

# Cosmic-Ray Acceleration in Star Clusters & Microquasars

**Models & Spectrum Knee**

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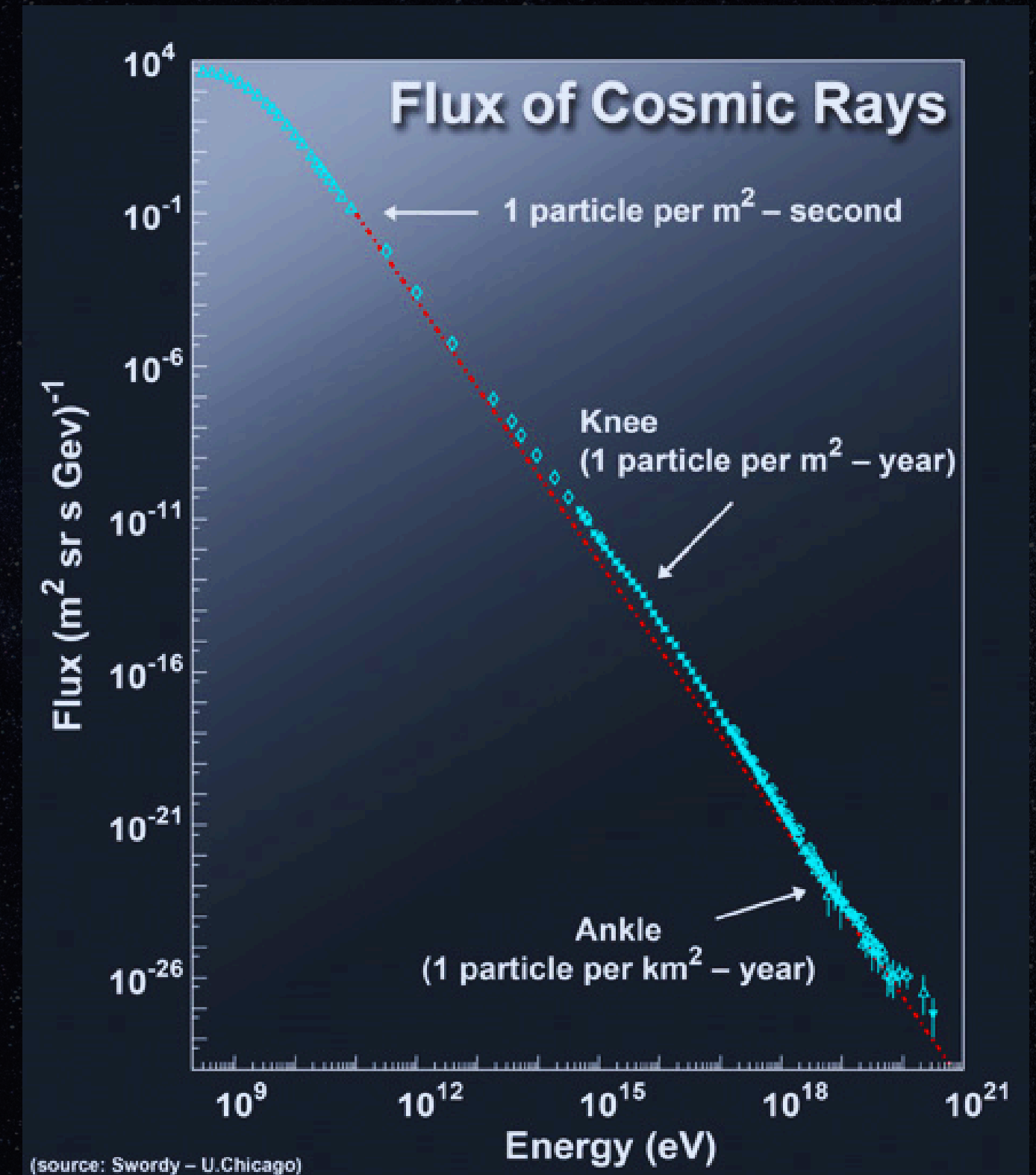
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# Cosmic Rays & the Knee

- Cosmic Rays are highly energetic particles consists of electrons and protons.
- CR energy spectrum: power law with a sharp break at  $\sim 3$  PeV (“knee”) where the slope steepens.
- The knee marks the limit of Galactic CR acceleration and hints at source transition.
- Impacts: influences CR composition, propagation, and source modeling.





