Are Diffuse High Energy Neutrinos from Starburst Galaxies Observable?

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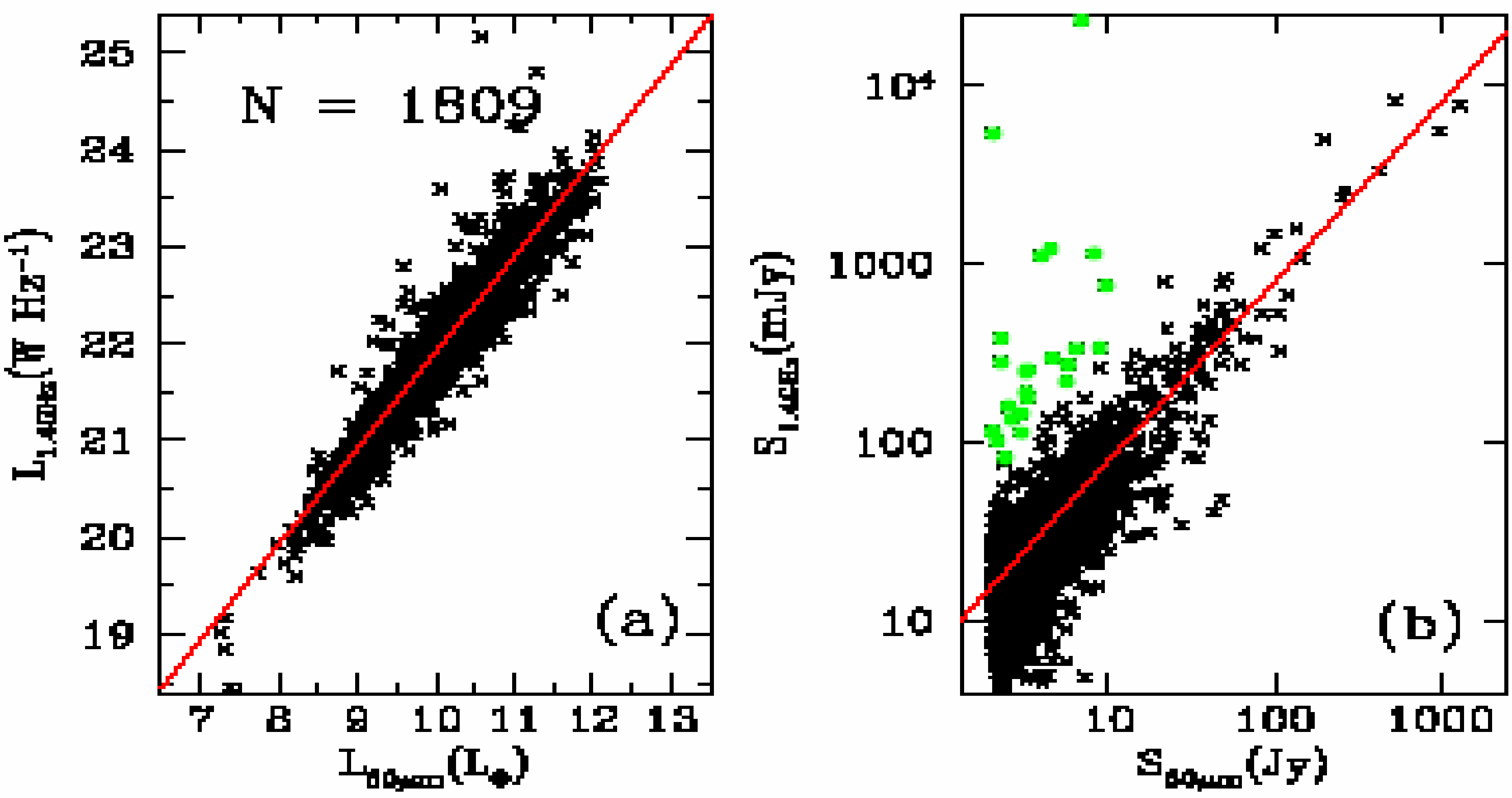
Observed Radio-FIR Correlation (Yun *et al.* 2001)



