BROAD-BAND SED FITTING OF BLAZARS

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EOSC-Future ESCAPE Science Projects meeting
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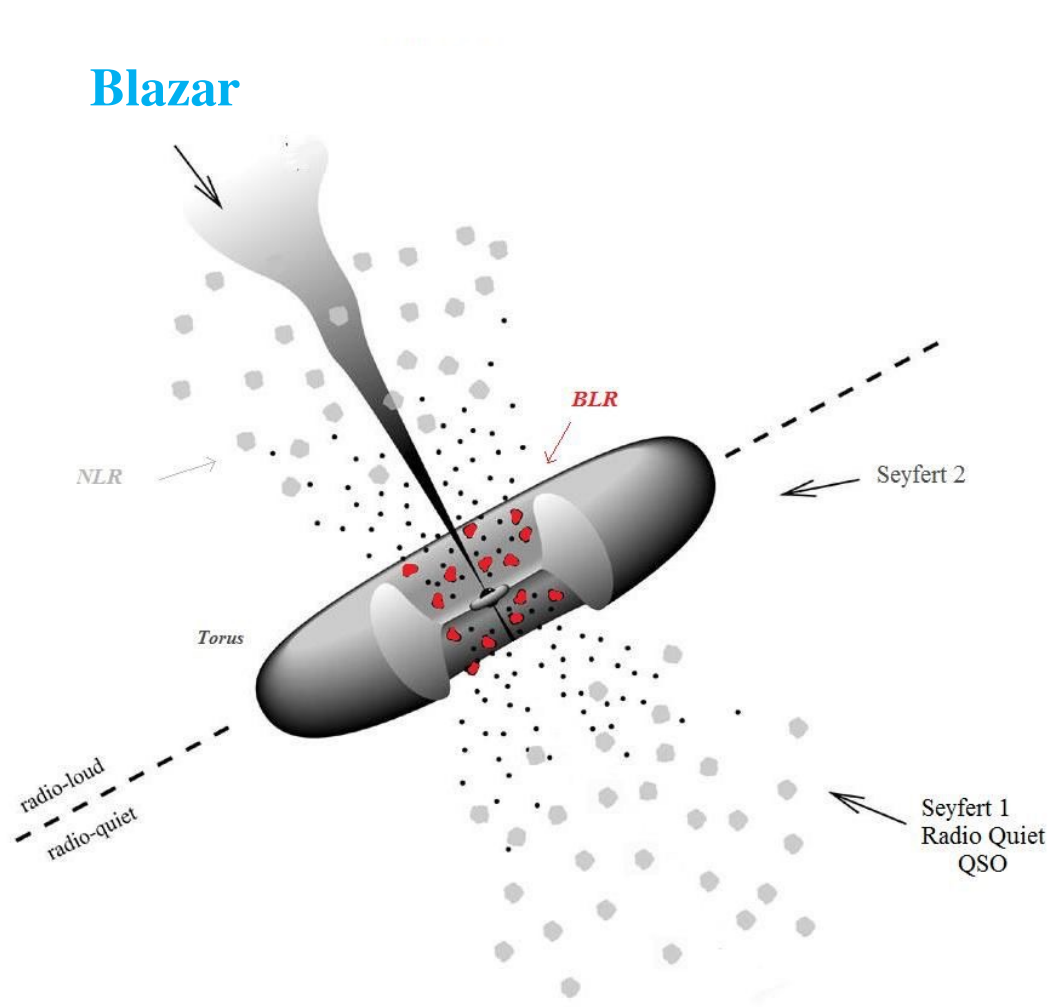
Active Galactic Nuclei model

