The Title of your Thesis

With a matching catchy subtitle

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Universiteit
Leiden
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The Title of your Thesis

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A thesis submitted in partial fulfillment
of the requirements for the degree of

Master of Science
in
Astronomy

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Universiteit Leiden
Observatory

P.O. Box 9513, 2300 RA Leiden, The Netherlands

Abstract

This is chapter is reserved for an abstract.

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

Acknowledgements

This is chapter is reserved for acknowledgements.

This is the second paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

And after the second paragraph follows the third paragraph. Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like “Huardest gefburn”? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language.

Contents

List of Tables

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Nomenclature

Acronyms

Notation	Description	Page List
2MASS	Two-Micron All Sky Survey	9
AGN	active galactic nucleus	4
ALMA	Atacama Large Millimeter Array	9
CMB	cosmic microwave background	9
COM	center of mass	9
GC	globular cluster	4
HR-diagrams	Hertzsprung-Russelldiagram	9
HST	Hubble Space Telescope	9
LSST	Legacy Survey of Space and Time	9
M31	Messier 31, also known as the Andromeda Galaxy	4
M5	Messier 5	4
M6	Messier 6, also known as the Butterfy Cluster	4
Pal 5	Palomar 5	4
PCA	principal component analysis	4
SKA	Square Kilometre Array	9
VLBI	very-long-baseline interferometry	4

Constants

Notation	Description	Unit
k	constant of Boltzmann	$1.381 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
c	speed of light	$2.998 \times 10^{8}\,\mathrm{m\,s^{-1}}$
e	elementary charge	$1.602 \times 10^{-19}\,\mathrm{C}$
ϵ_0	vacuum permittivity	$8.854 \times 10^{-12}\,\mathrm{C^2\,kg^{-1}\,s^2}$
G	gravitational constant	$6.674 \times 10^{-11}\,\mathrm{m^3\,kg^{-1}\,s^{-2}}$
m_0	atomic mass unit	$1.661 \times 10^{-27}\,\mathrm{kg}$
$M_{B\odot}$	absolute B-band magnitude of the sun	5.48
m_e	rest mass of an electron	$9.109 \times 10^{-31}\,\mathrm{kg}$
m_p	rest mass of a proton	$1.673 \times 10^{-27}\,\mathrm{kg}$
$M_{V\odot}$	absolute visual magnitude of the sun	4.83
$m_{V\odot}$	apparent visual magnitude of the sun	−26.75
N_A	constant of Avogadro	$6.022 \times 10^{23}\,\mathrm{mol^{-1}}$
h	constant of Plack	$6.626 \times 10^{-34}\,\mathrm{J\,Hz^{-1}}$
R	gas constant	$8.314\,\mathrm{J\,K^{-1}\,mol}$
σ_{SB}	constant of Stefan-Boltzmann	$5.670 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$
σ_e	Thomson crossection of an electron	$6.652 \times 10^{-29}\,\mathrm{m^2}$
$T_\odot$	effective temperature of the sun	5778K

Units

Notation	Description	Unit
Å	Ångström	$10^{-10}\,\mathrm{m}$
′	arcminute	$\frac{1}{60}\,^\circ$
″	arcsecond	$\frac{1}{3600}\,^\circ$
AU	astronomical unit	$1.496 \times 10^{11}\,\mathrm{m}$
ρ	density	$\mathrm{kg\,m^{-3}}$
eV	electronvolt	$1.602 \times 10^{-19}\,\mathrm{J}$
F	flux	$\mathrm{J\,s^{-1}\,m^{-2}}$
Gyr	billion years (gigayear)	$1 \times 10^{9}\,\mathrm{year}$
$\mathrm{L}_\odot$	solar luminosity	$3.828 \times 10^{26}\,\mathrm{J\,s^{-1}}$
L	luminosity	$\mathrm{J\,s^{-1}}$
mas	milliarcsecond	0.001″
$\mathrm{M}_\oplus$	Earth mass	$5.972 \times 10^{24}\,\mathrm{kg}$
$\mathrm{M_J}$	Jupiter mass	$1.898 \times 10^{27}\,\mathrm{kg}$

