

Title: The Weird World of Quantum Theory

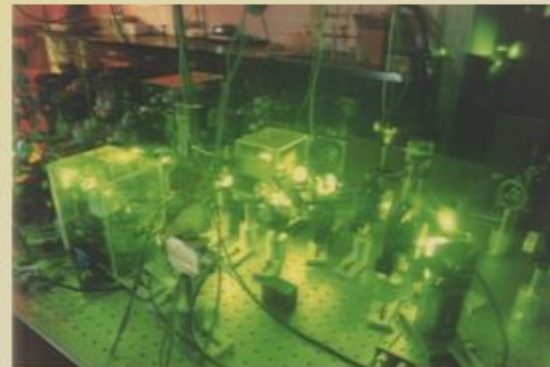
Date: May 27, 2007 12:00 PM

URL: <http://www.pirsa.org/07050091>

Abstract: <span>An introduction to the fascinating world of subatomic particles, entanglement, quantum computers and the like. This presentation will outline some of the main ideas behind quantum theory, arguably the most successful theory in the history of science. It will also connect these concepts to some of the topics researchers at the cutting-edge of this field are working on today.</span>

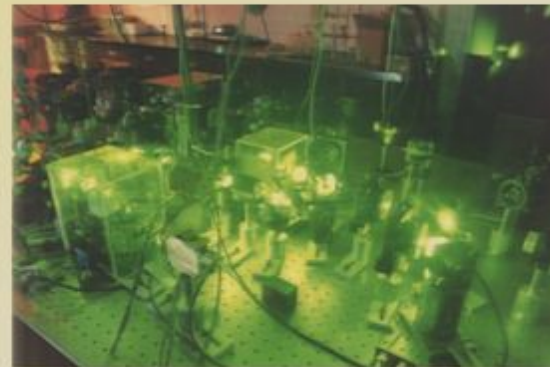
# The weird world of quantum physics.

$$|\psi\rangle = |0\rangle + |1\rangle$$



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$$|\psi\rangle = |0\rangle + |1\rangle$$



Superposition

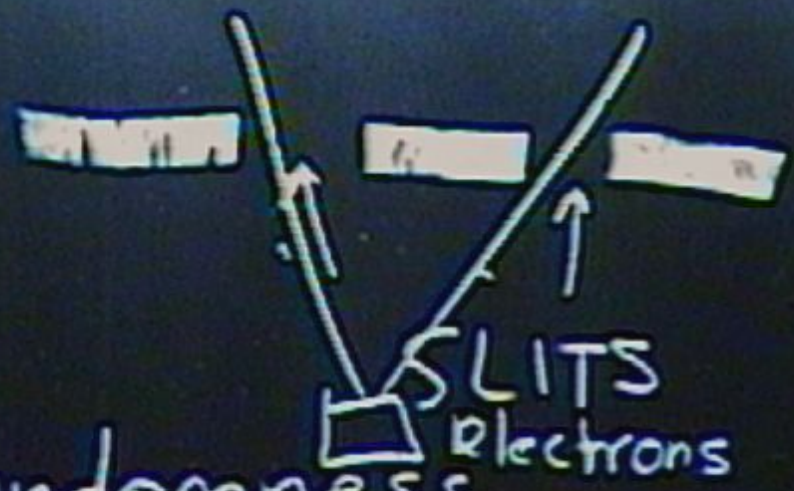
genuine randomness

entanglement

position

inherent randomness

entanglement



Exotic

Afternoon

( 2pm - ...

- teleportation in science fiction
- quantum physics
- quantum teleportation in theory
- quantum teleportation experiments

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# Star Trek and The Fly





# What is teleportation?

- Imagine a brave space explorer in her spaceship.



# Science Fiction Recipe for Teleportation



- 1. A machine scans the space explorer to find out everything about her. Eg. her height, her mass, what shoes she is wearing, the colour of her eyes etc.
- 2. It then sends this information to an nearby uncharted planet.
- 3. On the planet's surface, a receiving machine takes in the information & uses it to construct a perfect copy of the astronaut.

- *Essence of teleporting: constructing a perfect copy of an object at a distant location without sending the object itself*

- A problem: Heisenberg's uncertainty principle prevents us from knowing everything about an object
- somehow, quantum teleportation circumvents this problem
- **KEY POINT: We do not actually teleport the object itself.**
- teleport *its properties* & so get a perfect copy of it

# What do we really teleport?

- the quantum state  $|\psi\rangle$
- What is that?  
a real object?  
a representation of our  
knowledge?

