THE CHOICE OF INTEGRATION TIME FOR THE AT

AT/20.1/008

1) Introduction

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The user may well require (or think he requires!) data only at some longer interval nT, where n is an integer, but it is still advisable to store the data at intervals T in case it turns out that the atmosphere/ionosphere was less stable than the user thought, or he finds that he needs to map a wider field than originally expected. T must therefore be small enough so that good data is stored under the worst conditions that might reasonably be expected. On the other hand, too small a value of T will result in the storage of unnecessarily large volumes of data, perhaps leading to storage, financial, and even flow-rate problems.

The choice of T is therefore critical. Here we discuss the relevant factors. These fall naturally into 2 categories. The first category has most relevance for the long baseline array (LBA), and the second for the compact array (CA).

2) Maximum fringe rate at beam centre

The residual fringe rate at the beam centre will in general not be zero. If the residual fringe rate f is comparable to 1/T, then it has two effects:

a) The amplitude of the fringes is reduced. A correction for this may easily be applied if $f<1/10T$, but the signal to noise ratio is still worsened.

b) If $f>1/2T$, it becomes impossible to track the phase, because of 360° ambiguities. In practice, phase tracking in the presence of noise becomes difficult at considerably lower fringe rates.

In general, a good rule-of-thumb criterion which has evolved through experience with MERLIN is to require that

$$f<1/10T$$

which corresponds to a maximum phase difference between adjacent samples to be 36°, giving a 6% reduction in amplitude, for which a correction based upon the phase data may be made.

We now discuss the possible causes (other than instrumental problems) which can cause such a residual fringe rate. Each of the three effects discussed increases to some extent with baseline length, and so will be much more significant for the LBA than for the CA.

2.1) Ionospheric Stability

Ionospheric fluctuations have scale sizes in the range 20-1000km, amplitudes of a few percent of the total electron content, and produce phase variations in an interferometer of a few tens of degrees on time scales of tens of minutes to hours. (Warwick et al. 1976). Experience with MERLIN has shown that the effect of the fluctuations increases rapidly with baseline upto 50km, and increases slowly thereafter. The worst cases recorded with MERLIN at 408MHz are during periods of violent solar activity, when the phase, particularly at low elevations, can rotate at a few turns per minute on the longest (130km) baselines. However, such events are uncommon, and phase rates similar to those described by Warwick et al. are typical on all longer baselines.

Ionospheric effects are most pronounced at low frequencies. MERLIN is therefore usually operated with integration times of 10s at 408MHz, compared to the 30-60s used at higher frequencies. Since the fluctuations are not expected to increase rapidly for baselines >130km, 10s integration times will usually be adequate on the AT even at 408MHz on 600km baselines, although use of shorter times may occasionally be required.

2.2) Tropospheric Stability

Tropospheric fluctuations are most apparent at high frequencies. Their effects on long baseline interferometers are less well understood than ionospheric effects, because of the relative lack of experience. Furthermore, results of existing studies reach no consensus for the distribution of scale sizes (e.g. Rogers & Moran and references therein).

Experience with MERLIN at 22GHz shows typical fluctuations of one turn of phase in tens of minutes, reaching a maximum in normal conditions of 1 turn in 5 minutes on a 50km baseline (see Fig.1). Shorter baselines have somewhat smaller fluctuations. In practice, 30s integrations are used on MERLIN at 22GHz for sources above 20° elevation and 10s for sources below 20°.

For the AT the problem will be most severe on the long baselines at 50GHz, although mitigated to some extent by the relatively small maximum zenith angle at Parkes. Extrapolating from the MERLIN results, and assuming fluctuation scale sizes to be predominantly less than 50km, we may expect maximum fringe rates of 1 turn in 2 minutes, allowing integration times of ≈20s. The CA will also be affected by these fluctuations, which extend down to a scale size of 1km (Hinder & Ryle, 1971) but integration times of 30s will be adequate in this case.

2.3) Positional Errors

A common situation which has arisen with MERLIN, and will presumably arise with the LBA, is that a source whose position is known only to arcmin accuracy is to be mapped with sub-arcsec resolution. Closure phase techniques, which are insensitive to source position,

allow us to do this, provided that the assumed source position is not so far wrong that the residual phase rotates faster than one turn every few integration periods. In practice this means on MERLIN that any source can be mapped at 1660MHz provided that its position is correct to 2 arcmin. Single dish source positions (e.g. from OH surveys) are frequently of this order.

