Search for technosignatures using the Doppler Drift technique in the star HIP 45383 (HD 79555)

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ABSTRACT

In this study, the results of the application of the search technique for SETI signals or extraterrestrial technical signatures known as "Doppler Drift" are collected on the radio data files obtained by the Green Bank Radio Telescope when observing the star HIP 45383 and made available to the general public through the Breakthrough Listen initiative. The content of these files will be displayed in waterfall graphs using Python programming and specialized libraries such as blimpy developed specifically for the analysis of Breakthrough Listen files.

Keywords: extraterrestrial intelligence — Doppler drift — waterfall charts

INTRODUCTION

As an amateur astronomer and lover of radio astronomy, I am always in search of new challenges, such as the one proposed by the Max Planck Institute in 2016 (you can still find me on the official list of crackers in position 62 http://www2.mps.mpg.de/homes/heller/downloads/files/SETI_crackers.txt). On this occasion my motivation goes further and I have undertaken a personal project to search for SETI signals. This will be the first report of many, I hope.

With all this knowledge obtained over long decades, it was necessary to establish a well-defined study objective. After much thought I decided to focus on orange dwarf stars. I am personally convinced that we will find the first technosignature in a K-type star. For several reasons. It seems logical to focus on M-type red dwarfs: they are almost eternal, which gives a lot of room for intelligent civilizations to develop, it is what is most abundant, 70% to 80% of all the stars in our galaxy are M-type, with a long list of confirmed exoplanets... Yes, it seems logical but in my opinion they have their characteristics as a star and its planetary system against them: too close to the star, too much radiation, tidal effects... I find it difficult to believe that develop intelligent life easily... It also seems logical to look for yellow dwarfs like ours: Although they are much less abundant and not as long-lived, we have proof that it is possible and the habitable zone is far from the star, avoiding all the problems of the red ones. But compared to the red ones, their number is much smaller and their half-life is not as high, at least in comparison. The red ones have been explored a lot because they have confirmed planets and large systems like Trapisst, but that can also be a bias in our detection systems: the transit system favors the red ones and it is much more difficult to use it on orange or yellow ones due to the great distance of their orbits and the radial one works best with the Jovian planets...

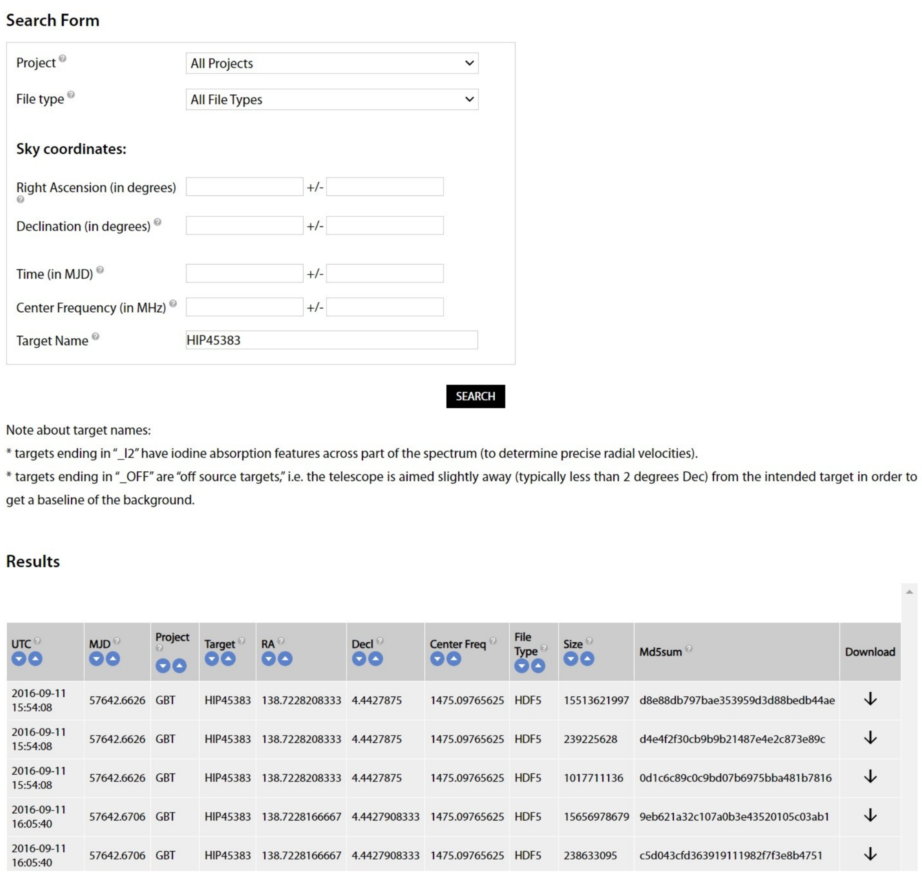
Thus we come to the conclusion that we must focus on the search for technosignatures in stars of spectral type K: they are very long-lived, 15 to 30 billion years, more than enough time to develop intelligent civilizations, with habitable orbits around 200 days, sufficiently far from their star and there are also three times as many orange dwarfs as yellow dwarfs...

So my research focused on K-type stars, from 50 light years away, starting with the star HD 21197, until I found an interesting one that presents possible evidence of technosignatures: the star HD 79555, with the number 45383 in the Hipparcos catalog, the latter catalog used in the Breakthrough Listen initiative so I will always refer to it as HIP 45383. It is an orange star that is 58 light years away from the sun https://www.stellarcatalog.com/estrellas/hd-79555, with spectral class K4V and a surface temperature of 4803ºK. It presents an exoplanet known as HD 79555 (AB)b that orbits its star at a distance of 11793.7600 AU https://exoplanet.eu/catalog/hd_79555_ab_b--9621/

METHODOLOGY

As I have already mentioned previously, in order to carry out this research I used the radio recording file search engine from the Breakthrough Listen open data archive https://breakthroughinitiatives.org/opendatasearch

Its use is quite simple. Simply type the name of the desired stellar object and it will return a list of available files.



Search Form

Project: All Projects
File type: All File Types

Sky coordinates:

Right Ascension (in degrees) +/-
Declination (in degrees) +/-
Time (in MJD) +/-
Center Frequency (in MHz) +/-
Target Name: HIP45383

SEARCH

Note about target names:
* targets ending in "_I2" have iodine absorption features across part of the spectrum (to determine precise radial velocities).
* targets ending in "_OFF" are "off source targets," i.e. the telescope is aimed slightly away (typically less than 2 degrees Dec) from the intended target in order to get a baseline of the background.

Results

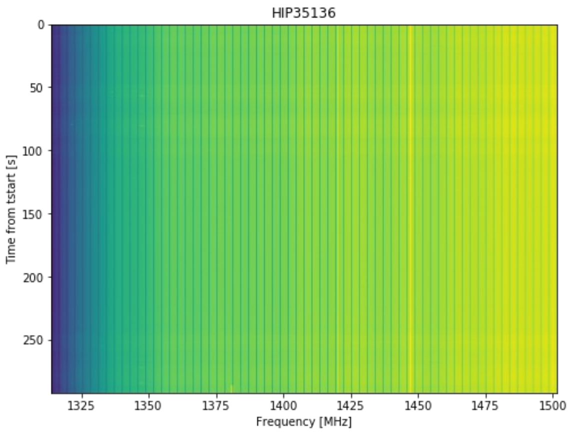
UTC	MJD	Project	Target	RA	Decl	Center Freq	File Type	Size	Md5sum	Download
2016-09-11 15:54:08	57642.6626	GBT	HIP45383	138.7228208333	4.4427875	1475.09765625	HDF5	15513621997	d8e88db797bae353959d3d88bedb44ae	↓
2016-09-11 15:54:08	57642.6626	GBT	HIP45383	138.7228208333	4.4427875	1475.09765625	HDF5	239225628	d4e4f2f30cb9b9b21487e4e2c873e89c	↓
2016-09-11 15:54:08	57642.6626	GBT	HIP45383	138.7228208333	4.4427875	1475.09765625	HDF5	1017711136	0d1c6c89c0c9bd07b6975bba481b7816	↓
2016-09-11 16:05:40	57642.6706	GBT	HIP45383	138.7228166667	4.4427908333	1475.09765625	HDF5	15656978679	9eb621a32c107a0b3e43520105c03ab1	↓
2016-09-11 16:05:40	57642.6706	GBT	HIP45383	138.7228166667	4.4427908333	1475.09765625	HDF5	238633095	c5d043cfd363919111982f7f3e8b4751	↓

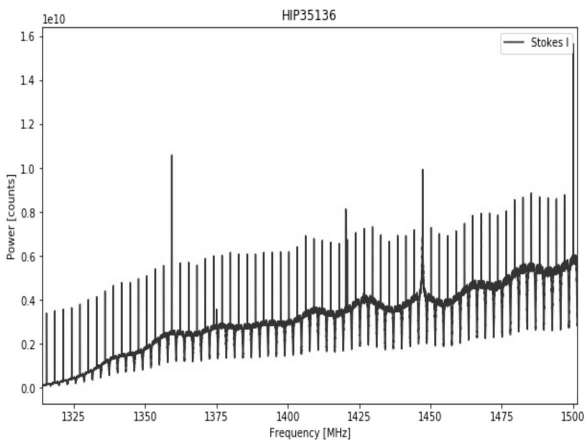
In this case, the Breakthrough Listen database returns us a list with 18 files, all in HDF5 format. These files are divided into three groups, High Spectral Resolution files (frequency resolution ~3 Hz, sample time ~18 seconds), High Time Resolution (frequency resolution ~366 kHz, sample time ~349 microseconds) and Medium Resolution (~3 kHz frequency resolution, ~1 second sample time). These are the results of data acquisition by the Green Bank Telescope dish. For a more detailed explanation of this process, you can consult the following document:https://arxiv.org/pdf/1906.07391

As described in the excellent UC Berkeley GitHub guide "How to find ET" https://github.com/UCBerkeleySETI/breakthrough/blob/master/GBT/README.md in point 2, "The source is narrow band but drifts in frequency" and in its section "Doppler drift search" I have been able to implement this technique and obtain a multitude of signals with Doppler drift and which I will methodically collect in the "Results" section.

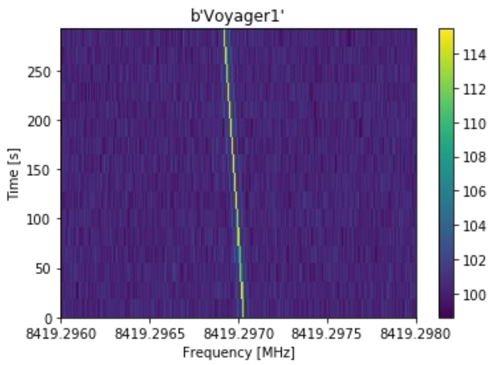
In order to begin analyzing the data files of the star HIP 45383 we need to install a Python work environment on our computer. I would recommend installing the Anaconda environment, with the Jupiter environment and Jupiter Lab. For a more detailed guide to this process you can consult page number 5 of the Breakthrough Listen at UC Berkeley website, http://seti.berkeley.edu/listen/data.html, with many links to tutorials. By installing Anaconda, at least in my updated version, the necessary libraries for this project are already pre-installed: numPy, Matplotlib, AstroPy, etc. and it will only be necessary to install the specialized blimpy library https://github.com/UCBerkeleySETI/blimpy.

Once all the previous steps have been completed, we are ready to start analyzing the HDF5 files. However, I strongly recommend before facing this task that we spend some time "training." This training will consist of both becoming familiar with the new Python tools and learning to recognize SETI signals, differentiating them from RFI (Radio Frequency Interference). For this training we have, again, the magnificent tutorials from UC Berkeley. I recommend starting with the basics, with the tutorial "Introduction to working with Filterbank files" https://github.com/UCBerkeleySETI/breakthrough/blob/master/GBT/filterbank_tutorial/Filterbank%20Tutorial%20(public).ipynb, where we will be shown the basic techniques for analyzing data files using the HIP 35136 star, learning how to create waterfall graphs and power spectrum graphs.





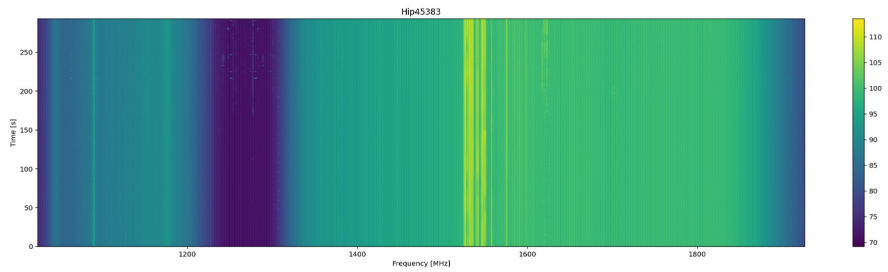
After this tutorial you can continue with the tutorial "Breakthrough Listen: Observations of Voyager 1"https://github.com/UCBerkeleySETI/blimpy/blob/master/examples/voyager.ipynb inside which the signal captured by the GBT of the Voyager 1 probe will be used to simulate what a SETI signal with Doppler drift could be like.



