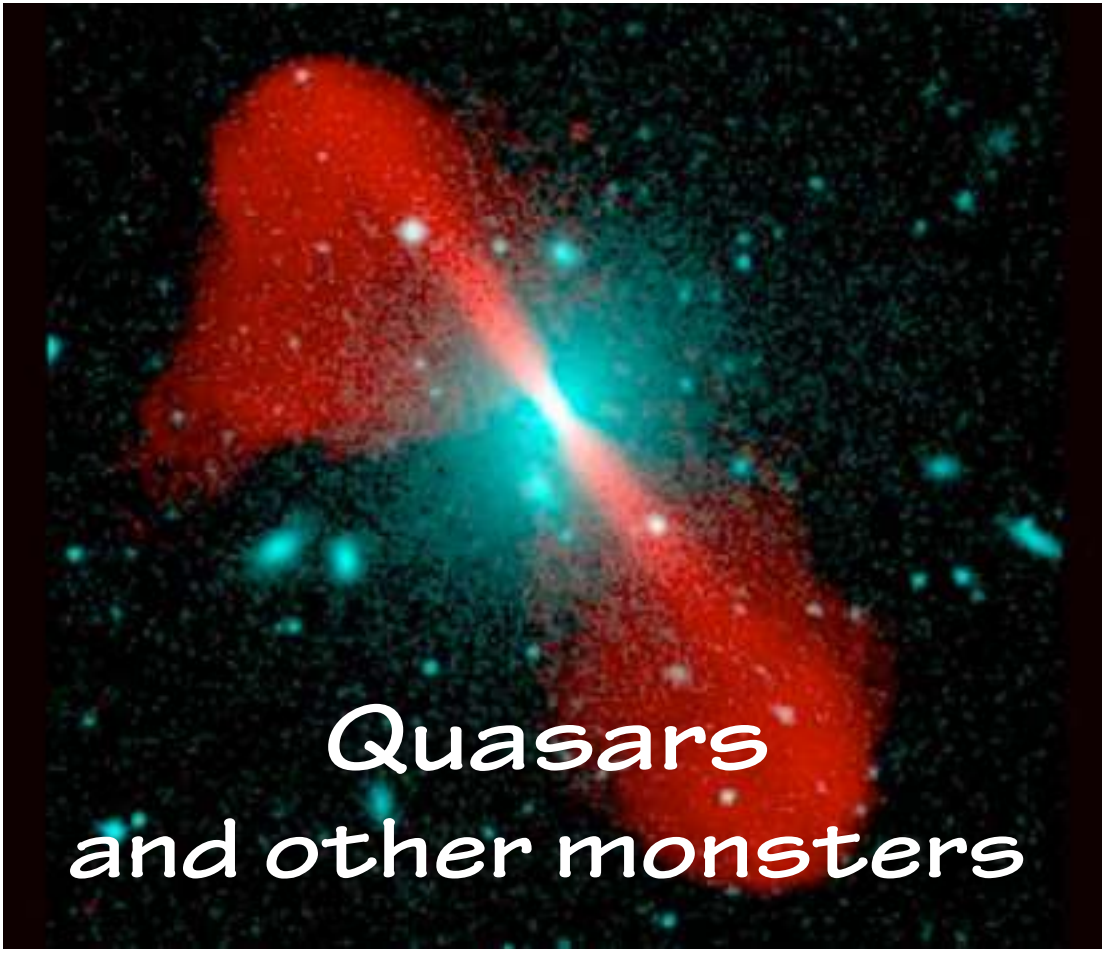
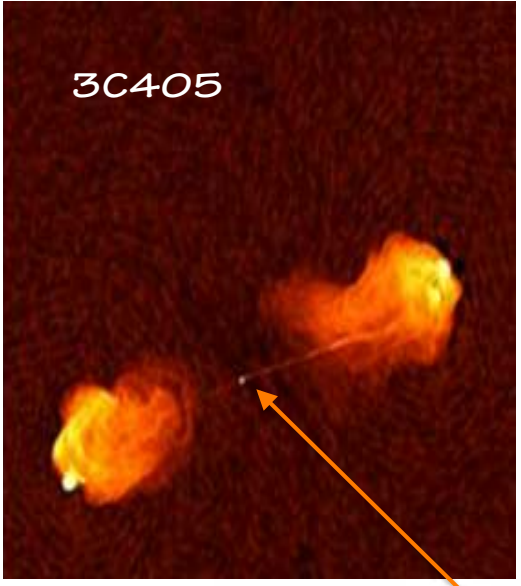
The Universe in my pocket



