Rajaji is 75!

Missed Opportunity!

- In 1957, we could have met but did NOT!

Some memories

- We first met in 1963 (when he was in Chicago and I was at Purdue) thru Raghavan(we shared an apartment) along with Ramachandran, Divakaran and Balachandran
- In 1970 when I spent 4 months at TIFR, we (Balachandran and I) lived in his flat at COBRA while he was away……..(where and why…?…)
- In my visits to TIFR during the '70s I spent a lot of time learning many things from him, all the new developments in particle theory were explained clearly….this was my font of knowledge! It was a wonderful time…

I got hold of his lectures on Yang-Mills theory given at Saha Inst. (around 1970-71) which became my bible; I still have my marked up and dog-eared copy…This contains many prescient remarks about confinement and other ideas.

In 1974 I was able to invite Rajaji to visit us in Hawaii for 2 months. It happened to be when the J/psi was discovered and we had some fun making a shopping list of possible interpretations of the data. We also worked on neutrino neutral currents and how to determine the space-time structure of the interaction…..

After he moved to Chennai, I had to make special pilgrimages to see him, first at Guindy and then here..

In 1984, he visited us in Hawaii again, but by this time the Standard Model was well-established and he lectured on superstrings,……and published a note of rejoinder to Glashow in defense of superstrings!

(S. Glashow and P. Ginsparg, "Desperately seeking superstrings?", Phys.Today, 39, 5(1986); G. Rajasekaran and S. F. Tuan, Phys. Today, 40,15(1987). In this they said:"there may be many superstring theories out of which only experiment….."-shades of the landscape!

In Rajaji's own words recalling the visits to Hawaii:

- **"I spent two months in '74 in Hawaii under invitation from Sandip and met San Fu(Tuan)……one day in november we heard on the radio the news of announcement of narrow resonances in e+e- collisions at 3.1 GeV. We did not have any peace over the next few days as San Fu bombarded us with questions and comments until we had exhausted all possibilities of explaining the data, and making us exhausted as well! He was only satisfied when the paper was ready. It was one of the (earliest) many similar papers. It contained an exhaustive list including the correct one."**

Rajaji in Hawaii 1974…..,farewell lunch! Apart from the Rajasekarans:
SP,San Fu Tuan, Leo Pilachowski,Peter Dobson,Caroline Chong,Dennis Roberts, Walt Simmons, Susan Muranaka

- “On my next visit to Hawaii, during the height of string theory revolution, I gave a series of lectures on strings, where he was an enthusiastic particpant. During this period, Physics Today published the anti-string-theory polemic by Ginsparg and Glashow: ”Desperately seeking SUSY”. I tried to respond to their critique in my lectures. San Fu insisted that this must be published and we converted our response to a joint letter to the editor in Physics Today and published eventually”

Papers we wrote together:

- Theoretical Implications of the Resonance Anomalies in the e+ - e- system, with S. F. Tuan, Phys. Rev. D11, 1345(1975). All possible interpretations of J/ψ resonance!
- On the general space-time structure of the neutral current interactions, Phys. Rev. D12, 113(1975). How to tell whether neutrino Neutral current is V, A or S, P, T?

  In the latter case the ratio R can be between 7.2 and 0.14 whereas for the V,A case it has to be between 3 and 1/3……

During 1975-82 Rajaji, with Probir Roy and Saurabh Rindani did extensive work on integrally charged quark model and constructed a viable electroweak theory.

- We collaborated on constructing observational tests to distinguish between FCQ(fractionally charged quarks) and ICQ(integrally charged quarks). This was during the period when Rajaji was at the Guindy campus in the mid ’80’s.

- p anti-p → W+ γ+X as a test of quark charges, with X-G. He and S. Laxmibala, Mod. Phys. Lett. A1, 277(1986). In this paper we considered this reaction which has a kinematic zero at cos(θ) = -1/3 for the case of FCQ but NOT for ICQ….

- e+ e- → γ + two jets as a test of quark charges, with X-G. He and S. D. Rindani, Phys. Lett. B185, 158(1987).

  In this case, the angular distribution of the γ is sensitive to quark charges but only ABOVE "color" threshold…….

- In may 1981 we met at KEK in Japan.

We spent time together commuting to Tokyo to eat good Indian food and attended several physics meetings in Tokyo and Kyoto……

My wife Heide and I were participants/guinea pigs in an experiment in which Rajaji was learning to drive and practising inside KEK campus……

Kyoto, 1981, at Matsuda's. SP, Zee, Rajaji, Junko Matsuda, Ramond.

Here is wishing Rajaji very active/productive and healthy (next) 75 years ……

And Now For Something Completely Different……

Galactic Neutrino Communication & SETI

(SETI=Search for Extra-Terrestrial Intelligence)

Sandip Pakvasa
University of Hawaii

“Work” in collaboration with:

Walt Simmons, Xerxes Tata,
John Learned, Tony Zee, Rolf-Peter Kudritzki

This work is NOT supported by: DOE, NSF, NASA, DOD, DARPA…………Not even by the SETI Institute!

Neutrino Communication is a very old idea:

- H. Saenz et al., 1977
- J. Albers, P. Kotzer & D.Padgett, 1978
- M. Subotowicz, 1979
- J. Pasachoff & M. Kutner, 1979

They had the basic idea to use neutrino beams for interstellar and terrestrial communication based on the penetrating power of neutrinos………

Also proposed use for communicating with submarines, getting the US Navy interested! (Needless to say, one way only!)

A recent proposal is to use neutrino beams from muon colliders: Z. Silagadze, arXiv:0803.0409(2008).

Idea of neutrino communication with submarines has been revived very recently: P. Huber, arXiv:0909.4554(2009).

