An Example Thesis Made With LaTeX for Astronomy Students

by

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B.Sc., University of WhoKnowsWhere, 2053
M.Sc., University of AnotherOne, 2054

A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

in the Department of Physics and Astronomy

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Abstract

This document is a possible Latex framework for a thesis or dissertation at UVic. It should work in the Windows, Mac and Unix environments. The content is based on the experience of one supervisor and graduate advisor. It explains the organization that can help write a thesis, especially in a scientific environment where the research contains experimental results as well. There is no claim that this is the *best* or *only* way to structure such a document. Yet in the majority of cases it serves extremely well as a sound basis which can be customized according to the requirements of the members of the supervisory committee and the topic of research. Additionally some examples on using LaTeXare included as a bonus for beginners.

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Acknowledgements

I would like to thank:

my cat, Star Trek, and the weather, for supporting me in the low moments.

Supervisor Main, for mentoring, support, encouragement, and patience.

Grant Organization Name, for funding me with a Scholarship.

surprisingly appropriate quote from video game
Donkey Kong

Dedication

Input any dedications here.

Chapter 1

Introduction

The main goal of this AstroExample PDF, is to give an overview of what this template thesis will look like to the user. Additionally, the different sections contained within give specific examples of how to properly integrate typical astronomy-related content into a thesis. Chapter 2 will cover what I believe to be the most comprehensive table packages that work well together, while also fulliling typical conventions for astronomy (these have been layed out similar to the `deluxetable` environment in AASTex). Chapter 2.3 will cover how to properly cite references in a thesis, using the `natbib` package and the `aasjournal` bibliography style.

1.1 UVic-based Information

Unfortunately, UVic no longer provides a LaTeXtemplate for thesis writing. This used to be found on the UVicSpace site at the following location https://libguides.uvic.ca/uvicspace/etds/latextemplate. Although there are useful related links found there, an actual template is not provided.

What is somewhat useful, are the sample pages and UVic Thesis Guide, found at the following: https://www.uvic.ca/graduatestudies/forms-policies/data/sample-samplepages.pdf. This guide is what UVicSpace will accept in terms of formatting and content. The thesis template provided here conforms to these guidelines as of the writing of this document.

Chapter 2

Tables

Similarly with other topics in LaTeX, there are a multitude of different ways to achieve the same output. As with most basic implementations, Overleaf has fantastic resources. The following link is a great place to start for basic and slightly more advanced table implementations: https://www.overleaf.com/learn/latex/Tables.

2.1 Comprehensive Tables

This section will cover what I believe is a fantastic way to implement basic and complex tables. This comes from my experience in working with the `deluxetable` environment in AASTex, and the related `aastex` package. Through the process of converting my paper content into my thesis template, I found that the `deluxetable` environment was not compatible with the University's thesis template, at least not to the extend that I needed it to be (the only change I could not make was the automated setting for the fontsize of the table).

Because of this, I searched for a more basic implementation in some other packages and workflows. While the generic `tabular` environment is a great place to start, it does not account for the complex table implementations that I needed (tables with merged cells, tables that spilled over pages, landscape tables, etc.).

The following is a list of the packages that allowed me the most flexibility in creating tables that I needed for my thesis. These are in order of the most basic to the most complex:

2.1.1 Basis Packages

These are what I describe as basis packages, which add in the ability to create tables that are more complex than the basic `tabular` environment, but are not as complex as the packages that will be discussed later in this section, which essentially have the abilities to *merge* these environments together under one umbrella environment.

- `longtable` - Allows the ability for tables to continue onto the next page. This is great for tables that are too long to fit on a single page.
- `tabularx` - Allows the column designator `x` to be used, which will automatically adjust the column width in order for the table to fill the declared width of the environment.
- `threeparttable` - Provides a scheme for tables that have a structured note section after the caption.
- `booktabs` - Provides some additional commands to enhance the quality of tables.
- `caption` - Provides the ability to customize the caption of the table. Specifically useful for tables that are too long to fit on a single page (continued captions).
- `multirow` - Provides the ability to merge cells in the row direction.
- `pdflscape` - Provides the ability to create landscape tables.

2.1.2 Extension Packages

As mentioned above, these packages are extensions of the basic packages, and allow for more complex table implementations. These are what made all the different packages work together in a seamless way.