Quasars and other monsters

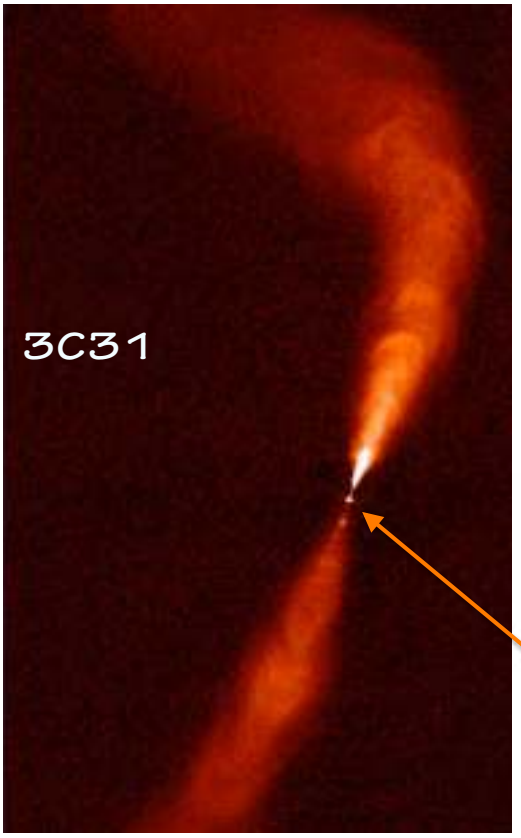
TUIMP No. 6 THE UNIVERSE IN MY POCKET

Grażyna Stasińska
Paris Observatory



Left:
A modern radio image of one of the brightest radio sources in the sky: 3C405.

Right:
Space Telescope visible light image of Cygnus A, the galaxy located between the two radio lobes of 3C405 and hosting a quasar.



Left: The radio source 3C31.

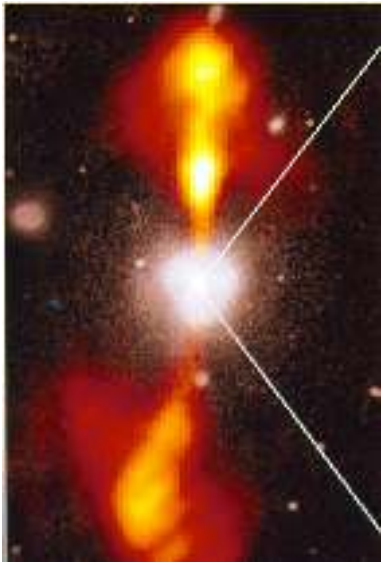
Right:
NGC 383, the galaxy from which the radio lobes of 3C31 originate.

The discovery of quasars

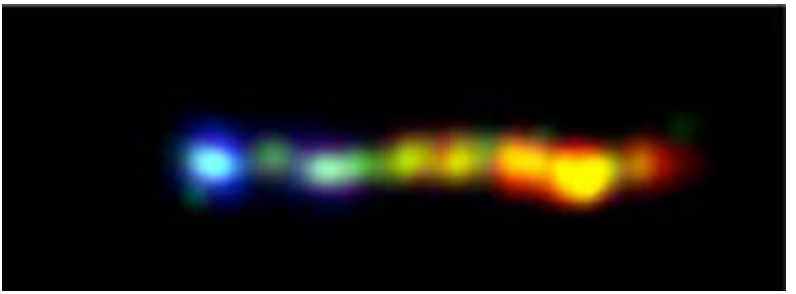
Although quasars are the most luminous objects in the Universe, they were only discovered about 60 years ago.

Radio signals from many celestial sources had already been recorded at that time. When astronomers tried to find visible light matches to the radio sources, they discovered that the central zones of many extended radio sources were occupied by faint, stellar-like blue objects.

The spectra of these objects revealed that they were very far away (well outside our galaxy, more distant than many known galaxies) and they were not stars. They received the name of quasars (for quasi-stars).



Composite image of NGC 4261. Left: the radio lobes (200,000 light-years long) are in orange and the optical image of the galaxy is in white.
Right: Hubble Space Telescope image of the central zone showing a disk of dust 400 light-years across.



Composite image of the 3C273 jet (100,000 light-years long) in X-rays (blue), visible (green) and infrared (red) by the Chandra, Hubble, and Spitzer space telescopes.

Disks, jets and other features

With the Hubble Space Telescope, astronomers can see details not visible with telescopes on Earth.

