News & views

Astronomy

'Little red dots' could be black holes in disguise

Rodrigo Nemmen

Analysis indicates that the light from 'little red dots' is generated by young supermassive black holes obscured by dense clouds of gas. **See p.574**

The Universe has a habit of playing tricks on astronomers. In the 1960s, the sky was found to be full of strange 'tiny blue stars' that seemed to belong to the constellations of the Milky Way but were, in fact, quasars: supermassive black holes far outside the Galaxy. In 2022, astronomers faced a new mystery: 'little red dots' (LRDs). These points of light are – like their blue predecessors – compact, bright and baffling. LRDs have sparked a fierce debate over whether they are young, unexpectedly star-filled galaxies or anomalously massive black holes that are accreting glowing gas. On page 574, Rusakov *et al.*[1] report an analysis of the light from LRDs that supports the latter scenario but indicates that the black holes are hidden behind a thick curtain of gas, which made them seem more massive in earlier analyses than they really are.

The James Webb Space Telescope (JWST) first observed these distant objects less than two weeks after it began collecting infrared radiation from space. LRDs were initially thought to be galaxies in which the total mass of stars was greater than in the Milky Way. But this was difficult to reconcile with the fact that the observed objects were present in the early Universe, around 600 million years[2] after the Big Bang, a time that would generally be associated with lower total stellar masses. Furthermore, the amount of visible matter that is available in a galaxy to form stars is a fixed fraction of the mass of dark matter that it contains. According to conventional cosmological models, the mass of dark matter in LRDs is too small for them to be high-stellar-mass galaxies[3].

The most abundant element in the Universe is hydrogen. When hydrogen gas is energetically excited, its atoms can emit light. The spectrum of this light exhibits discrete intensity spikes, or emission lines, at certain well-defined frequencies. The hydrogen emission lines from astronomical objects are broad peaks that span a range of frequencies called the linewidth. Emission-line broadening can be caused by the gas moving at a high velocity (the Doppler effect), or by photons bouncing off objects such as electrons.

The hydrogen emission lines in LRDs are particularly broad[4,5], which indicates that the glowing gas is moving at velocities of thousands of kilometres per second. Such extreme speeds are a smoking gun of an active galactic nucleus (AGN), a region in some galaxies in which matter heats up and glows as it is accelerated by the gravitational pull of a supermassive black hole at the galactic centre.

AGNs always emit X-rays, which come from the hot gas close to the edge, or event horizon, of the black hole. Radio waves, too, can be emitted from powerful jets of plasma, launched from the vicinity of the black hole, in which electrons spiral around magnetic fields. However, there have been no confirmed observations of either X-rays or radio waves from LRDs[6,7].

Then the plot thickens further. The width of the hydrogen emission line of an AGN reflects the characteristic velocities of particles as they are pulled into the black hole. A heavier black hole accelerates the gas more, so the width of hydrogen lines can be used to measure the black hole's mass. This method is commonly used for nearby AGNs, but when it was applied to LRDs, the resulting black-hole masses were found to be closer to the total stellar masses of the host galaxies than is typical for AGNs[8].

Astronomers were left with two mutually exclusive interpretations, each riddled with

