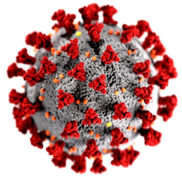
Lockdown Challenge

In early 2020 life as we knew it changed. Life in lockdown.



Stephen Hawking: "*Remember to look up at the stars and not down at your feet. Try to make sense of what you see and wonder about what makes the universe exist.*"

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The Challenge

The Universe is vast and ancient. Large telescope have imaged galaxies that are billions of light-years distant.

Is it possible to capture an image of one of these very remote objects ***without*** a telescope?

(Spoiler alert: Yes, it is)

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Quasar Survey

The Astrophysical Journal Supplement Series, 243:5 (35pp), 2019 July https://doi.org/10.3847/1538-4365/ab20d0

The Extremely Luminous Quasar Survey in the Pan-STARRS 1 Footprint (PS-ELQS)

Jan-Torge Schindler[1,2], Xiaohui Fan[1], Yun-Hsin Huang[1], Minghao Yue[1], Jinyi Yang[1], Patrick B. Hall[3], Lukas Wenzl[2], Allison Hughes[1], Katrina C. Litke[1], and Jon M. Rees[4]

A **quasar** is the nucleus of a galaxy that emits enough light to be seen at a distance of billions of light-years

parent sample of 74,318 sources. After exclusion of known sources and rejection of candidates with unreliable photometry, we have taken optical identification spectra for 290 of our 334 good PS-ELQS candidates. We report the discovery of 190 new $z \geqslant 2.8$ quasars and an additional 28 quasars at lower redshifts. A total of 44 good PS-ELQS candidates remain unobserved. Including all known quasars at $z \geqslant 2.8$, our quasar selection method has a selection efficiency of at least 77%. At lower declinations, $-30 \leqslant$ decl. $\leqslant 0$, we approximately treble the known population of extremely luminous quasars. We provide the PS-ELQS quasar catalog with a total of 592 luminous quasars ($m_i \leqslant 18.5$, $z \geqslant 2.8$). This unique sample will not only be able to provide constraints on the volume density and quasar clustering of extremely luminous quasars, but also offers valuable targets for studies of the intergalactic medium.

Key words: galaxies: nuclei – quasars: general

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Ancient Light

Quasar – Artist's Impression

Quasar Survey

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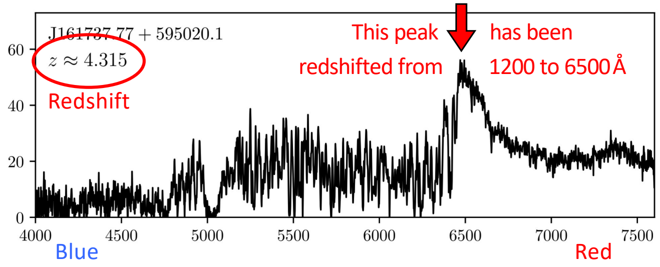


A redshift of 4.315 means that this quasar is VERY remote!

Camera and Tracker

iOptron SkyTracker

Nikon D7500
300 mm f/4 lens

The tracker rotates the camera at 1 rev/day to follow the stars

Camera and Lens

Note: The Nikon D7500 digital SLR camera and 300 mm f/4 lens are the camera equipment that I use for wildlife photography – they are not 'customised' or 'modified' for astrophotography.

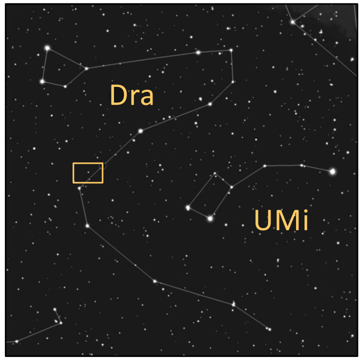
If this camera and lens can be used to photograph zebras …

… can they also be used to photograph a quasar?

Location in Draco

The quasar is located in the constellation of Draco.

The rectangle shows the field of view of the 300 mm lens.



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Expose For 2 Hours

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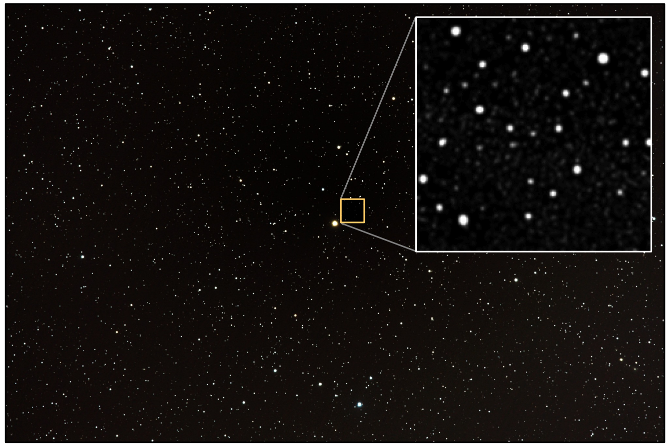
The Quasar



