Virgo

A Versatile Spectrometer for Radio Astronomy

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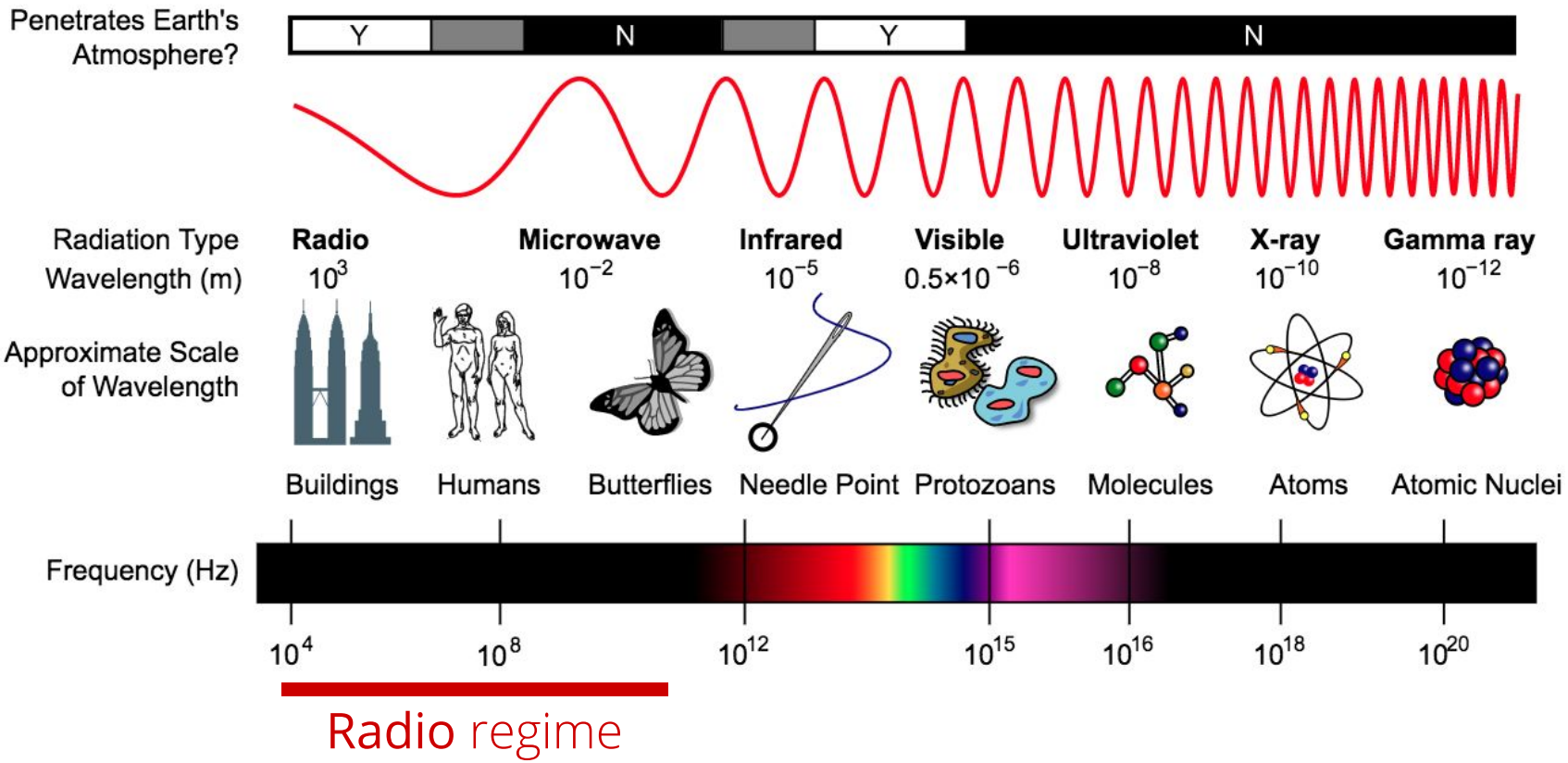
What even *is* **Radio Astronomy**?

