

DISSERTATION TITLE

By

Firstname Lastname

M.S. in Physics, 2020

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Dissertation approved on

June 30, 2023

by the following dissertation Committee:

Research advisor

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Second member

Third member

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With a project of this kind, there is also an enormous list of resources, services, and software to acknowledge:

This research made use of data provided by

ABSTRACT

DISSERTATION TITLE

Firstname Lastname

June 30, 2023

The Rosette nebula is a large, ring-shaped emission nebula with a distinctive central cavity excavated by its central cluster of OB stars. Toward understanding the three dimensional structure and fundamental physical processes of this object, we have acquired flux-calibrated, 4-degree field, deep exposures of the Rosette region through 3 nm bandwidth $H\alpha$ (656.3 nm) as well as $H\beta$ (486.1nm), [OIII] (500.7 nm) and [SII] (671.6 nm) filters with 4.5 nm bandwidth. The 4 arcsec/pixel images are supplemented with 4 degree field slit spectra and combined with archival data from the Galactic Evolution Explorer satellite (GALEX), Akari, the Infrared Astronomical Satellite (IRAS), the Midcourse Space Experiment (MSX), the Wide-field Infrared Survey Explorer (WISE), the Wilkinson Microwave Anisotropy Probe (WMAP) and the Planck mission, along with published single dish radio data of the hydrogen continuum at 1410, 2700, and 4750 MHz. These disparate sources have been converted to the same flux and spatial scale as our own wide field data to create a multispectral data cube which allows comparative analysis across the electromagnetic spectrum. Using ratios of data cube slices, spatial maps of extinction and ionization have been constructed to explore the spatial variation of these parameters across the nebula. Comparison of emission in different wavelengths across the data cube allows genera-

tion of a spectral energy distribution (SED) to probe dust temperature and geometry. A radial profile analysis of emission from the Rosette in each band supports a spherical shell model of three dimensional structure, and visual representations of this model have been generated in both Python and Javascript/GLSL. An investigation of anomalous dust emission in the center of the nebula via supplemental spectroscopy, conducted on the Anglo-Australian Telescope, is also presented.

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CHAPTER I

INTRODUCTION

I.1 About \LaTeX for Dissertations

\LaTeX is very widely used to produce dissertations in the sciences and engineering, particularly in Astronomy, Physics, Mathematics and Electrical Engineering where typesetting mathematics is critical. However, many university graduate programs specify dissertation styles that are based on Microsoft Word and do not have the philosophy that is at the core of \LaTeX . That is, \LaTeX was created so that someone could take the burden of layout and style from you, and let you simply write. Regrettably, the current generation of powerful word processing software including Word, LibreOffice, and Google Docs, offer considerable freedom, but start with a blank page and hand to you the task of making everything look consistent, conform to a required style, and possibly even look beautiful. You will likely spend as much time creating formats and trying to “control” the program as you will in writing. Additionally, entering mathematics in these systems is tedious, and the results are sometimes disappointing. By contrast, with \LaTeX there are hundreds of style files available written by students or their advisors to help conform to their school’s requirements. The downside is that in reality, unless you are skilled at \LaTeX coding, you need a *class* file to start with that produces at least a close facsimile to a standard style for your university.

This package is one such attempt for the University of Louisville. It is now in its 6th generation and now it is based on the *memoir* L^AT_EX class that is designed for customized layouts. The result, while not a perfect emulation of the standard shown in our most recent dissertation guide, is close. It can be customized to fit your discipline, and it should be straightforward to modify both the class file and the template dissertation source file for those specific issues that may come up in your own writing.

Another advantage to using L^AT_EX is that most science journals provide templates for submitting articles in this format. It is very simple to modify all or parts of your dissertation for submission to those journals for publication, or in the reverse, to take the source you used for published papers and incorporate it into your dissertation document.

To that end the Overleaf website offers on-line storage of your documents, web-based editing, compiling, pdf production and sharing of the resource files.

<http://www.overleaf.com>

Use this resource so that you do not have to maintain a L^AT_EX system on your own computer, and to have interactive help with immediate display of your formatted dissertation. It allows you to share your work with your advisor too and fellow students too.