# Importance of the Knee



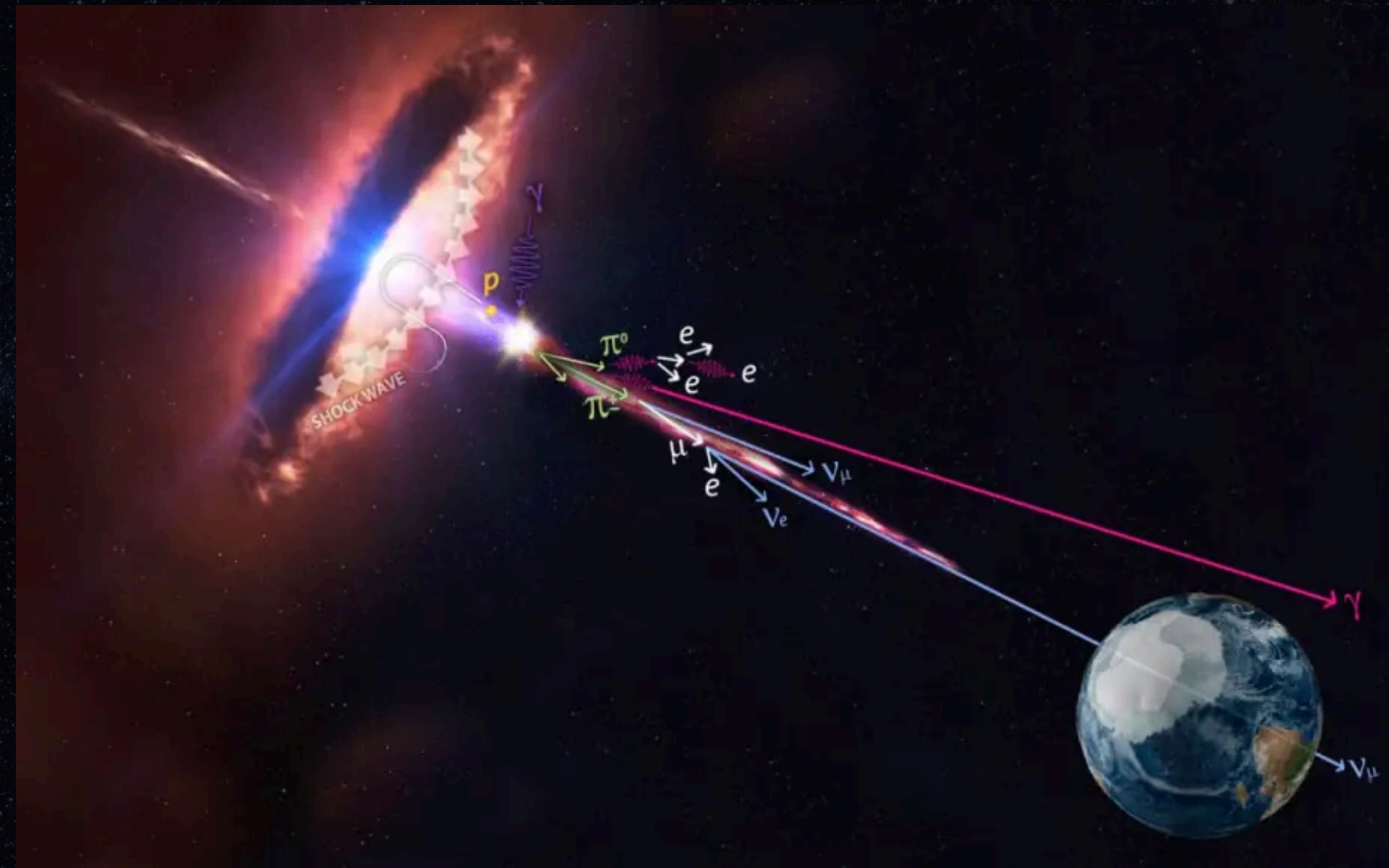
- Observations up to  $\sim 100$  TeV hint at acceleration near the CR knee.
- Matching knee suggests Cygnus Cocoon contributes to Galactic CR, especially light nuclei.
- Helps understand transition of CR sources at PeV energies.

