Search for Primordial Black Hole evaporation using current and next generation very-high-energy gamma-ray facilities

Rubén López-Coto, INFN Padova
Less Travelled Path of Dark Matter
13/11/20

Istituto Nazionale di Fisica Nucleare
Sezione di Padova

Fellowship for Innovation at INFN

Funded by H2020 Marie Sklodowska Curie FELLINI - Grant 754496

Search for PBH with VHE gamma-ray observatories

- From the experimental point of view, different techniques trying to measure signatures of PBH
- Signatures for evaporation at different stages of the life of PBHs
  - Focus of this talk: PBHs evaporating now
- BH evaporation spectrum is very well known, we need to search for this signature in our data

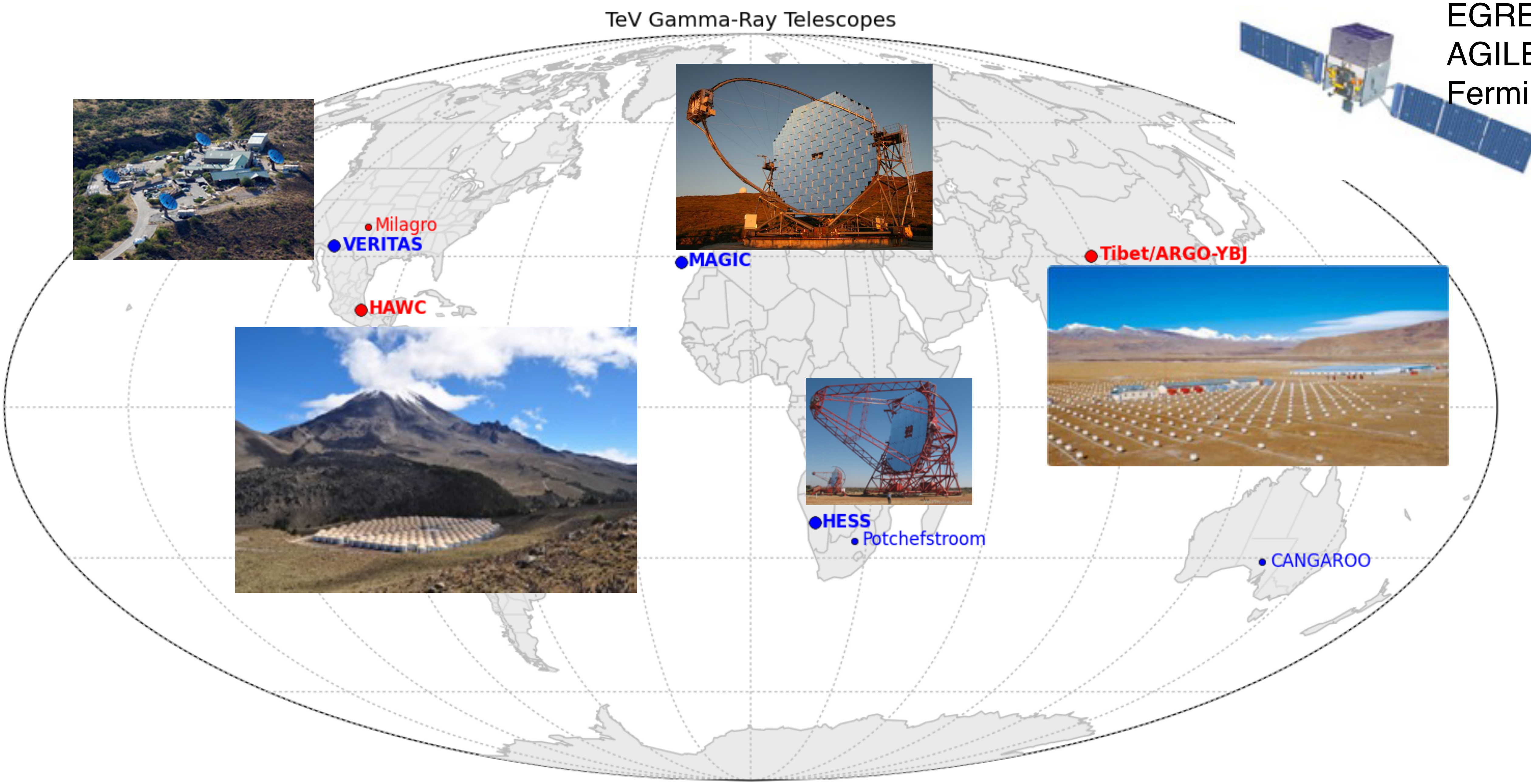
Limits for evaporation **now**

- Evaporation limits for PBHs evaporating *now*
  - PBHs of mass ~10^{14} g, generated in the Big Bang, should be evaporating ~now $\tau \sim \frac{G^2 M^3}{\hbar c^4}$
  - The Extragalactic Gamma-ray Background (E~100 MeV) gives very good ***Cosmological*** constrains on PBH evaporation [Burst Density < 10^{-6} pc^{-3} yr^{-1}]
  - On **Galactic** scales, clusters of PBHs should produce an anisotropy in the Gamma-ray measurements (E~100 MeV) [Burst Density < 0.42 pc^{-3} yr^{-1}]
  - On **kiloparsec** scales, the antiproton background can be used to derive limits [Burst Density < 10^{-3} pc^{-3} yr^{-1}]

Serendipitous events

- VHE gamma-ray experiments have sensitivity to detect single events occurring at ~parsec distances
- Wide FoV detectors (Milagro/HAWC/SWGO)
  - Thanks to their large FoV and exposures, cover a large *Volume* and therefore can establish the best limits nowadays
- Imaging Atmospheric Cherenkov Telescopes (IACTs) (MAGIC/HESS/VERITAS/**CTA**)
  - Thanks to their very good background rejection and the low expected signal, they are able to have the longest *reach.*