- `threeparttablex` - This package extends the `threeparttable` package to work with tables created using the `longtable` package.
- `xltabular` - This package extends the `longtable` and `tabularx` packages to work together. Introduces the `xltabular` environment.

2.2 Example Tables

Here is a regular `tabular` environment, modified by the `booktabs` package. This is a great way to start creating tables, as it is simple and easy to understand. The `booktabs` package provides some additional commands to enhance the quality of tables such as the `toprule`, `midrule`, and `bottomrule` commands.

The following is the templated code for the table:

```
1 \begin{table}[h!]
2     \centering
3     \begin{tabular}{cccccccc}
```

```
        \toprule
        {$m$} & {$M_\odot$} & {$R_\odot$} & {$L_\odot$} & {$A_\nu$} & {$A_m$} & {$\varphi(m)$} & {$\varphi(a)$} \\ \midrule
        1  & 16.128 & +8.872 & 16.128 & 1.402 & 1.373 & -146.6 & -137.6 \\
        2  & 3.442  & -2.509 & 3.442  & 0.299 & 0.343 & 133.2  & 152.4  \\ \midrule
        3  & 1.826  & -0.363 & 1.826  & 0.159 & 0.119 & 168.5  & -161.1 \\
        4  & 0.993  & -0.429 & 0.993  & 0.086 & 0.08  & 25.6   & 90     \\ \bottomrule
    \end{tabular}
\end{table}
```

The compiled from the above templated code is the following:

m	$M_\odot$	$R_\odot$	$L_\odot$	A_ν	A_m	$\varphi(m)$	$\varphi(a)$
1	16.128	+8.872	16.128	1.402	1.373	-146.6	-137.6
2	3.442	-2.509	3.442	0.299	0.343	133.2	152.4
3	1.826	-0.363	1.826	0.159	0.119	168.5	-161.1
4	0.993	-0.429	0.993	0.086	0.08	25.6	90

Extending this to use a `threeparttable` environment, including a caption and notes, would be the following:

```
\begin{table}[h!]
    \centering
    \begin{threeparttable}
        \caption{Example Table with ThreePartTable and Caption
        \label{tab : example-table-threeparttable }}
        \begin{tabular}{cccccccc}
            \toprule
            {$m$} & {$M_\odot$} & {$R_\odot$} & {$L_\odot$} & {$A_\nu$} & {$A_m$} & {$\varphi(m)$} & {$\varphi(a)$} \\ \midrule
            1  & 16.128 & +8.872 & 16.128 & 1.402 & 1.373 & -146.6 & -137.6 \\
            2  & 3.442  & -2.509 & 3.442  & 0.299 & 0.343 & 133.2  & 152.4  \\ \midrule
            3  & 1.826  & -0.363 & 1.826  & 0.159 & 0.119 & 168.5  & -161.1 \\
            4  & 0.993  & -0.429 & 0.993  & 0.086 & 0.08  & 25.6   & 90     \\ \bottomrule
        \end{tabular}
        %
```

```
        \begin{tablenotes}[flushleft]
            \footnotesize
            \item \textbf{First Note:} This is a note.
            \item \textit{Second Notes:} This is also a note.
        \end{tablenotes}
    \end{threeparttable}
\end{table}
```

The compiled from the above templated code is the following:

Table 2.1: Example Table with ThreePartTable and Caption

m	$M_\odot$	$R_\odot$	$L_\odot$	A_ν	A_m	$\varphi(m)$	$\varphi(a)$
1	16.128	+8.872	16.128	1.402	1.373	-146.6	-137.6
2	3.442	-2.509	3.442	0.299	0.343	133.2	152.4
3	1.826	-0.363	1.826	0.159	0.119	168.5	-161.1
4	0.993	-0.429	0.993	0.086	0.08	25.6	90

First Note: This is a note.
Second Notes: This is also a note.

