A Message from the Cepheids?

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http://xxx.lanl.gov/PS_cache/arxiv/pdf/0809/0809.0339v2.pdf, submitted to Phys. Lett. B

SETI

Search for **E**xtra**T**errstrial **I**ntelligence

- By almost any reckoning there should be many civilizations out there, or have been.
- Most peculiar, Fermi question: Where are They?
- Much speculation over last >50 years (self extinguishing, killed off by GRBs, galactic transport not practical, too wise to be seen, they are here, they are indeed trying to communicate,….)
- Concern about hostile life… maybe not want to communicate openly?
- Maybe ETI want to communicate warning, rules of society, instructions on other means of communication?
- Can invent innumerable scenarios, most wrong; our strategy, forget guessing, let us look for signals wherever possible.

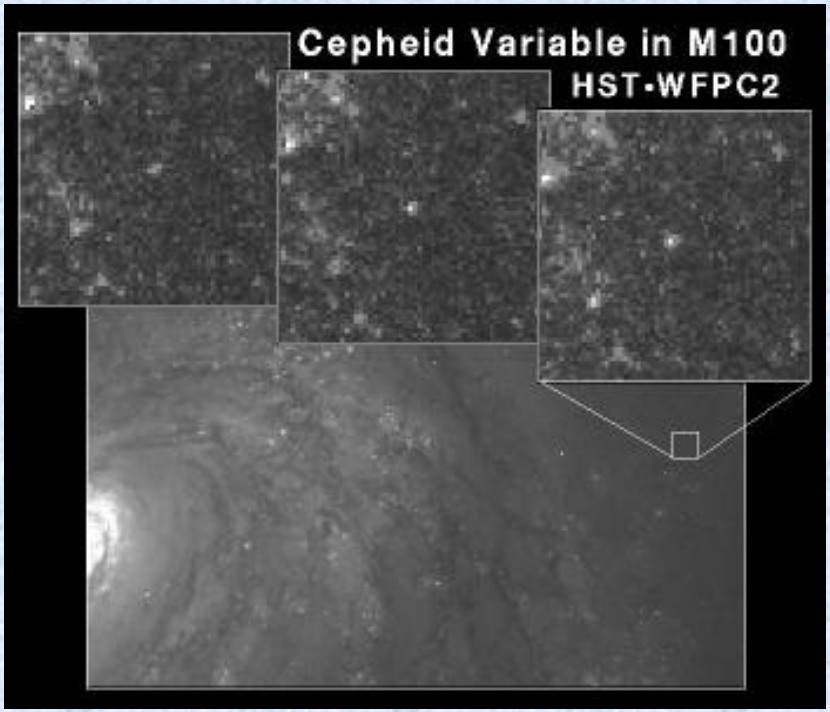
Standard SETI Searches

- Typically look in radio band, eg. Allen array.
- Scan for something signal-like (what is that?).
- Power considerations make non-targeted signals impossible even from nearest stars.
- Other suggestions in radio at other frequencies (e.g. microwave bursts)
- Very short (ns) optical pulses (e.g. Princeton)
- High energy neutrinos either as time standard or as targeted private channel (to be seen in upcoming detectors).
- Look for artifacts in our solar neighborhood.
- Etcetera….

Neutrino Beam to Tickle a Star?

- Idea 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.
- Fringe benefit: any civilization would monitor Cepheids as distance markers.
- And can be seen from distant (Virgo cluster) galaxies.

Cepheids Observed for >100 Years



- 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.

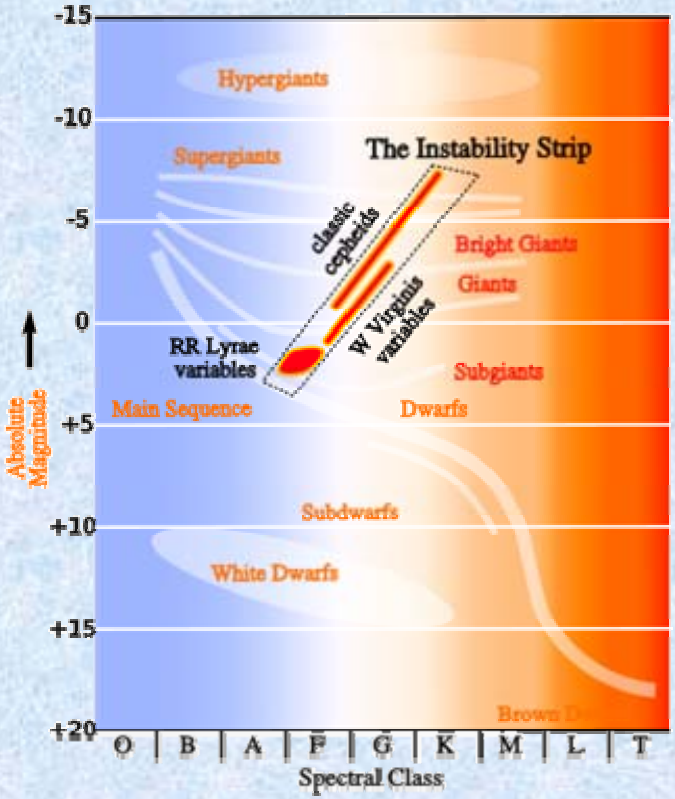
- This correlation was discovered and stated by Henrietta Swan Leavitt in 1908 and given precise mathematical form by her in 1912.

