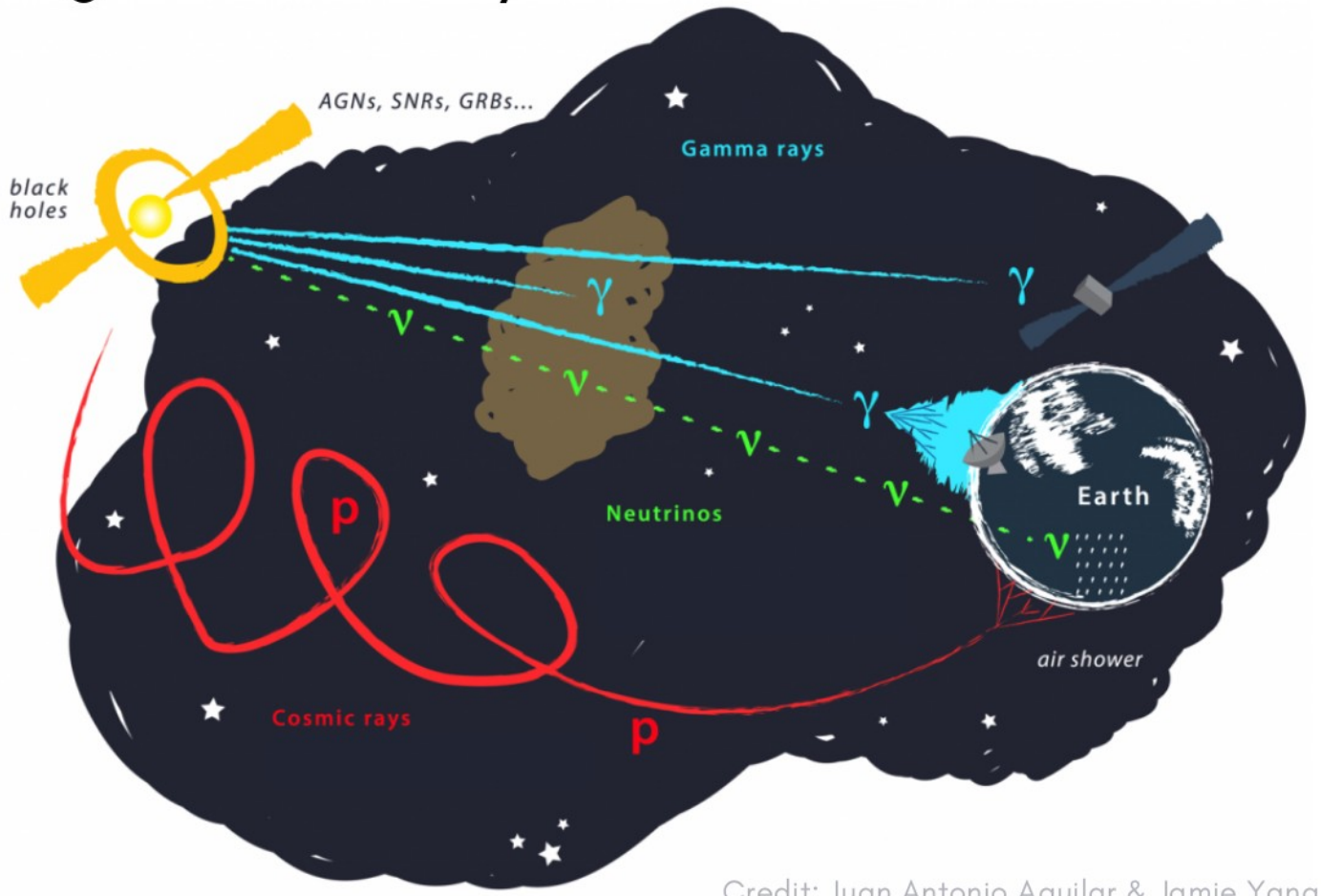
How to find and acccess Multiwavelength data

Lea Heckmann

Multi-messenger astronomy

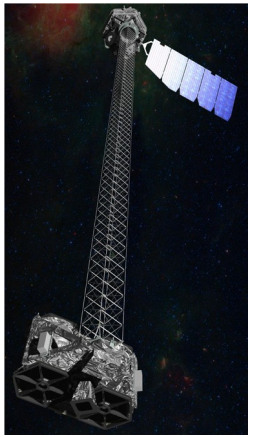


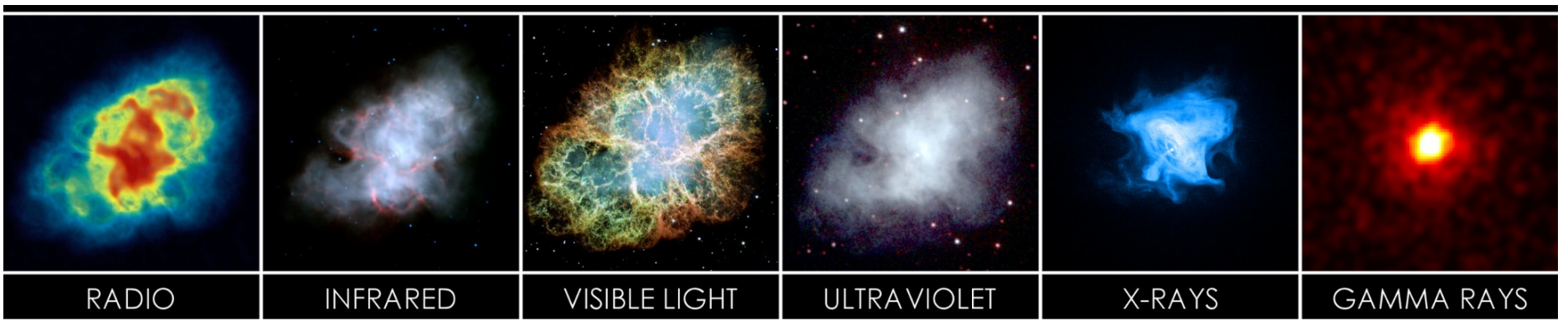
Credit: Juan Antonio Aguilar & Jamie Yang, IceCube/WIPAC

