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SUPERNOVA DETECTORS, NEUTRINO DARK MATTER† AND TRANSIENT NEUTRINO SOURCES

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ABSTRACT

We discuss the information obtained from a future SuperNova Neutrino Burst Observatory (SNBO), concentrating on the determination of a neutrino mass in the range of 15eV to 50eV. Progress on a new very massive detector based on the neutral currernt interaction of the neutrino is described. We discuss progress on a *real time* SuperNova Watch Network (SWN). Finally, we discuss some exotic sources of neutrino bursts and give an example of a Primordial Black Hole explosion.

1. INTRODUCTION

The future of the Cosmological understanding of the universe may well depend on the properties of neutrinos as well as new (so far undetected) sources of cosmic neutrinos both transient and continuous. Many of the results of this report were presented at the 2nd International Conference on Gamma Ray and Neutrino Cosmology held at the University of California Los Angeles (UCLA) on February 13-15, 1992. Some of the most salient results reported at this meeting were[1]

a) Evidence that Galaxy-Galaxy correlated functions suggest a neutrino-like hot dark component; an 8eV neutrino mass is implied.

b) Evidence from solar neutrino studies and use of the *seesaw mechanism* suggests one massive neutrino.

c) Modeling of the large scale structure (walls, voids) with a massive neutrino give structures similar to that observed.

d) New data from Gamma Ray Observatory (GRO) strongly suggests the existence of cosmological sources of gamma rays and, by implication, cosmological neutrino sources.

e) Nearby primordial black holes could explain some of the gamma bursts observed by Batse (GRO) and imply intense transient neutrino bursts. (For other possibilities see Table 1.)

f) Many new ideas are emerging for neutrino detectors for both low energy and high energy neutrinos.

g) The SuperNova Watch, a supernova or transient watch network that would signal such processes to all relevant detectors on earth is being planned.

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In this report we concentrate on items c,d,e and f, above. One may refer to the proceedings of the UCLA conference mentioned previously to find information on items a,b and g[1].

2. NOVEL NEUTRINO SOURCES: CONTINUOUS AND TRANSIENT

So far the only extraterrestrial neutrinos detected have been continuous, i.e. solar neutrinos, and transient, i.e. SN 1987A. Both of these processes produce low energy neutrinos. As the universe is studied in relation to gamma rays, we can imagine many other sources of both continuous and transient neutrinos. Detection of these other sources of neutrinos would definitely initiate the field of neutrino astronomy and cosmology.

3. NEUTRINOS AS DARK MATTER: THE SUPERNOVA WATCH

One or more stable neutrinos, with a mass in the region of 30 eV, could supply the missing or dark matter. The mass relationship is $\Omega_\nu = 1$ for $M_{\nu_x} = 92\ h^2 eV$, where H is the Hubble Constant ($h = 1$ for $H = 100\ km/s^{-1}MPC^{-1}$; for $h = 1/2$, $M_{\nu_x} = 23$ eV to give closure of the Universe and for $h = 0.6$, $M_{\nu_x} = 33$ eV)[2]. We thus consider the neutrino mass range of 10 - 40 eV to be of cosmological significance. There are no known laboratory techniques to uniquely detect such a mass directly. It is possible that some form of neutrino oscillation experiment could be used to infer a mass in this range, however, this will depend on the uncertain level of neutrino mixing. The only technique that is known to provide a unique mass measurement is to use the difference in flight times for neutrinos from a distant supernova that goes as (Fig. 1)

$$\Delta t = 51.4\, R_{MPC} \left[\left(\frac{M_{\nu_x}}{E_{\nu_x}} \right)^2 - \left(\frac{M_{\nu_e}}{E_{\nu_e}} \right)^2 \right] \text{ sec}$$

where M_{ν_x} and M_{ν_e} are measured in electro volts, E_{ν_x}, E_{ν_e} are measured in MeV and R (the distance to the supernova) is measured in Mega Parsecs. The μ and τ neutrinos are expected to have higher average energies since they escape from deep inside the supernova core[3].

We assume an instantaneous source of ν_x neutrinos with a distribution of the form[2]

$$E_{\nu_x}^2 e^{-E_{\nu_x}/T}$$

and an assumed detection efficiency that scales as $E_{\nu_x}^3$ (i.e. the cross section scales like $E_{\nu_x}^2$ and detection of secondary products like E_{ν_x}) gives

$$\delta t = 51.4 R_{MPC} \frac{\int E_{\nu_x}^5 \left(\frac{M_{\nu_x}}{E_{\nu_x}} \right)^2 e^{-E_{\nu_x}/T}\, dE_{\nu_x}}{\int E_{\nu_x}^5\, e^{E_{\nu_x}/T}\, dE_\nu}$$

and for the case of μ, τ neutrinos we expect[2] $T \simeq 25/3$, giving

$$\delta t = 0.037\ M^2_{\nu_x}\ R_{MPC}\ \text{sec}$$

For a galactic supernova $R_{MPC} = 0.01$MPC and for $M_{\nu_x} = 30$ eV we find

$$\delta t = 330\text{ms}$$

Note that the mean time separation and shape of the time distribution are altered in a characteristic manner by the different neutrino masses. It is this characteristic that must be used to extract a cosmologically significant mass from a Galactic Supernova. The detailed time distribution for a galactic supernova is shown in Figure 2.

Table 2 lists the reactions that can be used for supernova burst detection and the experimental techniques that can be employed. Note from Table 2 that no detector will provide information on all the possible channels. In this note we are mainly concerned with the prospects for extracting a neutrino mass of the μ and τ neutrino if the mass value is in the 10 - 40 eV mass range of cosmological significance. Note also that the mean time distribution for these cases are (Tables 3a and 3b)

$$\delta t = 35\ \text{ms} \qquad M_{\nu_x} = 10\ \text{eV}$$
$$\delta t = 590\ \text{ms} \qquad M_{\nu_x} = 40\ \text{eV}$$

In a sense the galaxy is simply too small to obtain large time differences for cosmologically interesting neutrino mass. From Fig. 1 it is clear that the shape of the time pulse changes with M_{ν_x} and that the mean width of the initial pulse is (Fig. 2)

$$\delta t \simeq 400\ \text{ms} \quad \text{for} \quad M_{\nu_x} \simeq 10\ \text{eV}$$
$$\delta t \simeq 1\ \text{sec} \quad \text{for} \quad M_{\nu_x} \simeq 40\ \text{eV}$$

and thus

$$(\delta t)_{\text{pulse width}} > (\delta t)_{\text{time difference (-) between } \overset{(-)}{\nu}_x \text{ and } \overset{(-)}{\nu}_x \text{ neutrino arrival}}$$

It is clear that a very large number of events and very good time resolution is required to resolve the effects in the lower neutrino mass range due to the shape of the time pulse near the origin. We propose to use the derivative of the pulse to give a zero crossing estimate of the arrival times to obtain the required accuracy.

