Where have all the Quasars gone?

John Parejko

Advisors: Michael Vogeley and Anca Constantin

Drexel University

Where have all the quasars gone?
Long time passing.

Where have all the quasars gone?
Long time ago.

Where have all the quasars gone?
Do galaxies have them, ev’ry one?
When will we ever learn?
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Apologies to Pete Seeger

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INVESTIGATION OF THE RADIO SOURCE 3C 273 BY THE METHOD OF LUNAR OCCULTATIONS

By C. HAZARD, M. B. MACKEY and A. J. SHIMMINS
C.S.I.R.O. Division of Radiophysics, University Grounds, Sydney

THE observation of lunar occultations provides the most accurate method of determining the positions of the localized radio sources, being capable of yielding a positional accuracy of the order of 1 sec of arc. It has been shown by Hazard[1] that the observations also provide diameter information down to a limit of the same order. For the sources of small angular size the diameter information is obtained from the observed diffraction effects at the Moon's limb which may be considered to act as a straight diffracting edge.

The method has so far been applied only to a study of the radio source 3C 212 the position of which was determined to an accuracy of about 3 sec of arc[1,2]. However, 3C 212 is a source of comparatively small flux density and although the diffraction effects at the Moon's limb were clearly visible the signal-to-noise ratio was inadequate to study the pattern in detail and hence to realize the full potentialities of the method. Here we describe the observation of a series of occultations of the intense radio source 3C 273 in which detailed diffraction effects have been recorded for the first time permitting the position to be determined to an accuracy of better than 1″ and enabling a detailed examination to be made of the brightness distribution across the source.

The observations were carried out using the 210-ft. steerable telescope at Parkes, the method of observation being to direct the telescope to the position of the source and then to record the received power with the telescope in automatic motion following the source. Three occultations of the source have been observed, on April 15, at 410 Mc/s, on August 5 at 136 Mc/s and 410 Mc/s, and on October 26 at 410 Mc/s and 1,420 Mc/s, although in October and April only the immersion and emersion respectively were visible using the Parkes instrument. The 410 Mc/s receiver was a double-sided band receiver, the two channels, each of width 10 Mc/s, being centred on 400 Mc/s and 420 Mc/s, while the 136 Mc/s and 1,420 Mc/s receivers each had a single pass band 1·5 Mc/s and 10 Mc/s wide respectively.

The record of April 15, although of interest as it represents the first observation of detailed diffraction fringes during a lunar occultation, is disturbed by a gradient in the received power and is not suitable for accurate position and diameter measurements. Therefore, attention will be confined to the occultation curves recorded in August and October and which are reproduced in Fig. 1. It is immediately obvious from these records that 3C 273 is a double source orientated in such a way that whereas the two components passed successively behind the Moon at both immersions, they reappeared almost simultaneously. The prominent diffraction fringes show that the angular sizes of these components must be considerably smaller than 10″, which is the order of size of a Fresnel

spond to spectral indices for components *A* and *B* of −0·9 and 0·0 respectively. The spectral index of *A* is a representative value for a Class II radio source; but the flat spectrum of *B* is most unusual, no measurements of a comparable spectrum having yet been published. If the spectral indices were assumed constant down to 136 Mc/s then at this frequency component *A* must contribute almost 90 per cent of the total emission, a conclusion which is confirmed by a comparison of the times of immersion at 136 Mc/s and 410 Mc/s on August 5.

It has been shown by Scheuer[4] that it is possible to recover the true brightness distribution across the source from the observed diffraction pattern, the resolution being subject only to limitations imposed by the receiver bandwidth and the finite signal to noise ratio and being independent of the angular scale of the diffraction pattern. However, in this preliminary investigation we have not attempted such a detailed investigation but based the analysis on the calculated curves for uniform strip sources of different widths as published by Hazard[1]. As a first step in the investigation approximate diameters were estimated from the intensity of the first diffraction lobe and the results corresponding to the three position angles defined by the occultations and indicated in Fig. 2 are given in Table 1.

As already indicated here, the 136-Mc/s measurements refer only to component *A* and hence no diameter measurements are available for *B* at this frequency. The 410-Mc/s observations of the August occultation are the most difficult to interpret owing to the components having both comparable flux density and small separation relative to the angular size of the first Fresnel zone. At immersion the widths were estimated by using a process of curve fitting to reproduce Fig. 1(*d*); at emersion (position angle 313°) the diameter of component *B* was assumed to be 3″ as indicated by the estimates at position angles 105° and 83°. The individual measurements at each frequency are reasonably consistent but there is a striking variation of the angular size of component *A* with frequency and evidence of a similar variation for component *B*. As at the time of the August occultation the angular separation of the Sun and the source was about 50° and hence coronal scattering of the type observed by Slee[5] at 85 Mc/s is not likely to be significant, this variation in size suggests that the model of two uniform strip sources is inadequate.

Therefore, a more detailed analysis was made of the intensity distributions of the lobe patterns given in Figs. 1(*c*) and 1(*f*), and it was found that in neither case can the pattern be fitted to that for a uniform strip source or a source with a gaussian brightness distribution. The 1,420-Mc/s observations of component *B* can be explained, however, by assuming that this source consists of a central bright core about 0·5″ wide contributing about 80 per

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3C 273: A STAR-LIKE OBJECT WITH LARGE RED-SHIFT

By DR. M. SCHMIDT
Mount Wilson and Palomar Observatories, Carnegie Institution of Washington, California Institute of Technology, Pasadena

THE only objects seen on a 200-in. plate near the positions of the components of the radio source 3C 273 reported by Hazard, Mackey and Shimmins in the preceding article are a star of about thirteenth magnitude and a faint wisp or jet. The jet has a width of 1″–2″ and extends away from the star in position angle 43°. It is not visible within 11″ from the star and ends abruptly at 20″ from the star. The position of the star, kindly furnished by Dr. T. A. Matthews, is R.A. 12h 26m 33·35s ± 0·04s, Decl. + 2° 19′ 42·0″ ± 0·5″ (1950), or 1″ east of component B of the radio source. The end of the jet is 1″ east of component A. The close correlation between the radio structure and the star with the jet is suggestive and intriguing.

Spectra of the star were taken with the prime-focus spectrograph at the 200-in. telescope with dispersions of 400 and 190 Å per mm. They show a number of broad emission features on a rather blue continuum. The most prominent features, which have widths around 50 Å, are, in order of strength, at 5632, 3239, 5792, 5032 Å. These and other weaker emission bands are listed in the first column of Table 1. For three faint bands with widths of 100–200 Å the total range of wave-length is indicated.

The only explanation found for the spectrum involves a considerable red-shift. A red-shift $\Delta\lambda/\lambda_0$ of 0·158 allows identification of four emission bands as Balmer lines, as indicated in Table 1. Their relative strengths are in agreement with this explanation. Other identifications based on the above red-shift involve the Mg II lines around 2798 Å, thus far only found in emission in the solar chromosphere, and a forbidden line of [O III] at 5007 Å. On this basis another [O III] line is expected at 4959 Å with a strength one-third of that of the line at 5007 Å. Its detectability in the spectrum would be marginal. A weak emission band suspected at 5705 Å, or 4927 Å reduced for red-shift, does not fit the wave-length. No explanation is offered for the three very wide emission bands.

It thus appears that six emission bands with widths around 50 Å can be explained with a red-shift of 0·158. The differences between the observed and the expected wave-lengths amount to 6 Å at the most and can be entirely understood in terms of the uncertainty of the measured wave-lengths. The present explanation is supported by observations of the infra-red spectrum communicated by Oke in a following article, and by the spectrum of another star-like object associated with the radio source 3C 48 discussed by Greenstein and Matthews in another communication.

Table 1. WAVE-LENGTHS AND IDENTIFICATIONS

λ	λ/1·158	λ_0	
3239	2797	2798	Mg II
4595	3968	3970	Hε
4753	4104	4102	Hδ
5032	4345	4340	Hγ
5200–5415	4490–4675		
5632	4864	4861	Hβ
5792	5002	5007	[O III]
6005–6190	5186–5345		
6400–6510	5527–5622		

The unprecedented identification of the spectrum of an apparently stellar object in terms of a large red-shift suggests either of the two following explanations.

