INTERNATIONAL YEAR OF Quantum Science and Technology

The Physics of Teaching

Igor Bray, John Curtin Distinguished Professor

Director of Theoretical Physics
Head, Physics and Astronomy
Curtin University, Perth, Western Australia

Curtin Colombo, Sri Lanka, 10th of December, 2025

PAWSEY supercomputing centre TACC TEXAS ADVANCED COMPUTING CENTER NCI AUSTRALIA Australian Government Australian Research Council Curtin University

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Outline

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Study Maths, Physics and Chemistry

Introduction

- In the knowledge-based economy STEM graduates have the best careers:
  - Energy: renewables to nuclear
  - Climate: computational modeling to mitigation
  - Space: interplanetary travel to searching for alien life
  - Engineering: resources to robotics
  - Supercomputers: data science to AI
  - Science: applications and discovery
- All require highest level of Maths and Science
- Complement with music, literature and sport
- Choose a career by the people you want to spend you life with

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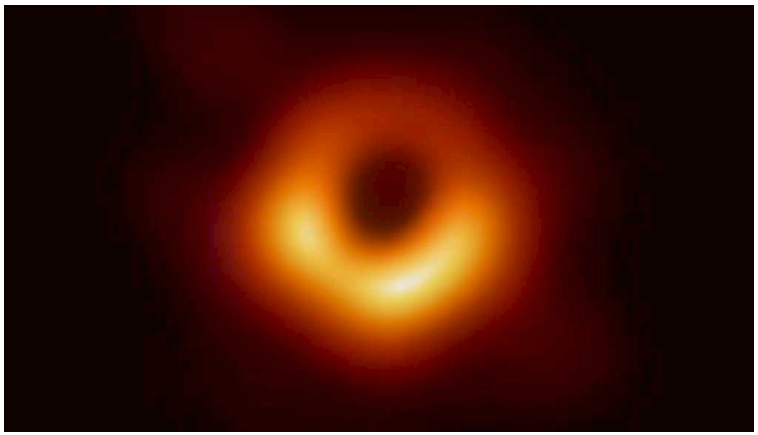
Black Hole imaged for the first time

- 2019: Black Hole imaged by an extended light source



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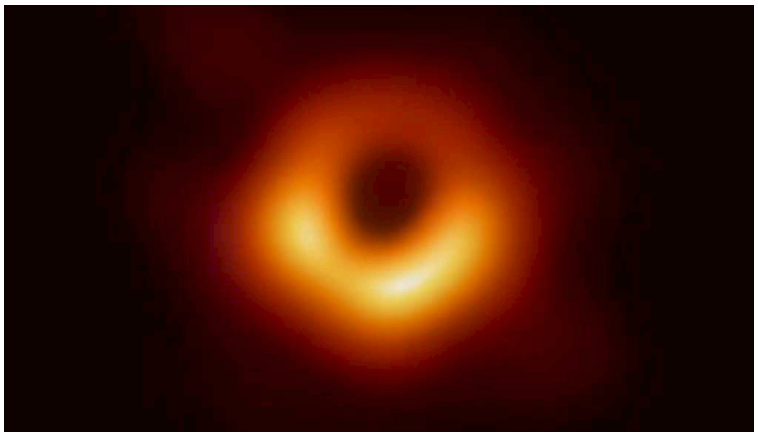

- As predicted in 1986:

PHYSICAL REVIEW D VOLUME 34, NUMBER 2 15 JULY

Kerr black hole as a gravitational lens

Igor Bray
Department of Mathematical Physics, University of Adelaide, GPO Box 498, Adelaide, SA 5001, Australia
(Received 24 June 1985)

We present approximate solutions to the equations of motion for a ray of light in the Kerr metric which are correct up to and including second-order terms in $m/r_{\min}$ and $a/r_{\min}$, where m and a are the Kerr mass and spin, respectively, while $r_{\min}$ is the distance of closest approach. We use these expressions to investigate the multi-imaging aspect of the gravitational lens effect.

Atomic and Molecular Collisions

What are they?

- Collisions on the atomic scale go on all around us
- Difficult to calculate:
  - Governed by the Laws of Quantum Physics
  - Countably infinite discrete spectrum
  - Uncountably infinite target continuum
  - Charged particles interact out to infinite distances
- Solved by the Convergent Close-Coupling method
  - Valid at all energies and for all collision processes
  - 600+ publications, 200+ coauthors, 17,000+ citations
  - Continuous ARC funding ($30M) since 1992

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What are they good for?

