SETI FROM NARROWBAND TO WIDEBAND : A REVOLUTION CALLED KLT

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ABSTRACT. SETI is the extraction of very weak radio signals out of the cosmic background and terrestrial noise. Back in 1959, when SETI was born, it was natural to attempt this extraction by the only detection algorithm well known at the time, i.e. the Fourier Transform (FT). In fact:

1) SETI radio astronomers assumed that a candidate ET signal would necessarily be a sinusoidal carrier, i.e. a very narrow-band signal. Over such a narrow band, the noise is necessarily white. So, the basic mathematical assumption behind the FT that the background noise must be white was "perfectly matched" to SETI for the next fifty years!
2) In addition, the Americans J. W. Cooley and J. W. Tukey discovered in April 1965 that all FT computations could be speeded up by a factor of N/ln(N) (N is the number of numbers to be processed and ln(N) is its natural logarithm) by replacing the old FT with their own Fast Fourier Transform (FFT) algorithm. Then, SETI radio astronomers all over the world gladly, and unquestioningly, adopted the new FFT for all SETI searches.

In 1983, however, the French SETI radio astronomer, François Biraud, dared to challenge this view. He argued that the shifting trend on Earth was from narrowband to wideband telecommunications, and that we can only make guesses about ET's telecommunication systems, the narrow-band assumption being just an warranted assumption in SETI. We must, on the contrary, be inspired by up what is happening on the Earth first.

A new transform was thus needed that could detect signals over both narrow and wide bands, regardless of the colored noise distribution over any finite bandwidth. Such a transform had actually been discovered as early as 1946 by the Finnish mathematician, Kari Karhunen and the French mathematician, Michel Loève, and is thus named KLT for them. In conclusion, François Biraud suggested to "look for the unknown in SETI" by adopting the KLT rather than the FFT for SETI.

Independently of him, the American radio astronomer, Bob Dixon, of Ohio State University, reached the same conclusions also, but published his results only much later.

And, independently of them both, this author also reached the same KLT conclusions and started "preaching the KLT for SETI" in 1987: first at the SETI Institute itself, then at the Italian CNR SETI facilities located at Medicina, near Bologna. But while François Biraud and Bob Dixon were both halted by the difficult computational problem of finding the eigenvalues and eigenvectors of the very large symmetric autocorrelation matrices, the story took a different path in Italy. The director of the CNR radio telescopes, Stelio Montebugnoli, was willing to help, and, little by little, young bright students (notably Domenico Caliendo) succeeded in programming the KLT algorithm at the Medicina CNR radio telescopes. By the year 2000, the advent of programmable cards finally made the "miracle" happen: the KLT for SETI was fully implemented at the SETI-Italia facilities for the first time in SETI history, and is now able to detect weaker signals than the FFT.

This paper describes what the KLT mathematical revolution is, and how it works for SETI.