Expanding now to use the `tabularx` environment for automatic re-sizing of the columns. For reference, in this example, all columns but the first use the `X` designation. The following code would be used:

```
\begin{table}[h!]
    \centering
    \begin{threeparttable}
        \caption{Example Table with ThreePartTable and Caption
        \label{tab: example-tabularx}}
        \begin{tabularx}{\textwidth}{cXXXXXXX}
            \toprule
            {$m$} & {$M_\odot$} & {$R_\odot$} & {$L_\odot$} & {$A_\nu$} &
    {$A_m$} & {$\varphi(m)$} & {$\varphi(a)$} \\ \midrule
            1  & 16.128 & +8.872 & 16.128 & 1.402 & 1.373 & -146.6 &
    -137.6 \\
            2  & 3.442  & -2.509 & 3.442  & 0.299 & 0.343 & 133.2  & 152.4
      \\ \midrule
            3  & 1.826  & -0.363 & 1.826  & 0.159 & 0.119 & 168.5  &
    -161.1 \\
            4  & 0.993  & -0.429 & 0.993  & 0.086 & 0.08  & 25.6   & 90
      \\ \bottomrule
        \end{tabularx}
```

```
        %
        \begin{tablenotes}[flushleft]
            \footnotesize
            \item First Note: This is a note.
            \item Second Notes: This is also a note.
        \end{tablenotes}
    \end{threeparttable}
\end{table}
```

The compiled from the above templated code is the following:

Table 2.2: Example Table with ThreePartTable and Caption

m	$M_\odot$	$R_\odot$	$L_\odot$	A_ν	A_m	$\varphi(m)$	$\varphi(a)$
1	16.128	+8.872	16.128	1.402	1.373	-146.6	-137.6
2	3.442	-2.509	3.442	0.299	0.343	133.2	152.4
3	1.826	-0.363	1.826	0.159	0.119	168.5	-161.1
4	0.993	-0.429	0.993	0.086	0.08	25.6	90

First Note: This is a note.
Second Notes: This is also a note.

The last example will be a combination of all the above packages, including the `longtable` package to allow the table to continue onto the next page, the `multirow` package to merge cells in the row direction, and the `pdflscape` package to create a landscape table. The following code will be used (data and header information have been selectively trimmed for readability):

```
\begin{landscape}
    \begin{ThreePartTable}
        \begin{TableNotes}[flushleft, para]
            \footnotesize
            $^{\text{a}}$ Properties of the Gaussian fit to the ALMA
   emission: peak flux, integrated flux, major and minor axes of the FWHM,
    and position angle of the FWHM. \\
            $^{\text{b}}$ Properties of the deconvolved Gaussian fit:
   major and minor axes of the FWHM, and position angle of the FWHM.
   Unresolved sources are indicated by values of -1.
        \end{TableNotes}
        \centering
        \scriptsize
        \begin{xltabular}{\linewidth}{Xccccccccccccc}
            \caption{Observed Properties of ALMA Detections
```

```
12            \label{tab:observed-properties}}\\
13            \toprule
14            Scr &  R.A.  &  Decl. & Pk$^{\text{a}}$ & Pk$_{\text{err
    }}$$^{\text{a}}$ & Tot$^{\text{a}}$ & Tot$_{\text{err}}$$^{\text{a}}$ &
     FWHM$_{\text{a}}$$^{\text{a}}$ & FWHM$_{\text{b}}$$^{\text{a}}$ &  P.A
    .$^{\text{a}}$ & \multicolumn{2}{c}{FWHM$_{\text{a,d}}$$^{\text{b}}$ (
    arcsec)} & \multicolumn{2}{c}{FWHM$_{\text{b,d}}$$^{\text{b}}$ (arcsec)
    } & \multicolumn{2}{c}{P.A.$_{\text{d}}$$^{\text{b}}$ (deg)}\\
15            & (J2000) & (J2000) & \multicolumn{2}{c}{($\text{mJy}^\text{
    beam}^{-1}$)} & \multicolumn{2}{c}{($\text{mJy}$)} & \multicolumn{2}{c
    }{(arcsec)} & (deg) & fit & err & fit & err & fit & err \\
16            \midrule
17            \endfirsthead
18
19            \caption[]{(continued from previous page)} \\
20            \toprule
21            *** (SAME AS ABOVE) ***
22            \midrule
23            \endhead
24
25            \bottomrule
26            \multicolumn{16}{r}{\footnotesize to be continued on the next
    page}
27            \endfoot
28
29            \bottomrule
30            \insertTableNotes
31            \endlastfoot
32
33            *** (DATA GOES HERE) ***
34        \end{xltabular}
35     \end{ThreePartTable}
36 \end{landscape}
```

