Newborn Pulsars as Ultrahigh Energy Cosmic Accelerators

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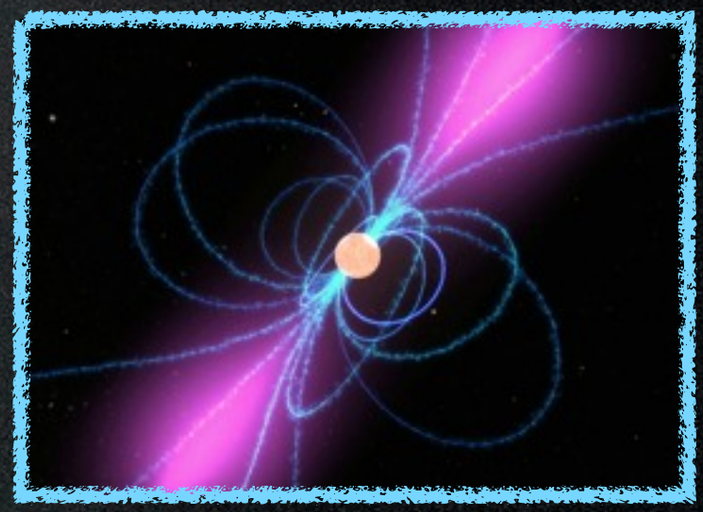
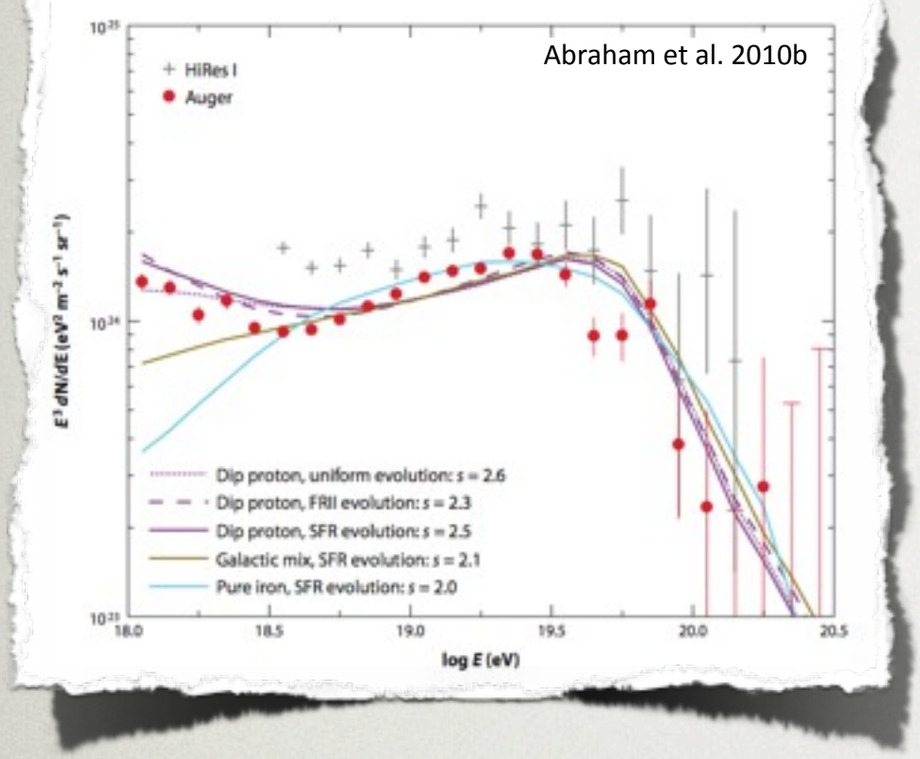
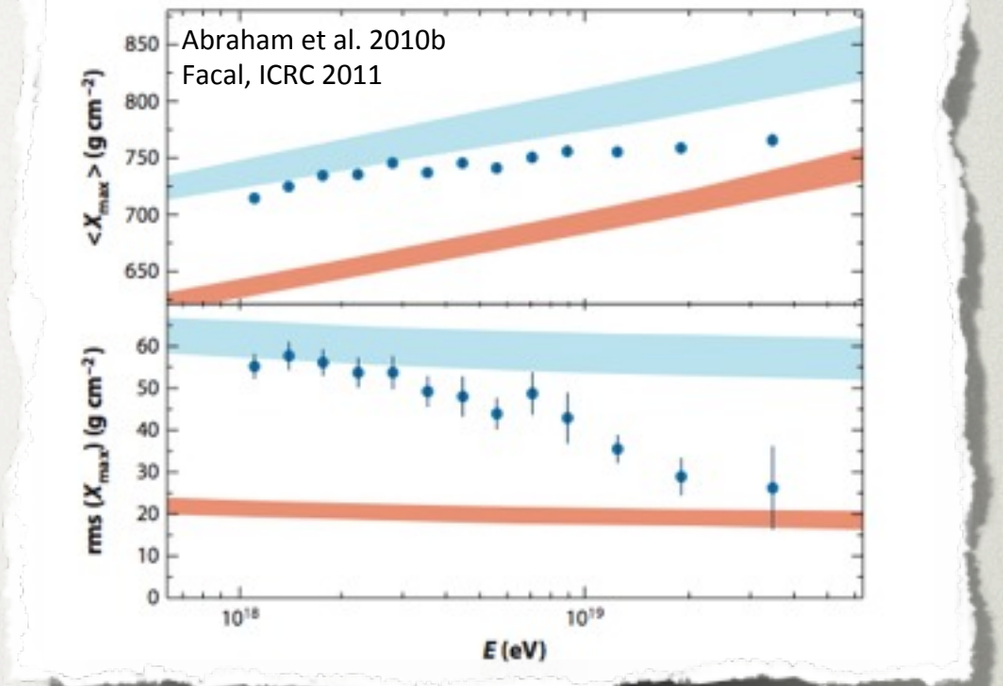


