27-31 August 2007 Venice, Italy

ltra High Energy Neutrino MENU:

sto: Neutrino-antineutrino annihilation in extradimensional scena

piatto: The target, the diffuse relic supernova neutrino flux

do piatto: The UHE neutrino beam, the GZK neutrinos

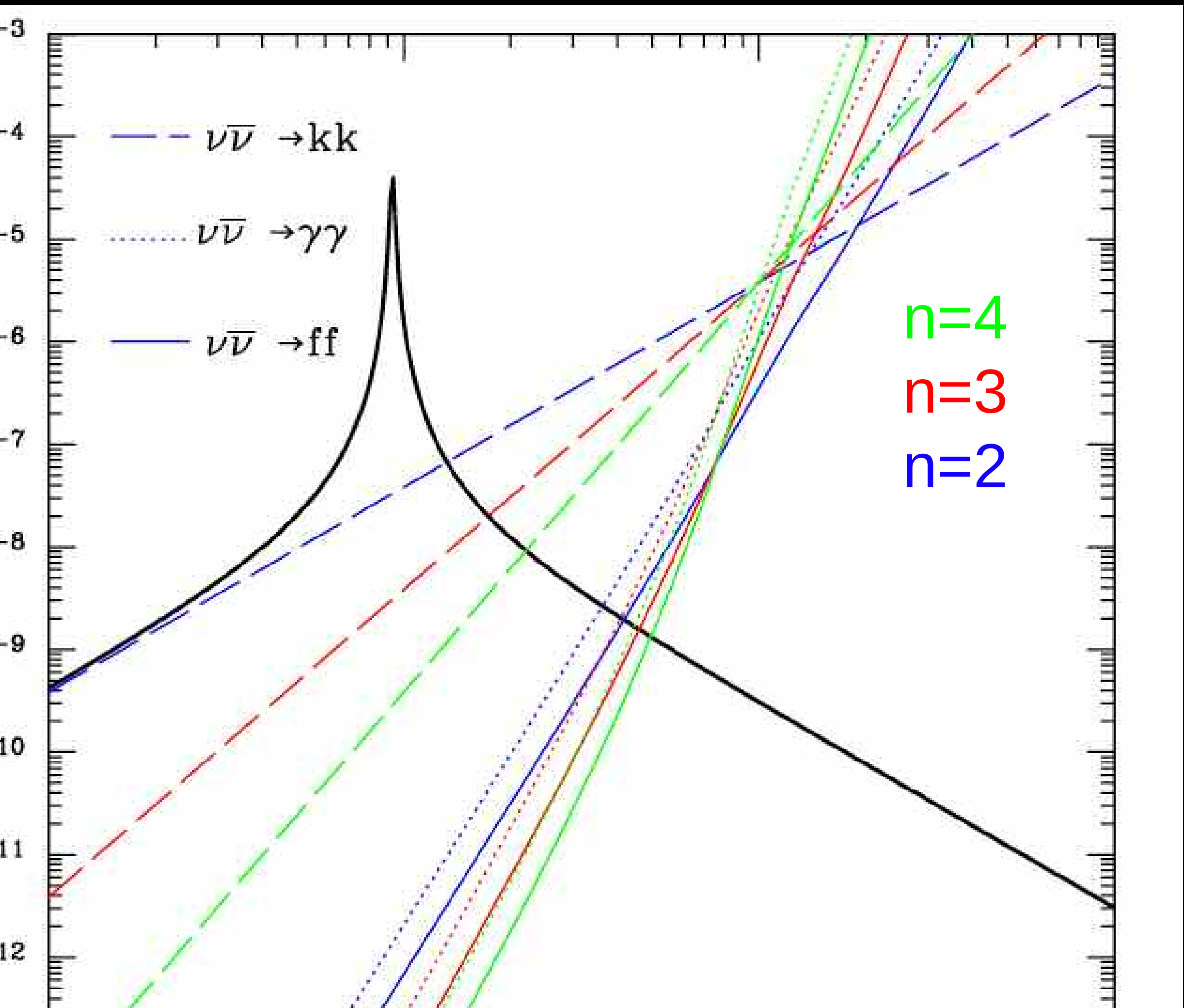
The UHE neutrino flux suppression

s, Arkani-Hamed, Dimopoulos & Dvali): (Antoniadis' talk)

$$\sigma_{\nu\bar{\nu}\to g_{KK}} = (\pi^2/s)(s/M_S^2)^{n/2+1}$$

(Han, Lykken & Zhang, PRD'99; Gupta, Goyal & Mahajan, PRD'01)

hysics scale M_S constrained from SN 1987A observations, star cooling dynamic
> 30, 4 and 1 TeV for n= 2, 3 and 4 ED



