NML CYGNI OH MASER WITH A SMALL RADIO DISH
Job Geheniau – Januari 2022

Dear fellow amateurs,

For over 2 months I have been working on my project 'NML Cygni OH maser', stimulated by observations by Eduard Mol and Michiel Klaassen.
This project involves the reception of the OH spectral line of NML Cygni with a relatively small radio dish. JRT - Job's Radio Telescope, 1.8 meters.

NML Cygni
NML Cygni is a red hypergiant in the constellation Swan. NML Cygni has a radius of between 1183 and 2770 solar radii and is among the largest known stars.
The star was discovered in 1965 by Neugebauer, Martz and Leighton, who searched for extremely cool stars. The name of the star (NML) refers to the discoverers.
Location: 20H46M21S 40D06M59S. (20:46:21 40:06:59)
This star NML Cygni , a red giant, shows a radio signal/spectral line at 1612.231 MHz.

As Eduard Mol has nicely put it:

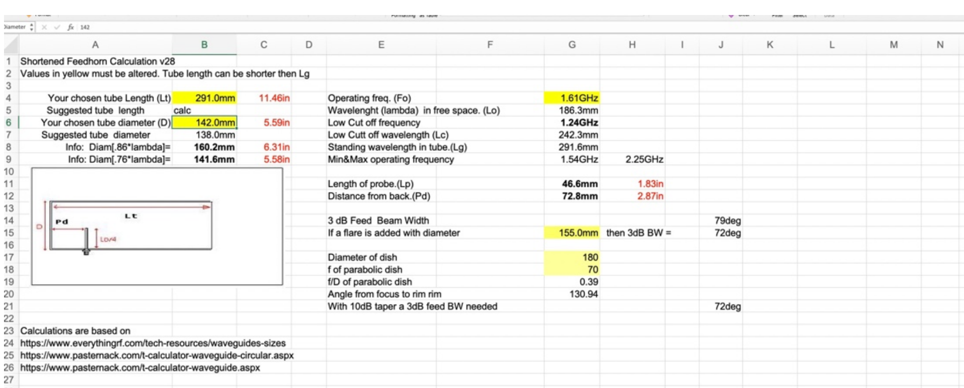
"Normally these spectral lines are far too weak to detect with an amateur radio telescope, but under special circumstances OH lines can become much stronger. This is due to stimulated emission. Stimulated emission is the reverse of absorption. In absorption, an atom or molecule picks up a photon that has just the right energy to move the atom into a higher energy state. In stimulated emission, the atom or molecule falls back from the higher to the lower energy state by interacting with a photon with the right energy. In this process, the excess energy is emitted as an additional photon. When the majority of atoms or molecules are in a higher energy state, stimulated emission dominates over absorption and light that has the correct wavelength (i.e. photon energy) can be greatly amplified. Of course, there must be a mechanism to constantly "pump" the atoms or molecules back into the higher energy level. In the case of the OH line, this can be done by strong infrared radiation or by collisions of the OH molecules with other atoms and molecules. Objects that emit enhanced OH lines through stimulated emission are called "OH masers." The term "maser" stands for Microwave Amplification by Stimulated Emission of Radiation. "

Hardware and software

It is a weak signal and as far as I know not previously recorded with a 1.8-meter radio telescope. Why this number? My radio telescope is 1.5 meter, but I extended the diameter to 1.8 meters with additional pieces of mesh. This is mainly to prevent overspill but after measurements on a solar drift scan I also found that the beam of the dish is 8 degrees instead of the 10 degrees that is stated for a 1.5-meter dish. This is favorable for a weak signal measurement. [Fig 1]

Fig 1. The radiotelescope

Furthermore, I had to improve the sensitivity by using a specific Feed (receiver) on the dish specially tuned for 1612 MHz.
I built the feed myself from aluminum and a copper probe. [Fig 3]
Using an Excel sheet from Michiel Klaasen, I applied the correct measurements. [Fig 2]. The bottom of the feed is completely sealed. With a nano VNA tried to create the best possible SWR. 1 : 1.37. [Fig 4]