In order to expedite your writing, it is strongly recommended that you begin using a bibliography file very early on, and add to it as you develop content for your dissertation. With that, including citations in the dissertation is simple, and L^AT_EX with *bibtex* will organize citations for you. An example **.bib** file is included in this package and you will find support with Google searches if you need to know how to add entries. The style of the bibliography and the citations can be changed by altering only a few lines of the source documents.

For Physics and Astronomy, if you need a citation try using the NASA ADS website <https://ui.adsabs.harvard.edu/> to search for relevant papers. The archive includes most of the mainstream physics literature, and essentially all of astronomy and astrophysics. For any entry you find, there is a clickable link that will generate a bibliography entry for *bibtex*. Many journals that are included in the database are identified by acronyms in the bibliography, and a list of them is in the file “journals.tex” which is included in the ulthesis template.

I.2 How to Write a Dissertation

The body of the work goes here. You may benefit from reading a book on writing for scientists and engineers. Although now from the past century, a good one is **The Technical Writer’s Handbook** by Matt Young [1]. Above all, follow the advice of your research advisor.

Here is a short list of grammatical “do’s” that appeared in the Physical Review Letters and still remains useful in technical writing today [2] –

1. Make sure each pronoun agrees with their antecedent.
2. Just between you and I, the case of pronouns is important.
3. Watch out for irregular verbs which have crope into English.
4. Verbs has to agree in number with their subjects.
5. Don’t use no double negatives.
6. Being bad grammar, a writer should not use dangling modifiers.
7. Join clauses good like a conjunction should.
8. A writer must not shift you point of view.
9. About sentence fragments.

10. Don't use run-on sentences you got to punctuate them.
11. In letters essays and reports use commas to separate items in series.
12. Don't use commas, which are not necessary.
13. Parenthetical words however should be enclosed in commas.
14. Its important to use apostrophes right in everybodys writing.
15. Don't abbrev.
16. Check to see if you any words out.
17. In the case of a report, check to see that jargonwise, it's A-OK.
18. As far as incomplete constructions, they are wrong.
19. About repetition, the repetition of a word might be real effective repetition.
20. In my opinion, I think that an author when he is writing should definitely not get into the habit of making use of too many unnecessary words that he does not really need in order to put his message across.
21. Use parallel construction not only to be concise but also clarify.
22. It behooves us all to avoid archaic expressions.
23. Mixed metaphors are a pain in the neck and ought to be weeded out.
24. Consult the dictionery to avoid mispelings.
25. To ignorantly split an infinitive is a practice to religiously avoid.
26. Last but not least, lay off cliches.

I.3 Overview on Figures

The Rosette Nebula (NGC 2237-39, 44, 46) is a large and distinctive ring-shaped HII region occupying better than a degree of the northern sky. It is situated just south of the galactic plane in the constellation Monoceros. The nebula is shown in Fig. 1.

Figures are included by reference this way: `Fig.\ref{fig:optical}` using a label that is included in the figure caption within the \LaTeX source. See the tex files in this package for examples such as this one.

I.4 About Sections and Equations

\LaTeX accepts input from a file and uses it in place. Your master file will read the chapter files, which enables you to write one chapter at a time easily. Within a chapter you may have sections such as this one taken from a recent astrophysics dissertation. [3]. It shows how to use the *align* option to display a multi-line set of equations.

One of the defining physical processes of HII regions is the equilibrium between ionization and recombination within the gas. For clarity, it is useful to consider the case of a single ionizing star in a cloud of pure, uniform hydrogen gas. The ionization equilibrium can then be expressed by equation

$$n(H^0) \int_{\nu_0}^{\infty} \frac{4\pi J_{\nu}}{h\nu} a_{\nu}(H^0) d\nu = n(H^0) \int_{\nu_0}^{\infty} \phi_{\nu} a_{\nu}(H^0) d\nu \quad (1)$$

$$= n(H^0) \Gamma(H^0) = n_e n_p \alpha(H^0, T). \quad (2)$$

Here, $n(H^0)$, n_e , and n_p are the density per unit volume of the neutral atom, electron, and proton respectively, while $\alpha(H^0, T)$ is the recombination coefficient [4]. Therefore, the right-hand side of the equation gives the number of recombinations per unit volume per unit time. At equilibrium, this recombination rate will be equal to the rate of ionization per unit time, shown on the left-hand side of the expression. There,

