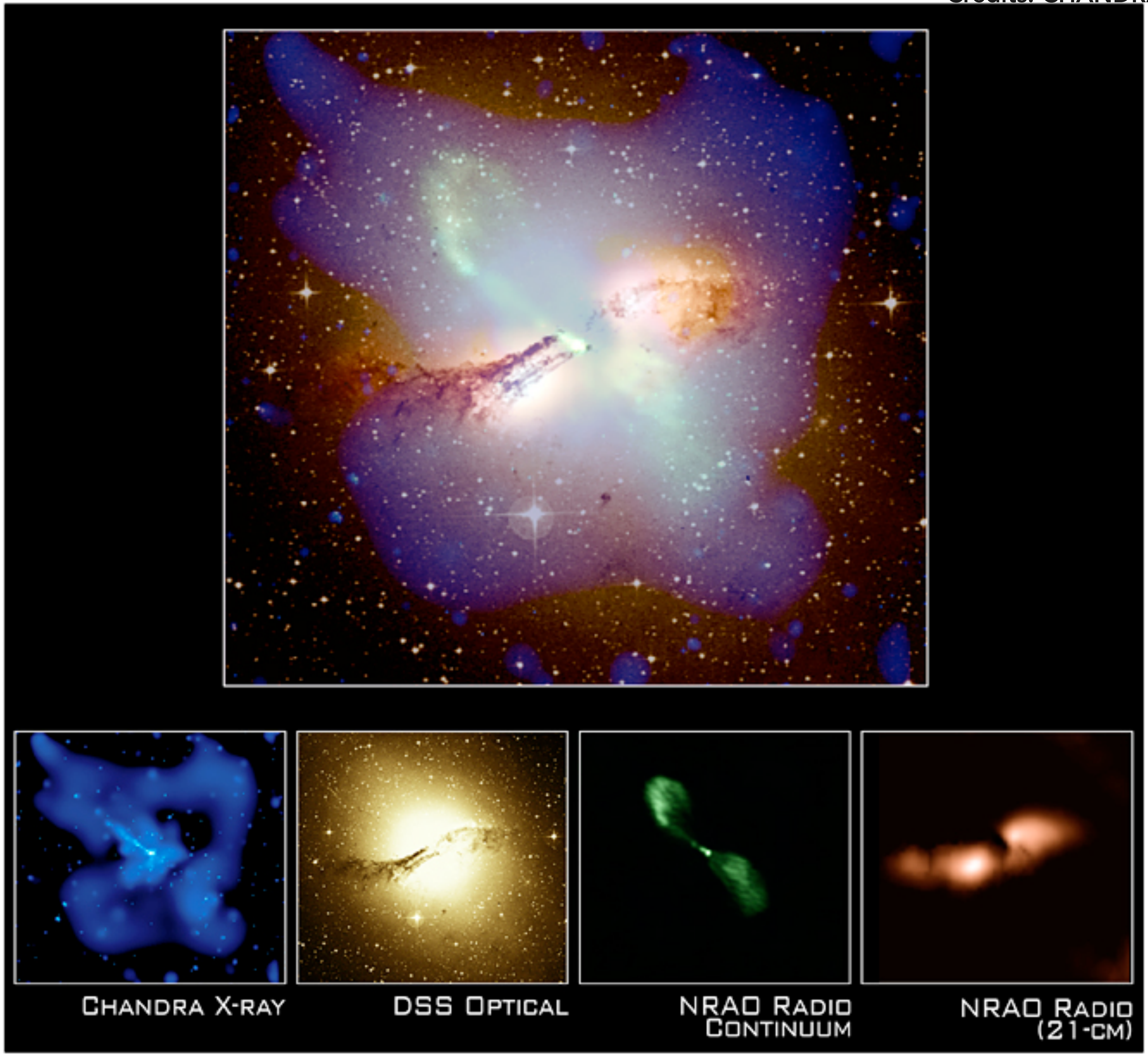
host galaxy
or globular cluster

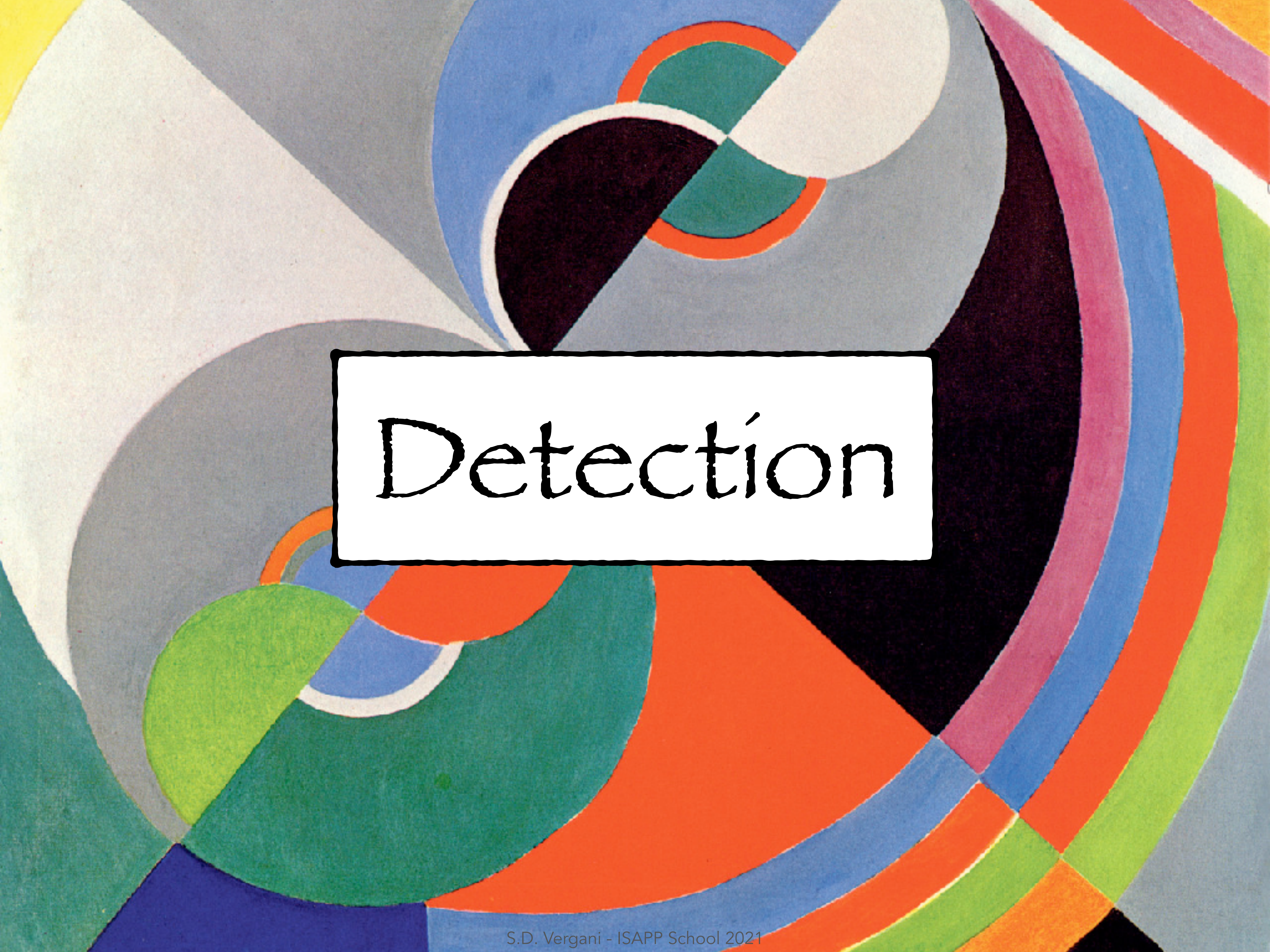
Knowledge based on models and 1 event



Credits: NASA

Credits: CHANDRA





Detection

LIGO-Virgo-Kagra events

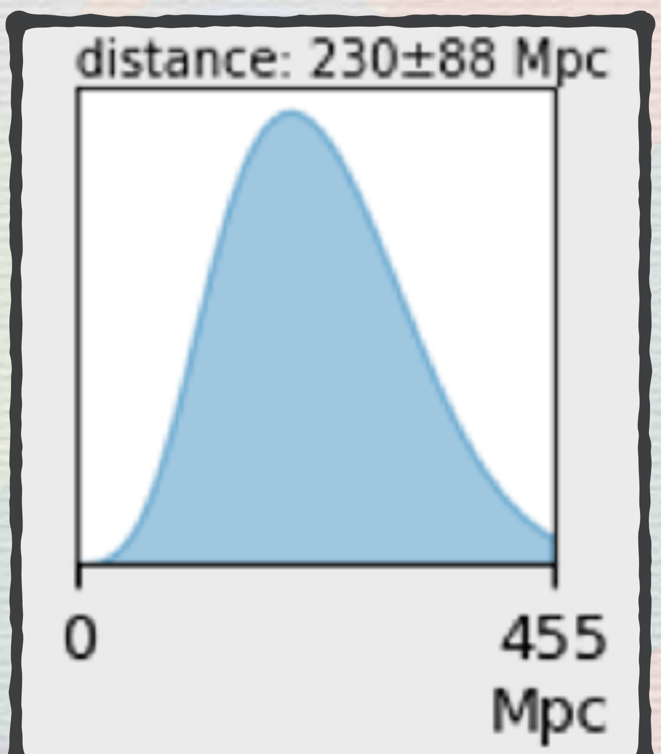
Mergers of binary systems of neutron stars
NS-NS or BNS

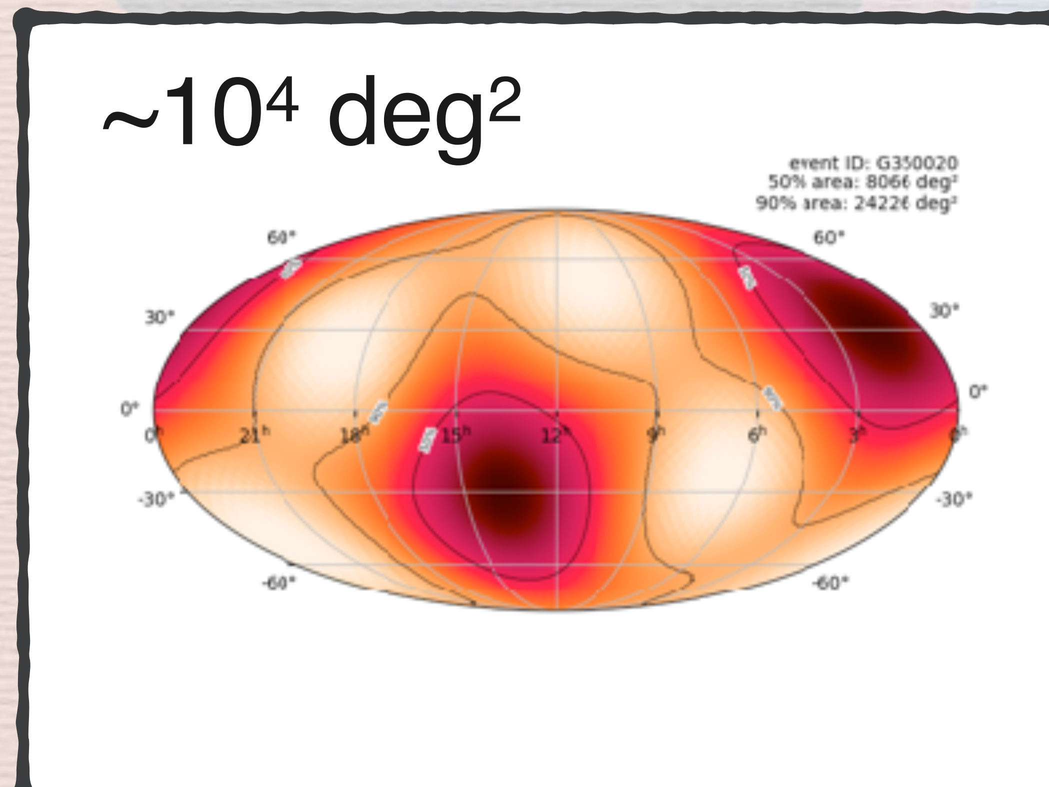
Sky map & Distance

LIGO-Virgo-Kagra events

Mergers of binary systems of neutron stars
NS-NS or BNS

Sky map & Distance

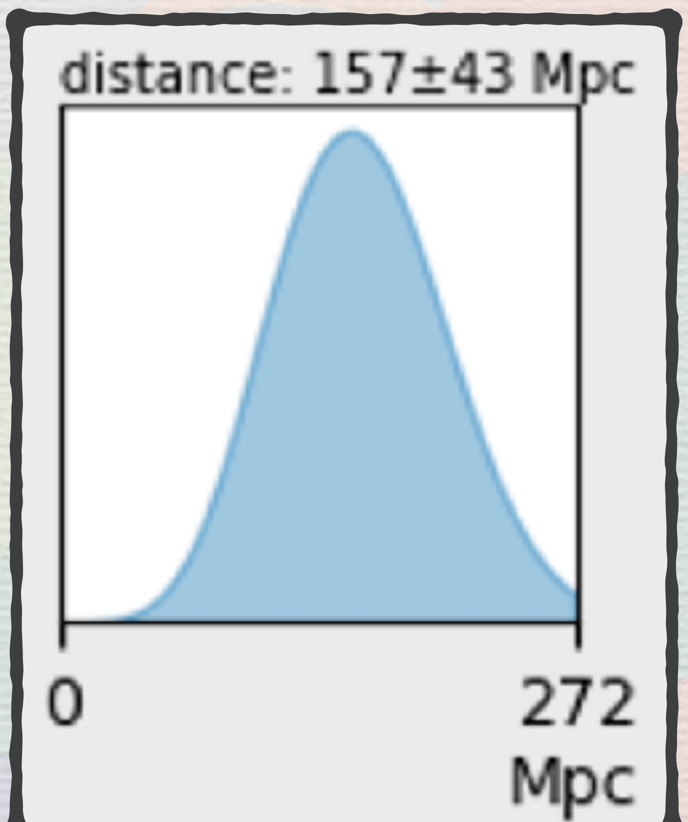


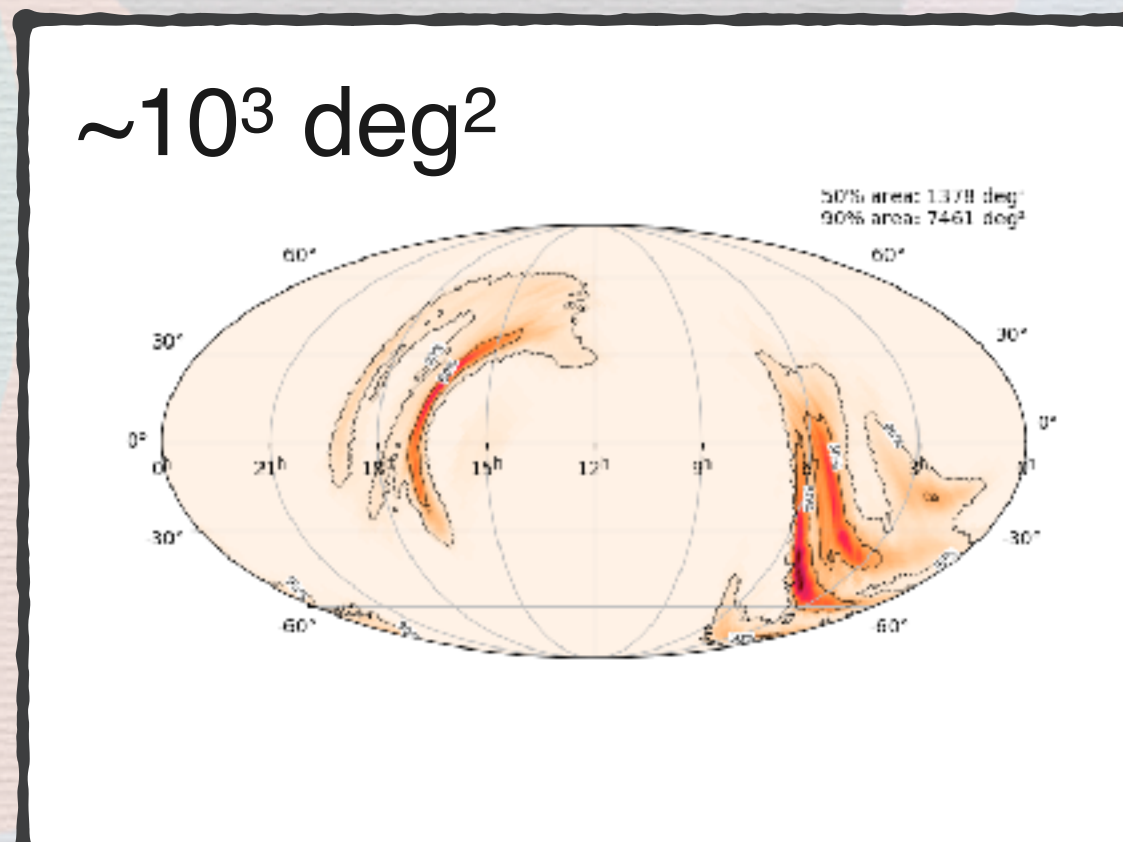


LIGO-Virgo-Kagra events

Mergers of binary systems of neutron stars NS-NS or BNS

Sky map & Distance

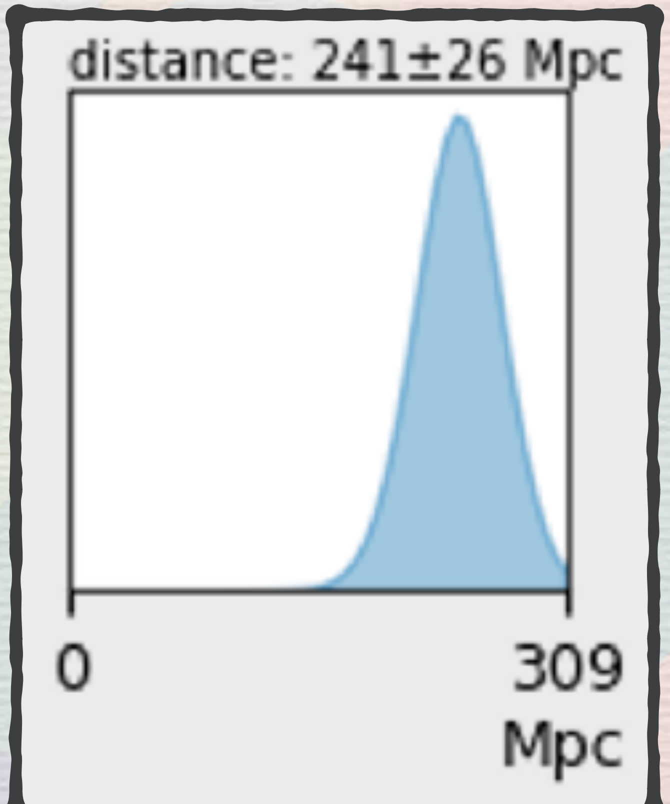




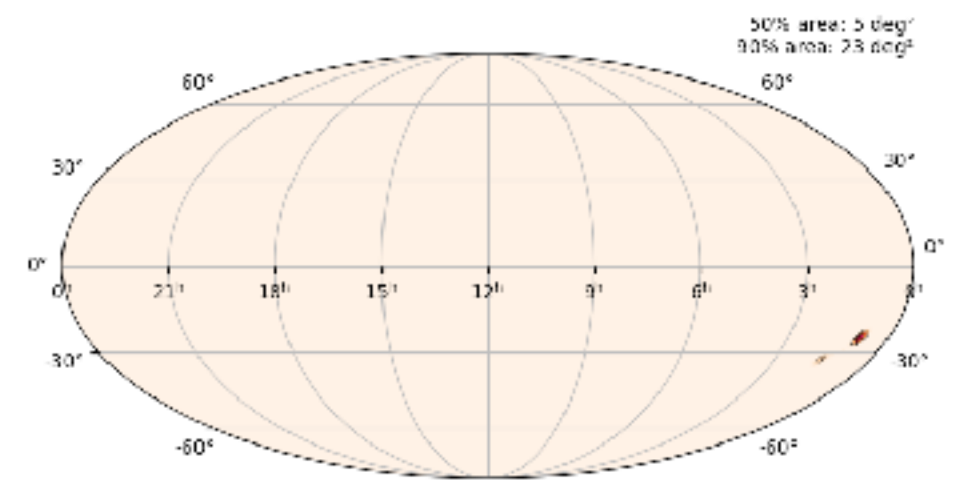
LIGO-Virgo-Kagra events

Mergers of binary systems of neutron stars
NS-NS or BNS

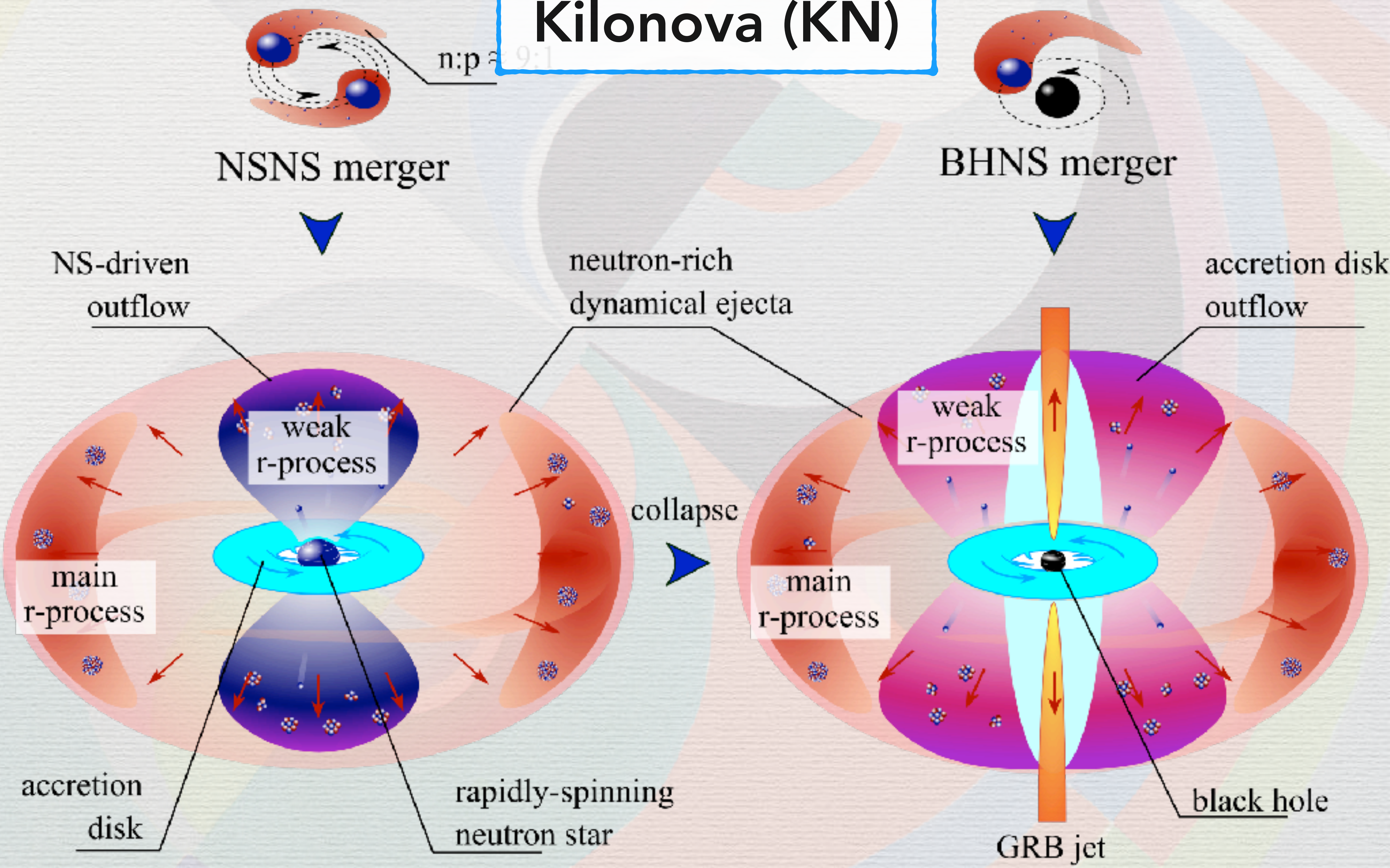
Sky map & Distance



~10 deg^2

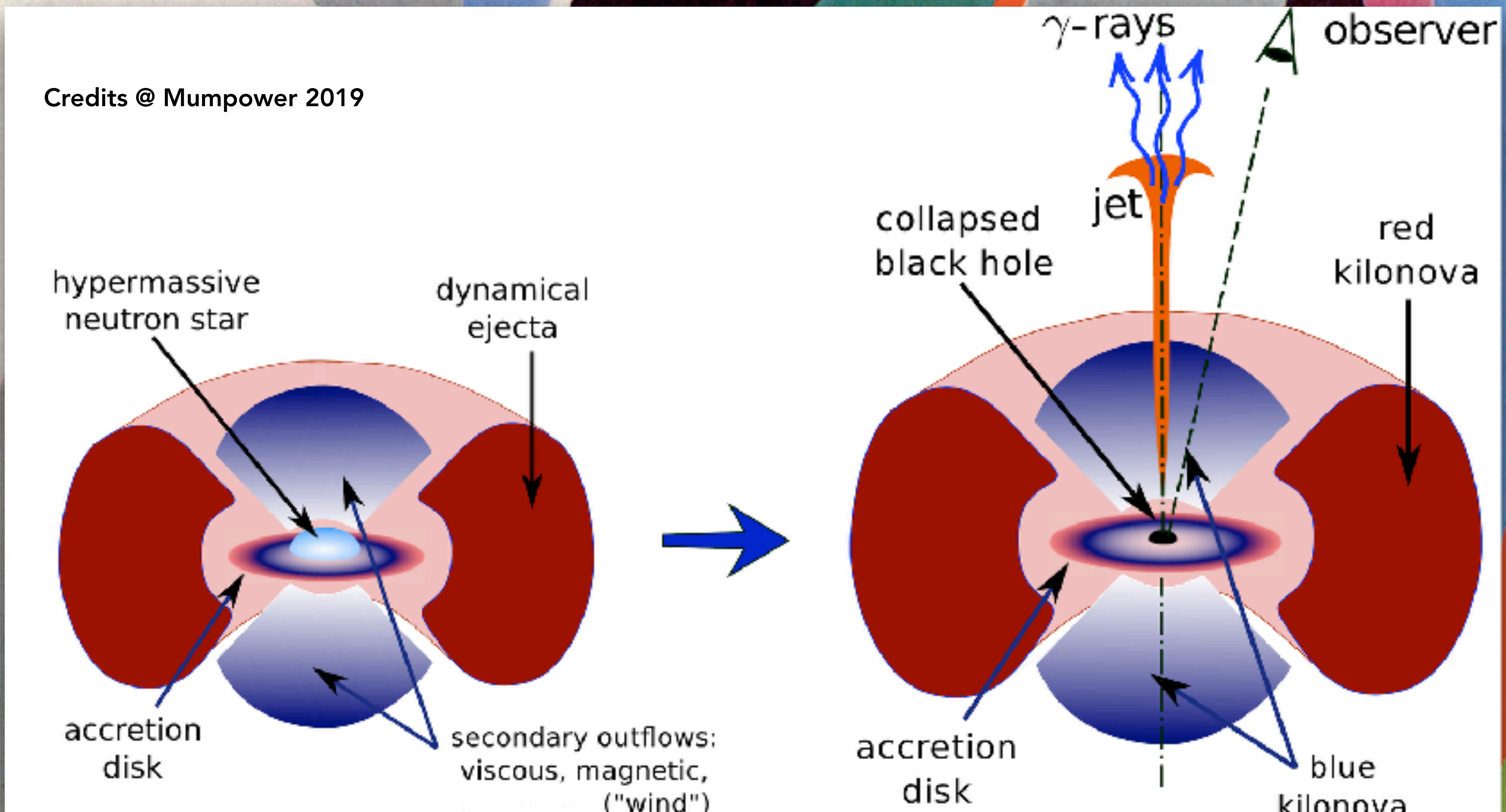


Kilonova (KN)



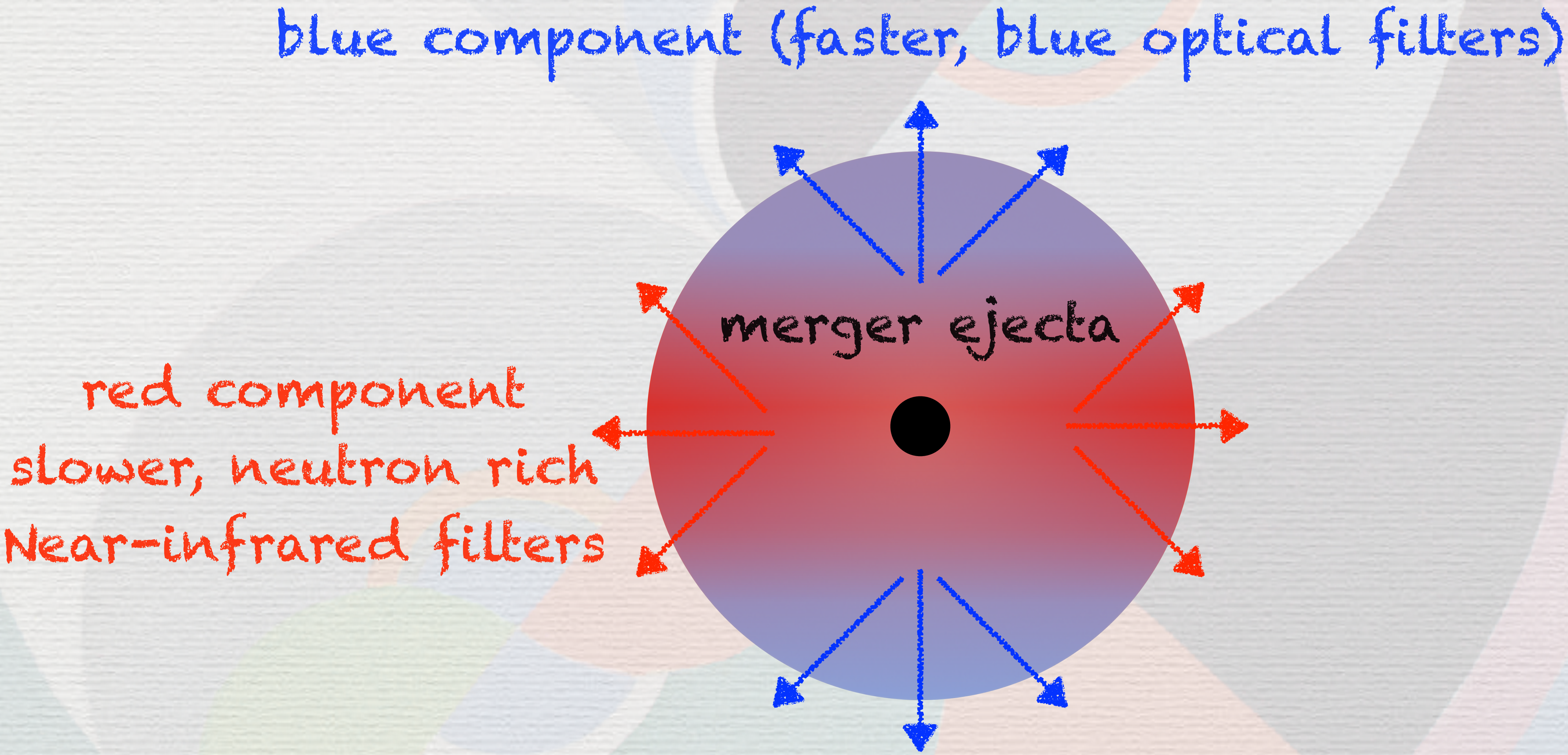
Credits @ Mumpower 2019

Kilonova (KN)

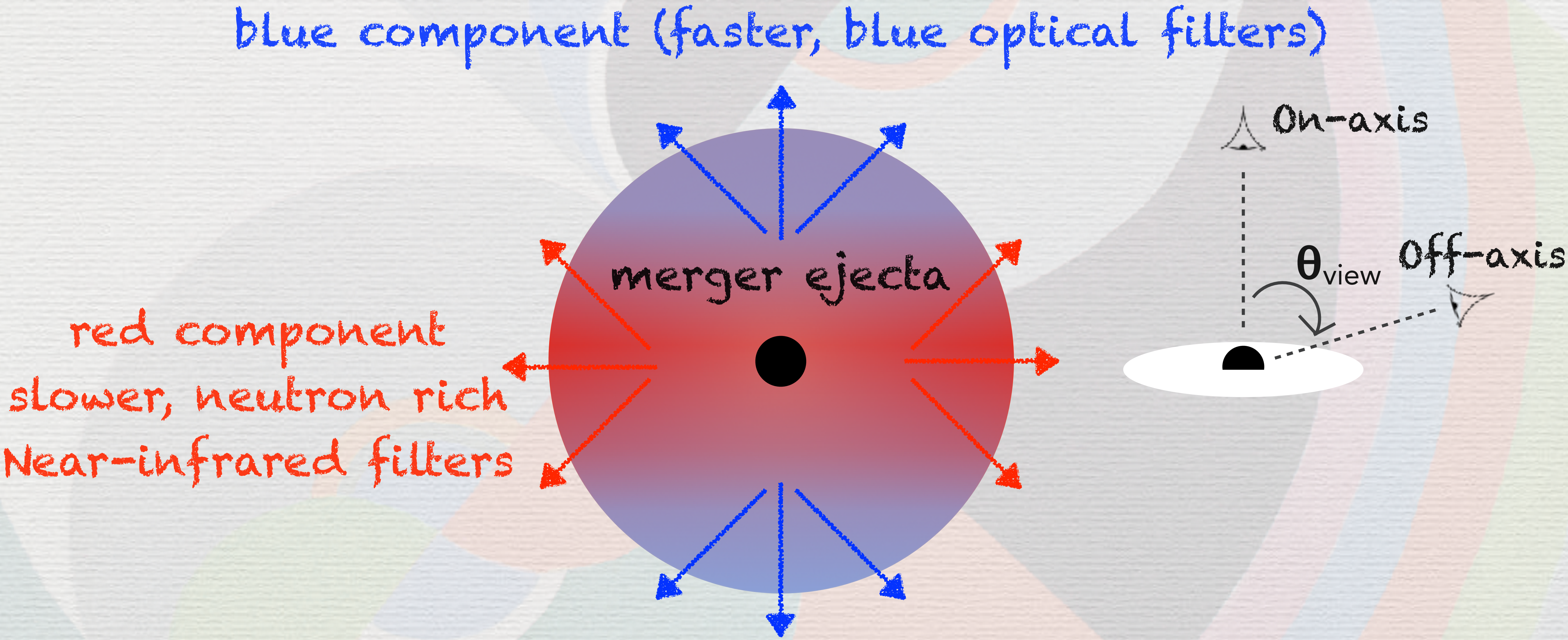


Credits @ Mumpower 2019
hypermassive neutron star
dynamical ejecta
accretion disk
secondary outflows: viscous, magnetic, ("wind")
γ-rays
observer
jet
collapsed black hole
red kilonova
accretion disk
blue kilonova