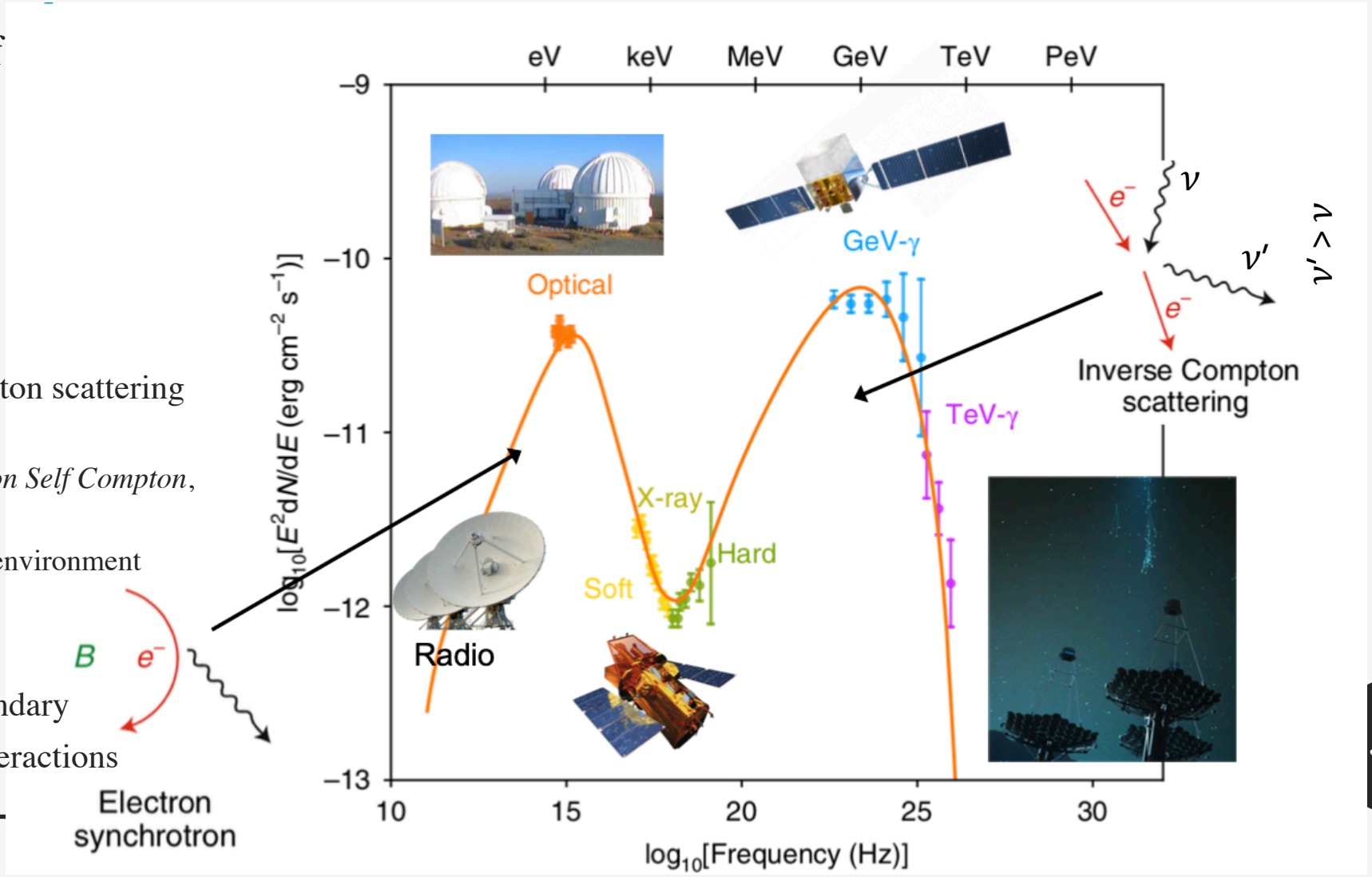


- AGN Unified Model
  - AGN classification depends on orientation only
  - 2 classes: Type 1 = Broad-line AGN

    Type 2 = Narrow-line AGN
  - Subclasses based on the presence of a jet
    - Jet towards the observer = **Blazars**
      - **BL Lac:** lack UV/opt emission-lines
      - **Flat Spectrum Radio Quasars (FSRQ)**

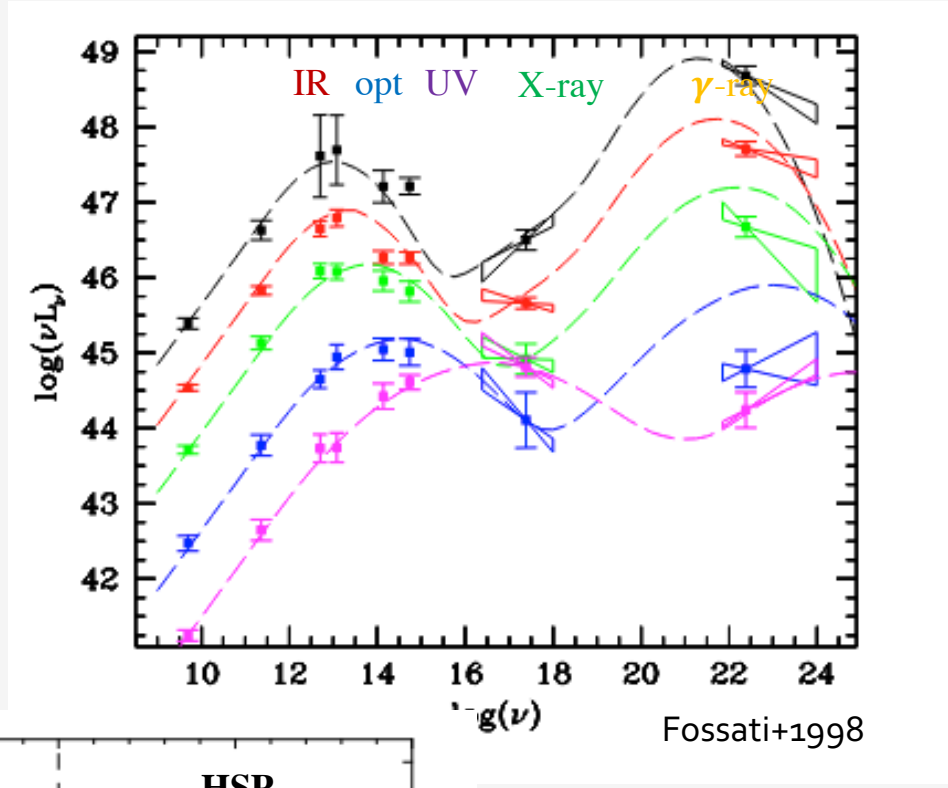
Blazars Broad Band Emission

- Observed over the full range of wavelengths
- Typical 2-humps spectrum
  - 1st peak: e⁻ synchrotron
  - 2nd peak :
    - Leptonic model → Inverse Compton scattering synchrotron e⁻ interact with
      - synchrotron photons (*Synchrotron Self Compton*, SSC)
      - external photons from the local environment (*External Compton*)
    - Hadronic model → synchrotron emission by protons, and/or secondary leptons produced in proton- γ interactions

