University of Sussex

An Introduction to PhD Study

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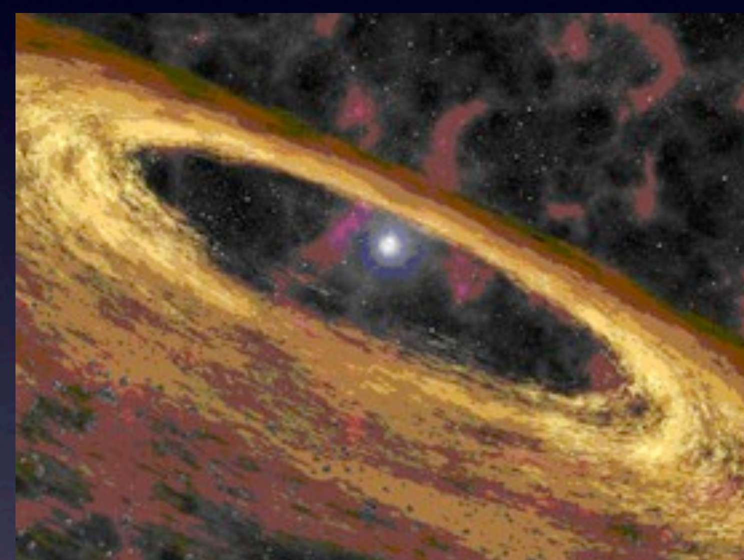
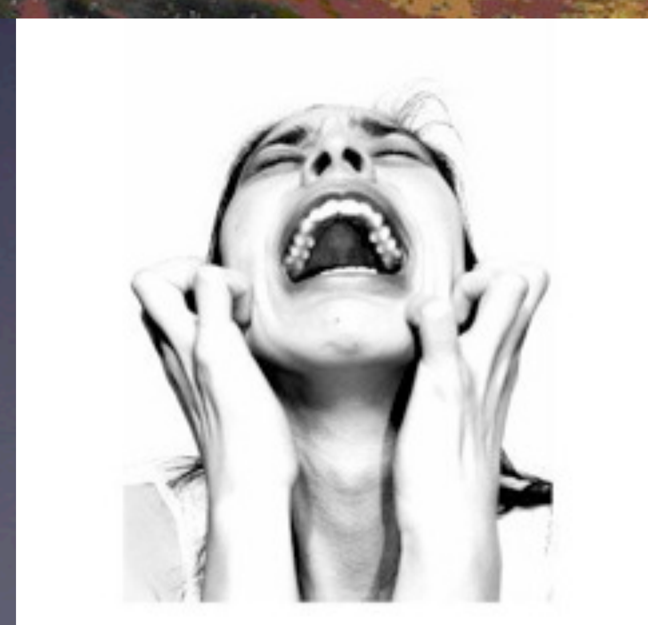





Microsoft-free presentation

A little bit about me

- I completed my own PhD in 1989. I’ve been professor here at Sussex since 2000.
- My own research work is in theoretical cosmology, plus observational involvement in the Planck Satellite and the Dark Energy Survey.
- I have supervised 14 PhD students to completion, have 3 more in progress, and have examined 22 PhD theses.
- I am currently Chair of STFC’s Education, Training and Careers Committee, which has overall responsibility for STFC’s PhD programme (220 students per year, roughly half in astronomy).

What is a PhD?

A PhD is a degree awarded in recognition of the creation of new knowledge.

E.g. at Sussex the entire criteria for award are

> "For the award of the **Doctor of Philosophy**, that the thesis makes a substantial original contribution to knowledge or understanding."

It is assessed solely by a viva - i.e. an oral examination usually with two examiners.

Why are you doing a PhD?

There are various reasons. Which one is you?

A) I've always wanted to be involved in astronomical research and never considered anything else.

B) My grades were good so I thought I'd apply for PhDs. As I got offered a place, I didn't really consider alternative career options.

C) I considered other career options, but decided I'd like to try a PhD first.

D) I started a different career, but decided to return to academia for a PhD.

E) Professor X who taught me as an undergraduate was so cool I decided I wanted to end up exactly like them.

Practicalities

Things you will want to be sure you know at the outset:

- **How long are you funded for?**

The STFC average is 3.5 years, but departments choose the duration of individual projects.

- **What rules govern completion?**

E.g. does your department insist on a four-year maximum?

