Scottish Universities Physics Alliance

# SUPA Astronomy & Space Physics

Ian Bonnell

University of St Andrews

# Astronomy and Space Physics in Scotland

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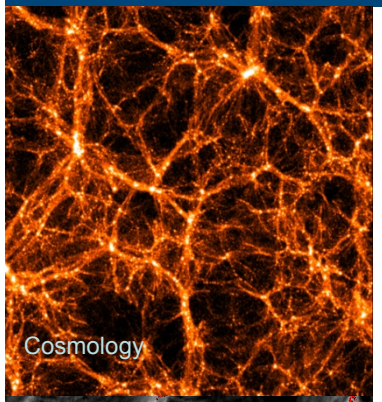
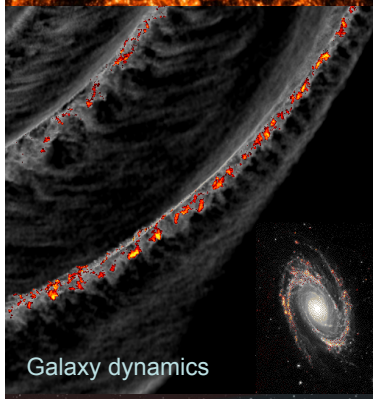
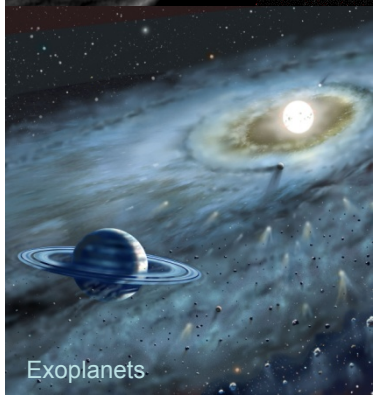
Ian Bonnell


Cosmology


Galaxy dynamics


Exoplanets

## AREAS OF EXCELLENCE

**COSMOLOGY:** World-leading expertise in studies of the high-redshift universe, using wide field galaxy redshift surveys to measure formation history and cosmological parameters.

**GALAXIES:** Understanding the processes that drive galaxy formation and structure, star formation, active galactic nuclei and supermassive black holes

**GRAVITATIONAL WAVES:** Institute for Gravitational Research (IGR) is a major collaborator on very large projects world-wide (GEO 600, LIGO and LISA). This work is poised to make a significant impact on astrophysics, detecting pulsars, supernovae and mergers of black holes.

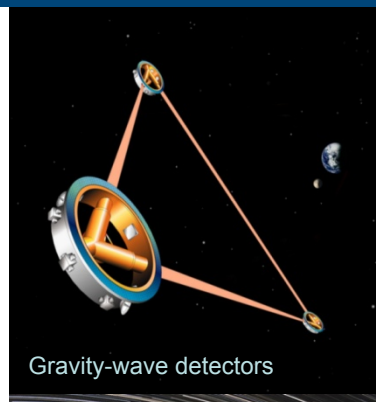
**STARS:** The studies of low-mass stars and brown dwarfs, their atmospheres, magnetic activity and interactions with their environment including extrasolar planets.

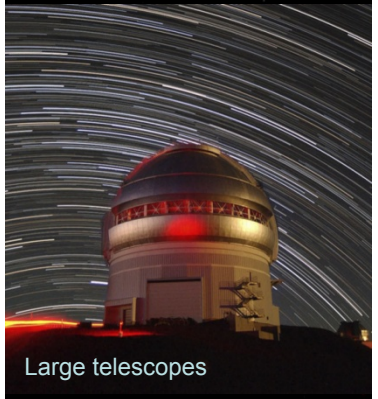
**THE SUN:** Our primary research is in solar flares, focusing on non-thermal plasma diagnostics (X- and gamma-rays), multi-wavelength data analysis and plasma kinetic theory.

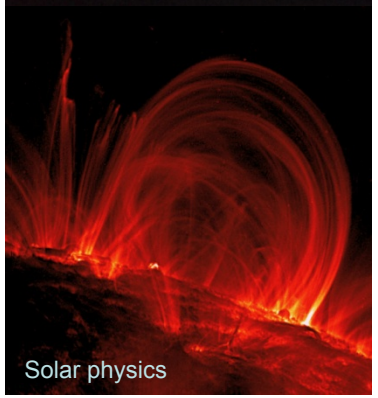
**EXOPLANETS:** Scotland is an international leader in the discovery and characterisation of extrasolar planets and in studying how planet formation occurs in circumstellar discs.

**ASTROBIOLOGY:** Studying the preconditions for, and signatures of life in the solar system and in extrasolar planets.

**INSTRUMENTATION:** Developing the next generation of astronomical instrumentation for ground and spaced based observatories (ELT JWST)


Gravity-wave detectors


Large telescopes


Solar physics

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# Glasgow joins UK DKIST consortium

**Daniel K. Inouye Solar Telescope**

- World's largest solar telescope.
- 4m Gregorian, first light in 2019
- UK providing cameras/detectors
- Will address fundamental questions at the core of contemporary solar physics via:
  - sub-second imaging
  - spectroscopy and magnetometry of photosphere, chromosphere and corona