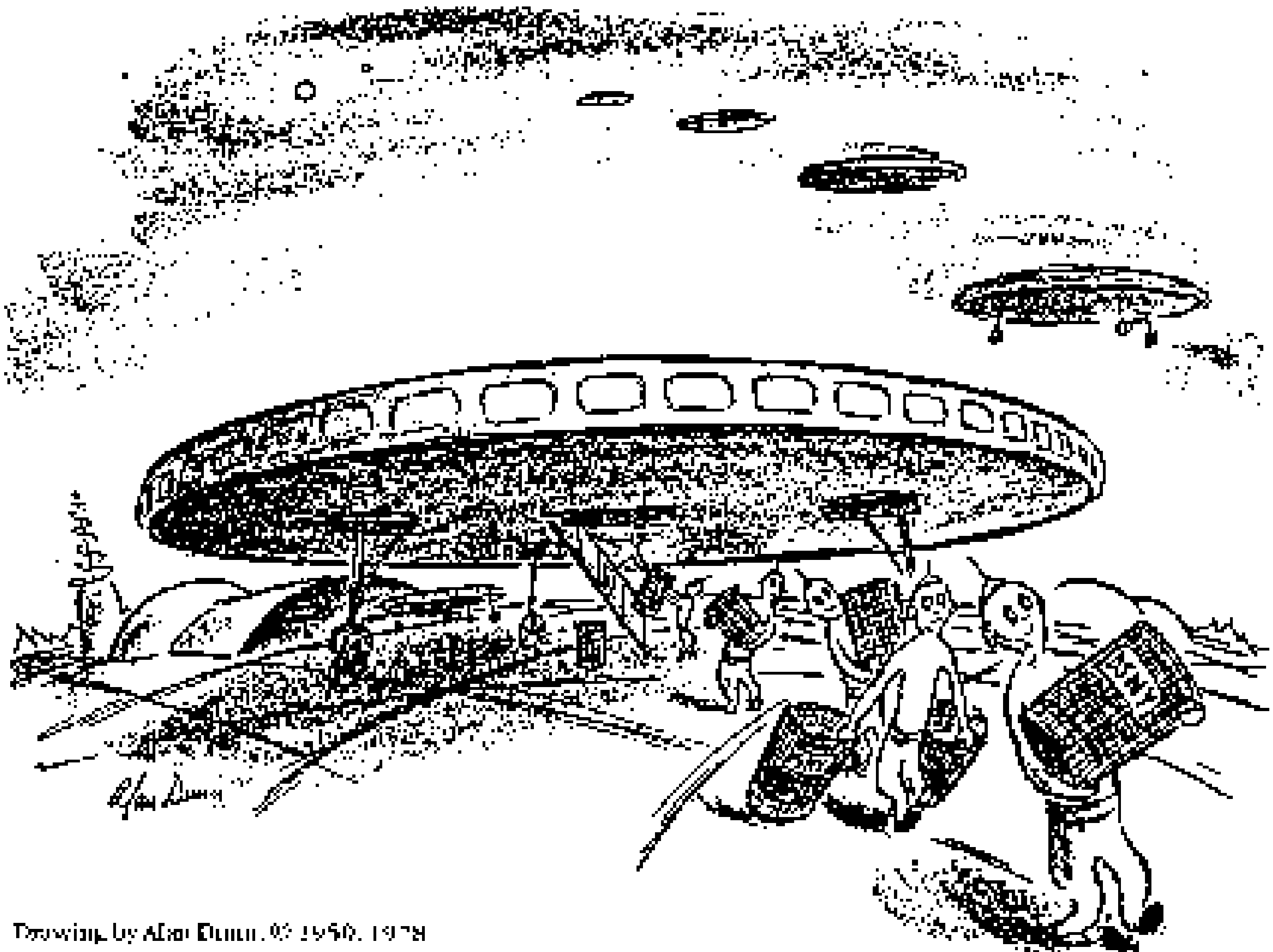
SETI: Search for Extra-terrestrial Intelligence

- There should/might be many advanced civilizations(ETI) out there in the galaxy……
- Fermi’s question(1950): where are they (the signals)? Namely, if they are out there why havent we seen or heard from them?
- Maybe security concerns prevent them from revealing themselves?
- Maybe they would like to send info on a variety of topics…..?
- Too Many Possible Scenarios, no point in trying to guess, just look for signals…

History/origin of “The Fermi question”

- 1950: Herb York, Edward Teller, Emil Konopinski and Fermi were meeting for lunch at Los Alamos. Before Fermi arrived, the talk was abut a recent cartoon in the New Yorker magazine about two recent headline making news-reports, one on flying saucers and the other on disappearing trash cans in NYC!

