UNIVERSITÀ DEGLI STUDI DI TORINO

A local fading accelerator and the origin of TeV cosmic ray electrons

Sarah Recchia

S. Recchia, S. Gabici, F.A. Aharonian and J. Vink

Overview

- The detection of CR electrons up to ~ 20 TeV poses strong constraints on the possible distance and age of the possible sources
  - t_a ~ 20 kyr, depending on energy losses
  - d ~ 100-500 pc, depending on the interstellar diffusion coefficient

- Such limitations on age and distance also poses constraints on the number of contributing sources
  - very few source likely dominate the multi-TeV electron spectrum
  - maybe one single source

- Given the drop of the positron fraction below above ~400-500 GeV, such source(s) should produce more electrons than positrons in the multi-TeV domain

- What is the nature of such source(s)?

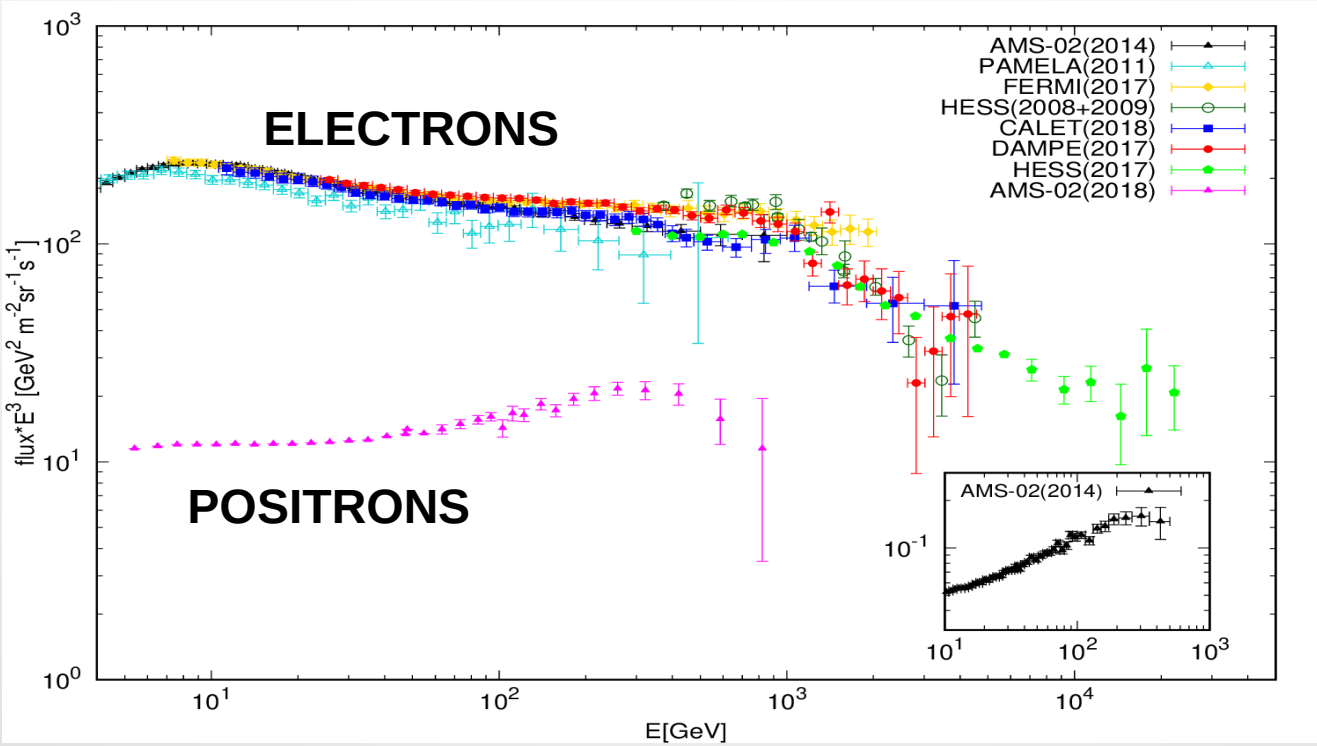
CR electron and positron spectrum

CR electron spectrum shows:

- break at ~ 1TeV
- no visible cut-off up to ~ 20 TeV

CR positron fraction shows:

- rises between ~1-200GeV
- Saturates at ~0.15 at ~200 GeV
- Drops above ~ 400-500 GeV



Implications on CR sources

- **energy losses in the multi-TeV domain:**
  - synchrotron (on the interstellar magnetic field)
  - inverse Compton scattering (on the interstellar radiation field)
  - T_{loss} (20 TeV) ~ 2×10^4 yr