Rendering of the DKIST on Haleakala, Maui. Image NSO/NSF/AURA

University of Glasgow

Science & Technology Facilities Council

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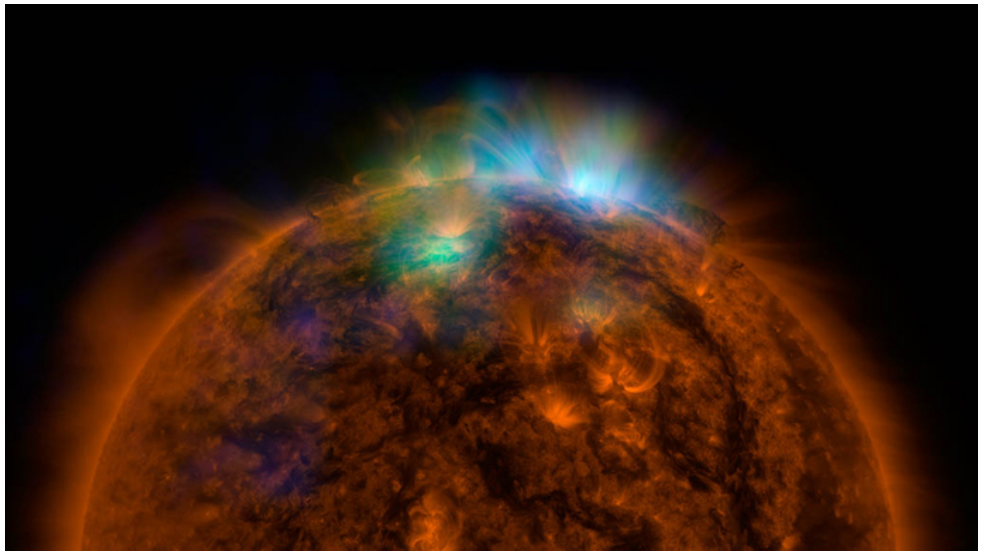
# First image of the Sun from NuSTAR

GU solar physicists are part of consortium to make the first solar observations with NuSTAR (Nuclear Spectroscopic Telescope Array)



Green/blue = NuSTAR X-ray emission above an active region, superposed on SDO AIA. Image Caltech/JPL

- NuSTAR sensitivity sufficient to detect X-rays from the 'quiet' corona during solar minimum.
- Test for "nanoflares" – hypothesised coronal heating mechanism.

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THE ROYAL SOCIETY

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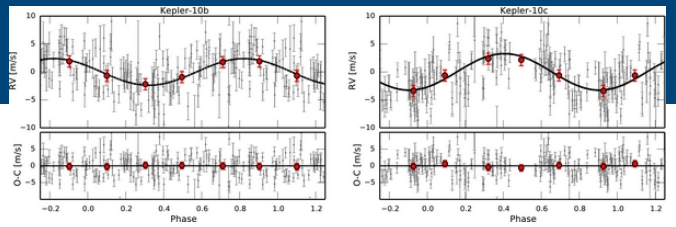
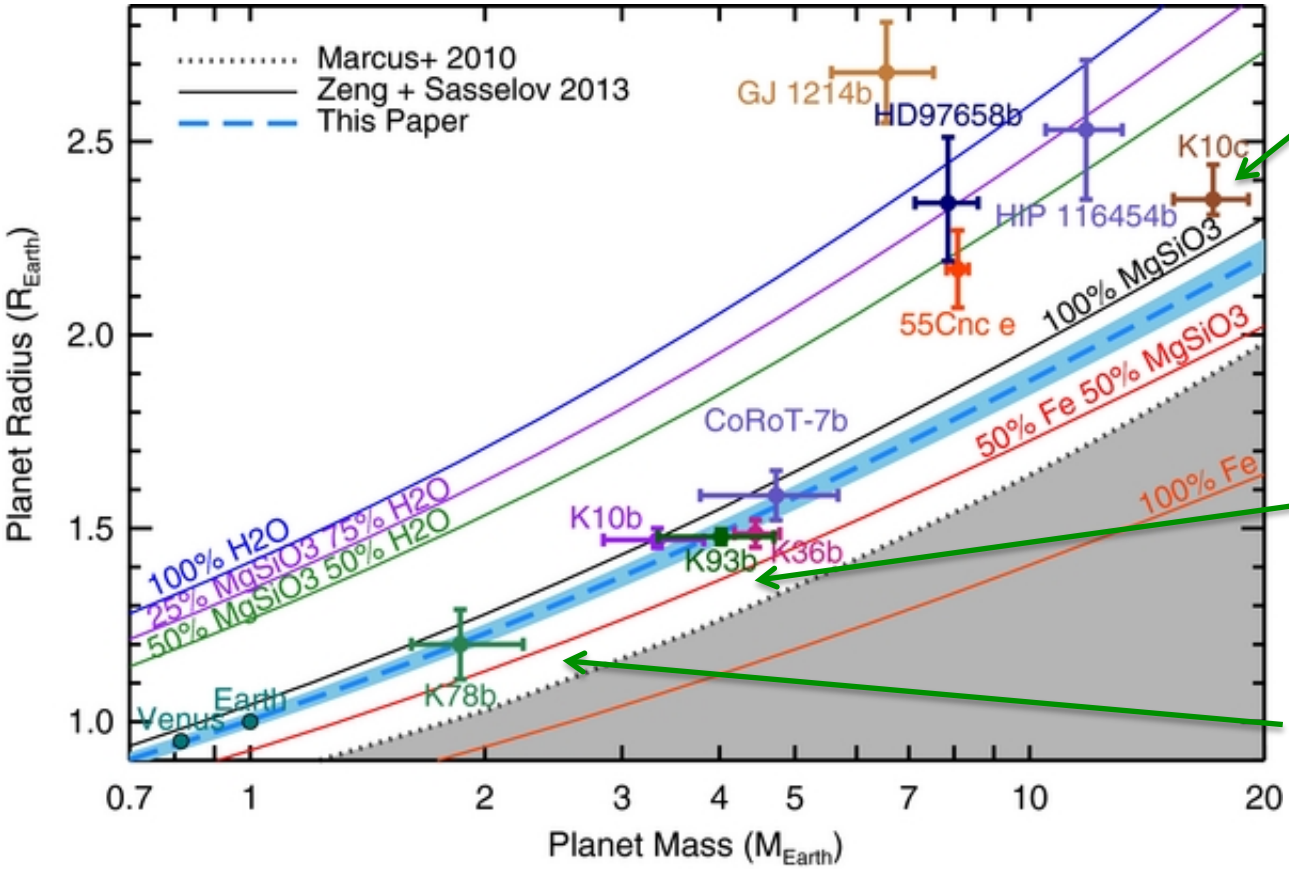
# Harps-North: Characterisation of close-in Exoplanets