New Yorker 1950

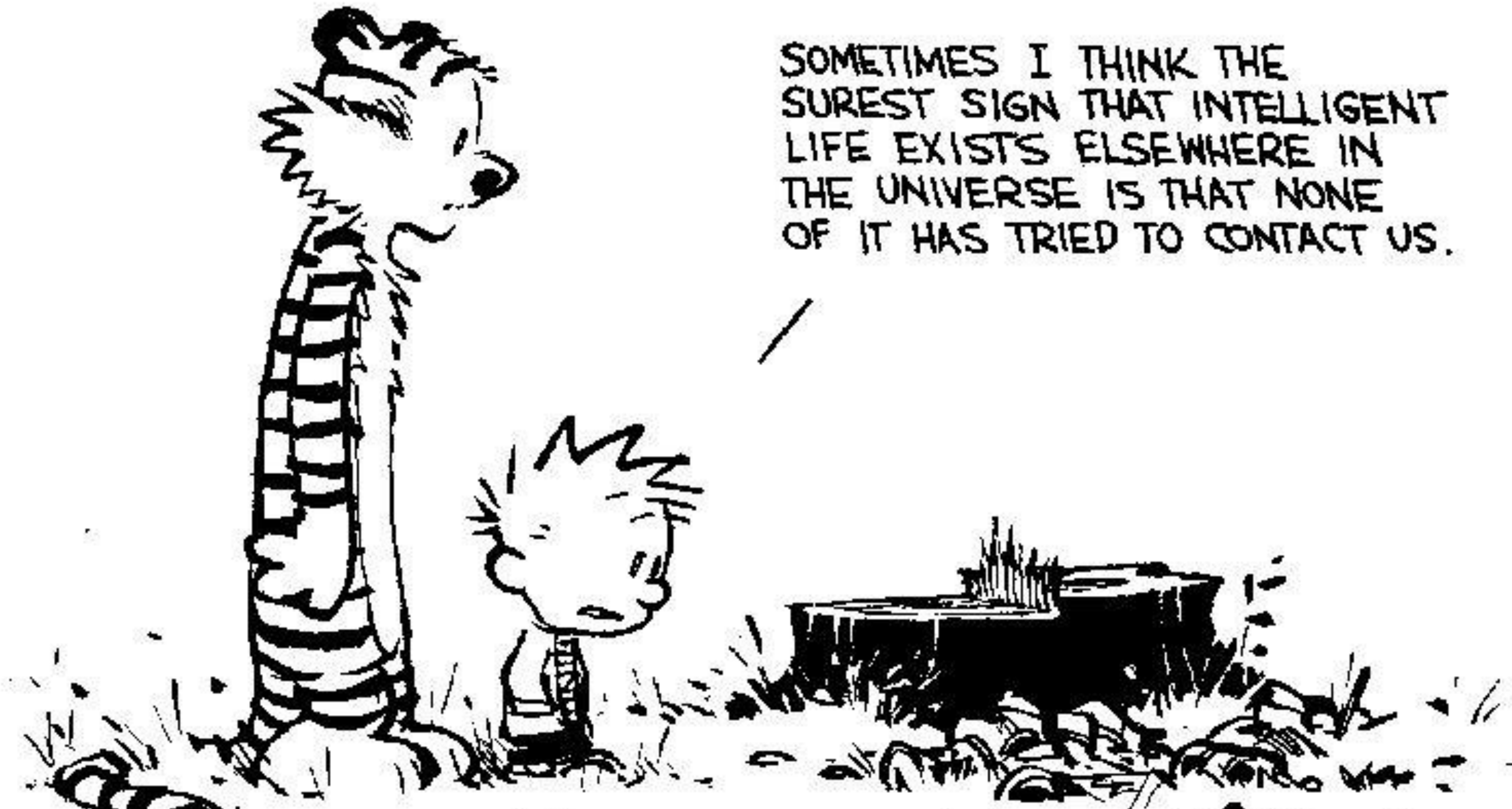


- On arrival, Fermi’s reaction was that the the “model” in the cartoon was obviously correct as it explained TWO unrelated events!
- Later during the lunch, in the middle of a conversation about something else altogether, Fermi is reported to have exclaimed “Where are they?”
- It was clear to the others what he had meant…….

Fermi’s Question has given rise to much discussion and attempts to answer it…..including books..

- One implication was that since we have not seen/heard from them, there are no ETI: there is no one out there.
- One simple response is: Absence of evidence is NOT evidence of absence!
- An even simpler and telling one is due to Calvin and Hobbes: The fact that no one has tried to contact us IS Itself Proof of Extra terrestrial Intelligence!!(November 12, 2008).
- Judging by our activities, they(ETI) may think WE are not intelligent enuf..

Calvin vs Fermi!



Comment in the Walt Kelly Strip Pogo by Porcupine:

- “There’s only two possibilities. There is life out there in the Universe that’s smarter than we are, or we’re the most intelligent life in the Universe. Either way, it’s a mighty sobering thought.”

- For several decades (almost 50 years) Standard Searches for ETI have concentrated on radio (e.g. the 21 cm line), microwave or optical frequencies
- Photons can be obscured/attenuated as opposed to neutrinos; also scattered leading to jitter in time & direction.
- Less backgrounds and noise for a Neutrino signal……….

Neutrinos & SETI: Obviously a very hot topic judging by citations:

- Walt Simmons, John Learned, Xerxes Tata, SP, Q. J. Roy. Astro. Soc. (1994).

  #Cit.= 1
- John Learned, Tony Zee, SP, Phys. Lett. B(2009).

  #Cit. = 3
- John Learned, Tony Zee, Rolf-Peter Kudritzki, SP, arXiv:0809.0339(rejected by Phys. Rev. Lett.).

  #Cit. = 0

Although many in non-technical magazine e.g. The Economist etc……!

Also in this section

90 A smart, new asthma inhaler

90 Stress and ageing

91 Cuckoos and sparrowhawks

Astrophysics and alien intelligence

Talking to the neighbours

A modest proposal for an interstellar communications network

ALMOST as soon as radios were invented, people speculated about using them to listen to—and maybe even talk to—extraterrestrial civilisations. Since the 1960s attempts have been made to do so by sifting through signals from outer space in search of alien chit-chat. More recently, the use of lasers in telecommunications has suggested to some that they might be a better way to communicate across vast distances, so searching for telltale flashes from the sky is now in vogue.

But techniques that work well on Earth are not necessarily ideal for talking across the vast chasms that separate stars. And for several years John Learned of the University of Hawaii and Anthony Zee of the University of California, Santa Barbara, have been promulgating what they believe is a better idea. They suggest that any alien civilisation worth its salt would alight not on the photons of the electromagnetic spectrum—whether optical or radio-frequency—to send messages to other solar systems. Rather, it would focus its attention on a different fundamental particle, one that is rather neglected by human technologists. That particle is the neutrino.

Neutrinos, it must be confessed, are neglected for a reason. Though abundant (the universe probably contains more of them than any other sort of particle except photons), they are fiendishly difficult to detect. That is because they interact only occasionally with other forms of matter. But that is precisely why Dr Learned and Dr Zee like the look of them. Light and radio waves are absorbed and scattered by interstellar gas and dust. Neutrinos would pass straight through such obstacles, and could easily be detected by neutrino telescopes on Earth (which typically consist of giant vats of water or, more recently, huge chunks of Antarctic ice).

The two researchers go further. They argue that powerful beams of neutrinos could be used to turn entire stars into flashing beacons, broadcasting information across the galaxy. Outlandish as this sounds, it is an idea that can easily be checked, for astronomers are already sitting on the data that might contain these extraterrestrial messages. They just need to analyse those data from a new perspective. Dr Learned and Dr Zee are therefore trying to persuade someone who studies the data in question to take their idea seriously and spend a little time having a look.