- **What travel support do you have?**

STFC supplies funds (the RTSG) to enable student travel to conferences, and a separate pot for overseas fieldwork.

- **Where's your computer?**

You should expect your department to supply you with any essential computing equipment, e.g. a laptop.

The supervisor

Most PhD students have a single main supervisor, though some may have joint supervisors.

Most of you will already know who your supervisor is, but some universities leave that decision until after students arrive.

Those with a main supervisor should also have a `second supervisor', who has oversight of the project progress.

The project

The supervisor's principal responsibility is to ensure you have a good project to work on. This might

- Be supplied by the supervisor.
- Arise from discussions between you and your supervisor.
- Be your idea, supported by the supervisor.

Projects typically carry some level of risk, which the supervisor can hopefully judge accurately.

Your thesis might be one long project, or several shorter ones linked by a theme.

Working with your supervisor

Different supervisors have different approaches to supervision. Normally you can expect some mixture of regular scheduled meetings and more informal contacts.

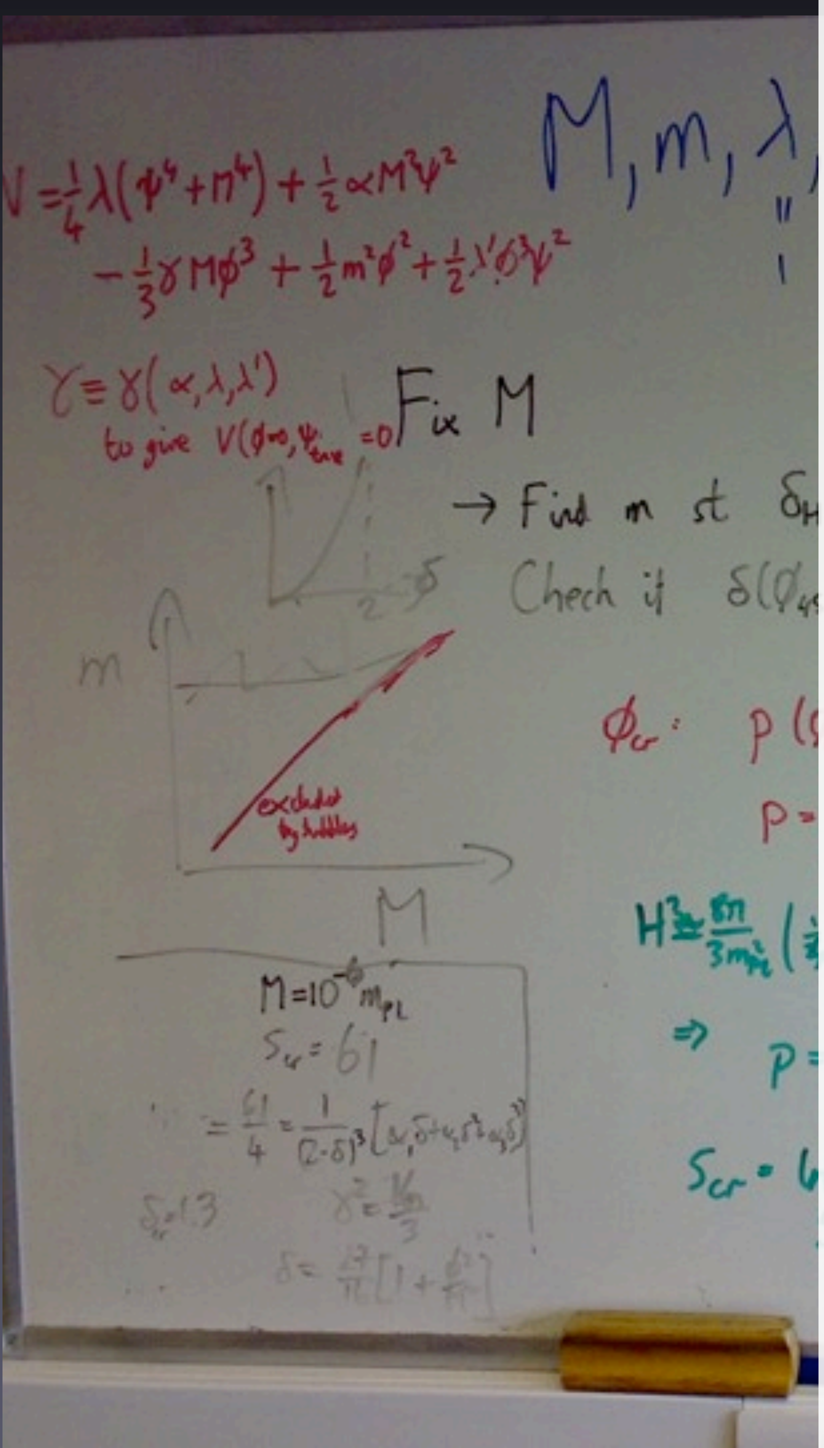
Top tips:

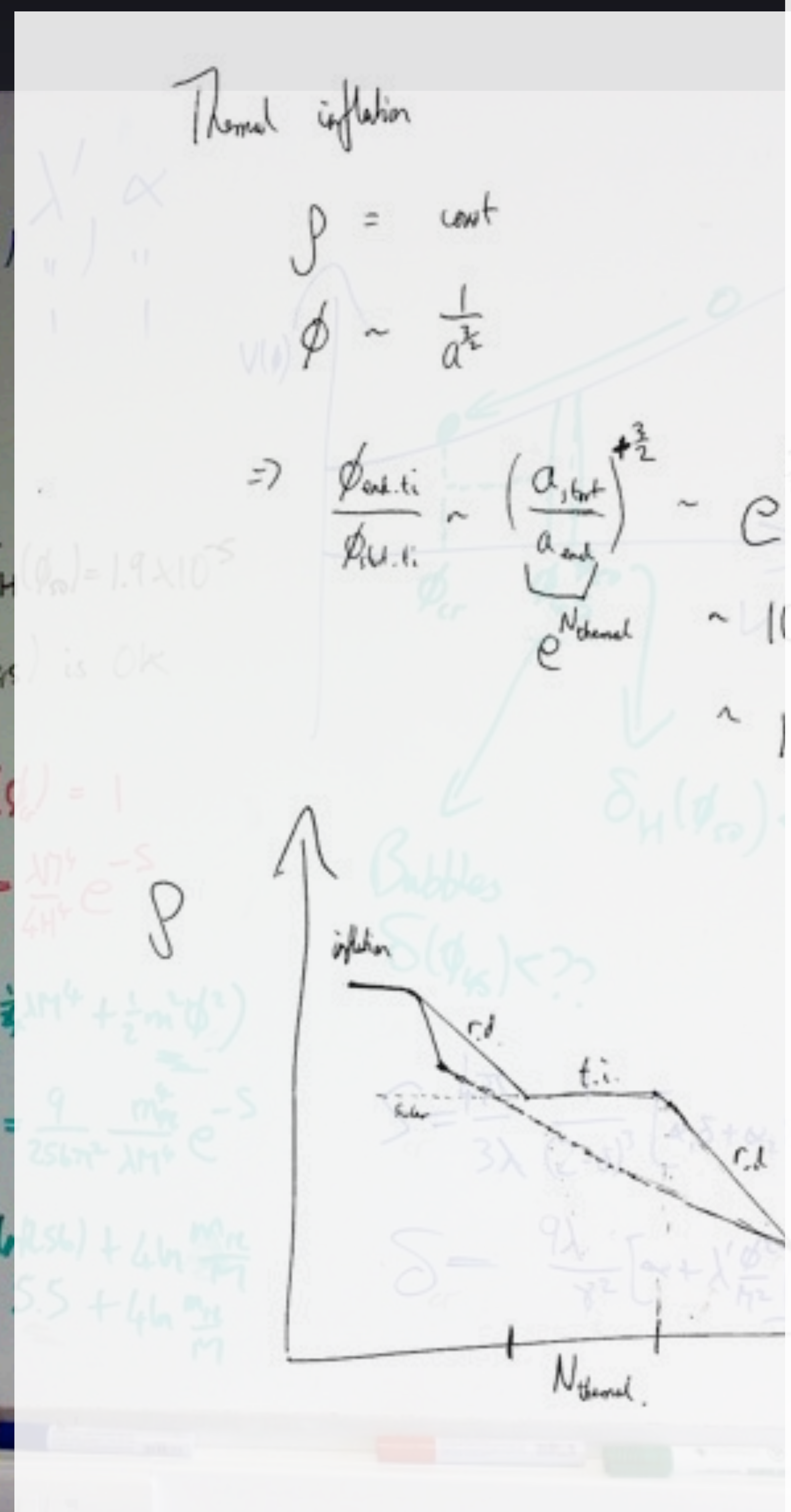
- Don't see your supervisor too rarely.
- Don't see your supervisor too often.
- Grab opportunities to learn from other group members, e.g. postdocs and experienced PhD students. Pay this back later by helping the next generation.

