Investigating the Epoch of Galaxy Formation with Artificial Intelligence

by

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Abstract

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Publications

Preface

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Contents

"A dedication quote/sentence"

Acknowledgements

"A quote"

By whom *From what source*

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Chapter 1

Introduction

1.1 A title

Chapter 2

Herschel-ATLAS Data Release III

2.1 The Herschel-ATLAS

The *Herschel* Astrophysical Terahertz Large Area Survey (H-ATLAS; Eales et al. 2010) was the largest open-time sub-mm survey carried out with *Herschel*. The survey was observed across five photometric bands using two instruments onboard the *Herschel Space Observatory*: the Photodetector Array Camera (PACS, Poglitsch et al. 2010) at 100 and 160 μm, and the Spectral and Photometric Imaging Receiver (SPIRE, Griffin et al. 2010) at 250, 350 and 500 μm. Compared to the first SMGs (Assumption: I have already described SMGs and their initial discovery in the 90s.) detected using SCUBA at 850 μm(Smail et al. 1997; Barger et al. 1998; Hughes et al. 1998), the PACS and SPIRE wavebands span the peak of the infrared spectrum for low redshift (z < 1) galaxies. Their intrinsic brightness at the SPIRE wavelengths makes their detection in the thousands more achievable.

The complete survey covers $\sim 660\,\mathrm{deg}^2$, split into three regions located to avoid emission from Galactic dust and to utilize complimentary spectroscopic surveys including the Sloan Digital Sky Survey (SDSS, York et al. 2000), the 2df Galaxy Redshift Survey (2dfGRS, Colless et al. 2001) and the Galaxy and Mass Assembly (GAMA, Driver et al. 2009). The North Galactic Pole (NGP) region covers $\sim 180\,\mathrm{deg}^2$ of the northern sky, centered at R.A 13^h18^m and declination +29°13' (J2000); three equatorial fields, located at approximately R.A 9^h, 12^h and 15^h coinciding with the GAMA survey (henceforth named GAMA9, GAMA12 and GAMA15 fields), each with an area of approximately $54\,\mathrm{deg}^2$, and the South Galactic Pole (SGP) region, centered at R.A 0^h6^m and declination -32°44' (J2000) with an area of $\sim 318\,\mathrm{deg}^2$.

2.1.1 Detecting Submillimeter Sources on Herschel Images

Due to [...] sub-mm images suffer from two types of noise; instrumental noise [...] and confusion noise which is highly correlated between pixels, most of its contribution coming from the blending

together of faint sources. Source confusion is of particular importance to sub-mm surveys [...]. The result of combining instrumental noise with confusion noise is that almost all sources in the Herschel images are unresolved and the optimum filter for detecting these unresolved sources is no longer the point spread function (PSF). Consider a *Herschel* map in which there is only one source of noise: an image with instrumental noise but no confusion noise (i.e. there is only one point source and no fainter, confusing sources), the optimal detection of this source is obtained by convolving the image with the PSF of the instrument. On the other hand, a map with no instrumental noise, but many confused point sources would be optimally detected with its best signal to noise ratio (SNR) by taking the Fourier transform of the image, dividing by the Fourier transform of the PSF and taking the inverse Fourier transform to obtain a perfect deconvolution of the original map (Reference). For images that have a variable ratio of instrumental to confusion noise like the *Herschel* images of H-ATLAS, Chapin et al, 2011 showed that a convolving function or "matched filter" can be calculated to provide the maximum SNR for an unresolved source.
To detect H-ATLAS sources from the 250 μmmaps using a matched filter (the 250 μmband is the most sensitive of the SPIRE bands and given the lower sensitivity of the PACS instrument, all sources detected on the PACS images would also be detected on the SPIRE 250 μmimage), Maddox et al, 2020 developed a source detection algorithm called the Multi-band Algorithm for Source Detection and eXtraction (MADX). The MADX algorithm works in the following way. Firstly, Galactic dust emission is removed from the images using Nebuliser. Next, the images are convolved with the matched filter (which needs description). The variance map is created by convolving the map of variance in instrumental noise with the matched filter and adding the confusion noise. It is from this map that the SNR of a detected source is determined. The same process is repeated with the 350 and 500 μmmaps and interpolated to the same pixel scale as the 250 μmmaps. The detection map used to extract sources is then created from a weighted average of the three SPIRE maps, however, due to the smaller PSF at 250 μmwhich leads to more accurate positions and the increased number of sources when using the 250 μmmaps, zero weighting is given to the 350 and 500 μmimages.
Sources are identified by peak values $> 2.5\,\sigma$ in the filtered detection map.

2.1.2 Data Releases of the H-ATLAS

2.2 Identifying Multiwavelength Counterparts to Herschel Sources

2.2.1 The Likelihood Ratio Method

Chapter 3

Conclusion

"A quote"

By whom *From what source*

Appendix A

An Appendix

A.1 An Appendix

Bibliography

Barger A. J., Cowie L. L., Sanders D. B., Fulton E., Taniguchi Y., Sato Y., Kawara K., Okuda H., 1998, *Nature*, 394, 248

Colless M., et al., 2001, *MNRAS*, 328, 1039

Driver S. P., et al., 2009, Astronomy and Geophysics, 50, 5.12

Eales S., et al., 2010, *PASP*, 122, 499

Griffin M. J., et al., 2010, *A&A*, 518, L3

Hughes D. H., et al., 1998, *Nature*, 394, 241

Poglitsch A., et al., 2010, *A&A*, 518, L2

Smail I., Ivison R. J., Blain A. W., 1997, *ApJ*, 490, L5

York D. G., et al., 2000, *AJ*, 120, 1579