Detection of Virgo A

Detection of Extragalactic Radio Source VIRGO A with Amateur Radio Astronomy Equipment

This page describes the detection of an extragalactic radio object known as Virgo A during February 2008 using an amateur interferometer at 406MHz.

Virgo A is a giant elliptical galaxy - Messier 87 (NGC 4486, 3C274) and is one of the most remarkable objects in the sky. It is perhaps the largest galaxy in the closest big cluster to us, the famous Virgo Cluster of galaxies (sometimes called "Coma-Virgo cluster" and lies at the distance of this cluster (about 60 million light-years). See the photograph opposite.

Virgo Cluster

The galaxy is over half a degree in extent (more than the diameter of the full moon) as shown in long exposure photographs and this corresponds to a linear diameter of more than half a million light years .

Its coordinates are 12^h 30^m 49.42338^s RA and +12° 23′ 28.0439″ Dec.

M87 Relativistic Jet

M87 was identified with the radio source Virgo A by W. Baade and R. Minkowski in 1954. In 1956, a weaker radio halo was found by J.E. Baldwin and F.G. Smith of Cambridge.

The galaxy has a spectacular jet which is better seen on short exposure photographs as shown opposite. This is a directional beam of relativistic plasma issuing from the core of the galaxy and contributes strongly to its radio emissions.

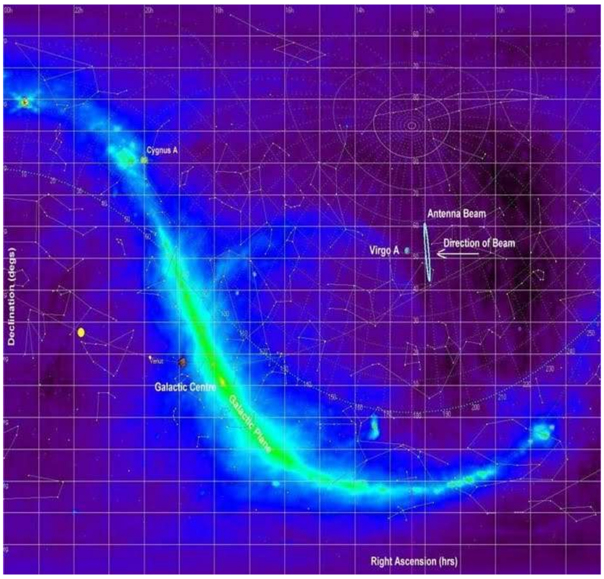
Freq: 38 MHz	Flux: 3200 Janskys
Freq: 178 MHz	Flux: 970 Janskys
Freq: 240 MHz	Flux: 800 Janskys
Freq: 408 MHz	Flux: 519 Janskys
Freq: 412 MHz	Flux: 500 Janskys
Freq: 958 MHz	Flux: 300 Janskys
Freq: 1420 MHz	Flux: 200 Janskys
Freq: 2700 MHz	Flux: 120 Janskys
Freq: 3200 MHz	Flux: 100 Janskys
Freq: 5000 MHz	Flux: 67.6 Janskys

