INR, Moscow,
April 16, 2005

THE SUN AS AN ULTRA-HIGH-ENERGY NEUTRINO TELESCOPE?

Malcolm FAIRBAIRN (Stockholm U.)

Timur RASHBA (MPI, Munchen)

Sergey TROITSKY (INR, Moscow)

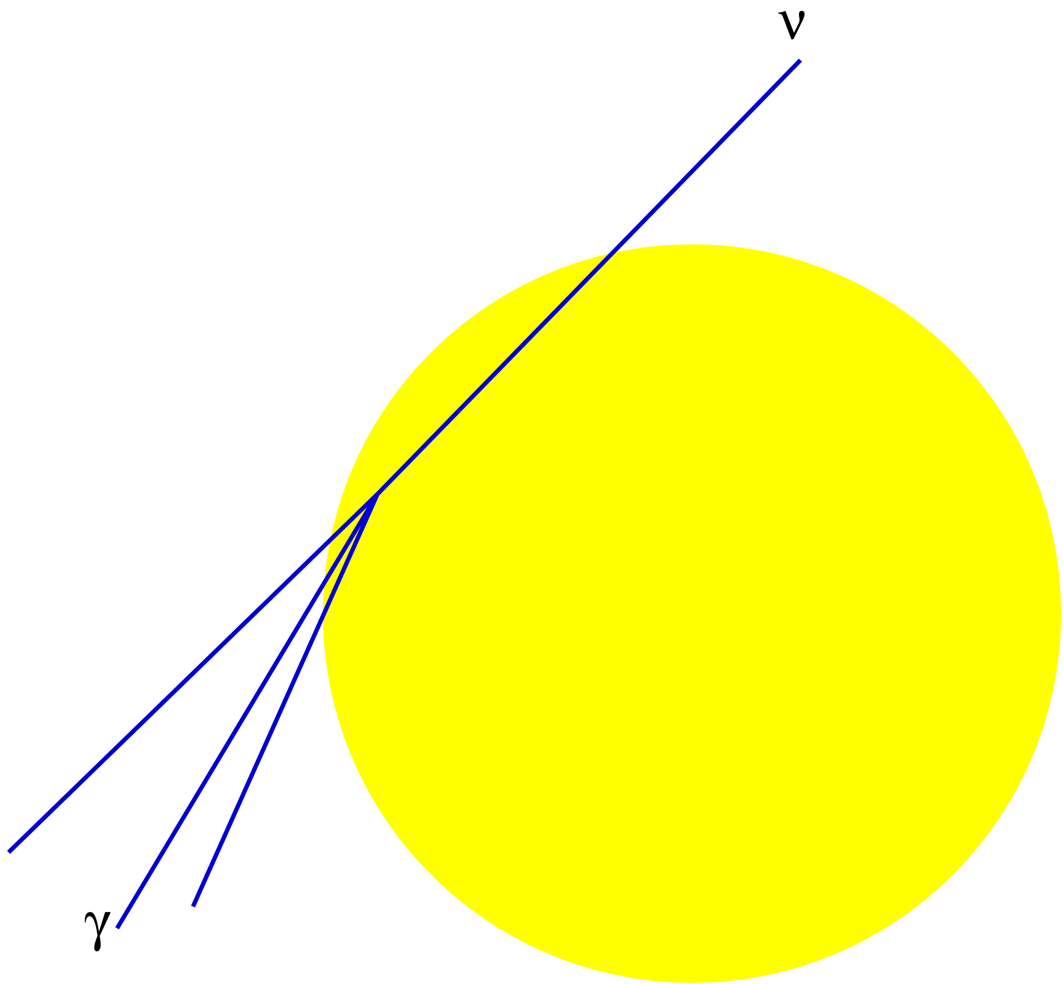
(preliminary)

THE SUN

AS AN ULTRA-HIGH-ENERGY NEUTRINO TELESCOPE?

