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DL3 data model beyond the IACT community ?

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cherenkov telescope array

Motivation

• Event lists [ID, energy, direction, time] are suitable for event-based, neutrino and cosmic-ray observatories.

• Applicable to large aperture γ-ray observatories (e.g., HAWC).

• Common formats (and tools) ease multi-messenger analyses.

• Openness (data, standards, software, mind…) also brings returns to experiments: larger impact of results, externally developed software, crosscheck analyses …

• Already happening: many astroparticle observatories are making available event sets (web, electronic journals).

Who are we and why are we proposing this?

H2020 project ASTERICS (Astronomy ESFRI and Research Infrastructure Cluster)

"Implementation and operation of cross-cutting services and solutions for clusters of ESFRI and other relevant research infrastructure initiatives".

Work package OBELICS (Observatory E-environments Linked by common ChallengeS):

- To enable interoperability and software re-use for the data generation, integration and analysis of ESFRI and pathfinder facilities.
- To create an open innovation environment for establishing open standards and software libraries for multi-wavelength/multi-messenger data.
- To develop common solutions for streaming data processing and extremely large databases, as well as studying advanced analysis algorithms and software frameworks for data processing and quality control.

Who are we and why are we proposing this?

• Within ASTERICS, we are in charge of surveying and testing existing data formats (all levels) and making proposals for standards.

Project	Field	Data
CTA	Gamma	Events
H.E.S.S.	Gamma	Events
MAGIC	Gamma	Events
KM3NeT	Neutrino	Events
IceCube	Neutrino	Events
ANTARES	Neutrino	Events
E-ELT	VNIR	Images

Project	Field	Data
LSST	Visible	Images
Euclid	Visible	Images
SKA	Radio	Signals
e-VLBI	Radio	Signals
LOFAR	Radio	Signals
LIGO	GW	Signals
Virgo	GW	Signals

• In CTA, we are in the Data Model sub-work package within the Data Management work package.

Strategy to make DL3 standards more general

• Keeping in mind other experiments/particles to name and define generic enough parameters.

• Making some parameters only related to IACTs optional (or allowing null values).

• Defining and grouping parameters and IRFs that cover the needs of a given type of experiment.

• Enriching this initiative of DL3 standards with contributions from the wide astroparticle community.

Some identified difficulties

• DL3-equivalent data level not necessarily defined in every experiment.

• Some essential variables not always given, e.g., energy is sometimes replaced by a related observable (proxy).

• Different concepts of operation, e.g., all-sky observation instead of source pointing. This even applies to IACTs (extended sources ?).

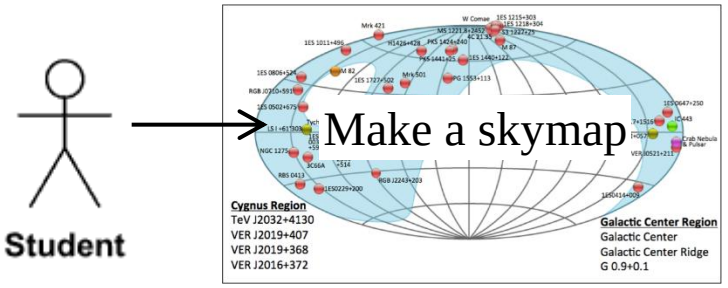
• IRFs will be different, e.g., exposure ($km^2 \cdot sr \cdot yr$) instead of effective area. The very term "IRF" is not used in some experiments, but still applicable (at least for many high-level analyses ?).

• "Runs" make no sense for continuous observation.
May "observation periods" (months, years) be equivalent to "runs" ?

Simple use cases

One can think of many simple use cases involving data from one or more astroparticle observatories to test the approach:

- Making a skymap.
- Building a spectrum.
- Crosschecking a time series.
- Correlating events with GRBs, BL Lacs….

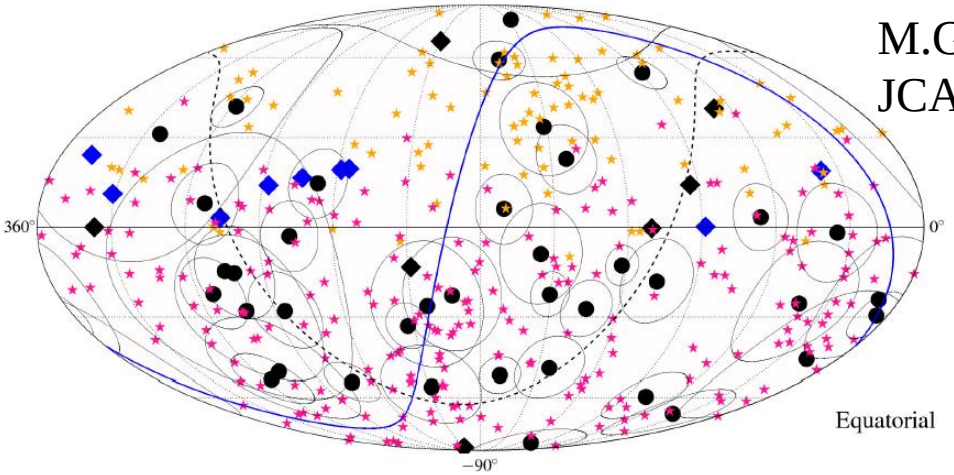


To be developed during the meeting ?