For n=4 ED, the total cross sect

$$\sigma_{\nu\bar{\nu}\to \mathrm{tot}} \approx 3\times 10^{-23}\left(\frac{\sqrt{s}}{10\ \mathrm{TeV}}\right)^{1}$$

Violates perturbative unitarity al
10 TeV (Giudice, Ratazzi & Wells, NPB

m: A "guaranteed" source of UHE neutrino fluxes, originated by the UHECR
ons with the CMB photons dominantly via Δ processes: GZK or cosmogenic neu
and Hooper talks)
get: The Diffuse cosmic supernovae neutrinos, sum of neutrinos from all past
vae. Detection of neutrinos from SN1987A proves its existence.

backgrounds"?

neutrino relics?

c neutrino background relics constitute an additional possible target.
.95 K temperature makes them a negligible "secondary target",
compared to the 10 MeV SN relic neutrinos.

interactions, neutrino-Nucleon in the atmosphere?

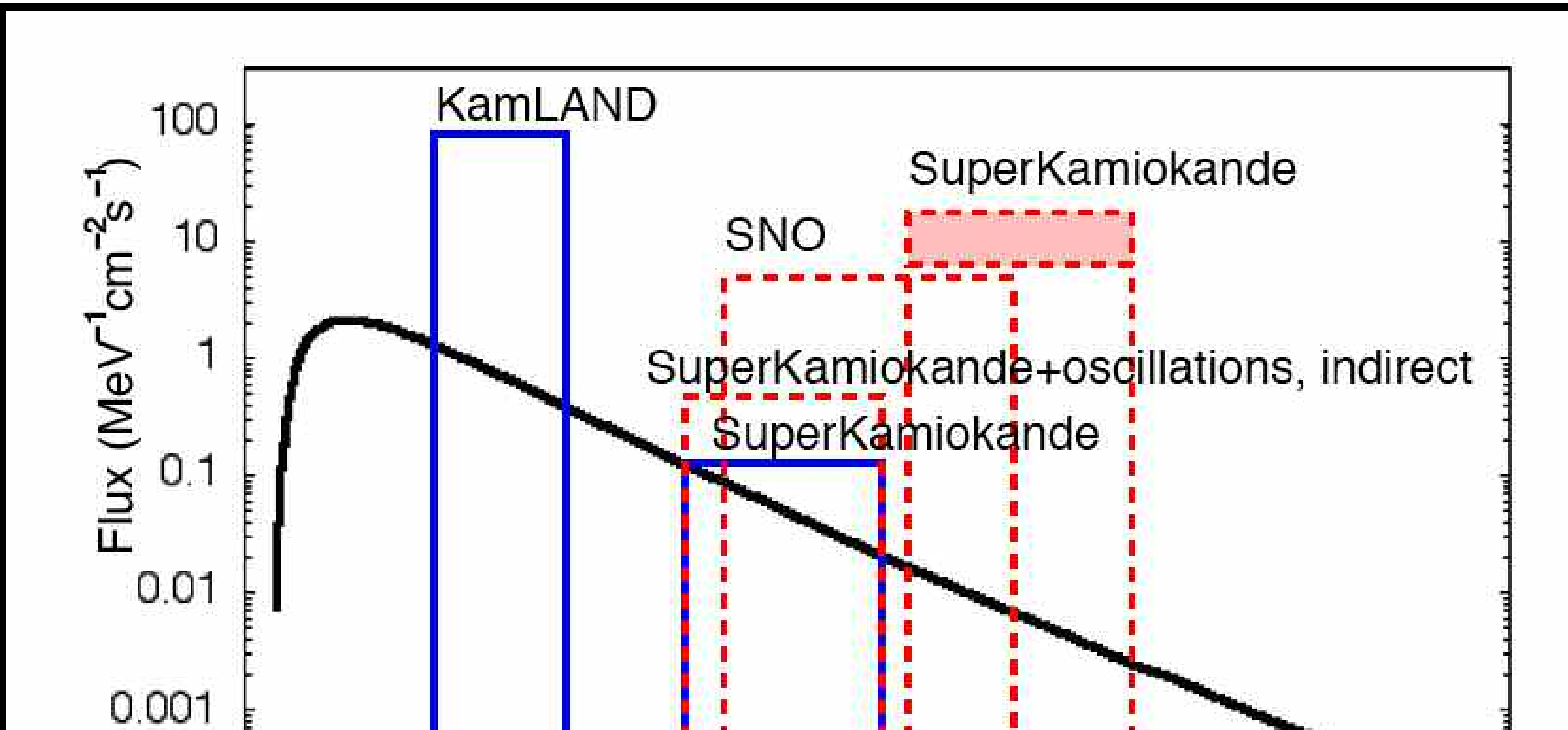
eutrino-Nucleon cross section is enhanced as well!
l., Alvarez-Muniz et al., Anchordoqui et al., Barger et al., Cullen et al.,
n et al., Goyal et al., Kowalski et al, Jain et al.)

