Ultraviolet Imaging Telescope (UIT): Scientific Programs

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1 Introduction

This document outlines the UIT Science Team's scientific programs, and is intended to aid prospective Guest Investigators in (GIs)designing their programs. The UIT's observations on the Astro-1 flight are described in the *Astrophysical Journal (Letters)* vol. 395 (1993), devoted to UIT results, in subsequent publications, and the Appendix, "UIT Observation Summary", attached.

1.1 Unique Capabilities

The ultraviolet provides an important, new window on cosmic phenomena which has only recently been opened to serious imaging studies. Deep imaging and wide field spectroscopic surveys represent the primary means by which fundamentally new phenomena or astrophysically important examples of known classes of objects will be recognized in the UV. Only one all-sky UV survey has been carried out in the 1200-3000 Å region to date. But this (from the TD-1 satellite) had a limiting UV magnitude ~ 9, far brighter than the threshold of the Hubble Space Telescope or the Astro instruments, for example.

The Ultraviolet Imaging Telescope is taking a pioneering role in exploring the deep UV window. It is not designed for survey work, but it is nonetheless capable of providing a great deal of information about the UV sky. UIT covers the same vacuum UV wavelength domain as does the HST. The strengths of HST and UIT complement one another. HST offers much superior spatial resolution and 40 times greater collecting area. UIT's field of view, however, is 170 times larger than the WF/PC and is well matched to the diameters of star clusters, nearby galaxies, or medium-distant clusters of galaxies.

Furthermore, the UIT detectors are solar blind (i.e. have low visible/UV response ratios) and can take full advantage of the enormous contrast between hot and cool objects which prevails in the UV. A hot horizontal branch star, for instance, will be brighter than a K2 giant of equal V magnitude by 16 magnitudes (a factor of 2×10^6) at 1500Å; the contrast between a nonthermal nucleus and the surrounding stellar population will be typically 6-7 magnitudes better at 1500 Å than at 5500 Å.

The capabilities of the UIT suggest that its scientific contributions will be greatest in the following areas:

1.1.1 Search and survey of the UV sky.

Direct imaging and slitless spectroscopy frames from the UIT will constitute a fundamental resource for the detection of new cosmic phenomena in the UV, Astrophysically important new examples of known phenomena, and statistical surveys of UV-bright objects. The UIT can act as a pathfinder for other UV facilities, including the Astro spectroscopic instruments, HST, and FUSE.

A typical Astro mission will permit about 300 stabilized pointings. UIT exposures will be taken at every opportunity, whether or not the nominal target is of high priority for the UIT in itself (assuming there are no "over-bright" point sources in the field.) With 1000-second exposures, each mission could therefore return a UV survey to $m(uv) \sim 19$ ($V \sim 23$ for hot, unreddened sources) covering an equivalent sky area of ~ 70 square degrees. The objective grating may be used to classify the spectra of targets in the field.

1.1.2 Massive Main Sequence Stars in Star Clusters and Galaxies.

Individual hot main sequence stars in our own or nearby galaxies can be identified with groundbased telescopes. However, for more distant objects or where the background due to cool giant light is significant, UIT has a distinct advantage. UV photometry also provides better temperature discrimination for objects between 15000 and 50000 K than possible at longer wavelengths. It therefore yields improved information on the star formation history, the initial mass function (IMF), and the associated problems of the supernova rate and the ionizing radiation field. Through spectral synthesis techniques, this advantage can be extended to systems too distant to resolve individual stars.

1.1.3 Advanced Evolutionary Stages of Low Mass Stars.

Several advanced phases of evolution for stars of ~ 1 $M_{\odot}$are UV-bright and may readily be studied in local globular clusters and in nearby galaxies with UIT. The post-asymptotic-giant-branch collapse phase ("planetary nebulae nuclei"), the hot horizontal branch (HHB), and the poorly understood phases of evolution hotter or brighter than the HHB ($T \sim 15000$K) are best studied in the UV. The hot, low-mass populations of globular clusters and nearby galaxies are of particular interest. In the integrated UV light of more distant galaxies, these evolutionary phases can help trace the past history of star formation and chemical enrichment. They appear to be responsible for the far-UV excesses observed in elliptical galaxies and spiral bulges.