- Transit detections: radii
- Harps radial-velocities: mass ➡ composition (rock/gas)




Mass-radius diagram

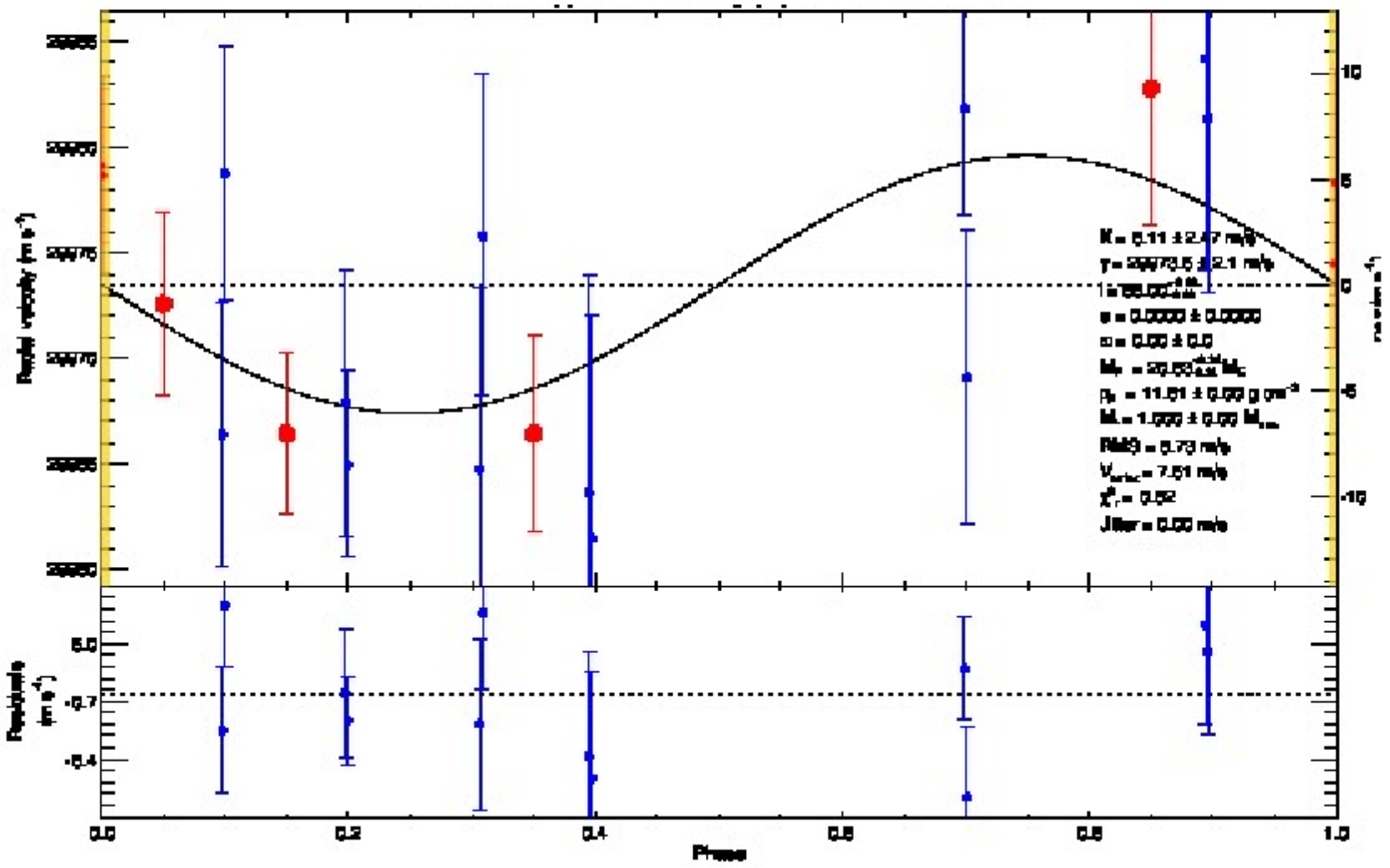
Kepler 10c: A giant planet core without a gas envelope?
Dumusque et al. 2014)

Kepler-93b: rocky planet consisting mostly of iron

Kepler-78b: An Earth-sized planet with an Earth-like density

(Dressing et al. 2015)