(1) The stellar object is a star with a large gravitational red-shift. Its radius would then be of the order of 10 km. Preliminary considerations show that it would be extremely difficult, if not impossible, to account for the occurrence of permitted lines and a forbidden line with the same red-shift, and with widths of only 1 or 2 per cent of the wave-length.

(2) The stellar object is the nuclear region of a galaxy with a cosmological red-shift of 0·158, corresponding to an apparent velocity of 47,400 km/sec. The distance would be around 500 megaparsecs, and the diameter of the nuclear region would have to be less than 1 kiloparsec. This nuclear region would be about 100 times brighter optically than the luminous galaxies which have been identified with radio sources thus far. If the optical jet and component A of the radio source are associated with the galaxy, they would be at a distance of 50 kiloparsecs, implying a time-scale in excess of 10^5 years. The total energy radiated in the optical range at constant luminosity would be of the order of 10^{59} ergs.

Only the detection of an irrefutable proper motion or parallax would definitively establish 3C 273 as an object within our Galaxy. At the present time, however, the explanation in terms of an extragalactic origin seems most direct and least objectionable.

I thank Dr. T. A. Matthews, who directed my attention to the radio source, and Drs. Greenstein and Oke for valuable discussions.

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3C 273 : A S…

Mount Wilson and Palomar Observa…

RED-SHIFT OF THE UNUSUAL RADIO SOURCE: 3C 48

By DR. JESSE L. GREENSTEIN
Mount Wilson and Palomar Observatories, Carnegie Institution of Washington, California Institute of Technology
AND
DR. THOMAS A. MATTHEWS
Owens Valley Radio Observatory, California Institute of Technology

THE radio source 3C 48 was announced to be a star[1] in our Galaxy on the basis of its extremely small radio diameter[2], stellar appearance on direct photographs and unusual spectrum. Detailed spectroscopic study at Palomar by Greenstein during the past year gave only partially successful identifications of its weak, broad emission lines; the possibility that they might be permitted transitions in high stages of ionization could not be proved or disproved. Hydrogen was absent but several approximate coincidences with He II and O VI were suggested.

The discovery by Schmidt (a preceding article) of much broader emission lines in the apparently stellar radio source, 3C 273, suggested a red-shift of 0·16 for 3C 273 if the lines were interpreted as the Balmer series. In 3C 48 no such series was apparent; measurable lines still do not coincide with the hydrogen series. However, the possibility of a very large red-shift, which had been considered many times, was re-explored successfully. 3C 48 has a spectrum containing one very strong emission feature near λ3832 which is 35 Å wide and about 10 other weaker features near 23 Å in width. The sharper lines are listed in Table 1 in order of decreasing intensity. Some broad lines or groups of lines between 50 and 100 Å width may be red-shifted hydrogen lines.

Table 1. IDENTIFICATIONS AND OBSERVED RED-SHIFTS

Wave-length λ*	λ lab.	Source	λ*/λ lab.
3832·3	2796} 2803} 2798	Mg II	1·3697:
4685·0	3426	[Ne V]	1·3676
5098	3729} 3726} 3727	[O II]	1·3679
4575	3346	[Ne V]	1·3673
5289	3868	[Ne III]	1·3671
4065·7	2975 :	[Ne V]	1·3667 :

The weighted mean red-shift $d\lambda/\lambda_0$ is 0·3675 ± 0·0003, an apparent velocity of +110,200 km/sec. The slightly discrepant value for λ2975 of [Ne V] is compatible with the uncertainty of ± 3 Å in the wave-length predicted by Bowen[3]. The Mg II permitted resonance doublet has a small additional displacement to longer wave-lengths, possibly caused by self-absorption in an expanding shell; it is the strongest emission line in the rocket-ultra-violet spectrum of the Sun. The forbidden lines are similar to those in other intense extragalactic radio sources.

So large a red-shift, second only to that of the intense radio source 3C 295, will have important implications in cosmological speculation. A very interesting alternative, that the source is a nearby ultra-dense star of radius near 10 km containing neutrons, hyperons, etc., has been explored and seems to meet insuperable objections from the spectroscopic point of view. The small volume for the shell required by the observed small gradient of the gravitational potential is incompatible with the strength of the forbidden lines.

The distance of 3C 48, interpreted as the central core of an explosion in a very abnormal galaxy, may be estimated as 1·10 × 10⁹ parsecs; the visual absolute magnitude is then −24·0, or −24·5 corrected for interstellar absorption. The minimum correction for the effect of red-shift is of the order of 2 v/c and a value between 4 and 5 times v/c is probable for a normal galaxy. The absolute visual magnitude of 3C 48 is then brighter than −25·2 and possibly as bright as −26·3, 10–30 times greater than that of the brightest giant ellipticals[4] hitherto recognized, which are near −22·7 and another factor of five brighter than our own Galaxy, near −21·0.

As a radio source at a distance of 1·1 × 10⁹ parsecs 3C 48 is not markedly different from other known strong radio sources like 3C 295 or Cygnus A. The one feature in which it does differ from most sources is in its high surface brightness. This is partially due to its extremely small radio size of ⩽ 1 sec of arc[2]. The optical size is comparable, being also ⩽ 1 sec of arc[5]. At the assumed distance such angular sizes indicate that both the optical and radio emission arise within a diameter of ⩽ 5500 parsecs. The radio diameter might even be comparable with or less than that of 3C 71 (NGC 1068) the diameter of which is about 700 parsecs. However, 3C 71 has 5 orders of magnitude less radio emission.

If we determine the integrated radio emission of 3C 48 from the observed spectral index of the radio spectrum, and correct for the red-shift, we find that 3C 48 is comparable with 3C 295, emitting 4 × 10⁴⁴ erg/sec of radio-frequency power. The cut-off frequencies were 7 × 10⁷ c/s and 10¹¹ c/s. The lower limit is indicated by the observed radio spectrum and the upper limit is an assumed one.

The absolute magnitudes of the galaxies connected with 3C 295 and Cygnus A, corrected for interstellar absorption, are M_v = −21·0 and −21·6 (using a red-shift correction of 2 v/c) or M_v = −22·4 and −21·8 (using a correction

