The Italian participation to the WSO/UV Project  
A review on the status of the project for the INAF SC evaluation  

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8 April 2006  

WSO/UV is an international collaboration led by Russia (Roscosmos) to build a UV (100-310nm) mission with capabilities which are presently, in the near and long term future unavailable to the world-wide astronomical community. The mission consists of a 1.7m telescope able to perform:  
- high resolution (R~55,000) spectroscopy by means of two echelle spectrographs covering the 100--310 nm range;  
- long slit (1 × 75 arcsec) low resolution (R~500-5000) spectroscopy;  
- deep UV and diffraction limited optical imaging.  
It will be operated like a ground-based telescope, i.e. capable to perform “real time“ operations in an orbit free of visibility constraints (L2).  

This document is structured in two sections. Section 1 is intended to give information on:  
- the science objectives of the Italian community (pag. 1);  
- the status of the project and the international framework (pag. 10);  
- the Italian contribution and the benefits to the Italian scientific community (pag. 12).  
Technical information on the mission (telescope, payload, launcher, ground segment etc) are given in Section 2 (pag.14).  

SECTION 1  

1.1. The WSO/UV Science Objectives  
Most resonance transitions from ions, atoms, and molecules of astrophysical significance are in the ultraviolet (UV) wavelength domain. Hence, UV spectra provide the most sensitive tools to trace the distribution of baryonic matter in the Universe and to diagnose the chemical composition, the physical properties, and kinematics of astronomical objects of all types.  
The NASA GALEX telescope is currently providing wide field and very low resolution spectra of a large number of astronomical objects which will require detailed UV follow-ups. After the failure of the STIS spectrograph on HST in August 2004, no facilities to get UV (medium/high resolution) spectra in the classical range (100—300 nm) are available to the astronomical community. The upgrade of HST with the Cosmic Origin Spectrograph (COS) is also uncertain at the moment, due to the well known difficulties of the Shuttle flights to provide servicing missions to HST. In any case, HST is planned to work till 2013 in case the SM4 will fly. Hence, WSO/UV, planned to operate for 5(+5) years starting from late 2011, will fill in the gap in UV facilities after the HST era and before the advent of future large UV telescopes.  
As detailed in Section 2, the focal plane instruments of WSO/UV consist of three UV spectrometers covering the spectral band from Lyman alpha to the atmospheric cutoff with R~55,000 and offering long-slit capability over the same band with R~(500 – 5000) as function of the spectral region. In addition, a number of UV and optical imagers view adjacent fields to that sampled by the spectrometers. Imagers can be operated for parallel observations (survey mode) or for targeted projects. The imaging performance compares well with that of HST/ACS. The sensitivity of the high resolution spectrographs will exceed that of HST/STIS by a factor 10-20 (see a comparison between the effective area of WSO/UV HIRDES and HST/STIS in Figure 4).  
In addition, WSO/UV is planned to operate at the L2 point of the Earth-Sun system providing a significant increase in operational efficiency over low Earth orbit. Furthermore, all the observing time will be available for UV astronomy. Taking all these factors into account will yield a net increase in UV productivity of a factor ~30-60, compared to HST. Furthermore, the UV-Optical capabilities of WSO/UV extend our possibilities to perform coordinated multi-wavelength campaign on selected sources, covering a spectral region, which, together with the Far/Mid-IR one, were scarcely available in the past.
The topics that can be addressed by WSO/UV concern numerous astrophysical aspects, from planetary science to cosmology. Here following, we highlight the main interests of the Italian community, as expressed up to date, while at the end of this paragraph (from §1.1.8) we give some hints on other important topics.

1.1.1. Stellar magnetic activity.
The study of the outer atmospheres of cool late-type stars (isolated and in binaries) and their magnetism can benefit from UV/FUV photometry and spectroscopy, that provide tools to investigate their chromospheres, transition regions and corona in full details, in particular their active structures, that are shaped by the magnetic field, and their dynamics. A resolution of R≥30,000 is sufficient to resolve most of the narrow chromospheric emission lines seen in dwarf stars, which typically have FWHM >10 km/s. The hotter TR lines are broader owing to higher thermal velocities, but they also benefit from good resolution for deblending purposes, dynamical studies, and Doppler imaging. The WSO/HIRDES (UVES & VUVES) sensitivity allow us to reach the faint, interesting objects beyond the solar neighbourhood, out to at least 150 pc to include, for example, the important young galactic clusters α Per and the Pleiades, as well as the key TW Hya star-forming region. With the LSS spectrograph we can study flares and other types of variability with R~3--5,000 (i.e., velocity resolution better than 100 km/s) because then one can have cleaner separation of close lines, some velocity discrimination in short-period binary systems, and the possibility of measuring hypersonic dynamics in large flare events. The telescope operation at L2 will permit long-duration uninterrupted observations of targets to obtain high quality Doppler maps, flare light curves and statistics.

The UV camera, equipped with suitable narrow-band filters tuned to important TR lines like C IV is able to monitor flares and rotational modulations of active regions in dozens of late-type stars at the same time, for example, members of a compact galactic cluster or PMS candidates in a star-forming region.

1.1.2. Accretion and Outflow processes
The complex interplay of accretion and outflow processes is identified in stars at different stages of their evolution such as in Young Stellar Objects down to compact star binaries (Black-Holes, Neutron Stars and White Dwarfs) as well as in extragalactic objects such as AGNs, spanning the enormous range of 10⁻¹⁰ in mass. Common properties such as energy excess with respect to central object, jet generation and violent ejections characterize the phenomenon whose underlying physics is still far from being understood. It is out of doubt that detailed modelling of accretion discs and their generated winds including magnetic interaction of galactic objects require UV spectroscopy sampling a much larger number of systems than done by HST so far. For accreting binaries containing compact objects the higher sensitivity and long visibility window of WSO can provide a statistically significant increase (at least three times) of systems to be observed at low resolution which can provide time-resolved spectra 1) to map disc structure as a function of inclination angle 2) to test in details disc instability theory; 3) to map the influence of magnetism in the flows, 4) to identify SNIa progenitors and failed SNIa systems and 5) to univocally identify signatures of irradiation, self-occultation by warping and transition radii in BH transients. Furthermore effective temperatures, masses of accreting white dwarfs have been derived from HST low resolution UV spectroscopy only for a few tens of systems out of about 1000, while abundances and rotation rates with high UV spectral resolution only for a handful of systems, heavily hampering any attempt to determine the influence of accretion on the white dwarf properties. This has an enormous impact on theories of close binary evolution including ultra-compact (double-degenerate) binaries. The high resolution spectral capabilities of WSO will allow a detailed systematic of elemental abundances and rotation rates of at least a dozen of accreting white dwarf binaries. Furthermore any attempt to resolve structure and kinematics of the immediate surroundings of the central supermassive Black-Hole in AGNs passes through high-and low ionization emission line profile intercomparison and through reverberation mapping, for which UV data of HST-like quality and better are strictly necessary (see also § 1.1.7). The Italian Community is deeply involved in the study of accreting objects of both galactic and extragalactic nature. In particular the coordination of X-ray observations with those in UV domain has demonstrated in the past to be a very efficient method to put constraints on accretion processes in interacting compact binary systems as well as in AGNs.

1.1.3. SNe with WSO
Thanks to the very high luminosity and rather regular properties Type Ia SNe have been extensively used as cosmological distance indicators to trace the structure of the Universe at high redshift. SNe are also the primary contributors to the chemical evolution of the Universe and play a crucial role in triggering/quenching star formation.