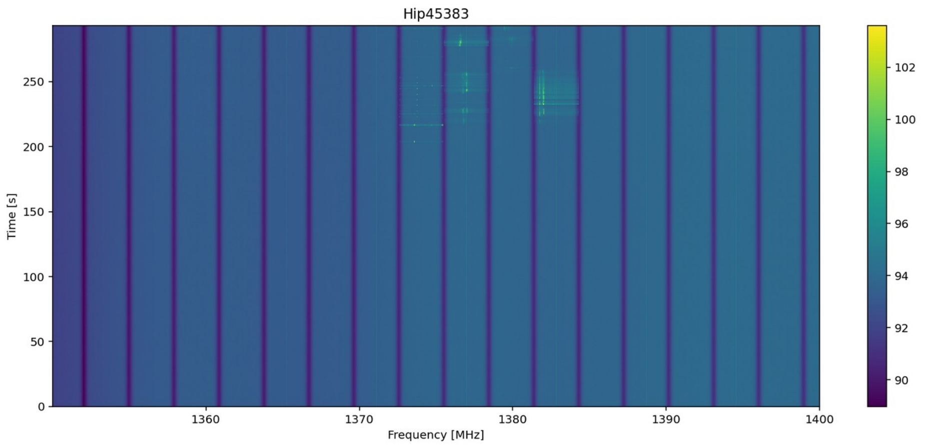
From here, if you feel confident, you can move on to analyzing the HIP 45383 data files or continue studying more tutorials available on the UC Berkeley GitHub website.

The methodology that I followed to analyze the data files consisted of a series of steps that I describe below:

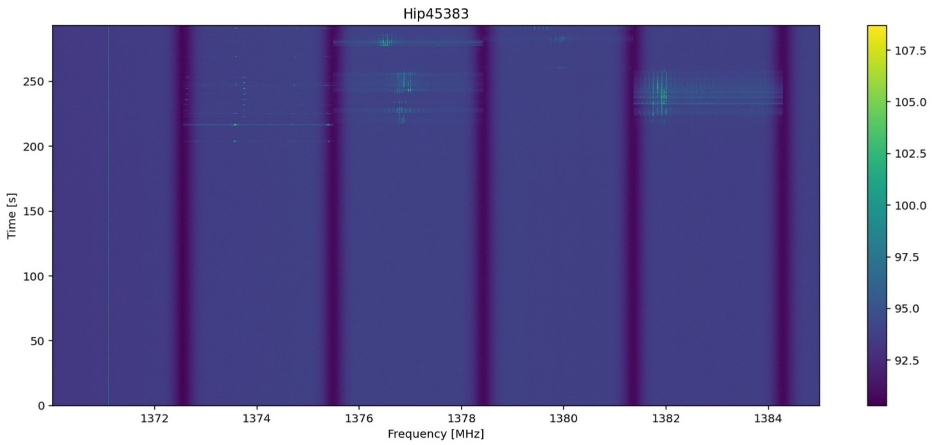
1. I generate a general waterfall plot of a scan number, for example, 13, using a medium spectral/temporal resolution (MR) file, 0002. I do this as a matter of reducing processing and rendering wait time, since the resolution and size of the file to be processed is about ten times smaller than HSR files. My goal is to get an idea of whether it might contain something interesting or not and verify the integrity of the file.

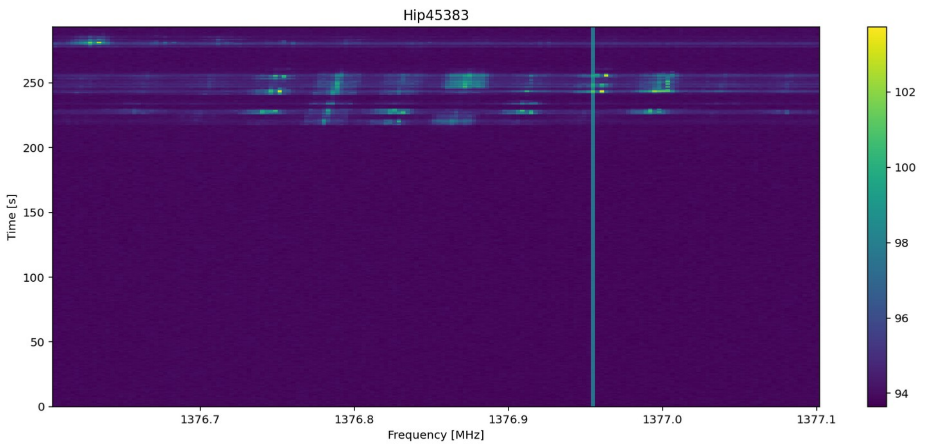
   To do this I use the following combination of Python commands:
   obs = Waterfall('spliced_blc0001020304050607_guppi_57642_58629_Hip45383_0013.gpuspec.0002.h5')
   obs.info()
   print(obs.header)
   print(obs.data.shape)
   plt.figure(figsize=(25,6))
   obs.plot_waterfall()
2. I go through the file sequentially, generating partial waterfall graphs in the search for signals with Doppler drift. At first it generated graphics in 100 MHz steps. I didn't find anything so I decided to give it a second chance, jumping from 50 to 50 MHz. And there the signals with Doppler drift began to appear. To do this to the Python code from point 1 you have to add a couple of parameters to the expression:
   obs = Waterfall(file_path, f_start=1350, f_stop=1400)



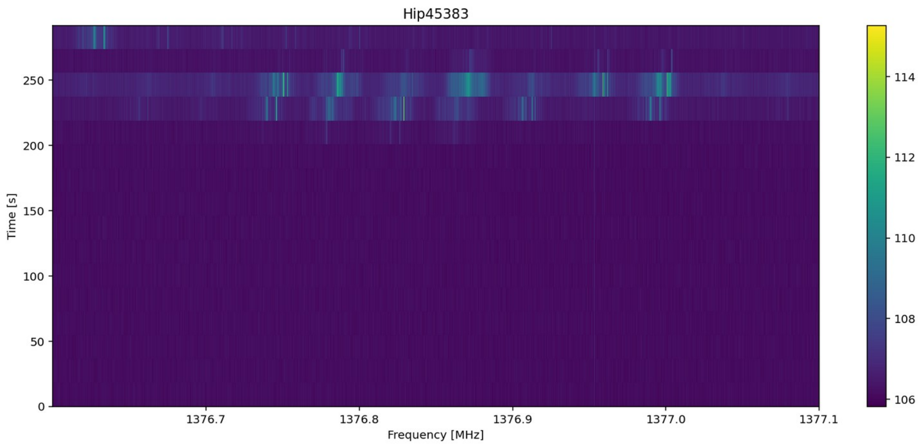
3. Once the supposed signals with Doppler drift have been located, we proceed to make extensions to the frequencies where they appear:
obs = Waterfall(file_path, f_start=1371, f_stop=1385)



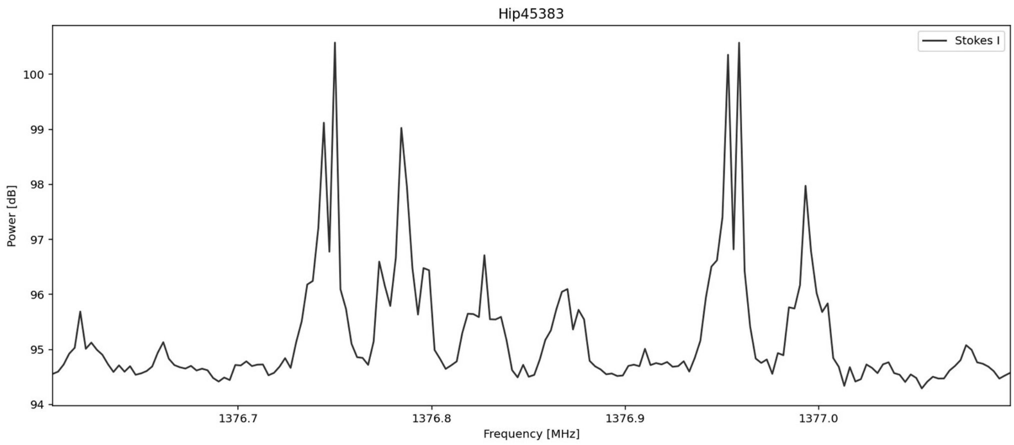
obs = Waterfall(file_path, f_start=1376.6, f_stop=1377.1)



4. We verify using the higher resolution HSR 0000 file:



5. We now use a power spectrum graph to obtain more signal data (in this case signals). The Python code is the same as point 1 and 2 except for the last line, which would be: *obs.plot_spectrum(logged=True, t=225)*



Pay attention to the t parameter! Remember the tutorials: they indicate the integration that they are going to show us, if we choose 0 or 50 it will not show us anything other than the peak of an RFI and it would seem that our signals are not there...

6. From here comes the hardest work: calculating the frequencies of the signals, their Doppler drift, finding a possible RFI origin, although it is assumed that all RFI on planet Earth should not have Doppler drift; perhaps it comes from one of our space probes; errors in the capture of radio waves by the radio telescope; in registration in storage systems, etc...

RESULTS

Many radio signals with Doppler drift have been found. I will proceed to list and describe those you consider most interesting or promising. Of course these signs are among those that I have found but there could be many more that I have not been able to detect.

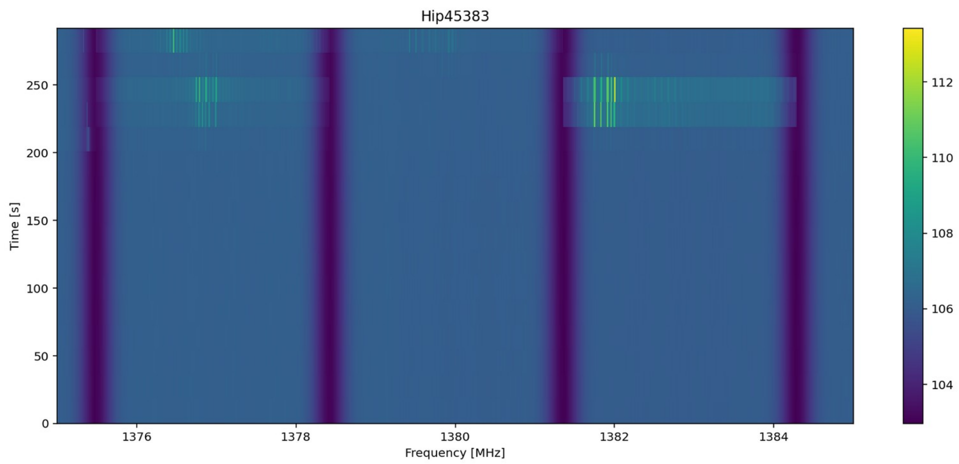
The nomenclature what I have implemented tries to make the task of locating its more or less exact location within the file much easier.

SG_StarName_NumScan_FileType_Frequency (Average)

Example: SG_HIP45383_0013_0002_1376MHz

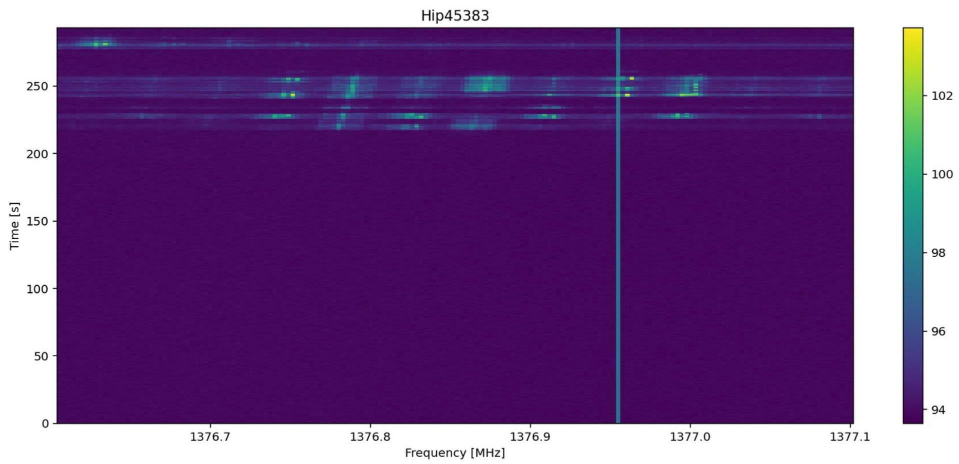
Group of Signals in the frequency range 1375-1385 MHz

In this frequency range, two separate groups of signals with Doppler drift can be seen: One around the frequency 1376 MHz and another at 1381 MHz. In order not to make this report too long, I am going to synthesize each of the groups into a single signal and I will do the same for the rest of the signal groups.

