Ultraviolet astronomy: Spektr-UF Project

Boris Shustov
Institute of Astronomy RAS
Plan of the lecture

1. UV Astronomy
   - What we name Ultraviolet Astronomy?
   - Why we need UV-astronomy?
   - Major scientific achievements of UV-astronomy
   - UV experiments and observatories in space

2. Project Spektr-UF aka World Space Observatory – Ultraviolet (WSO-UV)
   - General description
   - Scientific equipment
   - Organizational features

3. Science with WSO-UV
Astronomy and astronomies

- fundamental physical science
- Getting new knowledge of the nature of the Universe at various space and time scales.
- A. is a part of physics (φύση, φυσικός = «nature, natural»)

- object-oriented
- galactic
- extragalactic
- stellar
- solar
- planetary
- etc...

- methods
- radio
- infrared
- optical
- ultraviolet
- gamma
- X-ray
- neutrino
- gravitational
- etc....
Multi-wavelength approach

- maximum possible number of channels for obtaining observational information
- consistent analysis of this data (e.g. using Big Data technologies)
Transparency of the Earth atmosphere

Transparency of the Galaxy

Transparency \( \propto \nu^{-3} \)
In a common life (e.g. in medicine):
- A (UVA) – 400-315 nm
- B (UVB) – 315-280 nm
- C (UVC) – 280-100 nm

In astrophysics:
- EUV – 10-91.2 nm
- XUV – 10-30 nm (rarely used)
- Lyman UV – 91.2-121.6 nm
- FUV – 91.2-200 nm
- NUV – 200 – 320 nm
- Atmospheric UV – ultraviolet bands in many photometric systems, e.g. band $\lambda_c$ – 358 nm, WHM ($\text{Å}$) – 55 nm. In the range of 300-400 nm are lines [O II] and [Ne V] and Balmer jump which are used to determine the parameters of stellar atmospheres (T, g).
UV astronomy is a powerful tool for diagnosing the properties of various objects (ISM, IGM, stars, planetary atmospheres, etc.). Both continuous spectra and especially UV-spectral lines are quite informative.

In UV there lie many strong (resonance) transitions of common chemical elements (both atoms and ions) - H, D, He, C, N, O, Mg, Si, S, Fe, resonance transitions in molecules: H$_2$, OH, CO, CS, C$_2$, large molecules such as the PAHs etc. Do not forget ISM dust extinction feature at 220 nm.

Unique capability provides UV-spectroscopy of lines:

- Lyα lines of H, D, Lyman-Werner bands of D$_2$,
- Lines of ions O VI, C IV, N V, C III, C IV
- Lyman discontinuity in the spectra of galaxies at large z
UV images allow us to perform a fine structural analysis of objects: star formation zones, auroras, etc. Here, an example is star formation in galaxies.

S-201 UV camera, Apollo 16: 1st lunar observatory (0.075-m telescope, 20º FOV). Astronaut J.Young pointed it at the LMC.

Both spectroscopy and imaging in UV-domain are powerful astrophysical techniques!
One more advantage – lower UV background

<table>
<thead>
<tr>
<th>Achievements of UV astronomy</th>
<th></th>
</tr>
</thead>
</table>
| Direct detection of H$_2$ molecules | Carruthers (1970)  
“Aerobee-150” |
| Discovery of the hot phase of the ISM | Jenkins, Meloy (1974) 
“Copernicus” |
| Measuring of D/H | Rogerson, York (1973)  
“Copernicus” |
| Massive accurate determination of the chemical composition of stars  
Detailed studies of stellar mass loss phenomena across the H–R diagram  
Studies of the chromospheres of cool stars | IUE (1978 - 1996) |
| Identification of the search direction of hidden (missing) baryons | HST  
FUSE (1999 – 2007) |
| Discovery of intense SF at galactic outskirts | GALEX (2003 – 2012) |
| Revealing the nature of the structures (e.g. crowns, rings of neutral gas, etc.) in the outer regions of atmospheres of the giant planets, hydrogen exospheres of exoplanets | HST |
ORFEUS-SPAS (Orbiting & Retrievable Far & Extreme UV Spectrometer - Shuttle Palette Satellite) is a joint NASA - DARA project of 90-cm aperture UV telescope for spectroscopy. It flew in 1993 (5\text{d}) and 1996 (14\text{d}).
# UV observatories