THE KEY IDEA:

TO COUNT SECONDARY (STILL UHE) PHOTONS FROM NEUTRINO INTERACTIONS IN THE OUTER REGIONS OF THE SUN



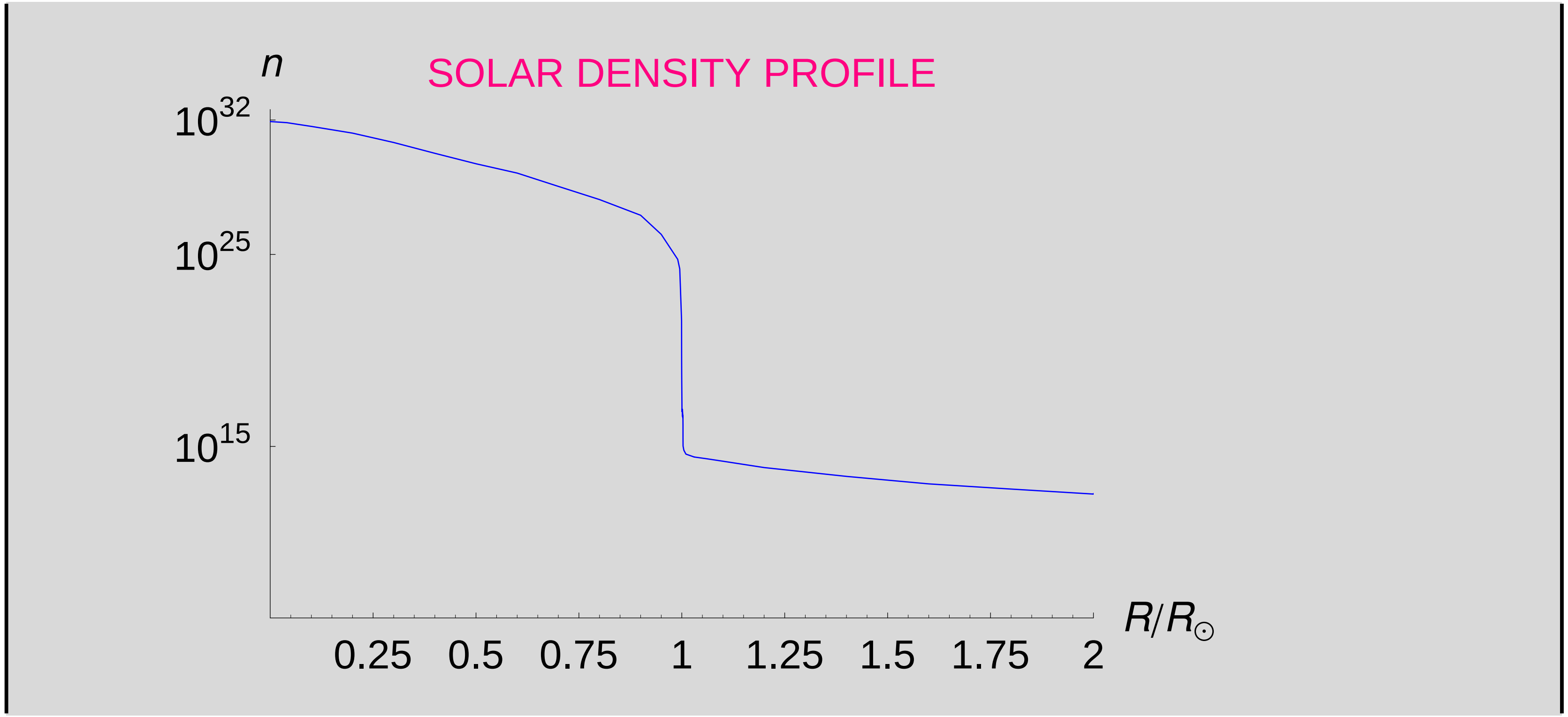
AN ORDER-OF-MAGNITUDE ESTIMATE OF THE FLUX

