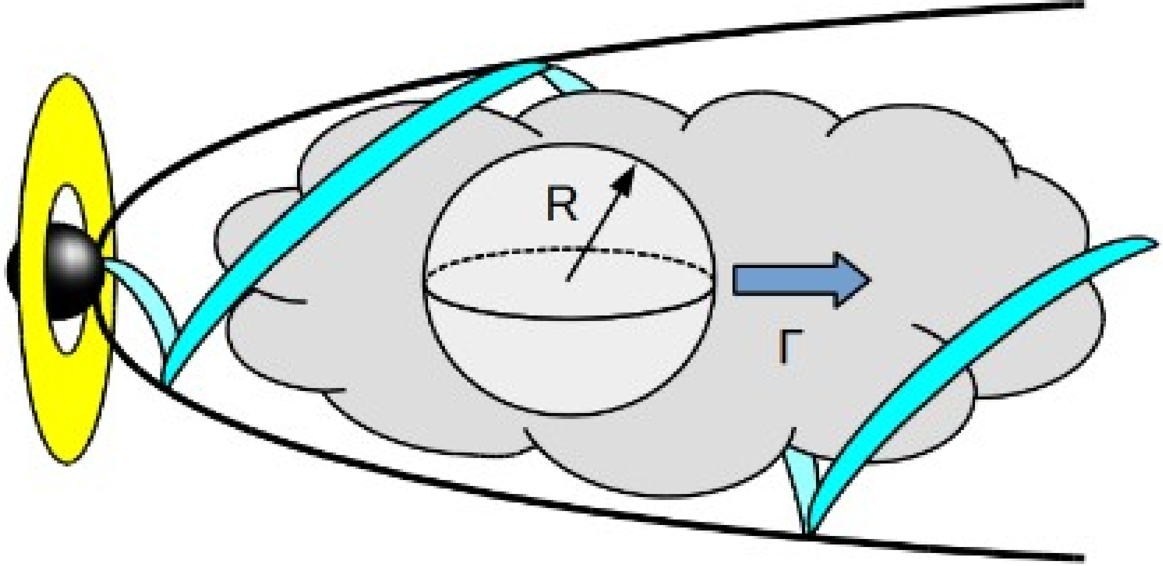

Modified from Hörbe et al. 2020.

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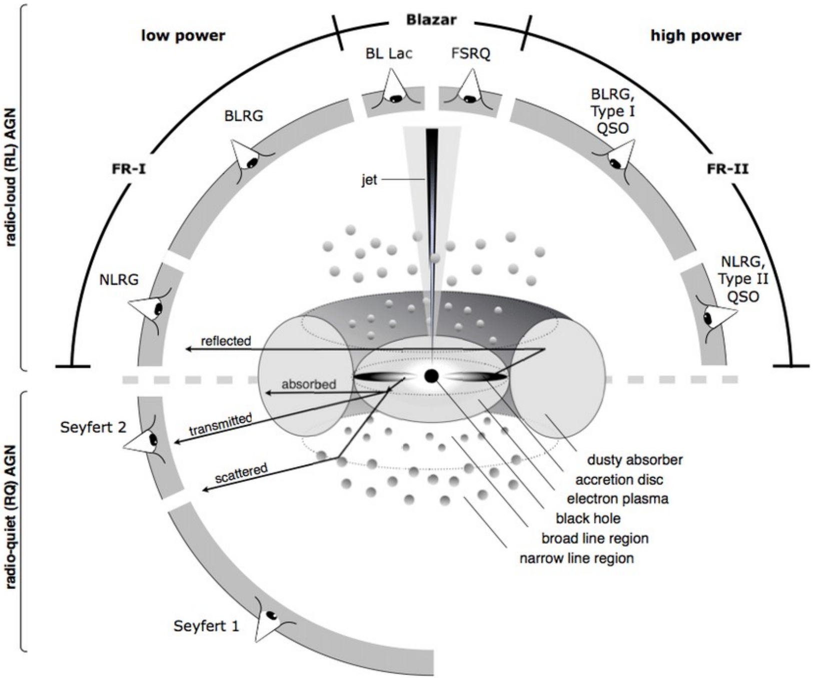
RAPP Center

NUMERICAL LOCAL SOURCE MODELING OF ACTIVE GALACTIC NUCLEI

Leander Schlegel, Marcel Schroller, Mario Hörbe, Vladimir Kiselev, Julia Becker Tjus