<table>
<thead>
<tr>
<th>Observatory</th>
<th>Agency</th>
<th>Dates</th>
<th>Telescope aperture cm</th>
<th>Pointing regime</th>
<th>Observation regime</th>
<th>λλ nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>OAO – 2</td>
<td>NASA</td>
<td>1968.12 – 1973.01</td>
<td>20</td>
<td>sp</td>
<td>is</td>
<td>100 – 425</td>
</tr>
<tr>
<td>TD – 1A</td>
<td>ESRO</td>
<td>1972.03 – 1974.05</td>
<td>28</td>
<td>s</td>
<td>is</td>
<td>135 – 280+</td>
</tr>
<tr>
<td>OAO – 3</td>
<td>NASA</td>
<td>1972.08 – 1981.02</td>
<td>80</td>
<td>p</td>
<td>s</td>
<td>90 – 315</td>
</tr>
<tr>
<td>ANS</td>
<td>SRON</td>
<td>1974.08 – 1977.06</td>
<td>22</td>
<td>p</td>
<td>s</td>
<td>150 – 330+</td>
</tr>
<tr>
<td>IUE</td>
<td>ESA+</td>
<td>1978.01 – 1996.09</td>
<td>45</td>
<td>p</td>
<td>s</td>
<td>115 – 320</td>
</tr>
<tr>
<td>ASTRON</td>
<td>USSR</td>
<td>1983.03 – 1989.06</td>
<td>80</td>
<td>p</td>
<td>s</td>
<td>110 – 350+</td>
</tr>
<tr>
<td>EXOSAT</td>
<td>ESA</td>
<td>1983.05 – 1986.</td>
<td>2x30</td>
<td>p</td>
<td>is</td>
<td>25+</td>
</tr>
<tr>
<td>ROSAT</td>
<td>DLR</td>
<td>1990.06 – 1999.02</td>
<td>84</td>
<td>sp</td>
<td>i</td>
<td>6 – 20+</td>
</tr>
<tr>
<td>EUVE</td>
<td>NASA</td>
<td>1992.06 – 2001.01</td>
<td>12</td>
<td>sp</td>
<td></td>
<td>7 – 76</td>
</tr>
<tr>
<td>ALEXIS</td>
<td>USA</td>
<td>1993.04 – 2005.04</td>
<td>35</td>
<td>S</td>
<td>l</td>
<td>13 – 18.6</td>
</tr>
<tr>
<td>FUSE</td>
<td>NASA</td>
<td>1999.06 – 2007.07</td>
<td>4x(39x35)</td>
<td>p</td>
<td>s</td>
<td>90.5 – 119.5</td>
</tr>
<tr>
<td>CHIPS</td>
<td>NASA</td>
<td>2003.01</td>
<td>?</td>
<td>sp</td>
<td>s</td>
<td>9 – 26</td>
</tr>
<tr>
<td>GALEX</td>
<td>NASA</td>
<td>2003.04 – 2013.06</td>
<td>50</td>
<td>sp</td>
<td>is</td>
<td>135 – 280</td>
</tr>
<tr>
<td>FIMS</td>
<td>KARI</td>
<td>2003.09 – 2008</td>
<td>(5x8)</td>
<td>s</td>
<td>s</td>
<td>90 – 175</td>
</tr>
<tr>
<td>SWIFT</td>
<td>NASA</td>
<td>2004.11 –</td>
<td>30</td>
<td>P</td>
<td>is</td>
<td>170 – 650</td>
</tr>
<tr>
<td>ASTROSAT</td>
<td>ISRO</td>
<td>2015.09 –</td>
<td>2x38</td>
<td>sp</td>
<td>is</td>
<td>130 – 320</td>
</tr>
</tbody>
</table>
ASTRON is an UV space observatory with 80 cm aperture telescope equipped with a scanning spectrometer: \((\lambda \lambda 110-350 \text{ nm}, \Delta \lambda \sim 2 \text{ nm})\) onboard. Some significant results: detection of OH \((\text{H}_2\text{O})\) in Halley comet, UV spectroscopy of SN1987a, Pb lines in stellar spectra etc. (Photo of flight model at Lavochkin Museum).
“Spektr” mission series

Federal Space Program (2016-2025) includes as major astrophysical projects:

➢ **Spektr-R** (Radioastron) – 2011 - 2018

➢ **Spektr-RG** – launched in 2019

➢ **Spektr-UF**  
International name is *World Space Observatory - UltraViolet (WSO-UV)*. Launch is scheduled for 2025.
**WSO-UV project**

**WSO-UV** is an international space observatory for observation in FUV+NUV spectral range (115 - 320 nm). The WSO-UV includes the telescope with primary mirror of 170 cm and scientific instruments – imaging field cameras and 3 spectrographs (resolving power ranges from 1000 to 55000).

