GBT MEMO 137

THE CASE FOR EQUIPPING THE GBT WITH 26.5 - 40 GHz RECEIVERS

David Frayer and Paul Vanden Bout

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The band 26.5-40.0 GHz is not included in the first set of receivers to be built for the GBT. This band received priority #3, along with the bands 2.6-4.0, 5.8-8.2, and 10.0-12.4 GHz. This memo argues for making receivers to cover the two bands 26.5-33.0 and 33.0-40.0 GHz the highest priority for GBT receivers beyond the current set under design and construction. Scientifically, we are probably missing a big bet by not having these receivers on the GBT from the outset.

Studying CO and other molecular line emission at high redshift is one of the most exciting opportunities presented by the GBT. Despite the difficulty of detecting such sources with present telescopes, the evidence for CO emission from at least two sources is unimpeachable: FSC 10214+4724 and the Cloverleaf, lying at redshifts of $z = 2\text{-}3$ and 2.6, respectively. These sources can be seen in CO emission using present telescopes either because they represent the brightest members of their class or because, as some have argued, they are lensed by intervening galaxies. The GBT is an ideal telescope to search for fainter examples.

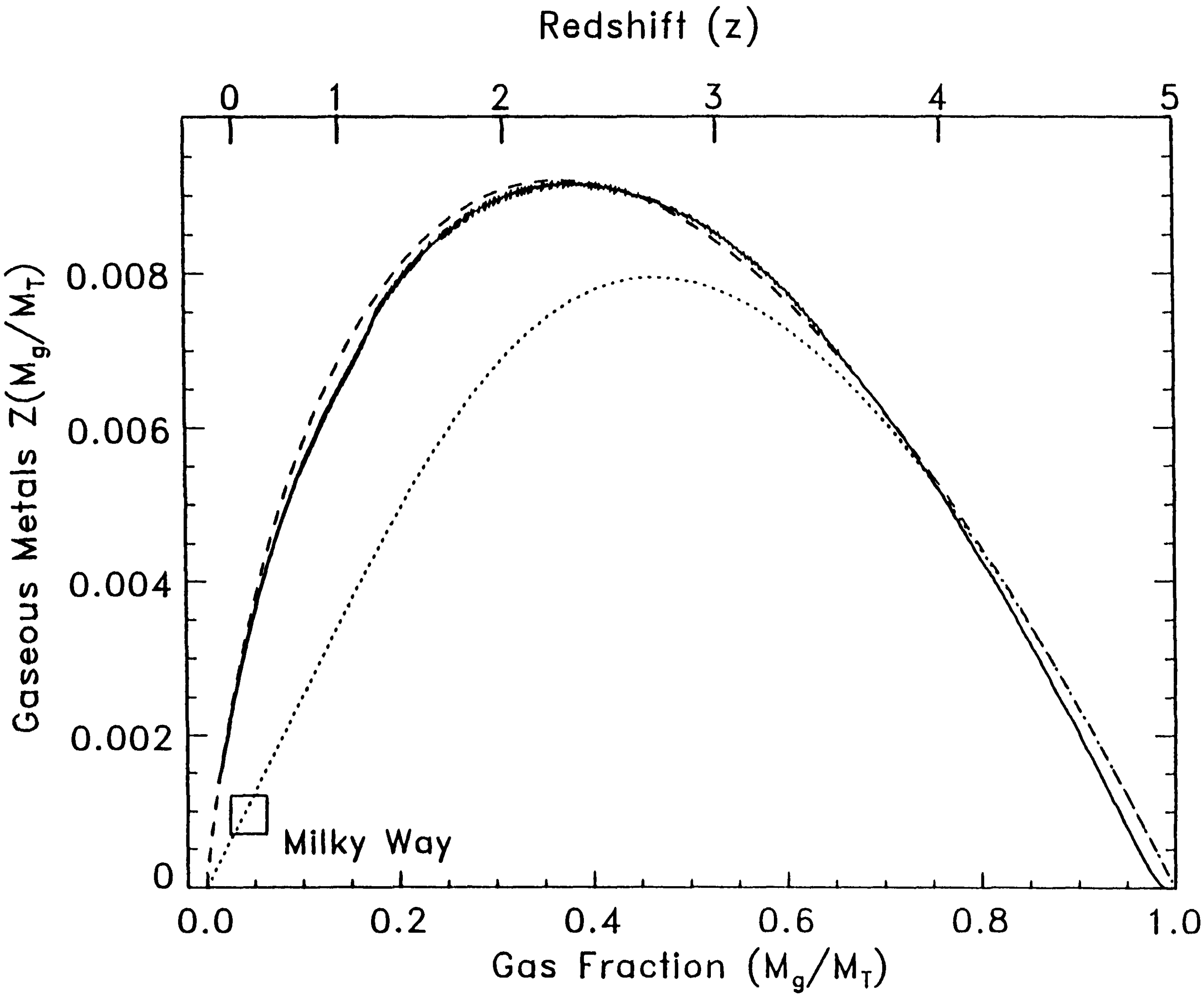
We have found that the most promising redshift range for searches is roughly $z \sim 2\text{-}3$. It is at these redshifts that the mass of metals in the gaseous state is maximum. Figure 1 shows the results obtained from various models of gaseous metal evolution. Generally, all models predict that the maximum of gaseous metals occurs when approximately one-half of the total baryonic mass is in stars and the other half is gas which, depending on the adopted cosmological model and various assumptions about star formation rate and initial mass function, corresponds to redshifts of $z \sim 2$.