1.1.4 Interstellar and Circumgalactic Gas and Dust.

Narrow band imagery or low dispersion spectroscopy with the UIT of the strongest UV emission lines, including Lyman alpha (in redshifted objects), C IV, and C III can supply important information on the physical properties of the interstellar medium, notably the carbon abundance and the nature of Lyman alpha line transfer. In nearby galaxies, C IV imagery could help identify new supernova remnants and planetary nebulae and may also allow detection of hot gaseous halos around spiral galaxies.

The high extinction of dust grains in the UV together with the convenient signature of the 2200 Å feature make UV imagery a particularly sensitive method for studying the nature of dust. Among the interesting applications in this area are searches for a low-density interstellar medium in elliptical galaxies and determining the extinctive properties of grains in disturbed galaxies such as M82 or NGC 5128. Scattered UV light from dust may prove to be a sensitive probe of cool circumgalactic material.

1.1.5 Non-thermal Sources.

Sources with power law indices typical of the Crab nebula, active galactic nuclei, and QSO's are brighter in the UV than the optical. Together with the fainter cool star background in many applications, this gives UV imagery a significant edge in the detection and analysis of nonthermal sources in supernova remnants, galactic nuclei, and the jets associated with active nuclei.

1.2 UIT Scientific Programs

A set of UIT observations of a single object may be relevant to several distinct scientific programs. In this section we describe the programs which the UIT team plans to undertake for Astro-2. Each of these has several subcategories. Although we will observe a large variety of objects, we do not intend to undertake an exhaustive study of each of the problems described below. Instead, we will focus on those which prove most promising on the basis of data in hand after the mission. Despite the comprehensive nature of the problems listed which are of interest to the UIT team at some level, there is ample opportunity for GI science.

Some of the UIT team's scientific programs are based on "co-observation" of fields surrounding targets of primary interest to HUT or WUPPE, which will therefore be selected by those experiment teams. Where co- observing is a primary component of a UIT program, this is noted in the discussion.

SCIENCE CATEGORY: 1. Planets, Satellites, Asteroids

General: UIT's spatial resolution is not well suited for the study of planets. However, UIT offers an opportunity for synoptic UV imagery to determine the albedo, phase function, limb brightening, and cloud structure of planets which can help bridge the gap between flyby missions. From the night side of the orbit, it should be possible to image the Lyman alpha halos surrounding the planets, the Io torus, etc., even in the presence of a bright geocorona. THIS PROGRAM IS BASED ON CO-OBSERVATION OF HUT OR WUPPE TARGETS.

1.1 Continuum imagery

1.2 Circumplanetary material, Lyman alpha halos

SCIENCE CATEGORY: 2. Comets

Comets are *targets of opportunity* for Astro-2. UIT will permit UV continuum imagery for investigations of dust distribution as well as medium-bandwith studies of particular ionic species.

SCIENCE CATEGORY: 3. Circumstellar Material

General: Many types of stars are known to be surrounded by circumstellar material resulting from radiation or pressure-driven outflows. In some cases this material is cool, in others, ionized. Although in most instances, the

UIT resolution of 2 arc-sec will be inadequate to detect this material, it is likely that a few of the stellar targets selected by HUT or WUPPE will have larger circumstellar regions which could be detected by dust scattering in the continuum or by emission lines. This program is confined by the UIT bright limit to stars with UV magnitudes fainter than 9. THIS PROGRAM IS BASED ON CO-OBSERVATION OF HUT OR WUPPE TARGETS.

3.1 Cool material

3.2 Ionized material

SCIENCE CATEGORY: 4. Open Star Clusters

General: Clusters are typically a few parsecs in diameter and in most cases are well matched to the UIT field of view. They provide the opportunity for simultaneous determination of UV colors of many stars at once, for the detection of Astrophysically interesting subluminous stars (particularly in nearby clusters), and for studies of the extinction properties of dust.

The choice of targets is constrained by the presence of unusually bright stars in the field, either foreground or cluster member. The "Trumpler Class" is a guide to the latter since it describes the equivalent of a luminosity function, the number, and luminosity range of the cluster stars. THIS PROGRAM IS BASED LARGELY ON CO-OBSERVATION OF HUT OR WUPPE TARGETS.