# HARPS-N follow-up of rocky K2 planets



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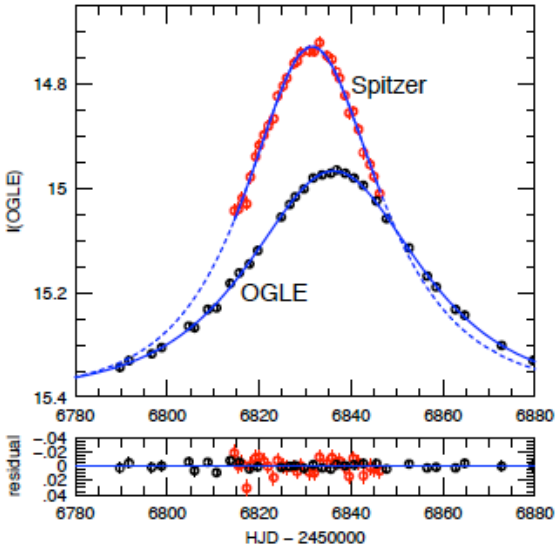
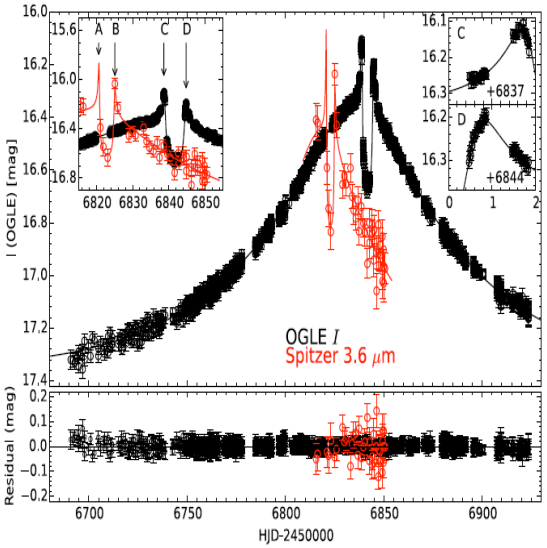
# Earth-Spitzer Microlens Parallaxes

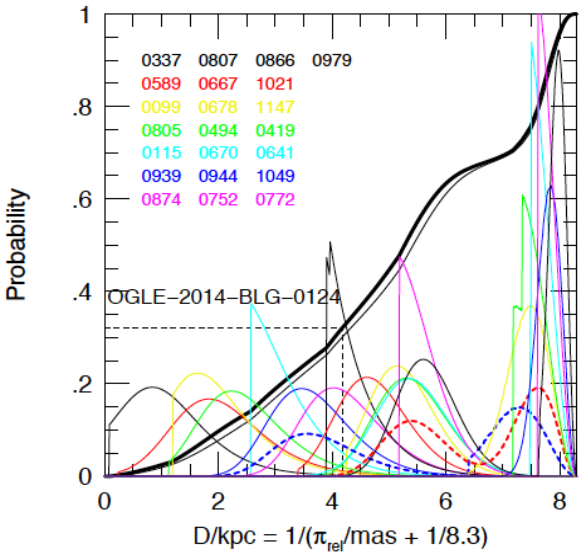
## Accurate lens Masses and Distances to determine the Galactic Distribution of Planets



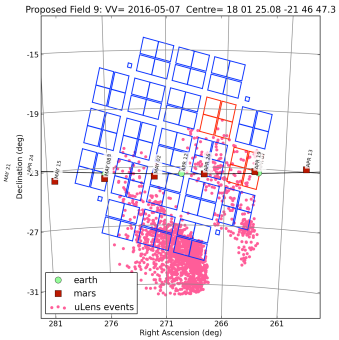

Single star:
M=0.23+/-0.07 Msun
D=3.1+/-0.4 kpc
Yee et al. (2014) arXiv




Star + planet:
Udalski et al. (2015) ApJ 799, 237.




22 stars, 1 planet
Calchi-Novati et al. (2015) ApJ




## 2016 : Earth-Kepler parallaxes (mass function of free-floating planets)

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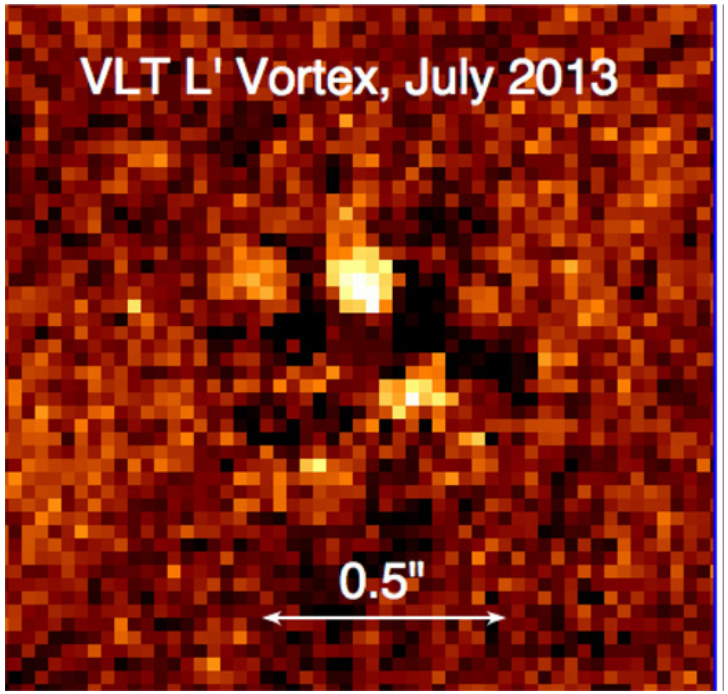
# Planet formation: caught in the act?