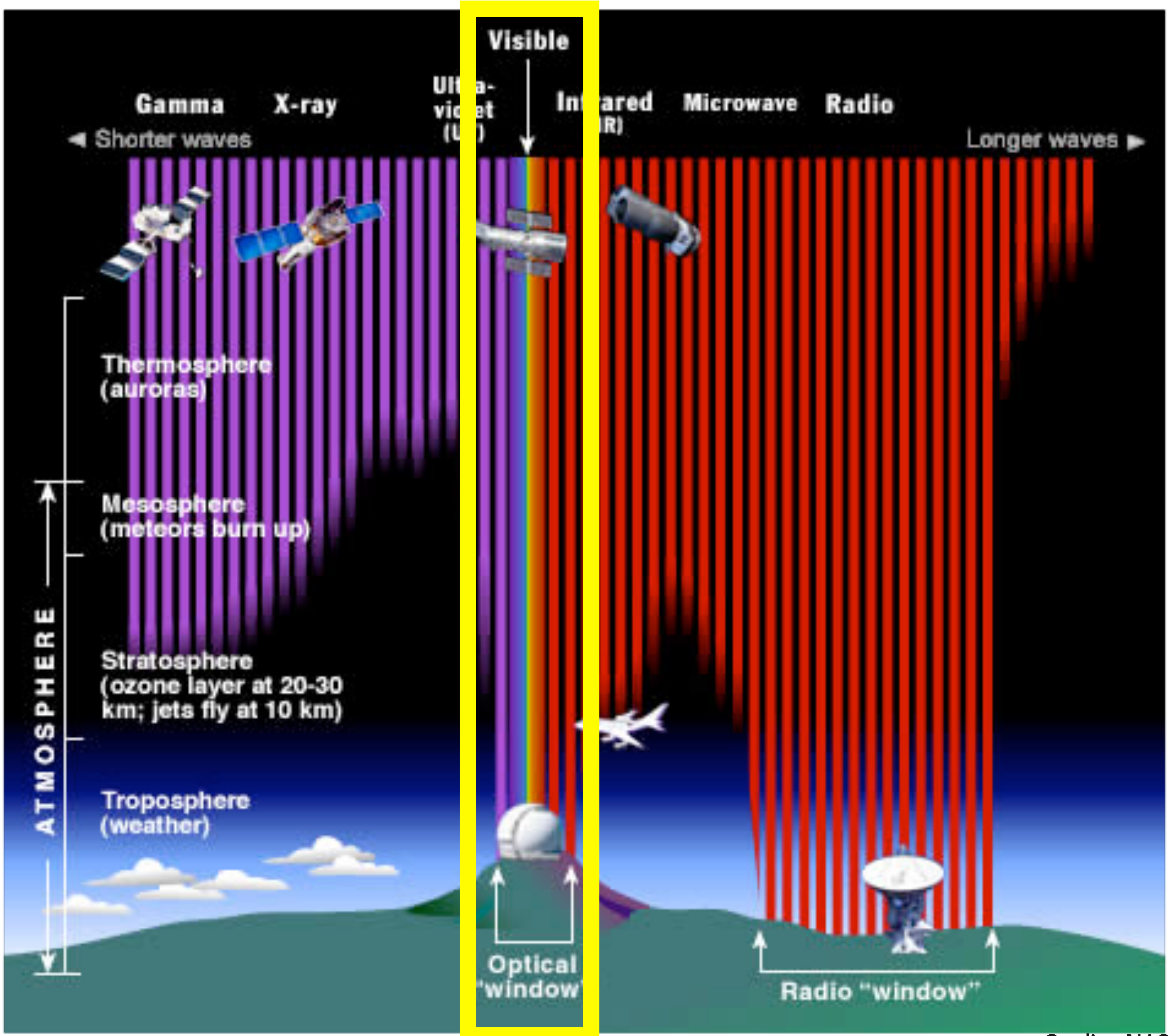
Kilonova (KN)


blue component (faster, blue optical filters)
merger ejecta
red component
slower, neutron rich
Near-infrared filters

Kilonova (KN)



what we see depends on our viewing angle



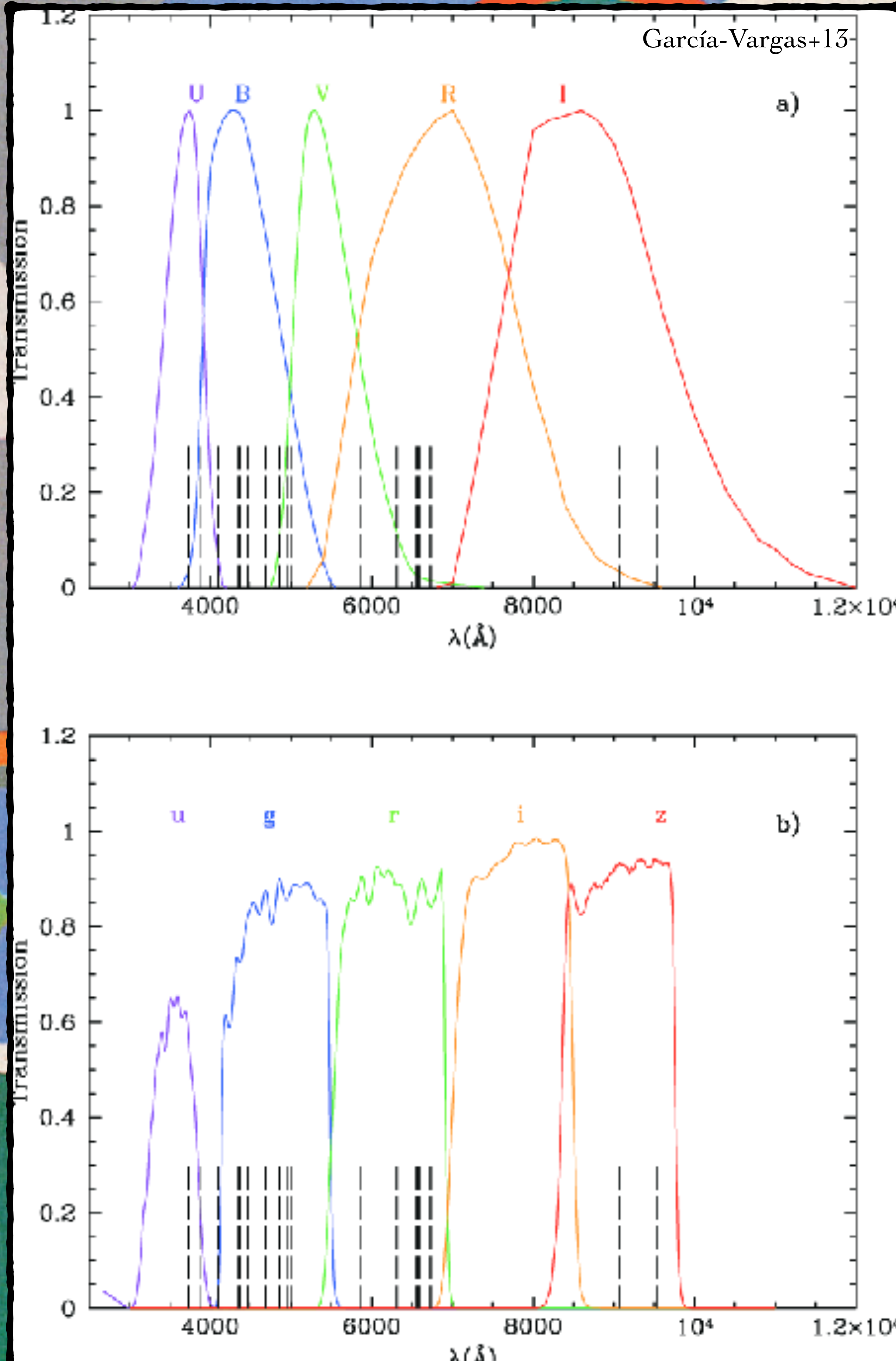
Credits: NASA

Optical Filters

UV → InfraRed

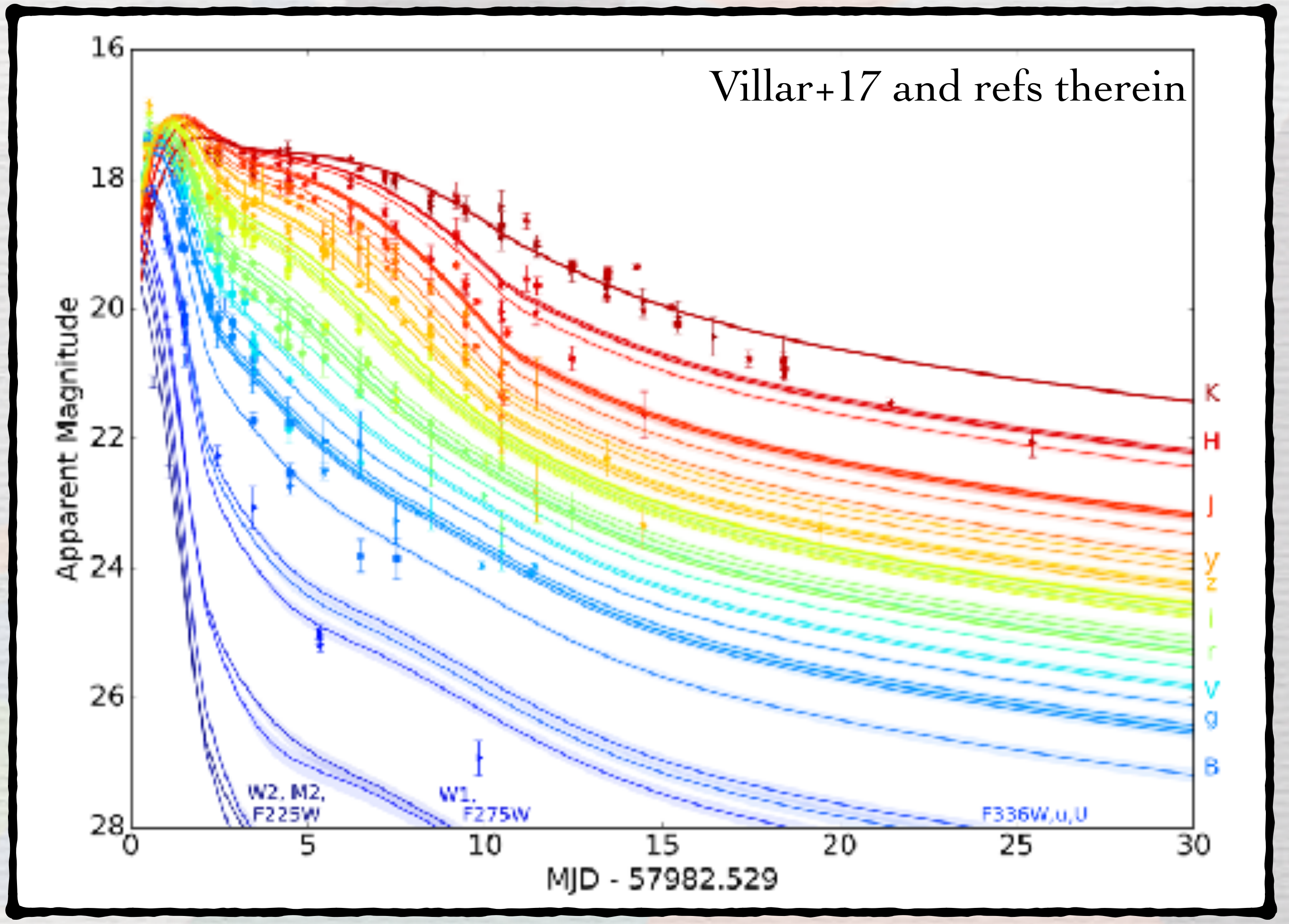
U B V R I J H K

u g r i z y J H K


García-Vargas+13
a)
U
B
V
R
I
Transmission
λ(Å)
b)
u
g
r
i
z
Transmission
λ(Å)

Kilonova (KN)

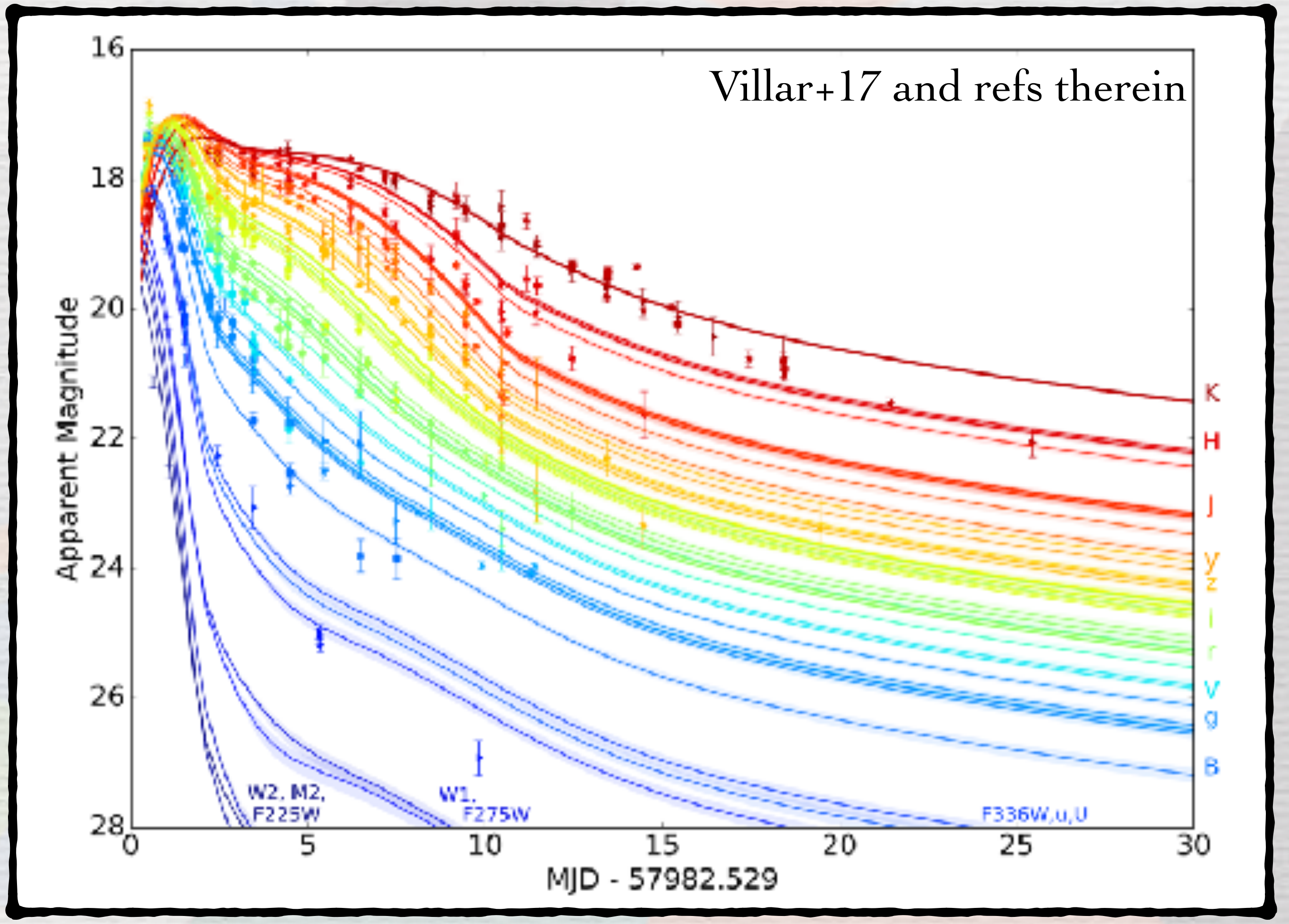
Light-curve



GW170817/AT 2017gfo

Kilonova (KN)

Light-curve



GW170817/AT 2017gfo

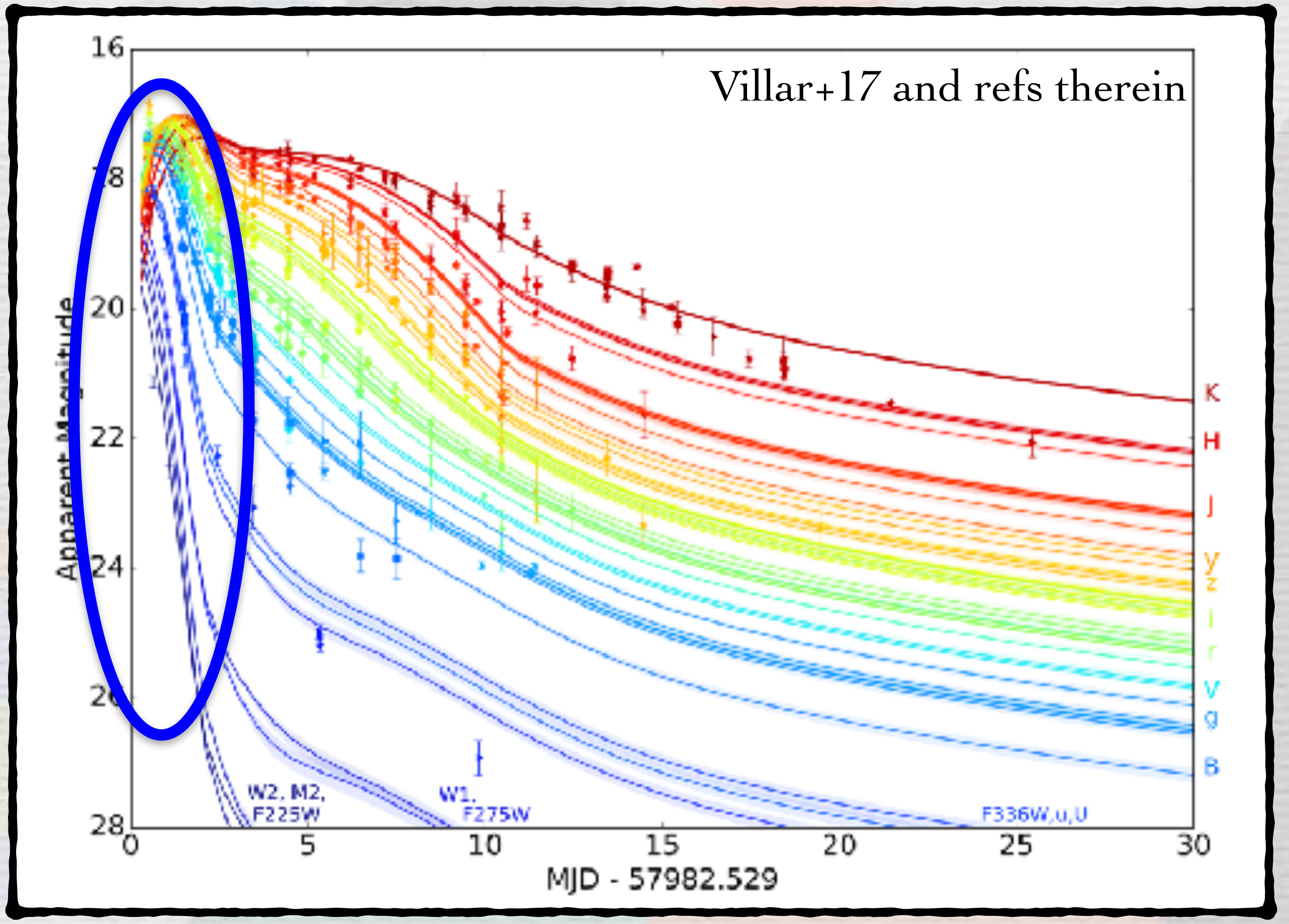
Apparent Magnitude

$$m_x = -2.5 \log_{10}\left(\frac{F_x}{F_{x,0}}\right)$$

$$L_\nu = 4\pi R^2 f$$

Kilonova (KN)

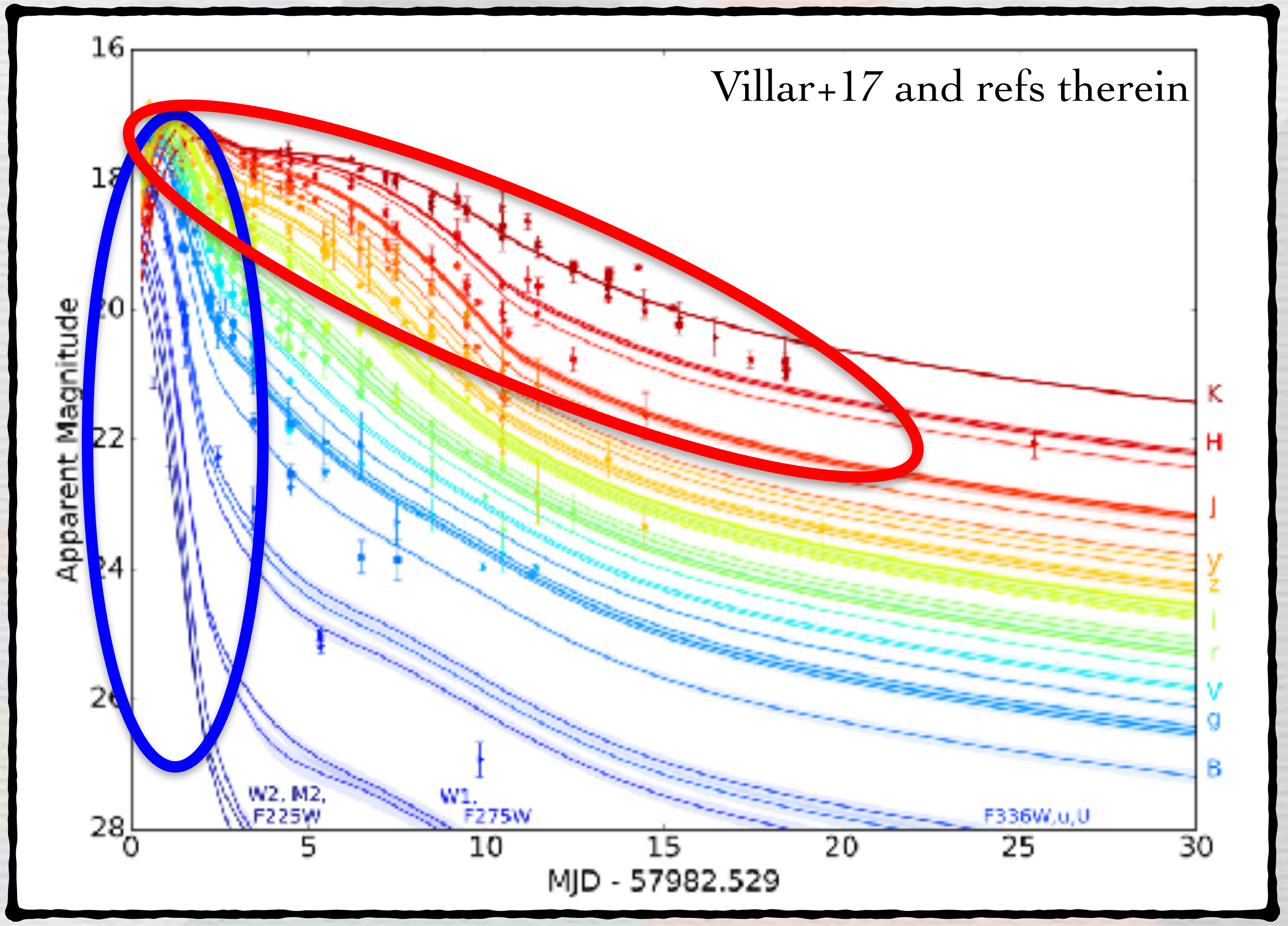
Light-curve



GW170817/AT 2017gfo

Kilonova (KN)

Light-curve



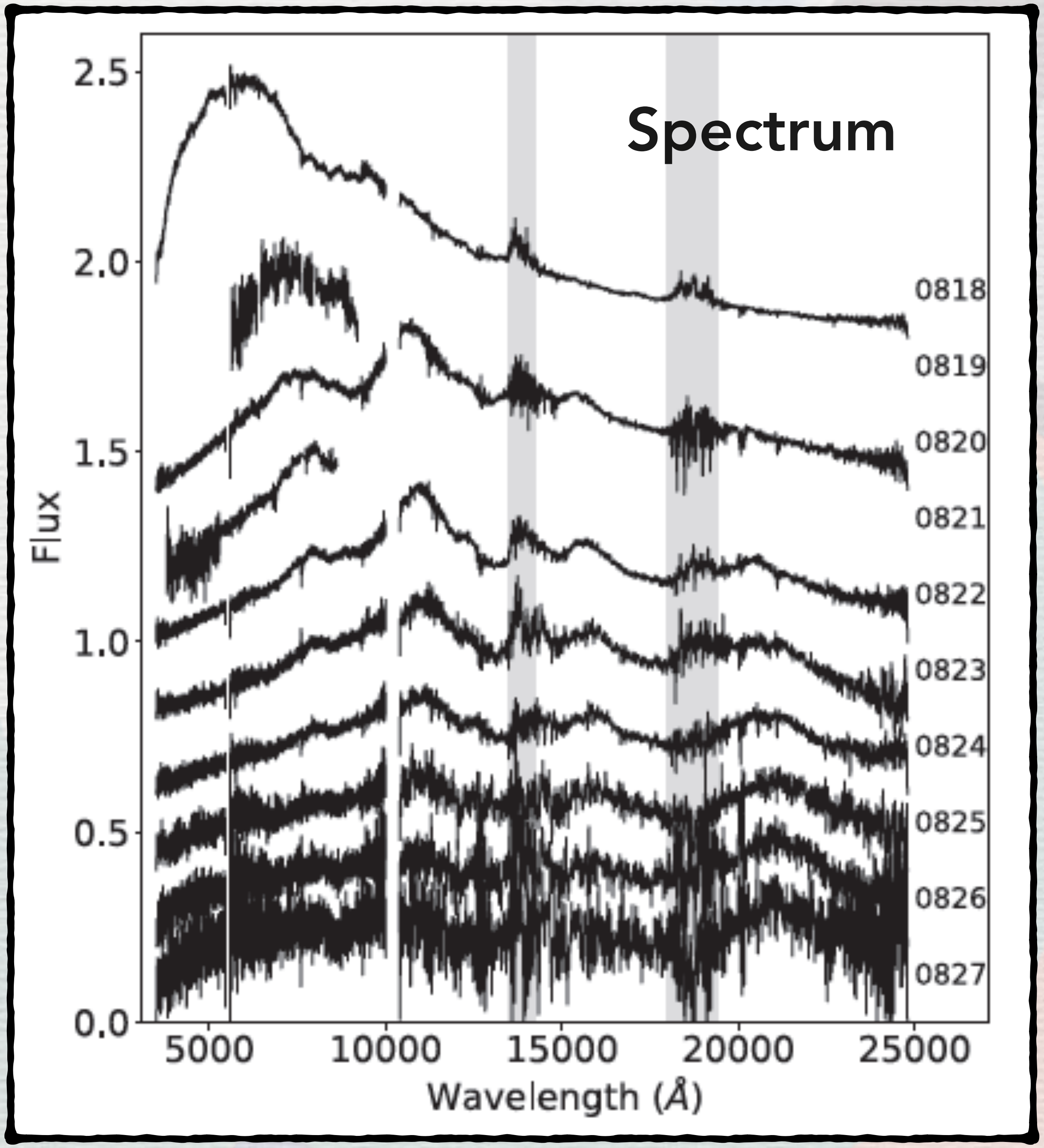
GW170817/AT 2017gfo

Ejecta components
Velocity of the ejecta
Ejected Mass

Kilonova (KN)

ESO-VLT/X-Shooter

Pian et al. 2017, Nature

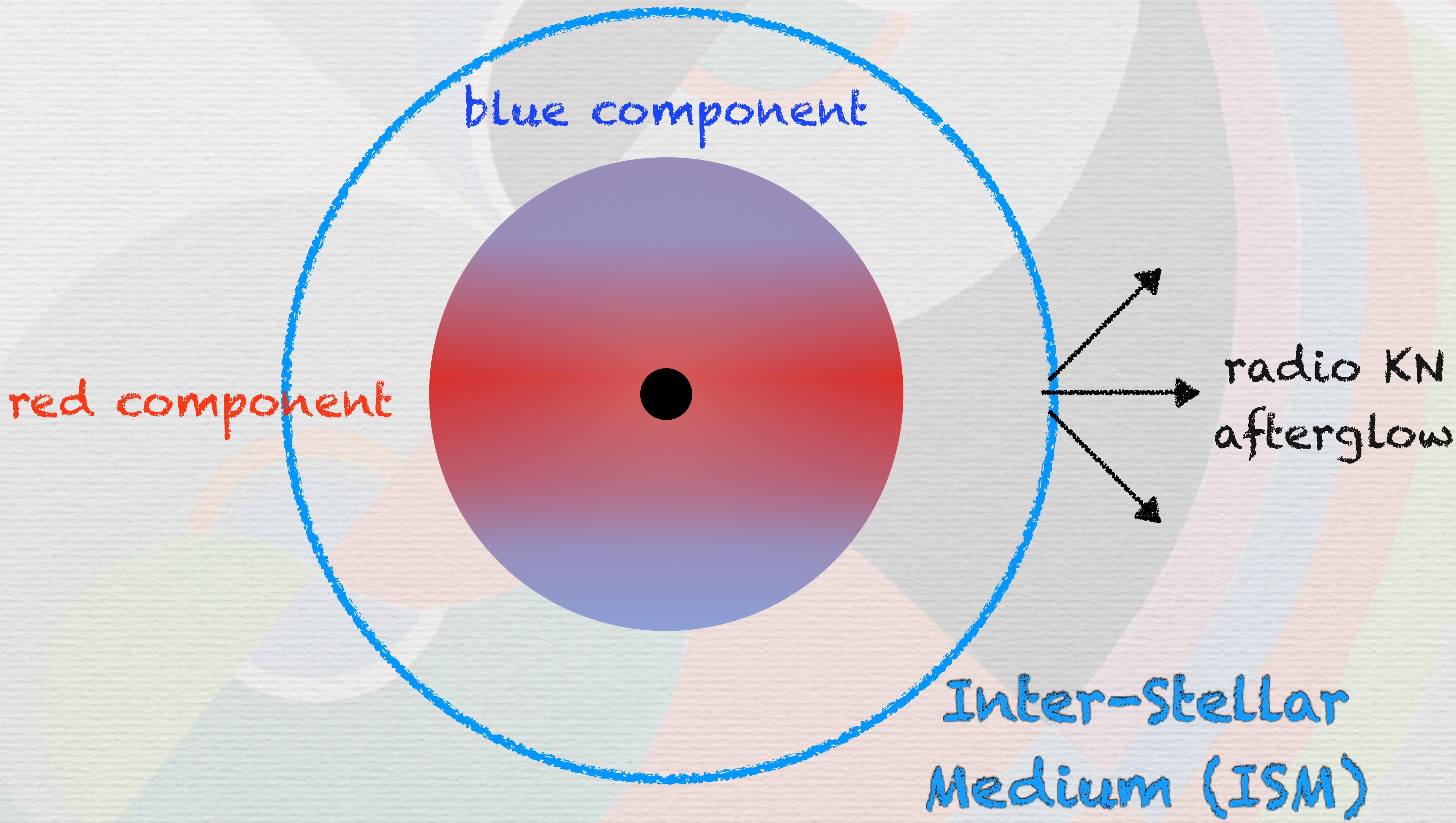


First spectral identification of a KN

- radioactive decay of **r-process nucleosynthesis**
- BNS merger **site for heavy element production in the Universe**