Motes and beams

To detect artificial neutrinos using existing telescopes means screening out the natural neutrino background. Fortunately, much of that is produced by nuclear reactions in stars, and such stellar neutrinos have relatively low energies. If the aliens made their beams out of neutrinos that were a billion times more energetic than the ones emanating from stars (something the researchers argue is not completely beyond the bounds of current technological imagination), the background noise would disappear. At high enough energies the rest of the galaxy is so quiet that if someone detected even a couple of energetic neutrinos arriving from the same direction, it would almost certainly mean they were artificial.

Moreover, Dr Learned proposes a specific energy that aliens might favour. The magic number is 6.3 quadrillion electron-volts. (An electron-volt is the energy with which a one-volt battery can accelerate an electron.) A neutrino with this energy has a good chance of producing a particle known as a W^- when it passes through a detector. The W^- particle will then decay in a characteristic way, leaving an unambiguous record of the neutrino's passage.

This is not the first time that beams of neutrinos have been proposed as a means of interstellar communication. But past suggestions required enormous energies (of the order of the entire output of the sun) to create a sufficiently intense beam. Dr Learned and Dr Zee have come up with a design for a particle accelerator that would do the job a good deal more modestly, using another type of subatomic particle, the pion, as an intermediary. According to their estimates, this should require no more energy than a typical Earth-bound power station can provide. Aliens might therefore be willing to give it a go—as, indeed, might humanity, if that were thought wise.

Once a civilisation has mastered the trick of generating high-energy neutrinos, though, Dr Learned's imagination suggests it might signal its existence to the waiting universe another way—and this is where the existing astronomical archives come in. For 100 years astronomers have paid ▸▸

Three Possible Scenarios to be discussed (in order of more to less conservative):

- Timing Data Communication with neutrinos
- Sending a focused beam of neutrinos of a definite energy
- Disturbing a cepheid variable star with a neutrino beam to modulate its period

Timing Data Communications & SETI (1994)

- Currently our time standards based on Cs Fountain Clocks, accuracy 1 part in 10^{16}, Josephson junctions can potentially go to 10^{19}.

- Due to chaos and GR corrections, need synchronization signals to keep accurate time, not necessarily frequent, e.g. VLBI will need accurate timing data over huge distances. Local clocks need to exchange timing data to remain synchronized.

- Hence need stable clocks of highest precision->fast processes for transmitting and receiving markers & form of radiation to convey faithfully data over enormous distances.

- A very advanced ETI would presumably need ever more accurate timing eventually physics limit timing.

- Shortest time interval known today is the Z lifetime about 10^{-25} sec.

This suggests use of neutrinos from the decay of Z as an ideal carrier. (open problem: how to make Z-clocks!)
We imagine that an ETI is doing just that at distances of order of kiloparsecs in the galaxy for its own spread out outposts…
We expect to see neutrinos of energy of about 45.5 GeV.
To get a few events per year in a KM3 detector, we estimate power requirement at the source to be enormous: about solar luminosity!
Such an ETI source would look like a "Dyson shell"!
Who knows, after all there are over 50,000 IR sources Identified by IRAS…….In any case this is not OUR problem. (this will be my Mantra). All we need to do is wait and look for the neutrino signal at half the Z mass, clean with no backgrounds. ICECUBE is waiting….

Simmons,Learned,Pakvasa & Tata, Q.J.R.Astr.Soc. 35,321(1994)

“Dyson Shell”

- Dyson shell is a name for stars which are being harnessed by advanced civilizations and have energy being expended to sustain them, using up most of the radiation energy by having a bunch of absorbers around the star. Dyson first discussed them(1960) and pointed out that they would be sources of intense infra-red radiation due to the thermal energy output.

Focused/Directed beam of neutrinos

- Why would ETI want to send us a focused beam?
- Don't know and don't care! Maybe they want to get our attention and then send us information(e.g. "Beware string theory!" or just the opposite). Due to long time scales, may remain monologue for a while.
- Many different possibilities: intercept signals sent by ETI to their "military" outposts, we just happen to intercept them.....

- Sending a focused beam has the advantage of not being seen by all, and would be less "dangerous", perhaps an advanced ETI wants to transmit to a TES(Technologically Emergent Society) like ourselves.

- Perhaps they have been tracking us and know that we as a TES are ready to receive neutrino signals with large KM3 detectors?
- Beam choice: electron antineutrinos of energy 6.3 PeV. The cross-section on electrons in detectors is large and characteristic of the Glashow Resonance (produce on-shell W with a resultant shower). No BG and a unique characteristic energy.
- Range in Water at this energy ~ 100 km planned detectors will catch ~ 1 % of the flux (down-going and horizontal).