The potential sources for the knee can either be star clusters or microquasars. We will now focus our study on the star cluster: **Cygnus Cocoon** and the microquasars: **SS433** and **V4641 Sgr**



# CR Acceleration Mechanisms

- Leptonic: electrons accelerated  $\rightarrow$  produce gamma rays via synchrotron + inverse Compton.
- Hadronic (PeVatron): protons/nuclei accelerated  $\rightarrow$  gamma rays via p-p interactions  $\rightarrow$  pion decay.
- Lepto-hadronic: hybrid models combining both electrons and hadrons.





# Star Cluster

## Cygnus Cocoon

- Superbubble around Cygnus OB2, extended GeV–TeV/PeV gamma-ray emission.
- HAWC and LHAASO confirm gamma rays up to tens of TeV.
- Potential Galactic PeVatron (accelerates to  $>100\text{ TeV–PeV}$ ).

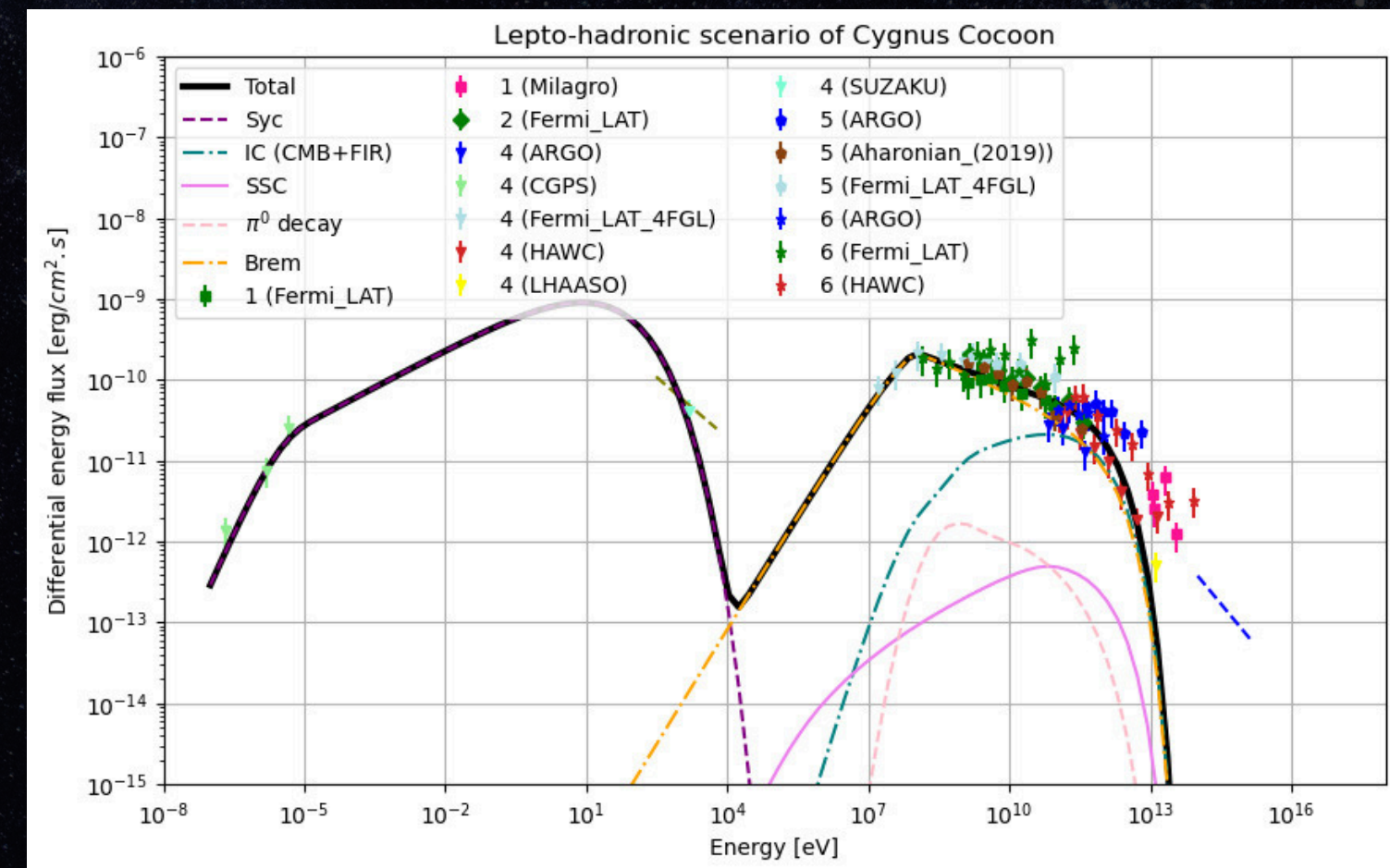
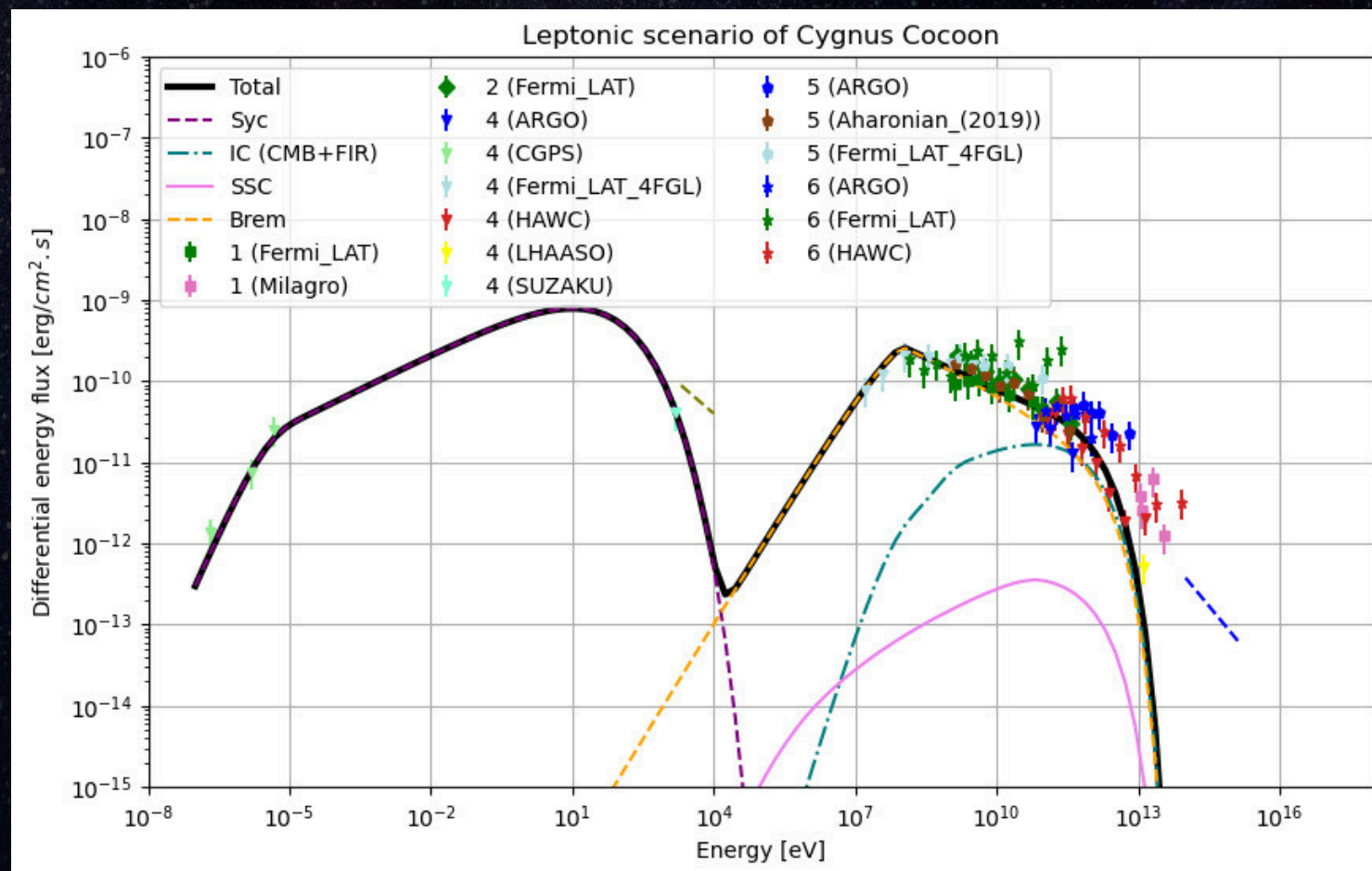




# Leptonic vs Hadronic Fits: Cygnus

- Hadronic models explain high-energy gamma and neutrino detections (e.g. IceCube muon)
- Leptonic fits (IC scattering) also contribute—multi-component SED works best.