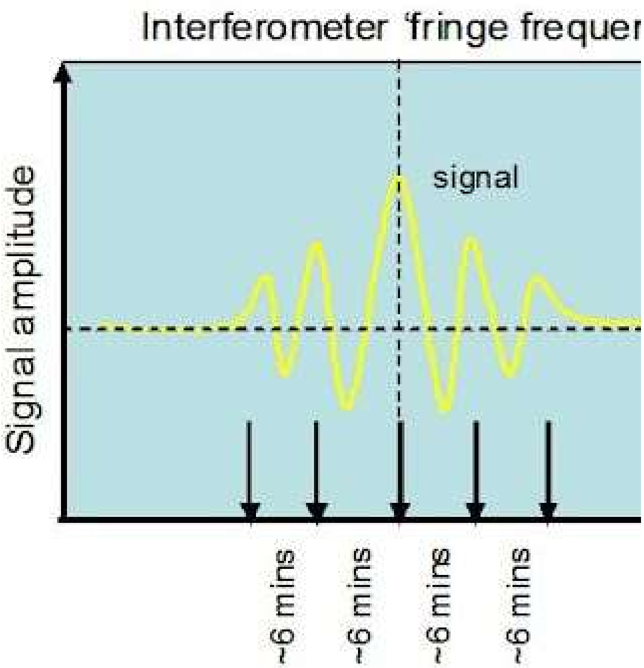
The calculated Spectral Index: 0.79 *

Flux Density of M87 at various frequencies

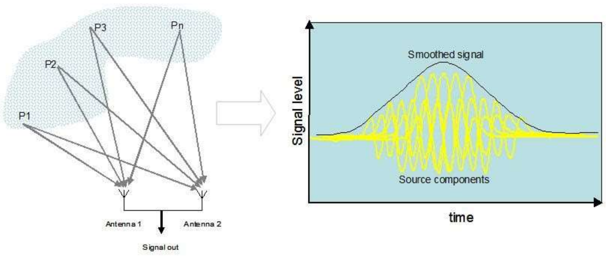
The detection of this object by amateur radio astronomers is somewhat of a challenge as it has a strength of only ~ 560Jy at 406MHz. (1Jy = 10^{-26} W/m^2).

The Interferometer was set up at a suitable declination for a transit scan to take M87 through the antenna beam as shown below.





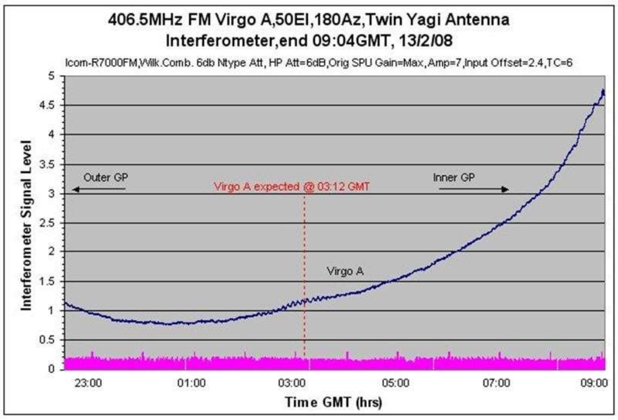
The angle separating the beams in this interferometer is 1.4^0, which means that as the earth rotates at 15^0 / hour the source passes through one of the interferometer beams in approximately 1.4 x 60/ 15 = 5.6 minutes. Thus the time between peaks in the received signal pattern is 5.6 minutes as shown in the figure opposite. This is known as the fringe frequency.



Extended sources do not generate fringes as a Total Power is produced

A radio interferometer will produce fringes if the angular dimension of the source object is smaller than the angular resolution of the interferometer. In this case clear signal fringes are formed as the ‘point source’ object moves through the beams. Traditionally interferometers have been used to measure the angular dimensions of small sources by increasing the length of the baseline until recognisable fringe patterns appear. At this point the interferometer can be said to have 'resolved' the source. In professional measurements resolutions of minutes or seconds of arc have been achieved.

When an interferometer is pointed toward an extended radio source (where its angular dimensions are greater than the interferometer resolution) no fringes will be observed and the receiver will revert to a ‘total power’ measurement. This occurs because there are signals from different parts of the source P1,2,3 to Pn (in the diagram opposite) being received by multiple antenna beams at any one time which ‘smoothes out’ the fringe pattern. See opposite.



Measurements of Virgo A were made with the 30m baseline interferometer at 406.5MHz during night-times in February 2008. The winter months are good for measurements because the temperature is usually low and relatively stable overnight. This makes the operation of the temperature control of the LNAs in the head amplifiers easier to achieve.