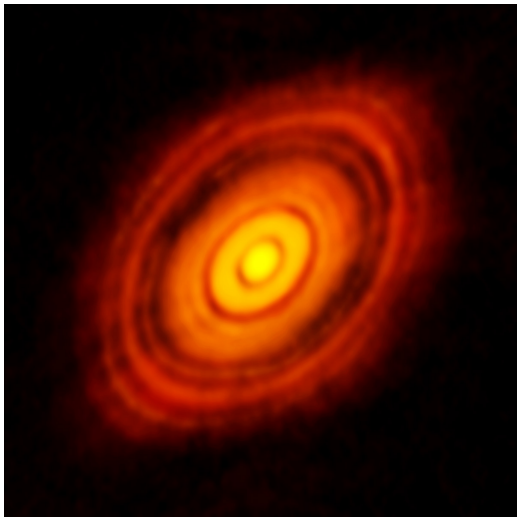
HD 169142 transition Disc

Brown dwarf of hot Jupiter in gap?

No near-IR counterpart




Biller et al 2014

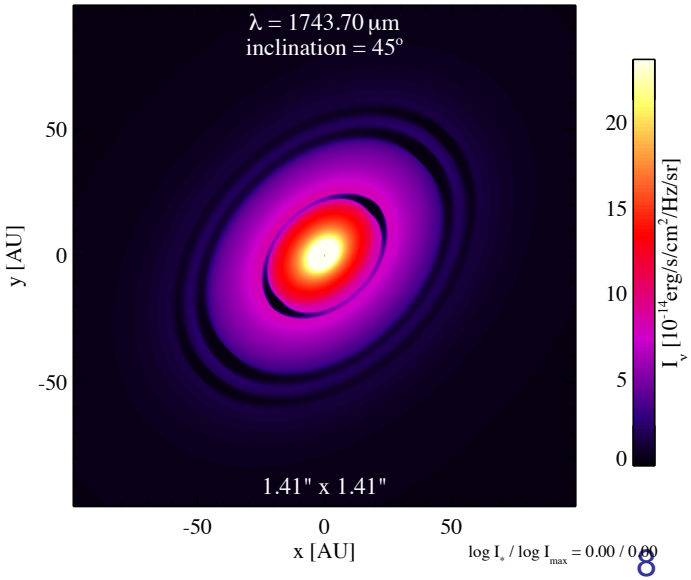


HL Tau
ALMA image

Gaps in discs
signs of planet
formation?

or disc vertical
structures

P. Woitke
G Laibe



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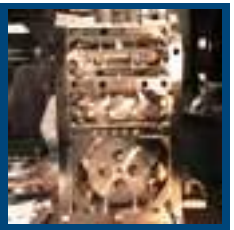
# Advanced LIGO :



## Most sensitive gravity-wave detector

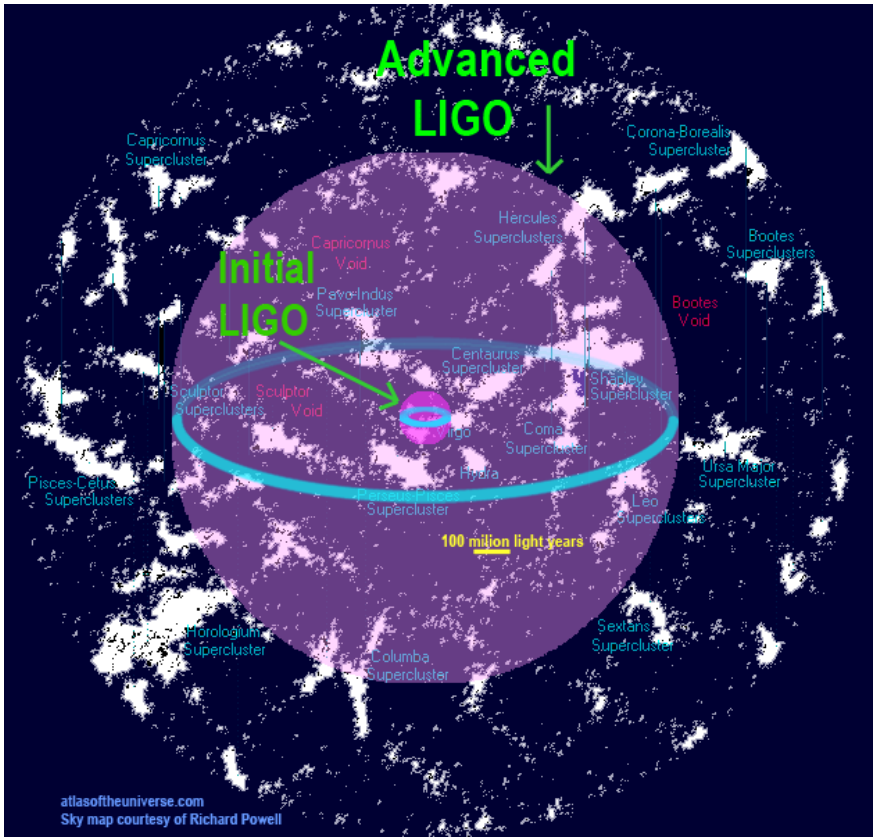
Glasgow : Fused-silica suspension for the 4 40kg primary mirrors