The best fitting model would provide insights into if the source is a PeVatron or not.

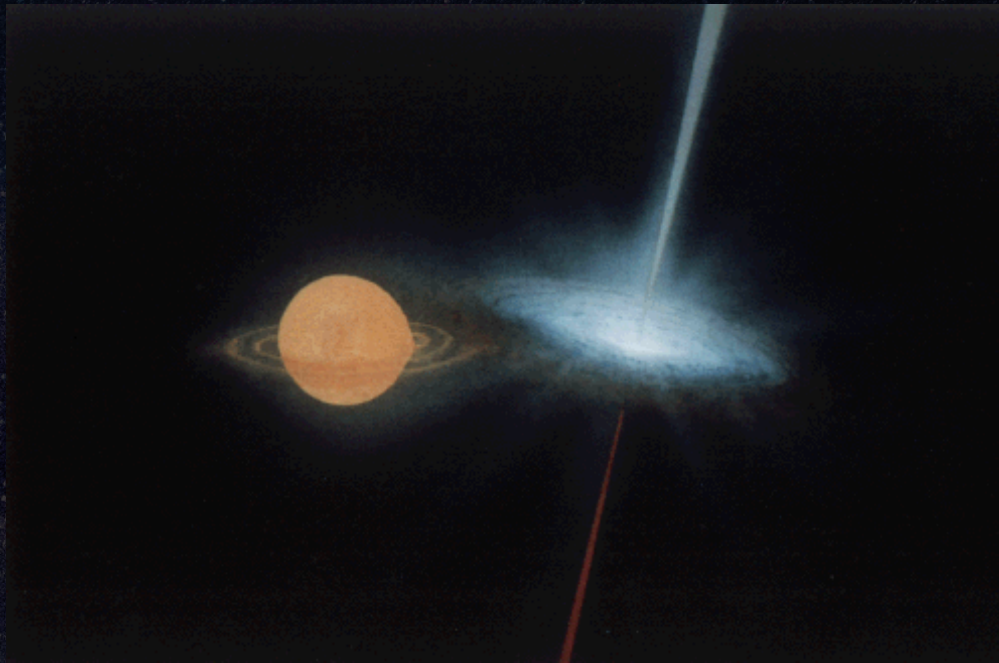




# Microquasars

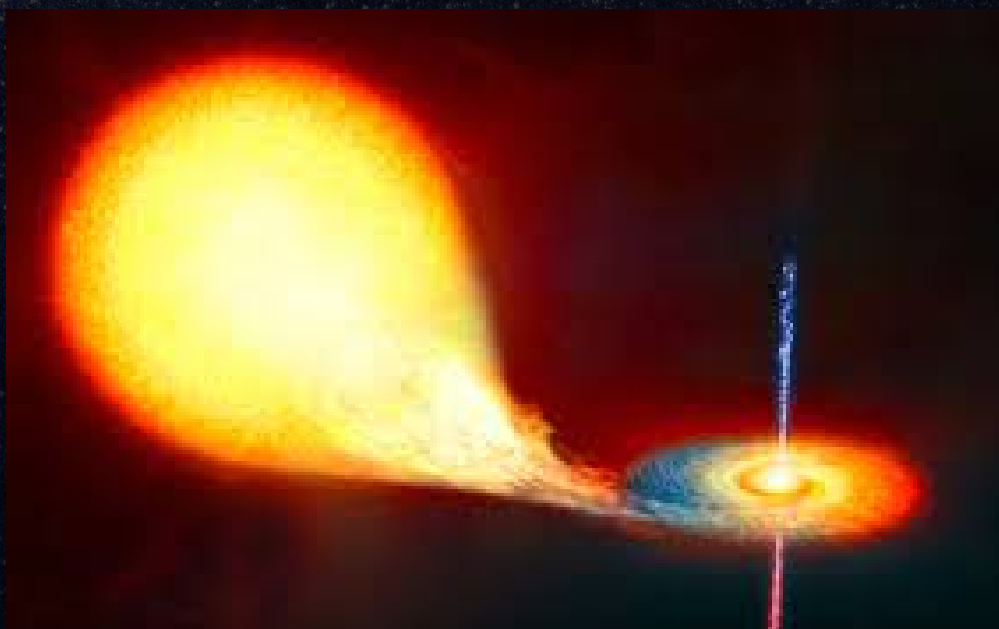
## SS 433

- SS 433 is the first discovered microquasar.
- Eclipsing X-ray binary system, consisting of a stellar-mass black hole accreting matter from an A-type companion star.