Multi-wavelength astronomy









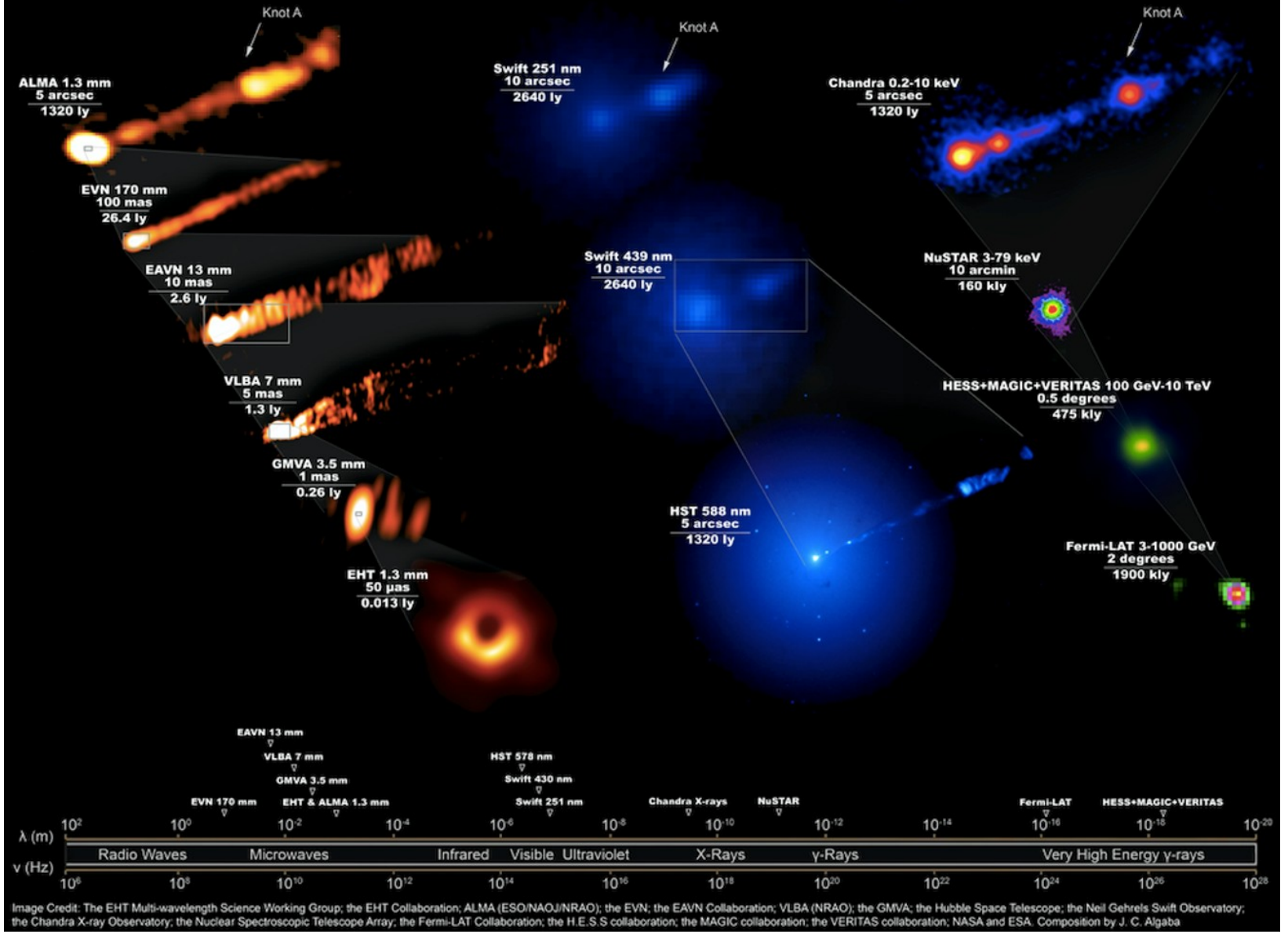
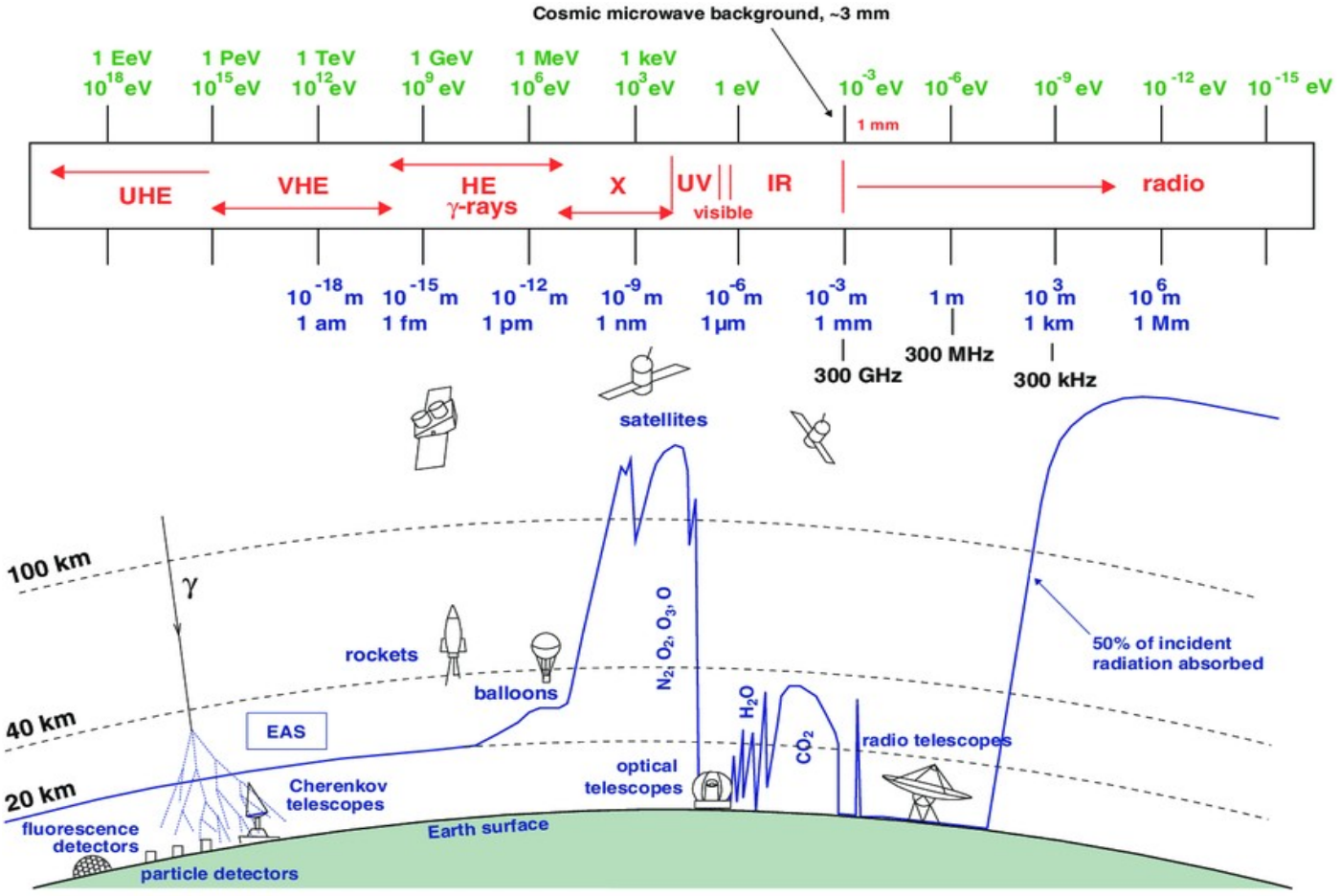