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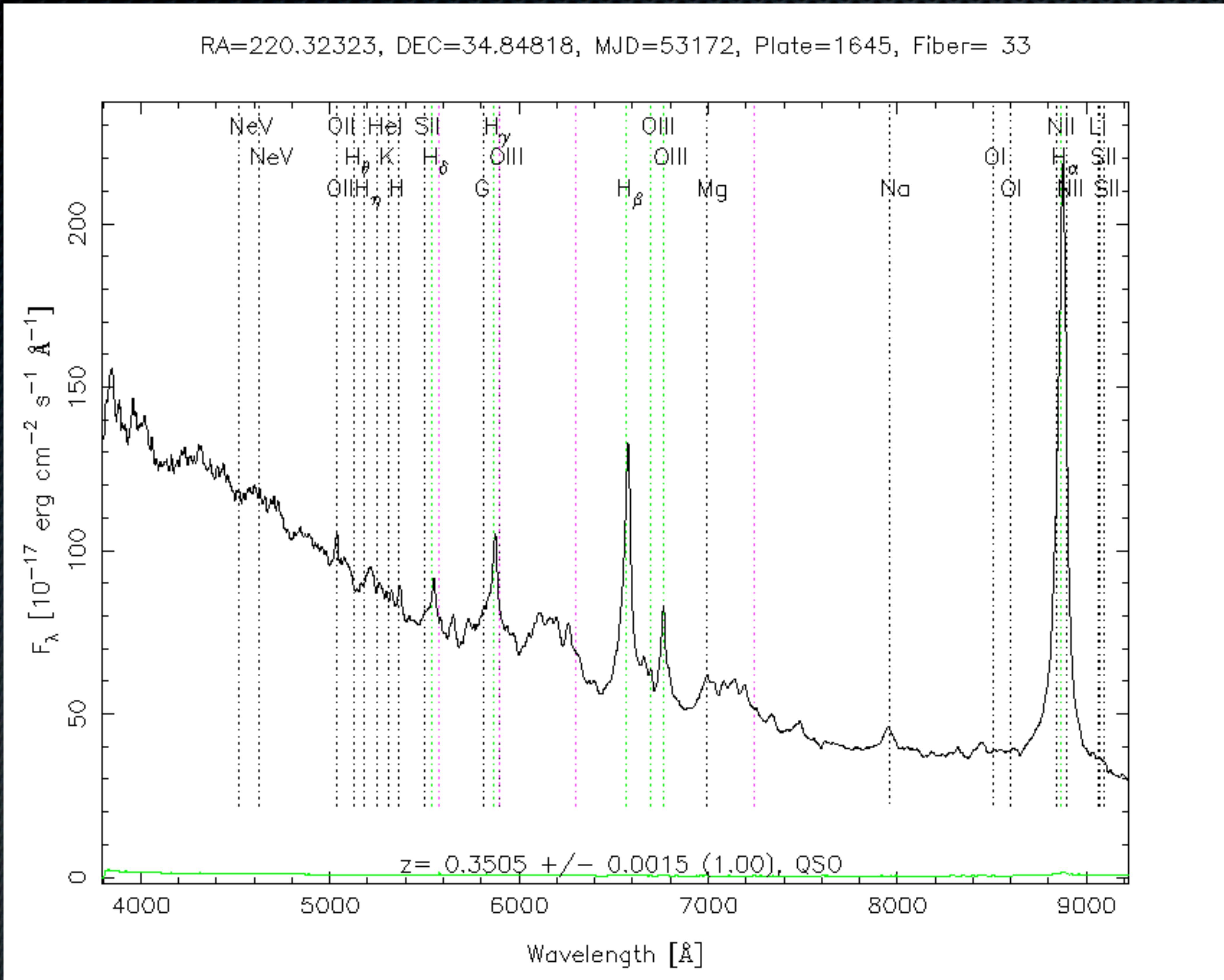
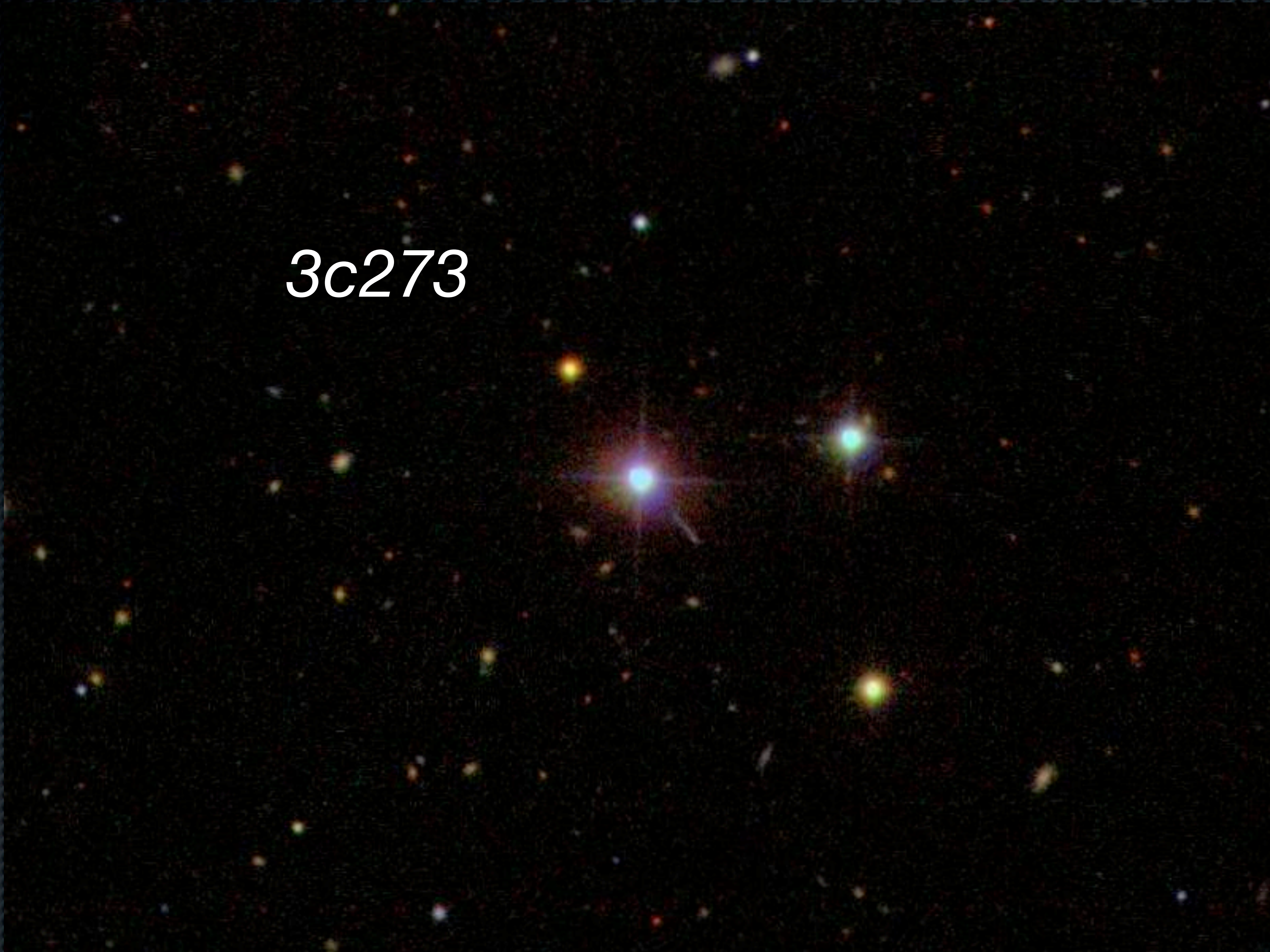


What did they see?

Identifying Active Galaxies



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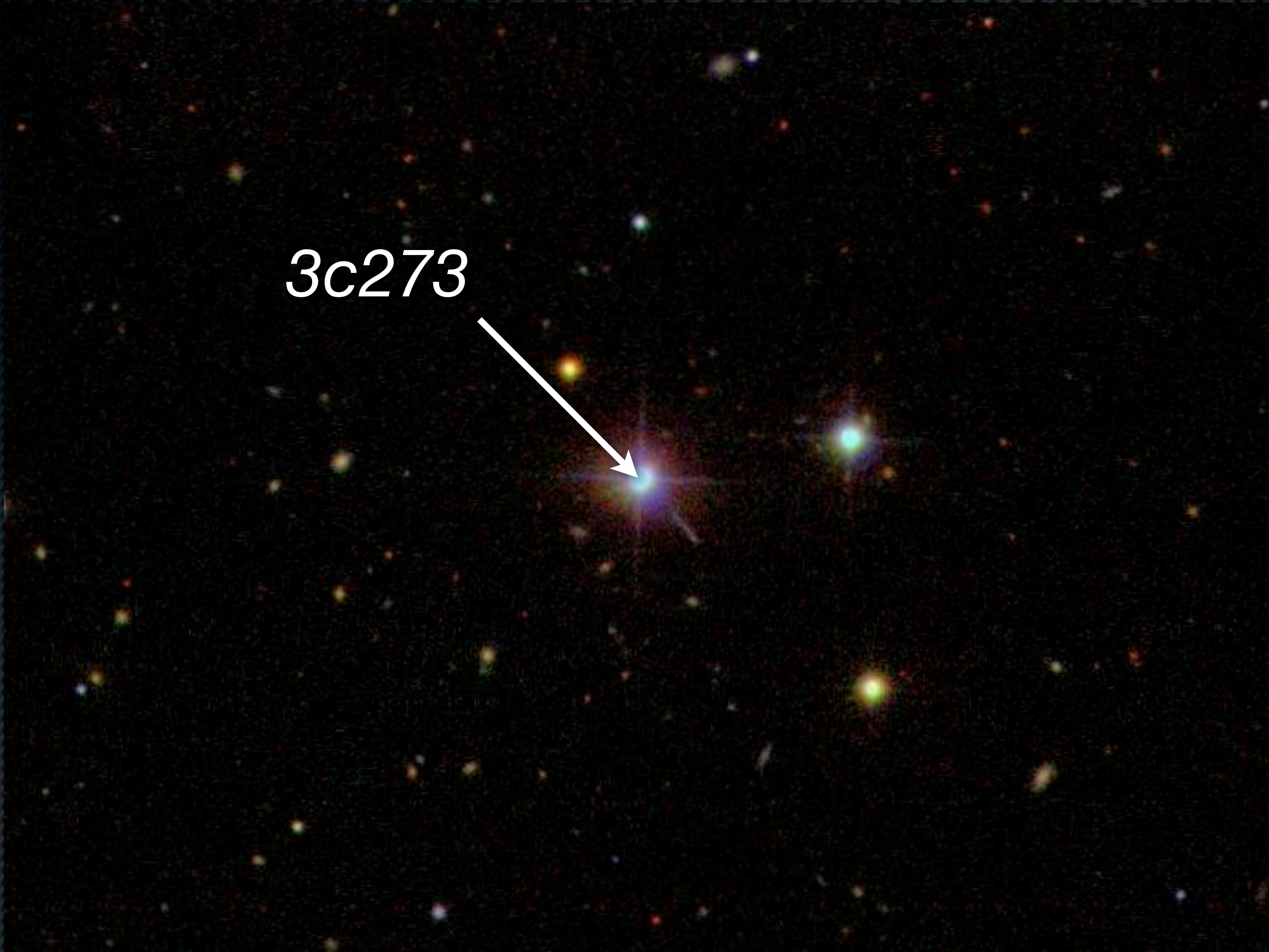