# Quantum teleportation in three easy steps

- To transmit something from A to B, we always need a means or route by which to send it.

Eg. a phone line, a wireless connection



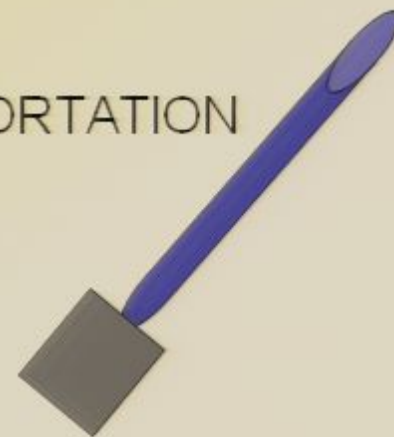
- To teleport the properties of a laser beam from A to B, we use two routes (a.k.a. *channels*).

1st CHANNEL

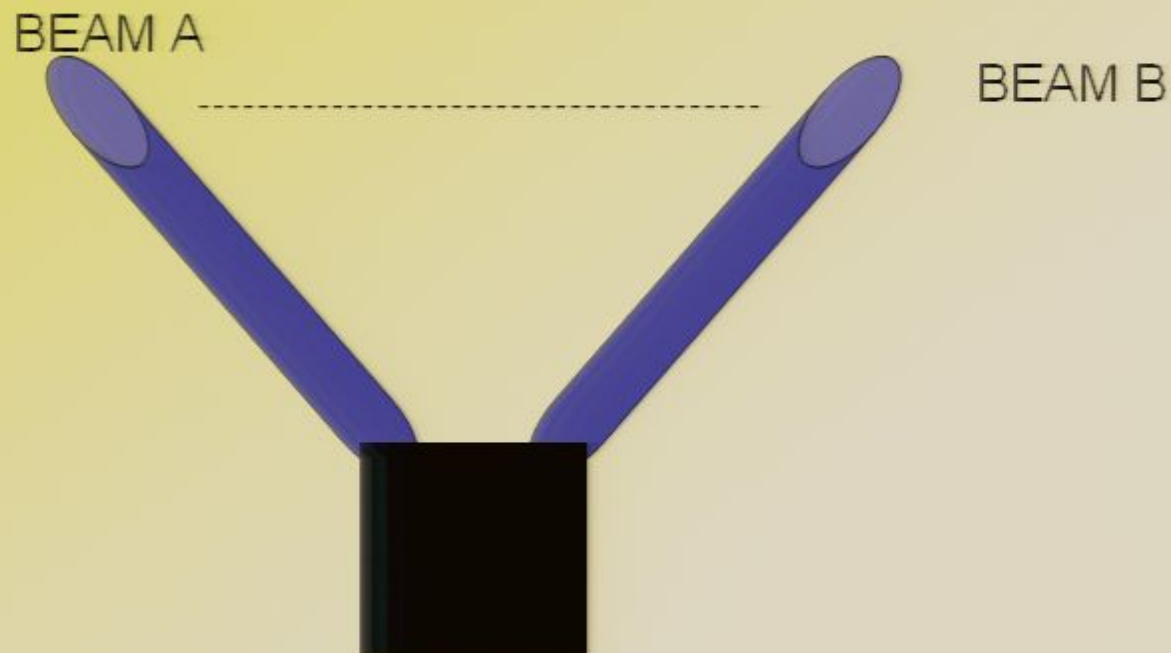


- any standard means of communication, such as a telephone.

TELEPORTATION  
BEAM



- 2<sup>nd</sup> CHANNEL
- Two laser beams sharing entanglement.