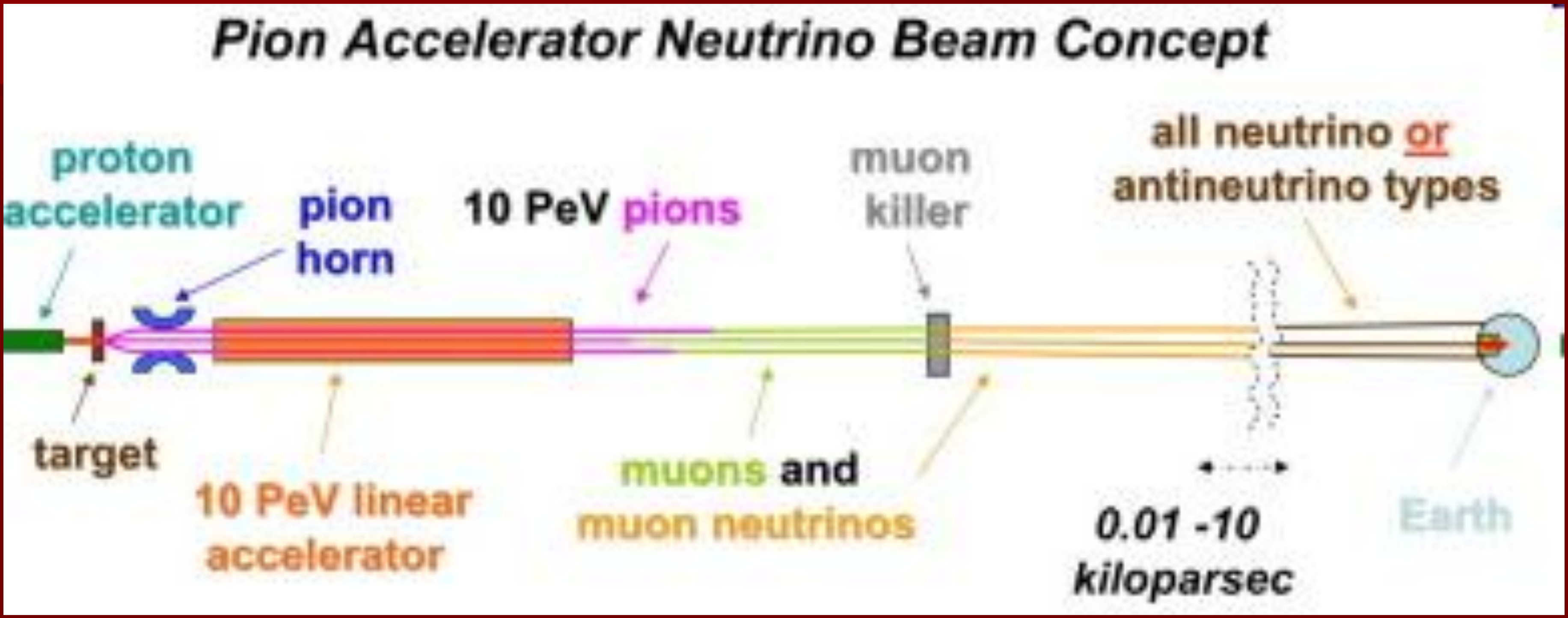
Glashow Resonance

- When a anti-ν_e hits an electron in the target at an energy of 6.3 PeV(10^6 GeV), the total energy in c.m. is just enuf to produce a W^- . At this resonant energy the cross-section is high and the signal due to the shower of the decay of the W is clear……….

Such a resonance was first discussed by Glashow in 1960.

- A possible way to make such neutrinos is an e^+-e^- Collider in a boosted frame with e^- overtaking the e^+, making Z's of high energy.....
- From 1 kpc away this beam would be 3000 AU across, for a pulse of 100 neutrinos, need 10^{26} neutrinos in the beam! Again NOT OUR PROBLEM!
- A much better choice is a pion accelerator....see e.g. next slide.

Learned, Pakvasa & Zee, Phys. Lett. B 671, 15(2009),arXiv:0805.2429.



Artist’s conception

- Protons hitting a target at ~30 PeV, switchable between π^+ and π-, decaying into μ and ν_μ or their antiparticles. Muons are removed as in usual beam dumps…A pure ν_μ beam, after a few light-days becomes a flavor mixture with $\nu_e:\nu_\mu:\nu_\tau = 4:7:7$.
- Encoding in a variety of ways: switching back and forth between neutrinos and antineutrinos, i.e. absence or presence of the Glashow Resonance, in addition to other signals(muons etc). One can also use timing/pulsing.
- Neutrino angle small ~ from 3 kpc, about 0.01 AU, much narrower than from Z decay.

AGAIN ALL WE HAVE TO DO IS SIT BACK AND WAIT FOR SIGNAL OF 6.3 PEV ELECTRON ANTINEUTRINOS IN KM3 DETECTORS……….

Neutrinos mix and oscillate.

At large distances, oscillations average out and the only effect is mixing. The propagation matrix is such that an initially

pure ν_μ beam becomes a mixture

given by $\nu_e:\nu_\mu:\nu_\tau = 4:7:7$

Also a beam of ν_μ produces NO antineutrinos needed for the Glashow resonance.

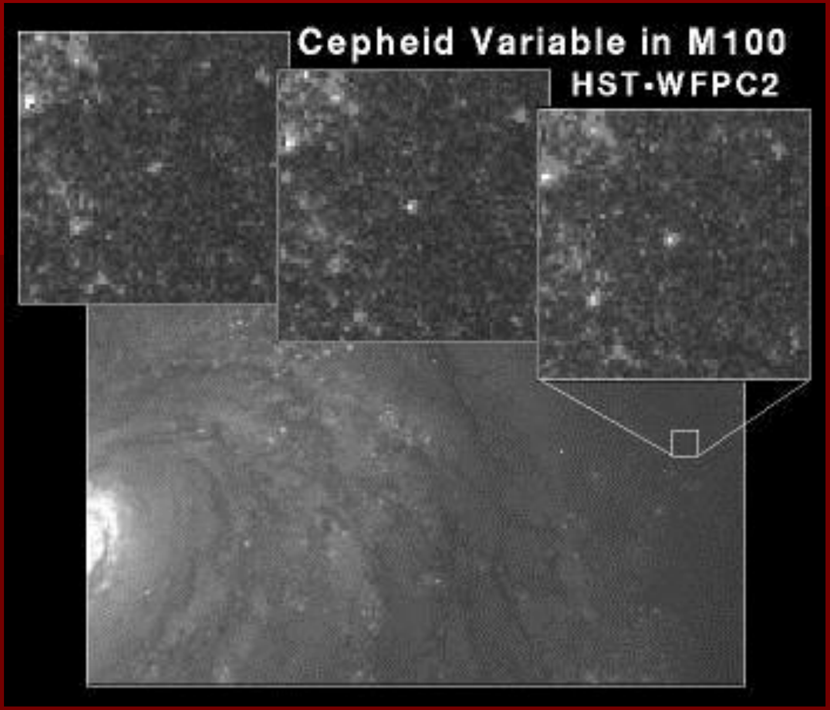
A Message from the Cepheids?

1908:

Henrietta Leavitt's discovery of the luminosity-period relation allowed Hubble to make his discovery & made cosmology possible (see recent biography "Miss Leavitt's Stars")

Learned, Kudritzki, Pakvasa, & Zee

http://xxx.lanl.gov/PS_cache/arxiv/pdf/0809/0809.0339v2.pdf, submitted to and rejected by Phys Rev.. Lett.