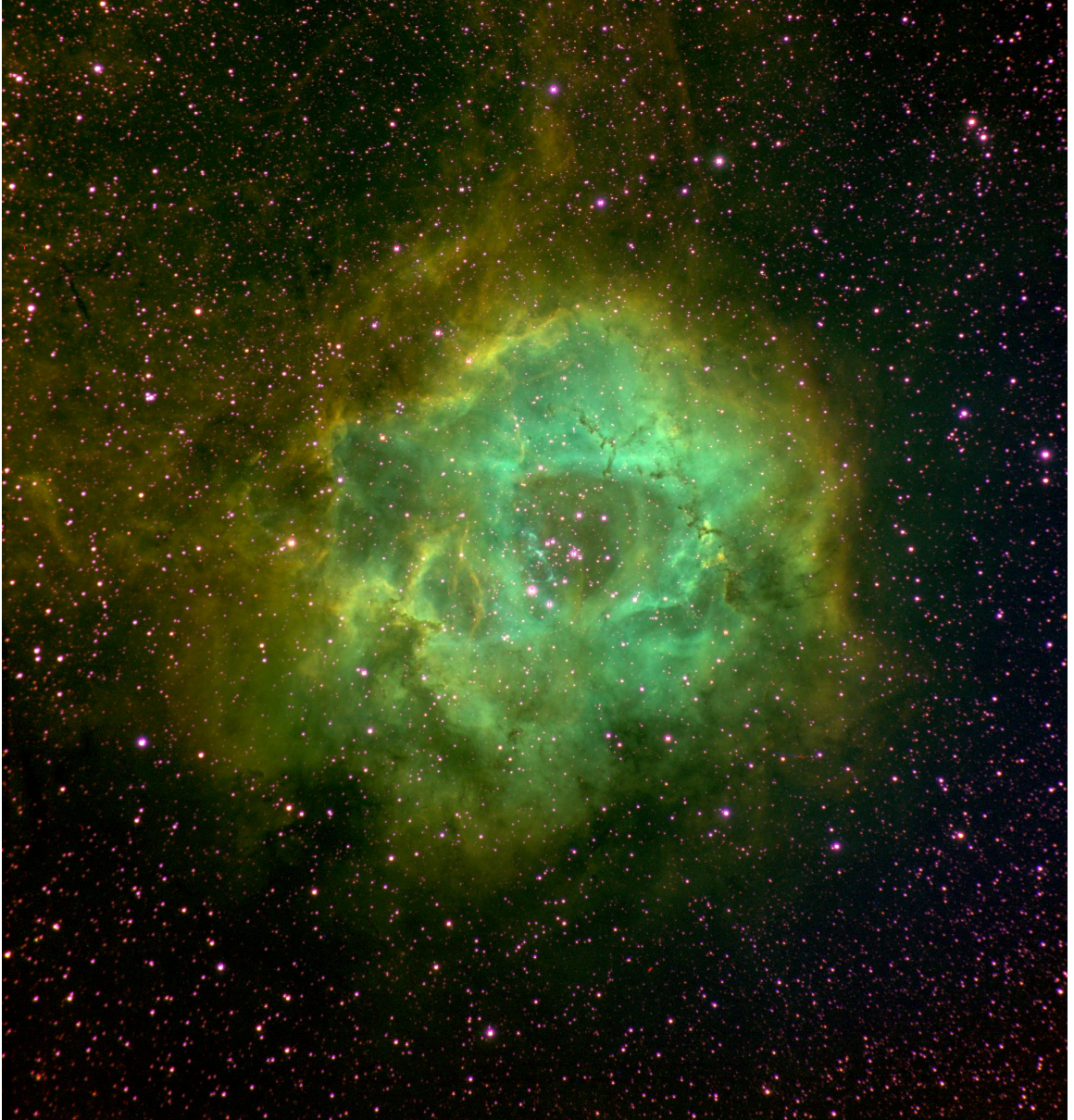


Figure 1. A false color view of the Rosette nebula composited from imagery collected during this project. The standard Hubble color scheme is used, with red [SII] emission, green $H\alpha$, and blue [OIII] emission. All filters are square root scaled, and relative flux from [OIII] and [SII] has been enhanced for clarity. [3]

J_ν is the mean intensity of radiation in energy units per unit area, per unit time, per unit solid angle, per unit frequency interval and therefore $\phi_\nu = 4\pi J_\nu/h\nu$ is the incident photons per unit area, per unit time, per unit frequency interval. The threshold energy for ionization is $h\nu_0$ (13.6 eV) and therefore ν_0 is the threshold frequency for an ionizing photon (3.29×10^{15} Hz). The quantity $a_\nu(H^0)$ is the ionization cross section for hydrogen by photons above the threshold energy, and consequently the integral product $\Gamma(H^0)$ gives the number of photoionizations per atom per unit time, as expected [4].