More information can be obtained by opening the file :
{ Detection of Extragalactic Radio Source VIRGO A.doc }
at the base of this page.

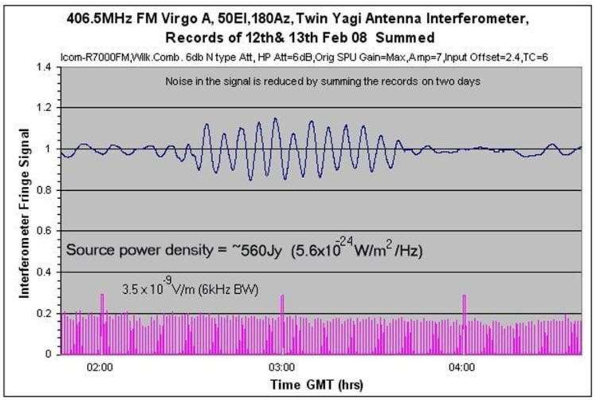
During this time Virgo A is also easily visible and at a reasonably high elevation of 50^0 which avoids thermal radio noise from the ground entering the antenna beam.

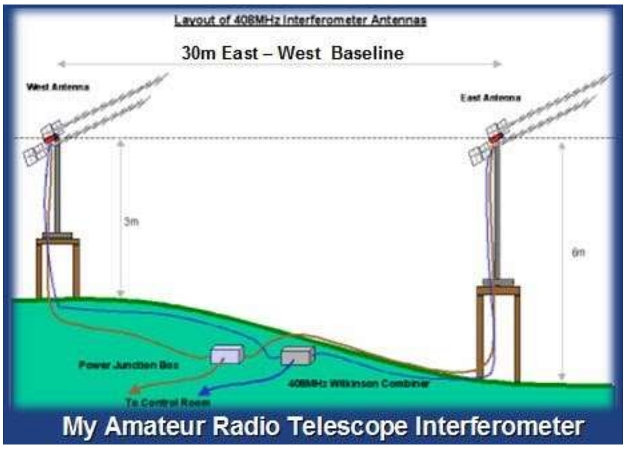
The recorded signal strength during the 10 hour transit scan is shown opposite.

Whilst the total power signal from the synchrotron radiation in the galactic plane is large, the signal from Virgo A is small and is indicated by the fringe pattern at just after 03:00 hrs GMT. It is possible to subtract out the total power signal leaving only the fringe pattern.

Перевести

With sufficient long term stability of the receiving system it is possible to process and combine records obtained on different days to improve the signal to noise ratio and bring out the fringe pattern features. This has been done to produce the record shown below which clearly indicates the detection of Virgo A.