We now consider the expected event ratio for various channels for planned or proposed detectors for supernova detection in the 1990's and beyond. Table 3 lists the approximate event rates for several detectors in the construction or planning stage (ICARUS, SNO, LVD, MACRO) and for two newly proposed detectors[4] (Table 4):

i) Super Kamiokande
ii) SNBO (Supernova Neutrino Burst Observatory) as well as the existing IMB and Kamiokande II detectors (other detectors are likely too small to give additional information).

We refer to Ref. [4] for discussions of the proposed Super Kamiokande detector. The SNBO detector would have the active mass of 100,000 tons of $CaCO_3$ and would be instrumented with a large number of neutron detectors. The detector concept has been described in Refs. [2] and [4]. This detector is mainly sensitive to ν_μ and ν_τ neutrinos due to the dynamics of the neutral current process which strongly discriminates against lower energy ν_e and $\bar{\nu}_e$ events, thus, it is a ν_μ, ν_τ detector. Therefore, this zero crossing technique could be applied to obtain the desired time resolution.

Figure 2 shows the expected luminosity function and mean energy of the ν_e, $\bar{\nu}_e$, $\overset{(-)}{\nu}_\mu$, $\overset{(-)}{\nu}_\tau$ neutrinos from the collapse. The important times are*:

(i)	Prompt ν_e Burst	$\sim (3-6)$ ms
(ii)	Rise time and time internal to acretion pulse	$\sim (100-200)$ ms
(iii)	Width of the acretion pulse	~ 400 ms
(iv)	Explosion starts	$\sim (300-600)$ ms
(v)	Start of neutrino cooling	$\sim (300-600)$ ms
(vi)	Full width of cool-down	$\sim (10-20)$ sec

These characteristic times of the SuperNova neutrino emission process are set by scale of the SuperNova collapse dynamics[2] (see Tables 3a and 3b). In turn the detailed study of these characteristic time structures in a future SuperNova event would provide real detailed information about the dynamics of the SuperNova process. In addition, these time structures are important if we are to use the SuperNova neutrinos flight time to determine SuperNova mass (see Section 4c for more details). The time dispersion for different neutrino masses is shown in Fig. 3.

* I have been coached in this subject by Jim Wilson

4. NOVEL NEUTRINO DETECTOR CONCEPTS

As the field of neutrino astronomy broadens novel detectors will be needed to probe for other neutrino sources. We can divide up the new types of detectors in terms of the neutrino energy range they are sensitive to:

1) Very High Energy and Ultra High Energy Detectors to detect in the range 1TeV→ 100TeV and 1PeV → 1EeV respectively.
2) Low Energy Detectors will operate in the range $1 \simeq 1000$MeV.

4.a. Very High Energy and Ultra High Energy Detectors

In the energy range of 1TeV→ 100TeV several new or novel detector concepts are being studied. One of such concept is DUMAND. Others are:

1) using ice as a detector material an PMTs to record the light,
2) using large lakes as the detector medium and PMTs as the detector,
3) using ice and radio wave detection,
4) using the atmosphere and large ground based light collectors (Flys Eye, etc.).

4.b. Low Energy Detectors

In the energy range of $1 \simeq 1000$MeV there are also several concepts being considered. These are:

1) the use of liquid argon (LAr) Detectors (ICARUS at Gran Sasso, for example),
2) the new generation of solar neutrino detectors (SNO, Barox, etc.),
3) a very large detector that uses neutron detection and the neutral current reaction (SNBO detector being designed for the WIPP site in New Mexico).

4.c. SuperNova Neutrino Burst Observatory

A new concept in supernova neutrino burst detection has recently been proposed. The detector uses high energy neutrinos from stellar collapse to drive neutral-current inelastic-scattering excitation of nuclei in the detector. The excited nuclei can decay by emitting neutrons. These neutrons would be detected by inexpensive counters. There are four important points regarding this proposed detector: (see Table 5)

(1.) Large, relatively pure deposits of SNBO detector material exist in nature in well-shielded sites. Preparation of the detector material should therefore be minimal. In addition, detectors are relatively simple, inexpensive BF_3 neutron counters. The technology of these detectors has been available since the 1950's and is well-understood. The SNBO potentially is an inexpensive, easily-prepared, and easily-maintained neutrino-burst detector that would run for decades with little maintenance. This is important because the stellar collapse rate in our galaxy is only one event every ten to one hundred years so that neutrino detectors will probably have to run for several decades before the next galactic supernova is seen.

(2.) Because the basic design of the SNBO is to place neutron counters into holes drilled into the detector medium, the mass of the SNBO is easily increased by drilling new holes and adding new counters. The advantage of the SNBO over water detectors is clear. The feasibility of the detector may be tested by placing a neutron counter into a chunk of detector medium which could then be transported to a neutrino source (such as the Los Alamos Meson Physics Facility) and tested. Should the detector indeed prove feasible, a small-scale SNBO could then be started with only a few neutron counters in place. As experience with the detector grows, more holes could be drilled and more counters added. This is the only proposed cosmic neutrino detector which could be scaled up to very large size. The ultimate mass of the SNBO could reach 10^5 tons or more, which would give tens of thousands of counts for a galactic supernova. This large number of counts could yield detailed information on the supernova mechanism as well as provide a good limit on the μ and τ neutrino masses.

(3.) Because the detector medium produces neutrons almost exclusively by neutral current reactions, the SNBO would be able to count neutrinos of all three flavors coming from a supernova. In addition, the threshold for the detector, which is set by the neutron separation energy of the nuclei of the detector medium, is high ($\gtrsim 12\,\mathrm{MeV}$) so that only high energy neutrinos would be counted. In the case that there are no oscillations between neutrino flavors, the average energy of electron neutrinos from a supernova is roughly 15 MeV, while that of the μ and τ neutrino are more like 20-25 MeV. As a consequence, the SNBO would essentially count only μ and τ neutrinos.
Neutrinos with a mass in the range 10-50 eV are again becoming attractive as candidates for the dark matter of the universe. The upper limit on the mass of the electron neutrino is currently 18 eV. Improvement in ^{3}H endpoint experiments could reduce this upper limit below the cosmologically interesting range. Any MSW resonant neutrino oscillation explanation for the solar neutrino puzzle would suggest that, at best, $\Delta m^2 \approx 10^{-6} - 10^{-4}\,\mathrm{eV}^2$ so that m_{ν_e} would be very small but conceivably $m_{\nu_\mu} \simeq 10^{-2}\,\mathrm{eV}$ and "see-saw" schemes for neutrino masses would then suggest $m_{\nu_\tau} \sim 10\,\mathrm{eV} - 40\,\mathrm{eV}$. This would leave the τ neutrino as the potential closure neutrino. The only way to measure the mass of μ and τ neutrinos in this mass range is, at present, by time-of-flight measurements from supernovae, a task for which the SNBO is ideally suited because of its ability to operate for a long time, its large number of counts and its particular sensitivity to μ and τ neutrinos.

