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EUVITA - an Extreme UV Imaging Telescope Array with Spectral Capability

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The number of electrons is still in question.

Introduction

The production of EXOSAR provided the first detailed look at the interstellar medium in the solar system, which was crucial for understanding the nature of these objects. The number of electrons in the solar system, whether it's 3 or 10, is still in question. However, recent findings from the EXOSAR mission have shed light on the properties of these objects.

Abstract

EXOSAR - an Extreme UV Imaging Telescope Array with

Special Capabilities
Figure 1: Schematic view of a EUVITA telescope with its multilayer mirror and detector box.

Table 1: Comparison of EUV experiments: EUVITA, EXOSAT LEIT telescope with CMA detector (N. White, 1991), ROSAT WFC (K., Pounds et al., 1992) and EUVE DS/S telescope with SW spectrometer or Deep Survey instrument (EUVS Handbook, 1995).

<table>
<thead>
<tr>
<th>Telescope number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of view (10')</td>
<td>12</td>
<td>24</td>
<td>30</td>
<td>40</td>
<td>60</td>
<td>100</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>Angular resolution (arcsec)</td>
<td>0.01</td>
<td>0.05</td>
<td>0.1</td>
<td>0.5</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Useful mirror area (cm²)</td>
<td>175</td>
<td>149</td>
<td>132</td>
<td>102</td>
<td>83</td>
<td>70</td>
<td>59</td>
<td>40</td>
</tr>
<tr>
<td>Central wavelength (Å)</td>
<td>15</td>
<td>20</td>
<td>30</td>
<td>50</td>
<td>60</td>
<td>60</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Resolution λ/Δλ</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Filter</td>
<td>MgF₂</td>
<td>MgF₂</td>
<td>MgF₂</td>
<td>MgF₂</td>
<td>MgF₂</td>
<td>MgF₂</td>
<td>MgF₂</td>
<td>MgF₂</td>
</tr>
<tr>
<td>Maximum effective area (cm²)</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Table 2: Parameters describing the EUVITA bandpasses: the central wavelength of the peak, bandwidth of the peaks with Δλ = FWHM, the peak reflectivity, and the filters used for each telescope. The maximum effective areas and the "grasp" I (see section 4) are given for different filters.
2 Instrument characteristics

This section briefly describes the EUVITA instruments. More detailed technical information will be given by Zehnder et al. (in preparation). Figure 1 gives a schematic view of one EUVITA telescope. Each telescope has a normal incidence multilayer coated parabolic mirror. The diameter of the mirrors is 20 cm with a focal length of 140 cm. The relative thickness of the individual layers of mirror coating defines the reflectivity as a function of the wavelength (see figure 2). It is possible to produce multilayers for the EUV with peak reflectivities of 10 to 45 % and a bandwidth smaller than 10 % FWHM.

The EUVITA-detector will be mounted on-axis at the prime focus of the mirror in the detector electronic box supported by a spider arrangement. Note that in such a configuration the detector does not point towards open space. The detector box will also contain the front-end detector electronics. It consists of a microchannel plate stack (MCP) in zigzag configuration and a wedge and strip position sensitive readout anode (Siegmünz et al., 1986). The ion grid prevents positive ions from reaching the detector. A broad band metal filter is mounted close to the front of the MCP stack so as to block off photons with energies lower than the bandpass peaks of the mirrors, in particular in the far UV region where the mirror reflectivity increases.

In order to enhance the quantum efficiency a photocathode layer is deposited directly onto the top MCP. Further quantum efficiency enhancement is obtained by applying a negative bias to the filter mesh mounted in front of the MCP. In this way electrons emitted from the MCP surface are forced back into the MCP channels without any loss of spatial resolution. The front-end electronics are mounted directly behind the detector. This design ensures low noise levels.

The useful geometric mirror area is 221 cm² on-axis, taking into account the shadow of the detector and support. The field of view is 1.2 degrees (diameter). The angular resolution of the telescope is given by the aberration of the mirror, the spatial resolution of the detector and the jitter of the telescope and is roughly 10 arcseconds.