- A Cepheid variable is a member of a particular class of variable stars, notable for tight correlation between their period of variability and absolute luminosity.

- Namesake and prototype of these variables is the star Delta Cephei, discovered to be variable by John Goodricke in 1784.

- This correlation was discovered and stated by Henrietta Swan Leavitt in 1908 and given precise mathematical form by her in 1912.

- Period-luminosity relation can be calibrated with great precision using the nearest Cepheid stars.

- Distances found with this method are among the most accurate available.

The Cepheid variables proved very very useful:

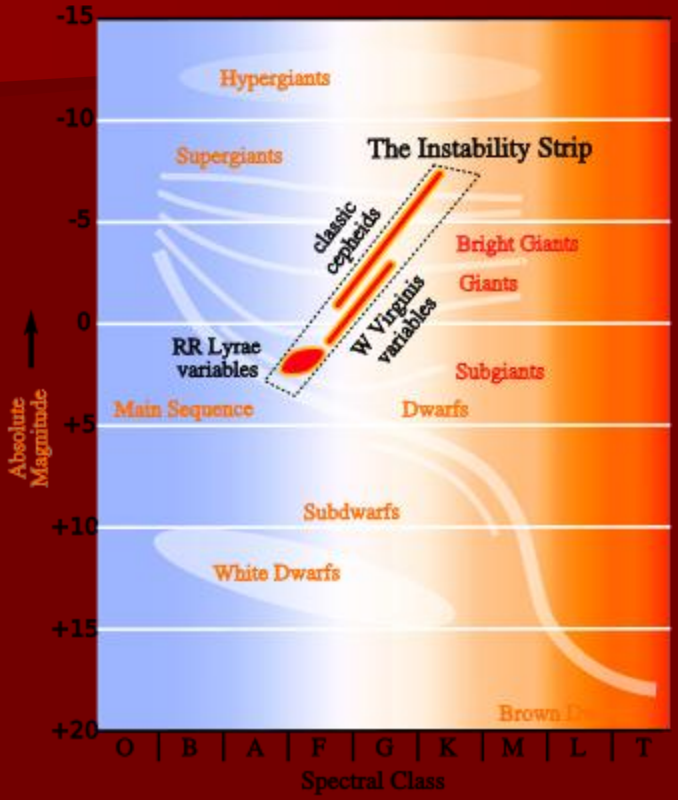
In 1915 they were used by Harlow Shapley to measure the size & shape of the milky way, and the location of the sun in it.

In 1924, Edwin Hubble used them to measure distance to the Andromeda galaxy and proved that it is not part of the milky way! (End of the Island Universe idea!)

In 1929, Humason and Hubble showed that the universe is expanding!

In mid –'40s, Baade showed that there are two Different classes of Cepheid variables with differing velocity-luminosity relationship and thus revised The distance scale by about a factor of 2……(classical and type II).

Cepheid Mechanism



Cepheid usually a population I giant yellow star, pulsing regularly by expanding and contracting, regular oscillation of its luminosity from 10^3 to 10^4 times $L_{\odot}$

Cepheids, population I stars: “Type I Cepheids”,
Similar (population II) W Virginis: Type II Cepheids.

Luminosity variation due to cycle of ionization of helium in the star's atmosphere, followed by expansion and deionization. Key: ionized, the atmosphere more opaque to light.

Period equal to the star's dynamical time scale: gives information on the mean density and luminosity.

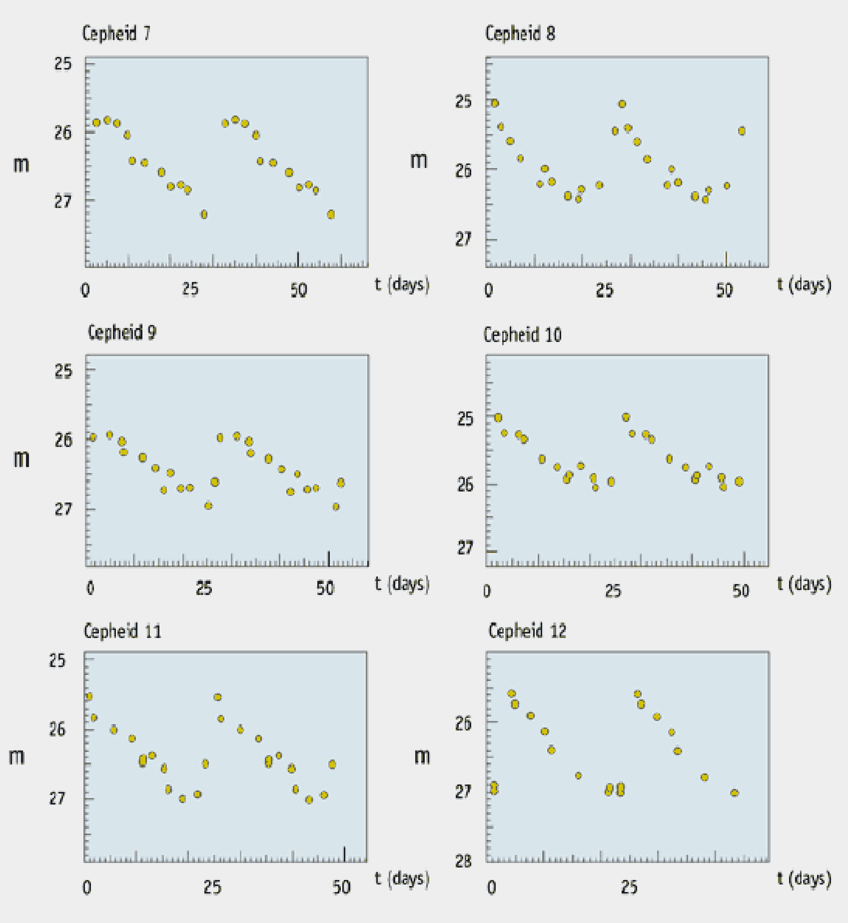
Model for Cepheid Variablity

- Basic idea given by Eddington in 1917:

Doubly ionized He is more opaque(than, say singly ionized He) At the dimmest point of the cycle, the gas is most opaque, and outermost layers heat and expand, as the gas expands, it begins to cool, so becomes less ionized and hence more transparent, radiation escapes. The expansion stops and star contracts due to gravity. And the process repeats.