## V4641 Sgr

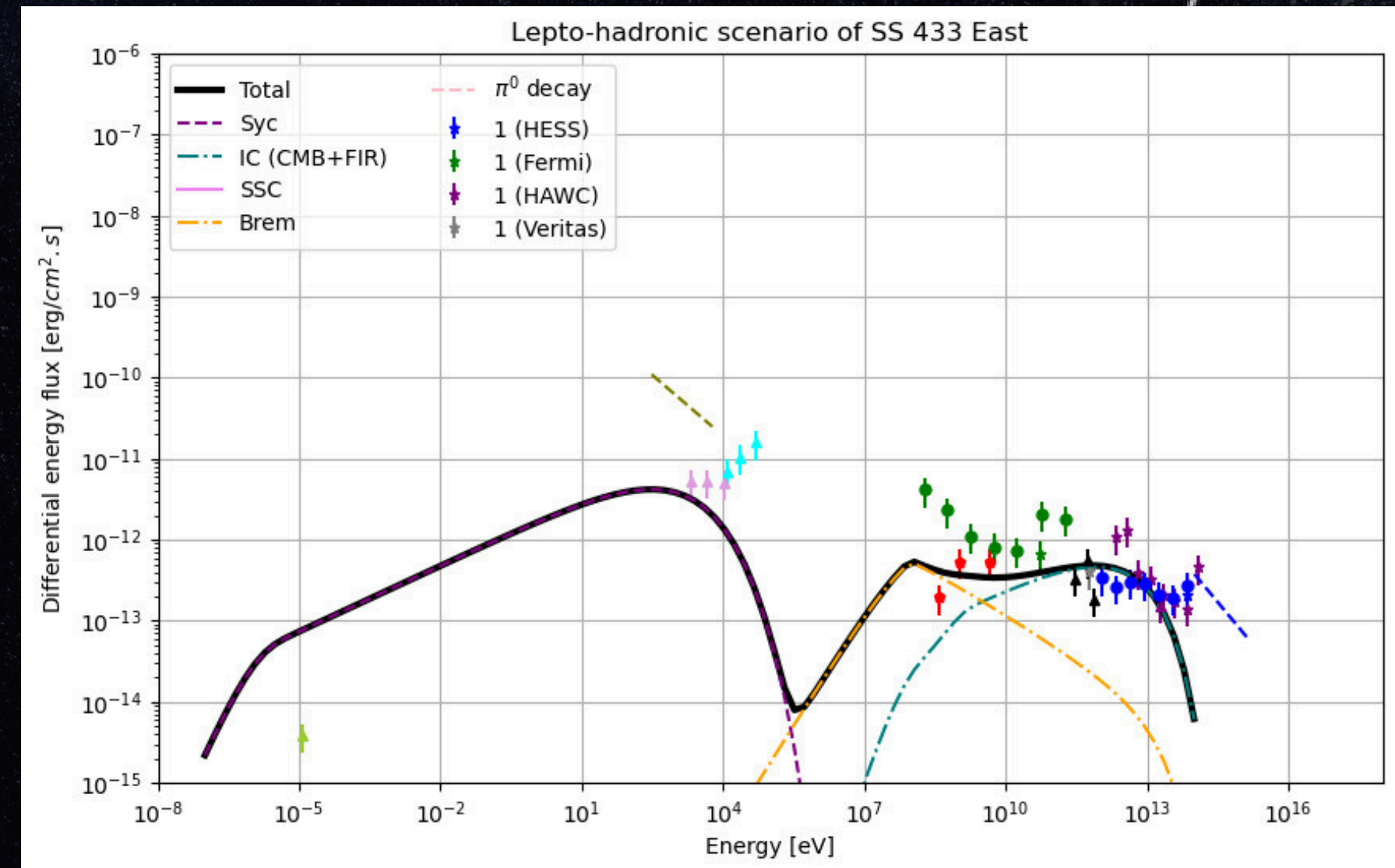
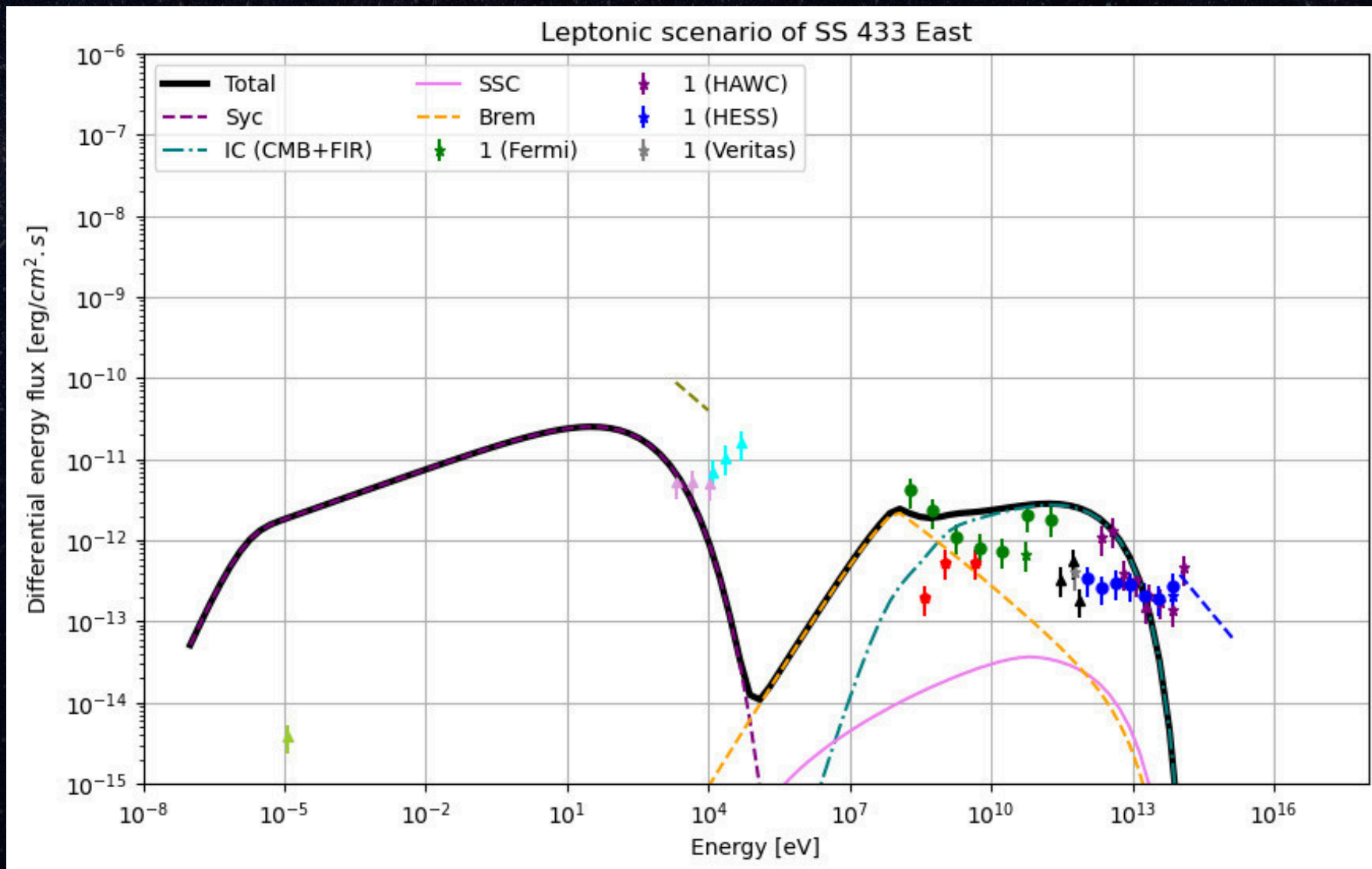
- V4641 Sgr is a X ray binary star system in the constellation Sagittarius.
- This system consist of a late B class giant with three times Solar masses orbiting a black hole about twice as massive every 2.8 days.