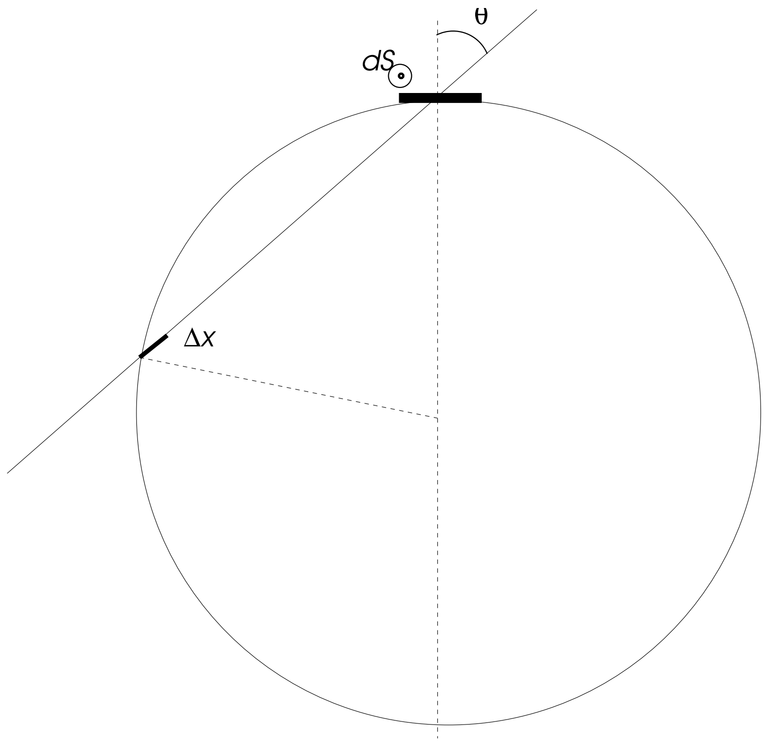
(SOLAR-SHOWER MODELLING TO BE DONE)

THE SOLAR MODEL

Allen, Astrophysical quantities

NUCLEON NUMBER DENSITY PROFILE





$dS = dS_\odot \cos\theta$

$x(\theta) =$ OPTICAL DEPTH FOR NEUTRINO ALONG THE CHORD

$$x = \sigma_\nu \int_{-R_\odot \cos\theta}^{+R_\odot \cos\theta} n(\sqrt{y^2 + R_\odot^2 \sin^2\theta})\, dy$$

$\Delta x \sim 2\sigma_\nu/\sigma_\gamma$ (FROM WHERE PHOTONS ESCAPE)

$P \sim \mathrm{e}^{-x} \cdot \Delta x =$ FRACTION OF NEUTRINOS WHICH INTERACT IN $(x, x + \Delta x)$

$1/3$ OF NEUTRINO FLUENCY AT $E_\nu \Rightarrow$ PHOTONS AT $E_\nu/100$

SOLAR LUMINOSITY IN SECONDARY PHOTONS:

$$
\begin{array}{ccccc}
f_\gamma \;\sim\; \frac{1}{3} & F_\gamma & \int_0^{\pi/2} d\theta\, 2\pi \sin\theta & \int dS_\odot\, \cos\theta & 2\frac{\sigma_\nu}{\sigma_\gamma}\; \mathrm{e}^{-x} \\
\uparrow & \uparrow & \uparrow & \uparrow & \uparrow \\
\frac{\mathrm{eV}}{\mathrm{s}} & \frac{\mathrm{eV}}{\mathrm{m}^2 \cdot \mathrm{s} \cdot \mathrm{sr}} & d\Omega & dS & P
\end{array}
$$

