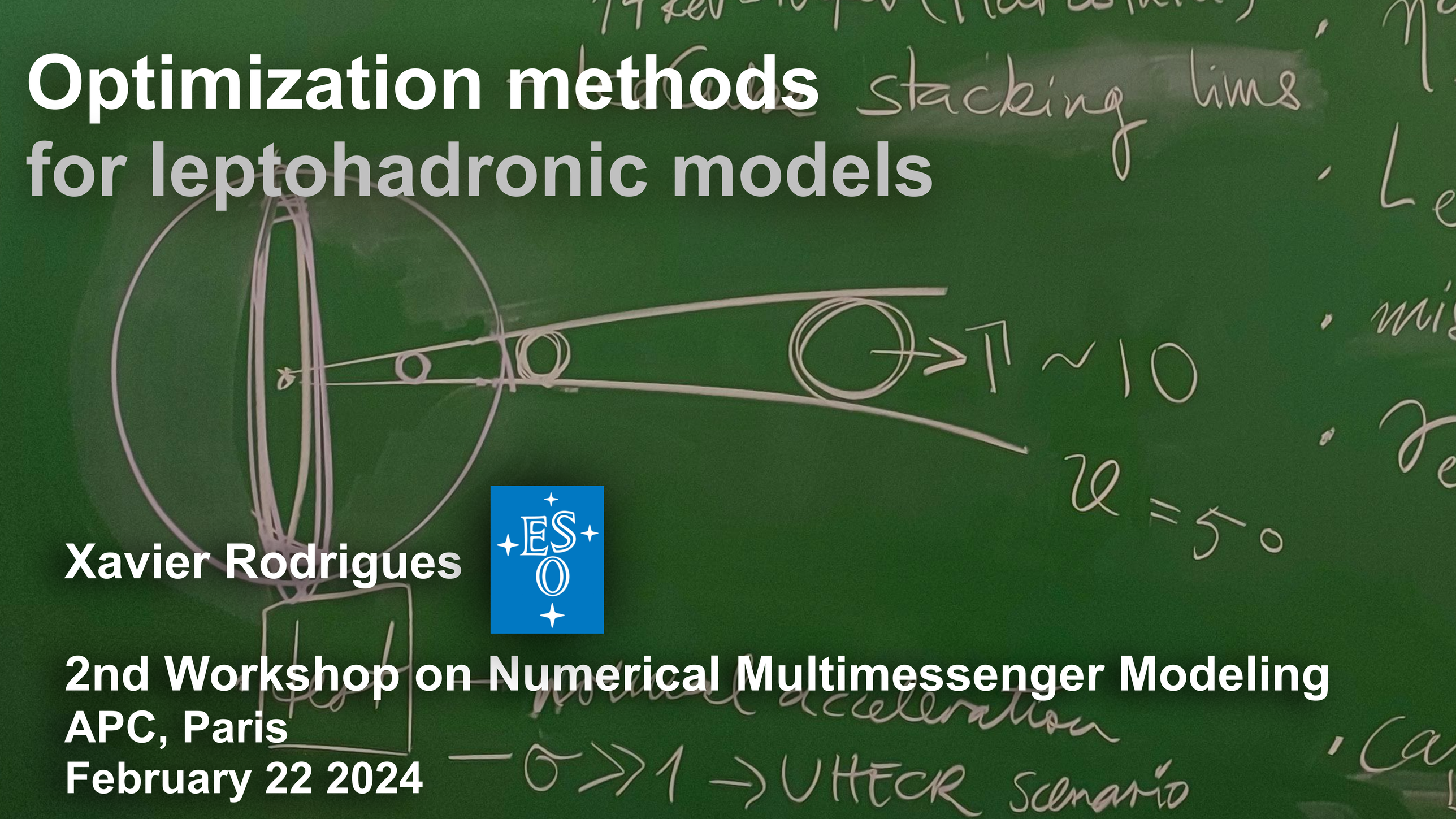
Optimization methods for leptohadronic models