Observational facts of Ultrahigh energy cosmic rays



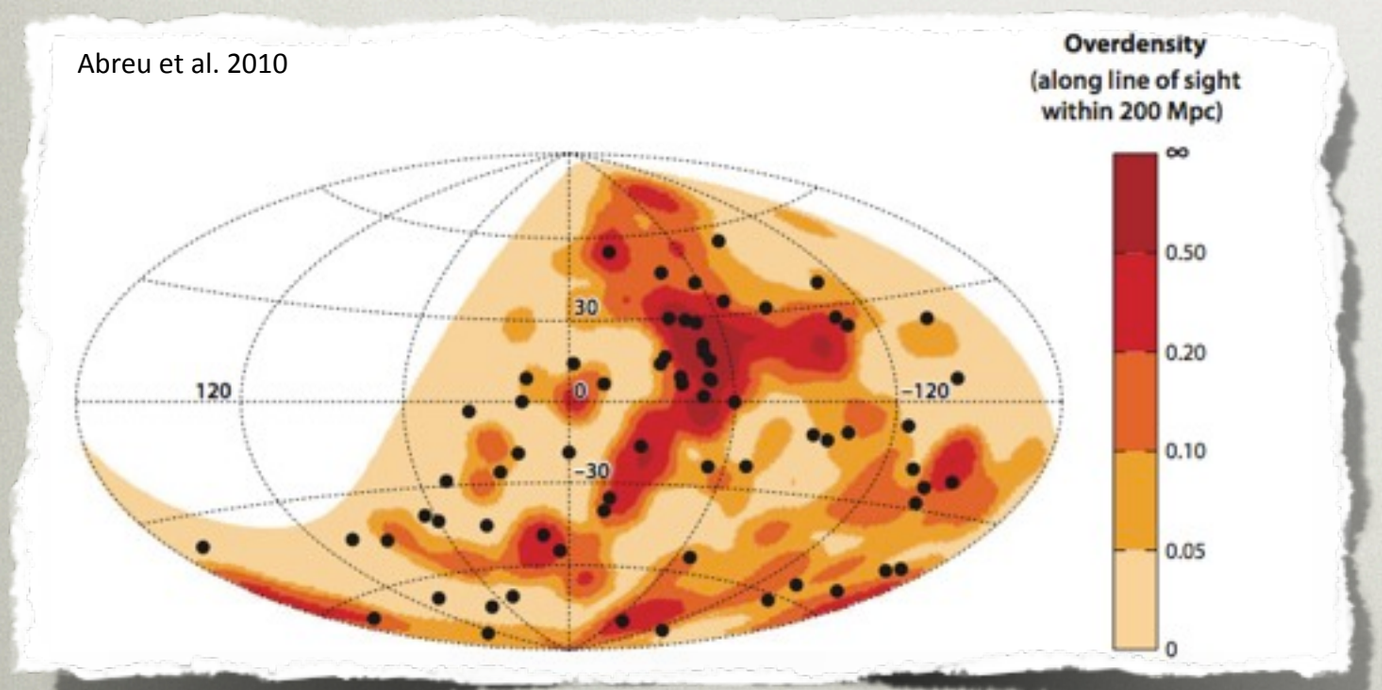
Energy Spectrum s~2 at source



Chemical composition

Intermediate and heavy above 10EeV

TA indicates light composition



Direction of events

No strong evidence of clustering of data

A tale of newborn pulsars

Blasi & Olinto 2000
Arons 2003
KF, Kotera, Olinto 2012
KF, Kotera, Olinto 2013

Goldreich-Julian charge density at the stellar surface

$$\dot{N}_{GJ} = \frac{\Omega^2 \mu}{Zec}$$

Pulsar spins down due to electromagnetic radiation (neglect GW)

$$\dot{\Omega} = -\frac{\dot{E}_{EM}}{I\Omega} \propto -\mu^2 \Omega^3$$

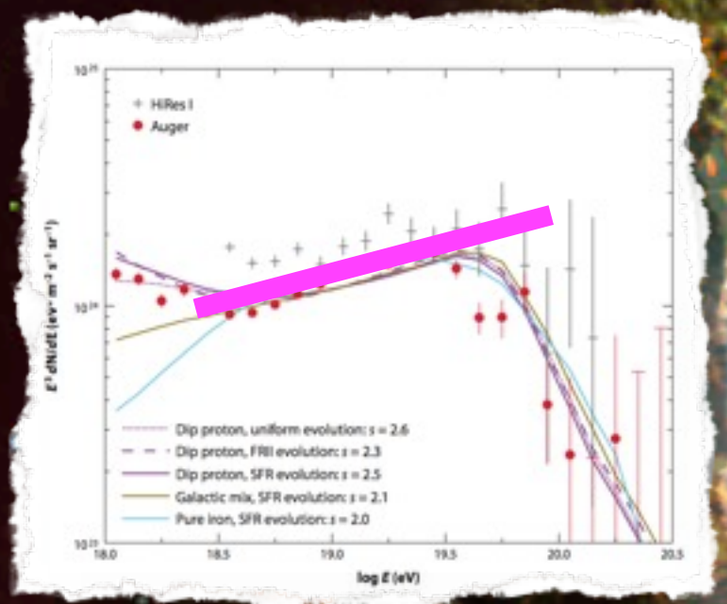
Particles can be accelerated by the induced E-field

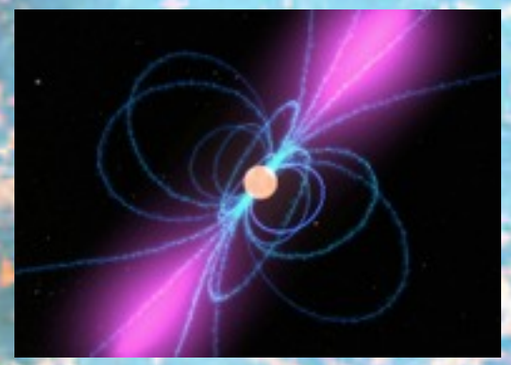
$$E = Ze\Phi\eta = 3\times10^{20} Z_{26}\eta_1 \Omega_4^2 \mu_{30.5} eV$$

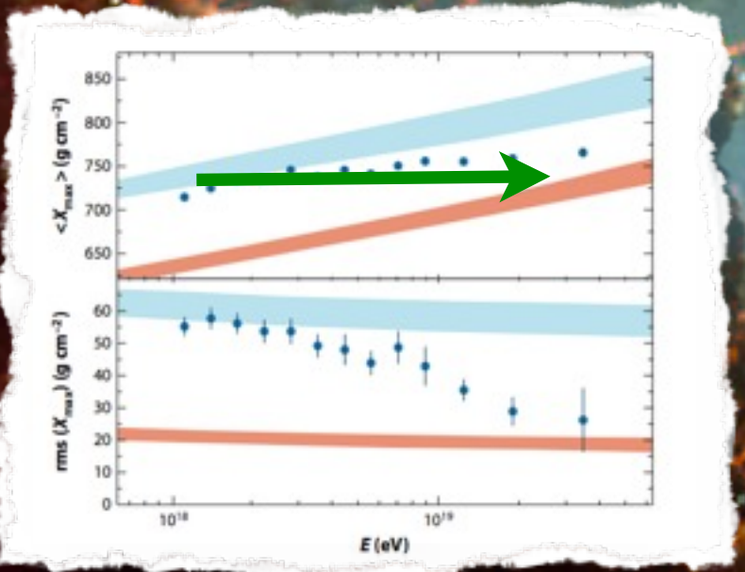
$$t_{spin}(E) = 1yr\left(\frac{3\times10^{20} eV}{E}\right)\frac{Z_{26}\eta_1}{\mu_{30.5}}$$

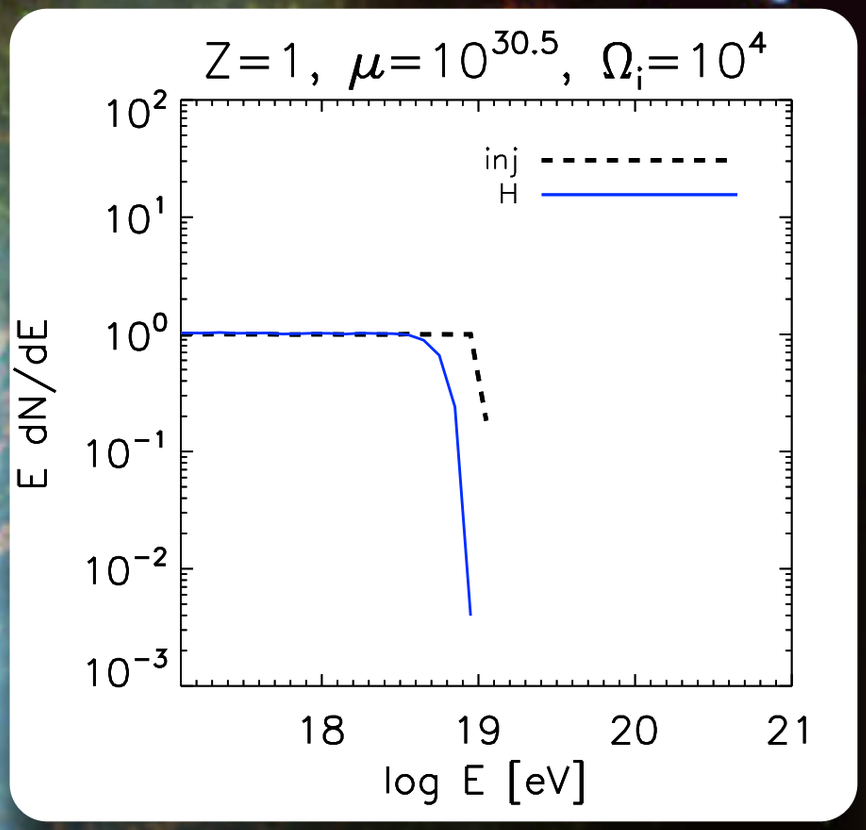
$$\frac{dN_i}{dE} = 5\times10^{23}(Z_{26}\mu_{30.5}E_{20})^{-1} eV^{-1}$$

