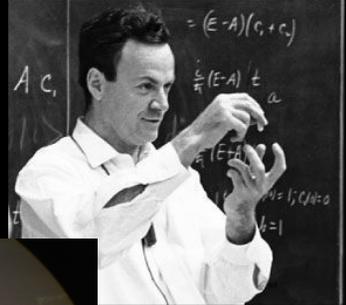
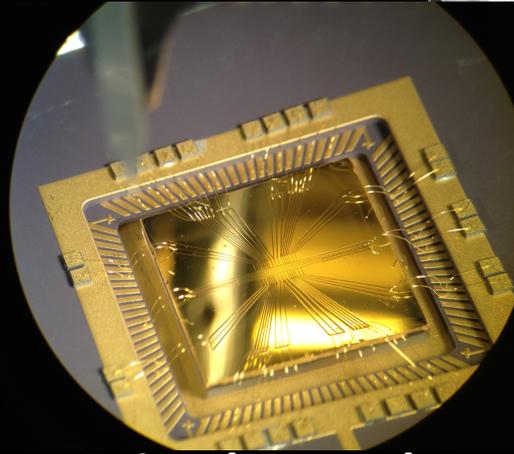
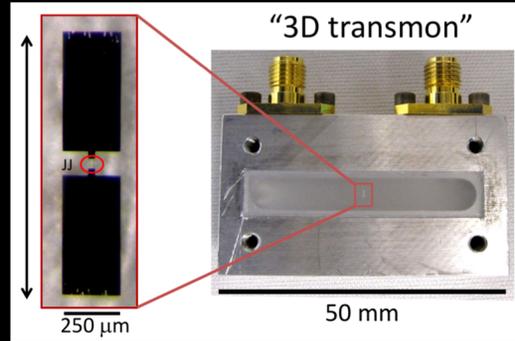




# Quantum Sensors for Fundamental Physics



Ian Shipsey, Oxford



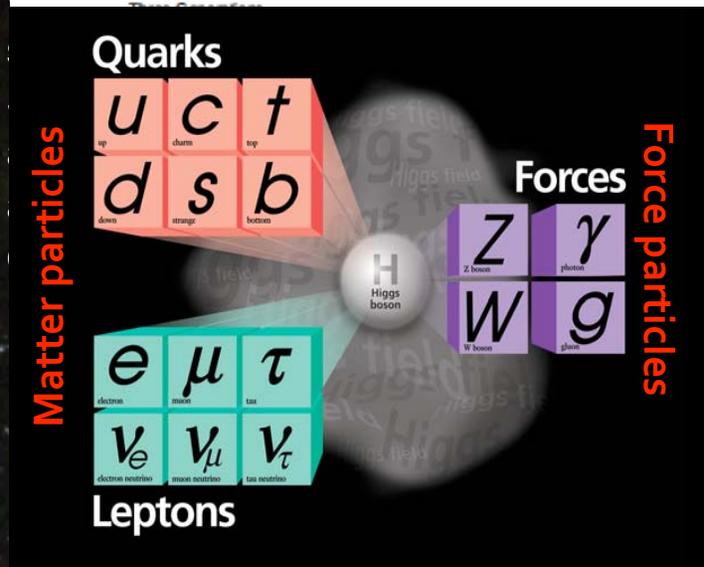
**Institutions:** Aberdeen Birmingham Bristol Brunel Cambridge  
Cardiff Durham Edinburgh Glasgow Imperial KCL Liverpool  
Manchester Nottingham Open Oxford QMUL QUB RAL RHUL  
**Partners:** Sheffield Soton Strathclyde Sussex Swansea UCL Warwick +....



