Working in Theory

formal HEP theory
string theorist

Chris Blair

(TP 2006-08
Maths 2008-10)

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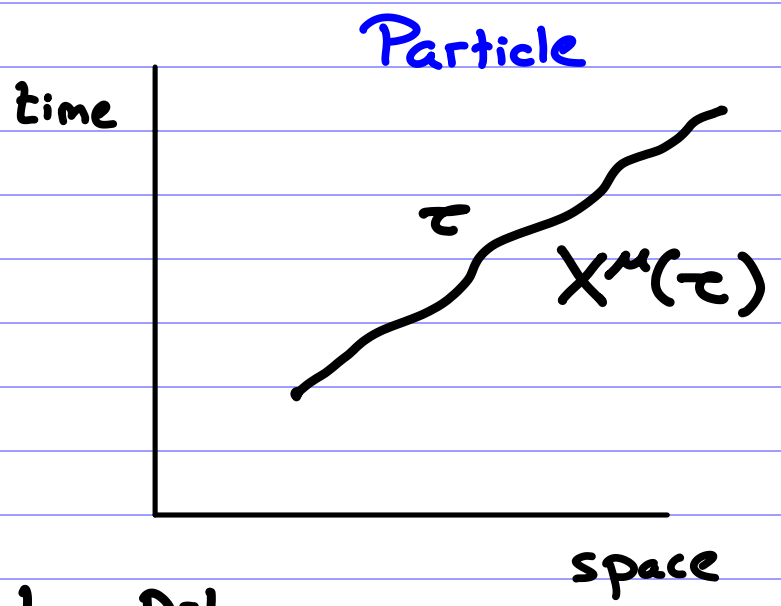
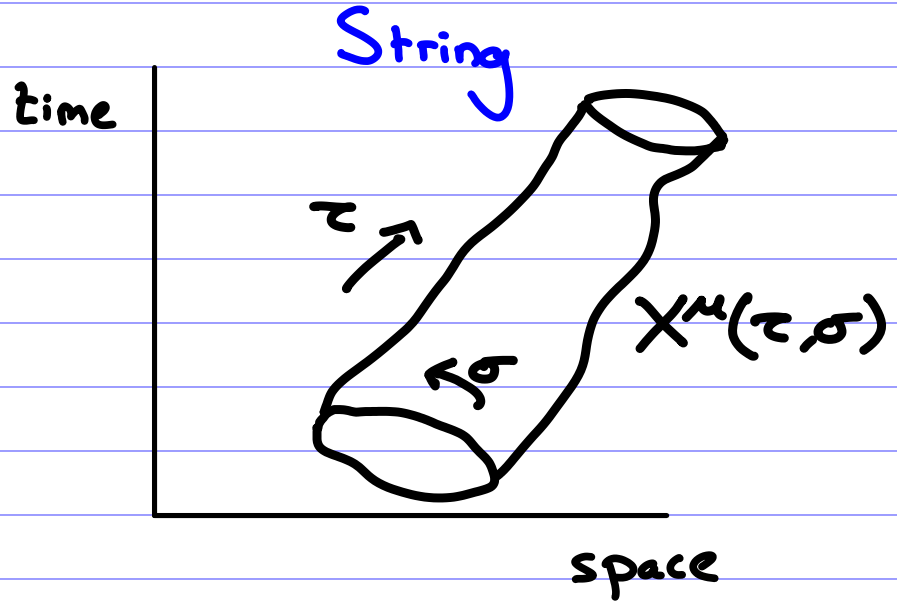
DISCLAIMER: all advice subjective + biased!
(also based on pre-Covid experiences...)

Classical strings are waves





$\mu = 0, 1, \ldots D-1$

$$\frac{d^2X^\mu}{d\tau^2} = 0$$

$$\frac{\partial^2 X^\mu}{\partial \tau^2} - \frac{\partial^2 X^\mu}{\partial \sigma^2} = 0$$

$$X^\mu = X_L^\mu(\tau+\sigma) + X_R^\mu(\tau-\sigma)$$

Quantum strings are harmonic oscillators

$$X^\mu_{(\tau,\sigma)} = x^\mu + l_s^2 p^\mu \tau + i\frac{l_s}{\sqrt{2}} \sum_{n\neq 0} \frac{1}{n} \left(\alpha_n^\mu e^{-in(\tau-\sigma)} + \tilde{\alpha}_n^\mu e^{-in(\tau+\sigma)} \right)$$