(The identification of He was due to Zhevakin in 1953. Extensive detailed modeling for the P and time variation of P exists in the literature.)

Cepheid Light Curves



Typical saw tooth pattern

Period-luminosity relation

$$M_v = -2.81 log(P) - (1.43 \pm 0.1)$$

Feast & Catchpole, 1997

How to modulate the period and create a signal ?

- If the period can be modulated one can magnify the signal and send it out over enormous distances---intergalactic!
- This requires depositing energy deep inside the star so that the cycle ends earlier and the period is shortened….
- This is where neutrinos come in, as any other method will not reach deep inside the star…..

Neutrino Beam to Tickle a Star?

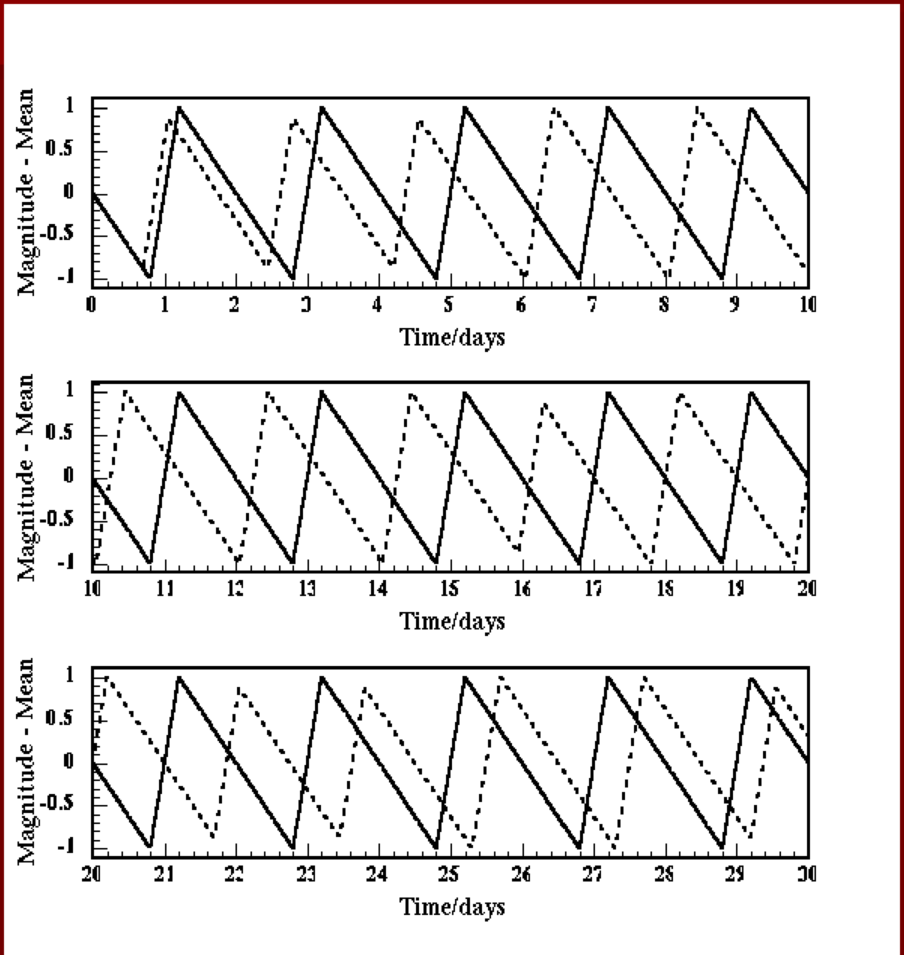
- Idea is to use neutrinos to deliver energy at controlled depth to star, as giant amplifier.
- Cepheids fill this need…. Bright pulsing stars with period of instability.
- Any civilization would monitor Cepheids as distance markers.
- Can be seen from distant galaxies (we see Cepheids in the Virgo cluster).

- Try to avoid details (which we cannot know) here, consider big picture.
- Guess at energy input: take deposition time of roughly speed of sound crossing nucleus (~0.1 s).
- Take power to be 10% of stellar core output.
- Need Pwr ~10^{-6} L_{ceph} . Few day Cepheid, would need 10^{28} J! But again, NOT OUR PROBLEM!

Tickling a Cepheid….?

- Could be much less needed… have not done studies. Not useful for now.
- Not to melt, need accelerator at r>100 AU, capture radiation from area ~0.1AU^2
- Accelerators are efficient, well known physics at lower powers, but need large technology extrapolation.
- Want neutrinos of order 1 TeV to deposit energy deep inside star with exponentially increasing density (energy choice selects radius of deposition).
- Studies needed to determine how little one needs to jump start expansion. But we need not solve that problem for present purposes, simply aver that it is solvable and the ETI would do so.

Light Curve of Simulated Cepheid



• Ordinate is stellar magnitude relative to the mean, abscissa is time in days.