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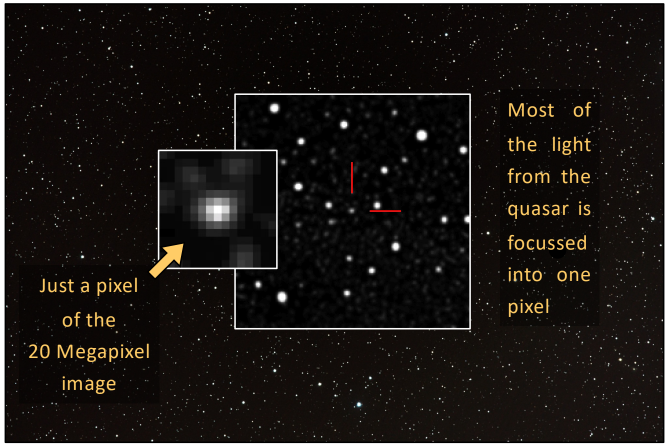
The Quasar



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Just a Pixel?

Technical aside:

What resolution can we expect from the lens and the camera?

	μ radians	*arcsec*
300 mm f/4 lens	9	< 2"
Nikon D7500 DSLR	15	3"

For comparison, at a distance of a few billion light-years the Milky Way would appear to have a diameter of ~ 30 μrad or 6".

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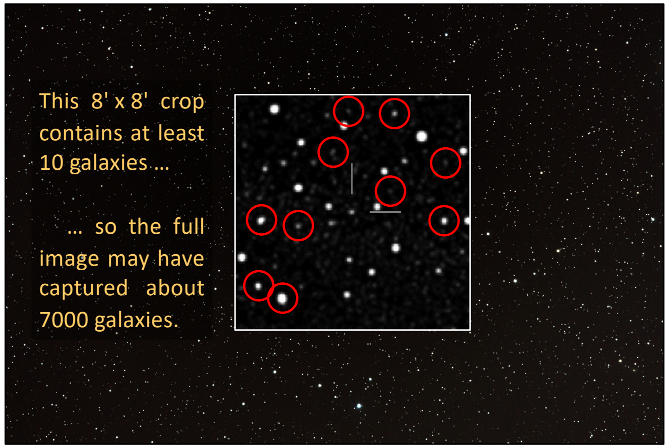
Barrett Deep Field



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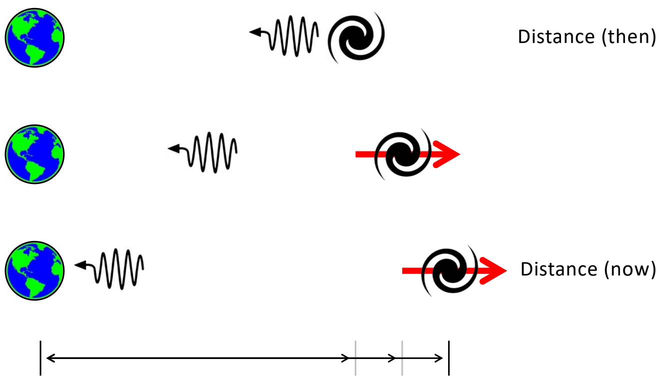
"The" Distance



What is "the" distance to the quasar?

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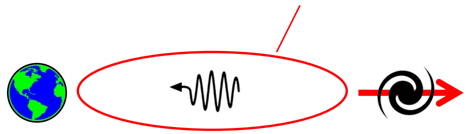
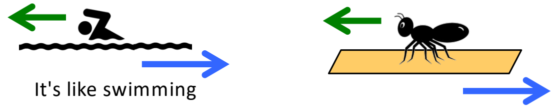
"The" Distance

What distance has the light travelled?
That's tricky: Space continues to expand as the light travels.





It's like swimming against the tide ...

... or an ant walking along a rubber band that is being stretched.

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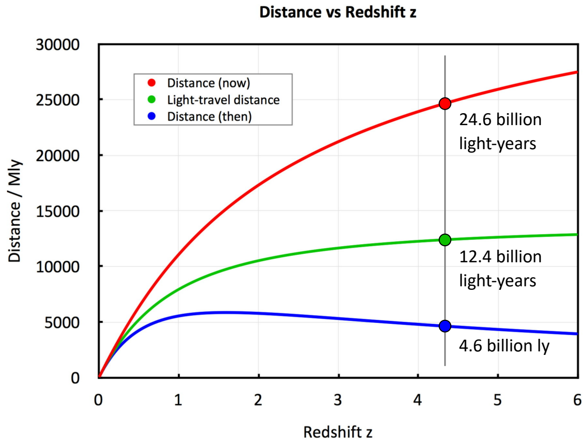
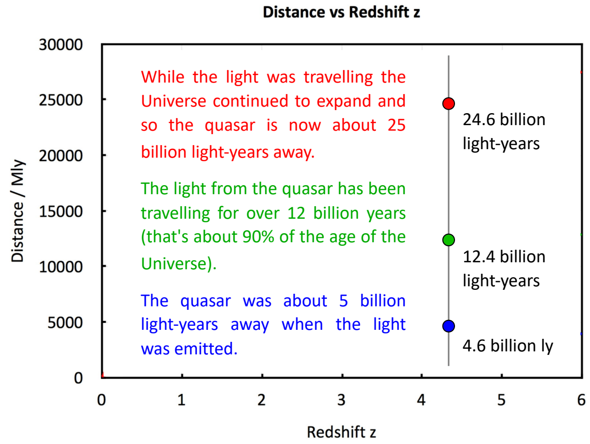
Ancient Light