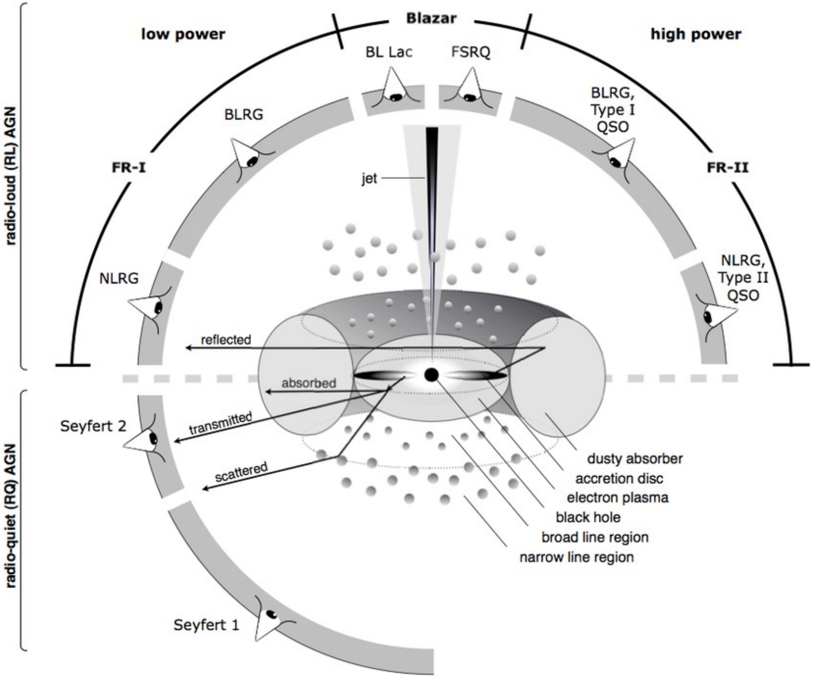
Motivation

Motivation

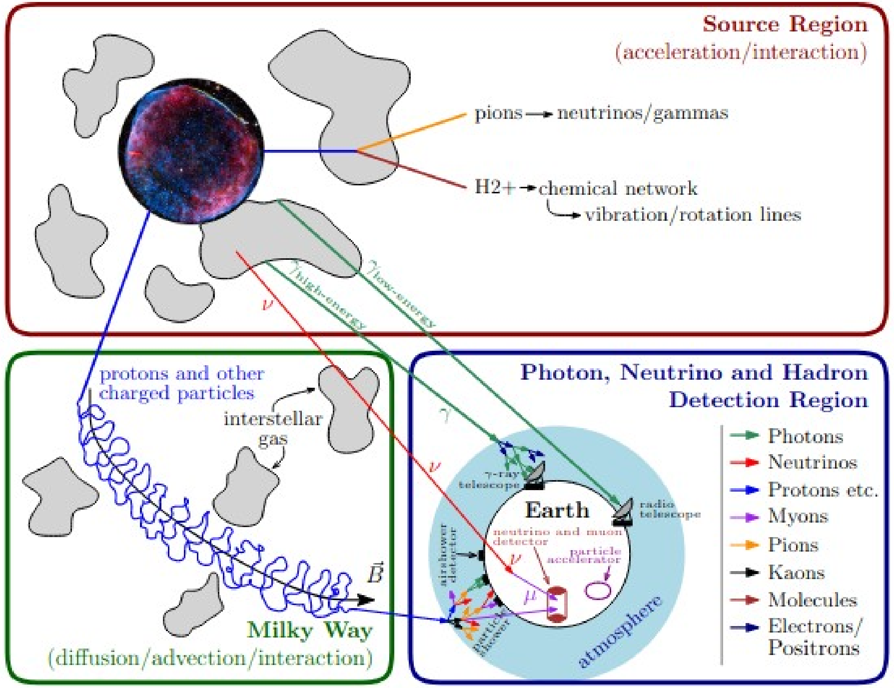


(Beckmann & Shrader 2012)

Motivation

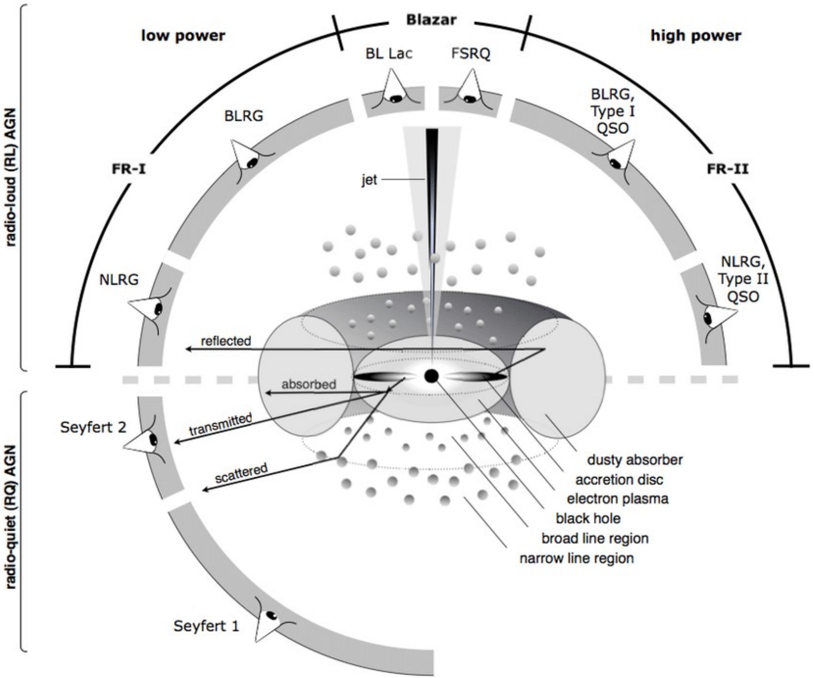


(Beckmann & Shrader 2012)