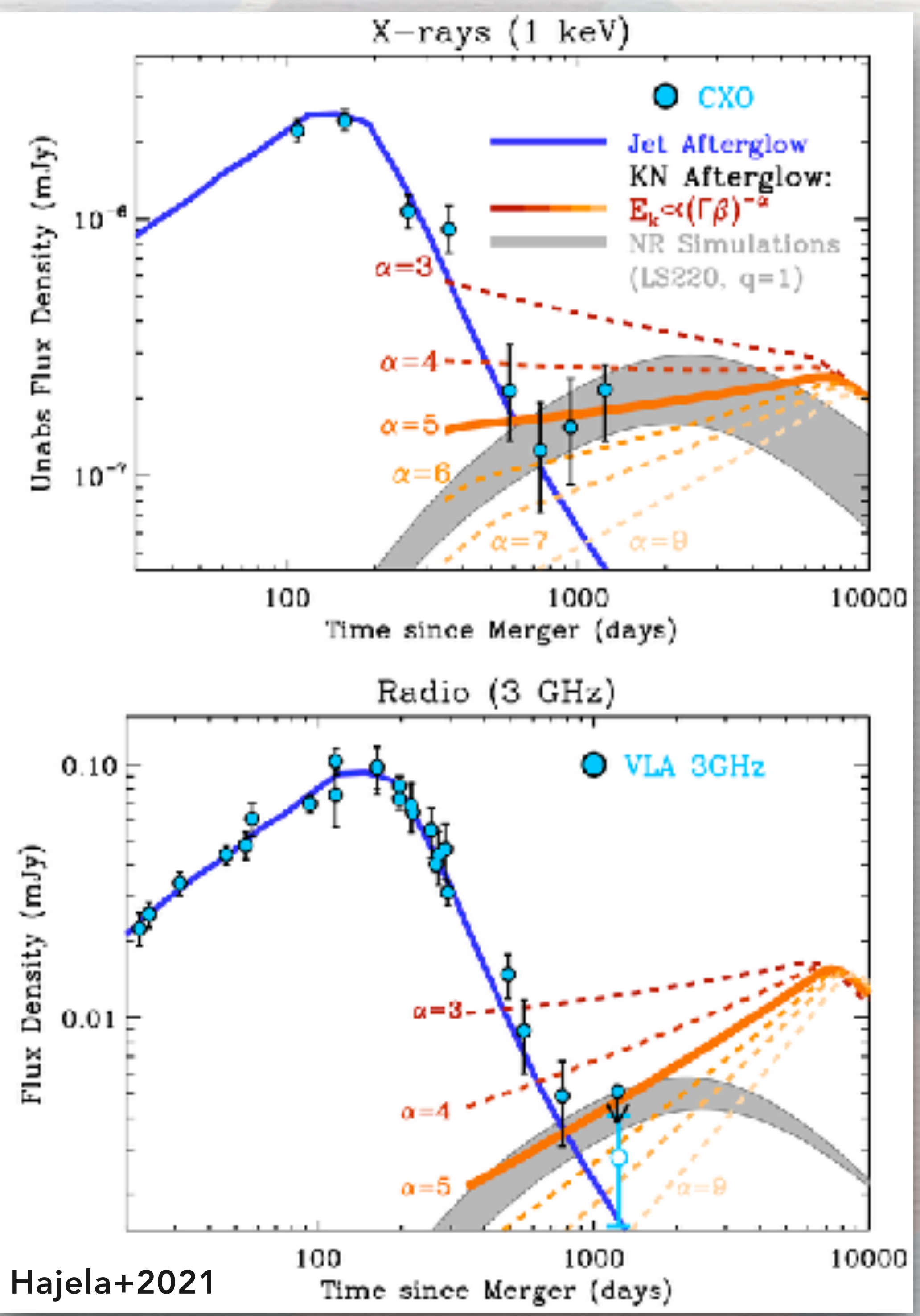
GW170817/GRB170817/AT2017gfo

Kilonova (KN)



blue component
red component
radio KN afterglow
Inter-Stellar Medium (ISM)

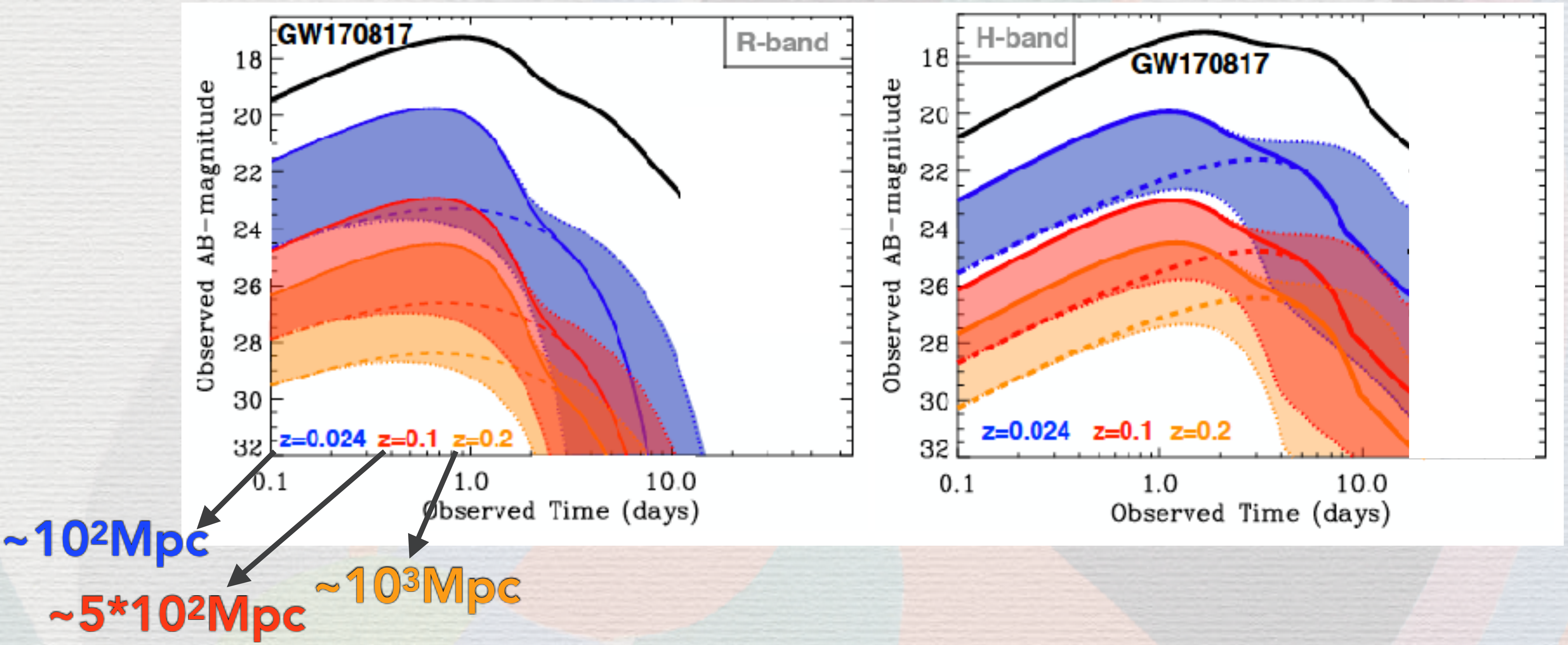
Kilonova (KN)



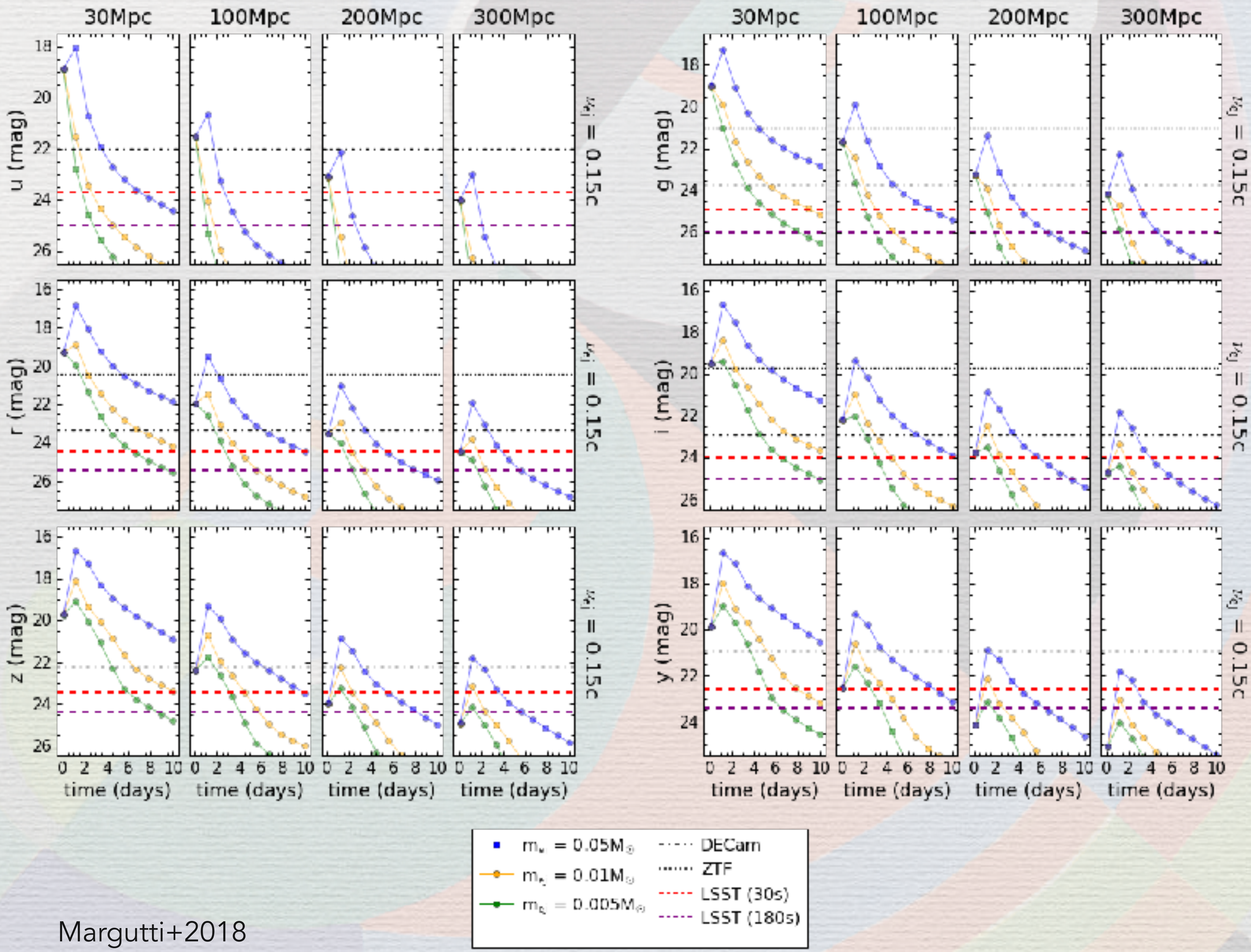
Hajela+2021

Kilonova (KN)

adapted from Chornock+2019

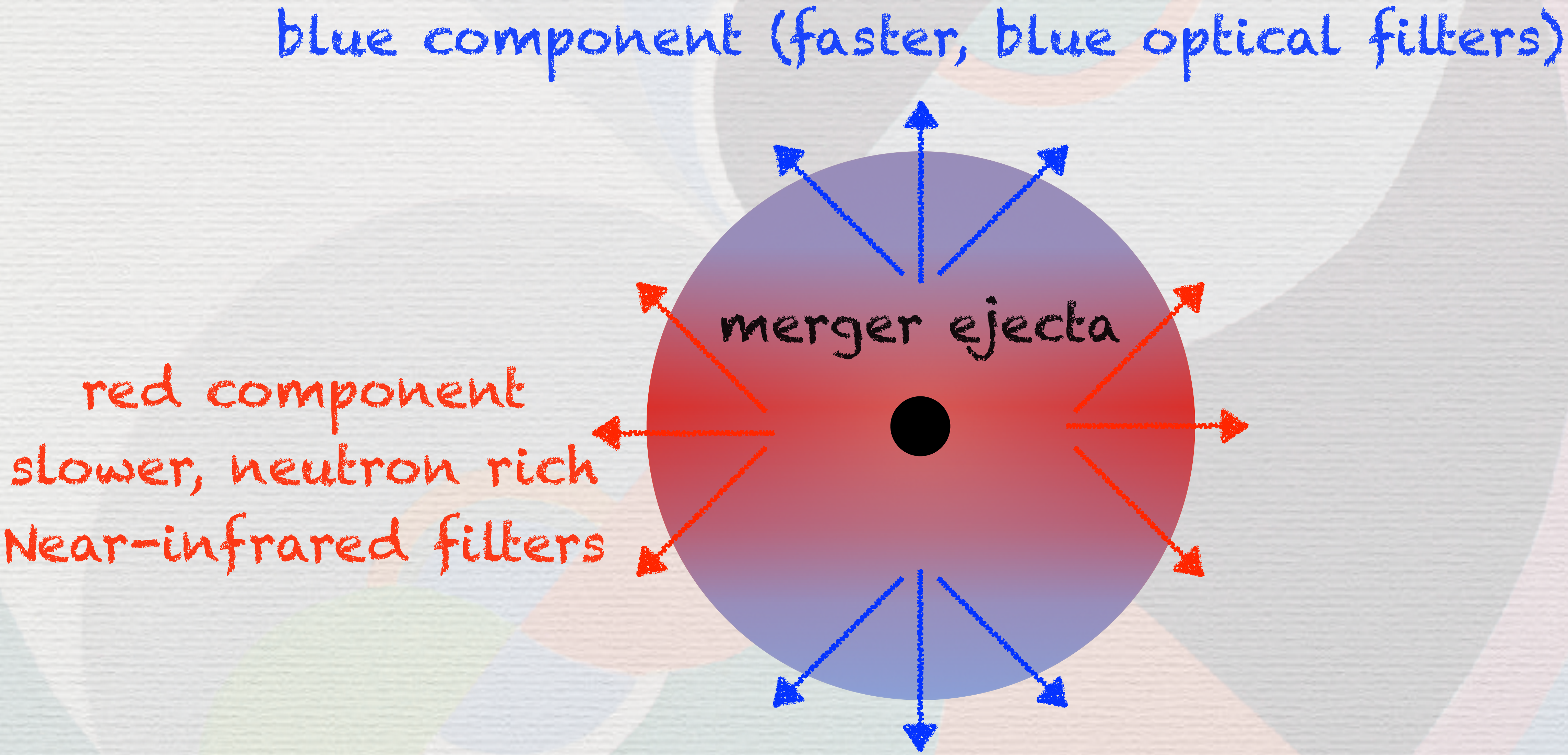


Kilonova (KN)



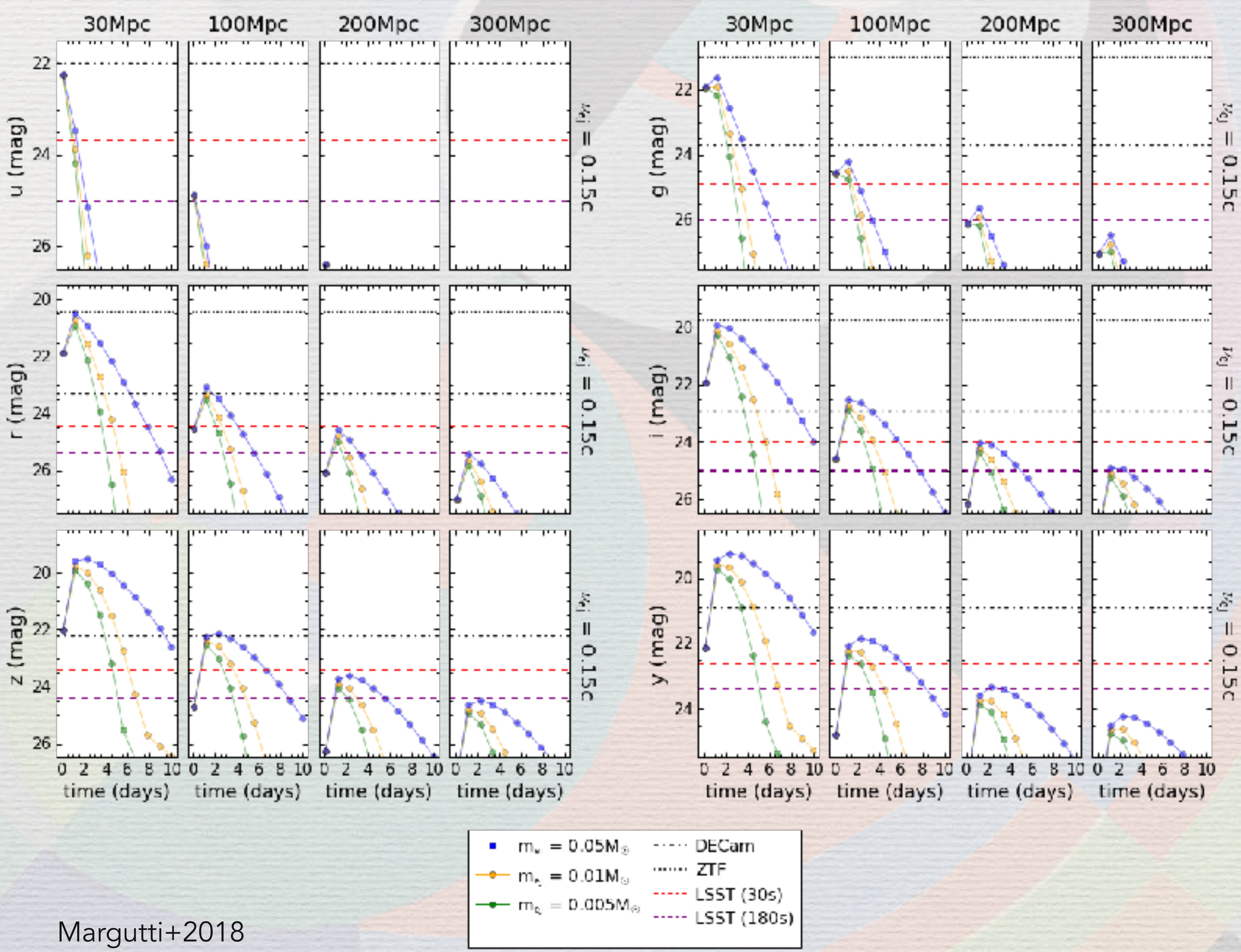
Margutti+2018

Kilonova (KN)



what we see depends on our viewing angle

Kilonova (KN)



Margutti+2018

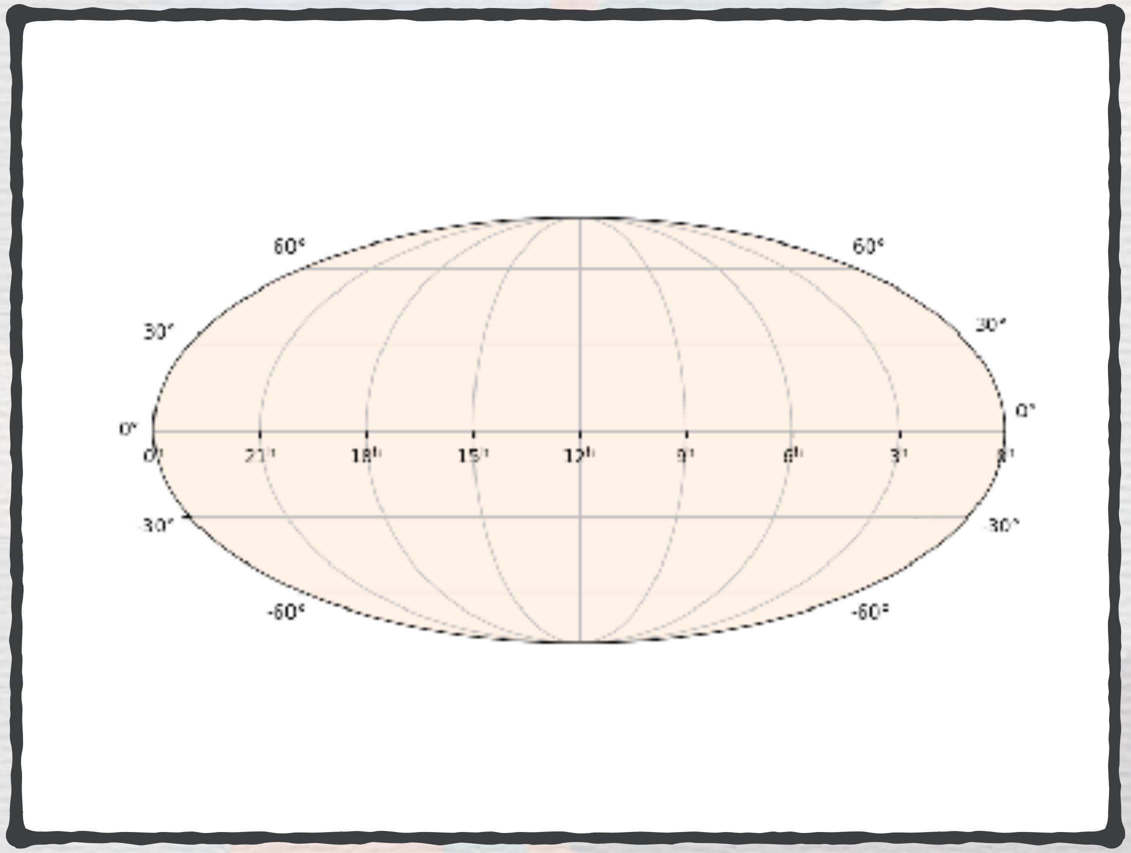
Detection

I need observations that :

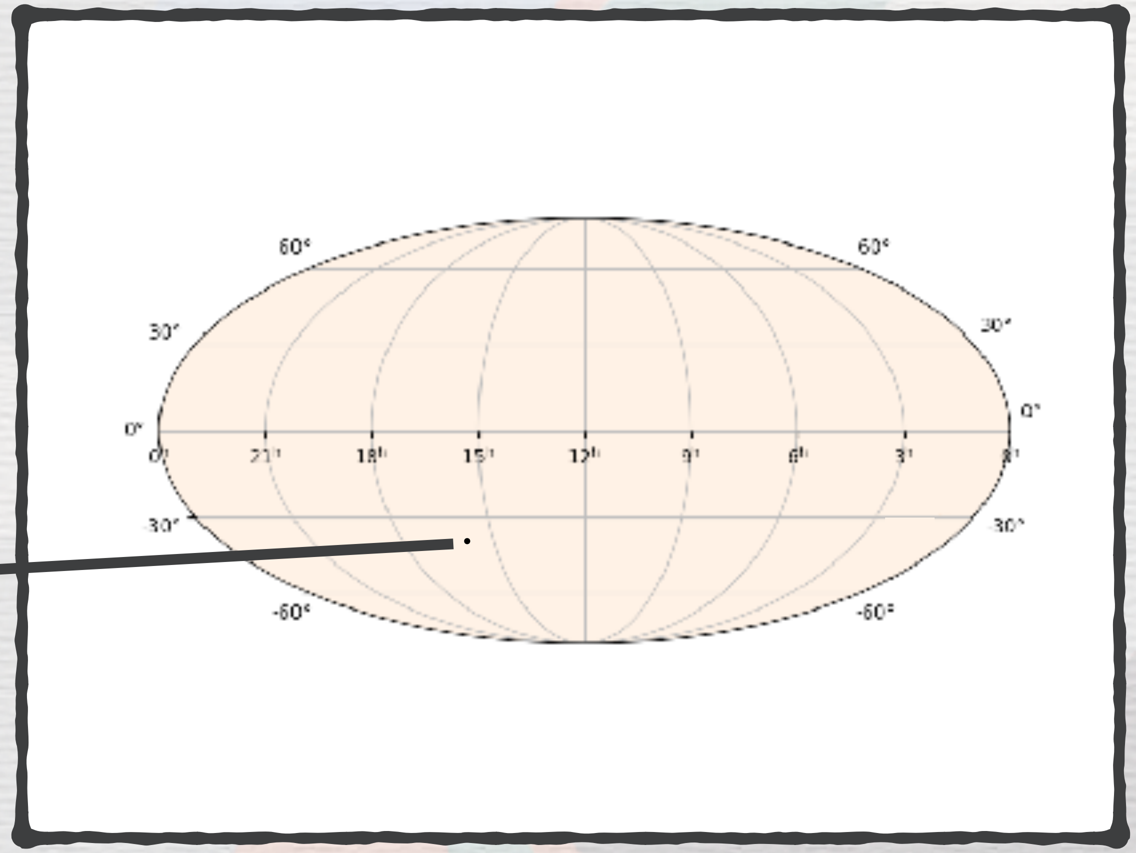
- cover the sky map
- reach the expected magnitudes
  (in a "small" amount of time)

N.B.: The telescope time is limited!!!

Field of view (FOV)



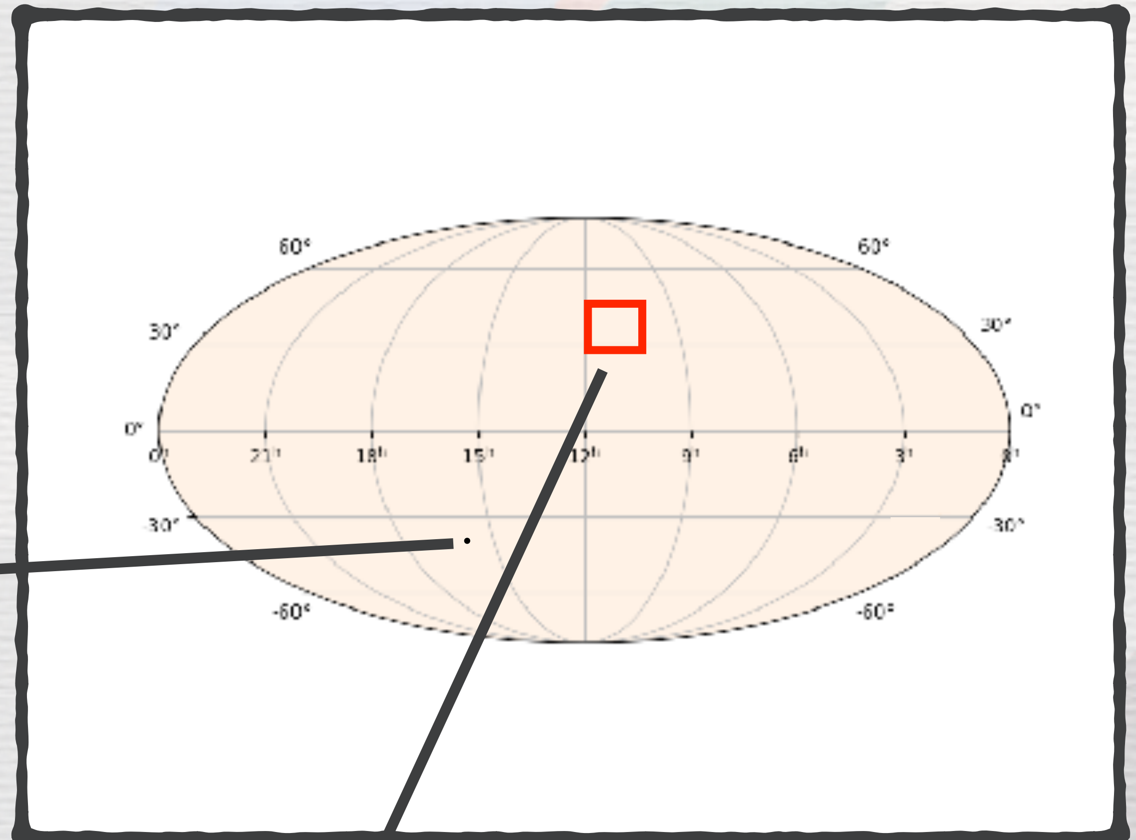
Field of view (FOV)



largest telescopes

Credit: ESO

Field of view (FOV)



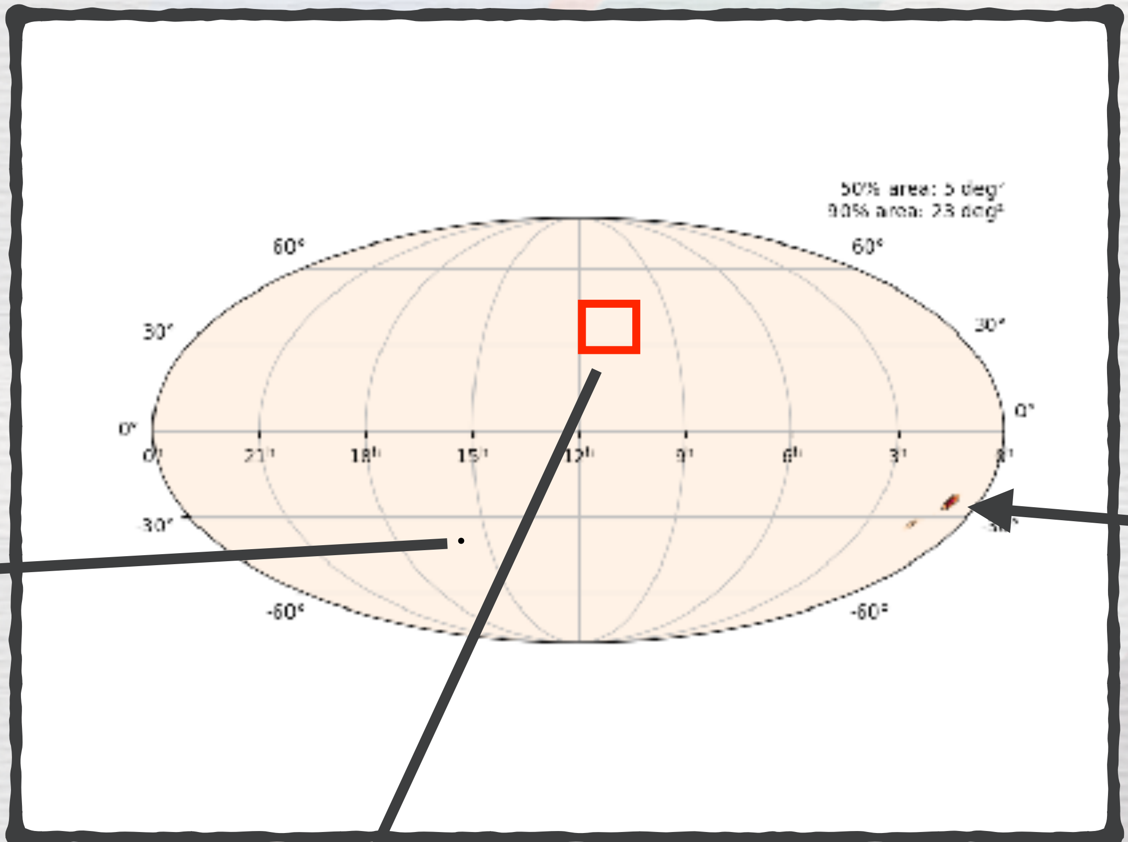
largest telescopes

Credit: ESO

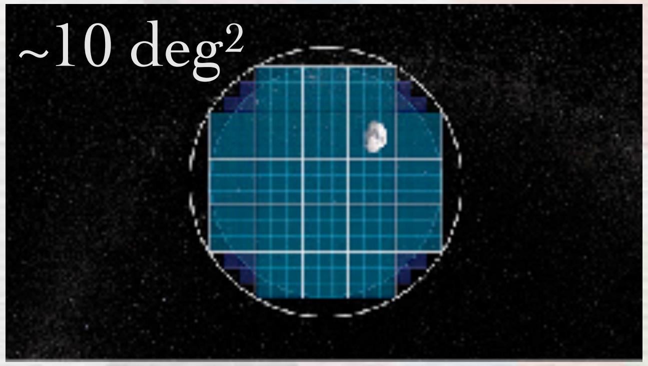
very small telescopes

Credit: SVOM

Field of view (FOV)



Vera Rubin Telescope



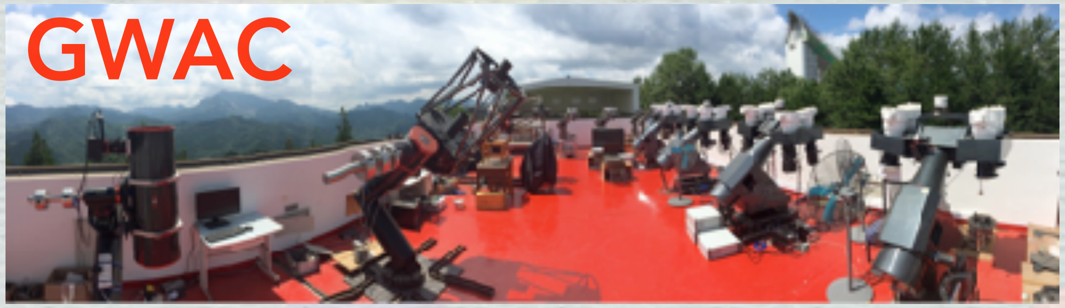
Source : National Accelerator Laboratory

Survey telescopes

largest telescopes

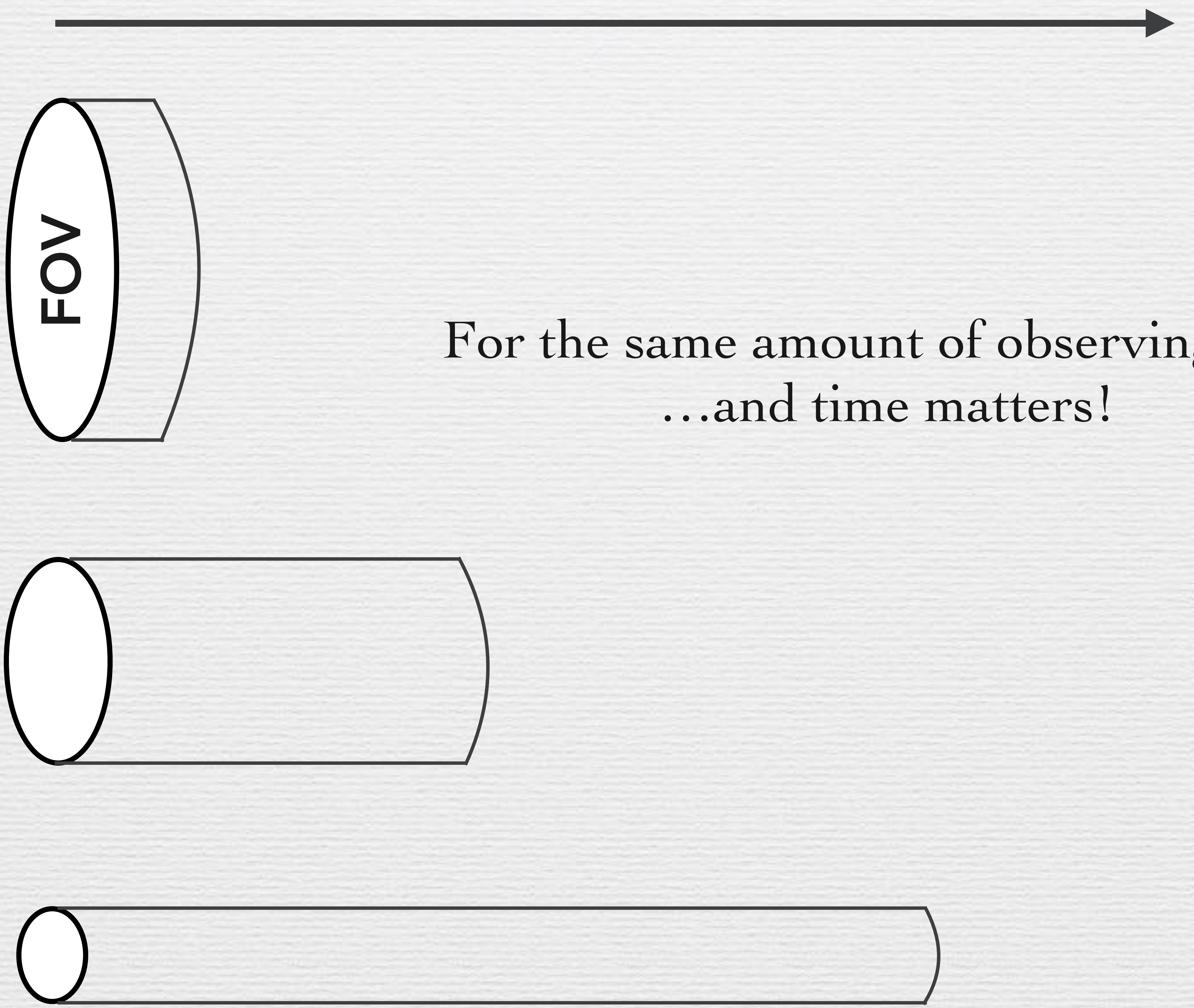
Credit: ESO

very small telescopes



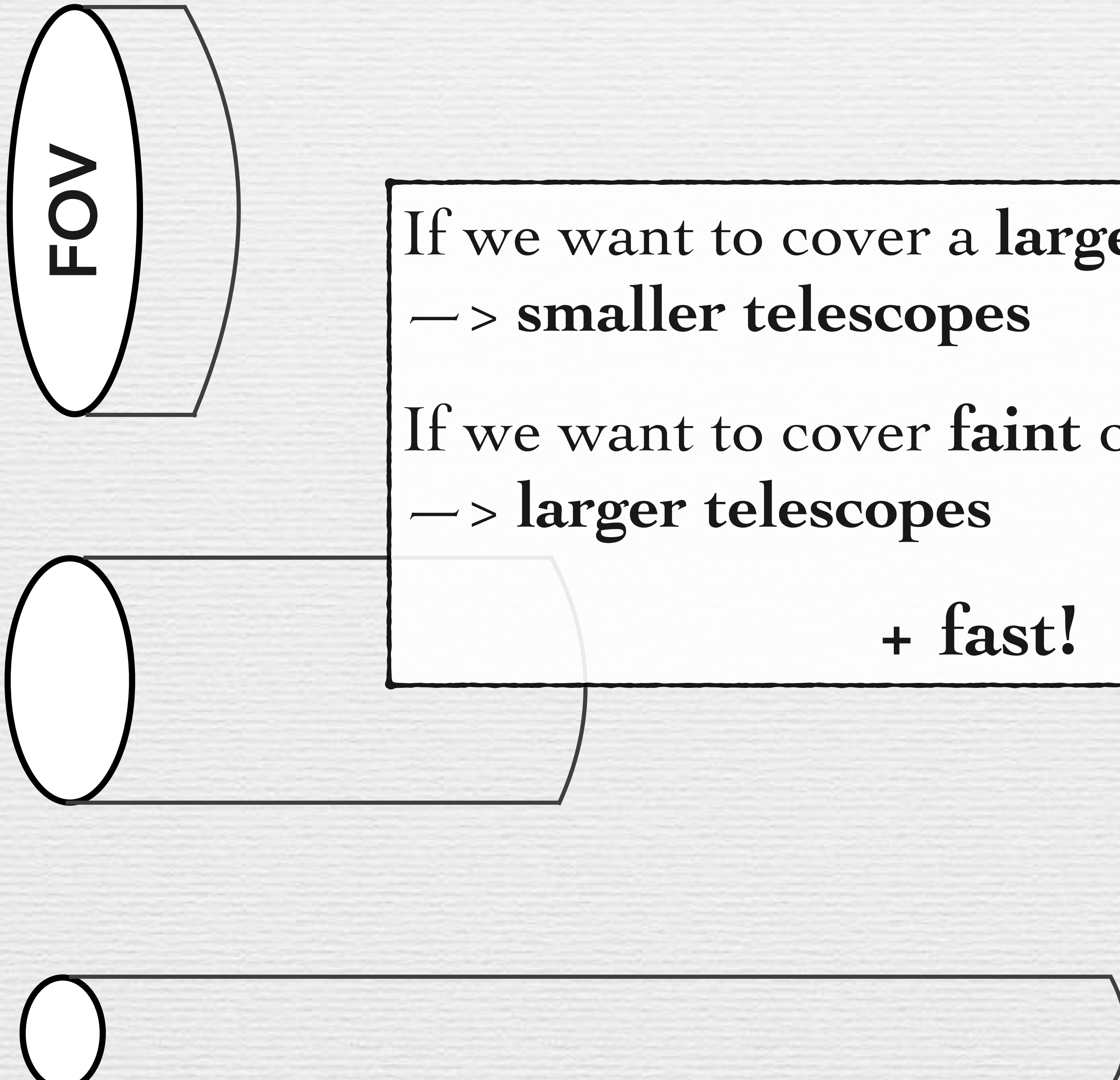
Credit: SVOM

fainter objects (fluxes):
intrinsically fainter or more distant



For the same amount of observing time
…and time matters!