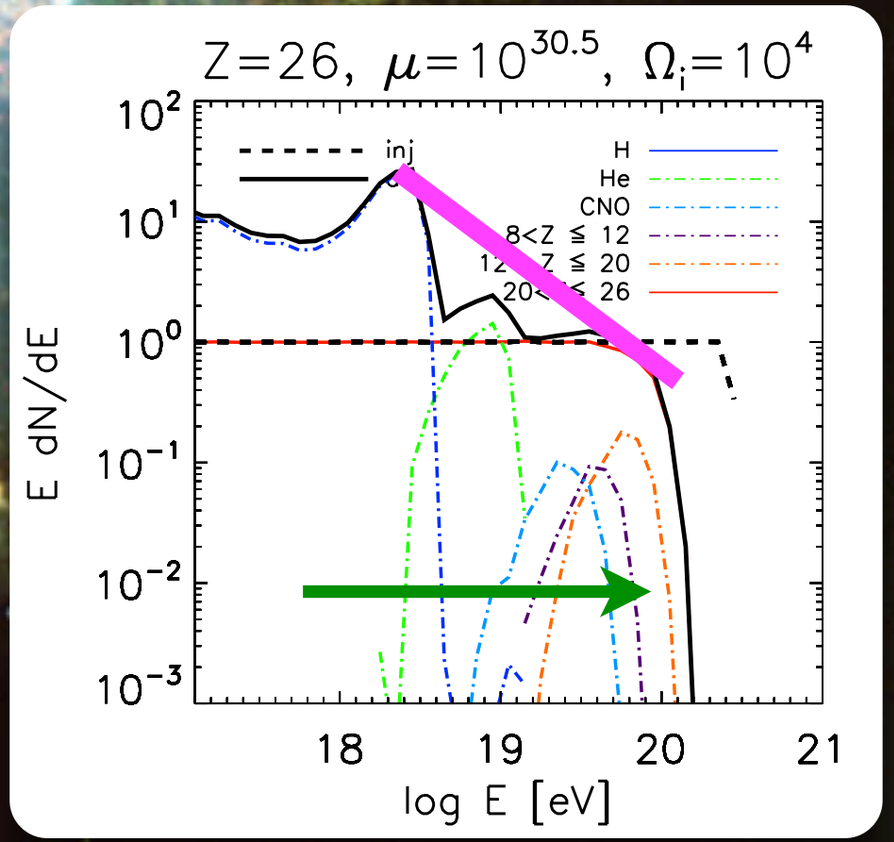
Monte-Carlo propagation
hadron interactions with EPOS + CONEX





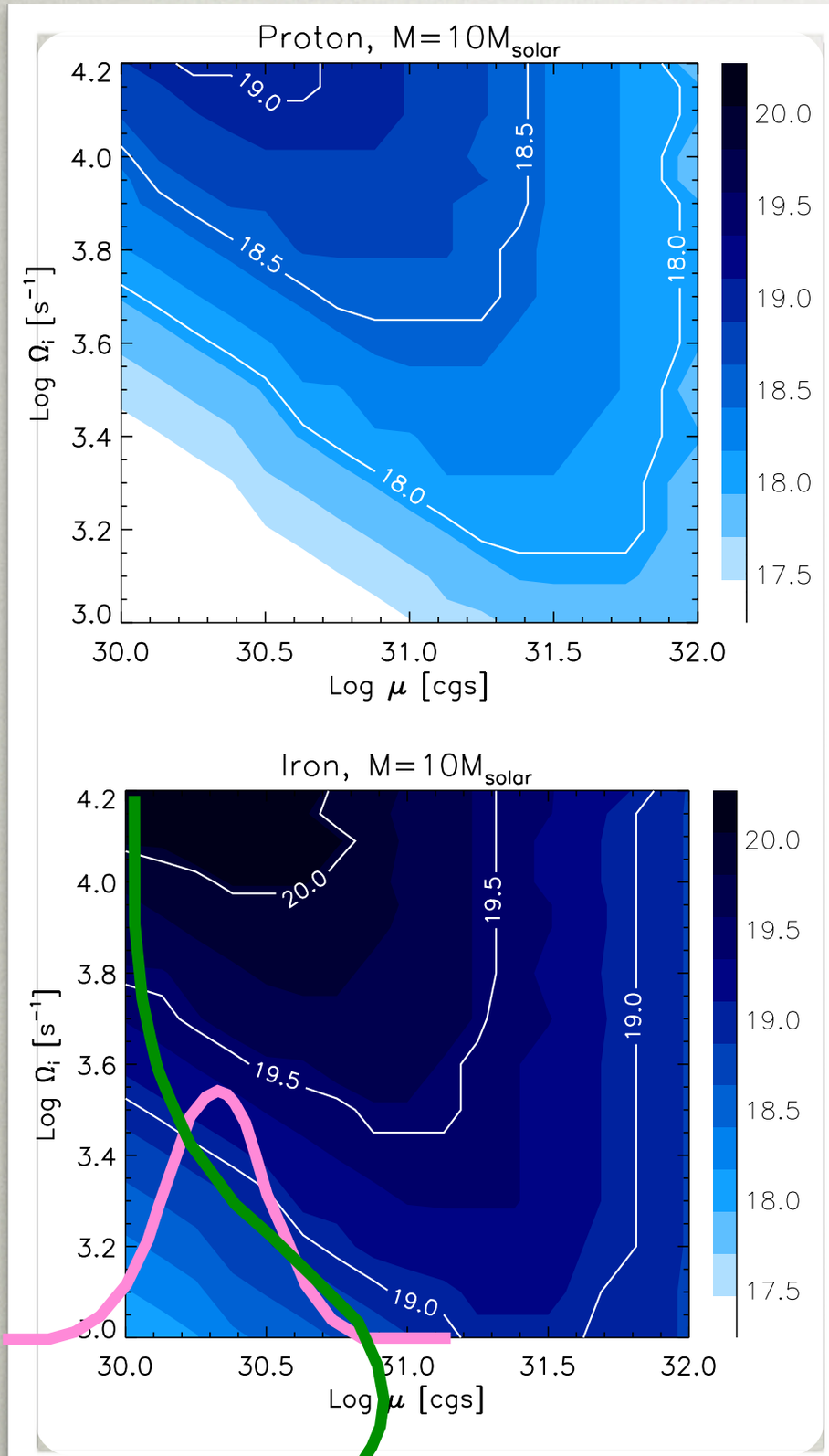






KF, Kotera & Olinto, ApJ, 750:118, 2012

Pulsars that allow escape



UHE Protons
can hardly escape
(except for very dilute envelope)