Table 2.3: Example Table with ThreePartTable, LongTable, Caption, Notes, Landscape

Scr	R.A. (J2000)	Decl. (J2000)	Pk[a] (mJy beam^{-1})	Pk$_{err}$[a] (mJy beam^{-1})	Tot[a] (mJy)	Tot$_{err}$[a] (mJy)	FWHM$_a$[a] (arcsec)	FWHM$_b$[a] (arcsec)	P.A.[a] (deg)	FWHM$_{a,d}$[b] (arcsec) fit	FWHM$_{a,d}$[b] (arcsec) err	FWHM$_{b,d}$[b] (arcsec) fit	FWHM$_{b,d}$[b] (arcsec) err	P.A.$_d$[b] (deg) fit	P.A.$_d$[b] (deg) err
1	05h46m06.01s	-00d09m32.70s	0.36	0.08	4.60	1.03	5.471	4.622	58.8	5.26	1.22	4.43	1.07	58	53
2	05h46m07.26s	-00d13m30.27s	9.48	0.16	12.22	0.33	1.849	1.511	71.2	0.84	0.09	0.74	0.08	65	66
3	05h46m07.33s	-00d13m43.49s	31.37	0.16	36.88	0.31	1.779	1.433	70.1	0.68	0.03	0.56	0.03	57	12
4	05h46m07.51s	-00d13m54.79s	0.45	0.16	1.36	0.63	2.978	2.177	162.1	2.67	1.19	1.42	1.04	162	42
5	05h46m07.53s	-00d11m49.22s	0.97	0.14	5.25	0.90	4.345	2.694	152.4	4.14	0.74	2.14	0.49	153	11
6	05h46m07.73s	-00d12m21.27s	14.37	0.17	21.73	0.38	1.977	1.658	82.8	1.15	0.06	0.94	0.06	110	12
7	05h46m07.84s	-00d09m59.61s	6.45	0.11	7.59	0.21	1.726	1.361	65.2	0.81	0.07	0.36	0.10	62	8
8	05h46m07.86s	-00d10m01.33s	2.74	0.11	3.44	0.23	1.754	1.427	63.0	0.88	0.17	0.56	0.23	57	48
9	05h46m08.42s	-00d10m01.03s	0.86	0.09	5.53	0.69	4.752	2.702	38.9	4.52	0.60	2.33	0.34	38	8
10	05h46m08.49s	-00d10m03.10s	8.13	0.10	7.55	0.17	1.444	1.284	83.2	-1.00	-1.00	-1.00	-1.00	-1	-1
11	05h46m08.92s	-00d09m56.11s	2.07	0.11	2.28	0.20	1.576	1.392	73.8	0.51	0.31	0.36	0.21	129	73
12	05h46m10.04s	-00d12m16.83s	39.04	0.15	40.36	0.28	1.657	1.352	72.0	0.31	0.03	0.19	0.09	165	24
13	05h46m13.13s	-00d06m04.94s	9.41	0.14	11.18	0.27	1.655	1.379	67.3	0.71	0.07	0.50	0.08	60	19
14	05h46m14.20s	-00d05m26.71s	0.51	0.13	0.54	0.24	1.704	1.177	80.5	-1.00	-1.00	-1.00	-1.00	-1	-1
15	05h46m27.91s	-00d00m52.11s	65.62	0.14	73.72	0.27	1.662	1.409	74.0	0.52	0.02	0.49	0.02	43	26
16	05h46m28.34s	+00d19m49.18s	1.47	0.14	1.79	0.28	1.816	1.387	78.5	0.93	0.36	0.42	0.27	77	82
17	05h46m28.61s	+00d20m58.08s	0.50	0.13	0.49	0.23	1.675	1.212	127.5	0.00	1.59	0.00	0.60	-1	-1
18	05h46m30.91s	-00d02m35.07s	7.55	0.15	17.54	0.47	2.456	1.972	63.7	1.89	0.07	1.45	0.06	58	7
19	05h46m31.09s	-00d02m32.95s	16.15	0.15	25.05	0.35	1.862	1.736	151.5	1.31	0.03	0.73	0.05	160	5
20	05h46m43.12s	+00d00m52.47s	1.70	0.13	2.40	0.28	1.759	1.619	2.1	1.15	0.33	0.56	0.42	169	36
21	05h46m46.52s	+00d00m16.09s	1.00	0.12	1.04	0.22	1.532	1.370	63.8	0.00	1.05	0.00	0.50	-1	-1
22	05h46m47.03s	+00d00m27.20s	1.96	0.13	3.55	0.34	2.212	1.652	109.8	1.69	0.25	0.83	0.30	118	13
23	05h46m47.43s	+00d00m23.24s	1.10	0.09	12.48	1.10	5.314	4.321	37.9	5.11	0.47	4.09	0.39	36	22
24	05h46m47.51s	+00d00m29.50s	0.85	0.10	7.75	1.04	5.548	3.319	9.5	5.38	0.75	2.97	0.45	9	9
25	05h46m47.69s	+00d00m25.02s	5.38	0.13	7.22	0.27	1.810	1.496	53.6	1.01	0.11	0.64	0.13	37	15
26	05h46m47.97s	+00d01m41.80s	1.10	0.13	2.55	0.42	2.665	1.684	38.5	2.24	0.48	0.99	0.43	34	15
27	05h46m57.30s	+00d23m57.94s	3.39	0.16	4.25	0.33	1.666	1.417	72.1	0.83	0.21	0.55	0.34	61	72
28	05h47m00.92s	+00d26m21.98s	2.65	0.16	9.34	0.71	2.782	2.363	161.4	2.46	0.21	1.87	0.19	163	15
29	05h47m01.31s	+00d26m23.09s	4.91	0.17	6.96	0.37	1.784	1.484	92.6	1.05	0.12	0.72	0.13	99	21
30	05h47m10.61s	+00d21m13.78s	12.17	0.16	16.31	0.35	1.755	1.491	83.6	0.93	0.06	0.70	0.06	94	12
31	05h47m15.95s	+00d21m22.89s	2.02	0.13	2.70	0.28	1.805	1.553	89.0	0.92	0.29	0.75	0.51	111	77
32	05h47m24.84s	+00d20m58.98s	16.42	0.15	51.09	0.60	2.773	2.400	133.8	2.39	0.04	1.84	0.04	144	3
33	05h47m32.45s	+00d20m21.60s	5.56	0.15	7.19	0.30	1.742	1.502	98.7	0.91	0.14	0.60	0.20	129	21
34	05h47m36.56s	+00d20m05.89s	8.36	0.15	10.28	0.29	1.651	1.508	79.1	0.75	0.07	0.58	0.12	173	35

