Institution: Keele University

Unit of Assessment: B9 Physics

Title of case study: Impact of WASP discovery of extra-solar planets

1. Summary of the impact (indicative maximum 100 words)

Keele's WASP program of discovering extra-solar planets has had an impact on an international audience of: newspaper science writers; TV science-program producers; radio-program producers; popular-science writers; internet web-page writers; popular book and textbook writers; and through them the wider public. More locally Keele's exoplanet outreach has had an impact on school teachers and children in the surrounding area, on visitors to Keele campus, and through local newspapers and radio. Thus the WASP program has helped to develop the public's interest in planets and astronomy and our understanding of Earth's place in the universe.

2. Underpinning research (indicative maximum 500 words)

The first extra-solar planet around a normal star was found as recently as 1995. We are the first generation to know that many stars have planets orbiting them and to know what planets outside our solar system are like. This research is having a large impact on society, spreading out through newspapers, the internet, TV programs and books into popular culture.

For understanding exoplanets the transiting systems are crucial since they are the only ones for which we can get reliable sizes and masses and hence obtain their density and deduce their composition. The first transiting exoplanet was found only in 2001. There are now 200 known transiting exoplanets with measured sizes and masses. The WASP project (Wide Area Search for Planets) has produced over one third of these, and, along with NASA's Kepler mission, is currently the world's most successful search for transiting exoplanets.

WASP-South is WASP's Southern Hemisphere transit-search facility. It was built by Keele University in 2005 and Keele have operated it ever since. Keele process the WASP-South data and have led the discovery of Southern Hemisphere transiting exoplanets, collaborating with other WASP institutes and the Universities of Geneva and Liege for spectroscopic and photometric followup. WASP-South, led by Keele, has found 57 of the 58 brightest transiting-exoplanet systems in the Southern Hemisphere.

Since 2006 there have been 120 refereed-journal papers from the WASP project with Keele as authors, and Keele is the lead-author institute on 37 of them. Keele has lead-authored the discovery papers for more transiting exoplanet systems than any other institute worldwide. There have been more than 3800 citations to these WASP papers (from NASA's ADS). In 2010 the WASP consortium were awarded the Royal Astronomical Society's Group Achievement Award.

The Keele WASP team is led by Prof. Coel Hellier and includes academics Dr. Pierre Maxted (Reader) and Dr. Barry Smalley (Senior Lecturer), all of whom have been involved since the beginning of WASP-South in 2004, and Dr. John Southworth (a WASP PDRA from 2009, then an STFC Advanced Fellow, and now also a lecturer at Keele).

The WASP discoveries have had a vast influence on our understanding of extra-solar planets, particularly the hot Jupiter class. WASP discoveries include the most bloated known planet, the first planet found in a retrograde orbit, the Jupiter-sized planets with the shortest orbits and highest stellar irradiation, the planetary system with the highest planet-star tidal interaction, and the first

planet with a suggested carbon-rich atmosphere (contrasting with our oxygen-rich solar system). While the US space mission Kepler has dominated the discovery of smaller transiting exoplanets, WASP, with a much larger search area, has dominated the discovery of larger, Jupiter-sized transiting exoplanets.

3. References to the research (indicative maximum of six references)

Of Keele's 120 WASP-related refereed-journal papers since 2006, papers from which press releases were directly derived include:

Wilson, D. M. etal 2008, Astrophysical Journal Letters, 675, L113, "WASP-4b: A 12th Magnitude Transiting Hot Jupiter in the Southern Hemisphere" [60 citations, Keele lead-authored, STFC press release].

Anderson, D. R. etal 2008, Monthly Notices of the Royal Astronomical Society, 387, L4, "WASP-5b: a dense, very hot Jupiter transiting a 12th-mag Southern-hemisphere star" [40 citations, Keele lead-authored, STFC press release].

Hellier, C. etal 2009 Nature, 460, 1098, " An orbital period of 0.94 days for the hot-Jupiter planet WASP-18b" [81 citations, Keele lead-authored, Nature press release].

Anderson, D. R. etal 2010, Astrophysical Journal, 709, 159, "WASP-17b: An Ultra-Low Density Planet in a Probable Retrograde Orbit" [100 citations, Keele lead-authored, STFC press release].

Triaud, A. H. M. J. etal 2010, Astronomy & Astrophysics, 524, 25, "Spin-orbit angle measurements for six southern transiting planets. New insights into the dynamical origins of hot Jupiters" [152 citations; all the planets in this paper came from Keele's WASP-South; ESO press release].

Madhusudhan etal 2011 Nature, 469, 64, "A high C/O ratio and weak thermal inversion in the atmosphere of exoplanet WASP-12b" [81 citations, Nature/NASA/STFC press release].

Grants:
STFC Rolling Grant (PI Coel Hellier) 2006-2009 (1 WASP PDRA) £0.7M
STFC Rolling Grant (PI Coel Hellier) 2009-2012 (2 WASP PDRAs) £1.5M
STFC WASP Project Grant (PI Coel Hellier) 2008-2011 (1 PDRA) £1.3M
STFC WASP Project Grant, extension (PI Coel Hellier) 2011-2012 (1 PDRA) £0.2M
STFC Consolidated Grant (PI Coel Hellier) 2012-2015 (1 WASP PDRA) £1M.

4. Details of the impact (indicative maximum 750 words)

Recognising the public interest in extra-solar planets we have aimed to maximise the impact of WASP discoveries at the international, national and local level. An STFC press release about the first Keele-led, WASP-South planets (published 2008) led to CNN and Time magazine listing the discovery in their "Top ten science discoveries" of the year. As a result our discoveries were mentioned by then Prime Minister Gordon Brown as an example of "British scientists continuously breaking new ground" in the 2009 Romanes lecture at Oxford, on British science policy.