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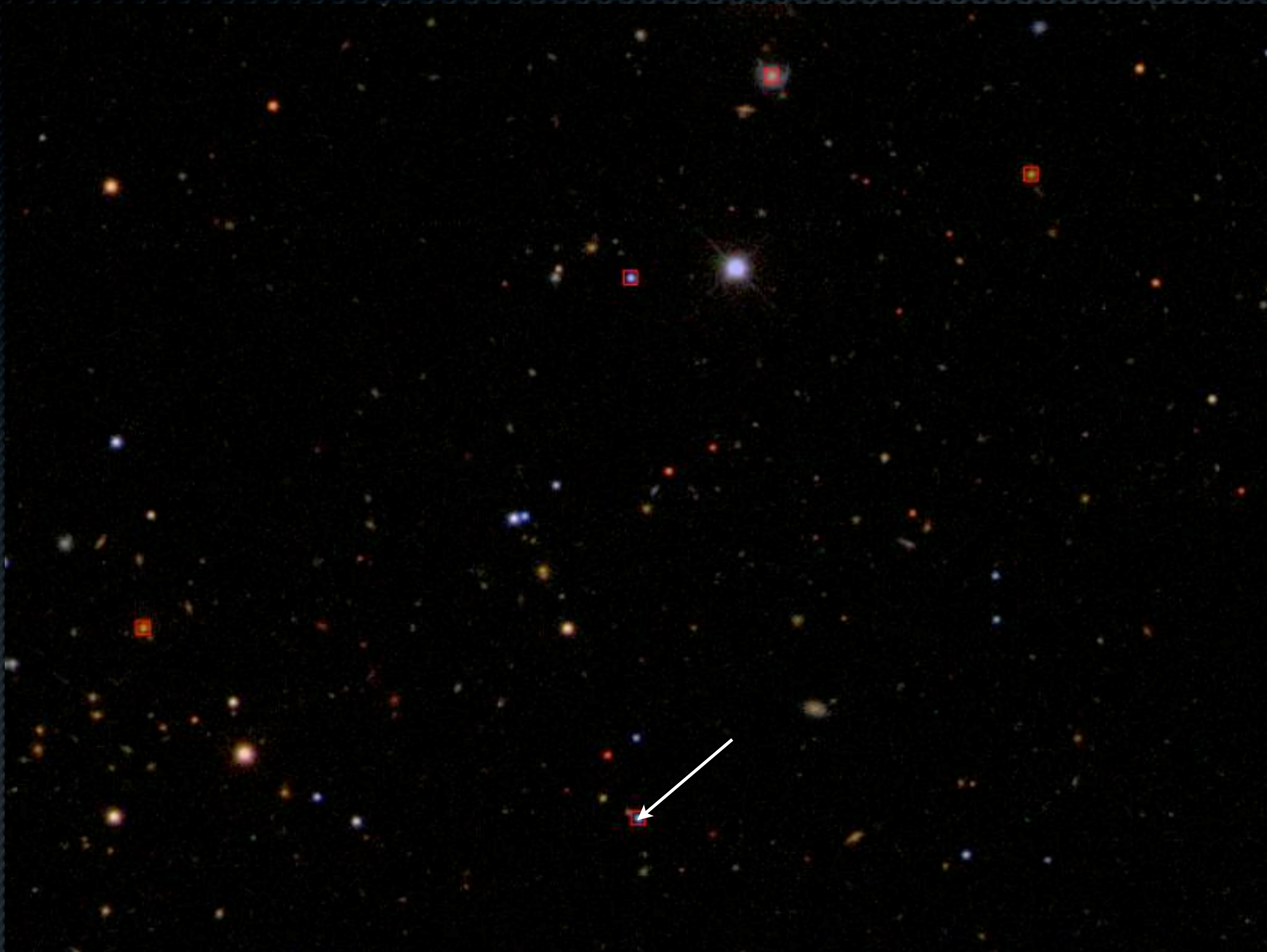

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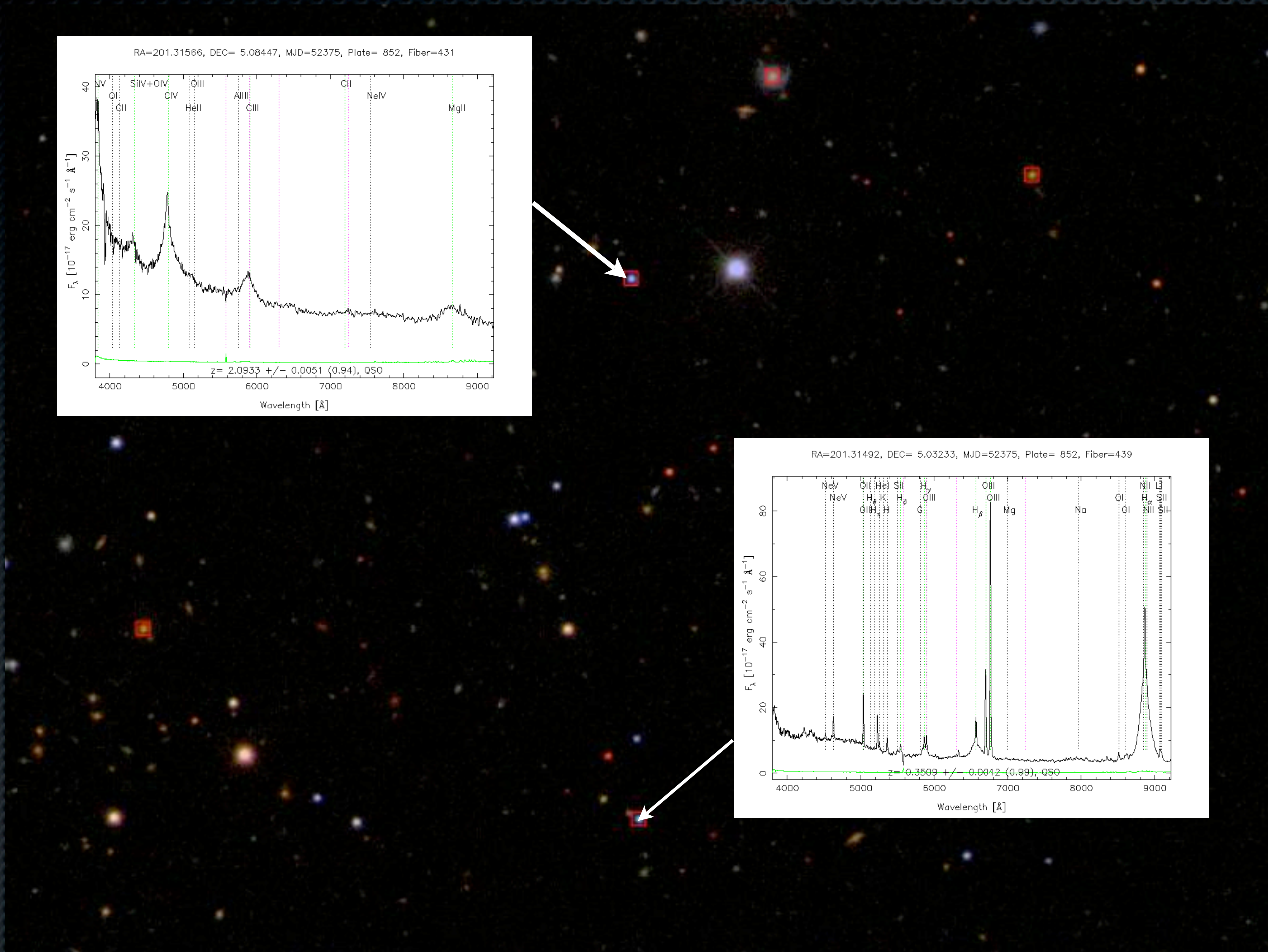