	A	B	C	E	G	H	J
1	Shortened Feedhorn Calculation v28						
2	Values in yellow must be altered. Tube length can be shorter then Lg						
3							
4	Your chosen tube Length (Lt)	291.0mm	11.46in	Operating freq. (Fo)	1.61GHz		
5	Suggested tube length	calc		Wavelenght (lambda) in free space. (Lo)	186.3mm		
6	Your chosen tube diameter (D)	142.0mm	5.59in	Low Cut off frequency	1.24GHz		
7	Suggested tube diameter	138.0mm		Low Cutt off wavelength (Lc)	242.3mm		
8	Info: Diam[.86*lambda]=	160.2mm	6.31in	Standing wavelength in tube.(Lg)	291.6mm		
9	Info: Diam[.76*lambda]=	141.6mm	5.58in	Min&Max operating frequency	1.54GHz	2.25GHz	
10							
11				Length of probe.(Lp)	46.6mm	1.83in	
12				Distance from back.(Pd)	72.8mm	2.87in	
13							
14				3 dB Feed Beam Width			79deg
15				If a flare is added with diameter	155.0mm	then 3dB BW =	72deg
16							
17				Diameter of dish	180		
18				f of parabolic dish	70		
19				f/D of parabolic dish	0.39		
20				Angle from focus to rim rim	130.94		
21				With 10dB taper a 3dB feed BW needed			72deg
22							
23	Calculations are based on						
24	https://www.everythingrf.com/tech-resources/waveguides-sizes						
25	https://www.pasternack.com/t-calculator-waveguide-circular.aspx						
26	https://www.pasternack.com/t-calculator-waveguide.aspx						
27							
28							

Fig 2. The feed dimensions

Fig 3. The feed

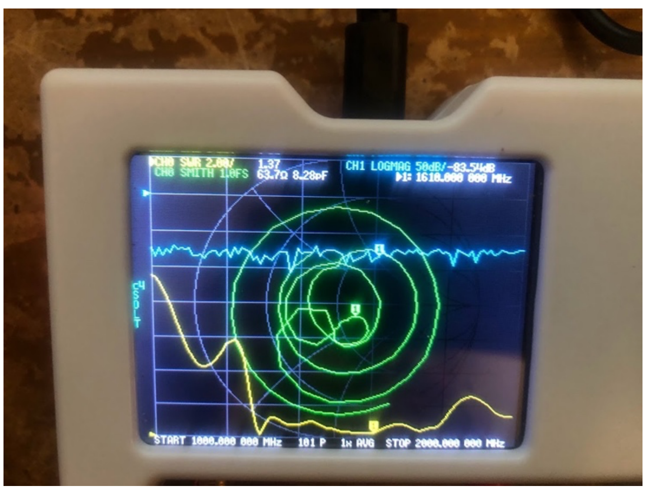


Fig 4. Tuning the probe

Finally, with noise-free LNAs (Low Noise Amplifiers) and a specifically built filter, I am trying to unlock exactly the 1612 MHz from rfi (interference) and achieve good gain. The filter was built by Bert Modderman. The LNAs are from Mini Circuits, ZX60-P33 ULN+, with a noise figure of 0.47 dB. [Fig 5]

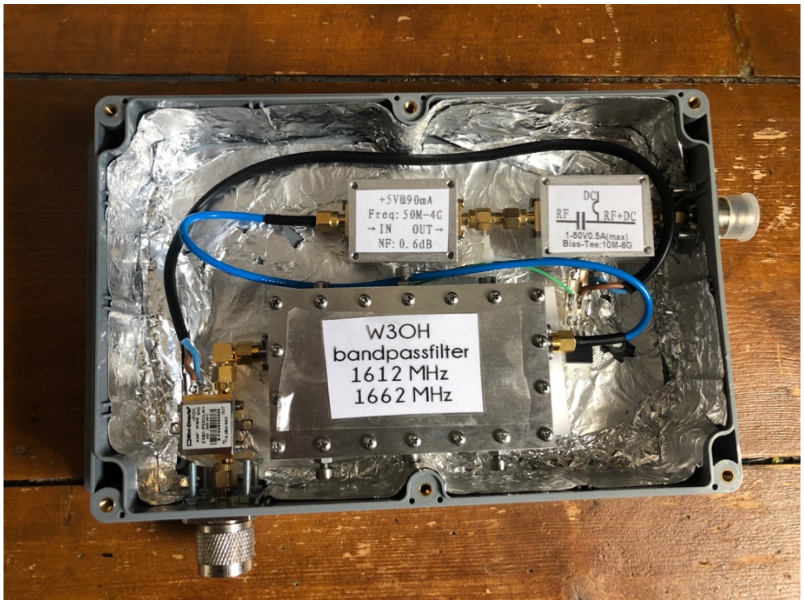


Fig 5. The lna's and the filter

All data was received with SDR# and an airspy mini as sdr.