ver, the UHE neutrino flux will be depleted in-route-to-the Earth,
interactions with the diffuse relic SN neutrinos

x of neutrinos from all SNe which have occurred along the universe's history.
rrent experimental limits:

xperiment,species	channel	energy interval	upper limit $(\mathrm{cm}^{-2}\mathrm{s}^{-1})$
amLAND, $\bar{\nu}_e$ [7]	$\bar{\nu}_e + p \rightarrow n + e^+$	$8.3 <$ E/MeV < 14.8	3.7×10^2 (90% C.L.)
K, $\bar{\nu}_e$ [3]	$\bar{\nu}_e + p \rightarrow n + e^+$	E/MeV>19.3	1.2 (90% C.L.)
K/indirect, ν_e [6]		E/MeV>19.3	5.5 ($\sim$ 98% C.L.)
K, ν_e [8]	$\nu_e + ^{16}\mathrm{O} \rightarrow ^{16}\mathrm{F} + e^-$	E/MeV>33	61-220 (90% C.L.)
NO, ν_e [9]	$\nu_e + ^2_1\mathrm{H} \rightarrow p + p + e^-$	$22.9 <$ E/MeV < 36.9	70
SD, $\nu_\mu + \nu_\tau$ [10]	$\nu_{\mu,\tau} + ^{12}\mathrm{C} \rightarrow ^{12}\mathrm{C} + \nu_{\mu,\tau}$	$20 <$ E/MeV < 100	$3 \cdot 10^7$ (90% C.L.)
SD, $\bar{\nu}_\mu + \bar{\nu}_\tau$ [10]	$\bar{\nu}_{\mu,\tau} + ^{12}\mathrm{C} \rightarrow ^{12}\mathrm{C} + \bar{\nu}_{\mu,\tau}$	$20 <$ E/MeV < 100	$3.3 \cdot 10^7$ (90% C.L.)