- 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.

- Leavitt, Henrietta S. "1777 Variables in the Magellanic Clouds". *Annals of Harvard College Observatory*. LX(IV) (1908) 87-110.
- Miss Leavitt in Pickering, Edward C. "Periods of 25 Variable Stars in the SMC". *Harvard College Observatory Circular 173* (1912) 1-3.

Cepheid Mechanism



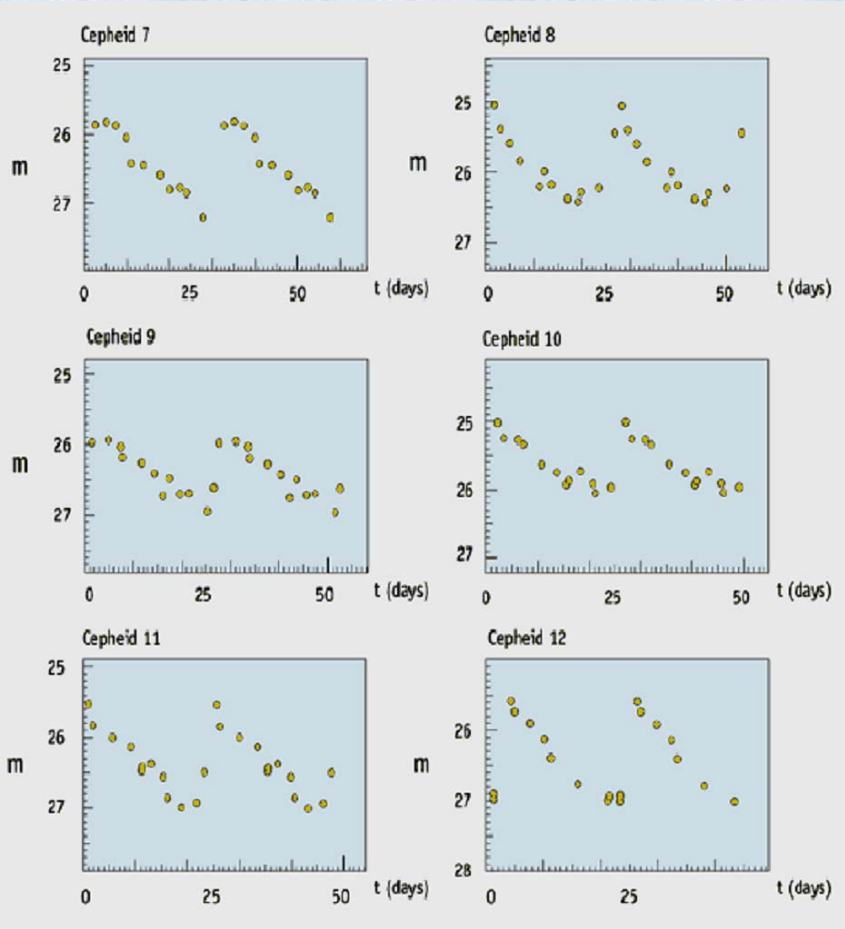
Cepheid usually a population I giant yellow star, pulsing regularly by expanding and contracting, regular oscillation of its luminosity from 10^3 to 10^4 times $L_\odot$

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

Sample of data from Hubble Key project measured 800 Cepheids, out through Virgo Cluster