A single line equation would be done this way.

$$\int_{\nu_0}^{\infty} \frac{L_\nu}{h\nu} d\nu = N_{UV} = \left(\frac{4\pi}{3}\right) R_S^3 n_e n_p \alpha_B. \quad (3)$$

As Eqs. 2 and 3 illustrate, it is often considered good practice to treat them as sentences and to punctuate them with a “.” when appropriate. This style is not universal.

CHAPTER II

OBSERVATIONS

II.1 Our Data

The narrow band, wide field data collected are inventoried in Table 1, which may be used as an example of how to include a table in your dissertation.

II.2 Archival Data

Add sections to your chapters as needed. This example also shows how to incorporate references to the literature by use of a bibliography file and a `\cite` instance.

Because the Rosette has such a large angular size on the sky, wide field single dish radio data covering the entire region were limited. Among the most recent of the available data were 1410 and 4750 MHz continuum maps by Celnik [5], and a 2700 MHz continuum map by Graham [6]. Due to their age, these data were presented in the form of printed contour maps. Fortunately, calibration information is included in tabular form, allowing a flux calibrated map to be recreated. The original digital data are not available.

Table 1. A complete list of all bands included in the data cube, along with identifying index numbers and a summary of physical processes responsible for this type of emission.

Instrument	Band Index	Wavelengths (m)	Frequencies (Hz)	Nebula Processes
Effelsberg 100 m	1	2.127×10^{-1}	1.410×10^9	HI 21 cm line and free-free emission.
	2	1.111×10^{-1}	2.700×10^9	
	3	6.316×10^{-2}	4.750×10^9	
WMAP	4	1.364×10^{-2}	2.280×10^{10}	Free-free, thermal dust, synchrotron, thermal dust, CO line, & anomalous microwave emission (likely due to spinning dust).
	6	1.000×10^{-2}	3.300×10^{10}	
	7	7.500×10^{-3}	4.070×10^{10}	
	9	5.000×10^{-3}	6.080×10^{10}	
	11	3.333×10^{-3}	9.350×10^{10}	
Planck	5	1.000×10^{-2}	3.000×10^{10}	Free-free, thermal dust, synchrotron, thermal dust, CO line, & anomalous microwave emission (likely due to spinning dust).
	8	6.818×10^{-3}	4.400×10^{10}	
	10	4.286×10^{-3}	7.000×10^{10}	
	12	3.000×10^{-3}	1.000×10^{11}	
	13	2.098×10^{-3}	1.430×10^{11}	
	14	1.383×10^{-3}	2.170×10^{11}	
	15	8.499×10^{-4}	3.530×10^{11}	
	16	5.505×10^{-4}	5.450×10^{11}	
Akari	17	3.501×10^{-4}	8.570×10^{11}	Thermal continuum from dust, line emission from [OI], [OII], [CII] and others.
	18	1.600×10^{-4}	1.875×10^{12}	
	19	1.400×10^{-4}	2.143×10^{12}	
	21	9.000×10^{-5}	3.333×10^{12}	
IRAS	22	6.500×10^{-5}	4.615×10^{12}	Thermal dust emission, PAH band emission.
	20	1.000×10^{-4}	3.000×10^{12}	
	23	6.000×10^{-5}	5.000×10^{12}	
	24	2.400×10^{-5}	1.2500×10^{13}	
MSX	29	1.200×10^{-5}	2.500×10^{13}	Thermal dust emission, PAH band emission
	26	2.134×10^{-5}	1.410×10^{13}	
	27	1.465×10^{-5}	2.040×10^{13}	
	28	1.213×10^{-5}	2.479×10^{13}	
WISE	31	8.280×10^{-6}	3.623×10^{13}	Thermal dust emission, PAH band emission, and CO line emission
	25	2.200×10^{-5}	1.364×10^{13}	
	30	1.200×10^{-5}	2.500×10^{13}	
	32	4.600×10^{-6}	6.522×10^{13}	
FSQ	33	3.400×10^{-6}	8.824×10^{13}	hydrogen, oxygen, and sulfur atomic line emission
	34	6.723×10^{-7}	4.462×10^{14}	
	35	6.565×10^{-7}	4.570×10^{14}	
	36	5.008×10^{-7}	5.990×10^{14}	
GALEX	37	4.863×10^{-7}	6.169×10^{14}	helium line emission UV dust scatter
	38	2.271×10^{-7}	1.321×10^{15}	