What will you actually do each day?

A day in the life …

What cosmology actually looks like ...





C. Tracker potentials

Cosmological tracker potentials/solutions have been studied in detail by numerous authors [2, 17, 18, 19, 20]. These potentials are such that the late-time evolution of the field can be essentially independent of initial conditions, thus providing a possible solution to the coincidence problem. This behaviour is achieved through a type of dynamical attractor solution, and the conditions for it to be possible given a particular potential have been given and studied in detail by Steinhardt *et al.* [18]. Defining $\Gamma \equiv V''V/V'^2$, where prime denotes a derivative with respect to the field, the two sufficient conditions for a potential to possess a tracker solution are

$$\Gamma > 1 - \frac{1-w_b}{6+2w_b}, \tag{16}$$

$$\left|\Gamma^{-1}\frac{d\Gamma}{d\ln a}\right| = \left|\frac{d\phi}{d\ln a}\left(\frac{V'}{V}+\frac{V'''}{V''}-2\frac{V''}{V'}\right)\right| \ll 1. \tag{17}$$

The first of these conditions ensures convergence to the tracker solution (i.e. perturbations away from it are suppressed), and the second ensures an adiabatic evolution of the field that is necessary for the first condition to be applicable (and is what one would expect of a function that is to maintain a dynamical attractor independent of initial conditions).

If these conditions are fulfilled, the field will eventually approach the tracker solution (unless the initial quintessence energy density is too low), and the equation of state will then evolve according to

$$w_\phi \approx w_{\rm tracker} = \frac{w_b - 2(\Gamma-1)}{1+2(\Gamma-1)}, \tag{18}$$

possibly breaking away from the tracker solution if either of the conditions later become violated. In assessing whether tracking is taking place, one also has to check whether the actual evolution on the tracker potential corresponds closely to the tracker solution. An illustration of tracker behaviour can be seen in Fig. 1.

We additionally impose the condition $w_\phi < w_b$, where w_b is the background energy density. This is to ensure a possible solution of the coincidence problem by having the dark energy density grow with respect to the matter. This third condition is usually avoided by specifying the tracker condition as $\Gamma > 1$ rather than Eq. (16). The reason for not choosing $\Gamma > 1$ as our condition is related to our numerical treatment, and is discussed further in Section IV C 1.

As we need a non-zero second derivative of the potential with respect to the field for Γ to fulfil the tracker conditions, we restrict ourselves to the quadratic potential and the Padé series for the tracker viability analysis.

III. OBSERVABLES

The observables used are essentially geometric and are hence related to the comoving distance for a cosmology

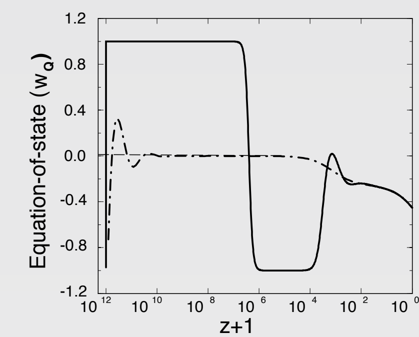


FIG. 1: Examples of the behaviour of the equation of state (here called w_Q) for a tracker potential. The thin-dashed line originating at $w_Q = 0$ corresponds to the tracker solution. Reproduced from Ref. [18].

described by the parameter vector $\mathbf{\Theta}$, given by

$$r(z;\mathbf{\Theta}) = H_0^{-1}\int_0^z \frac{dz'}{E(z';\mathbf{\Theta})} \tag{19}$$

where

$$E(z;\mathbf{\Theta}) = \left[\Omega_m(1+z)^3 + (1-\Omega_m)e^{F(z;\mathbf{\Theta})}\right]^{1/2} \tag{20}$$

and

$$F(z;\mathbf{\Theta}) = 3\int_0^z (1+w_\phi(z';\mathbf{\Theta}))\, d\ln(1+z'). \tag{21}$$

We have not included growth-of-structure observations, which are not yet competitive with the measures we do use (see e.g. Ref. [21] for a directly-comparable example).