The designs of the individual telescopes are identical. The telescopes differ only in the multilayer coatings of the mirrors, in the filters and in the photocathode materials. These three elements define the bandpass of each telescope and are chosen in such a way as to optimise the overall sensitivities.

3 Effective areas

The EUVITA bandpasses are described in table 2. The various components listed in this table are not yet definitively optimised, but should serve as a guide for the scientific discussion below.

Figure 2 shows how the mirror reflectivity, the filter transmission and photocathode quantum efficiency contribute to the effective area of telescope 5, centered at 83 Å. Globally, the mirror reflectivities follow Lorentzian profiles with an increase in the UV determined by the reflectivity of the mirror substrate (Silicon). The reflectivities used in this paper are based on both measurements and calculations performed in the EUV by the Nizhny Novgorod group.

The effective area for each telescope is plotted as a function of wavelength in figure 4. Beyond 1000 Å, the effective areas of the detectors have dropped well over 6 orders of magnitude below peak areas. For the present simulations, MgF2, CsI, KBr and NaBr photocathodes have been considered in turn, and a global transmission of 0.64 has been used for the filter mesh and the ion repelling grid.

4 Minimum detectable fluxes

The signal to noise ratio \( \frac{S}{N} \) is given by:

\[
\frac{S}{N} = \frac{S}{\sqrt{S + (1 + \frac{1}{k})N_{bgd}}}
\]

where \( S \) is the number of counts per detection area (see below), \( N_{bgd} \) the background counts per detection area, and \( k \) is the number of detection areas from which the average sky and detector noise background are measured. In the present case \( k \) is large enough so that \( (1 + \frac{1}{k}) \approx 1 \). By inverting (1) one obtains the minimal number of counts per detection area necessary to achieve the desired \( \frac{S}{N} \) ratio:

\[
S_{min} = \frac{1}{2} \times \left( \frac{S}{N} \right)^2 \times \left[ 1 + \sqrt{1 + 4 \times \frac{N_{bgd}}{(\frac{S}{N})^2}} \right]
\]

The minimum detectable flux \( F_{min} \) for a pointlike source is then:

\[
F_{min} = \frac{S_{min}}{Surface \times P \times t \times I}
\]
2. Scientific capability

A series of models has been developed for different fluids and extraterrestrial environments to predict the propagation of electromagnetic (EM) waves through these conditions. The models incorporate various factors such as absorption, dispersion, and scattering effects. These models are essential for understanding how EM signals travel in different media, which is crucial for applications ranging from telecommunications to radar technology.

The models have been extensively validated against experimental data and have shown good accuracy across a wide range of frequencies and environments. They are used by researchers and engineers to design and optimize communication systems, sensor networks, and other technologies that rely on EM wave propagation.

The models are continually updated and refined as new experimental data become available and as computational methods advance. This ensures that they remain relevant and effective in predicting EM wave behavior under various conditions.
Another type of source is thermal emission from the hot surface of single neutron stars. Surface temperatures for ages between $10^{10}$ and $10^{11}$ years are expected to be in the range 10$^6$ to 10$^8$ K (Seward and Wang, 1989). Therefore, significant emission from neutron stars is not expected to contribute to the thermal emission observed from nearby galaxies, which are more likely to be dominated by the thermal emission from gas and dust in ordinary galaxies.

EUVITA (Extended UV Imaging Telescope for Astronomy) is an x-ray telescope that will observe the thermal emission from neutron stars. EUVITA is planned to be launched in 2017 and will provide significant improvements to our understanding of these objects.
Table 1: Estimated contribution in (per 100) for the different model factors.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor A</td>
<td>0.12</td>
</tr>
<tr>
<td>Factor B</td>
<td>0.08</td>
</tr>
<tr>
<td>Factor C</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Note: The data in Table 1 is based on an estimated model developed from a large dataset. Further analysis is required to validate the results.
6 Synthetic photometry

The aim here is to investigate how EUVITA observations can be used to measure the astrophysical properties of a given source. Calculations were made with different emission models applicable to astrophysical sources (black body, power law and optically thin plasma models). For each model we compute flux ratios between EUVITA bandpasses for different source parameters. These ratios prove to be good indicators of both the source parameters and the amount of absorbing galactic hydrogen.

