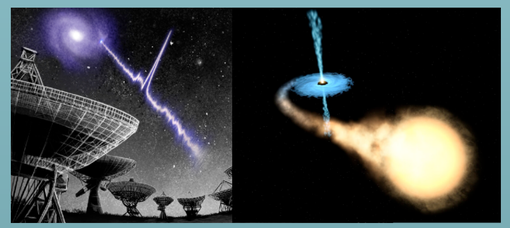
S.D. Vergani

Time Domain Astrophysics

AtLAST workshop - Paris - May 2025

PROVIDERS OF TRANSIENTS : EM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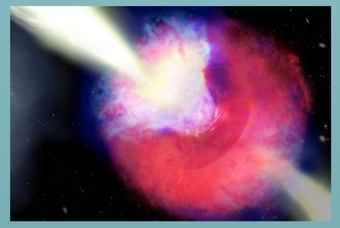
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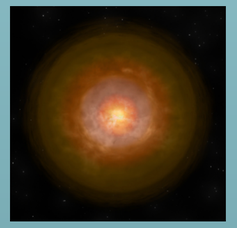
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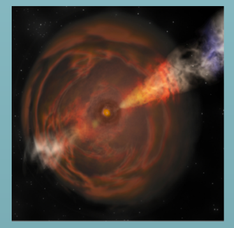