Notation	Description	Unit
$M_\odot$	solar mass	1.988×10^{30}kg
κ	opacity	$m^2\,kg^{-1}$
pc	parsec	3.086×10^{16}m
I	intensity	$J\,s^{-1}\,m^{-2}\,sr^{-1}$
$R_\oplus$	Earth radius	6.378×10^{6}m
R_J	Jupiter radius	7.149×10^{7}m
$R_\odot$	solar radius	6.957×10^{8}m
F_λ	spectral flux	$J\,s^{-1}\,m^{-3}$
F_ν	spectral flux	$J\,s^{-1}\,Hz^{-1}\,m^{-2}$
I_λ	specific intensity	$J\,s^{-1}m^{-3}\,sr^{-1}$
I_ν	specific intensity	$J\,s^{-1}\,Hz^{-1}\,m^{-2}\,sr^{-1}$

1. The template

This template can be used to write your thesis. The colorpalette used in this template is built around the blue of the Leiden University logo (Lei-blauw). The colors in the palette are shown in figure 1.1.

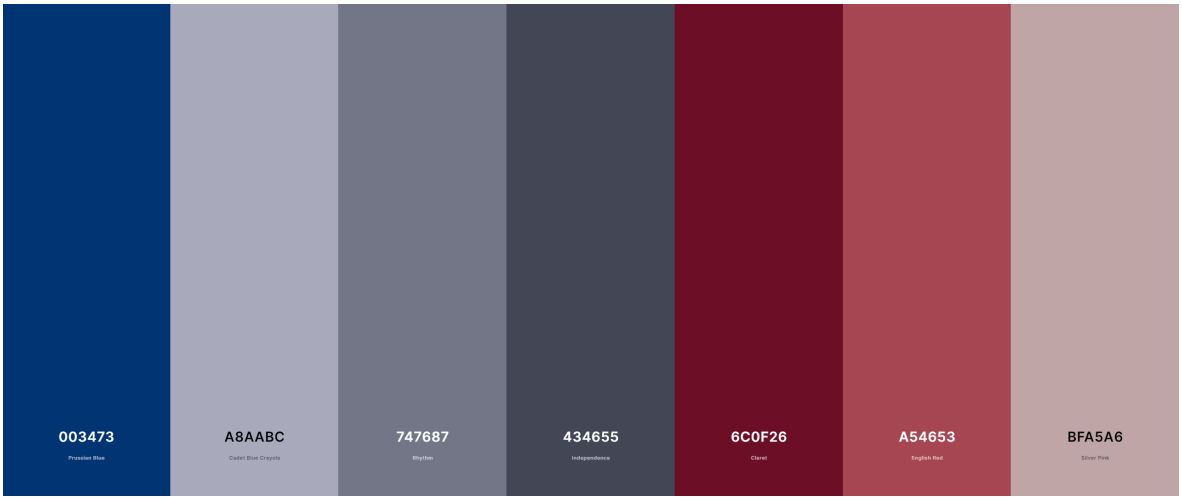

Figure 1.1: *Colorpalette used in this template. Colorcodes are in hex format (HTML).*

Chapter 2 contains some useful tips and tricks on how to use this template and all its features. Most of these features are showcased in chapter 3. A Python script is included in appendix A.

2. Tips and tricks

This chapter contains some tips and tricks for using this template. Section 2.1 contains tips and tricks specific to this template, and section 2.2 contains useful info on some of the packages used by this template.