(4.) If vacuum mixing angles and mass difference between ν_e and ν_μ or ν_τ are as expected in any of the MSW oscillation solutions to the solar neutrino problem, then neutrino flavors might be mixed on their way down the density gradient in the supernova. This

would complicate the clear identification of high energy neutrinos as corresponding to ν_μ and ν_τ. We point out, however, that in a mass hierarchy in which $m_{\nu_\tau} > m_{\nu_\mu} > m_{\nu_e}$ the anti-neutrinos have no resonant transitions so that a $\bar{\nu}_e$ signal in LVD or a water detector serves to give a "fiducial mark" to calibrate the ν_e ($\bar{\nu}_e$) flux. This, coupled with a detailed time history of events from SNBO, could give interesting constraints on neutrino masses and mixing angles in a region of parameter space potentially very different from solar neutrino experiments. We note that since our experiment involves neutral currents we can still identify high energy peaks from $\bar{\nu}_\mu$ and $\bar{\nu}_\tau$ and place mass limits as discussed in point.

Note that the SNBO detector could also provide a higher mass limit on one of the neutrinos if the rate of events is considerably below the prediction. This would imply that one of the neutrinos has a mass of > 100 eV or is unstable. The two newly proposed detectors provide additional information that could be used to uniquely detect a ν_μ or ν_τ mass even in the 10 eV range. This is due to the fact that the Super Kamiokande detector gives adequate numbers of $\nu_x e \rightarrow \nu_x e$ events to possibly make the separation in the high mass case and the SNBO detector (when combined with the other detector results) provides a very large number of pure ν_μ and ν_τ events. With 5000 ν_μ and 5000 ν_τ events it should be possible to make a unique separation of low mass neutrinos (i.e. $M_{\nu_\mu} \simeq 0$; $M_{\nu_\tau} \sim 30$ eV) and mixed cases such as ($M_{\nu_\mu} \simeq 10$ eV, $M_{\nu_\tau} \sim 30$ eV). (Note that the zero crossing technique is difficult to use in the case of a mixed, overlapping ν_e, ν_x sample.)

The construction and long term operation of such detectors in a self triggered "Supernova Watch" detection mode is essential to determine if the μ and τ (and possibly ν_e) neutrinos have mass values that are important for the cosmology of the universe. At this time there appears to be no other viable proposal of techniques to carry out the important measurement. In addition to the neutrino mass determination the detection of thousands of $\bar{\nu}_e$, ν_e and ν_μ/ν_τ events from a future supernova will provide crucial information about other properties of neutrinos (such as a magnetic moment in the range of $10^{-11} - 10^{-14} \mu_B$) and exotic $\nu\nu$ interactions as well as the dynamics of stellar collapse and explosion.

Detailed response calculations have been carried out at LLNL for the configuration[2]. The SNBO could be constructed in a limestone deposit in places like Arizona. Figure 6 shows a conceptual design of such a detector. Prototype neutron detectors are being developed by the collaboration (see Figure 4)[2].

Using the complete array of detectors around the world it should be possible to extract a neutrino mass in the range of 10 - 50 eV; the scheme for doing this is outlined in Table 6. Figure 5 shows the time response of the SNBO detector for different ν_τ masses[6].

5. SUPERNOVA WATCH NETWORK

The detection of neutrinos from SN 1987 A by the Kamiokande II, IMB and other detectors demonstrated that the final stages of a type II SN was more or less as had been expected by theory and modeling studies. However, there were many questions left open about the details of the collapse and the properties of the neutrinos that are emitted. In the future the detection of the neutrino burst by several terrestial detectors would have a profound effect on may diverse fields of physics as elementary particles (neutrino mass), nucleon physics (equation of state) and so forth. Recently a workshop was held at UCLA to discuss the SuperNova Watch and to discuss a possible Real Time Network that could link the different detectors[6]. In Table 1 we list some of the SuperNova Detectors operating, being constructed or being planned around the world. This is an impressive array of detectors. The basic idea of a SuperNova Watch Network is shown schematically in Figure 6. A Real Time SuperNova Watch discussion group has been formed following the UCLA meeting and progress in the development of this concept is expected during the next year or so. Other possible sources of transients that could be correlated with the SuperNova Watch Network are given in Table 7.

6. PRIMORDIAL BLACK HOLE GAMMA RAY & NEUTRINO BURSTS

Many years ago S. Hawking proposed (1) the existence of Primordial Black Holes (PBH) and (2) PBH can *decay* in a short time giving bursts of different types of radiation. Recently we have re-examined these concepts and concluded that some nearby PBH bursts might be detected (Ref. 5). In Table 8 we summarize some of the conclusions of this study.

TABLE 1.

Possible Mechanism for γ Ray Bursters
(UCLA Mtg.)

1. **Neutron Star Quakes**: Theronuclear Processes

   Characteristics: can fit most γ Burster data

   Processes: Luminosity $\sim 10^{40}$ergs

   – events should be in galactic plane ...

2. **Neutron Star Mergers**: 10^{-7}year^{-1}/Galaxy

   Characteristics: Similar to SuperNova ν pulses but $\nu\bar{\nu} \rightarrow e^+e^- \cdots$

   $\hookrightarrow \gamma$ required

   Processes: Luminosity $\sim 10^{50} - 10^{52}$ergs

   – Problems with absorption of γ's by plasma

3. **Matter – Antimatter**: "Stars"

   (J. Moffet, preprint)

   Characteristics: Model can be made to fit many bursts

   Processes: Luminosity $\sim 10^{51}$ergs

   "Cosmological"

4. **Cosmic Strings, Primordial Black Holes, Etc.**:

   (may explain small fraction of the γ burst data)

   Characteristics: many problems – number of strings in the universe

TABLE 2.

SUPERNOVA NEUTRINO DETECTION IN THE 1990'S				
REACTIONS:	$\bar{\nu}_e p \rightarrow e^+ n$	$\nu_x e \rightarrow \nu_x e$	$\nu_x N \rightarrow \nu_x N$	$\nu_x N \rightarrow \nu_x N^* \hookrightarrow n$
PARAMETERS:				
CROSS SECTION	LARGE (KII, SK, IMB, LVD)	SMALL $\sim E_\nu^2$ (ICARUS)	LARGE For Coherent Process	LARGE At High E_{ν_x} SNO/SNBO
NEUTRINO ENERGY ESTIMATE	YES $\sim E_e$	PARTIAL $E_{\nu_e} \sim f(E_e)$	NO	NO But a threshold may set E_{ν_x}
ν DIRECTION	NO	YES	NO	NO
TIME INFORMATION	YES	YES	YES	YES
DOWN TIME (guess)	$\gtrsim$ 10%	$\sim$ 30%	?	(could be small)
MAXIMUM DETECTOR SIZE	2×10^5 Tons (H_2O) LENA $\lesssim 10^4$ Tons Liq. Scint. (LVD)	$\sim 2 \times 10^5$ Tons (H_2O) or $\sim 10^3$ Tons Cryogenic (ICARUS)	? Kilograms No detector proposed so far	$\sim 10^5 - 10^7$ Tons of $CaCO_3$ (SNBO) or $\sim 10^3$ Tons D_2O(SNO)
BACKGROUNDS	SMALL If e^+ and n capture detected - OK for H_2O Galactic Signal	SMALL If directionality used to reject background	?	DEPENDS on Radioactivity of material

TABLE 3a.