In this framework UV observations of SNe are important in several respects. They allow to determine the metallicity of the precursor stars, to study the ISM and IGM in the direction of the parent galaxy, to study the kinematics of the outermost fast moving layers and the interaction of the ejecta with the circumstellar matter.
Despite this wide interest to date UV observations have been obtained only in a very few special cases. In a recent review Panagia (2003) reminds that only 36 SNe have been observed in the UV with IUE and HST and only a fraction got sufficient temporal coverage (>5 spectra) among which are 10 SNIa, 6 SNlb/c, 4 SNII including SN1987A, and 3 SNIIn. Considering that most of these observations have been collected with the small IUE satellite, hence are of poor S/N ratio, it is fair to say that the behaviour of SNe in UV is largely unknown. On the basis of these facts, in 2004 a large fraction of the worldwide SN community successfully submitted a large SN programs for observations of SNe with HST (P.I. Filippenko). The program, initially focussed only on SNIa, was approved with 150 orbits but, due to the failure of STIS, could not obtain the proposed observations and subsequently was withdrawn.

WSO/UV constitutes an important possibility to fill this gap of information. The main scientific targets for SN observations with WSO/UV can be summarized as follows.

1.1.3.1. Overall behaviour in the UV (present vs. past)

The determination of the properties, rate, environments, and energy output of high redshift SNe is one of the main science drivers of HST legacy programs, as well as of future missions like the JWST. However, observations of high redshift SNe observed by HST in the optical, or by JWST in the near-IR, actually sample the rest-frame UV of these objects.

Therefore, a characterization of the SED of nearby SNe in UV is of outmost importance to fruitfully exploit the potential of present and future high redshift SN observations. In fact, knowledge of the SED, and its behaviour with time, is required in order to estimate the luminosity and determine the type and properties of the SN. Although sometimes is it argued that the properties of SNe in the UV can be obtained from optical observations at z<0.5-1, it is clear that these observations cannot account for the evolutionary effects that we are expecting to take place over such long time intervals.

Broad and intermediate band photometry of nearby (D<20 Mpc) SNe is required for this project. Magnitudes ranges between B=12-15 at maximum to 20 at the faint end. High angular resolution is required for disentangling the targets from the (typically) complex background of the parent galaxies. Low resolution spectroscopy (R=500) over the entire spectral range will also be extremely useful in the first month past maximum. According to ETC of HIRDES exposure times should range between 0.5 and 3h to obtain S/N≈20. ToO mode (hence some form of flexible scheduling) is mandatory over time intervals of the order of two months. Observations of the temporal evolution of five objects for each SN class are required to sample the SN diversity.

1.1.3.2. The progenitors

An embarrassing situation in SNe research is that we do not yet know much on SN progenitors. For a few SNII, high resolution optical pre-explosion images are available on which the exploding star was detected providing information on the mass and evolutionary status. However because of the short wavelength baseline, the errors on the mass determination are large. The collection of a database of snapshot UV images for nearby galaxies together with the images already available from HST will allow the a-posteriori detection of the precursors stars of core-collapse SNe and the determination of its mass with an unprecedented accuracy.

For this project we need to obtain high angular resolution, broadband images the brightest (B<12) galaxies closer than the Virgo clusters, for a total of about 200 galaxies. On the basis of the statistics of the last 10yr, they are expected to produce about 5 SNe/yr, 3/5 of which are core collapsed and whose progenitors might be identified. With the exception of few very extended beasts, a mosaic of fours tiles is sufficient to cover the entire galaxies.

For thermonuclear SNe we do not know how the WD reaches the Chandra limit, whether it even reaches the Chandra limit, and how it explodes. Establishing the SN Ia progenitor systems and explosion mechanisms will give greater confidence in the use of SNe Ia as cosmological probes, and will quantify potential evolutionary trends from progenitor age and initial composition. Detailed UV spectroscopy can be combined with ground based spectroscopy and spectropolarimetry to study the evolution of the high velocity components, and therefore to provide constraints on the nature of the CSM around SNe Ia.

Calculations of the explosion mechanism have led to predictions that can be directly tested observationally. Specifically, we will use our state-of-the-art radiative transfer and spectral synthesis codes to place constraints on acceptable progenitors and explosion mechanisms. For example, Mg II 2800 is an indicator of the boundary between explosive C and O burning. Elements produced by incomplete Si burning are used to identify the regions of complete and incomplete Si burning. These temperature transitions are critical parameters in models of SNe Ia.

High-quality UV spectra will permit measurements of explosion products, such as Mg II 2800A, that will break degeneracies in current optical/near-IR observations, and will constrain models for the effects of temperature, density, and non-thermal ionization. Moreover early times UV observations can also help to determine the extent of C/O in the outer layers; this provides a discriminant between burning modes which leave different amounts of unburned C and O. In addition, early-time UV observations may show whether Ni
and Co (best seen in the UV) from the combustion are present in the outer layers (high velocities) as predicted by some models.

1.1.3.3. Interaction with circumstellar material
The few core collapse SNe studied so far in the UV have shown clear evidences (high ionisation lines, broad wings, blue continua) of ejecta-CSM interaction at various epochs after the explosion. Detailed analyses of these observations have revealed that the lines can be produced in the CSM itself or within the ejecta depending on the epoch of observation, energy of the explosion, density and distribution of the material. Well sampled observations allow therefore a sort of tomography of the ejecta and the CSM, revealing the last few years of mass loss history of the exploding stars. Because of the large expansion velocities involved, low-res spectroscopy with HIRDES is sufficient. For the nearest (D<5-10 Mpc), strongly interacting targets (e.g. SN 1993J) it will be possible to perform also high-res spectroscopy with the UVES arm (1800-3200 Å).

1.1.4. Science from high astrometric performances of WSO
On the basis of the optical quality of WSO we expect to reach, in the near-UV-optical a resolution of the order of 0.07 arcsec (at worst), with a well sampled PSF. As fully demonstrated on WFPC2 and ACS/HST images (Anderson & King 2000, King & Anderson 2002, Bedin et al. 2004) it is possible to reach an astrometric accuracy of the order of 1/100 of the resolution on well exposed (S/N>100) undersampled images, and up to 1/150 of the resolution in well sampled images (as shown by Anderson et al. 2006, on ground based images). This implies that we expect to have in near-UV-optical a resolution of the order of 0.5 milliarcsec (mas) on single, well exposed point sources. As shown by the experience on HST images, (Anderson and King 2000, 2002), the astrometric accuracy scales with the number (N) of images used to measure point source positions as the sqrt(N). Therefore, with a sample of 25-30 well exposed images, we expect to have an astrometric accuracy in near-UV-optical of the order of 0.1 mas, comparable with if not better than what is presently attainable with HST. This astrometric accuracy becomes of great importance in the measurement of proper motions (both relative and absolute). Most importantly, we can take advantage of the huge amount of high resolution images in the HST archive for real breakthrough science. The WSO observations, expected in the 2010-2015 for a huge and absolute). Most importantly, we can take advantage of the huge amount of high resolution images in the HST archive for real breakthrough science. The WSO observations, expected in the 2010-2015 for a huge UV-optical of the order of 0.1 mas, comparable with if not better than what is presently attainable with HST. This implies that we expect to have in near-UV-optical a resolution of the order of 0.5 milliarcsec (mas) on single, well exposed point sources. As shown by the experience on HST images, (Anderson and King 2000, 2002), the astrometric accuracy scales with the number (N) of images used to measure point source positions as the sqrt(N). Therefore, with a sample of 25-30 well exposed images, we expect to have an astrometric accuracy in near-UV-optical of the order of 0.1 mas, comparable with if not better than what is presently attainable with HST. This astrometric accuracy becomes of great importance in the measurement of proper motions (both relative and absolute). Most importantly, we can take advantage of the huge amount of high resolution images in the HST archive for real breakthrough science. The WSO observations, expected in the 2010-2015 for a huge amount of Galactic and extragalactic fields, coupled with the HST dataset will provide multipoch observations spanning a temporal interval of up to 20-25 years. This immediately translates into a capability of measuring proper motions with an error of the order of (and in some cases better than) 5 microarcsec. These proper motions can be measured for stars up to 5 magnitudes fainter than GAIA, and, most importantly also in crowded fields, unreachable by GAIA. It is therefore a matter of fact that WSO will be fully complementary, and in some cases competitive, with GAIA, and this, long before (10 years at least) the full GAIA catalog will be available. From the point of view of astrometry, WSO is an absolutely mandatory instrument.