A project **WSO-UV** started in 1997 at the ESA conference “Ultraviolet Astrophysics Beyond the IUE Final Archive” held in Sevilla, Spain, from 11th to 14th November 1997.

A. Boyarchuk  
W. Wamsteker
Scheme of implementation of a space telescope

scientific goal

detector + $D + F + \omega$

optical scheme + telescope structure + instruments

S/C

mission

this talk is being delivered in reverse order
Platform: “Navigator”  
Russia

Telescope: T-170M, $\varnothing 1.7$ m, f/10  
Russia

Spectrographs: WUVS (R = 55000, 1000)  
Russia

Imagers: FCU  
Russia & Spain

Launch: Launcher “Angara”  
Russia
geosynchronous orbit, $i = 35 - 40^\circ$

(first large telescope above geocorona)

Ground Segment:  
Russia & Spain
Roscosmos takes care about the Project

Spanish participation is important

Japan participation: a letter of intention (LOI) between Institute of Space and Astronautical Science (ISAS, JAXA), INASAN and IKI RAS was signed

The T-170M telescope qualification is in progress

WUVS – work on QEM is in progress

FCU – Detailed design is in progress. 2023 –FM model

The Spektr-UF (WSO-UV) project is in a mature stage of development. There are no fundamental technical difficulties for the implementation of the project.
# The “Navigator” platform

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life time</td>
<td>&gt; 5 years</td>
</tr>
<tr>
<td>Spacecraft mass with propellant</td>
<td>2 900Kg</td>
</tr>
<tr>
<td>Payload mass</td>
<td>1 600Kg</td>
</tr>
<tr>
<td>Power supply for payload</td>
<td>750W</td>
</tr>
<tr>
<td>Data transmission rate</td>
<td>4 Mbit s⁻¹</td>
</tr>
<tr>
<td>Pointing accuracy</td>
<td>0.1 arcsec</td>
</tr>
<tr>
<td>Stabilization (for 1h exposure)</td>
<td>0.1 arcsec (3σ)</td>
</tr>
</tbody>
</table>

It was successfully used in the projects "Spektr-R", "Spektr-RG" and in the remote sensing S/C "Electro-L“ and "Arktika-M".
Structure of the T-170M telescope

- Solar blind
- Secondary Mirror
- Instrument compartment
- WUVS (Spectrographs)
- FCU (Field Camera Unit)
- Protective cover
- Primary Mirror baffle
- Primary Mirror
- WUVS & FCU detectors radiator
- KONUS-UF
Optical features of the T-170M telescope

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical system</td>
<td>Ritchey – Chrètien aplanat</td>
</tr>
<tr>
<td>Aperture diameter</td>
<td>1700 mm</td>
</tr>
<tr>
<td>Telescope f-number</td>
<td>10.0</td>
</tr>
<tr>
<td>FoV angular diameter</td>
<td>0.50°</td>
</tr>
<tr>
<td>Wavelengths range</td>
<td>100 – 350 nm (extended to visible)</td>
</tr>
<tr>
<td>Primary wavelength</td>
<td>200 nm</td>
</tr>
<tr>
<td>Mass (payload)</td>
<td>1570 kg</td>
</tr>
<tr>
<td>Optical quality</td>
<td>Diffraction optics at the center of FOV</td>
</tr>
</tbody>
</table>

![Diagram 1](image1.png)

![Diagram 2](image2.png)
Mirrors of the T-170M telescope

- Astrositall CO-115M
- PM diameter – 1715 mm
- Central hole – 530 mm
- Thickness at
  - center – 110 mm
  - edge – 25 mm
- Mass (of glass) – 360 kg

For reflectance measurements we use spectrophotometer VUVaS-1000 (McPherson Co, USA) at $\lambda \lambda$ 115-350nm.
We control contamination of optical surfaces till launch using mirror samples (eyewitnesses).