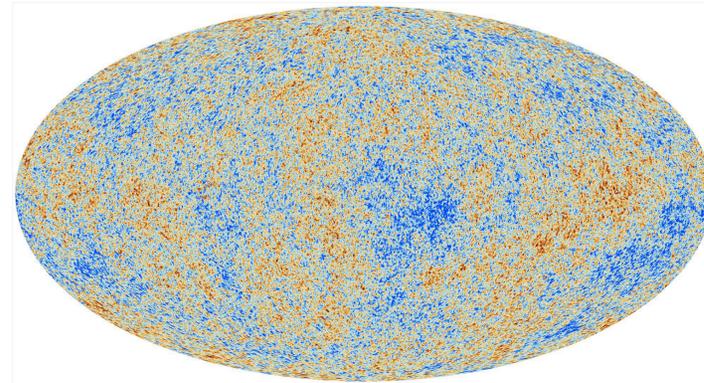
QSEP 2, January 2019 -- I. Shipsey

# BUILDING AN UNDERSTANDING OF THE UNIVERSE: A WORK A CENTURY IN THE MAKING

- **PARTICLE STANDARD MODEL**

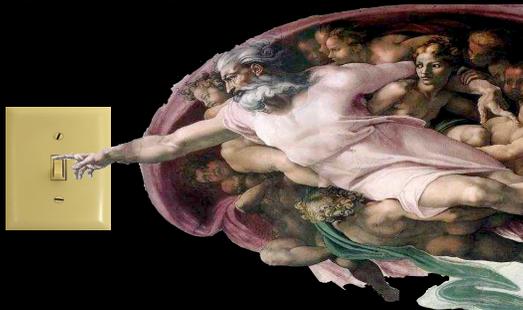


- **COSMOLOGY STANDARD MODEL**



# THE POTENTIAL NOW EXISTS TO REVOLUTIONIZE OUR KNOWLEDGE AGAIN

## Mystery: The Higgs

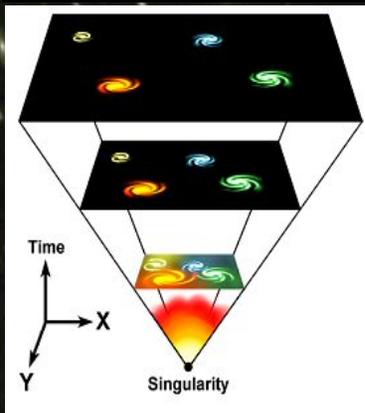


## Mystery: Dark Matter



5/6

## Mystery: Dark Energy



70%  
of the  
universe

Mystery: Why are there so many types of particles?

Mystery: how did matter survive the  
birth of the universe?

Mystery: What powered cosmic inflation?