to be continued on the next page

Table 2.3: (continued from previous page)

Scr	R.A. (J2000)	Decl. (J2000)	Pk[a] (mJy beam^{-1})	Pk$_{err}$[a]	Tot[a] (mJy)	Tot$_{err}$[a]	FWHM$_a$[a] (arcsec)	FWHM$_b$[a]	P.A.[a] (deg)	FWHM$_{a,d}$[b] (arcsec) fit	err	FWHM$_{b,d}$[b] (arcsec) fit	err	P.A.$_d$[b] (deg) fit	err
34	05h47m36.56s	+00d20m05.89s	8.36	0.15	10.28	0.29	1.651	1.508	79.1	0.75	0.07	0.58	0.12	173	35
34	05h47m36.56s	+00d20m05.89s	8.36	0.15	10.28	0.29	1.651	1.508	79.1	0.75	0.07	0.58	0.12	173	35
34	05h47m36.56s	+00d20m05.89s	8.36	0.15	10.28	0.29	1.651	1.508	79.1	0.75	0.07	0.58	0.12	173	35
34	05h47m36.56s	+00d20m05.89s	8.36	0.15	10.28	0.29	1.651	1.508	79.1	0.75	0.07	0.58	0.12	173	35
34	05h47m36.56s	+00d20m05.89s	8.36	0.15	10.28	0.29	1.651	1.508	79.1	0.75	0.07	0.58	0.12	173	35

[a] Properties of the Gaussian fit to the ALMA emission: peak flux, integrated flux, major and minor axes of the FWHM, and position angle of the FWHM.

[b] Properties of the deconvolved Gaussian fit: major and minor axes of the FWHM, and position angle of the FWHM. Unresolved sources are indicated by values of -1.

2.3 Citations

In this section, a *very* rough explanation on how biliographies and their implementation work in LaTeX will be given. This is not a comprehensive guide, but rather a quick overview.