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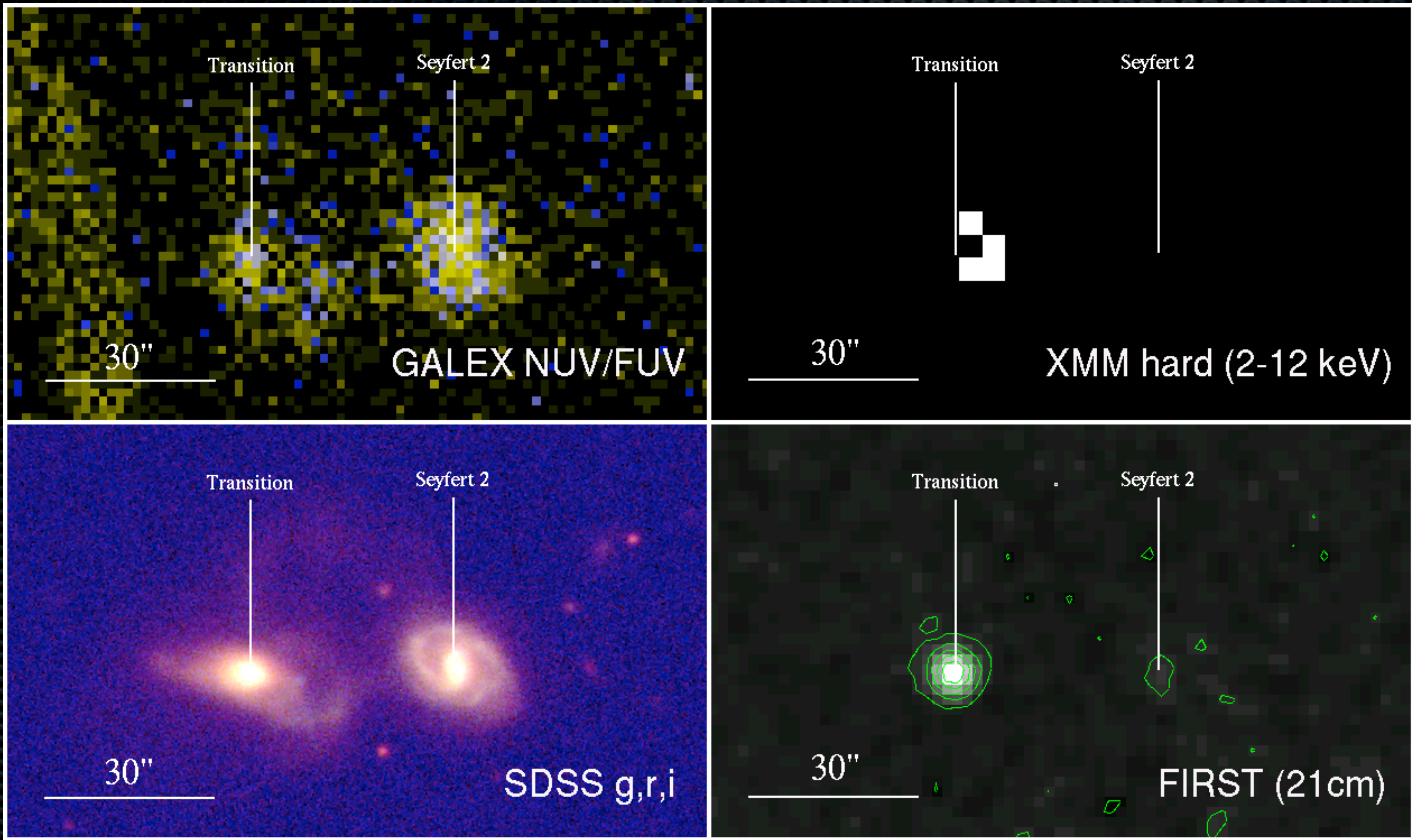
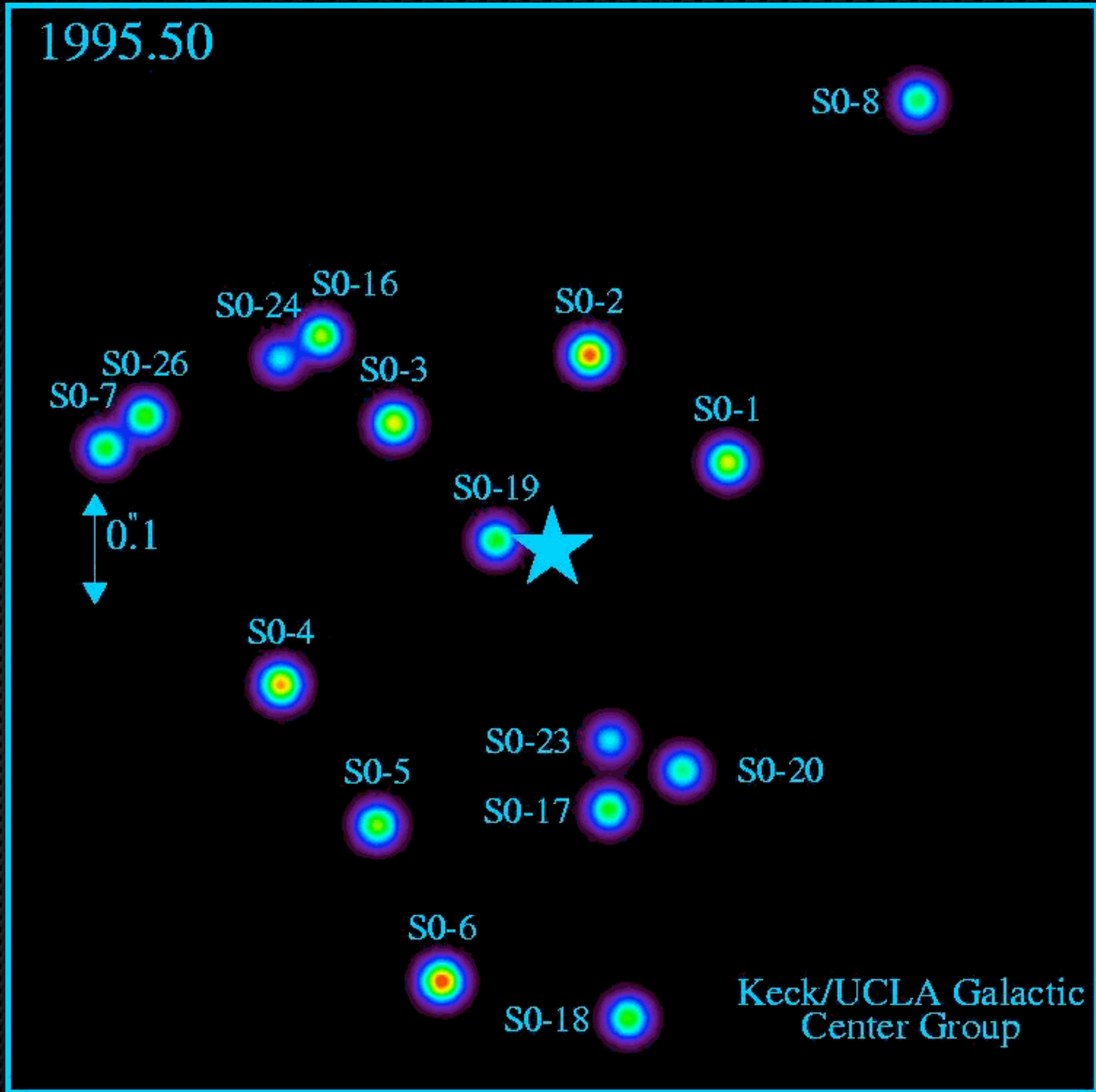


AGN: more than just quasars

Our own 4 million solar-mass black hole: Sgr A*

Ghez et. al, via the Keck telescopes



Especially important are the stars S0-2, which has an orbital period of only 15.56 years, and S0-16, which comes a mere 90 astronomical units from the black hole.