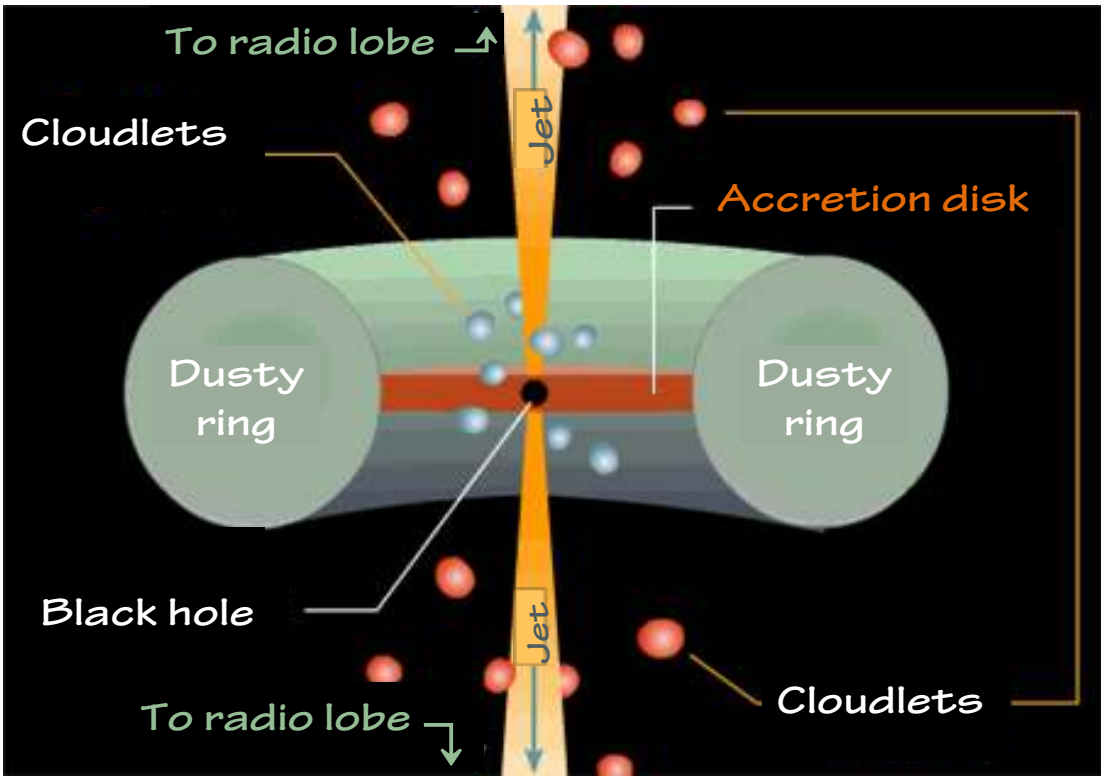
We can now distinguish the shapes of the galaxies from which the radio jets originate.

Dusty disks are seen in the central zones of the nearest ones. In some cases, optical `jets' are seen to point away from the galactic nucleus.

X-ray telescopes show that quasars and their related galaxies are bright X-ray sources.

In the meantime, though, astronomers have discovered many objects with the same properties as quasars but not emitting radio waves. These are called radio-quiet quasars.

The anatomy of a quasar



A supermassive black hole (radius 1 light-hour) is surrounded by a thin, hot accretion disk (radius 1 light-month) fuelling the black hole. The disk emits radiation which interacts with the neighbouring gaseous cloudlets.

The disk connects to a fat, dusty ring of radius 1000 light-years. If the dusty ring is edge-on, the accretion disk is hidden from view.