Thanks to “Red Team” (esp. to Jeff Linsky and Steve Ostermann)!
Mechanical tests of the T-170M telescope

All the mechanical and thermo-vacuum tests have been passed successfully.
## Spectrographs

<table>
<thead>
<tr>
<th>Spectrograph (WUVS channel)</th>
<th>λλ nm</th>
<th>R</th>
<th>$A_{\text{eff}}$ cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>VUVES</td>
<td>115-176</td>
<td>50000</td>
<td>900-1100</td>
</tr>
<tr>
<td>UVES</td>
<td>174-310</td>
<td>50000</td>
<td>200 (120 nm) – 400 (160 nm)</td>
</tr>
<tr>
<td>LSS</td>
<td>115-305</td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>

Teledyne-e2V CCD: 4096 × 3112 pixels of 12 μm
Protective MgF₂ window
CCD working $T$: -100 °C

Thermo-vacuum tests

Detector sensitivity measured at synchrotron
# Field Camera Unit

<table>
<thead>
<tr>
<th>Parameters</th>
<th>FUV channel</th>
<th>NUV channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector</td>
<td>MCP (Spain)</td>
<td>CCD (e2V)</td>
</tr>
<tr>
<td>Spectral range, nm</td>
<td>115 – 176</td>
<td>174 – 310 (1000)</td>
</tr>
<tr>
<td>Effective area, m²</td>
<td>0.068</td>
<td>0.27</td>
</tr>
<tr>
<td>Field of view, arcsec</td>
<td>ø162</td>
<td>ø451</td>
</tr>
<tr>
<td>Resolution, arcsec</td>
<td>0.08</td>
<td>0.146</td>
</tr>
<tr>
<td>Detector size, mm</td>
<td>40</td>
<td>ø37</td>
</tr>
<tr>
<td>Number of filters</td>
<td>Up to 10</td>
<td>Up to 15</td>
</tr>
</tbody>
</table>

*Tests of mechanical structures*

*MCP detector (CsI, UVIT based) (SENER, Spain)*
Towards standard photometric system for UV astronomy

<table>
<thead>
<tr>
<th>Band ID</th>
<th>Spectral Range</th>
<th>Objective</th>
<th>Comments on implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV1</td>
<td>90-110 nm</td>
<td>FUSE window</td>
<td></td>
</tr>
<tr>
<td>UV2</td>
<td>120-140 nm</td>
<td>Far UV avoiding geocoronal Ly-alpha</td>
<td>[CsI photocathode + F125LP (CaF2)] – [CsI photocathode + F140LP (BaF2)]</td>
</tr>
<tr>
<td>UV3</td>
<td>140-180 nm</td>
<td>GALEX FUV</td>
<td>As in GALEX</td>
</tr>
<tr>
<td>UV4</td>
<td>180-210 nm</td>
<td>Continuum shortward of the UV bump</td>
<td></td>
</tr>
<tr>
<td>UV5</td>
<td>210-230 nm</td>
<td>UV bump</td>
<td></td>
</tr>
<tr>
<td>UV6</td>
<td>230-280 nm</td>
<td>Near UV continuum, Fe bands</td>
<td>F250W (ACS/HRC)</td>
</tr>
<tr>
<td>UV7</td>
<td>280-350 nm</td>
<td>Ozone cut-off window</td>
<td>F330W(ACS/HRC)</td>
</tr>
</tbody>
</table>

Tentative UV bands. Some of them, UV2, UV3, Uv6 and UV7, are already implemented since they come from Hubble instruments or from GALEX. For the new bands, simple (unrealistic) boxcar functions have been used with transmittances similar to the rest of the bands (IAU WG on UV astronomy. Chair A.I.Gomes de Castro)

Submitted to the IAU Resolution Committee
The leading science organization – Rikkyo University (Japan). The main industrial contractor – MEISEI. Partners are IKI and INASAN (Russia)/.

UVSPEX is the additional science instrument onboard WSO-UV mounted on FCU.

The main scientific goal is characterization of Earth-like exoplanets. Expanded exosphere can be observed in UV wavebands, during an exoplanet transit.