Lunardini,
eutrino'06

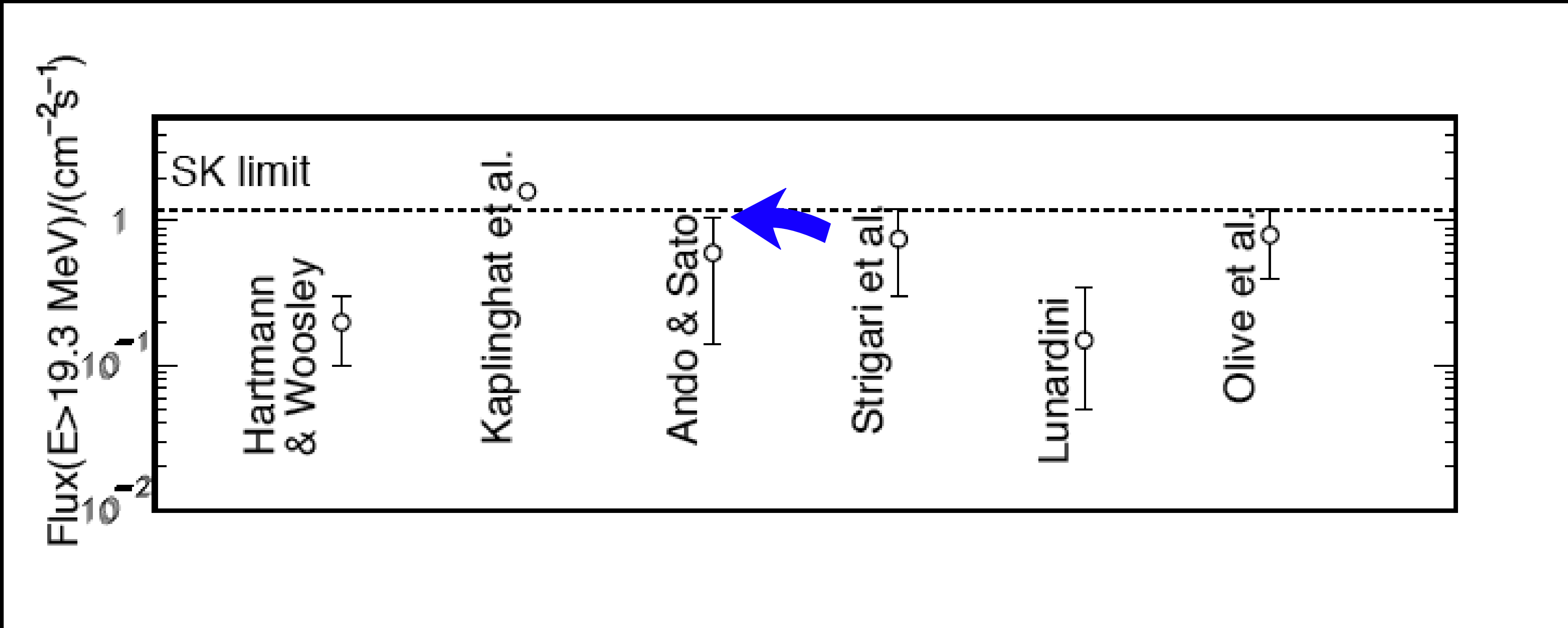


ally:

$$\Phi(E) = \frac{c}{H_0} \int_0^{z_{max}} R_{SN}(z) \sum_{w=e,\mu,\tau} \frac{dN_w(E')}{dE'} P_{we}(E,z) \frac{dz}{\sqrt{\Omega_m (1+z)^3 + \Omega_\Lambda}}$$

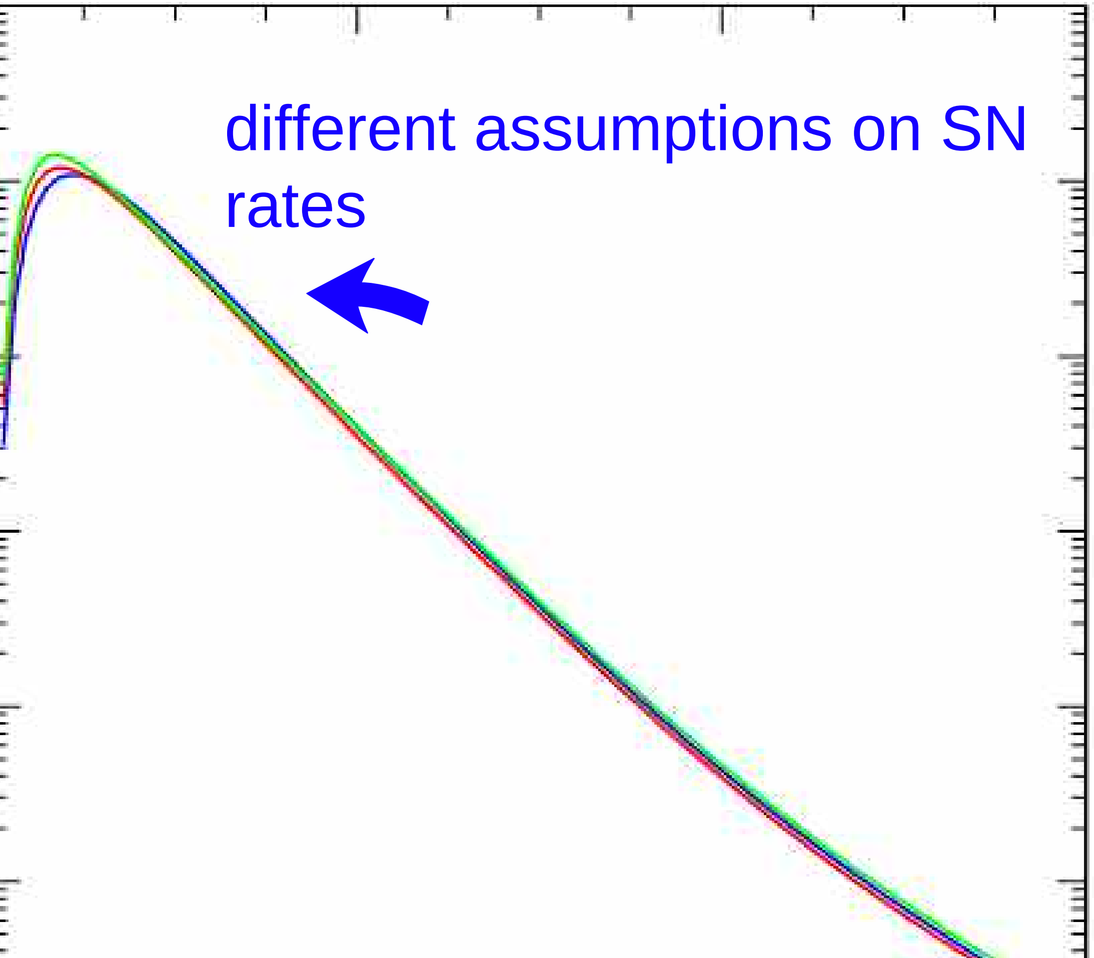
ent theoretical predictions due to the different assumptions on SFRs and umerical simulations of the neutrino spectra