- x^μ: centre of mass posn.
- l_s: String lengthscale
- p^μ: momentum
- α_n^μ, $\tilde{\alpha}_n^\mu$: vibrational modes $\Rightarrow$ quantum harmonic oscillators

$$[\alpha_n, \alpha_n^\dagger] = n \qquad n>0$$

$$\alpha_n^\dagger = \alpha_{-n}$$

Quantum strings are harmonic oscillators

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- x^μ: centre of mass posn.
- $l_s^2 p^\mu \tau$: l_s = string lengthscale; p^μ = momentum
- α_n^μ, $\tilde{\alpha}_n^\mu$: vibrational modes ⇒ quantum harmonic oscillators

"$E=mc^2$": $c=1$

$$E^2 = \vec{p}^{\,2} + \frac{1}{l_s^2}(N_{osc.} - \#)$$

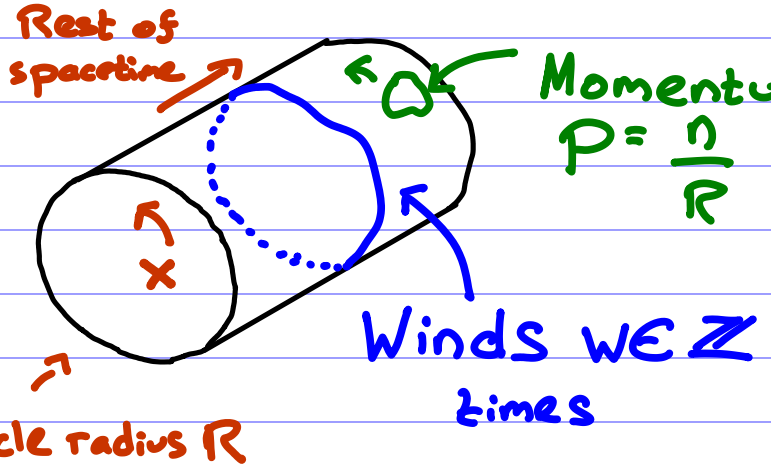
each oscillator excitation adds $+n$

$D=26$ or 10 ⟶ QUANTUM GRAVITY

↳ i) Massless states $E^2 = \vec{p}^{\,2}$ — photon, graviton, fermions

ii) Massive states $E^2 = \vec{p}^{\,2} + M^2$ — ∞ tower

Strings on circles see double



$$X(\tau, \sigma)$$

$$X(\sigma + 2\pi) = X(\sigma) + 2\pi w R$$

$$X = x + l_s^2 \underbrace{\frac{n}{R}}_{p} \tau + wR\sigma + \text{osc.}$$

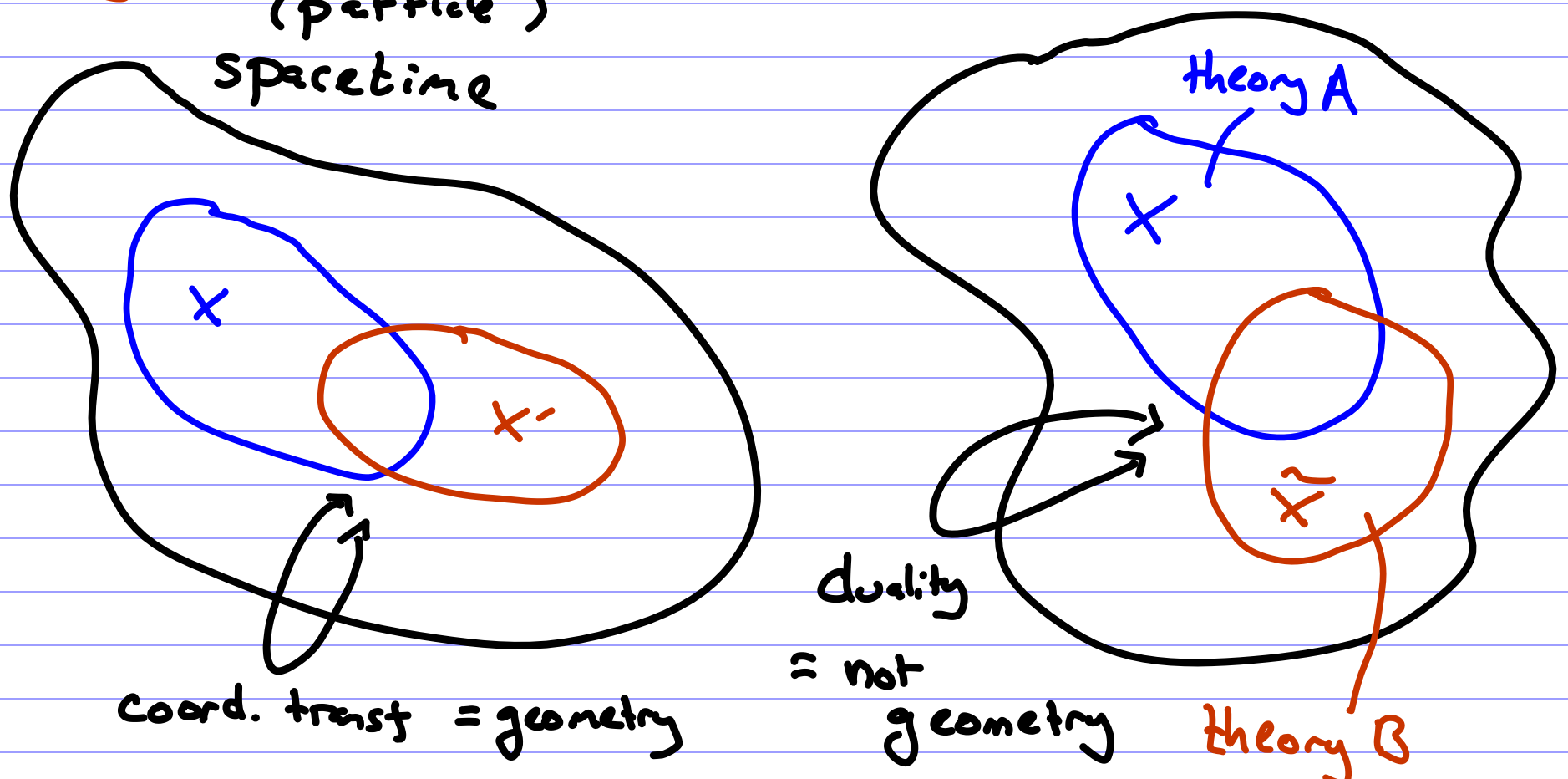
$$E^2 = \vec{p}^2 + \left(\frac{n}{R}\right)^2 + \left(\frac{wR}{l_s^2}\right)^2 + \text{osc.}$$

DUALITY

small circles $\longleftrightarrow$ big circles

$n \leftrightarrow w$, $R \to \frac{l_s^2}{R}$

My research explores "stringy geometry"



My own worldline

2006-2010 TP/Maths
TCD

2010-11 Part III
2011-15 PhD
Cambridge
(St John's College)

2015- Postdoc
Vrije Universiteit Brussel
via 2 personal fellowships