UV


X-rays


GAMMA

Today

2030

2040

ZTF

VERA C. RUBIN OBSERVATORY

SKAO

ROMAN SPACE TELESCOPE

ULTRASAT Ultraviolet Transient Astronomy Satellite

UVEX

einstein probe 愛因斯坦探針 exploring the dynamic x-ray universe

Swift

SVOM

Fermi Gamma-ray Space Telescope

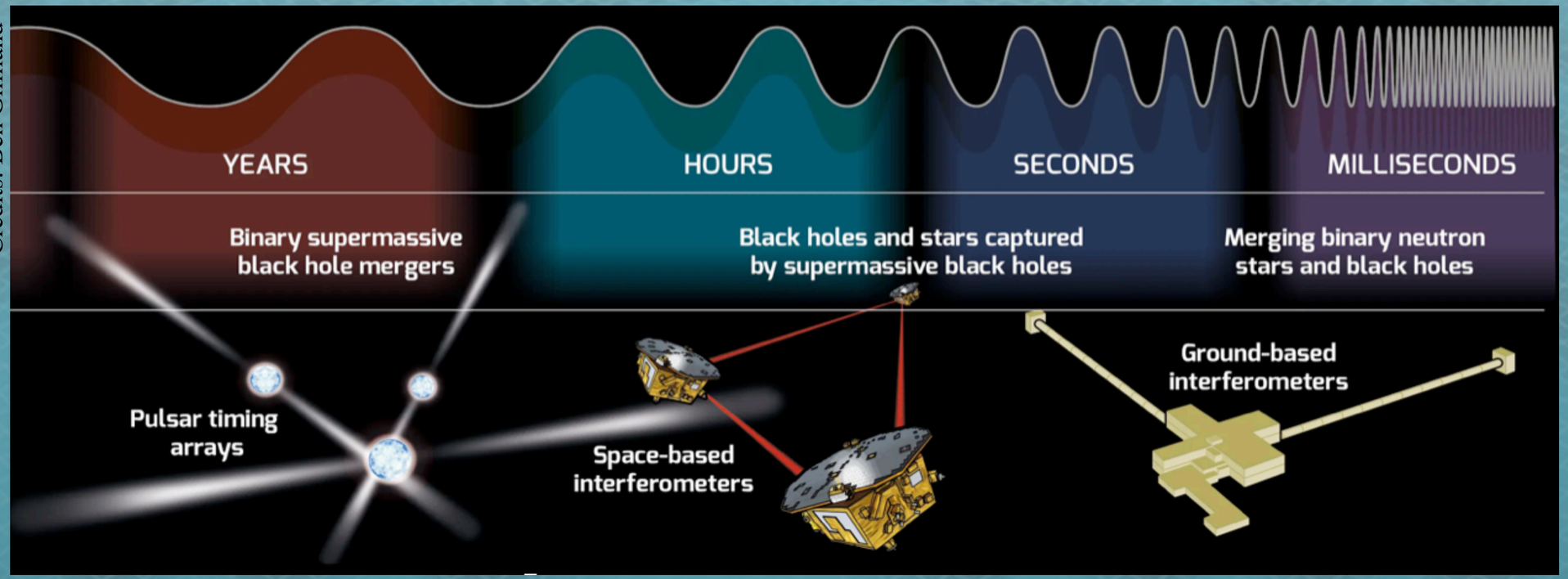
CTAO

? THESEUS

PROVIDERS OF TRANSIENTS : GW

10^{-9}-10^{-6}Hz 10^{-5}-10^{-1}Hz 1-10^{4}Hz

Credits: Ben Gilliland



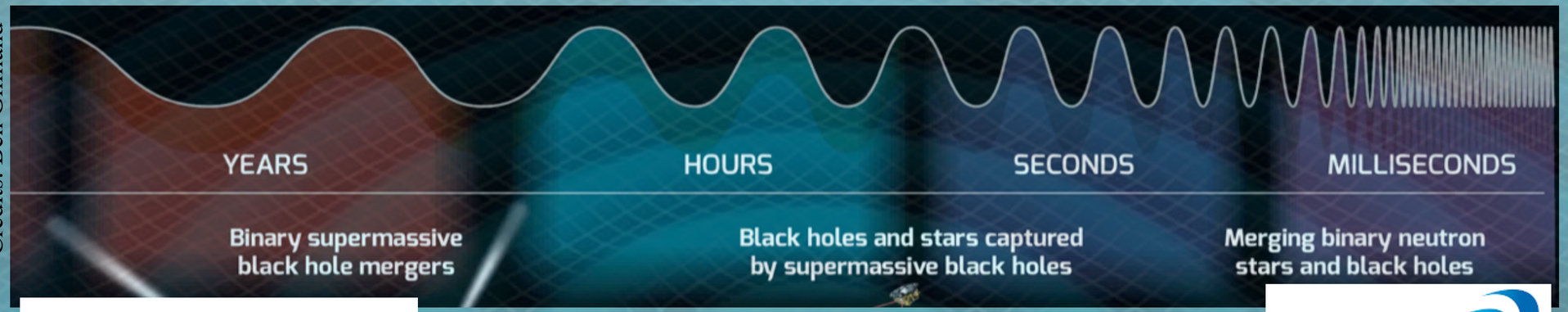
PROVIDERS OF TRANSIENTS : GW

10^{-9}-10^{-6}Hz

10^{-5}-10^{-1}Hz

1-10^{4}Hz

Credits: Ben Gilliland



Today

2030

2040

EPTA

LIGO VIRGO KAGRA

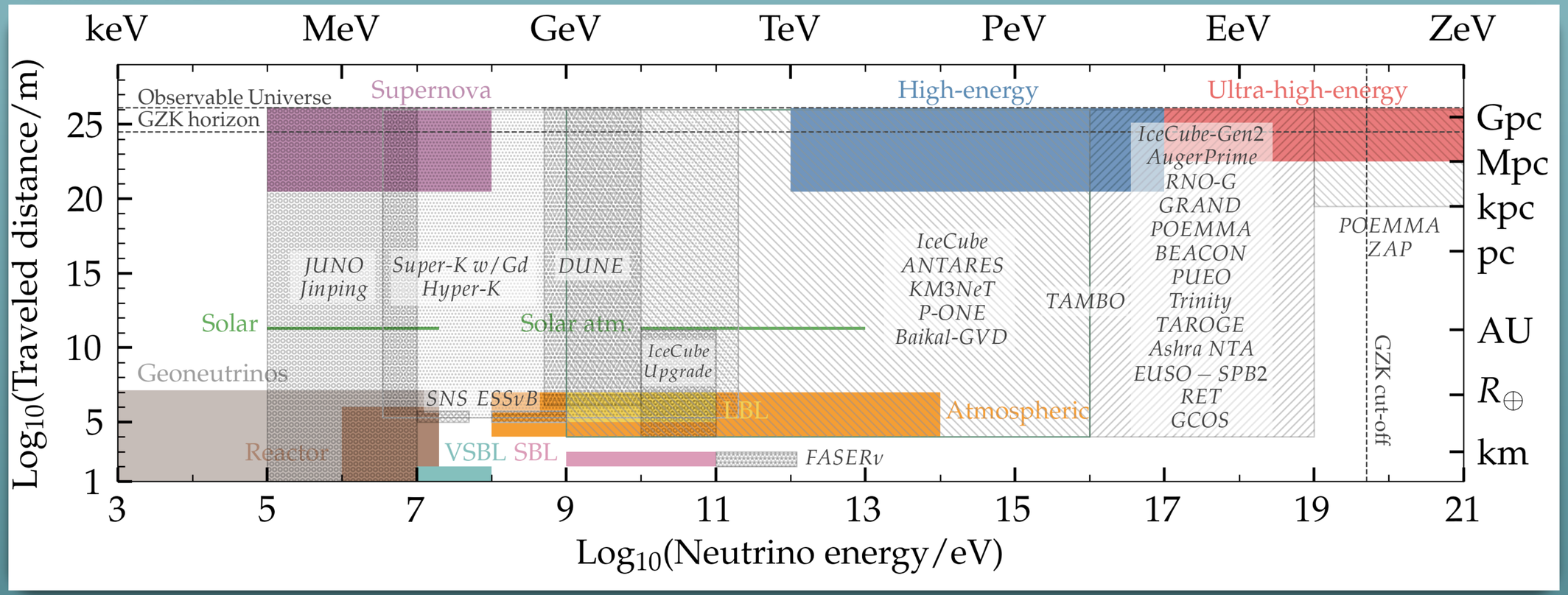
lisa

ET EINSTEIN TELESCOPE

COSMIC EXPLORER

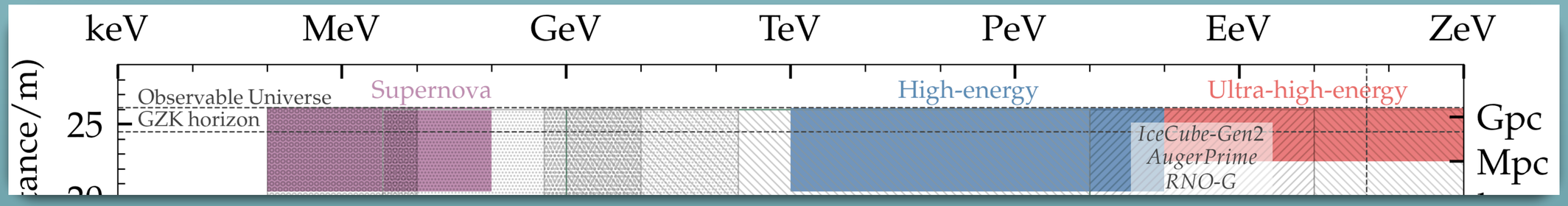
PROVIDERS OF TRANSIENTS : ν

Ackermann et al. 2022



PROVIDERS OF TRANSIENTS : ν

Ackermann et al. 2022



Today

2030

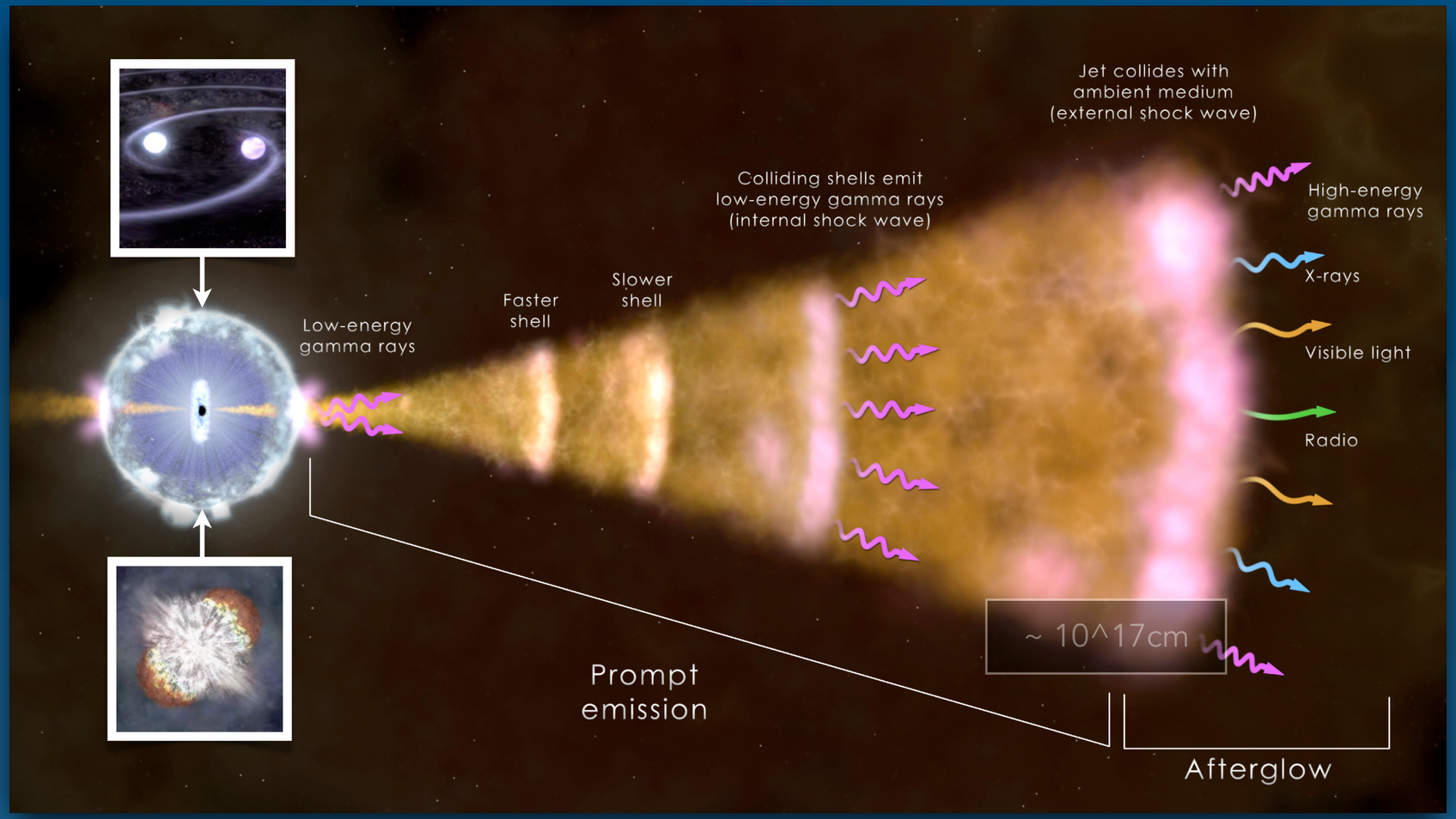
2040

ICECUBE NEUTRINO OBSERVATORY

KM3NeT

ICECUBE GEN2

Gamma-ray bursts (GRBs)

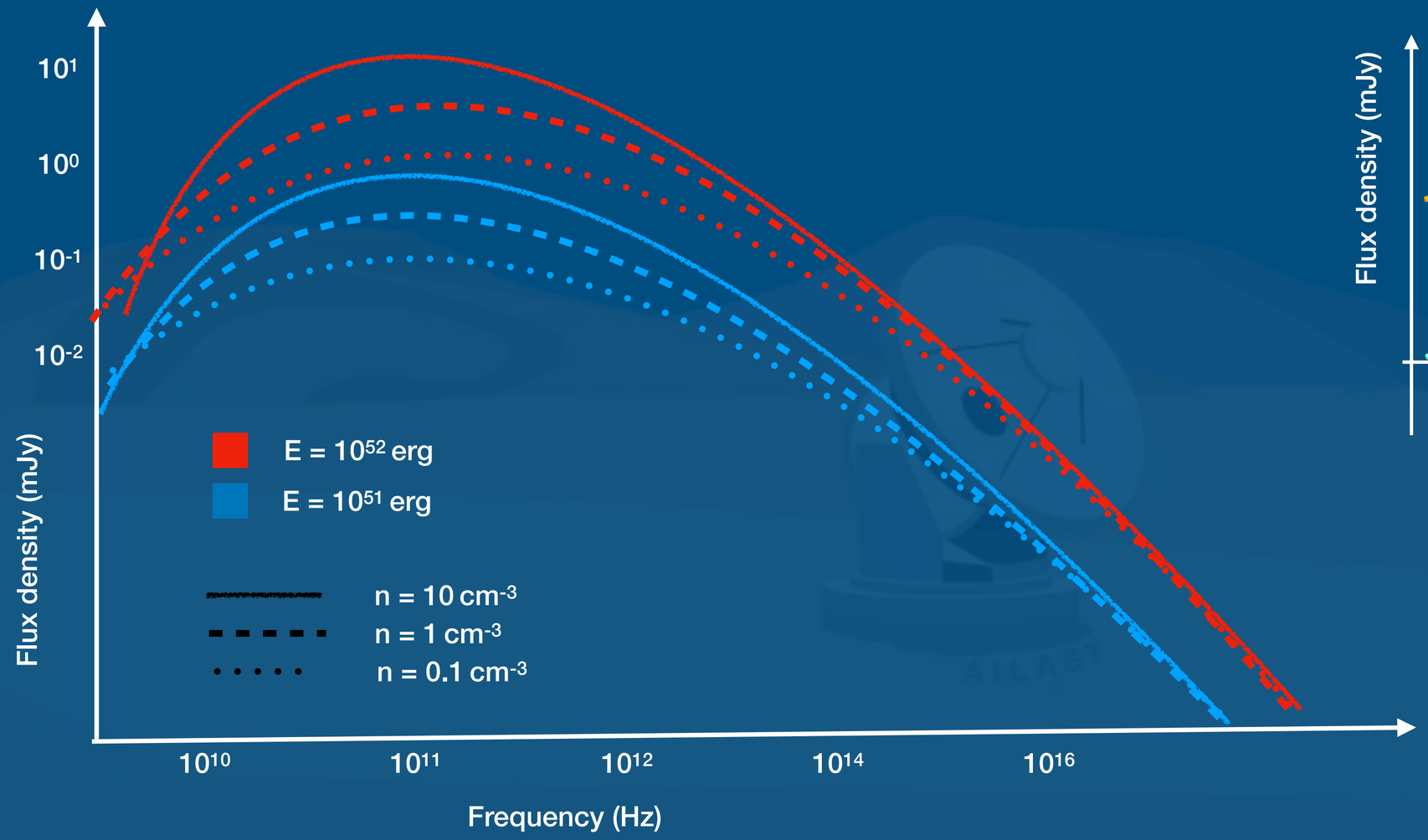


GRB physics with mm observations

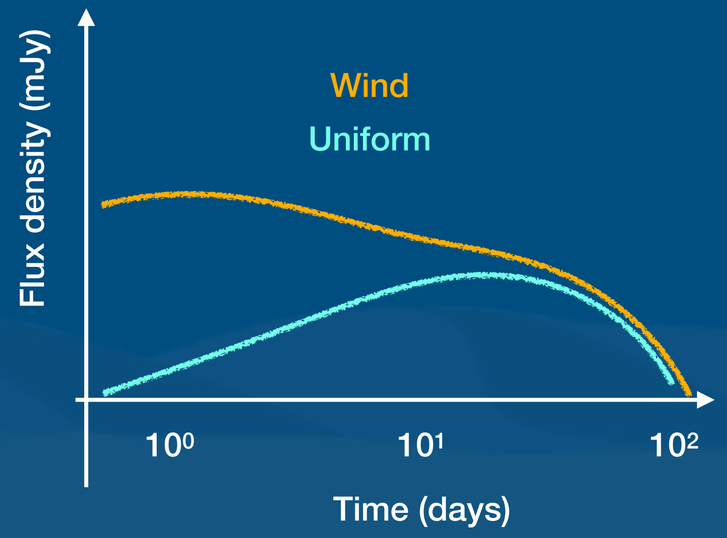
Determine the Energy and electron density
Determine the Lorentz factor
Determine the radial density profile
Observe the reverse and forward shock contributions
Study the synchrotron emission