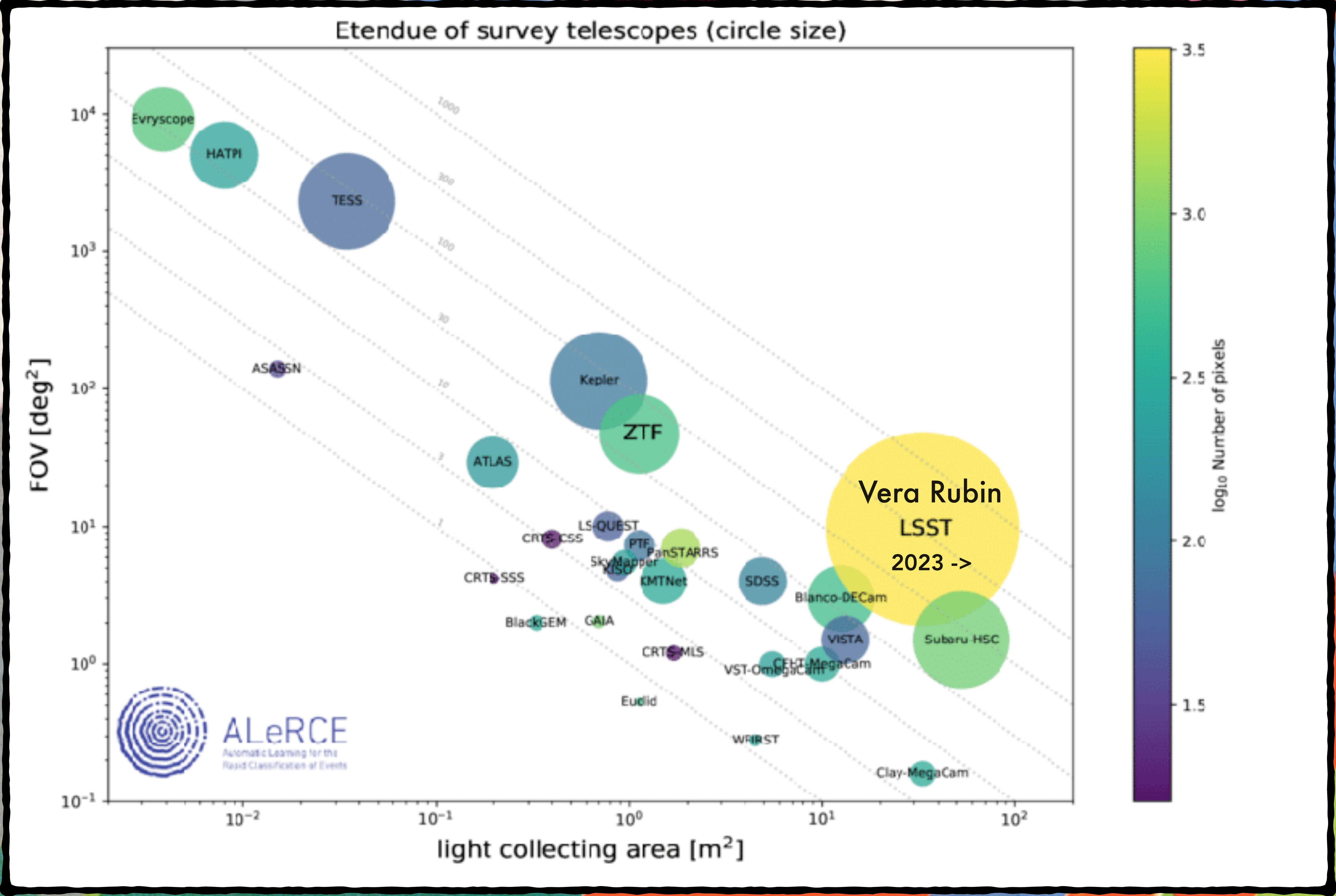
fainter objects (fluxes):
intrinsically fainter or more distant



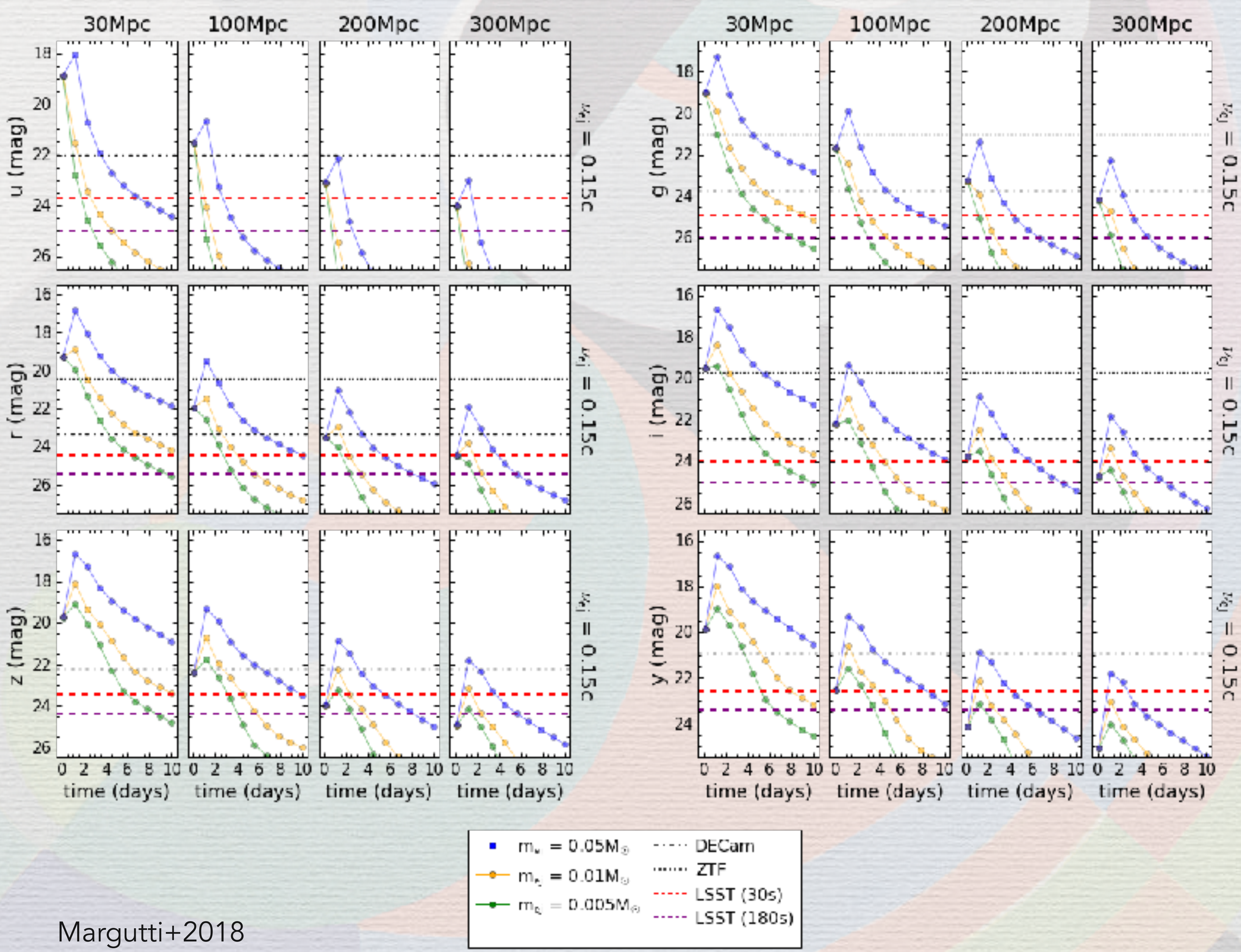
If we want to cover a **large** part of the sky
—> **smaller telescopes**

If we want to cover **faint** objects
—> **larger telescopes**

+ fast!

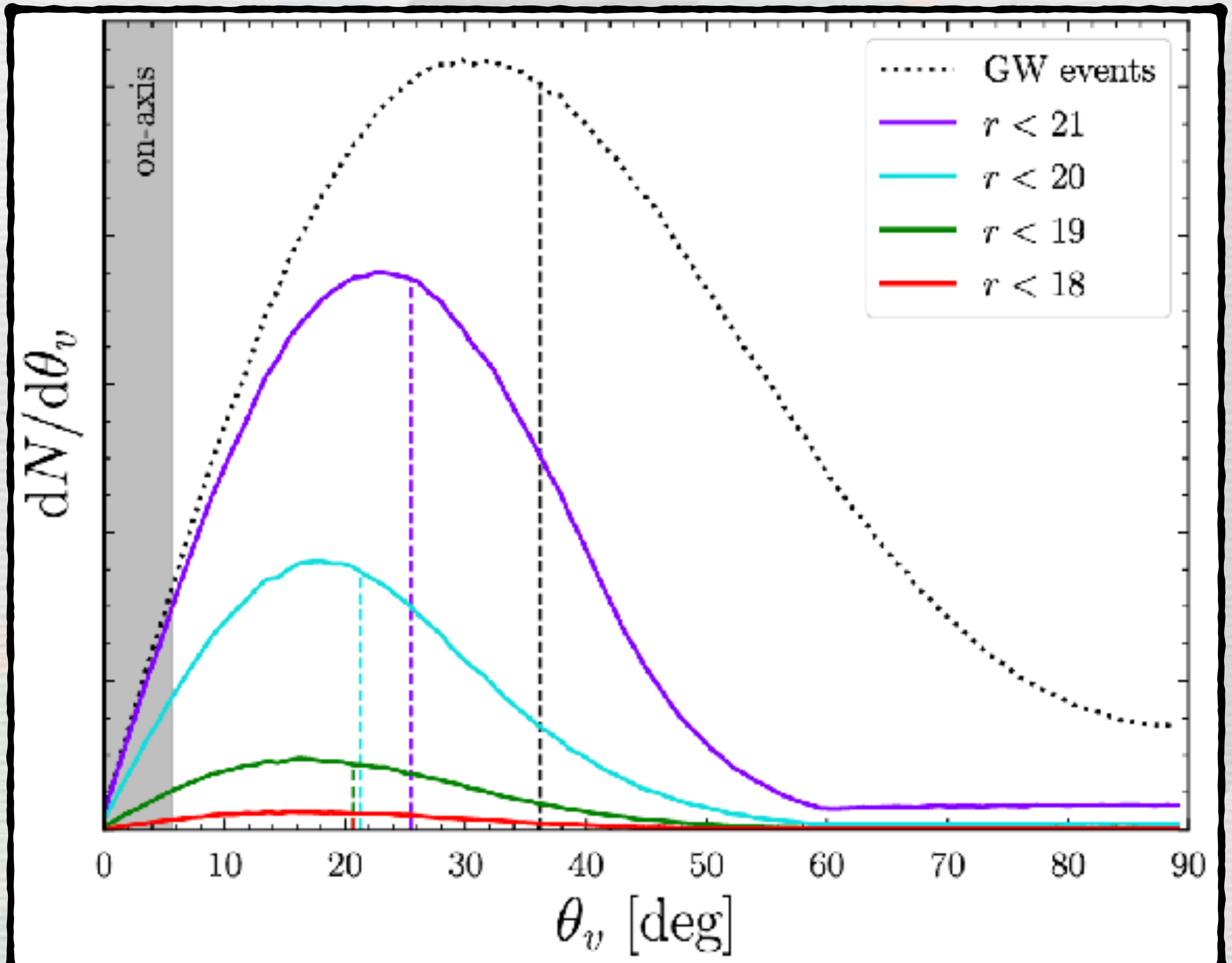

Etendue of survey telescopes (circle size)
FOV [deg^2]
light collecting area [m^2]
log₁₀ Number of pixels
Evryscope
HATPI
TESS
ASASSN
Kepler
ZTF
ATLAS
LS-QUEST
CRTS-CSS
PTF
PanSTARRS
SkyMapper
KISO
KMTNet
CRTS-SSS
SDSS
Blanco-DECam
BlackGEM
GAIA
VISTA
Subaru HSC
CRTS-MLS
VST-OmegaCam
CFHT-MegaCam
Euclid
WFIRST
Clay-MegaCam
Vera Rubin
LSST
2023 ->
ALeRCE

Kilonova (KN)



Margutti+2018

Kilonova (KN)

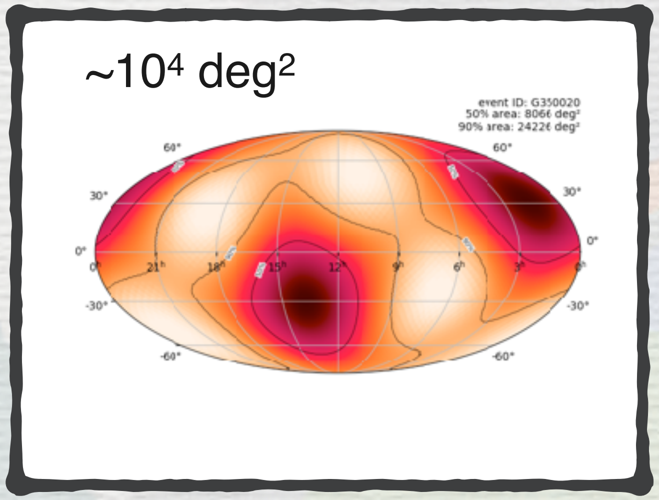


Mochkovitch+2021

Lack of sensitive transient survey telescopes in the NIR

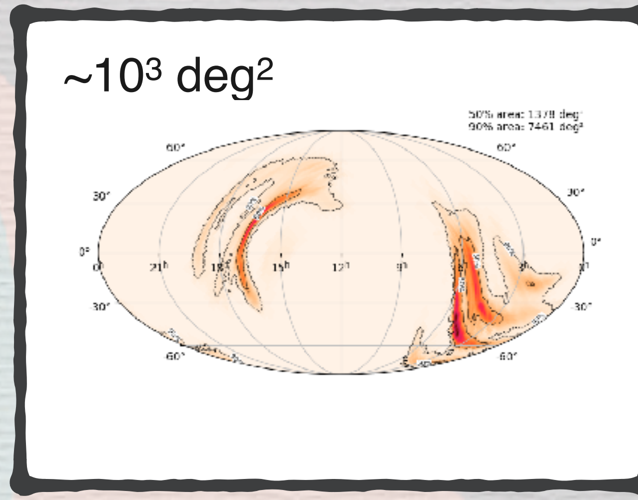
Kilonova (KN)

Do we have instruments with
- wide enough FOV
- enough sensitive
- (and rapid)?



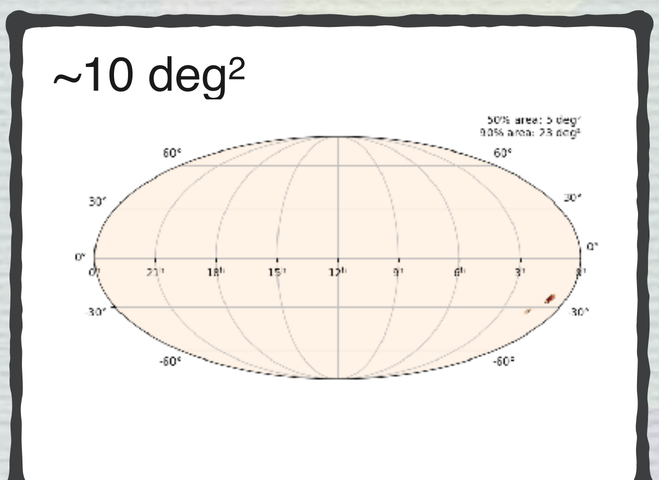
~ **maybe OK**
for very close ones

~ **NO**
for the rest



~ **OK**
for very close ones

~ **NO**
for the far ones

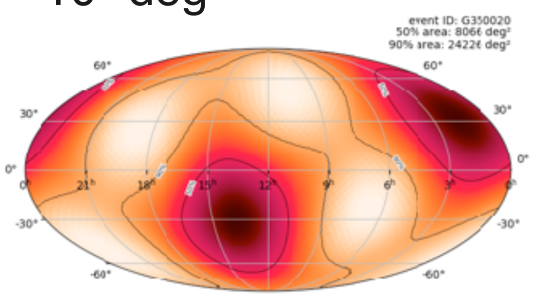


OK
except for the far ones

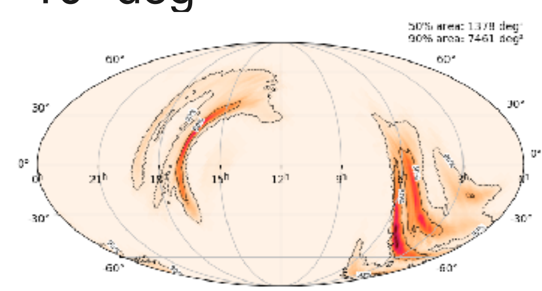
Kilonova (KN)

Do we have instruments with
- wide enough FOV
- enough sensitive
- (and rapid)?

~10^4 deg^2

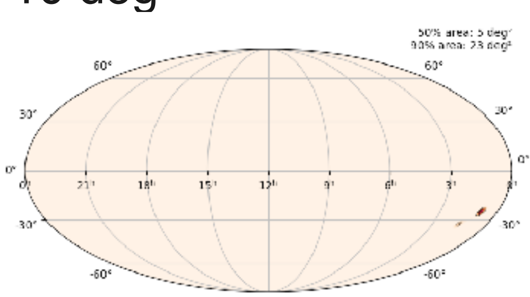


~10^3 deg^2



OK
except for the very far / red

~10 deg^2

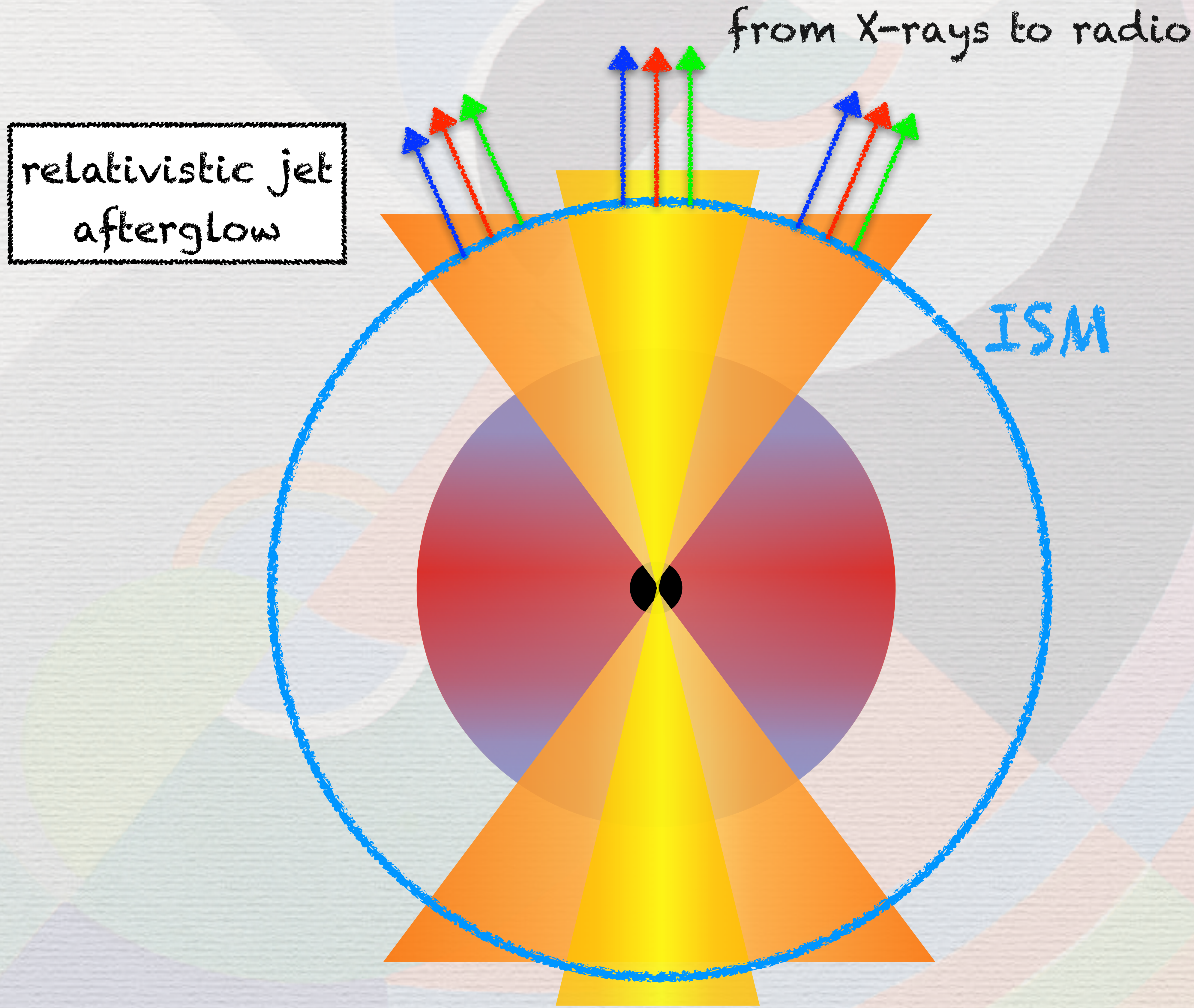


LSST key role for detection !

Kilonova (KN)

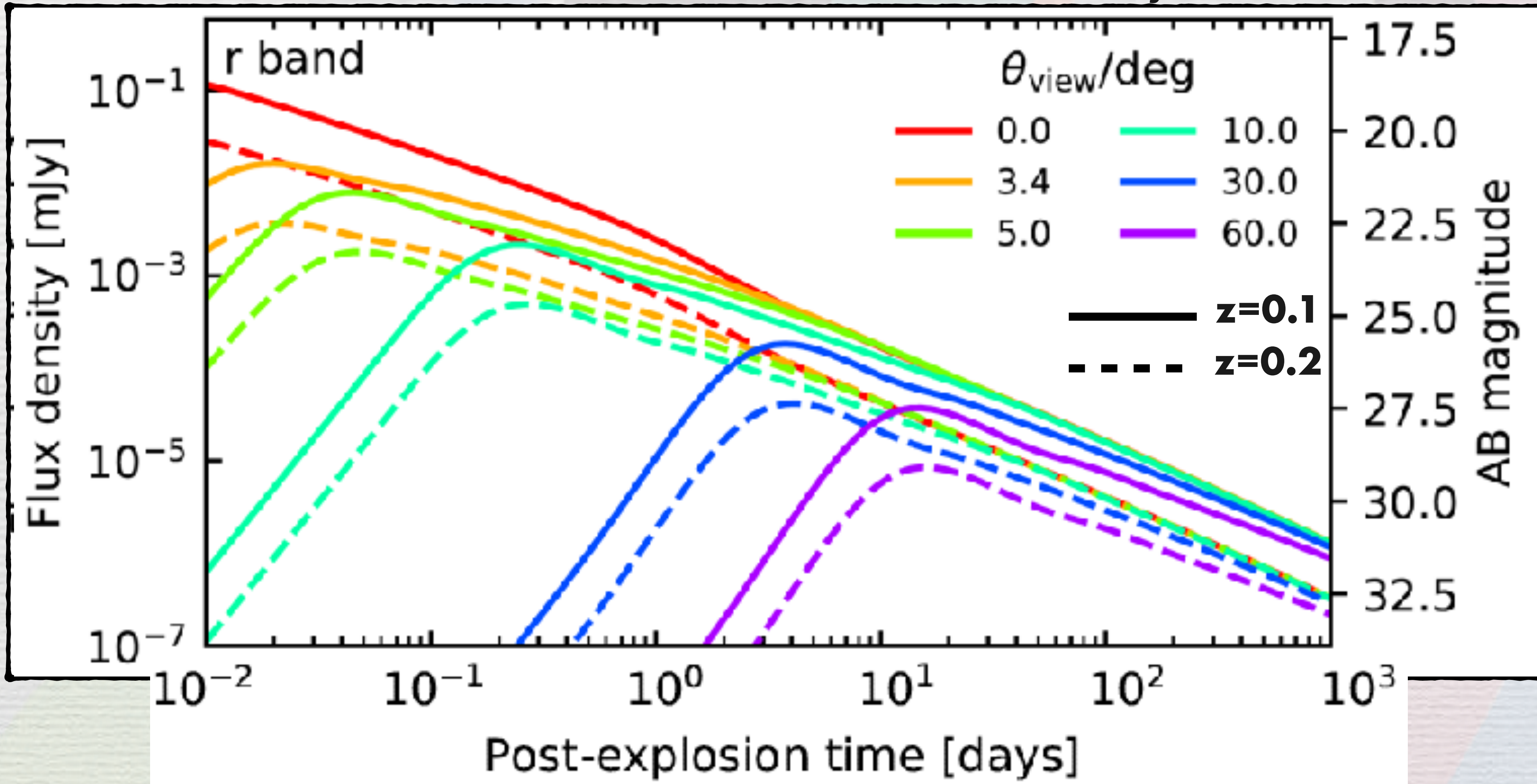
		P of success
Distance	↑	↓
Sky map extent	↑	↓
Viewing angle (with on-axis caveat)	↑	↓

Relativistic jet (Gamma-ray burst)



Relativistic jet (Gamma-ray burst)

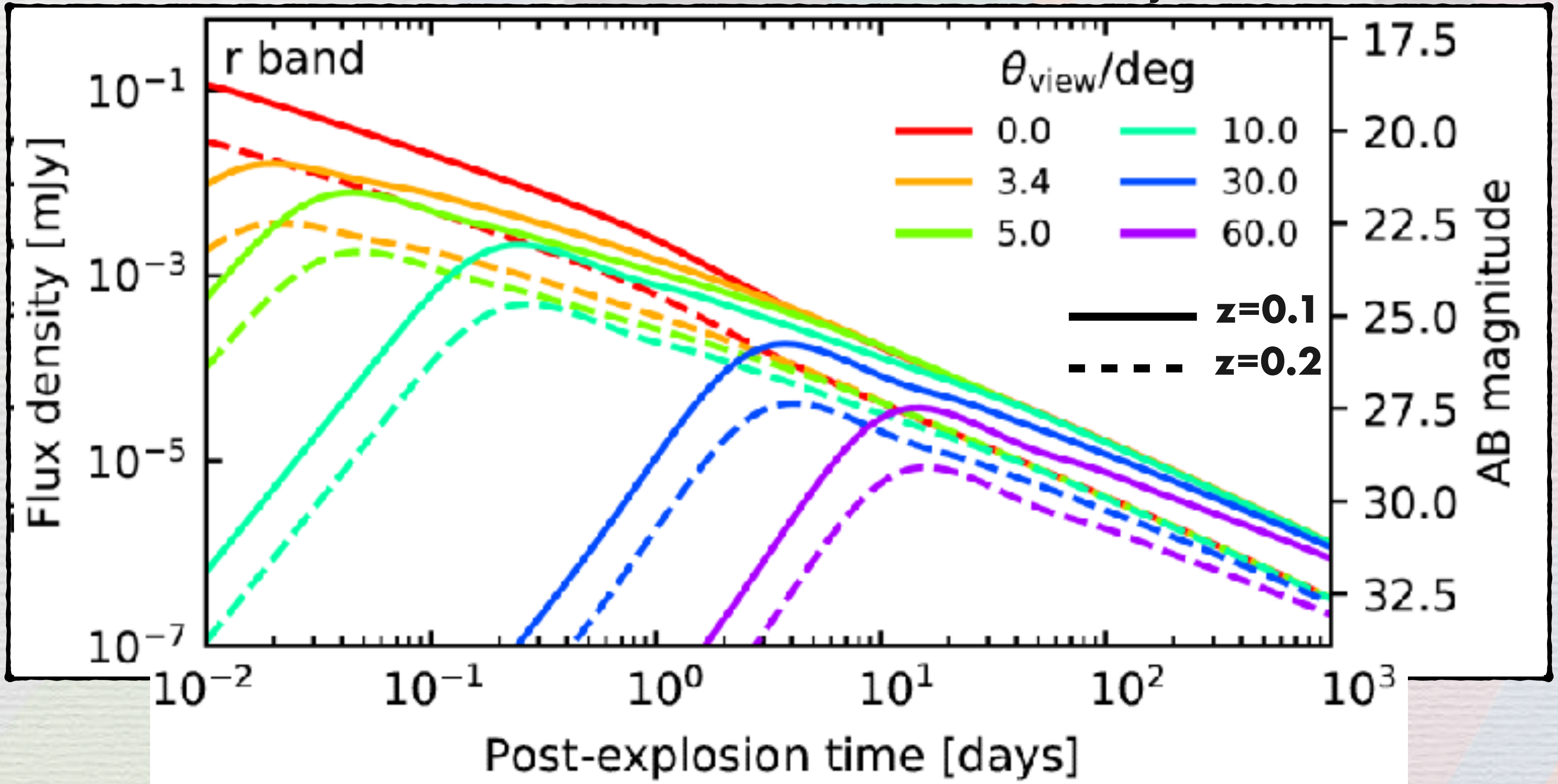
Courtesy of Om Sharam Salafia



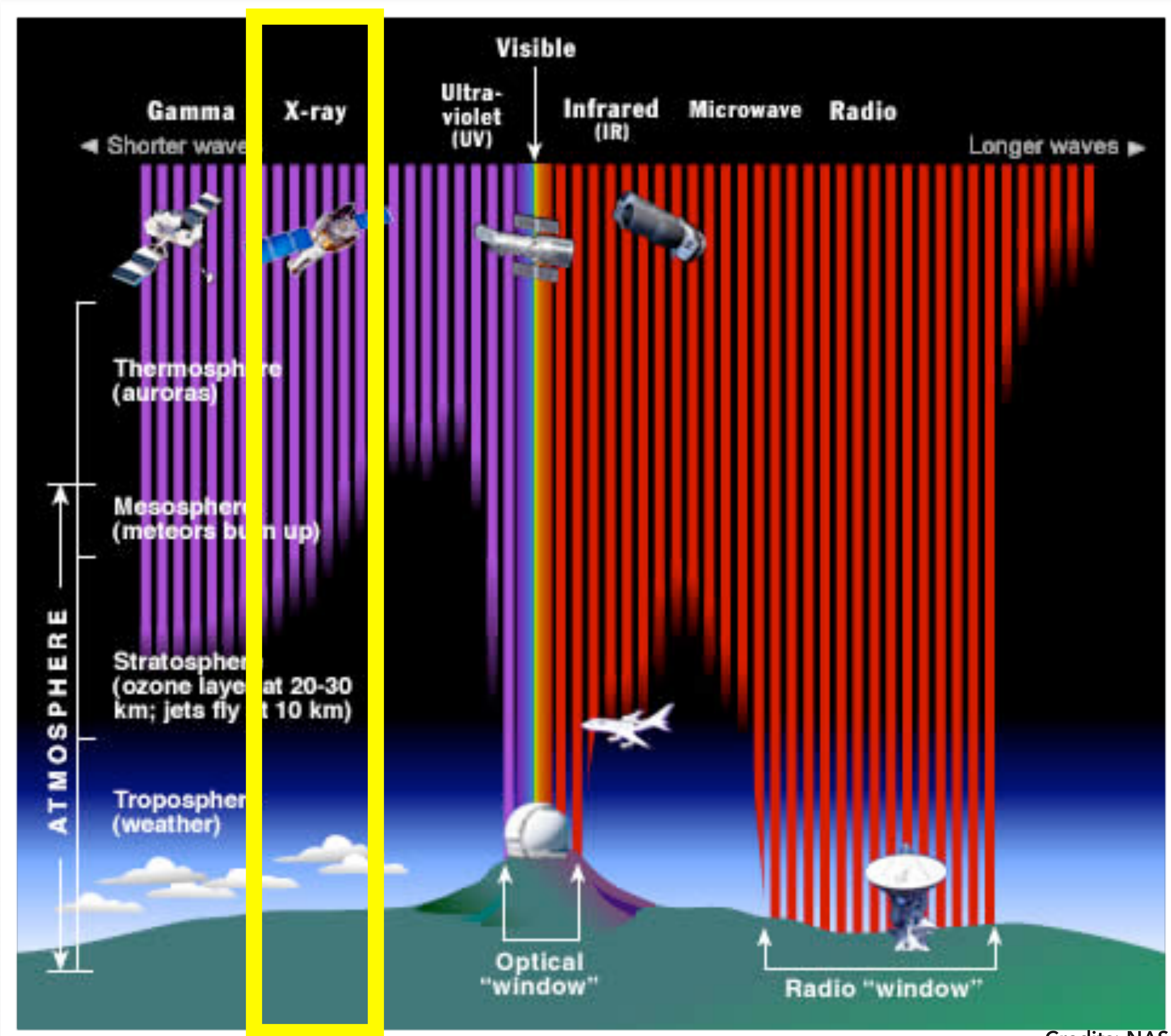
- Viewing angle of the observer
- Jet structure
- Burst energetic
- Density of the inter-stellar medium