of Flemish research foundation
(atypical)

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Alternate Branchings

Masters physics, comp. sci., actuary, ...

Jobs finance, teaching, software, energy policy, ...

PhDs IE, UK, US, EU, ...

More Jobs hedge funds, tech, investment banks, consultancy, civil service, ...

Change field other physics, mathematical biology, ...

Research your PhD

approx., doublecheck!

e.g.	Undergrad	Masters	PhD	Funding?	Deadlines
UK	3	1	3-4	"maintenance"	Nov - Mar
US	4(?)	n/a	5-7	✓ teaching	Dec (but GREs!)
EU	{ 3 + 2 }		4	✓ salary	Feb - June

How to find opportunities:

inspirehep.net/jobs

Academic Jobs Online

Departmental websites
↳ email lecturers

What you need:

- CV, transcript
- personal statement
- 2 letters of recommendation
- US: GREs, UK/EU: interviews
- prior research experience?
  - ↳ final year / Masters thesis
  - summer opportunities
    - DESY, CERN, DIAS, TCD?, ...

far from essential!

You cannot make the perfect decision...

Topic — look at papers (inspirehep.net or arXiv.org) (hep-th)
do they seem interesting? Gut feeling?
what background knowledge do you need?

Supervisor (+ Group) — current students? collaborators? previous students?

People who can help you during your PhD

ASK

- their experience?
- group size/dynamics?
- location? work/life balance?
- opportunities to travel? (schools + conferences)
- teaching duties? (good experience)

What was 1st thing my supervisor said to me?