For the AT LBA, if we wish to observe a source, whose position is known only to 1 arcmin, at 22GHz on a 600km baseline the residual fringe rate will be 1 Hz. Clearly no reasonable choice of integration time will allow us to operate in this mode, and in general to observe such a source it will first be necessary to obtain a more accurate source position using the CA.

At any frequency, source positions can quickly and easily be measured on the CA to within one synthesised beamwidth. This will then give a maximum fringe rate on the LBA, at any frequency, of 1 turn in 3 minutes. An integration time of 20s is thus adequate for this type of observation.

3) Maximum fringe rate at the map edge

For wide field mapping, we wish to be able to map the entire primary beam with the CA. However, because of the differing fringe rate across the map, the visibility at the edge of the map is reduced (Thompson 1982). This problem does not arise on the LBA because of the relatively small fields to be mapped with it.

Consider the CA tracking a source at the south pole. At the edge of the field of view, we have a maximum fringe frequency of

$$f = (L/\lambda)\Omega \sin\theta \sin H$$

where L is the maximum baseline,
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At the edge of the field of view of the CA

$$(L/\lambda)\sin\theta \sim 6\text{km}/22\text{m} \sim 272$$

giving $f \sim 0.02$Hz.

Using a box-car integrator of length T on a fringe of frequency f gives a reduction in fringe amplitude of

$$R = \sin(\pi f T)/(\pi f T)$$

$$1-(\pi f T)^2/6$$

$$= 0.984 \text{ for } T = 5\text{s}$$

This 1.6% degradation is the the reduction in the observed amplitude of the fastest fringe that would be encountered, assuming an integration time of 5s. However, as far as the final map is concerned, we must allow for 2 factors not considered above:

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The degradation observed after a full 12h. synthesis will depend on the mean value of sinH :

$$\langle \sin^2 H \rangle = 0.5$$

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The arguments above show that integration times of 10s and 20s are adequate for the CA and LBA respectively. In practice, it may be convenient (because of the relatively small volume of data from the LBA) to use the same integration time of 10s for both arrays. There appears to be little need to double the data storage requirements by adopting a 5s integration time.