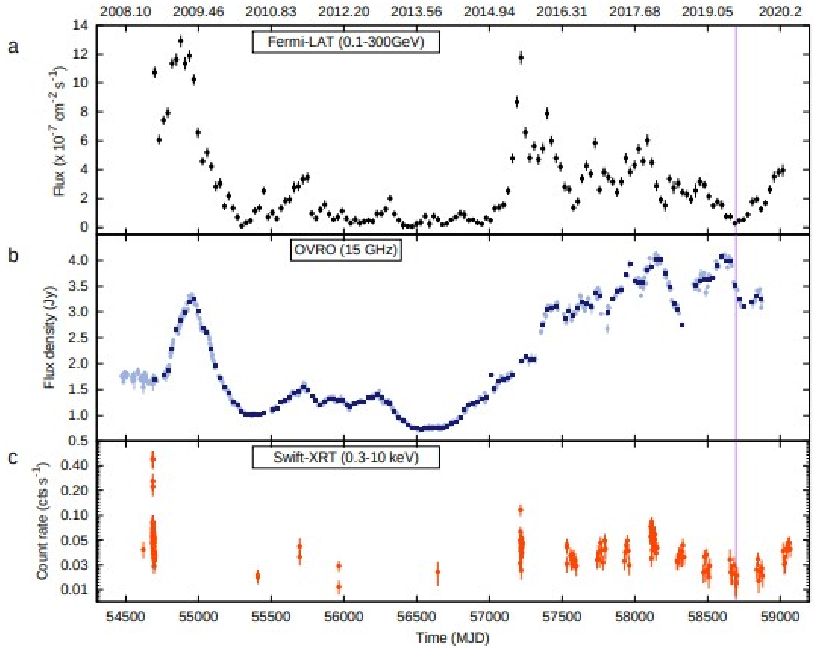


(Tjus, Merten 2020)

Motivation



(Beckmann & Shrader 2012)



(Kun et al 2021)

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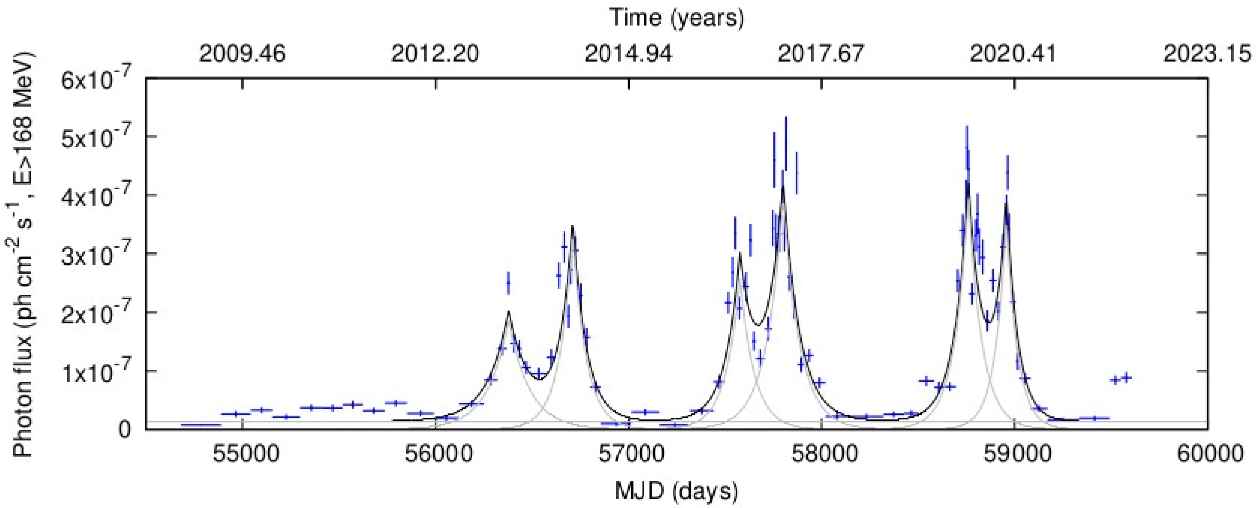
Quasiperiodic source J1048+7143



(Kun, ..., L.S., et. al 2022)

-J1048 shows QPOs in Gamma ray lightcurve.

-Possible explanation is spin-orbit precession.

-Radio data gives observational hint on jet precession.

