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Galactic communication with neutrinos and SETI

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Galactic Neutrino Communication & SETI

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Nutech at ICTP, Trieste, july 17, 2009.

“Work” in collaboration with:

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

- 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. = 1
- John Learned, Tony Zee, Rolf-Peter Kudritzki, SP, arXiv:0809.0339(submitted to Phys.Rev.Lett.).

  Cit. = 0

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!

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

SETI: Search for Extra-terrestrial Intelligence

- There should/might be many advanced civilizations(ETI) out there in the galaxy……
- Fermi's question: where are they?*
- 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…

*Absence of evidence is NOT evidence of absence.

- For several decades Standard SETI 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.

Three Possible Scenarios to be discussed:

- 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. 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)

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…..

- Rose and Wright(2004) propose sending large amounts of data(photons or neutrinos) inefficient and maybe better to leave artifact...and send info on how to locate it!

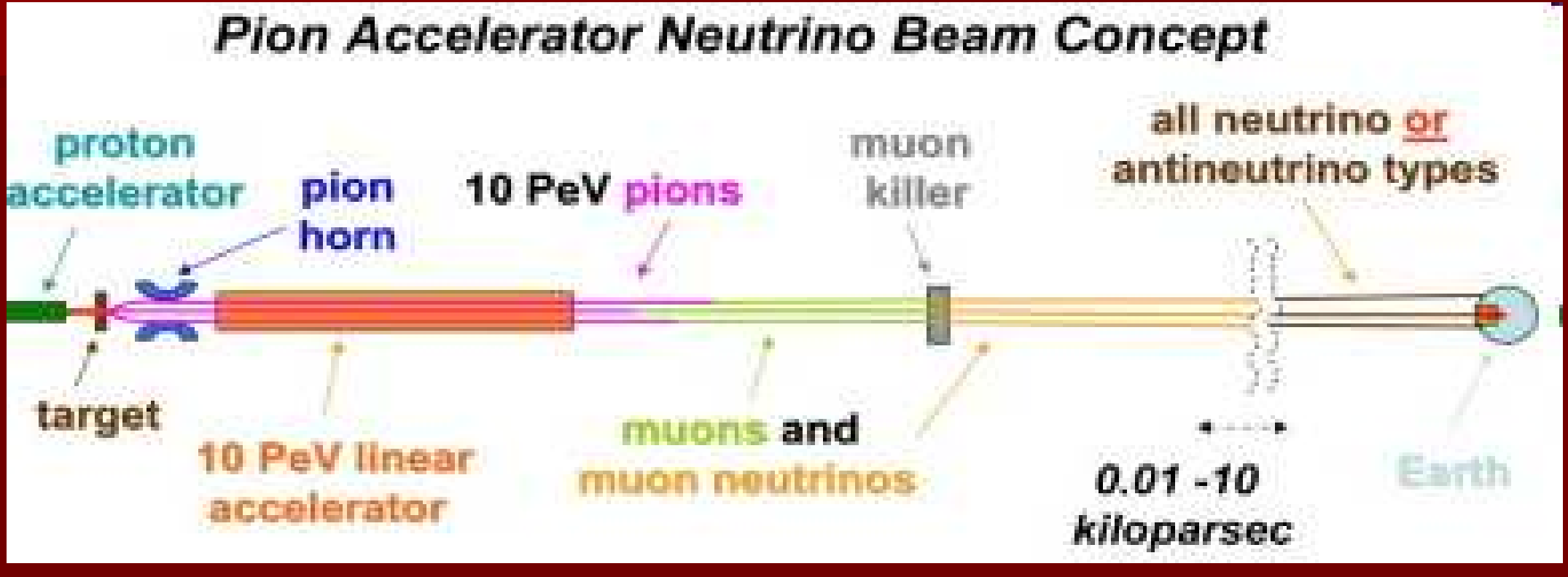
(Interesting argument but not compelling)

- 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. No BG and a unique characteristic energy.
- Range in Water at this energy ~ 100 km planned detectors will catch ~ 1 % of the flux(downgoing and horizontal).