- **WHAT IS ENTANGLEMENT?**

- If two quantum particles (or beams) are entangled with each other then they are instantaneously linked no matter how far apart they are
- Act as if they are a single object
- *“Entanglement means that the left hand knows what the right hand is doing even when the hands are at opposite ends of the universe.”*

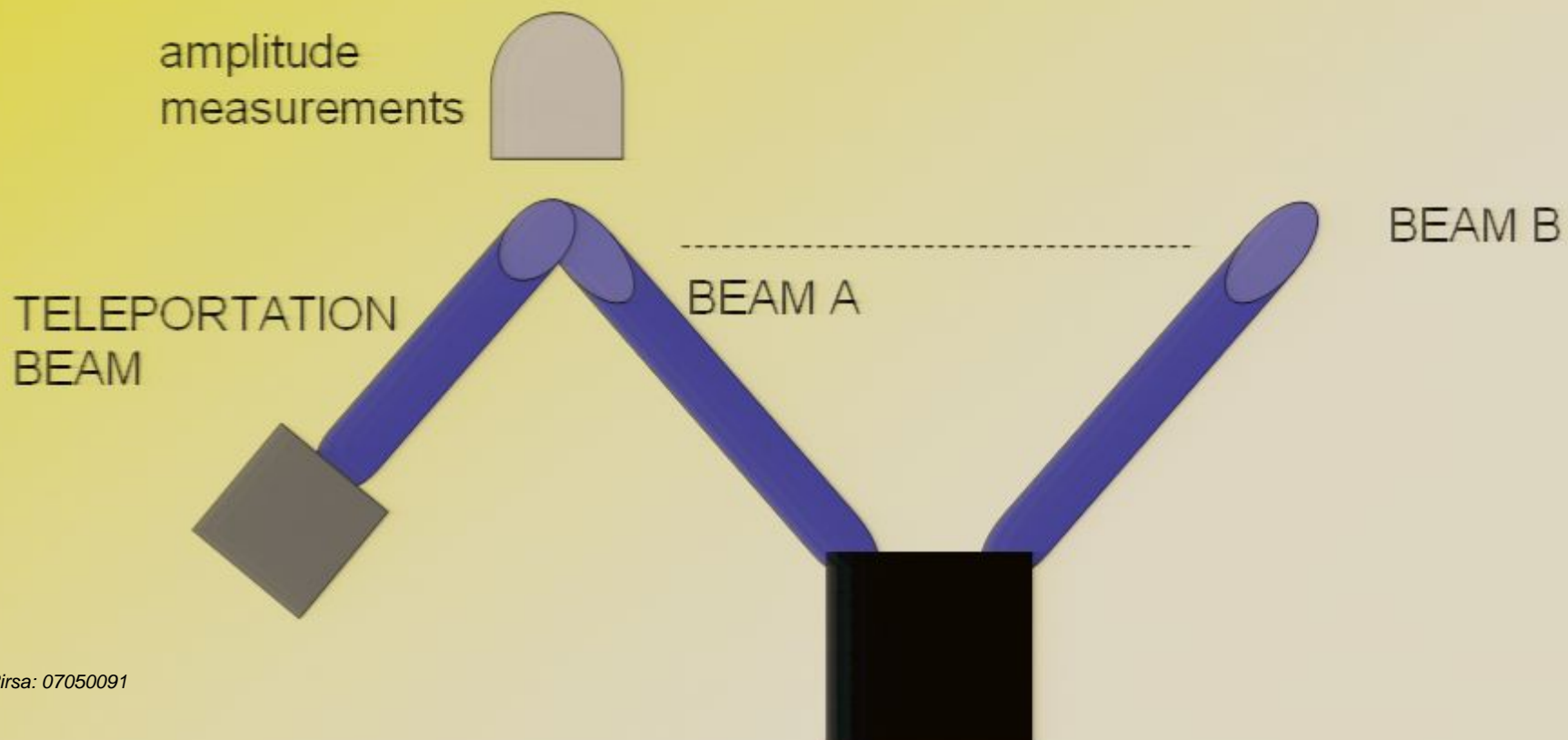


- If two dice were entangled then they would always roll the same numbers if thrown at the same time at opposite ends of the universe