4.1 White dwarfs and other hot subluminous stars

Open clusters covering a wide range of ages are near enough that UIT will be able to search for intrinsically faint, hot stars and to do this for a number of clusters covering a range of ages. Such stars are of interest for several reasons. First, they can be used as probes of the intervening ISM by spectroscopic experiments. Second, the white dwarf cooling sequence can be used to provide highly accurate distances to clusters. Third, identification of white dwarf cluster members will help to establish the minimum mass at which stars can become Type II supernovae, producing neutron stars instead of white dwarfs. This is important not only for understanding supernova physics but also to the question of the chemical evolution of galaxies.

4.2 Upper main sequence stars

4.3 Pre-main-sequence stars

Such stars are often surrounded by circumstellar dust shells, for which UV photometry may provide useful information. Many such objects can be studied simultaneously in young clusters.

4.4 Interstellar material

All hot stars in clusters, particularly where correlative optical or UV spectral information is available, can be used to determine the distribution and extinctive properties of dust within clusters and along the line of sight. UV imaging in emission lines will also sensitively indicate the distribution of ionized material in clusters.

SCIENCE CATEGORY: 5. Globular Star Clusters

General: Globular clusters are of intrinsic interest because they are the most ancient stellar systems known and they may illustrate in miniature the physical processes important during galaxy formation. They are also important because they are the best laboratories we have for the understanding of stellar evolution. Current interest focuses on the physics of giant branch mass loss and nucleosynthesis. The hot phases of evolution subsequent to the giant branch, such as the horizontal branch, post-HB, and post-AGB collapse phase are intimately connected to the physics of the giant branch. Apart from the information they yield on global properties (age, abundances) in the cluster, the hot phases are of intrinsic interest and are not well understood. UV photometry will be of great importance in clarifying their Astrophysical status. Near-complete samples of hot objects can be obtained with UIT, since the crowded background of cool main sequence and giant-branch stars in the cluster cores is strongly suppressed in the UV. The UV also permits sensitive searches for hot accreting binaries, planetary nebulae, and objects associated with X-ray sources.

5.1 Horizontal branch and related objects.

5.2 Supra-HB UV-bright stars

5.3 White dwarfs and cooling physics

The UV permits sensitive searches for hot white dwarfs in globular clusters. Existing visible surveys are severely limited by cool star contamination and image crowding. It is estimated that ~ 1000 white dwarfs in Galactic globular clusters are within range of the UIT. With a large statistical sample of white dwarf temperatures and luminosities, one can study the physics of the cooling mechanism in degenerate stars, which is expected to be dominated by neutrino cooling. This project requires very deep, dark side imaging on relatively nearby clusters, preferably metal rich ones to minimize UV image confusion. The white dwarf cooling sequence also offers a potentially valuable method of determining distance to globular clusters.

5.4 Hot binaries
5.5 Mass segregation
5.6 X-ray sources
5.7 Interstellar gas and dust

SCIENCE CATEGORY: 6. H II Regions/Reflection Nebulae/Dark Clouds

6.1 Dust scattering properties

H II regions have been shown to be primarily reflection nebulae in the UV, with a small two-photon emission component. UV imaging can yield the properties of the grains and the geometry of the scattering material with respect to the stars. The dust albedo in the UV, the scattering phase function, and the size distribution of the particles are needed to constrain plausible models of grains. The scattering phase function at large angles can be obtained where the star is outside the nebulosity. The albedo is best obtained when the star is inside the nebula.

6.2 Structure and distribution of absorption clouds

Since the optical depth in the UV is several times that of the visible and the most luminous hot stars are many times brighter in the UV, deep exposures will exhibit much structure in absorption clouds against the diffuse light not observable in the visible. This has already been demonstrated to be the case in other galaxies. A serendipity program based on regions surrounding hot stars of interest to WUPPE and HUT will be undertaken.

6.3 High latitude reflection nebulae

Isolated dark globules illuminated by the general galactic radiation field will be sensitive indicators of the asymmetry of the scattering phase function. UV measurements of the remarkable high latitude "cirrus" revealed by IRAS will be of great interest. Combined UV/21-cm observations of high latitude regions will provide better information on the dust-to-gas ratio.

