50 & 100 YEARS AGO

50 YEARS AGO

A research station to study the effects of the aurora on radio reception is to be set up on the site of a former radar station at Hillhead, near Fraserburgh, in Aberdeenshire. This investigation, part of a programme of ionospheric studies, will be undertaken by the Stanford Research Institute of America in collaboration with scientists from the Royal Radar Establishment of the Ministry of Supply. Observations will be made with a large parabolic reflector about 140 ft. in diameter brought from America … The Aberdeenshire site has been chosen because of its geographical suitability for the study of auroral phenomena. There will be no radiation danger, and interference with radio and television will be prevented by the operating conditions laid down for the installation.

From *Nature* 28 February 1959.

100 YEARS AGO

In the February number of *Naturen* Dr. L. Stejneger adduces further evidence in favour of the theory of the existence, at a comparatively recent date, of a land-bridge between Scotland and Scandinavia. This evidence is mainly based on the distribution of the species, or races, of charr (Salvelinus) … *Salvelinus alpinus* is considered to be common to western Scandinavia and Scotland, while in eastern Scandinavia we have the typical *S. salvelinus* of the Alps. Iceland is the home of *S. nivalis*, while further north occur *S. insularis* and *S. stagnalis*. Lapland is the home of an intermediate form known as *S. salvelino-stagnalis*, while another annectant type, *S. alpino-stagnalis*, occurs in Greenland.

ALSO:

At the meeting of the Royal Society on Thursday, February 18, telegrams of congratulations on the hundredth anniversary of the birth of Charles Darwin were read from the University of Christiania, the University, Kharkoff … the Society of Naturalists, Kharkoff … and the Swedish Academy of Sciences, Stockholm.

From *Nature* 25 February 1909.

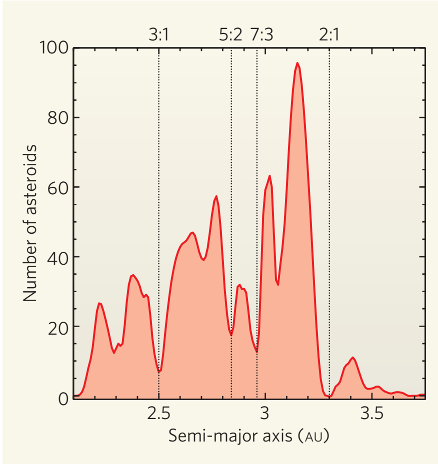

Figure 1 | Kirkwood gaps. The noticeable gaps in the distribution of asteroids as a function of the semi-major axes of their orbits (essentially their distances from the Sun) correspond to asteroid orbits whose periods are integer ratios of Jupiter's orbital period: 3 orbits for each 1 of Jupiter (located about 2.5 astronomical units (AU) from the Sun); 5 orbits for every 2 of Jupiter (2.82 AU); 7 orbits for every 3 of Jupiter (2.95 AU); 2 orbits for each 1 of Jupiter (3.27 AU).

expanding their orbits owing to the exchange of energy and angular momentum during close encounters with the planetesimals[4].

But planets have a much stronger effect on the planetesimals, and can destabilize their orbits throughout the asteroid belt. Looking at asteroid orbits in the main asteroid belt, as Daniel Kirkwood did in 1867 (ref. 5), we find big gaps, known as Kirkwood gaps. These gaps correspond to the location of orbital resonances with Jupiter — that is, of orbits whose periods are integer ratios of Jupiter's orbital period. For example, if an asteroid orbited the Sun 3 times for every time Jupiter did, it would be in a 3:1 orbital resonance with the planet, and would thus have an unstable orbit and eventually be cleared away from the asteroid belt (Fig. 1).

A consequence of planet migration is that the locations of planets' resonances also move, in turn affecting different parts of the asteroid belt at different times. Thus, if nothing has completely reshaped the asteroid belt since the planets settled into their current orbits, signatures of past planetary orbital migration may still remain. These are exactly what Minton and Malhotra[1] searched for.

In their study, the authors examined the same orbital parameter that Kirkwood did — the semi-major axis, which is essentially the size of the orbit, or distance from the Sun — for each of the 690 largest asteroids in the asteroid belt. At the very least, this sample of asteroids has already been subject to the basic wear-and-tear — the occasional collision or ejection due to perturbations from the giant planets — of about 4 billion years of evolution after any planetary migration stopped. So Minton and Malhotra modelled the asteroid belt and followed the 4-billion-year evolution of the asteroids using a computer simulation that included the perturbing effects of the giant planets in their current orbits.

Comparison of the simulated asteroid population with the observed one revealed the expected Kirkwood gaps, but also a surprising feature: an excess depletion of asteroids in the observed population, both on the inner edge of the asteroid belt and on the outer edges of each Kirkwood gap. Qualitatively, it looks as if a snow plough were driven through the main asteroid belt, kicking out asteroids along the way and slowing to a stop at the inner edge of the belt.

Minton and Malhotra thus concluded that the observations could not be accounted for by considering the orbital evolution of the asteroid population solely under the gravitational tug of giant planets in their current orbits. But when the effects of the orbital migration of Jupiter and Saturn in the Solar System's early history were also taken into account, the simulations reproduced the observations quite well. In particular, the authors found that, with a relatively rapid migration of Jupiter inwards and the other giant planets outwards, the asteroid belt's population became substantially depleted as the resonances associated with each planet swept through it. The simulation's surviving population had a semi-major axis distribution similar to that observed, including the depletion

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Figure 2 | The Moon's basins. The age of large basins on the Moon suggests that the Solar System went through a rapid period of 'late heavy bombardment' of impactors some 600 million years after planet formation. Minton and Malhotra's work[1] shows that the migration of giant planets about 4 billion years ago could have created plenty of potential impactors by removing asteroids from the main asteroid belt.