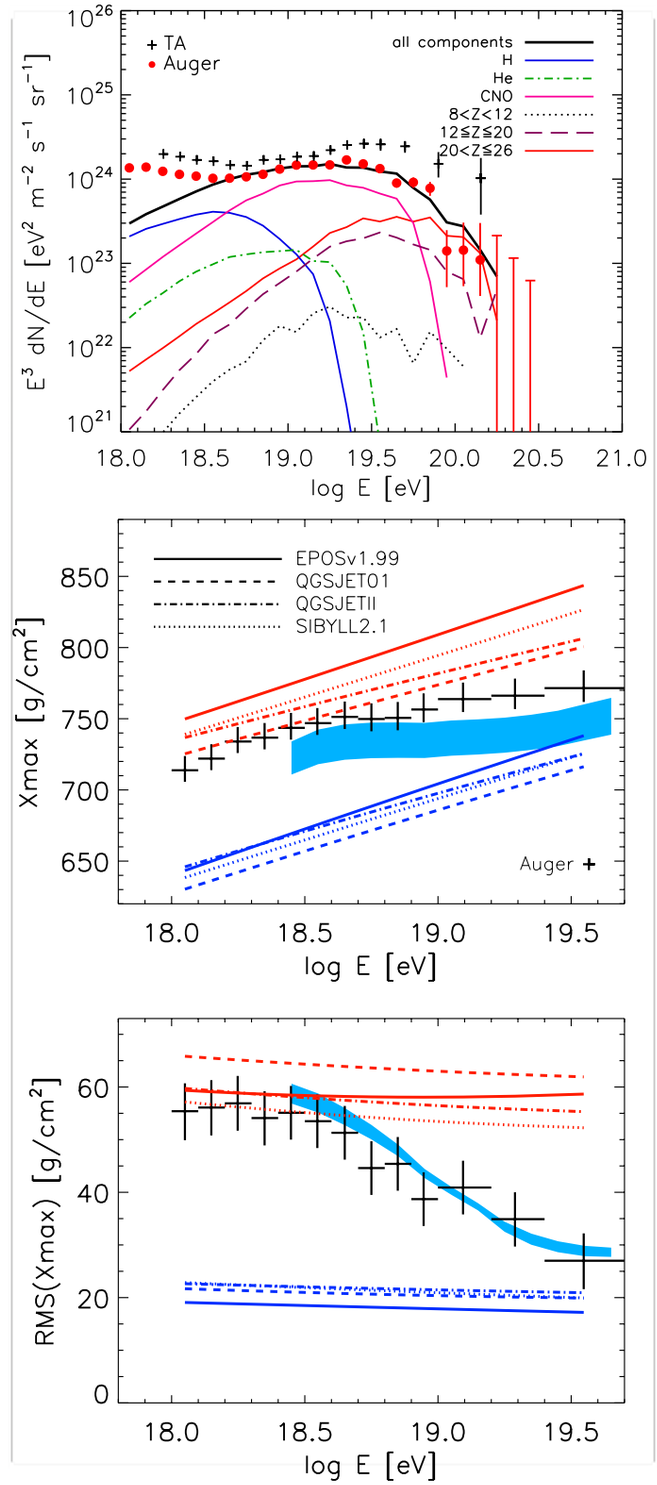
UHE Iron Nulcei
can escape from newborn millisecond pulsars

Pulsar distribution in the galaxy
Faucher-Giguère & Kaspi 06

- log-normally on B
  - <log B> = 12.65 G
  - σ= 0.55 G
- normally on P
  - <P> = 300 ms
  - σ= 150 ms
- pulsar burst rate
  1 per 60 yr per galaxy

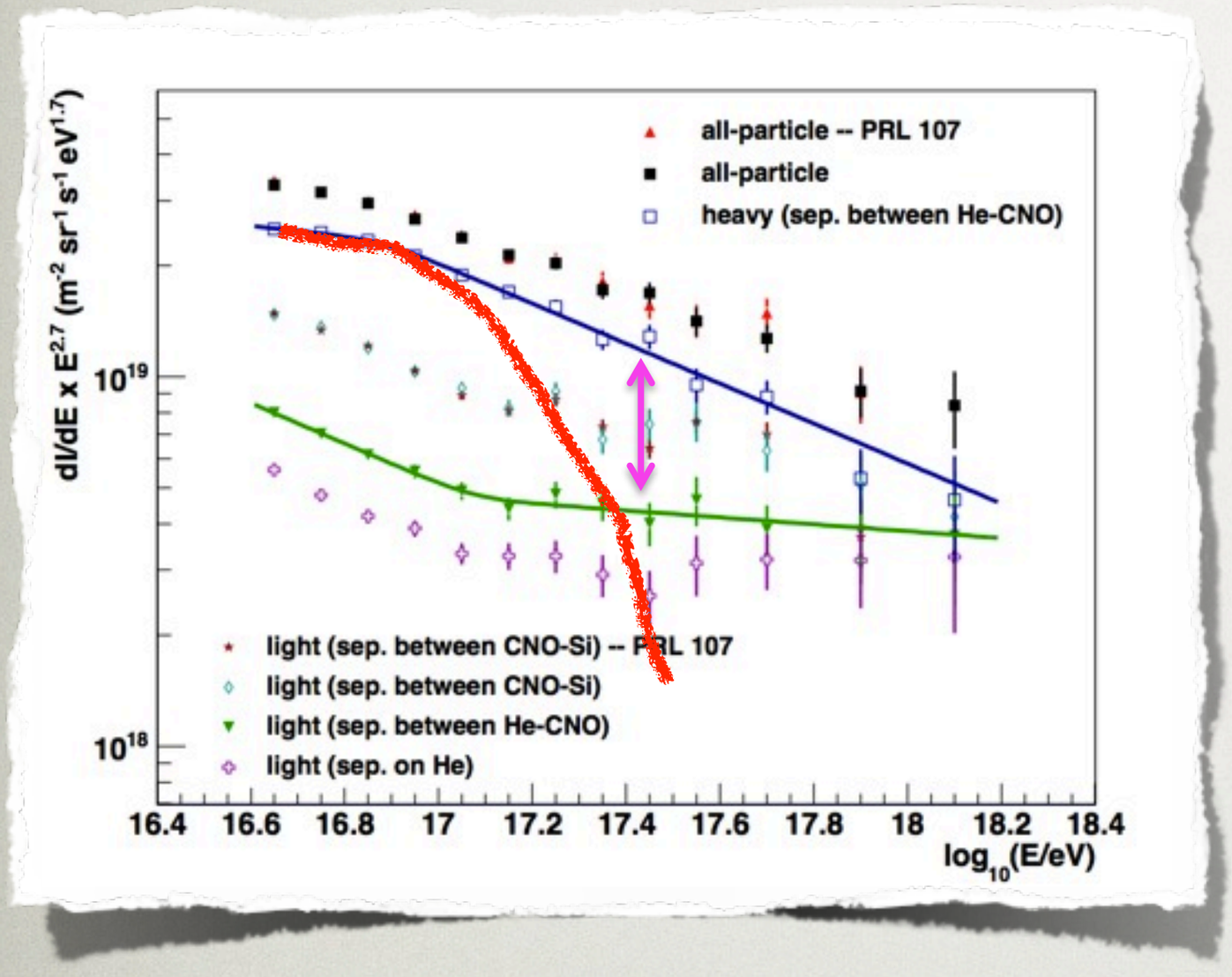
Conclusion I
Newborn pulsars can be successful UHECR accelerators