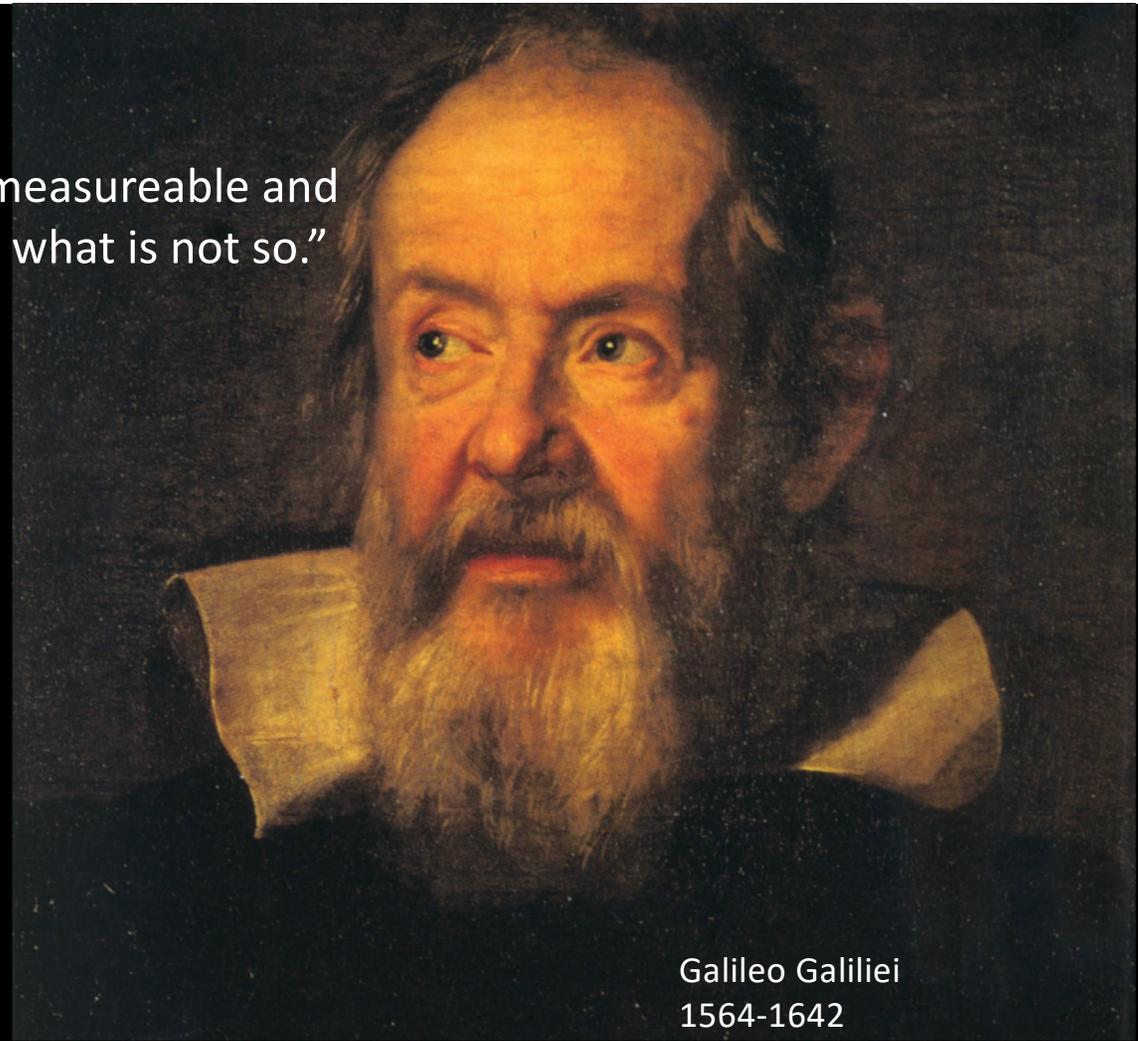
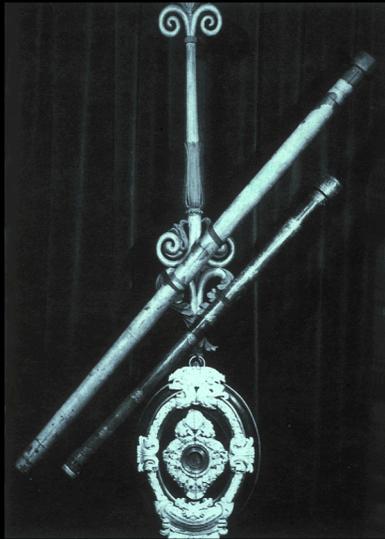
Mystery: What is gravity?

QSP 2 January 2015 - Slides

3

We are in a data driven era

“Measure what is measurable and  
make measurable what is not so.”