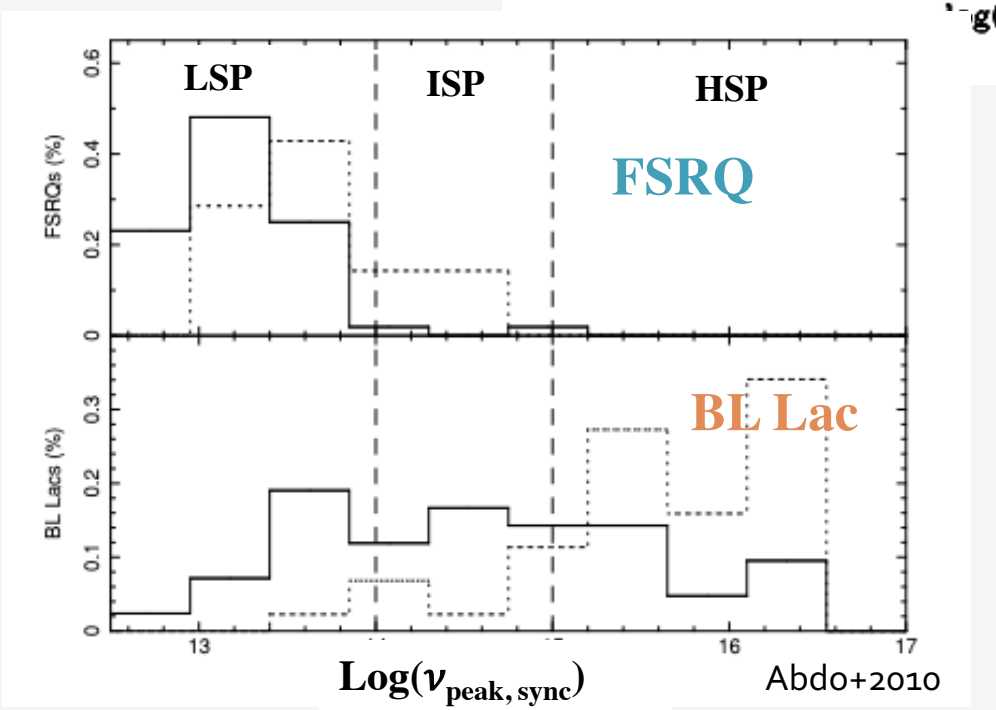


Blazars SED classification

- SED classification depending on the peak frequency of their synchrotron bump (= low-E peak)
  - low-synchrotron-peaked (LSP): $\nu < 10^{14}$ Hz [IR]
  - intermediate-synchrotron-peaked (ISP): $10^{14} < \nu < 10^{15}$ Hz [IR - opt]
  - high-synchrotron-peaked (HSP): $\nu > 10^{15}$ Hz [UV – soft X-rays]