SCIENCE CATEGORY: 7. Supernova Remnants

General: Old, evolved supernova remnants show the characteristic rich UV emission line spectrum of the shocked interstellar medium. Young SNR's have spectra dominated by the ejecta. The UIT field and spatial resolution is sufficient to undertake meaningful studies of gradients and structure in C IV and C III] emission regions. In combination with HUT, WUPPE, or HST spectroscopic observations, UIT imagery can be a powerful probe of SNR physics. Imagery with the 2200 Å filter will delineate the regions in and surrounding the remnant where dust has been concentrated by the sweeping action of the expanding material. Observations of the SN1987A field will be made to measure the UV light echo from the supernova. THIS PROGRAM IS BASED LARGELY ON CO-OBSERVATION OF HUT OR WUPPE TARGETS.

7.1 Nonthermal radiation

7.2 Ionization structure

7.3 Dust sweeping

SCIENCE CATEGORY: 8. Planetary Nebulae

General: Planetary nebulae have high excitation UV emission line spectra dominated by C IV, He II and C III]. The carbon lines are important in the thermal structure of nebulae. Imaging of these lines can act as a powerful constraint on theoretical models for the ionization and thermal equilibrium of nebulae. Dust can be studied by the scattering of UV continuum radiation from the central star. The classical problem of the radiative transfer of Lyman alpha in an optically thick, moving atmosphere cannot be studied directly because of the large amount of neutral hydrogen in the line of sight. However, the equivalent problem can be investigated in the C IV resonance lines, which will be readily observable in many planetaries.

It is expected that many planetaries will be bright enough to observe on the daylight side of the orbit, at least in emission lines.

8.1 Ionization structure

8.2 Dust scattering

8.3 C IV resonance line transfer

SCIENCE CATEGORY: 9. Hot Stellar Populations in our Galaxy

General: The survey capability of UIT is described in section I above. For stellar Astrophysics the primary results of UIT UV surveys will be identification of particularly interesting UV-bright stars for follow-up by Astro, the Hubble Space Telescope, or other instruments and a statistical analysis of the properties of the faint, hot stellar population of the Galaxy.

9.1 High Latitude Fields

At higher Galactic latitudes, interstellar extinction will be minimized. Objects of primary interest here are hot, low mass stars including cataclysmic variables, hotter horizontal branch stars, planetary nebula nuclei, OB subdwarfs, hot white dwarfs, and related objects. Use of the grating can provide photometric information. As an example of the sensitivity of UIT, the hot white dwarf HZ 43 ($T \sim 110,000$K) could be detected at a distance of ~ 16 kpc in a direction with little extinction. A search for UV-bright stars at various distances against which HUT or the HST could study the absorption spectrum of the hot Galactic halo is one example of a relevant UIT survey.

9.2 Low Latitude Fields

Most low latitude imagery will occur in fields surrounding targets of principal interest to the spectroscopic experiments. Extinction will be higher but often patchy. UV-bright objects discovered in directions with high extinction will automatically become interesting objects for follow-up. Objects of primary interest are as in 9.1 with the addition of distant, massive main sequence stars. Two technical complications are present in low latitude fields: i) many will not permit use of the grating owing to image crowding; ii) unusually UV-bright stars ($m(uv) < 9$) in the field could damage the instrument or produce large amounts of scattered light. Pre-screening of each field will be necessary.

9.3 Selected Fields of Special Interest

Special observations of particularly interesting search/survey fields will be scheduled. Examples include Baade's window and other regions toward the Galactic bulge with relatively low extinction, the Berkeley-Leiden high latitude deep survey fields, and regions known to have low H I column densities (in a search for UV bright sources that could serve as targets for far-UV experiments).

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SCIENCE CATEGORY: 10. Young Stellar Populations in Galaxies (Localized Regions and Resolved Objects)

General: Some aspects of the physics of star formation, such as the initial mass function (IMF) for massive stars and the influence of environment, can be studied better in other galaxies than in our own. Because they are up to 50 times brighter in the UV than the visual, massive stars are best studied in the UV. The UIT could in principle detect individual O stars at a distance modulus of 30. (However, in most objects beyond the Local Group, we must confine our attention to the integrated properties of young star clusters owing to UIT's limited spatial resolution.) The UV not only provides greater sensitivity to hot objects and much reduced cool star contamination, but it also yields much improved temperature discrimination (a factor of 5-10 relative to B-V photometry of comparable observational precision). Information on massive star populations yields important information on the associated problems of the supernova rate (and nucleosynthetic enrichment) and on the ionizing radiation field. UV energy distributions of hot star are also sensitive directly to their chemical composition.