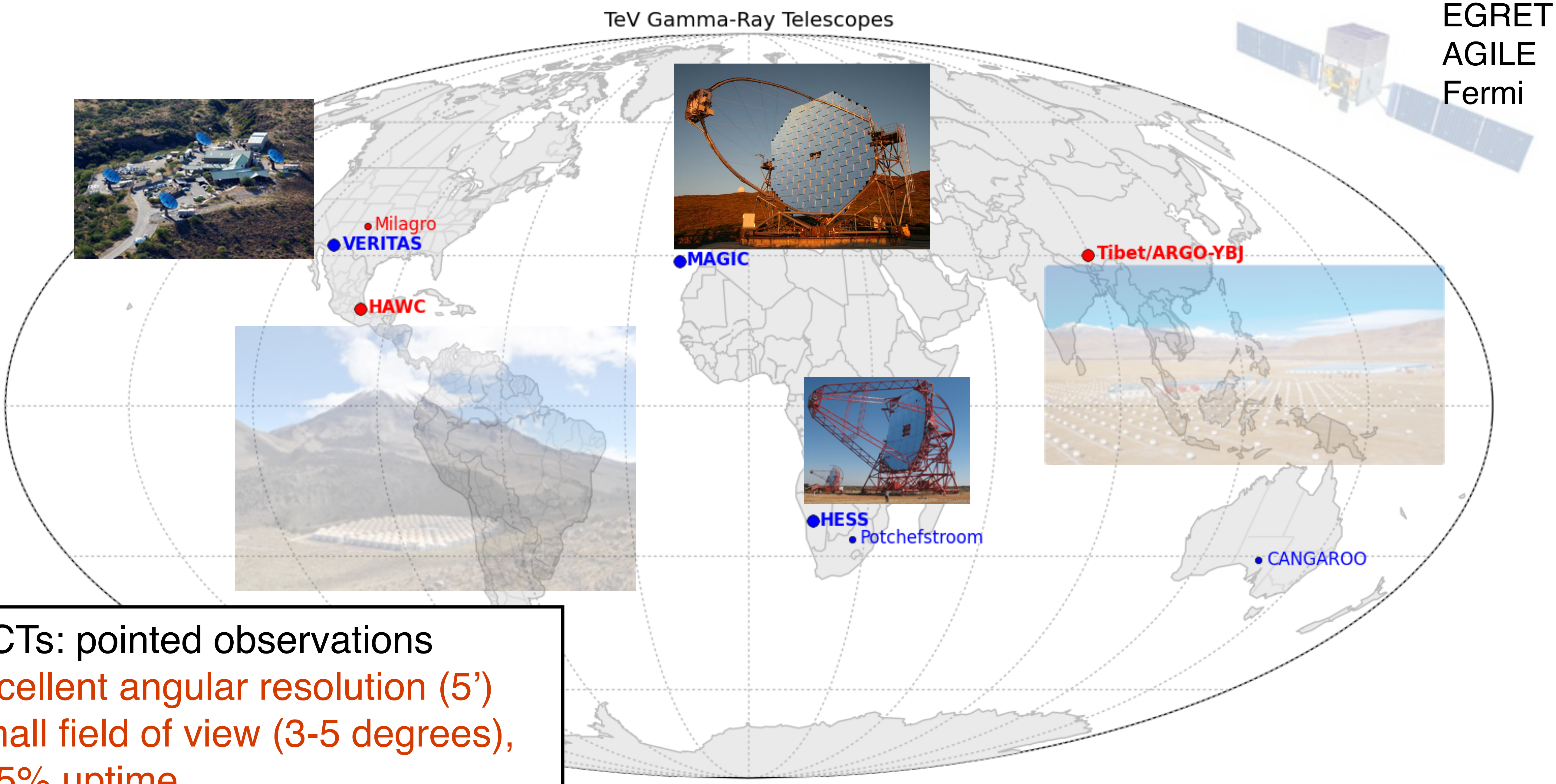
Gamma-ray astronomy



EGRET
AGILE
Fermi

Rubén López-Coto - 13/11/20 - LTPDM

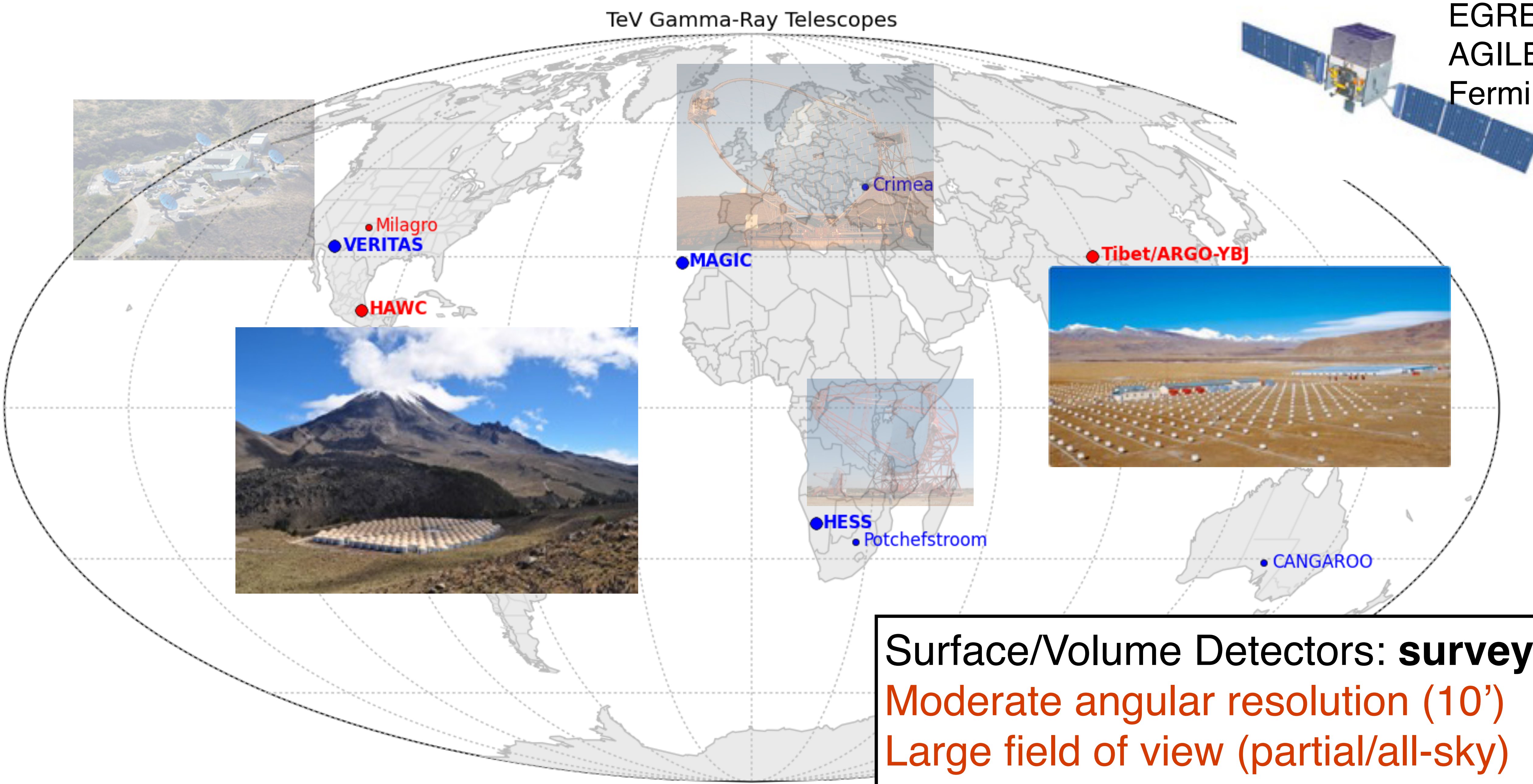
Gamma-ray astronomy



EGRET
AGILE
Fermi

IACTs: pointed observations
Excellent angular resolution (5')