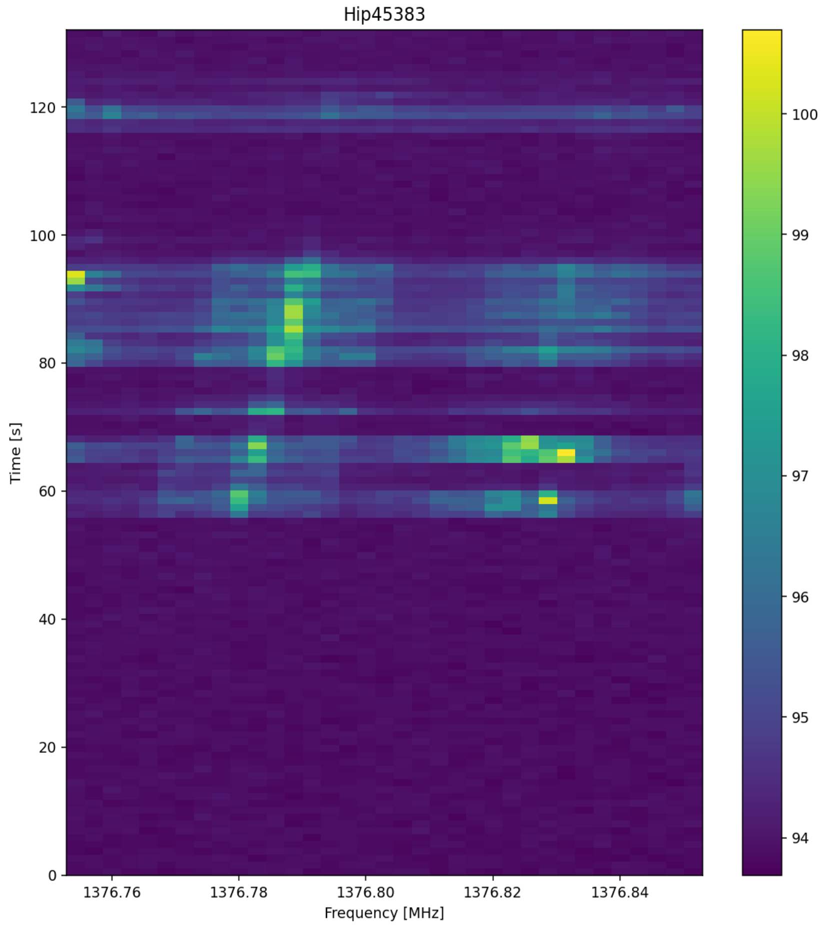


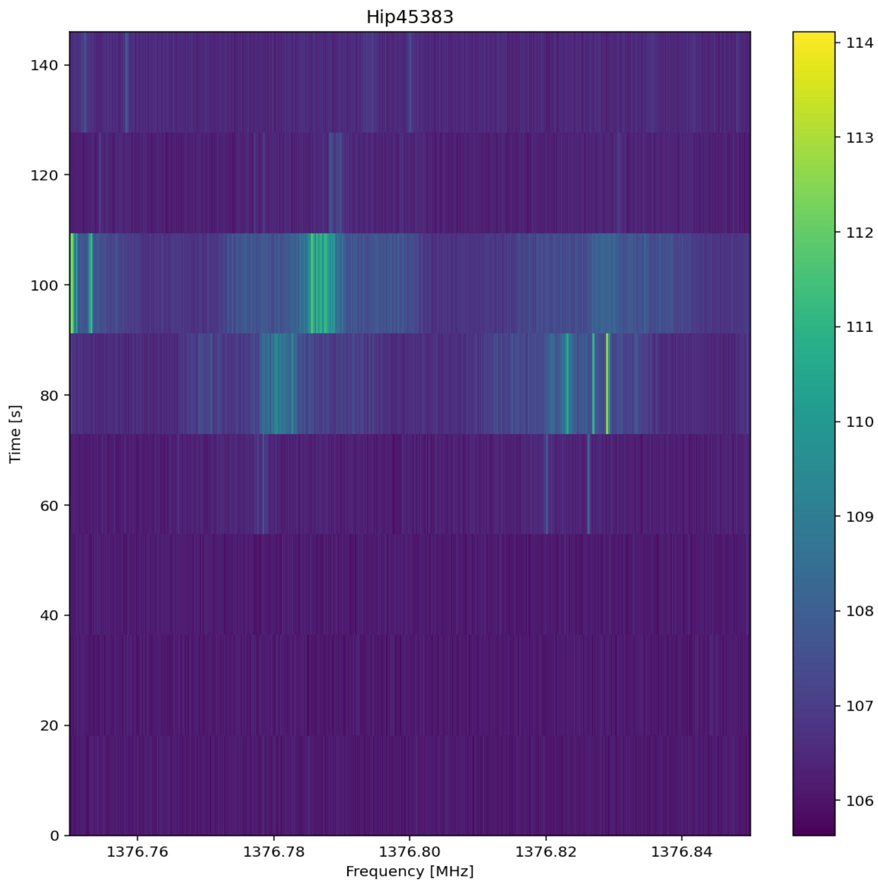
1. Signal SG_HIP45383_0013_0002_1376MHz

Here we have the waterfall graph of the area around the frequency 1376 MHz.



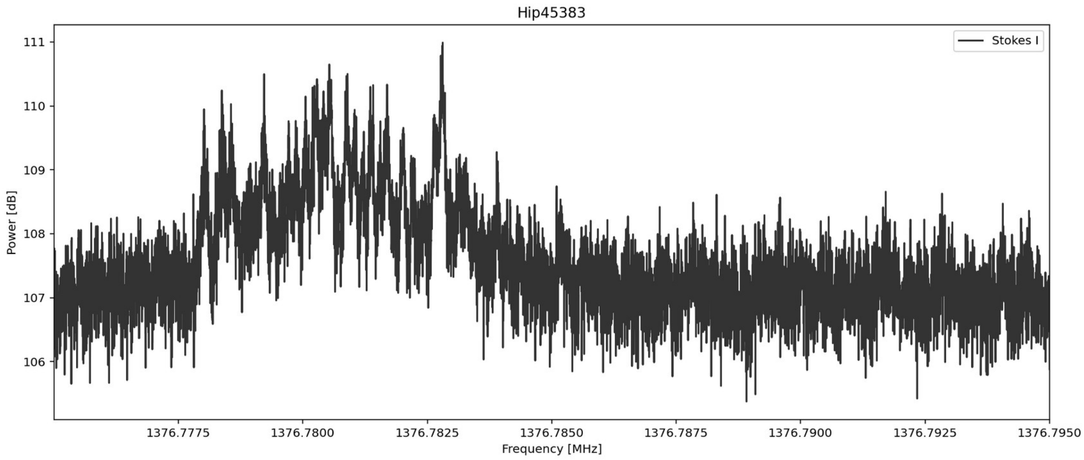
Of all the signals, it seemed clearest to me to use the signal that is between the frequencies 1376.75 and 1376.85 MHz:


Hip45383
Time [s]
Frequency [MHz]
0
20
40
60
80
100
120
1376.76
1376.78
1376.80
1376.82
1376.84
94
95
96
97
98
99
100


Hip45383
Time [s]
Frequency [MHz]
0
20
40
60
80
100
120
140
1376.76
1376.78
1376.80
1376.82
1376.84
106
107
108
109
110
111
112
113
114

Signal data SG_HIP45383_0013_0002_1376MHz:

- Date: 2016-09-11
- Time: 16:20:49
- Frequency (MHz): 1376.7785 to 1376.7900 (11.5 KHz)
- Duration (mm:ss): 01:12
- Drift Rate(Hz/sec): 159.72



Signal data in other scans:

Signal data SG_HIP45383_0011_0002_1376MHz: Does not appear in this scan.

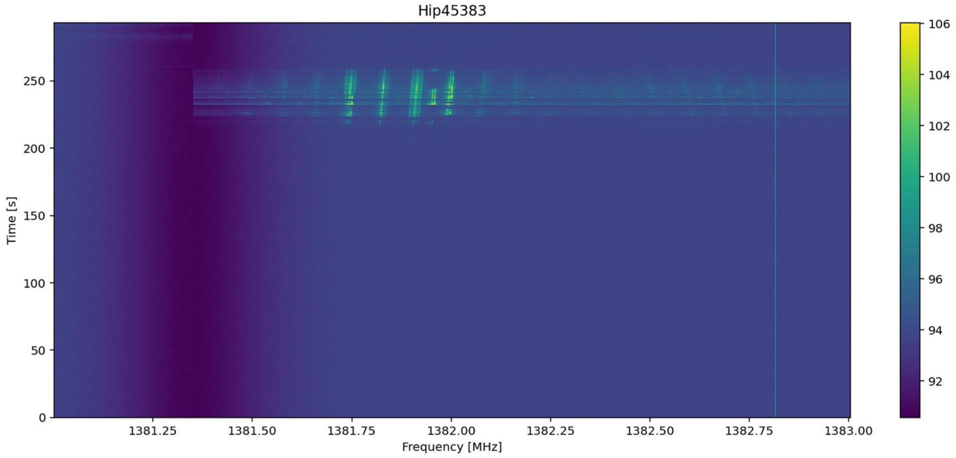
- Date: 2016-09-11
- Time: 16:05:41
- Frequency (MHz):---------
- Duration (mm:ss): --------
- Drift Rate(Hz/sec): --------

Signal data SG_HIP45383_0009_0002_1376MHz: Does not appear in this scan.

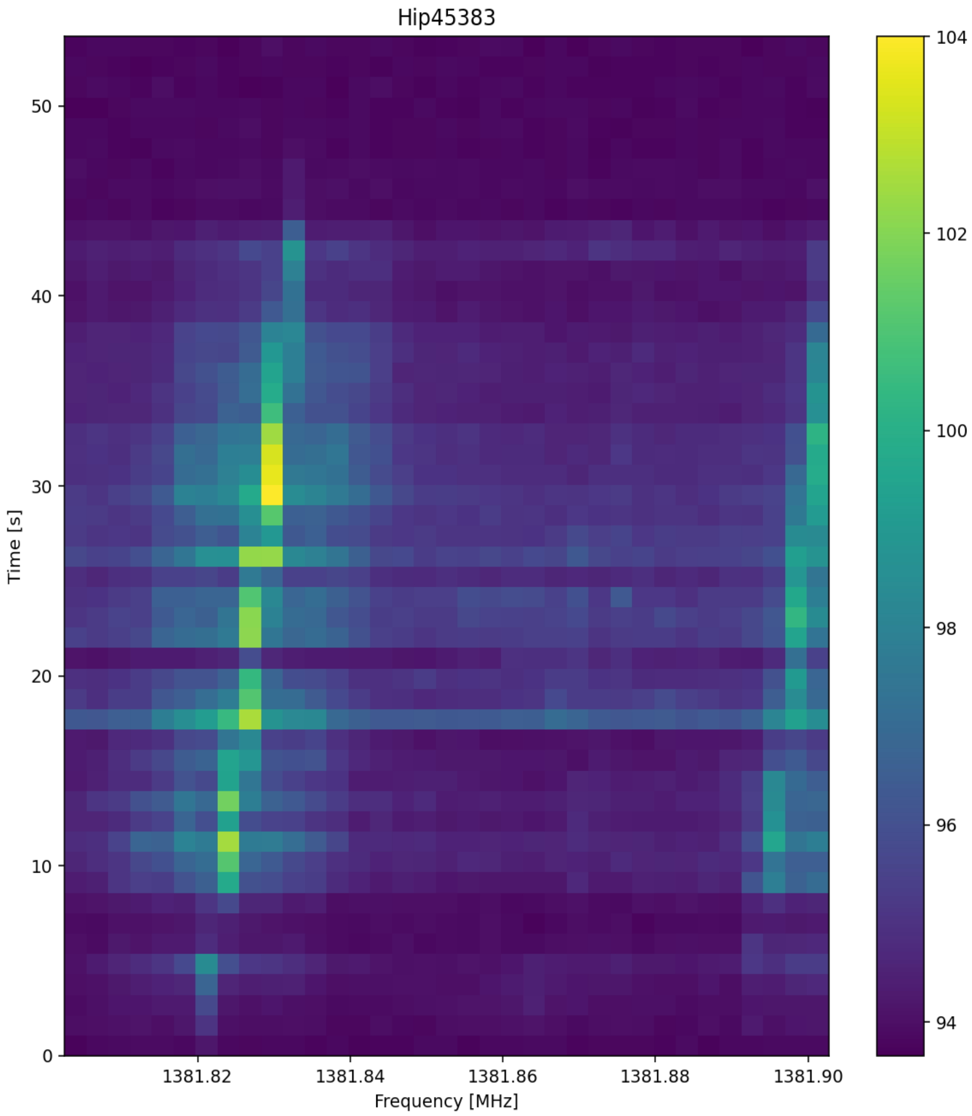
- Date: 2016-09-11
- Time: 15:54:09
- Frequency (MHz):---------
- Duration (mm:ss): ---------
- Drift Rate(Hz/sec): ---------

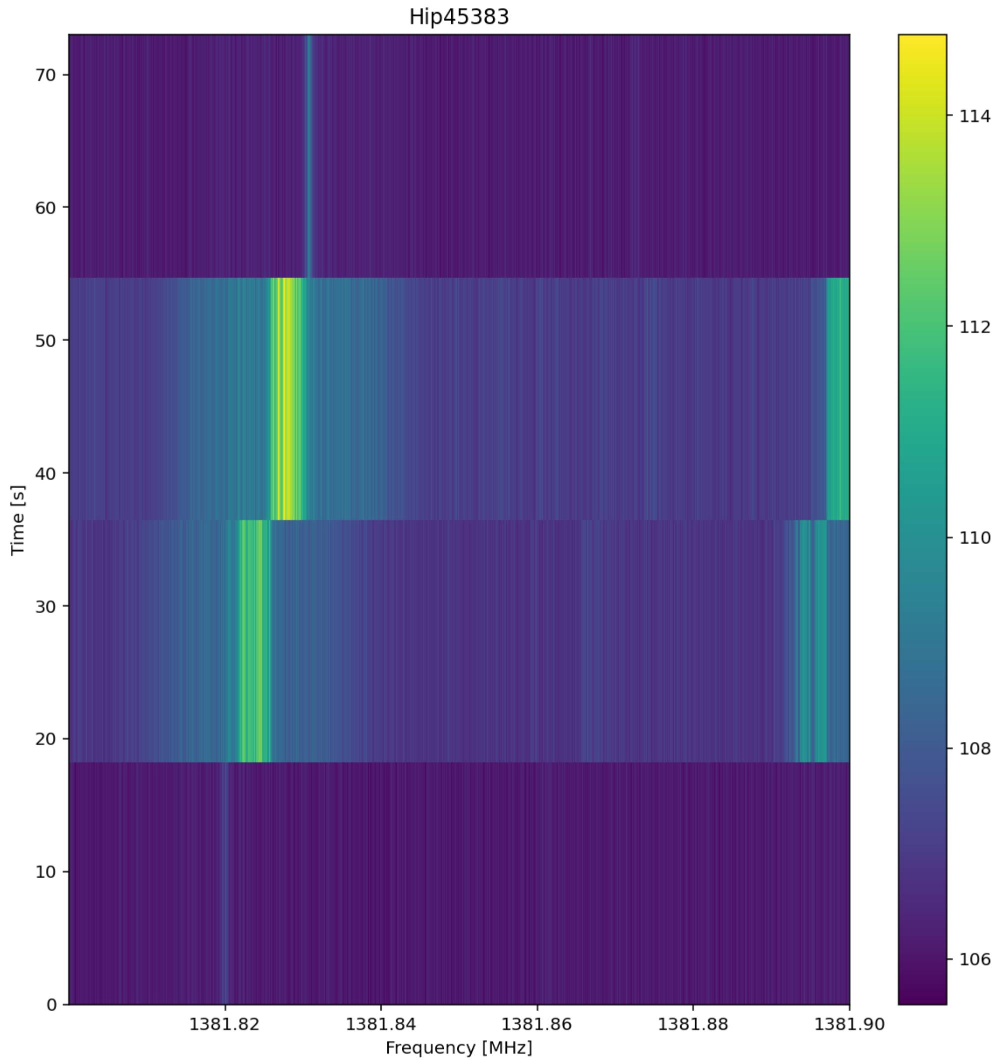
2. Signal SG_HIP45383_0013_0002_1381MHz

Here we have the waterfall graph of the area around the frequency 1381 MHz.