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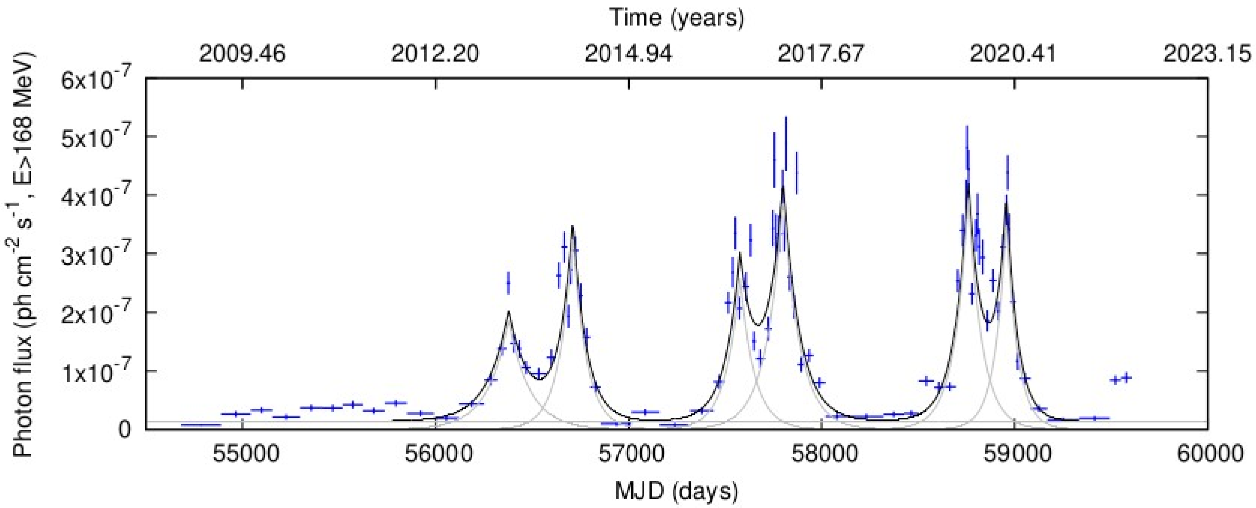
Quasiperiodic source J1048+7143



(Kun, ..., L.S., et. al 2022)

-J1048 shows QPOs in Gamma ray lightcurve.

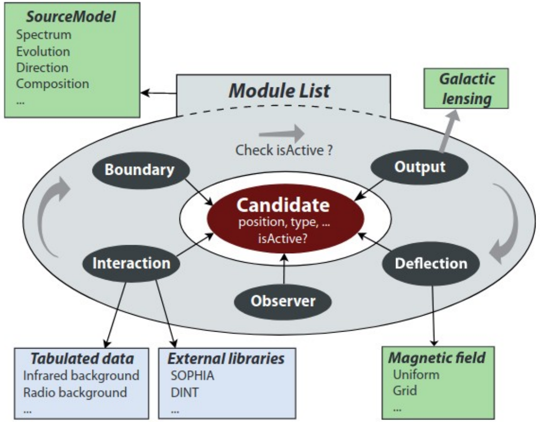
-Possible explanation is spin-orbit precession.

-Radio data gives observational hint on jet precession.

Further understanding of these observations can benefit from detailed numerical modeling of the local environment of AGN jets.

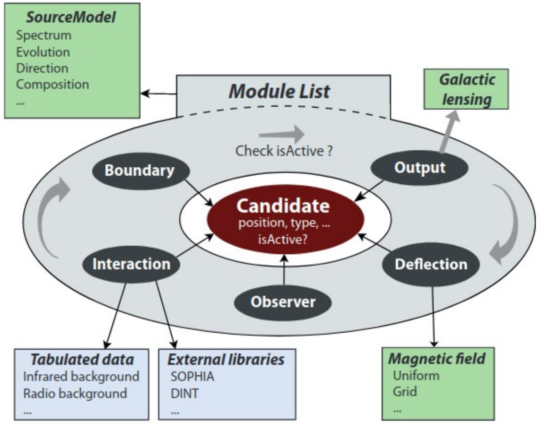
Numerical simulation approach

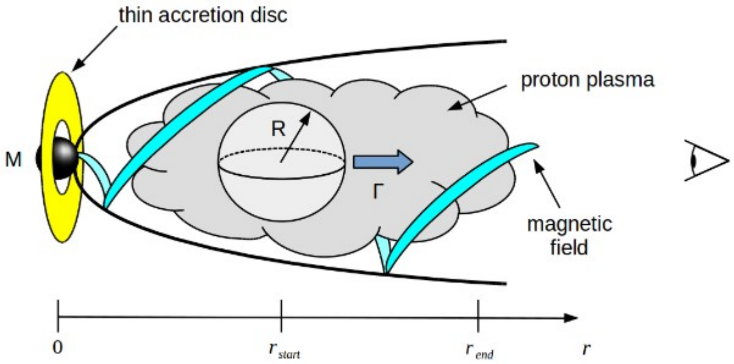
CRPropa 3.1



(RA Batista et al. 2016)