A. SNIa luminosity–redshift relation

The luminosity distance is given by

$$d_L(z;\mathbf{\Theta}) = \frac{\mathcal{D}_L(z;\mathbf{\Theta})}{H_0} = (1+z)r(z;\mathbf{\Theta}). \tag{22}$$

The apparent magnitude $m(z;\mathbf{\Theta})$ of a type Ia supernova can be expressed as

$$m(z;\mathbf{\Theta}) = M + 5\log_{10}\frac{d_L(z;\mathbf{\Theta})}{\rm Mpc} + 25, \tag{23}$$

where M is the absolute magnitude of SNIa (supposing they are standard candles). This can be rewritten as

$$m(z;\mathbf{\Theta}) = \mathcal{M} + 5\log_{10}\mathcal{D}_L(z;\mathbf{\Theta}), \tag{24}$$

where $\mathcal{M} = M - 5\log_{10}(H_0\,{\rm Mpc}) + 25 = M - 5\log_{10}(h_{70}) + 43.16$ [where $h_{70} = H_0/(70\,{\rm km/s/Mpc})$].

Things you will do

- Working on your research. Typically this means staring at a computer or an article or a piece of paper, but for some of you it might mean building some apparatus.
- Undertaking academic courses, usually in year 1.
- Undertaking skills training.
- Being a Teaching Assistant for undergraduate classes.
- Carrying out an observing run at a large facility.
- Attending and perhaps speaking at a conference.
- Visiting another university for collaborative research.

Counting the days

The overall investment in you to undertake a PhD is approximately £100,000 pounds.

3.5 years equals	1278 days
Minus weekends	912 days
Minus holidays	824 days
Minus coursework	744 days
Minus teaching	694 days
Illness, domestic emergencies	670 days

So each of your research days costs around 150 pounds.

What makes a good PhD?

To obtain a PhD, your research work needs both quantity and quality.

Usually the best guide is published papers. In large collaborations, first-author papers are of particular importance.

The typical numbers depends strongly on the topic. Check the output of past students of your supervisor.

If you plan to apply for postdocs, seek to maximize your publication record at time of application.

Astronomy careers

To become a professional astronomer, you will need to follow up your PhD with several years of postdoctoral research. It is a tough career to pursue.

- Focus on producing papers. Do not spend too much time writing your thesis.
- Establish connections, e.g. by visiting other universities where you would like to work. Your supervisor can help with this.
- If you are working in a big collaboration, ensure that project leaders are aware of your individual contribution. Carve out your own science area.
- Develop your skills, especially presentation skills. Take very opportunity to present your work.

When problems emerge ...

There WILL be ups and downs during your PhD.

But there may also be real difficulties, which fortunately are relatively rare. Examples:

- Prolonged illness or caring responsibilities prevent you working effectively.
- Financial or accommodation problems divert your time away from your work.
- Equipment problems or lack of observing time derail your project.
- Your relationship with your supervisor breaks down.

When problems emerge ...

So what should you do?

- Wait and see if things get better?
- Whinge about it to partners / friends / family?
- Wait for an annual review of progress?
- Address the issue at an early stage?

The first port of call is to talk with your second supervisor. If that doesn't help, the director of the graduate programme is next in line, then ultimately the head of department.

Plan out your preferred resolution:

- Change of project?
- Change of supervisor?
- Change of career plan?

Advice from the future you

A 2009 STFC survey of former astronomy PhD students asked what advice they would give to new students. The most common replies were

- "Make the most of the opportunities on offer during a PhD to develop and demonstrate transferable skills."
- "Be proactive in creating career opportunities, in particular by networking."
- "Be aware that some employers are looking for team working and communication skills as much as technical ability."

Advice from the future you

The top ten most mentioned skills were:

1. Writing software and programming skills
2. Problem Solving
3. Subject specific knowledge
4. Quantitative data analysis
5. Communication and team working
6. Original, innovative and creative thinking
7. Writing skills
8. Teaching and mentoring
9. Project management
10. Research methodologies

Areas that could usefully have been given more emphasis were:

* Career planning
* Knowledge of the process for funding research
* Project management
* Building and maintaining networks of contacts