Fossati+1998

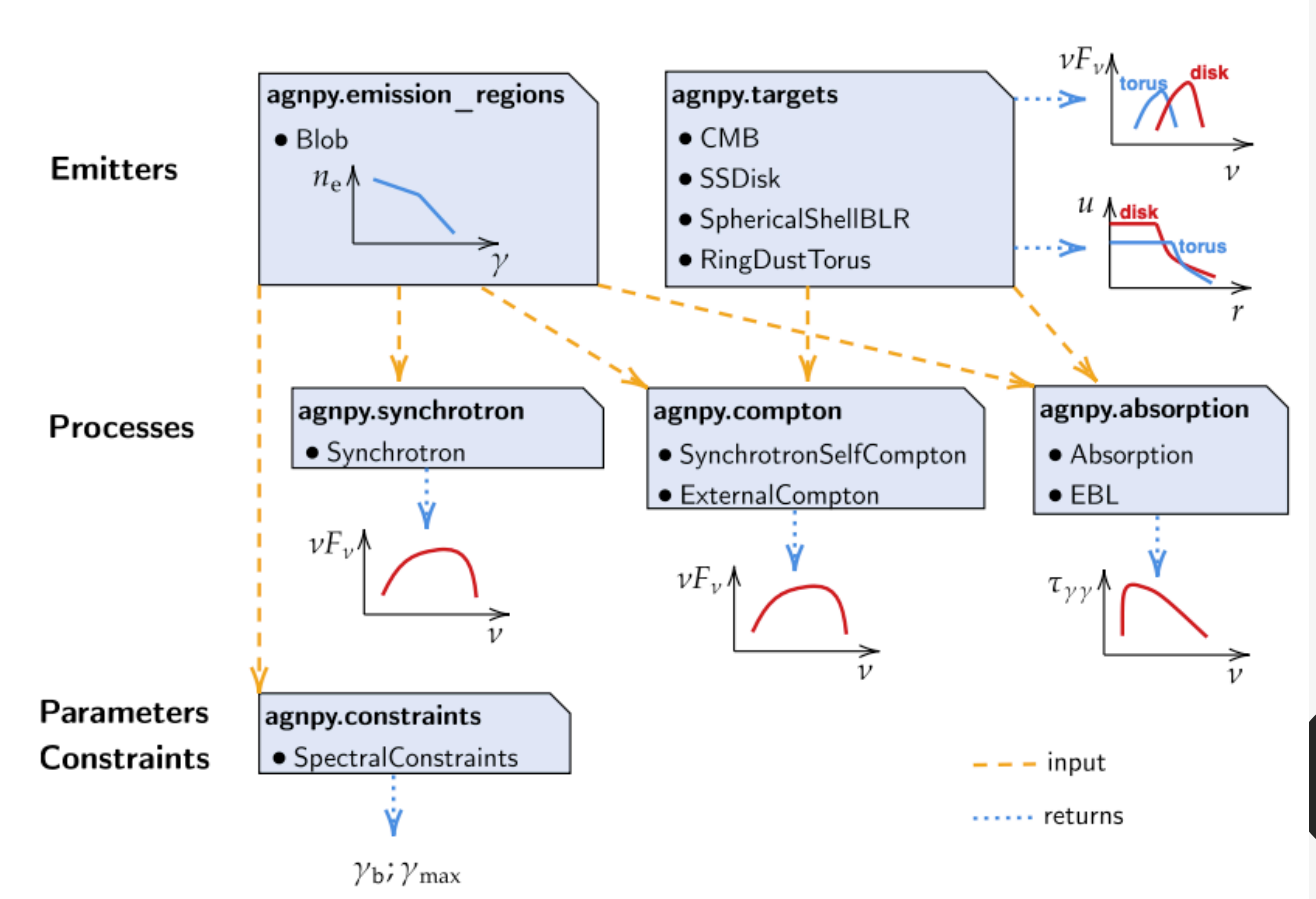


Abdo+2010

agnpy: modelling the radiative process of jetted AGN

https://agnpy.readthedocs.io/en/latest/index.html

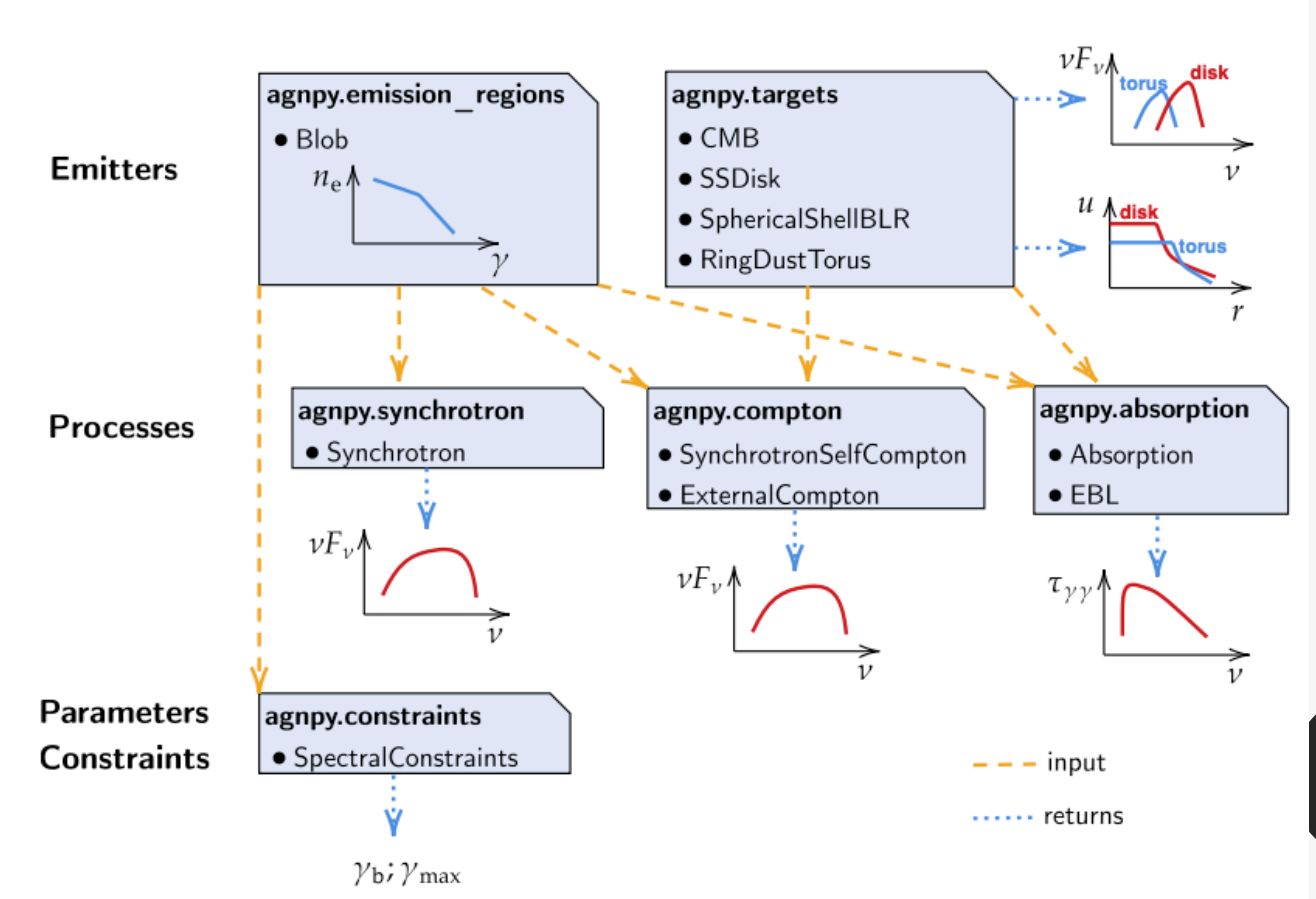
- open-source python package (Nigro+2022)
  - `Github` & Zenodo
- SED from radio to γ-rays, modelling leptonic radiative processes
- Emission:
  - Non-thermal e^- = simple spherical plasmoid along the jet (`blob`)
    - e^- distribution: power-law, broken power-law and log-parabola
  - Line & thermal emissions
    - For FSRQ



