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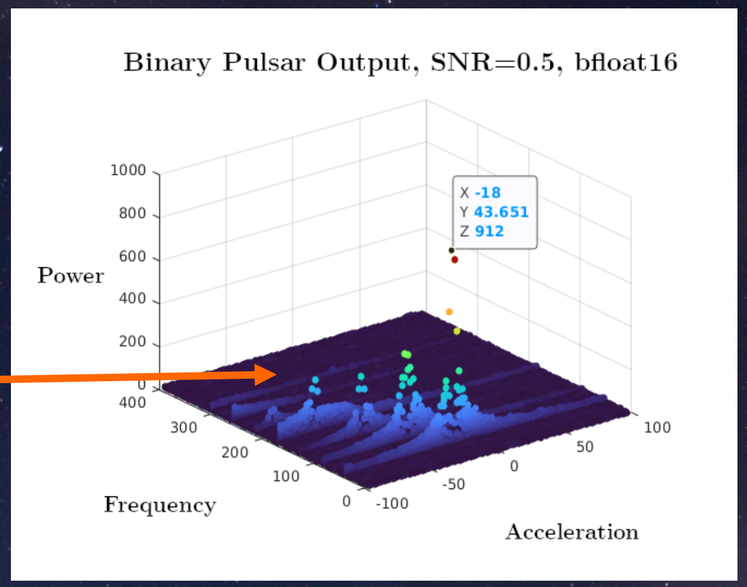
Mixing up FFTs in Radio Astronomy

How do we search for pulsars in radio astronomy? [1]

1. Radio telescopes produce a time series of samples
2. Convert these (via FFT) into the frequency domain
3. Convolve them with the templates of candidate pulsars in the frequency domain, called “Fast Convolution” [2]
4. If a template matches the parameters of a real pulsar in the dataset, there will be peaks that look like this



What is the target application of this project?

- The Square Kilometre Array is a £0.5bn international project to build the most sensitive radio telescope ever
- SKA-Low will produce **5 Zettabytes** of data every year [3]
- Annual internet traffic only passed 1 Zettabyte in 2016

What is “Mixed Precision”?

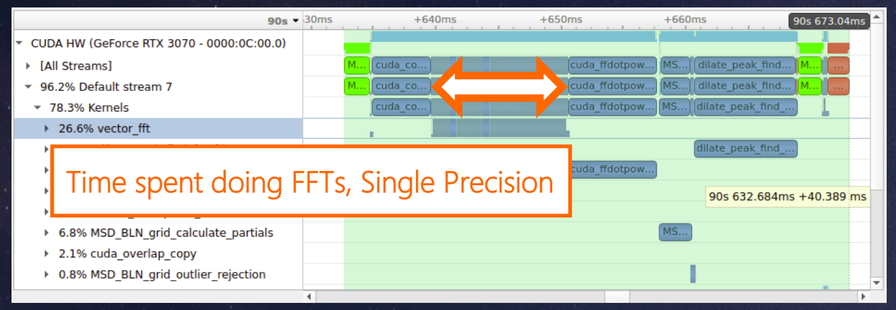
- Using multiple levels of floating point precision in a given signal processing pipeline

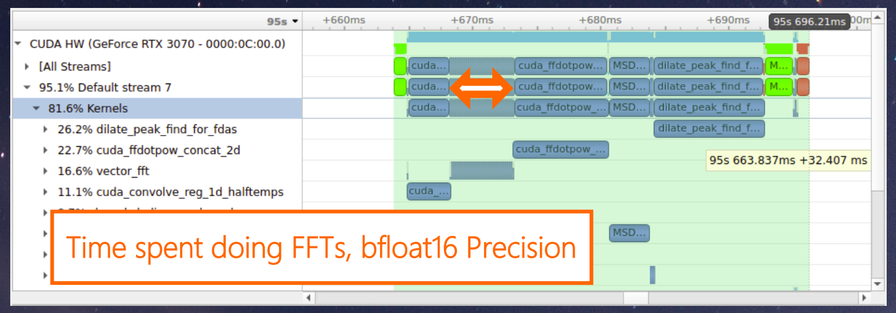
Why would we want to try Mixed Precision FFTs?

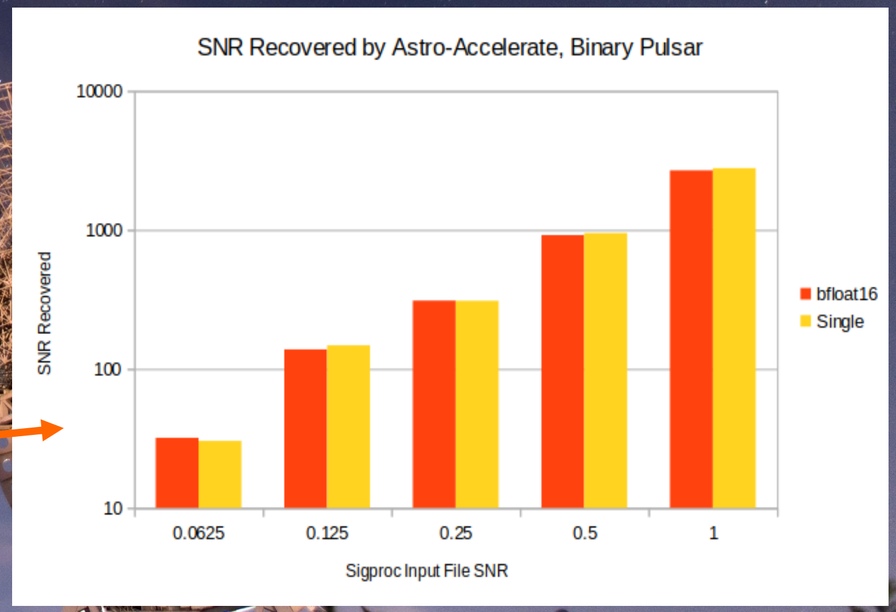
- The existing implementation [4] is bottlenecked by GPU memory bandwidth, using 32-bit (“Single”) precision
- Halve the precision = double the speed!

Is it faster to use bfloat16 FFTs?

- We have reduced the time spent on FFTs by 50%
- Reducing overall execution time by 30% is feasible
- This work is the foundation for savings of ~£20m on compute hardware and electricity savings of ~£2m/yr







Can you detect pulsars with bfloat16 FFTs?

- Yes
- Surprisingly well, in fact
- This is very promising, and encourages continuing the work to reduce/mix precision in other sections too
- In the continuation of this work, we intend to quantify and compare the vanishing point of extremely faint pulsars between the two precisions

References

[1] D. R. Lorimer and M. Kramer. Handbook of Pulsar Astronomy. Vol. 4. 2004

[2] Karel Adámek et al. GPU Fast Convolution via the Overlap-and-Save Method in Shared Memory. 2020. arXiv: 1910.01972 [cs.MS]

[3] Rebecca Pool, Drowning in Data, 01/05/2020, https://spie.org/news/photonics-focus/mayjun-2020/square-kilometer-array-big-data

[4] Sofia Dimoudi et al. “A GPU Implementation of the Correlation Technique for Real-time Fourier Domain Pulsar Acceleration Searches”. In: 239.2, 28 (Dec. 2018), p. 28. arXiv: 1804.05335 [astro-ph.IM]