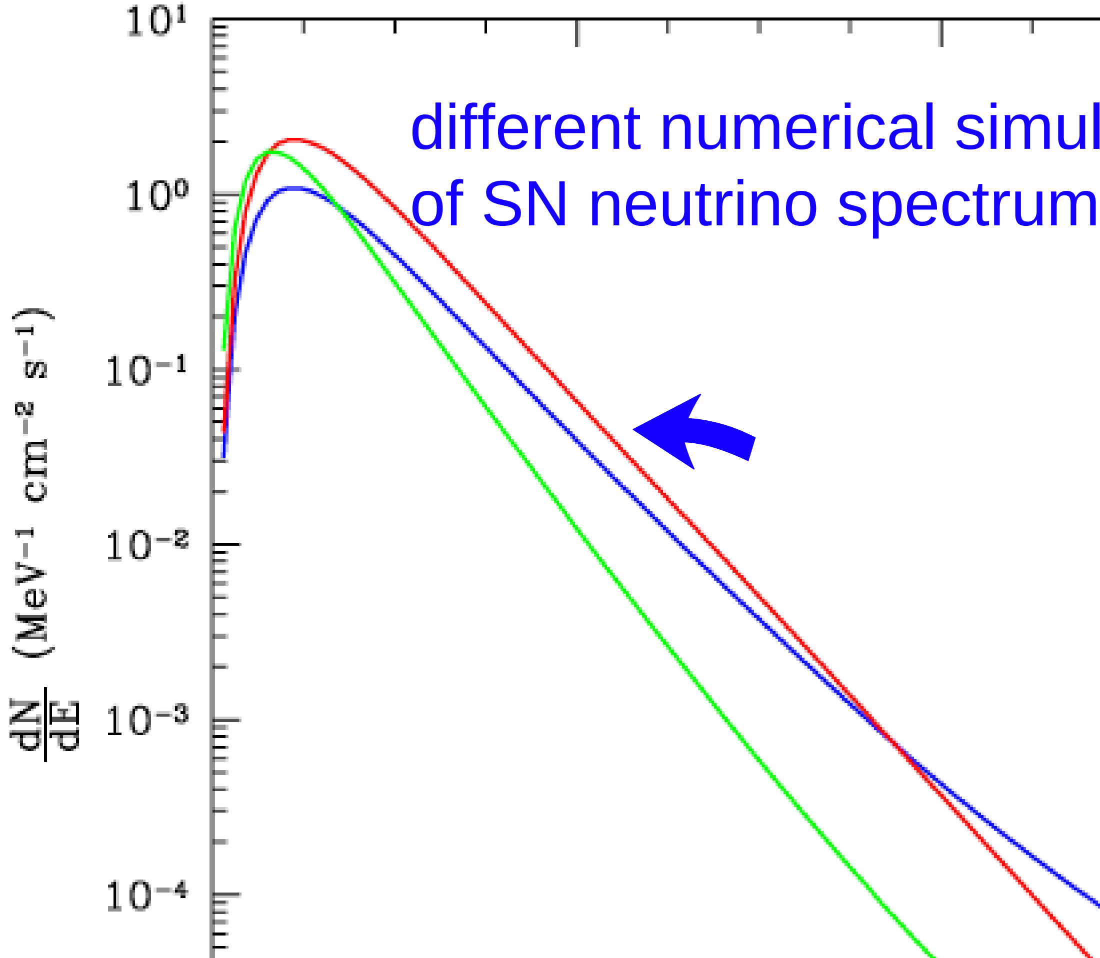
unardini,
rino'06



$$\Phi(E) = \frac{c}{H_0} \int_0^{z_{max}} R_{SN}(z) \sum_{w=e,\mu,\tau} \frac{dN_w(E')}{dE'} P_{we}(E,z) \frac{dz}{\sqrt{\Omega_m(1+z)^3 + \Omega_\Lambda}}$$

ent theoretical predictions due to different assumptions on SN rates,
ent numerical simulations of the neutrino spectrum and others.





$$\Phi(E) = \frac{c}{H_0}\int_0^{z_{max}} R_{SN}(z) \sum_{w=e,\mu,\tau} \frac{dN_w(E')}{dE'} P_{we}(E,z) \frac{dz}{\sqrt{\Omega_m(1+z)^3+\Omega_\Lambda}}$$

IEGLECT FLAVOR OSCILLATION EFFECTS INSIDE THE STAR because the dimensional neutrino-antineutrino interaction is FLAVOR BLIND!