# Modeling SS 433 Emission

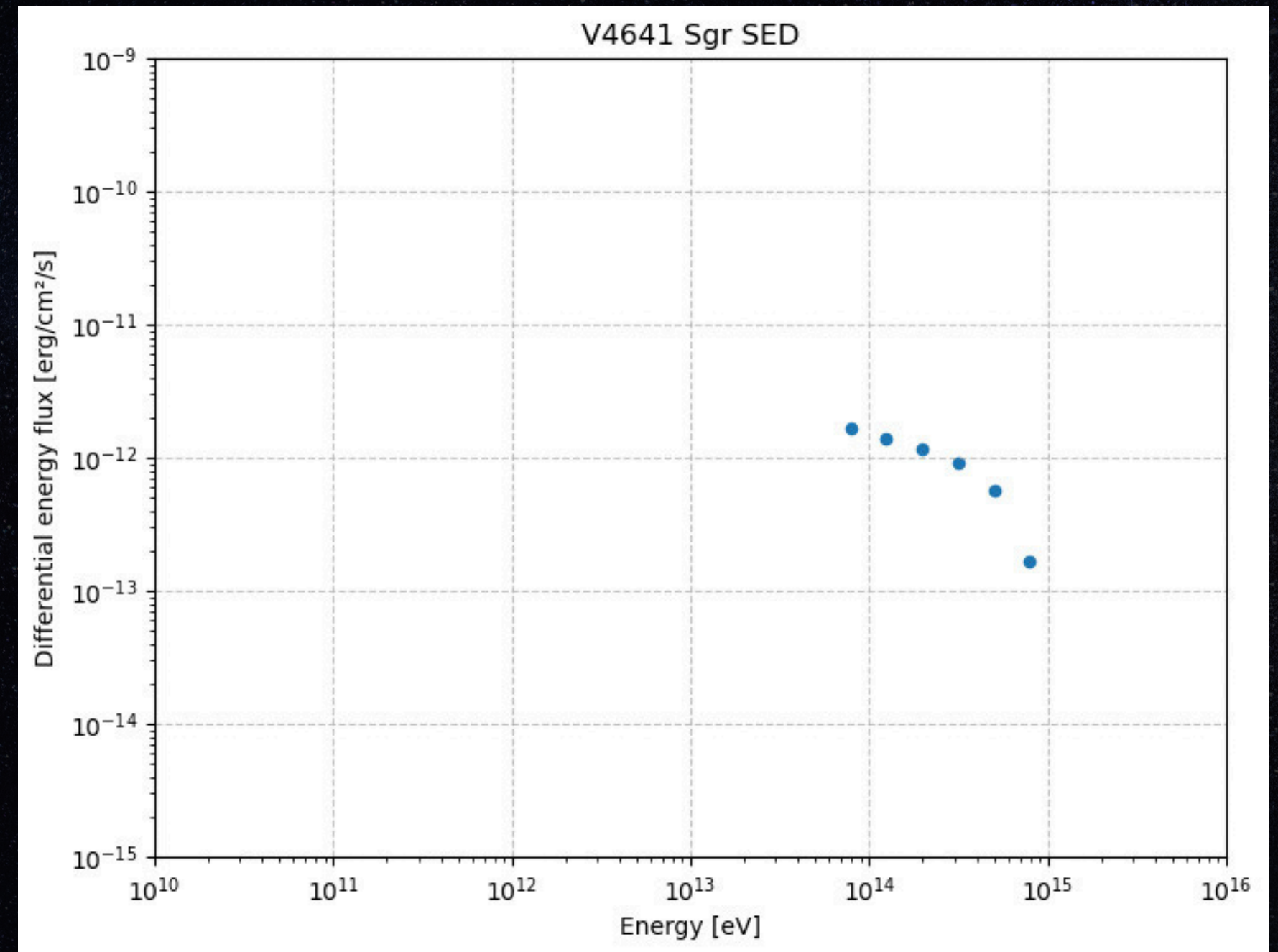
- Both leptonic (IC by electrons) and hadronic (proton interactions) models fit GeV–TeV data.
- Leptonic favored by energy-dependent morphology of X-ray knots; hadronic still viable.





# V4641 SED

- The available data is plotted as shown
- Lower energy data is not there.
- Model fitting, continue...





# Summary & Future Work

- Will try to fit the SS433 data more precisely.
- Find more data for the V4641 Sgr at lower energy and fit with the model.
- CTAO stimulation for all the sources to study and test its sensitivity and limits.





# Thank You

*Please ask if you have  
any questions :)*