<table>
<thead>
<tr>
<th>UVSPEX parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda\lambda$</td>
<td>117-144 nm</td>
</tr>
<tr>
<td>$\Delta\lambda$</td>
<td>0.3 nm</td>
</tr>
<tr>
<td>Lines of interest</td>
<td>H Ly$\alpha$: 121.6 нм; O I: 130 нм; C II: 133.5 нм</td>
</tr>
</tbody>
</table>
Detector of the UVSPEX

**Preliminary UVSPEX FUV detector specifications:**

- **Photocathode**: CsI
- **MCP**: 1 stage – funnel
- **MCP pore**: 12 µm pitch
- **Readout system**: Optical, CMOS STAR-1000
- **Number of pixels**: 333x1024
- **Observation modes**: Photon counting, Accumulation
WSO-UV time sharing policy

- **Core Program (CP):** Fundamental science to be carried by the project team
- **Funding Bodies Program (FBP):** Guaranteed Time to the countries funding the project
- **Open Program (OP):** Open program to the world-wide scientific community
The observatory is a multi-purpose one. Many Russian astronomers and physicists expressed their interest to use it in their research. There is also interest in the world scientific community. The Network for Ultraviolet Astronomy (NUVA) regularly holds conferences dedicated to current problems, projects, and technologies in UV and topic of the WSO-UV is in the scope of discussion (see https://www.nuva.eu/)

Core Program

- The diffuse baryonic content in the Universe and its chemical evolution: warm-hot IGM, damped Lyman-alpha systems, the role of starbursts and the formation of galaxies
- Stellar physics - activity on stars (obs. support of mass transfer theory in CB, mass loss from massive stars, physics of WD etc.)
- The early evolution of stars and role of UV in the evolution of the young planetary disks and astrochemistry in UV field
- Atmospheres of (exo)planets

The following slides illustrate some astrophysical problems that researchers at the Institute of Astronomy are interested in.
Galactic issues
Missing baryons and missing metals

Remember recent talk by Michael Shull at UV Club

Evolution of baryon census
Davé, 2004

OVI lines in quasar H1821+643 STIS spectrum at $z = 0.22497$ and $z = 0.22637$. (Tripp+2000 ).

Peeples+2014

Vasiliev+2009
CGM: Fermi bubbles structure

A composite image of Fermi bubbles created on the basis of X-ray data from the eROSITA telescope (blue-green color) and data obtained in the gamma-ray range by the Fermi telescope (red color).

*Predhel+Syunyaev 2020*

Sources (AGN of FUV<18m) available for observations with WSO-UV.

*Fox+2020*

Tashley@stsci.edu
THE FUTURE? We have started to explore the deep-UV discovery space with HST, but we have only observed a handful of sightlines, and currently there are no plans to develop a spectroscopic UV telescope to follow after HST. HST is increasingly suffering serious hardware problems, and the unique deep-UV window will close soon. To understand how galaxy evolution is driven and regulated by the baryon cycle, the time has come to plan for the future of UV astronomy.

Let’s try with the WSO/UV?
Roederer 2019. The estimates are based on line strength calculations for lines with $1800 \leq \lambda \leq 10000$ Å in a dwarf star with $T_{\text{eff}} = 6000$ K, $\log g = 4.2$, and $[\text{Fe/H}] = -5.0$. Usually only ~5-10 elements can be detected in the optical spectra, and the UV spectra contain lines of ~20 elements (ranging from lithium to zinc, $3 \leq Z \leq 30$).

At INASAN group by L. Mashonkina works in the field.
The period–luminosity dependence of classical Cepheids is the basis of the scale of distances in the Universe. From the UV data for stars like RR Lyr, it is known that the amplitudes of the light curves in UV are several stellar magnitudes greater than at optical wavelengths (Bonnell and Bell, 1985). Quite unusual is the fact that there are almost no UV light curves of classical Cepheids with full coverage of the light curve in the pulsation phases. At INASAN group by M.Sachkov works in the field.
Decrease of UV flux caused by taking into account the absorption in the lines near the Lyman alpha affects the outgoing flux in the lines of the infrared triplet (Ca II 849.8 nm).