Results

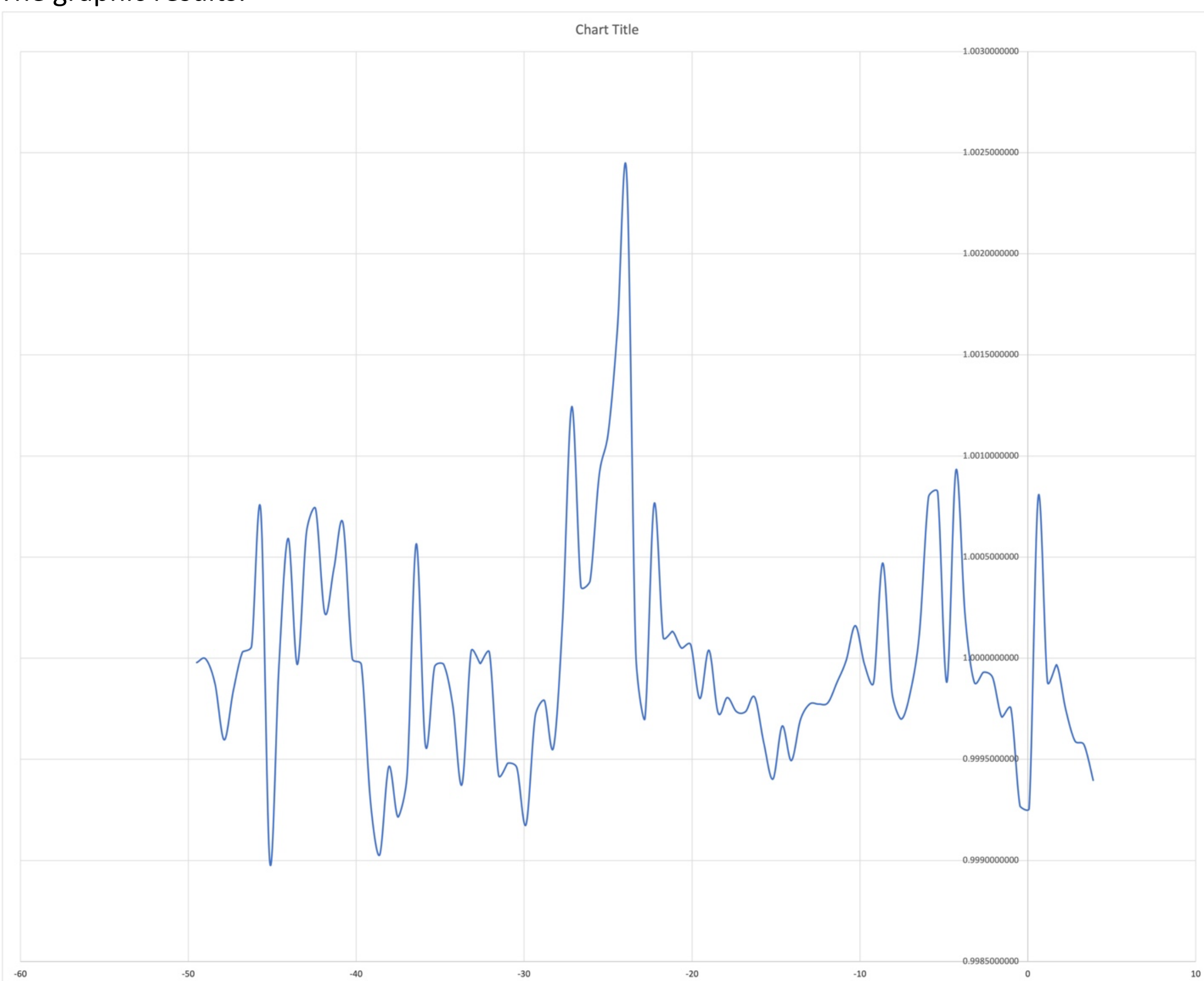
The signal from NML Cygni is extremely weak and difficult to detect with my modest setup. Experimented a lot in the last 2 months and ventured more than 25 different attempts with different starting points. For example, with Virgo soft and rtl-sdr bandwidth 2.4 MHz. Or with SDR# with a rtlsdr 2.4 MHz, but also sdr# with airpsy mini on 3 MHz and 6 MHz bandwidth. On sunny days, on rainy days, etc.
20 different recording attempts failed (it's a beautiful hobby), but 5 recordings stood out. The best combination in this case was SDR# with an Airpsy mini set to 3 MHz bandwidth. Separate recordings of 5 minutes stacked.
By the way, all recordings were followed for at least 6 hours with the rotor.
NML Cygni has a blueshift of around -25 km/s.
Some recordings exactly meet this blueshift, others are slightly off. This surprises me and I can't figure out what might be causing it.
I have tried to apply VLSR to the measurements (the doppler shift of the Earth's rotation), but that is a complicated process and perhaps there are some minor measurement errors there.
By the way, the December 22, 2020 recording was not adjusted with VLSR.