- **diffusion plus losses:**
  - $D(E) \sim 10^{28} E^{0.3}_{GeV}$ cm^2/s
  - Maximum distance of sources ~ 100-500 pc

Few sources, maybe only one, may dominate the multi-TeV electron spectrum

Such source(s) should produce mainly electrons over positrons

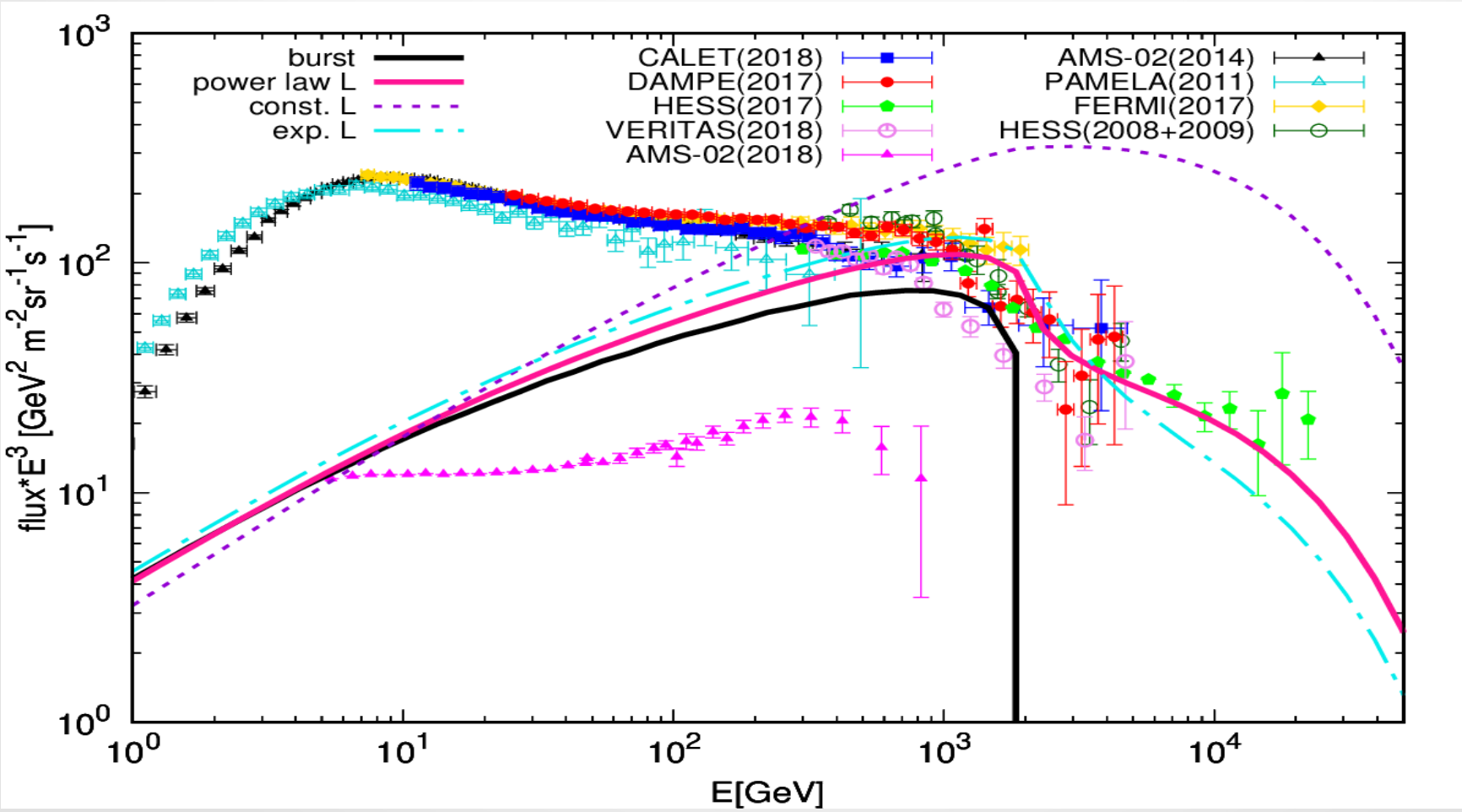
Model with local electron TeVatron

- **distant sources:**
  - continuous, stationary and homogeneous distribution in a disk, beyond ~ 500 pc from Earth
  - power-law injection spectrum $E^{-2.4}$
  - luminosity $L \sim 10^{39}$ erg/s
- **local source:**
  - power-law injection spectrum $E^{-2.3}$
  - time-varying electron luminosity L(t)
  - burst-like, constant luminosity, fading…
  - $L(t) = L_0/[1 + (t/\tau)]^2$
  - $L(t) = L_0^{-t/\tau}$
  - $\tau\,\mathrm{typical\,fading\,time-scale}$