GRB physics with mm observations

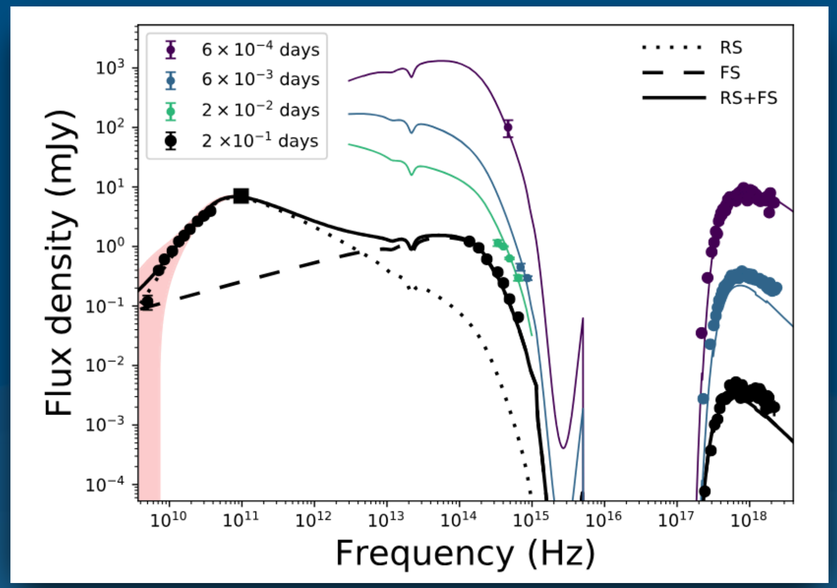
Energy & Electron Density



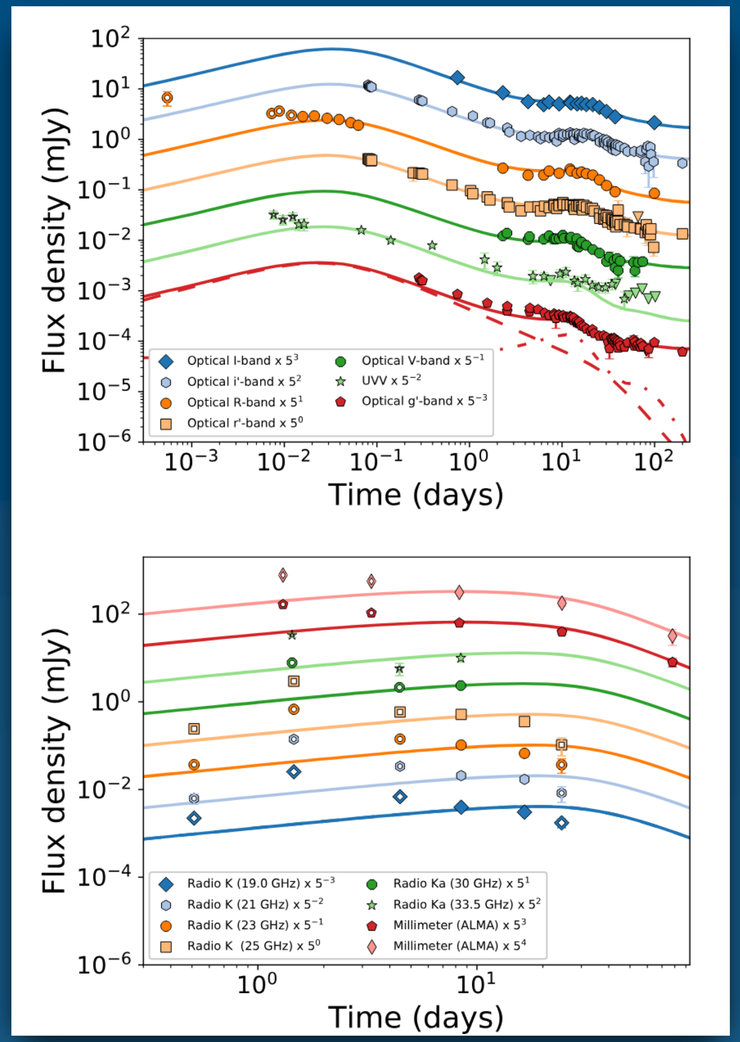
Radial Density Profile

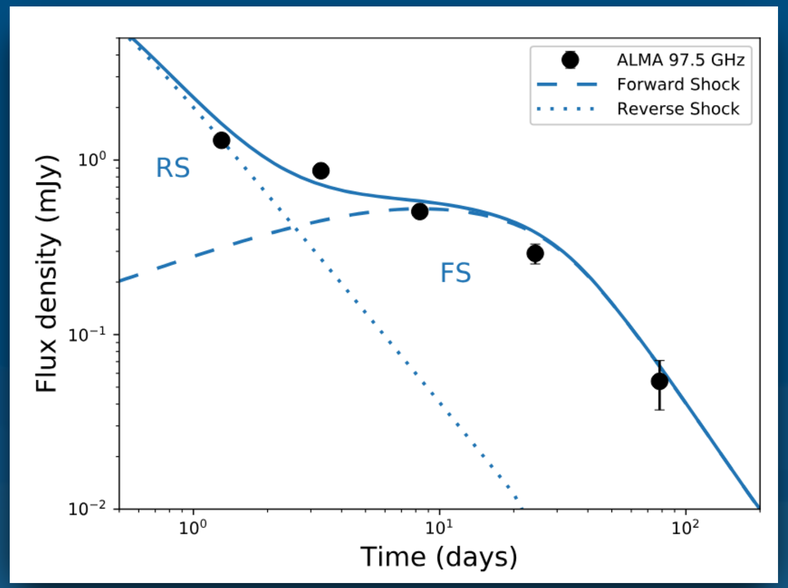


GRB physics with mm observations



Laskar et al. 2019





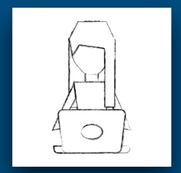
Laskar et al. 2018

GRB OBSERVATIONS

Alert from satellites

RRM (s)

s



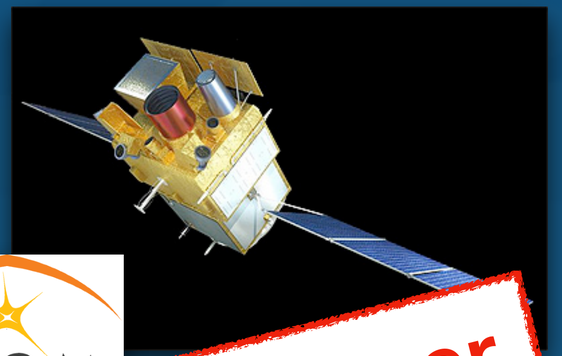
ToO (hrs)

