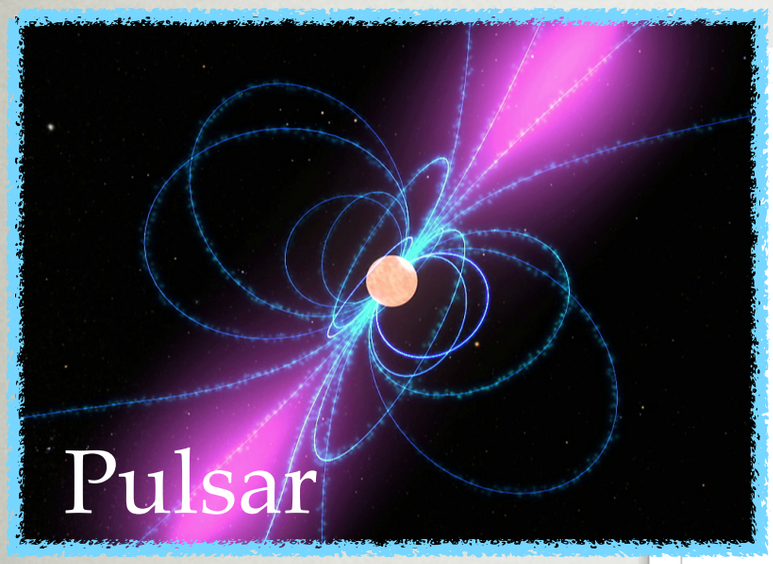
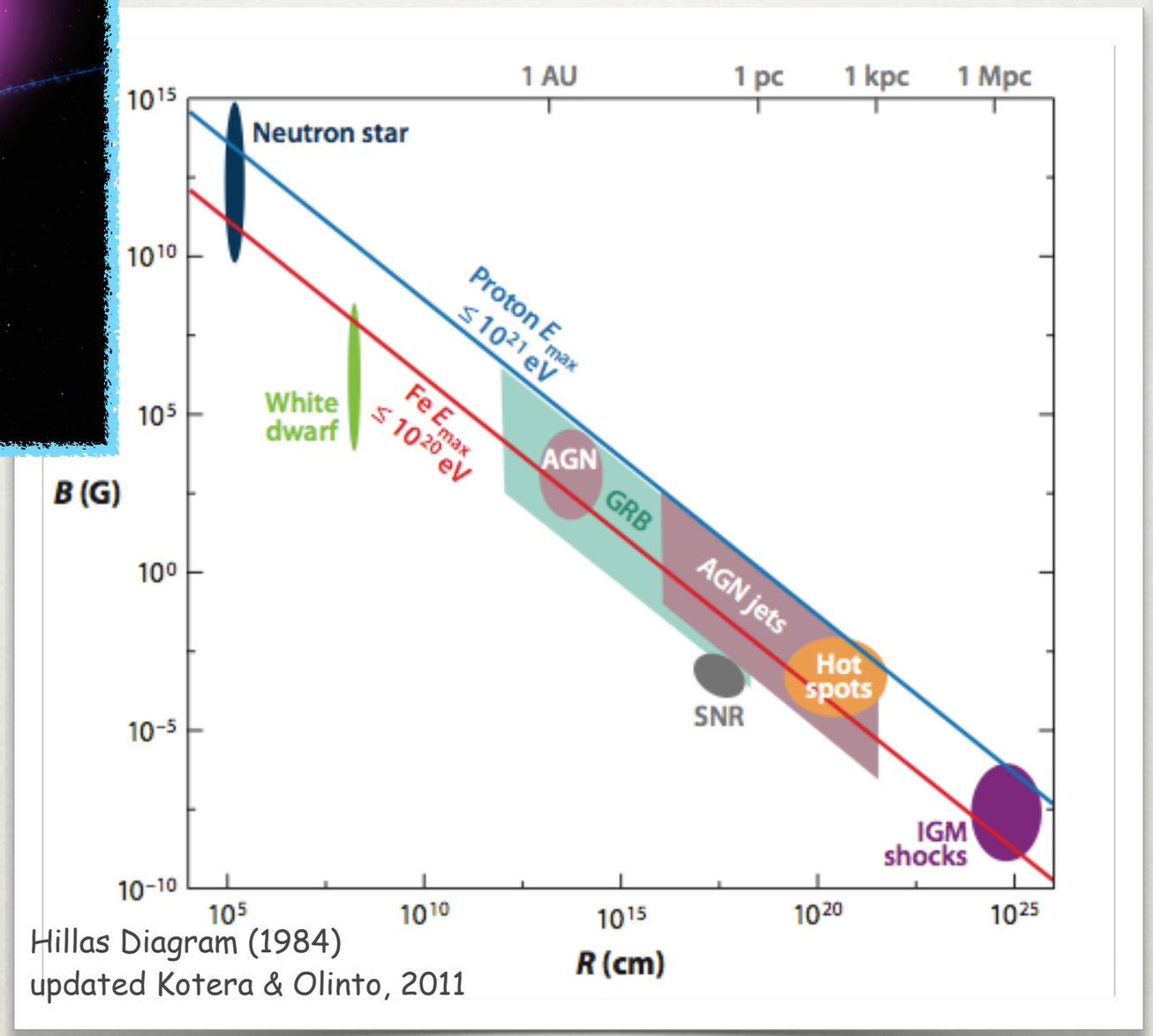
Newborn Pulsars as Ultrahigh Energy Cosmic Accelerators

