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 radio frequencies (not visible light!).

Penetrates Earth's Atmosphere?

<table>
<thead>
<tr>
<th>Radiation Type</th>
<th>Wavelength (m)</th>
<th>Approximate Scale of Wavelength</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio</td>
<td>$10^3$</td>
<td>Buildings</td>
<td>$10^4$</td>
</tr>
<tr>
<td>Microwave</td>
<td>$10^{-2}$</td>
<td>Humans</td>
<td>$10^8$</td>
</tr>
<tr>
<td>Infrared</td>
<td>$10^{-5}$</td>
<td>Butterflies</td>
<td>$10^{12}$</td>
</tr>
<tr>
<td>Visible</td>
<td>$0.5 \times 10^{-6}$</td>
<td>Needle Point</td>
<td>$10^{15}$</td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>$10^{-8}$</td>
<td>Protozoans</td>
<td>$10^{16}$</td>
</tr>
<tr>
<td>X-ray</td>
<td>$10^{-10}$</td>
<td>Molecules</td>
<td>$10^{18}$</td>
</tr>
<tr>
<td>Gamma ray</td>
<td>$10^{-12}$</td>
<td>Atoms</td>
<td>$10^{20}$</td>
</tr>
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</table>

Radio regime
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 ($\alpha = 20h, \delta = 40^\circ, l = 77^\circ, b = 3^\circ$).
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')
```
Install with `pip`

```
Terminal

pip install astro-virgo
```

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

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

Get in touch: 0xcoto@protonmail.com
References & Sources:


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


Thanks!

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