📡 A subfield of astronomy that studies celestial objects at <u>radio</u> frequencies (*not* visible light!).



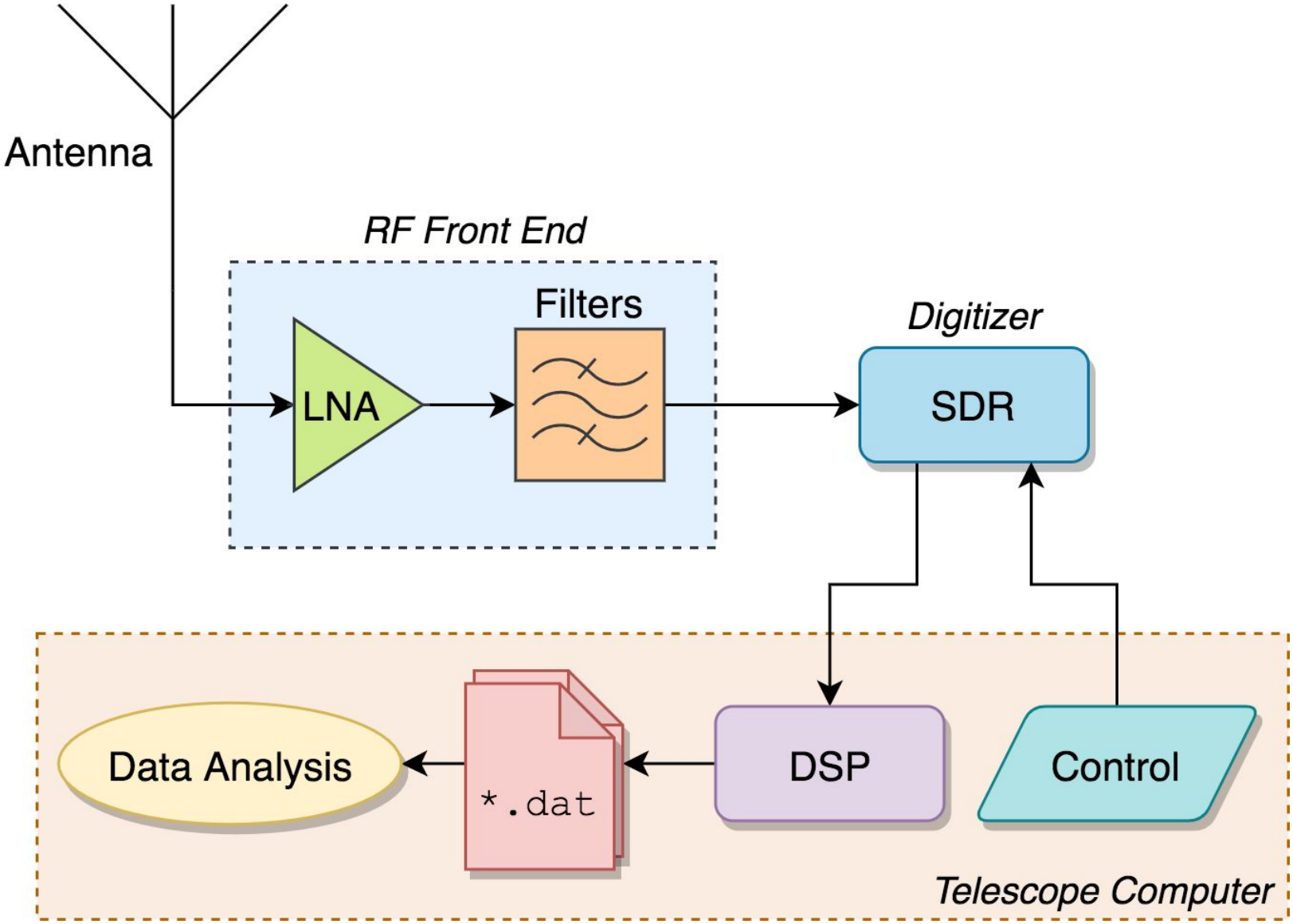


Fig. 1: Typical block diagram of a Radio Telescope.