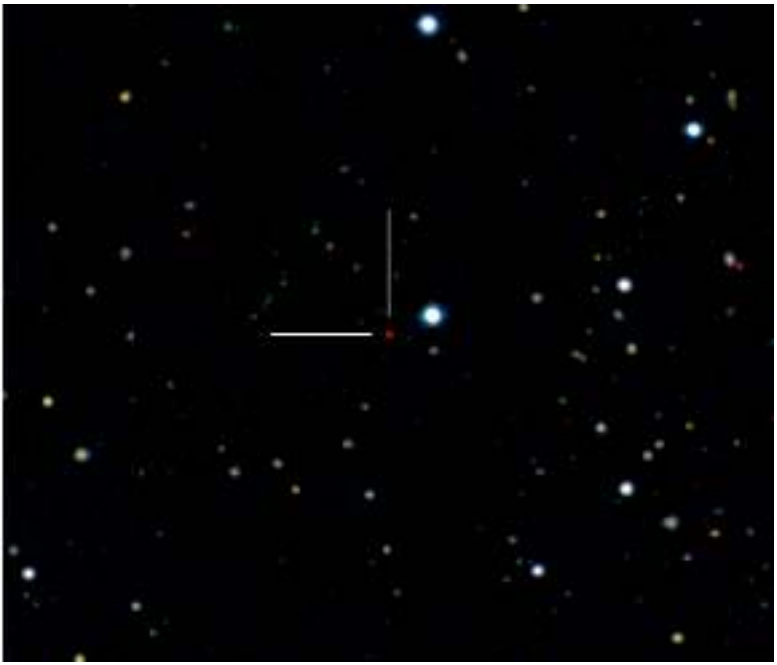
Jets of fast particles originate from the black hole, perpendicular to the accretion disk. They end up in radio lobes, up to one million light-years in size.

How quasars work

Typically, quasars radiate as much energy per second as 1000 galaxies, but from a region a million times smaller than one galaxy. How can this be? Clearly the origin of the radiation cannot be stellar.

It is now accepted that quasars host in their center a supermassive black hole, that attracts whatever matter lies nearby. Before falling into the black hole, the matter spirals down onto an 'accretion disk', where it is heated to very high temperatures, producing ultraviolet light and X-rays. More massive black holes are more luminous.

This radiation interacts with the surrounding gas, producing the characteristic spectra of quasars.



Trying to find very distant quasars is an important but difficult task.

This image was created from data taken with both the Sloan Digital Sky Survey and the UKIRT Infrared Deep Sky Survey.

It allowed the discovery of the most distant quasar known so far, ULAS J1120+0641 (the faint red source indicated by the two white lines). Only the colour distinguishes the quasar from the other sources, most of which are ordinary stars in our own galaxy.

What we do not understand

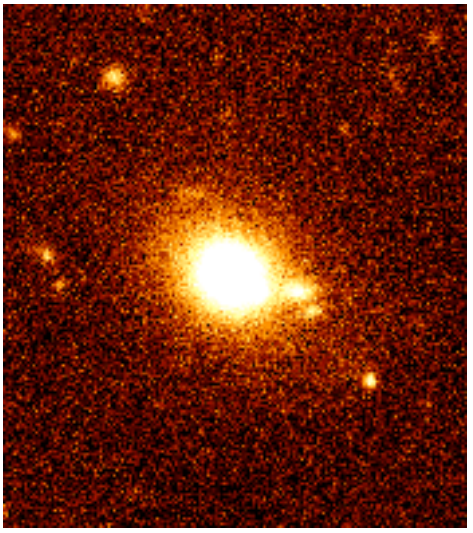
There are still many important questions about quasars that need to be solved.

Perhaps the most important question is how the supermassive black holes were created.

Quasars are so luminous that they can be detected at very large distances and the light from them takes a long time to reach us. The light we receive from the most distant one, ULAS J1120+0641, was emitted only 800 million years after the Big Bang. Several scenarios try to explain how a black hole with two billion times the mass of the Sun could have formed so quickly after the birth of the Universe.

NGC 1068, one of the galaxies described by Seyfert in 1943 and now considered the archetype of active galactic nuclei, ie. some sort of mini-quasar.

A visible light image of Arp220, an ultraluminous infrared galaxy. Much of the stellar light is absorbed by dust and reemitted in the infrared. Arp 220 contains an active nucleus that emits X-rays.