Searches at redshift $z = 2\text{-}3$ for the CO $J = 1\text{-}0$ line fall in the band 29-39 GHz. The GBT will be a very powerful telescope in this band. Figure 2 shows the gain and aperture efficiency of the GBT as a function of frequency. These quantities are plotted for the cases: Phase 1 (as delivered by the contractor) for both zenith/horizon and rigging angle elevations; Phase 2 (active surface driven by lookup table to remove only gravitational distortions); and Phase 3 (active surface driven by laser metrology to remove all distortions including thermal). The active surface eliminates the gain variations with elevation angle, so the Phase 2 and Phase 3 curves are independent of elevation. The aperture efficiency includes both surface efficiency and feed efficiency, both derived from GBT Memo 119 and references therein. The jagged appearance of the curves is a result of the individual feed efficiency variations. Information on low-frequency feeds is incomplete and is plotted only for feeds that have been designed. Extrapolations were made across S-band and from 26.5 to 40 GHz, where no feeds have been designed. Above 52 GHz reasonable assumptions were made for the efficiency of the feeds to make it possible to show the expected high-frequency peformance. For a Phase II system, the GBT will deliver 1.5 K/Jy at 35 GHz, more than three times the gain of the Effelsburg 100 meter and an improvement of 10 in integration time. The 140 Foot is effectively unusable in this band for searches of this sort.