Image Credit: The EHT Multi-wavelength Science Working Group; the EHT Collaboration; ALMA (ESO/NAOJ/NRAO); the EVN; the EAVN Collaboration; VLBA (NRAO); the GMVA; the Hubble Space Telescope; the Neil Gehrels Swift Observatory; the Chandra X-ray Observatory; the Nuclear Spectroscopic Telescope Array; the Fermi-LAT Collaboration; the H.E.S.S collaboration; the MAGIC collaboration; the VERITAS collaboration; NASA and ESA. Composition by J. C. Algaba

Multi-wavelength astronomy



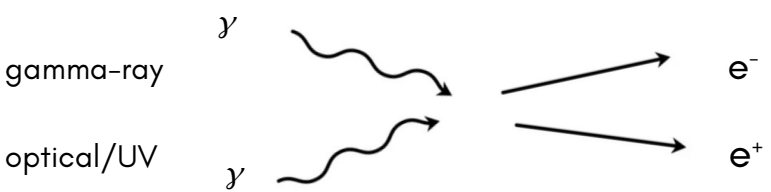
Credit: Longair, S. M. (1992)

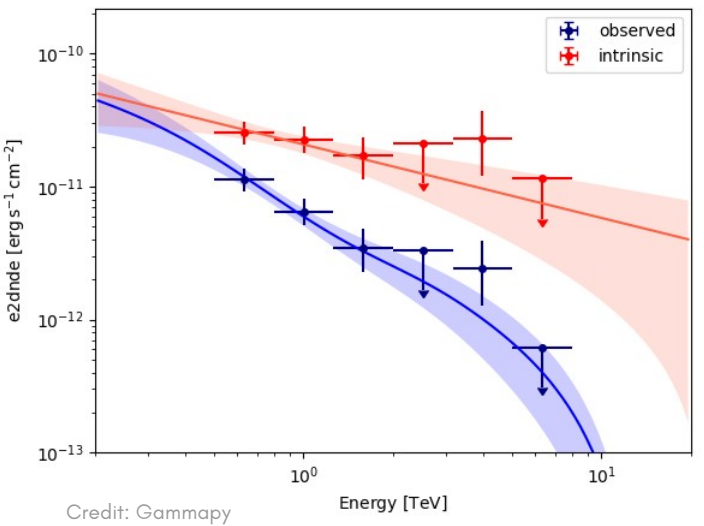
Absorption, extinction,...

Put in your model or correct your data for it

- Radio: Synchrotron self-absorption
- IR - UV: Interstellar extinction
- Optical: Host galaxy contribution
- X-rays: Interstellar medium grain absorption

- Gamma rays: Gamma-gamma absorption
  - Extragalactic background light
  - Internal photon fields, e.g. accretion disk photons





Gamma-rays

High-energy gamma-rays

Fermi

Credit: NASA

Very high-energy gamma-rays

<100 GeV

Cherenkov telescopes

Air shower arrays

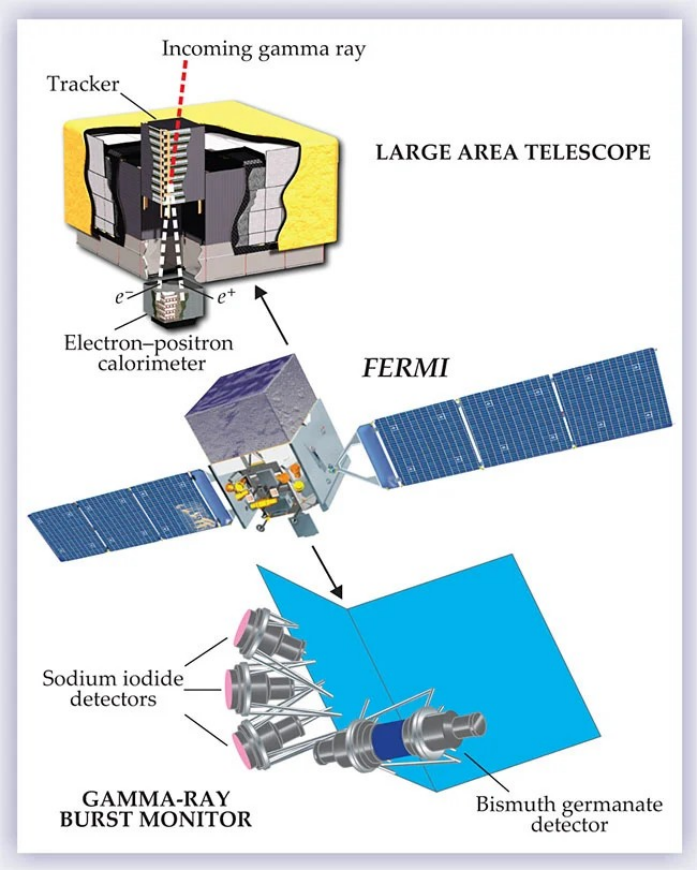
HAWC

Credit: HAWC

LHAASO

Credit: LHAASO

Fermi



Credit: David J. Thompson et al. 2012, Physics today

LAT:

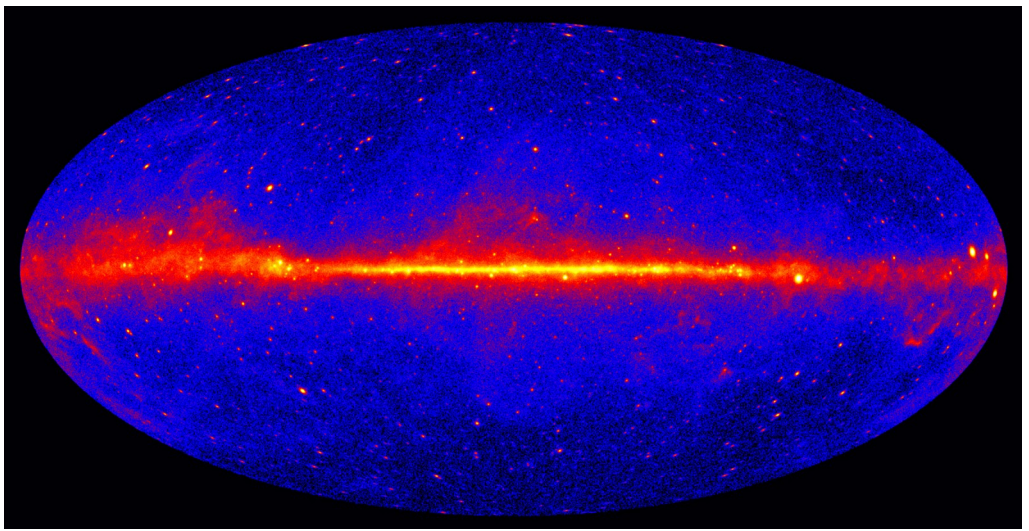
- 20 MeV to >300 GeV
- covers the whole sky every 3 hrs
  → Gamma-ray spectra and localizations

GBM:

- 8 keV to 40 MeV
- covers the full unocculted sky
  → GRBs and fast transients

Fermi

- More info: https://fermi.gsfc.nasa.gov/
- Data acess: https://fermi.gsfc.nasa.gov/ssc/data/access/
- Data calatogs:
  - 4FGL-DR4
    14 years of LAT data



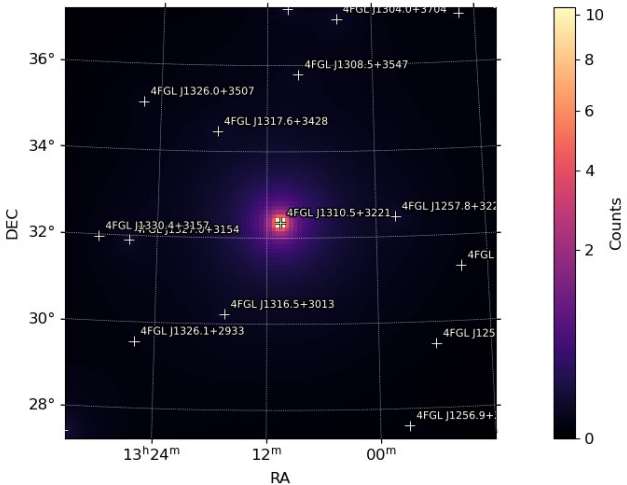
Credit: Fermi/NASA

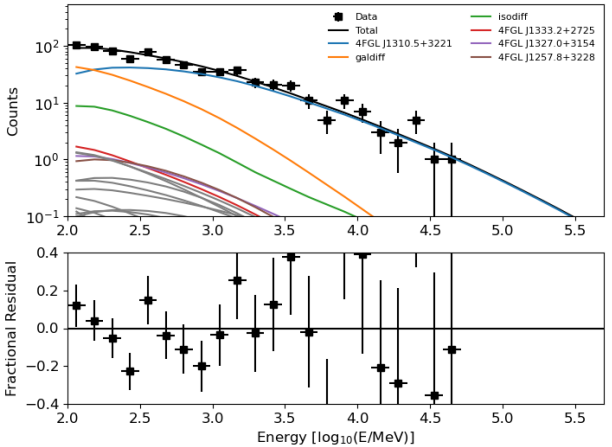
Fermi-LAT data analysis

- 3D fits

- Fermitools:
  main analysis pipeline
  - Binned likelihood tutorial

- Fermipy:
  python wrapper
- Also readable with Gammapy





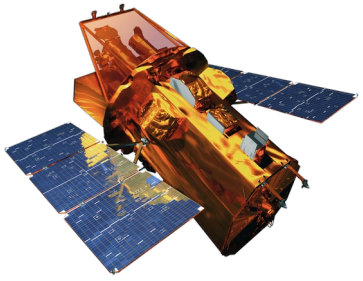
- Important:
  - Choose the appropiate IRFs (see data preparation)
  - Choose the appropiate diffused backgrounds
  - Choose which parameters/sources to leave free in the fit

X-rays

Chandra

NICER

eROSITA



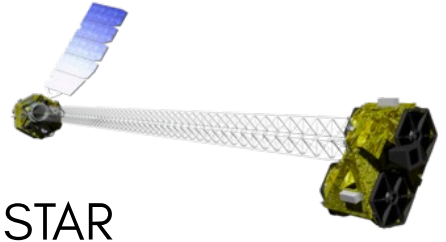
Swift

XMM-Newton

IXPE

INTEGRAL

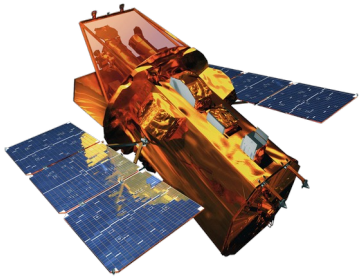
AstroSat



NuSTAR

Credit: Wikipeda

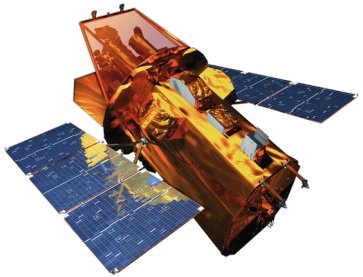
X-rays



Swift

- Swift-XRT
  - 0.3–10 keV
  - fast repointing, medium imaging and spectroscopy
    → Transients, bright AGN,...
- Swift-BAT:
  - 15–150 keV
  - Large field of view 1.4 sr
    → GRB triggers, all-sky survey hard-X-ray transients
  - +UV

X-rays



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- Swift-BAT:
  - 15–150 keV
  - Large field of view 1.4 sr
    → GRB triggers, all-sky survey hard-X-ray transients
  - +UV

- Public data access without proprietary period here
- Target of Opportunity triggers (ToO) here
- Observation Proposal usually due around Sept
- Data analysis overview and instructions here

X-rays

Chandra

- 0.1-10 keV
- High-resolution of 0.5 arcsec
  → optimized for X-ray images

X-rays

Chandra

- 0.1-10 keV
- High-resolution of 0.5 arcsec
  → optimized for X-ray images

- Public data access here
  - Proprietary period varies, usually 1 year
- Target of Opportunity triggers (ToO) more rare (connected to proposals)
- Observation Proposal usually due around March
- Data analysis overview and instructions here

X-rays

NICER

- 0.2-12 keV
- High-precision timing + spectra
  → observations of neutron stars, pulsars

X-rays

NICER

- 0.2-12 keV
- High-precision timing + spectra
  → observations of neutron stars, pulsars

- Public data access here
  - No proprietary period, but validation period 2 weeks
- Target of Opportunity triggers (ToO) here
- Observation Proposal usually due around March
- Data analysis overview and instructions here

X-rays

eROSITA

- 0.2–10 keV
- All-sky survey, field of view 1.03 deg

X-rays

eROSITA

- 0.2-10 keV
- All-sky survey, field of view 1.03 deg

- German/Russian collaboration
- Public data releases of the German data (Western sky)
- First 6 months released here with analysis instructions
  - more too come?