Below we briefly list a number of science topics which can be carried out taking advantage of WSO capability to perform high accuracy astrometry and proper motion measurements. This list should just give the flavor of the impressive quantity (and quality) of the science that space astrometry based on UV-optical images in space allows. Astrometry based on large size UV-optical telescope is a very new science, and many investigation fields have just been started, thank to HST. The probable end in 1-2 years of HST operations will leave a huge, promising, but virtually unexplored research field without any possibility of further progress. It is also important to note that the astrometric accuracy that we can expect for JWST in the near-IR is similar to the accuracy above described for WSO. JWST will work in a quite different wavelength interval, and therefore fully complementary to JWST. In fact, for a number of applications, this is an undoubtable advantage. For example, for the observations in the very central core of the hot component, or the main sequence (e.g., in the programs on the binary population, see below) stars in globular clusters, near UV observation have the great advantage of minimizing the contribution of giant (evolved) stars, whose flux is dominant in the optical-near-IR.

1.1.4.1. Galactic star clusters
- separation field/clusters in any Milky Way region, also in crowded environments (galactic disk, bulge, central regions of the Galaxy);
- measurement of internal proper motions in all open and Galactic globular clusters, from the crowded (unreachable by GAIA) centers to the outskirts; this measurement will allow: (1) a measurement of accurate distances (independently from GAIA, e.g. by comparing internal proper motion dispersion with radial velocity dispersion in the central parts), and (2) the development of realistic dynamical models of the cluster, able to follow the cluster dynamical evolution and the evolution of its stellar population (e.g. formation of exotic objects as a consequence of dynamical interactions, estimate of the cluster stellar initial mass function accounting for the loss of stars due to various dynamical processes, etc.);
measurement of the \textit{cluster absolute proper motions} using background QSOs and galaxies as reference frame;

- particularly in globular clusters, determination of \textit{the fraction of clusters which host central intermediate mass black holes (IMBH)}, and \textit{measurement of the IMBH mass} by mapping the proper motion and the acceleration of the stars in the very inner core (as done for the Galactic center);

- measuring the fraction and the properties (period, orbit separation, masses) of binaries with massive (black hole, neutron star, white dwarf) components in the cluster central core. This study is of great importance for the development of cluster dynamical models (binaries are the most important energy sources in the cluster cores), but they are also important for stellar evolution, and for the estimate the amount of dark matter in the cluster cores.

1.1.4.2. \textbf{Extragalactic systems}

- \textit{separation field/clusters in the Magellanic Clouds and other Local Group galaxies}, including M31 and M33; this separation is of great importance for the study of the cluster stellar population, also in regions where field contamination is a severe limitation;

- \textit{internal proper motions in Magellanic Clouds and other Milky Way satellites and their clusters} (assuming a 20 yr temporal baseline);

- \textit{absolute motions of stars and stellar systems in Milky Way satellites and in M31}. Note that at the distance of M31, 50km/s correspond to 15 mas/yr, 3 times our expected accuracy in proper motion measurement with a 20 yr temporal baseline (using HST images as first epoch data). This kind of measurement becomes important for the mapping of the gravitational potential and the measurement of the dark matter content.

1.1.5. \textbf{Stellar Populations}

1.1.5.1. \textit{The UV upturn in stellar populations}

The “UV upturn” manifests itself as a rising flux shortward of 250 nm of the spectral energy distribution of old stellar populations. Although the UV upturn is usually associated with the spectra of ellipticals, it was actually discovered in the bulge of the nearby spiral M31 (Code, 1969). Prior to the early UV observations, spiral bulges and ellipticals were thought to contain only cool, passively-evolving populations of old stars. Although ellipticals have very similar optical spectra, their UV-to-optical flux ratios, as measured by the $m_{1550} - V$ color index, show strong variations, correlated with metallicity (Burstein et al., 1988), such that galaxies with higher metallicity (optical Mg2 index) are bluer. There were many candidates for the source of the UV emission, including young massive stars, binaries, hot white dwarfs, extreme horizontal branch (EHB) stars, post-asymptotic giant branch (post-AGB) stars, and non-thermal activity.

In the past decade, the satellite UV observations of ellipticals in both the local and distant Universe have proved that extreme horizontal branch (EHB) stars are the dominant source of the UV upturn. Multiband UV photometry of resolved stellar systems with WSO is expected to provide fundamental constraint on the hot component of old stellar population in resolved stellar systems which is presently poorly understood. For example:

- Observation in nearby galaxies has shown that EHB stars are the dominant source of the UV upturn, even in those galaxies with very weak UV emission, such as M32. Unfortunately, a surprising dearth of AGB-Manque’ and post-AGB stars is also found (Brown et al 2000) disclosing an unacceptable discrepancy with theoretical predictions. As we look to ellipticals at higher redshift, the UV-upturn fades, but not as rapidly as might be expected, suggesting either a large dispersion in the parameters that govern the formation of EHB stars, or another source of UV emission that becomes dominant at earlier ages (Brown et al. 2003). Although the UV upturn may be the most sensitive indicator of age in an evolved population (Greggio and Renzini 1990) it is a diagnostic that is poorly constrained by our current understanding of EHB stars.

1.1.5.2. \textit{Integrated UV color of stellar populations}

Multicolor UV imaging of unresolved distant stellar systems as obtained in the range of wavelength available with WSO discloses the possibility of deriving age evaluation of young stellar populations. The contribution to the integrated UV light of the main sequence turn off stars make possible the use of UV colors for age determination. For example:

- In the range of 1100-3100 A it has been proved that a two color diagram, which is free by uncertainties on the distance determination, can be calibrated in terms of age when dealing with stellar population younger than 1 Gyr (es. Barbero et al. 1990). Moreover, the same two color diagram make possible the investigation of the HB morphology in non resolved stellar systems.
1.1.5.3. An innovative tool to investigate unresolved stellar populations

The Surface brightness fluctuation (SBF) technique (Tonry & Schneider 1988) is one of the most powerful methods to derive extragalactic distances of gas-free stellar systems. It has proven to be effective at distances of over 50 Mpc from the ground (e.g. Tonry et al. 2001, Liu et al. 2002) and to more than 100 Mpc from space (Jensen et al. 2003). Multiband SBF appears to be a very promising tool for investigating the evolution of unresolved stellar populations in similarly distant galaxies, and attempts have been made to derive consistent estimations of age and metallicity for galaxy samples by several groups (e.g. Blakeslee et al. 2001, Cantiello et al. 2003, Raimondo et al 2005).

The WSO is expected to provide high S/N images in the 110-310 nm range disclosing the possibility of using this innovative technique to study the hot stellar content in distant galaxies.

For Example:

- Since SBF signal is determined by the brightest stars emitting at the observed wavelength, the WSO is expected to provide the opportunity of studying the stellar population responsible of the UV upturn in ellipticals where the single stars cannot be resolved due to their distance.

WSO instruments for imaging (FCU) are expected to provide the high quality images required by this technique. A preliminary evaluations shows that exposure times of the order of ~ 1h with WSO should be able to provide a S/N high enough to derive reliable UV SBF measurements for elliptical with high UV emission (i.e. (m1550-V)~ 4).

1.1.5.4. UV observations of old stellar populations

The last frontier of our understanding of the physics of old stellar populations resides in the ultra-violet (UV). The behaviour of old stellar populations in the UV has puzzled astronomers for almost four decades now, and in spite of major recent progress, we are still a long way from a fully satisfactory picture. In particular deep UV observations would provide us with a unique opportunity to collect crucial data to untangle the intricacies of the latest stages of the evolution of low-mass stars, so as to allow a deeper understanding of the UV properties of old stellar populations.

In this respect the systematic study in the UV of the hot stellar contents in stellar systems (like Galactic Globular Clusters, GGCs) would be of paramount importance.

The aim is the systematic study of the hot stellar content in old stellar system, which include the extreme horizontal branch (EHB) stars, at the hot end of the horizontal branch (HB), the short-lived but more luminous supra-HB and post-asymptotic-giant-branch (post-AGB) stars, the Blue stragglers Stars (BSS) and other collisionally-induced exotic stars.