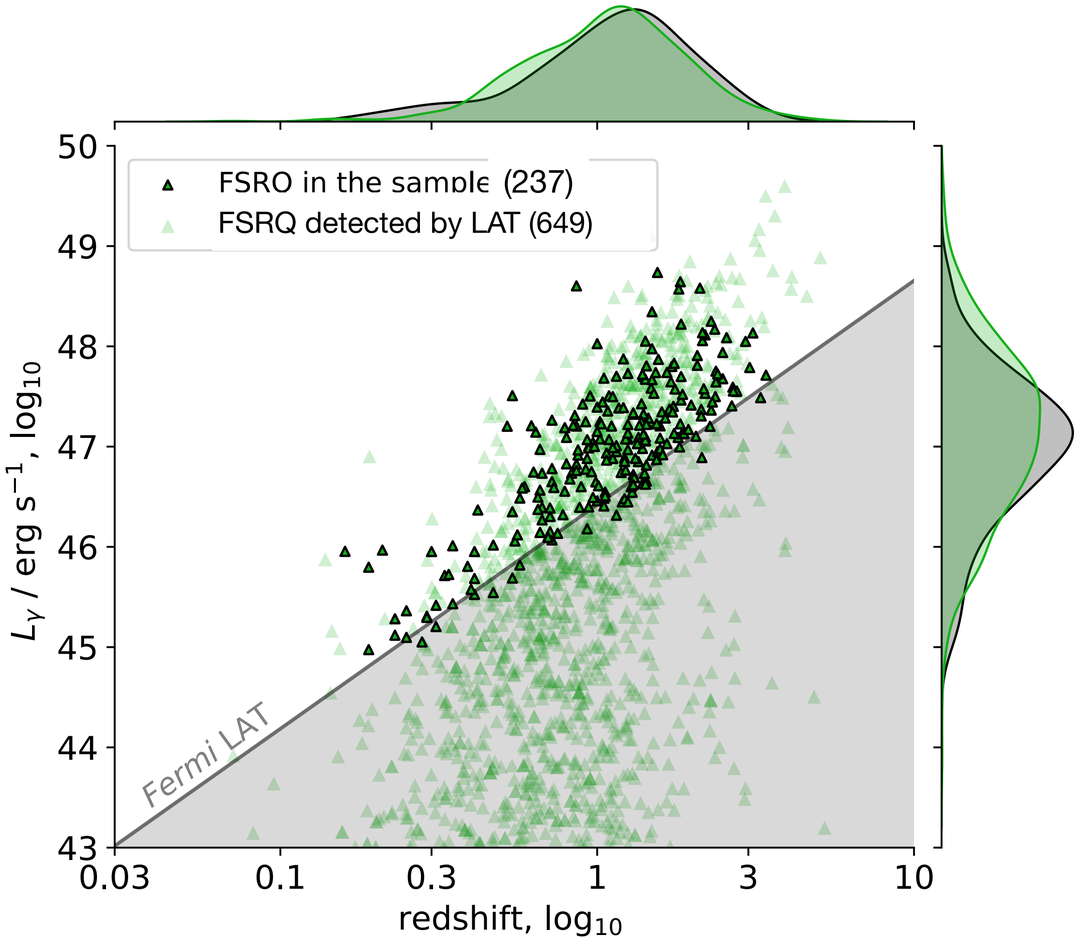
Xavier Rodrigues

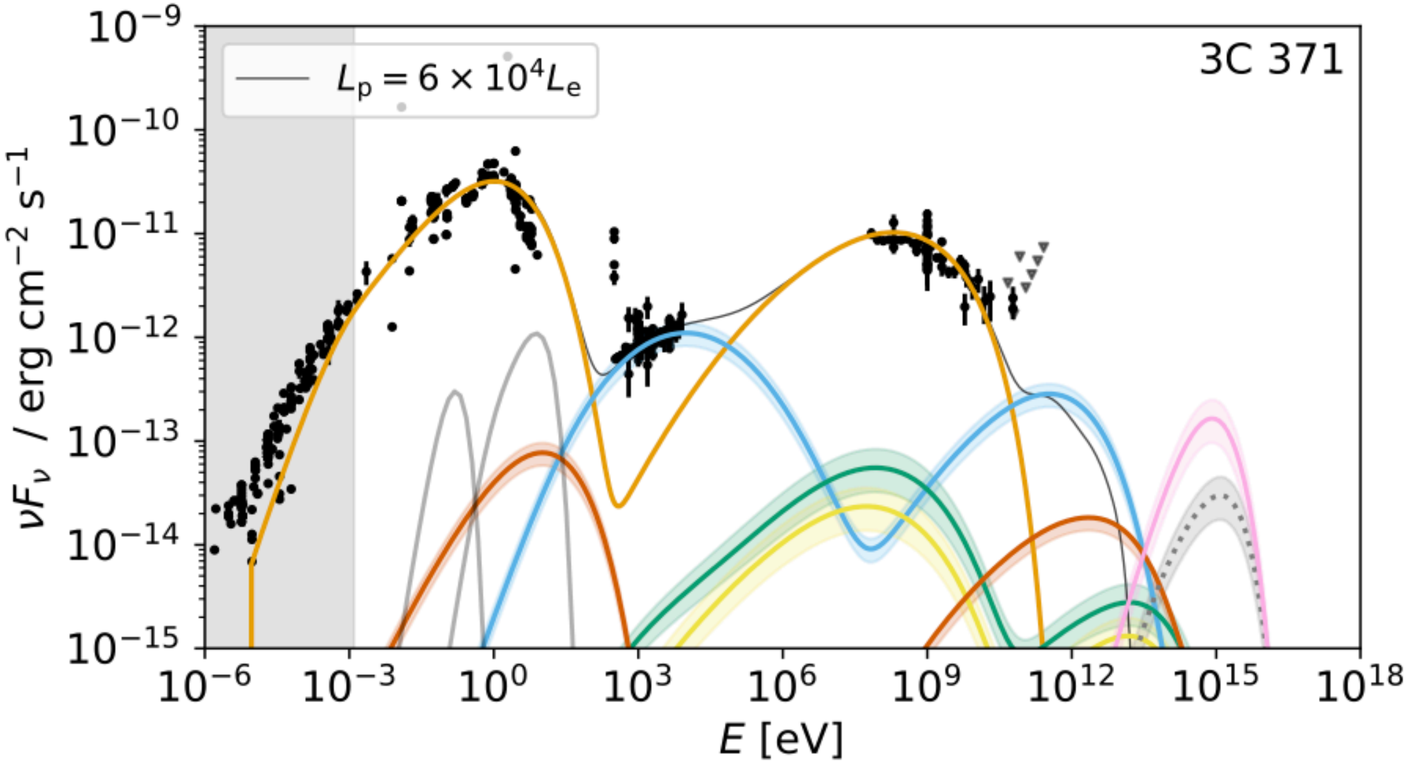
2nd Workshop on Numerical Multimessenger Modeling
APC, Paris
February 22 2024

Robust global optimization with
Genetic Algorithms (GAs)

Physics-driven optimization with
layered grid scans

Leptohadronic modeling of 324 LSP objects (mostly FSRQs)

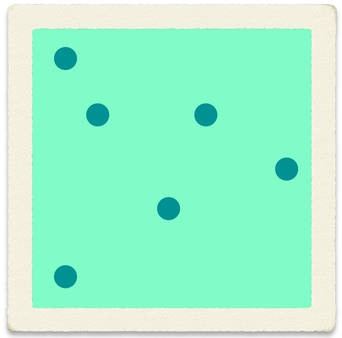




XR, Paliya, Garrappa, Omeliukh,
Franckowiak & Winter 2024, A&A 681

Structure of a genetic algorithm

Generate *population* of 10^4 <u>random</u> *individuals*

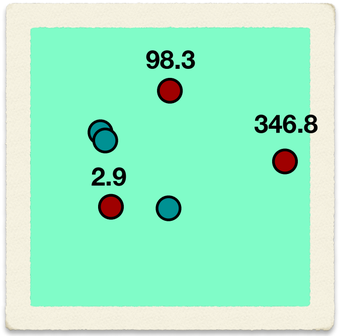


Each individual is an array of 10 *genes*

(log R_b, log B, Γ_b, log L_e, log L_p, …)