Among the issues to be addressed are the variation in the IMF with radial position (and hence chemical abundance) in spirals; the distinction between star formation processes in spiral rams and in irregular galaxies lacking density waves; and the nature of violet bursts of star formation in the "starburst" systems, interacting galaxies, or galaxies with active nuclei.

Most of these problems require intermediate band continuum photometry with the use of 2200 Å band images to estimate extinction. Grating imagery can also be useful in determining integrated spectral energy distributions, isolated stars with strong P Cygni profiles, etc.

10.1 Normal spirals.

10.2 Normal irregulars

10.3 Normal E/SO's

Some E/SO systems, mostly low-luminosity or peculiar objects, exhibit evidence for relatively mild, recent star formation. It is important to press the search for this phenomenon to much lower levels using UV imagery for several reasons. First, the extent of recent star formation is an essential ingredient in understanding the cycling of material between stars and the interstellar medium of early-type galaxies and in assessing the role played by galactic winds. Second, continuing star formation at even low levels implies that the colors of E/SO galaxies viewed at significant lookback times can be much different than expected in simple "single generation" evolutionary models.

10.4 Dwarf systems

Younger populations in both dwarf irregulars, with obvious recent star formation, and dwarf ellipticals (e.g. NGC 205), with evidence for low amplitude bursts of star formation, can be studied to advantage in the UV.

10.5 High star formation rate systems

Objects, mostly irregular galaxies, with distributed, but intense, recent star formation. Included are spheroidal systems experiencing large scale star formation (e.g. NGC 1510, 5102) and "amorphous" systems like NGC 5253, which apparently are capable of smoothly distributed (unclumped) star formation, possible with an IMF truncated on the bright end.

10.6 Peculiar or interacting systems

10.7 Starburst/hot spot nuclei

Objects with localized, intense star formation bursts (e.g. M83, NGC 7714).

SCIENCE CATEGORY: 11. Advanced Stellar Evolution in Nearby Galaxies (Resolved Objects)

General: The study of hot phases of low-mass stellar evolution in nearby galaxies serves a dual purpose. First, it provides information on the early history of star formation and metal enrichment – particularly in the nearby dwarf spheroidal galaxies, whose properties contain clues to the evolution of the Galaxy/Magellanic Clouds system. Second, the ultimate stages of evolution are themselves of great Astrophysical interest. The evolutionary status of the various types of hot subluminous stars and the links between them are not understood, and there are apparently significant differences between the globular clusters and the Galactic field which are important to examine further.

The brightest O subdwarfs found by Greenstein and Sargent in the local field could be studied at the distance of M31 with UIT in long exposures. Stars on the hot horizontal branch will be visible in the nearer dwarf spheroidals (e.g. Draco, Sculptor, Ursa Minor). Analysis of the hot evolved star populations of the dwarf spheroidals, the Magellanic Clouds, and M31 will serve as a basis for interpretation of integrated UV energy distributions in more distant, E, SO and early-type spiral galaxies.

SCIENCE CATEGORY: 12. Integrated Stellar Populations (Galaxy Surface Photometry)

General: Stellar populations in galaxies too distant to resolve individual stellar types of interest can be analyzed by spectral synthesis of their integrated light. All of the problems discussed under Categories 10 and 11 are of interest in this context. One of the most important issues not covered there is that of the far-UV excess found to be common in early-type systems. This is apparently produced by low-mass stars with $T \geq 20,000$K. During Astro-1, UIT detected spatially extended far-UV excess populations which exhibited large color gradients. However, a positive identification of the hot component and an Astrophysical understanding of its relation to other populations are not available yet. Much more information on the spatial structure of this component and its dependence on galaxy morphology and luminosity are essential.

12.1 Normal spirals

12.2 Normal irregulars

12.3 Normal E/SO's

12.4 Dwarf systems

12.5 High star formation rate systems

12.6 Peculiar or interacting systems

12.7 Compact galaxies

12.8 Edge-on disks

12.9 Standard photometric calibrators

Observations of galaxies with excellent optical surface photometry available (e.g. NGC 3115, M31) can help to calibrate both the UIT and ST photometric systems.

