



# Latest results of Falcon searches: continuous gravitational wave atlas.

Vladimir Dergachev

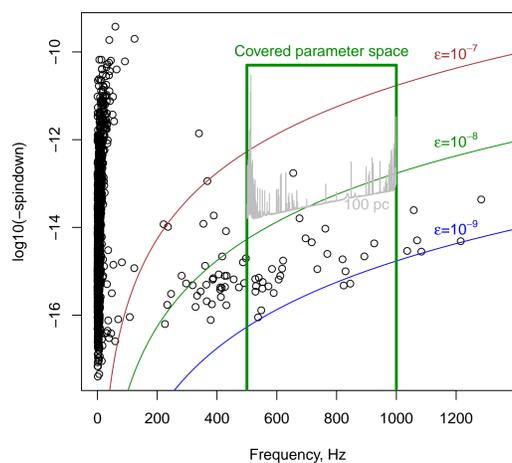


## Introduction

Continuous waves from non-axisymmetric neutron stars are orders of magnitude weaker than transient events from black hole and neutron star collisions.

However, once discovered, a continuous wave source allows repeated observations. Ideally, we want to find a source that can be studied in gravitational and electromagnetic channels simultaneously.

## All-sky search



Only a small fraction of our galactic neutron stars have been discovered through electromagnetic and particle observations. The plot above shows their parameters (black circles) in relation to *equatorial ellipticity*  $\epsilon$  - a measure of neutron star deformation necessary to produce gravitational wave signals.

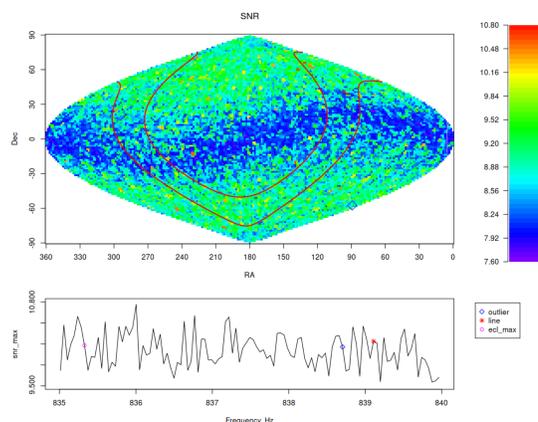
Modern algorithms and computing facilities allow to perform an all-sky search to find unknown neutron stars. Because continuous waves persist, it is possible to improve sensitivity by integrating months of data, albeit at a great computational cost.

For this first look at O3 data we have chosen the frequency band between first and second harmonics of violin modes. There the neutron stars are fairly common, while producing strong emission even for weak deformations.

## References

- [1] <https://github.com/volodya31415/libMVL>
- [2] <https://cran.r-project.org/package=RMVL>
- [3] [https://github.com/volodya31415/gaia\\_mvl](https://github.com/volodya31415/gaia_mvl)
- [4] Gaia data in MVL format [https://www.atlas.aei.uni-hannover.de/work/volodya/Gaia\\_dr3/](https://www.atlas.aei.uni-hannover.de/work/volodya/Gaia_dr3/)
- [5] Continuous gravitational wave atlas in MVL format [https://www.atlas.aei.uni-hannover.de/work/volodya/O3a\\_atlas/](https://www.atlas.aei.uni-hannover.de/work/volodya/O3a_atlas/)

## Gravitational wave atlas



In the past, searches for continuous wave sources produced frequency-dependent upper limits and a handful of outliers that stood out in the data, with most of intermediate computational results lost.

Our newest Falcon search has produced an atlas [5], where for every frequency band we have images of the entire sky giving both upper limits and signal-to-noise ratios. Some of the results have been followed up, but the majority are unexplored. New searches can be made by using results of the expensive first stage of Falcon search.

The atlas data is provided in a new MVL file format that allows analysis on small computers, such as your notebook. Queries by sky position can use a spatial index.

The atlas comes with examples that show how to

- retrieve upper limits and SNRs for specific sky locations and frequencies
- produce upper limits and SNR over entire frequency band for a specific sky location
- find all points above a fixed SNR threshold
- generate a skymap and a frequency plot for any frequency range (example above)

## Introduction to MVL

Mappable Vector Library (MVL) is a file format optimized for memory mapping. It is designed for direct access to data by both low-level C code [1] and high-level scripting languages (such as R [2]).

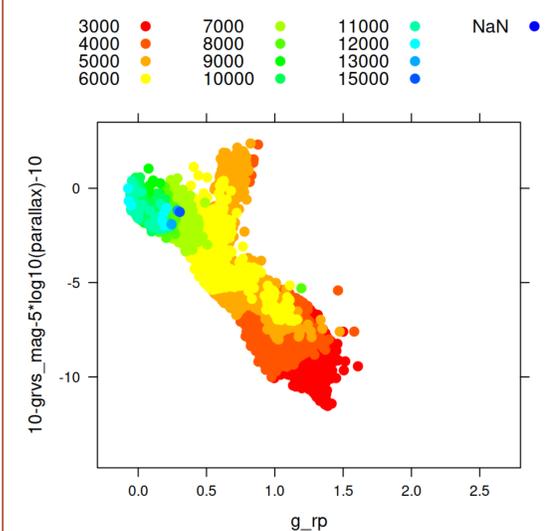
You can use MVL files to:

- Analyze as much data as fits on your solid state drive
- Exchange bulk binary-level data between C and R programs
- Share large data between multiple processes running on the same computer

In addition to seamless array-style access, MVL libraries provide database functionality of sorting the data and creating hash-based value and spatial indices.

The library functions have been optimized to reduce the number of writes to solid state drives.

## Gaia data in MVL format



Gaia mission collected a wealth of data on nearby stars. While one can use on-line databases to search for a given object, it would be nice to explore Gaia data as a whole. To make this possible, Gaia data was converted to MVL format [4] (available for download using HTTP and Torrent).

Besides raw data, we provide indices allowing to search and scan in order of distance from Earth, or by sky position.

## Gaia example

```
library("RMVL")
M<-mvl_open("gaia_dr3.mvl")
Mpi<-mvl_open("parallax_index.mvl")
# Find closest one million stars
idx<-Mpi$parallax_index[1:1000000]
plot(M$gaia[idx, "parallax"], log="xy")
```