s

Robotic telescopes

s

Large telescopes



SVOM

Trigger

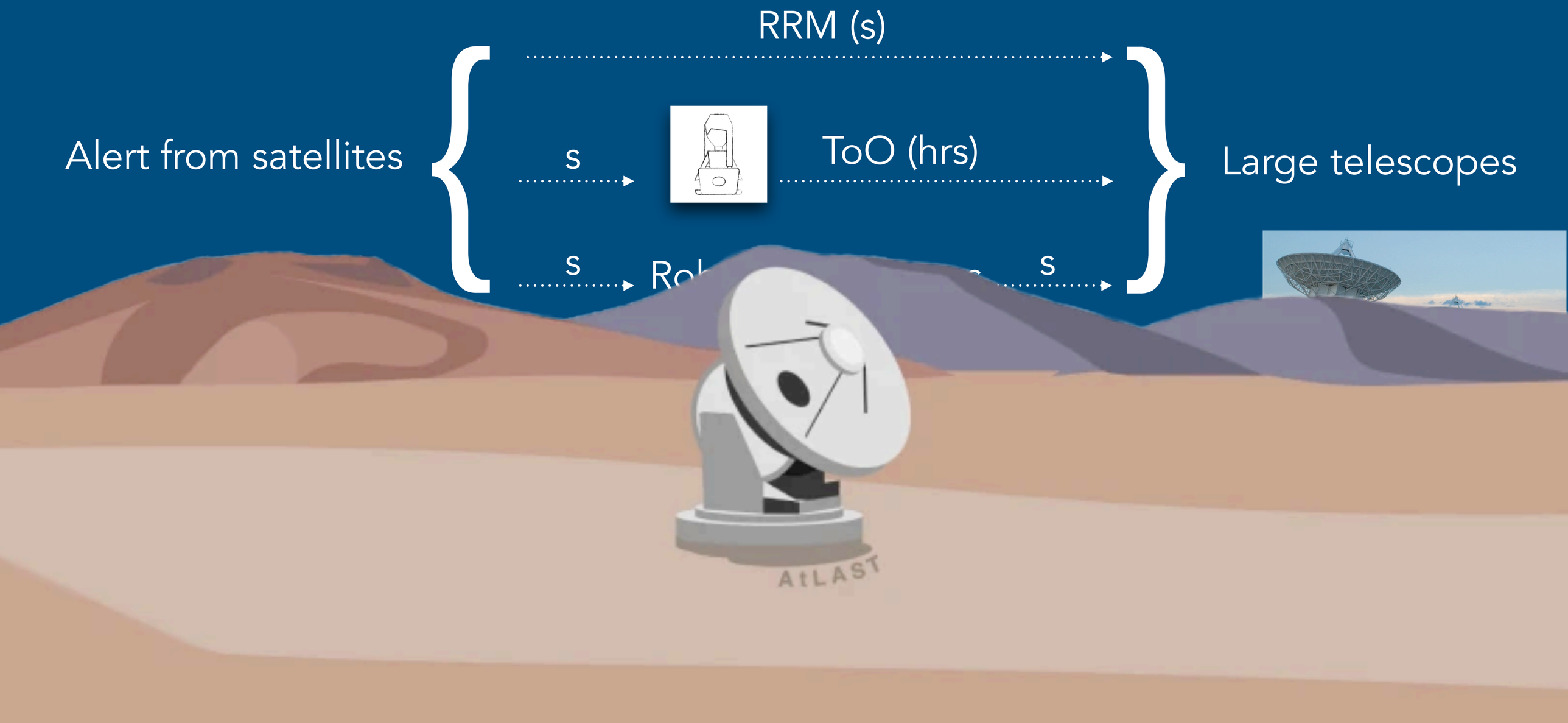
+

Precise localization + early lightcurve

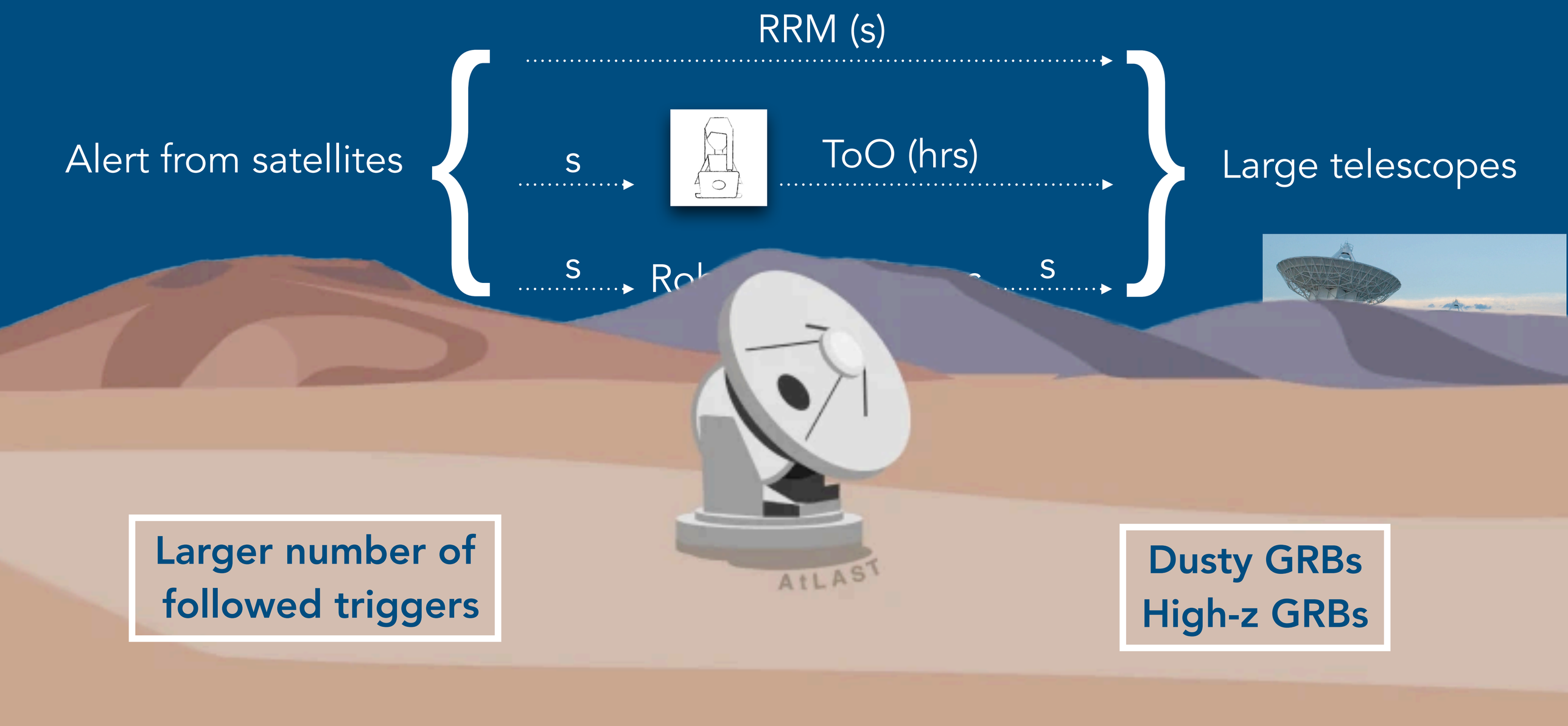
+

Follow-up observations

GRB OBSERVATIONS



GRB OBSERVATIONS



Larger number of followed triggers

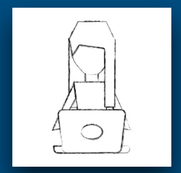
Dusty GRBs
High-z GRBs

GRB OBSERVATIONS

Alert from satellites

RRM (s)

s



ToO (hrs)

s

s

Large telescopes

Larger number of followed triggers

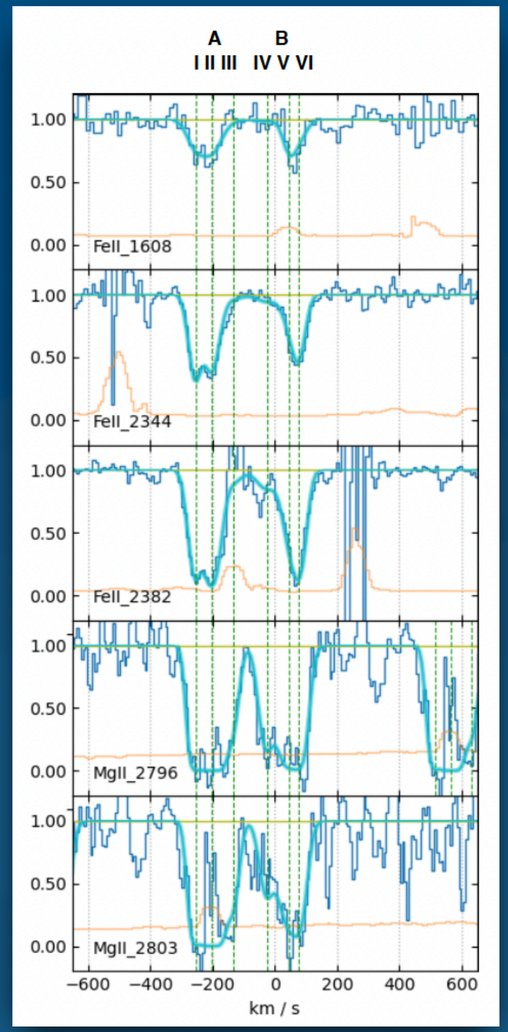
z for < 30% of GRBs

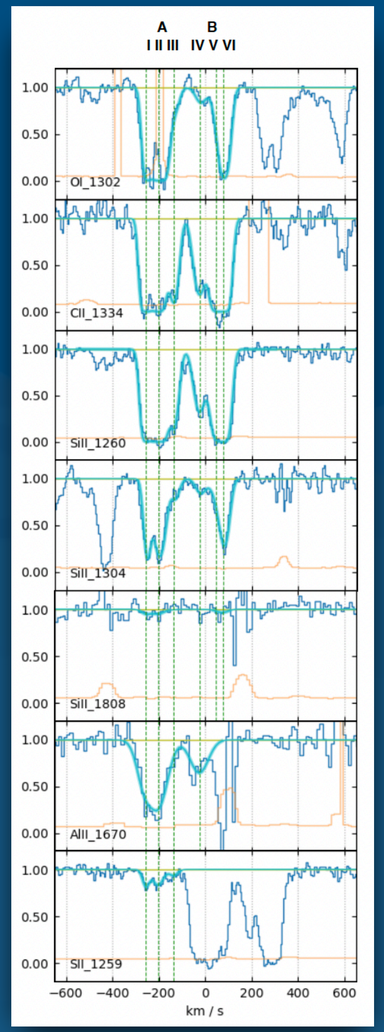
Dusty GRBs
High-z GRBs

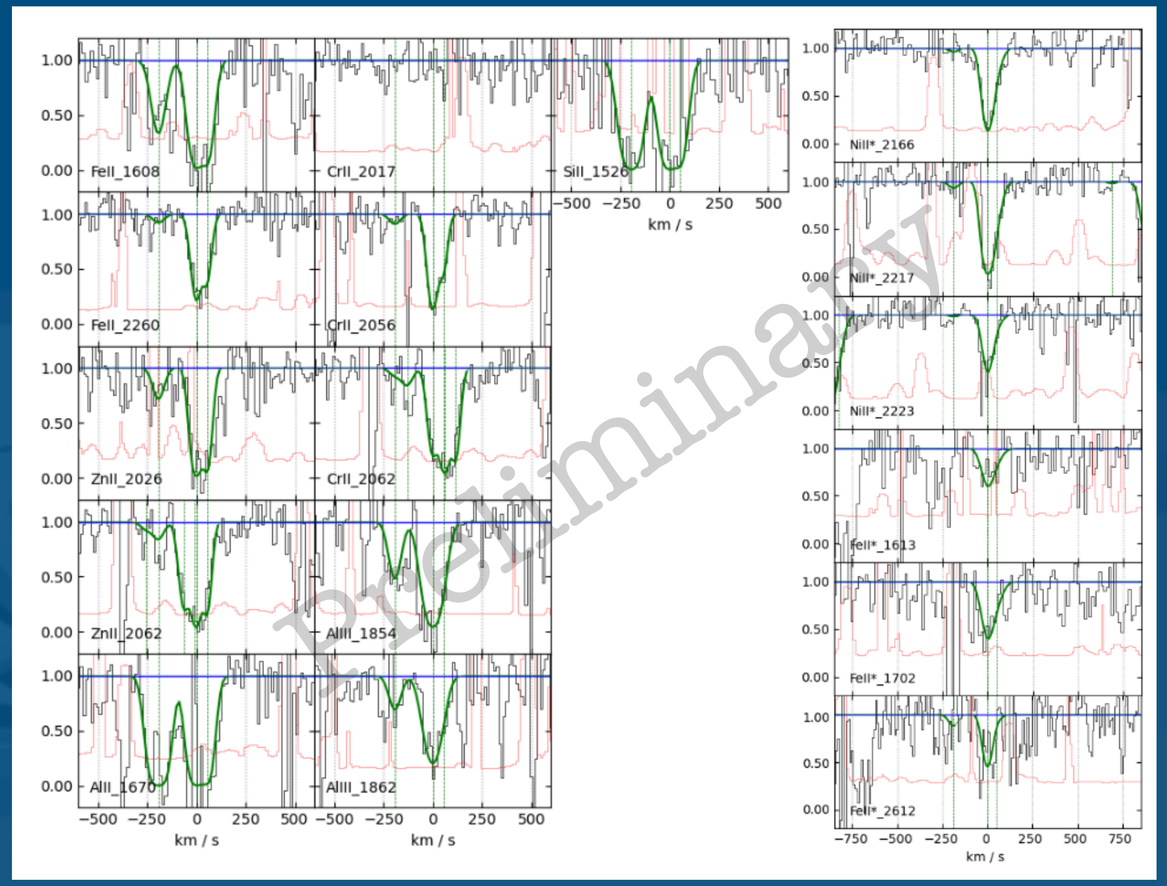
GRB OBSERVATIONS

GRB210905A @ z=6.3

Saccardi et al. 2023





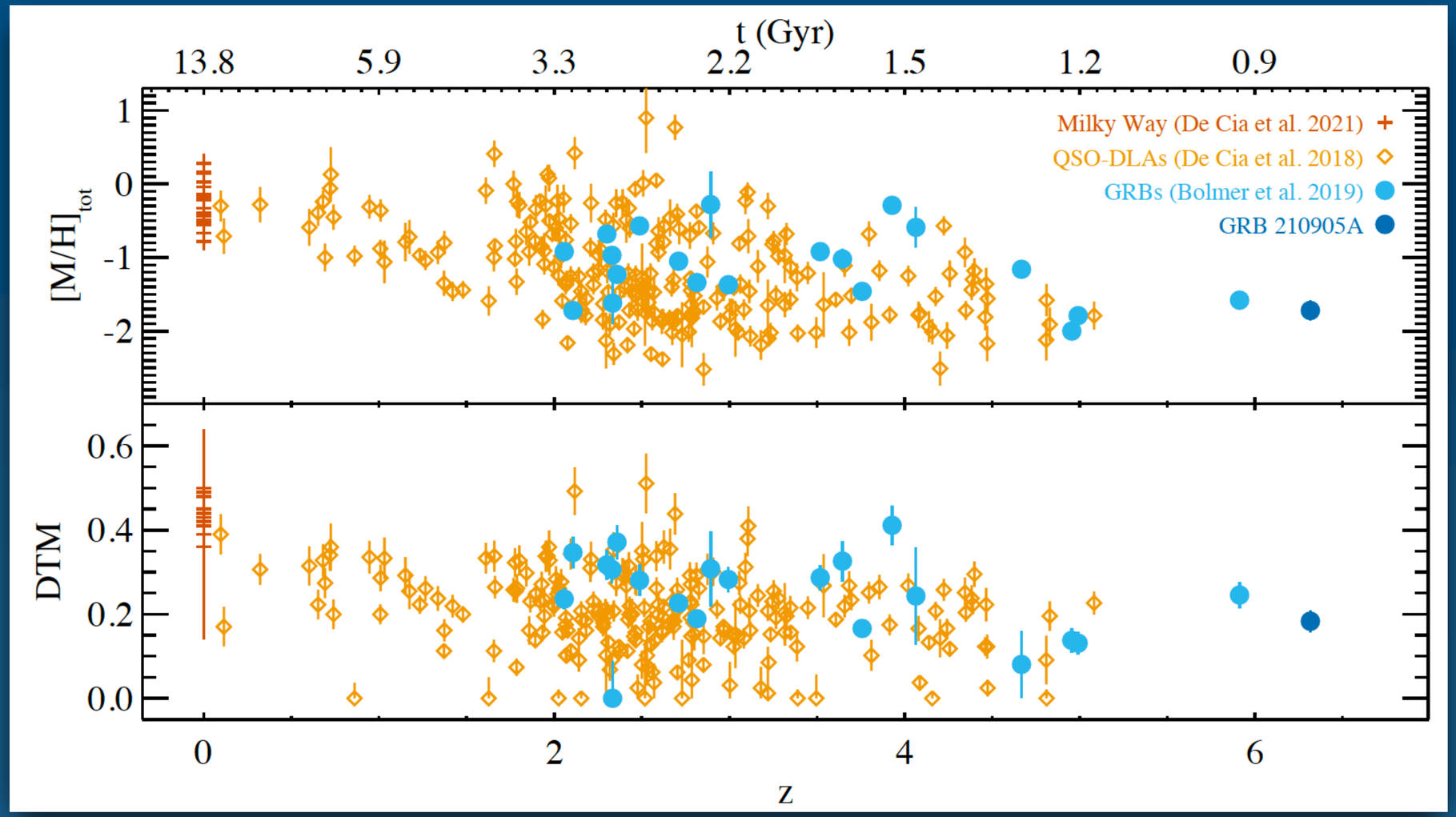


GRB 240218A z=6.782

Saccardi et al. in prep.