multi-TeV electron spectrum

1 TeV cooling break, sharp cut-off in a burst-like source

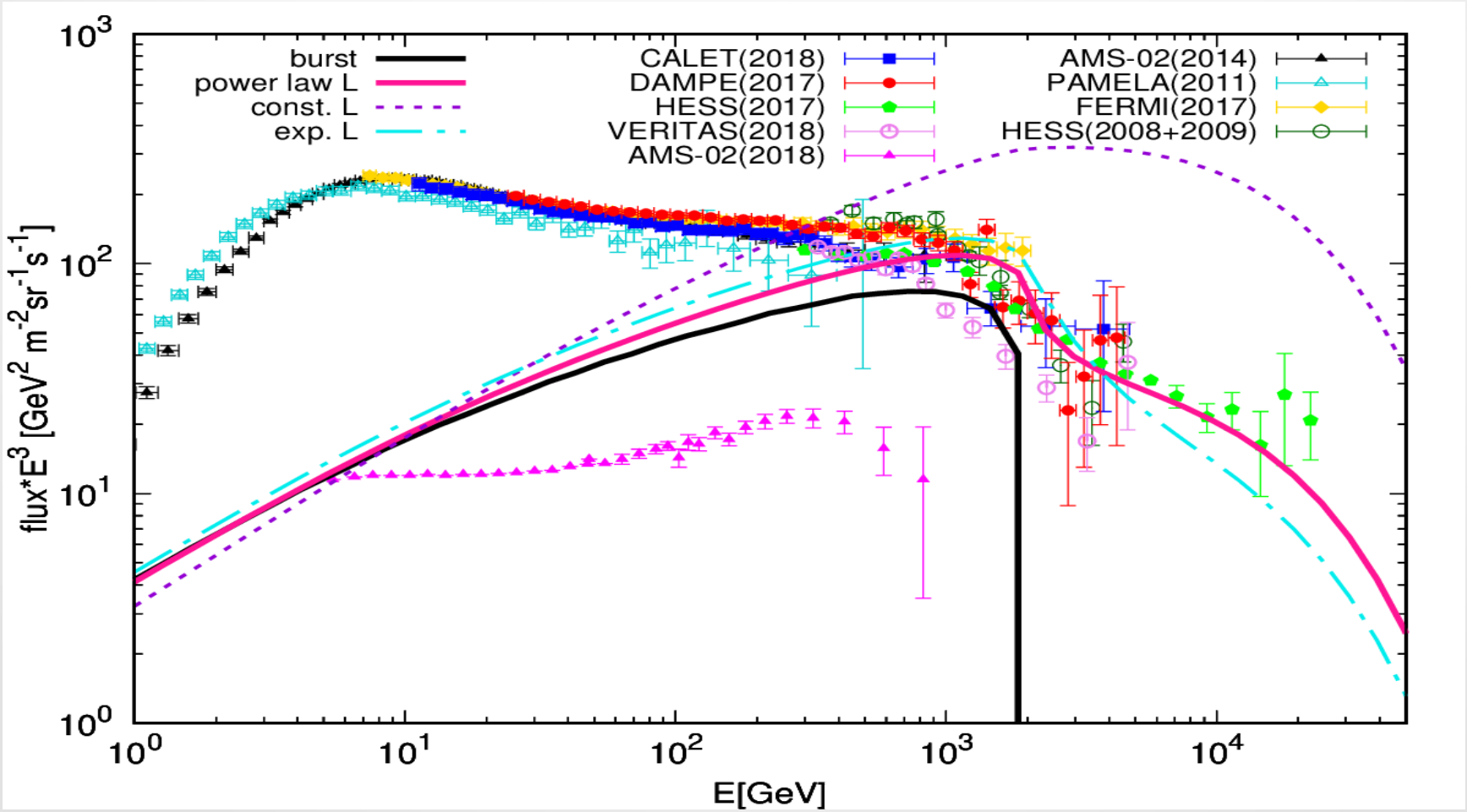
$$t_{loss}(1\,\mathrm{TeV}) = \mathrm{age}$$