Small field of view (3-5 degrees),
~15% uptime

Gamma-ray astronomy



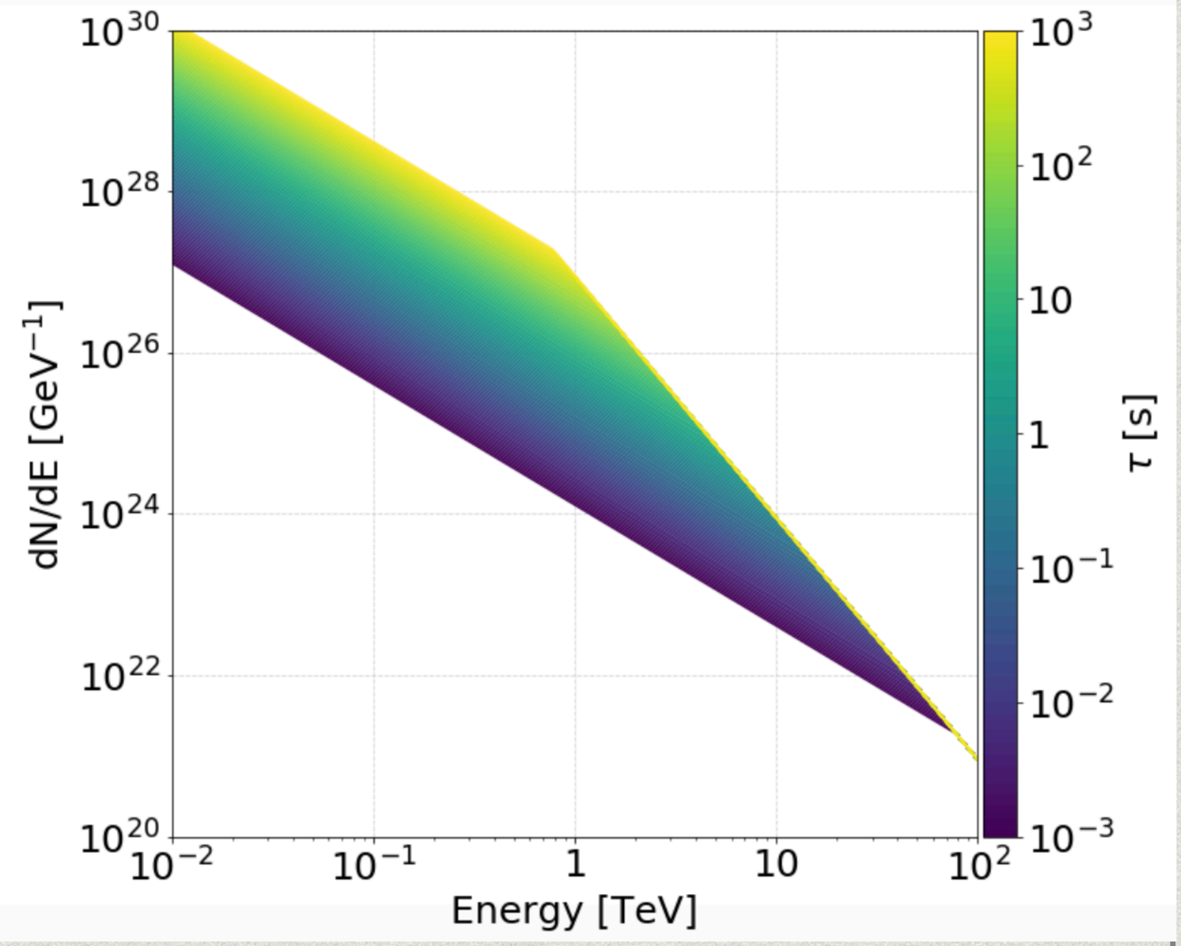
EGRET
AGILE
Fermi

Surface/Volume Detectors: **surveys**
Moderate angular resolution (10’)
Large field of view (partial/all-sky)
Continuous monitoring