The primary motivation is to provide accurate collision data for science and industry:

- Fusion research
- Neutral Antimatter creation
- Astrophysics
- Lighting industry
- Nanolithography
- Medical imaging
- Medical therapy

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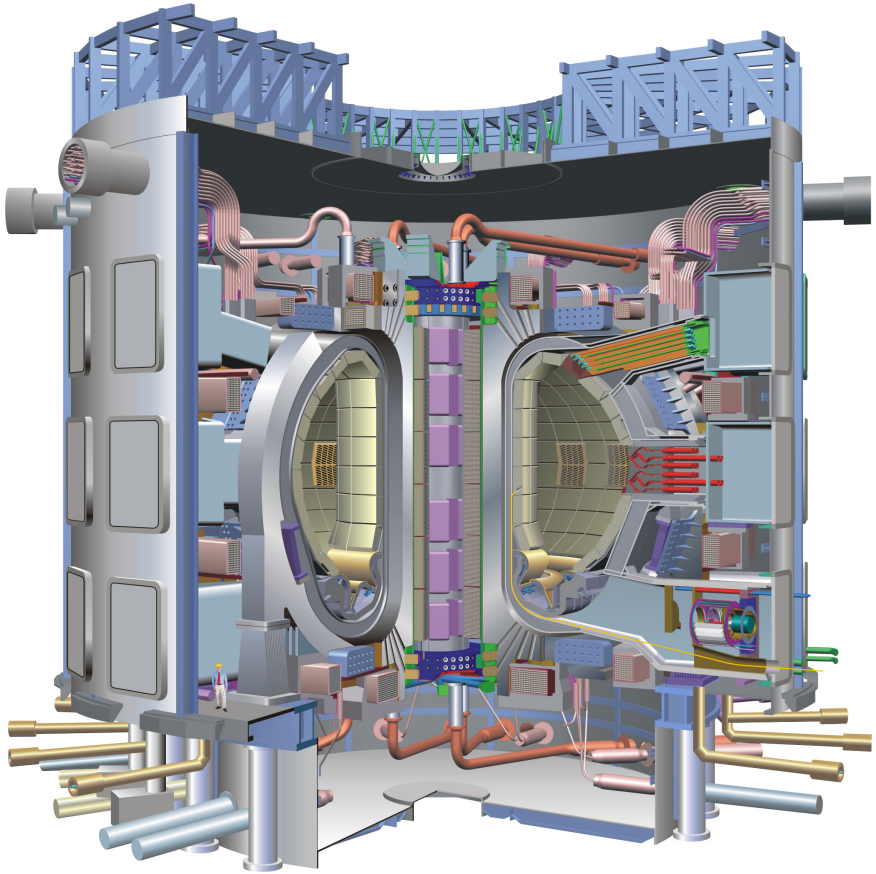

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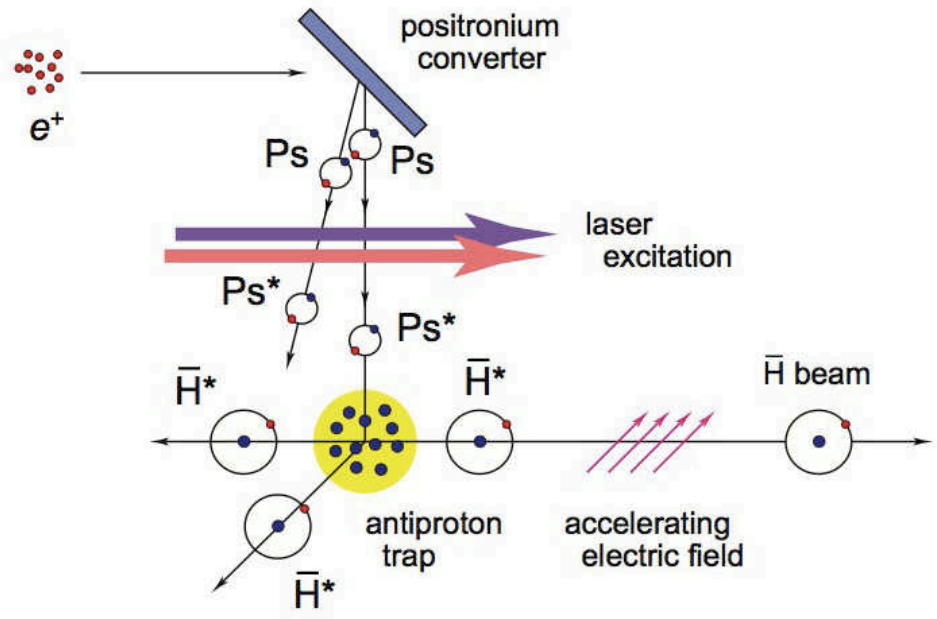