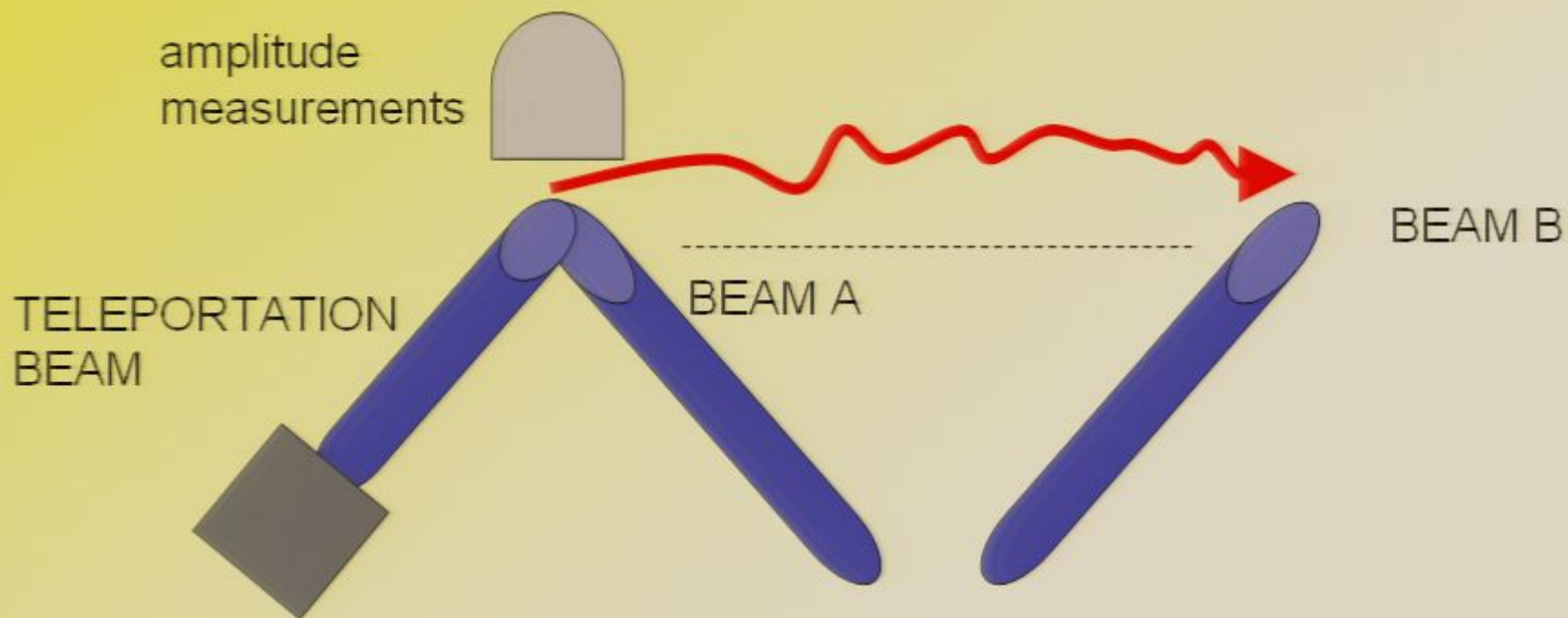


"[Entanglement is] spooky action at a distance."