Rosette Region Data

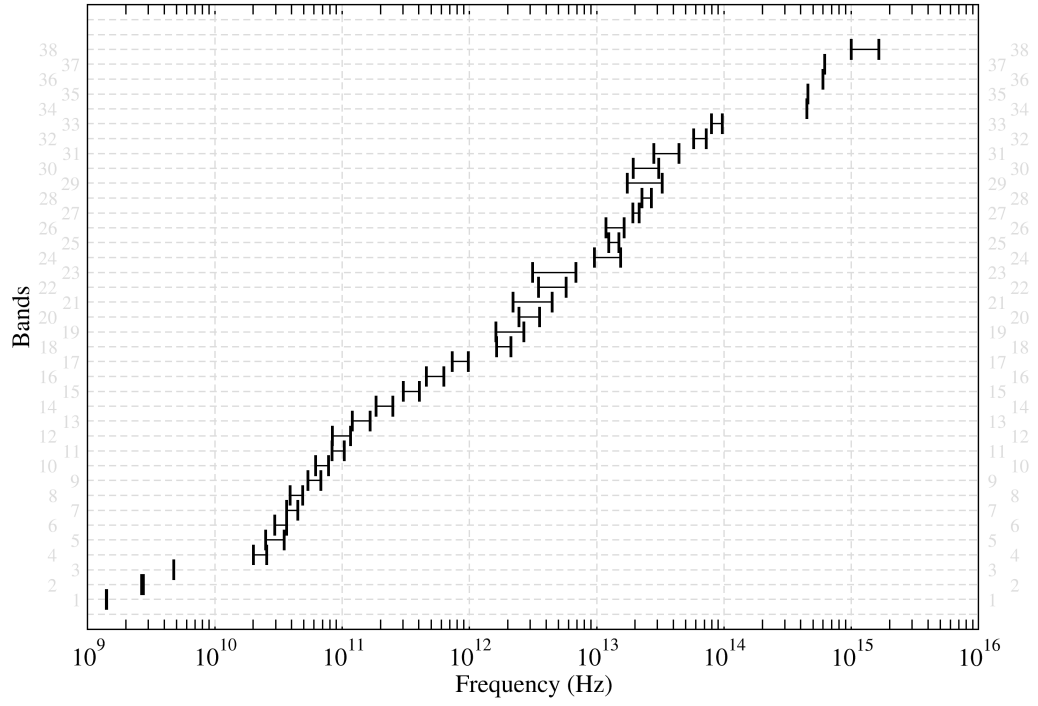


Figure 2. A visualization of frequency bandwidth coverage for each Rosette data cube slice. Index values on the vertical axis correspond to those in Table 1.

CHAPTER III

ANALYSIS

You may prefer to begin a new chapter without a section number to offer a paragraph that describes what is coming. A more organized style would use a section perhaps called “Summary” at the top of the chapter.

III.1 What to Make of our Data

As a first step, it was necessary to determine

A survey of the literature shows some uncertainty in

The resulting map of V-band extinction is shown in Fig. 3.

The figure is an example of how to use a short caption that will appear in the list of figures in the front matter, and to include a label that is used in the reference in the text. Take care not to confuse `\ref` with `\cite`. The former is for a label, the latter for a literature citation.

III.2 Additional Analysis

Of course you may add other sections to the analysis within the master chapter file. Alternatively, you can add to the chapter with separate files by using the `input` command within the main dissertation file.