Some Salient Features of Neutrino Bursts (Burrows)

1)	Shock break-out flash of ν_e's (and sudden spectral change)*
2)	Post-break-out hardening of spectra
3)	"ν_μ" emission
4)	Abrupt turn-on of $\bar{\nu}_e$'s and "ν_μ"'s, followed by a slow ($\sim$ 20ms) rise of $\bar{\nu}_e$'s (and ν_μ's)*
5)	Oscillations in ν_e and $\bar{\nu}_e$ luminosities
6)	Luminosity pulse and spectral hardening at explosion
7)	Drop in luminosities after "long-term" explosion due to reversal of accretion: <u>Mechanism</u>
8)	Long-term decay of luminosities and softening of spectra (10's of seconds)
9)	Black hole formation (abrupt turn-off)
10)	Onset of transparency

TABLE 3b.

Time Scales in SN II Process (Wilson)

1)	Prompt ν_e burst	$\sim (3-6)$ms
2)	Rise time and time interval for acretion pulse – possible sharp break-out pulse* –	$(100-200)$ms
3)	Width of acretion pulse	~ 400ms
4)	Explosion starts	$(300-600)$ms
5)	Start of neutrino cooling	$300-600$ms
6)	Full width of cool down	$(10-20)$sec

* not observed in all simulations

TABLE 4.

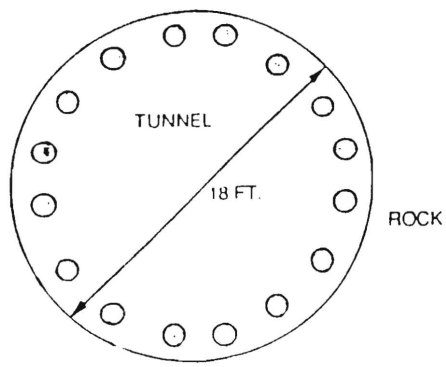
Future Spernova Detection of Galactic SNII Event

COMPARISION OF FUTURE SUPERNOVA ν DETECTORS						
PROCESS:	$\bar{\nu}_e p \rightarrow e^+ n$	$\bar{\nu}_e e \rightarrow \bar{\nu}_e e$	$\bar{\nu}_x e \rightarrow \bar{\nu}_x e$	$\nu_e N \rightarrow N^* \nu_e$	$\nu_\mu N \rightarrow N^* \nu_x$	
	$\bar{\nu}_e d \rightarrow ppe^-$		$x = \mu,\ \tau$	$\hookrightarrow n$	$\hookrightarrow n$	ν_e Prompt
DETECTORS:						
ICARUS (3kT)	–	~ 140	25	–	–	4*
SNO (1kT)	~ 500	60	20	~ 200	~ 400	5*
($D_2O + H_2O$)	(H_2O Shield + D_2O)			–	–	5 – 20*
LVD/MACRO (3kT) scent	~ 1000	–	–	–	–	
Kam.II/IMB	(~ 480)	(~ 60)	(~ 20)	–	–	–
SUPER Kam. (30 kT) H_2O	~ 4000	~ 600	200	–	–	~ 5*
SNBO (100kT)	(100's)?			~ 100's	10,000	–
COMMENTS:	measure t_ν,	$t\nu$		$t\nu$ only		$\Delta t \simeq 10$ ms
	$E_\nu \sim E_e$	E_ν estimated from E_e		No E_ν !		
	No Direction	Θ_ν Measured		No Θ_ν		

* Depends on Energy Spectrum of Prompt ν_e and Detector Threshold

TABLE 5.

Super Neutrino Burst	
1)	GOAL: To measure τ neutrino mass – direct unambiguous measurement –
2)	METHOD: Use time of flight from Galactic SN
3)	DETECTOR: Rock ($\nu + A \rightarrow \nu' + A' + n$) (threshold exists since n is initially bound)
4)	ENERGY: Average ν_τ energy is about 3/2 average ($\nu_e, \bar{\nu}_e$) energy



5)	COUNTS: More than 10^4 counts expected from Galactic SN Use "inexpensive" neutron detectors – and detectors requiring little direct maintenance
6)	FROM CALCULATIONS: $\langle E_{\nu_e} \rangle = 12\text{MeV} \quad \langle E_{\bar{\nu}_e} \rangle = 15\text{MeV} \quad \langle E_{\nu_{\mu,\tau}} \rangle = 25\text{MeV}$
7)	RISE TIME: $L_{\bar{\nu}_e}$ and $L_{\nu_{\mu,\tau}}$ rise rapidly at almost the same time (about 0.1sec)
8)	FIRST PREDICTION: Take model output for spectra and $L_{\bar{\nu}_e}$ and $L_{\nu_{\mu,\tau}}$ and feed into detector response to predict first 0.35 seconds of detection
9)	MEASUREMENT DATA: Use Kamiokande II data for supernova in Milky Way to measure $L_{\bar{\nu}_e}$ rise time
10)	LIMITS: Compare ν_μ and/or ν_τ signal to find limits on m_{ν_μ} and/or m_{ν_τ}

LLNL Cal. for SNBO Detector:

No. of Counts $= 2 \times 10^4 \frac{V}{R^2}$ with V in meters^3, R in Mpc;

For Milky Way R = 0.01 Mpc; Let V = 10^4 meters^3

Then No. of Counts $= 2 \times 10^4$

TABLE 6.

Possible Analysis of Future SN II Data (Galactic SN)

ASSUME:

Č or Scint. Detector (LVD, Macro, Superkam ...)
Records $\gtrsim 10^3 \bar{\nu}_e + p \rightarrow \eta + e^-$
Events (gives $t = 0$, $m_{\nu_e} \sim 0$ SN time distribution)

ASSUME:

SNBO Detect. gives $\sim 10^4$ counts that are mainly ν_μ and ν_τ
$[1/2\ (\bar{\nu}_\mu + \bar{\nu}_\tau)\,,\ 1/2\ (\nu_\mu + \nu_\tau)]$
Other Detect. give $\sim \mathcal{O}(100\text{'s})$ $(\nu_x + e \rightarrow \nu_x + e)$
+ SNO ($\sim$ 500 events) etc. ICARUS

FIT TO: $m_{\nu_e} = 0$, $m_{\nu_\mu} = 0$, $\{m_\tau\}$
$\Delta t \simeq 200$ms for $m_{\nu_\tau} \sim 20$eV
$\Delta t \simeq 50$ms for $m_{\nu_\tau} \sim 10$eV

Fit of all data gives m_{ν_τ} to ~ 15eV !!
To $\sim 3\sigma$ below this mass it is more dificult
(rise time of dispersed ν_τ pulse is ~ 100ms – this fits the scale)
Unless a Sharp "Break-Out Pulse" Occurs or Oscillations (A. Burrows)

TABLE 7.