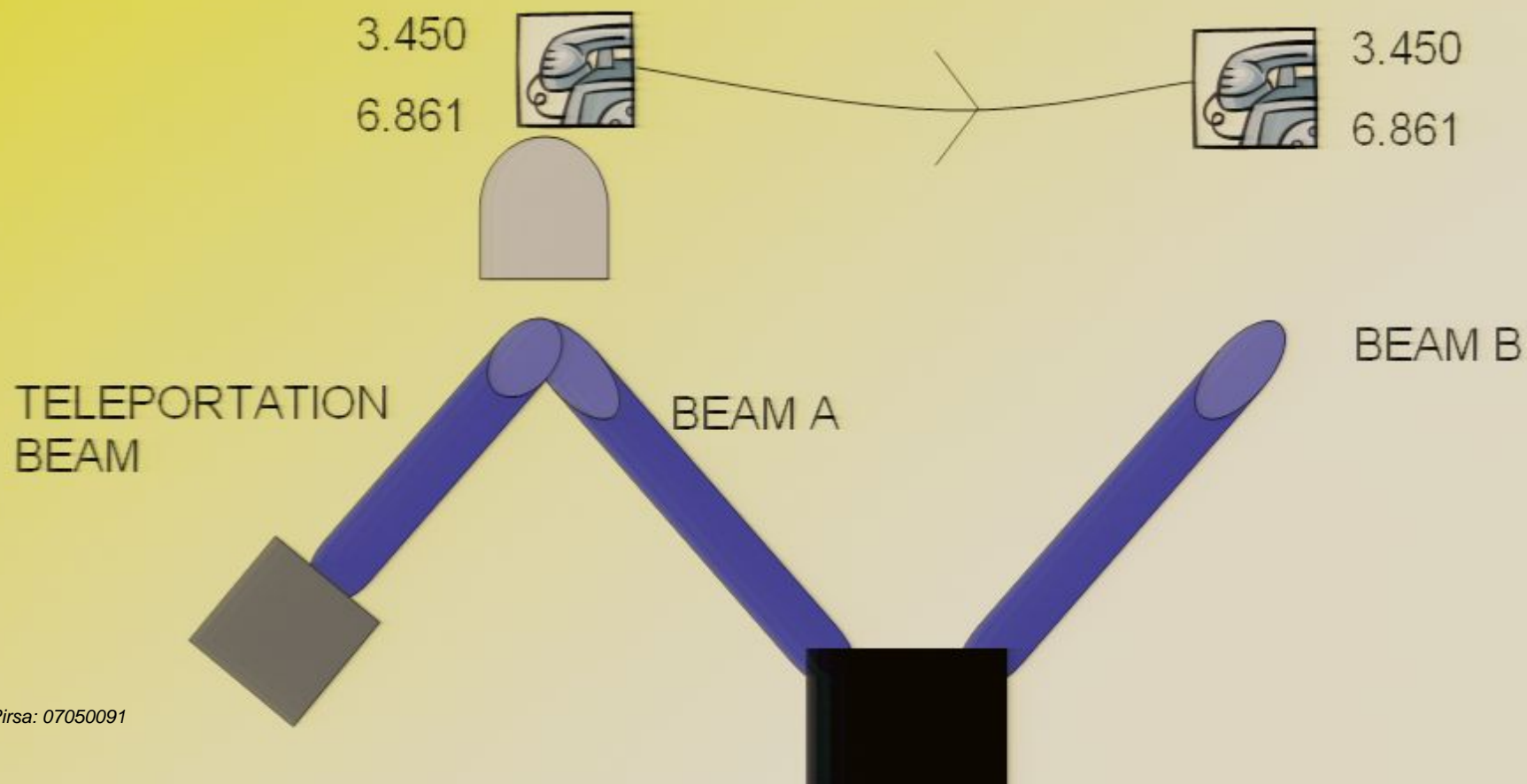
- STEP 1: Combine the beam we wish to teleport with beam A & then measure two components of the overall amplitude



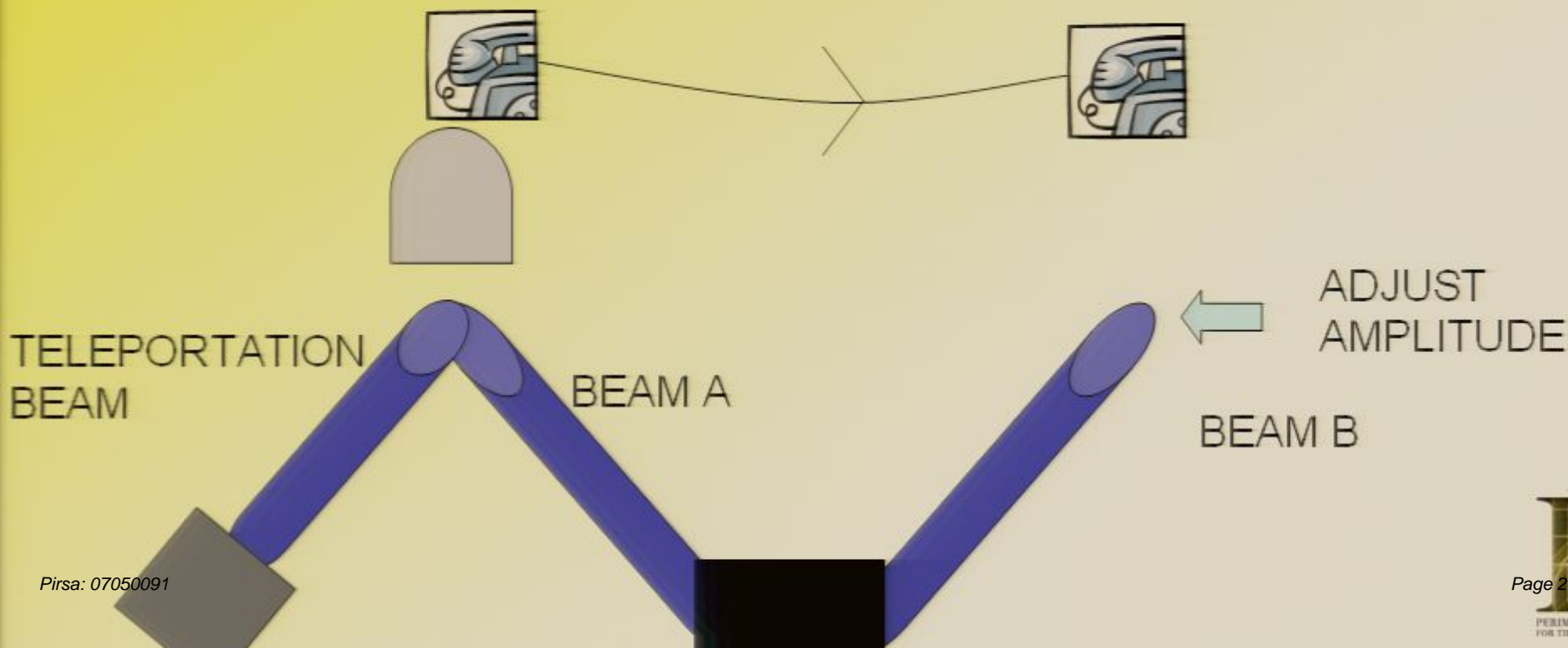
- A natural way to think of this is to say that it instantaneously (nonlocally) ‘zaps’ information about the teleportation beam to beam B.