SCIENCE CATEGORY: 13. Spiral Structure

General: The Hubble morphological sequence of galaxies encompassing the prominent spiral class is based on blue-sensitive emulsions. That the appearance of galaxies is wavelength-dependent is not surprising but is not widely recognized. Zwicky emphasized this point through his "composite analytical photography" technique. UV imaging offers a powerful new tool for the study of spiral structure, especially because it emphasizes the hot stars, H II regions, and dust features which are associated with spiral arms and suppresses the cool star background of the bulge and underlying disk. The arm-interarm contrast will be greatly enhanced.

13.1 Grand design

One may study the true "grand design" of spirals using the locus of hot stars which will emerge in the UV. The detailed distribution of hot stars and dust clouds near spiral features will help distinguish between the stochastic and density-wave models for the persistence of spiral structure.

13.2 Related structures (fragments, rings, inner arms, etc.)

13.3 Barred systems

Bar-like structures are present in many spirals. They may have important dynamical effects on the structure of galaxies and may in some cases (starburst galaxies) act as gas conduits feeding intense star formation. UV imaging will provide important new information on the nature of the stellar populations and interstellar material associated with bars.

13.4 Irregular galaxies

Incipient spiral structures in Irr galaxies may be identifiable in the UV and will shed light on the origin of spiral structure.

13.5 Anemic and related galaxies

These are spiral systems in which current star formation is inconspicuous at optical wavelengths. UV observations will emphasize such peculiarities and assist in determining the global history of star formation.

SCIENCE CATEGORY: 14. Interstellar Medium of Galaxies

General: The UV provides important advantages for ISM studies. The cool star background is minimized, isolating hot stars and emission regions. Uniquely important spectral features such as Lyman alpha are present, which can be studied in systems sufficiently redshifted to avoid the geocorona. C IV is an excellent signature of the more highly ionized regions associated with planetary nebulae or supernova remnants. Information on the carbon ionization equilibrium can be obtained by comparing C IV and C III], leading to improved carbon abundance estimates. Abundance gradients can be studied in nearby spirals with distributed H II regions.

Interstellar dust is particularly conspicuous because of its high UV extinction; this makes it important, for example, in searching for the presence of a thin ISM in E/SO galaxies. The 2200 Å feature is useful in separating extinction from temperature effects in integrated energy distributions. Its behavior in different environments is an important index of the physical nature of grains; the feature appears to be sensitive to metal abundance. It will be of particular interest to obtain the extinction law for grains in disturbed galaxies such as NGC 5128.

14.1 Spiral patterns

14.2 Distribution and extinction properties of dust grains

14.3 Interstellar medium in E/SO galaxies

14.4 Lyman alpha in H II regions (redshifted)

14.5 Identification of supernova remnants, planetary nebulae

14.6 Carbon abundances

14.7 Extended hot components in C IV

SCIENCE CATEGORY: 15. Circumgalactic Material

General: It has been recognized for many years that late-type galaxies are often surrounded by cool material (detectable in H I) which extends from a few to 10 Holmberg diameters. Interest in these circumgalactic regions has increased owing to the detection of multiple absorption systems in QSO's (suggesting the presence of halos extending up to 100 kpc around galaxies), hot gas in the halo of our galaxy, accretion flows in X-ray emitting clusters of galaxies, low surface brightness shells surrounding early-type galaxies, and tidal debris surrounding interacting systems.

The usefulness of the UV in the study of these regions was demonstrated by the detection of faint spiral features in M101, invisible in the optical, whose dust component was scattering UV light from the main body of the galaxy. Since the UV sky is up to 3 magnitudes fainter than the visible sky, there will be a significant gain in the detectability of faint extended regions with energy distributions equivalent to spectral type F5 or earlier. An object with an energy distribution like a star of (B-V) = 0 will yield a factor of 25 greater contrast against the sky at 2000 Å than in the visible. This means that UV imagery offers an advantage in the detection of circumgalactic regions which, for example, experienced star formation as long ago as several Gyr. It is also possible that hot halos of galaxies may be detectable in C IV resonance photons either emitting by the halo gas or scattered from the disk.

It is not possible to make good estimates of the UV brightness of most circumgalactic regions; UIT work in this area will mostly be based on very deep, broad band images.