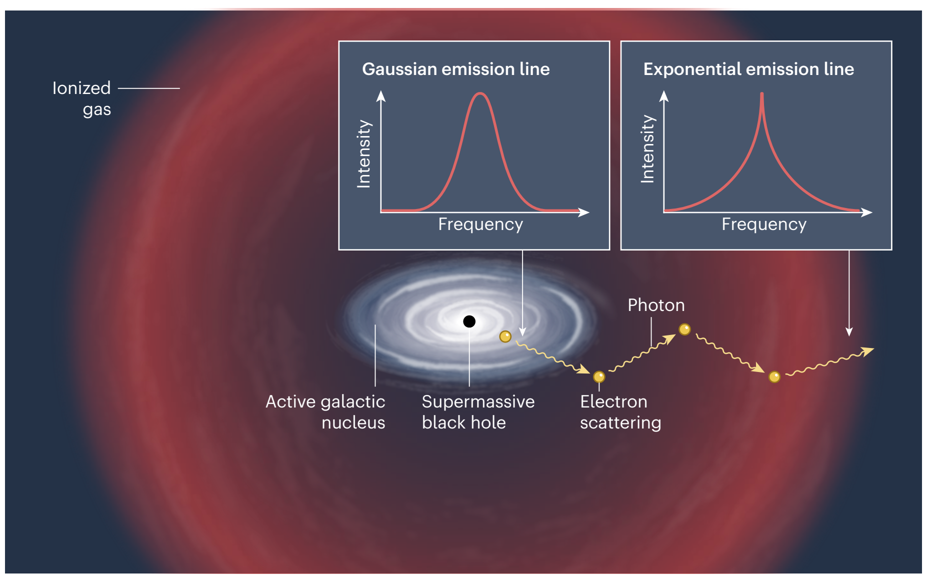

Figure 1 | Hydrogen spectra shed light on 'little red dots'. The light emitted by excited hydrogen gas exhibits intensity peaks called emission lines at well-defined frequencies. Rusakov *et al.*[1] investigate the nature of mysterious astronomical objects called little red dots (LRDs) using their hydrogen spectra. It has been proposed that the light emitted by LRDs could come from stars in a young galaxy, or from a galactic centre called an active galactic nucleus (AGN), in which light is emitted by material that is pulled towards a supermassive black hole. The authors show that LRD emission lines have the shape of exponential functions, indicating that the light photons had travelled through an ionized gas in which they scattered off electrons. The authors' models indicate that the observed emission lines are produced by AGNs. When the authors subtracted the effects of electron scattering from their model of hydrogen spectra, this left a narrow Gaussian peak, which they used to calculate the masses of the black holes.

contradictions. Whether LRDs were galaxies or black holes, they seemed to be disproportionately massive to have formed so early in the history of the Universe[9].

Rusakov *et al.* performed an analysis of JWST observations of Hα, a hydrogen emission line with a wavelength of 656.28 nanometres. They looked at the shape of the Hα lines of 12 LRDs. When the light from the most distant of these objects started its journey to Earth, the Universe was less than 10% of its current age, and the Milky Way did not yet exist.

If light from an astronomical object reaches Earth unimpeded by gas clouds, the expected emission-line shape is that of a bell curve, or Gaussian distribution. By contrast, a tent-shaped profile, which is fit by a double-sided exponential curve, points to a highly charged, ionized medium surrounding the light source; in such a medium, each photon bounces, or scatters, off electrons multiple times before it reaches an observer. Rusakov *et al.* found that the hydrogen line profiles fit much better with an exponential model than a Gaussian one. This is particularly clear for the spectra in which random noise from the detector and background astronomical sources is small compared with the emission-line signal.

To understand what kind of object could have produced such a light spectrum, the authors used a simple model that treated the scattering medium as a shell surrounding a central light source. Their results show that the Hα spectra observed by the JWST are consistent with a luminous object surrounded by dense clouds of ionized material. According to this model, the brightest light sources in the sample had a luminosity equivalent to that of more than 250 billion Suns, and they were all less than one-tenth of a parsec across — much smaller than a galaxy. The only plausible explanation was a dense, compact object that was converting the gravitational potential energy of infalling gas into light — in other words, a supermassive black hole (Fig. 1).

The authors subtracted the effects of electron scattering from their model of the hydrogen spectra, which left a narrow Gaussian peak. The width of a Gaussian-shaped emission line can be used to estimate the velocity of the light-emitting gas; this was around 300 kilometres per second for most of the LRDs. Assuming that the gas was orbiting the centre of the LRD, this was consistent with black-hole masses of between 10^5 and 10^7 Solar masses. These values are about a 100 times lower than previous estimates, which treated the Hα emission line as a purely Gaussian peak.