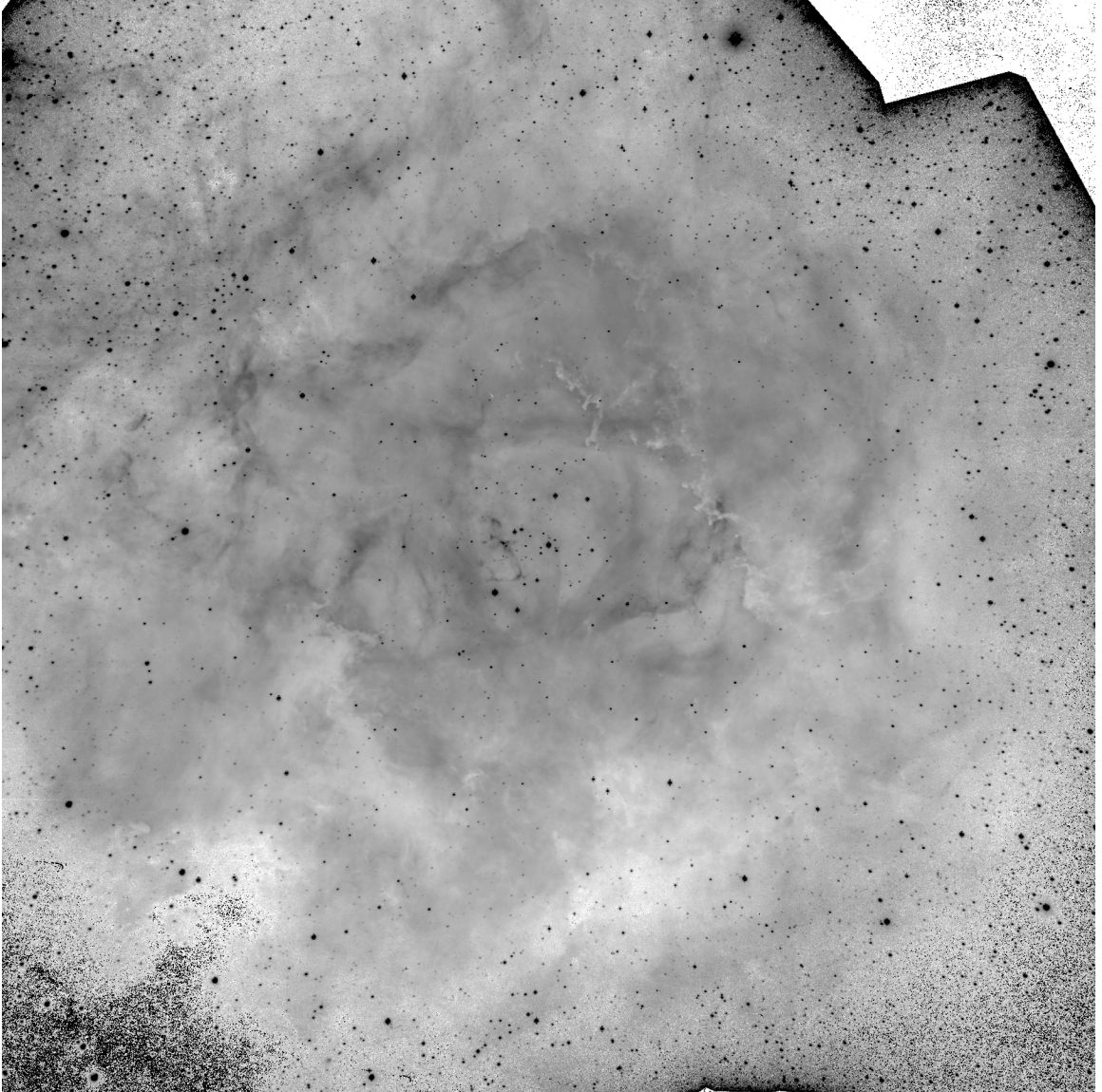


Figure 3. A plot of V-band extinction ($A(V)$) across the Rosette Nebula, derived from the flux calibrated 1410 MHz / $H(\alpha)$ ratio map and reddening factors determined from Cardelli 1989 [7]. The map is shown on a square root scale from a minimum ratio value of zero to a maximum of 7. Note that the Effelsberg 1410 MHz data had a half power beam width of 9.24 arcminutes, so detail below that level is oversampling from the $H\alpha$ map. This map was used in the extinction correction of the $[OIII]/[SII]$ map of the ionization parameter discussed later.

CHAPTER IV

CONCLUSIONS

IV.1 Conclusions

After all that work, what have you found out?