Increased sensitivity
to reach 15x further

**Increased expected rates by 3000**

Neutron star binaries to 300 Mpc
BH-coalescence to z~0.4

Observations starting in 2015



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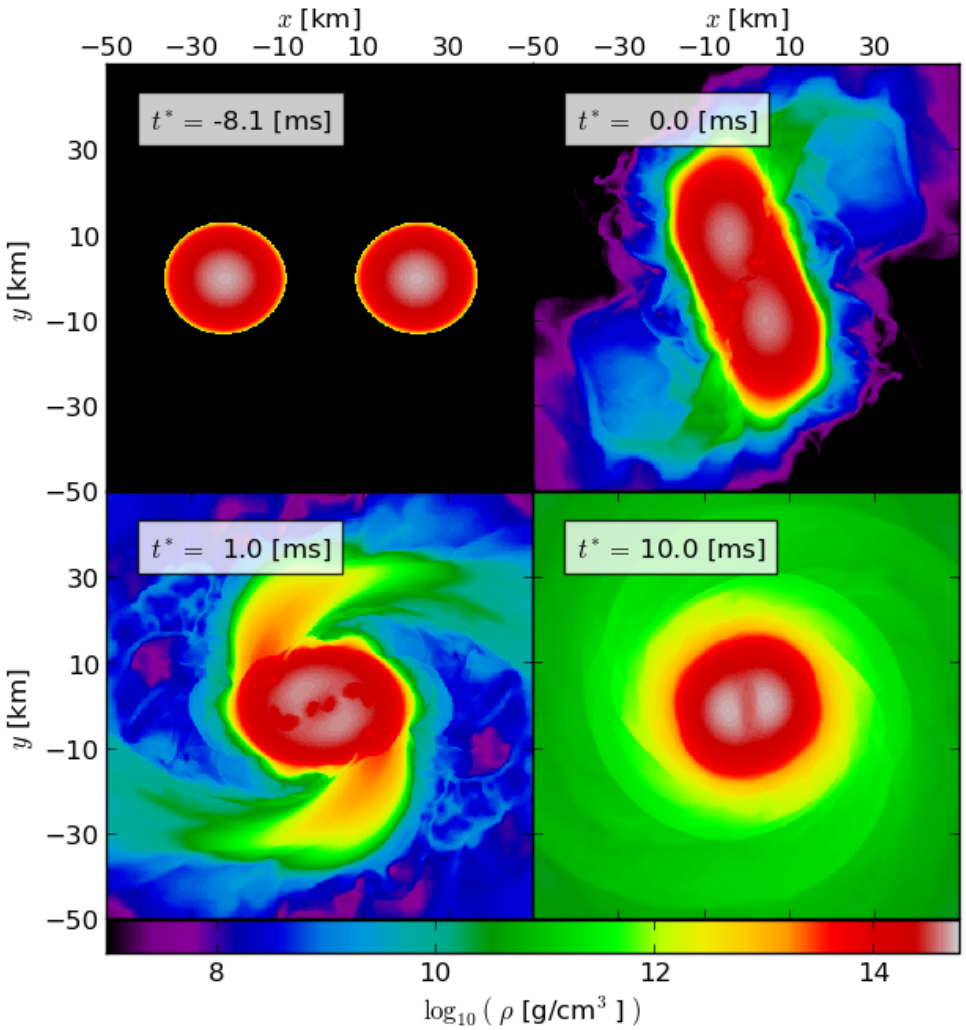
# Gravity waves as cosmological probes




Simulations of gravity wave emission from inspiral of binary neutron stars

Direct probe of cosmological parameters from gravity waves alone!

Messenger et al 2014

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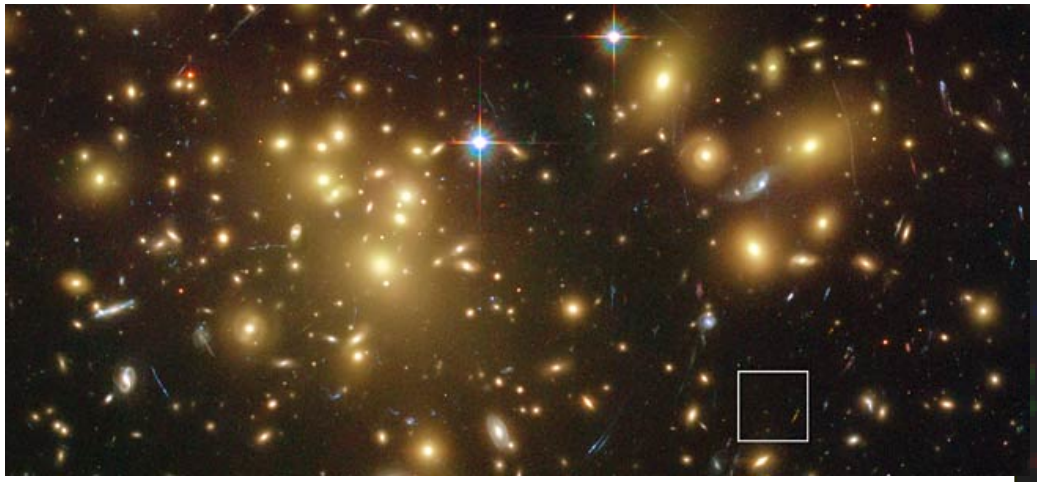
# Dusty galaxy in the early universe