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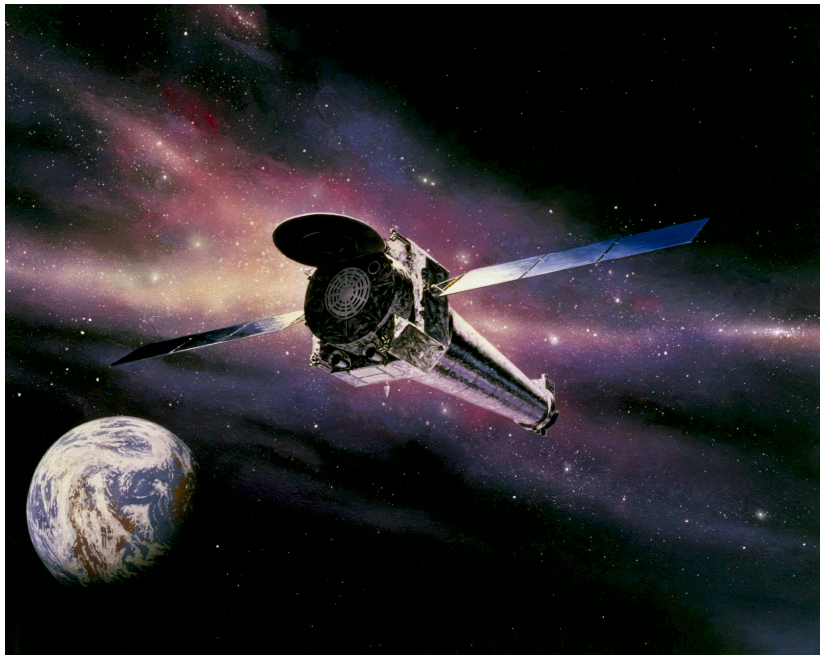

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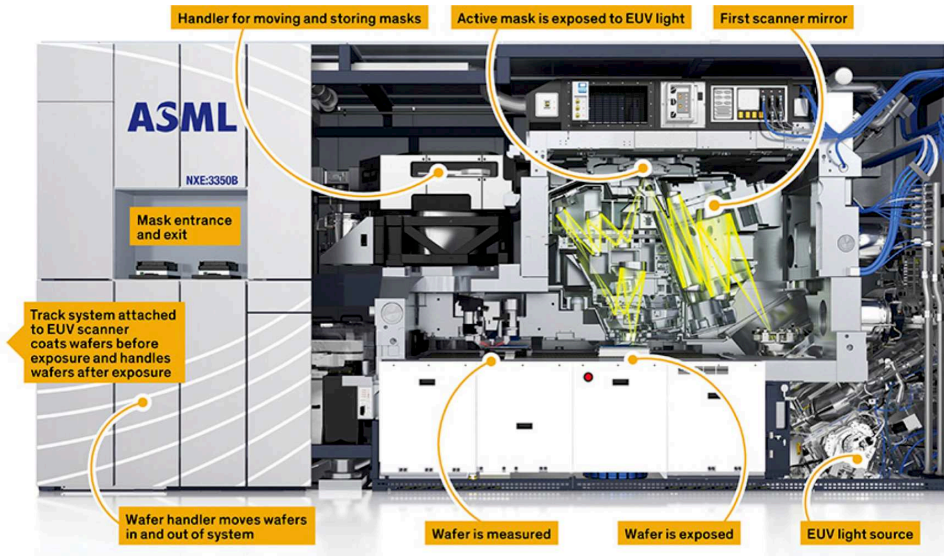

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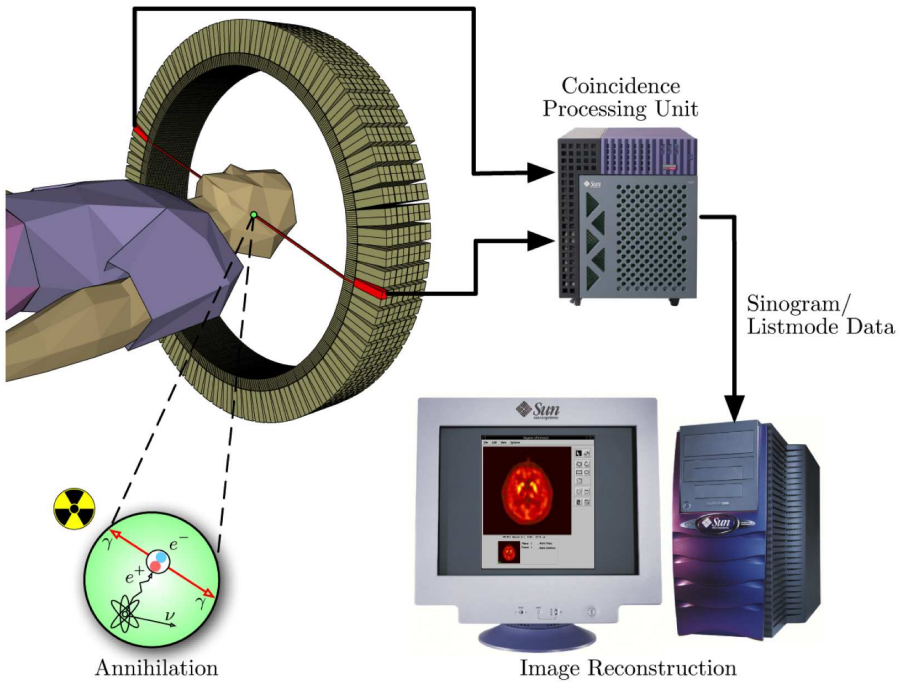