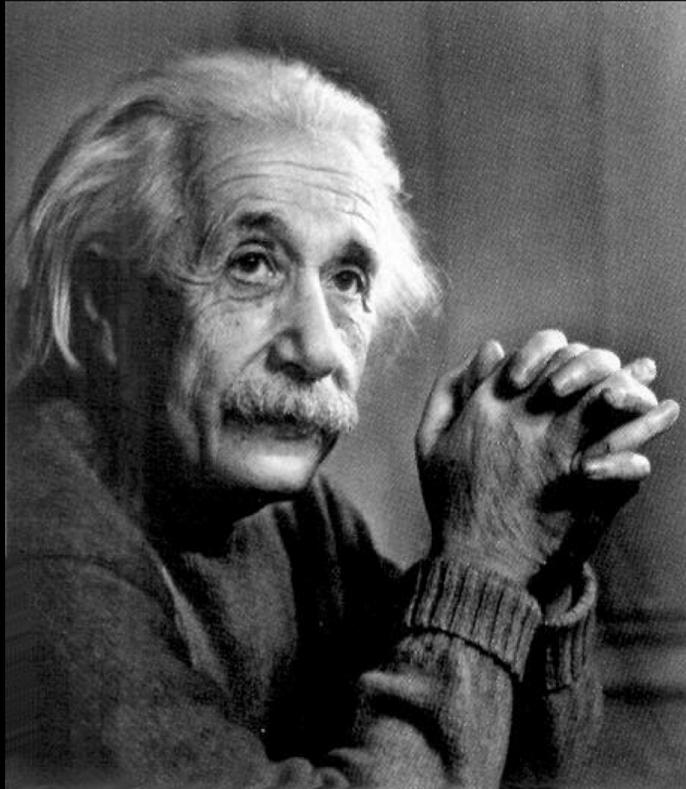
Galileo Galilei  
1564-1642

## Double Slit with Electrons

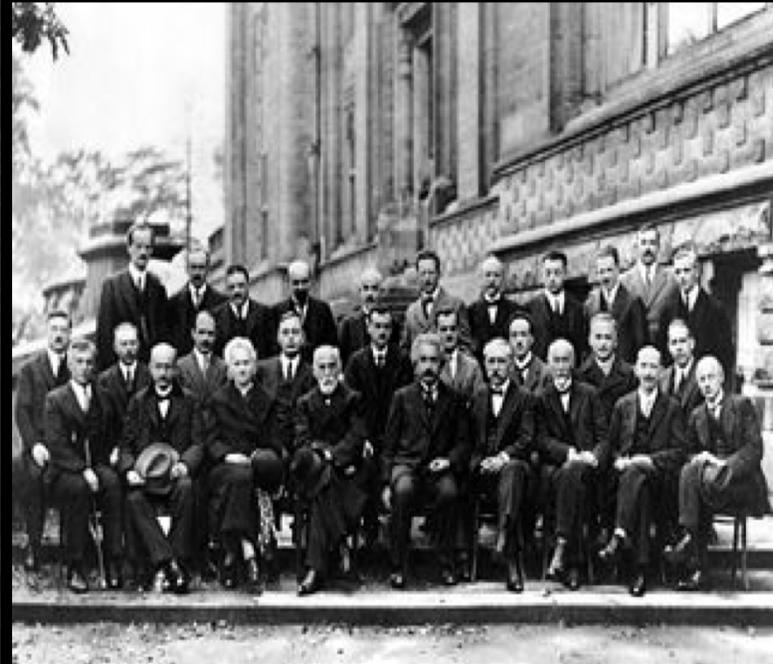
“[A] phenomenon which is impossible, *absolutely* impossible, to explain in any classical way, and which has in it the heart of quantum mechanics. In reality, it contains the only mystery.”

-- Richard Feynman





General Relativity



Quantum Mechanics

QSFP 2 January 2019-- I. Shipsey

## **Quantum Sensors for Fundamental Physics**

Why is this good for all the partners?

The exciting science will benefit all the partners involved: universities, labs & hubs

Leverage the current Hubs to bring state of the art sensors to this new application.

There will likely be a tension between performance and “manufacturability” but the Phase II Hubs should be able to deliver research to push performance, and additional support for user communities from STFC that could feed into and benefit from the Hubs activity

**Why is this good match to the SPF?**

This is a genuinely new *interdisciplinary* partnership between STFC EPSRC and other partners - so plays well to the UKRI era.



Quantum Sensors Workshop October 2018 Oxford >140 from EPSRC & STFC

# Quantum Sensors for Fundamental Physics and Society- Workshop #1

The workshop had four goals

#1 To survey the extraordinary science opportunities and UK capabilities to exploit this science in a world-class programme

#2 To demonstrate to STFC, EPSRC and UKRI the immense interest in the UK in QSFP

#3 To begin to form teams around key experiments that would be funded by QSFP

#4 To work with STFC and EPSRC on the QSFP bid..



Quantum Sensors for Fundamental Physics, St. Catherine's College, Oxford, UK

16 October - 17 October 2018  
Oxford, UK

## Quantum Sensors for Fundamental Physics - Next Steps

The submission into SPF wave 2 was made by STFC/EPSRC December 20. This requests the funding to create the QSFP programme (£40M/ 3 years)

Feedback: The QSFP consortium has been essential to demonstrating the interdisciplinary interest & formation of a community . Without it there would have been no bid to SPF.

If the SPF bid is successful in gaining the funding for a QSFP programme (Feb 19) an open call will be made to the community ~ March/April 19 with a deadline of ~June 2019

QSFP Opportunities Funding from STFC was awarded to build a community and consortium to prepare for the call. We will support workshops that facilitate the formation of teams and the development of proposals around key experiments that would be funded by QSFP.