CRPropa 3.1 + Jet model

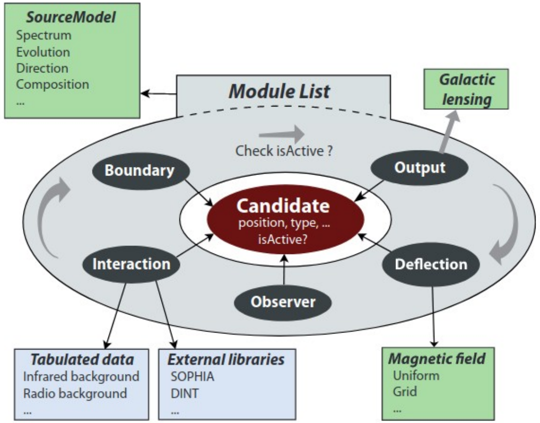




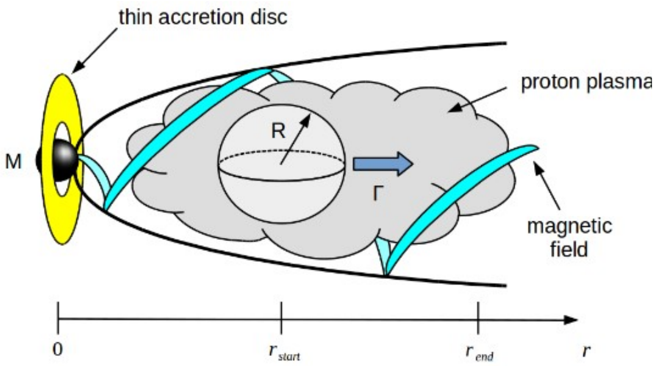
(RA Batista et al. 2016)

(Hörbe et al. 2020)

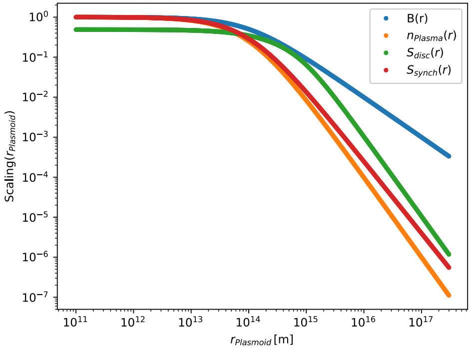
CRPropa 3.1 + Jet model + Modifications and Scalings



(RA Batista et al. 2016)



(Hörbe et al. 2020)



After (Hörbe et al. 2020)

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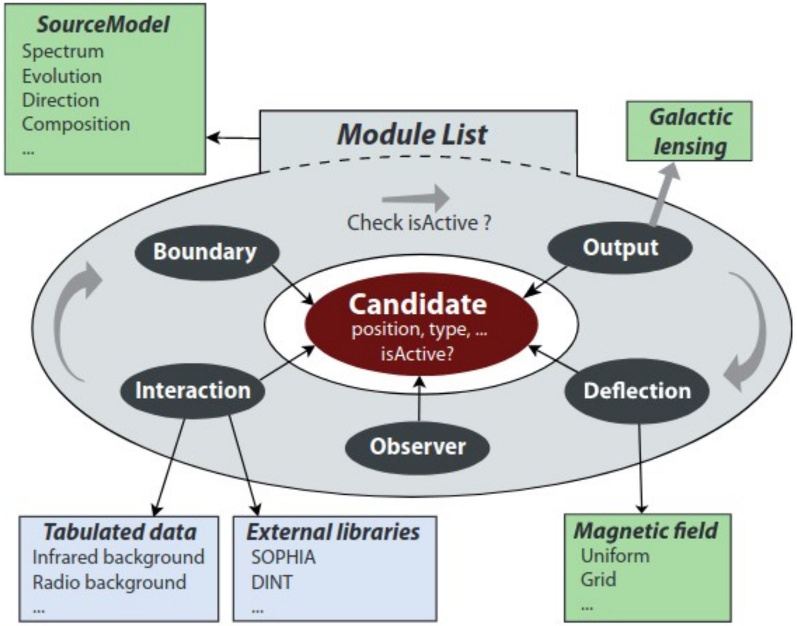
The CRPropa 3 software



(RA Batista et al. 2016)

CRPropa 3 **(RA Batista et al. 2016)** and 3.1 **(Merten et al. 2017)** now 3.2 **(RA Batista, … L.S. et al)** is a publicly available code for the propagation of nuclei in up to 4 dim. (3 spatial + 1 redshift evolution).

- Provides either ballistic propagation(Cash-Karp/BorisPush) or diffusive propagation (Stochastic Differential Equations).

- Photohadronic and electromagnetic interaction processes.

- Magnetic fields (turbulent and general gridbased fields).