- 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!
- Roughly the info rate ~ 140,000 bits/yr, using muon lifetime as time interval, and 1 nanosecond as minimum detectable now.
- A better choice is a pion accelerator….see next slide.

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



Artist's conception

Artist = John Learned

- 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. presence or absence 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…….

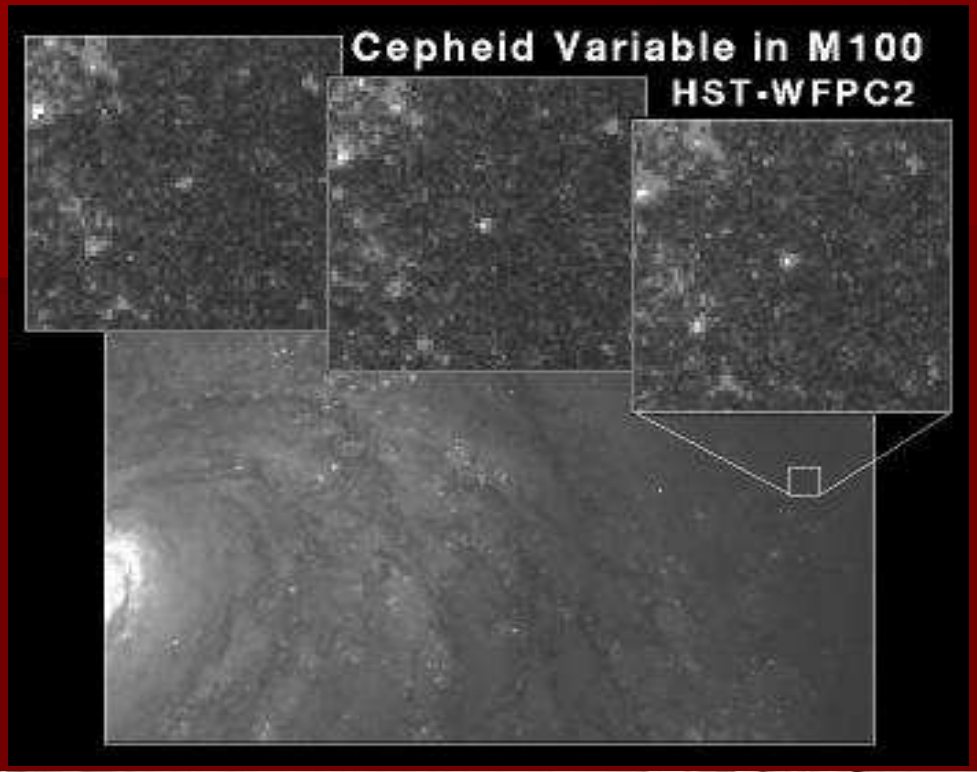
A Message from the Cepheids?

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 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.

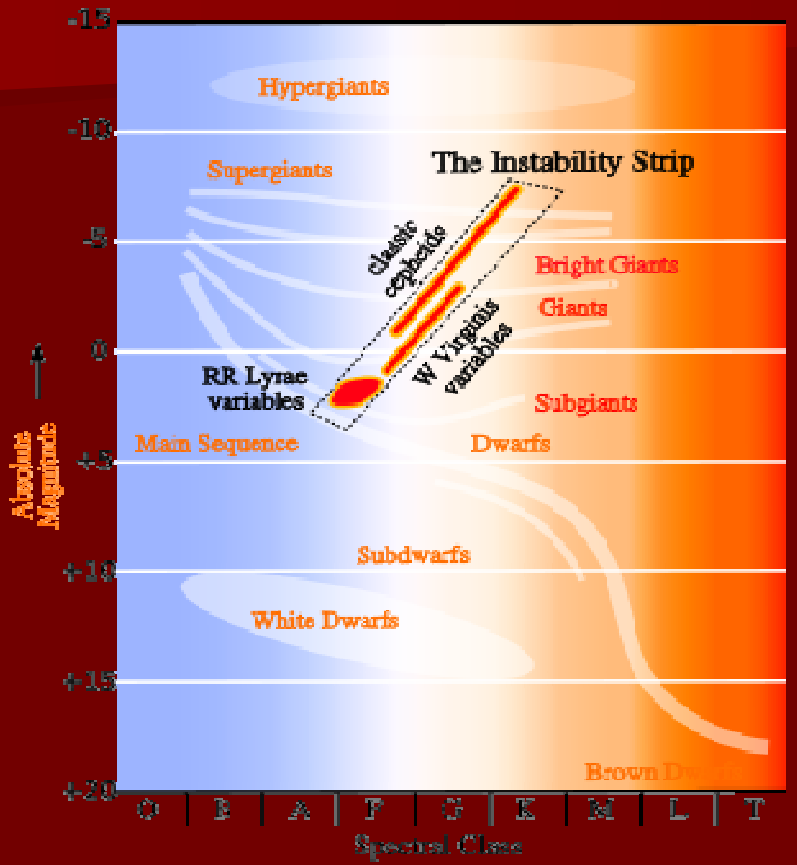
• Distances found with this method are among the most accurate available.