Period-luminosity relation

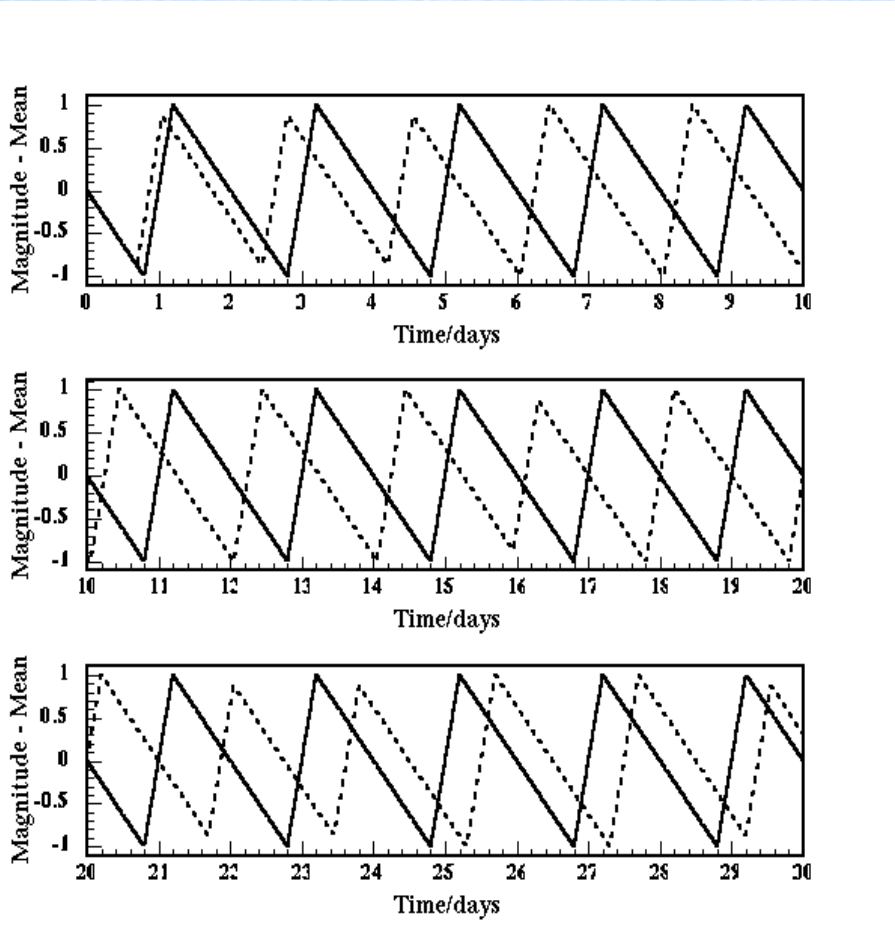
$$M_v = -2.81 log(P) - (1.43 \pm 0.1)$$

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!
- 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.

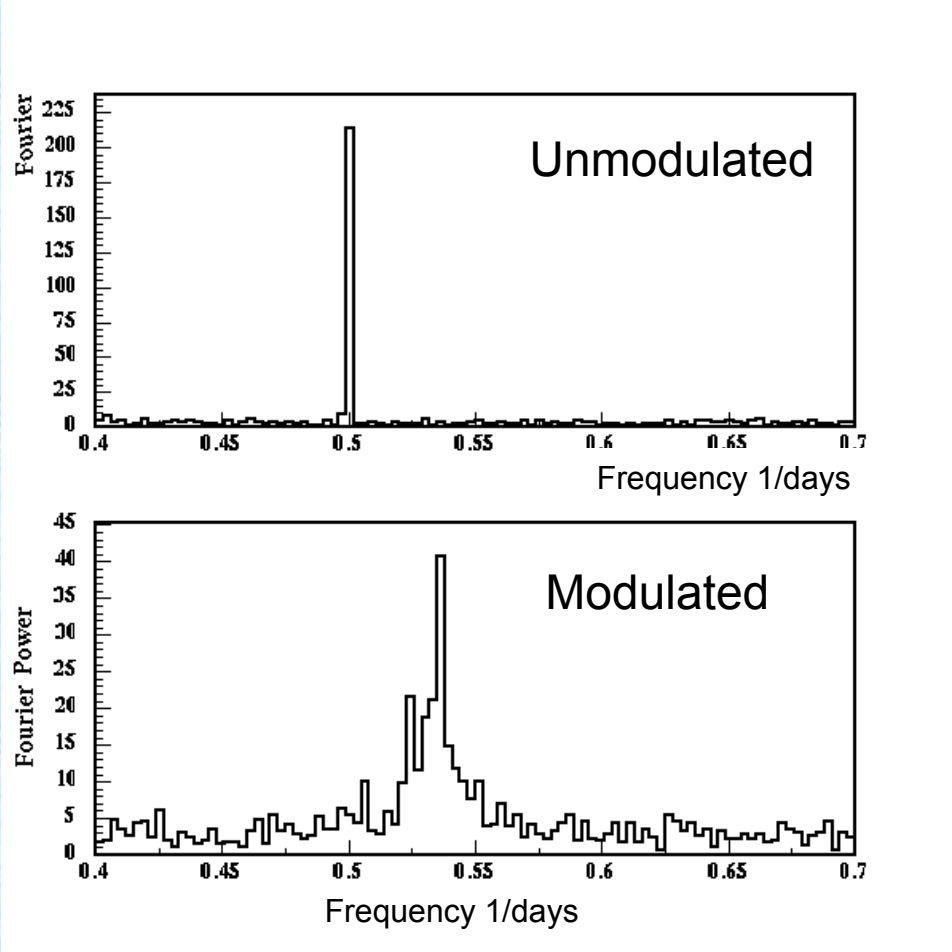
- Solid curve: unmodulated (idealized) Cepheid with 2 day period and 2 magnitude luminosity excursion, with expansion taking 0.4 days.