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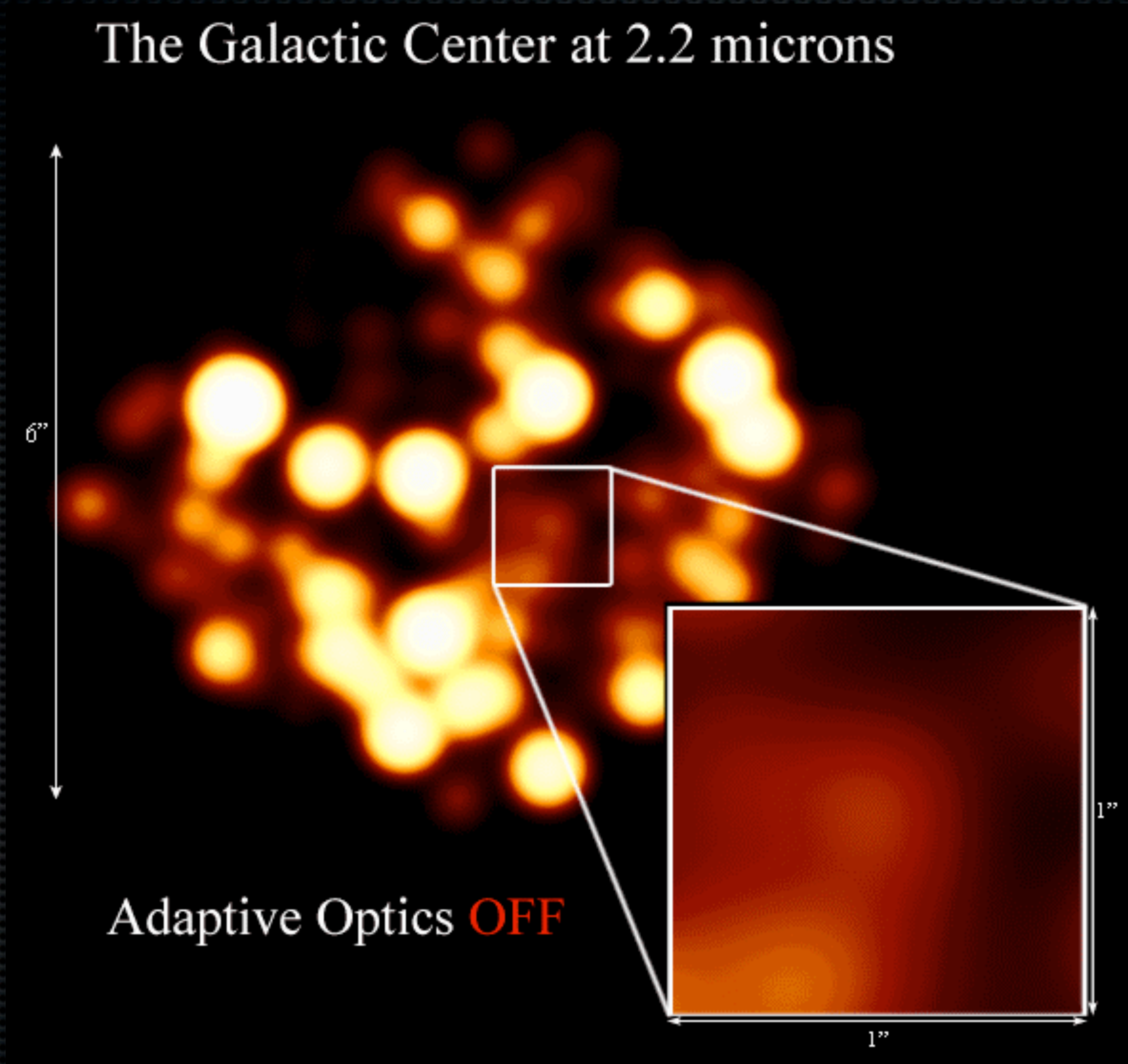

Where else do we find them?
- Train wrecks!

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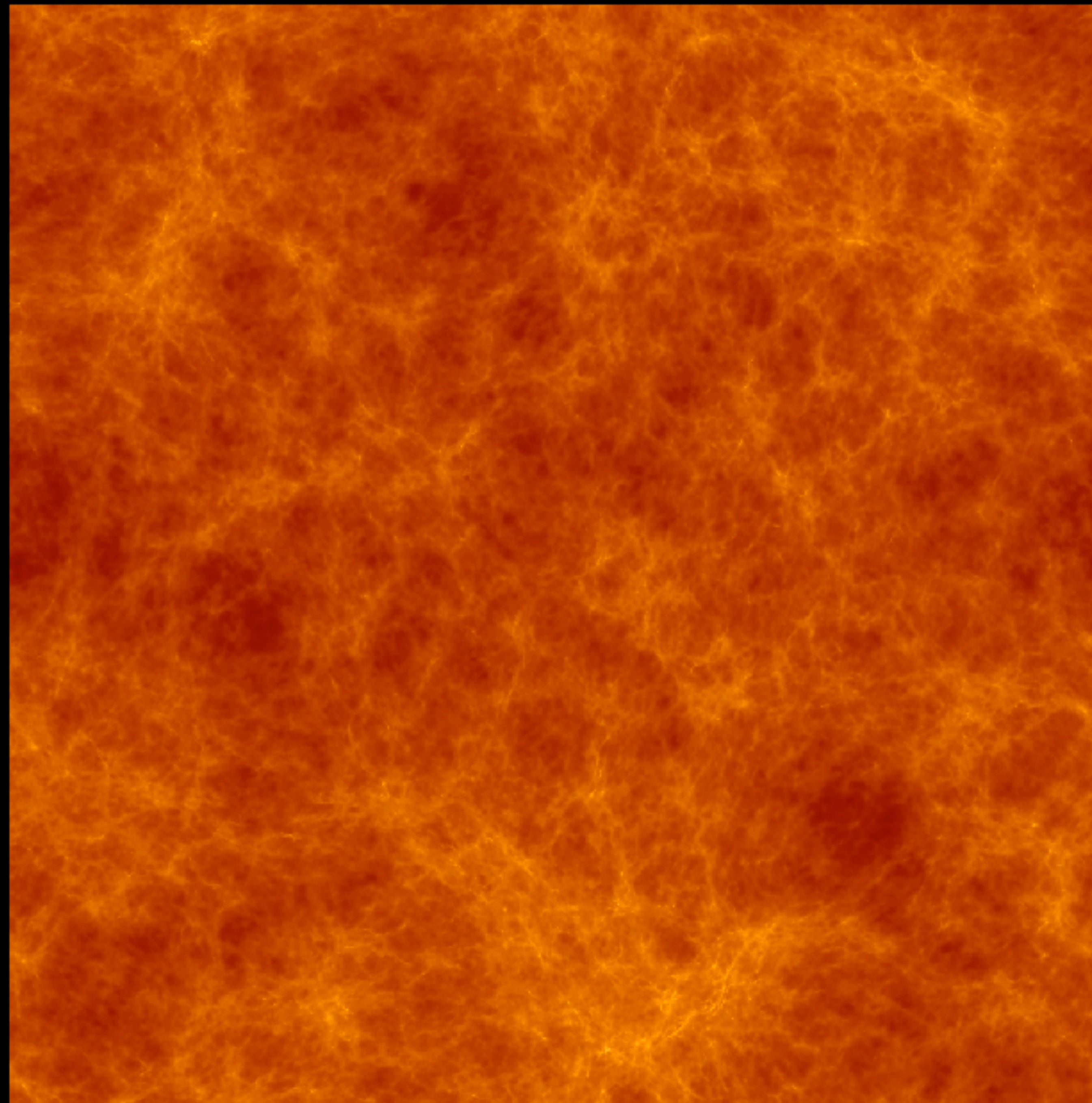
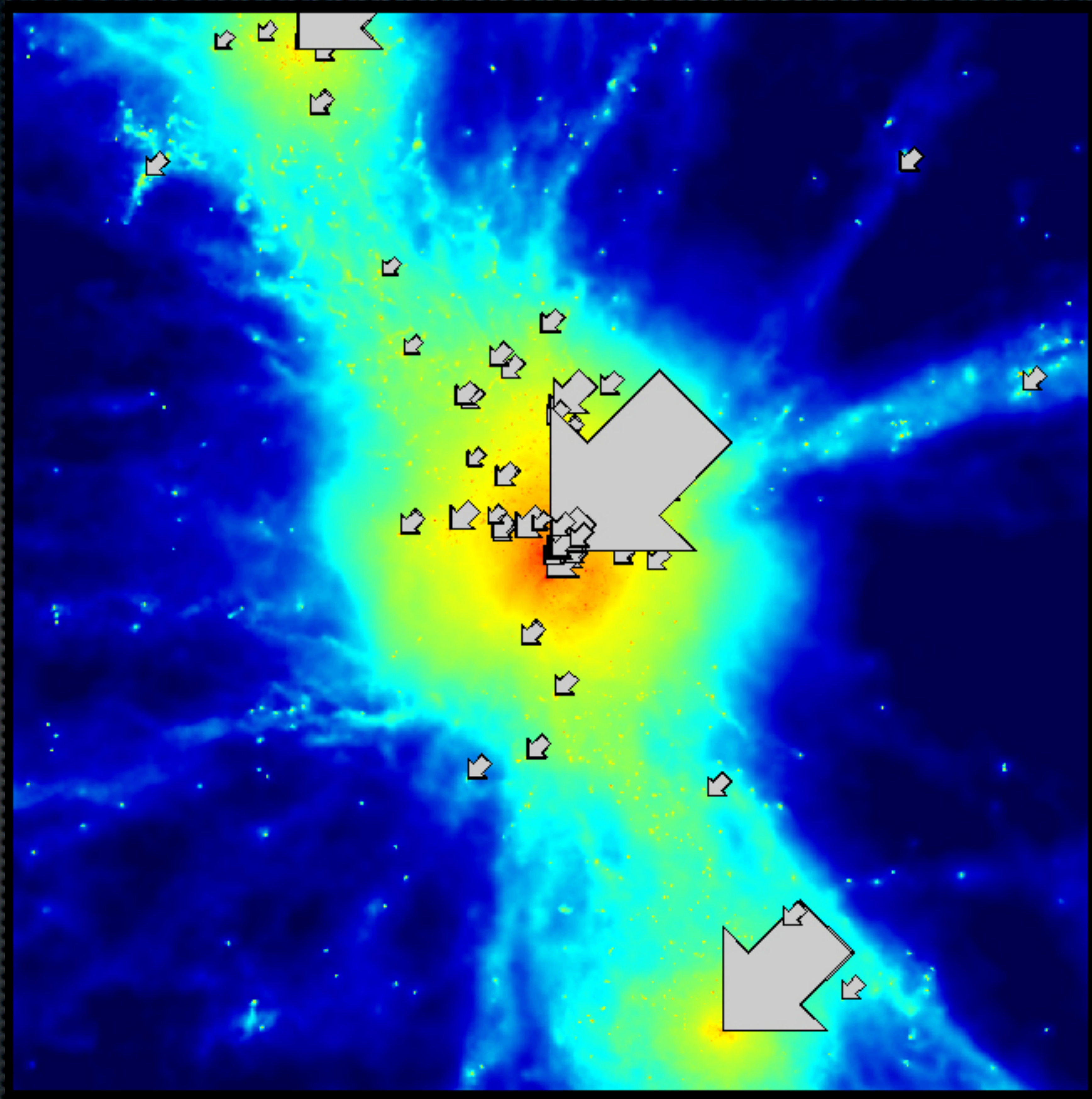
The growth of structure in the Universe