2.1 Template

- At the top of the *thesis.tex* file you can change the language passed to *documentclass*. When changing this to Dutch, the nomenclature titles and Leiden University logos will also be changed to the Dutch versions.
- For a bachelor thesis, pass bsc instead of msc to *documentclass*.
- You can change parameters such as author, supervisors and coverimage right after the start of the document in *thesis.tex*.
- The logo's are defined in *layout/observatory-thesis.cls*, with \coveraffiliationlogo for the logo on the coverpage, and \affiliationlogo for the logo on the titlepage. Note that the current logo on the coverpage is the diapositive version; if your coverimage is lighter, use the normal logo instead.
- Folder *layout/figures/free_frontpage* contains some other free frontpage images that don't require credit (although I do advocate giving credit regardless). You can remove unused images to save space.
- There are additional caption settings available. When defining a caption, you can use \caption[short caption]{long caption}. The short caption will be listed in the list of figures or list of tables at the start of the document, and the long caption will be shown below the figure or above the table. Use \imref{} to add an image credit entry below the caption, as shown in figure 3.1 and figure 3.2.
- If you want to print your thesis, you can pass *twoside* instead of *oneside* to *documentclass* in *thesis.tex*. This will make the inner margin bigger than the outer margin, ensure all chapters start at the left page, and display the chapter title at the top of the left page and the section title at the top of the right page.

- If you input chapters (or even sections) separately, you can comment out the *include* of the chapters you are currently not editing to make the document compile faster.
- This template uses the AASTeX bibliography style, see section 3.1 for examples of citations. All journal abbreviations used in the ADS BibTeX entries are defined at the bottom of the class file. Examples are *aap* (A&A) and *aap* (ApJ).
- The included bibliography, *bib.bib*, shows more (uncited) examples of sources, such as conference proceedings and unpublished work.
- When you get errors after adding a new entry in your bibliography, it is most commonly caused by a special character in a name, for example é and ö. You can fix this by replacing the character with the corresponding latex encoding, in this case \'{e} and \"{o} respectively.

2.2 Packages

- This template includes the `cleveref` package, which has advantages over the the normal \ref. The commands of this package are \cref and \Cref. When using this, it will automatically include the word of whatever it is you are referring to before the number (such as chapter, section, appendix, table, figure). This way you don't have to worry about manually changing all the references when you change the structure of your thesis by for example changing a chapter into a section.
- The package `siunitx` includes many useful features for displaying (scientific) numbers and units. You can also define your own custom units; some astronomy units have already been added in *glossaries/custom_units.tex*.
- This template uses the packages `glossaries` and `glossaries-extra`. It is set up such that it automatically creates a table with acronyms, constants and units. You can find these after the list of figures and list of tables. You can see how the acronyms, constants and units are defined in *glossaries/acronyms.tex*, *glossaries/units.tex* and *glossaries/constants.tex* respectively, such that you can add new ones yourself. Section 3.1 shows various ways to use the acronyms in your text. All of these are clickable and will take you to the corresponding table at the start of the document.
- You don't want acronyms in titles or in captions to be clickable. Always use \glsfmtshort and \glsfmtlong for the acronym and the full word respectively.
- This class includes package `adjustbox`, which allows figures to float outside the page margins whilst remaining centered. Although for aesthetics it is not recommended to do this, if you see no other way to include your figure in a clearly readable way, you can make it exceed the margins by using: *\includegraphics[width=1.2\textwidth, center]{figures/figuretitle.png}*

3. Showcase

Section 3.1 shows examples of the usage of the package `glossaries` and of adding citations. Section 3.2 displays what subsections look like in this template, and section 3.3 showcases a large variety of math symbols and equations. The last section, section 3.4, shows a large patch of text with some (wrap)figures and table.

3.1 Acronyms and references

Here is a nice acronym test: two big globular clusters (GCs) are Palomar 5 (Pal 5) and Messier 5 (M5). Messier 6, also known as the Butterfy Cluster (M6) is an open cluster, whereas Messier 31, also known as the Andromeda Galaxy (M31) is a galaxy. Here is another acronym that starts with a "p": principal component analysis (PCA). When acronyms are referenced a second time, it only shows the short name: Pal 5, M5. One single GC, and multiple GCs. One active galactic nucleus (AGN), multiple AGN, and multiple long active galactic nuclei. This is an example of an unclickable short reference, VLT, an unclickable long reference, very-long-baseline interferometry, and an unclickable plural form of a short reference GCs. Unclickable references do not show up in the nomenclature if they are not referred to anywhere else in the text. You will see that very-long-baseline interferometry (VLBI) is listed in the nomenclature, but VLT is not.