-

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).

Cepheid Mechanism



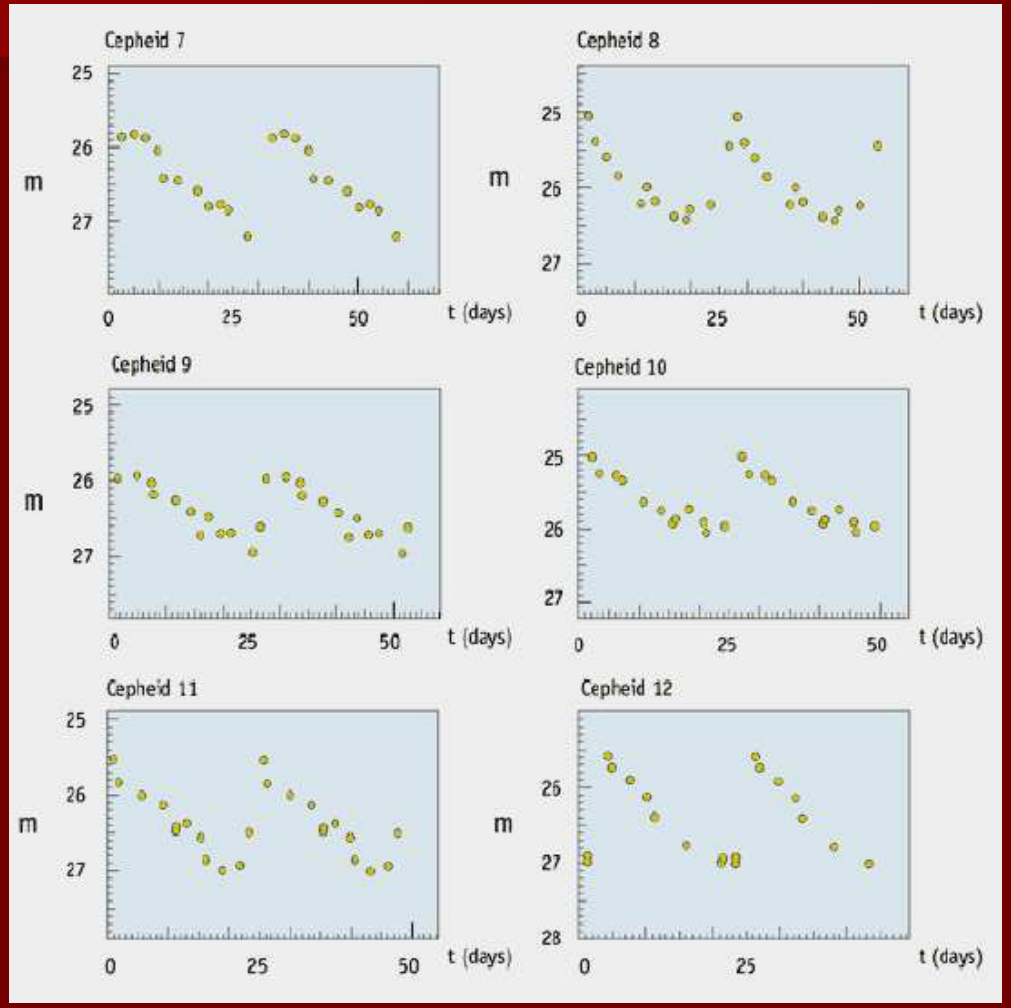
Cepheid usually a population I giant yellow star, pulsing regularly by expanding and contracting, regular oscillation of its luminosity from 10^3 to 10^4 times $L_\odot$

