

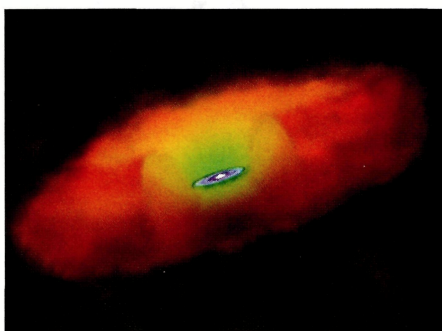
Theory demystifies supermassive black holes

The existence of powerful quasars at high redshift raises the question of the rapid formation of supermassive black holes. How could early black holes accrete 1 billion solar masses in less than 1 billion years after the Big Bang? Was there an epoch with conditions particularly favourable for such a rapid growth of black holes?

These questions have been tackled by cosmologists Marta Volonteri and Martin Rees at Cambridge University. They attempt to identify what was different in the early universe that allowed black holes to grow as quickly as suggested by the existence of fully mature quasars in the Sloan Digital Sky Survey (SDSS) dataset at a redshift of about 6.

The first problem is the origin of the seed black holes. They could be low-mass (less than 1.5 solar masses) primordial black holes, formed during the first seconds of the Big Bang, but Volonteri and Rees do not want to rely on such a hypothesis. They propose that the seeds are intermediate-mass black holes, formed by the core collapse of massive stars of the very first generation.

Such Population III stars, which are composed only of primordial hydrogen and helium, can have masses up to 1000 times that of the Sun, thus exceeding by an order of magnitude the most massive metal-rich stars existing today. When exploding as supernovae



Artist's impression of a mature quasar with a thin accretion disc enshrouded in a torus of metal-rich gas. (Courtesy CXC/M Weiss.)

at the end of their lives they would form black holes with masses approximately 20–600 times that of the Sun.

These pregalactic seed black holes would form in gas halos, collapsing at a redshift of 20–30 at the peaks of the primordial density field. Before too many heavy nuclei were released by stars, the newborn black holes would benefit from unique conditions to accrete gas at a very high rate. The calculations of Volonteri and Rees indeed suggest that there was a brief window of rapid black-hole growth during the “dark ages”, before the stellar radiation fully re-ionized the intergalactic gas (CERN Courier October 2003 p13).

Their calculations show that the absence of

heavy nuclei and the effective cooling by hydrogen atoms via line emission allow the formation of a “fat” disc of relatively cold (approximately 5000–10 000 K) gas around the seed black hole at the centre of the halo. The thickness of the disc allows quasi-spherical accretion into the black hole’s event horizon at a much higher rate than for thin discs. However, the growth of the black hole increases the radius of the inner disc, which becomes increasingly thin with respect to the size of the black hole. This super-accretion will therefore no longer be sustained once the black hole has reached a significant mass.

Although the details of the process are still quite uncertain, the absence of heavy nuclei seems to play a critical role in the early growth of massive black holes. Super-accretion with a very low luminosity compared with the amount of matter falling into the black hole was likely to have stopped once the universe had been enriched by metals at a redshift of 6–10. But by then, a population of supermassive black holes would already have formed, which became fully mature quasars by turning matter into light much more efficiently than before.

Further reading

M Volonteri and M J Rees 2005
<http://arxiv.org/abs/astro-ph/0506040>.

Picture of the month

This false-colour infrared image taken by NASA's Spitzer Space Telescope shows the South Pillar region of a star-forming area called the Carina Nebula. Eta Carinae, the famous and most massive star of the nebula, is above the picture frame, too bright to be observed by Spitzer. The inset visible-light picture shows dark dust pillars eroded by the ultraviolet emission of this star of 100 solar masses. In the image from Spitzer, the pillars appear pink, with much more detail. Their transparency in infrared light reveals newborn stars (yellow or white) being formed inside them. Hot gases are shown in green and foreground stars are blue. (Image courtesy NASA/JPL-Caltech/N Smith, University of Colorado at Boulder.)