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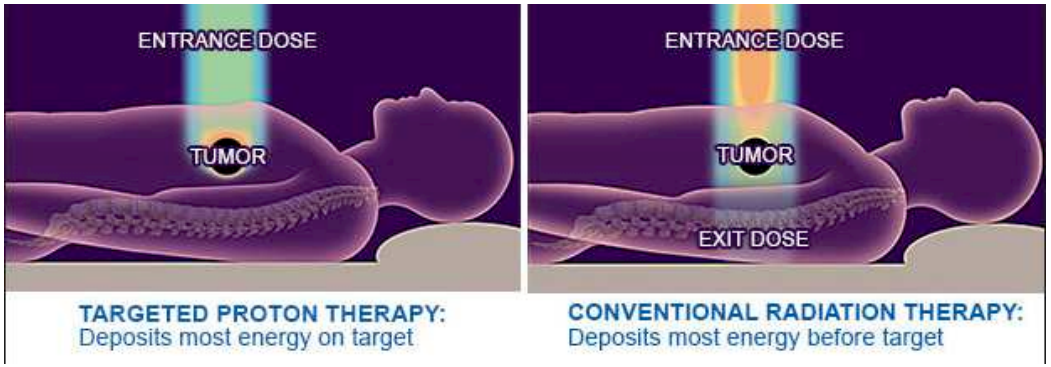

The Physics of Teaching

What are Physics and Teaching?

- Physics:
  - Evidence-based, derivable, falsifiable
  - Humanities: “You are not entitled to any opinion, only what you can argue for”
- Teaching:
  - Information transfer from older to younger generations
  - Builds character (confidence, empowerment, resilience, work-ethic)
  - Question: which is more important:
    - information transfer, or
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Principles of Physics

- 2nd Law of Thermodynamics: Entropy increases, information decreases; Creates arrow of time
- Life fights entropy increase (ageing):
  - Multigenerational:
    - Life is about paying it forward, leads to enlightenment
    - Children $\Leftarrow$ Parents/Teachers $\Leftarrow$ The rest!
  - Action: good; inaction: bad (neglect, ignore)
  - Teaching is fundamental to fighting entropy increase
- Robert Pirsig's evolutionary hierarchy of Quality
  1. Intellectual (least entropy, maximum information)
  2. Social
  3. Biological
  4. Physical (most entropy, minimum information)
- Teaching: health, mutual care, academic excellence

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Equilibrium: stable or unstable

- In Physics, two kinds of equilibrium:
  - Stable: a small perturbation leads to restoration
  - Unstable: a small perturbation leads to collapse
- Adversarial systems are based on unstable equilibrium: Law, Politics, destructive competition
  - National Rifle Association: “The only thing that stops a bad guy with a gun is a good guy with a gun”
  - Mutually Assured Destruction (MAD) of Cold War
  - Personal or organisational conflict
- Cooperative (good-will) systems are based on stable equilibrium: Physics, constructive competition
  - Transition from unstable to stable equilibrium
  - Classroom management: cooperative or adversarial?

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Student-Teacher balance

- Physics problems: one-body, two-body, three-body, few-body, many-body, statistical
- Student perspective: one-body problem
- Teacher perspective: teaching is a statistical problem
- Zen: When a student is ready the teacher will appear
- Societies/organisations/classrooms:
  - Individualistic: “Look after #1”
  - Totalitarian: “Some of you may die, but it is a sacrifice I’m willing to make!”
  - Balanced: “All for one, one for all!”

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Physics culture good for Teaching

Einstein:

- "Things should be made as simple as possible, but not simpler". Too simple: misuse of
  - Collective nouns (gender, religion, nationality)
  - Metrics (ATAR, money)
  - $v = u + at$ should be $v(t) = v(t_0) + a[t - t_0]$
- "There are things that count which cannot be counted, and there are things that can be counted which do not count".
  - Quality cannot be counted, requires right culture
  - "Culture eats strategy for breakfast"
  - Good culture: individual action benefits all

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- Progress: teamwork with “responsible leadership”
  - “champion team will beat a team of champions”
  - is incremental, rarely revolutionary
- Hard is good!
- Unifies: concentrates on message not messenger
- Communication: a balance of clarity and brevity
- Conflicts, personal/organisational, are opportunities
- If a solution exists, Physics will find it!

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