Evaporation models

$$\frac{\mathrm{dN}}{\mathrm{dE}} \approx 9\times10^{35} \begin{cases} \left(\frac{1\ \mathrm{GeV}}{T}\right)^{\frac{3}{2}} \left(\frac{1\ \mathrm{GeV}}{E}\right)^{\frac{3}{2}} \quad \mathrm{GeV}^{-1} & E < T \\ \left(\frac{1\ \mathrm{GeV}}{E}\right)^{3} \quad \mathrm{GeV}^{-1} & E \geq T \end{cases}$$

- If we assume the evaporation model from Ukwatta, D. et al. (2016)

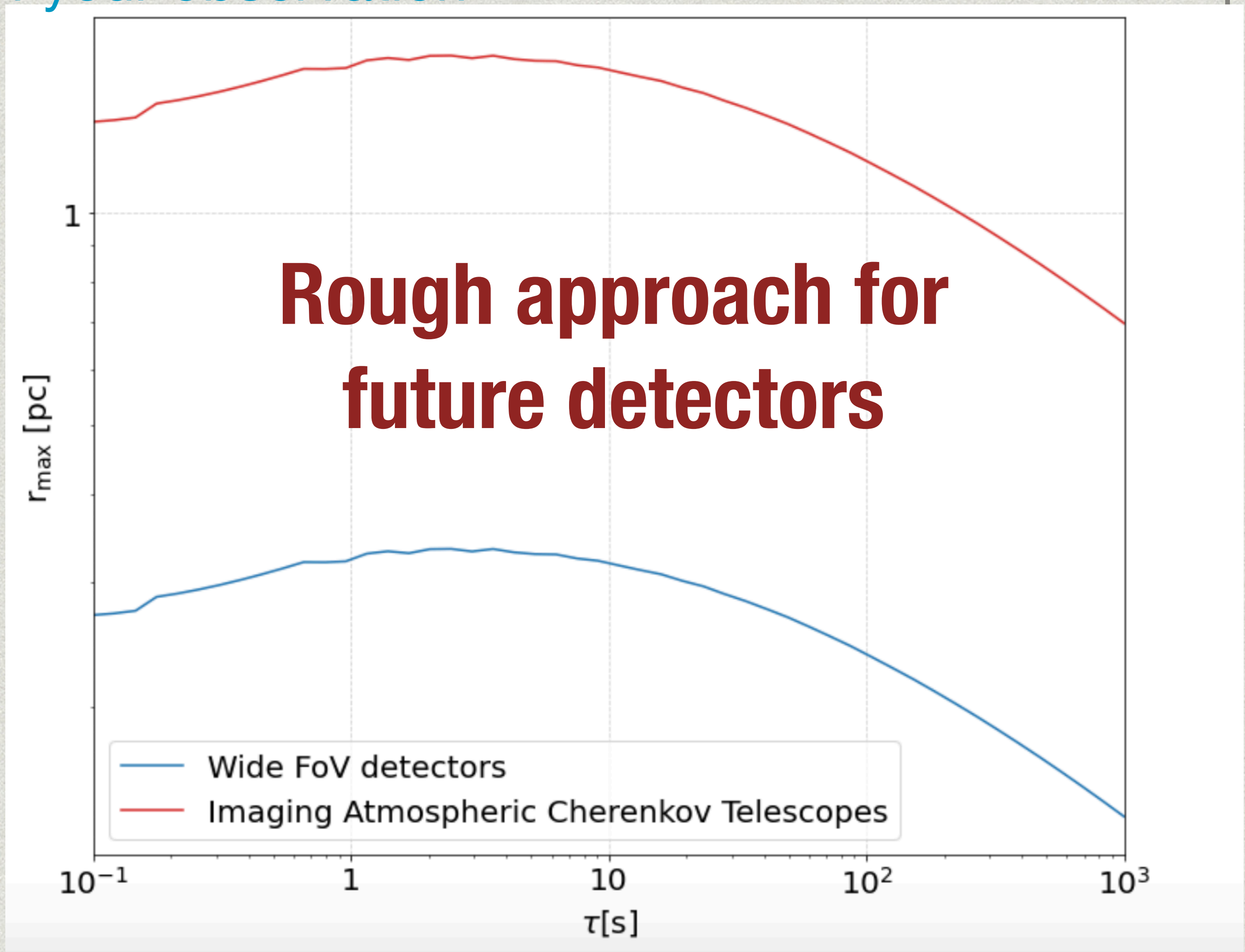


- with kT* = 7.8 $(\tau/1\mathrm{s})^{-1/3}$ TeV

* $T_{BH} \sim \left(\frac{\hbar^2 c^5}{8^3 \pi^3 G k^3} \frac{1}{\tau}\right)^{1/3}$