- STEP 2: Use the 1<sup>st</sup> channel to send the result of the amplitude measurements to B.



- STEP 3: Adjust the amplitude of beam B, depending on the information received. As if by magic, beam B is now identical to the beam we initially wished to teleport. The teleportation is complete!



# A Comparison

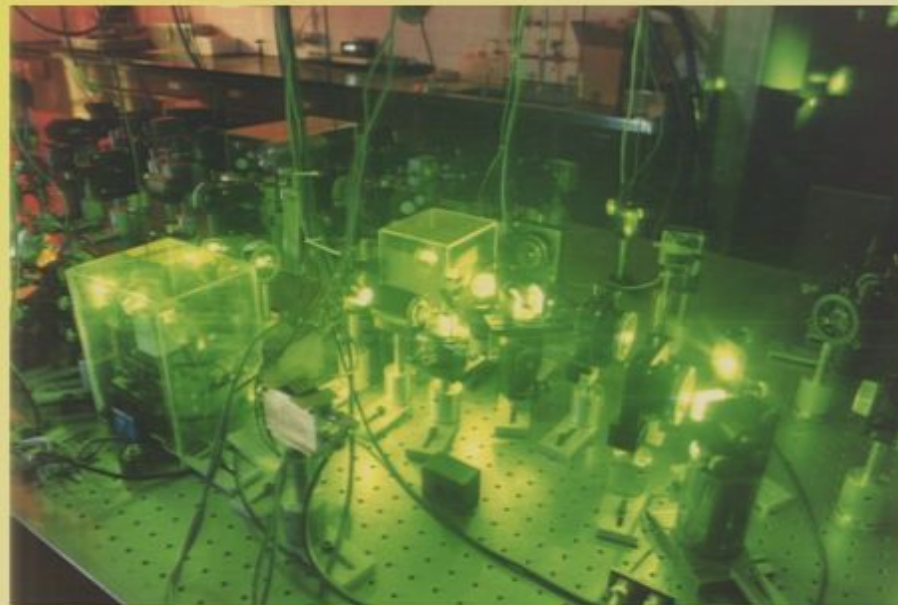
Star-Trek Teleportation	Quantum Teleportation
	
Instantaneous?	Takes a small amount of time
The object itself is teleported.	Only the structure or properties are teleported (i.e. information)
Done with people.	Done with photons & atoms
The original is destroyed in the process.	The original is destroyed in the process
Can teleport to an uncharted planet.	Need to have something set up at the teleportation destination.
Done over thousands of kilometres.	Done over 600 metres at most

# 1997: Vienna, Austria a single photon (About 50 cms)



Picture of equipment used to perform an early teleportation experiment with individual particles of light (photons). (University of Vienna, Austria.)