We will also appoint a International Review Board of world-leading experts from outside the UK that will review the proposals providing crucial feedback to strengthen them



# First AION Workshop at Imperial College London March 25/26 2019



*Organised by:  
T. Bowcock,  
O. Buchmueller [Coord.],  
J. Coleman,  
J. Ellis [Theory],  
I. Shipsey*

**2-Day Workshop:  
Day 1: Instrumentation  
Day 2: Physics case**

**If you like to participate or  
require further information  
please contact:**

**[fundamental-physics-admin@imperial.ac.uk](mailto:fundamental-physics-admin@imperial.ac.uk)  
with "AION" in title.**

# Quantum Sensors for Fundamental Physics - Next Steps

**Dec. 18 Groups self organised and produced outline papers**

There are currently 9 work packages circulated to all in December

## Quantum Sensors for Fundamental Physics



16 Oct 2018, 09:00 → 17 Oct 2018, 19:15 Europe/London

<https://indico.cern.ch/event/760005/>

Bernard Sunley Room (St. Catherine's College, Oxford)

Ed Daw , Ian Shipsey (University of Oxford (GB)) , Stig Topp-Jorgenson (Oxford)



WP1-qsfp-darkmatt...

WP2-qsfp-MaQS pr...

WP3\_qsfp\_AION-fi...

WP4\_qsfp-neutrino...

WP5\_qsfp-Quantu...

WP6-Quantum-Net...

WP7-5Force-DM-pr...

WP8\_precision-stu...

WP9-LorentzInvari...

## **Quantum Sensors for Fundamental Physics and Society- Next Steps**

WP1 Using Quantum Technology to Search for Low-mass Particles in the Hidden Sector

WP 2 MaQS Macroscopic quantum superpositions for physics beyond the standard model

WP 3 AION A UK Atom Interferometer Observatory and Network

WP4 Absolute neutrino mass

WP5 Quantum Simulators of Fundamental Physics

WP6 QSNET Networked Quantum Sensors for Fundamental Physics

WP7 Searches for a Fifth Force and Dark Matter using Precision Atomic Spectroscopy

## **Quantum Sensors for Fundamental Physics and Society- Next Steps**

WP8 Fundamental physics from precision studies of exotic atoms

WP9 LIST – Lorentz Invariance Space Test

+ developing .....

## Quantum Sensors for Fundamental Physics - Next Steps

**17 January consortium meeting to hear presentations from each workpackage, cross-fertilise, give feedback, merge if required, last chance of any late-breaking new ideas**



Quantum Sensors for Fundamental Physics, St. Catherine's College,  
Oxford, UK - workshop 2

# Quantum Sensors Workshop 2

Thursday 17 Jan 2019, 08:00 → 19:00 Europe/London

10:00	→ 10:15	<b>Introduction and Status</b> Speaker: Ian Shipsey (University of Oxford (GB))	15m	
10:15	→ 10:45	<b>WP1 Using Quantum Technology to Search for Low-mass Particles in the Hidden Sector: a UK Programme Status &amp; Plans</b> Speakers: Edward Daw (The University of Sheffield), Stafford Withington (University of Cambridge) Withington Oxford ...  Withington Oxford ...  WP1-qsfp-darkmatt...	30m	
10:45	→ 11:15	<b>WP2 MaQS Macroscopic quantum superpositions for physics beyond the standard model Status &amp; Plans</b> Speakers: Gavin Morley (University of Warwick), Sougato Bose (Prof) WP2-qsfp-MaQS pr...	30m	
11:15	→ 11:30	<b>Coffee Break</b>	15m	
11:30	→ 12:00	<b>WP3 AION A UK Atom Interferometer Observatory and Network Status and Plans</b> Speakers: Jonathon Coleman (Physics Dept, University of Liverpool), Oliver Buchmuller (Imperial College (GB)) WP3_qsfp_AION-fi...	30m	
12:00	→ 12:30	<b>WP4 Absolute Neutrino Mass Status and Plans</b> Speakers: Armin Reichold (Oxford University), Ruben Saakyan (UCL) WP4_qsfp-neutrino...	30m	
12:30	→ 13:00	<b>WP5 Quantum Simulators of Fundamental Physics Status and Plans</b> Speakers: Hiranya Peiris, Silke Weinfurter (The University of Nottingham) WP5_qsfp-Quantu...	30m	
13:00	→ 14:00	<b>Lunch</b> In the Main Hall	1h	

14:00 → 14:30 **WP6 QSNET: Networked Quantum Sensors for Fundamental Physics Status and Plans**

🕒 30m 

**Speaker:** Giovanni Barontini

 WP6-Quantum-Net...