agnpy: modelling the radiative process of jetted AGN

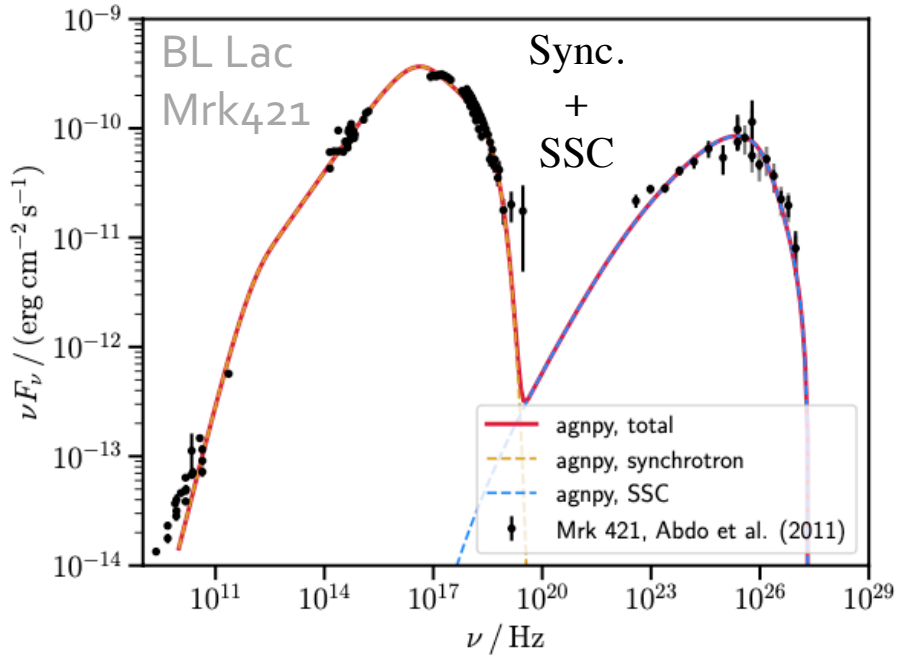
https://agnpy.readthedocs.io/en/latest/index.html

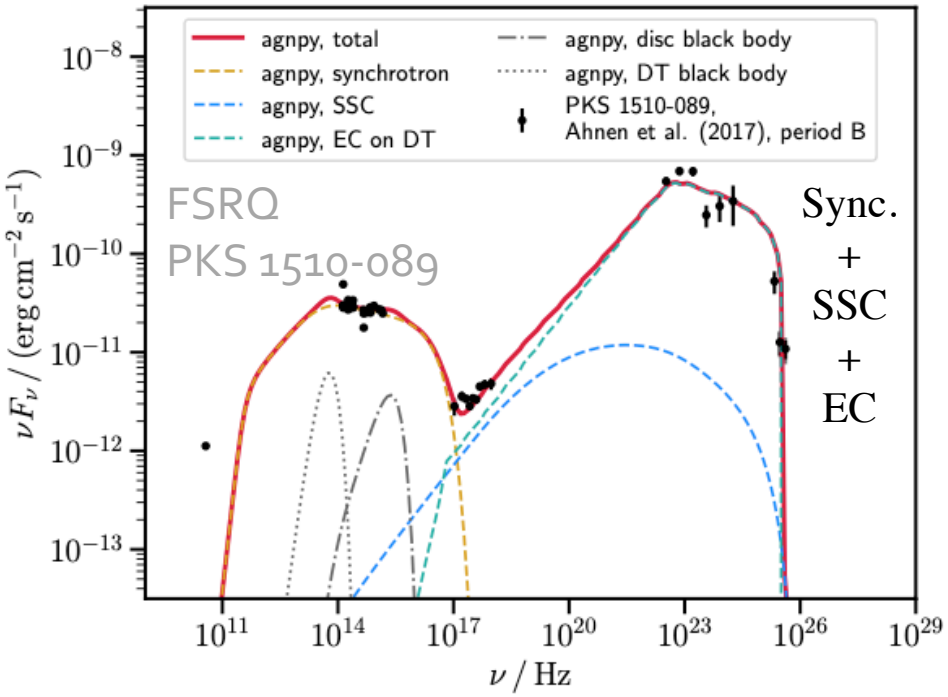
- Radiative process:
  - non thermal radiation
    - Synchrotron radiation → low-E peak
    - SSC radiation
  - Extra emitters
    - Target for External Compton
- Absorption:
  - Due to $\gamma\,\gamma$ pair production (self-absorption)
  - By Extragalactic Background Light on l.o.s.



agnpy: Tuto

- `agnpy` is modelling the SED but an external package (gammapy or sherpa) is necessary to perform the fit
- Online examples for both BL Lac and FRSQ sources using these 2 packages are available online
  - https://agnpy.readthedocs.io/en/latest/tutorials/ssc_gammapy_fit.html
  - Notebooks also available on https://github.com/cosimoNigro/agnpy/tree/master/docs/tutorials
    - 1/ define a custom model wrapping agnpy function to compute synchrotron and Compton SED
    - 2/ load your multi-wavelength data (+ add systematics errors)
    - 3/ perform the fit
    - 4/ visualize the results