AT THE EARTH:

$$
\begin{array}{ccc}
F_\gamma^\odot & \sim \frac{2}{3}\frac{\sigma_\nu}{\sigma_\gamma}\left(\frac{R_\odot}{D}\right)^2 \xi & F_\nu \\
\uparrow & & \uparrow \\
\frac{\mathrm{eV}}{\mathrm{m}^2 \cdot \mathrm{s} \cdot} & & \frac{\mathrm{eV}}{\mathrm{m}^2 \cdot \mathrm{s} \cdot \mathrm{sr}}
\end{array}
$$

$$F_\gamma^\odot \sim \frac{2}{3}\frac{\sigma_\nu}{\sigma_\gamma}\left(\frac{R_\odot}{D}\right)^2 \xi F_\nu$$

$$\xi = \int_0^{\pi/2} d\theta\, 2\pi \sin\theta \cos\theta \, \mathrm{e}^{-\sigma_\nu \int_{-R\cos\theta}^{+R\cos\theta} n\left(\sqrt{y^2+R_\odot^2 \sin^2\theta}\right) dy}$$

$\xi \sim 0.4$, SATURATED AT $\theta \sim 75°$

$$R_\odot / D \approx 1/215$$

$$\sigma_\nu(4 \cdot 10^{21}\ \mathrm{eV}) \sim 10^{-6}\ \mathrm{barn}$$

$$\sigma_\gamma(4 \cdot 10^{19}\ \mathrm{eV}) \sim 10^{-2}\ \mathrm{barn}$$

$$\boxed{F_\gamma^\odot \sim 10^{-9}\ \mathrm{sr}\ F_\nu}$$

EXPERIMENTAL DATA

AGASA	$E > 4 \cdot 10^{19}$ eV	ZA$< 45^\circ$	ASSUME ALL PHOTONS
YAKUTSK	$E > 4 \cdot 10^{19}$ eV	ZA$< 60^\circ$	ASSUME ALL PHOTONS
SUGAR	$E > 4 \cdot 10^{18}$ eV	ZA$< 45^\circ$	ASSUME ALL PHOTONS OF 10 TIMES LARGER ENERGY

EXPERIMENTAL DATA

AGASA	$E > 4 \cdot 10^{19}$ eV	ZA$< 45^\circ$	ASSUME ALL PHOTONS
YAKUTSK	$E > 4 \cdot 10^{19}$ eV	ZA$< 60^\circ$	ASSUME ALL PHOTONS
SUGAR	$E > 4 \cdot 10^{18}$ eV	ZA$< 45^\circ$	ASSUME ALL PHOTONS OF 10 TIMES LARGER ENERGY

AGASA: EXPECTED 0.03 OBSERVED 1 FLUX $\leq$4.

YAKUTSK: EXPECTED 0.001 OBSERVED 0 FLUX $\leq$2.4

SUGAR: EXPECTED 0.29 OBSERVED 0 FLUX $\leq$2.

TOGETHER EXPECTED 0.32 OBSERVED 1 FLUX $\leq$4.

EXPOSURE TO THE SUN:

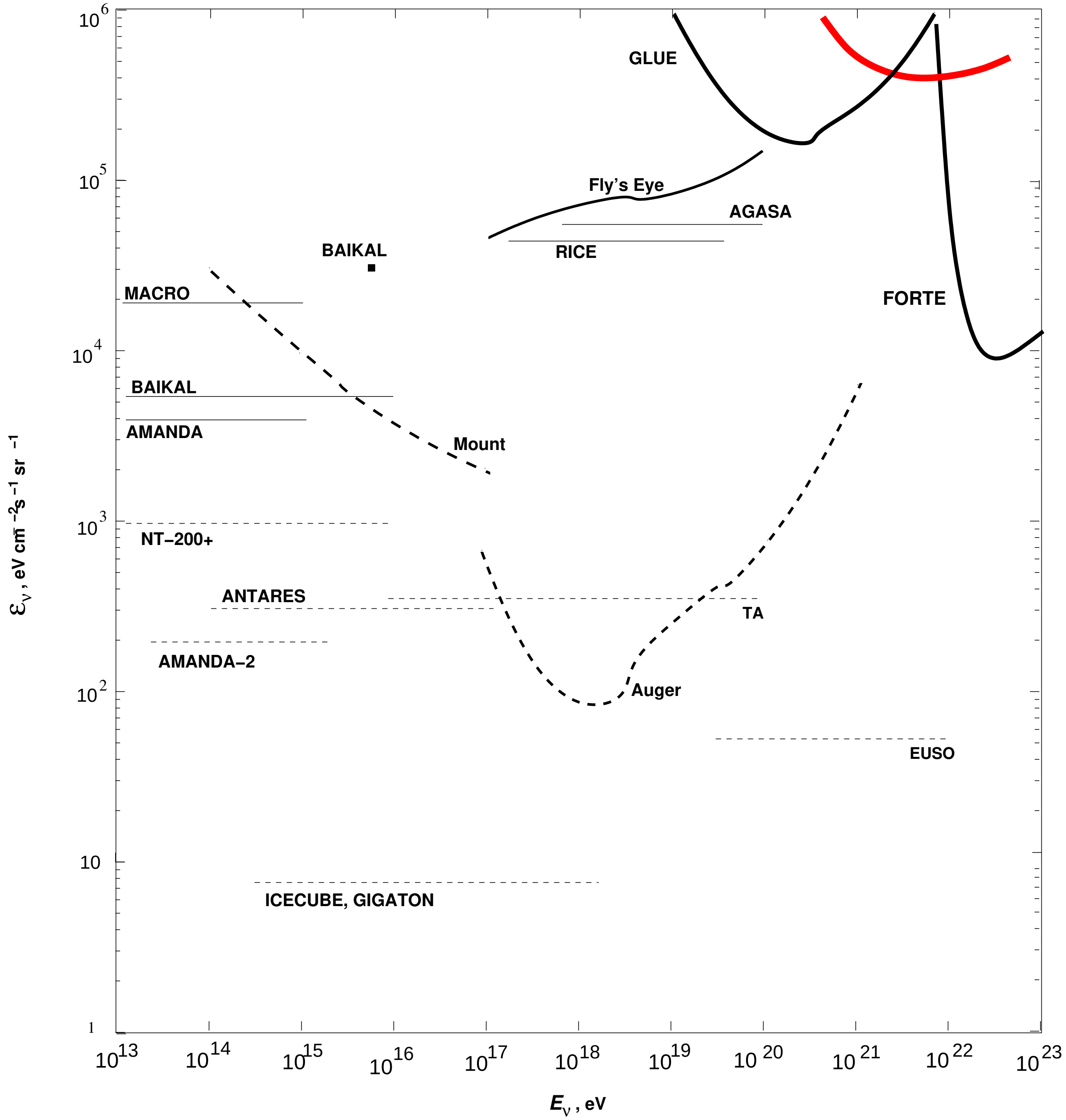
$$\int dt\, Sc\left(z_{\odot}(t)\right)$$

$$c(z) = \begin{cases} z, & z < 45^\circ; \\ 0 \end{cases}$$

AGASA (45°): 1030 effective hours per year

YAKUTSK (60°): 798

SUGAR (45°): 1136



GLUE
Fly's Eye
AGASA
RICE
BAIKAL
MACRO
FORTE
BAIKAL
AMANDA
Mount
NT–200+
ANTARES
TA
AMANDA–2
Auger
EUSO
ICECUBE, GIGATON
ε_ν, eV cm^{-2}s^{-1} sr^{-1}
E_ν, eV

POSSIBLE LIMITS: COMPARABLE TO GLUE, FORTE

ACCOUNT OF THE SECOND INTERACTION PLUS LARGE EXPOSURES: BETTER LIMITS

(REQUIRES LOW ENERGY ARRIVAL DIRECTIONS AND TIMES)

SENSITIVITY TO ENORMOUS ENERGIES (UP TO $E \sim 10^{24}$ eV)