A 2009 Nature press release about WASP-18 (the most intense planet-star tidal interaction) led to an Associated Press article and was widely published in British, European and US newspapers (e.g. The Independent, The Times, The Guardian), and featured on 62 internet websites including

the BBC News front page. A 2010 STFC press release on WASP-17 (the first planet in a retrograde orbit) was reported in over 20 newspapers worldwide including The Independent, Guardian, New York Times, LA Times, and a Brazilian newspaper, and again featured on over 50 websites including the BBC News. An ESO press release in 2010 led to coverage across Europe, including in The Times. A 2011 Nature/NASA/STFC press release on the "Carbon planet" WASP-12 was widely reported in newspapers (e.g. The Times, Telegraph, LA Times, Time magazine) and over 60 internet websites. Other newspaper coverage of WASP included a six-page feature on exoplanets in The Sunday Times magazine (readership 2.5 million) April 8th 2012, an article in the Wall Street Journal (Sept 2011), and an article in Time Magazine (Dec 2010). Keele astronomers have also been interviewed by BBC Radio Wales, BBC Radio Five, and other stations including Colombian National Public Radio.

Turning to television, WASP featured on BBC1's "Bang goes the Theory" and "The Sky at Night" (both 2009), while an episode of BBC2's "Cosmos: A Beginners Guide" with Adam Hart-Davis was centred on WASP. In 2011 Brian Cox's "Wonders of the Solar System" (BBC2, March 2011) featured a "visit" to the WASP-8b as a high-gravity planet (simulated with a centrifuge); the audience of 3.34 million was the highest on BBC2 that week.

In 2012 Jan 18th BBC2's "Stargazing Live" with Brian Cox centred on exoplanets and featured WASP, including a live link-up to WASP-South and an interview with a Keele postdoc. Prof. Hellier acted as an advisor. With 2.7m viewers Stargazing Live was the most-viewed BBC2 program that week. The impact of such programs is demonstrated by the fact that Amazon.co.uk reported a 500% increase in sales of telescopes that week.

In conjunction with the 2013 Stargazing Live, BBC1's Midlands Today (audience 600,000) featured research by Midlands' Universities that had appeared on Stargazing Live, and included an interview with Prof. Hellier. Other TV programs featuring WASP discoveries are the Discovery Channel programs made by Pioneer TV "Planets from Hell" (July 25 2012) and "Extreme Orbits" (August 8 2012). Prof. Hellier acted as an advisor for these.

WASP-discovered exoplanets are now featuring in undergraduate-level textbooks (e.g. "Transiting Exoplanets", Haswell, 2010, CUP, and “The exoplanet handbook”, Perryman, CUP), popular-level books (e.g. “Strange new worlds: the hunt for alien planets and life beyond our solar system”, Jayawardhana, 2011, Princeton and “Exoplanets: finding, exploring and understanding alien worlds”, Kitchin, 2012, Springer) and even some children's books (e.g. "Exploring Exoplanets", Searchlight Books: What's Amazing about Space?, 2012, and "The Alien Hunter's Handbook: How to Look for Extraterrestrial Life", Kingfisher, 2012).

We have also promoted WASP science locally, recognising that many areas of Stoke-on-Trent are deprived, and that such research can be an important inspiration for local children to pursue science and to aim for university. We have featured in the local paper (The Evening Sentinel) on seven occasions and on BBC Radio Stoke four times. When doing so we include invitations to Keele campus observatory, which is open to the public twice weekly and on special occasions. Over 500 visitors came during each Stargazing Live week, where we link viewing planets through our observatory’s telescopes to Keele's WASP research. In addition the regular openings attract 1000 visitors per year, while we host many visits from school and scout groups over a year. We have three times run evening classes on exoplanets for mature students, and, further, Keele's Science Learning Centre has ten times run CPD courses for schoolteachers featuring exoplanets and the WASP discoveries.

Recognising, however, that those attracted to Keele campus will be mostly those who already have an interest in science, we have also developed an outreach program taking WASP science into schools. Funded by an STFC Science in Society grant “An Exoplanetarium for Schools" (PI Rob Jeffries, 2011, £6850), since Feb 2012 (up until July 2013) Keele's travelling "exoplanetarium" has been seen by 5000 schoolchildren (ages 4-18; about 2800 from postcodes in the most disadvantaged two quintiles). Overwhelmingly positive feedback from teachers, included comments such as "The children loved it and learned lots – they were talking about it for days!"; “The reactions of ' fantastic' and 'the best thing ever in science' were some of the pupils comments”; "A fabulous experience, something that we could never convey in books or words to them"; "An exciting and informative activity for all the children who were all overwhelmed by the experience". In evaluations 44/47 teachers said pupils had benefited from the experience and 42/47 said they would book the exoplanetarium again, while 65% of secondary students agreed that the Exoplanetarium had made them “think about university as a future option” (cf. HE participation rates in Stoke-on-Trent being 23%, well below the national average).

5. Sources to corroborate the impact (indicative maximum of 10 references)

Appearances in newspapers and on TV can be corroborated from those organisations; numbers quoted for internet sites were from Google searches at the time. Keele keeps records for Observatory visitors and all Exoplanetarium school visits and evaluations. Quotes are attributable to science teachers at Rosary Catholic Primary School Birmingham, Moorside High School Werrington, Burnwood Community School Chell Heath, St Joseph’s Catholic School Tunstall.