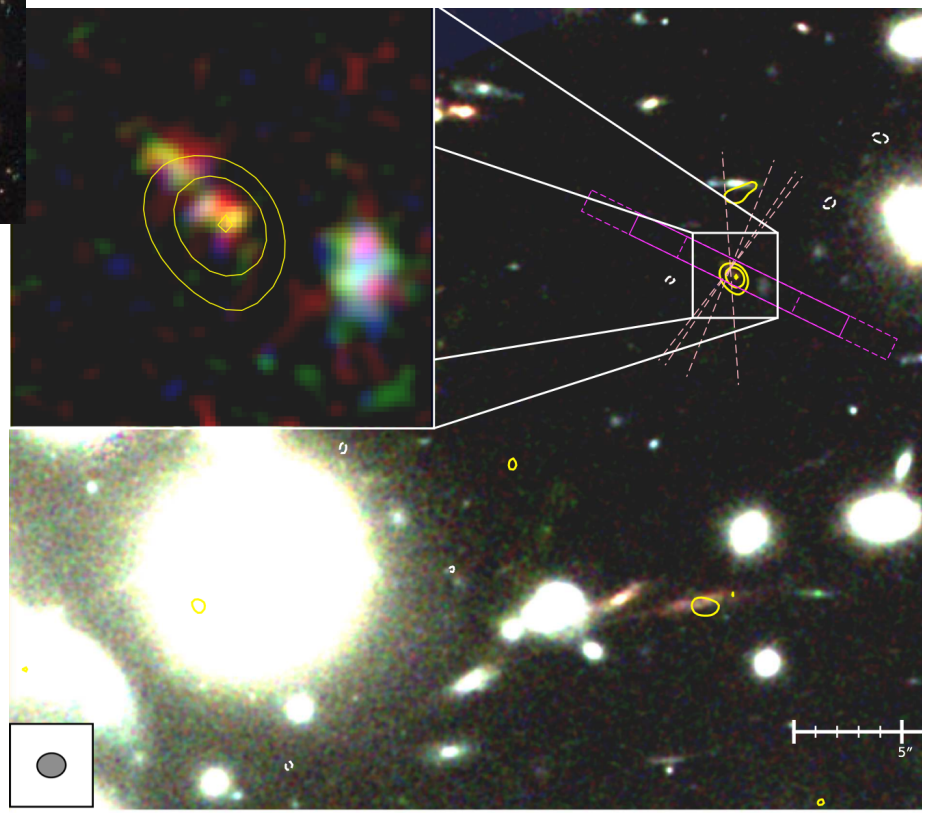


Gravitational lensing from foreground cluster of galaxies: Abel 1689

ALMA mm interferometry

First detection of dust in distant (young) galaxy

Dust formation (chemical evolution) must be very fast
< 100 Myrs




Watson et al 2015, nature

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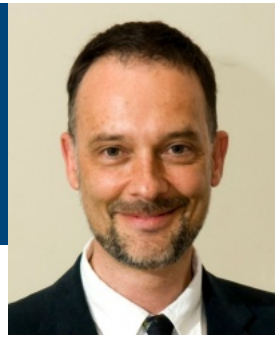
# Shaw Prize in Astronomy 2014: John Peacock



## Measurements of the large-scale structure of galaxies

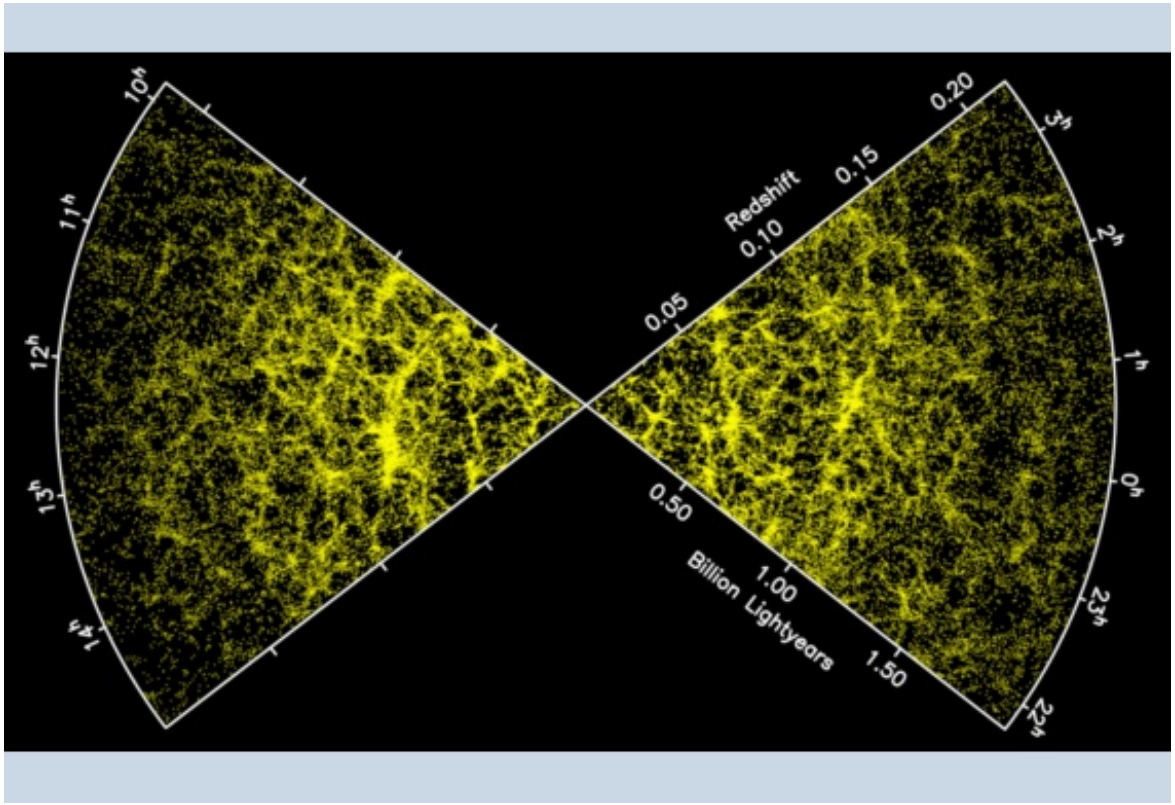
2 Degree Field Galaxy reshift Survey
catalogued 220,000 galaxies