= 5 (Epoch where gravitational collapse is supposed to start)

te is a fraction of the Star Formation Rate:

$$R_{sn}(z) \; = \; 0.0122 \times 0.32 h_{70} \frac{\exp(3.4z)}{\exp(3.8z)+45} \times \left[\frac{\Omega_m(1+z)^3+\Omega_\Lambda}{(1+z)^3}\right]^{1/2} \; \mathrm{yr}^{-1}\ \mathrm{Mpc}^{-3}$$

Porciani & M

hermal relic SN neutrino spectra is:

$$
\begin{aligned}
P(E_{\nu,\mathrm{uhe}}; z_{\mathrm{uhe}}) &= \exp\left[-c\int_0^{z_{\mathrm{uhe}}} dz' \frac{dt}{dz'} \mathcal{L}^{-1}(E_{\nu,\mathrm{uhe}}, z')\right] \\
&= \exp\left[-\mathcal{K}\frac{c}{H_0^2}\int_0^{z_{\mathrm{uhe}}} \frac{dz'}{(1+z')\sqrt{\Omega_m(1+z')^3+\Omega_\Lambda}}\right. \\
&\quad \times \int_{z'}^{z_{\mathrm{sn,max}}} \frac{dz}{(1+z)^{3/2}} \frac{\exp(3.4z)}{\exp(3.8z)+45} \\
&\quad \times \left.\int_0^{E'_{\nu,\mathrm{sn,max}}} dE_{\nu,\mathrm{sn}} \frac{dN_{\bar{\nu},\mathrm{sn}}}{dE_{\nu,\mathrm{sn}}} \sigma_{\nu\bar{\nu}}(s)\right]
\end{aligned}
$$

really ugly and complicated but is just the exponential of the annihilation section times the relic SN neutrino number density!

free path for 10^{19} eV GZK neutrino in our local universe (z=0): 37 Mpc

$$E_\nu J_{\nu,\mathrm{GZK}} = \mathcal{N}_{\mathrm{CR}} \int_0^{z_{\max}} dz_{\mathrm{uhe}} \frac{S(z_{\mathrm{uhe}}) P(E_\nu; z_{\mathrm{uhe}})}{\sqrt{\Omega_m (1+z_{\mathrm{uhe}})^3 + \Omega_\Lambda}} \times \int dE_p^s \frac{dN_p}{dE_p^s} Y(E_p^s, E_\nu, z_{\mathrm{uhe}})$$