This study will be able to address a wealth of fundamental scientific topics related to the different families of old hot stars, namely:

- **Extreme HB stars and the origin of the Ultraviolet Radiation in External Galaxies**

  The UV properties of old stellar populations have been a subject of intense scrutiny ever since the discovery of the UV-upturn of late-type galaxies (Code 1969). While it has become clear in the last decade that EHBs are responsible for most of the UV emission "excess" observed in old stellar populations (e.g. Greggio & Renzini 1990; Dorman et al. 1995), our understanding of the physics underlying the formation of such stars is still plagued by major theoretical uncertainties. Undeniably, one of the sources of difficulty is the absence of an accurate, comprehensive, statistically representative, homogeneous dataset describing the properties of the stars responsible for the UV emission in GGCs. Moreover, the most age sensitive part of the integrated light of a distant system is the near-UV emission from the Main Sequence Turn Off (MS-TO) stars because the light from the luminous red stars is suppressed. While it is in principle possible to develop absolutely calibrated near-UV measures of age, one must first understand the other contributors to the near-UV. For example, Peterson et al. (2003) show that Blue-HB and EHB stars are required to explain the near-UV spectrum of the massive M31 globular G1.

- **Supra-HB and Post-AGB stars**

  These short-lived but UV-bright stars are hard to find in optical surveys. However, they might be important contributors to the integrated UV emission of old stellar populations. So far the only systematic survey of these objects based on UV images was conducted with UIT (Stacher et al. 1997), and only 14 GGCs were studied in total (see reviews in Moheler 2001; O’Connell 1999). A systematic UV-large field survey can double the number of GGCs surveyed, so as to boost the statistics of these objects. The integrated UV magnitudes and colors for the entire GGC sample can be obtained with the aim of better characterizing the correlations of these quantities with global and structural parameters, such as mass, age, overall metallicity and abundance ratios. Correlations with orbital characteristics and stellar evolution features, such as the morphology of the horizontal branch will also be studied. It is important to stress that such correlations are currently based on inhomogeneous, and often poor-quality, data (for a discussion, see Dorman et al. 1995). Therefore these data will constitute a fundamental contribution to the field of old stellar population synthesis models in the UV.
Blue Stragglers Stars and Cluster Dynamics

GGCs are important astrophysical laboratories for the study of both stellar evolution and stellar dynamics. In recent years it became clear that these two astrophysical processes cannot be studied independently; physical interactions between single stars as well as the formation, evolution, survival and interactions of binary systems have a significant role in the evolution of the clusters and of their stellar populations (Chernoff & Weinberg 1990). In particular, such interactions generate objects that cannot be explained by standard stellar evolution (like blue stragglers, X-ray binaries, millisecond pulsars, etc.). We can learn much on the dynamical evolution of the cluster and on the complex interplay between stellar and dynamical evolution from the study of these stars. Indeed the most abundant products of this activity are the so-called BSS. They are commonly defined as those stars brighter and bluer (hotter) than the MS-TO stars. BSS lie along an extrapolation of the MS, and thus mimic a rejuvenated stellar population. They are significantly more massive than the normal MS stars, hence they are suspected to be the product of either mass transfer between binary companions, the merger of a binary star system, or stellar collisions. A UV satellite with a large field of view and high sensitivity would allow a survey of BSS over the entire spatial extent of GGCs. This is very important, because in the few GGCs for which such an extensive survey has been performed the radial distribution of BSS frequency has been found to be bimodal: in addition to the well-known central peak, a remarkable secondary peak has been found at several core radii from the center (Ferraro et al. 1993; 2004). The availability of a wide-field UV facility will allow to map the spatial distribution of BSS for a sample of selected clusters with different properties in order to study the correlations of the BSS bimodal distribution with global and structural parameters (such as mass, concentration, dynamical state, core morphology) imposing thus a crucial constraint on the possible BSS formation scenarios.

1.1.6. The local Universe

The knowledge of the local Universe at UV wavelengths is fundamental in order to get information to interpret the optical-IR observations of high-z objects. The study of UV properties of nearby SNe of various types is crucial in order to properly use them at high redshift as distance indicators for the measurement of the acceleration of the Universe and to measure the history of SFR. In this respect WSO is fully complementary to the JWST.

1.1.6.1. Local Galaxies

Since the time it was recognized our Milky Way system belongs to a loose association of galaxies dubbed "The Local Group" (LG), observers realized that the existence of such a few, nearby objects does offer the twofold opportunity of studying different galaxy types in detail, as well as of calibrating the luminosities of several kinds of secondary standard candles. What is more, the Virgo cluster of galaxies located at about 20 Mpc can provide detailed pieces of information also on giant ellipticals, a kind of galaxy missing in the LG. In particular, the WSO Short Focus Camera, capable of assuring a subarcsec resolution within a FOV as large as 5 arcmin, is ideally suited for identifying any compact, UV-bright star-forming region of individual galaxies, down to a surface brightness of about m_u~15-16.

Since the UV luminosity is, in turn, proportional to the current star formation rate (SFR), the combination of WSO UV and Optical imaging will provide a highly reliable calibration of the UV-SFR relationship to be used also for the interpretation the observation of the rest UV emission of high-redshift young galaxies. A UV-based alone estimate of the galaxy/group SFR can also be achieved by resorting to the specific calibrations of Kennicutt (1998) and Buzzoni (2002).

1.1.6.2. Local Group Analogs

The possible detection of low-mass, star-forming systems within nearby LG analogs - made easy at UV wavelengths by WSO - is essential to address the so-called "missing satellite" problem, a key issue concerning the evolution of our own LG, too (which lacks luminous satellite galaxies). The expected number of dark matter clumps around galactic, Milky Way-sized halos exceeds the number of satellites actually observed by an order of magnitude, indeed. Unless gas accretion and star formation are suppressed in dwarf dark matter clumps by some unknown mechanism, this investigation could ensure that the amplitude of the small-scale primordial density fluctuations is considerably smaller than expected in the cold dark matter scenario, thus affecting cosmological studies themselves.

1.1.6.3. Evolved populations in Galaxies

The capability of the WSO Optical Camera (OC) of detecting in the blue extended objects down to a surface brightness m_360 ~ 20-21 keeps the promise of reconstructing the evolution of the UV-upturn phenomenon - i.e. the rise of the UV emission shortward of 200 nm, typical of massive, metal-rich ellipticals and spiral bulges - as a function of look-back time for objects at z > 1. This issue is, in turn, a crucial piece of information to understand the late phases of stellar evolution.
1.1.7. Galaxies and Active Galactic Nuclei.

The structure of Broad Line Region (BLR) in AGN’s remains a profoundly open issue, not last because the BLR is spatially unresolved even in the nearest AGN. A major tool to explore the physical and kinematical conditions within the BLR would consist in comparing the emission line profiles of the high with the low ionization potential ionic species (i.e., CIV, OVI, on the one hand, and HI, MgII on the other). Proper evaluation of line profile ratios (possible with the WSO/UV planned resolutions) provides extremely valuable information on the optical depth, density and ionization within the BLR as a function of radial velocity.

WSO/UV will cover a spectral range of great interest for the study of radio-quiet and radio-loud AGN. Considering radio-loud AGN, the expected performances of the instruments could be useful to better understand the role of the BRL emission lines in the energetics of blazars, and this will allow us to discriminate among the different models proposed to explain their multiwavelength emission. In a more general view, the broad emission lines may be used also to estimate the masses of the compact objects residing in the nuclear centres (likely a supermassive black holes), and their study may help in investigating the interplay between the accretion disc and the relativistic jet. In this contest observations in the UV region are crucial as the emission comes from region having high ionization states, more representative of the dynamics near the central engine.