Used as inputs/test for

cosmological model

baryon acoustic oscillations

redshift-space distortions.



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# Awards and Honours

Martin Hendry : MBE in 2015 Queen's Honours list for 'Services to public engagement in science'

Sheila Rowan : Australian Institute of Physics 'Women in Physics' Lecturer 2014
seven-state Australian lecture tour in Oct/Nov 2014 with talks to schools and the public along with professional societies, reaching more than 2000 people

Marina Cortes: Butchalter Cosmology Prize :
*"The Universe as a process of unique events"*

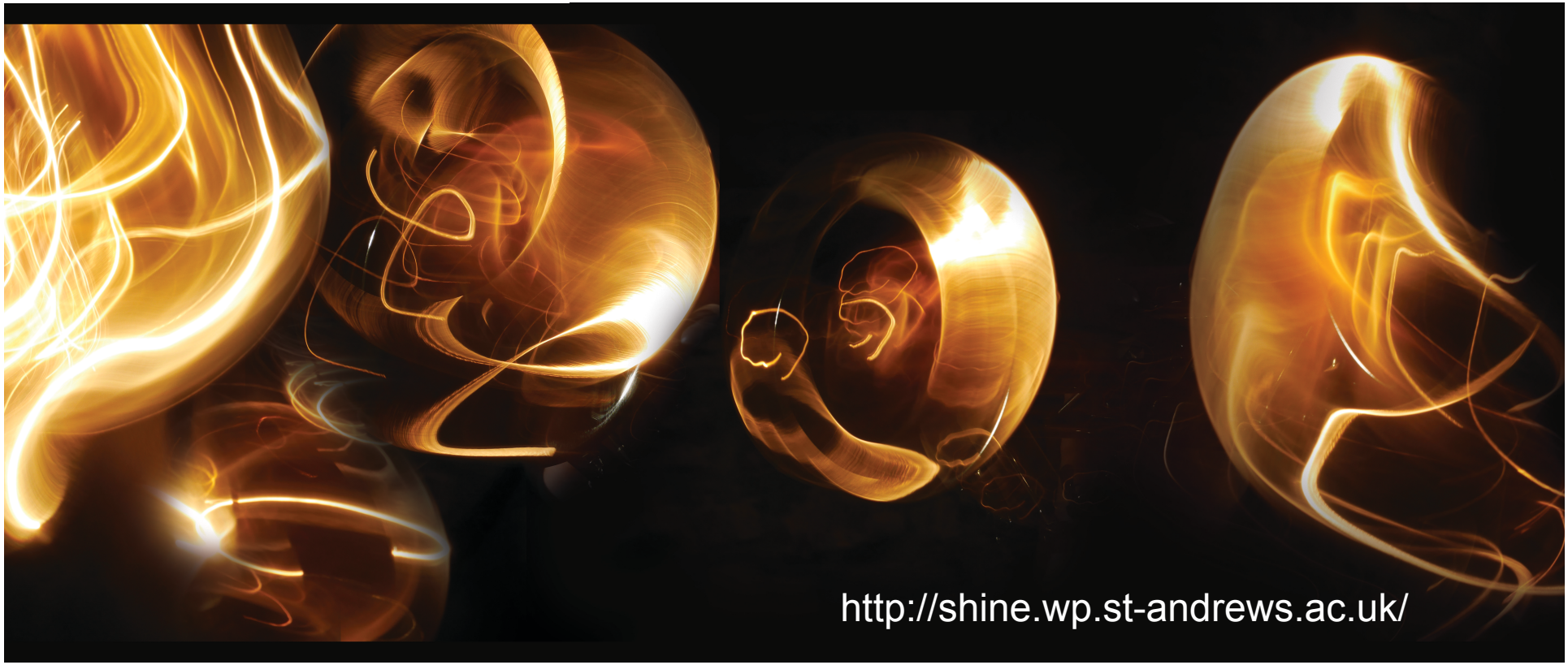
**Time as the fundamental concept out of which emerges cosmology and quantum gravity**

Cortes & Smolin 2014)

SHINE

Science, Art and Music during the International Year of Light in St Andrews

- Science demos showcasing light and sound
- Concerts inspired by light
- Art visualising science and music




A. Weijmans (astronomy), B. Williams (music centre), T. Fitzpatrick (Redfield art)

# Buchalter cosmology prize : Marina Cortes