14:30 → 15:00 **WP7 Searches for a Fifth Force and Dark Matter using Precision Atomic Spectroscopy Status and Plans**

🕒 30m 

**Speakers:** David Carty (Durham), To be determined

 WP7-5Force-DM-pr...

15:00 → 15:30 **WP8 Fundamental physics from precision studies of exotic atoms Status and Plans**

🕒 30m 

**Speaker:** David Cassidy (UCL)

 WP8\_precision-stu...

15:30 → 16:00 **WP9 LIST – Lorentz Invariance Space Test Status and Plans**

🕒 30m 

**Speaker:** Patrick Gill (National Physical Laboratory)

 WP9-LorentzInvari...

16:00 → 16:15

**Coffee & Cake**

🕒 15m

16:15 → 17:00 **Work Package meetings in parallel**

🕒 45m 

17:00 → 17:45 **Discussion & wrap-up**

**Speaker:** Ian Shipsey (University of Oxford (GB))

🕒 45m 

## **Quantum Sensors for Fundamental Physics - Next Steps**

**End March 2018 Draft workpackages due for review by IRB**

**End April 2018 Final workpackages due for review by IRB, formal costings initiated**

**We don't yet know the terms of the funding call, it is possible the value of individual proposals may be capped. In that event work packages would go into the bid as standalone proposals**

**If there is no cap, we have the option to submit as a consortium.**

**In which case a group of volunteers will be charged with developing wider aspects of proposal including metadata & coordinating with STFC/EPSRC towards submission**

**Either way in May consortium meeting to review/sign off the proposal(s)**

**Mid- June proposal(s) submission**

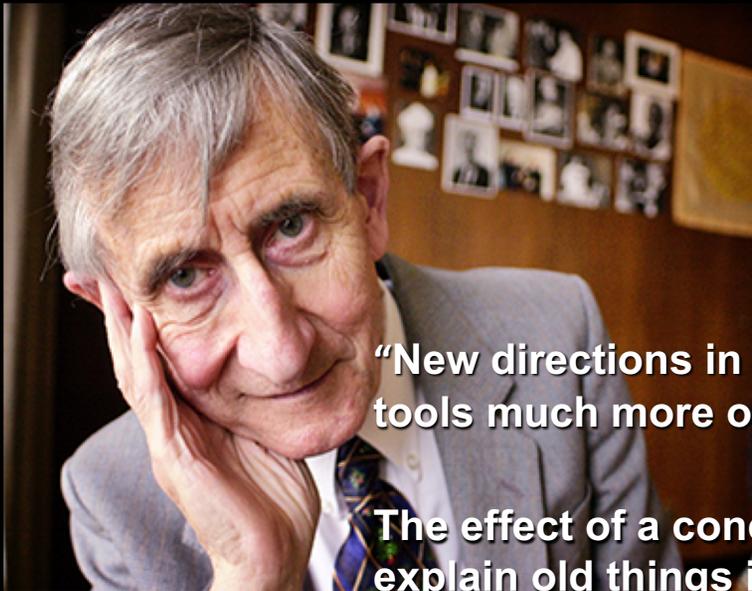
## Summary

In the US the QSFP interface area acts as a major attractor for creative, original young experimentalists and theorists. We believe this will be true in the UK as well. The programme will be world-leading, and highly complementary to the US programme and those of other nations

In this competitive area it is important to quickly develop the community that can launch the proposed programme. To do this expeditiously it will build on expertise, selected existing activities within the UK and exploitation of existing resources.

As the EPSRC, STFC and Space communities come together, and working with the quantum hubs, we anticipate entirely new and exciting science will emerge.

# Instrumentation: The Great Enabler



**“New directions in science are launched by new tools much more often than by new concepts.**

**“The effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained”**

***Freeman Dyson***