All evidence now points to the idea that most galaxies host a supermassive black hole (e.g. Kormendy et al. 1995) and the close connections between the SMBH mass and the properties of the host galaxy (e.g. Ferrarese & Merritt 2000) indicate that it exists an interplay between SMBH and galaxies (via star formation) growth. The growth of a SMBHs manifests as one of the many different form of AGN that then represent our best tool to investigate the evolution of black holes. UV observations open a unique window to explore the fundamental issue of the coevolution of SMBH and host galaxies, since both AGN and star formation emit most of the light in this observing band. The capabilities of the WSO can be exploited in several directions, providing novel and detailed diagnostics, two of which are treated below.

1) The steepness of the AGN luminosity function indicates that most accreting black holes are associated to the least active galaxies. While relatively bright AGN are most likely powered by standard optically thick disks, low luminosity AGNs might be associated to Radiative Inefficient Accretion Flows (e.g. Narayan & Yi 1995). The relevance of this issue relies in the low efficiency of RIAF, which can hide a substantial rate of accretion, possibly the dominant component when integrated over the galaxies population. This possibility can be tested by looking for the characteristic feature of standard disks, i.e. the so-called UV bump. The best approach to tackle this possibility is to derive the Spectral Energy Distribution of LLAGN: with the LSS on WSO, with an exposure time of 1 hour, it will be possible to obtain a SNR=5 spectrum of an AGN down to a luminosity of $10^{24}$ erg/s/cm2/ Å at 1500 Å at the distance of the Virgo cluster, a level corresponding to the currently known limit of the AGN luminosity function. Such a study has also the potential of unveiling AGN in galaxies presently considered as quiescent, extending our knowledge of the low luminosity end of the AGN population.

2) The presence of a direct connection between AGN and star formation has been suggested by several authors in the past and it has been ascribed to a common triggering mechanism, such as a merger event, driving gas toward the center of the galaxy, providing fuel for both star formation and accretion onto the black hole. In the novel context of galaxy/SMBH co-evolution, a new thrust must be given to this issue. However, we still lack a convincing evidence for the reality of this effect, as well as a quantitative assessment of its importance. Space based UV observations provide high spatial resolution images which enable to directly separate the regions of star formation from the UV light produced by the AGN. UV spectra can instead reveal the presence of UV absorption features formed in the photospheres (e.g. S V λ1501, C III λ1426) and fast winds (e.g. C IV λ1550, Si IV λ1400) of massive young stars. They will also allow a direct estimate of the star formation history of the source. Pioneering work in this field has been performed using HST, observing a small sample of nearby Seyfert galaxies (Gonzalez Delgado 1998). Direct imaging showed that these starbursts are compact and powerful, with sizes of less than 100 pc and luminosities similar to those of the active nucleus. Absorption features with equivalent widths of several Å have been detected from HST/GHRS observations at similar resolution of that achievable with the LSS on WSO. The enhanced sensitivity of the WSO instruments over the HST UV spectrographs will allow us to explore this issue using larger samples and extending the range of contrast between nuclear starburst and AGN luminosity.

Other science fields where WSO/UV can give an important contribution, potentially of interest to the Italian community, are:

1.1.8. Planetary Science

UV/FUV observations are essential to study the auroral variability in the major planets, the dynamics of planetary upper atmospheres, cometary evaporation and gas production. Also atmospheres of extrasolar...
planets can be efficiently characterized in UV: HST/STIS observations of the star HD209458 show a 15% change in the Ly-alpha depth during the transit of HR209458b a Jovian-like planet orbiting close to the star, that was interpreted by Vidal-Majar et al. 2003 as due to a planetary extended atmosphere suffering a mass loss rate $\geq 10^{10}$ g s$^{-1}$. Moreover, UV data show the presence of C and O in the HD 209458b atmosphere (Vidal-Majar et al. 2004).

1.1.9. Intergalactic Media
Ground based observations of high redshift objects (3.5 $< z <$4.5) with 10m class telescopes show that the metal abundance of primordial objects is about 1/100 of solar value, and that there is a marginally significant increase of metallicity (by a factor of 2). Then, how to explain the factor of 50--100 increase of metallicity from z=2 to present time, which represents 80% of the cosmic time? WSO can probe hot gas and deuterium in local group galaxies (inc. the Milky Way), ionized helium in our own galaxy and observe the hot IGM and galactic halos, studying galactic enrichment out to z=2. WSO/UV will be able to reveal how metals came to the IGM and what is real content of the IGM (either ICM). The possibility to reconstruct the overall evolution of metallicity in such a wide time span is guaranteed by the large number of QSO’s (800 – 1200) observable with WSO at high resolution (50000 resolving power and S/N = 15 in 10 hours).

1.1.10. Gamma-ray bursts and the afterglow
The capability of WSO to be slewed in real time to newly discovered gamma-ray bursts opens the possibility to verify the expected power law spectrum of the burst by including the energy distribution in the UV range, not yet known (low resolution mode in this case).
Also, cosmologically important information on the chemical abundances of the host galaxy can be obtained from high resolution spectra. Thanks to the background provided by the afterglow, the absorption spectrum of the host galaxy will become detectable, allowing determinations of chemical abundances of galaxies at intermediate redshift to be made. The UV range is the most suitable for this purpose being rich of resonance or low excitation lines of cosmically important ions.

1.1.11. Cosmology
We have already mentioned the rest frame studies of local counterparts to cosmological objects (galaxies, clusters, SNe etc.). Access to UV/FUV spectroscopy is essential for a variety of cosmological observations including: the cut off energy in QSOs, chemical evolution in AGN and normal galaxies, high velocity clouds in AGN, accretion rates and flows in massive central black holes, interaction between the radiation field and gas near central black holes and the physics of star bursts from the Lyman continuum. The search for baryonic matter in the nearby Universe is one key topic: from the CMB we know that baryons are about 4% of the matter in the Universe. The problem is that we can only observe part of baryonic matter. From mass-luminosity relation for galaxies the luminous matter density is estimated as 30% of the baryonic matter. WSO/UV will be able to look for the dark baryonic matter in the warm-hot phase of the local Universe (z<2) which contains about 80% of its volume.

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1.2. Status of the project and the international framework

The WSO concept was discussed for the first time in the conclusions and recommendations of the 8th UN/ESA Workshop for Basic Space Science in the Developing Countries. In order to assess the mission feasibility and to provide the conceptual design of the WSO/UV space/ground system, an ESA internal study was conducted under the ESA General Studies Programme (2000, Attachment 1) followed by an assessment study at JPL/NASA (2001, Attachment 2). Both studies demonstrated the feasibility of the mission under the considered assumptions.

The basic ideas under the WSO project are to use application innovation, but avoid technical development innovation, use heritage as much as possible, apply new engineering methods (concurrent design), and keep the mission simple. **Making use of existing technology reduces the development time** (a few years) and cost (about 350 million USD). The project is a development of the Spectrum UV mission -- a Russia, Ukraine, Germany and Italy project -- that was eventually cancelled because of the reduced funding of the Russian space programme after the restructuring and political changes that took place in the former Soviet Union countries.

In 2001 an open international committee of scientists - the World Space Observatory Implementation Committee (WIC) - was set to promote WSO/UV in the framework of international collaborations. Scientists representative of Argentina, Baltic Countries, China, ESA, France, Germany, Italy, Israel, Mexico, the Netherlands, Poland, South Africa, Spain, Russia (chair), United Kingdom, and UN sit in the WIC.

In 2004, the Russian Space Agency (Roscosmos) announced to be interested to take the leadership of the WSO/UV project and asked National Agencies of countries represented in the WIC to define their level of interest in the project. Finally, a major cornerstone for the project is that the Russian Federal Space Program for 2006-2015 was approved by the government in Oct 2005, with the WSO/UV project scheduled to be launched at the end of 2010. Web page of science missions in the Russian Federal Space Program on [http://www.federalspace.ru/science0615E.asp](http://www.federalspace.ru/science0615E.asp) (English).

Here following is a schematic view of the current international scenario for the WSO/UV project.