About **Virgo**

- A versatile & easy-to-use spectrometer/radiometer
- Based on **Python** and **GNU Radio**
- Carry out data acquisition, processing & analysis, observation planning and more
- Applicable to any radio telescope working with an SDR receiver
- Fully open source! 🚀

www.github.com/0xCoto/Virgo

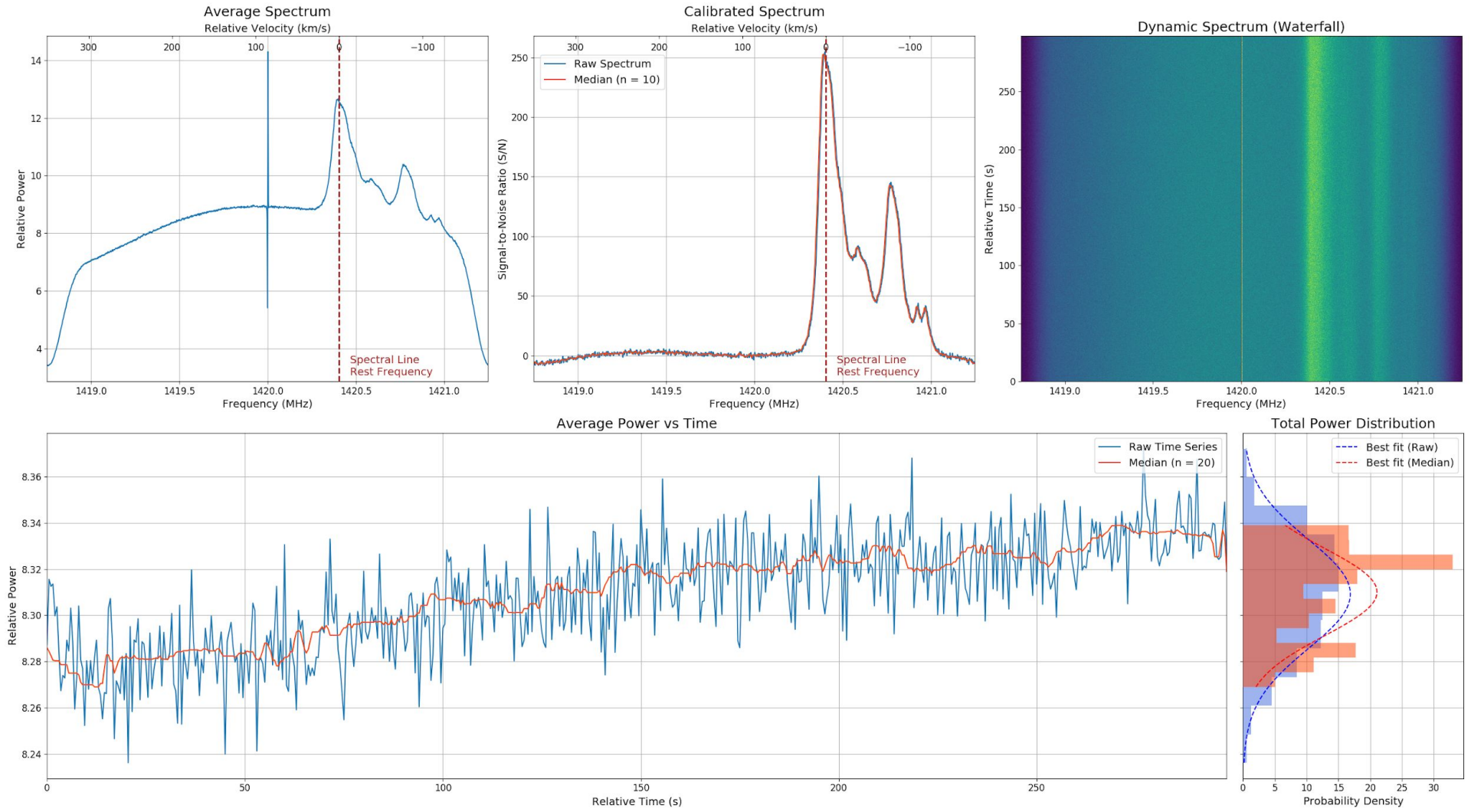


Fig. 2: Observation of galactic clouds of neutral hydrogen toward the constellation of Cygnus (α = 20h, δ = 40°, l = 77°, b = 3°).