Relativistic jet
(Gamma-ray burst)

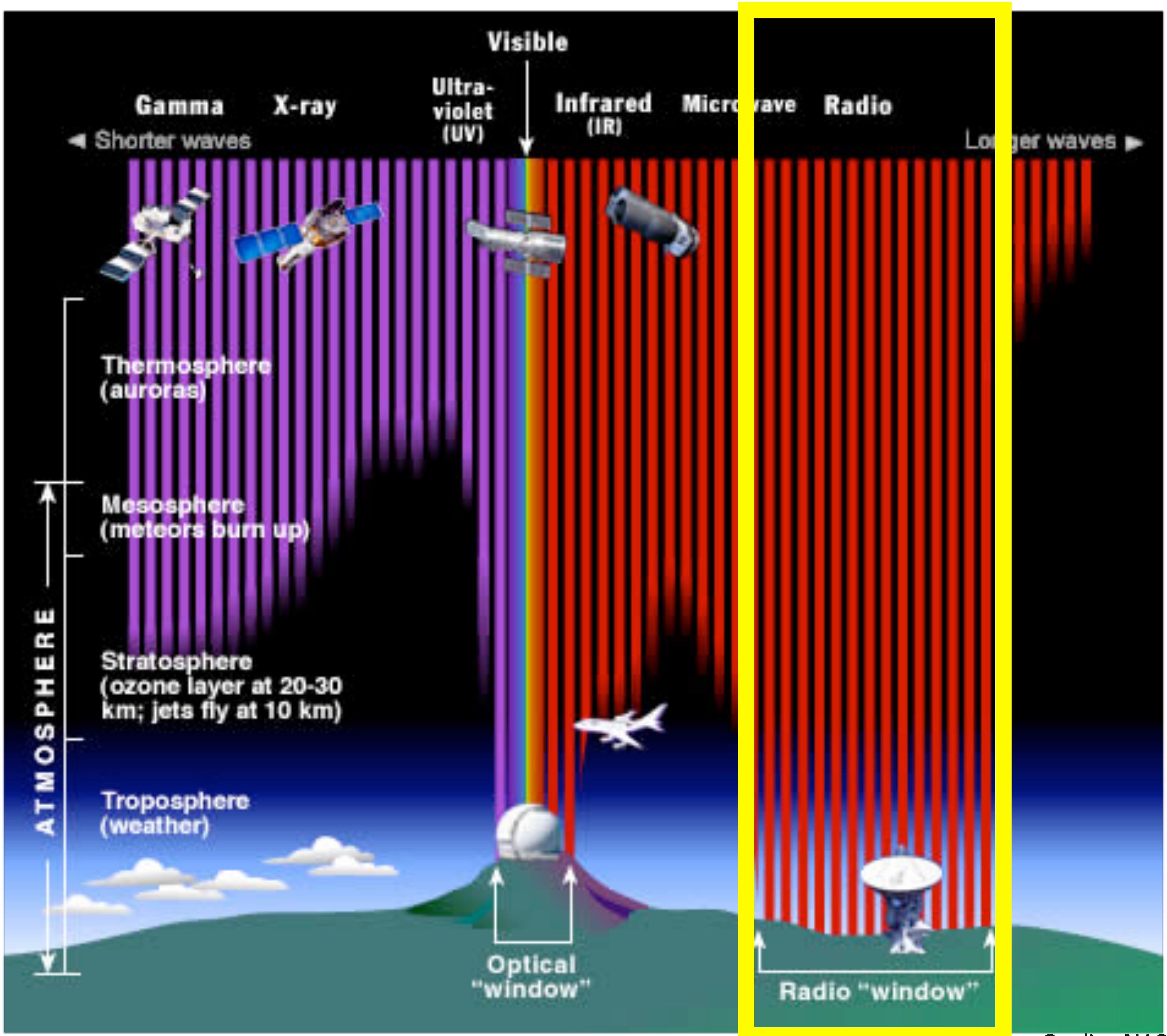
Courtesy of Om Sharam Salafia



- On-axis: good but we must be fast
- Off-axis/high z: (extremely) faint



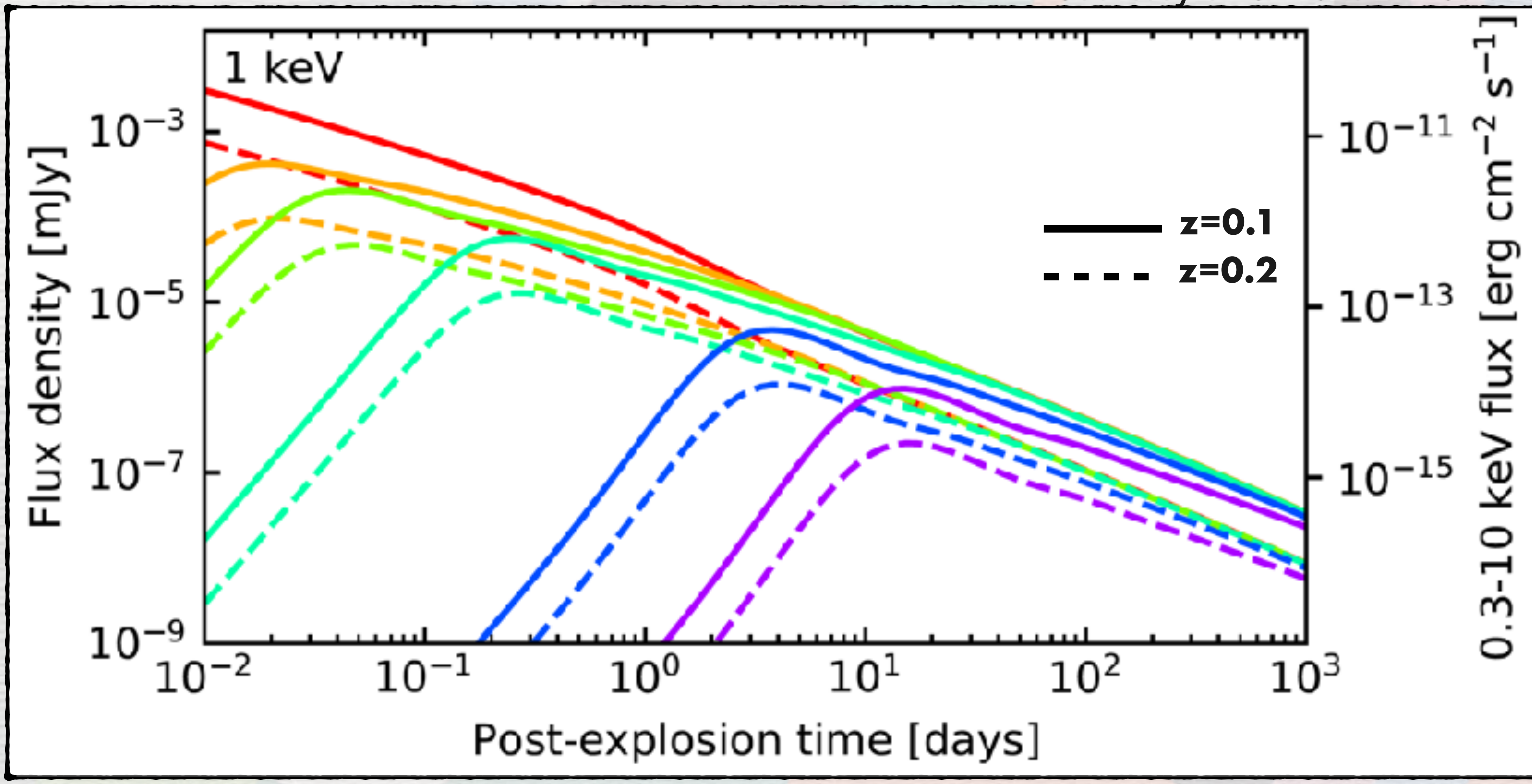
Credits: NASA



Credits: NASA

Relativistic jet (Gamma-ray burst)

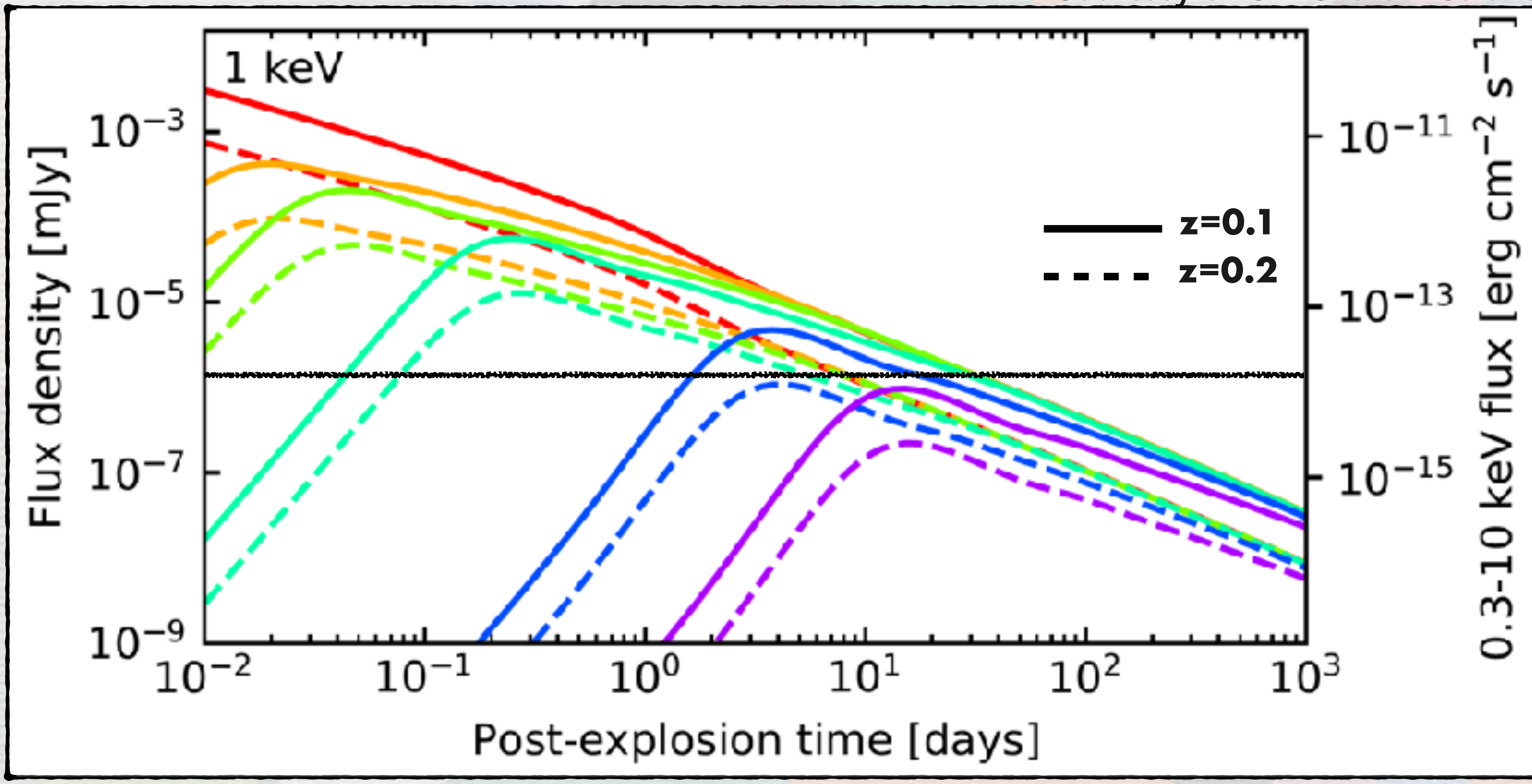
Courtesy of Om Sharam Salafia



- On-axis: good but we must be fast
- Off-axis: faint

Relativistic jet (Gamma-ray burst)

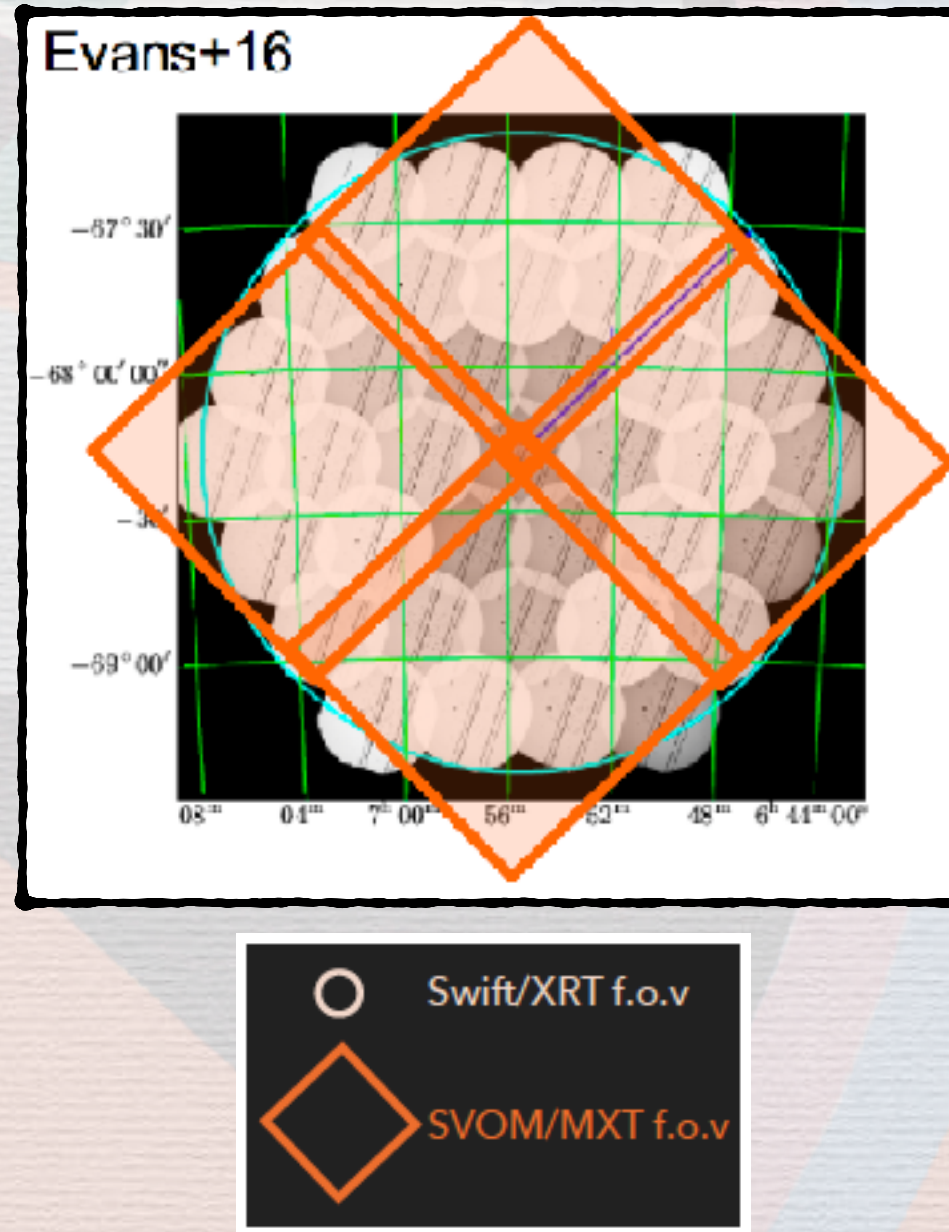
Courtesy of Om Sharam Salafia



If the localization is not precise
we need satellites capable of rapidly scanning the sky

XRT FoV: 23.6 x 23.6 arcmin

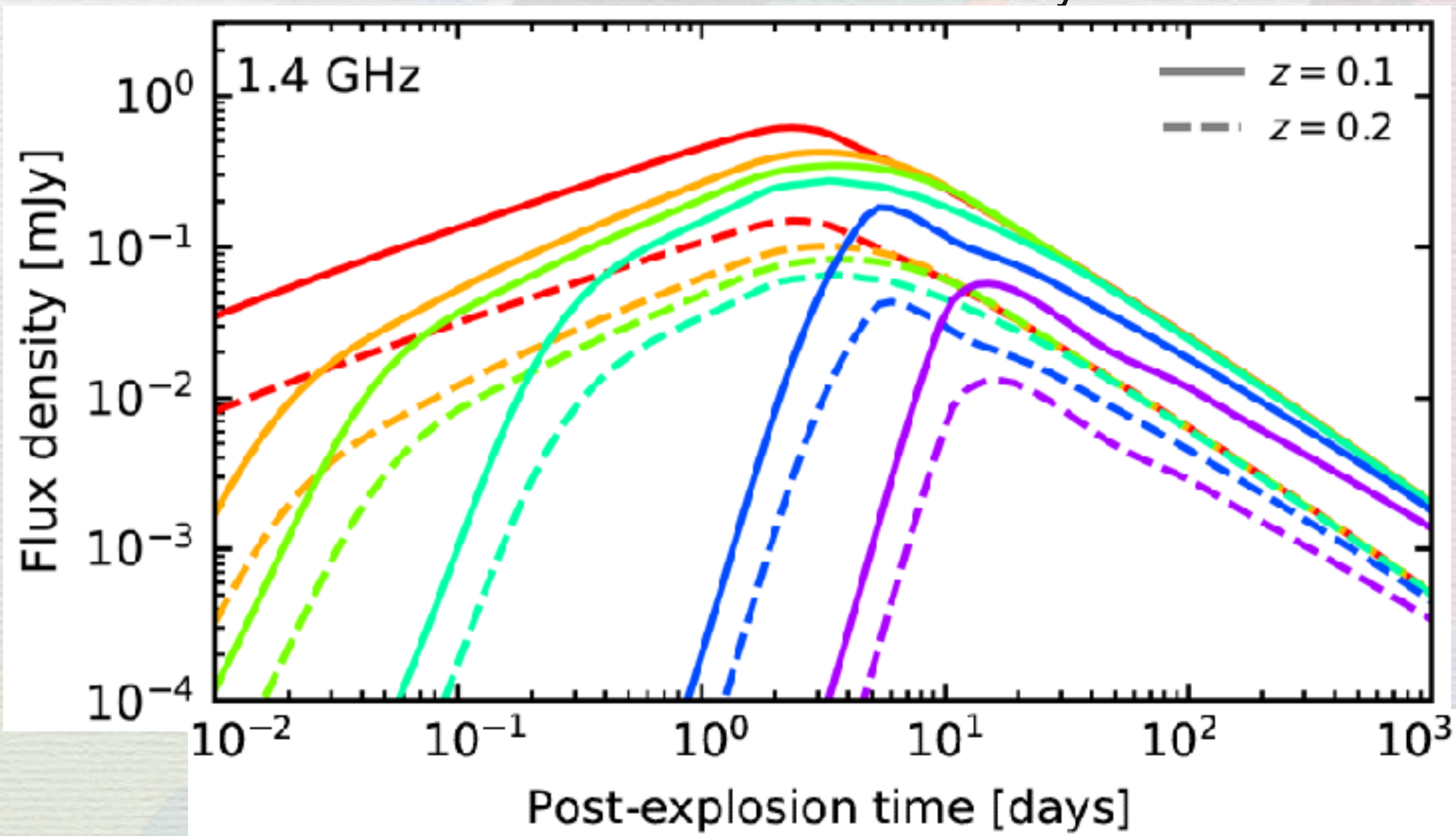
MXT FoV: 1.1° x 1.1°



but ~ same exposure time
to reach the same flux values!

Relativistic jet (Gamma-ray burst)

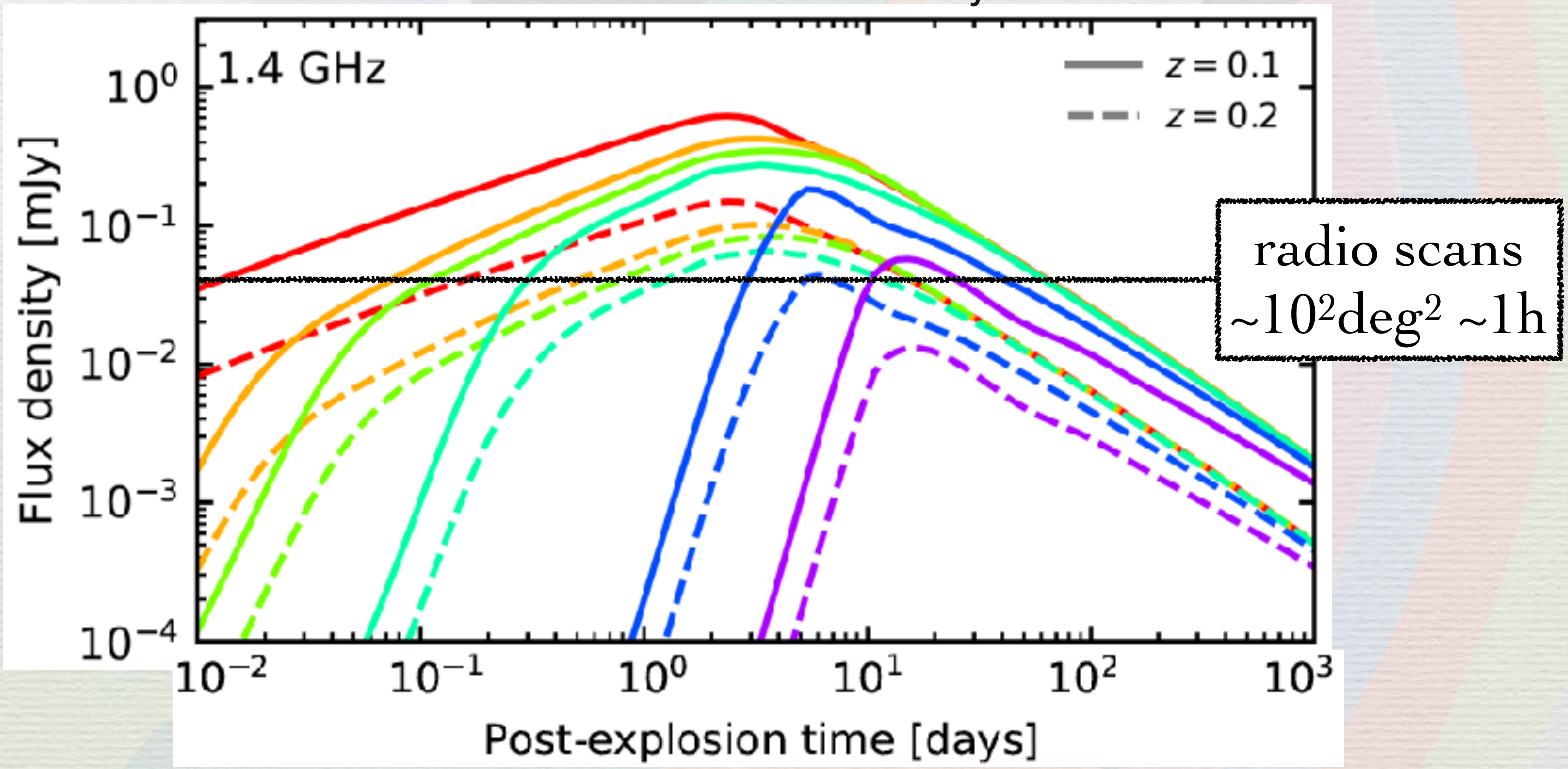
Courtesy of Om Sharam Salafia



- weak bursts peak earlier
- lower frequencies —> lower peak flux
- lower frequencies peak later

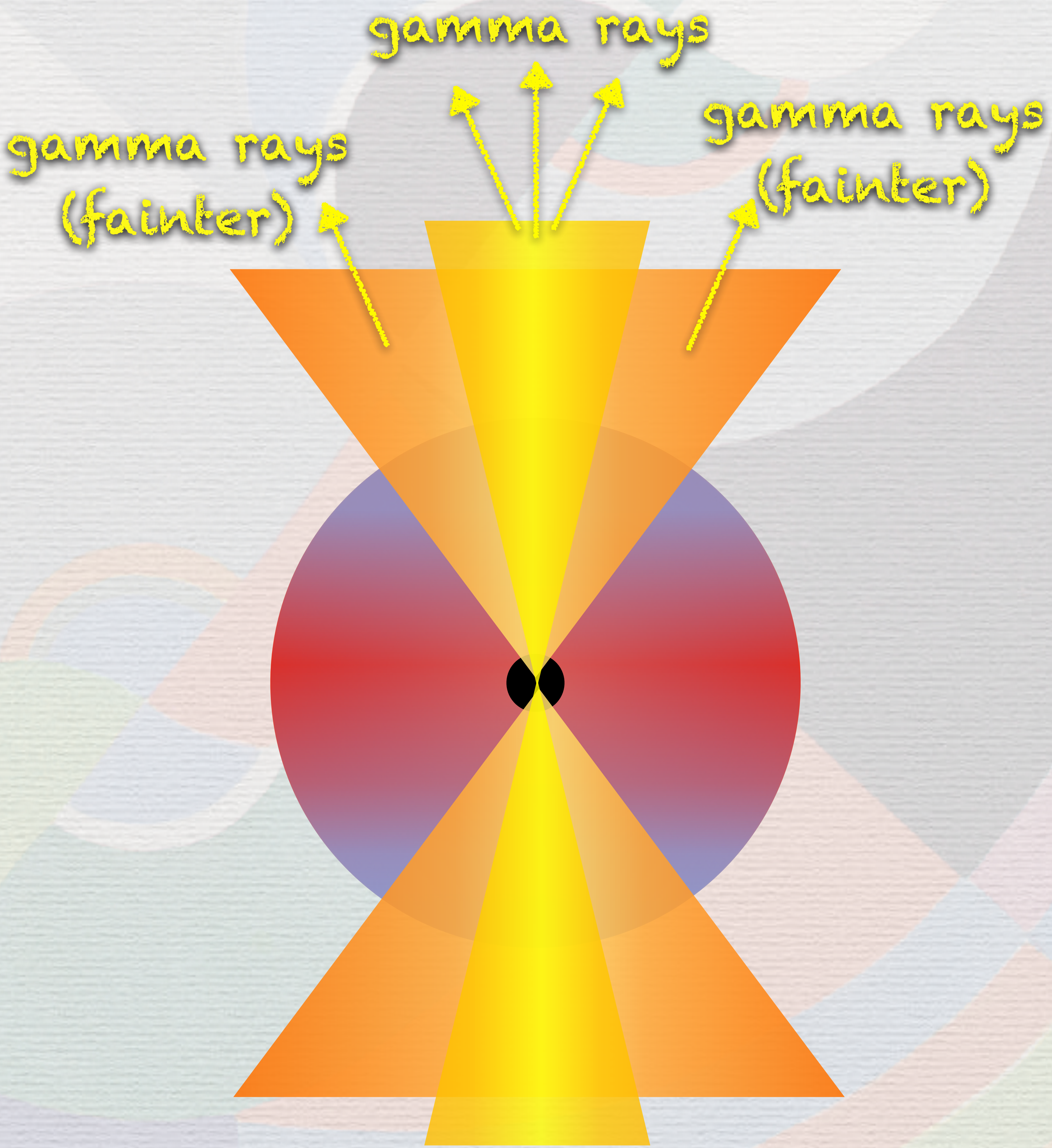
Relativistic jet (Gamma-ray burst)

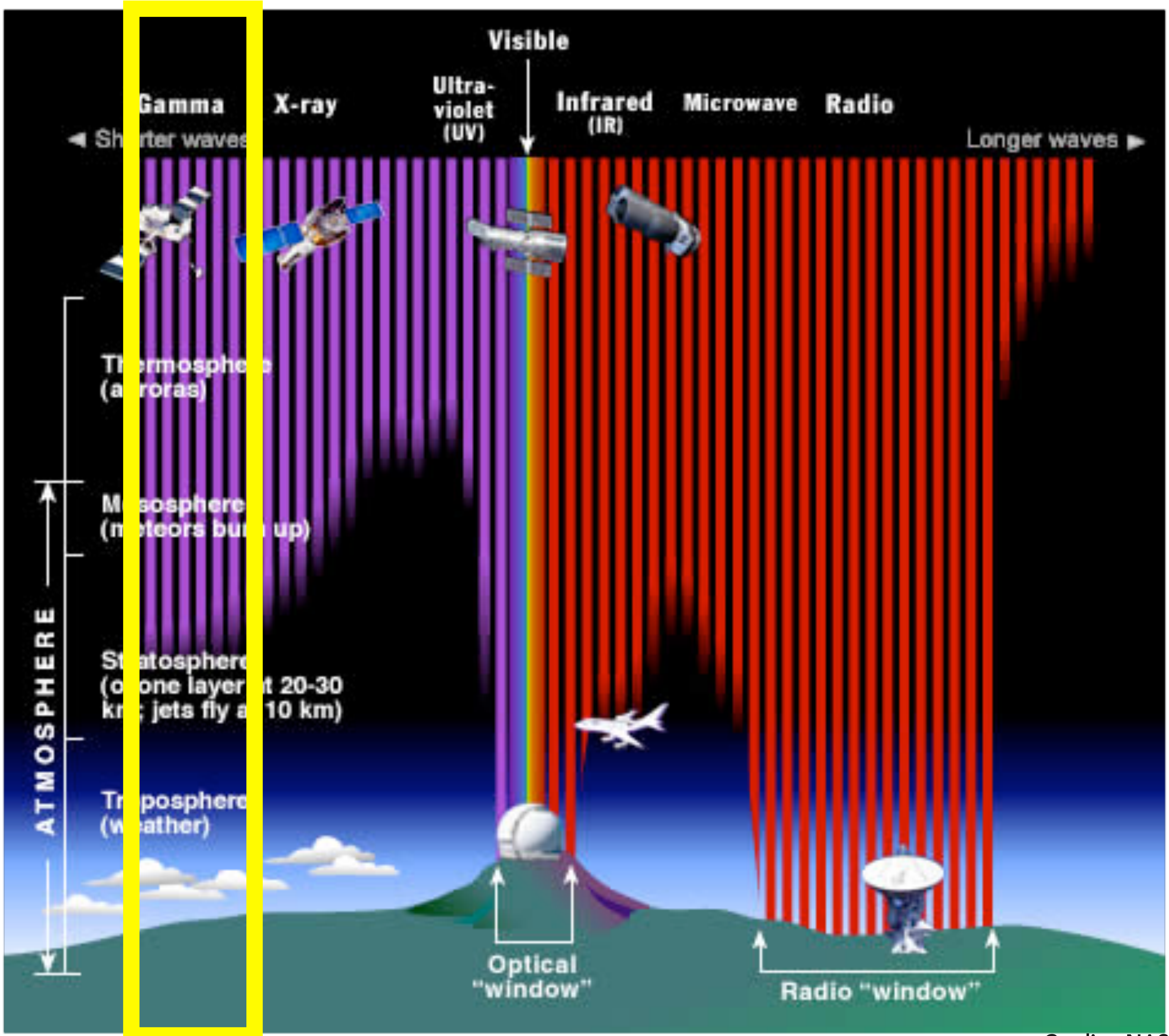
Courtesy of Om Sharam Salafia



- More time
- Faint but ~doable for small/intermediate off-axis angles
- large off-axis angles: good localization needed

Relativistic jet (Gamma-ray burst)



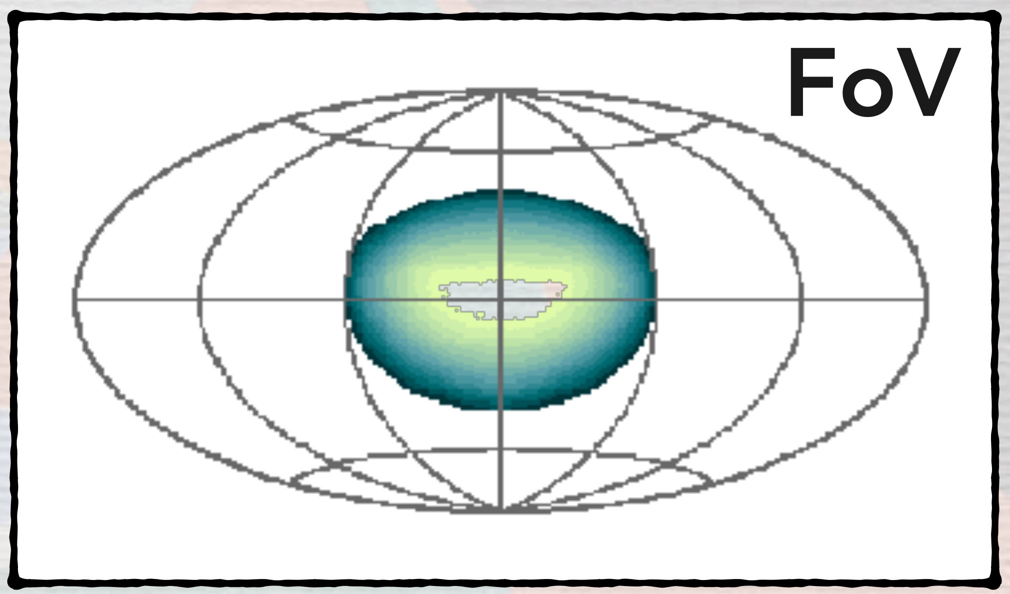


Credits: NASA

Fermi Gamma-ray Space Telescope

FoV: All sky

Localization: ~10-10^2 deg^2



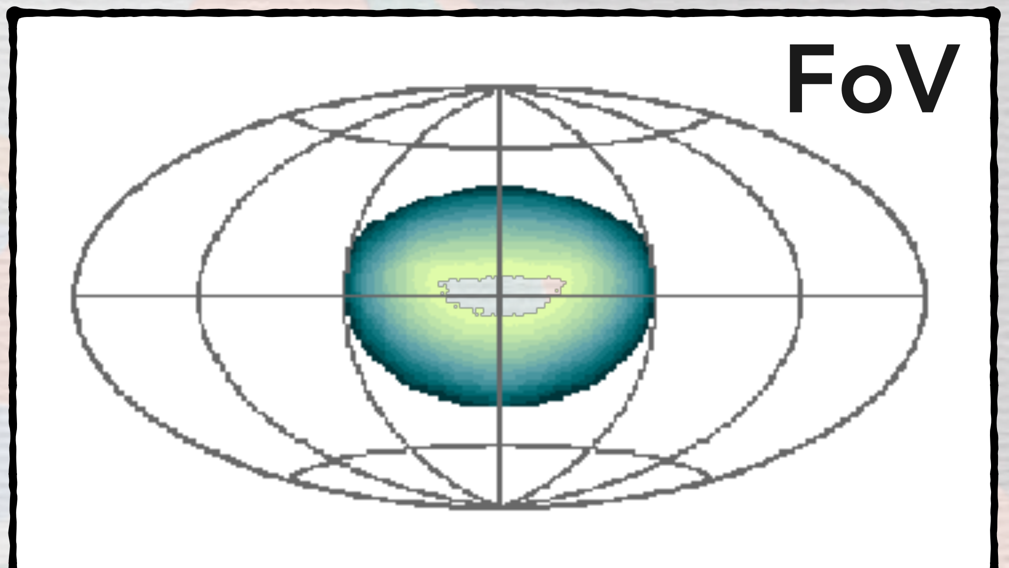
Localization: ~arcmin

Gamma-ray emission helps!