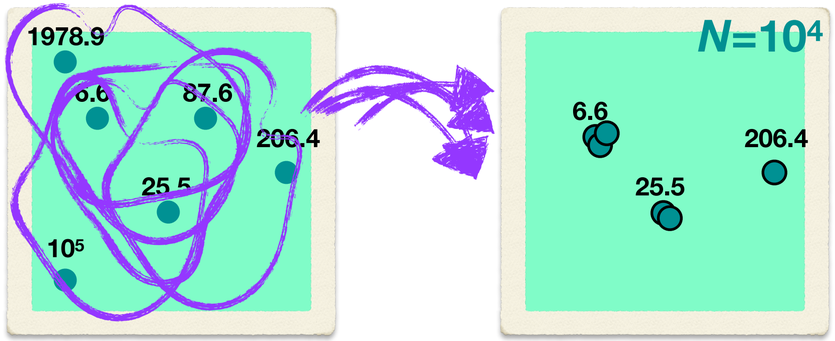
(16.3, 0.2, 5.2, 43.6, 44.4, …)
(15.9, 0.4, 5.2, 45.2, 40.7, …)
(16.7, 0.9, 4.5, 42.8, 45.1, …)
⋮

Evaluate new individuals



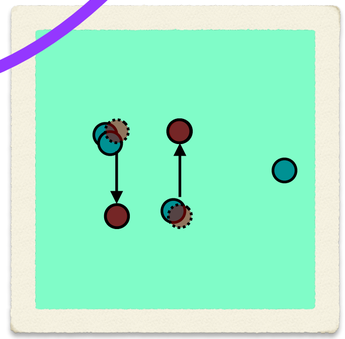
Run simulations in parallel & compare each result to SED

Select progenitors

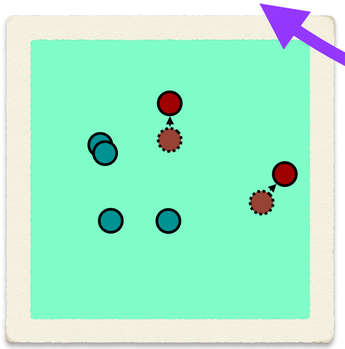


Conduct 10^4 tournaments with k=3 <u>random</u> participants. One winner per tournament