1.2.1. Countries with an official endorsement in the WSO/UV project

**RUSSIA** (Roscosmos) (about 75% total cost, if launcher and launch services are provided by Russia, about 55% if not)

(Pi: B. Shustov, INASAN

*Prime Contractor Lavochkin, Project Manager: A. Moisheev*

**Contribution:** Telescope, Platform, FGS, Launcher, Optical Bench, Mission and Science operation centers.

**Funds:** On 25/10/2005 the Federal Space Program of Russia for 2006 – 2015 was signed at ministerial level. The Program is now an official state document. Project WSO/UV, with launch in Oct 2010 stays in the space program, as a one of the major projects that implies substantial level of funding (funds equivalent to 250/300 MEuro (if launcher and launch services are included) in Europe – this is not a conversion from rublos to Euro, but it takes into account costs in Russia).

**Status:** Telescope is in Phase C (the dynamical model of the T-170M telescope is being prepared for testing in 2006, prototypes of the main and secondary mirrors are manufactured), Platform, Optical Bench, and FGS in Phase B. **Mission and Science Operation** in Phase A. Russia is constructing new GS (antennas) working in X band according to the international standard. These will be used for the project Fobos-Ground (launch 2009), and for WSO/UV. **Launcher** (Zenith2E) will be provided only in case China will not participate to the project.

The last complete study report “Addition to Preliminary Design” for the WSO/UV project (former Spectrum-UV) has been published in Russian in 2003. It consist of several books and an Executive Summary (Attachment 3). The work plan of Roscosmos include the freezing of negotiation for international major contributions in mid 2006. This will lead to the release of the preliminary design review (PDR) of the whole project at the end of 2007. This implies a revised date for the launch that will probably shift of 1 year (late 2011). Roscosmos is in the process to release an updated document for the programmatics.

**GERMANY** (DLR) (about 8% total cost)

(IATA, Tuebingen - Pi: N. Kappelmann, Univ. of Tuebingen)

**Contribution:** HIRDES (High Resolution Double Echelle Spectrographs)

**Funds and Status:** Phase A study of the HIRDES spectrograph release by Jena-Optronik, HIRDES- FR-DJO-001, HIRDES Phase A Study Final report, May 2001

Phase B1 study (funded by DLR) to be completed for March 2006. Complete Phase B at the end of 2006. MoU between Germany and Russia after the Phase B study.
ITALY (ASI) (about 5% total cost)
(INAF & Univ. FI & PD - PI: I. Pagano, INAF-CT)
Contribution: Field Camera Unit (FCU), Science operation center
Funds and Status: Phase A/B1 to be done in 1 year following the release of the request for quotation by ASI, released on Mar 21 2006 (see section 1.3). MoU between Italy and Russia after the Phase B study. Science operation center tbd.

UNITED KINGDOM (Univ. of Leicester) (about 1% total cost)
(Univ. of Leicester, PI: M. Barstow)
Contribution: Detectors for the Long Slit Spectrograph (part of the HIRDES instrument)
Funds and Status: Funds secured by Univ. of Leicester.

1.2.2. Countries whose endorsement is under negotiation

CHINA (CNSA) (about 20% total cost if launch and launch services included, 3% if not)
(PI Fu Zheng)
Contribution: Launcher, Mission and Science operation centers, Long Slit Spectrograph
Funds and Status: Negotiation between China and Russia is ongoing. Decision is expected during the 1st semester of 2006

SPAIN (INTA) (about 5% total cost)
(LAEFF, UCM, PI: A.I.Gomez de Castro)
Contribution: Mission and Science operation centers, filters for the imagers
Funds and Status: Spain asked support to ESA in the framework of ESA Support for NLP in Sep 2005. The ESA/AWG did not recommend it (12 Jan 2006). In any case, the interest of Spain to participate in the WSO/UV project has been confirmed in the course of a bilateral meeting between Spain and Russia in February 2006. The negotiation is in progress to define the terms of contribution.

UKRAINE (about 1% total cost)
(Crimean Observatory, PI N.Steshenko)
Participation in: Long slit spectrometer, expertise in optics of T-170M Telescope

MEXICO, SOUTH AFRICA, ARGENTINA under the flag of UN are willing to participate mainly in the Ground Segment
Status: Bilateral negotiation between each nation and Russia
1.3. Italian contribution and benefits to the Italian scientific community.

1.3.1. The WSO/UV Italian working group
Astronomers in Italy are strongly interested in the development and use of WSO/UV, because of the scientific and technical expertise matured in this field in past years. The Italian researchers who expressed interest to participate in the implementation of the Italian collaboration, both for the technical project and for the related science activities are listed in Attachment 4, where the role of each scientist is also indicated. The science objectives of the Italian community are mainly discussed in §1.1. From the technical point of view there is a proved expertise in design and development of payload instrumentation for UV in Italy, both in the industries and at INAF & Universities. In the past years the Italian community has been involved in projects for UV instruments: OUTEX, the Space Schmidt for the Spacelab, Spectrum-UV, Mouse, TRUST, JUNO and UVISS have allowed the Italian scientists to acquire a great and mature expertise to afford the WSO/UV enterprise. An overview of the scientific/technological activities in Italy in the field of space UV astronomy is given in the document “Feasibility Study on High Energy Astrophysics: fields of interest and perspectives for the national community” (Costa et al. 2004), that is the report of a study committed by ASI to the Astrophysical Community in 2004, and signed by 40 Italian scientists (Attachment 6). In the same document the support to the WSO/UV project is recommended.

1.3.2. The Italian contribution
ASI has released a call to the Italian WSO/UV working group to perform a Phase A/B1 study of the Italian contribution to the project (21 Mar 2006, received at INAF 3 Apr 2006). The possible Italian contribution has been agreed with the Russian partner (see the minutes of the ASI – Roscosmos bilateral meeting held on Dec 20 2006 in Rome (Attachment 5). The results of the Phase A/B1 study will be:
- the technical project of “Field Camera Unit” (FCU);
- the definition of programmatic and cost of the Italian contribution;
- the choice of the imagers passbands
- a report on the key science objectives of the instruments

A preliminary Work Package Organization for the Italian Team is draft in Figure 1. The technical team for the FCU project involves scientists from INAF - Catania Observatory and IASF-Milano, and from Department of Physics and Astronomy of Florence University. Interest from Galileo Avionica and Laben industries has been expressed to the project. The project will be presented to the Italian community as a first step of the preparation of the “Offerta” that will be submitted to ASI.

Figure 1 –Preliminary Work Package Structure of Italian activities
1.3.3. Benefits to the Italian scientific community
As discussed in § 2.7, a document regulating the time sharing will be released by the WSO Implementation Committee after the WIC meeting scheduled on Jun 28-29 2006. From the current discussion inside the WIC, the policy for telescope time is to have both guaranteed time (Core Programme) and open time (General Programme) that will be announced with Call for Proposals addressed to the whole community. The core program will be devoted to programs of the Science Team. The minimum return to the Italian community in terms of access to telescope time (spectroscopy and imaging) will be negotiated later between ASI and Roscosmos, starting from a time percentage of the order of the fractional cost of the Italian contribution (about 5%). Also commissioning time for the FCU instrument will be used from our community.
SECTION 2

2.1. Telescope
The heritage for the WSO telescope design is the Russian-led international space observatory ASTRON, launched in 1983. It functioned for six years and was the first UV telescope placed into a highly eccentric orbit. This led to the proposed development of the Spectrum UV mission -- a Russia, Ukraine, Germany and Italy project -- that was eventually cancelled because of the reduced funding of the Russian space programme after the restructuring and political changes that took place in the former Soviet Union countries. The WSO/UV telescope (T-170M) is a new version of the T-170 telescope designed in Russia by Lavochkin Association for Spectrum-UV mission. It was a Ritchey-Chretien with 1.7m aperture, equivalent focal length of 17.0 m, FOV of 40 arcmin (Ø=200 mm), optical quality of the two mirrors of lambda/30 rms at 633 nm, capable of 12.05 arcsec/mm angular resolution on the focal plane. Characteristics of the T170M are given in table 1. The T-170M consists of the optical system, structural module and service complex (Figure 2).