Fermi
Gamma-ray Space Telescope

FoV: All sky

Localization: ~10-10^2 deg^2



Localization: ~arcminutes

If on-axis & detected by *Swift*:
immediate X-rays & optical observations
Localization: arcsec precision!

Relativistic jet (Gamma-ray burst)

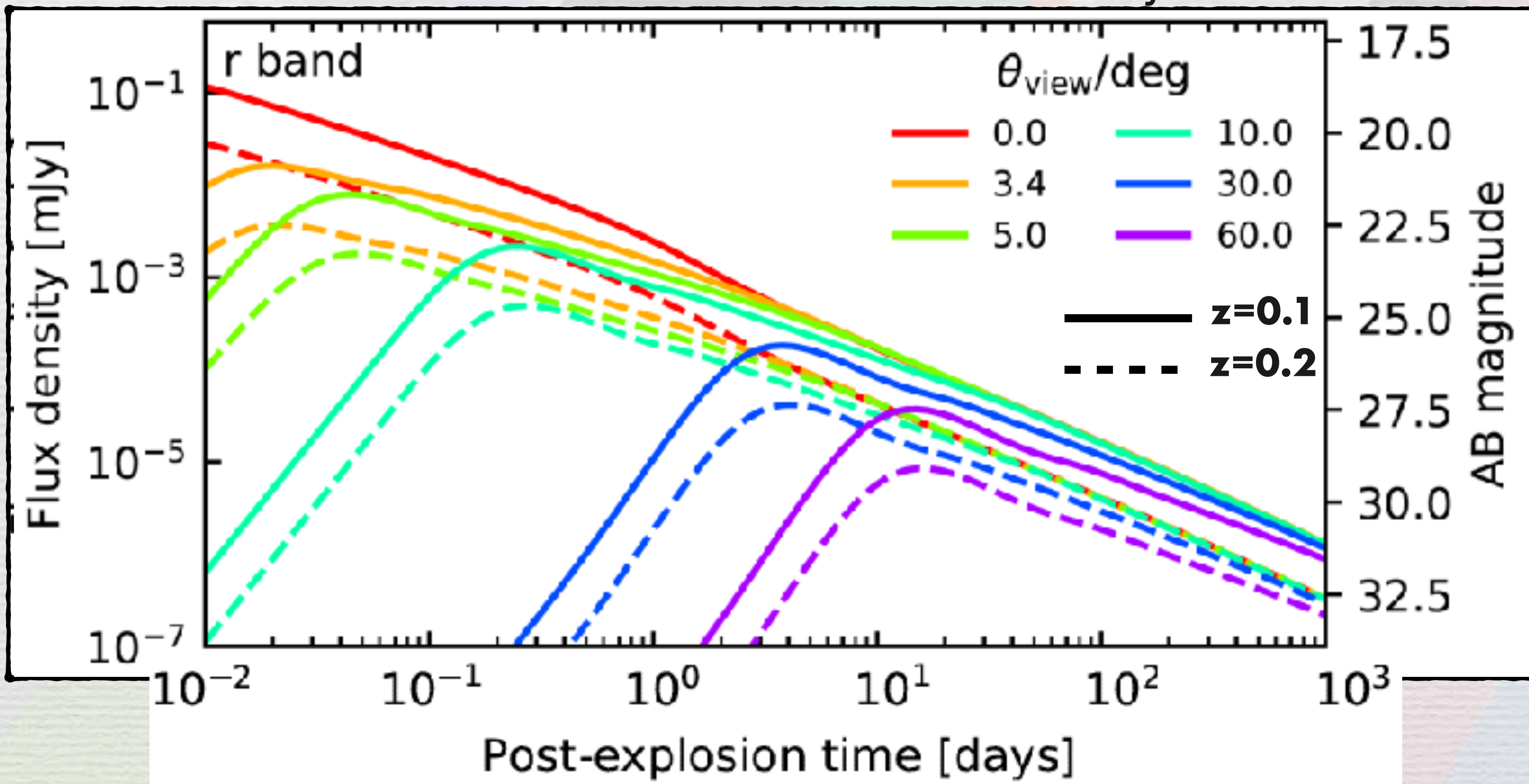
On-axis with detection of gamma rays
best case for relativistic jet (& host galaxy) detection

BUT

We may miss the KN!
(and many aspects of jet physics)

Relativistic jet (Gamma-ray burst)

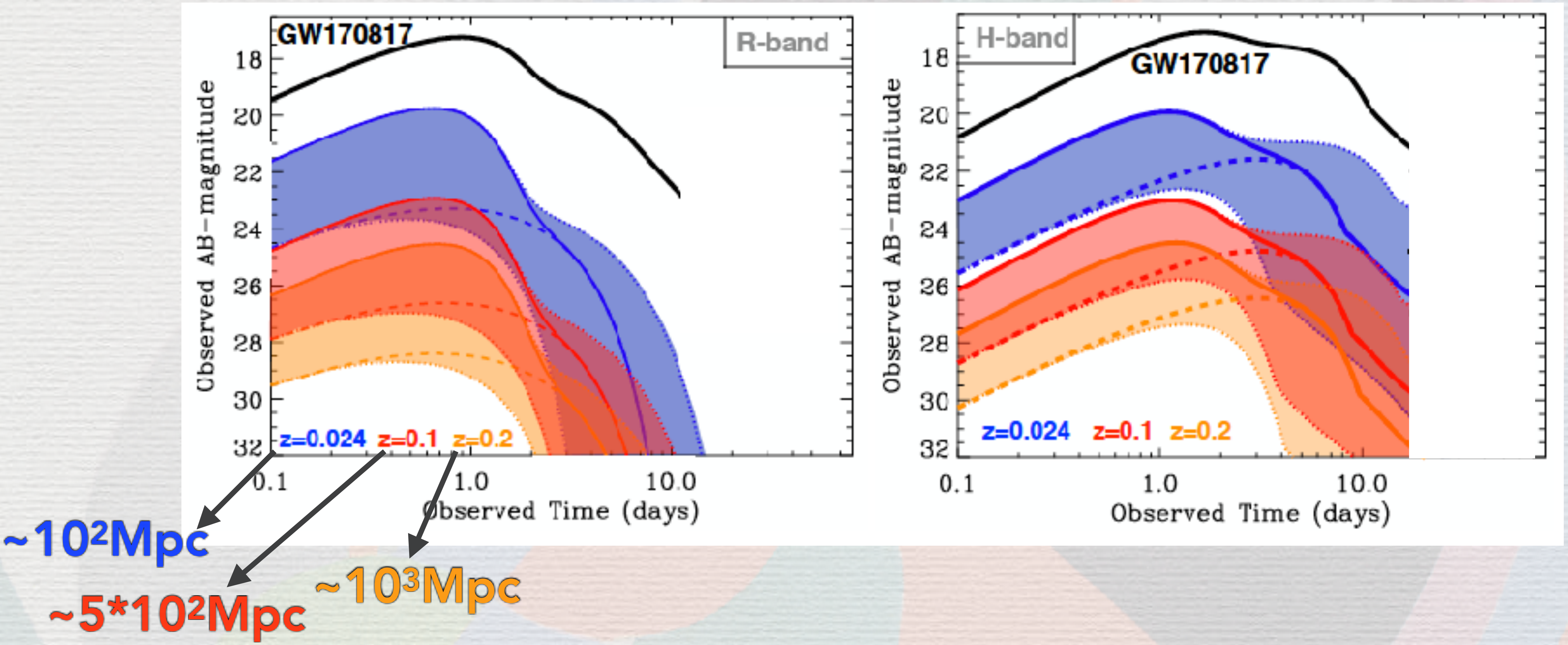
Courtesy of Om Sharam Salafia



- On-axis: good but we must be fast
- Off-axis/high z: (extremely) faint

Kilonova (KN)

adapted from Chornock+2019



Relativistic jet (Gamma-ray burst)

On-axis with detection of gamma rays
best case for relativistic jet (& host galaxy) detection

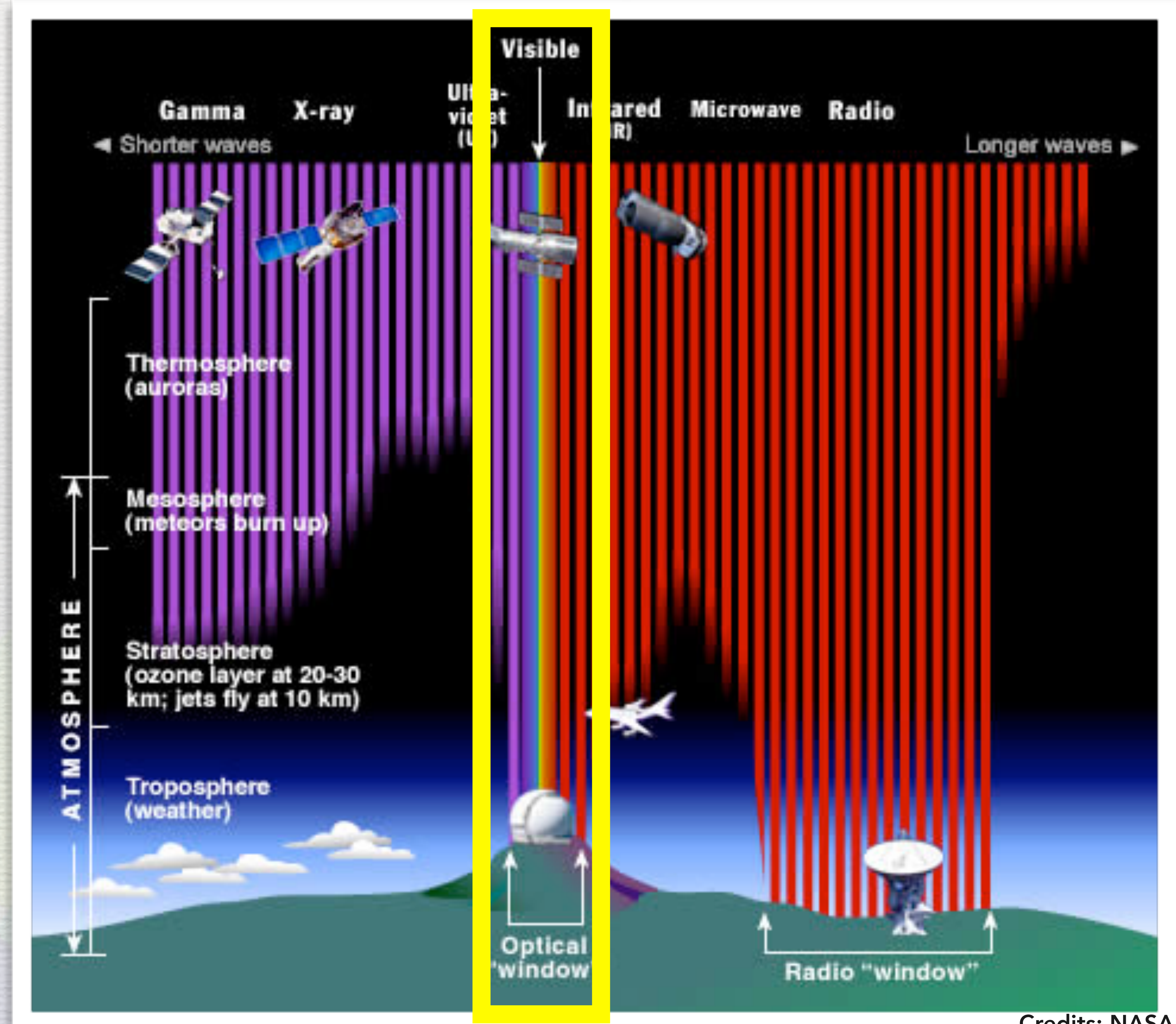
BUT

We may miss the KN!
(and many aspects of jet physics)

Relativistic jet (Gamma-ray burst)

		P of success
Viewing angle	↑	↓
Sky map extent	↑	↓
Distance	↑	↓
Burst Energetic	↑	↑
ISM density (excluding very high densities)	↑	↑

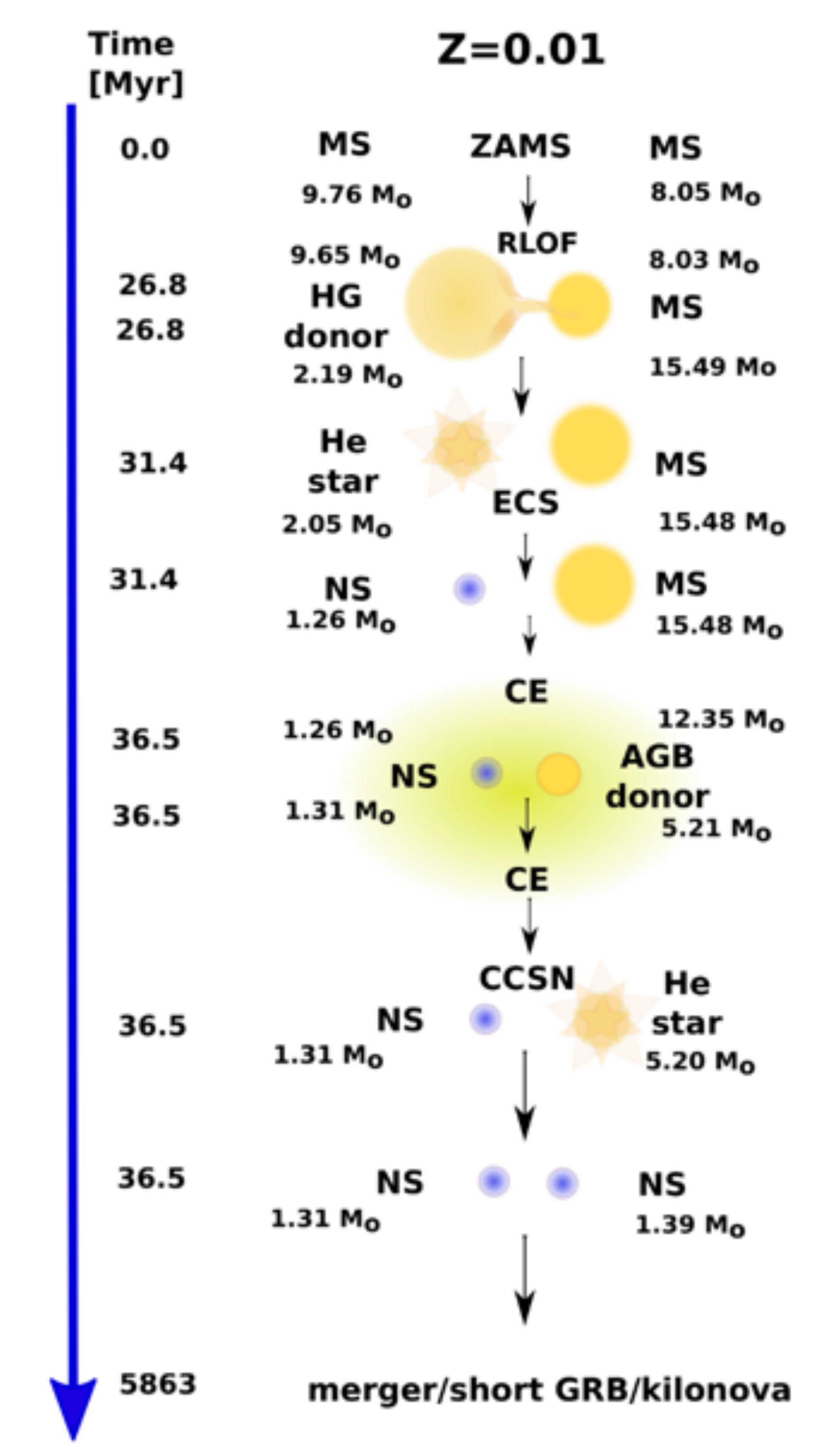
Host Galaxy



Credits: NASA

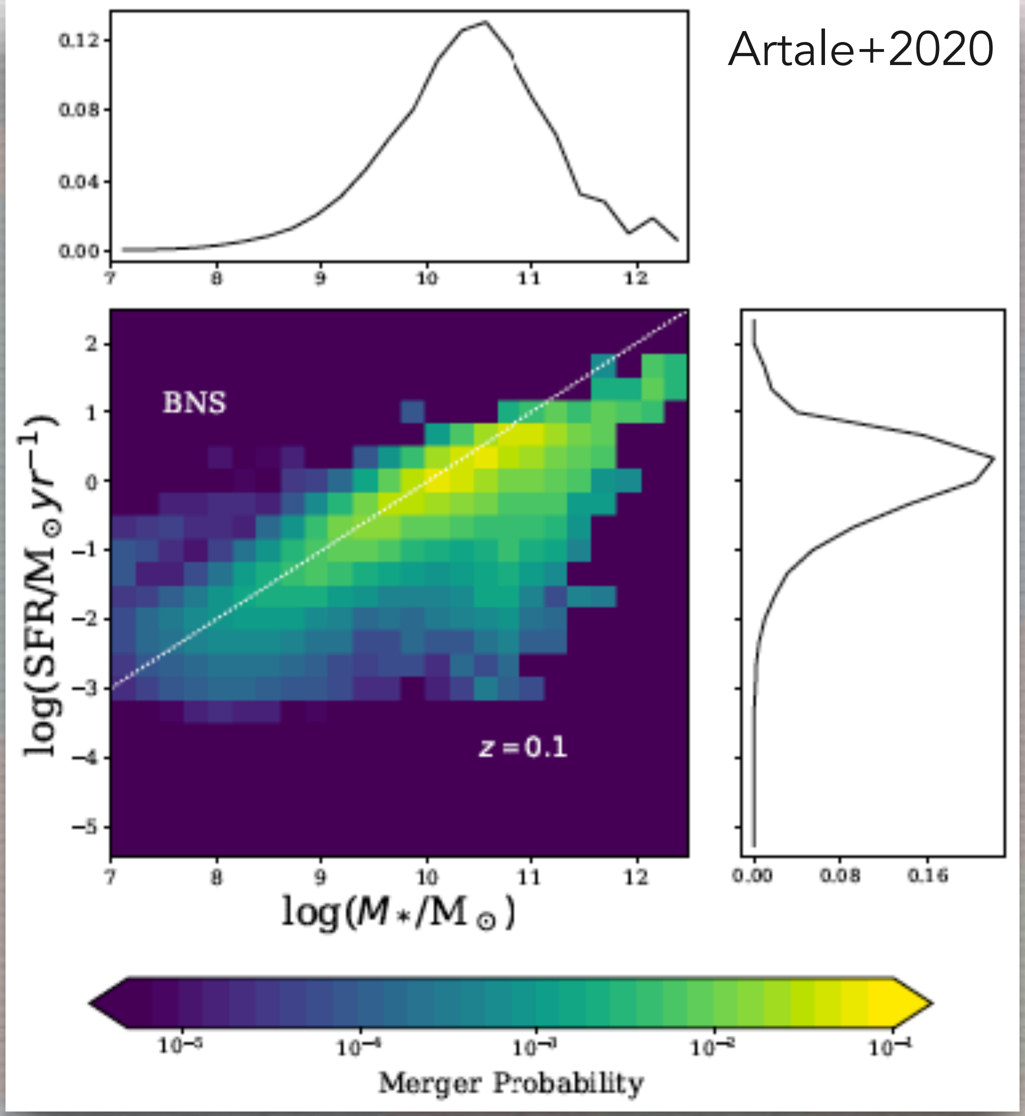
Host Galaxy

Belczynski+2018



High chance to host a BNS merger

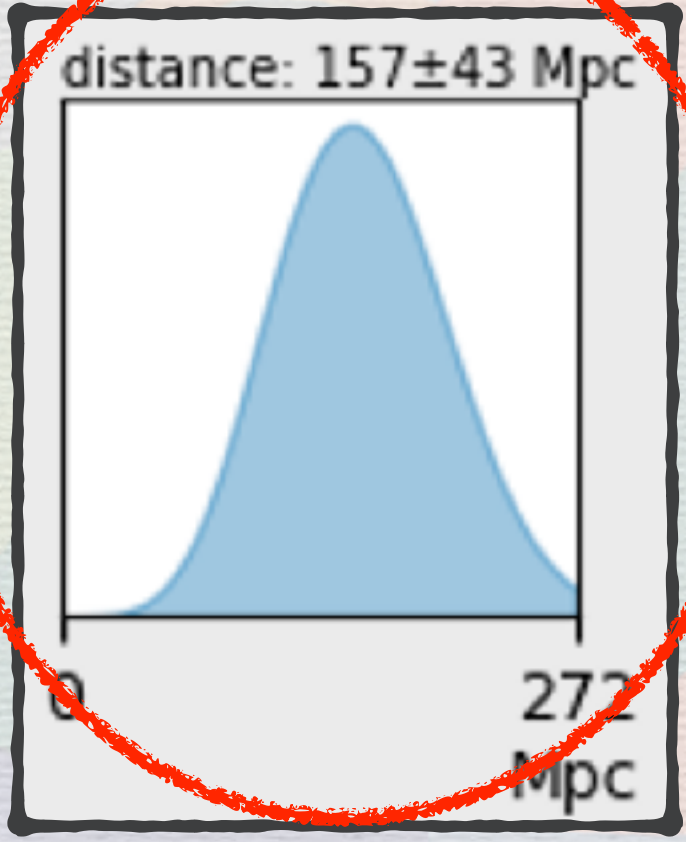
- massive (bright in NIR)
- some SFR (bright in UV-VIS)



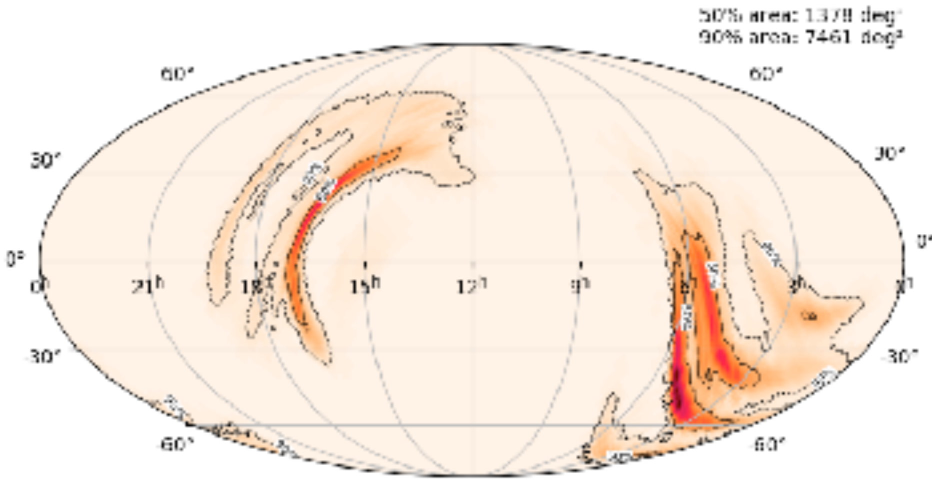
LIGO-Virgo-Kagra events

Mergers of binary systems of neutron stars
NS-NS or BNS

Sky map & Distance



~10^3 deg^2



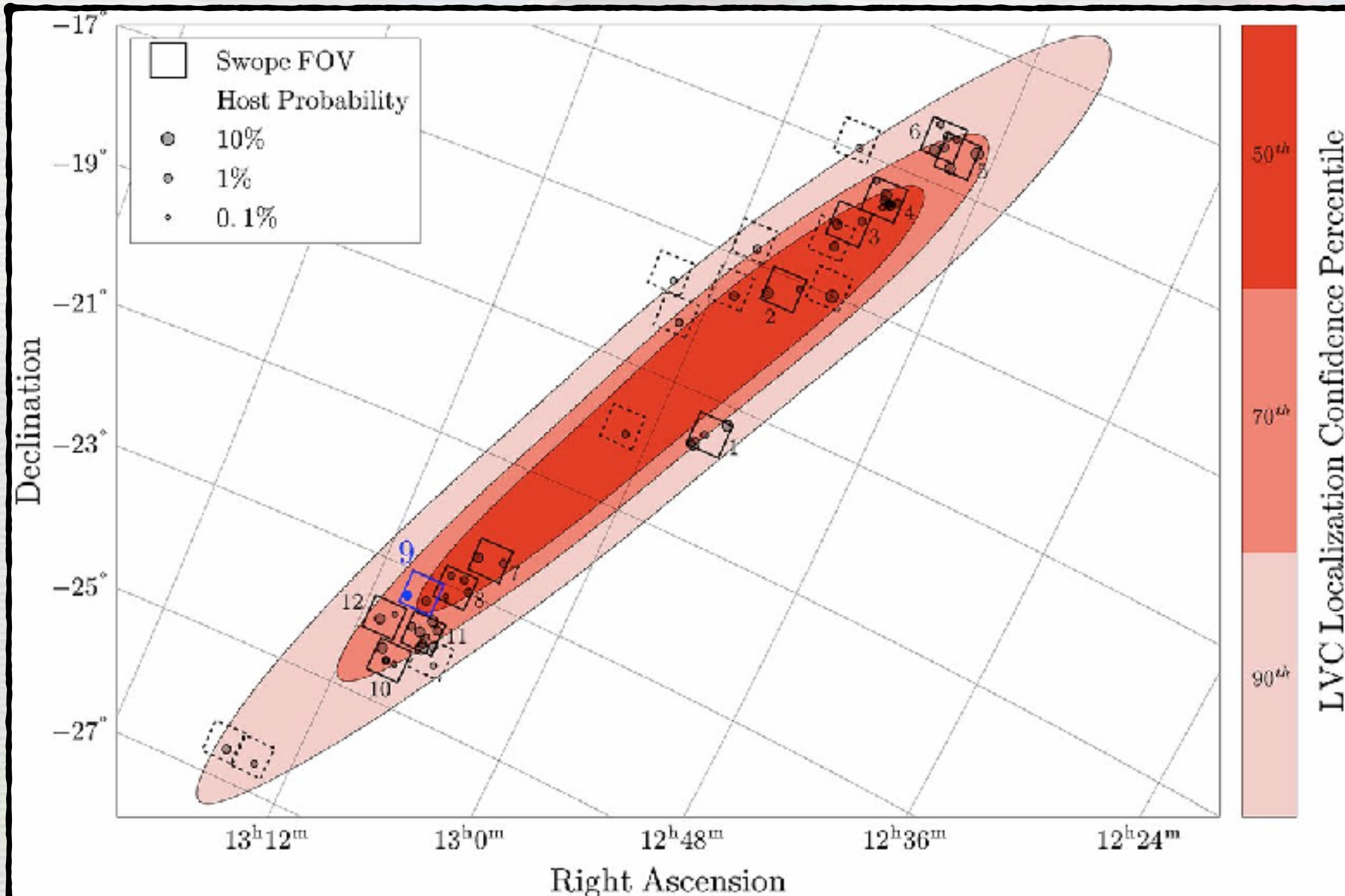
Detection

Galaxy surveys (all-sky)
with information on distance and magnitudes

We observe galaxies in the sky map by prioritizing:

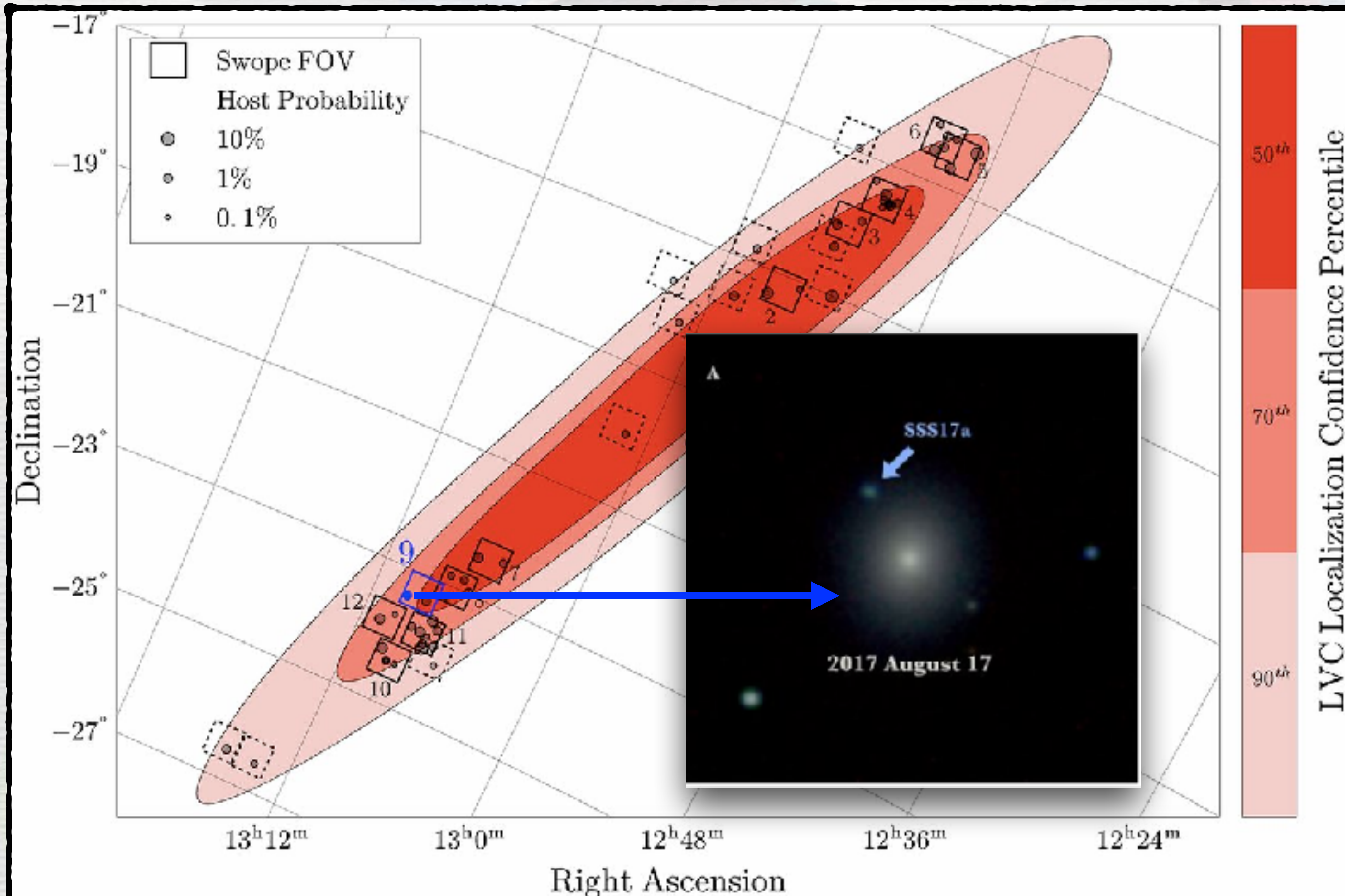
- high probability sky map regions
- galaxies with expected distance and properties