- 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

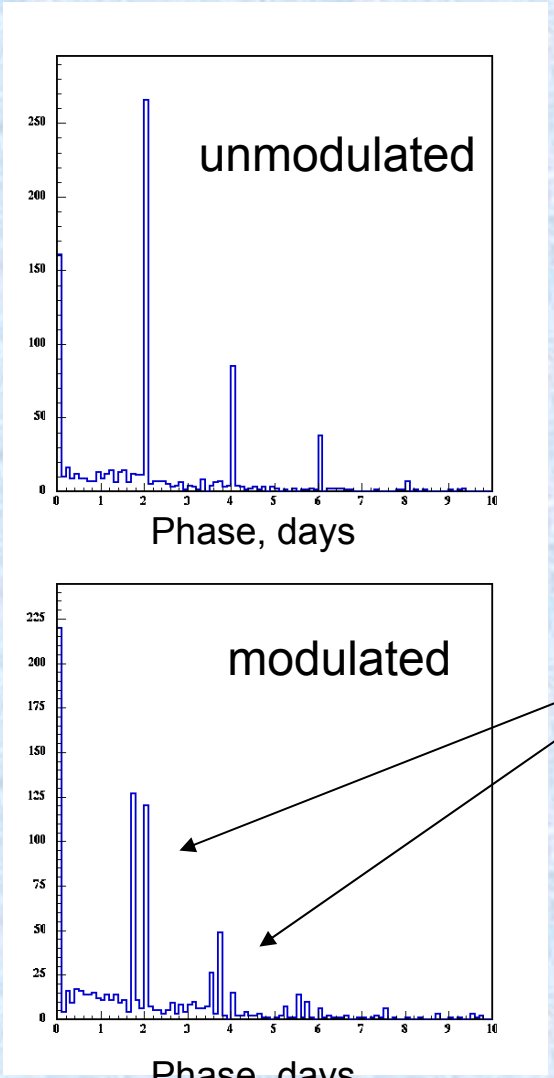


- Fourier spectra of simulated observations of a regular periodic Cepheid variable and one with binary phase modulation.

- Ordinate is the Lomb-Scargle parameter, similar to chi squared;
- Abscissa is frequency, 1/days.

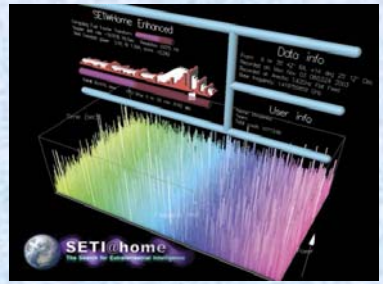
- More complicated structure of the modulated case is not so obviously different from a noisy spectrum: one could not immediately discern that the latter case was not ``natural''.

Phase Residuals



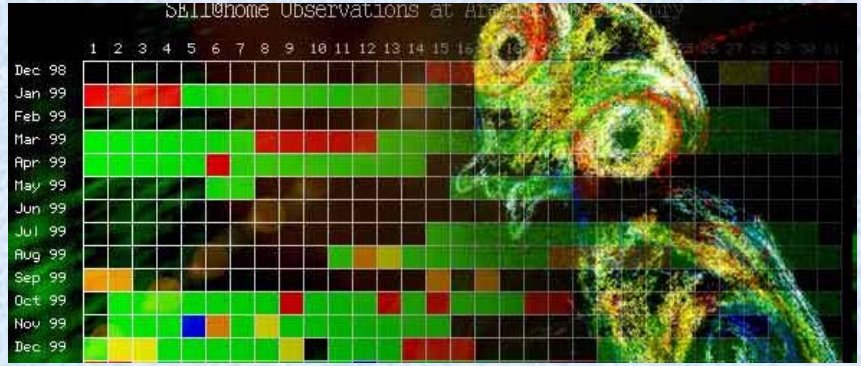
- Phase residuals of observations, when extrapolated to common phase at period given by Lomb-Scargle peak.
- Unmodulated data shows peaks for obervations in the next cycle, one skipped cycle, two missed cycles, etc.
- Modulated case shows splitting of these cases depending upon the combination of bits.
- Illustrates possible means of detecting ``unnatural" phase variation without dense sampling.

What is an ETI Signal?



- Interesting question: how can one tell for sure when a signal is not `random'?
- Information theory says maximally compact data is indistinguishable from noise!
- 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.