Ke Fang
University of Chicago

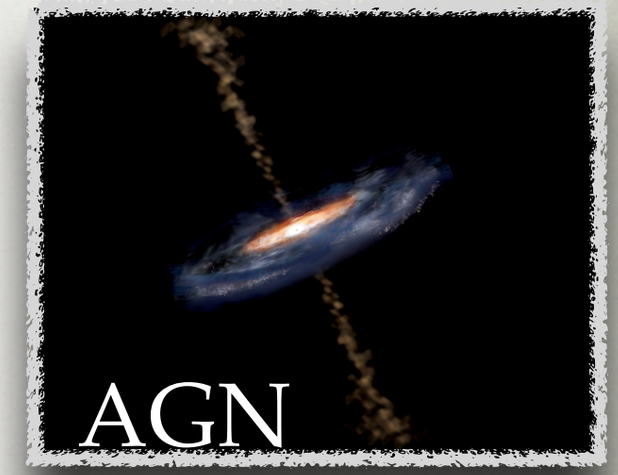
TAUP-poster preview Sep 11 2013

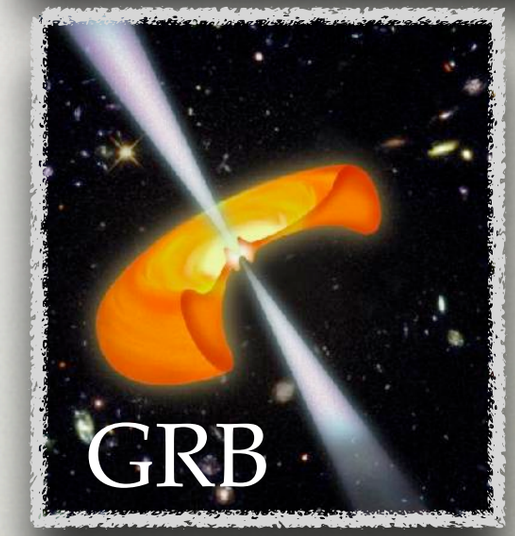
Possible Candidates of UHECR Sources





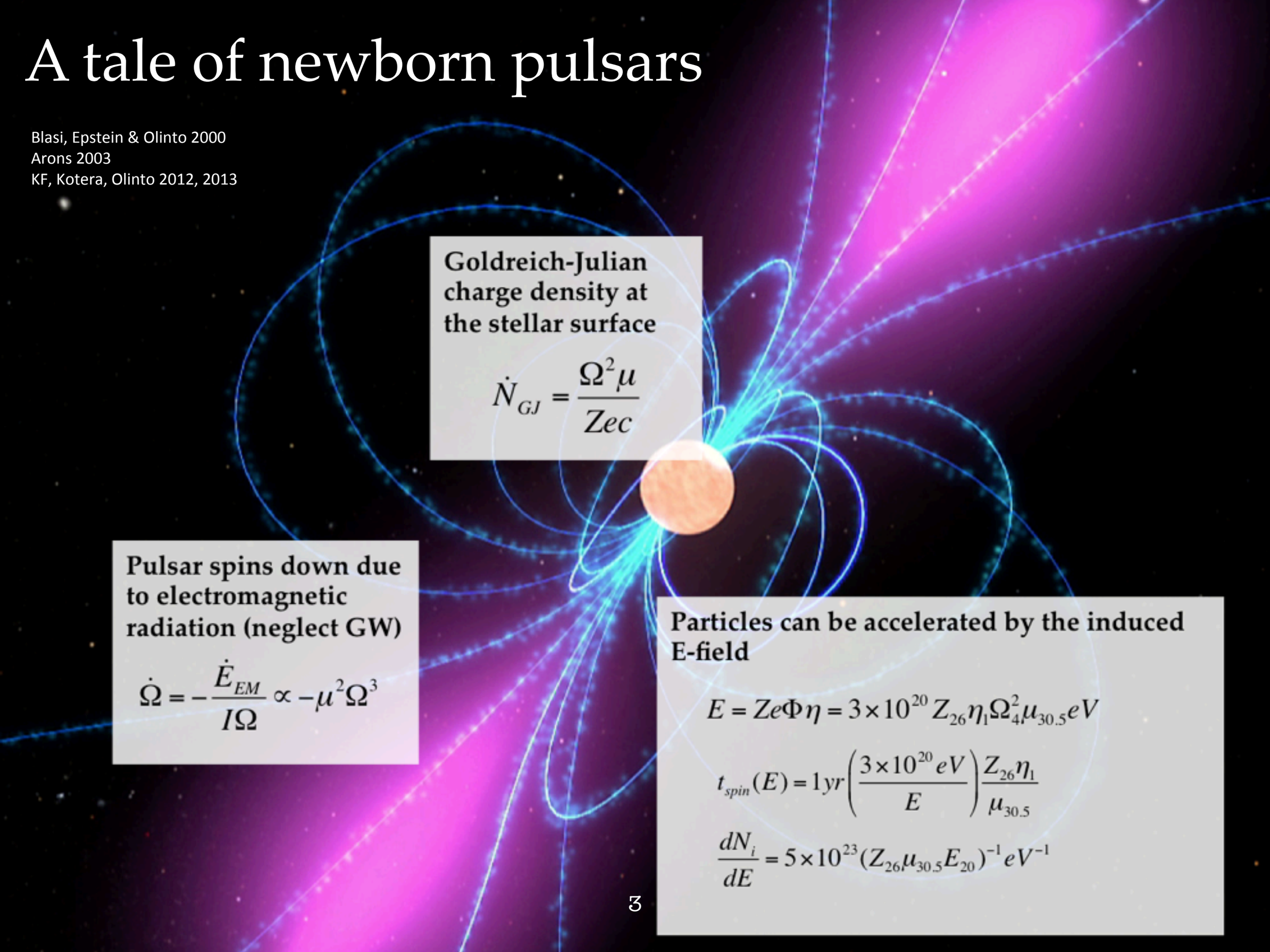
Hillas Diagram (1984)
updated Kotera & Olinto, 2011





A tale of newborn pulsars

Blasi, Epstein & Olinto 2000
Arons 2003
KF, Kotera, Olinto 2012, 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)

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

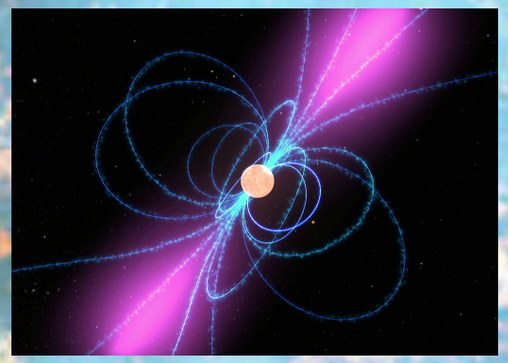
Particles can be accelerated by the induced E-field

$$E = Ze\Phi\eta = 3\times 10^{20} Z_{26}\eta_1 \Omega_4^2 \mu_{30.5} eV$$

$$t_{spin}(E) = 1yr\left(\frac{3\times 10^{20} eV}{E}\right)\frac{Z_{26}\eta_1}{\mu_{30.5}}$$

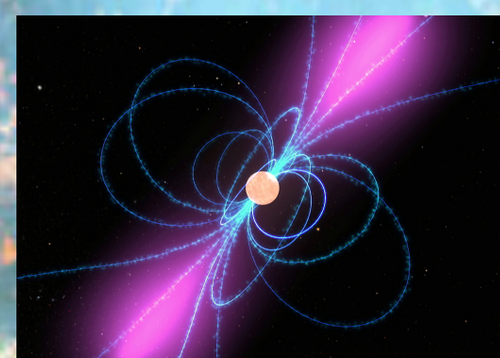
$$\frac{dN_i}{dE} = 5\times 10^{23}(Z_{26}\mu_{30.5}E_{20})^{-1} eV^{-1}$$

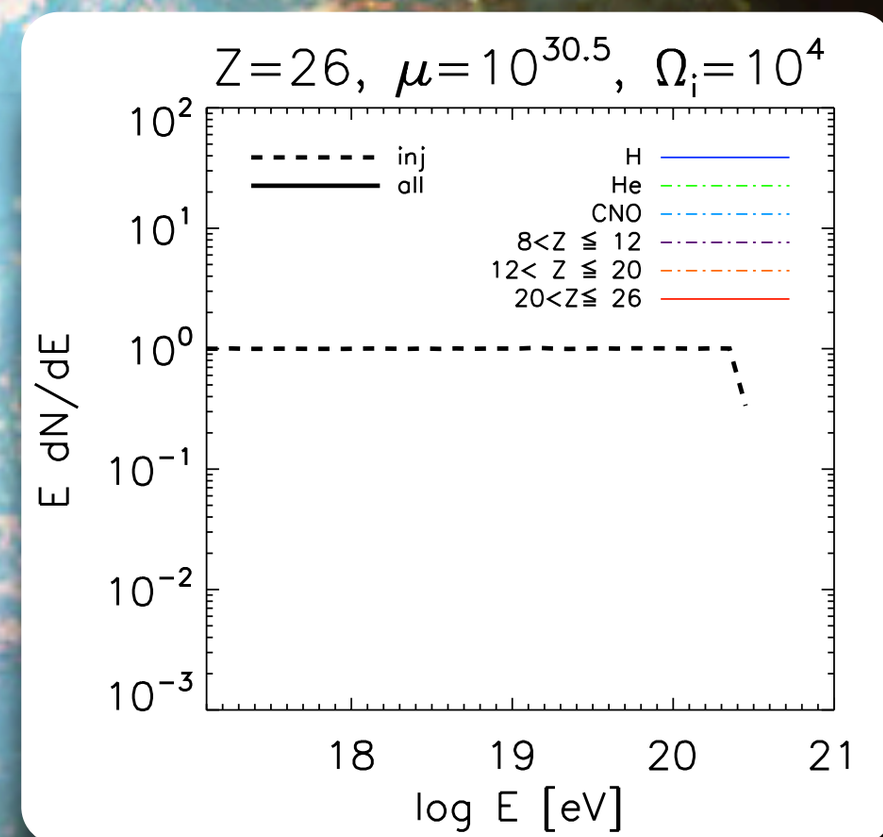
Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX



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

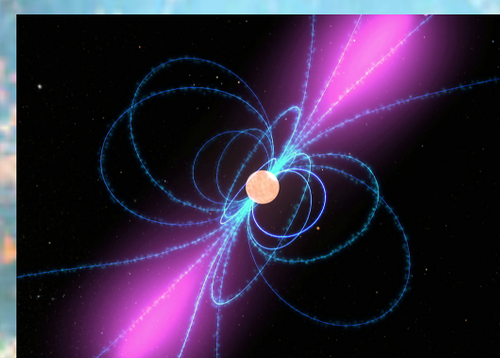
Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX

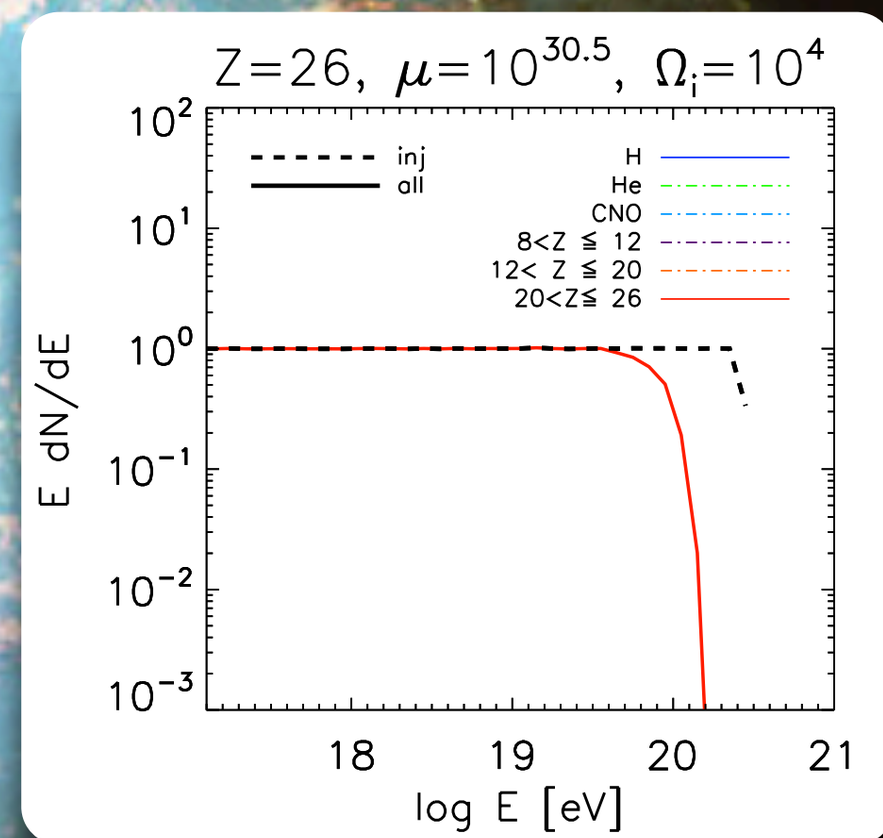




KF, Kotera & Olinto, ApJ, 750:118, 2012

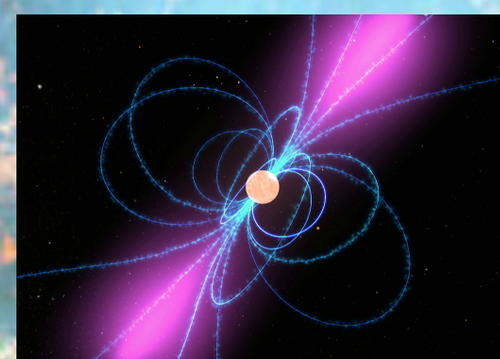
Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX

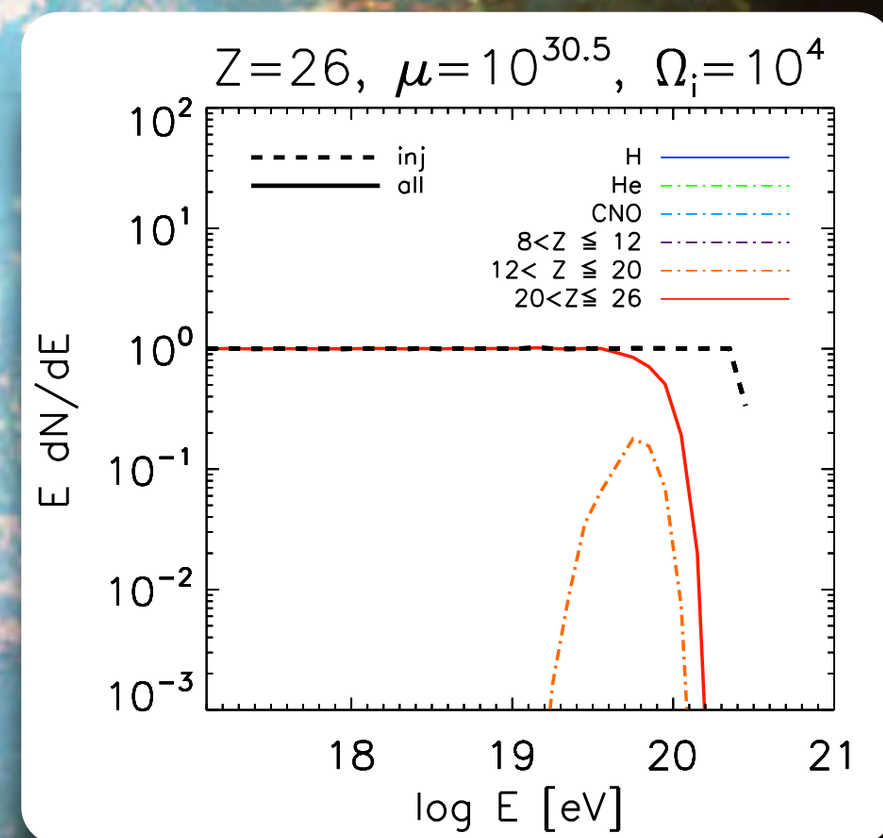




KF, Kotera & Olinto, ApJ, 750:118, 2012

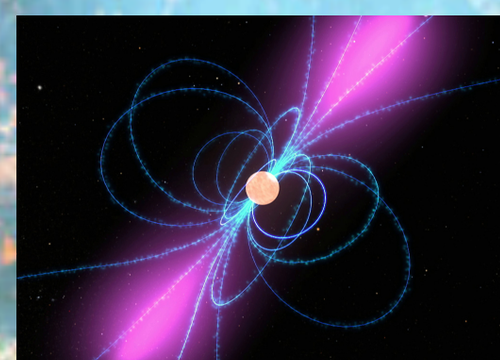
Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX

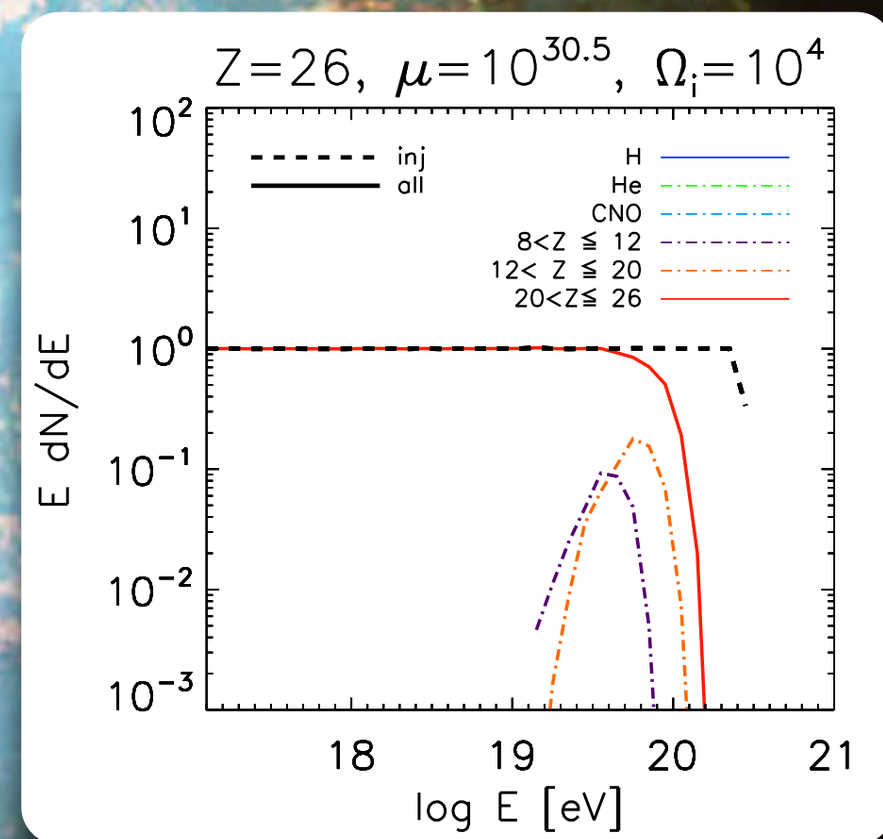




KF, Kotera & Olinto, ApJ, 750:118, 2012

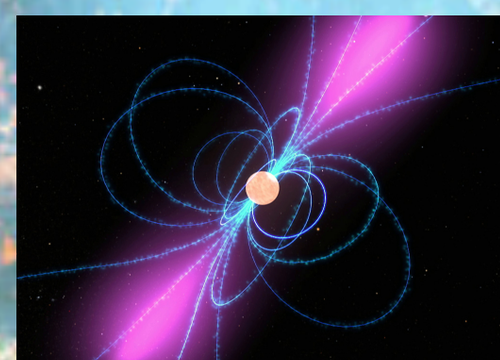
Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX

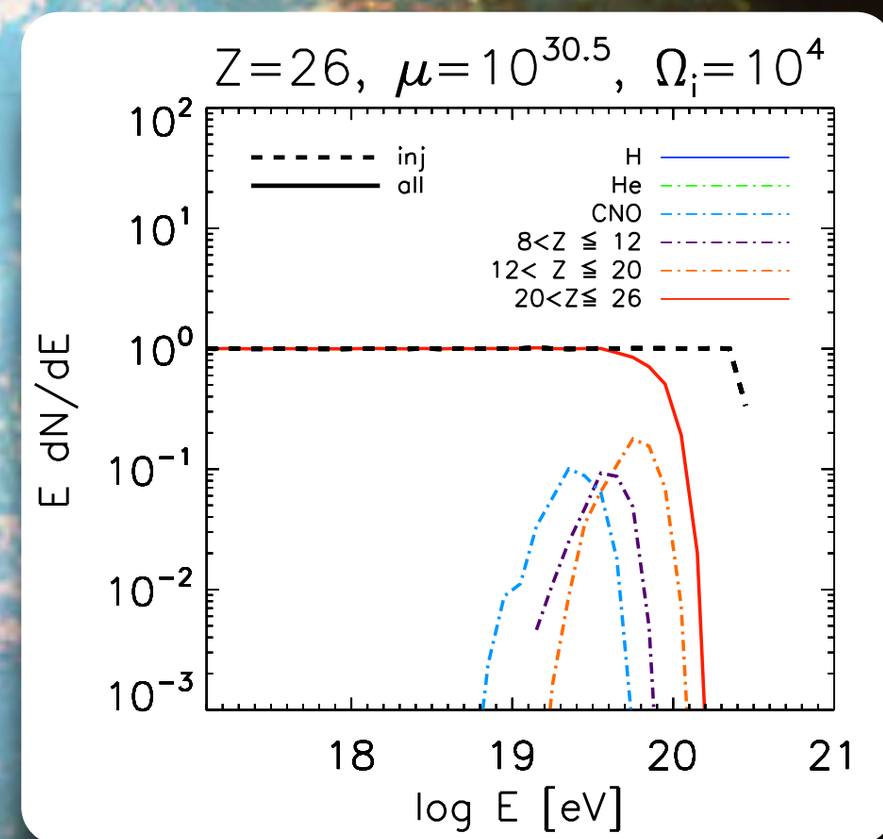




KF, Kotera & Olinto, ApJ, 750:118, 2012

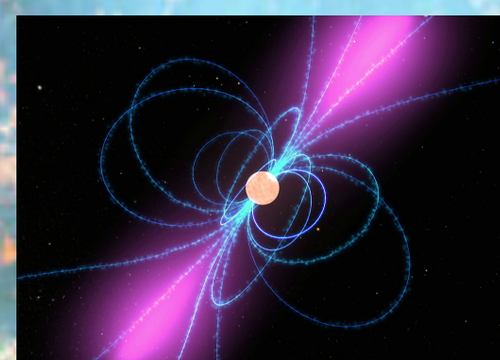
Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX

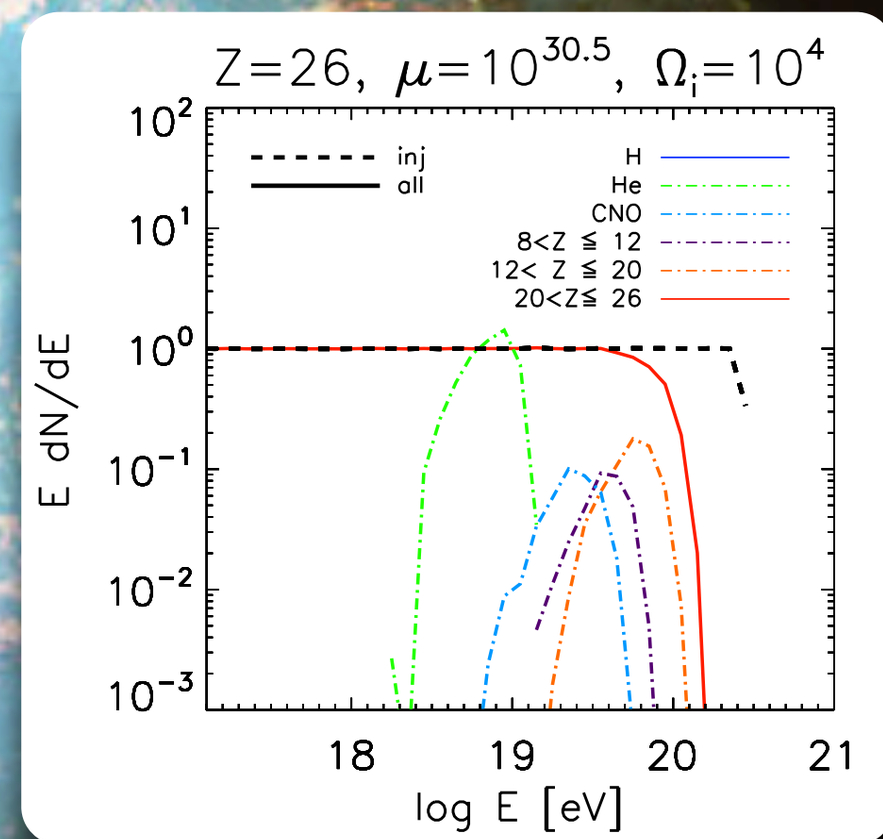




KF, Kotera & Olinto, ApJ, 750:118, 2012

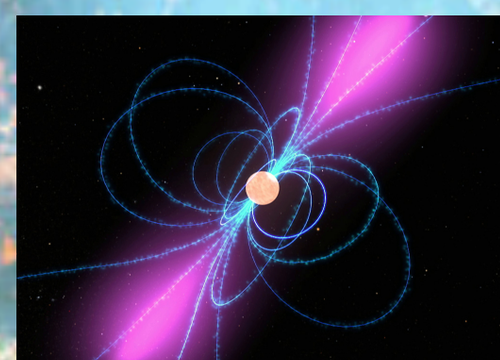
Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX

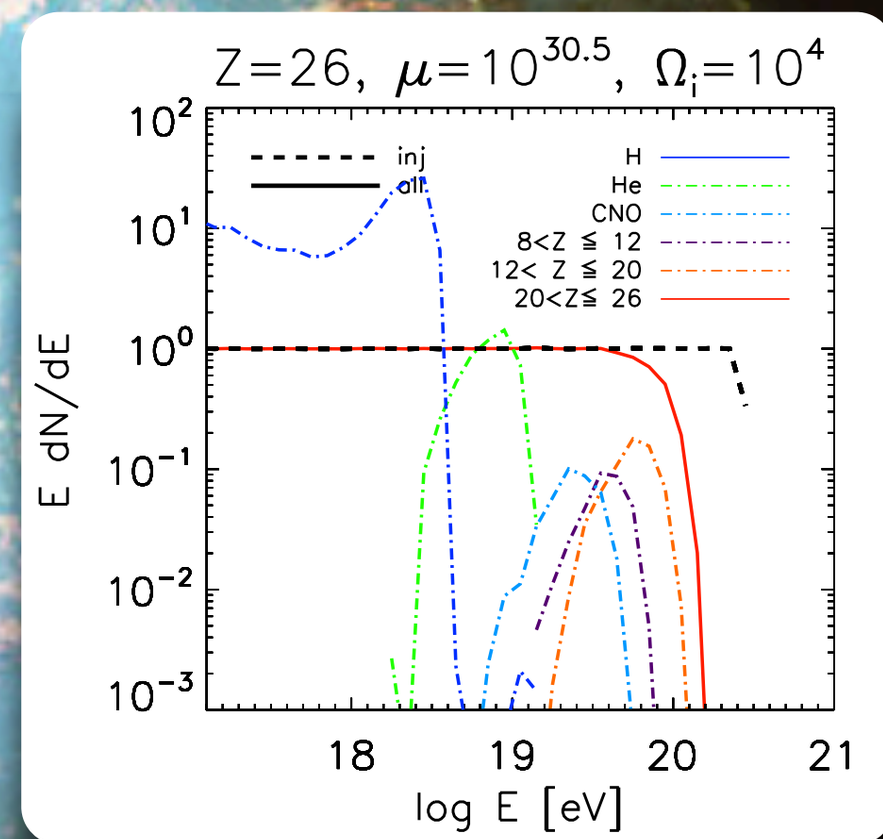




KF, Kotera & Olinto, ApJ, 750:118, 2012

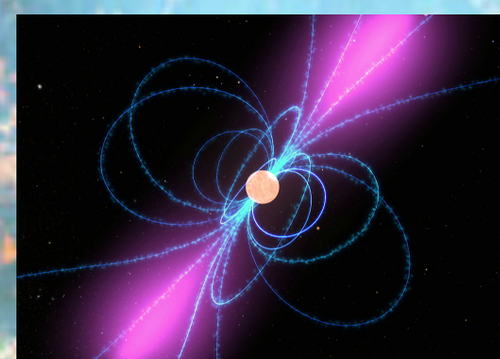
Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX

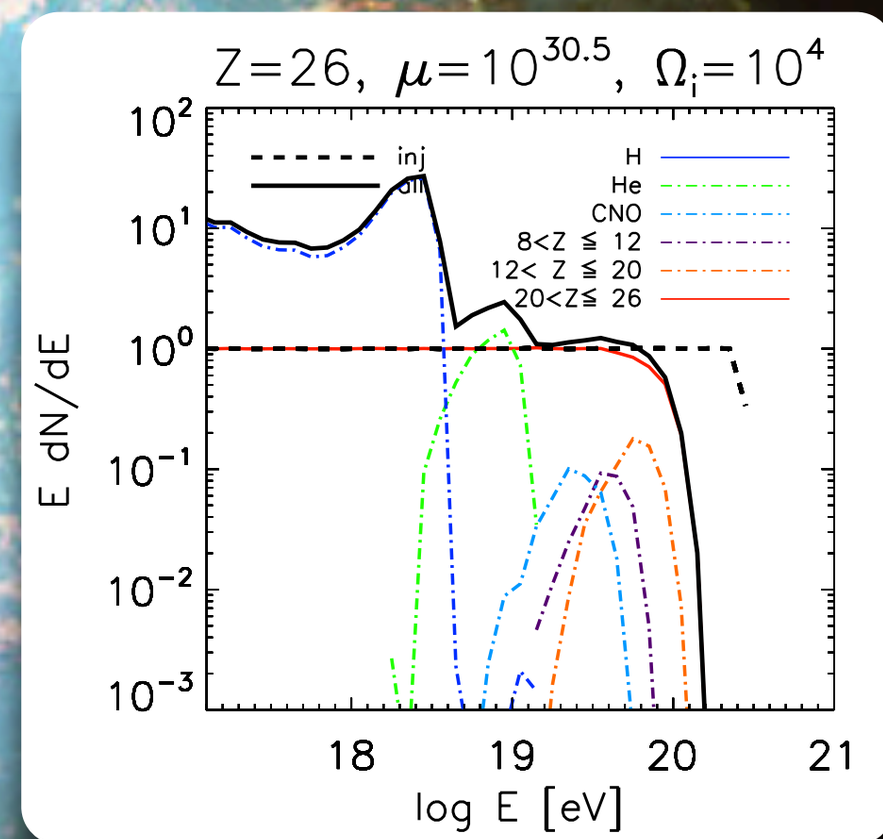




KF, Kotera & Olinto, ApJ, 750:118, 2012

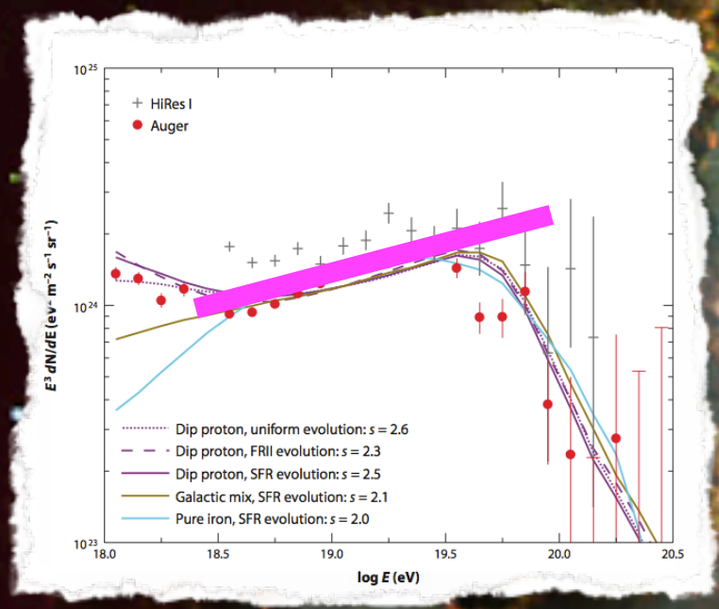
Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX

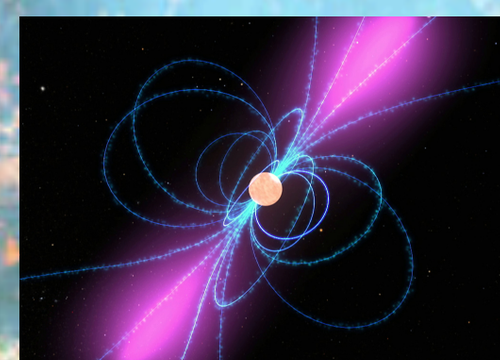


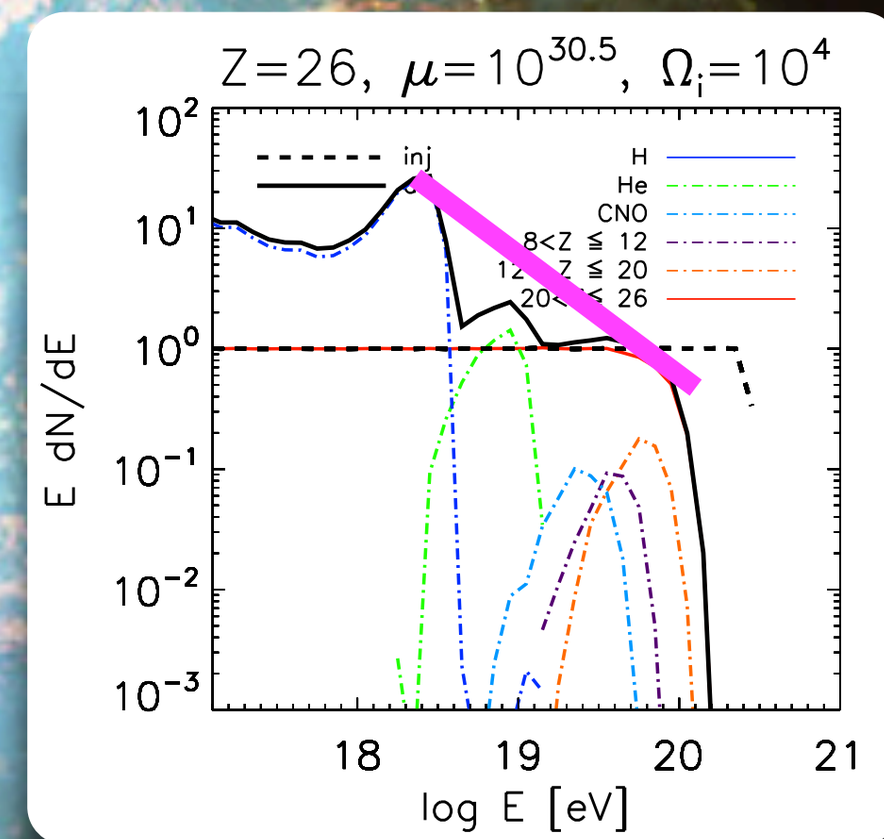


KF, Kotera & Olinto, ApJ, 750:118, 2012

Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX

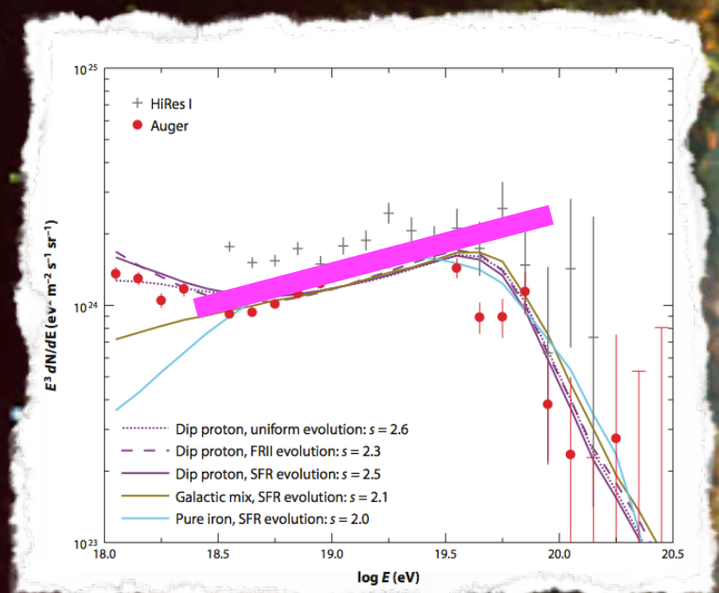


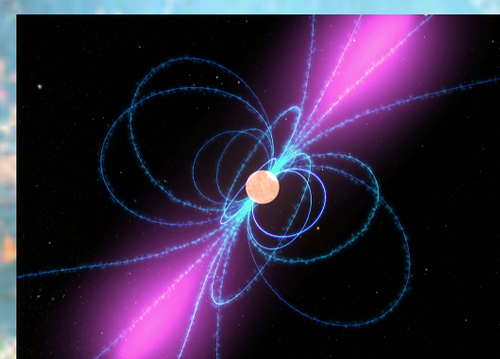


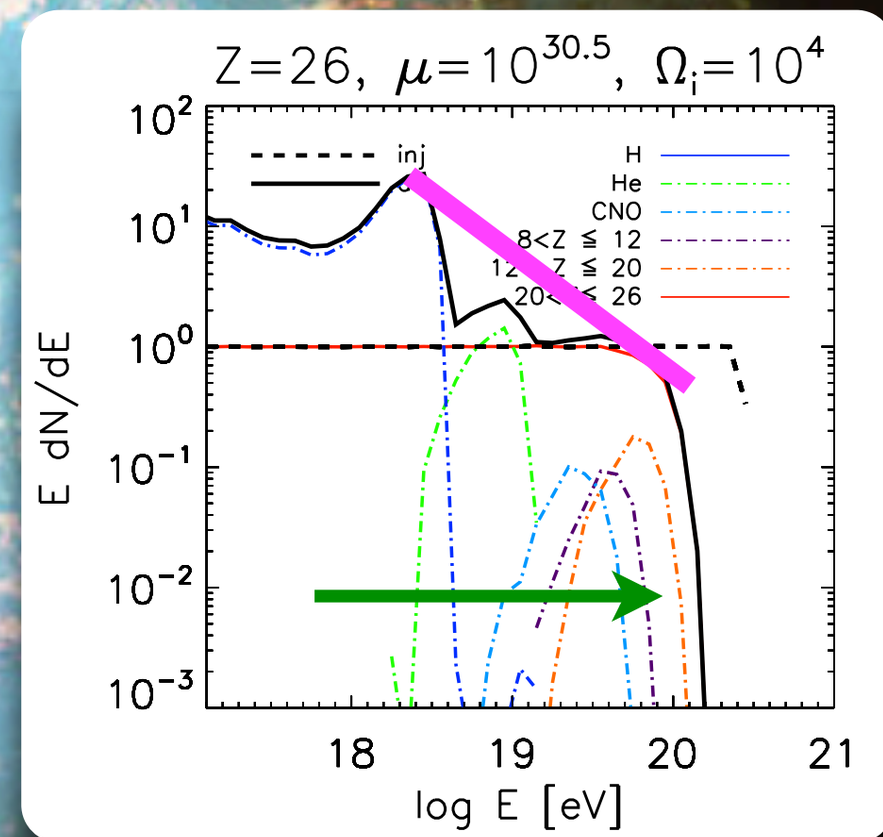


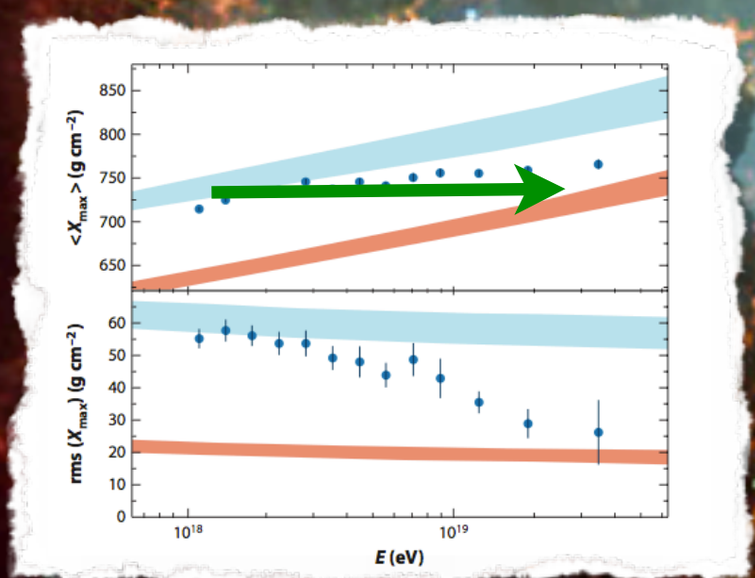
KF, Kotera & Olinto, ApJ, 750:118, 2012

Monte-Carlo propagation