Host Galaxy



Coulter+2017

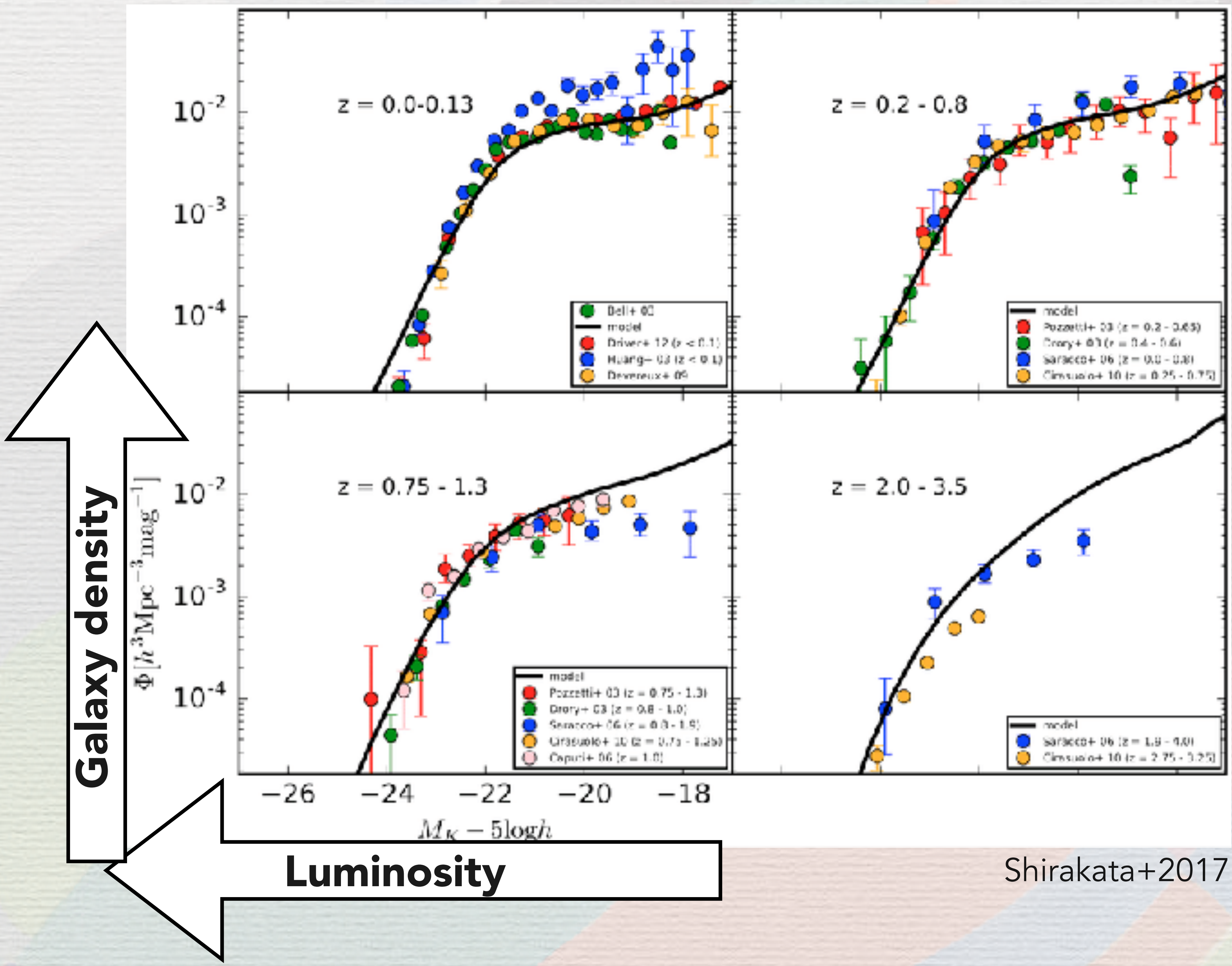
GW170817 - NGC 4993



Coulter+2017

GW170817 - NGC 4993

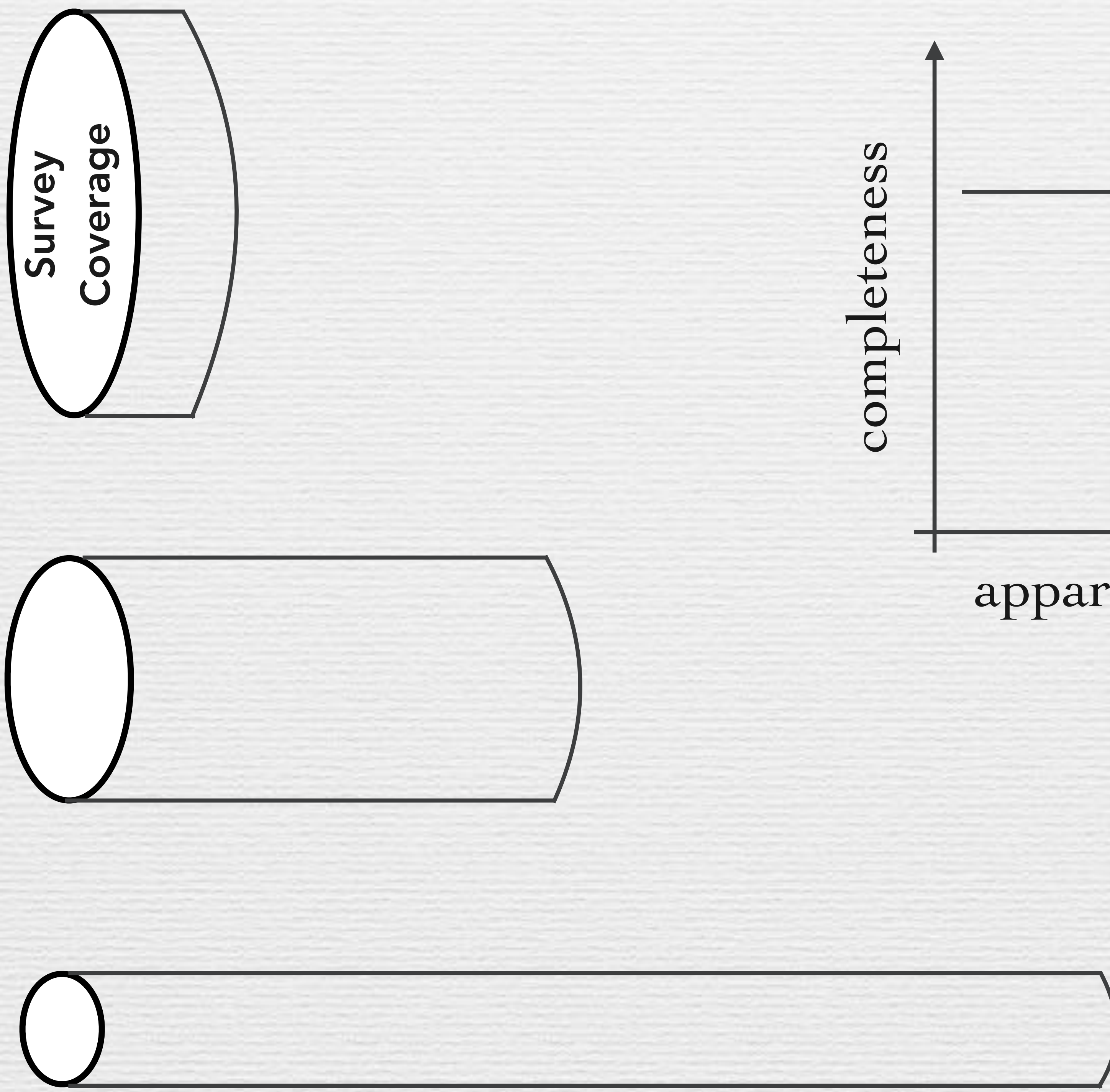
Host Galaxy

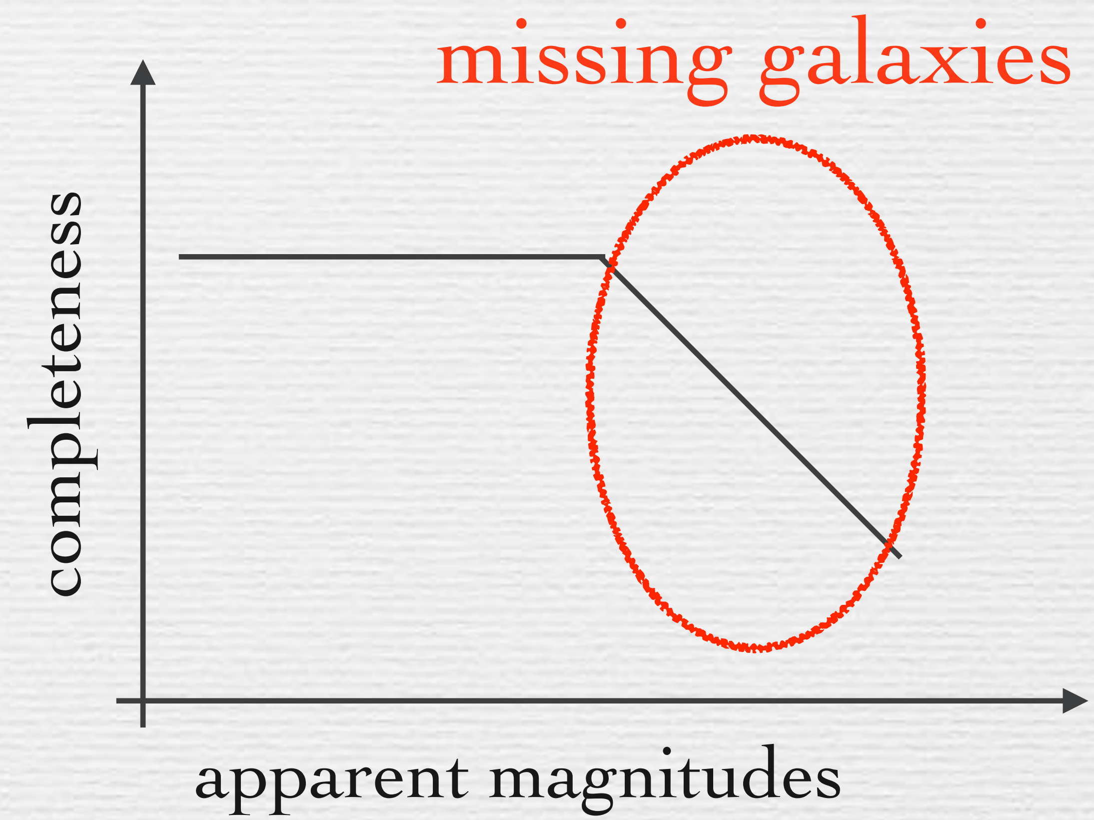


Shirakata+2017

NIR Galaxy luminosity function

fainter objects (fluxes): intrinsically fainter or more distant





Detection

Galaxy surveys (all-sky)
with information on distance and magnitudes

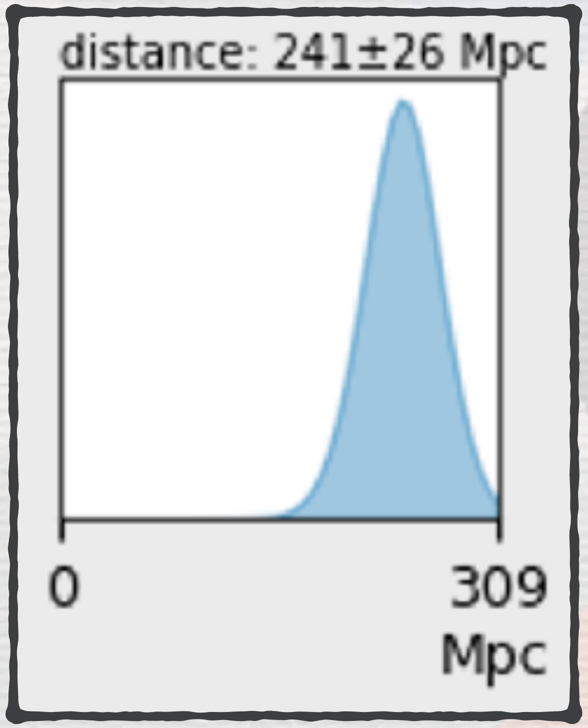
We observe galaxies in the sky map by prioritizing:

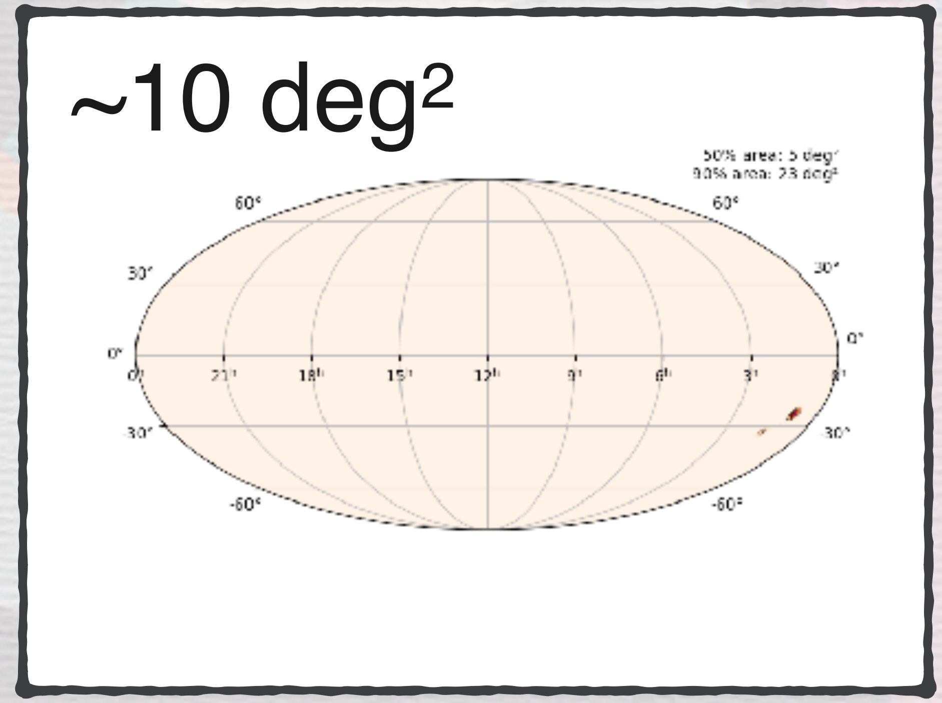
- high probability sky map regions
- galaxies with expected distance and properties

Issue: **Catalogue incompleteness**

Large sky map/distant event —> large number of galaxies
Limited telescope time + limited time window to detect the KN
Issue: **Observation incompleteness**

example from O3 run





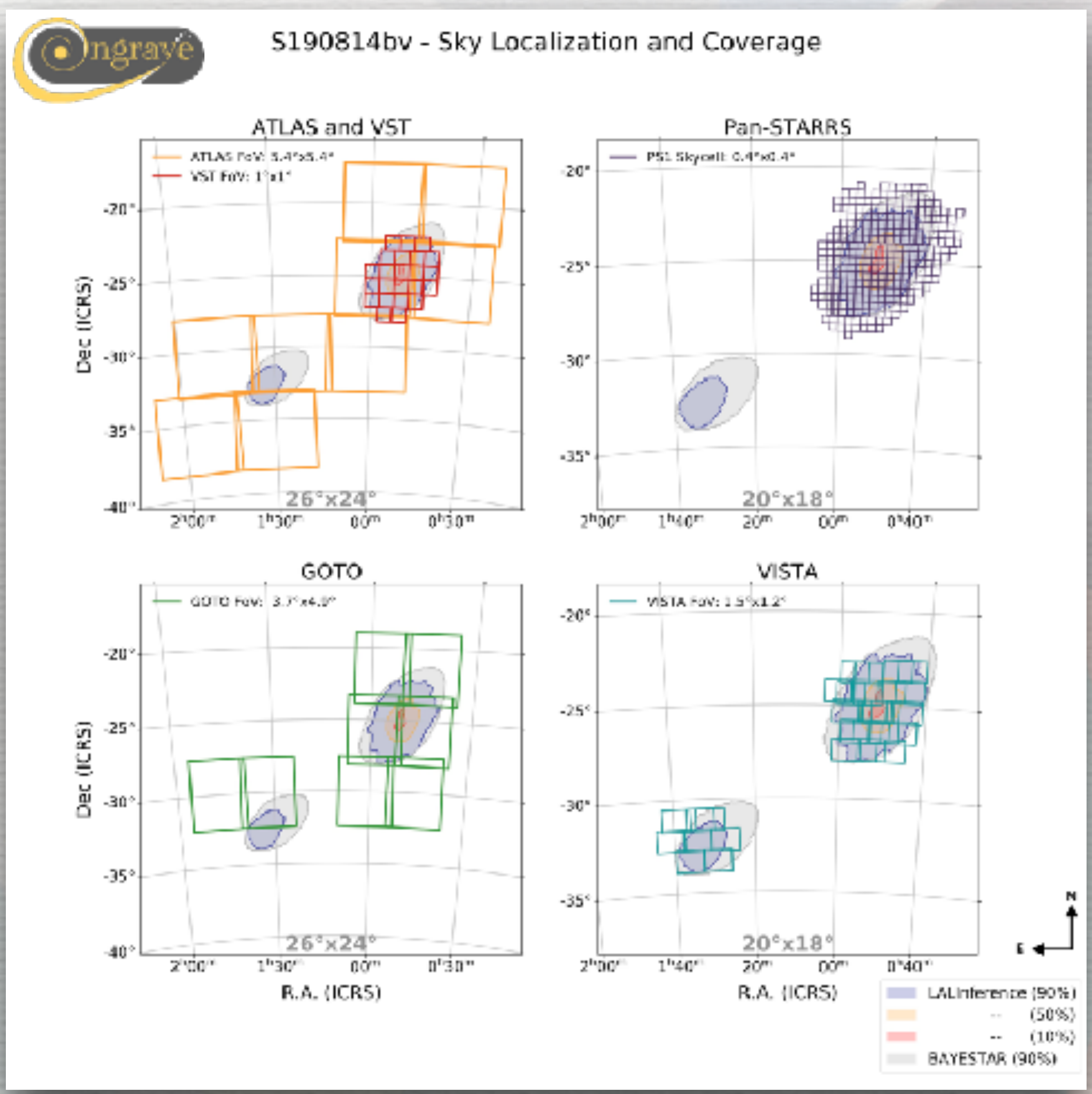
With transient surveys

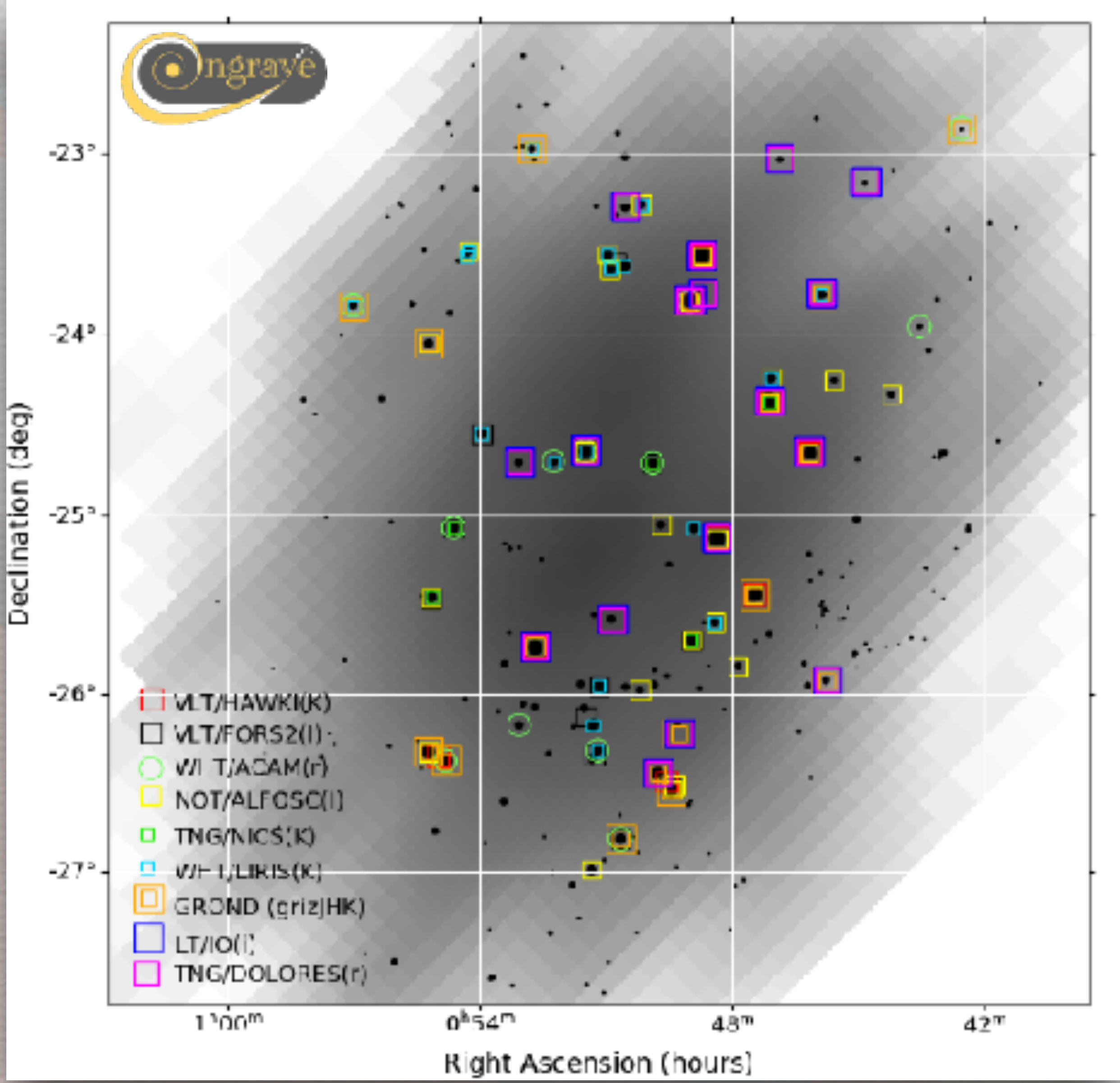
+

Dedicated galaxy observations

Ackley+2020

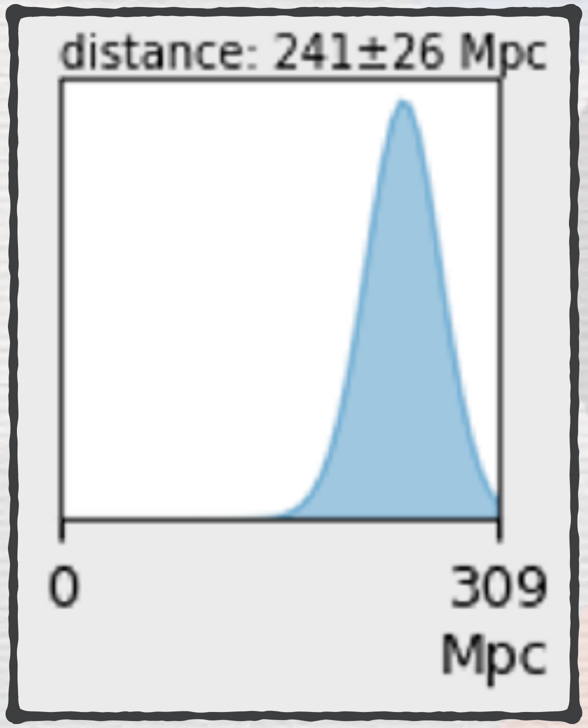
example from O3 run

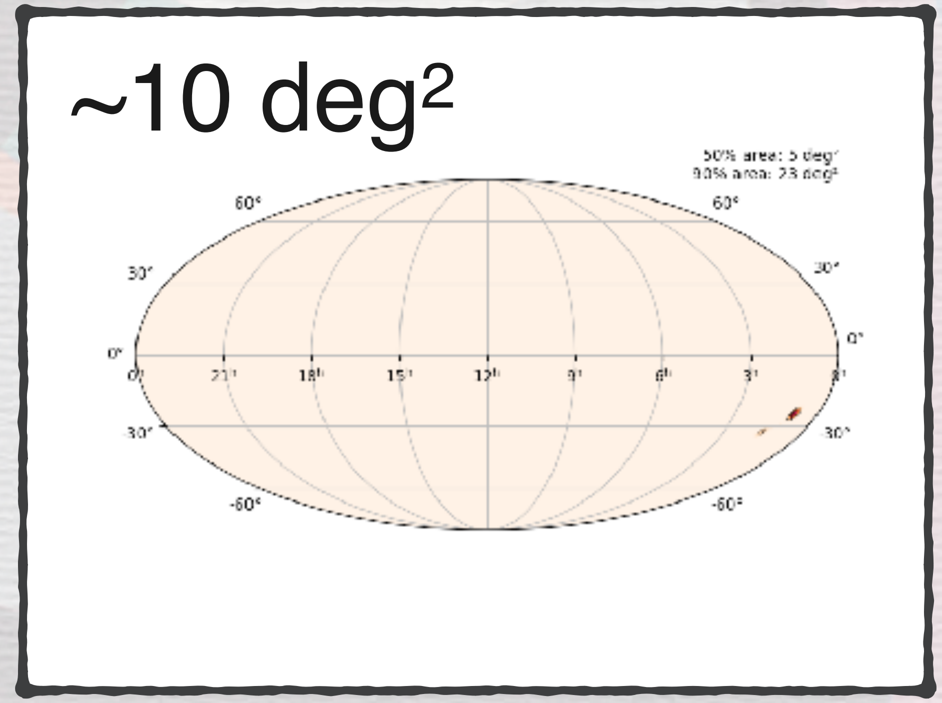


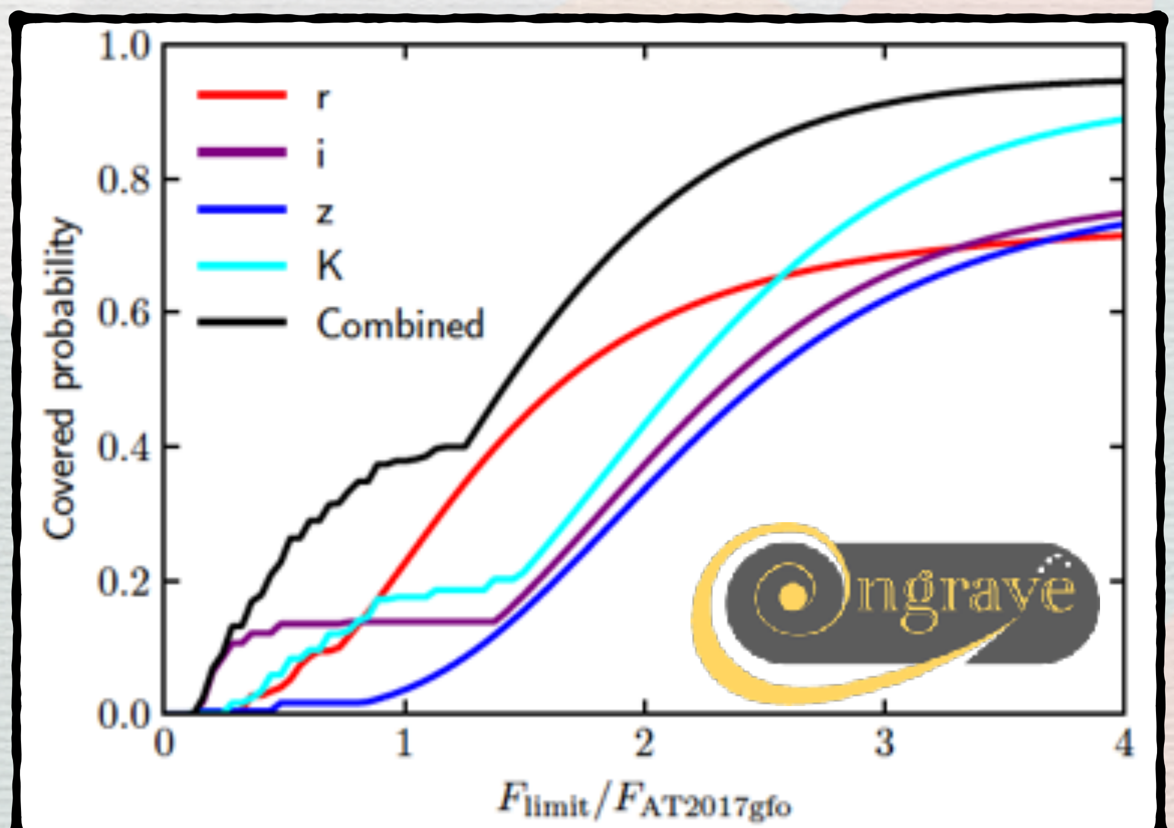


Ackley+2020

example from O3 run





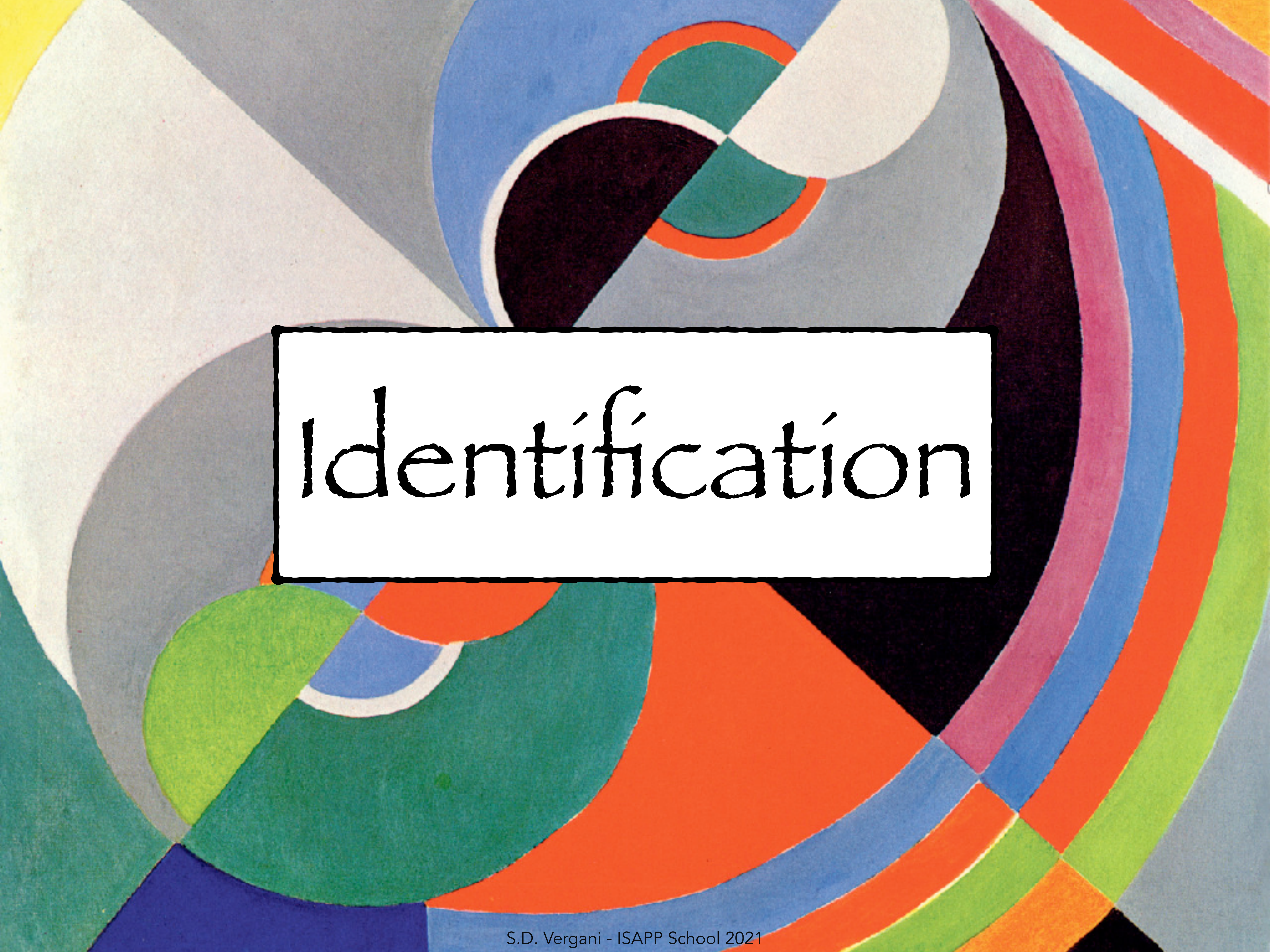


Ackley+2020

With transient surveys

+

Dedicated galaxy observations



Identification

We need **light-curve or spectrum**

(supposing that models are correct)

faint object and/or many candidates

how can we identify that it is the counterpart?

large localization: many transients!

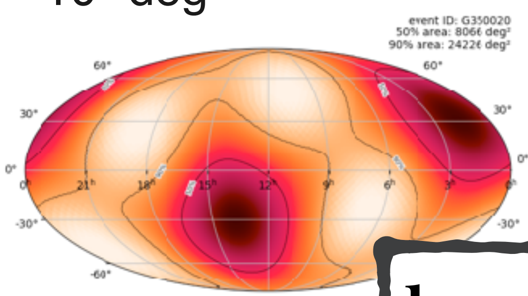
faint: just one point

radio: slow variability

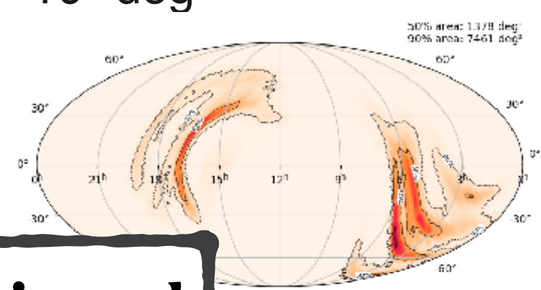
Kilonova (KN)

Do we have instruments with
- wide enough FOV
- enough sensitive
- (and rapid)?