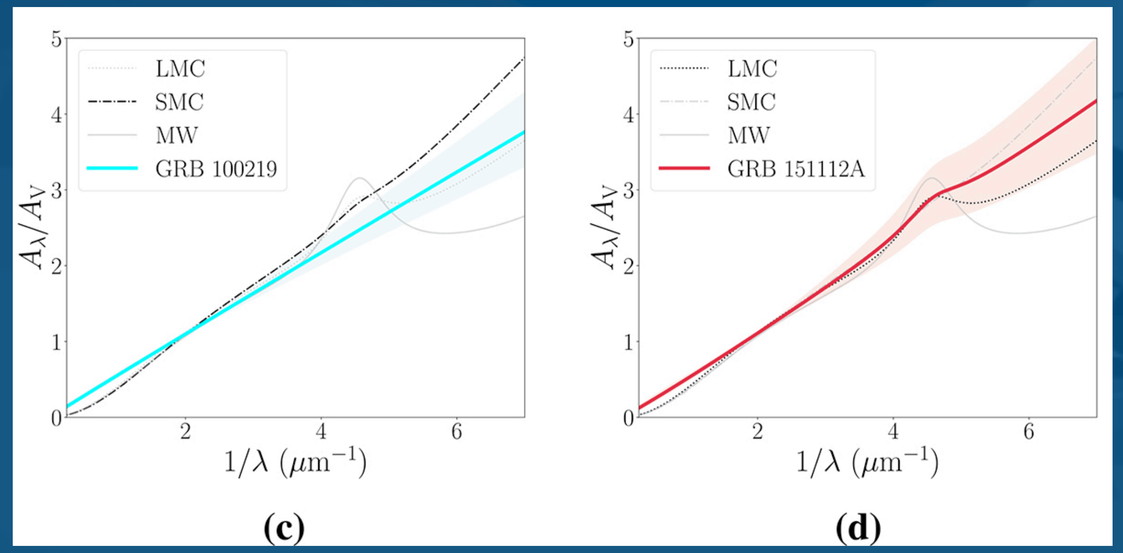
GRB OBSERVATIONS

Adapted from Saccardi et al. 2023



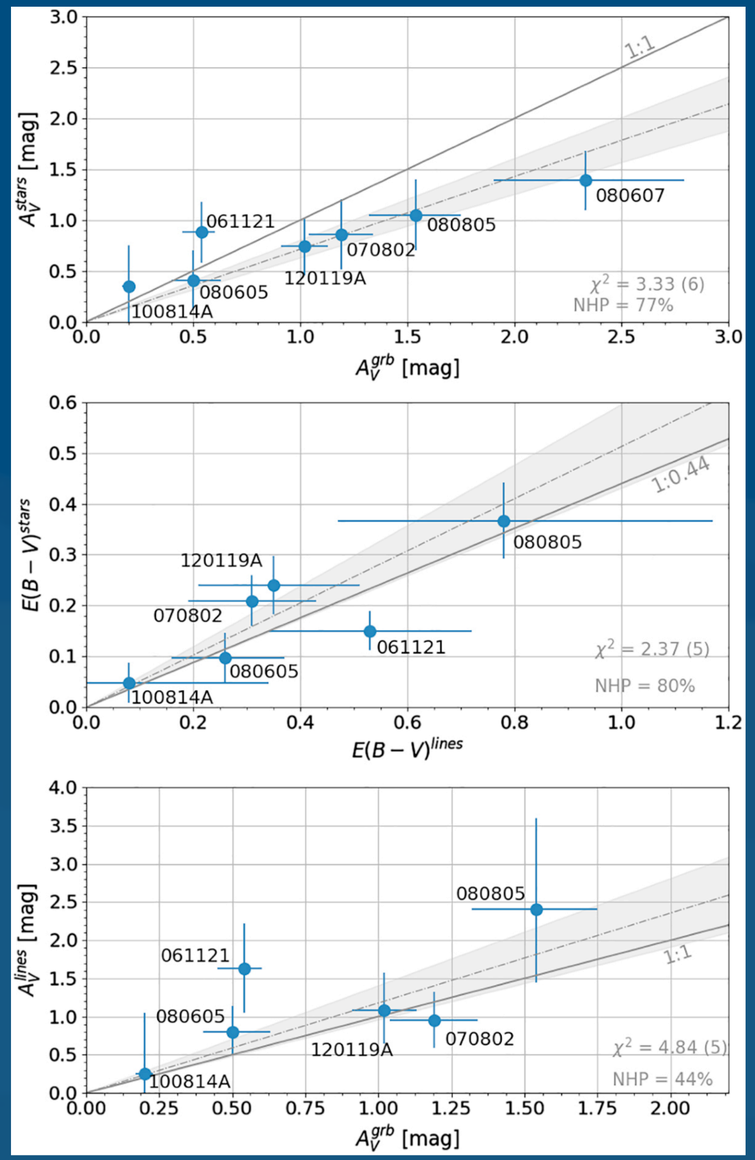
GRB OBSERVATIONS

Dust extinction low along the host line of sight
Dust attenuation from host SED
Dust extinction from host emission lines
Dust depletion in the ISM neutral gas