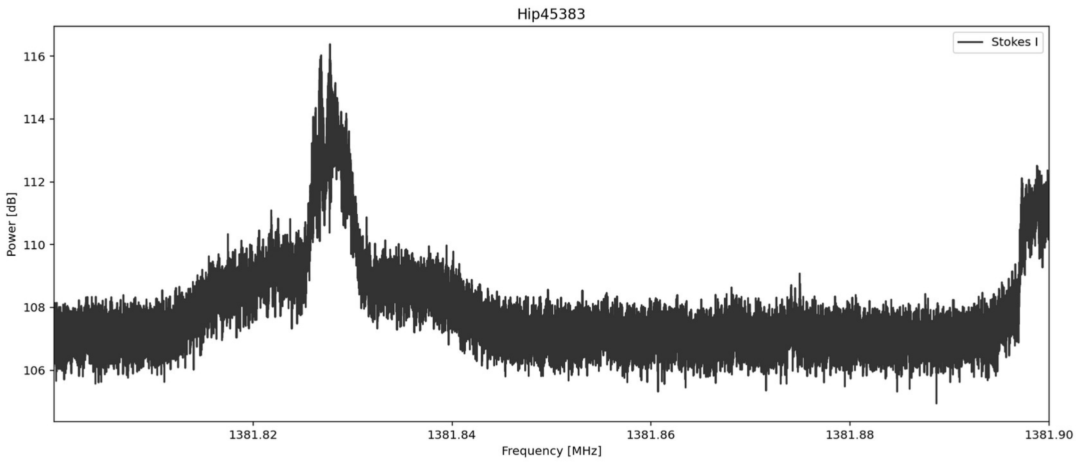
Of all the signals, it seemed clearest to me to use the signal that is between frequencies 1381.80 and 1381.90MHz:





Signal data SG_HIP45383_0013_0002_1381MHz:

- Date: 2016-09-11
- Time: 16:20:49
- Frequency (MHz): 1381.8195 to 1381.8315 (12 KHz)
- Duration (mm:ss): 01:12
- Drift Rate(Hz/sec): 166.66



Signal data in other scans:

Signal data SG_HIP45383_0011_0002_1381MHz: Does not appear in this scan.

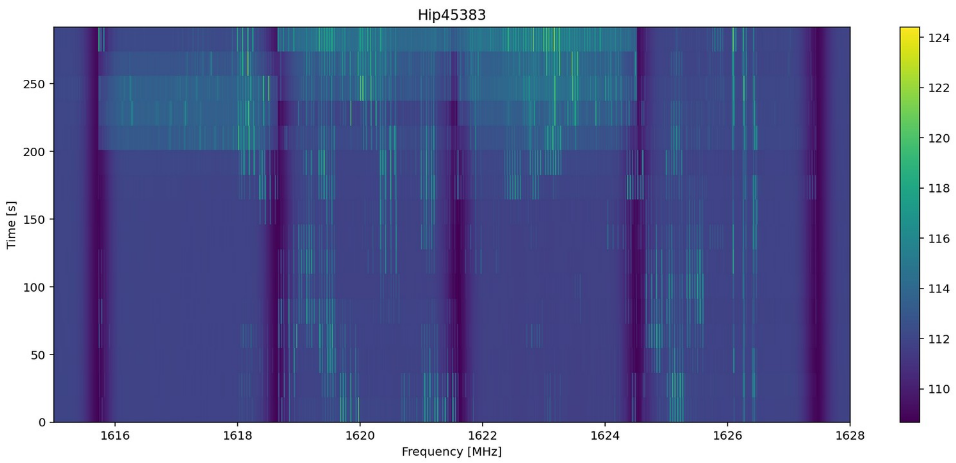
- Date: 2016-09-11
- Time: 16:05:41
- Frequency (MHz):---------
- Duration (mm:ss): --------
- Drift Rate(Hz/sec): --------

Signal data SG_HIP45383_0009_0002_1381MHz: Does not appear in this scan.

- Date: 2016-09-11
- Time: 15:54:09
- Frequency (MHz):---------
- Duration (mm:ss): ---------
- Drift Rate(Hz/sec):---------

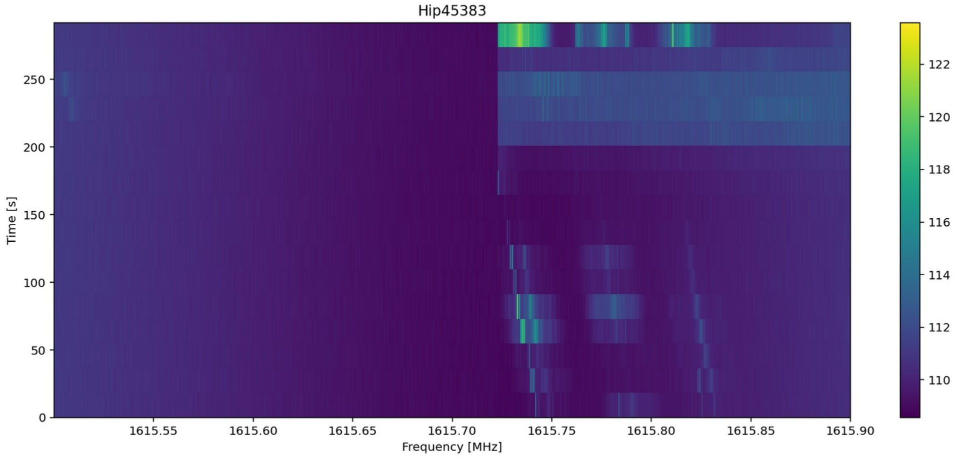
Group of Signals in the frequency range 1615-1628 MHz

In this frequency range you can see a huge amount of signals with Doppler drift. So many that it is impossible to study them in the context of this report.

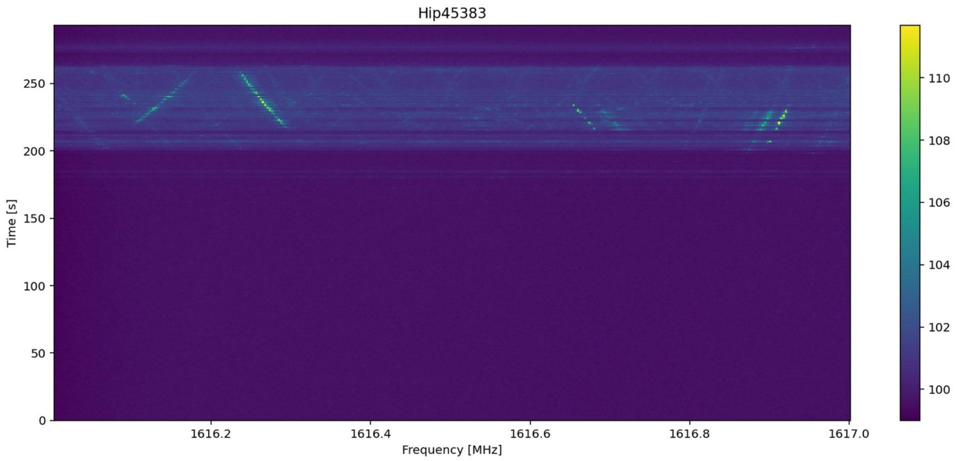


I'm going to post waterfall plots of just a few of the frequencies as a sample, but each group has notable differences in size, duration, and Doppler drift.

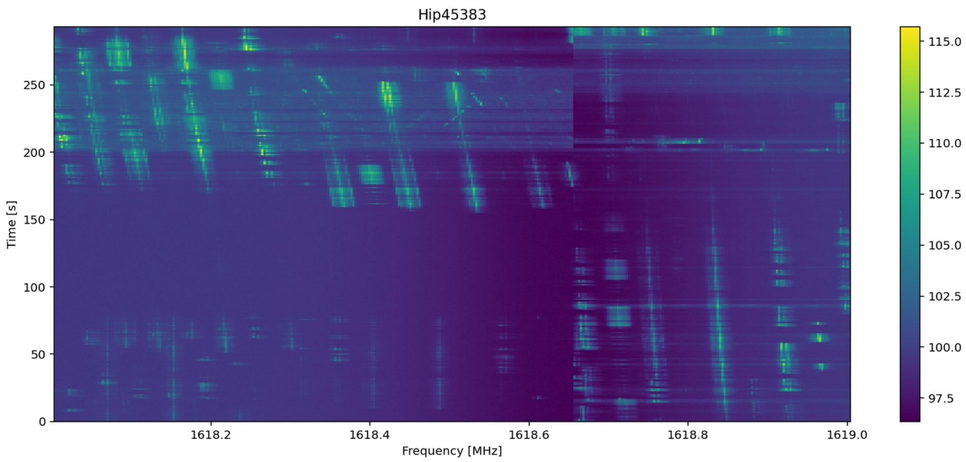
Group of signals around the 1615 MHz frequency:



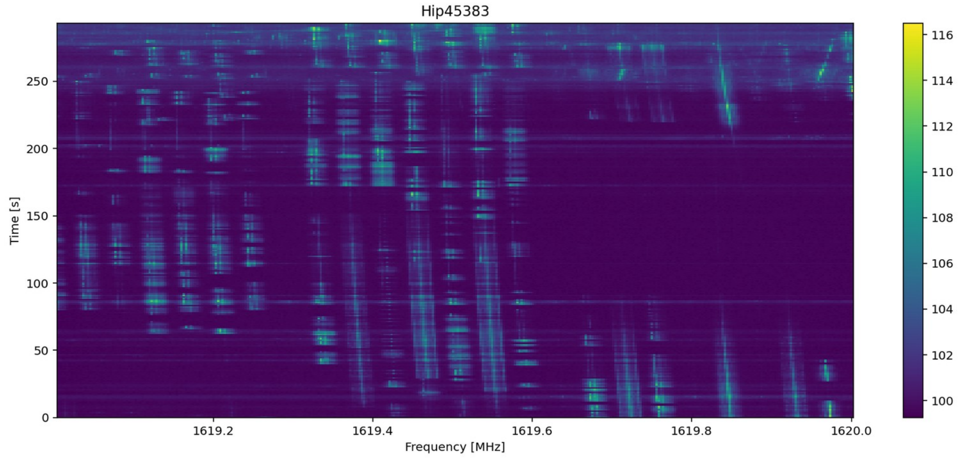
Group of signals around the 1616 MHz frequency:



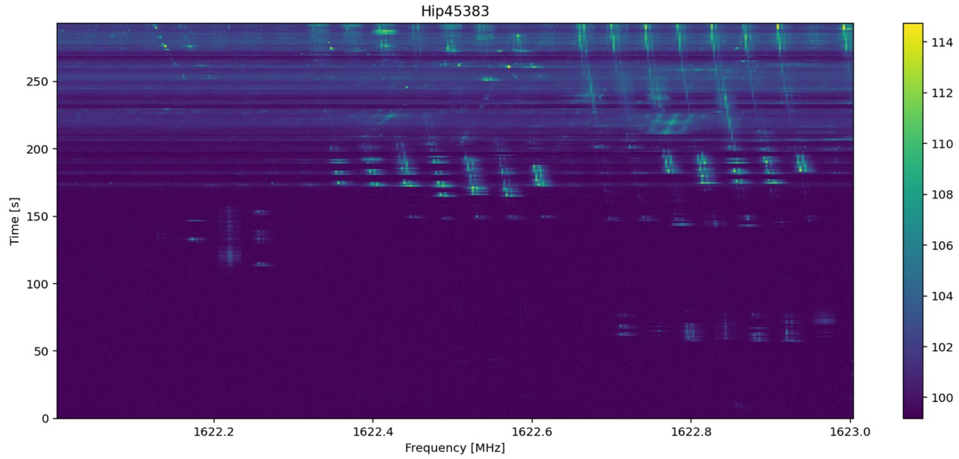
Group of signals around the 1618 MHz frequency:



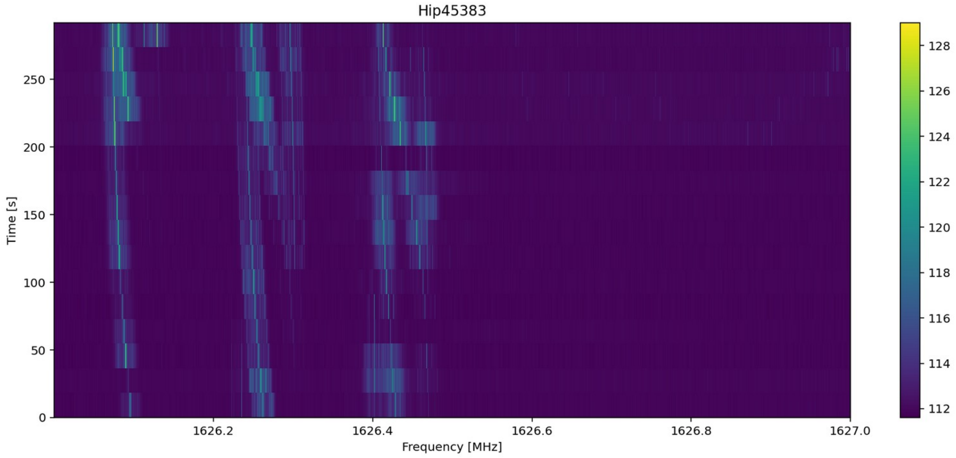
Group of signals around the 1619 MHz frequency:



Group of signals around the 1622 MHz frequency:

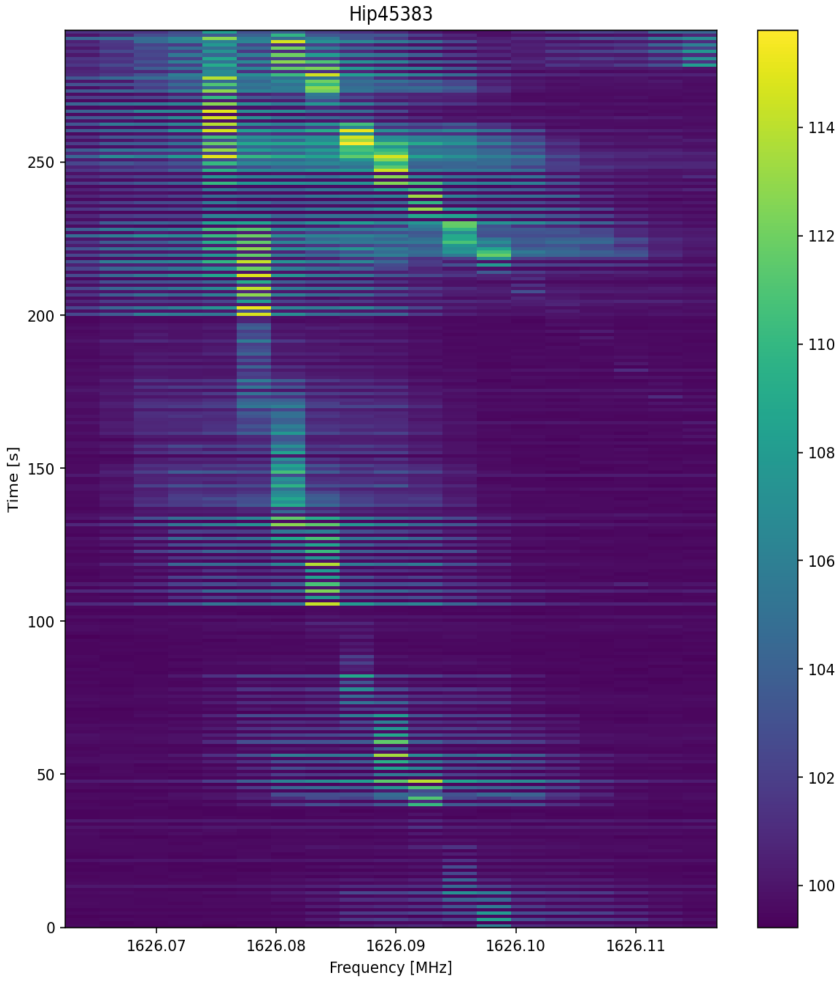


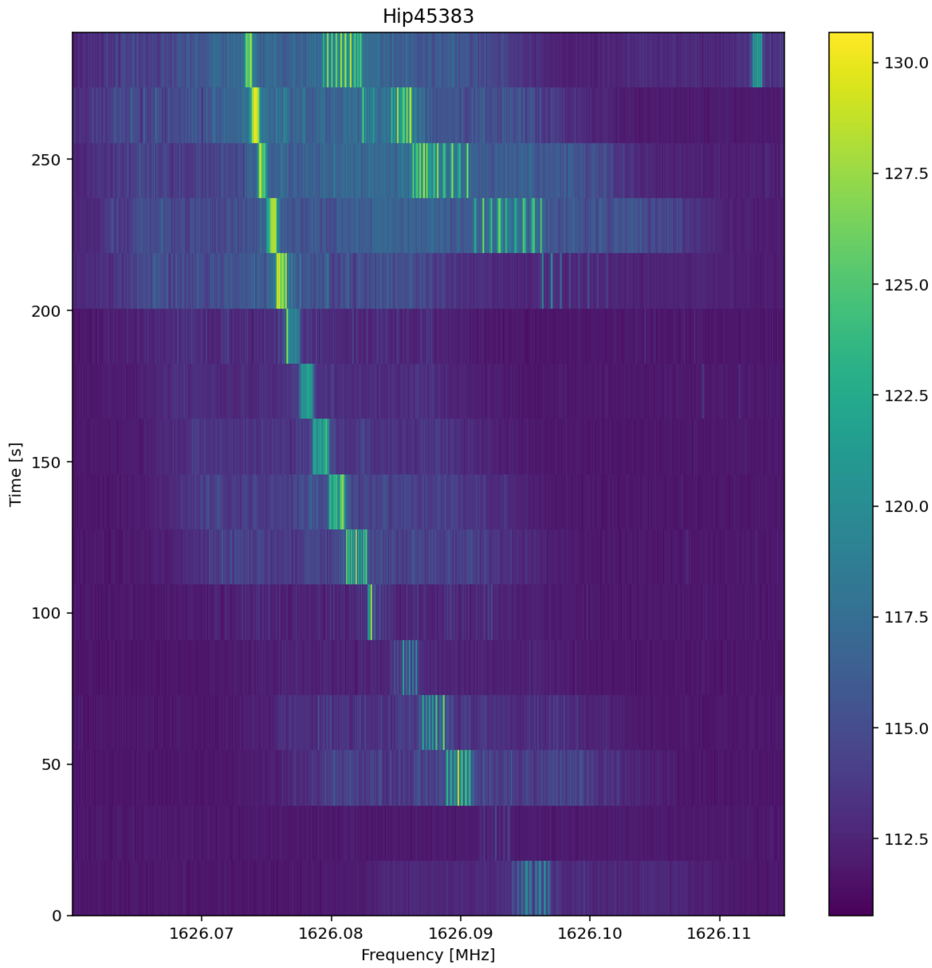
Group of signals around the frequency 1626 MHz and on which I am going to base myself to study one of the signals:



3. Signal SG_HIP45383_0013_0002_1626MHz

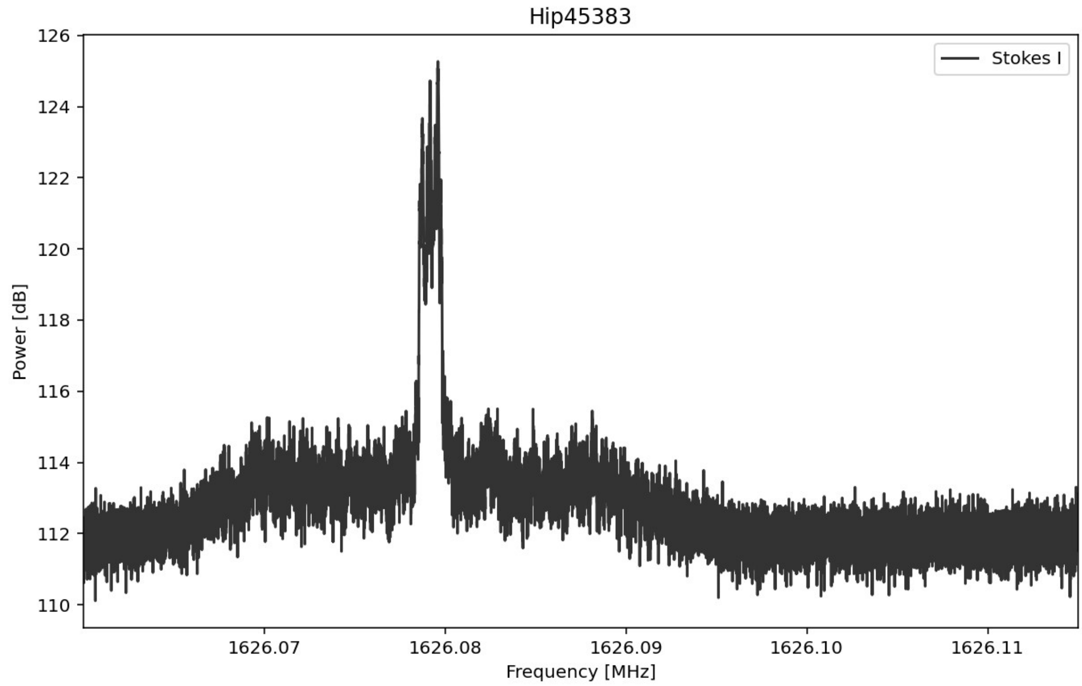
Due to its particular characteristics, I have decided to keep the first signal of the group of signals at the 1626 MHz frequency, which is between the frequencies1626 and 1626.20 MHz:





Signal data SG_HIP45383_0013_0002_1626MHz:

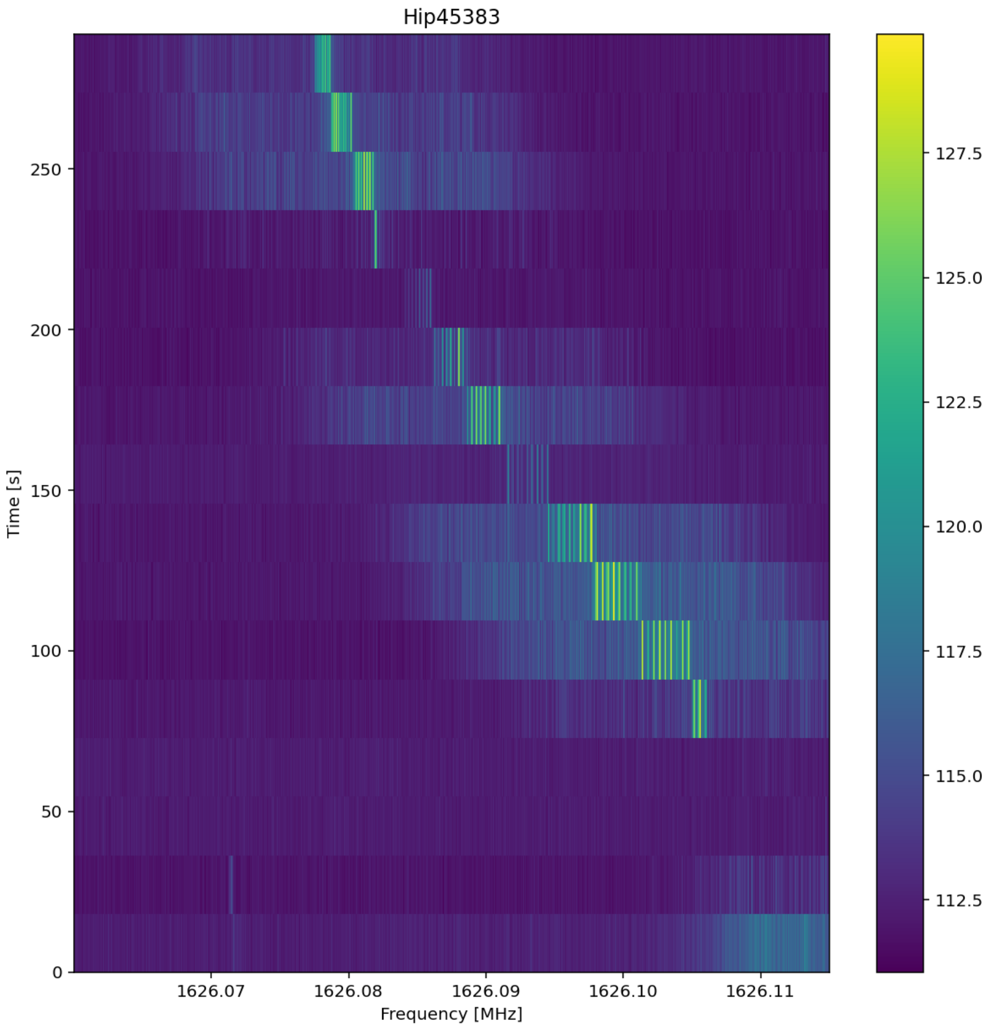
- Date: 2016-09-11
- Time: 16:17:09
- Frequency (MHz): From 1626.0997 to 1626.0756 (-24.1 KHz)
- Duration (mm:ss): 05:00
- Drift Rate(Hz/sec): -80.33



Signal data in other scans:

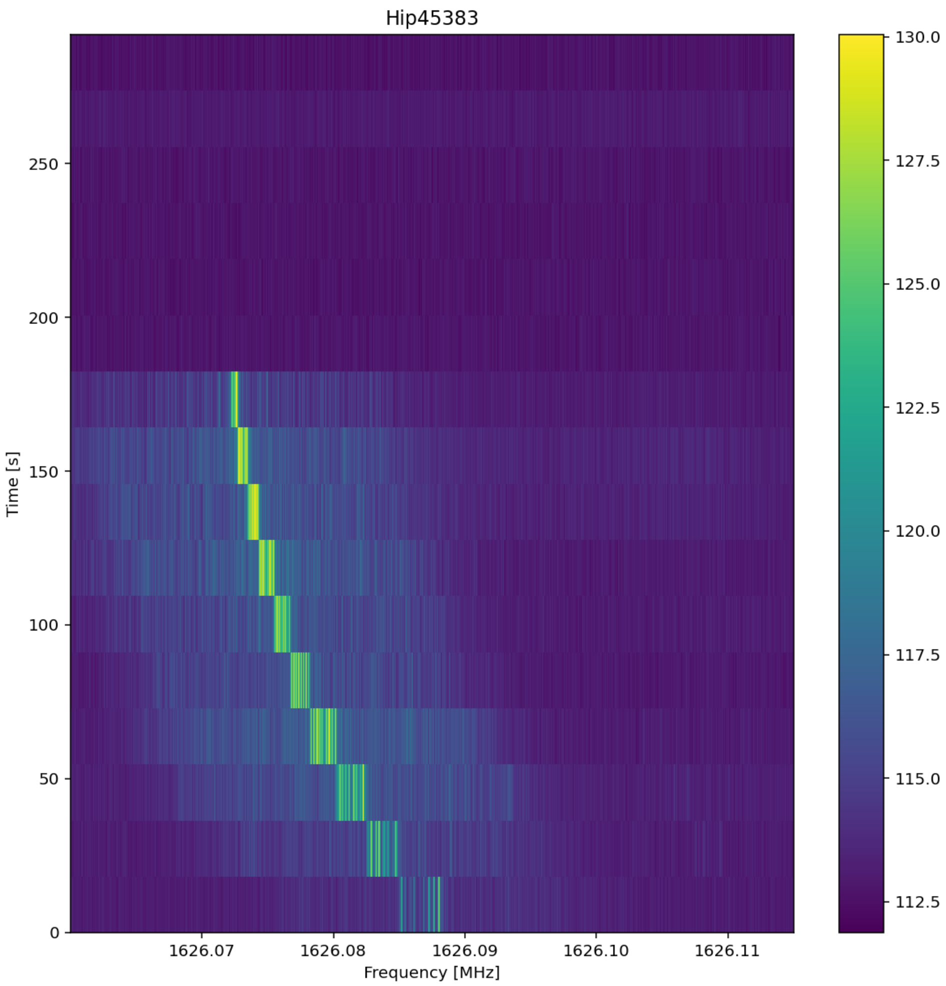
Signal data SG_HIP45383_0011_0002_1626MHz:

- Date: 2016-09-11
- Time: 16:05:41
- Frequency (MHz): From 1626.1150 to 1626.0780 (-37 KHz)
- Duration (mm:ss): 05:00
- Drift Rate(Hz/sec): -123.33



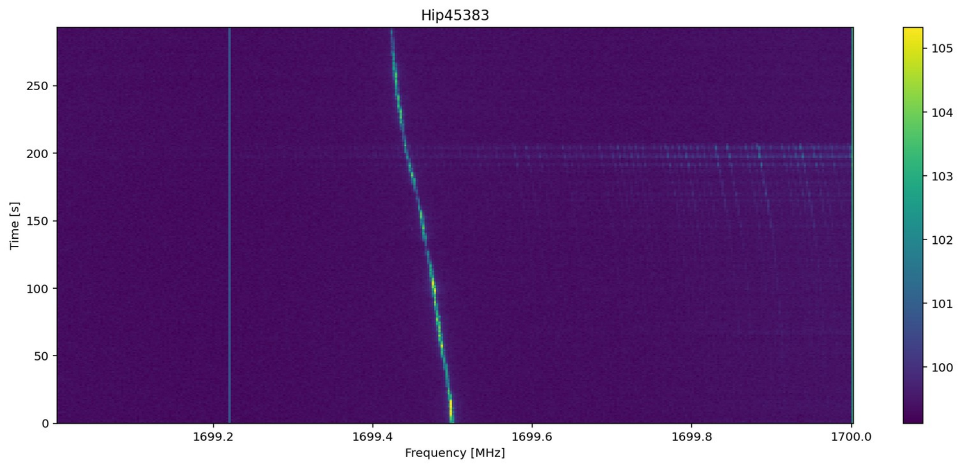
Signal data SG_HIP45383_0009_0002_1626MHz:

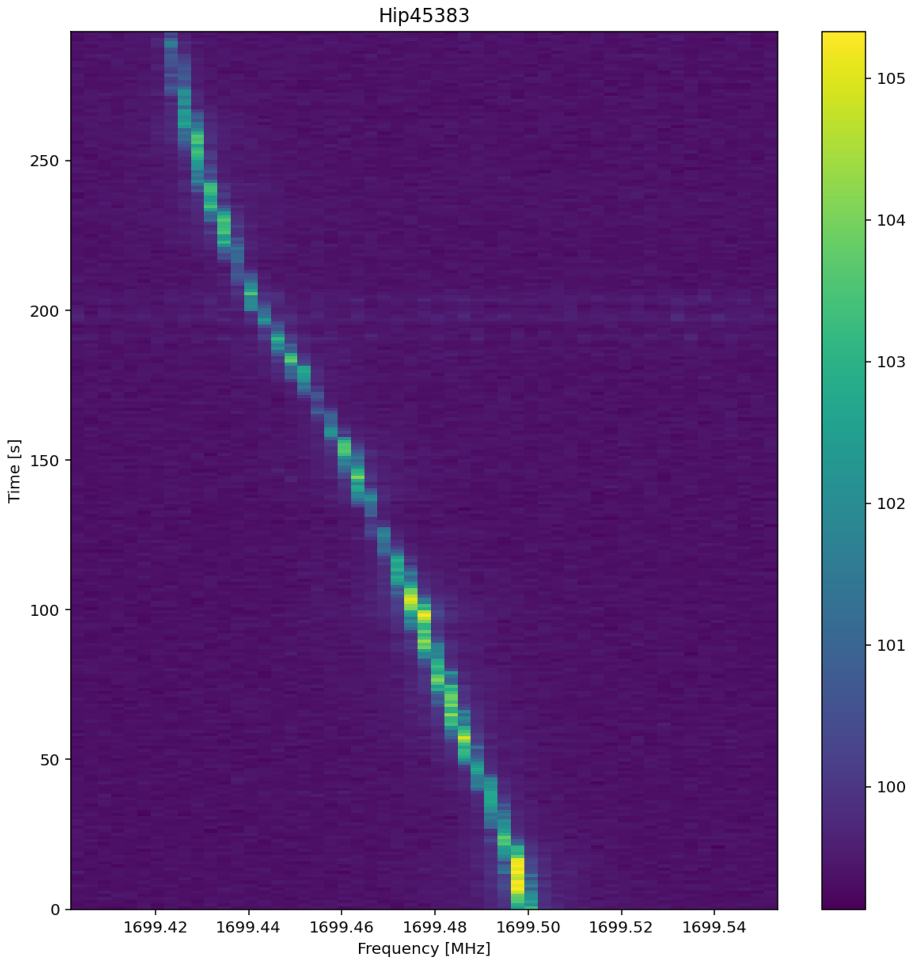
- Date: 2016-09-11
- Time: 15:54:09
- Frequency (MHz): From 1626.0888 to 1626.0725 (-16.3 KHz)
- Duration (mm:ss): 03:07
- Drift Rate(Hz/sec): -87.17

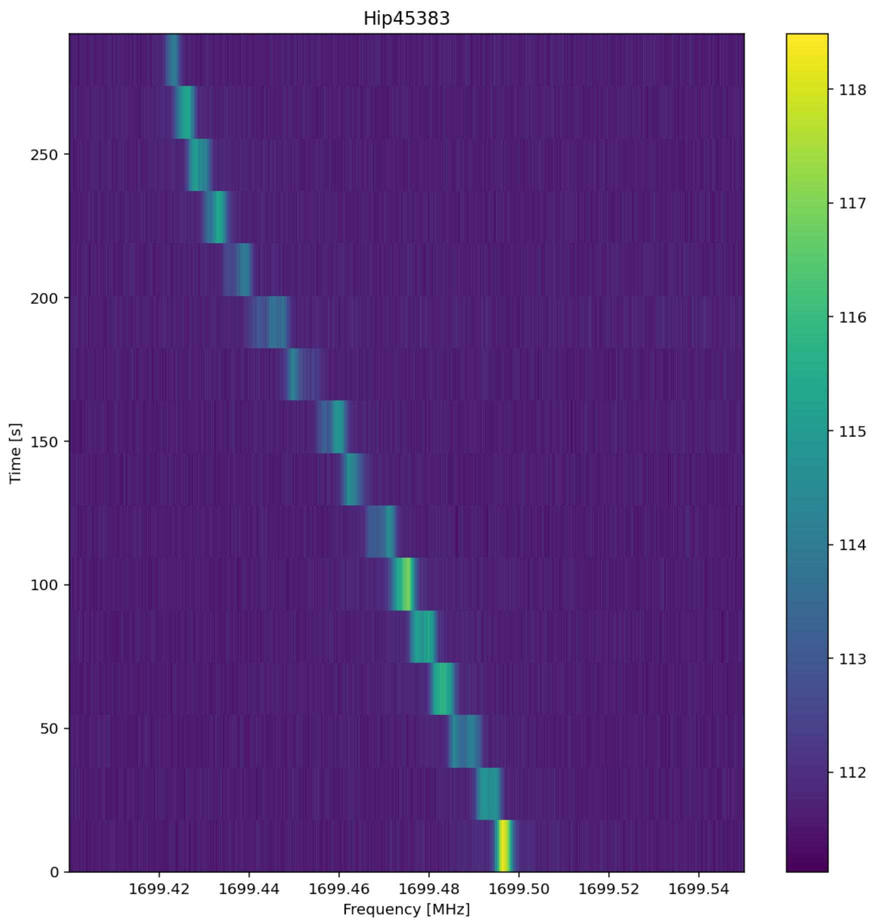


4. Signal SG_HIP45383_0013_0002_1699MHz

Here we have the waterfall graph of the area around frequency 1699MHz.

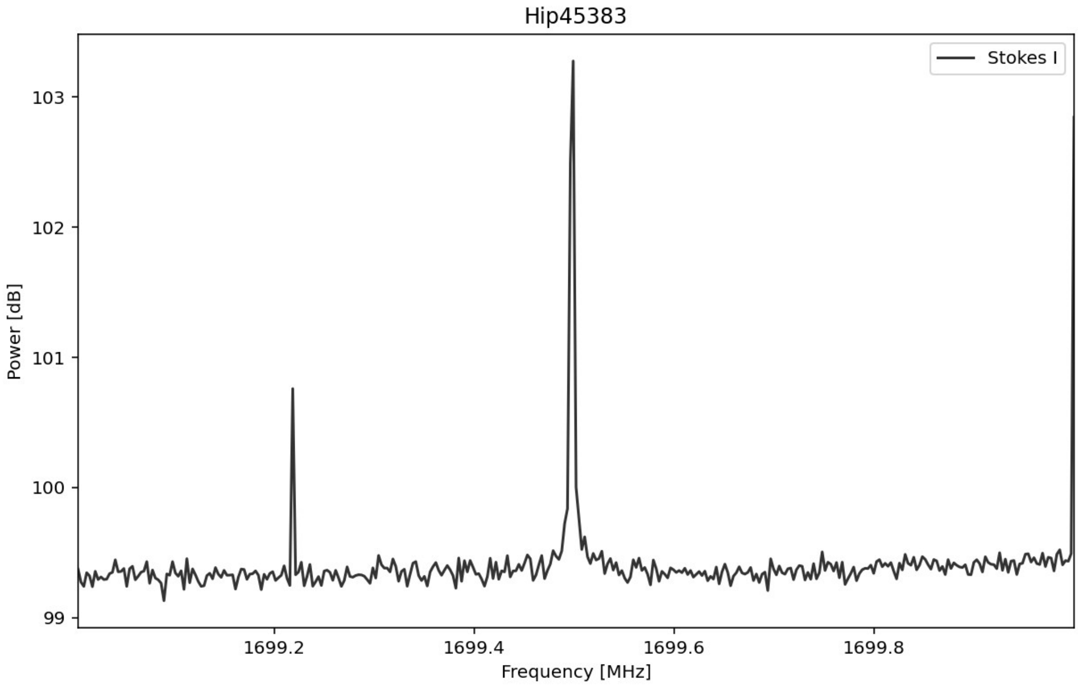



Hip45383
Time [s]
Frequency [MHz]
0
50
100
150
200
250
1699.42
1699.44
1699.46
1699.48
1699.50
1699.52
1699.54
100
101
102
103
104
105


Hip45383
Time [s]
Frequency [MHz]
0
50
100
150
200
250
1699.42
1699.44
1699.46
1699.48
1699.50
1699.52
1699.54
112
113
114
115
116
117
118

Signal data SG_HIP45383_0013_0002_1699MHz:

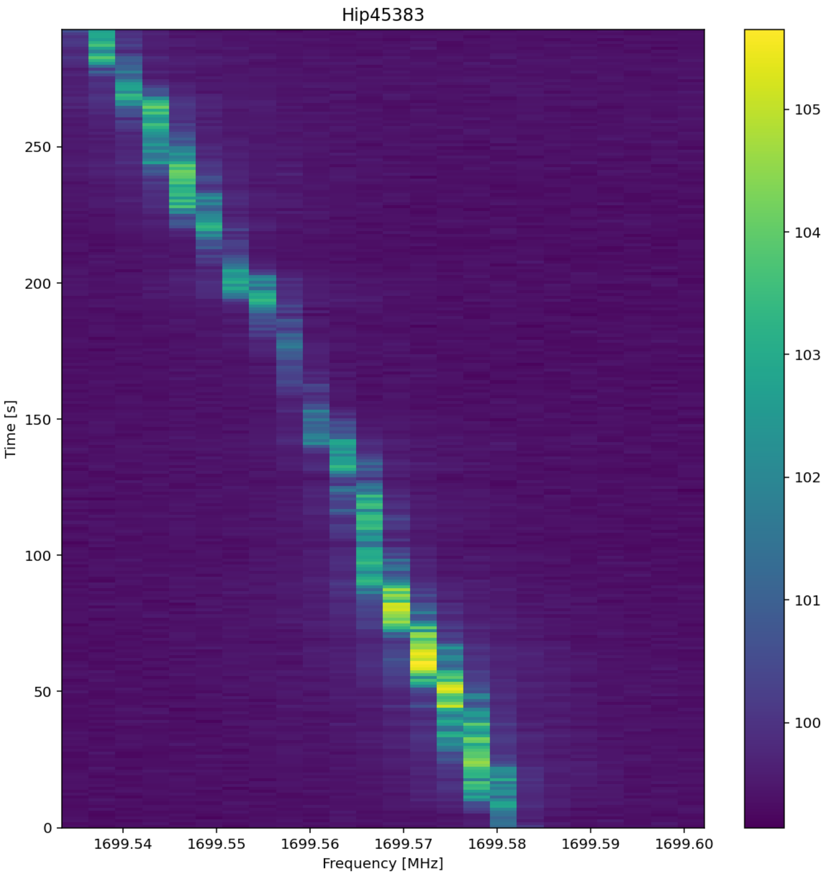
- Date: 2016-09-11
- Time: 16:17:09
- Frequency (MHz): From 1699.5025 to 1699.4235 (-79 KHz)
- Duration (mm:ss): 05:00
- Drift Rate(Hz/sec): -263.33



Signal data in other scans:

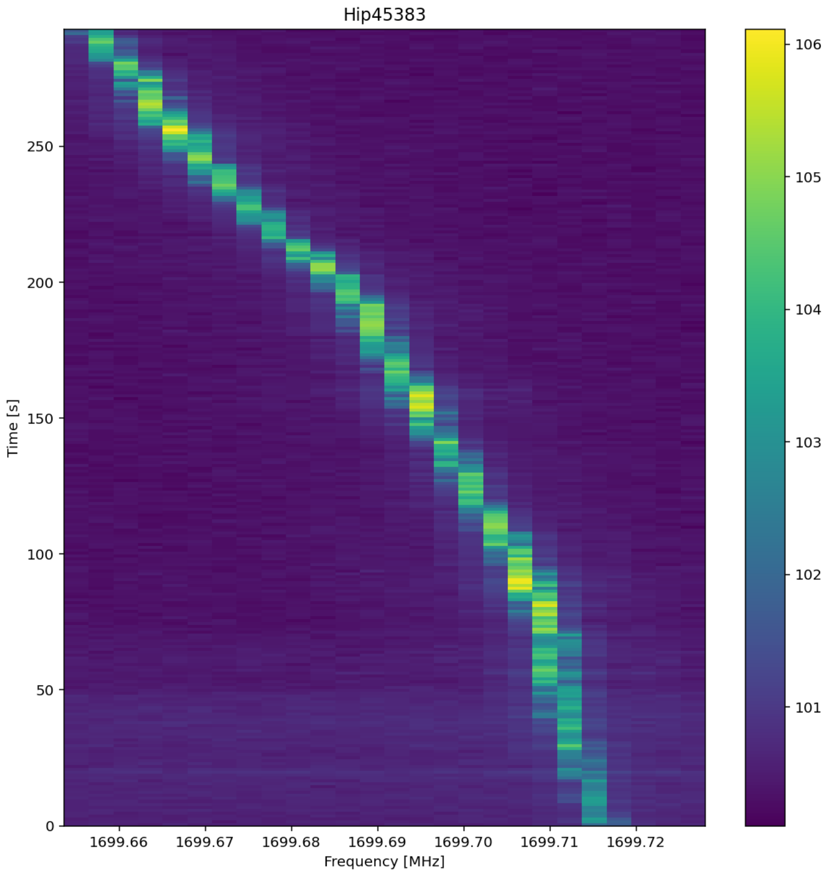
Signal data SG_HIP45383_0011_0002_1699MHz:

- Date: 2016-09-11
- Time: 16:05:41
- Frequency (MHz): From 1699.5825 to 1699.5360 (-46.5 KHz)
- Duration (mm:ss): 05:00
- Drift Rate(Hz/sec): -155



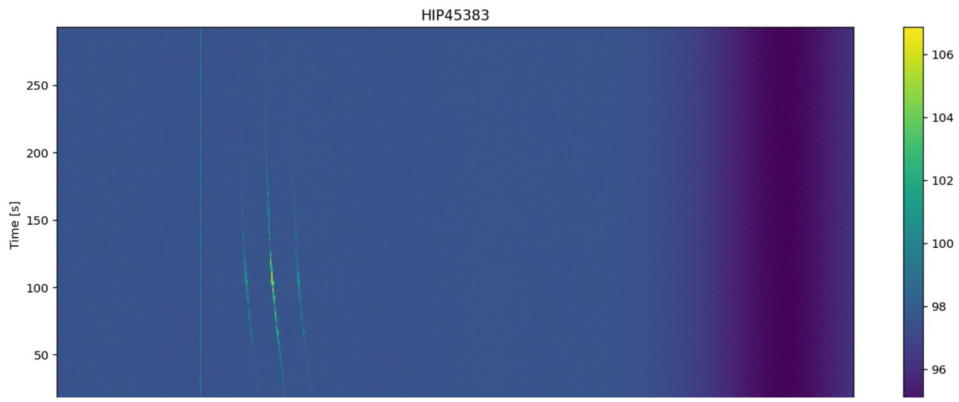
Signal data SG_HIP45383_0009_0002_1699MHz:

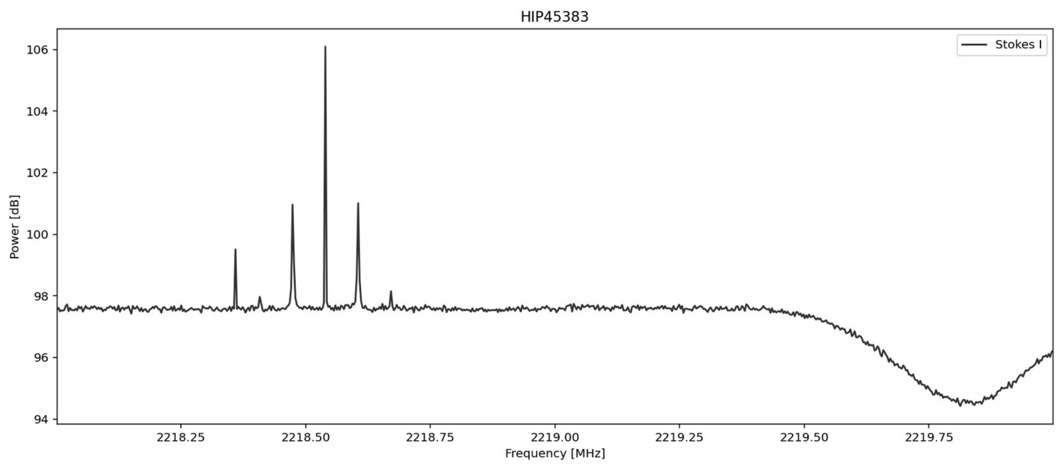
- Date: 2016-09-11
- Time: 15:54:09
- Frequency (MHz): From 1699.7160 to 1699.6536 (-62.4 KHz)
- Duration (mm:ss): 05:00
- Drift Rate(Hz/sec): -208

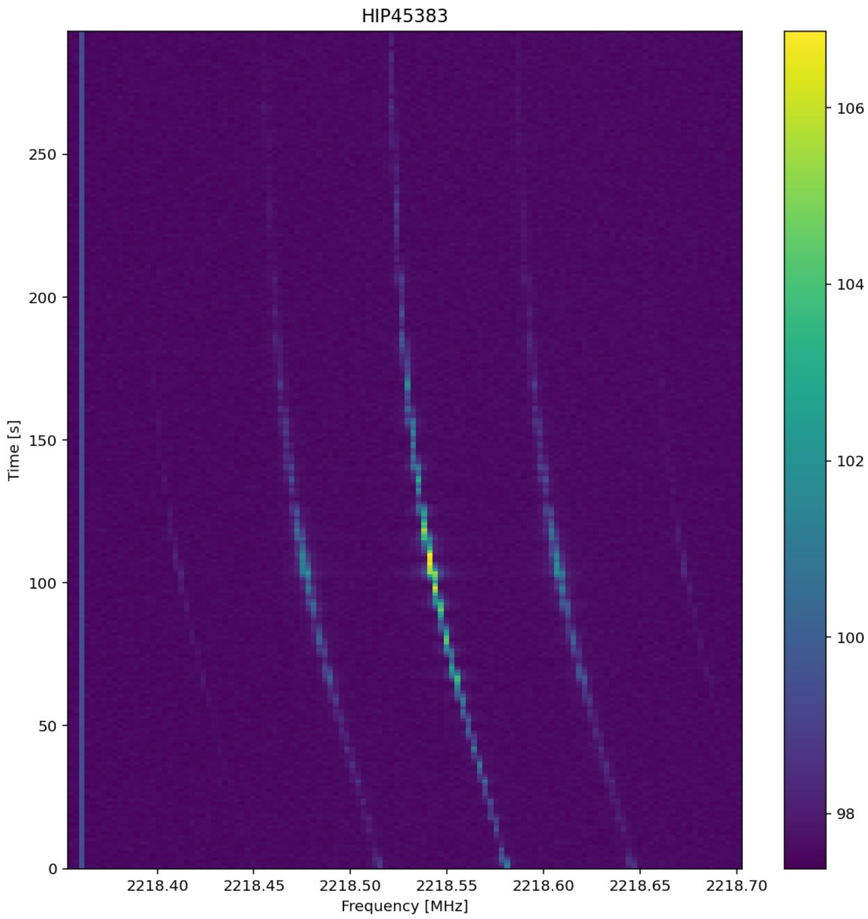


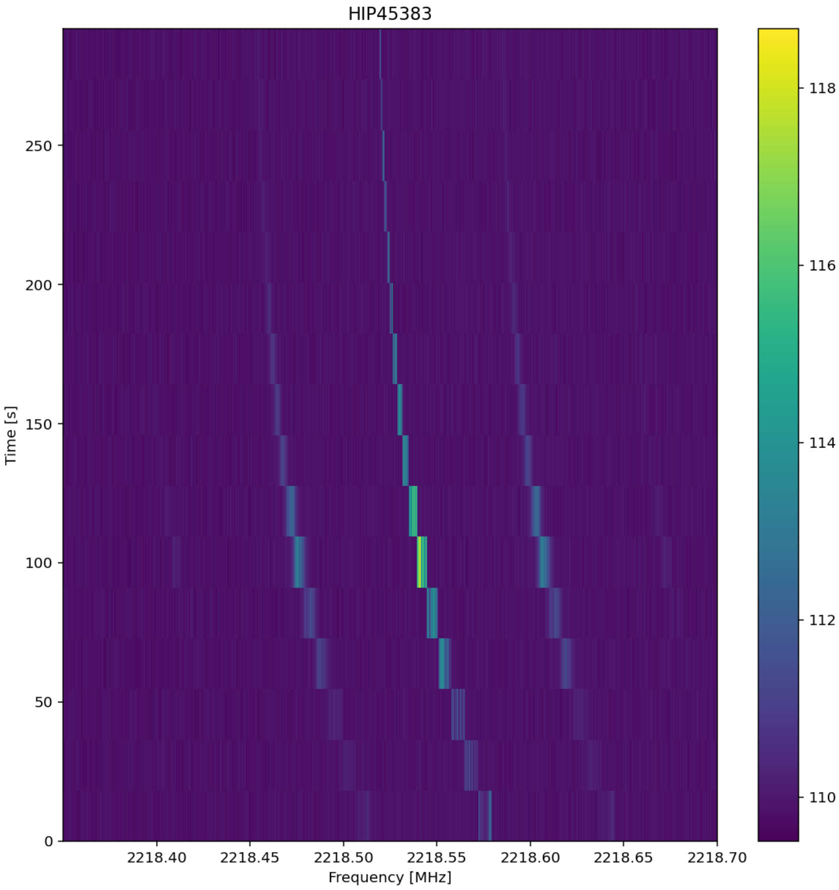
5. Signal SG_HIP45383_0023_0002_2218MHz

Here we have the waterfall graph of the area around the frequency2218 MHz.