Matteo et. al:
http://www.psc.edu/science/2006/blackhole/

The animation shows the universe evolving from about 200 million years after the big bang until about five billiion years, approximately what it looks like today, with brightness corresponding to gas density, revealing unprecedented structure.

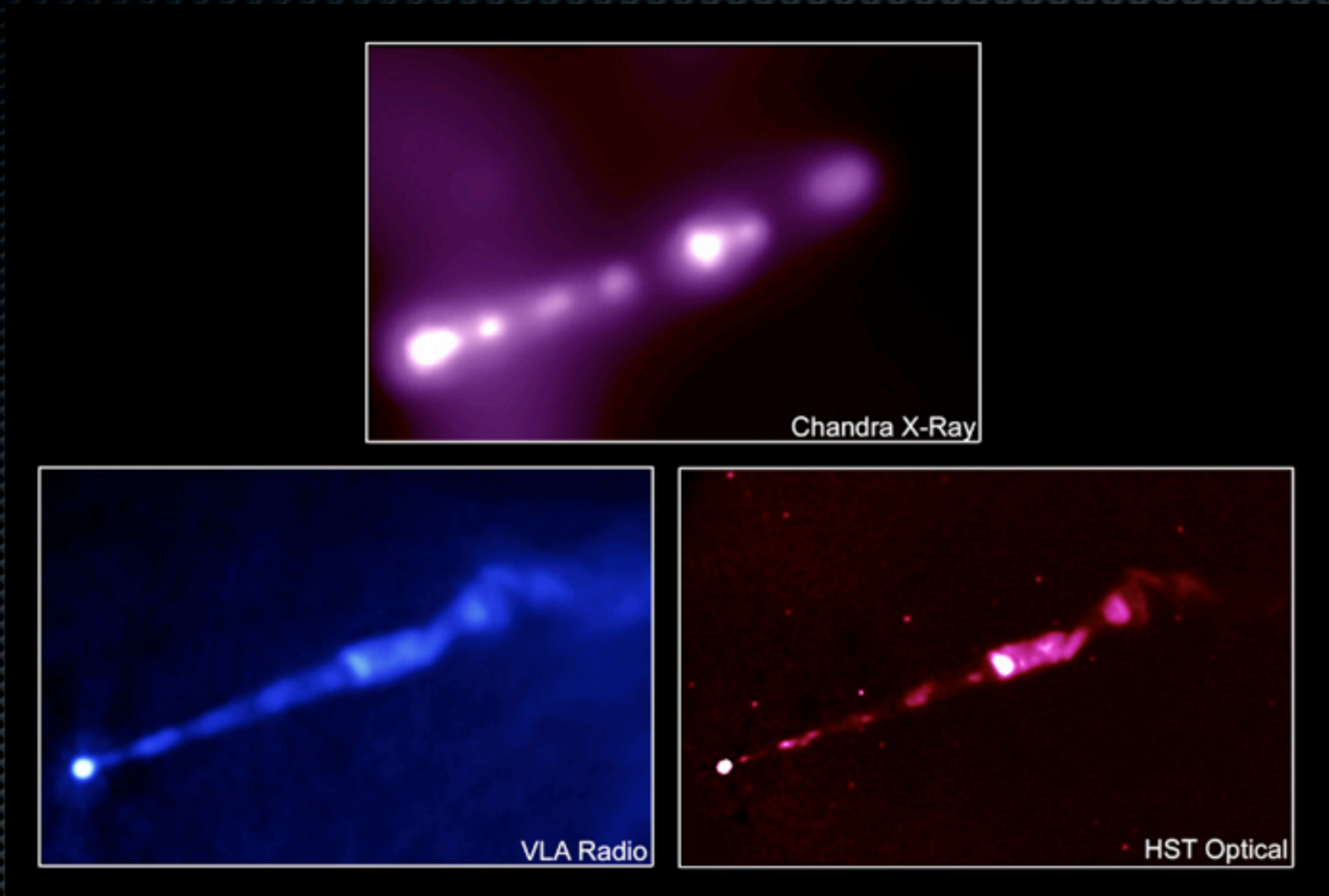
The growth of structure in the Universe: now with black holes.



Where are the blackholes? The arrows!

What do we see now?

M87 - Robert Gendler



What do we see now?