This code is the basis for our modifications (mainly Mario Hörbe and Marcel Schroller).

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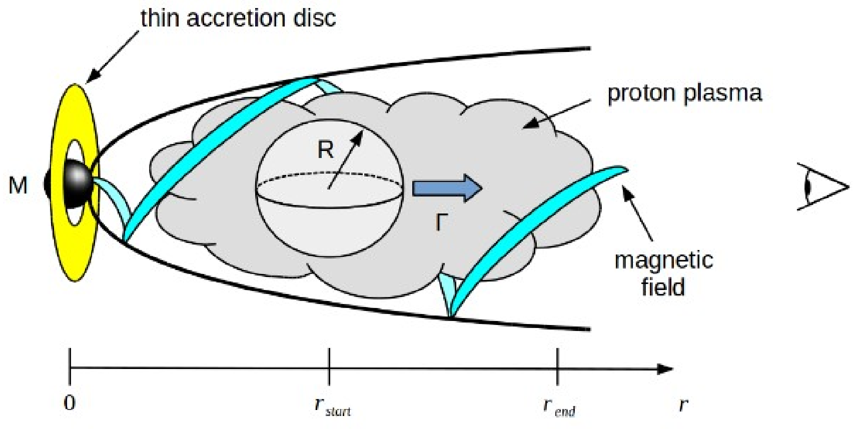
Requirements for local source modeling



(Hörbe et al. 2020)

To properly account for the physics on sub kpc scales, several modelation features are required additionally:

- Custom photon fields (e.g. accretion disc field)

- Time dependent interactions (e.g. along the axis of an AGN jet)

- Hadronic interactions (e.g. for modelation of neutrino producing processes)

- Interaction tagging (resolve origin of secondaries by processes)

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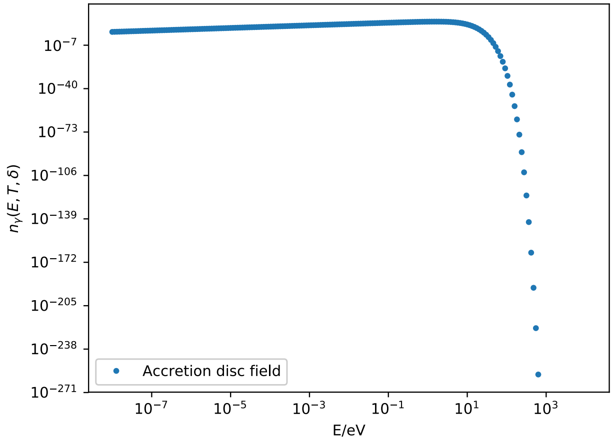
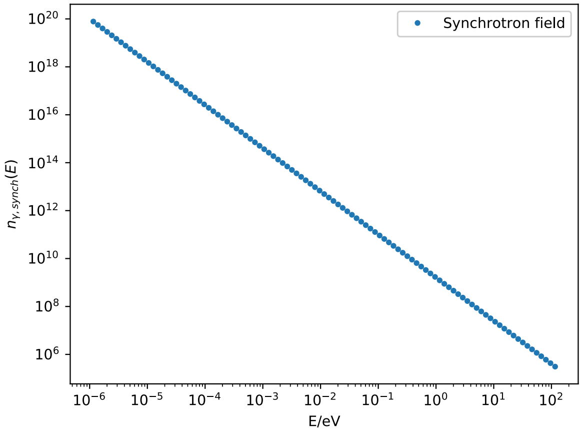
Custom photon fields

The code offers the possibility to use custom shaped photonfields, characterized by their (redshift-dependent) energy density ϱ(E,z), for the interaction processes.

Accretion Disc Field, T=10eV



Synchrotron Field, α = 2.6

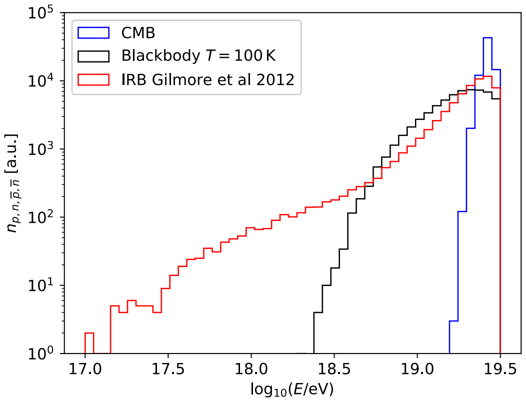


After (Hörbe et al. 2020)

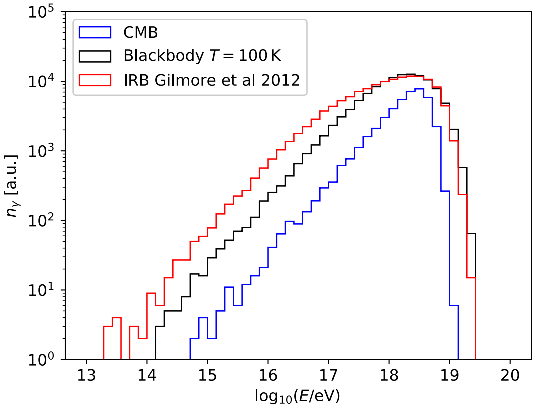
Custom photon fields

The feature was also implemented in CRPropa 3.2 recently as exemplarily shown for three arbitrary photonfields (CMB, Blackbody, IRB) and typical multi messenger info from a simulation.