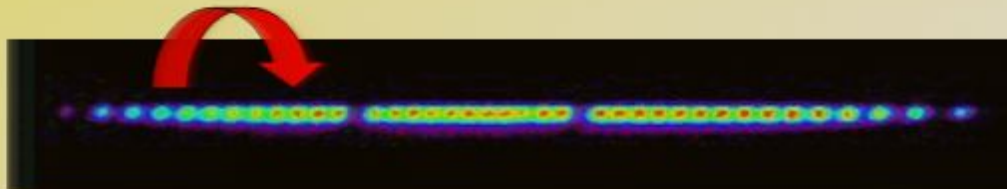
1998 & 2002:  
Caltech, USA &  
Canberra, Australia:  
A laser beam (About 50 cms)



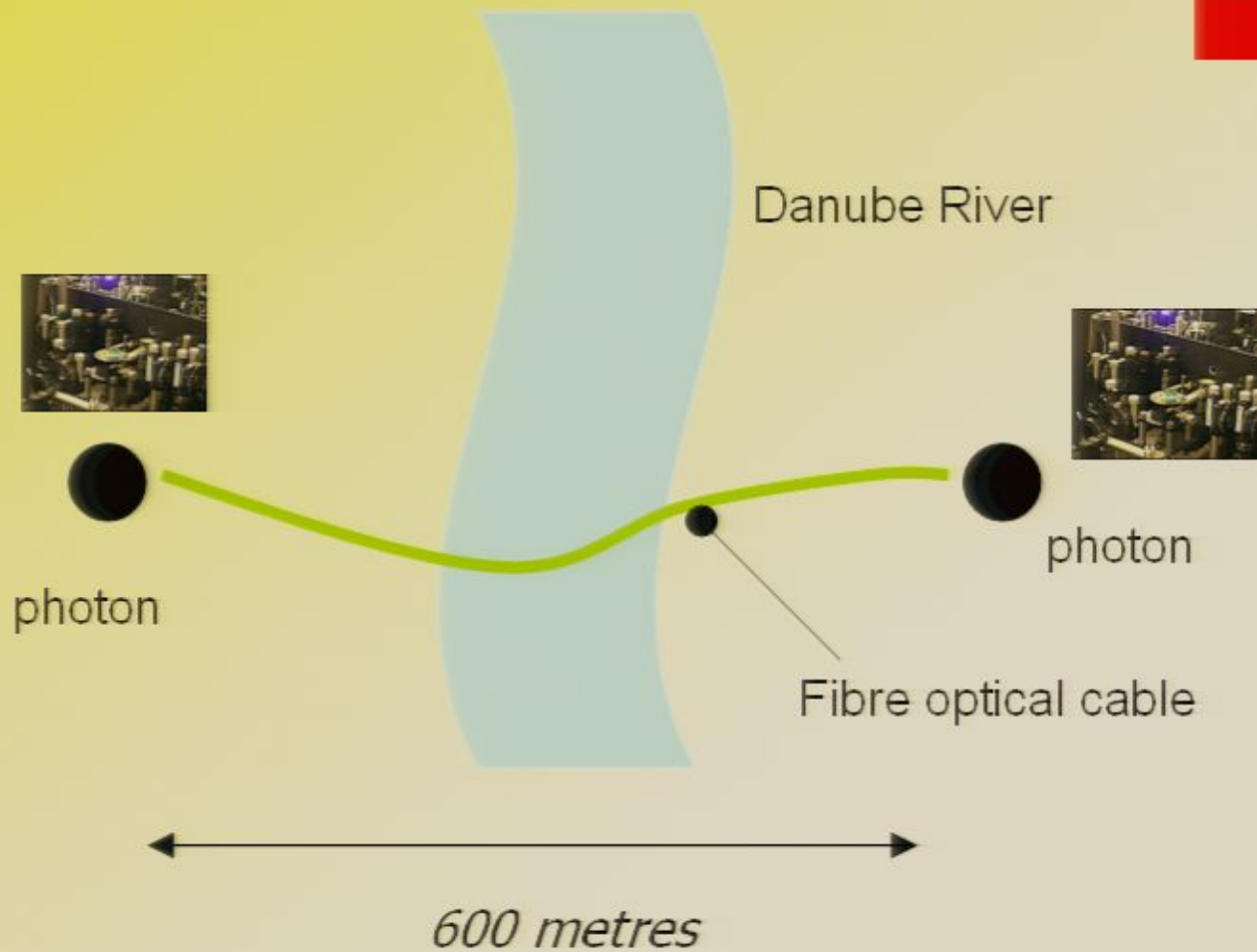
*"Beam me up, mate" --- CNN*



# 2004: Innsbruck, Austria & Boulder, Colorado, USA teleporting atoms: c. 1 mm



# 2004: Vienna, Austria a single photon: 600 metres (world record)



# What might we teleport in the future?

- Teleporting a grain of sand? One hundred years, perhaps.



