computational methods for astroparticle propagation

class 4: propagation methods

Rafael Alves Batista

Instituto de Física Teórica
Universidad Autónoma de Madrid

rafael.alvesbatista@uam.es

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modelling the propagation of astroparticles

astrophysical inputs

injection spectrum
initial composition
source distribution
source emissivity evolution

propagation

particle interactions
particle acceleration
background photon fields
background matter fields
magnetic fields

outputs

spectrum
composition
arrival directions
arrival times

observations

Table 2: List of simulation codes for UHECR propagation. The type of treatment of the code, Monte Carlo (MC) or using transport equations (TE) are indicated.

code	dimensions	approach	references
CRPropa	1D, 3D	MC	[119, 198–202]
SimProp	1D	MC	[203, 204]
PriNCe	1D	TE	[195]
TransportCR	1D	TE	[197]

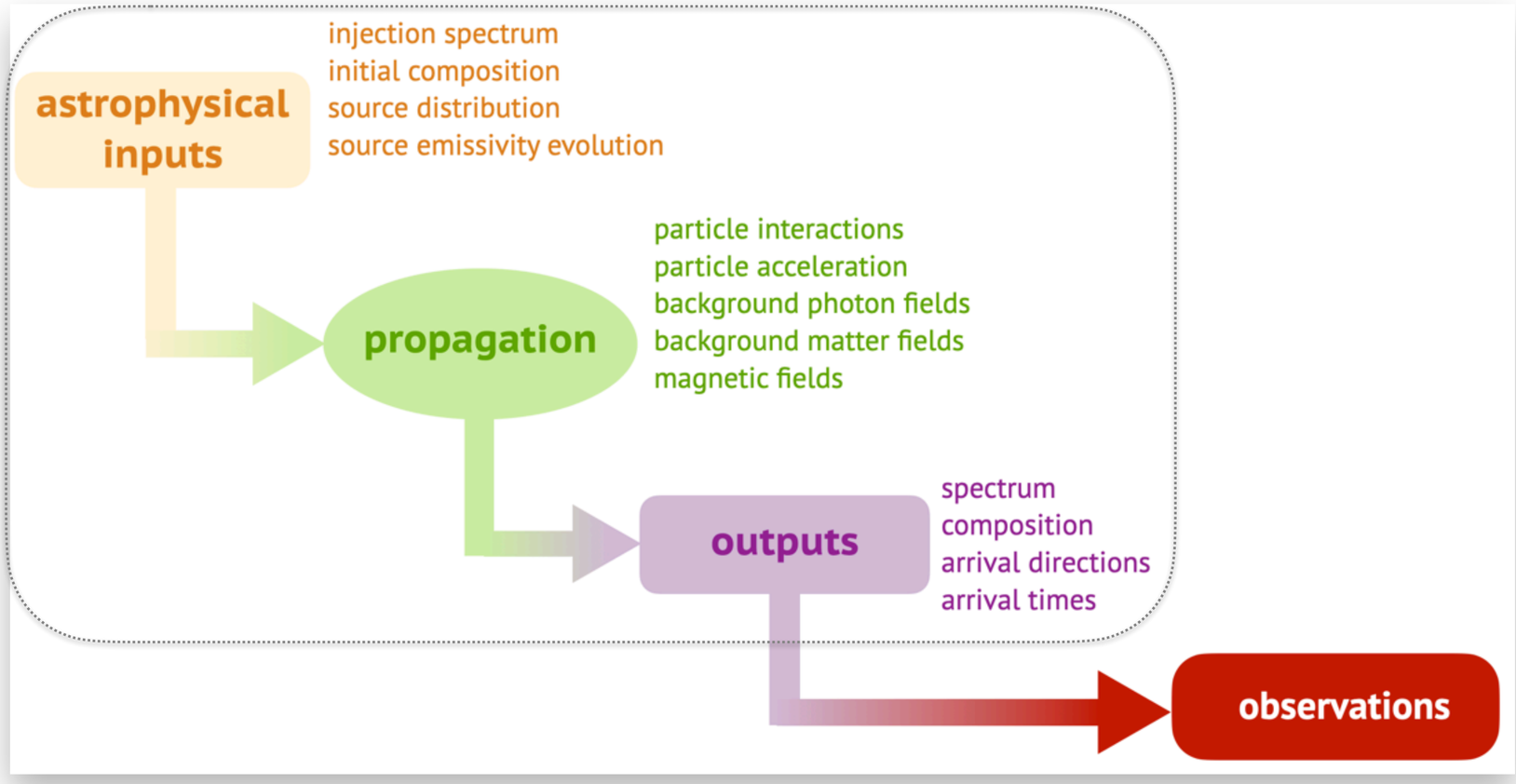
Table 3: List of simulation codes for GCR propagation. The type of treatment of the code, Monte Carlo (MC), employing grid-based transport equations (TE), or using stochastic differential equations (SDE) is indicated.

code	approach	references
CRPropa	SDE	[119, 198–202]
GALPROP	TE	[211, 212]
DRAGON	TE	[213–215]
PICARD	TE	[216]

Table 4: List of simulation codes for gamma-ray propagation. They also include the treatment of electron-photon interactions. The type of treatment of the code, Monte Carlo (MC) or transport equations (TE) is indicated, together with the dimensionality of the treatment (1D or 3D). If the code is only suitable for UHE ($E \gtrsim 1 - 10$ PeV), this information is also provided.

code	dimensions	$E < E_{\rm UHE}$	$E > E_{\rm UHE}$	approach	references
CRPropa	1D, 3D	✓	✓	MC	[119, 198–202]
Elmag	1D, 3D	✓		MC	[217–219]
DINT	1D	✓	✓	TE	[164]
CECsi	1D, 3D	✓		MC	[220]
EleCa	1D		✓	MC	[221]
γ-cascade	1D	✓		TE	[222]

modelling the propagation of astroparticles



- mixing all ingredients → interpret (fit) observations based on models
- this should be done ***self-consistently for all messengers***
- need to ***scan full parameter space*** of uncertainties

CRPropa

multimessenger simulation framework