Conclusion

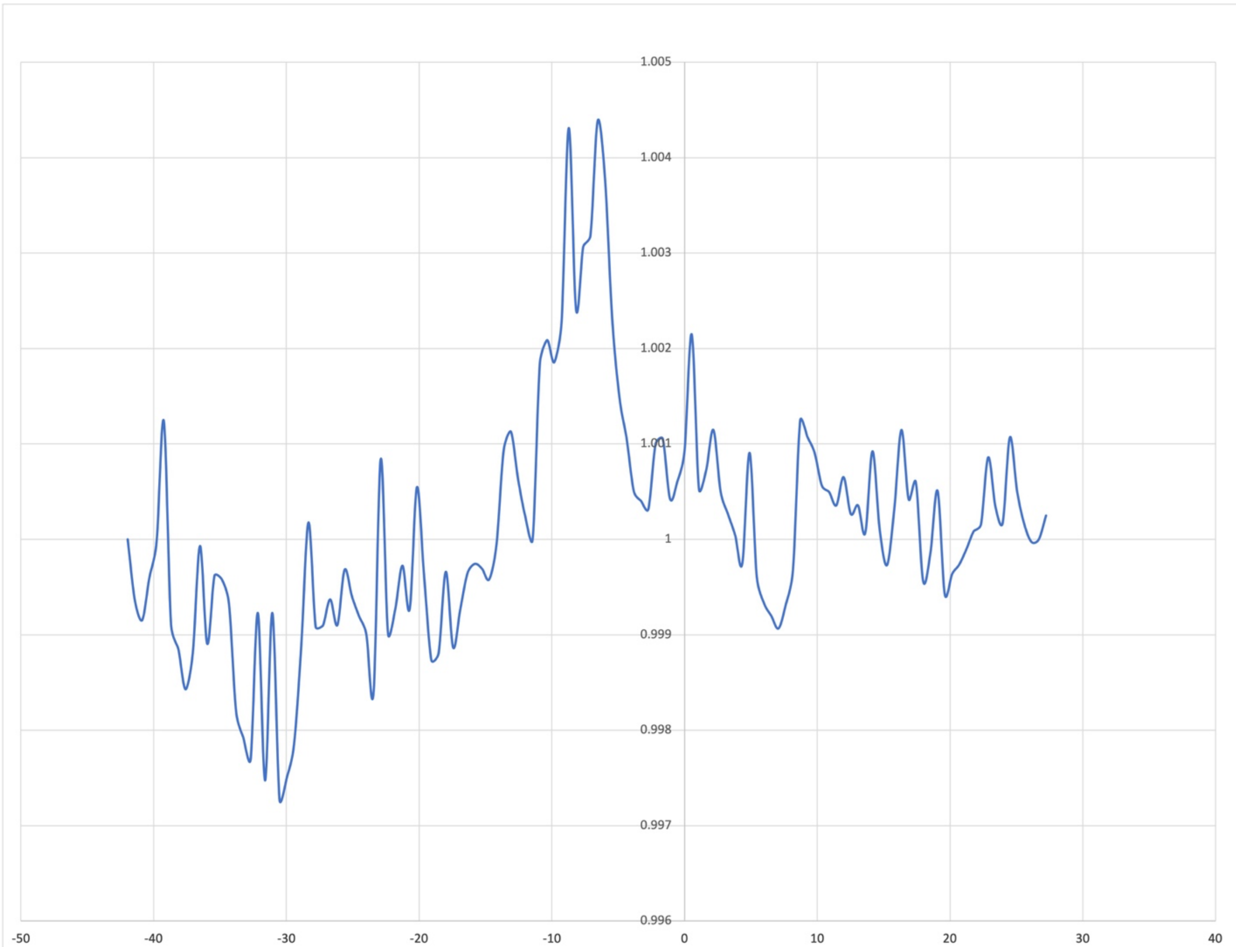
Because it is such an incredibly difficult signal to measure with my dish, I do not dare to make a 'claim' on the results but given the fact that at least 5 times a clear increase in the signal can be seen, I close with a satisfied feeling.
So soon the 1612 MHz feed will be replaced again for the 14120 MHz HI Feed as well as the lna's and filters.
Or..... am I going to venture to OH 26.5+0.6 (V437 Sct), or V669 Cassiopeia?
There is much more to discover......