Radio-FIR Quantitative Relation (Yun *et al.* 2001)

$$\log\,[\mathrm{FIR}/(3.75 \times 10^{12}\ \mathrm{W/m^2})] = \log\,[S_{1.4\mathrm{GHz}}/(\mathrm{W/m^2Hz})] + 2.34$$

$$\mathrm{FIR} = 1.26 \times 10^{-14}(2.58 S_{60\mu\mathrm{m}} + S_{100\mu\mathrm{m}})\ \mathrm{W/m^2}$$

Assumptions of Loeb & Waxman to get starburst galaxy ν flux:

- The presence of synchrotron-radiating relativistic electrons in starburst galaxies implies the presence of relativistic protons.
- The protons lose *all* of their energy to π production interactions with interstellar gas in starburst galaxies (*but* there are ***superwinds***).
- The energy loss rate of the protons can then be obtained from the radio flux by assuming that all of the e^+ and e^- radiating are the result of the decay of π's produced by the protons and are not directly accelerated, given a model for the **B** field.

Diffuse Neutrino Flux Formula (Loeb & Waxman)

$$E^2\Phi(1\ \mathrm{GeV}) = (ct_H/4\pi)\zeta[4f(dL_f/dV)]_{f=1.4GHz}$$

with radio luminosity density being obtained from FIR density

where $\zeta \sim 3$ takes account of galaxy evolution.

This estimate will only hold at TeV-PeV energies if one assumes that $\Phi(E_\nu) \sim E_\nu^{-2}$

BUT…

Loeb & Waxman assume that essentially *all* of the FIR background is from starburst galaxies to estimate the ν background from starburst galaxies using the radio-FIR correlation and normalizing to the 1.4 GHz flux using their other assumptions.

In actuality, only ~ 23% of the FIR background is from starburst galaxies.

Relative contributions to the Starburst Galaxy ν Flux

Redshift Range (Δz)	Fraction of Background	Starburst Contrib.	Reference
0 to 0.2	10%	$< 10\%$	Yun *et al.*
0.2 to 1.2	68%	$\sim 13\%$	Lagache *et al.*
>1.2	22%	$\sim 60\%$	Erb *et al.*

Neutrino Energy Fluxes (GeV cm^{-2} s^{-1} sr^{-1})

ν Source	$E^2\Phi$(10TeV)	$E^2\Phi$(100TeV)	$E^2\Phi$(1PeV)	Reference
Atm: AMANDA-II	2×10^{-6}	7×10^{-8}	$< 3 \times 10^{-9}$	Bouchta 2006
Atm (Vertical)	7×10^{-7}	$\sim 2 \times 10^{-9}$	—	Gaisser 2005
AMANDA-II Diff.Lim.	9×10^{-8}	9×10^{-8}	9×10^{-8}	Hill 2005
Starburst Galaxies	$< 2 \times 10^{-8}$	$< 2 \times 10^{-8}$	$< 2 \times 10^{-8}$	This paper
AGN Cores	5×10^{-10}	10^{-8}	10^{-7}	Stecker 2005
AGN	3×10^{-9}	3×10^{-8}	2×10^{-7}	Mannheim *et al.* 2001
GRB	5×10^{-10}	3×10^{-9}	3×10^{-9}	Waxman & Bahcall 1997
Icecube Sensitivity	—	4×10^{-9}	4×10^{-9}	Ribordy *et al.* 2005

Bottom Line

Since only about ~23% of the FIR background is from starburst galaxies, the corresponding predicted ν flux is lower than that given by Loeb & Waxman by a factor of 4-5.

Even this flux should be considered a very “optimistic” upper limit because it assumes complete proton trapping, no primary accelerated electrons, and a flat differential proton spectrum ($\Phi \sim E^{-2}$) up to PeV energies.

The neutrino flux from starburst galaxies is predicted to be lower than the atmospheric foreground up to energies of at least ~300 TeV and is below that predicted by AGN models at higher energies