For the given star parameters ($T_{\text{eff}} = 9400$ K, $\log g = 3.7$), the calculations with increased ultraviolet opacity lead to a stronger line in comparison with a standard case that does not take into account these “Lyman satellites” (Ryabchikova+2008). The correctness of the UV opacity data used in modeling can be tested only by comparison with the observations that can be obtained with a low-resolution spectrograph of the Spektr-UF project.
In a number of stars, radiation peaks are observed in the center of the H and K absorption lines of calcium (392 and 398 nm). These features are used to study the stellar dynamo, differential rotation of stars, and other effects. Meanwhile, these effects, which are practically imperceptible in some objects in the optical lines, are quite significant in the magnesium UV lines (279 and 281 nm). *Sachkov 2019*
Energy distribution in the spectra of white dwarfs of different temperatures. It can be easily seen that it is almost identical for the stars in the optical range (400–500 nm) accessible by ground-based telescopes, but significantly different in the UV region. Therefore, UV observations are extremely necessary for the accurate determination of the temperatures of white dwarfs.
The light curve of SN Ia (standard candles in cosmology) reaches its maximum in UV earlier than in optics. The UV spectrum contains a lot of information about the physics of the explosion. Very few SNe Ia has been observed so far in UV.

Theoretical (lines) and observed (points, from IUE-ULDA) light curves for six SN Ia. DD4-delayed detonation, B7-deflagration, LA4-He detonation. Blinnikov 2008.
In 27\textsuperscript{d} of TESS observations, the M dwarf planet host GJ 887 looked entirely quiescent (Jeffers et al. 2020).

Yet in just a few hours of far UV observations of HST, the same star looked like this (Loyd +2020).

EUV radiation of young active M-stars can destroy atmosphere of planets (earth, super-earth) on the scale of hundreds of millions of years (Loyd et al. 2018a). FUV observations allow us to estimate the flow in an adjacent EUV section. The role of UV is particularly strong during (super) flares. M-star flares in the UV occur regularly (At INASAN I. Savanov works in the field).

Model spectra for a 50Myr old star with $\text{T}_{\text{eff}} = 3500$ K: photosphere-only model (solid black curve), the photosphere + upper-atmosphere model (red curve), and a 3500K blackbody (black dashed curve). The data points are GALEX fluxes for a young (higher points) and old star (lower points) with the same $\text{T}_{\text{eff}}$. (Shkolnik+2014).
Outflows from exoplanetary atmospheres

Observations of transit of WASP-12b with the HST in NUV (Fossati+ 2010) have made it one of the most "mysterious" exoplanets. The light curves show that the transit in the ultraviolet bands is much deeper than in the visible region. In addition, an early entry was also detected.

HST NUV spectrum of hot Jupiter WASP-121b at transit. Sing+2019
Evidence for leaking of metals from exoplanets.
Attenuation curves measured for a variety of galaxy samples across a range of redshifts. 

Hagen+2019

In the next decade, we will need high resolution UV imaging to constrain the variation of the attenuation curve with respect to dust and galaxy properties.

Table 1: Observational Capabilities

<table>
<thead>
<tr>
<th>Capability</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>spatial resolution</td>
<td>FWHM ~ 0.1”</td>
</tr>
<tr>
<td>sensitivity</td>
<td>S/N = 100, B5V star</td>
</tr>
<tr>
<td>Photometry</td>
<td></td>
</tr>
<tr>
<td>UV central λ</td>
<td>0.11, 0.15, 0.19, 0.22, 0.25 μm</td>
</tr>
<tr>
<td>MIR central λ</td>
<td>3.2, 3.4, 3.6, 7.0, 10.0, 14.0 μm degrees</td>
</tr>
<tr>
<td>areal coverage</td>
<td></td>
</tr>
<tr>
<td>Spectroscopy</td>
<td></td>
</tr>
<tr>
<td>spectral resolution</td>
<td>500–1000</td>
</tr>
<tr>
<td>UV coverage</td>
<td>0.1–0.3 μm</td>
</tr>
<tr>
<td>MIR coverage</td>
<td>2.8–4.2 &amp; 8–30 μm</td>
</tr>
<tr>
<td># spectra</td>
<td>1000/galaxy</td>
</tr>
</tbody>
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We are open for contacts

Spektr–UF group at INASAN

Partners in Russia and Spain
Thanks a lot for your attention!