Distance vs Redshift



Distance vs Redshift



Faster Than Light

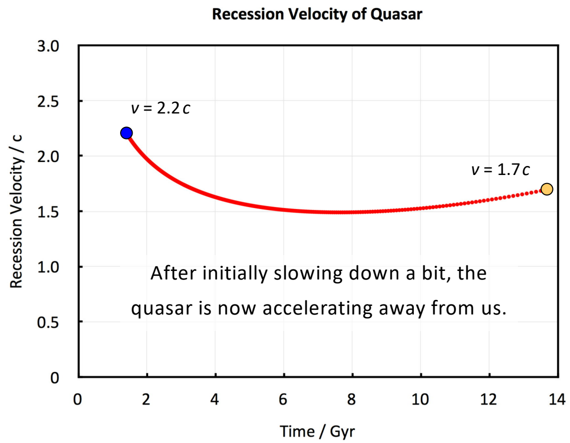
A quick back-of-the-envelope calculation using these numbers leads to a very interesting conclusion.

During the light-travel time of 12 billion years the distance to the quasar has increased by ***more*** than 12 billion light-years.

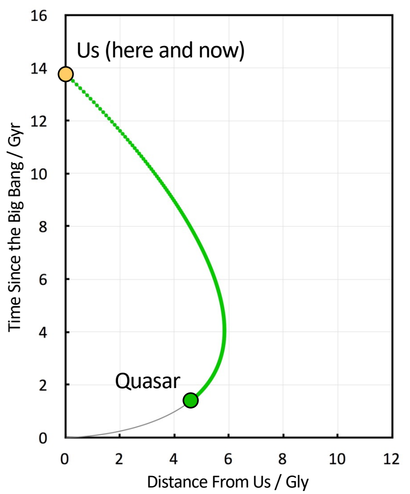
$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{20 \text{ billion ly}}{12 \text{ billion yr}} \approx 1.6\,c$$

This means that the quasar has been receding from us ***faster*** than the speed of light.

Quasar Velocity vs Time



The Light's Journey



The quasar is receding from us at twice the speed of light.

When the light was emitted by the quasar (green dot) it was 'dragged backwards' by the expanding Universe for over two billion years before it started to make headway and get closer to us.

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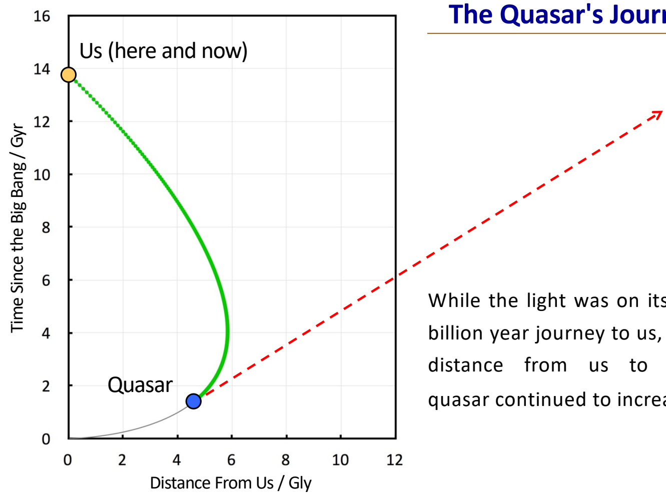
The Quasar's Journey



While the light was on its 12 billion year journey to us, the distance from us to the quasar continued to increase.

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Ancient Light

The light was emitted by the quasar 1.4 billion years after the Big Bang.

It had already been travelling for nearly 8 billion years when the Sun and the Earth were born. It continued on its journey through the void for another 4.5 billion years.

Life evolved on Earth. The light travelled on.

Dinosaurs came and went. The light travelled on.

In the last million years of its journey it arrived at the edge of our Milky Way galaxy, crossed a few spiral arms, and entered the Solar System.

In its last few hours it finally arrived at Earth, travelled through the atmosphere in a fraction of a second, hurtled towards England, dodged a few clouds, and entered the lens and hit the camera sensor.

Just a pixel in the image … but what a journey!

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