X-rays

XMM-Newton:

- 0.15-10 keV
- Wide field of view (30 arc min)
- High resolutions spectra (E/dE = 100-500)
  → Observations of faint or extended sources

X-rays

XMM-Newton:

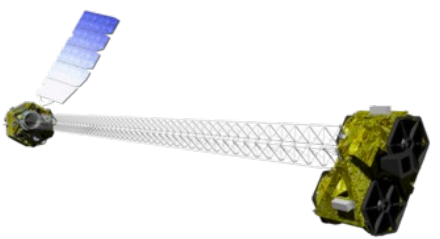
- 0.15-10 keV
- Wide field of view (30 arc min)
- High resolutions spectra (E/dE = 100-500)
  → Observations of faint or extended sources

- Public data access here or here
  - Some with a proprietary period of 1 year
- Target of Opportunity triggers (ToO) are rare, link here
- Observation Proposal usually due around October
- Data analysis overview and instructions here,
  quick look interactive analysis here

X-rays

NuSTAR:

- 3 – 79 keV, hard X-rays
- Focused imaging + spectra
  → Observations of higher energy X-rays, AGN

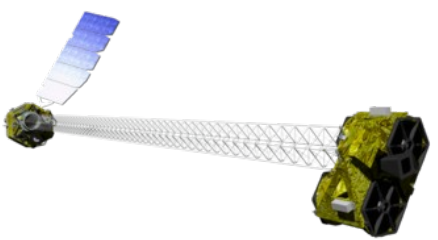


X-rays

NuSTAR:

- 3 – 79 keV, hard X-rays
- Focused imaging + spectra
  → Observations of higher energy X-rays, AGN

- Public data access here, some with a proprietary period of 1 year
- Target of Opportunity triggers (ToO) are rare, link here
- Observation Proposal usually due around January
- Data analysis overview and instructions here, quick start guide here



X-rays

AstroSat:

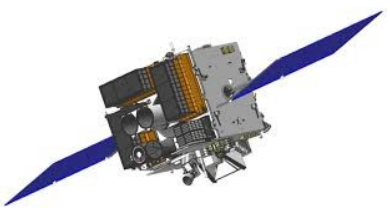
- 0.3–200 keV, up to hard X-rays
- + UV
- High time resolution
  → MWL observations and time-domain studies

X-rays

AstroSat:

- 0.3–200 keV, up to hard X-rays
- + UV
- High time resolution
  → MWL observations and time-domain studies

- Public data access here, proprietary period of 1 year
- Target of Opportunity triggers (ToO) for Indian proposers here
- Observation Proposal usually due around March
- Data analysis instructions here



X-rays

INTEGRAL:

- 15 keV to 10 MeV – up to gamma-rays
  + X-ray (3-35 keV) & optical (V-band)
- stopped in 2025
  → public archive here

X-rays

IXPE:

- 2-8 keV
- First X-ray polarization measurements

X-rays

IXPE:

- 2-8 keV
- First X-ray polarization measurements

- Public data access here within 1 week
- Target of Opportunity triggers (ToO) here
- Observation Proposal usually due around September
- Data analysis overview and instructions here,
  quick start guide here

X-rays

Table 28: *Comparison of XMM-Newton with other X-ray satellites*

Satellite	Mirror PSF	Mirror PSF	E range	A_e at 1 keV	Orbital target	Energy resolution
	FWHM [″]	HEW [″]	[keV]	[cm²][a]	visibility [hr]	at 1 keV [eV]
XMM-Newton	6	15	0.15 - 12	4650[b]	36.7[c]	4 (RGS)
Chandra	0.2[d]	0.5[d]	0.1 - 10	555 (ACIS-S)	44.4[c]	1 (HETG)
ROSAT	3.5	7	0.1 - 2.4	400	1.3[e]	500
ASCA	73	174	0.5 - 10	350	0.9[e]	100
Suzaku	96 - 120	108 - 138	0.2 - 600	1760 (XIS)	0.72[e]	50
RXTE	n.a.[g]	n.a.[g]	2-250	n.a.[g]	1[e]	n.a.[g]
Swift	8.8	18[f]	0.2-10 (XRT)	133.5	~0.8[e]	70
NuSTAR	18	58	3-79	n.a.[g]	~0.8[e]	n.a.[g]

Credit: ESA,
https://xmm-tools.cosmos.esa.int/external/xmm_user_support/documentation/uhb/xmmcomp.html