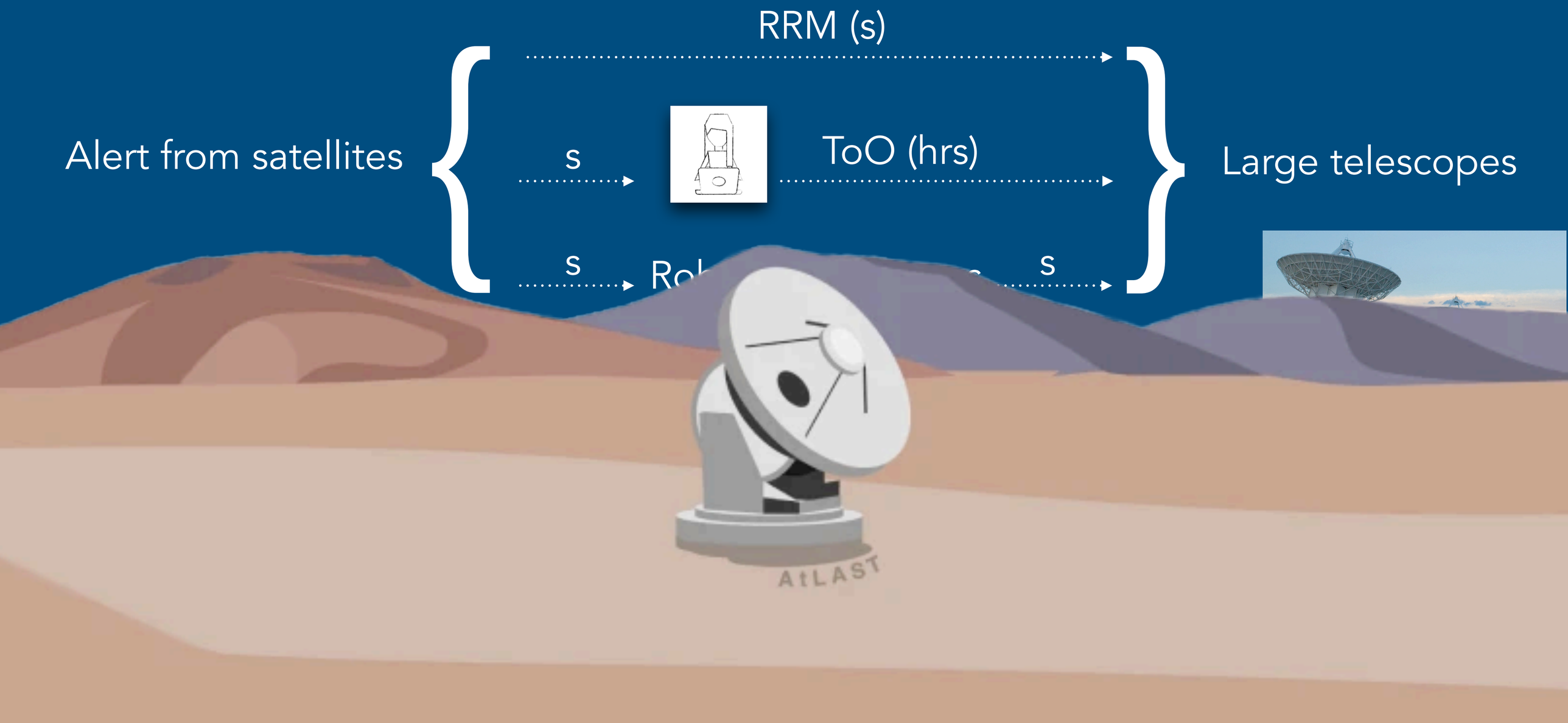


Rakotondrainibe et al. 2024 & references therein

Corre et al. 2018



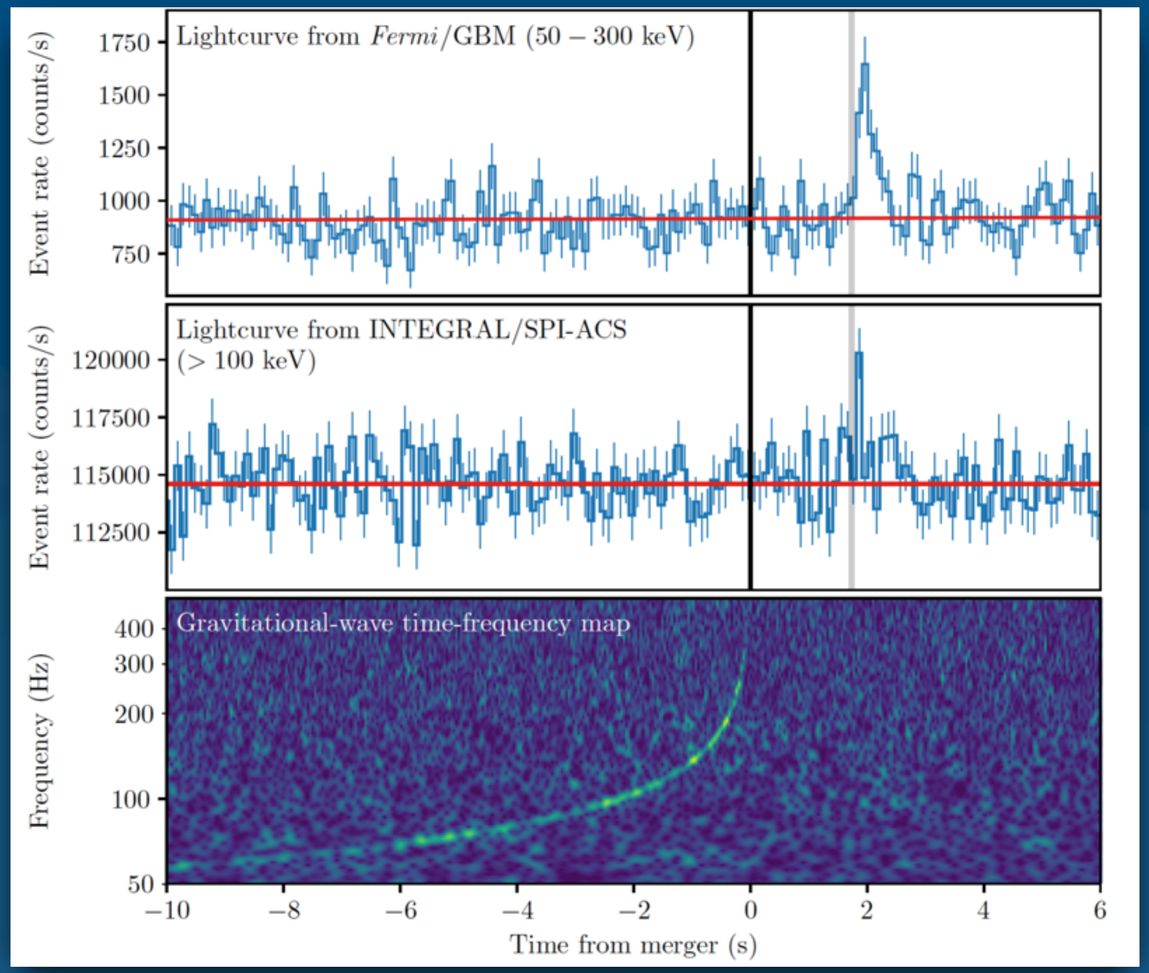
GRB OBSERVATIONS



GW Multi-messenger astrophysics with BNS

GRB170817

GW170817

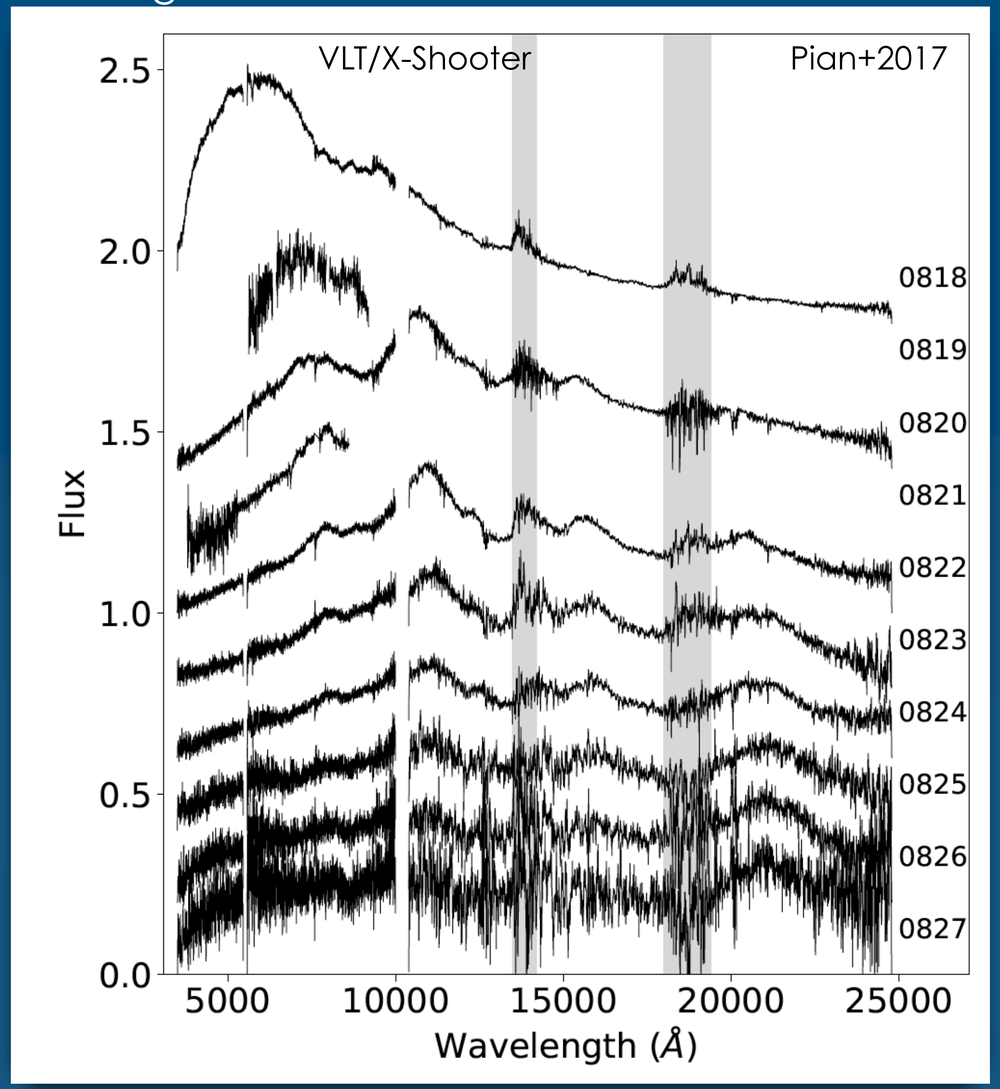


SGRB

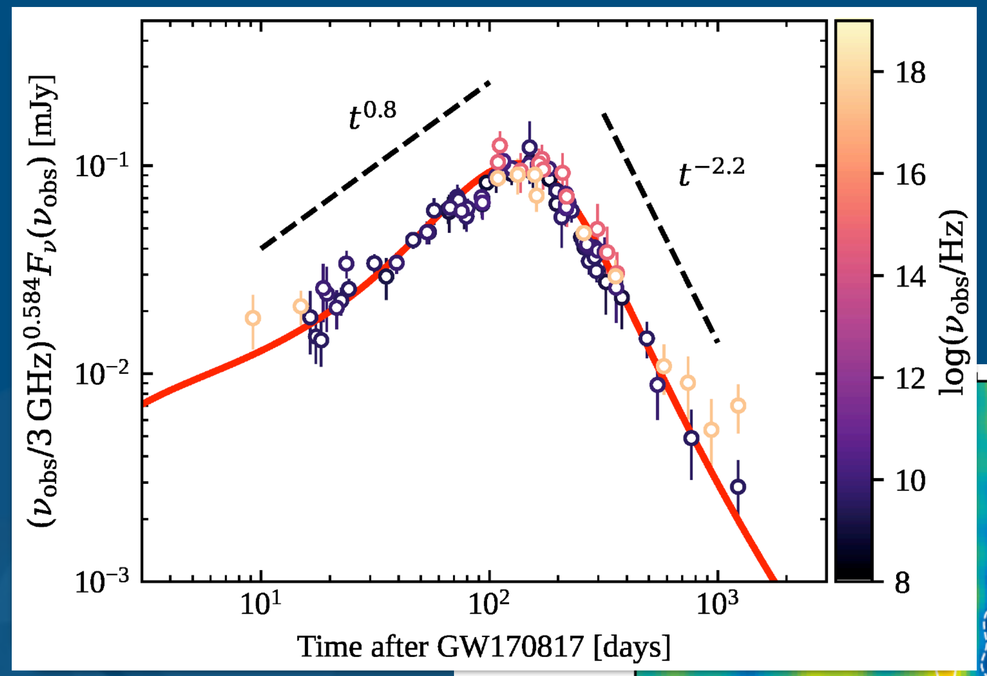
Binary neutron star merger (BNS)