Key Features: Observing

- **Four-tap WOLA Fourier transform spectrometer**
  - Adjustable SDR parameters
- **Spectral line support**
  - Passband calibration (rescaled to S:N units)
  - Slope correction (linear regression)
  - RFI mitigation
    - Median filtering
    - Channel masking
- **Continuum support**
  - Total power distribution (histogram) + Gaussian fit
  - Median filtering
- **Incoherent dedispersion** for burst search
- **Dynamic spectra (waterfall)** → output to `FITS`

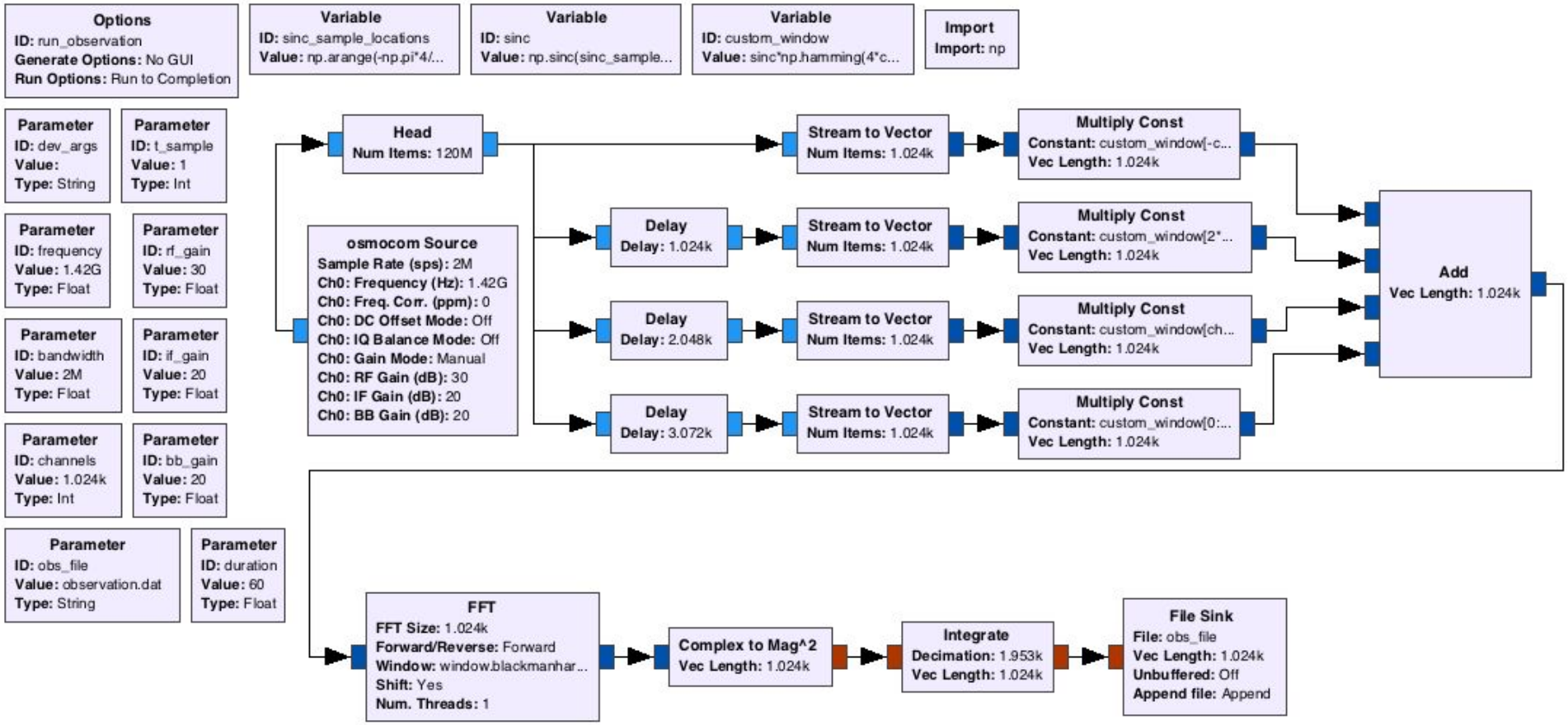


Fig. 3: GNU Radio flowchart consisting Virgo's real-time DSP segment (WOLA).

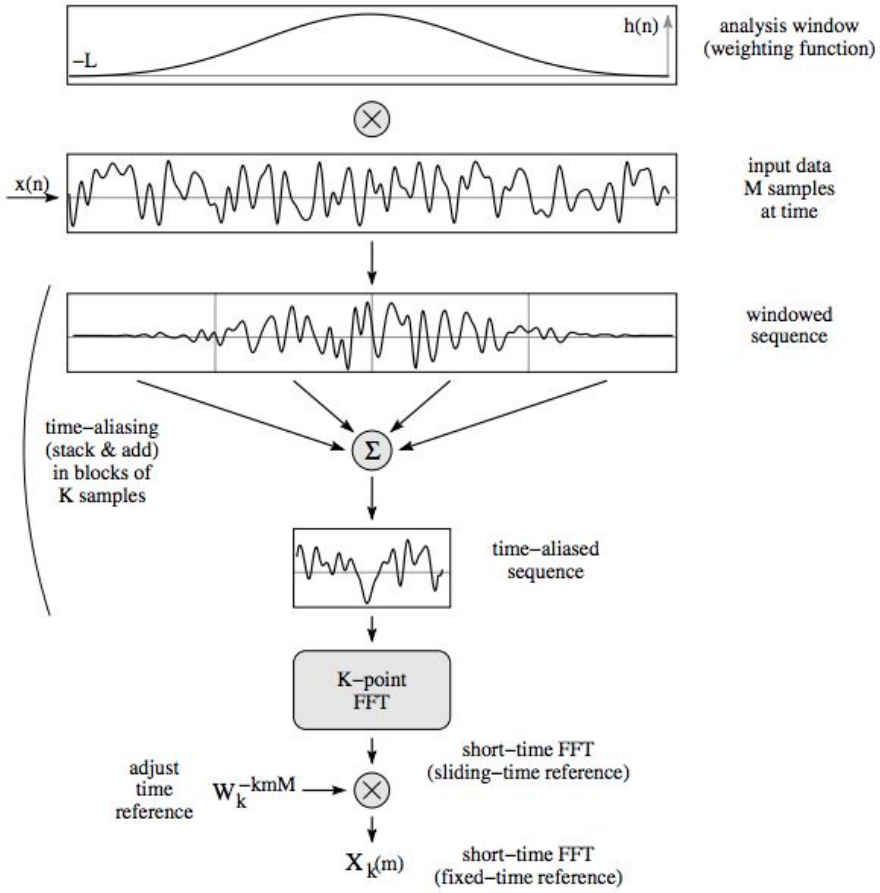


Figure 9. The Weighted Overlap-Add structure implements the Fourier transform filter-bank in terms of block-by-block analysis.