hadron interactions simulated
with EPOS + CONEX



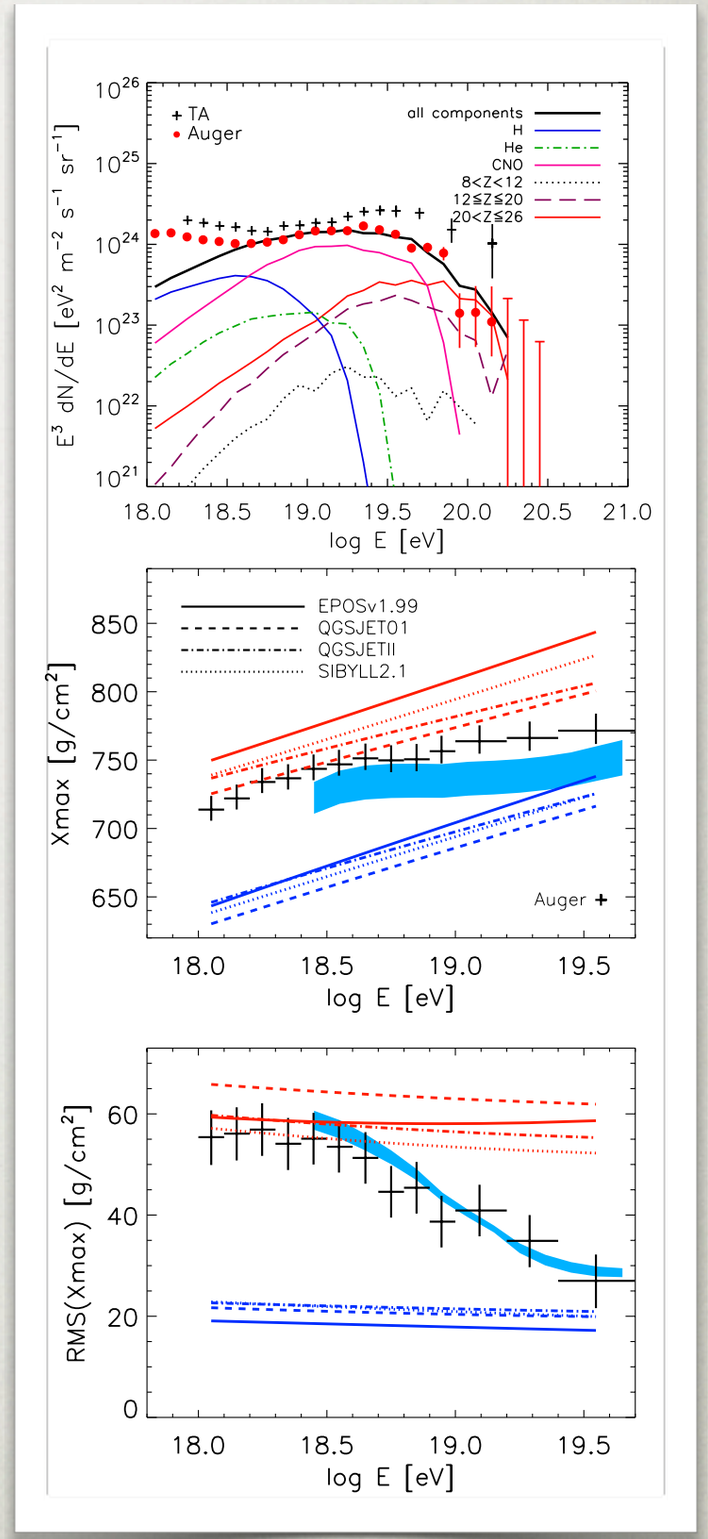




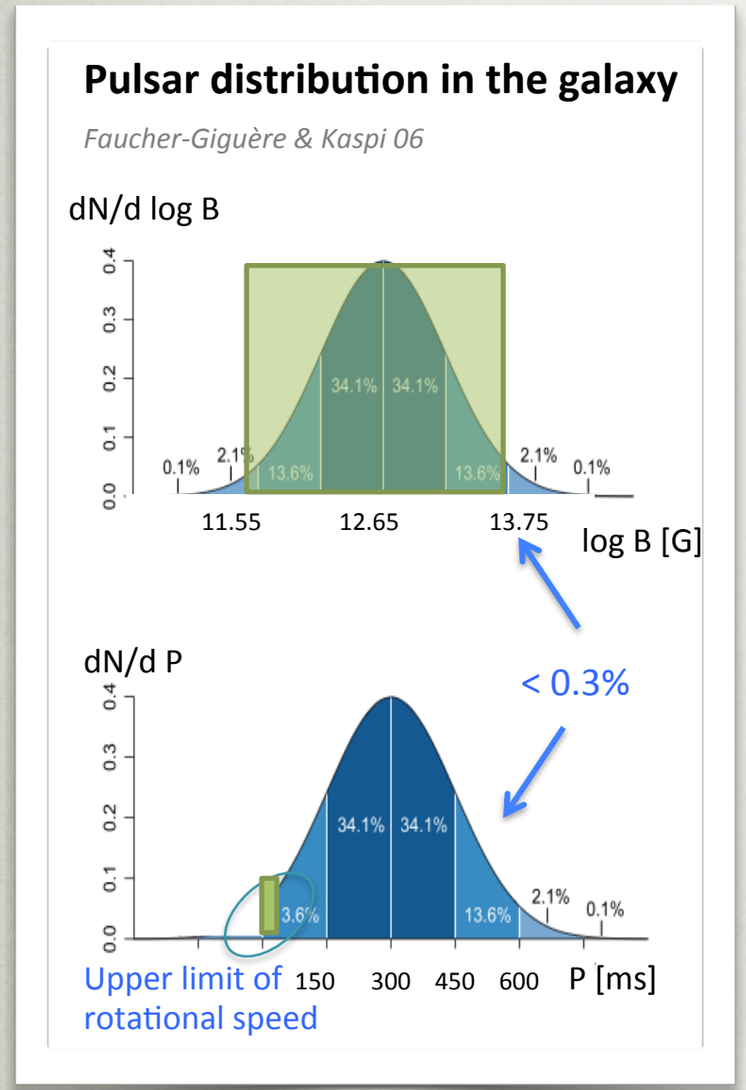


KF, Kotera & Olinto, ApJ, 750:118, 2012

Integrated Extragalactic Pulsars



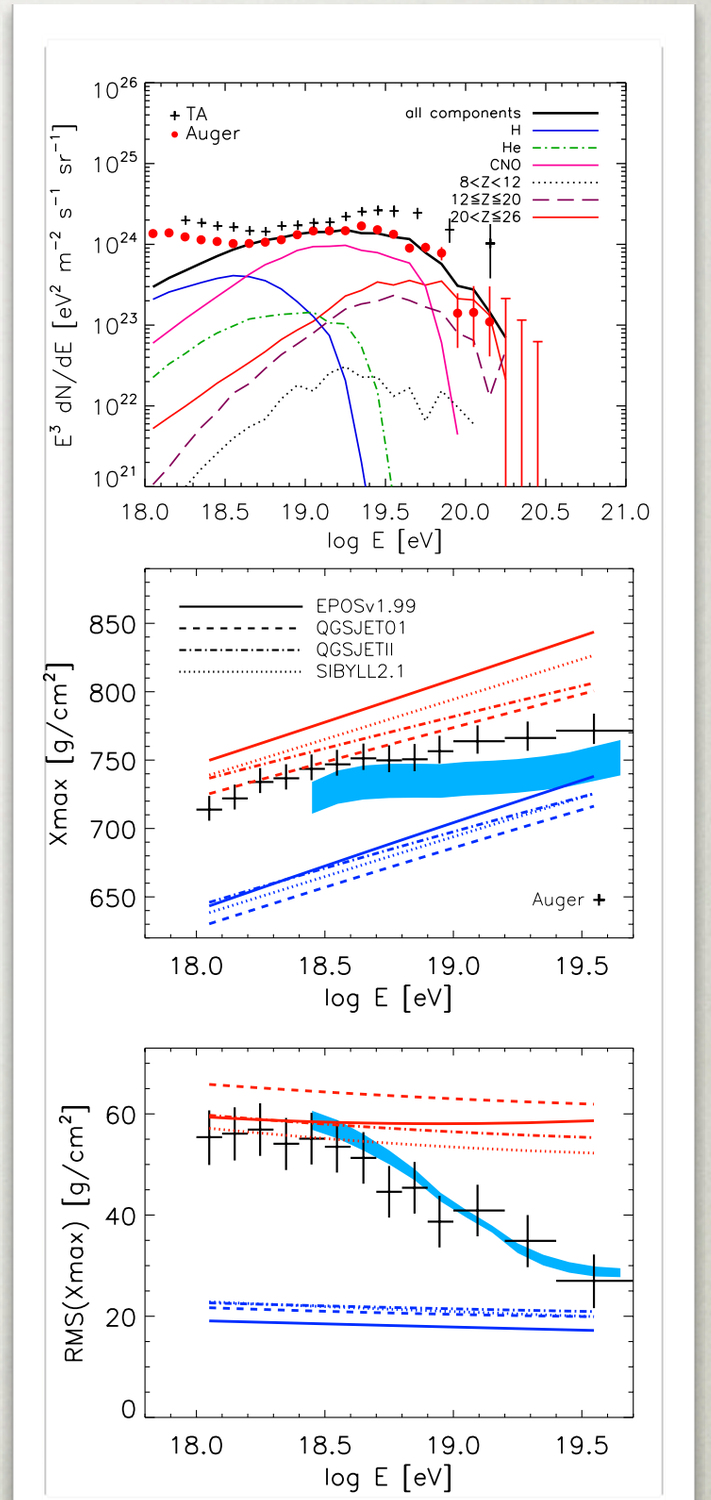
Integrated Extragalactic Pulsars



$$\frac{dN}{dE}(Z) = \int \frac{dN_{esc}}{dE}(\mu, \Omega, Z)\, f(\mu)\, f(\Omega)\, d\mu\, d\Omega$$