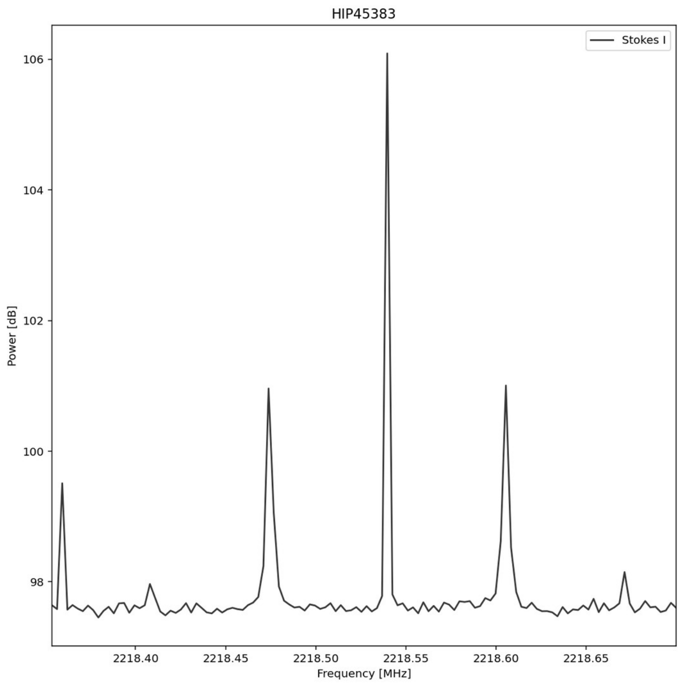



HIP45383
Time [s]
Frequency [MHz]
0
50
100
150
200
250
2218.40
2218.45
2218.50
2218.55
2218.60
2218.65
2218.70
98
100
102
104
106



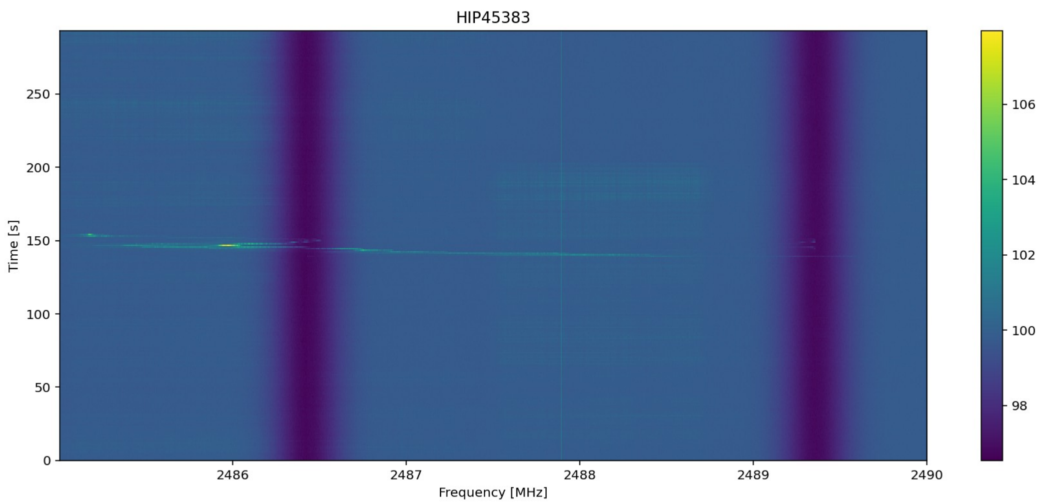
<u>Signal data SG_HIP45383_0023_0002_2218MHz</u>:

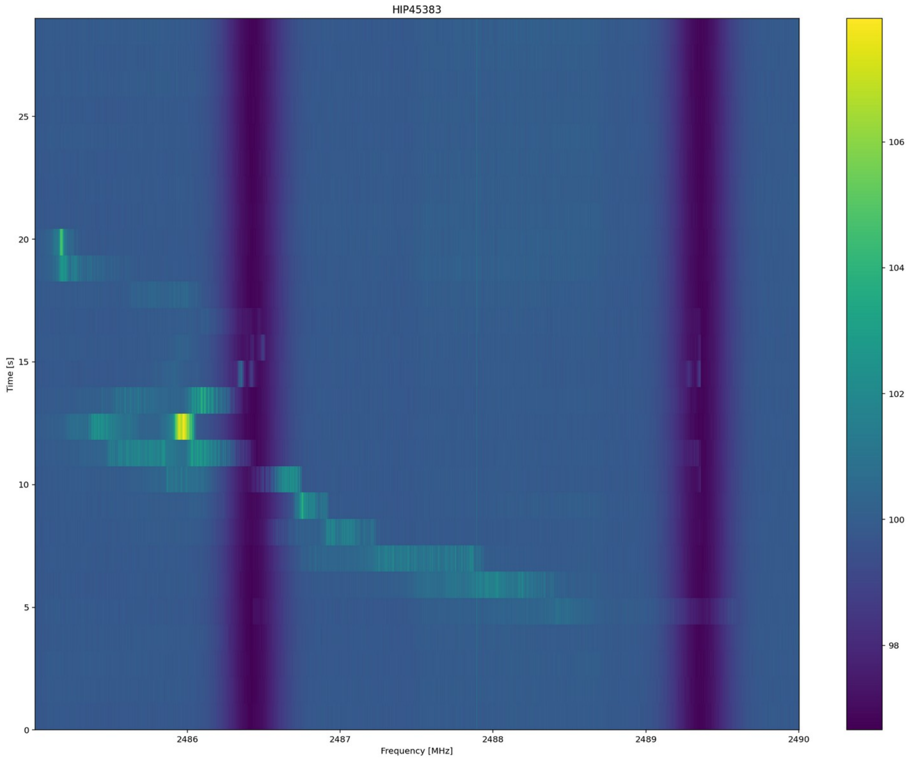
- Date: 2016-10-04
- Time: 15:46:58
- Frequency (MHz): From 2218.585 to 2218.520 (-65 KHz)
- Duration (mm:ss): 05:00
- Drift Rate(Hz/sec): -216.66



6. Signal SG_HIP45383_0025_0002_2486MHz

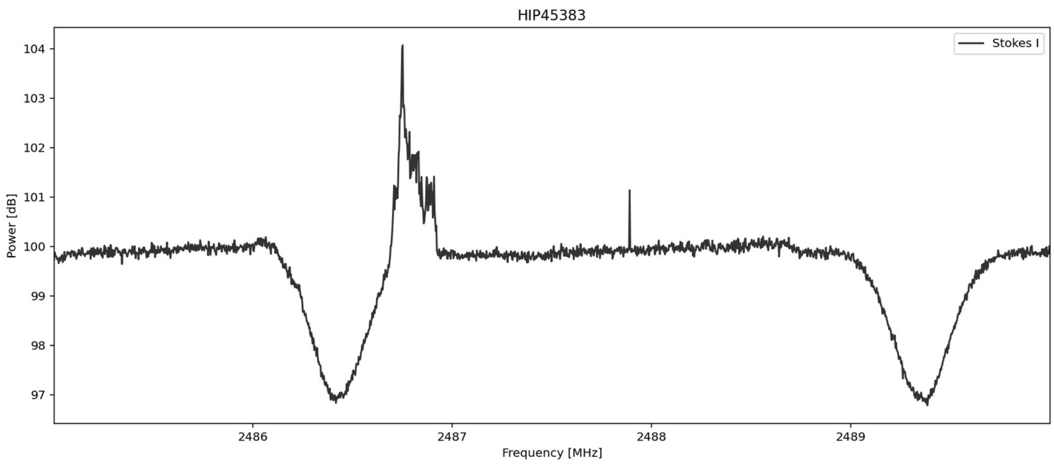
Here we have the waterfall graph of the area around the frequency2468 MHz.





<u>Signal data SG_HIP45383_0025_0002_2486MHz</u>:

- Date: 2016-10-04
- Time: 15:58:49
- Frequency (MHz): From 2489.70 to 2485.10 (-4,600 KHz)
- Duration (mm:ss): 00:20
- Drift Rate(Hz/sec): -230000



DISCUSSION

Within the types of signals with Doppler drift found in this study, two groups should be highlighted: isolated signals and groups of signals.

The groups of signals are most intriguing, such as the one found in the frequency range between 1615 and 1628 MHz. What does it mean? If we take into account that a priori Doppler drift signals are not RFI (Radio Frequency Interference), what could they be? Errors in the instruments for recording and/or recording RFI signals that cause this apparent drift? Satellite fleets in orbit like those of Starlink? And if we let ourselves be carried away by our imagination, radioelectric leak from an extraterrestrial civilization? This is how a radio band used by aliens would appear, like our FM or VHF... All possibilities are left open...

However, I believe that the greatest probability of the origin of these signals is that of a fleet of satellites like those of Starlink because the frequencies around 1600 to 1700 MHz in the radio spectrum are used mainly for satellite communications and global navigation systems, such as GPS (Global Positioning System).

Of the other individual signals, the most interesting is number 4, SG_HIP45383_0013_0002_1699MHz. Is it a satellite? Or rather in this case is it possible that we are capturing the signal from one of our probes in deep space? Or also an emission from a planet in the star HIP 45383 or a spacecraft on course towards Earth... Analyzing the spectrum of the signal we see that it does not have the carrier and the two side bands that carry the data of the vast majority of probes from deep space but we are still in the band used by GPS satellites so in all likelihood it is the latter.

Signal number 5, Signal SG_HIP45383_0023_0002_2218MHz, is perhaps the easiest to identify as human-made. First because it is located at the frequencies at which deep space probes usually work. These probes operate primarily in the S-band (approximately 2.3 GHz) for scientific data transmission and in the X-band (around 8.4 GHz) for data transmission toward Earth. They are the bands used by the Voyager 1 and 2 and Pioneer 10 and 11 probes. And because in the spectrum analysis graph the carrier signal and the signals of the two side bands are clearly seen. And we find exactly the same pattern with signals at the frequencies of 2230 MHz and 2253 MHz that I have not included in this report so as not to extend it unnecessarily.

And we come to the strangest signal detected in this report, number 6. Indeed the signal SG_HIP45383_0025_0002_2486MHz presents a very strange behavior, with a brutal drift of -230000 Hz/s, with a very short duration and that does not appear in the other scanners, 21 and 23. There has always been speculation about what SETI signals might look like, which should, perhaps, be very strange, but having not detected any so far, at least officially, we cannot compare it. So for now we will put it in the disaster box of “candidate signals”.

CONCLUSIONS

I have been able to get this far. Without more files available in the Breakthrough Listen initiative to continue analyzing them and without having access to any radio telescope due to my status as an amateur astronomer, there is little else I can do. If more files from the star HIP 45383 were dumped in the near future, I could compare and try to find, or not, SETI candidate signals. From here I invite any fan to use all these tools to continue analyzing other stars in the hope of finding the long-awaited answer to the big question: Are we alone in the Universe?

ACKNOWLEDGMENTS

Amateur astronomers like me are currently living in a golden age due to the enormous amount of tools available online through the Internet to carry out our personal projects, supported by a not inconsiderable amount of tutorials, courses and manuals to be able to handle them and get the most out of them, the highest possible performance with our humble knowledge. Apart from the main tool used in this research, the Breakthrough Listen open data archive and all its libraries developed in Python, I would like to highlight the GAVRT project http://galileo.gavrt.org/seti/ which provides all the tools and explanations to perform SETI effectively. You can learn a lot from its lessons. And its waterfall chart formats are absolutely brilliant, at least from the point of view of amateur astronomers. Obviously there are many more but in order not to go into too much detail I will mention another one that is also very interesting and instructive, the ZOONIVERSE project "Are we alone in the universe?"https://www.zooniverse.org/projects/ucla-seti-group/are-we-alone-in-the-universe

To all of them, thank you very much for your training work.

REFERENCES

- Breakthrough Listen https://breakthroughinitiatives.org/opendatasearch
- Decryption of Messages from Extraterrestrial Intelligence Using the Power of Social Media – The SETI Decrypt Challenge https://arxiv.org/pdf/1706.00653
- GAVRT Project http://galileo.gavrt.org/seti/
- Are we alone in the universe? https://www.zooniverse.org/projects/ucla-seti-group/are-we-alone-in-the-universe
- The Radio JOVE Project https://radiojove.gsfc.nasa.gov/
- PARTNeR Projec thttps://partner.cab.inta-csic.es/index.php
- Stellar Catalog https://www.stellarcatalog.com/index_es.php
- Star HD 79555 (HIP 45383) https://www.stellarcatalog.com/estrellas/hd-79555
- Planet HD 79555 (AB)b https://exoplanet.eu/catalog/hd_79555_ab_b--9621/ and https://www.exoplanetkyoto.org/exohtml/HD_79555_(AB)b.html
- Breakthrough Listen Open Data Archive http://seti.berkeley.edu/opendata
- The Breakthrough Listen Search for Intelligent Life: Public Data, Formats, Reduction and Archiving https://arxiv.org/pdf/1906.07391

- How to find ET https://github.com/UCBerkeleySETI/breakthrough/blob/master/GBT/README.md
- Breakthrough Listen at UC Berkeley http://seti.berkeley.edu/listen/
- blimpy https://github.com/UCBerkeleySETI/blimpy
- Breakthrough Listen I/O Methods for Python https://blimpy.readthedocs.io/en/latest/overview.html
- Introduction to Working with Filterbank Files https://github.com/UCBerkeleySETI/breakthrough/blob/master/GBT/filterbank_tutorial/Filterbank%20Tutorial%20(public).ipynb
- Breakthrough Listen: Voyager 1 Observations https://github.com/UCBerkeleySETI/blimpy/blob/master/examples/voyager.ipynb
- Welcome to the Blimpy Voyager Tour! https://github.com/UCBerkeleySETI/blimpy/blob/master/tutorial/blimpy_voyager_tour.ipynb
- Rainbow in the Dark http://seti.berkeley.edu:8000/doppler/
- Choosing a Maximum Drift Rate in a SETI Search: Astrophysical Considerations https://arxiv.org/pdf/1910.01148