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References

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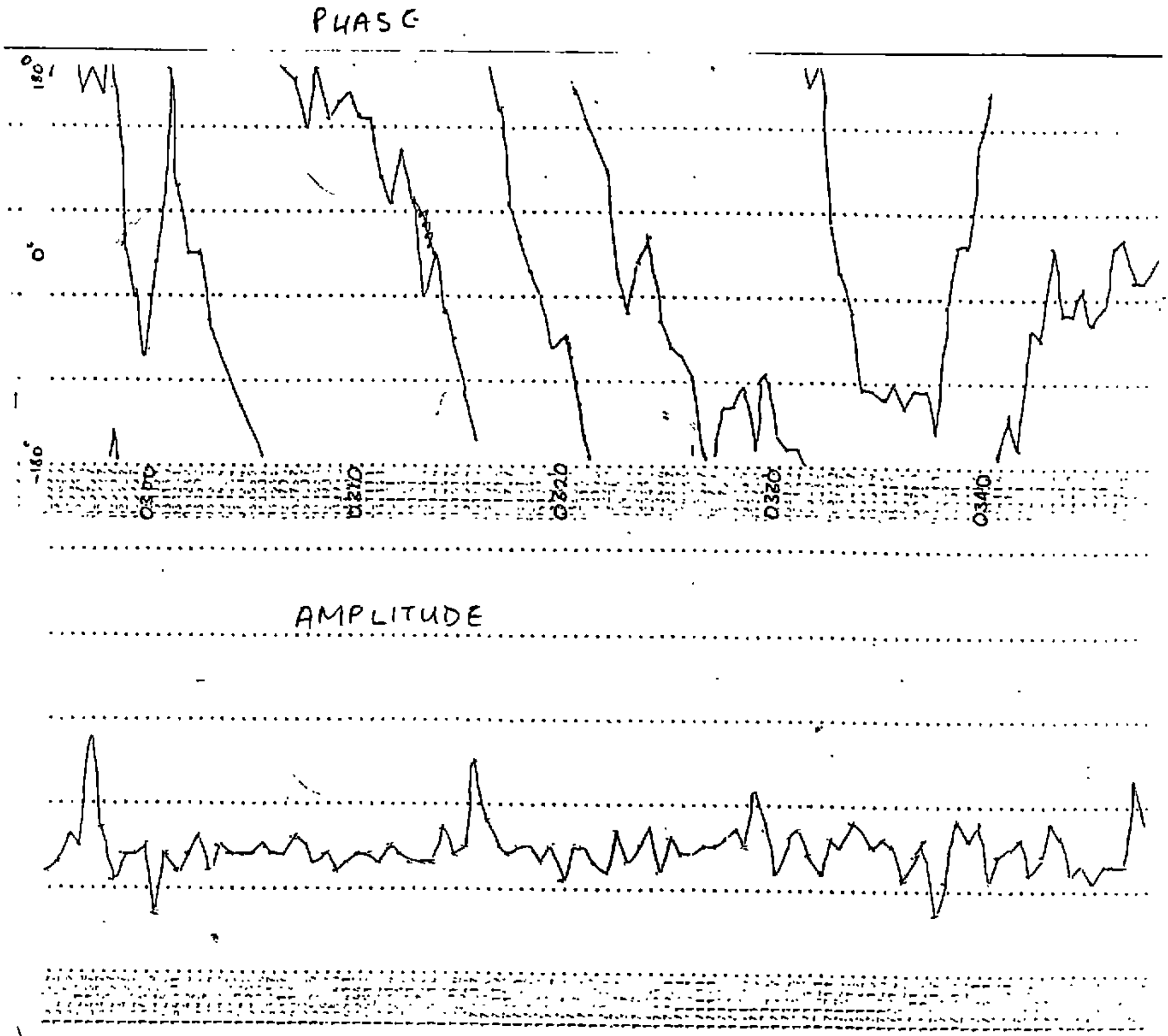
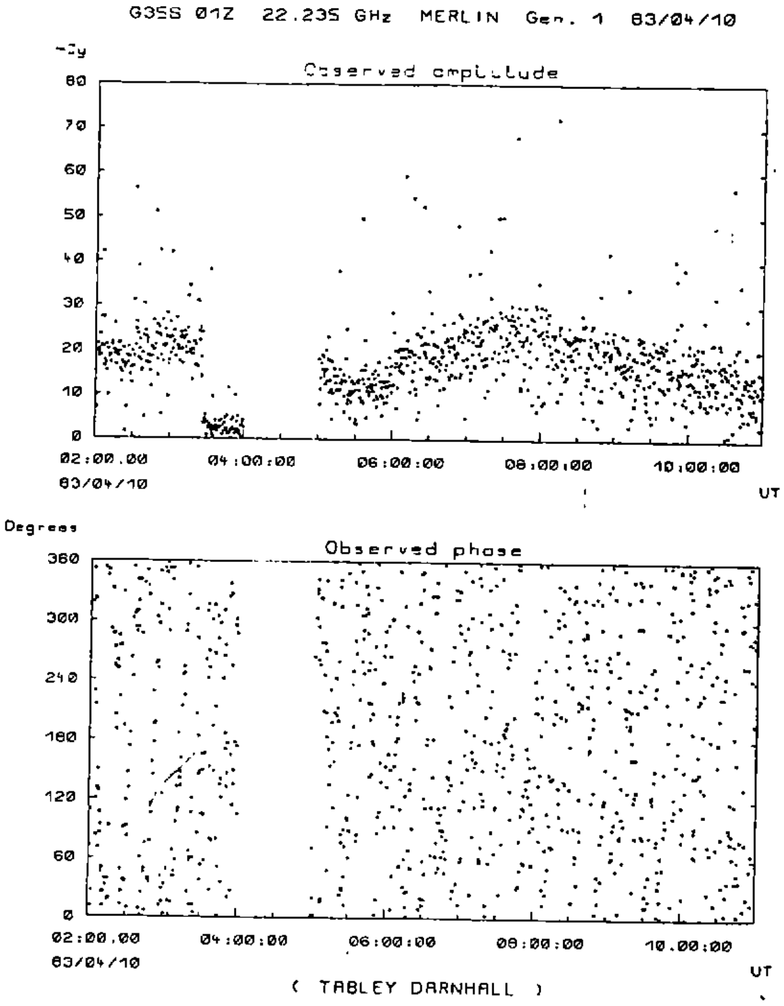