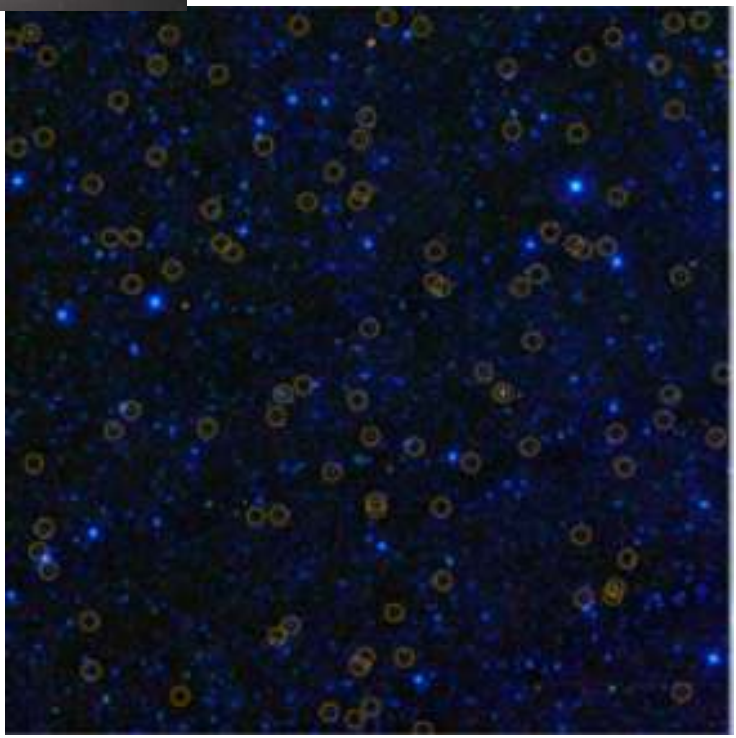
An image of the blazar HO323+022 obtained from Earth with the ESO NTT telescope. The image is dominated by light from the jet, which points towards the observer.

Other monsters

Before quasars were discovered, we already knew that some galaxies have especially bright nuclei and unusual spectra. Such galaxies were named Seyfert galaxies. They belong to the class of `galaxies with active nuclei', which also includes quasars and blazars. In all cases, a central black hole is accreting matter from its surroundings, but quasars are more massive and more luminous.

Recently, infrared observations of the sky revealed a population of galaxies very bright in the infrared but hardly detectable in the visible. Many of these are thought to contain active galactic nuclei.

The giant elliptical galaxy NGC 4889, which contains a very massive black hole (ten billion times the mass of the Sun). It could be a sleeping quasar.



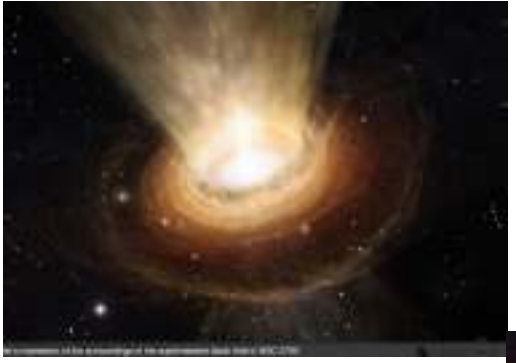
The Wide-field Infrared Survey Explorer has identified millions of objects that might be quasars. In this image the quasar candidates are inside the yellow circles.

Quasars in the Universe

Astronomers now think that all galaxies contain a supermassive black hole. Galaxies probably alternate between periods of 'hibernation' with stages of intense 'activity' during which the black hole devours the matter that passes too close to it.

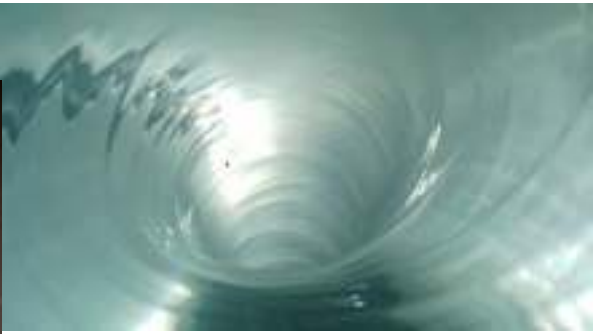
Present quasar catalogues based on optical discoveries contain about 300,000 objects. But there are already millions of candidates awaiting confirmation and many more to come with future surveys.

Because quasars are intrinsically so luminous, their spectra allow us to probe the matter out to the extreme edges of the Universe.



Quiz

What are these swirls ?



Answers on overleaf

How an artist imagines the surroundings of the massive black hole in NGC 3783

HST image of the galaxy NGC 1277 that contains an extremely massive black hole

Disk of cold gas and dust fueling the central black hole of the galaxy NGC 4261 observed with the HST

Swirl in an emptying bathtub

HST image of the galaxy NGC 7049 showing its circular dust lanes

The Universe in my pocket No. 6

This booklet was written in 2016 by Grażyna Stasińska from Paris Observatory (France) and revised by Stan Kurtz from the UNAM Radio Astronomy Institute in Morelia (Mexico)

Cover image: a composite image of the massive elliptical galaxy NGC 5532 (shown in blue) and of the jets of the radio source 3C296 (shown in red). The radio map was created with the Very Large Array of radio telescopes. Other images in this booklet are from HST, CXC, SAO, Spitzer and UKIRT.

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