$$\Re(0) \approx 3.3 \times 10^{-4}\,\mathrm{yr}^{-1}\,\mathrm{Mpc}^{-3}$$

50%P + 30%CNO+20%Fe

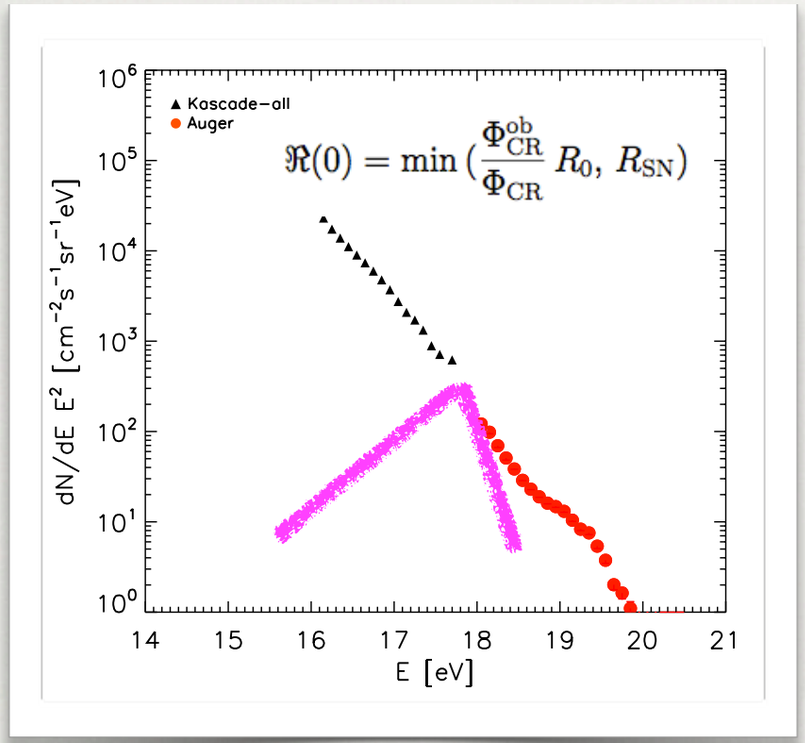


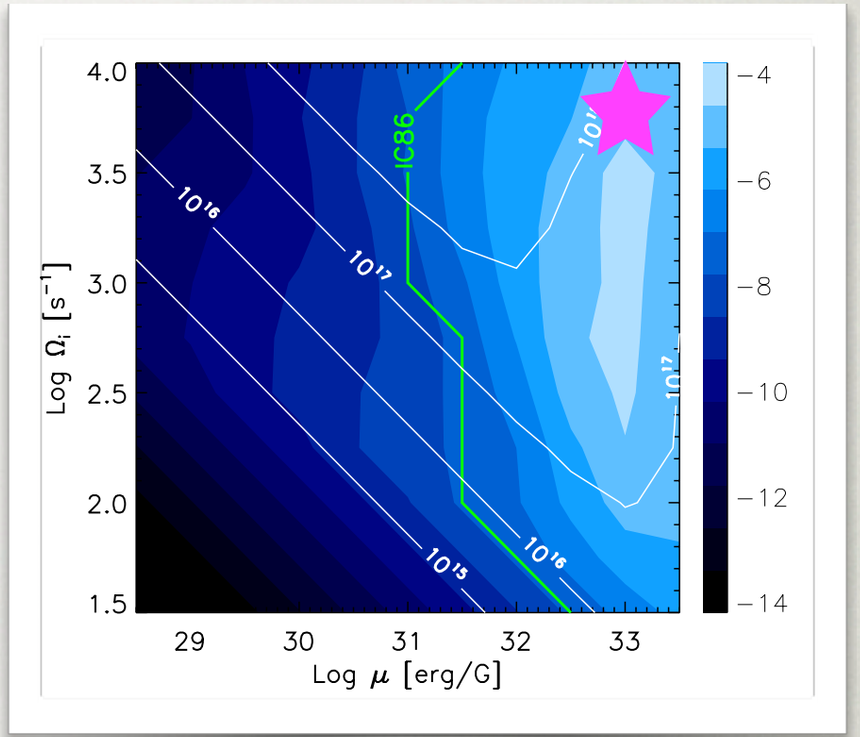
Conclusion I

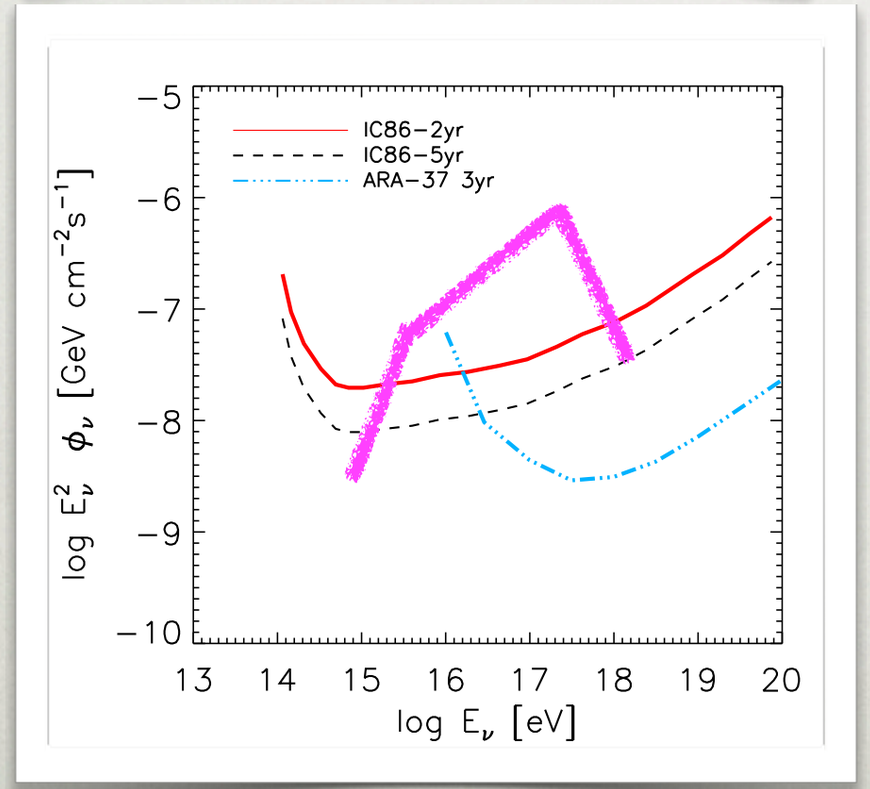
Newborn pulsars can be successful UHE sources!

On the non-detection of high energy neutrinos

KF, Kotera, Murase, Olinto, *in prep.*







Conclusion II

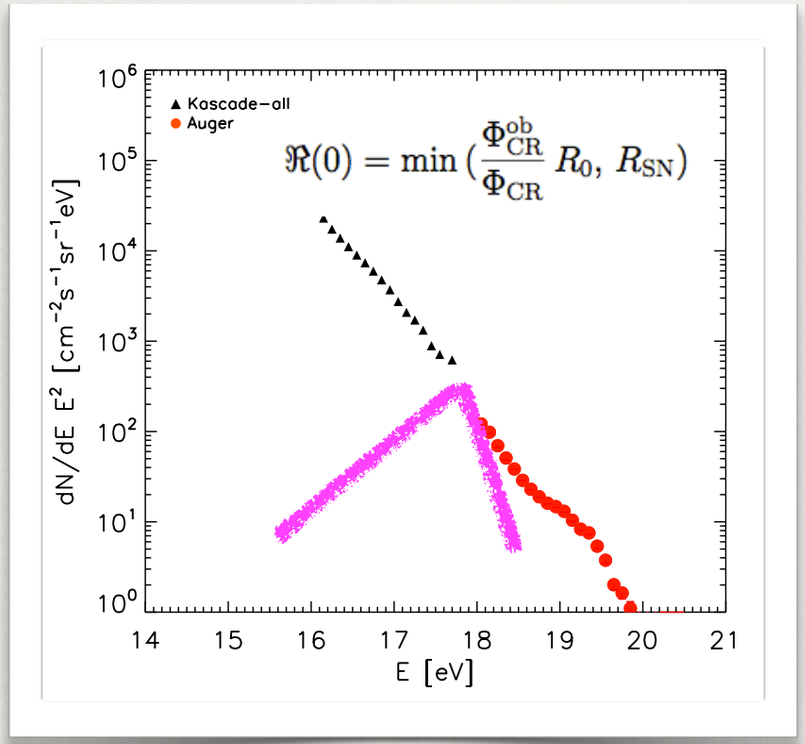
Magnetars with spherical structure cannot be the dominant UHE sources.

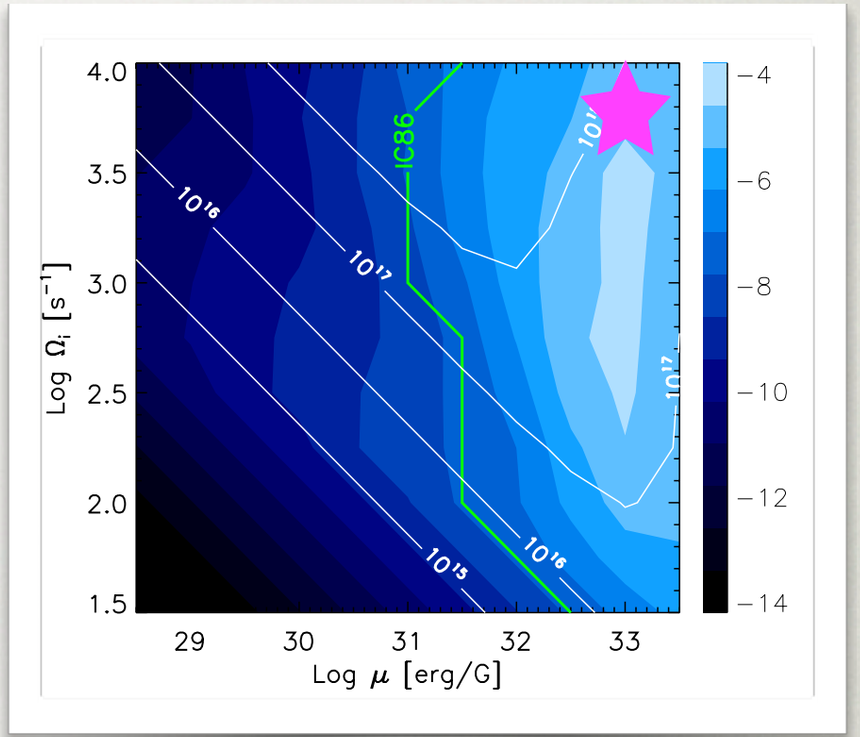
See poster for the destiny of pulsars with jets.

On the non-detection of high energy neutrinos

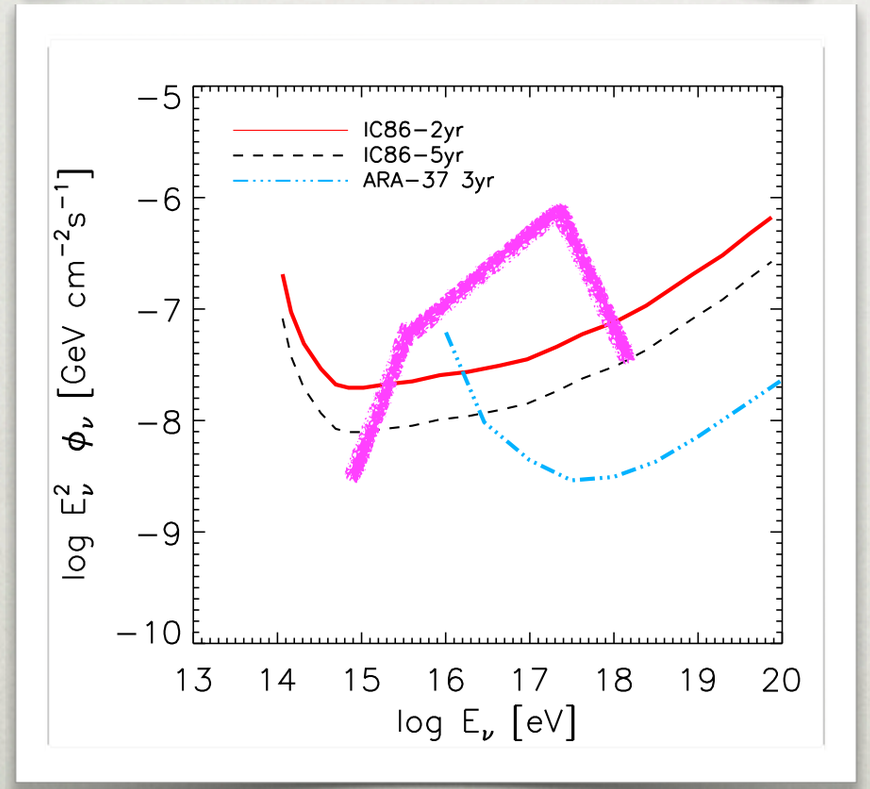
KF, Kotera, Murase, Olinto, *in prep.*

Using measured cosmic ray flux to confine source birthrate





Comparing the corresponding neutrino flux to detection upper limits



Conclusion II

Magnetars with spherical structure cannot be the dominant UHE sources.

See poster for the destiny of pulsars with jets.