Fig 1(a) Typical MERLIN 22GHz data in normal weather

Source: Cep A   Flux density ~ 1000 Jy
Baseline ~ 50km   Integration time ≈ 30s



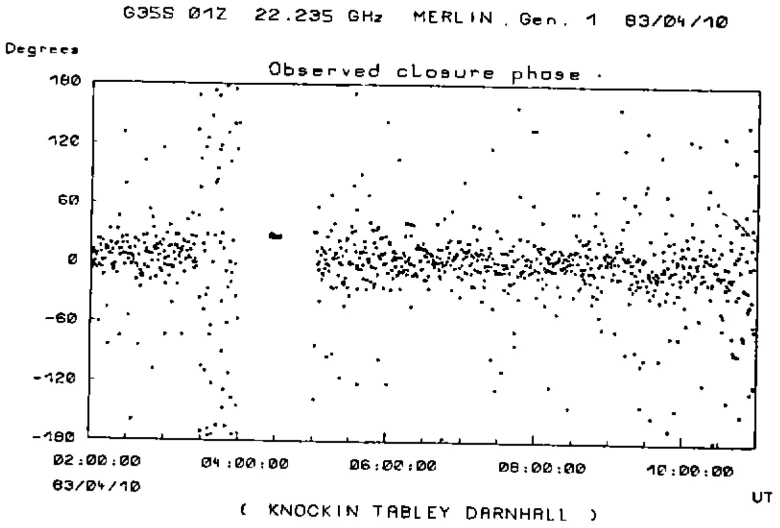


Fig 1(b) Typical MERLIN 22GHz data in bad weather
Source: G35.2 −0.7 Flux density: ~300 Jy
Max baseline ~50km. Integration time = 30s.

Note that phase rate approaches 1 turn/integration, but data is still mappable using closure phase.

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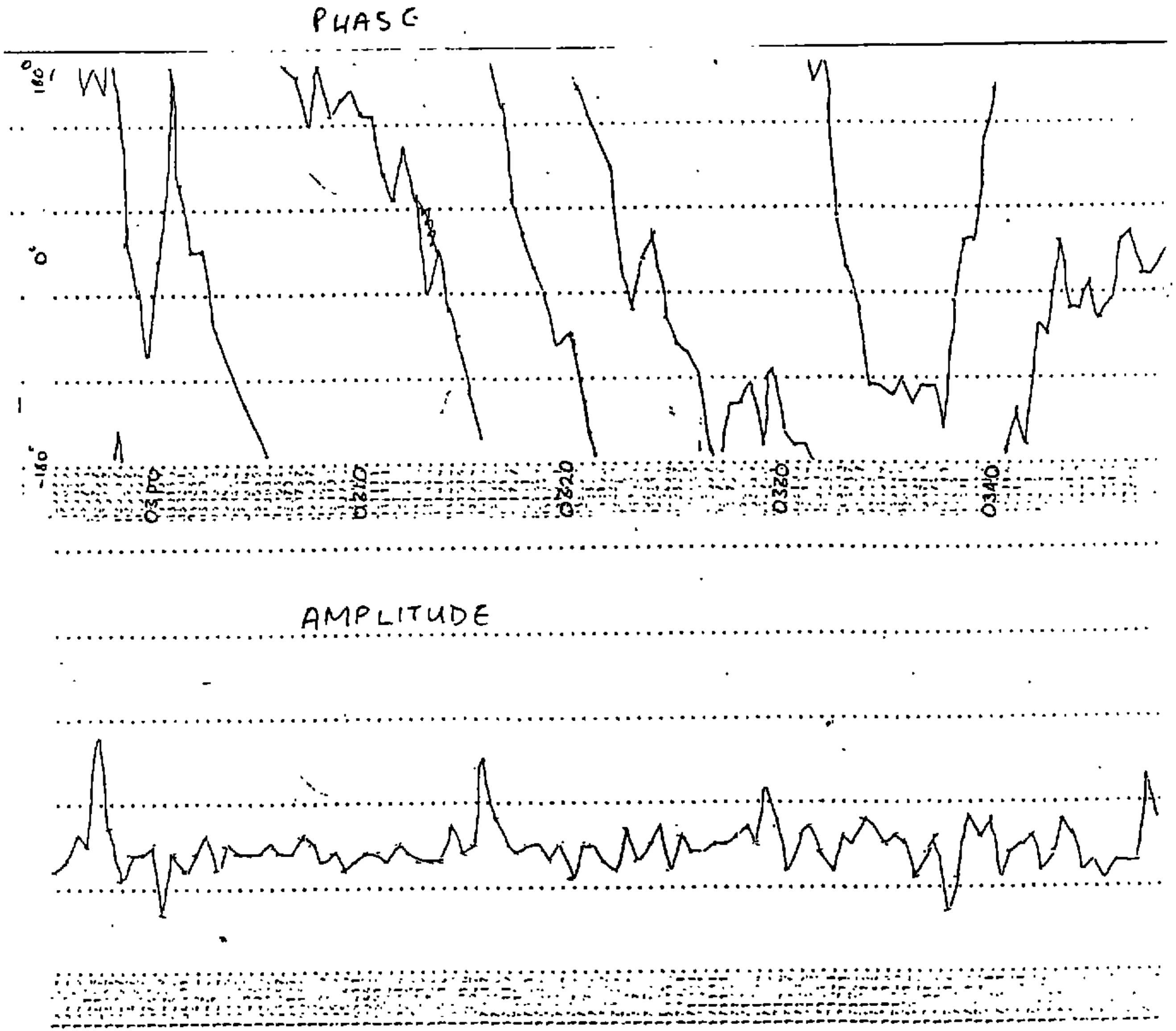