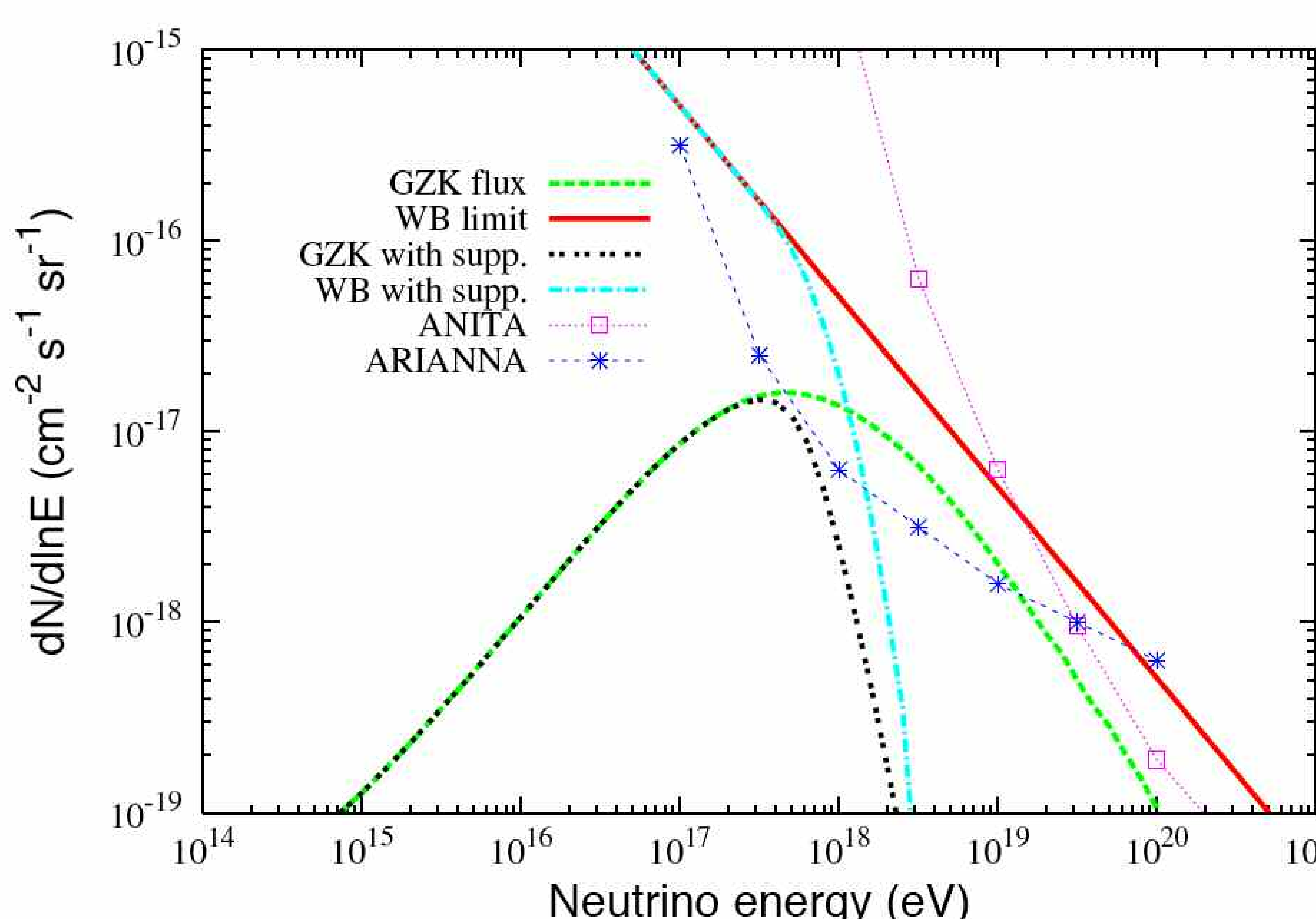
normalization factor which accounts for the observed UHECR fluxes.

sents the CR source redshift evolution.

UHE neutrino survival probability.

neutrino yield function, the number of secondary neutrinos generated per
ergy interval by a CR proton, due to their interactions with CMB photons.
IA Monte Carlo code, Engel, Seckel & Stanev PRD'01, Mucke et al'99.)

proton injection spectra (dN/dE) has an exponential cutoff at 3 x 10^{21} eV and
en integrated over the 10^{19} - 10^{22} eV energy range.



GZK flux
WB limit
GZK with supp.
WB with supp.
ANITA
ARIANNA
dN/dlnE (cm^-2 s^-1 sr^-1)
Neutrino energy (eV)
10^-15
10^-16
10^-17
10^-18
10^-19
10^14
10^15
10^16
10^17
10^18
10^19
10^20

usions

exists n=4 ED in nature and the SN relic neutrino flux is at the level of current the
tions, UHE neutrinos can not be the primaries responsible for the very high ene
events due to their annihilation with the relic SN neutrinos.

n=2,3 and/or the SN relic neutrino flux is detected at a much lower level
rent theoretical expectations, the flux suppression will occur at higher energies,
e effect will be more difficult to detect.

g an ED enhancement of UHE neutrino cross sections at ongoing/future neutrin
tories (ANITA, ARIANNA): extremely difficult.
utrinos would be depleted in their way to the Earth!

a < 10^{20} eV neutrino interact beyond the standard model with any
ground?

Large extra-dimensional models

(Antoniadis, Arkani-Hamed, Dimopoulos & Dvali)

Fast rising cross sections

Already explored for enhanced neutrino-Nucleon interactions to explain
CR data above GZK energy

Diffuse 10 MeV neutrinos from all past Supernovae

Detection of neutrinos from SN1987A proves its existence

0’s, Antoniadis, Arkani-Hamed, Dimopoulos and Dvali took a fresher look into th
y problem, i.e., why there is a desert between the electroweak and Planck scale
the electroweak scale is the only fundamental short distance in nature and the
onal force becomes similar to the gauge forces at the electroweak scale!