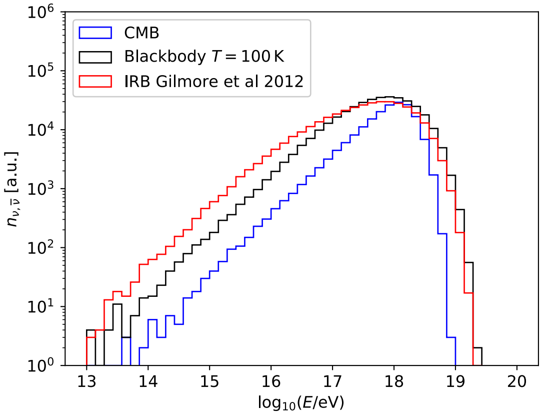
Nucleons



Gammas



Neutrinos



Made for the CRPropa 3.2 paper **(RA Batista,…, L.S., et al.)**

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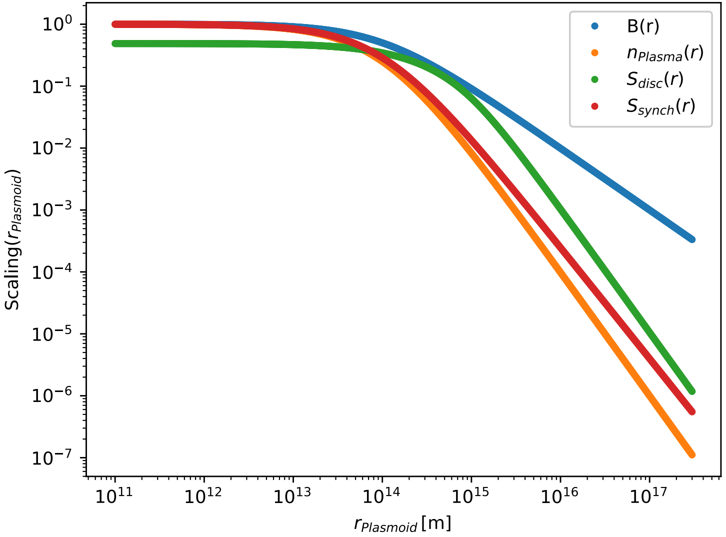
Time dependent interactions

Assuming that the mean free path of an interaction depends linearly on the target-density, allows to use a separation ansatz (see **(Diss. Hörbe 2021)**):

$$\frac{1}{\lambda} = \sigma \cdot n(\mathbf{r}, t) \qquad n(\mathbf{r}, t) = n_0 \cdot S(\mathbf{r}, t)$$



Available electromagnetic and hadronic interactions (and limitedly mag. fields) are available in this time and spatial dependence, using scaling functions S, provided on a generalized 4D - grid structure.

After (Hörbe et al. 2020)

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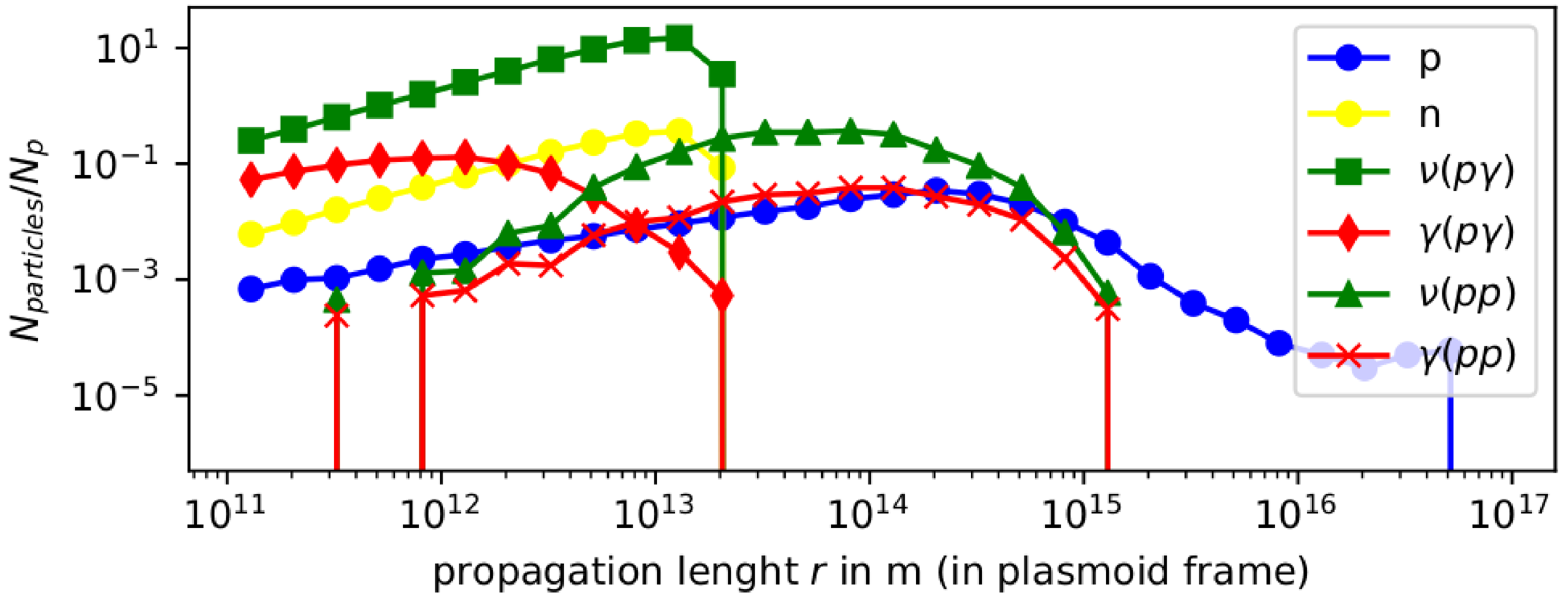
Results