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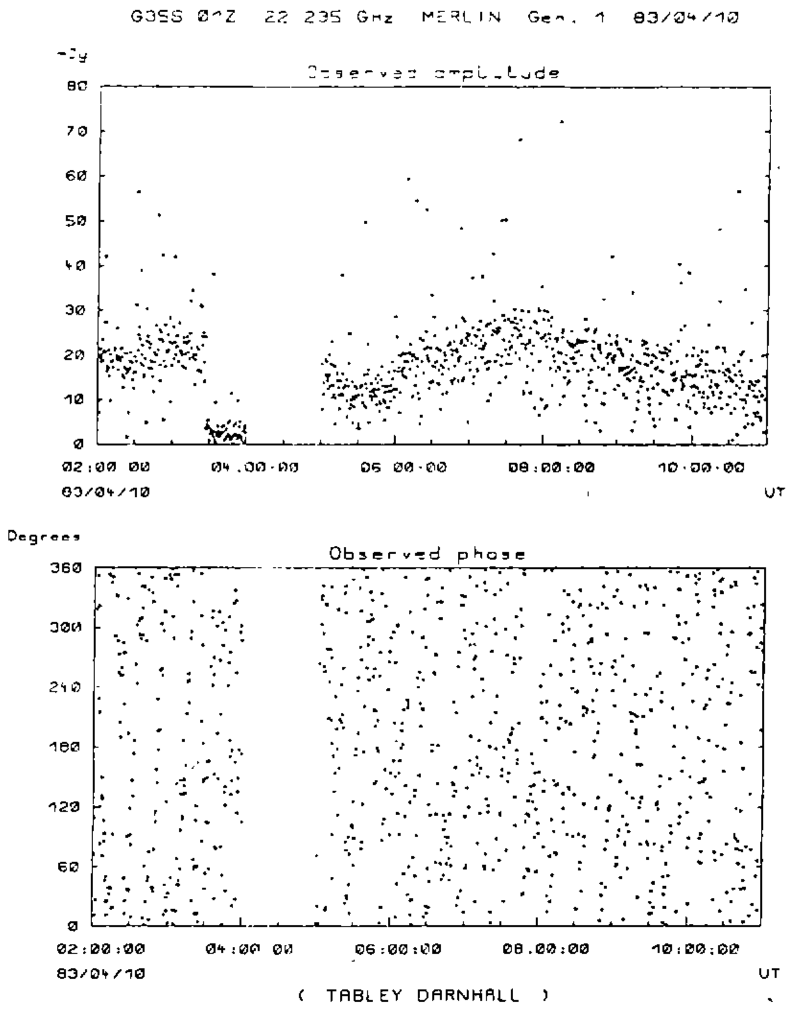

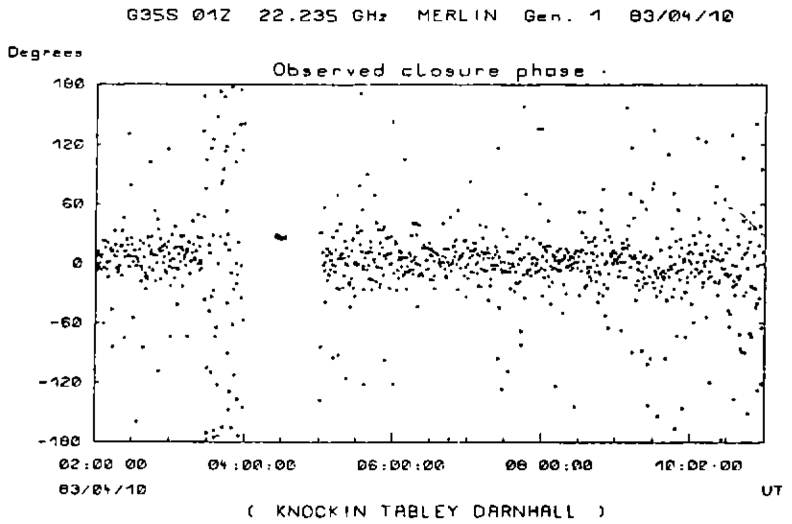

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