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.

Cepheid Light Curves



Typical saw tooth pattern

Period-luminosity relation

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

Feast & Catchpole, 1997

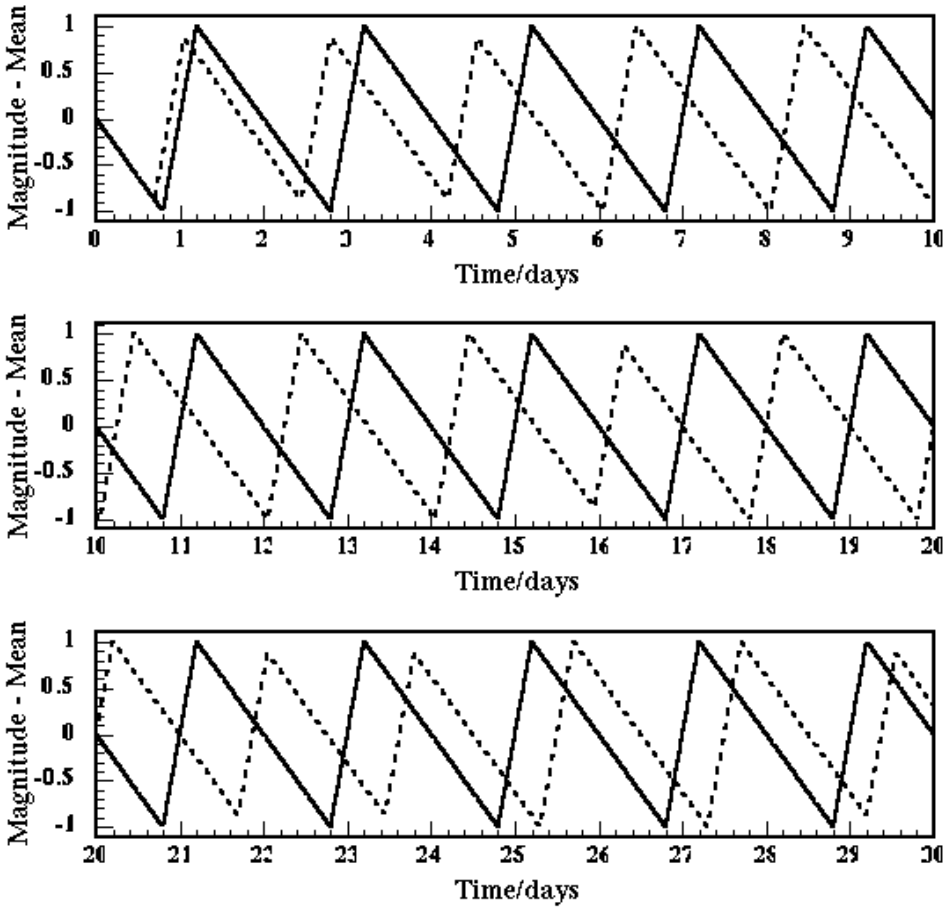
How to tickle a Cepheid

- 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!

How to Tickle 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.