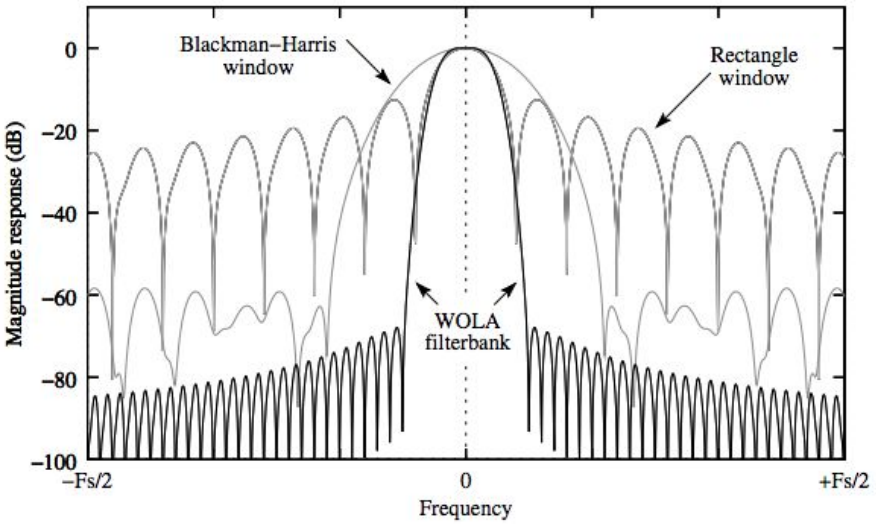
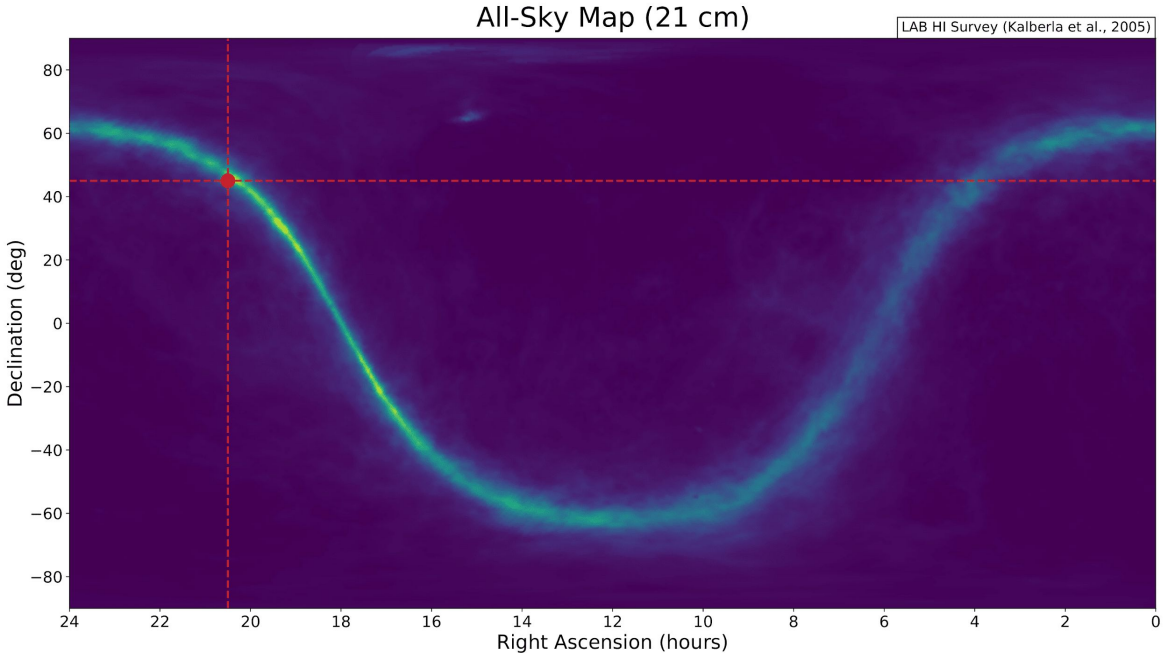