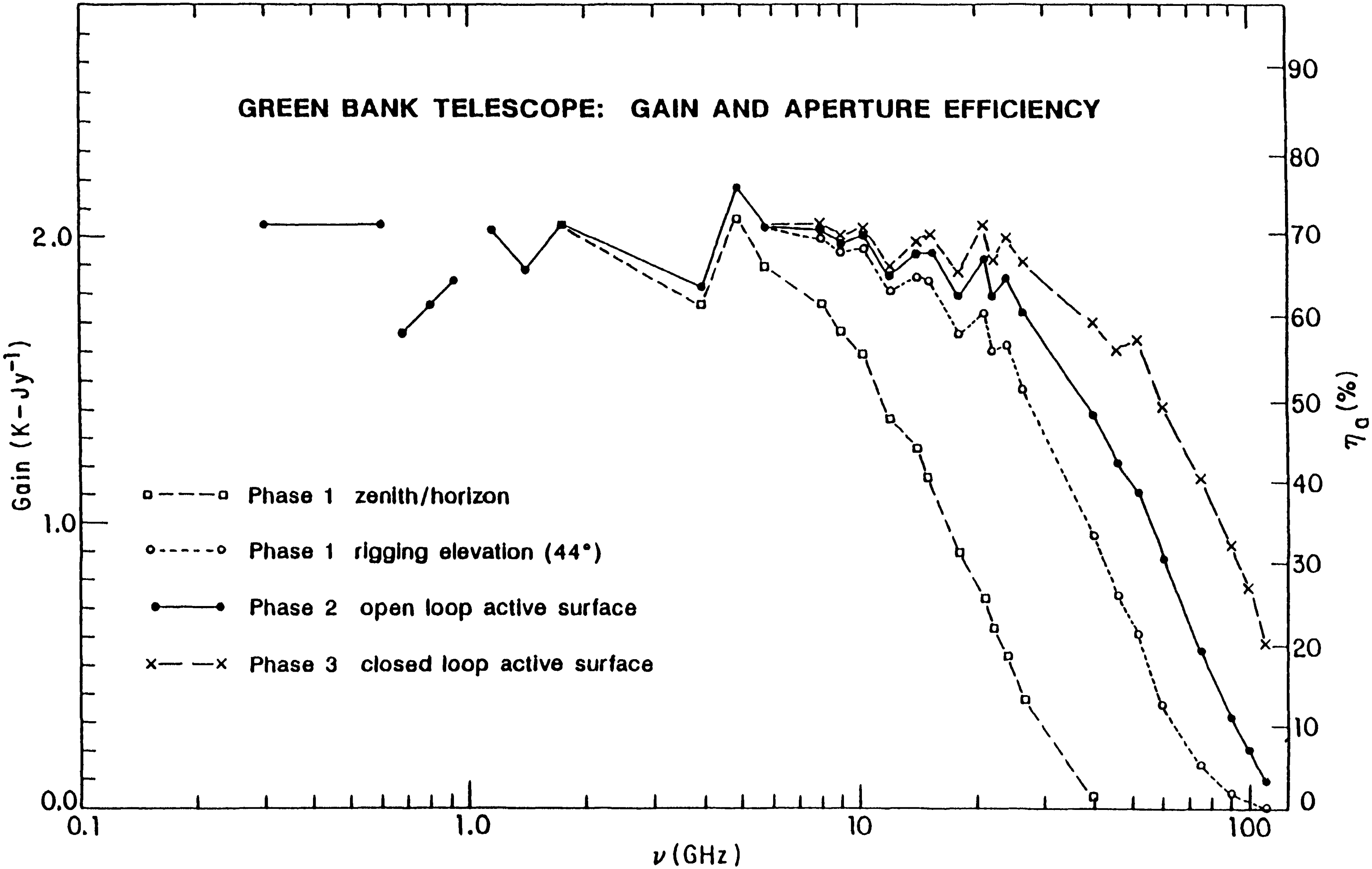
To illustrate the power of the GBT, consider observing the CO (J = 1-0) line in FSC 10214+4724 where the line is roughly 5 mJy in peak intensity. This line falls at 35 GHz, so an 8 mK signal is to be detected. With a T_{sys} ~45K and a channel bandwidth of 4 MHz (34 m s^{-1}), $\Delta T_{rms} \sim 8$ mK is reached in 20 seconds.(Assuming $\Delta T_{rms} = (\pi/2) T_{sys} \cdot (\Delta\nu \cdot t)^{-1/2}$ for the average of two independent receivers, each operated in a position-switched mode with equal time on and off source.) A 5σ detection would take 8 minutes. If 10214+4724 is lensed, the CO emission is enhanced by a factor of 5-10 according to models that appear to fit the data. So an unlensed 10214+4724 could be detected at the 5σ level in about 9 hours of integration, as could any source with a flux of 1 mJy in CO (J=1-0).

Other features of the GBT make it ideally suited for this area of research. The spectrometer will have 800 MHz of bandwidth, some 6860 km s^{-1} at 35 GHz. Because the redshifts are not well known for candidate sources, this is a powerful advantage in making searches. Furthermore, because the lines are expected to be wide (hundreds of km s^{-1}); the lack of spectral baseline has plagued searches with the instrumentation typically available at existing telescopes. For detecting weak, broad lines it is essential that baselines be flat. The GBT offset design is expected to deliver flat baselines,

Many variations on the detection observation described exist as do other searches and studies involving highly redshifted molecular gas emission. For CO, the best redshift range appears to lie in a frequency range which we will not cover with the initial complement of GBT receivers. The next receivers to be built after the initial set should cover 26.5-40 GHz.



Redshift (z)
0
1
2
3
4
5
Gaseous Metals Z(M_g/M_T)
0.008
0.006
0.004
0.002
0
Milky Way
0.0
0.2
0.4
0.6
0.8
1.0
Gas Fraction (M_g/M_T)



GREEN BANK TELESCOPE: GAIN AND APERTURE EFFICIENCY
Phase 1 zenith/horizon
Phase 1 rigging elevation (44°)
Phase 2 open loop active surface
Phase 3 closed loop active surface
Gain (K-Jy^-1)
ηa (%)
ν (GHz)
0.0
1.0
2.0
0.1
1.0
10
100
0
10
20
30
40
50
60
70
80
90