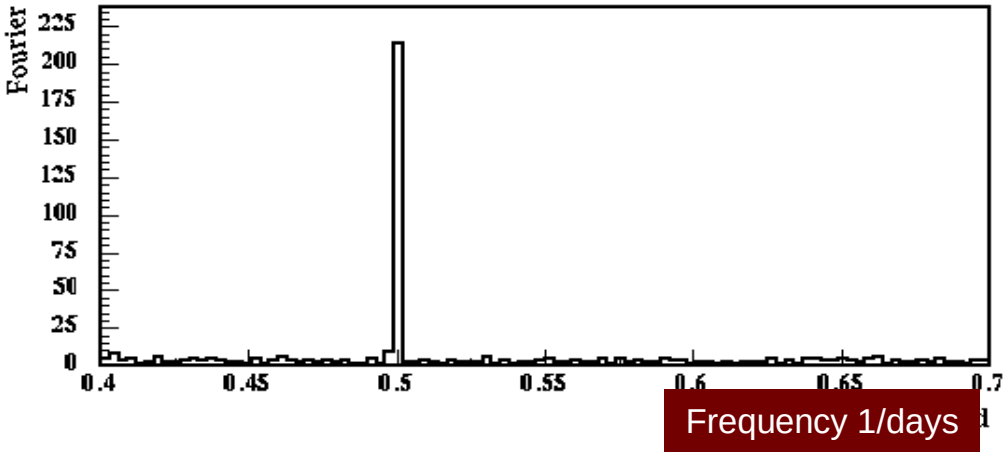
- Solid curve: unmodulated (idealized) Cepheid with 2 day period and 2 magnitude luminosity excursion, with expansion taking 0.4 days.

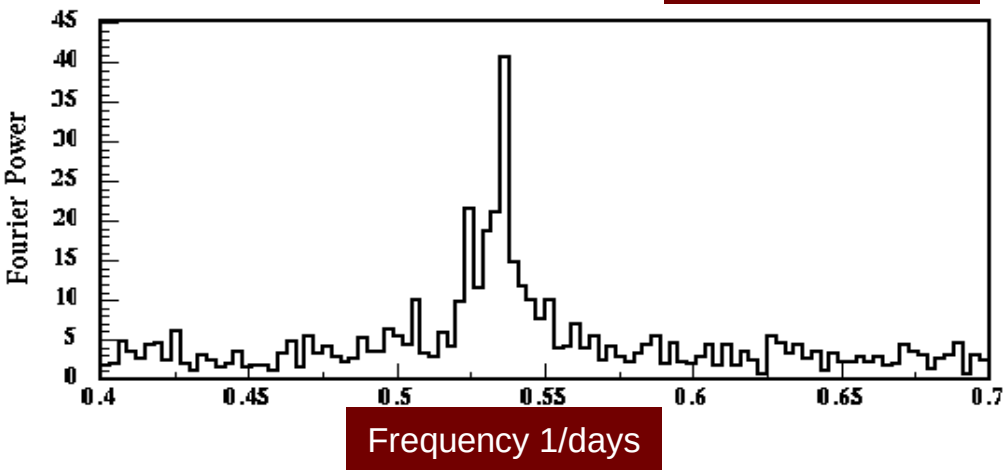
- Dashed curve: arbitrarily modulated light curve with triggered phase advance of 0.1 day (0.05 cycle) (Data = 1110000010100110).

- Units arbitrary but representative of real data.