R. Mewe et al. (1985, 1986) have computed continuum emission and line power output for an optically thin thermal plasma in ionisation equilibrium for several electron temperatures $T_e$. This type of plasma is found in stellar coronae, supernovae remnants and clusters of galaxies. In the case of AGN, the soft excess emission process is unknown, significant contribution might however be expected from a hot corona surrounding the accretion disc. In the following simulations a red-shift $z=0$ was taken and line profiles were not taken into account, since natural broadening and thermal Doppler broadening for temperatures below $10^9$ K are small: $\Delta \lambda \sim 10^{-4}$ [Å] and $\Delta \lambda / \lambda \leq 10^{-3}$. However macroscopic velocity fields greater than 3000 [km/s] would produce Doppler broadenings of $\Delta \lambda / \lambda \geq 10^{-2}$; this is no longer negligible, especially for the narrower bandpasses. Flux ratios between pairs of EUVITA telescopes were calculated for 13 electron temperatures between $\log(T) = 5.6$ and 6.8. For temperatures between $\log(T) = 5.6$ and 6, and no absorption, the lines contribute more than 80% of the total observed flux in all EUVITA telescopes. Exact knowledge of the bandpass profiles is crucial since these flux ratios are sensitive to the location of the bandpass peak. Figure 5 shows which lines contribute to the EUVITA bandpasses. It also illustrates how the bandpasses have been distributed in energy so as to measure different groups of strong emission lines. Figure 6 illustrates the ratio between line and continuum flux for each telescope in the case of unabsorbed emission. Figure 7 shows the contours of equal flux ratios for two pairs of EUVITA telescopes: $\text{flux}(1)/\text{flux}(3)$ and $\text{flux}(7)/\text{flux}(8)$. These ratios have been calculated for an optically thin plasma source. Figure 7 also shows how these ratios depend on the absorbing column density and on the temperature of the plasma. These graphs, together with the sensitivity to groups of lines, demonstrate that EUVITA will not only be able to measure temperatures, but will give other information about sources, like the ionisation mechanism and the abundance of heavy elements.

Figure 5. The spectrum of an optically thin thermal plasma at $T_e = 10^6$ and 6 (see R. Mewe et al. 1985, 1986). The continuum flux units are photons per second per Å. A shortcoming of source plasma photons per second per cm$^2$ per steradian, not absolute value above the continuum. Only the stronger lines have a label. The EUVITA wavelengths are also plotted in normalized, logarithmic scale for comparison.
Figure 5. Relation between line and continuum flux for each exposure in the case $N = 0$.

Figure 6. Optical depth for each element in the line. 

Figure 7. Optically thin plasma: contour plot of logarithmic flux ratios for two pairs of 

Figure 8. Log Flux (p/s cm³ A)
7 Conclusion

EUVITA has a good angular resolution (10 arcsec) over a field of view of 1.2°, with an effective area comparable to that of presently flown instruments. The novel feature of EUVITA is that it combines these 'standard' properties with a spectral resolution of a few Å. This should allow to resolve prominent groups of emission lines.

We have demonstrated that EUVITA will be able to detect several classes of galactic, and in favorable cases extragalactic sources, at signal-to-noise levels which are sufficient to allow a measurement of the source parameters in the EUV. For known sources, the bandpass combination allows to measure independently the source characteristics and the intervening column density.

The EUV and soft X-ray domain is still largely unexplored. In addition to the determination of astrophysical quantities in a new spectral region for known sources, we expect that instruments of the class of EUVITA will also produce a number of unexpected results. It is indeed true that each time that a new spectral window has been opened to astronomical investigations, new and exciting physical phenomena have been unveiled.

References

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