Figure 2 – A Scheme of the T170M

Secondary mirror unit (SMU), light cover with the deployment mechanism and rotary external baffle with its deployment mechanism and fixing unit are located in the top part of telescope’s tube. The external rotary baffle has an oblique cut for light exposure’s prevention of the telescope’s internal cavity. The light exposure could be caused by direct sunlight hit. It can be in two positions: transport and operational.

<table>
<thead>
<tr>
<th>Table 1: Characteristics of the T-170M telescope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical System</td>
</tr>
<tr>
<td>Aperture diameter</td>
</tr>
<tr>
<td>Telescope f-number</td>
</tr>
<tr>
<td>FOV</td>
</tr>
<tr>
<td>Wavelength range</td>
</tr>
<tr>
<td>Primary Wavelength</td>
</tr>
<tr>
<td>Optical quality</td>
</tr>
<tr>
<td>Mass</td>
</tr>
<tr>
<td>Size</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Transforming of the telescope’s external baffle from transport position to operational one is carried out after S/C insertion to the orbit (LEO) by turning it by 180°. The actuators located on the top frame’s part of telescope’s tube perform the turn.

2.1.1. Status: Beginning of Phase C for tube, PMU, SMU. Phase B for the instrumental compartment

2.1.2. Documentation: Phase A report released by Russian cooperation under Roscosmos (Attachment 7)
2.2. Payload

2.2.1. High Resolution Double Echelle Spectrographs (HIRDES)
WSO/UV has three spectrographs in its focal plane, as well as a set of optical and UV cameras. An industrial Phase A study for all spectroscopic capabilities in a single box, namely the HIRDES instrument -- designed using the heritage of the ORFEUS missions successfully flown on two space shuttle flights in 1993 and 1996 (Bamstedt, et al., 1999, Astron. & Astroph. Suppl. Ser. 134, 561; Richter et al., 1999, Nature, 402, 386) -- has been completed in 2001 by Jena-Optronik funded by the German DLR (Attachment 8).

2.2.1.1. Characteristics
HIRDES (see Figure 3) comprises two echelle instruments, UVES (178-320nm) and VUVES (103-180nm), that were designed to deliver high spectral resolution (R~50,000), and a low dispersion long slit instrument: LSS (R~1000). Low dispersion long slit instrument: LSS (R~1000 – 3000) is considered as a separate instrument, with integrated external electronics and housing structure with HIRDES.

Each of the three spectrometers has its own entrance slit lying in the focal plane of the T-170M telescope on a circle with diameter 100 mm. The three optical trains can be operated in sequential mode. This is managed by satellite motion with a pointing stability requirement of 0.1 arcsec to be monitored by three Fine Guidance System (FGS).

![Figure 3: Optical Layout of the two High Resolution Spectrographs and the Long Slit Spectrograph without housings (see Attachment 8)](Attachment 8)

2.2.1.2. Performances
A comparison of the Effective Area of the WSO/UV instruments with the UV spectrographs STIS on HST at comparable resolution is given in Figure 4. The spectral resolution provided by HIRDES is similar to that provided by HST-STIS, but higher than that provided by HST-COS, the instrument designed to replace STIS. As far as sensitivity is concerned, WSO/UV-HIRDES is comparable to HST-COS and definitely better than HST-STIS. Accounting also for the fact that WSO/UV will be a dedicated UV telescope and will have a high efficiency of observations at L2, WSO/UV will provide a net increase in UV productivity of a factor about 40-50 compared to HST/STIS at the same spectral resolution. A WSO/UV HIRDES Exposure Time calculator is available on the site: http://astro.uni-tuebingen.de/groups/wso_uv/exptime_calc.shtml
2.2.1.3. Status
A modified industrial Phase B1 study for VUVES and UVES spectrograph has been completed in Germany (Feb 2006) in collaboration with Russia, while an assessment study for a modified LSS with better spatial and spectral resolution is ongoing in China, Russia and Ukraine. The HIRDES Phase B1 study report will be presented during a meeting between Germany and Russia in Tübingen on Apr 6-7 2006, then it will be available to the public. DLR has funded the completion of the HIRDES phase B study, to be done by the end of 2006.

2.2.1.4. Documents:
HIRDES Phase B1 study report will be released to the public in April 2006.
Proposal about LSS implementation from China submitted to CNSA (PI. Prof. Cheng FuZhen)

2.1. Field Camera Unit (FCU)
2.2.2.1. Characteristics
High spatial resolution (diffraction limited) and high sensitivity UV and optical imaging are a key objective of the project. Therefore, the WSO Implementation Committee planned to include a complement of UV and optical imaging detectors in the focal plane, to provide both serendipitous science during spectroscopic observations and planned studies of specific target areas.

Science drivers for the imaging instruments are:
- the auroras in solar system planets,
- the UV luminosity function of galaxies in clusters, groups, fields and void;
- a deep UV survey of the Virgo cluster;
- astrometry of galactic crowded fields – e.g. astrometry of old population stars in globular clusters.

The latter is a HST heritage project; it will provide data complementary to the GAIA ones.

Much of the available volume in the focal plane, immediately behind the primary mirror, is occupied by the HIRDES. This leaves only a very narrow space (about 10cm diameter cylinder) on the telescope axis that can be used for a direct imager, which samples the best diffraction limited resolution of the optical system.

Preliminary design studies of the imagers for WSO/UV have been conducted in Russia according to the WSO/UV Implementation Committee requirements. For estimates of size, mass, electrical properties etc, the design of the TAUVE instrument (Israel) developed for Spectrum X-gamma, was considered as a prototype. Two main studies have been provided. The first one led to the “Conclusions and Action Items – WIC Meeting Moscow, 22/23 May 2002” document (Attachment 9), while the second one led to the “WSO/UV Implementation Committee Decision on Focal Plane Imaging Instruments” document (Attachment 10).
On March 1st 2006, the WIC approved the science specifications for the FCU, summarized in Table 2, under which the Phase A study has to be conducted. The FCU will include:
- An optical camera (OC), to work at the best diffraction limited resolution with the largest FoV that is possible to accommodate (FoV to be defined during the Phase A study), intended to perform astrometry of crowded field
- Two UV imagers: one F/50 camera with resolution of ~0.03 arcsec/pixel and ~1 arcmin FoV (LF), and one F/10 camera with ~0.15 arcsec/pixel resolution and ~5 arcmin FoV (SF). Each of these cameras is equipped with one or two filter wheels in order to accommodate passband filters according to the science case.

The possibility to accommodate redundant UV and optical cameras in the FCU has to be evaluated during the Phase A study (Figure 5 shows a possible design according to Attachment 10).

The final choice of detectors – MCP and/or CCD - will be a task of Phase A study. However, from a preliminary assessment study, the baseline choice is MCP for the UV cameras, and CCD for the optical camera.

<table>
<thead>
<tr>
<th>Camera</th>
<th>Range</th>
<th>Focal ratio</th>
<th>FOV arcmin</th>
<th>PSF sampling</th>
<th>Res. arcsec</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF</td>
<td>UV</td>
<td>F/10</td>
<td>6</td>
<td>0.15&quot;/pixel</td>
<td>0.3</td>
</tr>
<tr>
<td>LF</td>
<td>UV</td>
<td>F/50</td>
<td>1.2</td>
<td>0.03&quot;/pixel</td>
<td>0.1</td>
</tr>
<tr>
<td>OC</td>
<td>Visible</td>
<td>tbd</td>
<td>As large as possible</td>
<td>≤0.03&quot;/pixel</td>
<td>≤0.1</td>
</tr>
</tbody>
</table>

The imaging required performances compare well with that of HST/ACS. A preliminary evaluation of FCU imagers performances is given in Attachment 11.

2.2.2. Status
ASI has released a call for a Phase A/B1 study to be completed by the Italian team in 10 months from the kick-off project (Release of the call: 21 Mar 2006, received at INAF 3 Apr 2006).