Maximum reach

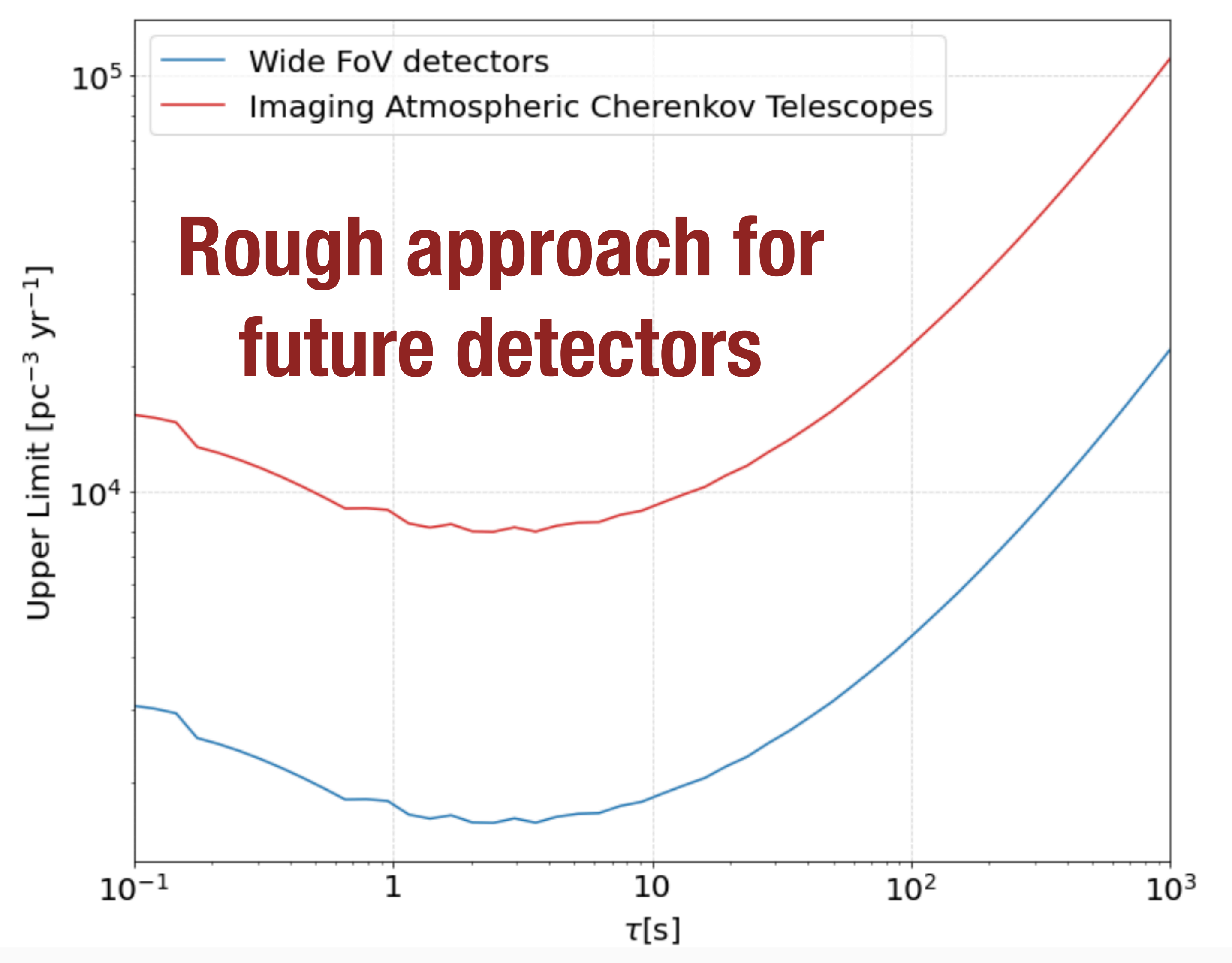
- One needs to evaluate the expected number of events selecting a given duration for the burst.
  - The result is the maximum reach of your observation
  - Closest star located at ~1 pc
  - Goal: maximum possible distance



Upper limits

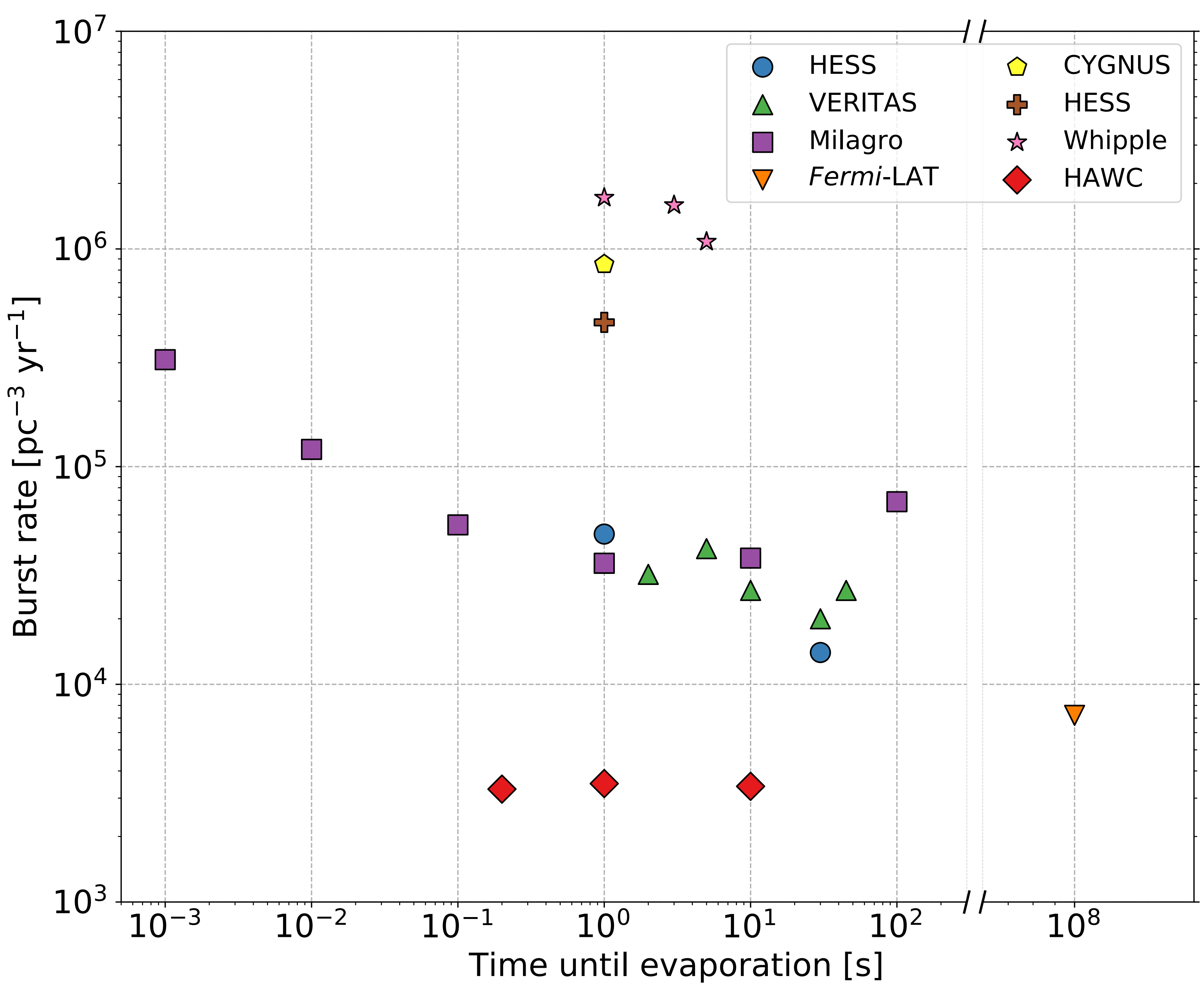
- Limits are put on the volume covered by the Field of View (FoV) of the detector.
  - Upper Limits established using Poissonian fluctuations