GW Multi-messenger astrophysics with BNS

AT2017gfo - Kilonova



Salafia & Ghirlanda 2022



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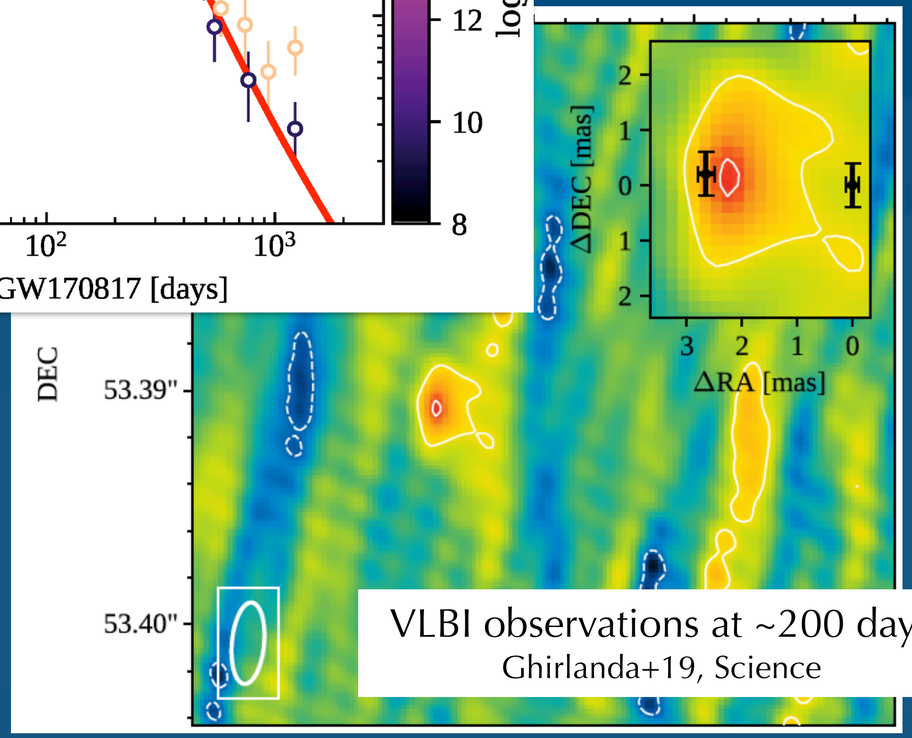
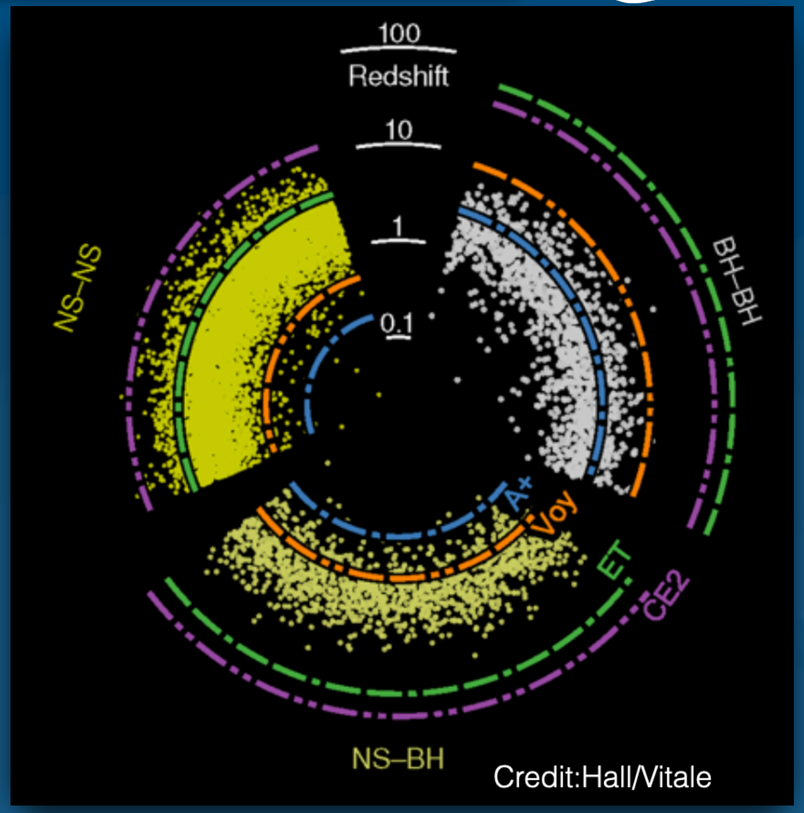


VLBI observations at ~200 days
Ghirlanda+19, Science

GW Multi-messenger astrophysics with BNS



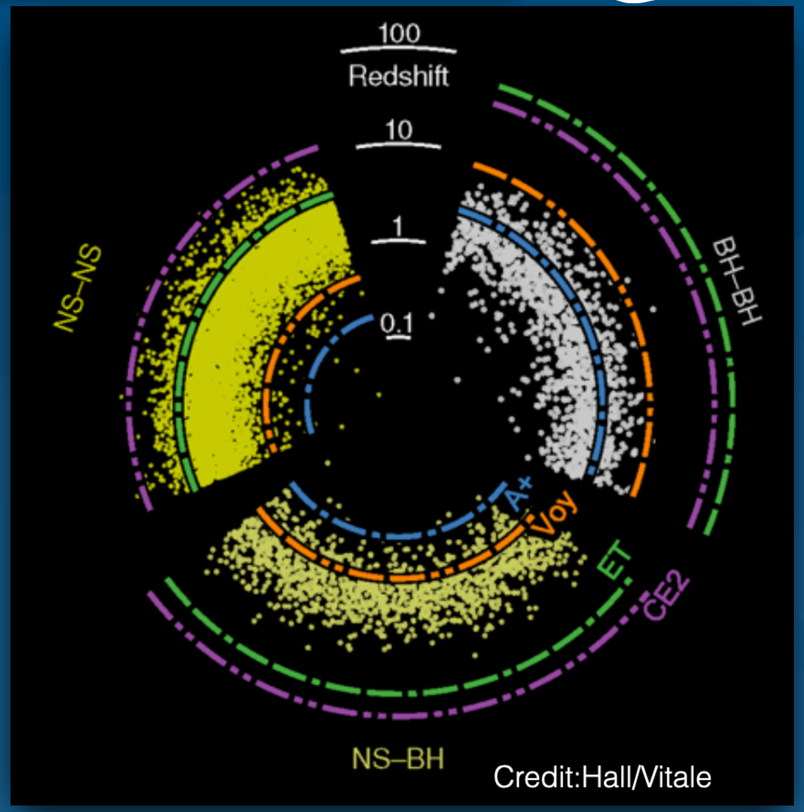
Beyond z~0.5 : GRBs !

Hubble constant

Jet physics and geometry

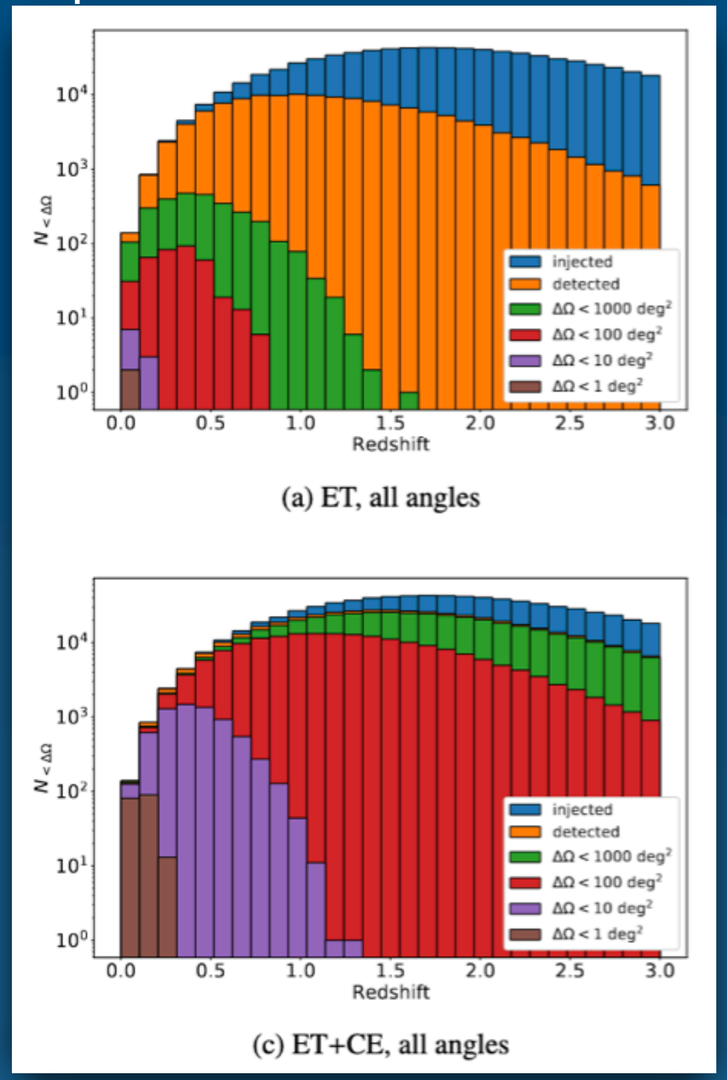
Link BNS - jets

GW Multi-messenger astrophysics with BNS



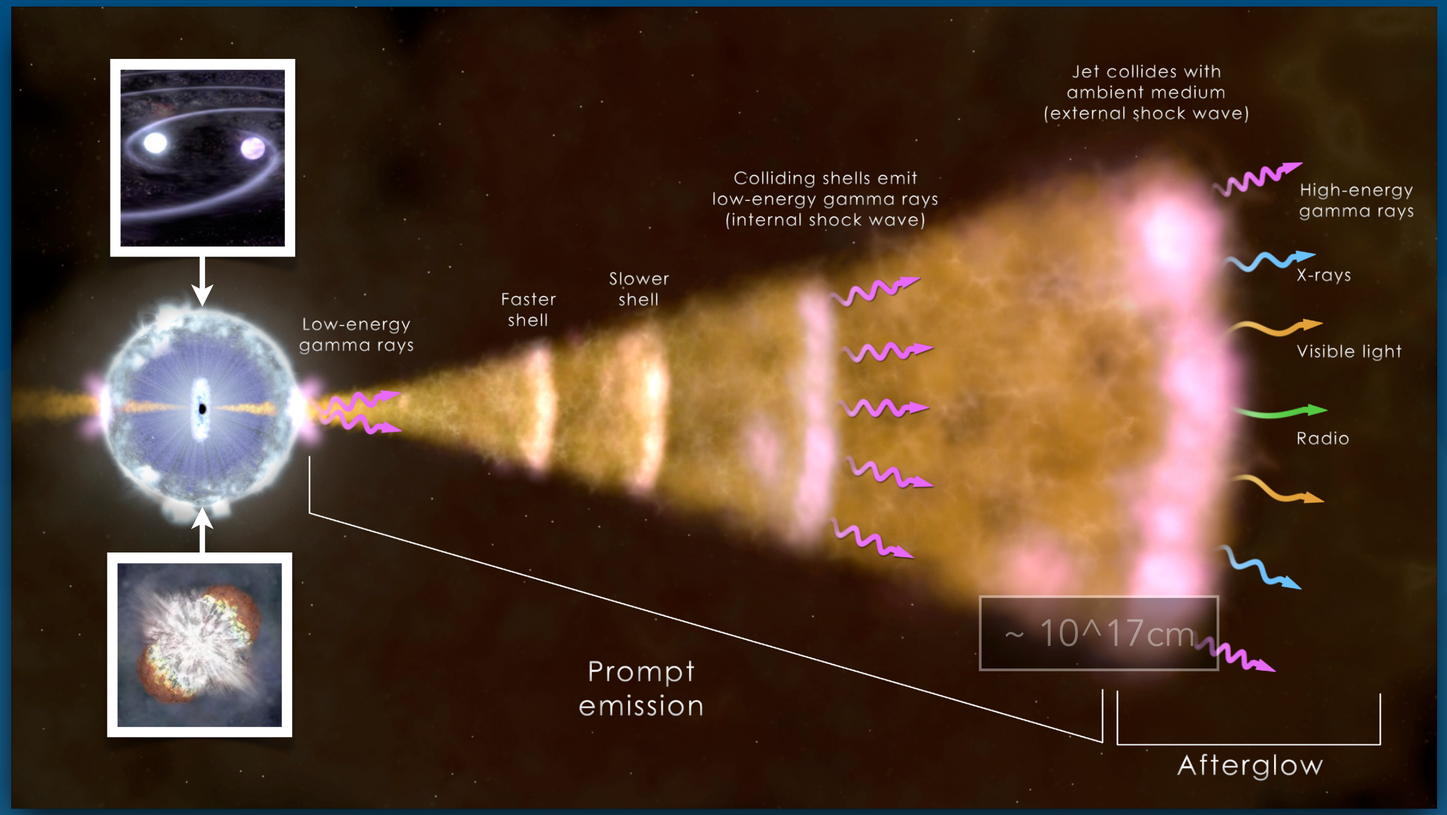
Beyond z~0.5 : GRBs !

