The Scientific Contribution of the Hubble Space Telescope

Christian Schmidt

Karl-Franzens-Universität Graz

Abstract

A space observatory is an instrument in outer space which is used for observations of distant astronomical objects. Space telescopes, such as the Hubble Space Telescope, can observe these objects without a disturbing atmosphere, which enhances the sensibility for light out of the visible spectrum. The atmosphere is absorbing Gamma-, X-rays and big parts of the UV radiation. Especially unmatched results in the observations of the ultraviolet and infra red areas of light can be produced. The main problem is that these instruments are very expensive to build and to maintain and the major question now is if space observations provide an adequate advantage despite the enormous costs, keeping in mind that new techniques have been developed for ground-based telescopes that will make it able to minimize the disturbing influences of the atmosphere. In this article, the Hubble Space Telescope will be used as an example to show that important scientific knowledge has been gained as well as new understandings in terms of development and morphology of galaxies. With the Hubble Deep Field, which has been produced by the Hubble Space Telescope, scientists were able to take the deepest look in our Universe so far and were able to detect unobserved redshifts. Through these new cosmological discoveries, by the example of the Hubble Space Telescope, it is proved that additional insights can and will be made by investing in future space observatories and telescopes. Therefore, it has to be considered that the benefits do outweigh the costs.

I. Introduction

Since the recognition of the earth being part of a larger whole, scientists wanted to discover the vast reaches of the universe. With the development of telescopes and their use, people were able to gain insight into the expanse of the universe. By constantly developing bigger telescopes and the progress in technology, these telescopes were equipped with the latest instruments, due to which we were able to gather information about very distant objects in the universe. However, there are various disadvantages of ground-based telescopes. Mainly, they are disturbed by the earth's atmosphere. Through the use of latest technology, such as adaptive optics and better instruments, the negative effects of the atmosphere could be minimized, but there is no way to completely lose these effects for ground-based telescopes. To improve current knowledge of the universe, scientists had to manage to get telescopes and observatories out of that influence.

With the invention of space observatories such as the Hubble Space Telescope, scientists were able to observe the Universe without atmospheric disturbances. Furthermore, they were able to work with light which has been partially absorbed before. One example would be UV light with a wavelength of less than 300 *nm*, which is absorbed by ozone in the atmosphere. The sensitivity to infrared light was enhanced and satellites were able to measure gamma- and x-rays with unequalled precision. Current projects are used in a wide variety of applications, ranging from space observatories to space telescopes. Especially the famous Hubble Space Telescope has developed to a very successful and productive project. The Hubble Space Telescope (HST) was launched in April 1990 and is operating ever since. The uniqueness of this space telescope is its ability to work with a wide range of wavelengths. The HST is able to cope with redshift, which is a product of the expansion of the universe, and can observe UV light, which is emitted by stars, pulsars and highly excited gas. Additionally, it is equipped with cameras created to work with the visible band. Scientists were able to obtain information about very distant areas of the universe by observations of the HST, especially the Deep Field images. They now evaluate the data produced with new projects and instruments. The most important task is to interpret the results correctly and to implement them for future projects.

II. Methods

The Hubble telescope works with a 2,4 m aperture Ritchey-Chrétien telescope, which is capable of capturing in the wavelength region from 115 nm out to the thermal infrared [2]. Hubble works with infrared light ranging from 0.8 to 2.4 μm. This enables us to see very distant objects, whose light has been redshifted into the near infrared area. This cosmological redshift, due to the expansion of the universe, is given by

$$z = \frac{\lambda_{obsv} - \lambda_{emit}}{\lambda_{emit}} \quad (1)$$

The HST is able to see these wavelengths with instruments like NICMOS and the WFC3. The NICMOS (Near Infrared Camera and Multi-Object Spectrometer) is a instrument designed to work with the infrared area only. The data NICMOS gathered showed that the instrument achieves great results with wavelengths longer than $\lambda = 1.6 \mu m$. This means it works better than initially expected [5].
One of the best-known scientific outputs of the HST is the Hubble Deep Field (HDF).

Figure 1: Hubble Deep Field

The HDF image was produced by combining the older optical camera WFPC2 with the newer NICMOS data. Additionally, the HDF was improved to some extent with ground-based near-infrared photometry. The HST was able to detect galaxies 100 times fainter than the practical spectroscopic limits of 10-m ground based telescopes and was able to detect magnitudes of $V \sim 30$. The Hubble Deep Fields were focus of deep field surveys of nearly all wavelengths [4]. Redshifts spanning from $0.089 < 5.60$ were calculated, which is unmatched by any previous field survey. Important Information about the morphology of these very distant galaxies was gained. At higher redshifts, evidence that the galaxies are more compact and brighter than expected, was found. These galaxies appear to be more compact at an earlier stage of development than nearby galaxies. By incorporating near infrared data, the uncertainty in the estimated redshifts was reduced by 40 % and it was possible to remove systematic uncertainties within the redshift range $1 < z < 2$. In addition to this, evidence was found that the global star formation rate increases with the redshift with the peak at $z \approx 1.5$ [1]
Submillimetre-wavelength surveys of the HDF show that the star formation rate is about 5 times higher in the range $2 < z < 4$ than previously estimated. This was concluded after the NICMOS instrument contributed data, which yields that more matter in these redshift areas is present. [3]

III. Conclusion

The scientific impact of the HST was examined in 2001. The data for the scientific impact is given by the 100 most cited astronomy papers published between 1991 and 1998 and the 425 astronomy papers published in Nature during 1989-1998. It was concluded that the HST has about 15 times higher citation impact than a 4-m ground-based telescope, but costs 100 times more. [6]. According to this report, the enormous costs exceed the scientific output of the

HST.
However, without the HST observing previously unrivalled redshifts would have been impossible and very important information about the morphology and development of galaxies could not have been collected. The Deep Field allowed scientists to take a deeper look into the universe than ever before. Particularly the infrared sensitivity of the HST made it possible to gain this knowledge. With projects such as the James-Webb-Telescope, we will be able to use the gained knowledge to take an even deeper look into our Universe, the past of it and its origins, which is an immense value not only for science but also for mankind.

References

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