The thesis created by this L^AT_EX class should meet the requirements of the Graduate School. However, before you print it, ask them to review it for style with enough lead time to make changes as needed. The class file you are using was written in January 2018 to match a style manual dating from 2015. The output will have some characteristics of the L^AT_EX system that may seem odd to someone used to processing with Microsoft Word. Making global changes in the class file is not trivial but often a solution can be found by searching Stackexchange or other web resources. If you encounter problems in producing the desired format you cannot solve, please contact Prof. Kielkopf in the Department of Physics and Astronomy. If you find something you think should be shared with other students writing dissertations, also please let me know so that it can be added.

REFERENCES

- [1] M. Young, *The Technical Writer's Handbook* (University Science Books, 1989).
- [2] G. L. Trigg, "Grammar," *Physical Review Letters* **42**, 747–748 (1979).
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- [6] D. A. Graham, C. G. T. Haslam, C. J. Salter, and W. E. Wilson, "A continuum study of galactic radio sources in the constellation of Monoceros," *Astronomy and Astrophysics* **109**, 145–154 (1982).
- [7] J. A. Cardelli, G. C. Clayton, and J. S. Mathis, "The relationship between infrared, optical, and ultraviolet extinction," *Astrophysical Journal* **345**, 245–256 (1989).

APPENDIX A: COMMONLY USED ACRONYMS

In scientific writing the use of acronyms (sometimes senseless letters, sometimes cute names) is common. It can be *very* annoying to a reader who is not a specialist in your discipline. Be cautious about how you use acronyms and always define them on first use. It is helpful to the reader to keep a list as you write, and to have an appendix such as this one in which you explain them. This is a simple listing, but a **description** environment would be nicer.

AAT - Anglo-Australian Telescope

GALEX - Galaxy Evolution Explorer

HFI - Planck's High Frequency Instrument

HPBW - Half Power Beam Width

IRAS - Infrared Astronomical Satellite

IRSA - Infrared Science Archive

LFI - Planck's Low Frequency Instrument

LTE - local thermodynamic equilibrium

JAXA - Japanese Aerospace Exploration Agency

JPL - Jet Propulsion Laboratory

LAMBDA - Legacy Archive for Microwave Background Data Analysis

MAST - Mikulski Archive for Space Telescopes

MSX - Midcourse Space Experiment

NASA - National Aeronautics and Space Administration

PAH - polycyclic aromatic hydrocarbons

PDR - photodissociation region

PSF - point spread function

SED - spectral energy distribution

SNR - supernova remnant

WCS - world coordinate system

WISE - Widefield Infrared Survey Explorer

WISPI - Widefield Spectral Imager

WMAP - Wilkinson Microwave Anisotropy Probe

YSO - young stellar object

ZAMS - zero age main sequence

APPENDIX B: CODE

This is an example of how to include code listing within dissertation. For help see the Overleaf page about presenting code in \LaTeX from which this Python example is taken.

```
import numpy as np

def incmatrix(genl1, genl2):
    m = len(genl1)
    n = len(genl2)
    M = None #to become the incidence matrix
    VT = np.zeros((n*m,1), int) #dummy variable

    #compute the bitwise xor matrix
    M1 = bitxormatrix(genl1)
    M2 = np.triu(bitxormatrix(genl2),1)

    for i in range(m-1):
        for j in range(i+1, m):
            [r, c] = np.where(M2 == M1[i, j])
            for k in range(len(r)):
                VT[(i)*n + r[k]] = 1;
                VT[(i)*n + c[k]] = 1;
```

```

VT[(j)*n + r[k]] = 1;
VT[(j)*n + c[k]] = 1;

if M is None:
    M = np.copy(VT)
else:
    M = np.concatenate((M, VT), 1)

VT = np.zeros((n*m,1), int)

return M

```

CURRICULUM VITAE

Your Name Here

Education

Ph.D., University of, Location, ST, Month Year ...

M.S. , University of, Location, ST, Month Year ...

B.S. University of, Location, ST, Month Year ...

Professional Positions

Visiting Assistant Professor of ..., dates

Graduate Research Assistant in ..., dates

Other positions ...

Honors and Awards

List professional or other awards and honors you want to have recorded forever.

Publications and Presentations

List papers and other works preceding this dissertation