Possible Sources of Neutrino Transients

1) PRIMORDIAL BLACK HOLE EVAPORATION:

$$M \sim 5 \times 10^{14} \text{gm decaying today}$$

2) QUIET SUPERNOVA EXPLOSIONS:

Possibly Higher Rate than Visible SN II's

3) COSMIC STRINGS:

4) SN II $\longrightarrow$ BLACK HOLES:

TABLE 8.

Primordial Black Holes Today (Ref. 5)

1) Formed IN EARLY UNIVERSE – Zel'dovich Spectrum

2) Follow Beckenstein's and Hawking's 1st law of BH Thermodynamics

3) $T = 10^{16}/M(\text{grams})\,\text{MeV}$

4) All PBH with $M < 5 \times 10^{14}$ GRAMS HAVE DECAYED

$$\dot{M} = -\alpha \left[\frac{M}{M^2}\right] \quad \sim (20/\text{year}\,??)$$

5) We STUDY DECAY of

$$M_{PBH} = 5 \times 10^{14}\,\text{g}$$

$$T = 20\,\text{MeV}$$

FINAL EXPLOSION PICTURE

- QCD-Like – Hard Spectrum
- Hagedorn-like $\sim$ Soft Spectrum (∞ # grams)
- Hybrid – Mixture of Hard and Soft
- In this model we get energy release of $\sim 10^{33}$ergs in $\sim \mathcal{O}(\text{ms})$

6) COMPARE WITH γ BURSTERS

A small fraction are compatible with this picture

7) What are CONSEQUENCES OF ASSUMING A FEW % ARE PBH

i) They are local [r < few parsecs]

ii) Neutrino Burst – SNBO

iii) Perhaps a small flux of higher energy γ's

- that can be detected in future γ telescopes
- $\sim (1 - 10)\,\text{m}^2$

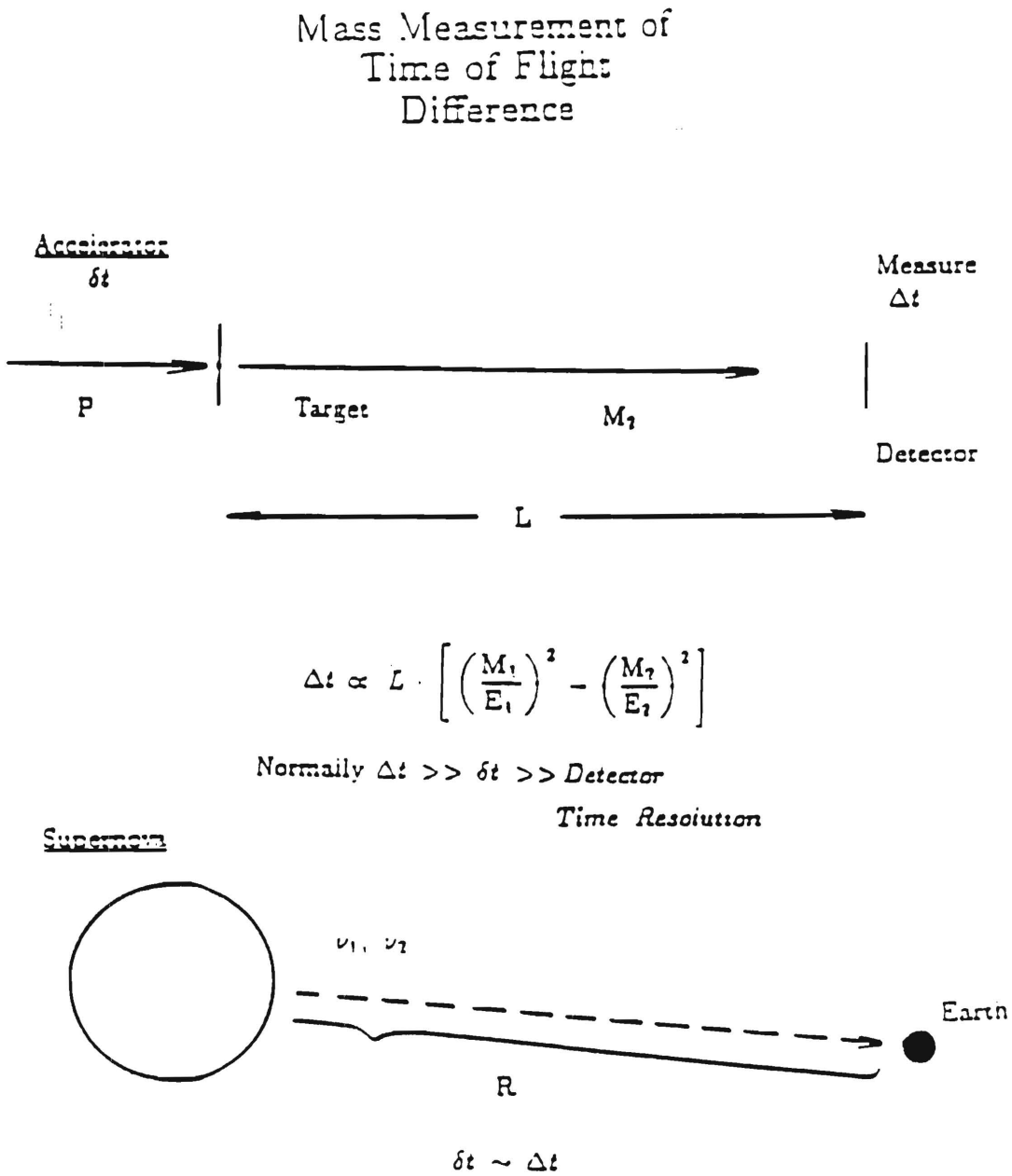


FIG. 1 Schematic of the technique to measure neutrino mass using time of flight from a supernova explosion compared to a similar accelerator experiment.