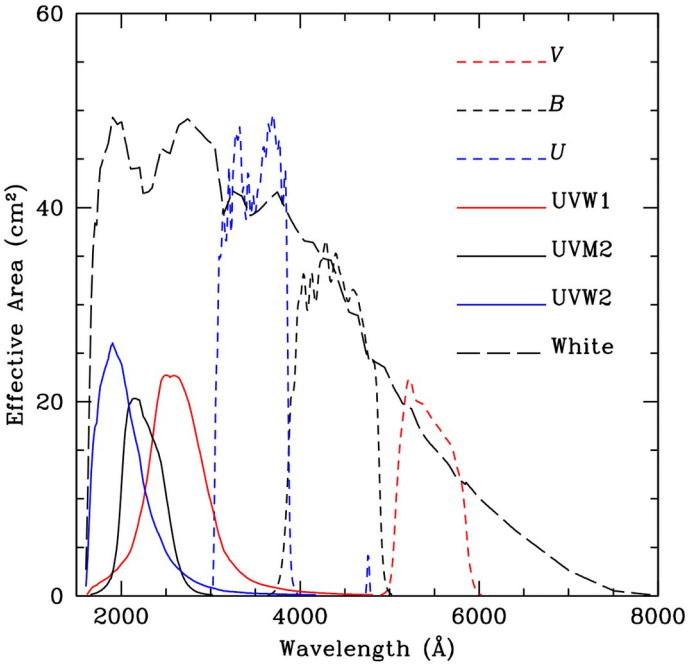
Credit: Wikipeda

I want to do...	I should look at...	Energy range	Timing Resolution	Spectral Resolving Power (E/ΔE or λ/Δλ)	Angular Resolution	Field of View	All Sky Monitoring
Imaging							
imaging in a large field of view, in soft-medium energy X-rays, with moderate spectral resolution (no gratings/ calorimeters)	XRISM/ Xtend	0.4-12 keV	...	~30 at 6 keV	≤1.7' (Half Power Diameter)	≥30'x30'	no
	Chandra/ ACIS-I	0.2-10 keV	0.2-10.0 s (3.2 s nominal)	10-20	0.5"	16.9'x16.9'	no
	XMM/ EPIC	0.3-12 keV	≤ 2.6 s	~ 20-50	4.1"	33'x33'	no
imaging in a large field of view, in hard energy X-rays, with moderate spectral resolution (no gratings/ calorimeters)	NuSTAR	3-79 keV	~1 ms	25-76	18"	≤ 10'	no
imaging, in medium energy X-rays, with high angular resolution	Chandra/ ACIS-S	0.2-10 keV	0.2-10.0 s (3.2 s nominal)	15-40	0.5"	8.3'x8.3'	no
optical/UV photometry	Neil Gehrels Swift UVOT	1800 - 6000 Å	0.5 s	< 150	~1"	~17'	no
	XMM/OM	1800 - 6000 Å	0.5 s	~ 180	~1"	~17'	no
Spectroscopy							
spectroscopy, in soft energy X-rays, with high spectral resolution	Chandra/ LETG-HRC-S	0.07-10 keV	~10 ms in default mode; 16μs in HRC-S Imaging mode, center segment only	≥1000 for λ=50-160 Å, ~20xλ=3-50 Å	...	3.4'x99'	no
	XMM/ RGS	0.35-2.5 keV	2.6 s	100-500	...	5'	no
spectroscopy, in medium energy X-rays, with high spectral resolution	Chandra/ HETG-ACIS-S	0.4-10 keV	3.2 s	65-1070	...	8.3'x50.6'	no
	XRISM/ Resolve	0.3-12 keV	≤ 1 ms	~1200 at 6 keV	≤ 1.7' (Half Power Diameter)	2.9'x2.9'	no
	XMM/ RGS	0.35-2.5 keV	2.6 s	100-500	...	5'	no
optical/UV spectroscopy	Neil Gehrels Swift UVOT	1800 - 6000 Å	0.5 s	< 150	~1"	~17'	no
	XMM/OM	1800 - 6000 Å	0.5 s	~ 180	~1"	~17'	no
Something Else							
X-ray timing studies	NICER	0.2-12 keV	300 ns	~100-400	5'	30'x30'	no
	XMM/ EPIC	0.3-12 keV	0.03 ms, up to 0.007 ms	~20-50	4.1"	33'x33'	no
a search for γ-ray transients	Fermi	8 keV - 300 GeV	2 μs	~10-20	< 3 degrees	<9.5 steradians	yes
a search for X-ray transients	Neil Gehrels Swift	0.2 - 10 keV	2.2 ms	~50	18"	23.6'x23.6'	yes

Credit: NASA, https://heasarc.gsfc.nasa.gov/docs/xmm/

UV

- Swift-UVOT
  - 6 filters (3 UV, 3 optical)
  - Follow-up of XRT and BAT
- AstroSat-UVIT
  - 3 UV channels
  - Follow-up of X-rays instruments
- Hubble
  - high-resolution UV imaging & spectroscopy



Credit: Swift

Credit: NASA, https://heasarc.gsfc.nasa.gov/docs/xmm/

Optial

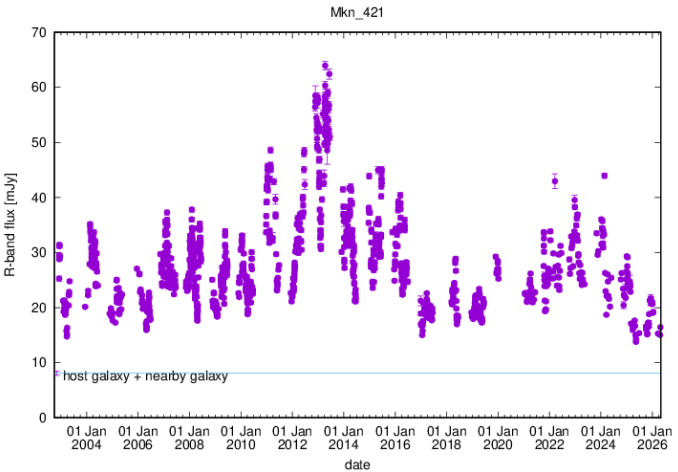
Credit: ZTF

Public all-sky surveys:

- ZTF
  - Scanning the Northern sky since 2018
  - Public data release here
- ATLAS
  - Hawaii ×2, Chile, South Africa starting in 2015 (sourthern sky a bit later)
  - Public data access (queue, login needed) here
- Pan-STARRS
  - Placed in Hawai since 2019
  - Public data access here
- ASAS-SN
  - Hawaii, Texas, two in Chile, South Africa, and China starting in 2013/14
  - Public data access here

- LSST - Vera Rubin: to begin soon

Optial

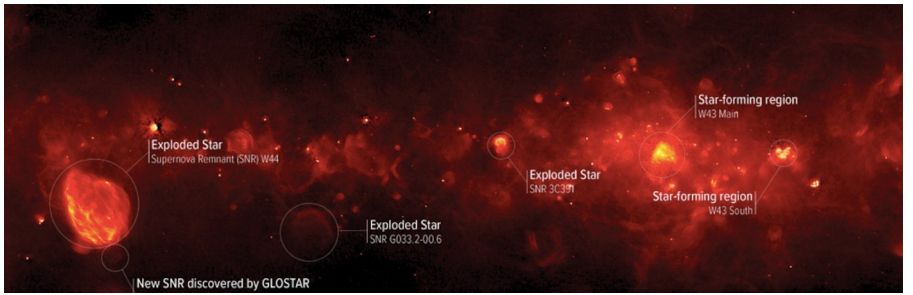


Credit: Tuorla

Time-domain Monitoring

- Tuorla: Data in the R-band since 2002
  - Data access on request, but overview of sources here
- GASP-WEBT: Huge network of telesocpes
  - Optical photometry + polarization
  - Private data access, but archival data can be asked for here
- Robopol: Optical photometry and polarization
  - Public data release 2013-2017 here
- CANICA: Near Infrared
  - Not public, but open to collaborate usually, find the PI here
- SALT: Southern sky optical observatory
  - Public data archive here