Multimessenger flux for 1e8Gev Proton-Flare



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Outlook and main goals

Summary

Based on CRPropa 3.1 a tool for the local propagation inside the jet of AGN was developed.

Requirements for local modelation like custom photon fields, time dependent interactions, pp interactions and interaction tags are provided.

Multimessenger signatures of plasmoids were already obtained (see Hörbe et al. 2020).

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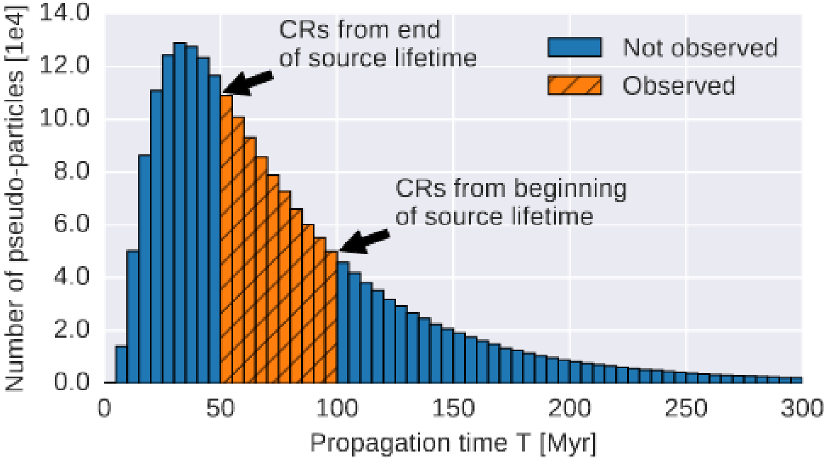
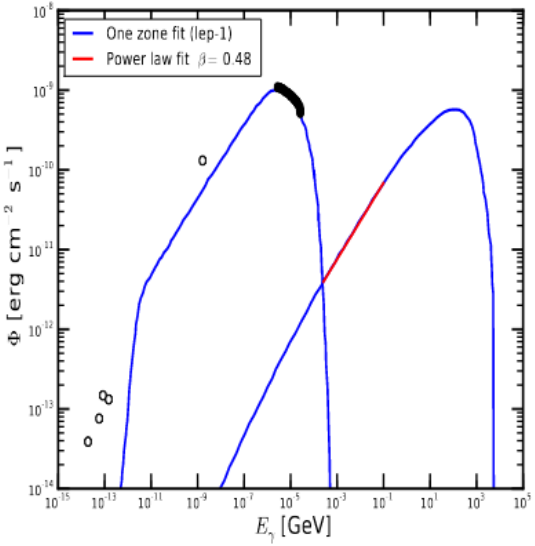
Outlook on code improvements

A next step that is recently investigated is the time dependent flaring of sources and trying to implement the non-linear self-synchrotron compton effect.



(Merten et al. 2018)



(Sahu et al. 2018)

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Key goals

We try to modelate the complex temporal behaviour of multimessenger emission of jetted AGN. In the scope of the MICRO project (MultI-messenger probe of Cosmic Ray Origins) we are especially interested in the following questions:

How do bursting signatures fit observed cosmic ray data?

How do UHECR observables constrain the 3D distribution of sources?

Do Neutrinos, Gammas and UHECRs come from the same sources? Can we predict the fluxes?

The code is under further development currently to improve the features and increase the modelation possibilities aiming for helping with a thorough understanding of the obervational findings.

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