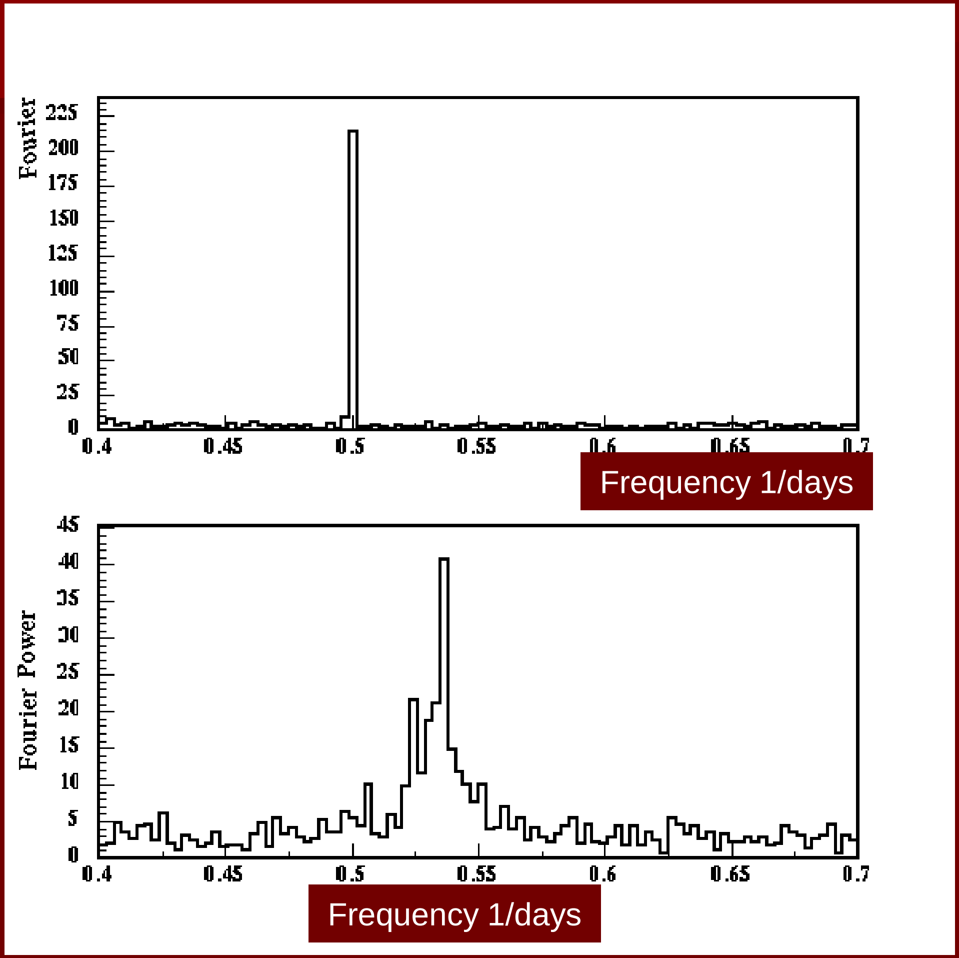
• Solid curve: unmodulated (idealized) Cepheid with 2 day period and 2 magnitude luminosity excursion, with expansion taking 0.4 days.

• Dashed curve: arbitrarily modulated light curve with triggered phase advance of 0.1 day (0.05 cycle) (Data = 1110000010100110).

• Units arbitrary but representative of real data.

•The sharpness of the transitions does not matter for the present discussions.

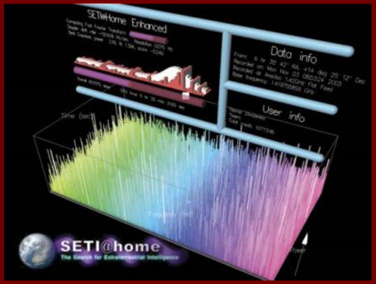
Fourier Transforms



- Ordinate is the Lomb-Scargle parameter, similar to chi squared;
- Fourier spectra of simulated observations of a regular periodic Cepheid variable and one with binary phase modulation.
- Abscissa is frequency, 1/days.

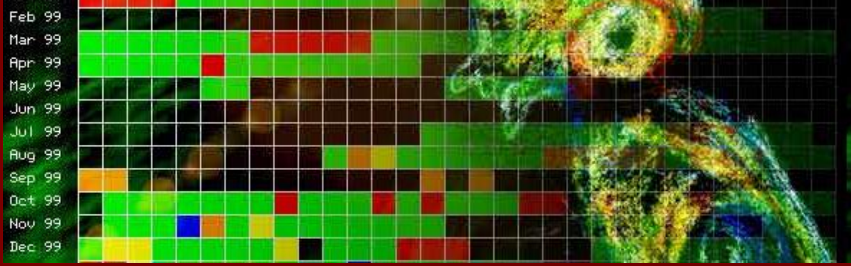
- More complicated structure of the modulated case is not so obviously different from a noisy spectrum: one could not immediately discern that the latter case was not ``natural''.

What is an ETI Signal?



- Information theory says maximally compact data is indistinguishable from noise.
- Interesting question: how can one tell for sure when a signal is not `random'? Or can we tell a ETI signal from a hole in the ground? (to quote John Ellis)
- ETI signal should have inexplicable regularities: repeated sequences, letters, frames, apparent structures…. (Applies to all SETI).
- Who knows how they might encode?
- Hopefully we will know it when we see it!

Outlook



- Unstable stellar systems such as the Cepheids can serve as gigantic signal amplifiers visible across the universe.
- Assume a sufficiently advanced civilization
  - able to tickle stars (?)
  - find it worthwhile (???).
- Signatures of ETI communication may be available in data already recorded, and that a search of Cepheid (and perhaps other variable star, such as Lyrae) records may reveal an entre' into the galactic 'internet'!
- Certainly a long shot, but should it be correct, the payoff would be immeasurable for humanity.
- Many possibilities for ETI communication: try all practical ones.
- The beauty of this suggestion: data already exists, and we need only look at it in a new way.

- We are NOT proposing to attempt building the neutrino beams nor try to tickle the nearest cepheid variable star*.
  Our proposals are much more modest.
  Assuming that there may be some ETI much more advanced technologically than us, and that they may be sending such signals (for whatever reasons of their own), we merely propose that we should:

*Nearest Cepheid is Polestar at 143 parsecs.

Summary:Action Items

- Look for 45.5 GeV neutrino signal in KM3
- Look for 6.3 PeV anti-electron-neutrinos in KM3 via Glashow Resonance
- Analyze Cepheid Data to look for modulation:

Signals are spectacular and the searches are practically free……

Large scale neutrino detectors…….”build them and they will come” !

Extra Slides

- More on Fermi Question:
- Many books and articles on this. For example: Stephen Webb, "Where is everybody?", Praxis Publishing, 2002.

Here are listed over 50 proposals for "solving" the Puzzle listed along with counter-arguments.

Classes of solutions proposed:

(1) They are already here!

e.g. They are Us, we ARE the aliens!

(2) They exist but have not yet communicated…..or don’t want to!

(3) They do not exist!?