- Teleporting a person? Who knows?



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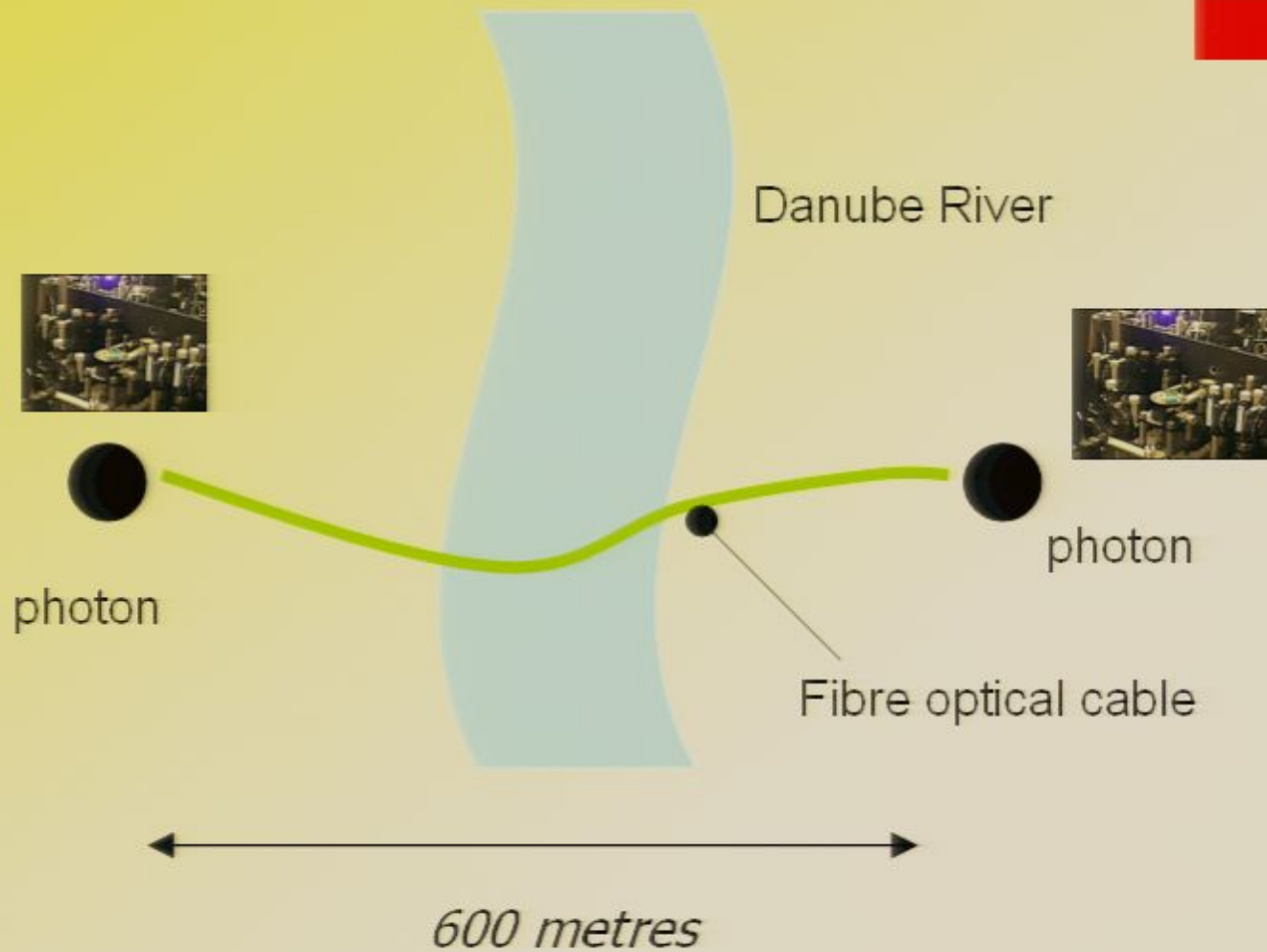
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