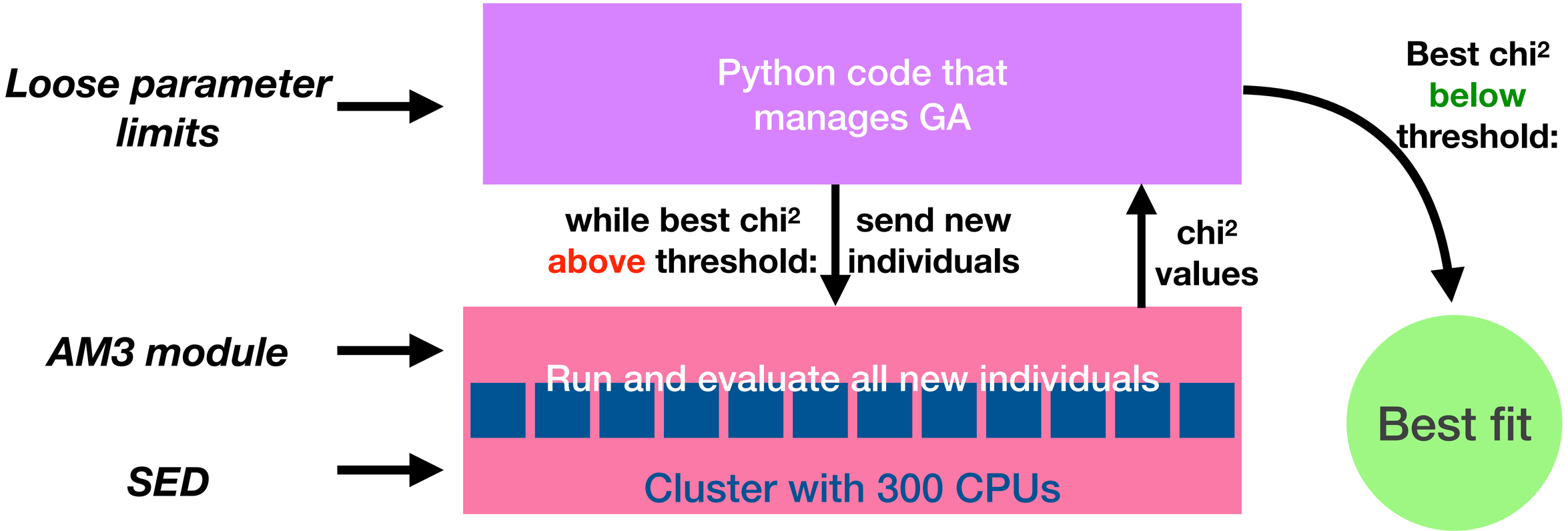
Crossover progenitors



Mutate offspring



Implementing a genetic algorithm

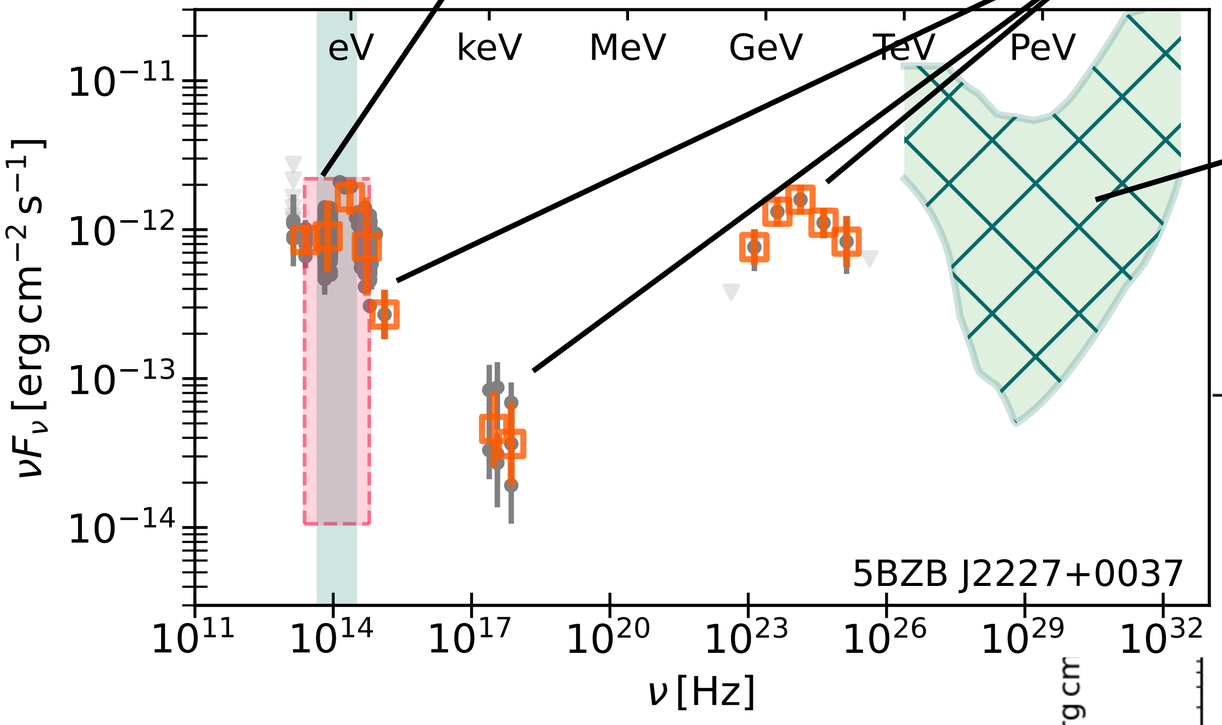


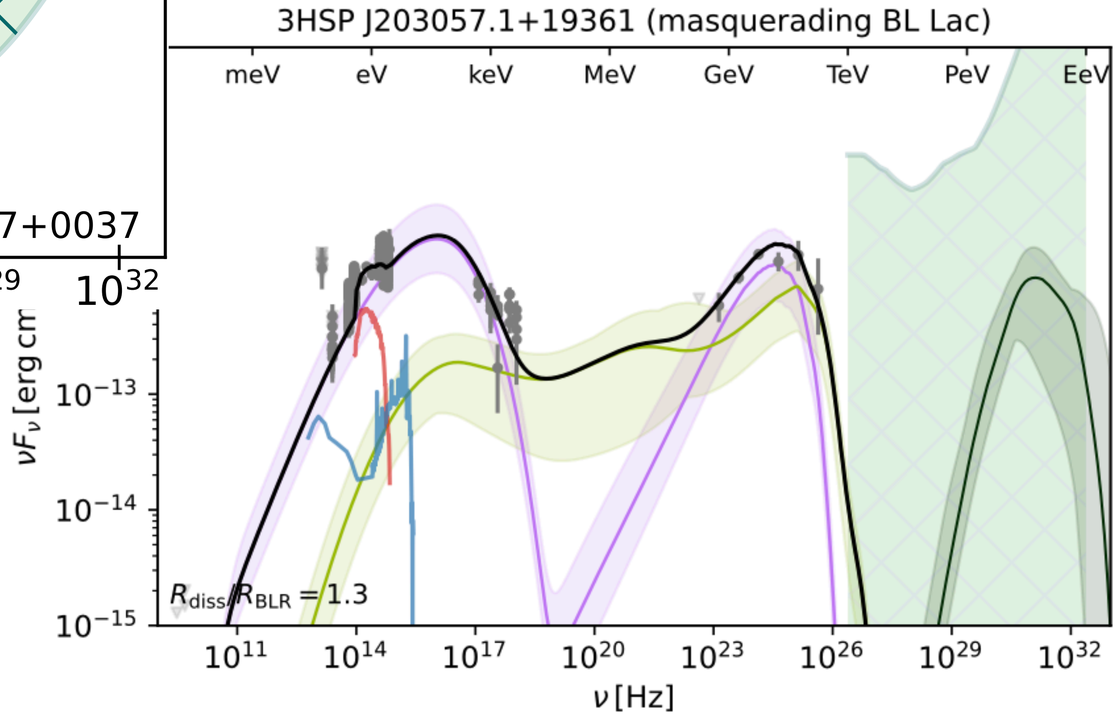
Modeling 34 HSP BL Lacs coincident with IceCube alerts (Giommi+2020)

Synchrotron peak frequency and flux

Energy-binned multi-wavelength SED

IceCube point source flux





XR, Karl, Padovani, Giommi, Paiano, Falomo & Petropoulou, in preparation

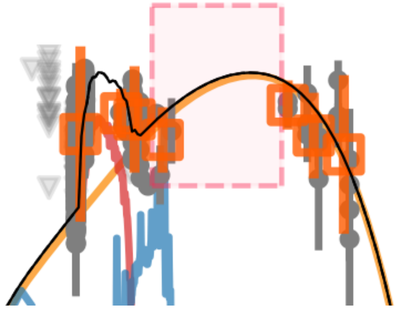
Physics-driven optimization with layered grid scans

Step 1

Electron synchrotron

R'_b B' Γ_b L'_e γ'^{max}_e p_e

10^6 simulations
× 8 ms
= 1 CPUh / source



Reject if synchrotron peak outside window

95-99% of 6-dim parameter space excluded

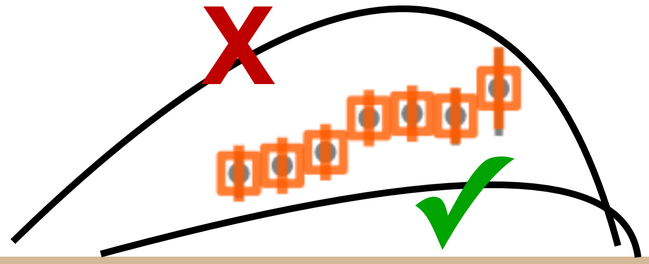
Step 2

Inverse Compton

Electromagnetic cascades

$R_{dissipation}$ *(controls external photon boost)*

5×10^4 simulations
× 50 ms
= 0.5 CPUh per source



Reject if LAT flux exceeded

Additional 90-98% of parameter space excluded

Step 3

All hadronic channels

Bethe-Heitler pair production

Proton synchrotron + inv. Compton

L'_p γ'^{max}_p p_p

2×10^4 simulations
× 300 ms
= 1.5 CPUh per source

Reject if IceCube flux undershot

Calculate chi²

Locally minimize best fit with iminuit

Genetic Algorithm	Layered grid scan
Robust with little intervention	Step-by-step data-driven model building
Little control over final solution	More insightful physics-wise
All computation burden put on CPU	Computing load is eased by data-driven filtering
No initial parameter guess	