This is an example of a paragraph with in-text citations using the aasjournal BibTeX style. Here is a reference to a journal article with a single author (Author, 1993), to a journal article with two authors without parenthesis Author & Author (1993), and to a journal article with six authors (Author et al., 1993). Here is a citation to a book (Author, 1993).

3.2 Subsectionconceptionsection

This is the first section of the subsectionconceptionsection. Let's start with some text. Nunc sed pede. Praesent vitae lectus. Praesent neque justo, vehicula eget, interdum id, facilisis et, nibh. Phasellus at purus et libero lacinia dictum. Fusce aliquet. Nulla eu ante placerat leo semper dictum. Mauris metus. Curabitur lobortis. Curabitur sollicitudin hendrerit nunc. Donec ultrices lacus id ipsum.

3.2.1 Subsection of the first section

Look, its a subsection.

3.2.2 Another subsection

And there is more!

3.2.3 Third's a charm

Welcome to the final subsection.

3.3 Math

Basic examples of equations:

- Moment of inertia:

$$\sum_{i=1}^{N} m_i \vec{r}_i^{\,2} \tag{3.1}$$

- Einstein's field equations:

$$G_{\alpha\beta} \equiv R_{\alpha\beta} - \frac{1}{2} g_{\alpha\beta} R + \Lambda g_{\alpha\beta} = \frac{8\pi\kappa}{c^2} T_{\alpha\beta} \tag{3.2}$$

- Main-sequence relations:

$$\frac{L}{\mathrm{L}_\odot} = \begin{cases} 0.35 \left(\dfrac{M}{\mathrm{M}_\odot} \right)^{2.62}, & M < 0.7\mathrm{M}_\odot \\ 1.02 \left(\dfrac{M}{\mathrm{M}_\odot} \right)^{3.92}, & M \geq 0.7\mathrm{M}_\odot \end{cases} \tag{3.3}$$

$$\frac{R}{\mathrm{R}_\odot} = \begin{cases} 1.06 \left(\dfrac{M}{\mathrm{M}_\odot} \right)^{0.945}, & M < 1.66\mathrm{M}_\odot \\ 1.33 \left(\dfrac{M}{\mathrm{M}_\odot} \right)^{0.555}, & M \geq 1.66\mathrm{M}_\odot \end{cases} \tag{3.4}$$

- Wave functions:

$$\Phi(k,t) = \frac{1}{\sqrt{h}} \int \Psi(x,t) \mathrm{e}^{-ikx} dx, \quad \Psi(x,t) = \frac{1}{\sqrt{h}} \int \Phi(k,t) \mathrm{e}^{ikx} dk \tag{3.5}$$

$$\langle f(t) \rangle = \iiint \Psi^* f \Psi d^3V, \qquad \langle f_p(t) \rangle = \iiint \Phi^* f \Phi d^3V_p \tag{3.6}$$

- Wave equation:

$$\nabla^2 u - \frac{1}{v^2} \frac{\partial^2 u}{\partial t^2} = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} - \frac{1}{v^2} \frac{\partial^2 u}{\partial t^2} = 0 \tag{3.7}$$

3.4 Text and figures

Check out figure 3.1, figure 3.2 and table 3.1! Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

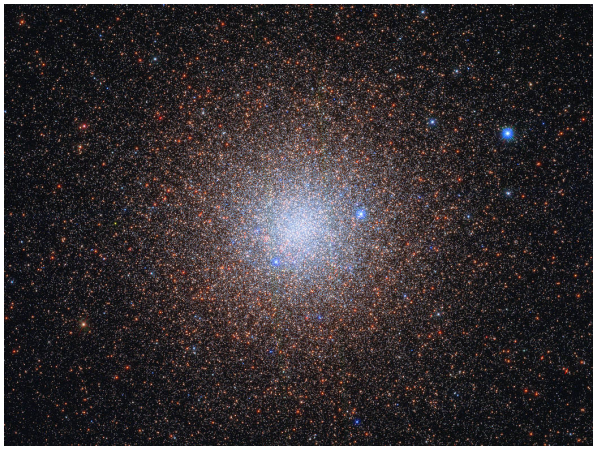

Figure 3.1: *A picture of NGC 6441, one of the most massive and luminous GCs in the Milky Way.*