$$V(\tau) = \frac{4\pi r^3_{\max}(\tau)}{3}\frac{\mathrm{FoV}}{4\pi}$$



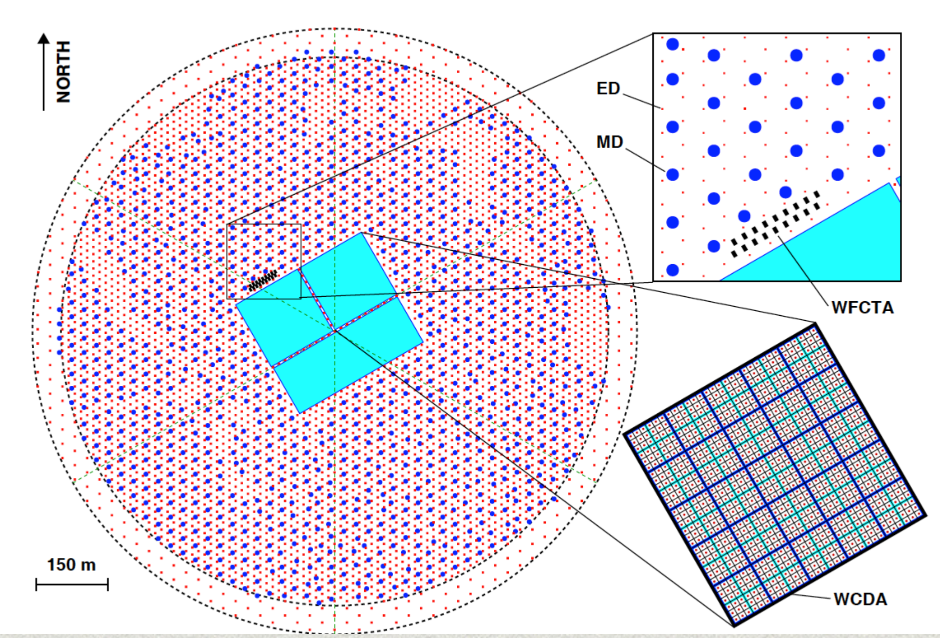
Rubén López-Coto - 13/11/20 - LTPDM

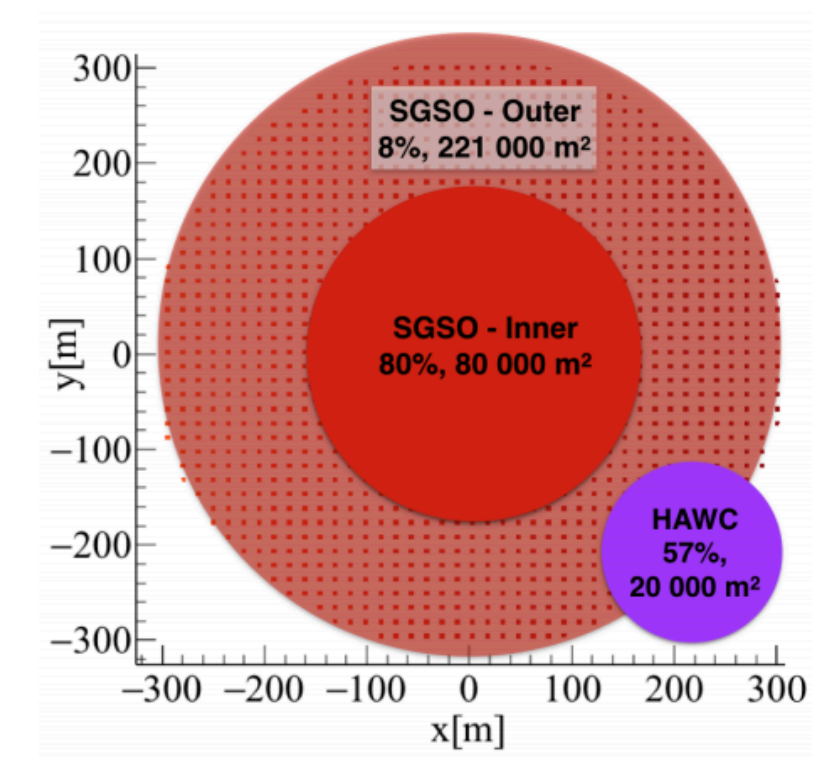
Current limits

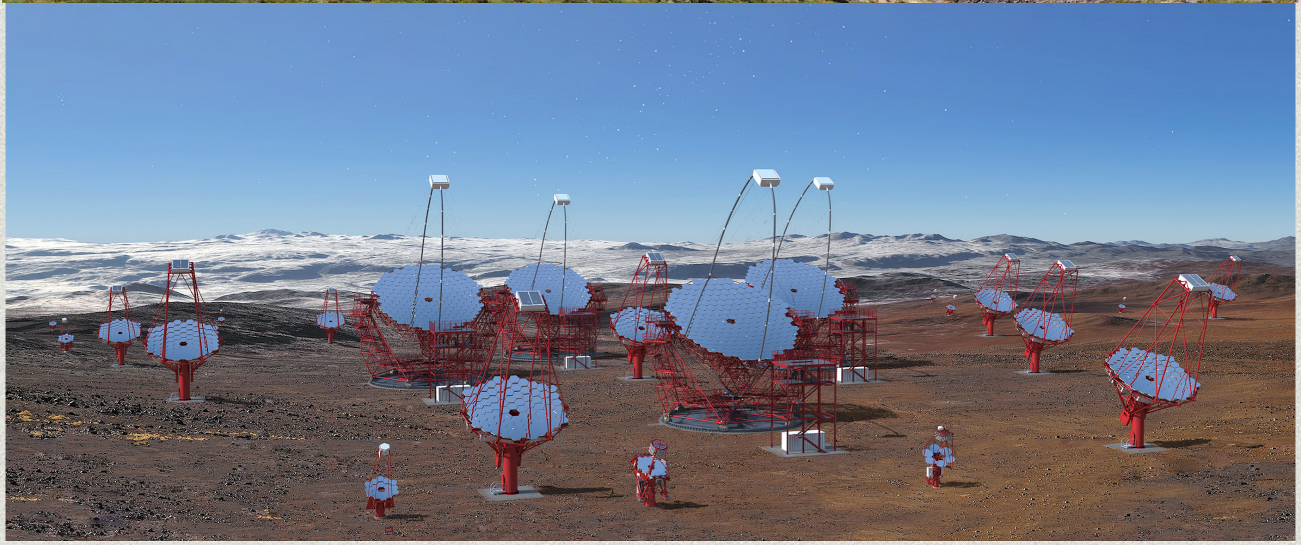


Future

- Wide FoV experiments
  - LHAASO
  - SWGO
- IACTs
  - The Cherenkov Telescope Array (CTA)