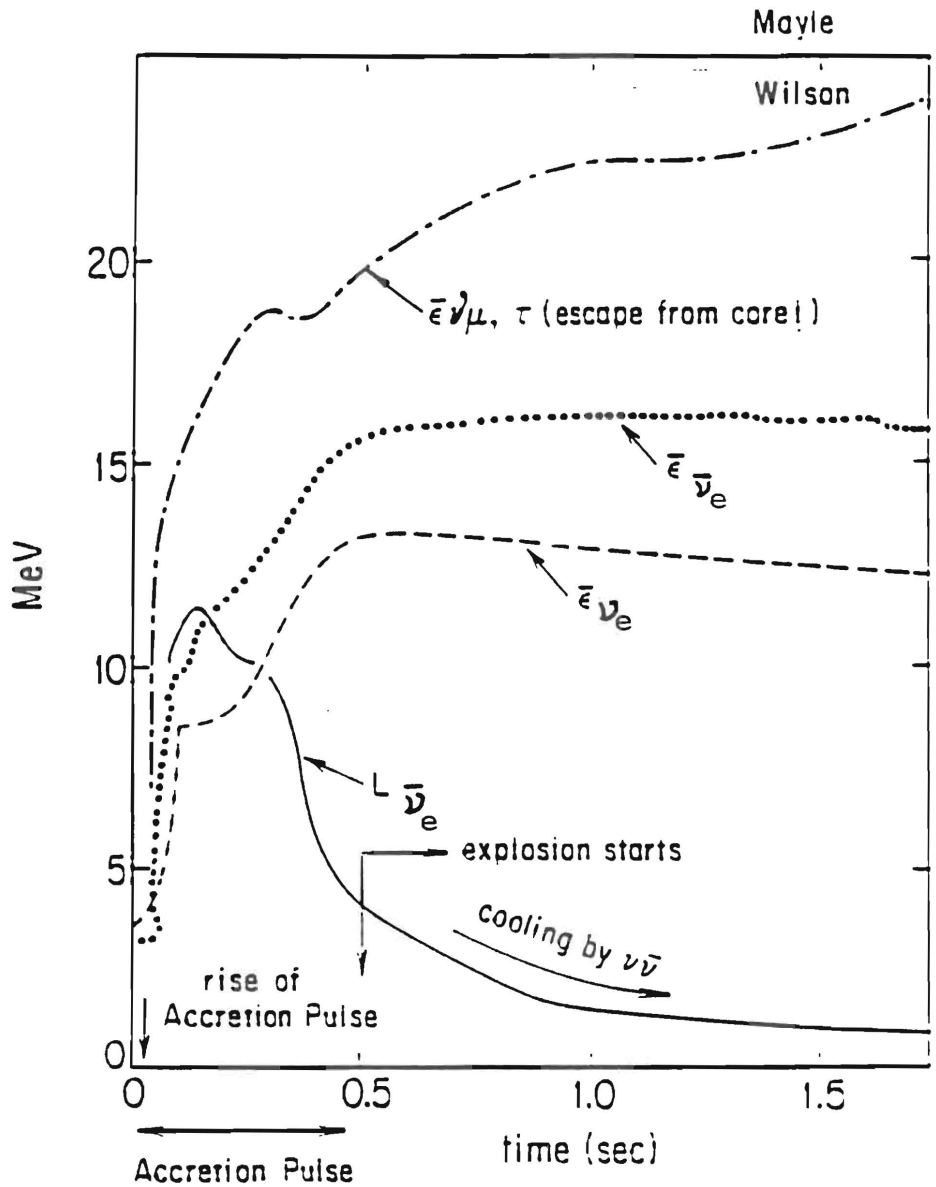


FIG. 2 The neutrino luminosity function and average energies of the various neutrinos vs. time.

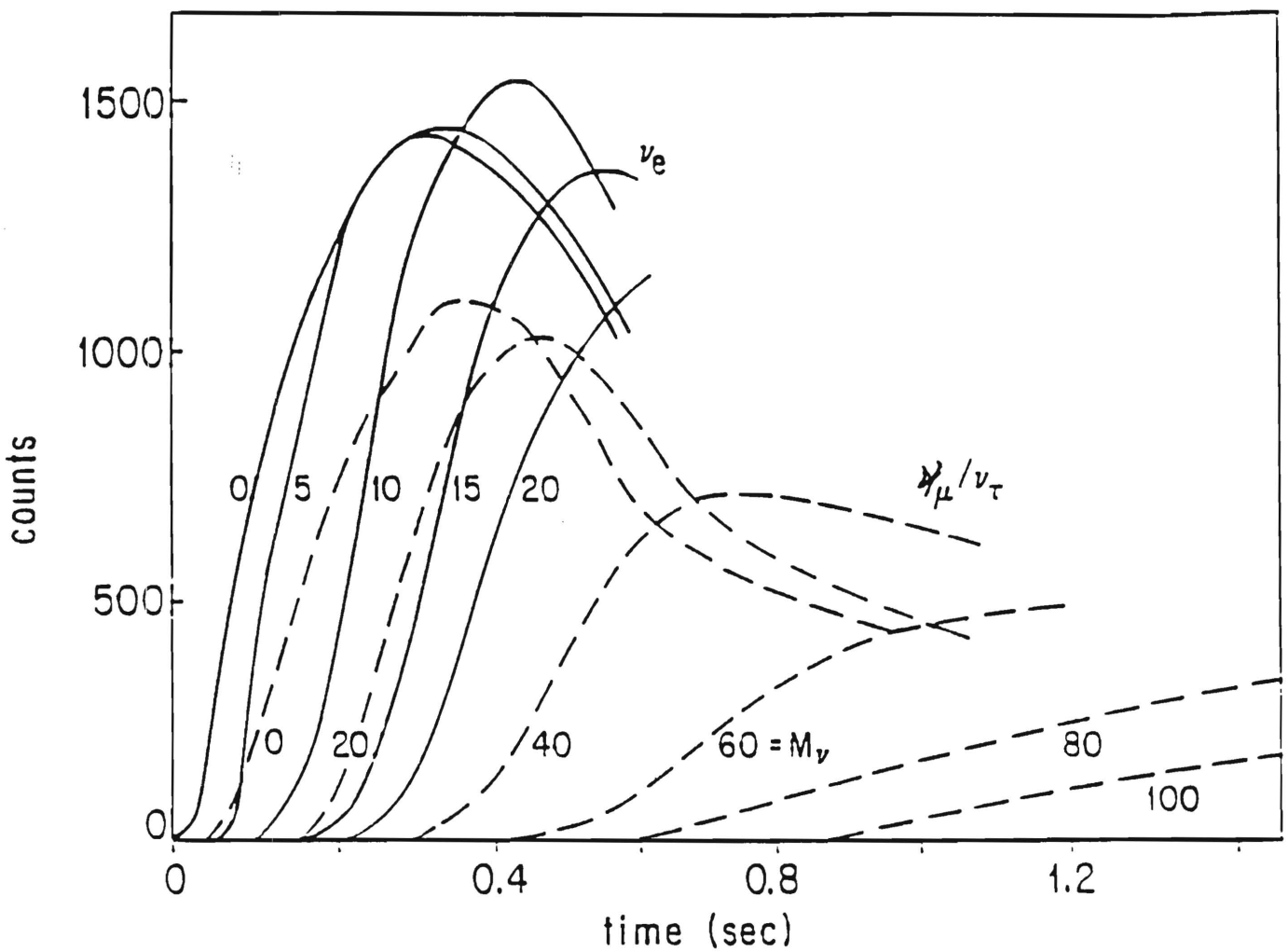


FIG. 3 Time distribution for the neutrino interactions from a galactic supernova as a function of the neutrino mass. The solid curves refer to ν_e and the dashed to ν_μ/ν_τ.