2.2. FGS
The system is intended for:
- Recording of images of stars in the focal plane of telescope and identification of their position in the coordinate system related with operational slits of spectrometer HIRDES or cameras;
- Measurements of deviation of the design point of guidance of telescope from centers of entrance slits of spectrometer HIRDES or from given point at camera detector surface.
- Formation of data on the image in the field of FGS detector with the purpose of the subsequent transmitting of the data to Earth
- Transfers of the measuring data. The data includes necessary volume of data sufficient for the monitoring of the system current condition. The data is transferred to the onboard computer complex (OCC).
- The FGS represents three electrically independent detectors, located in the telescope integrated optical system.
Three input slots of the spectrometer are located in the telescope focal surface. The guiding detectors are located close to the spectrometers entrance slits. Standard deviation of the FGS measurements at the rate of the side real sky is $< 0.1\arcsec$/sec. relatively the CCD – detectors.

**Status:** FGS is provided by Russians, who are performing a Phase A study. The master catalog is responsibility of INASAN (Moscow), based on USNO CCD Astrograph Catalog (UCAC2)

### 2.3. Spacecraft

The platform for WSO/UV is the same Roscosmos has developed for Spectrum-X-gamma\(^1\) (launch 2009 - 2010) except for the radio link unit, that will be tailored to the WSO/UV requirements.

A view of the WSO/UV spacecraft with solar panels folded and deployed is given in Figure 6.

![Figure 6. The WSO/UV Spacecraft](image)

The WSO/UV total mass is 2900 kg. Here following the mass budget is given.

**Platform:**
- wet mass 1300 kg
- dry mass 1150 kg. This is an upper limit estimate. Some substantial reducing is expected very soon.

**P/L:**
- Telescope+ science instrument - 1570 kg
- Truss (mechanical interface between platform and the Telescope - 30 kg

The S/C main features are given in Table 3.

<table>
<thead>
<tr>
<th>Platform (Service Module - SM)</th>
<th>Navigator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of S/C with propellant</td>
<td>2900 kg</td>
</tr>
<tr>
<td>SM mass</td>
<td>1300 kg</td>
</tr>
<tr>
<td>Mass of propellant of the SM</td>
<td>150 Kg</td>
</tr>
<tr>
<td>Propellant of the SM</td>
<td>Hydrazine</td>
</tr>
<tr>
<td>Mass of the P/L</td>
<td>1600 kg</td>
</tr>
<tr>
<td>Pointing accuracy with star sensors</td>
<td>4 (2) arcmin</td>
</tr>
<tr>
<td>Accuracy of pointing and stabilization with the FGS</td>
<td>0.1 arcsec</td>
</tr>
<tr>
<td>Slewing rate</td>
<td>Up to 0.1 deg/s</td>
</tr>
<tr>
<td>Maximal exposure time</td>
<td>30 hours</td>
</tr>
<tr>
<td>Download of scientific data</td>
<td>Up to 1 Mbaud</td>
</tr>
<tr>
<td>H/K data transmission rate</td>
<td>Up to 32 Kpbs</td>
</tr>
<tr>
<td>Electric power (EP) available for the P/L</td>
<td>750 W</td>
</tr>
<tr>
<td>EP for science instrument for the FP compartment</td>
<td>300 W</td>
</tr>
<tr>
<td>Voltage of electric power supply</td>
<td>$27\pm1.35$ V</td>
</tr>
</tbody>
</table>

#### 2.3.1. Status

The modified version of the Navigator platform, tailored for WSO/UV, is expected for 2008.

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\(^1\) The Roscosmos, ESA, MPE, IKI, and Univ of Leicester project Spectrum-X-Gamma share with WSO the bus and part of the GS: information on this mission on [http://hea.iki.rssi.ru/SXG/YAMAL/SXG-eng.htm](http://hea.iki.rssi.ru/SXG/YAMAL/SXG-eng.htm)
2.4. Launcher
Two launchers are considered: Zenith2 and Chinese Long March 3B. Both are capable to deliver S/C in vicinity of L2.

*Status:* The choice of the Chinese Long March 3B launcher is subject to the conclusions of the negotiation between Russia and China. The Russian Zenith2 launcher will be used in case of China will not participate in the project (decision expected for mid 2006).


2.5. Orbit
Primary option is a halo orbit around L2 point in the system Sun-Earth.

2.6. Ground Segment
A Phase A study for the Ground Segment concept was conducted by Spain, in the assumption of the availability of ESAC to the project. After the ESA decision on Jan 2006 to not give support to Spain to participate in the WSO/UV project, the definition of the GS depends upon Spain-Russia negotiations. Decision on this aspect are expected for mid 2006.

As a back-up, Roscosmos is considering a GS concept, based on what studied for Spectrum UV, consisting of a MOC in Russia and distributed SOCs. In Figure 7 the structure of the Ground Segment concept is drawn. Ground stations under consideration are located in Argentina, China, Russia, South Africa, and Spain.

![Figure 7 – The WSO/UV Ground Segment concept](image)

Control centers are considered to be co-located with the ground stations, the control centers execute the command timeline and process the telemetry received from the co-located ground station, using the mission control system. The Mission Operation Center is responsible for mission safety and security. Therefore, it has final authority on mission planning and command timeline approval. The mission control center includes the following subsystems: a) the mission planning facility; b) the flight dynamics facility; c) the mission analysis facility; d) the on-board software maintenance capability; e) the mission data archive; f) the control center capabilities. Although it is not required that the facilities above are physically located at the mission operations center, functions and products are coordinated by the MOC for quality control and safety reasons. The Science Operation Center is responsible for the quality of the science mission products and for the scientific performance of the mission. The science operations center is the final authority for: a) interaction with the mission operation centers; b) instrument calibration; c) long term planning; d) integrated science schedule; e) the science data archive; f) interaction with the science centers.

2.7. Data right policy
A meeting of the WSO Implementation Committee is scheduled on Jun 28-29, 2006 to approve a document on the time sharing policy. From the current discussion inside the WIC, the policy for telescope time is to
have both guaranteed time (Core Programme) and open time (General Programme) that will be announced with Call for Proposals addressed to the whole community. The core program will be devoted to programs of the Science Team.

2.8. Programmatic

Attachment 12 shows the schedule of the WSO/UV project payload development released by the Prime Contractor (Lavochkin Association) early this year. Attachment 13 is the time schedule provided by the German partner for the HIRDES development. The global time schedule is one of the items in agenda for the WIC meeting planned in Moscow on Jun 28-29 2006.
Attachments Index

1. ESA CDF-05 (A&B), Assessment Study Report WSO/UV, May 2000, also available on http://wso.vilspa.esa.es/docs/WCC/DOC/Attachments/GEN-TN-0002-1-0.pdf
2. JPL ADF, CL# 01-1168 Advanced Projects Design Team Assessment of World Space Observatory Proposal, June 2001, also available on http://wso.vilspa.esa.es/docs/WCC/DOC/Attachments/GEN-TN-0001-Draft-0.pdf
7. WSO/UV T170M telescope Phase A report (http://www.oact.inaf.it/gass/WSO/PHASEA.PDF)
10. WSO/UV Implementation Committee Decision on Focal Plane Imaging Instrument also available on http://wso.vilspa.esa.es/Conferences/Madrid_2003/decision_FP.PDF
12. Schedule of the WSO/UV project payload development released by the Prime Contractor (Lavochkin Association) (http://www.ct.astro.it/gass/WSO/WSO-payload-schedule.jpg)
13. Time schedule provided by the German partner for the HIRDES development (http://www.ct.astro.it/gass/WSO/HIRDES-schedule.jpg).
<table>
<thead>
<tr>
<th>ACRONIMI</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>ACS</td>
<td>Advanced Camera for Surveys</td>
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<td>Asymptotic-Giant-Branch</td>
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<td>Black Hole</td>
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<td>Blue Stragglers Stars</td>
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<td>Exposure Time Calculator</td>
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<td>Field Camera Unit</td>
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<td>Fine guidance System</td>
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<td>Global Astrometric Interferometer for Astrophysics</td>
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<td>Goddard High Resolution Spectrograph</td>
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<td>HIRDES</td>
<td>High Resolution Double Echelle Spectrograph</td>
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<td>HST</td>
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<td>Main Sequence Turn Off</td>
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