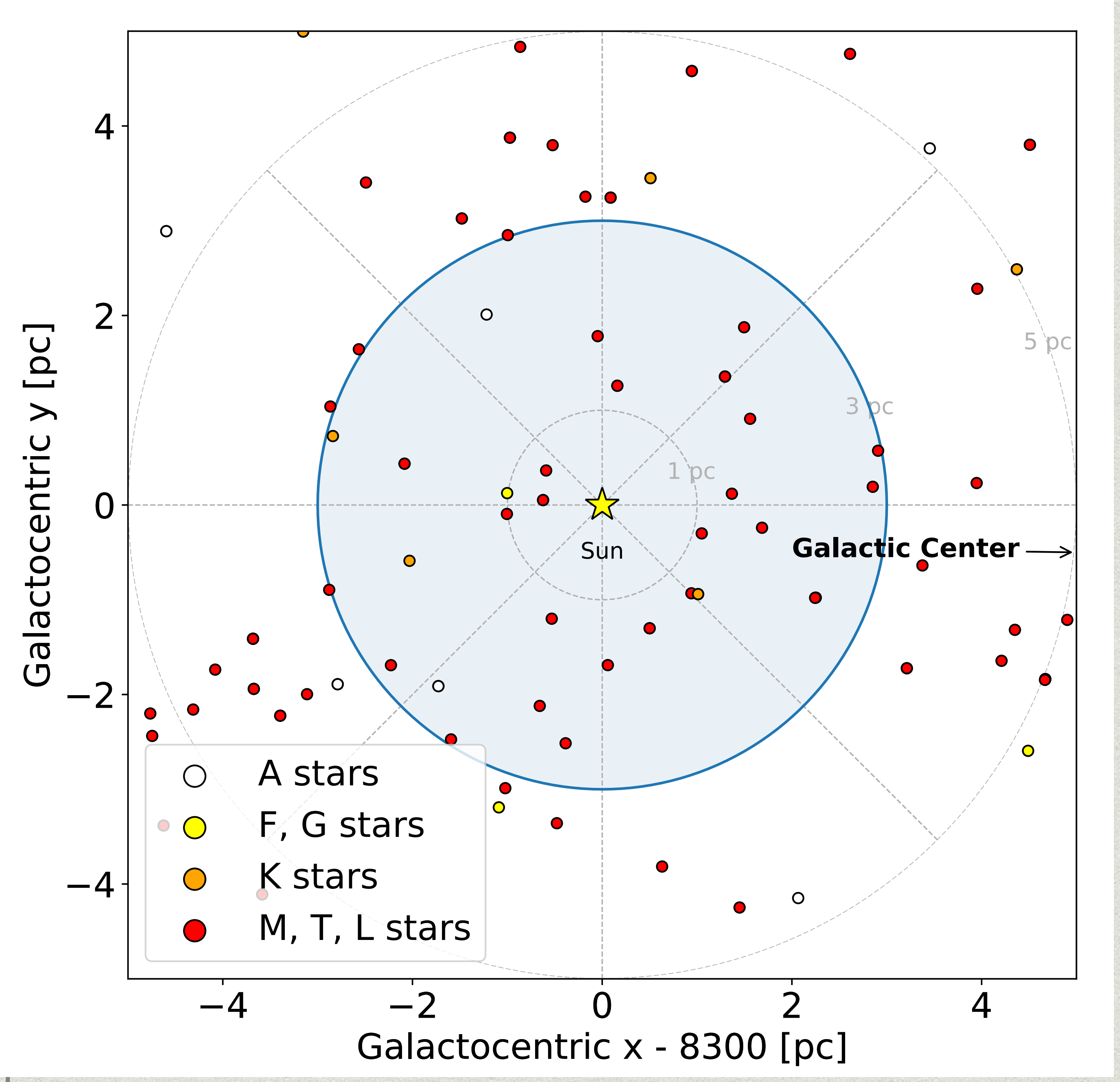


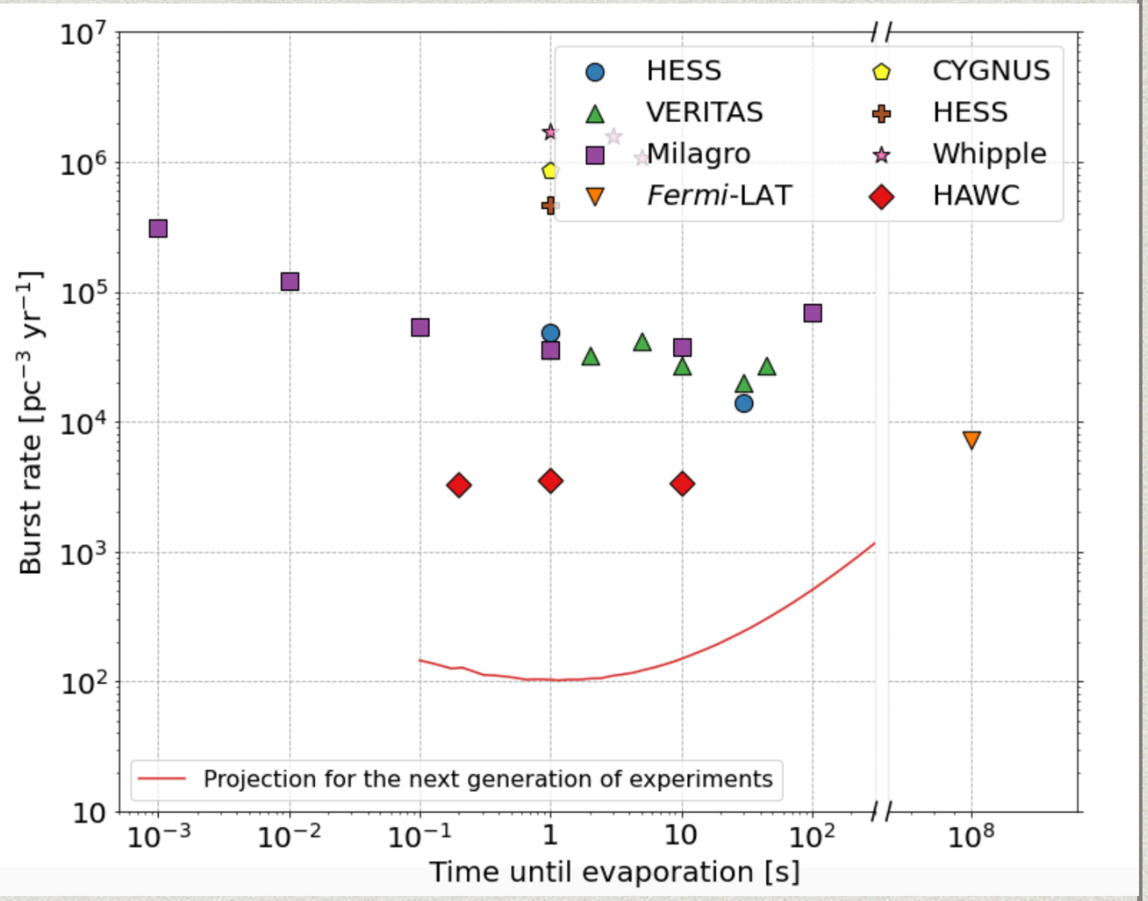




Rubén López-Coto - 13/11/20 - LTPDM

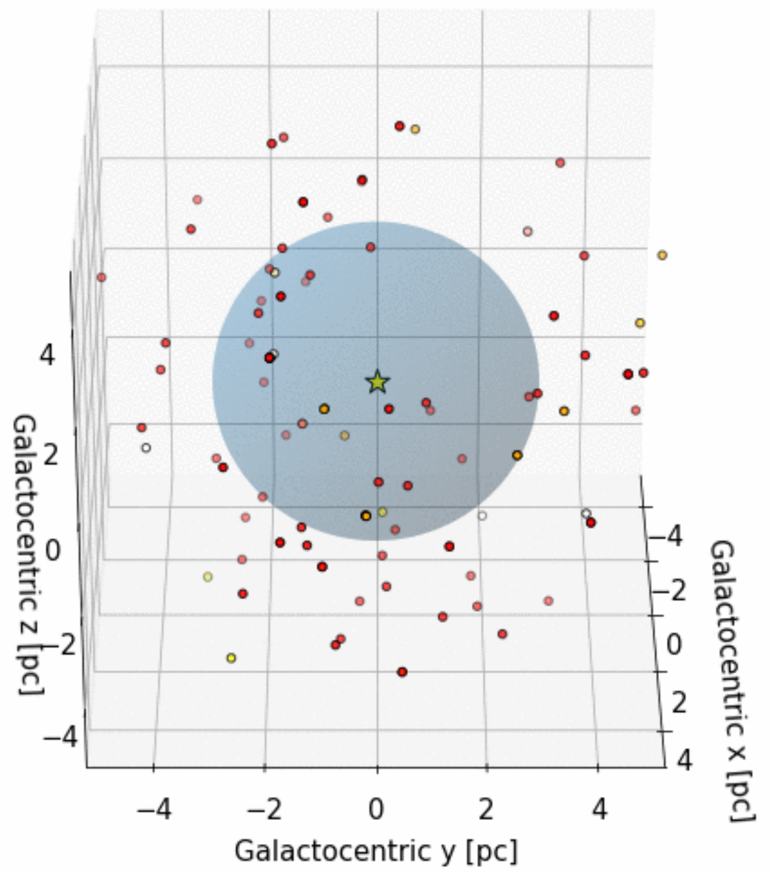
Projections for optimistic reach and limits





Summary

- PBH evaporation studied with VHE gamma-ray detectors is
  - Current limits of the order of ~< 10^3 bursts yr^{-1} pc^{-3}
  - r_{max} limit of less than 1 pc
  - Reach and limits expected to improve one order of magnitude with the next generation of experiments.
  - Let's hope for one interesting event!



Thanks!