Image credit: ESA/Hubble & NASA, G. Piotto

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Table 3.1: *An example table showing ranges for fundamental parameters.*

Parameter	Min	Max
Z	0.0001	0.0099
a	9.9	10.29
E	0	1
D	14	20
M	1000	80000
b	0.0	0.8

The ranges of the metallicity (Z), the log(age) (a), the extinction (E) in B-V colour index, the distance modulus (D), the mass (M) in solar masses and the binary fraction (B).

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Figure 3.2: *One of the largest HST images ever made of a complete galaxy; an image of NGC 1300.*

Credit: NASA, ESA, and The Hubble Heritage Team (STScI/AURA); Acknowledgment: P. Knezek (WIYN)

facilisis magna. Mauris quis magna varius nulla scelerisque imperdiet. Aliquam non quam. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

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Here are some more predefined acronyms to show different pages listed in the nomenclature: center of mass (COM), Hertzsprung-Russelldiagram (HR-diagrams), Legacy Survey of Space and Time (LSST), Hubble Space Telescope (HST), Atacama Large Millimeter Array (ALMA), Square Kilometre Array (SKA), Two-Micron All Sky Survey (2MASS) and cosmic microwave background (CMB).

A. A script

```python
import sys
import numpy as np
from astropy.io import ascii


def read():
    """Read "stars.txt". The output of this function is an astropy Table.
    """
    data = ascii.read("stars.txt", format="commented_header")
    return data


def apparent_magnitude(data):
    """Compute the apparent magnitudes of the stars. Add this column to the table.
    Print the properties of the star that is the brightest as seen from earth,
    and the star that is the faintest as seen from earth.
    The output of this function is the updated table.
    """
    data["app_mag"] = np.round(data["abs_magnitude"]+5*np.log10(data["distance"])-5, 2)
    print("\nProperties of the brightest star:\n", data[np.argmin(data["app_mag"])])
    print("\nProperties of the faintest star:\n", data[np.argmax(data["app_mag"])])
    return data


def luminosity(data):
    """Use the absolute magnitude of the stars to compute the luminosity in unit L_sun.
    Add this column to the table.
    The output of this function is the updated table.
    """
    abs_mag_zon = 4.75    # absolute bolometric magnitude of the sun
    data["luminosity"] = 10 ** (0.4 * (abs_mag_zon - data["abs_magnitude"])) # in [L_sun]
    return data


def mass_lifespan(data):
    """Compute the mass of the brightest and faintest star, and the ratio of lifetime
    on the main sequence between these stars.
    """
    brightest = data[np.argmin(data["app_mag"])]
    faintest = data[np.argmax(data["app_mag"])]

    # mass
    mass_brightest = (1/1.02) * brightest["luminosity"]**(1/3.92)   # mass in m_sun
    mass_faintest = (1/0.35) * faintest["luminosity"]**(1/2.62)     # mass in m_sun
    print(f"\nMass of the brightest star: {mass_brightest:.2f} [M_sun]")
    print(f"Mass of the faintest star: {mass_faintest:.2f} [M_sun]")

    # lifespan
    lifespan_brightest = mass_brightest**(-2.92)    # msq lifespan compared to the sun
    lifespan_faintest = mass_faintest**(-1.62)      # msq lifespan compared to the sun
```

```
    ratio = lifespan_faintest / lifespan_brightest
    print(f"\nMain-sequence lifespans:")
    print(f"The brightest star lives {lifespan_brightest:.5f} times as long as the sun.")
    print(f"The faintest star lives {lifespan_faintest:.2f} times as long as the sun.")
    print(f"De faintest star lives {ratio:.2e} as long as the brightest star before it "
          f"runs out of fuel.")


def main():
    stars = read()
    stars = apparent_magnitude(stars)
    stars = luminosity(stars)
    mass_lifespan(stars)


if __name__ == "__main__":
    sys.exit(main())
```

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