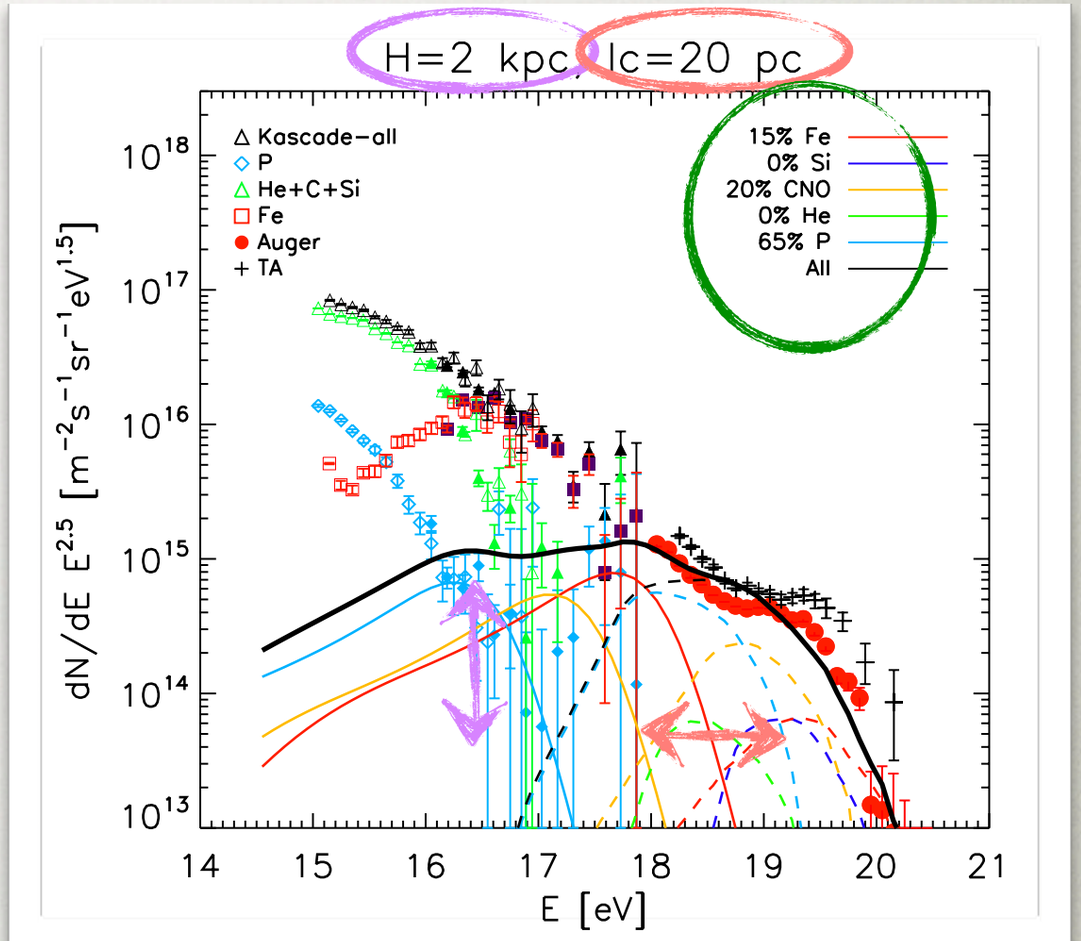
Integrated Extragalactic pulars



KF, Kotera & Olinto 2012, 2013

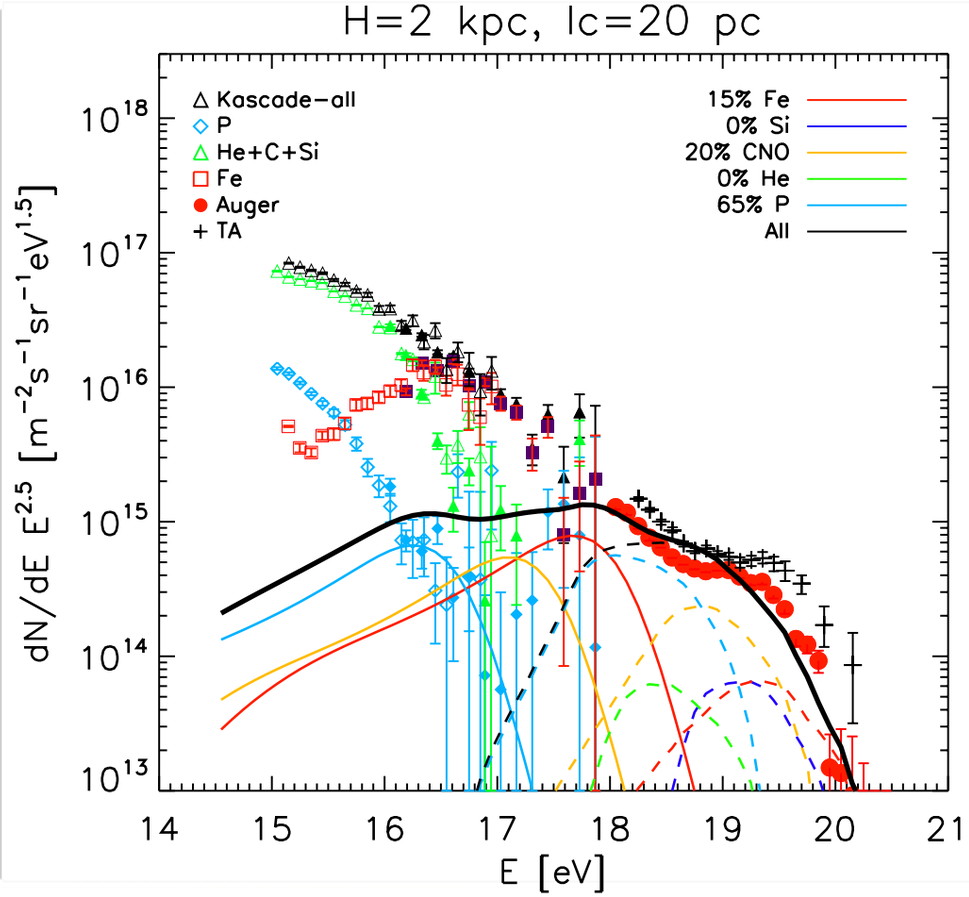
What about their Galactic Counterparts?

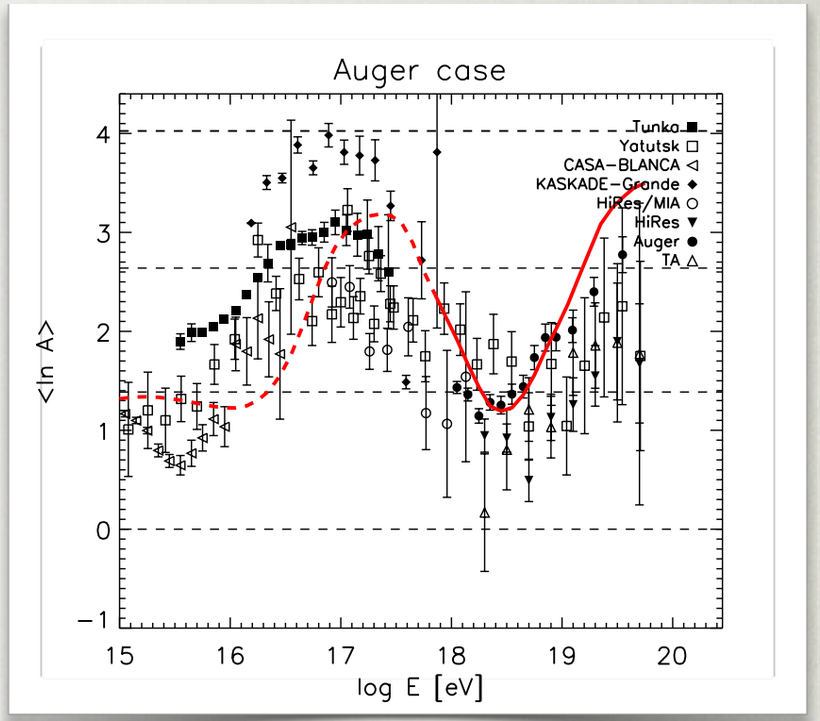


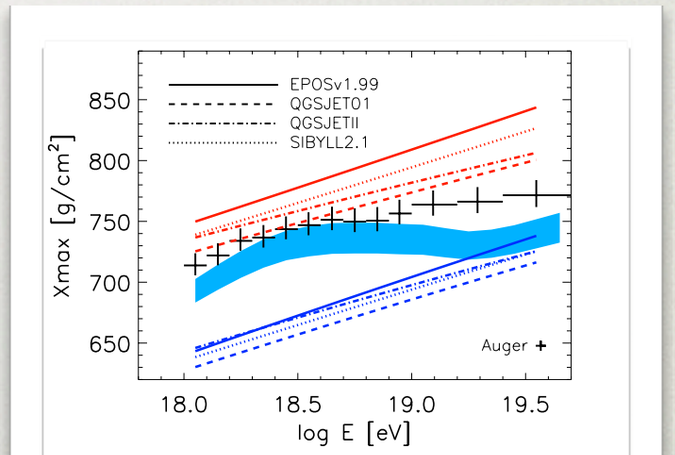


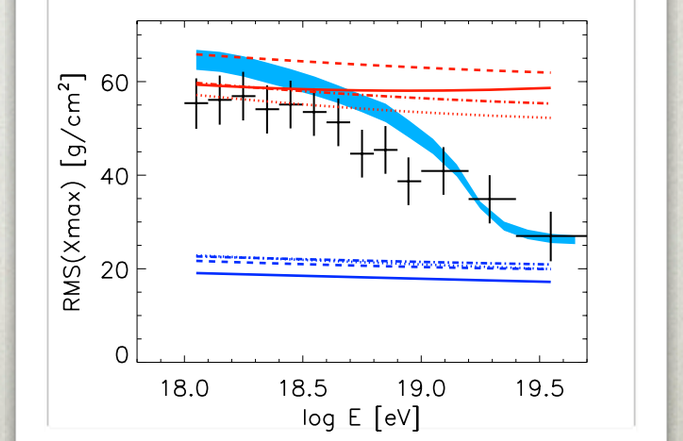
- No cutoff, Mind the gap!