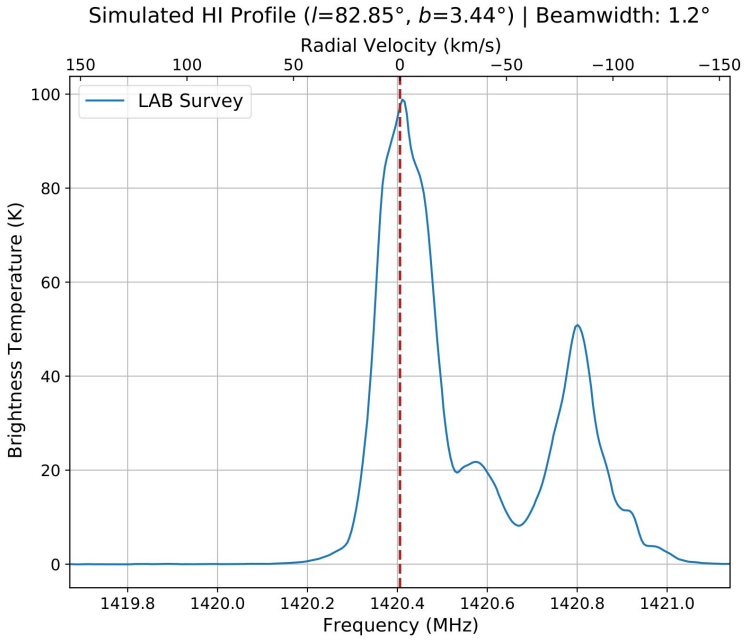
Figure 10. The frequency response of a single FFT bin is compared to an unweighted FFT (rectangle window), a Blackman-Harris window and to the WOLA method.

Fig. 4: Traditional FFT windows vs WOLA

Key Features: Planning

- Predict source altitude & azimuth vs time
- Plot telescope position on the 21 cm all-sky survey 🔭
- Retrieve 21 cm profiles based on the LAB HI survey
- Built-in tool for rapidly conducting RFI surveys ⚡
- Basic calculation toolkit for system sensitivity & performance determination 📡