M87 - The jets

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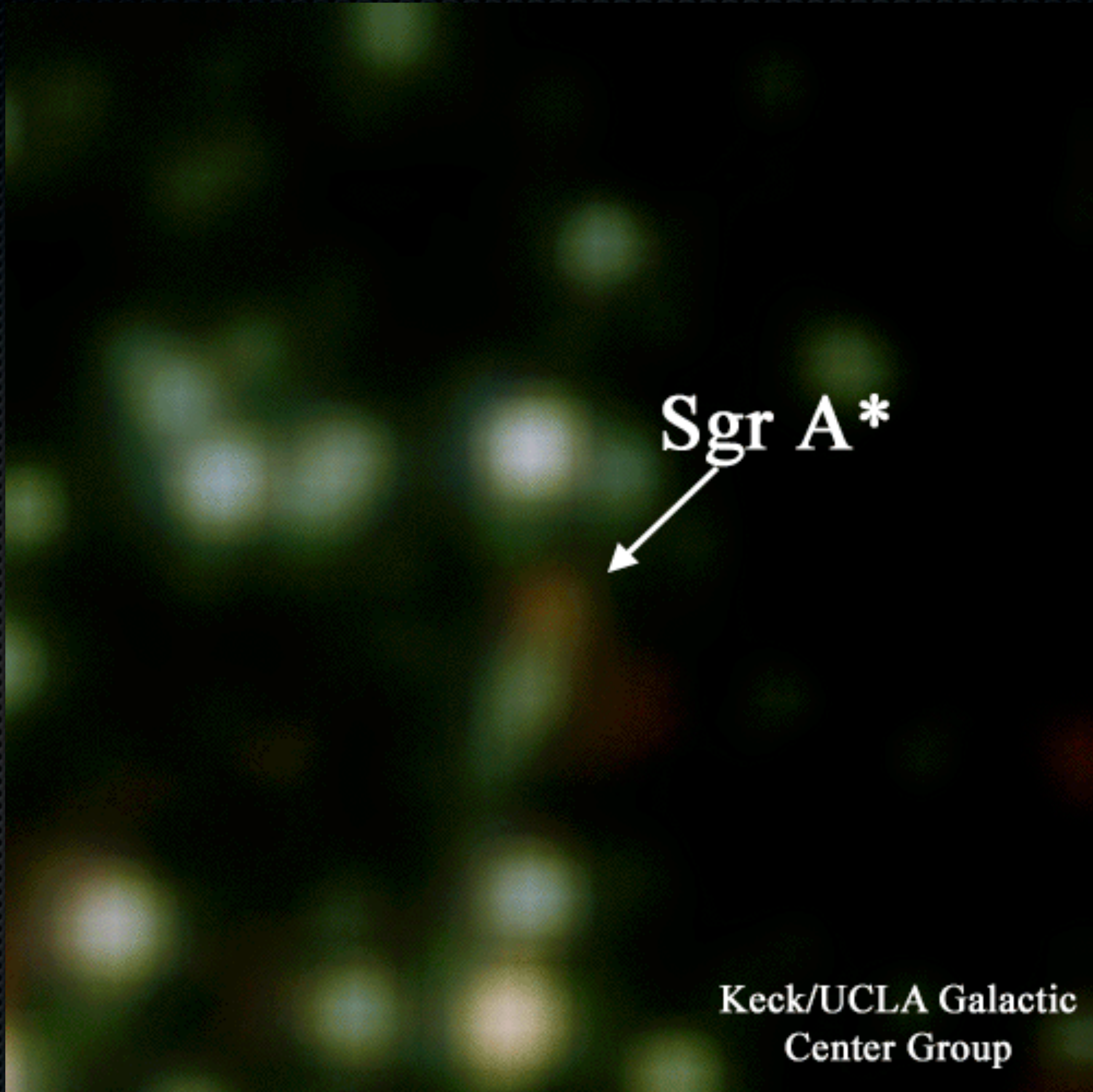
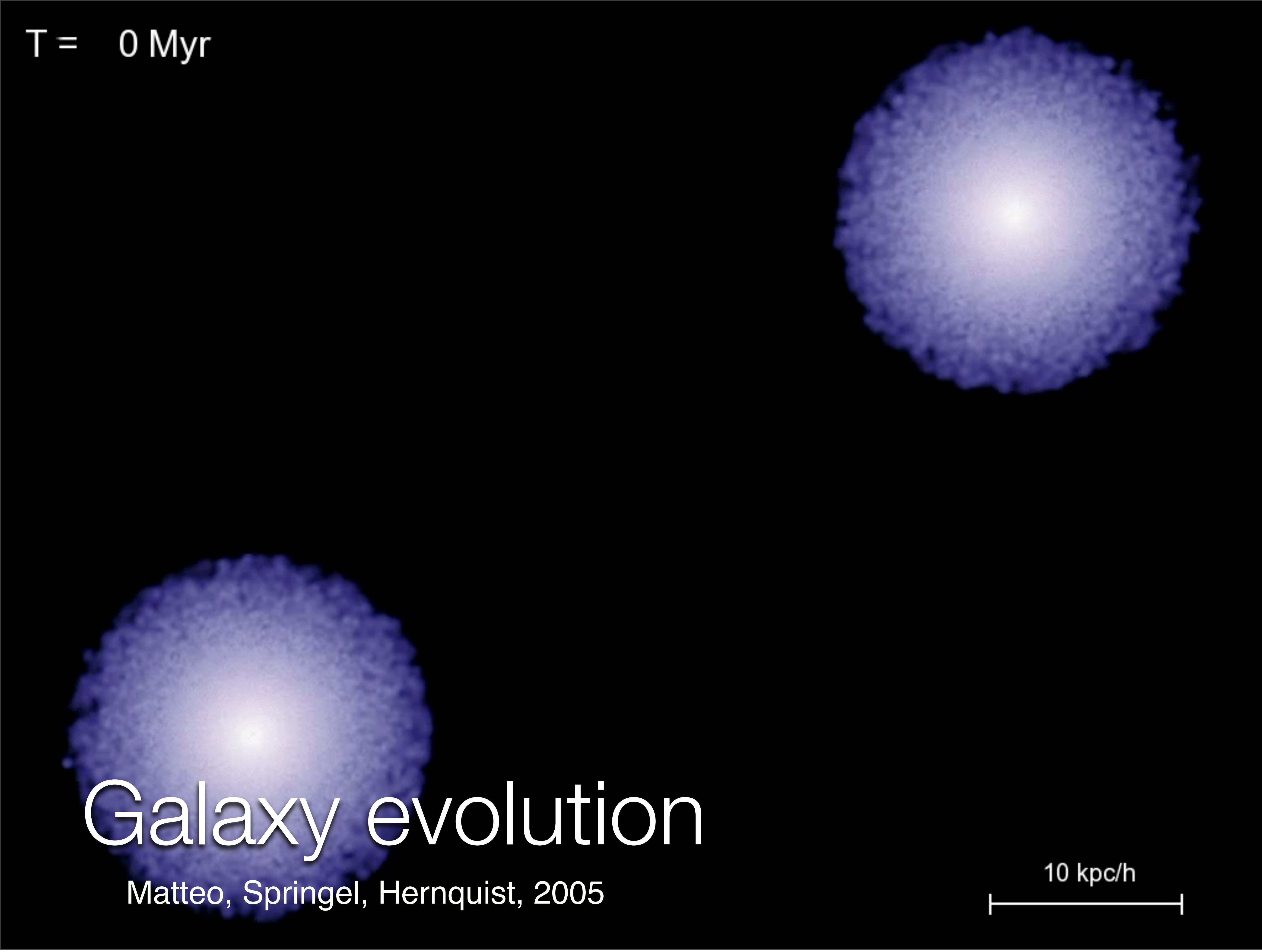


This three color animation, centered on Sgr A*-IR shows, for the first time ever, the broadband color of Sgr A*-IR throughout an outburst. The image is 1 arcsec on a side and covers about two hours of observations. For this false color animation, H (1.8 microns) = blue, K' (2.1 microns) = green, and L' (3.8 microns) = red. The animation was created from data obtained at the W. M. Keck Observatory using the Laser Guide Star Adaptive Optics System.

Galaxy evolution

Matteo, Springel, Hernquist, 2005

Al showed an earlier video: unfortunately we now know that that is wrong: you have to include the effects of the AGN, or the end result isn't quite right.



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--Marilyn Michalski

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I'd like to know too...

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I’d like to know too...

--- Guess I’d better get to work on that thesis ---

For more information:

- The Monster of the Milky Way:
  - http://www.pbs.org/wgbh/nova/blackhole/
- Galaxy Formation in an evolving universe:
  - http://www.psc.edu/science/2006/blackhole/
- SDSS:
  - http://www.sdss.org