Nigro+2022

e⁻ energy dist. Broken PL

blob

Accretion disc

torus

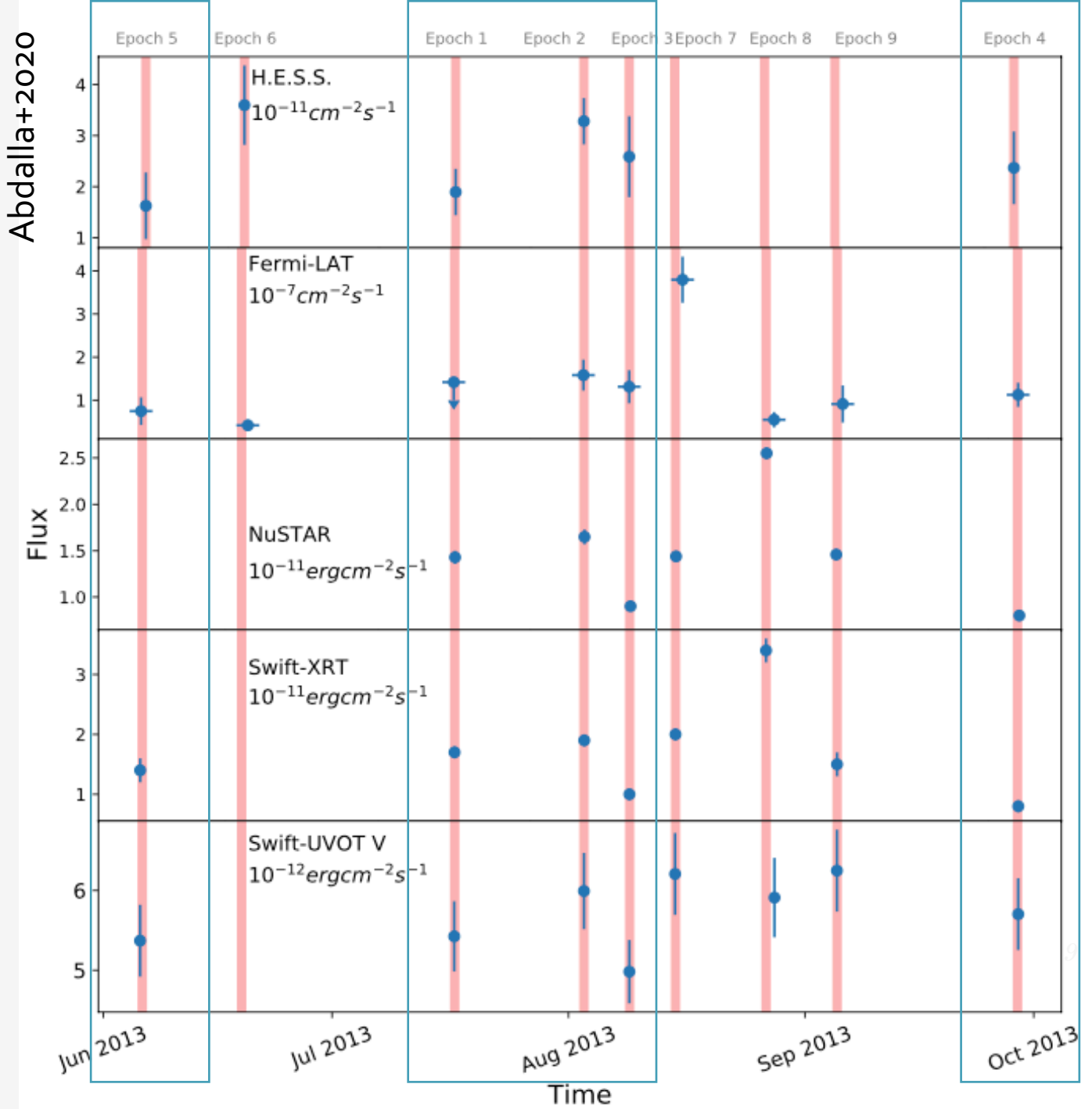
Parameter	Mrk 421 Gammapy	Mrk 421 sherpa	PKS 1510-089 Gammapy	PKS 1510-089 sherpa
(a) Best-fit parameters				
$\log_{10}(\frac{k_e}{\mathrm{cm}^{-3}})$	−7.89	−7.89	−2.06	−2.05
p_1	2.06	2.06	2.00	2.00
p_2	3.54	3.54	3.16	3.16
$\log_{10}(\gamma'_b)$	4.99	4.99	3.01	3.01
$\log_{10}(B/\mathrm{G})$	−1.33	−1.33	−0.42	−0.42
δ_D	19.74	19.76	–	–
χ^2/d.o.f.	271.2/80	271.2/80	230.5/36	230.5/36

Jet parameters

Parameter	Mrk421	PKS 1510-089
(b) Fixed parameters		
δ_D	–	25
γ'_{min}	500	1
γ'_{max}	10^6	3×10^4
R_b / cm	5.3×10^{16}	2.4×10^{16}
θ_s	2.90°	2.22°
r/cm	–	6×10^{17}
L_{disc}/(erg s^{-1})	–	6.7×10^{45}
η	–	1/12
$M_{BH}/M_\odot$	–	5.71×10^7
R_{in}/R_g	–	6
R_{out}/R_g	–	10^4
ξ_{DT}	–	0.6
R_{DT} / cm	–	6.5×10^{18}
T_{DT} / K	–	10^3
z	0.0308	0.361

PKS 2155-304

- One of the brightest and most luminous HSP blazar (HBL; z = 0.116)
  - Broad band spectrum: $\nu_{\text{peak, sync}}$ far-UV
- 1st time multi-wavelength observation campaign June – Oct 2013 from UV to TeV energies (Abdalla+2020)
  - *Swift* (UVOT & XRT), *NuSTAR*, *Fermi*-LAT and HESS
  - 4 nights with all simultaneous wavelengths + 1 night without *NuSTAR*