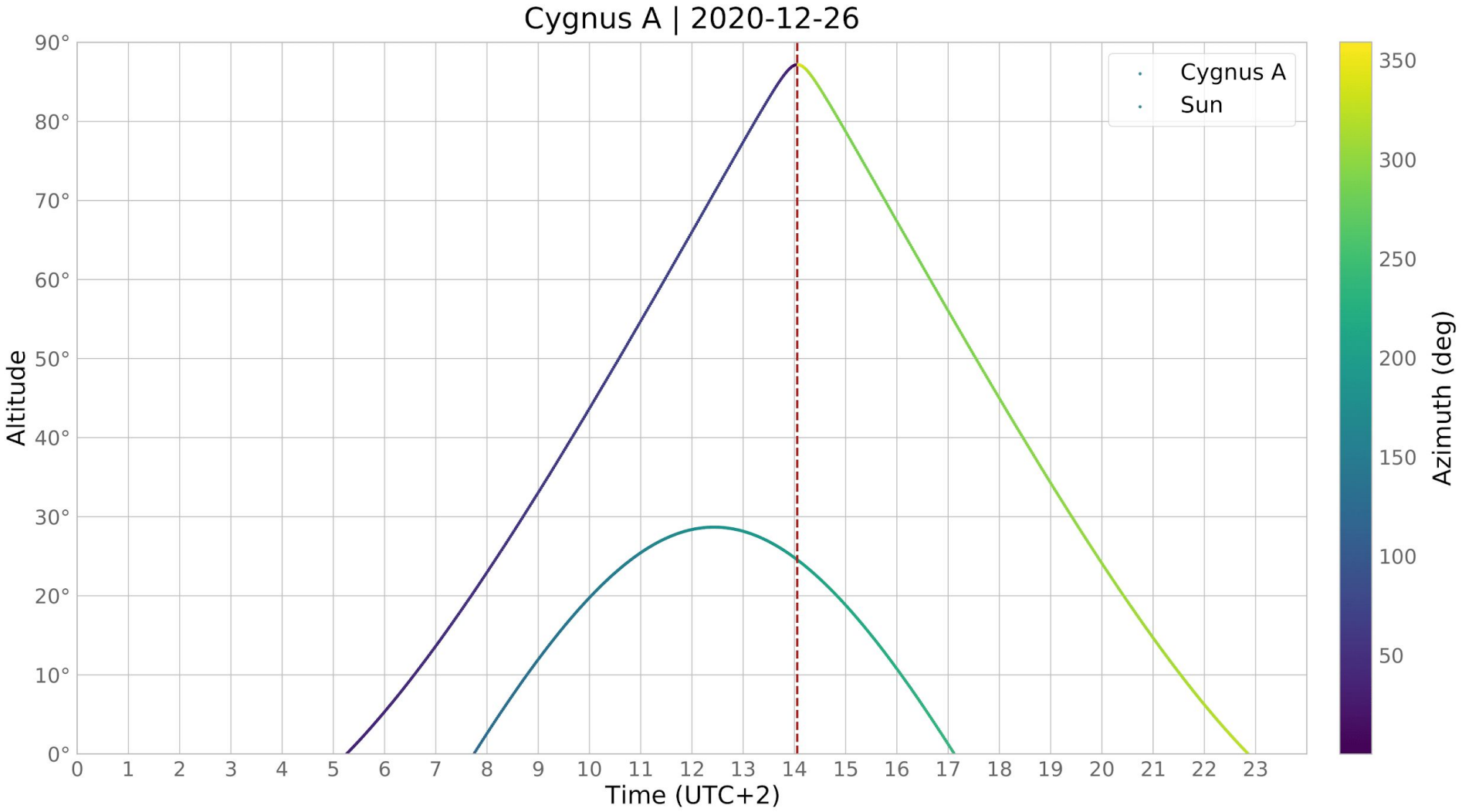


Fig. 5: Example prediction of the location of the Cygnus A radio galaxy (3C 405) in the celestial sphere of the observer.

Example Usage

```python
import virgo

# Define observation parameters
obs = {
    'dev_args': '',
    'rf_gain': 10,
    'if_gain': 20,
    'bb_gain': 20,
    'frequency': 1420e6,
    'bandwidth': 5e6,
    'channels': 2048,
    't_sample': 1,
    'duration': 60
}

# Check source position
virgo.predict(lat=39.83, lon=-74.87, source='Cas A', date='2020-12-26')

# Begin data acquisition in 10 sec
virgo.observe(obs_parameters=obs, obs_file='observation.dat', start_in=10)

# Analyze data, mitigate RFI and export the data as a FITS file
virgo.plot(obs_parameters=obs, n=20, m=35, f_rest=1420.4057517667e6,
           obs_file='observation.dat', cal_file='calibration.dat',
           rfi=[1419.2e6, 1419.3e6], waterfall_fits='obs.fits',
           slope_correction=True, plot_file='plot.png')
```


SIGNAL CORPS

Install with `pip`

https://pypi.org/project/astro-virgo

Thanks!

Contribute: www.github.com/0xCoto/Virgo

Get in touch: 0xcoto@protonmail.com

References & Sources:

[**Slide 2**] Inductiveload, NASA (https://commons.wikimedia.org/wiki/File:EM_Spectrum_Properties_edit.svg), released under the Creative Commons Attribution-Share-Alike License 3.0.

[**Slide 5**] NRAO: https://www.cv.nrao.edu/course/astr534/HILine.html

[**Slide 7**] Crochiere, R. E., & Rabiner, L. R. (1996). Multirate digital signal processing (1st ed.). Prentice Hall PTR. ISBN: 0136051626

[**Slide 8**] Klein, B., Philipp, S. D., Güsten, R., Krämer, I., and Samtleben, D., "A new generation of spectrometers for radio astronomy: fast Fourier transform spectrometer", in *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, 2006, vol. 6275. doi:10.1117/12.670831.

[**Slide 9**] Kalberla, P. M. W., Burton, W. B., Hartmann, D., Arnal, E. M., Bajaja, E., Morras, R., & Pöppel, W. G. L. (2005). The leiden/argentine/bonn (LAB) survey of galactic HI. Astronomy & Astrophysics, 440(2), 775–782. doi:10.1051/0004-6361:20041864

Thanks!

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