This result solves several conundrums surrounding LRDs. For one thing, it strongly favours the black-hole explanation over the galactic one. For another, Rusakov and colleagues predicted that the dense cocoon of ionized gas around the supermassive black hole would trap most of the radiation generated in the vicinity of the black hole — which would explain why the emission spectra of LRDs do not contain X-rays and radio waves.

With the corrected mass estimates, LRDs fit standard theories of cosmic evolution: according to the authors' findings, they are young AGNs. More work will be needed to confirm these findings in a larger sample of LRDs; to constrain estimates of the mass of the smaller black holes that eventually become LRDs; and to formulate a theory of how LRDs evolve.

It seems that the Universe has a sense of humour. In astronomy, youth is usually associated with the colour blue, because young stars burn hot and blue. But here, the youngest supermassive black holes are red. If Rusakov and collaborators are correct, these little red dots are quasars in chrysalis form — waiting to shed their cocoons and emerge as the little blue stars that so confused astronomers more than half a century ago.

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1. Rusakov, V. *et al. Nature* **649**, 574–579 (2026).
2. Labbé, I. *et al. Nature* **616**, 266–269 (2023).
3. Boylan-Kolchin, M. *Nature Astron.* **7**, 731–735 (2023).
4. Kocevski, D. D. *et al. Astrophys. J.* **954**, L4 (2023).
5. Matthee, J. *et al. Astrophys. J.* **963**, 129 (2024).
6. Yue, M. *et al. Astrophys. J.* **974**, L26 (2024).
7. Mazzolari, G. *et al.* Preprint at arXiv https://doi.org/10.48550/arXiv.2412.04224 (2025).
8. Maiolino, R. *et al. Astron. Astrophys.* **691**, A145 (2024).
9. Volonteri, M. Preprint at arXiv https://doi.org/10.48550/arXiv.2510.04599 (2025).

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Molecular biology

An atlas of human chromosome organization

Elzo de Wit

Our genomes are highly structured, which facilitates gene regulation. An ambitious project has catalogued the organization of DNA in the nuclei of human cells. **See p.759**

When you think of a chromosome, you might imagine an X-shaped structure. But chromosomes take this shape only during cell division; the rest of the time, they adopt a structure that looks amorphous when viewed under a standard microscope. At the molecular level, however, chromosomes are folded in a highly non-random manner, enabling the proper execution of crucial processes such as gene expression, DNA replication and DNA repair. In their flagship paper[1] on page 759, members of the 4D Nucleome Consortium report the outcome of the first phase of a project that aims to systematically catalogue the 3D organization of human chromosomes in the nucleus and how this changes over time.

DNA is wrapped around histone proteins to form a complex called chromatin. This can be biochemically modified, which alters how accessible DNA is to the transcriptional machinery and therefore regulates the expression of genes. Open and active chromatin segregates from closed and inactive chromatin, forming compartments[2]. Inactive compartments are commonly found at the nuclear periphery, whereas active compartments are found in the interior.

Another level of spatial organization is the formation of self-interacting genomic regions called topologically associating domains (TADs)[3], which are generally smaller than compartments. TADs are formed by a protein complex called cohesin, which acts as a molecular motor that makes loops in DNA through a process known as loop extrusion[4]. Through chromatin looping, the promoter sequences of genes in TADs can be brought into physical proximity with regulatory DNA sequences called enhancers, bridging hundreds of thousands of bases, to activate gene transcription. Regions known as TAD boundaries shield genes in other TADs from being inappropriately activated by enhancers. Proper chromatin organization is crucial for health: disruptions to TAD boundaries are associated with congenital birth defects[5] and cancer development[6], for example.

These discoveries have been fuelled by a set of techniques called chromosome conformation capture (3C). Such methods were pioneered by one of the lead researchers on the 4D nucleome project more than two decades ago, and were first used to measure the frequency of contacts made between