Contribution from Galactic pulsars II







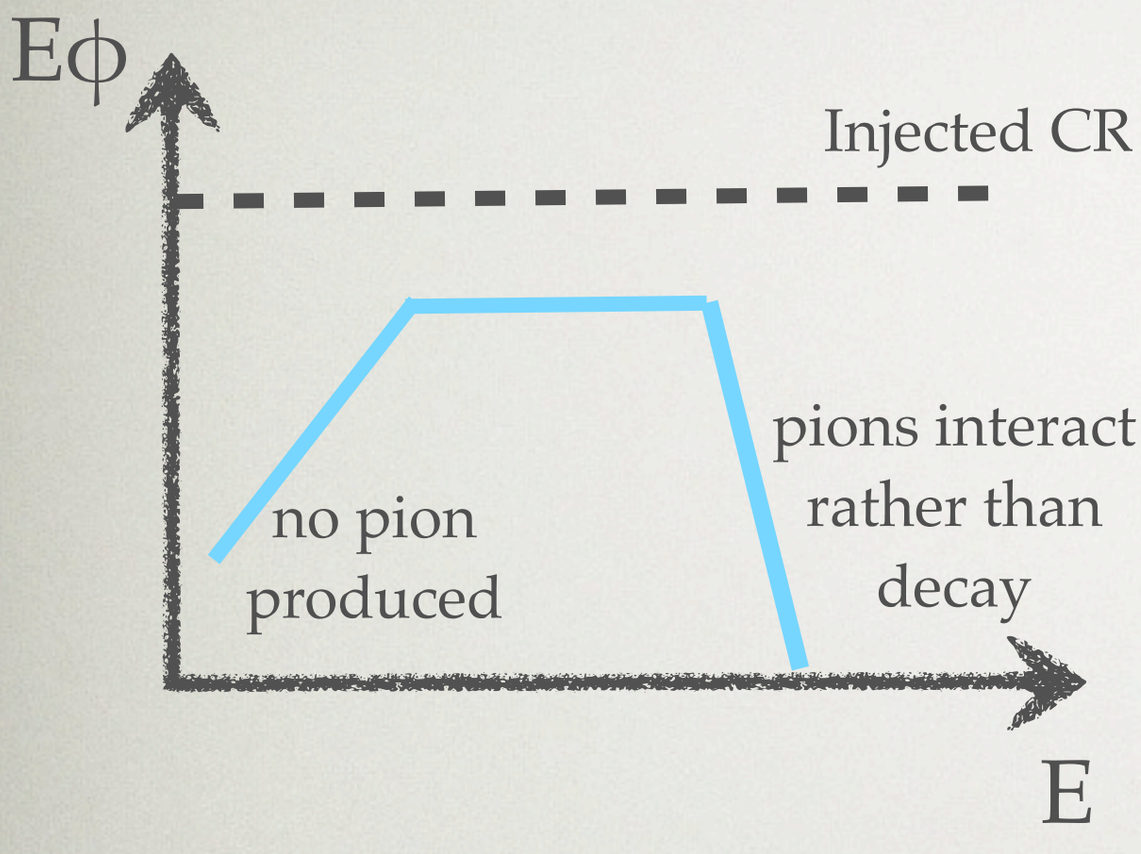


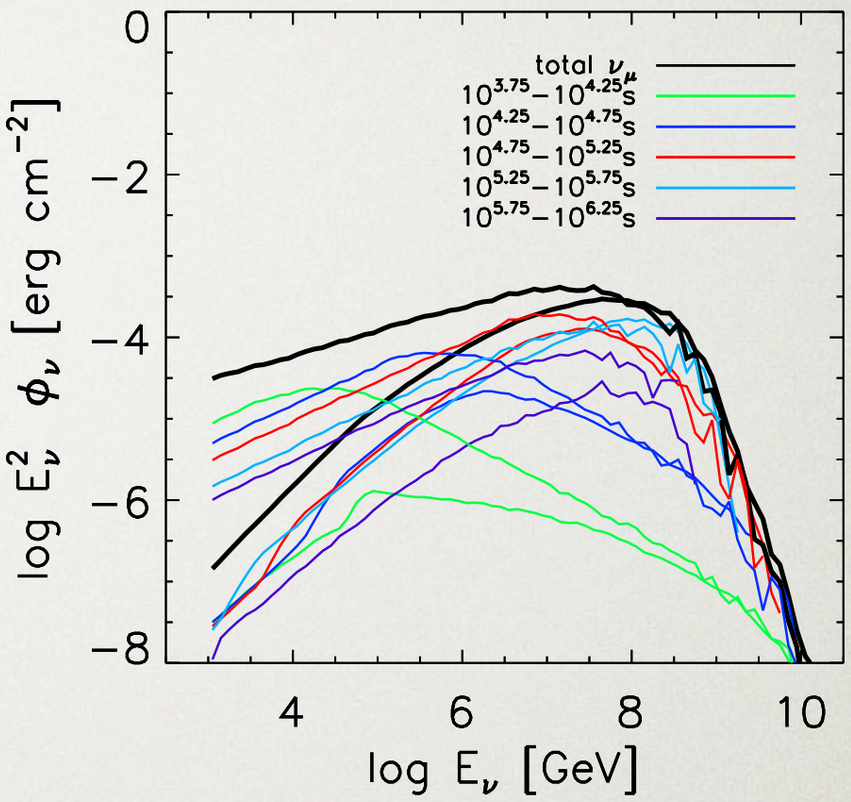
Conclusion II

Galactic pulsars can contribute between the knee and the ankle

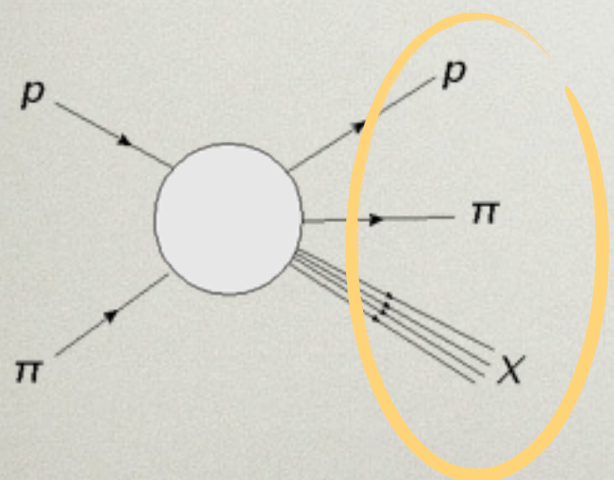
Neutrinos from Newborn pulsars

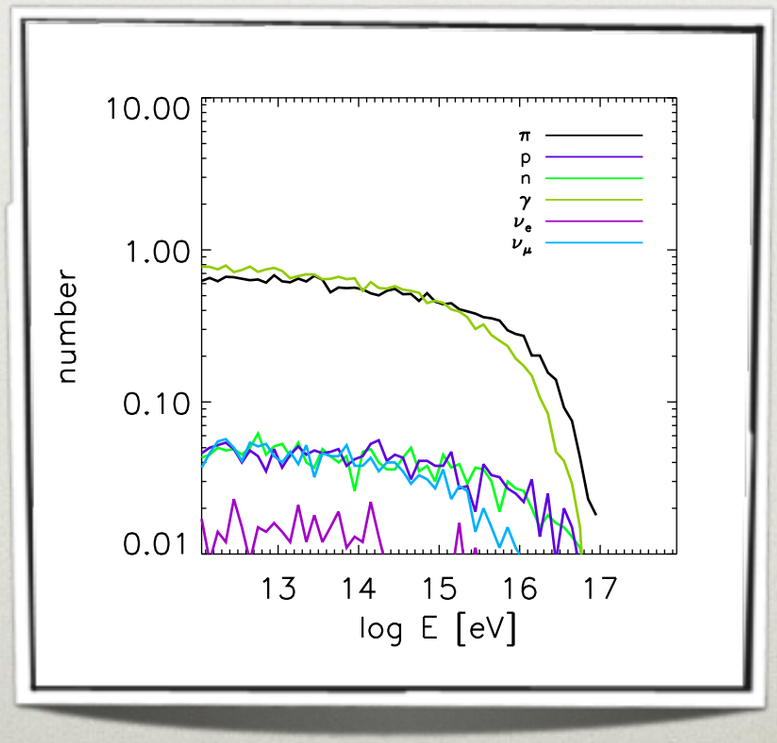
KF, *in prep.*