Job Geheniau
January 9, 2022

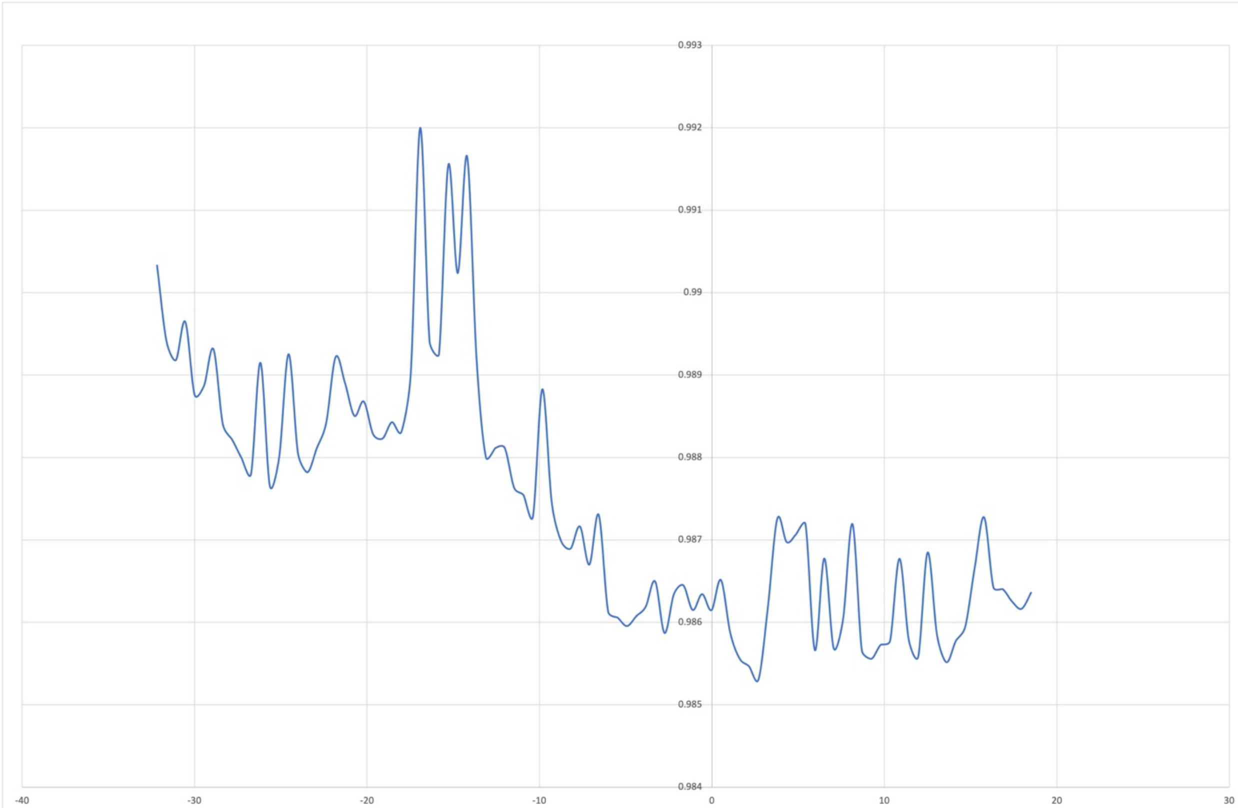
The graphic results:



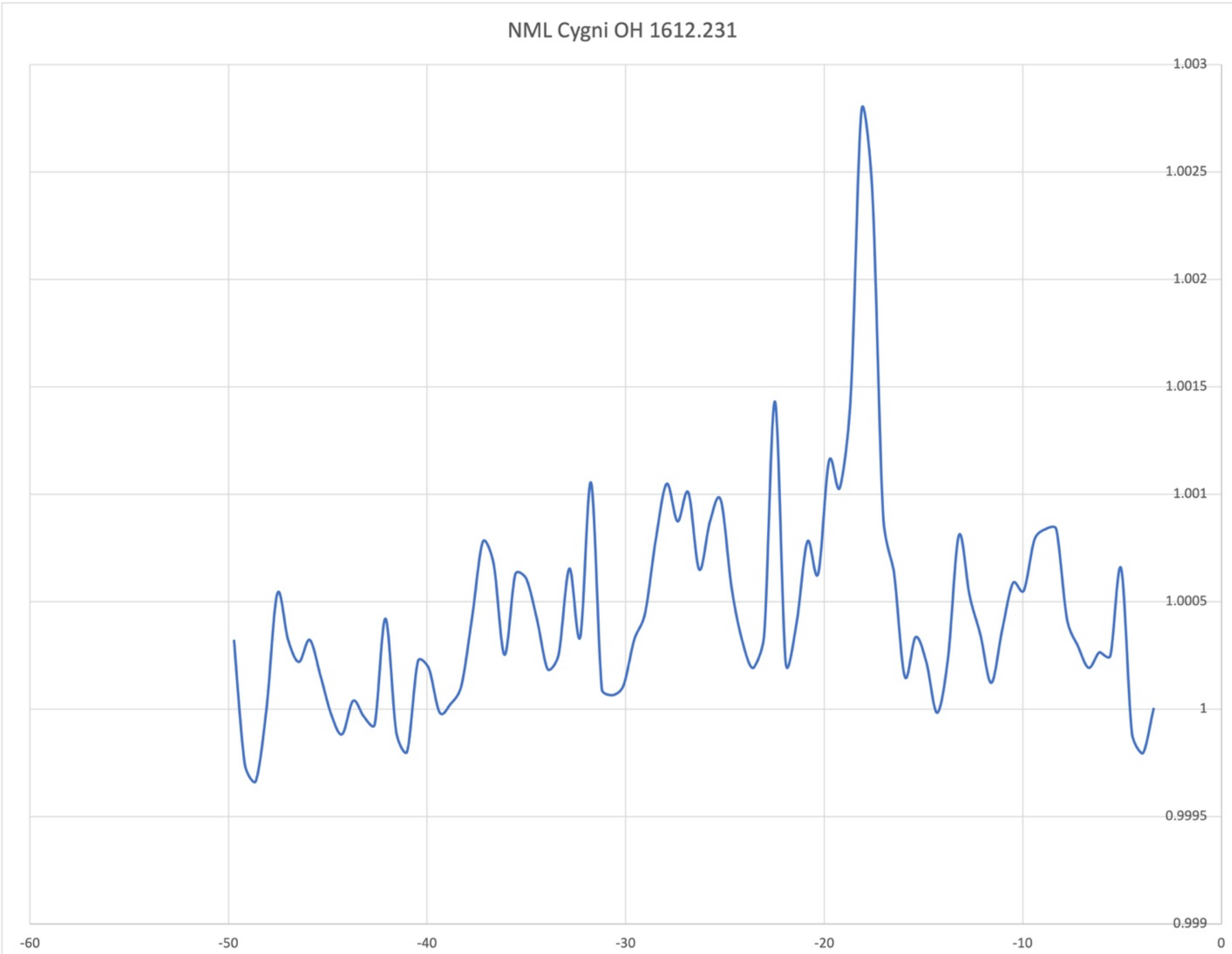
1612 MHz spectrum NML Cygni, 9 november 2021