In LaTeX, BibTeX is often used to describe various distinct aspects, which can lead to confusion. Some reference BibTeX as the program that LaTeX uses to compile the bibliography, while others refer to compilation of the file. Then there's the integration of a the backend that is used to compile; `bibtex` and `biber`, and what those represent.

To start, there are two main distinctions in the bibliography process: the *external programs* that process bibliography information, and roughly act as the middle-man between your `.bib` file and the LaTeX document, and the LaTeX *packages* that you import into your compilation to handle the formatting of your citations and bibliography. Here is a simple view of the process:

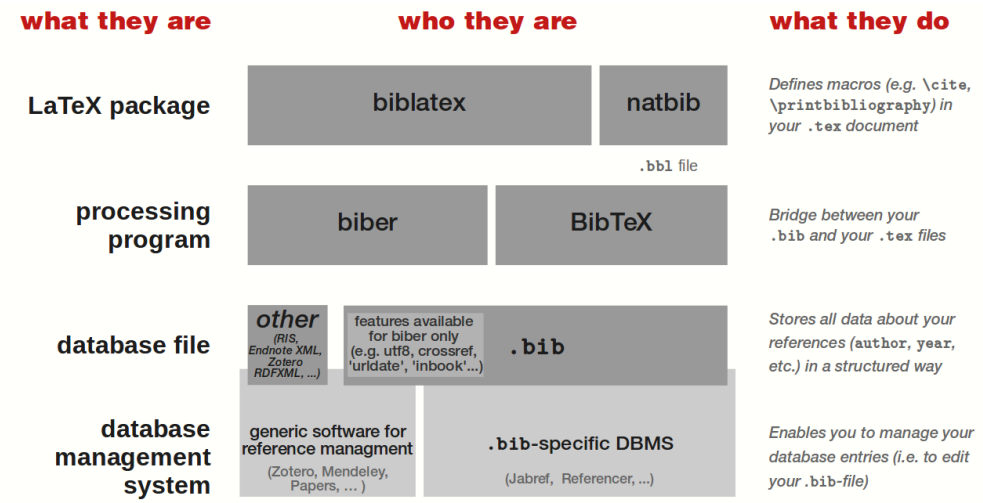

Figure 2.1: Bibliography Process Overview in LaTeX

At the highest level, there are two main front-end LaTeX packages that users interact with to handle citations, references, and bibliographies. These are `natbib` and `biblatex`. `natbib` is an older package, and although still maintained, may not be further developed. Despite this reasons, it is still widely used, and very reliable in nature. `biblatex` is a newer package that is more flexible and can handle more complex bibliography styles, and happens to be actively developed alongside the `biber` processing program (backend, more on this below). The humanities fields tend to use `biblatex` as many predefined styles are available (e.g., APA, MLA, Chicago). Science fields tend to go either way depending on the publishing journal's requirements and specific functionalities needed.

The backend or processing programs are the bridge between the LaTeX document and the bibliography file. The two main programs are `bibtex` and `biber`. `bibtex` interfaces with with specific `.bst` files, which are postfix language files that define the formatting of the bibliography. In the case of many major publication journals (especially in astronomy), the submission of manuscripts require the use of these `.bst` files, and as such, users are required to use the `natbib` LaTeX package. `biber` on the other hand is a relatively newer processing program that adds further functionality to `biblatex`.

It is important to note that the `biblatex` package can make use of either the `biber` backend or the `bibtex` backend, while the `natbib` package is restricted to the `bibtex` backend. Even more importantly, results with `biblatex` can differ depending on the backend: if `bibtex` is used, it only uses it for sorting, and not for formatting content.

The takeaways are the following: if you enjoy a particular style given in a particular journal, download it's `.bst` file and make use of the `natbib` package to compile your thesis work. In the case of this example PDF, the `aasjournal.bst` file is loaded, and it's style used in the bibliography:

```
1     \TOCadd{Bibliography} % add citations to TOC
2     \bibliography{AstroCitations.bib}{}
3     \bibliographystyle{aasjournal} % links to aasjournal.bst file
```

A citation example is given here (Hubble, 1929).

Bibliography

Hubble, E. 1929, Proceedings of the National Academy of Science, 15, 168, doi: 10.1073/pnas.15.3.168