15.1 Normal galaxies

15.2 Galaxies with extended H I distributions

15.3 Galaxies with optical shells

15.4 Peculiar or interacting systems

15.5 C IV resonance line scattering in hot halos

SCIENCE CATEGORY: 16. Active Galaxies

General: Much interest in galaxies containing active nuclei now centers on extended components: the classical narrow-lined regions, jets emitting non-thermal or thermal radiation (from entrained gas), and material associated with radio emitting lobes. These regions hold clues for the environmental processes which stimulate activity and for the transfer of energy between the nucleus and the surrounding medium. Although its spatial resolution for these problems is not as favorable as the HST's, UIT can make significant contributions. The dark UV sky and the faintness of the cool star background is a significant advantage. For instance, the well-known jet in M87 will be 1000 times brighter than the galaxy background at 1400 Å; star forming regions associated with nuclear activity, for instance the inner disk of Seyfert galaxies or the filaments of Cen A, can also be studied to advantage in the UV. Active nuclei produce higher ionization material, including C IV, which serves to distinguish nuclear-related gas from normal H II regions. THIS PROGRAM IS BASED PARTLY ON CO-OBSERVATION OF HUT OR WUPPE TARGETS.

16.1 Nonthermal jets and extended components

16.2 Ionized gas associated with active nuclei, jets, and radio lobes

16.3 Search for low-luminosity active nuclei in "normal" galaxies

Evidence is accumulating that many outwardly normal galaxies contain active nuclei which photoionize nuclear interstellar gas. The continuum radiation from the nuclei may be detectable in many cases in the UV. It is estimated that nonthermal nuclei up to 8 magnitudes fainter than the V flux in a spatial resolution element could be detected in a typical spiral bulge.

16.4 Stellar populations

SCIENCE CATEGORY: 17. QSO's

General: QSO's in the redshift range 0.4-1.8 will be detectable by UIT grating exposures through their characteristic spectral signature of Lyman emission lines and the Lyman absorption edge. Direct and grating exposures of high redshift QSO's (z's higher than 2) under study by HUT will provide important information on developing detection strategies for very high redshift objects in the dark UV sky, based on identification of the He I and He II resonance lines and continuum edges in the far-ultraviolet. It has been suggested that QSO's should possess halos of cool gas which would be visible as extended regions of Lyman alpha emission; ground-based studies have been unsuccessful in detecting such halos. Although UIT's resolution of 2 arcsec is not as favorable as the HST's, nonetheless studies of low redshift QSO's will be interesting in this regard. THIS PROGRAM IS BASED ON CO-OBSERVATION OF HUT OR WUPPE TARGETS.

17.1 Identification by UV grating

17.2 Far UV photometry/grating spectra

17.3 Lyman alpha halos

SCIENCE CATEGORY: 18. Clusters of Galaxies

General: Clusters of galaxies are the second largest recognized structural scale in the universe and the one on which most of our understanding of early galactic evolution will be based (through direct observations of clusters at large lookback times). Nearby clusters also afford the UIT, by virtue of its large field of view, the opportunity to obtain information on large samples of galaxies simultaneously. Clusters are also the sites of unique physical processes, most notably the recently-recognized accretion flows which result from the cooling of the hot, X-ray emitting intracluster gas.

18.1 Integrated UV properties of large galaxy samples, all types, for interpretation of objects at large redshifts.

Observations of distant galaxies increasingly suggest that strong evolution of stellar content has occurred over the last few billions years, at least for some fraction of the galaxy population. In particular, some clusters of galaxies at $z \sim 0.5$ contain a significant number of systems whose colors or spectra suggest recent bursts of star formation.

In order to understand the evolutionary state of these distant systems, UV observations of nearby clusters are essential for two reasons. First, the UV properties of galaxies of all types must be established at the current epoch in order to make proper K-corrections and evolutionary corrections to the light of distant galaxies. In order to average over individual evolutionary histories, it is important that large samples be obtained (and this is a task for which the HST is not well suited). Second, one can search in the UV for evidence of bursts of star formation 4-6 Gyr ago and determine the dependence of burst characteristics on galaxy luminosity, morphology, and environment. Calculations of model stellar populations demonstrate that maximum sensitivity to such bursts is obtained in the UV below 2500 Å in the rest frame.