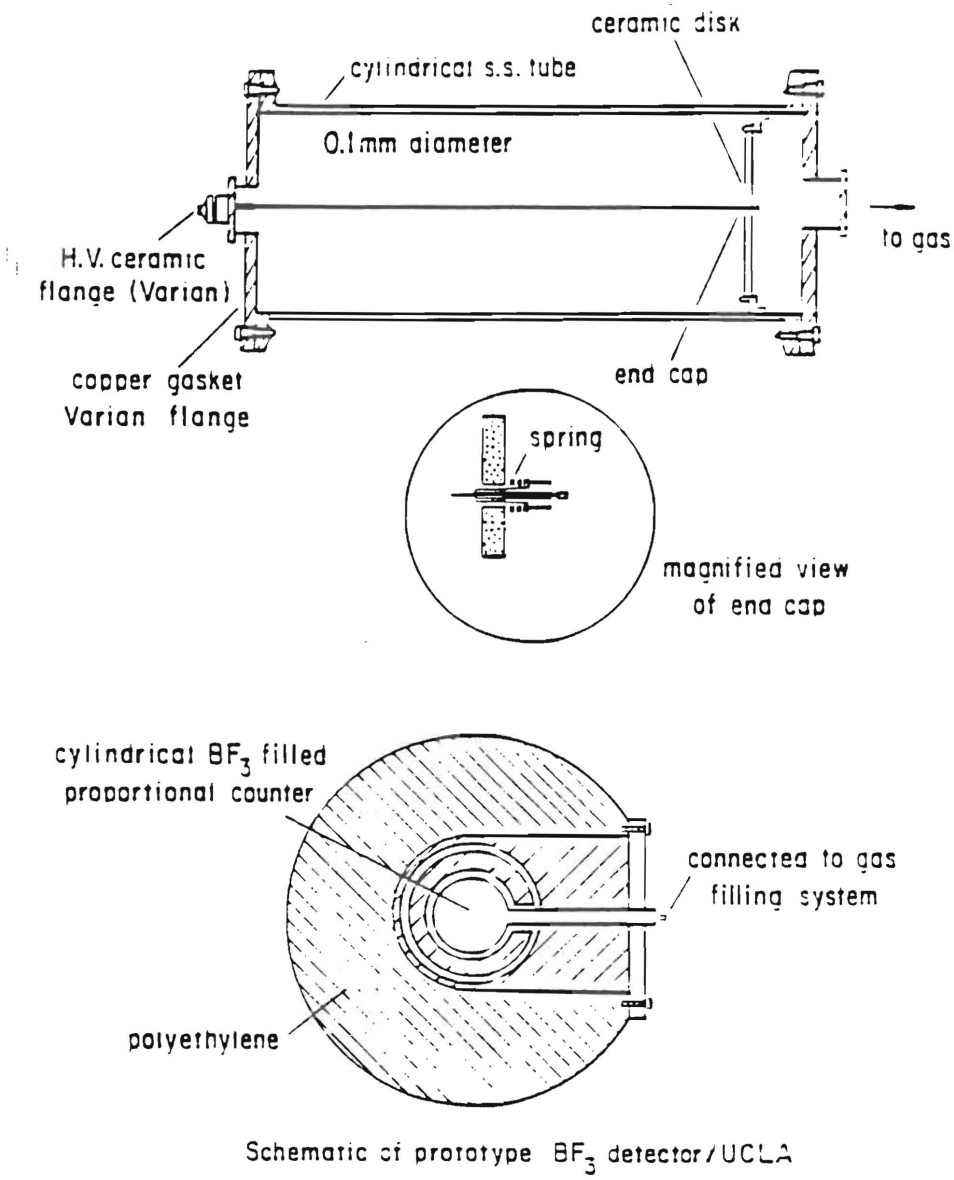


FIG. 4 Schematic of a BF_3 prototype detector for SNBO.