Expected BNS detections



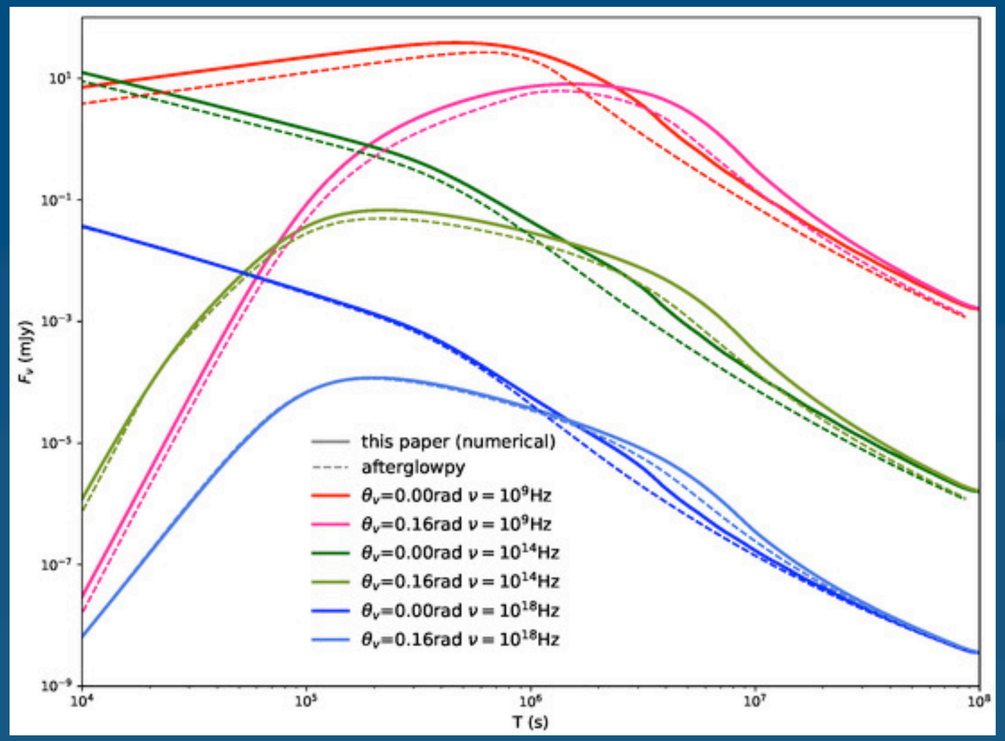
Ronchini et al. 2022

GRB & GW Multi-messenger astrophysics with BNS



On-axis afterglow

Off-axis afterglow

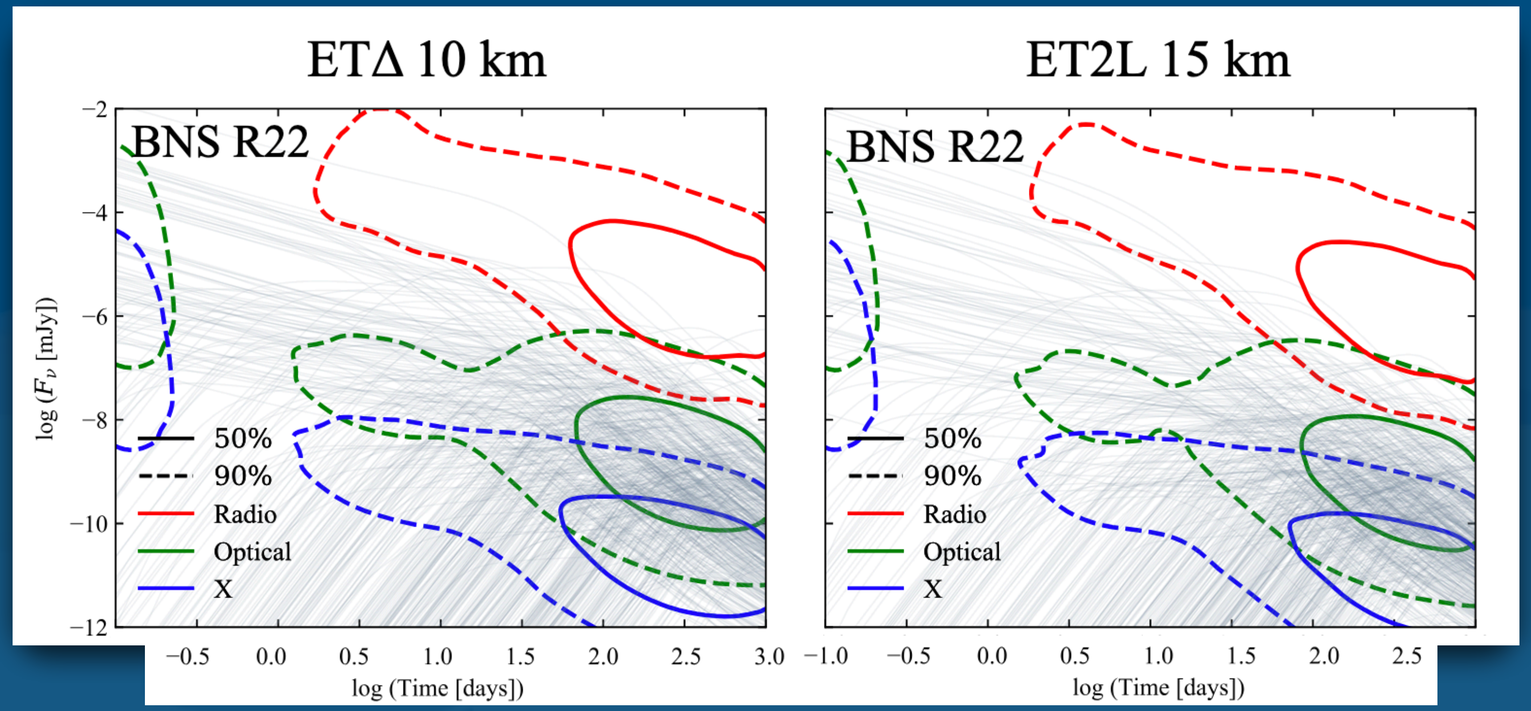


GRB & GW Multi-messenger astrophysics with BNS

On-axis GRBs :

10^{-2} - 10 mJy

GW counterparts : Afterglows



Einstein Telescope Blue book arXiv:2503.12263

GRB & GW Multi-messenger astrophysics with BNS

	Search					Characterization				
	FoV	Sensitivity	Spectral range	Resolution (spectral / spatial)	ToO? delays?	FoV	Sensitivity	Spectral range	Resolution (spectral / spatial)	ToO? delays?
radio	--	0.1mJy	> 1 GHz	~arcsec	hours	arcsec	0.01mJy	>1GHz	~arcsec	logarithmic monitoring for days, months, years
NIR	~ few arcmin	21 AB mag	1000-2000nm	broad band / arcsec	< min, RRM, ToO	arcsec	24 AB mag for photometry; 22 AB spectroscopy	1000-2000nm	1" spatial; low/mid spectral	RRM, ToO, <12h
optical	~ few arcmin	22 AB mag	500-900nm	broad band / arcsec	< min, RRM, ToO	arcsec	26 AB mag for photometry; 22 AB spectroscopy	300-900nm	1" spatial; low/mid spectral	RRM, ToO, <12h
X-rays	~ tens of arcmin	10^-13 erg/cm^2	0.2-10 keV	few arcsec	ASAP, < hours	~ tens of arcmin	10^-16 erg/cm^2/s	0.2-10 keV	few arcsec	< hours
gamma-rays	~80% sky (~10	~1 ph/cm2/s	10keV-10MeV	arcmin	--	--	--	--	--	--
VHE	> 1 deg^2	< 1e-10 erg/cm^	10 GeV - 30 TeV	0.1-1 deg; DE/E~20%	ASAP, < hours	1 deg^2	< 1e-11 erg/cm^2/s @100GeV	20 GeV - 10 TeV	0.1 deg; DE/E<~15%	ASAP, < hours

Einstein Telescope Blue book arXiv:2503.12263

https://apps.et-gw.eu/tds/ql/?c=17771

GRB & GW Multi-messenger astrophysics with BNS

	Search					Characterization				
	FoV	Sensitivity	Spectral range	Resolution (spectral / spatial)	ToO? delays?	FoV	Sensitivity	Spectral range	Resolution (spectral / spatial)	ToO? delays?
radio	>~1 deg^2	< 0.01 mJy	> 1 GHz	~ arcsec / --	from few days to years!	~ some arcsec^2	< 10^-3 mJy	> 1 GHz	-- / ~arcsec	logarithmic monitoring for days, months, years
NIR	>~1 deg^2	> 24 AB; < 10^(-3) mJy	>1000 nm	~ arcsec / --	from few days to years!	~ arcsec^2	> 25; < 3x10^(-4) mJy	1000-2000 nm	low-mid (spectroscopy) broad band / arcsec	ToO at first then logarithmic monitoring
optical	>~1 deg^2	> 26 AB; < 10^(-4) mJy	500-1000 nm	~ arcsec / --	from few days to years!	~ arcsec^2	> 27 ; < 5x10^(-5) mJy	300-900 nm	low-mid (spectroscopy) broad band / arcsec	ToO at first then logarithmic monitoring
X-rays	>~1 deg^2	< 10^(-16) erg/cm^2/s; < 10^(-7) mJy	0.2-10 keV	few arcsec / --	from few days to years!	~ some arcsec^2	< 10^(-17) erg/cm^2/s; < 10^(-8) mJy	0.2-10 keV	-- / few arcsec	logarithmic monitoring for days, months, years
gamma-rays	~80% sky (~10 sr)	0.01-0.1 ph/cm2/s	3 keV-10 MeV	arcmin / --	--	--	--	--	--	--

Einstein Telescope Blue book arXiv:2503.12263

https://apps.et-gw.eu/tds/ql/?c=17771

GRB & GW Multi-messenger astrophysics with BNS

Large FOV

++ for GW follow-up
++ high-z and dusty GRBs

Rapid pointing

++ for GRB physics

Sensitivity

Fundamental

Synergies with alert providers

Synergies with follow-up telescopes (over the entire EM spectrum)

Follow-up of transient factories

Large FOV	Rapid pointing	Sensitivity	Simultaneous spectral coverage
More transients	Transient physics Transient nature	More transients Transient physics	Transient physics

Synergies with alert providers

Synergies with follow-up telescopes (over the entire EM spectrum)

AtLAST as Transient provider

AtLAST as Transient provider

Commensal searches

See MeerKAT (e.g.: Anderson+2023)

Large FOV

Sensitivity

Real time alerts

Data processing
Rapid alert dissemination

Thank you!