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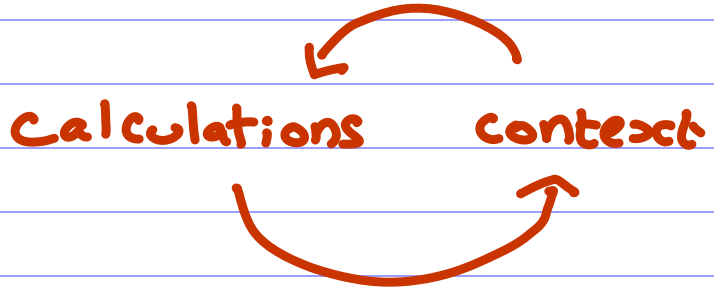
"I think it would be interesting for you to figure out how the massive modes of type II string theory fit into double field theory"

(I never [quite] have...)

Learning to do research takes time



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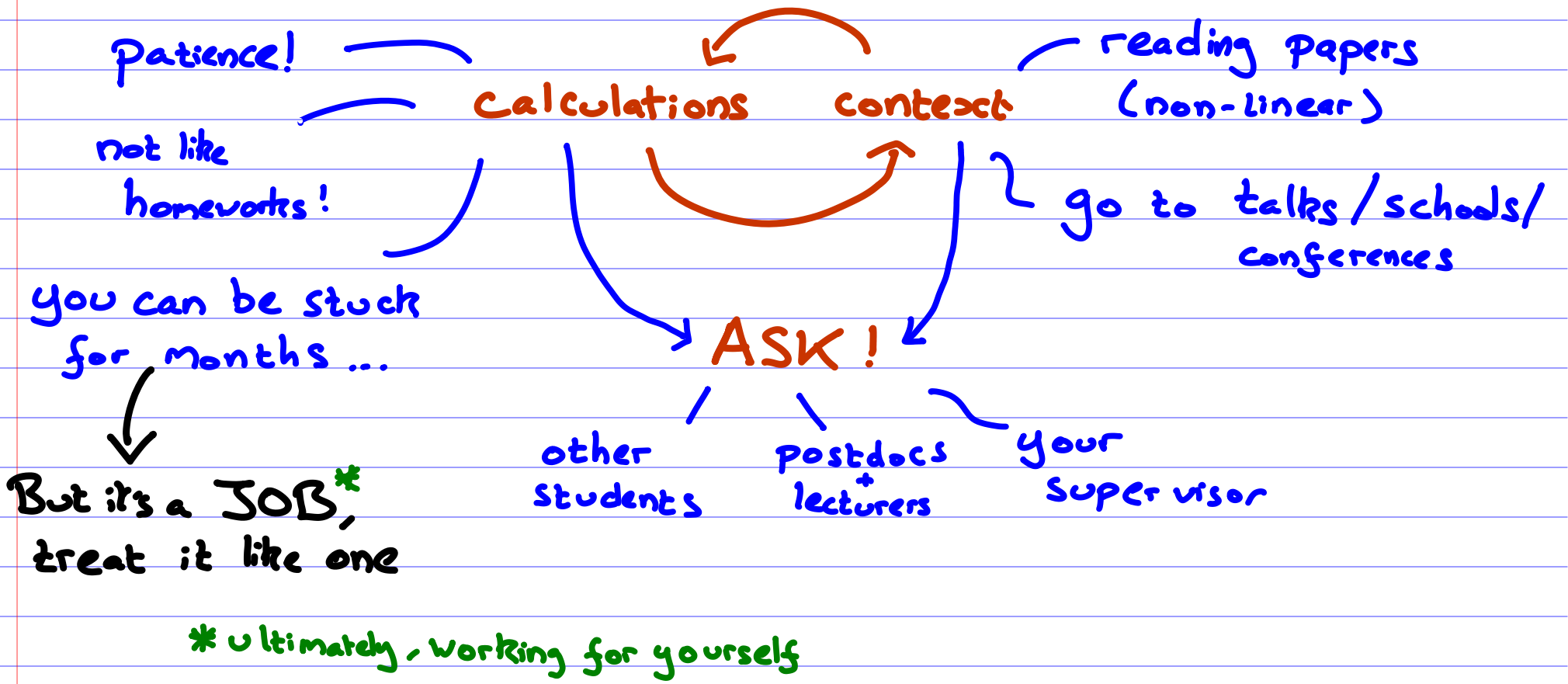
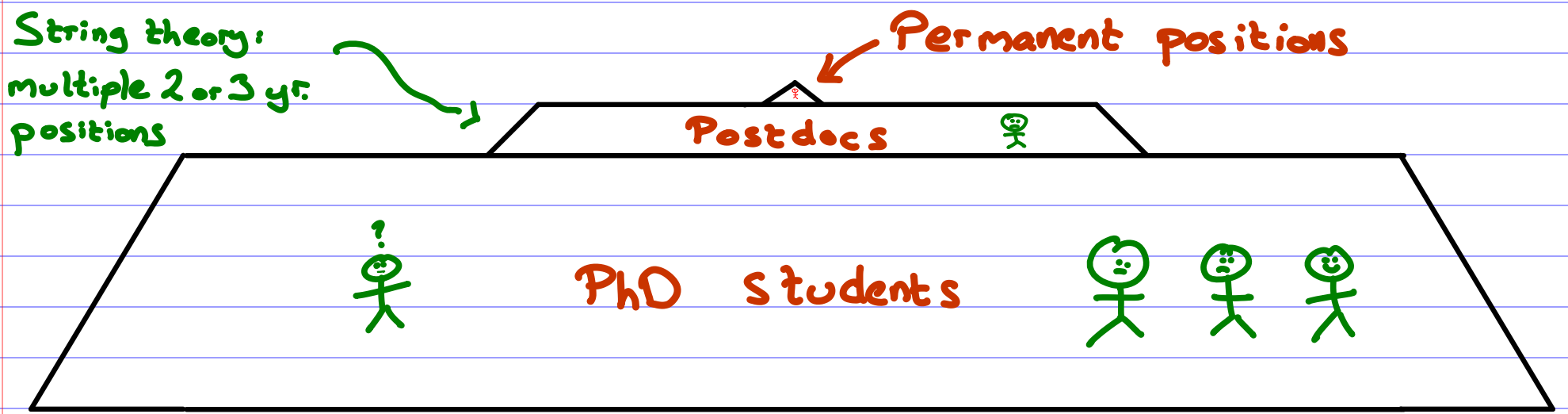