Radio

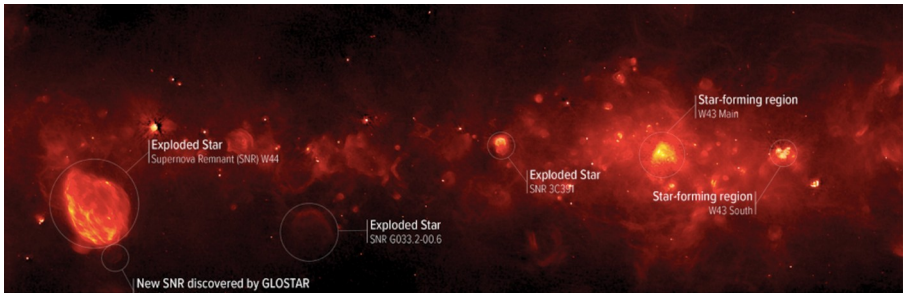


Credit: NRAO

Surveys

- Canadian Galactic Plane Survey, link here
- THOR northern Galactic plane survey, link here
- NRAO VLA Sky Survey, sky north of -40 deg dec, link here
- DAME CO survey covering most of the sky, link here
- FUGIN survey of parts of the galactic plane, link here
- Southern Galactic Plane Survey (SGPS), link here

Radio



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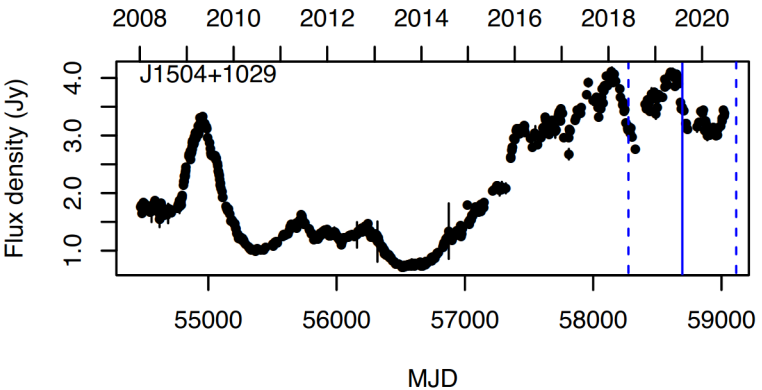
Time-domain monitoring:

- OVRO Radio monitoring of blazar at 15 GHz
  - Data access rules here, on request
- Metsähovi Radio monitoring of blazar at 37 GHz
  - Data access on request here
- Telamon (Effelsberg) radio monitoring of AGN + polarization
  - Data access on request here



Credit: OVRO

Tools for data access/overview

- CADE, link here
- Fermi LC repo, link here
- SED builder, link here
- Markarian MWL Data Center, link here
- Astrocolibri (see Sylvia's slides)

ACME

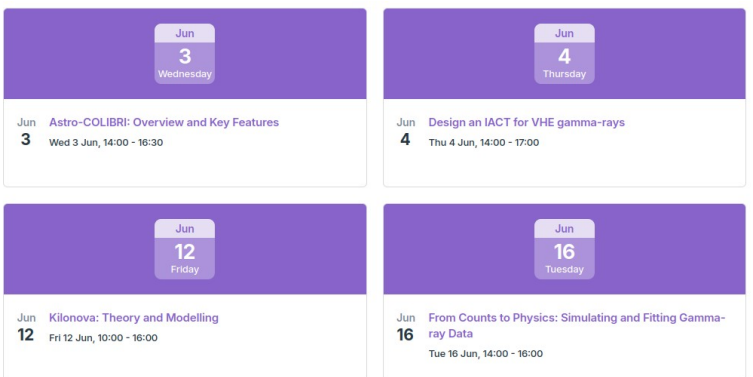
- Past training material, link here

Workshop/School	The gravitational wave sky and complementary observations (04/2025)	Video playlist, Slides
Workshop/School	Multimessenger Citizen Science: Training Event for Amateur Astronomers (06/2025)	Video playlist, Slides
Workshop/School	ACME training Workshop on Swift and XMM-Newton data analysis (10/2025)	Video playlist, Slides
Workshop/School	1st MAGIC Open Data-Analysis School	Video day 1/day 2, Materials

- Future events, link here

Date ▼	Name of the event ▶	Location (Country)	Category ▶
2026/11/03 — 2026/11/05	ACME Inter-Disciplinary Underground Science and Technology (I-DUST)	Apt (France)	Workshop
2026/11/02 — 2026/11/06	Cherenkov Astronomy Data School 2026	Paris (France)	School
2026/10/12 — 2026/10/16	Hands-On Observational School in Optical Follow-Up of Transients	Asiago (Italy)	School
2026/09/16 — 2026/09/23	The 8th LOFAR Data School	Dwingeloo (Netherlands)	School

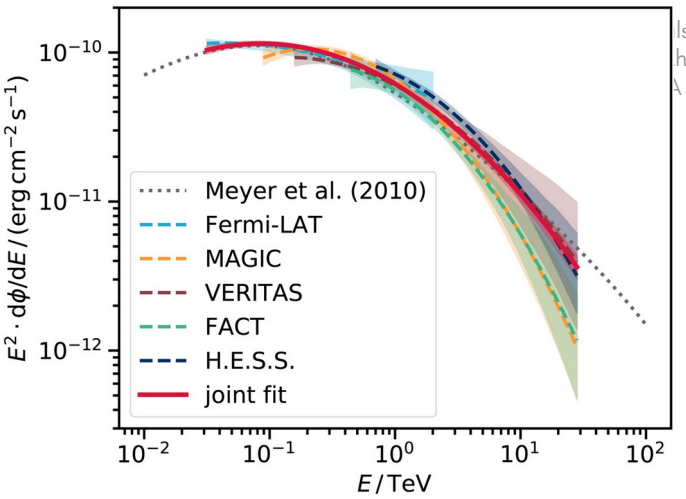
- Hands-on, link here



Gammapy & MWL data

- Works nicely for gamma-ray data and joint instrument fits:

C. Nigro et al. 2019, A&A 625, A10



lso see e.g.:
haronian et al. 2024,
A 686, A308

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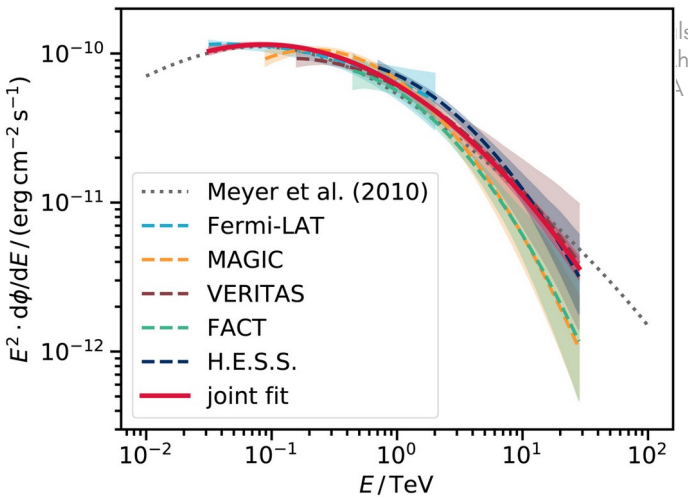

lso see e.g.:
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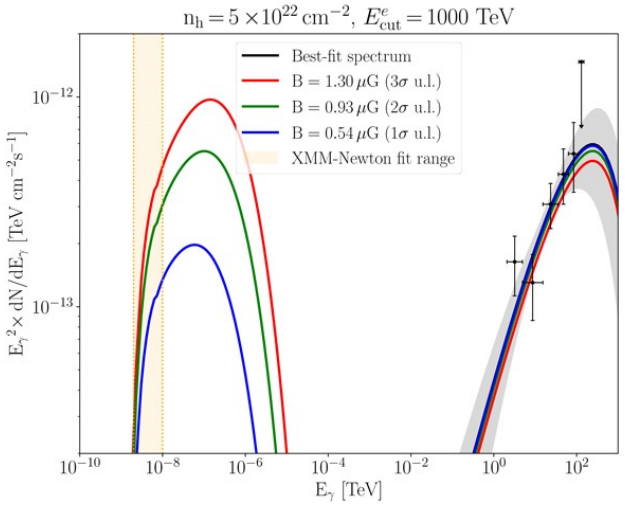
A 686, A308

- Extension to X-rays:

https://github.com/registerrier/gammapy-ogip-spectra



L. Giunti et al. 2022, A&A 667, A130

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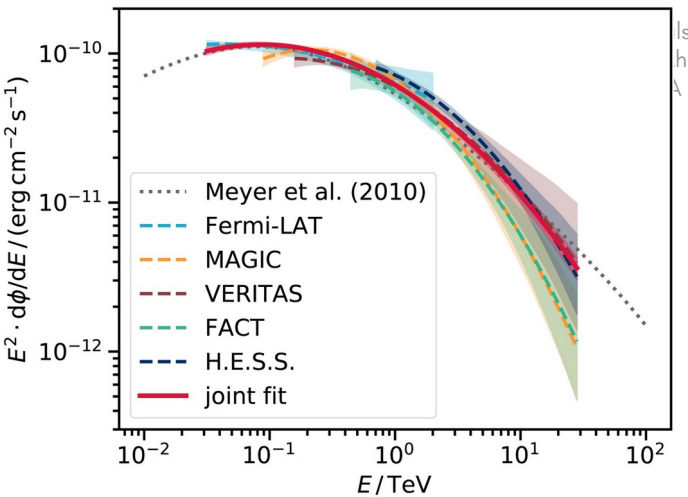
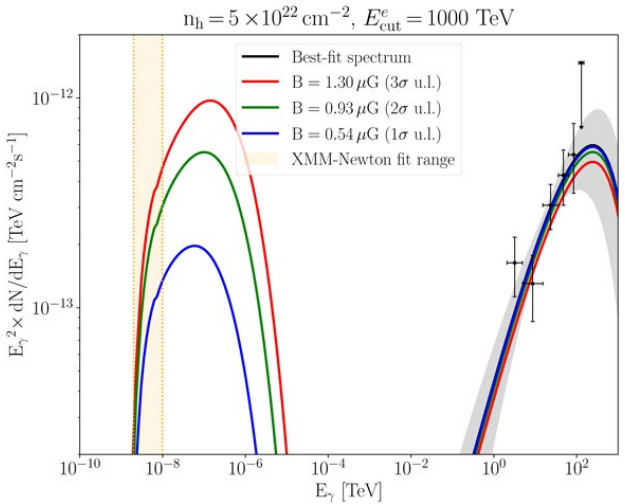
- Works nicely for gamma-ray data and joint instrument fits:

C. Nigro et al. 2019, A&A 625, A10



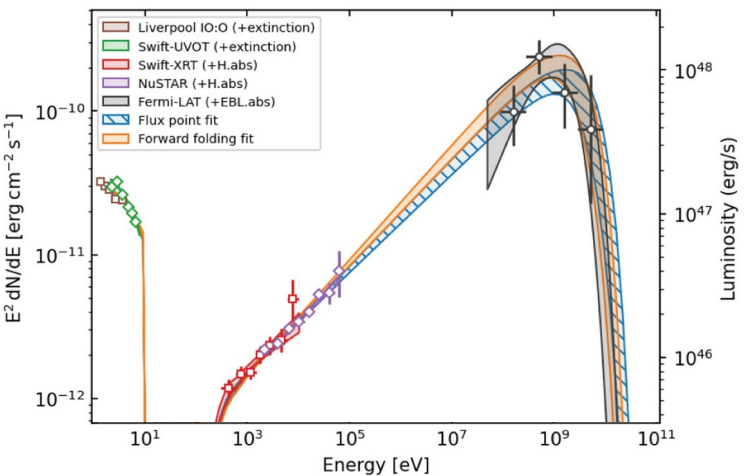
Also see e.g.:
Aharonian et al. 2024,
A&A 686, A308

- Extension to X-rays:
  https://github.com/registerrier/gammapy-ogip-spectra



L. Giunti et al. 2022, A&A 667, A130

- Extension to UV/ optical:
  https://github.com/mireianievas/gammapy_mwl_workflow



M. Nievas Rosillo et al. 2025, A&A, 693, A287

Gammapy & MWL data

- Gammapy-mwl
  - Public git repo: https://github.com/gammapy/gammapy-mwl
  - Subproject of Gammapy - Managed by Fabio
  - In development
    - Less easy to install yet as Gammapy
    - Changing constantly
  - But works nicely to do joint fits of data on events/counts not fluxes, which avoid bias
  - See my miniprojects groups presentation tomorrow