18.2 Integrated Lyman alpha observations of galaxies

Lyman alpha imagery of normal galaxies has not yet been obtained. The UIT will be capable of obtaining integrated Lyman alpha fluxes for galaxies of all types in clusters with $z > 0.035$. Such observations will form a basis of comparison for assessing the evolutionary state of galaxies observed at large redshifts by HST. (Because of the dark UV sky background, Lyman alpha may well prove more useful than lines at longer wavelengths in estimating the ionizing radiation field in faint, high redshift systems.

18.3 Ionized intracluster matter, cooling flows

Cooling intracluster gas is estimated to produce accretion flows onto centrally dominant cD galaxies which in some cases exceed 100 $M_{\odot}$per year and which may radically alter the evolutionary history of the accreting system. UV imaging, especially in Lyman alpha and the C lines, will be important in placing constraints on the physics of the accretion flows; the advantage of minimum cool star contamination is important here.

18.4 Dark matter decay emission

Clusters are major repositories of "dark matter", and rich clusters contain far more dark than visible matter. A wide variety of suggestions have been made for the identity of the dark material, but several of the more viable alternatives, including massive neutrinos and photinos, would produce relatively narrow UV emission features during decay processes. The dark UV sky background, especially below 2000 Å, provides an excellent opportunity to detect or place useful limits on such emission.

SCIENCE CATEGORY: 19. Deep Extragalactic Surveys

General: The wide field of UIT and the dark UV sky background lend themselves to deep extragalactic surveys for distant star forming galaxies, AGN's and QSO's. Luminous star forming galaxies with little internal extinction are brighter in the UV than the optical and would remain detectable to $z \sim 1$, where they would be barely resolvable by UIT. Counts of starlike projects in the UV may provide information on the population of even more distant blue galaxies.

Some fields of special interest for these problems will be specifically observed. However, most of the relevant material is expected to be obtained during co-observation of fields surrounding targets of primary interest for other UIT, HUT or WUPPE programs, for example, high latitude QSO's observed by HUT. THIS PROGRAM IS BASED MAINLY ON CO-OBSERVATION OF HUT OR WUPPE TARGETS.

19.1 Deep UV observations of pre-selected or random fields

Observations have recently been made at the thresholds of the VLA, ground based optical telescopes and also the Einstein X-ray observatory of selected extragalactic fields. UV observations of these fields will yield important new information on the population of distant, hot objects or nonthermal sources. As noted above, other fields will be selected from other Astro programs for this program.

19.2 Search for high redshift blue galaxies

High redshift galaxies undergoing intense bursts of star formation could be readily recognized by their unique spectra on UIT grating frames. They would have a steeply-rising far-UV continuum (up to 20 times brighter at 1000 Å in the rest frame than at 5000 Å), punctuated by Lyman emission or absorption and by the Lyman discontinuity at 912 Å in the rest frame. The spatial density and luminosity distribution of such objects is unknown, and they would not be readily recognized by ground-based observations (though Schmidt prism surveys have turned up a reasonable number of intermediate redshift starburst systems). The dark UV sky background provides a significant advantage over the optical region.

19.3 Galaxian luminosity function at low luminosities

The luminosity function for galaxies is fundamental to a wide variety of studies including determination of corrections to the number-magnitude relation, derivation of the spatial covariance function from the projected angular covariance function, determination of the local mass and luminosity density, and evaluating the source of quasar absorption lines. The luminosity function is well determined for bright magnitudes, i.e. $M_B < -18$. At fainter magnitudes ($M_B > -10$), however, different determinations vary by as much as a factor of 1000.

The late-type (irregular dwarf) galaxies falling in this magnitude range are especially amenable to UV studies because the color index (UV to V) baseline is so large. Galaxies of $M_B \sim -10$ at a distance of 10 Mpc have an apparent B magnitude of +20 but a UV magnitude of +16, readily detectable by UIT.

Each deep UIT field could contain images of a number of dwarf galaxies. UIT observations will clearly and meaningfully constrain the faint end of the luminosity function. In addition to the imagery of fields surrounding prime targets which will be obtained in the course of other UIT programs, it will be important to include fields which do not contain clusters or significant groups ("blank" fields).

19.4 Identification of distant clusters of star forming galaxies

19.5 Deep galaxy counts

Counts of galaxies to faint ultraviolet magnitudes are a necessary complement to similar data in the blue and visual to evaluation evolutionary effects at cosmological distances.