A pyramid schematic of academia



Data: European joint theory postdoc applications

(~30 universities)

446 applications

Obtained positions: 9% (participating uni.), 15% (elsewhere)

Doing PhD/postdoc involves trade-offs

Pros

- day to day freedom
- travel (pre-Covid obviously...)

Argentina, Canada, Croatia, France, Greece, Germany, Italy, Japan, Netherlands, South Africa, South Korea, Sweden, Thailand, US

- the people
- being the first human to understand some particular thing every now + again...

Cons

- job insecurity
- isolation
- measuring accomplishment
- publish or perish

Advice from the class of 2010

[redacted] Industry (bookmakers)

You could advise them to get the PhD funding then quit once they've enough to write up a masters. That way you get the fancy diploma paid for but you don't have to go through all the PhD hassle

18:28

[redacted] Postdoc expt. physics

Tell them that professors expectations for Phd students haven't adjusted to the modern situation where phd's are needed as cheap labour for large research institutes research, and the net result is that everyone will be disappointed in the end

19:40

[redacted] Teacher

> [redacted]
> OK then. Don't rule out finance until you have very solid grounds for doing so. That's where the majority of physicists go, and ultimately more regret not taking that route than taking it.

Not all - teaching is always an option! For those who find a vocation, or for those who can't do...

19:56

[redacted] PhD then industry (coding)

OK then. Don't rule out finance until you have very solid grounds for doing so. That's where the majority of physicists go, and ultimately more regret not taking that route than taking it.

19:38

[redacted] Postdoc lattice QCD

> [redacted]
> OK then. Don't rule out finance until you have very solid grounds for doing so. That's where the majority of physicists go, and ultimately more regret not taking that route than taking it.

My finances attest to that 😅

19:39

+

Don't get your heart set on one thing.

Follow your interests, be realistic, enjoy the opportunity!

more q's: blaircd@tcd.ie

A PhD ≠ your self-worth

You always have many options

Research is rewarding but ∃ trade-offs

Be curious, work hard, have fun!

Some scientific suggestions

- string theory!
- gravitational waves (positions at VUB now)
- Quantum information — Quantum computing / Holography / Quantum gravity
- Machine learning + HEP

97 solve BH information paradox? 2019