~10^4 deg^2

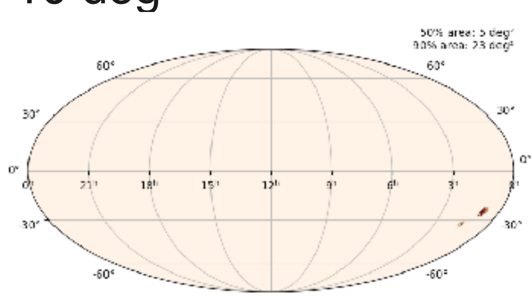


~10^3 deg^2



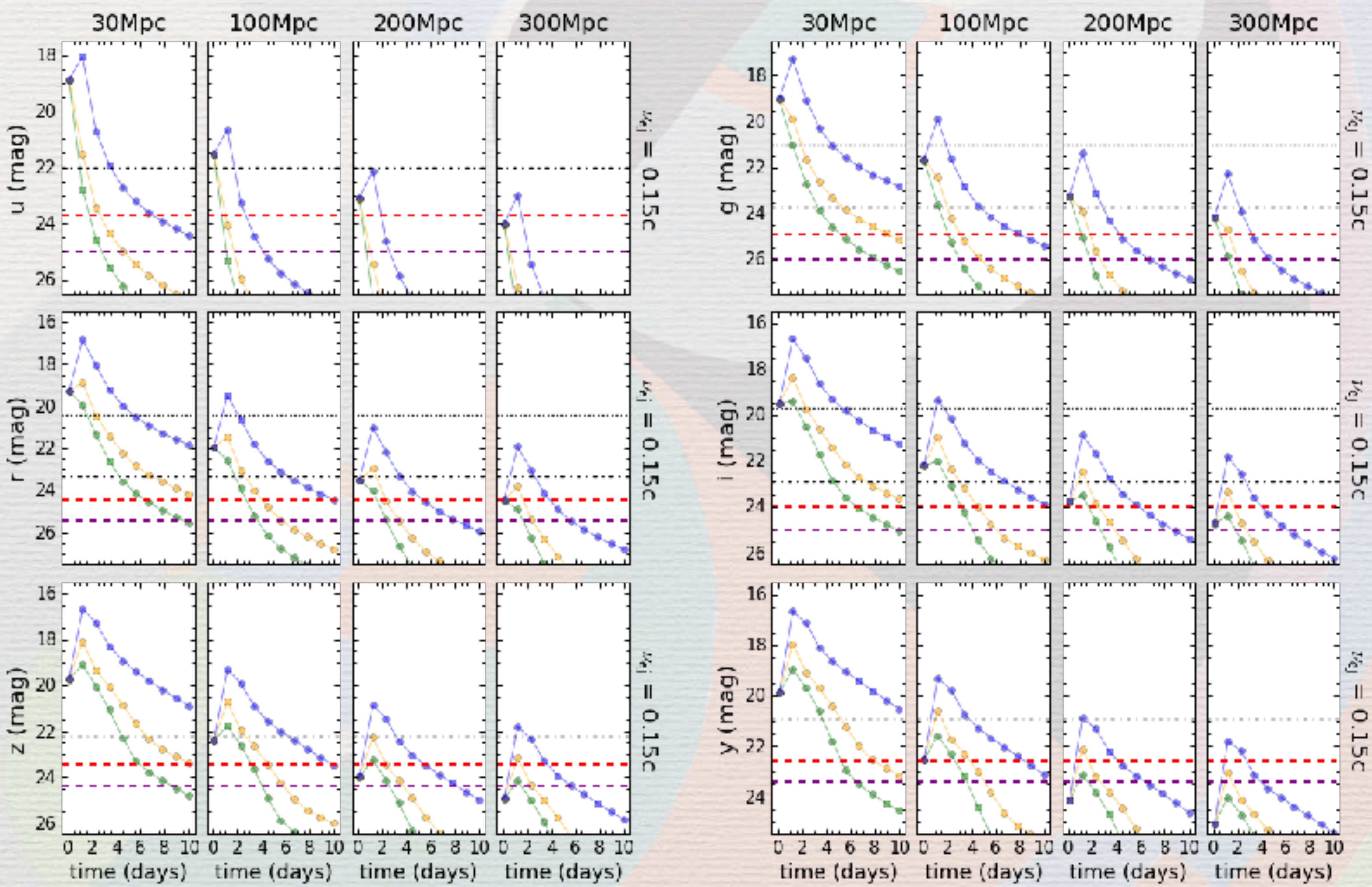
large localization: many transients!

~10 deg^2



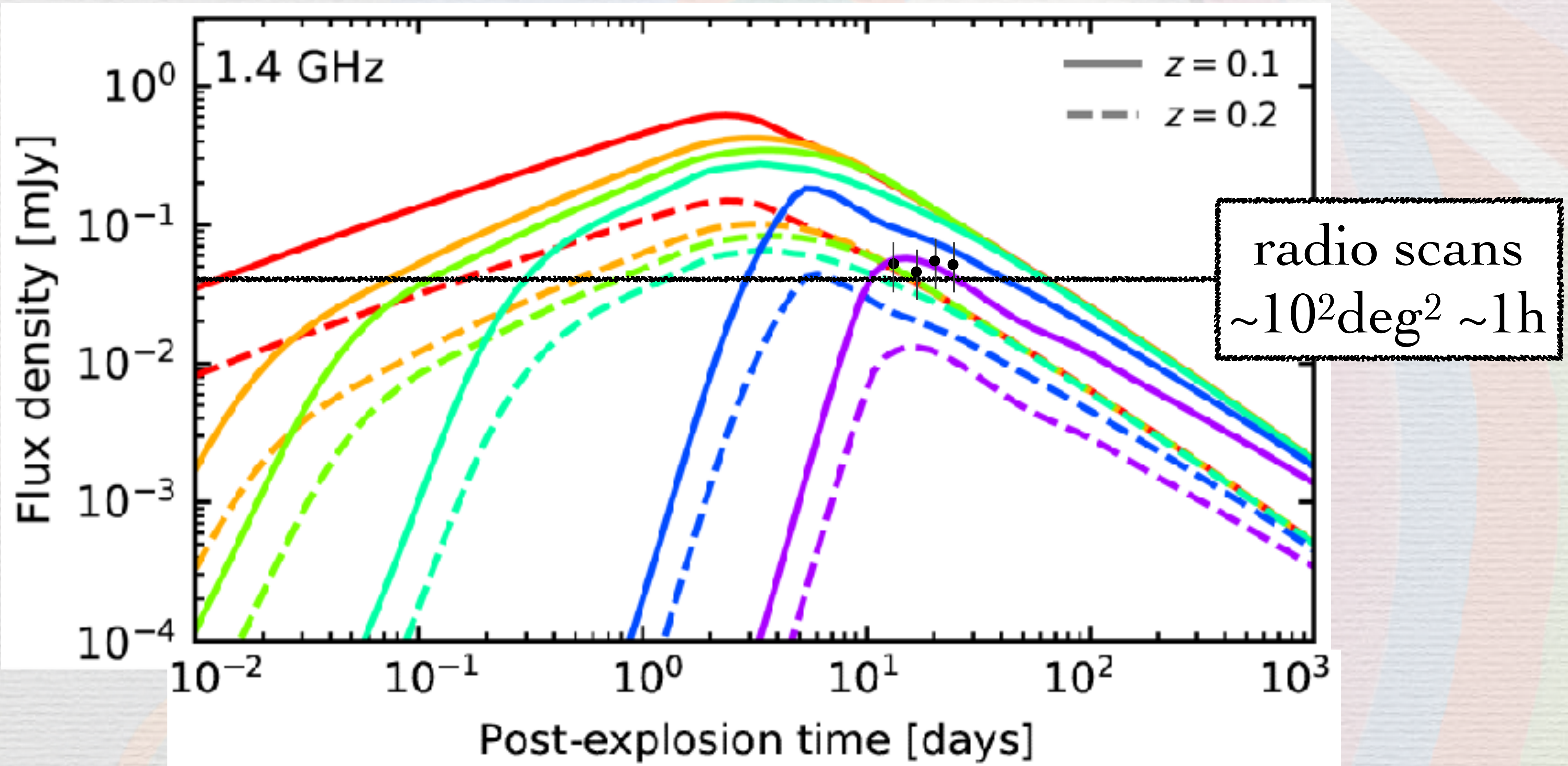
LSST key role for detection !

Kilonova (KN)



faint: just one point

Courtesy of Om Sharam Salafia



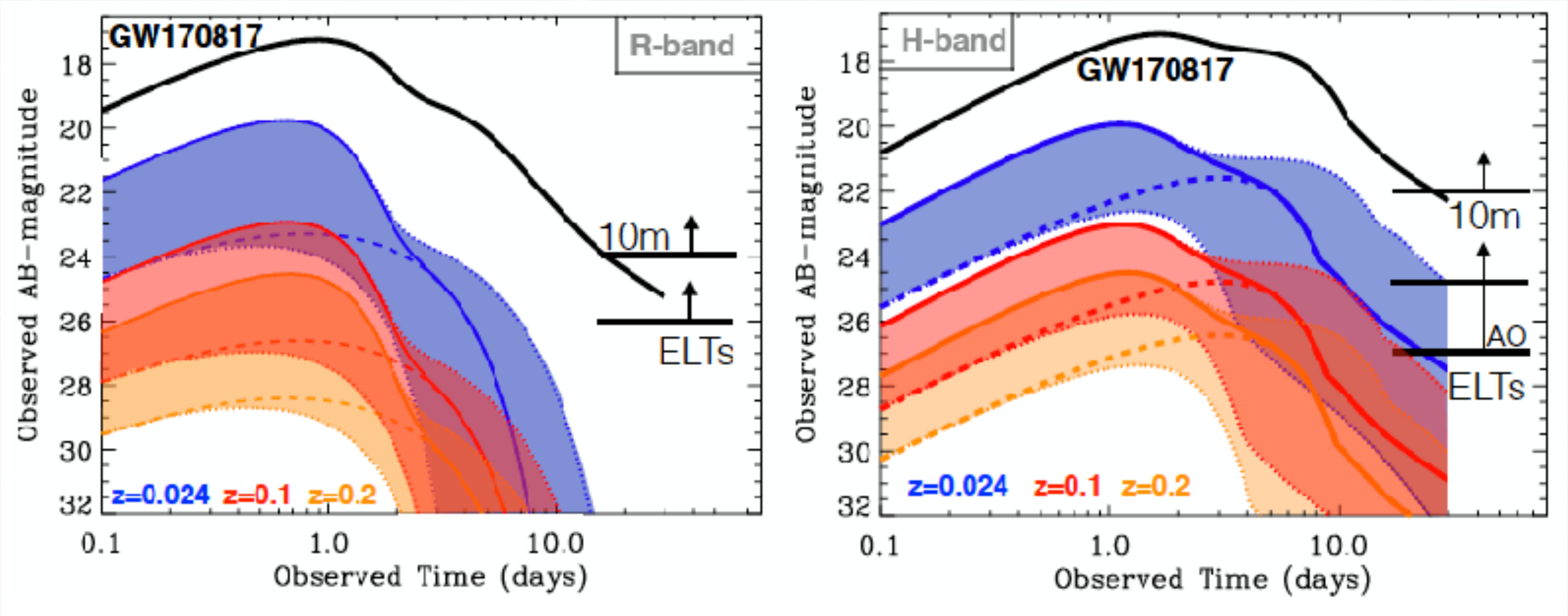
- Time association!
- Many transients
- Late time (faint at other wavelengths)

Multi-wavelength strategy with the best telescopes needed

Ok for few objets, not for many

Kilonova (KN)

adapted from Chornock+2019



Spectrum only with largest telescopes

Ok for few objets, not for many

Detection : necessary …but no astrophysics

Identification : necessary + some astrophysics

H_0, some spectral features, some rough properties of the KN ejecta (blue component, velocity,…)

Characterization : **Top!**

Detection : necessary ... but no astrophysics

Identification : necessary + some astrophysics

H_0, some spectral features, some rough properties of the KN ejecta (blue component velocity,...)

Characterization : top!

See Ghirlanda's lectures

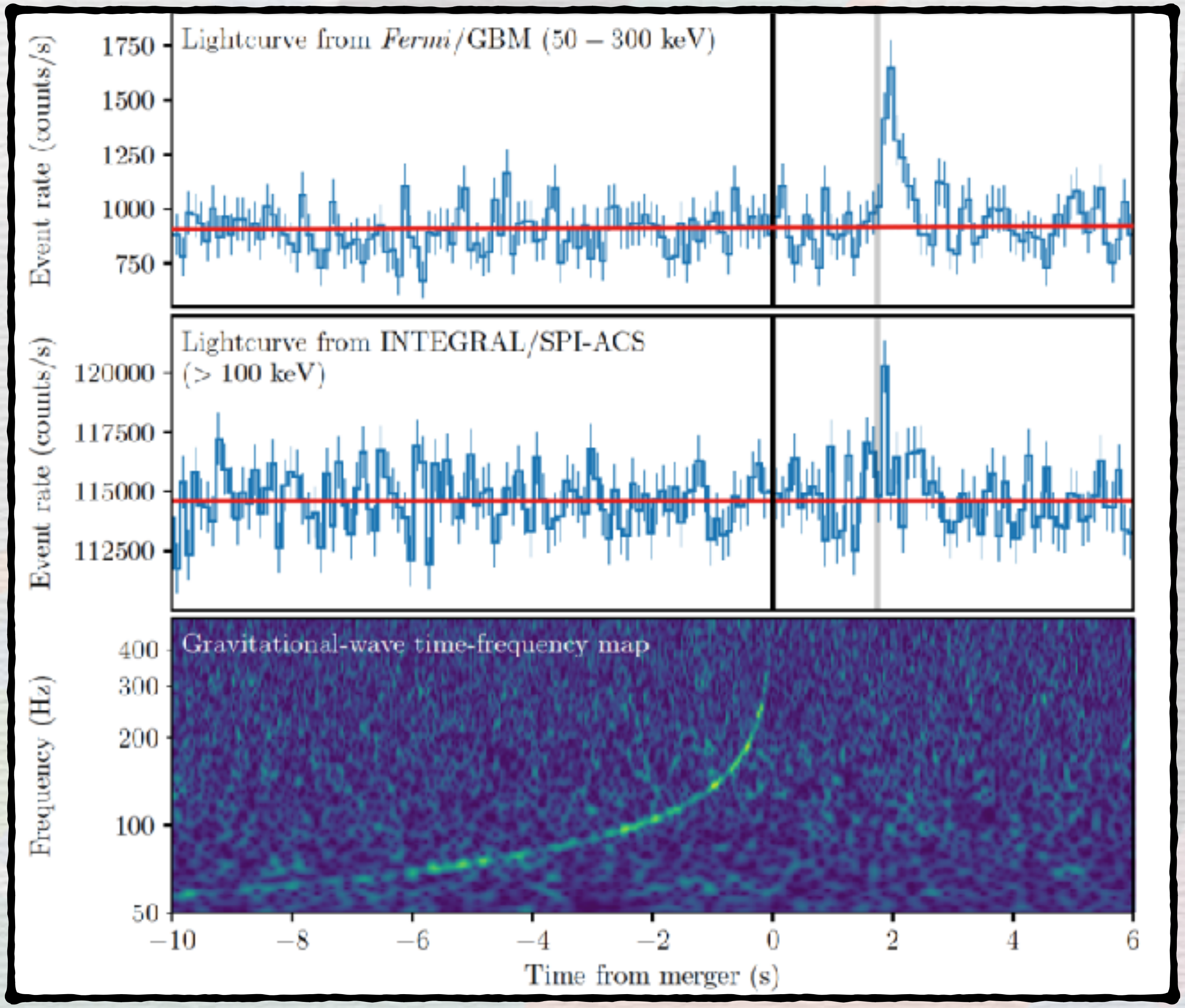
Challenging but not impossible!

Potentially high scientific return!

We will keep trying!

Thank you!

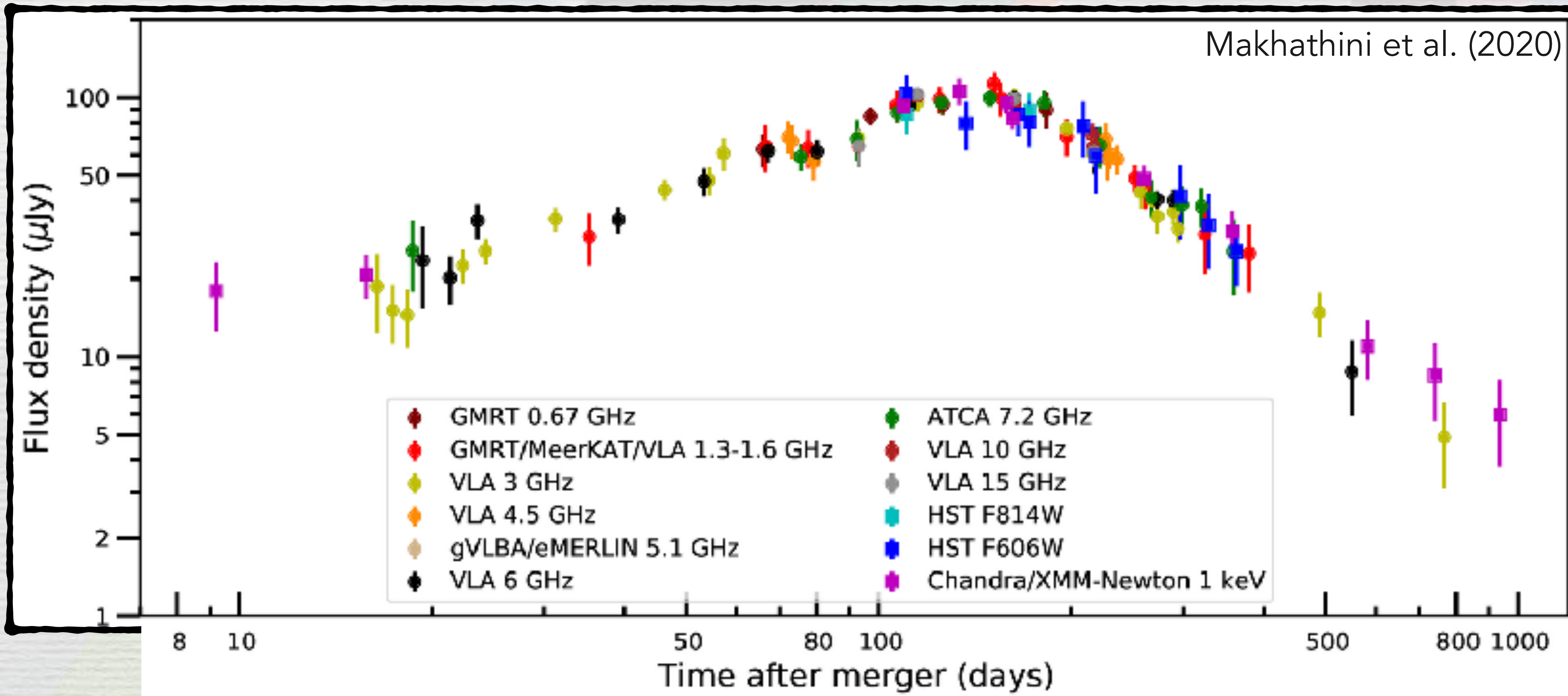
Relativistic jet (Gamma-ray burst)



Credit: LIGO/Virgo Collaboration

GW170817/GRB170817

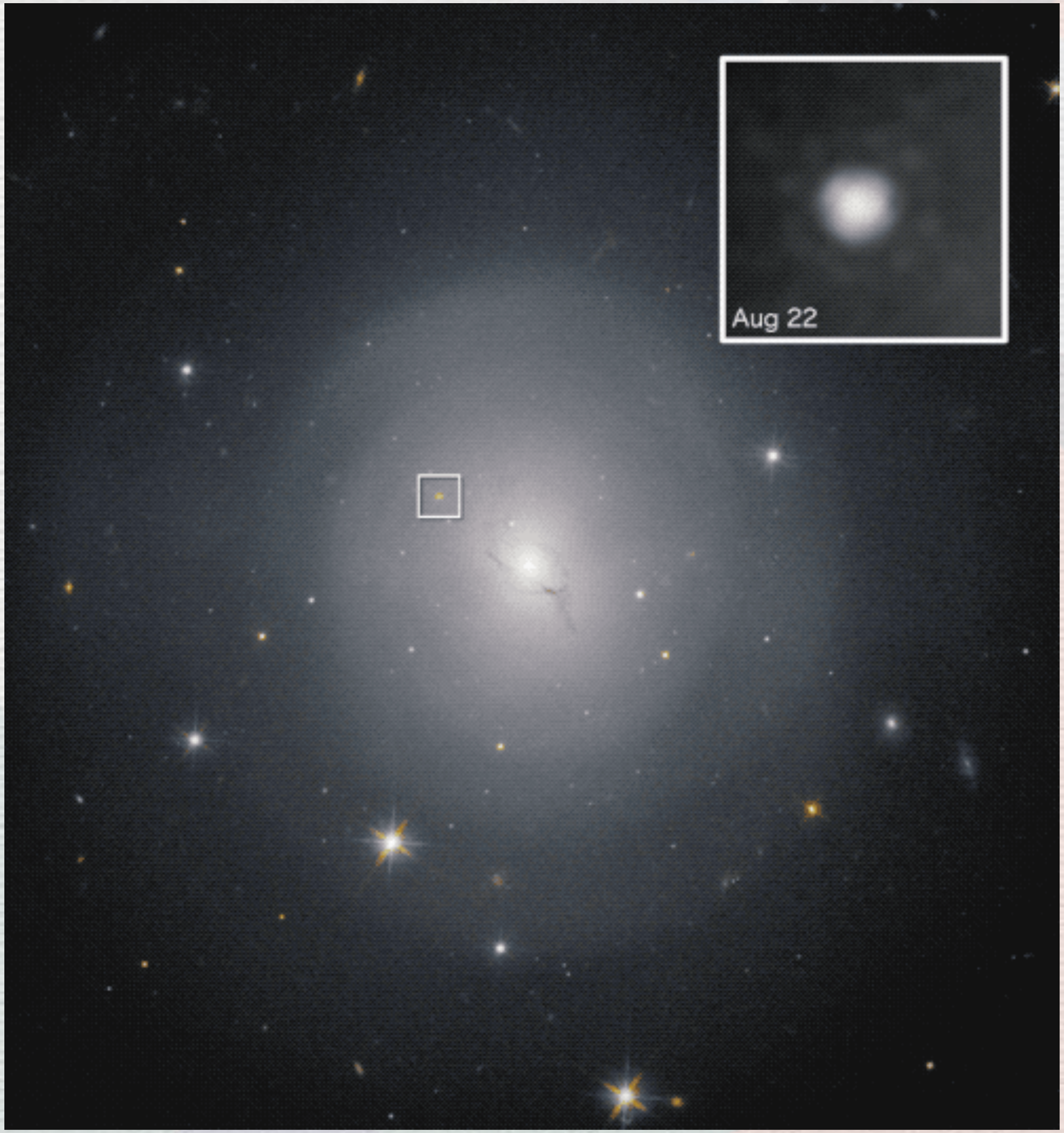
Relativistic jet (Gamma-ray burst)



GW170817/GRB170817

Relativistic, structured jet

host galaxy or globular cluster

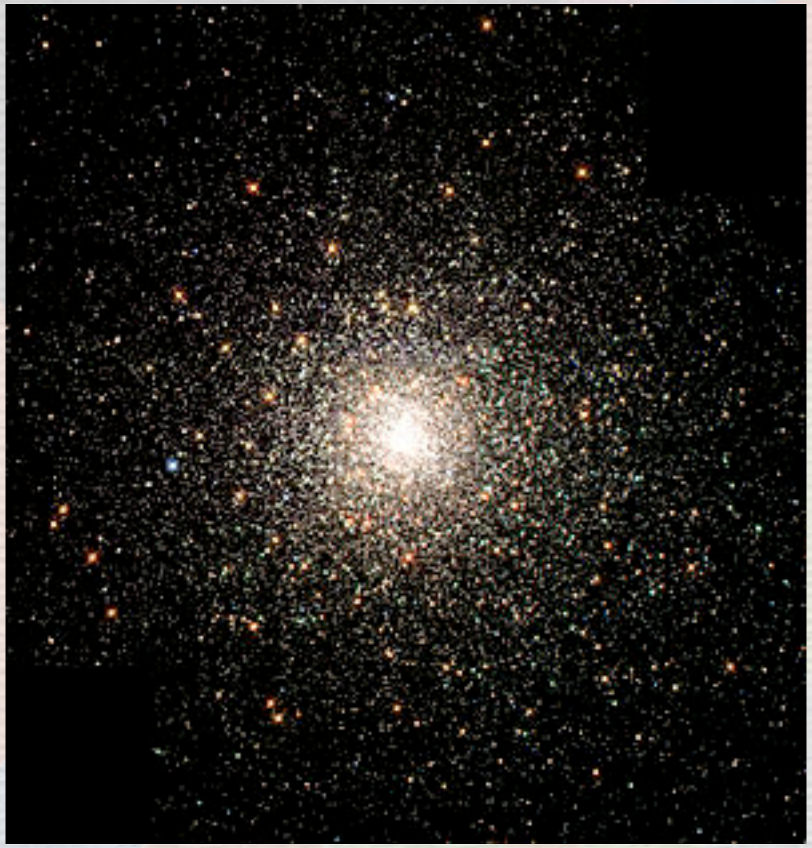


Credit: NASA

Distance information used for H_0

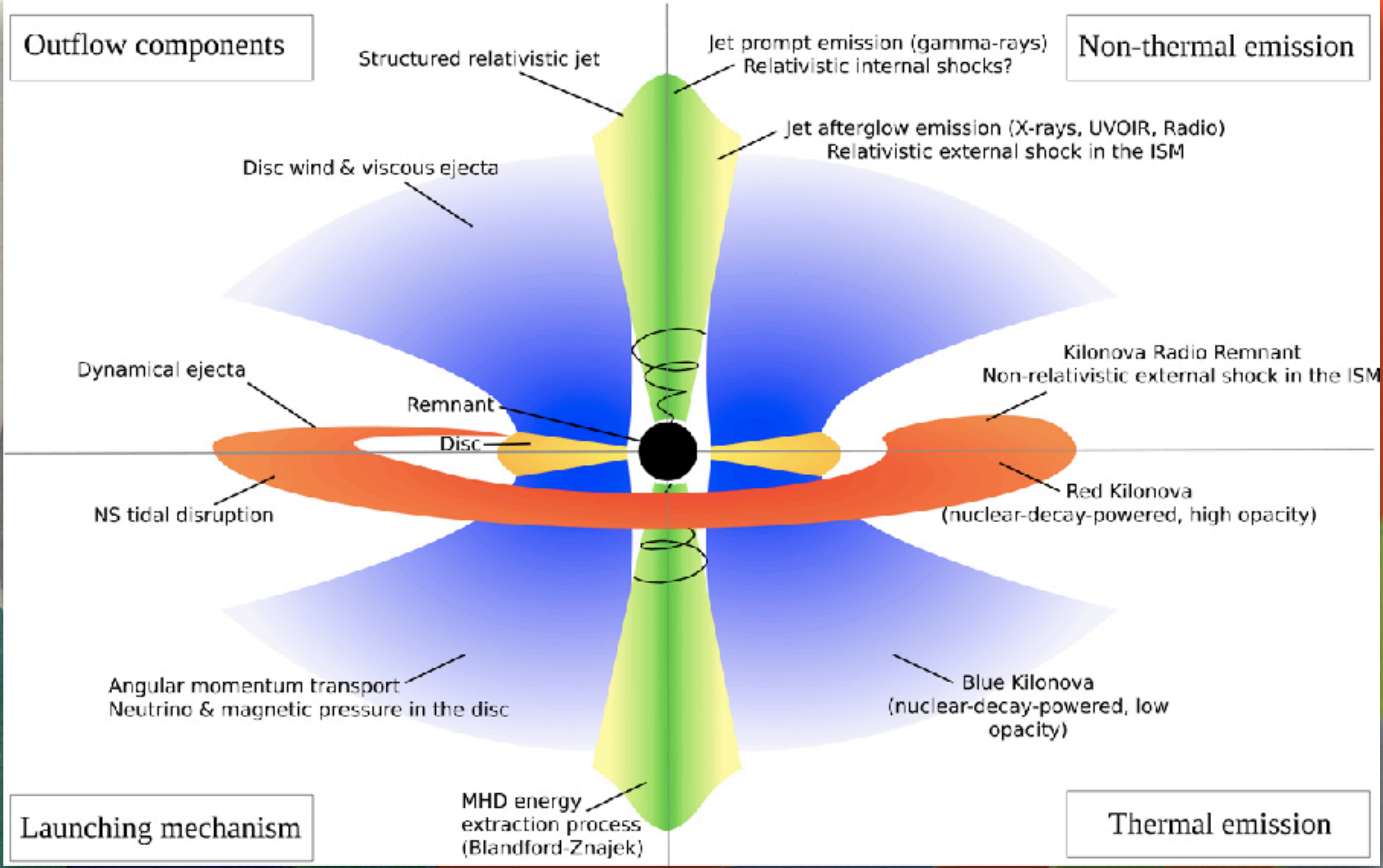
Environment

Evolutionary channel studies

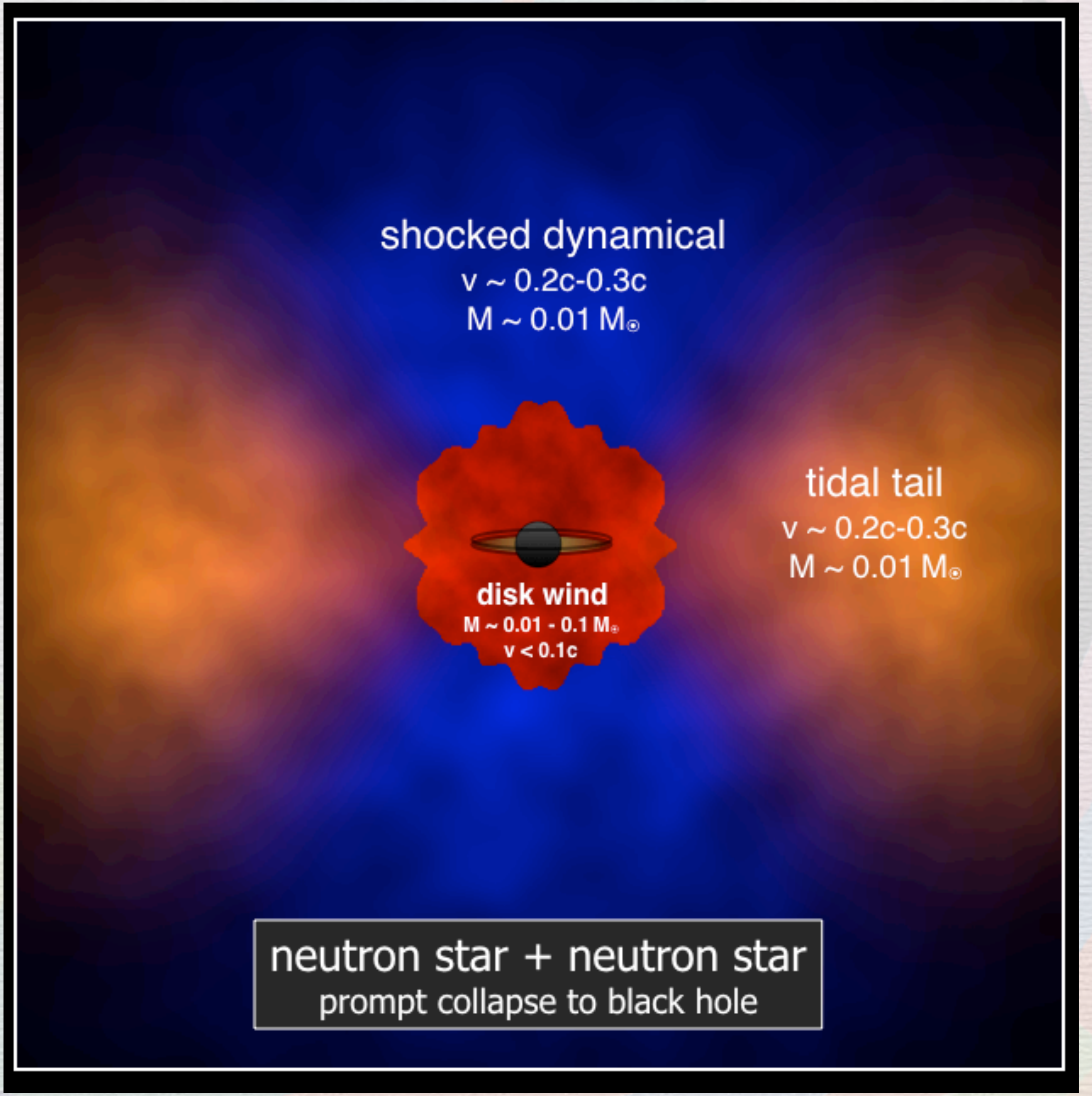


Credit: Space Telescope Science Institute

Kilonova (KN)



Outflow components
Structured relativistic jet
Jet prompt emission (gamma-rays)
Relativistic internal shocks?
Non-thermal emission
Jet afterglow emission (X-rays, UVOIR, Radio)
Relativistic external shock in the ISM
Disc wind & viscous ejecta
Kilonova Radio Remnant
Non-relativistic external shock in the ISM
Dynamical ejecta
Remnant
Disc
NS tidal disruption
Red Kilonova
(nuclear-decay-powered, high opacity)
Angular momentum transport
Neutrino & magnetic pressure in the disc
Blue Kilonova
(nuclear-decay-powered, low opacity)
MHD energy extraction process (Blandford-Znajek)
Launching mechanism
Thermal emission


shocked dynamical
v ~ 0.2c-0.3c
M ~ 0.01 M☉
tidal tail
v ~ 0.2c-0.3c
M ~ 0.01 M☉
disk wind
M ~ 0.01 - 0.1 M☉
v < 0.1c
neutron star + neutron star
prompt collapse to black hole