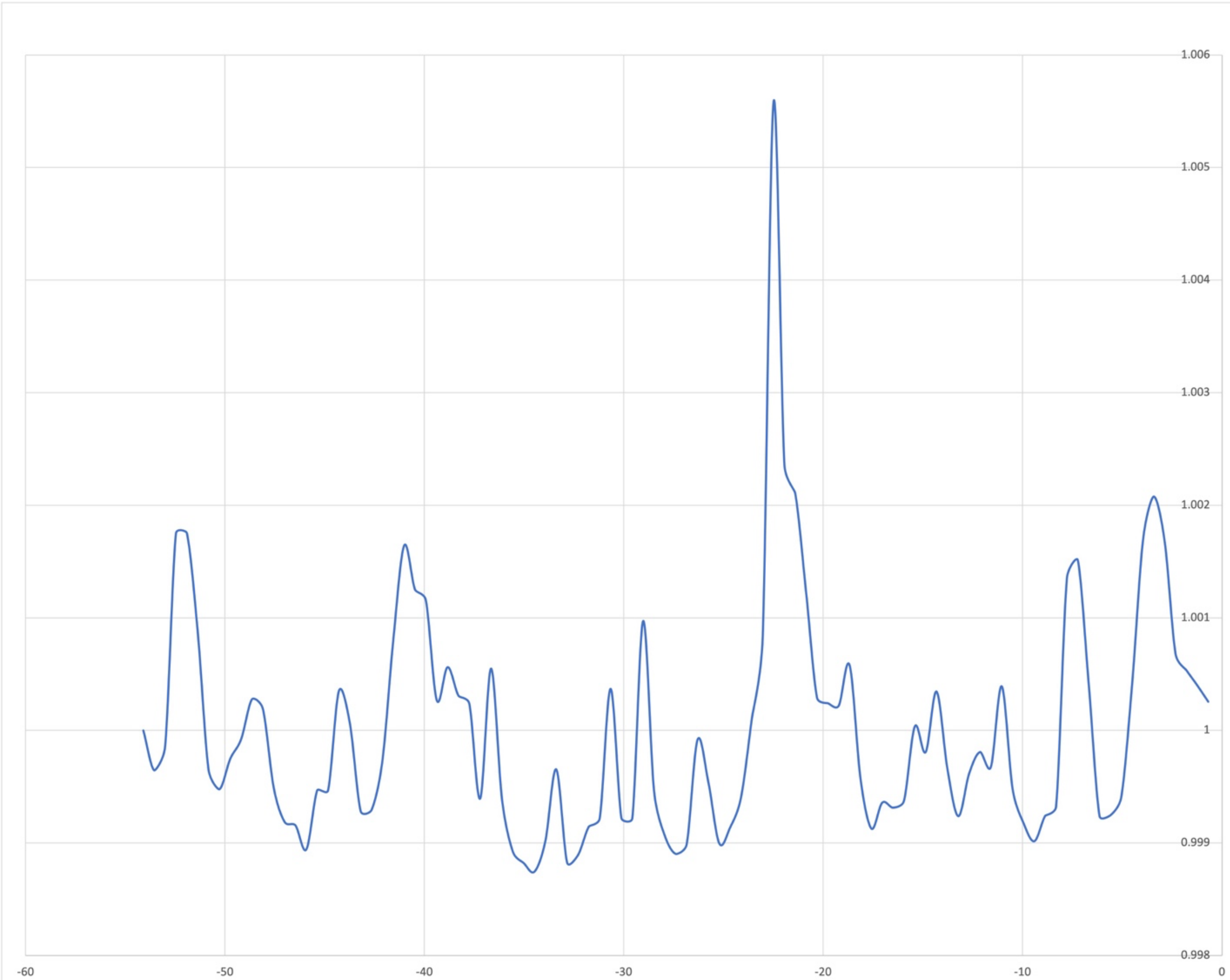
1612 MHz spectrum NML Cygni, 22 december 2021



1612 MHz spectrum NML Cygni, 26 december 2021



1612 MHz spectrum NML Cygni, 27 december 2021



1612 MHz spectrum NML Cygni, 8 januari 2022