Complex use case

"Search for correlations between the arrival directions of IceCube neutrino events and ultrahigh-energy cosmic rays detected by the Pierre Auger Observatory and Telescope Array".

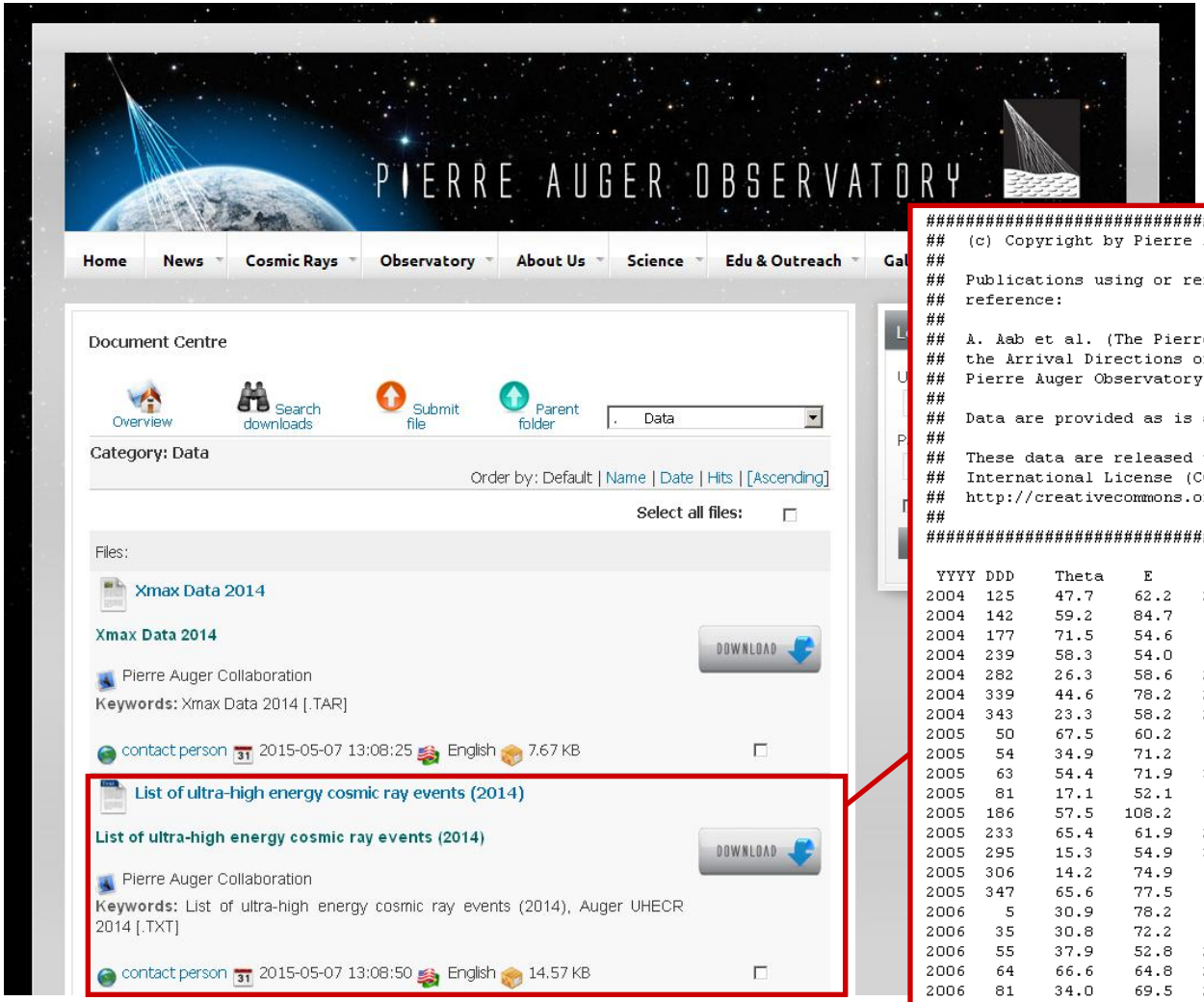
- HE event lists for selected observation periods.
- Angular resolutions: average values for Auger and TA, while event-dependent for IceCube.
- Model for an energy dependent Gaussian deflection of cosmic rays.
- Average relative exposures of Auger and TA as a function of declination.