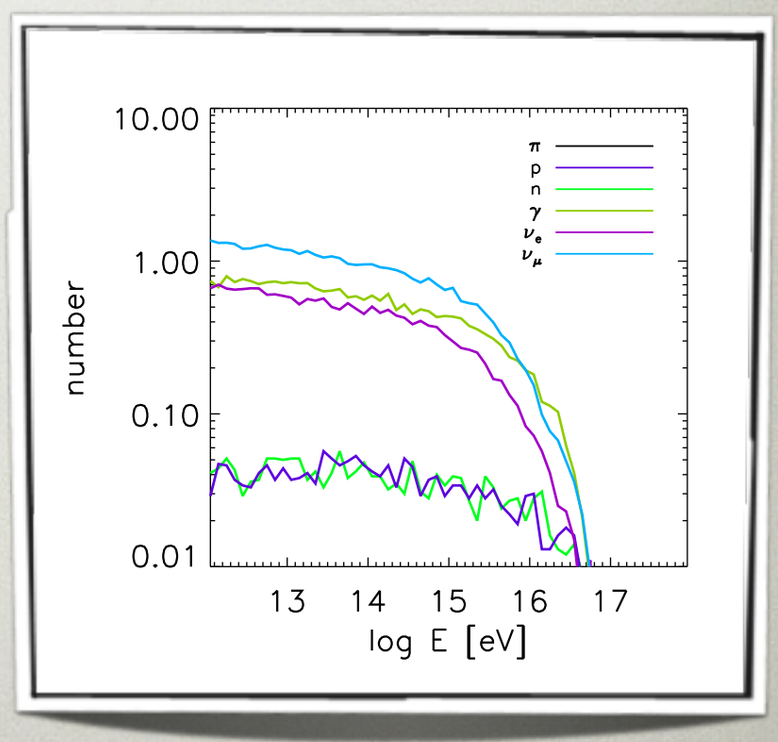




- Secondaries flatten the spectrum



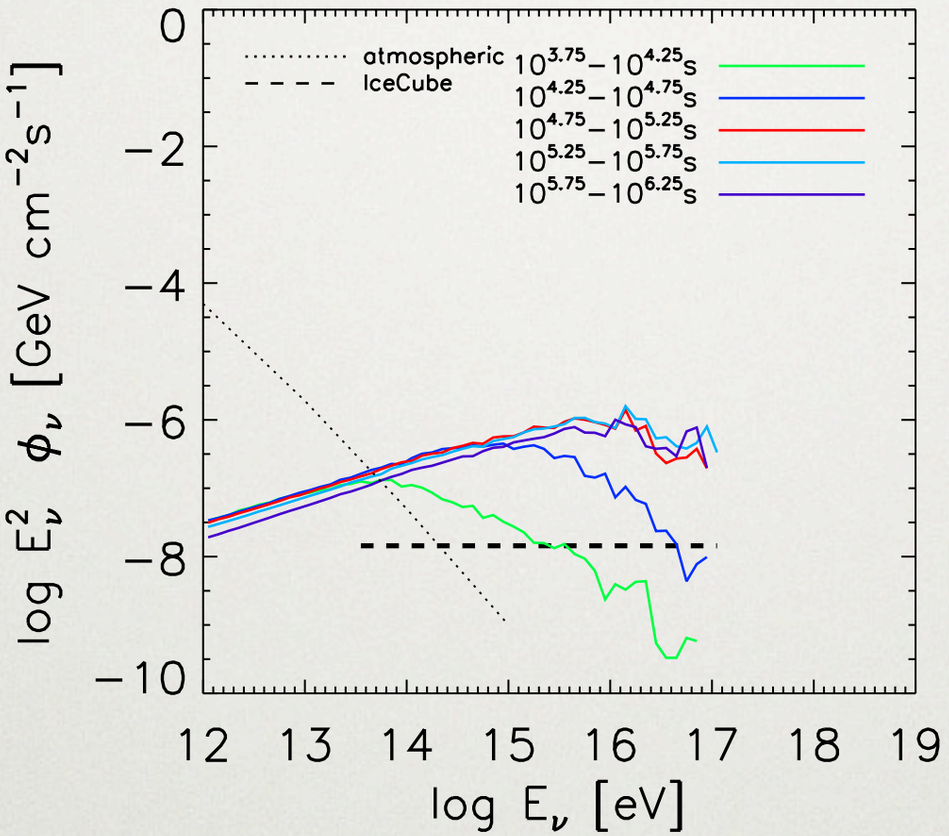




KF, *in prep.*

Neutrinos from a nearby pulsar

logμ= 31.35, P= 10 ms, 1Mpc



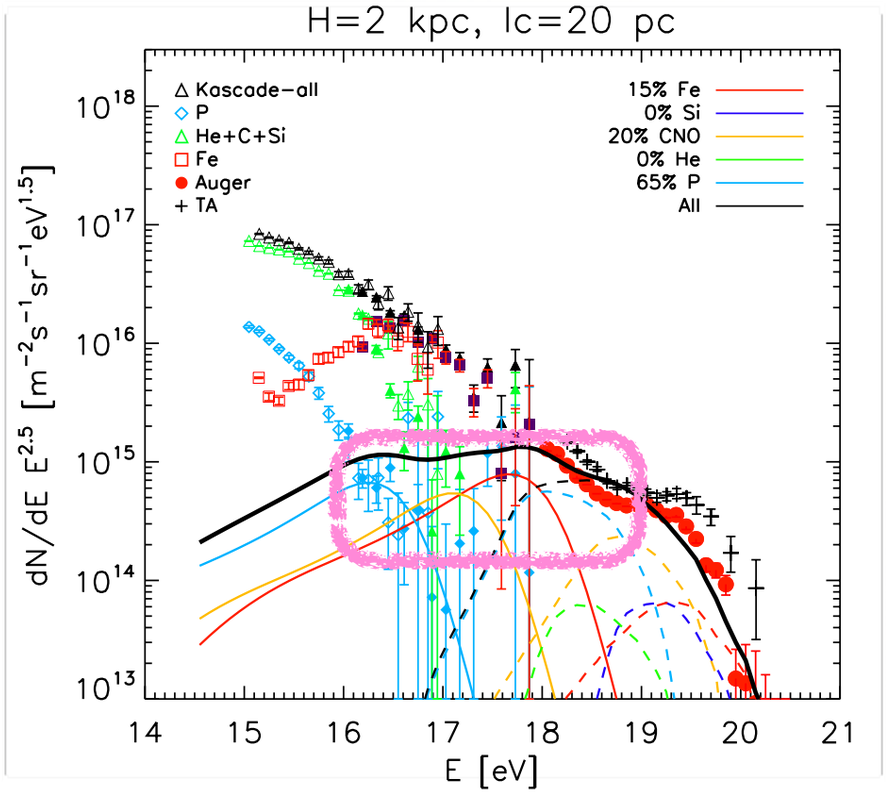
Conclusion III

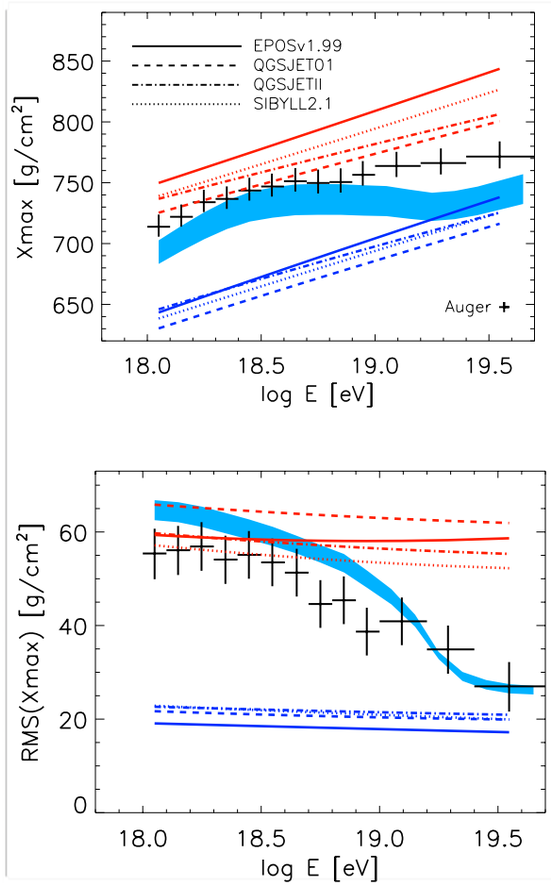