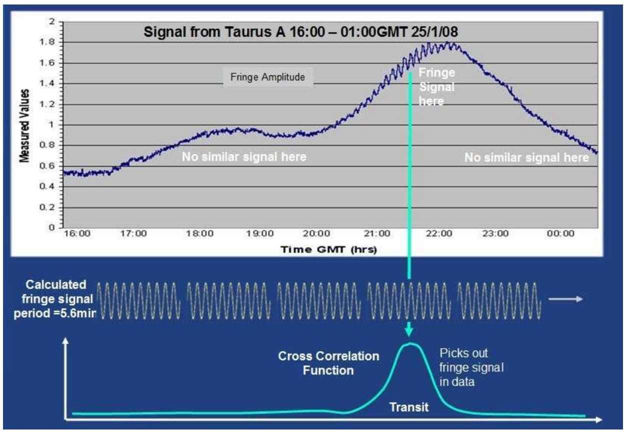


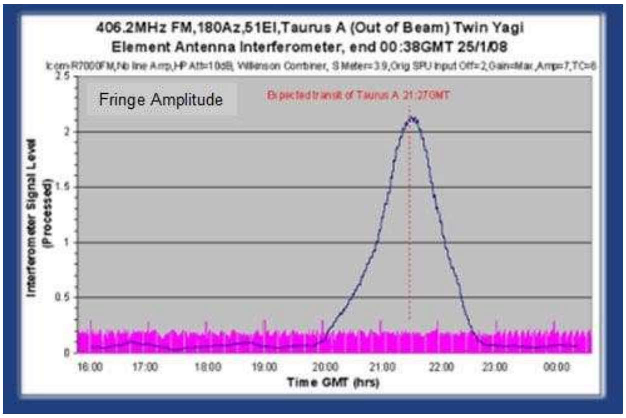


Using Cross Correlation to plot Fringe Amplitude

We can use a cross correlation technique to pick out the fringe pattern among the background signal, This can be done using the correlation function in a Microsoft Excel spreadsheet. It enables a plot of fringe amplitude as a function of position - or time in the case of a transit scan.

We can calculate the expected interferometer fringe frequency during a transit scan from the wavelength being observed, the beamwidth of the antenna pattern and the speed of rotation of the Earth.





The yellow line in the plot opposite demonstrates how effective correlation can be in picking out fringe signals from receiver data. The raw fringe signal is dwarfed by the galactic background noise, but the correlator 'pulls' out a clear detection profile.

The details are given below:

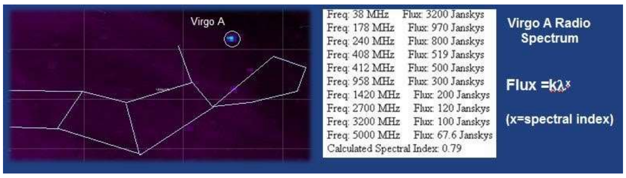
Frequency = 408MHz, λ= 0.735m, & baseline =30m

$\Delta\theta$ = 0.735/ 30 = 0.0245 rads or 1.4 degrees

Перевести

Earth rotation angular velocity = 150 / hr

So fringe frequency = 1.4 /15 hrs = 5.6mins



We can generate a sinewave with a period of 5.6 minutes and use this as the 'template' in the cross correlation process within Excel. Put simply the process 'looks for' signals with the same period in the receiver data and gives an output proportional to its amplitude.

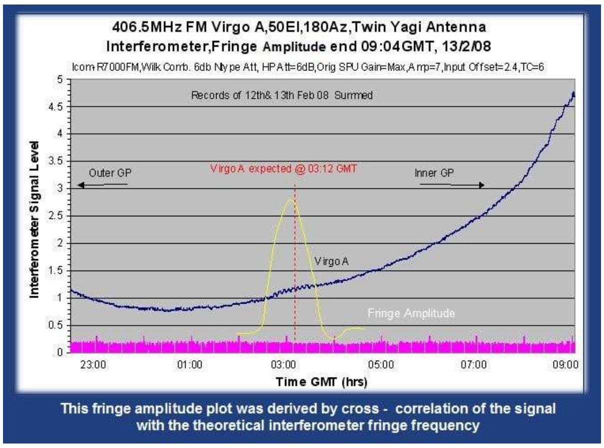
This is demonstrated opposite using data from a transit scan of Taurus A - The Crab SNR.

The actual output of the Excel correlation calculation for Taurus A is shown opposite.

The graph show a very strong detection of the source and the actual peak signal during the transit occurs at exactly the expected time.

Thus interferometers can be used to fix the position of sources with considerable accuracy.

The correlation process has also been applied to the data from Virgo A as shown below.



This fringe amplitude plot was derived by cross - correlation of the signal with the theoretical interferometer fringe frequency

More information can be found by opening the Power Point presentation at the base of this page.

W Detection of Extragalactic Radio S…	David Morgan, 6 Feb 2016, 08:25	v.1	
P Presentation Part 2A.ppt (4165k)	David Morgan, 8 Feb 2016, 02:27	v.1	

Комментарии

У вас нет прав для добавления комментариев.