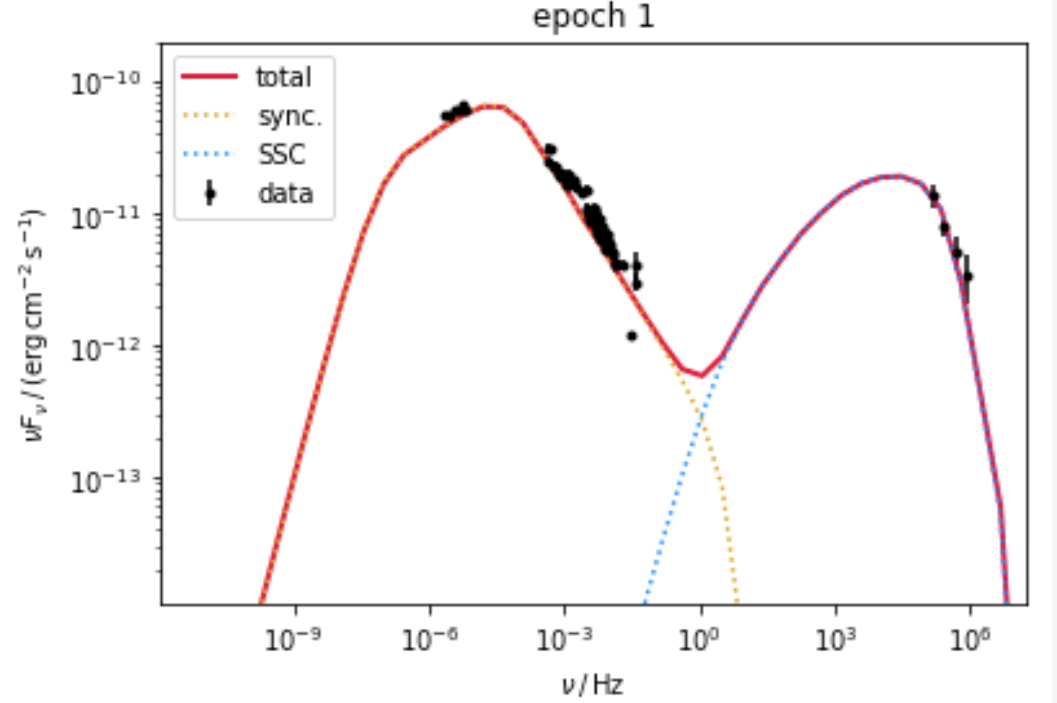


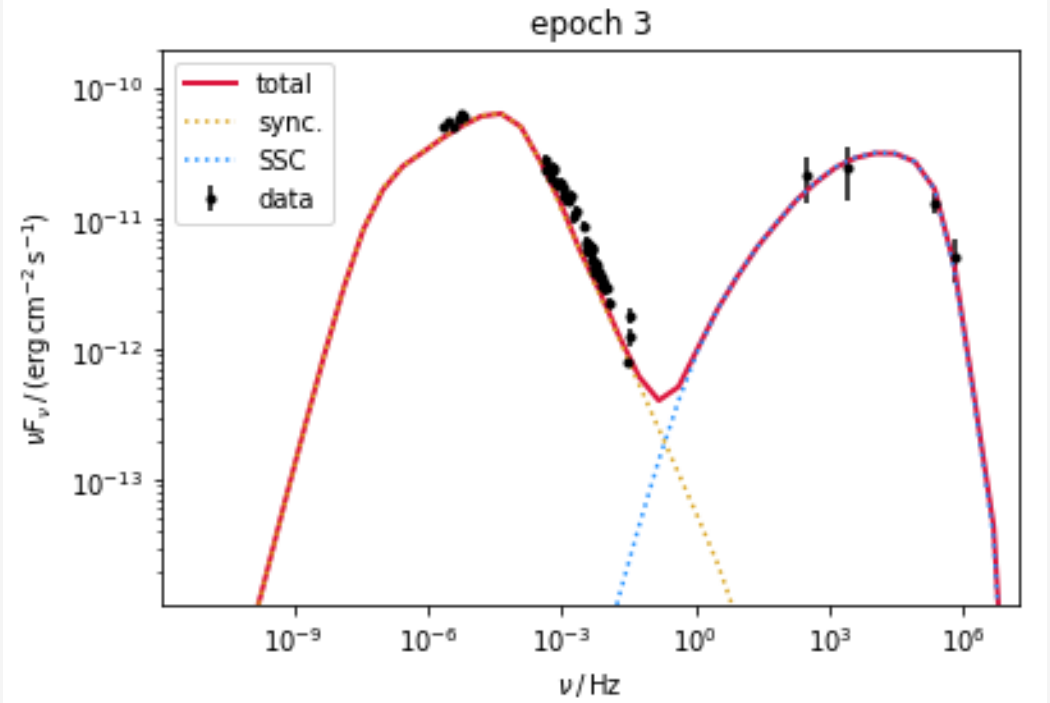
PKS 2155-304: VRE

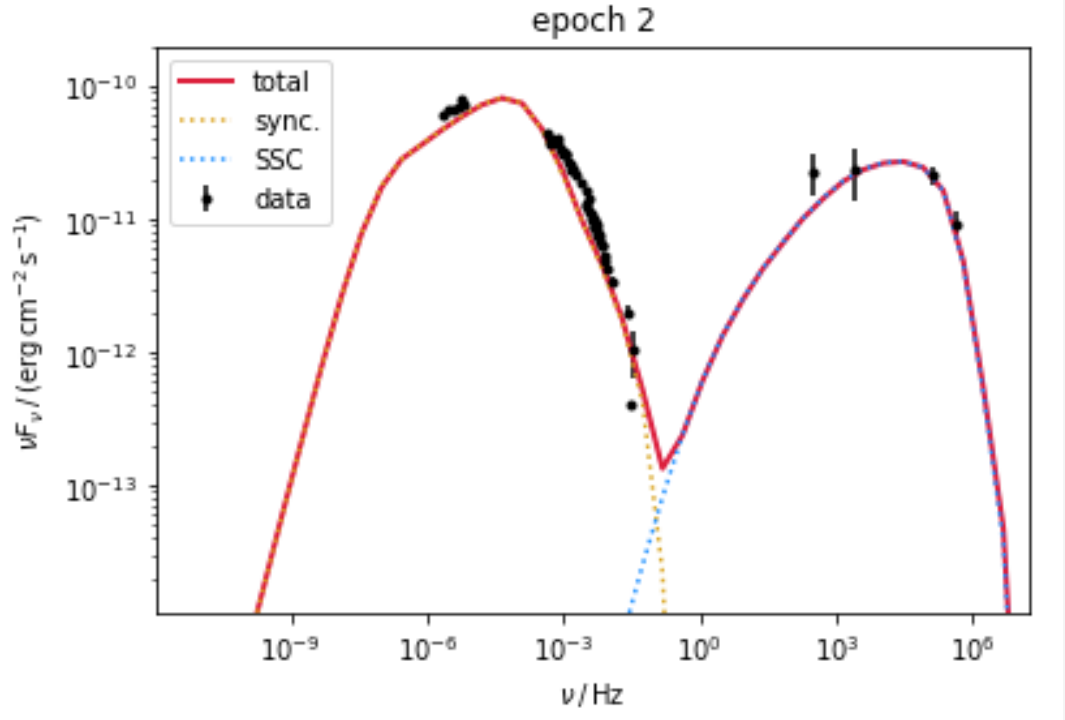
- VRE:
  - Environment with `agnpy` and `gammapy` in OSSR
  - Datasets and models uploaded in the Data Lake
  - All materials on GitLab

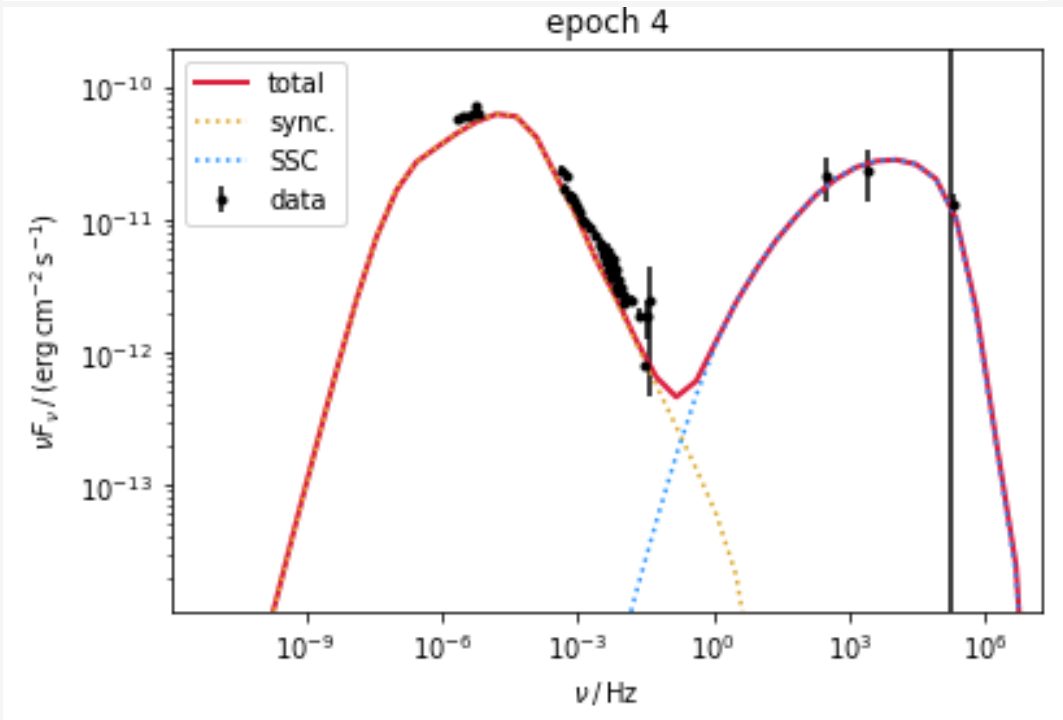
- `angpy` modelling (Abdalla+2020):
  - e^- energy distribution = broken PL
  - Synchrotron + SSC processes with self-absorption

  ➔ read saved fitted parameters from config files and re-compute / display `agnpy` model
    - Plot the different component of the model
    - Extract physical information on the emission region (e^- energy, jet power, Lorentz factor …)


epoch 1
total
sync.
SSC
data
$\nu F_\nu / (\mathrm{erg\,cm^{-2}\,s^{-1}})$
ν / Hz


epoch 3
total
sync.
SSC
data
$\nu F_\nu / (\mathrm{erg\,cm^{-2}\,s^{-1}})$
ν / Hz


epoch 2
total
sync.
SSC
data
$\nu F_\nu / (\mathrm{erg\,cm^{-2}\,s^{-1}})$
ν / Hz


epoch 4
total
sync.
SSC
data
$\nu F_\nu / (\mathrm{erg\,cm^{-2}\,s^{-1}})$
ν / Hz

Conclusion

- `agnpy`: python package modelling radiative processes of blazars on broad band SED
  - Classical leptonic model: synchrotron and inverse Compton processes

- Applications in VRE
  - `agnpy` and `gammapy` in OSSR
  - Models and data for PKS 2155-304 in DataLake / GitLab
  - Can be used to fit personal datasets / display models
  - Future interest: new TeV data will be available with LST and later on CTA