M.G. Aartsen et al., JCAP01 (2016) 037

Complex use case

Auger Document Center: https://www.auger.org/index.php/document-centre




```
##############################################################################################
##  (c) Copyright by Pierre Auger Collaboration 2014                                        ##
##                                                                                          ##
##  Publications using or referring to these data should cite the following                 ##
##  reference:                                                                              ##
##                                                                                          ##
##  A. Aab et al. (The Pierre Auger Collaboration), "Searches for Anisotropies in           ##
##  the Arrival Directions of the Highest Energy Cosmic Rays Detected by the                ##
##  Pierre Auger Observatory", arXiv:1411.6111                                              ##
##                                                                                          ##
##  Data are provided as is and might be subject to future changes.                         ##
##                                                                                          ##
##  These data are released under the Creative Commons Attribution-ShareAlike 4.0           ##
##  International License (CC BY-SA 4.0). For more details see                              ##
##  http://creativecommons.org/licenses/by-sa/4.0/                                          ##
##                                                                                          ##
##############################################################################################

 YYYY DDD    Theta     E       RA      dec      Glon     Glat
2004  125    47.7     62.2    267.2    -11.4     15.5      8.4
2004  142    59.2     84.7    199.7    -34.9    -50.8     27.7
2004  177    71.5     54.6     12.7    -56.6    -56.9    -60.5
2004  239    58.3     54.0     32.7    -85.0    -59.1    -31.8
2004  282    26.3     58.6    208.1    -60.1    -49.5      1.9
2004  339    44.6     78.2    268.4    -61.0    -27.6    -16.9
2004  343    23.3     58.2    224.7    -44.0    -34.1     13.1
2005   50    67.5     60.2     29.0    -14.0    174.9    -70.0
2005   54    34.9     71.2     17.5    -37.8    -76.0    -78.6
2005   63    54.4     71.9    331.2     -1.3     58.7    -42.4
2005   81    17.1     52.1    199.1    -48.5    -52.8     14.1
2005  186    57.5    108.2     45.6     -1.7    179.5    -49.6
2005  233    65.4     61.9    278.4     -1.3     29.7      3.4
2005  295    15.3     54.9    333.0    -38.1      4.4    -55.0
2005  306    14.2     74.9    114.8    -42.8   -103.9    -10.0
2005  347    65.6     77.5     18.3     29.2    128.6    -33.4
2006    5    30.9     78.2     18.9     -4.7    138.3    -66.8
2006   35    30.8     72.2     53.6     -7.8   -165.9    -46.9
2006   55    37.9     52.8    267.6    -60.6    -27.5    -16.4
2006   64    66.6     64.8    275.2    -57.2    -22.6    -18.6
2006   81    34.0     69.5    201.1    -55.3    -52.3      7.3
2006  100    33.7     54.7     28.8    -16.4   -179.9    -71.8
2006  118    57.3     56.3    322.5     -2.0     51.6    -35.6
2006  126    65.2     82.0    299.0     19.4     57.6     -4.7
```

Complex use case

IceCube Public Data Access: https://icecube.wisc.edu/science/data

Livetimes and effective areas also provided in HDF5 for different detector configurations and particle types.

```
1. IceCube Event ID
2. Right Ascension, degrees
3. Declination, degrees
4. Modified Julian Day, days
5. Energy Proxy, arbitrary units
6. Most probable muon energy for best-fit, TeV
7. Most probable neutrino energy for best-fit, TeV
8. Signal Probability for best-fit
-------------------------------------------------------------------------
116357,6324295    254   16.3  55421.5     289916      755   1693   0.96
116807,9493609    88.5  0.2   55497.3     199981      604   880    0.83
119136,66932419   37.1  18.6  55911.3     157871      397   713    0.88
116883,17395151   285.7 3.1   55513.6     147002      422   709    0.8
116701,6581938    331   11    55478.4     140113      317   466    0.81
116026,44241207   346.8 24    55355.5     139728      339   442    0.86
116574,20123342   267.5 13.8  55464.9     131950      302   400    0.82
119739,41603205   238.3 18.9  55987.8     130382      326   394    0.85
118210,47538807   235.2 19.3  55702.8     106898      252   393    0.77
118719,53077538   277.5 52.7  55829.3     91292       156   198    0.66
116269,59516168   323.3 2.8   55405.5     66558       134   193    0.41
116876,63208734   110.5 0     55512.6     64650       147   206    0.45
118631,36844560   9.4   7.8   55806.1     63994       139   179    0.5
117927,15766169   207.2 6.7   55642       60582       125   185    0.45
118475,52691508   152.2 6.8   55768.5     56734       124   156    0.45
116147,14170716   310.5 21.9  55387.5     53805       112   178    0.55
117639,30571557   307.9 1     55589.6     53542       116   184    0.33
118741,43101116   267.6 -4.4  55834.4     51756       116   191    0.56
119037,60175569   221.9 3.2   55896.9     51631       109   158    0.58
116082,62251639   138.9 47.6  55370.7     51112       109   189    0.37
118615,37865356   31.2  11.8  55803       50376       109   190    0.49
```

THANK YOU !

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