multi-TeV electron spectrum

fading source shows drop at $t_{loss}(1\,\mathrm{TeV}) = \mathrm{age}$

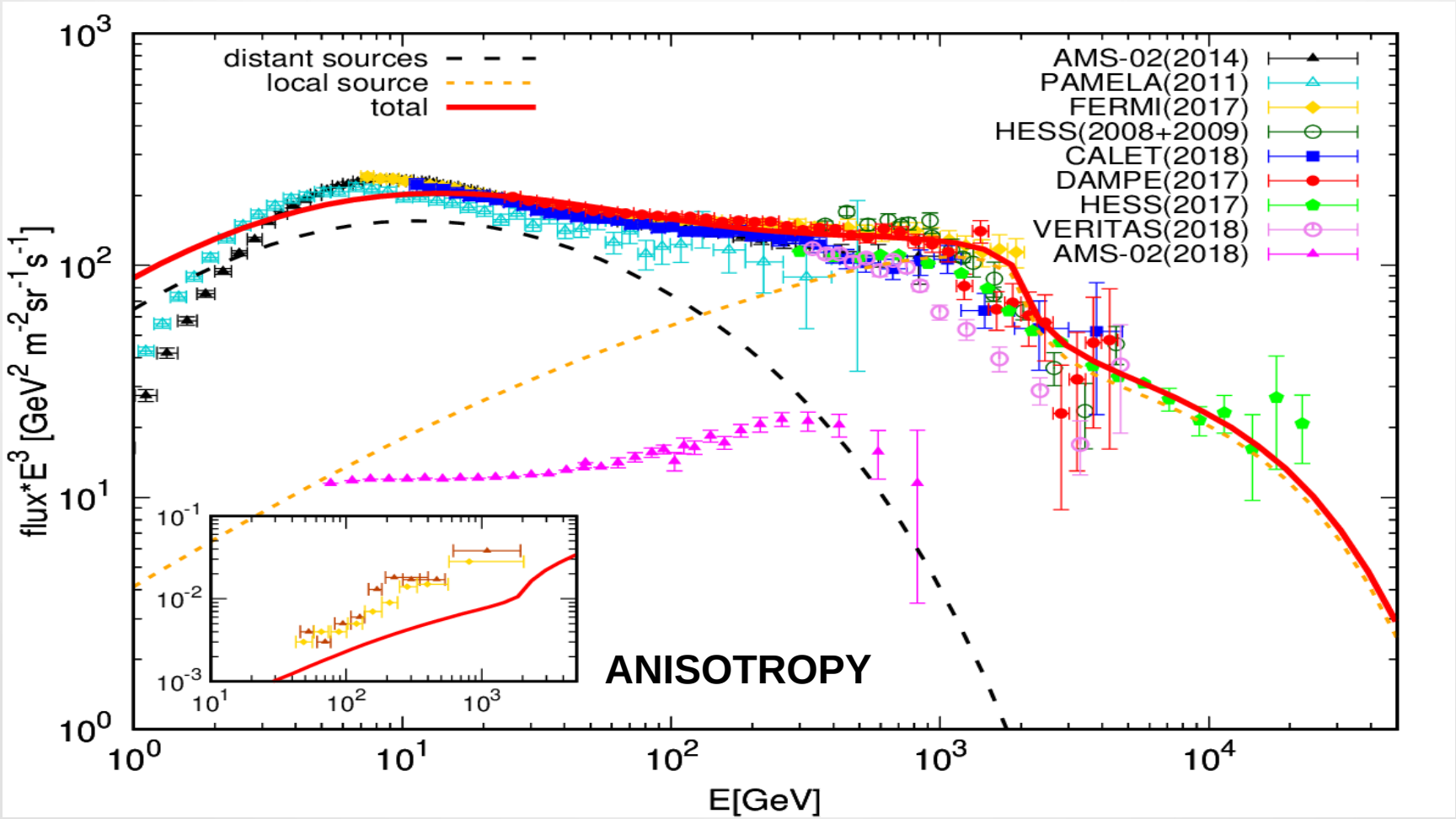
the height of the drop depends on τ/t



Fit to the data

local source:

age ~ 10^5 yr, d = 100 pc, τ /age ~ 0.08, $E_{TOT} \approx 4 \times 10^{47}$ erg



Conclusions

- A local, fading, electron TeVatron can account for the whole multi-TeV electron spectrum
  - the ~ 1 TeV break can be interpreted as a cooling break and implies a source age of ~100kyr
  - the spectral profile above ~ 1 TeV can be accounted for by a fading source luminosity
  - distance from Earth of ~ 100 pc for a typical interstellar diffusion coefficient

- What kind of source?
  - should inject electrons continuously with a fading luminosity
  - age ~ 100 kyr, fading time-scale ~ 10 kyr
  - accelerate mostly electrons
  - SNRs? Stellar winds? ...