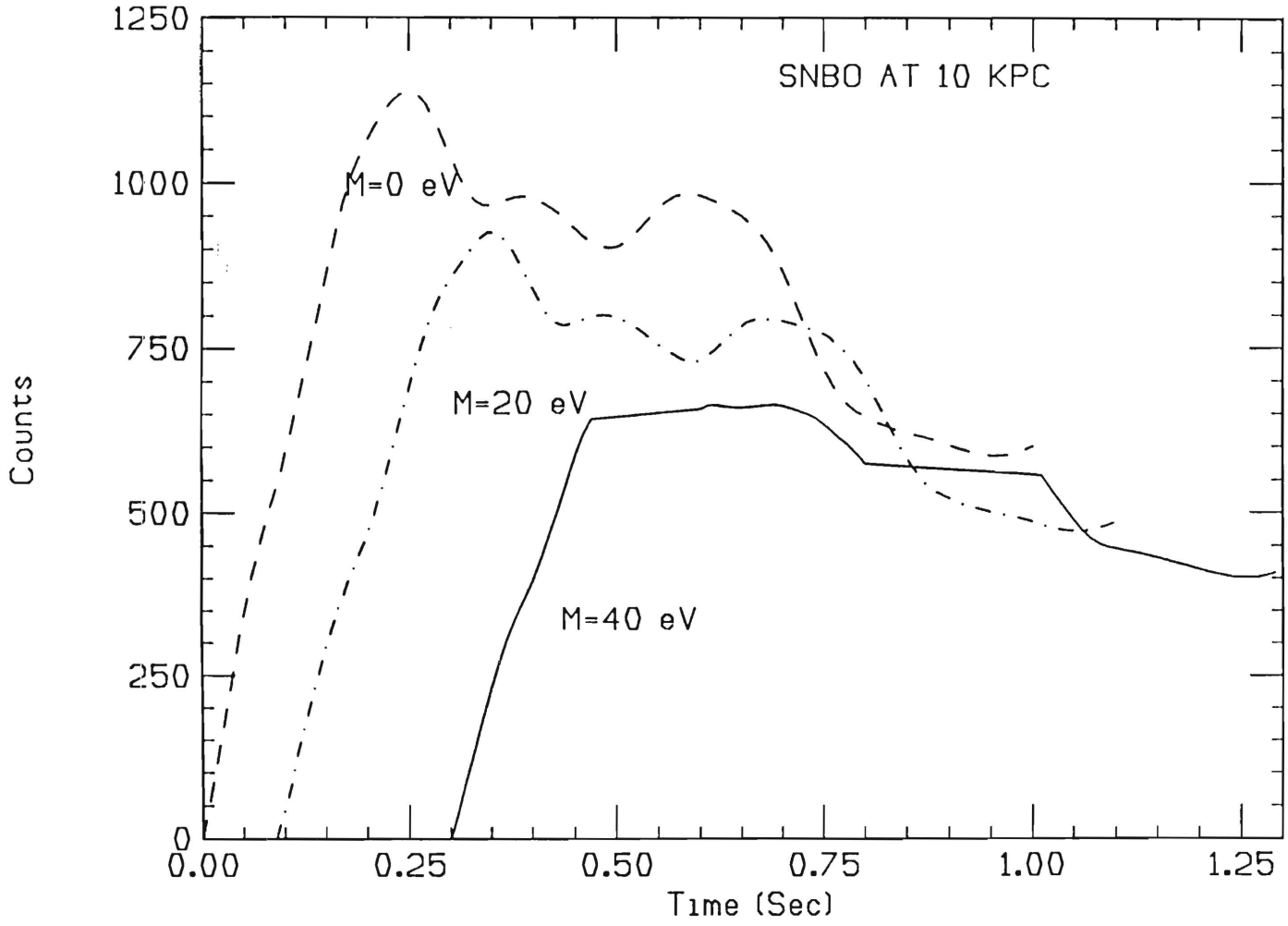
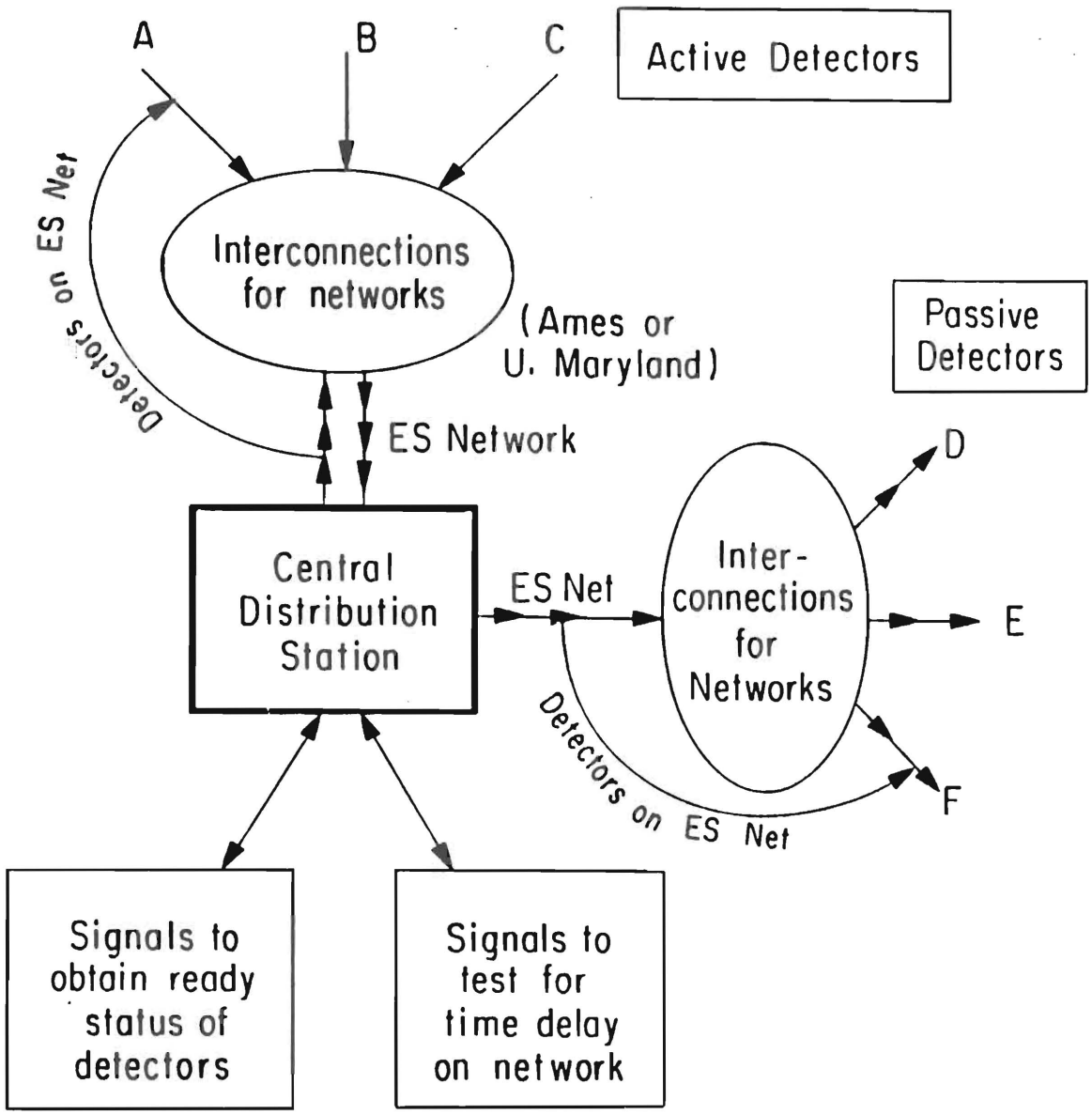

SNBO AT 10 KPC
M=0 eV
M=20 eV
M=40 eV
Counts
Time (Sec)
1250
1000
750
500
250
0
0.00
0.25
0.50
0.75
1.00
1.25

FIG. 5



Example of use of network:
- Supernova detection coordination
- Correlation between γ bursts in space and interactions on earth (i.e. air showers)

FIG. 6 Concept of a supernova or transient watch network.

REFERENCES

1. See proceedings of the UCLA Gamma Ray and Neutrino Cosmology Meeting to be published by World Scientific (1992).
2. T. Piran and J. Wilson (unpublished) and D. Cline, et al., Proposal to Study a New Type of Neutrino Burst Detector: The Supernova Neutrino Burst Observatory (SNBO), UCLA preprint 1990; and R. Boyd, et al., Proposal to Study a New Type of Neutrino Burst Detector: The SuperNova Neutrino Burst Observatory (SNBO), UCLA 1991.
3. J. Wilson and R. Mayle, Livermore preprint 1988 and to appear in Ap.J.
4. D. Cline et al., Techniques to Search for a Cosmologically Significant Neutrino Mass from a Galactic Supernova, UCLA preprint.
5. D. Cline and W. Hong, Possibility of Unique Detection of Primordial Black Holes with Gamma Ray Bursts, submitted to Ap.J. Letts. (1992) and UCLA preprint, and the references included in this paper.
6. D. Cline, W. Hong, F. Keyvan, S. Ramachandran and J. Wilson, Progress on a Real Time SuperNova Watch Network, UCLA preprint to be published in the proceedings of the UCLA Conference on Gamma Ray and Neutrino Cosmology, World Scientific (1992).