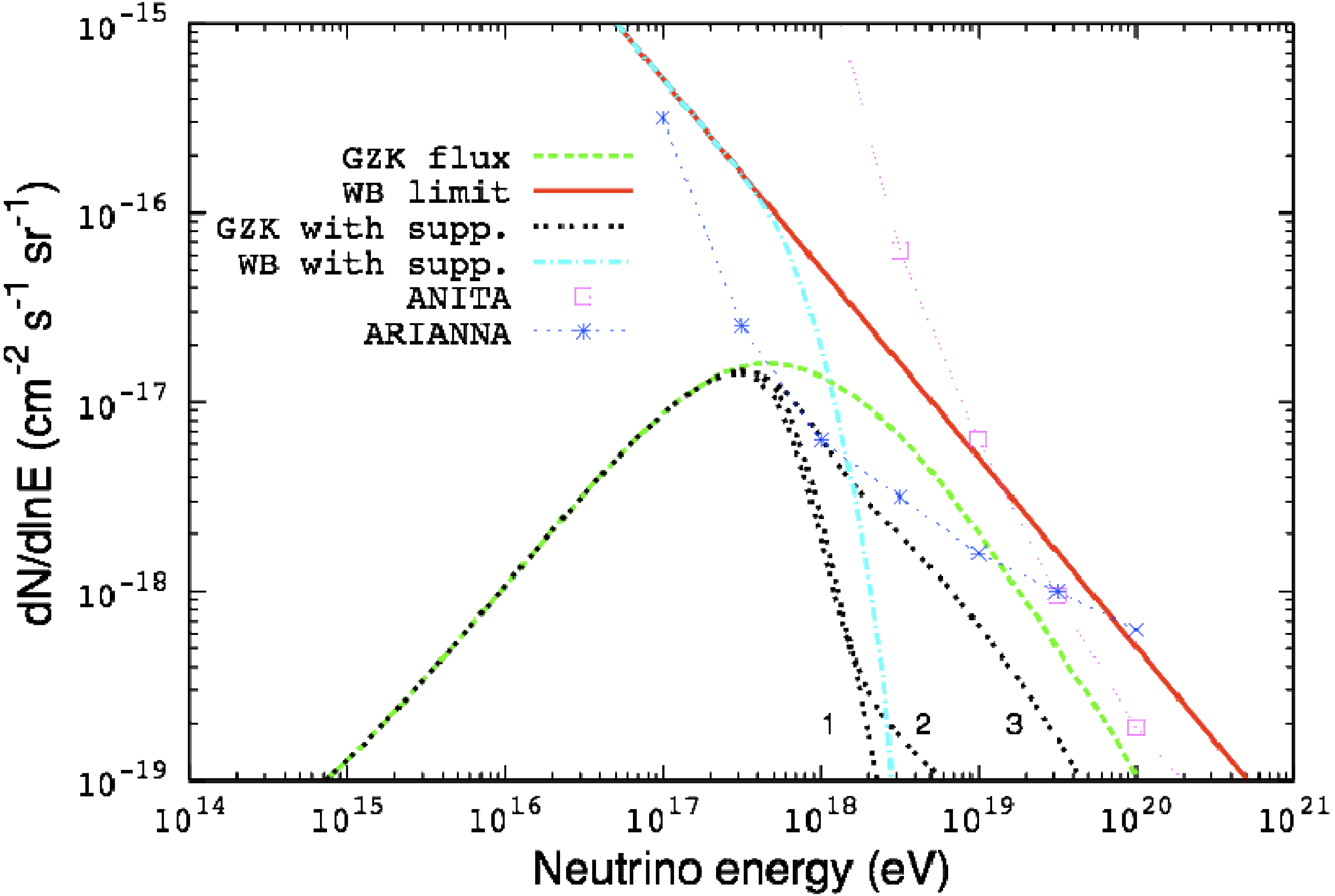
e observed value of our Planck scale is caused by the new spatial extra dimens
gets diluted” into the extra dimensions. The gravitational potential falls off faster
s smaller than R. At larger distances, the newtonian behavior is recovered.

e called large because R is much larger than the inverse of the fundamental sca

exists n extra compact spatial dimensions of radius R, and the 4+d Planck scal
veak scale:

$$ {}^{2}_{Pl} \sim M^{2+n}_{Pl(4+n)} R^n \qquad R \sim 10^{\frac{30}{n}-17}\mathrm{cm} \times \left(\frac{1\mathrm{TeV}}{m_{EW}}\right)^{1+\frac{2}{n}} $$

e massless 4+d graviton can freely propagate in the extradimensions, which car
s a number of massive Kaluza Klein (KK) fields propagating in our 4d world.
e theories have been formulated involving KK exchange at very high values of t
of mass energy


GZK flux
WB limit
GZK with supp.
WB with supp.
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2
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dN/dlnE (cm^{-2} s^{-1} sr^{-1})
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10^{-17}
10^{-18}
10^{-19}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}

Kay, Panda and Ralston, PLB'00