Averagely every ~10,000 yrs there is a newborn pulsar that contributes to measurable neutrino flux

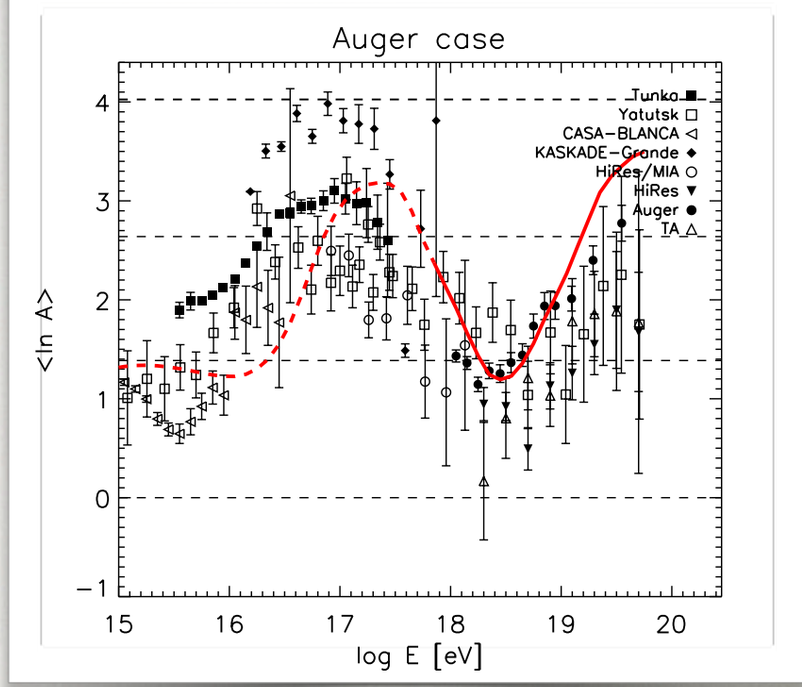
Backups

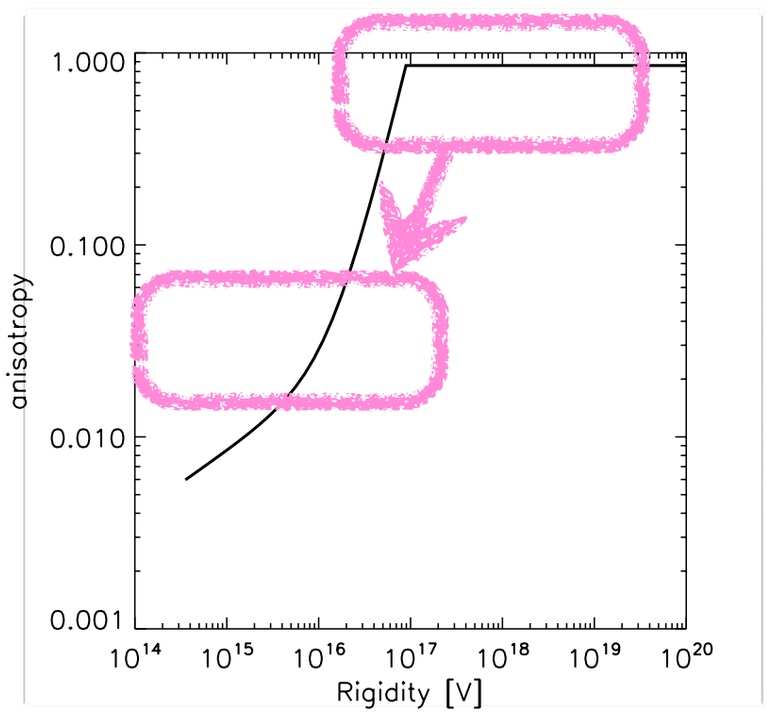
Contribution from Pulsar Sources

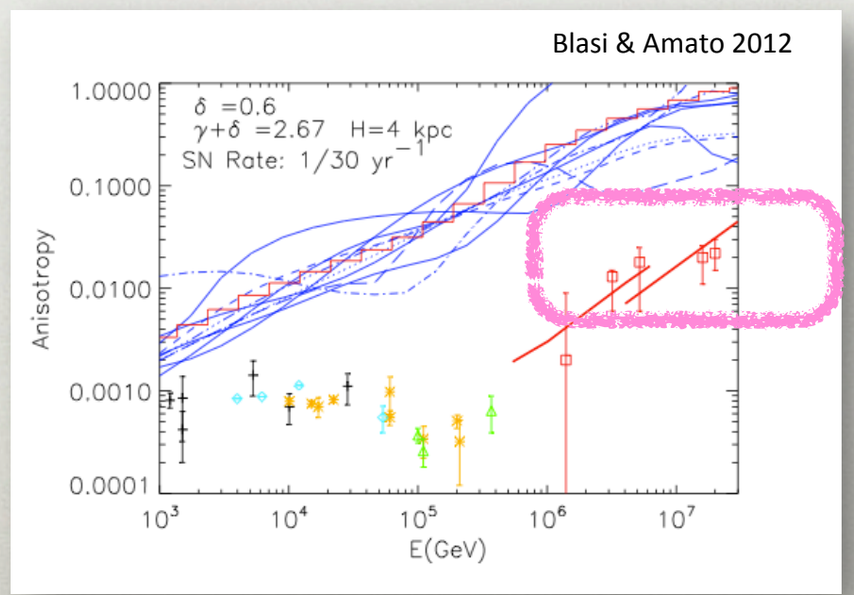
KF, Kotera & Olinto, JCAP, 010: 03, (2013)











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