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

Fourier Transforms

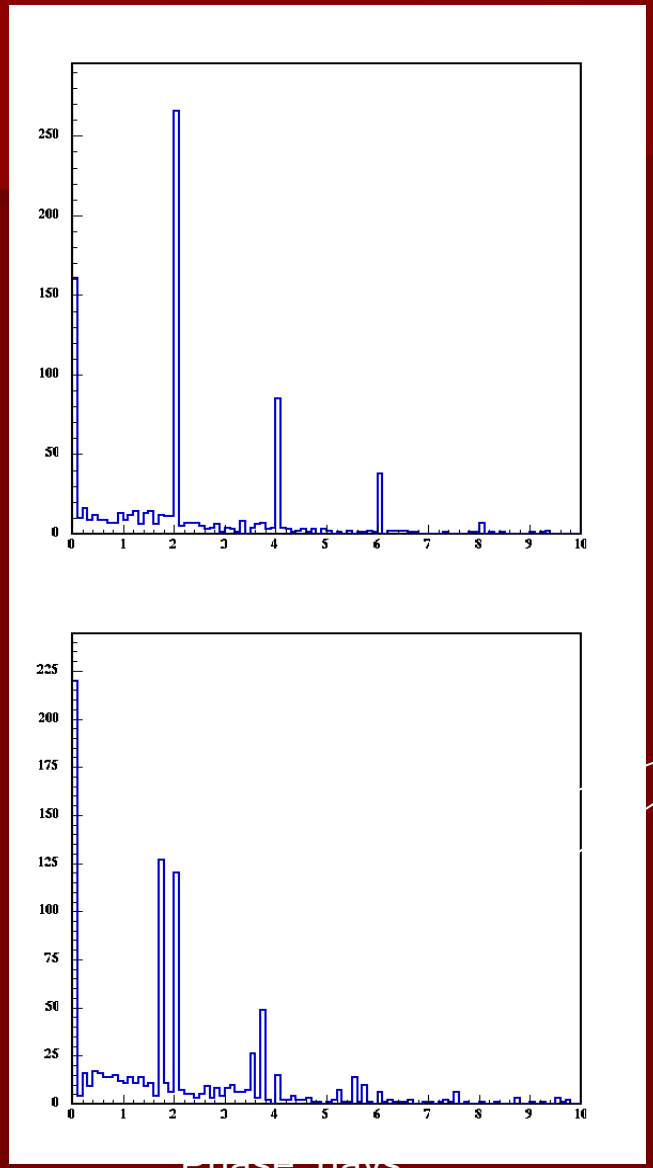




- Ordinate is the Lomb-Scargle parameter, similar to chi squared;
- Fourier spectra of simulated observations of a regular periodic Cepheid variable and one with binary phase modulation.
- Abscissa is frequency, 1/days.

- 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''.

Phase Residuals

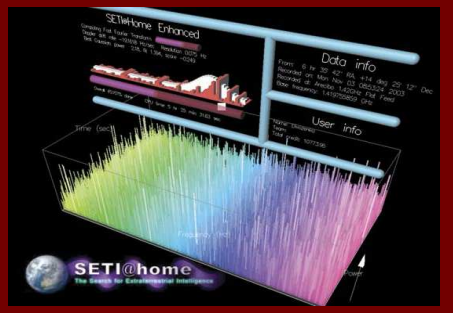


- Unmodulated data shows peaks for obervations in the next cycle, one skipped cycle, two missed cycles, etc.
- Phase residuals of observations, when extrapolated to common phase at period given by Lomb-Scargle peak.

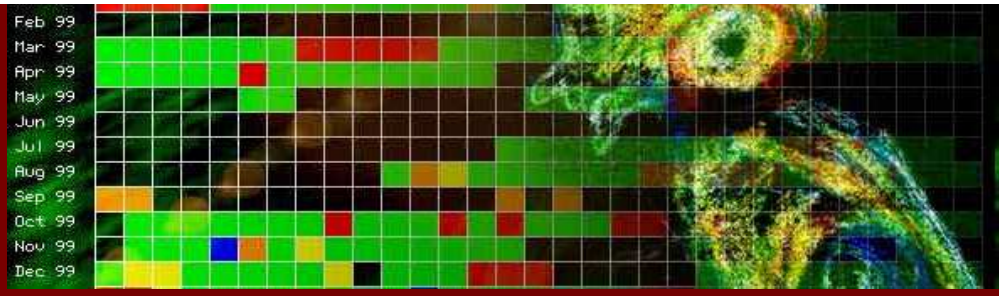
- Modulated case shows splitting of these cases depending upon the combination of bits.

- Illustrates possible means of detecting ``unnatural'' phase variation without dense sampling.

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 from a hole in the ground?
- 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 proposal is much more modest.

  Assuming that there may be some ETI much more advanced technologically than us, and that they may be sending such signals, we merely propose the following:

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
- These signals may be coming from the future (as we heard from Tom Weiler)!
- 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” !