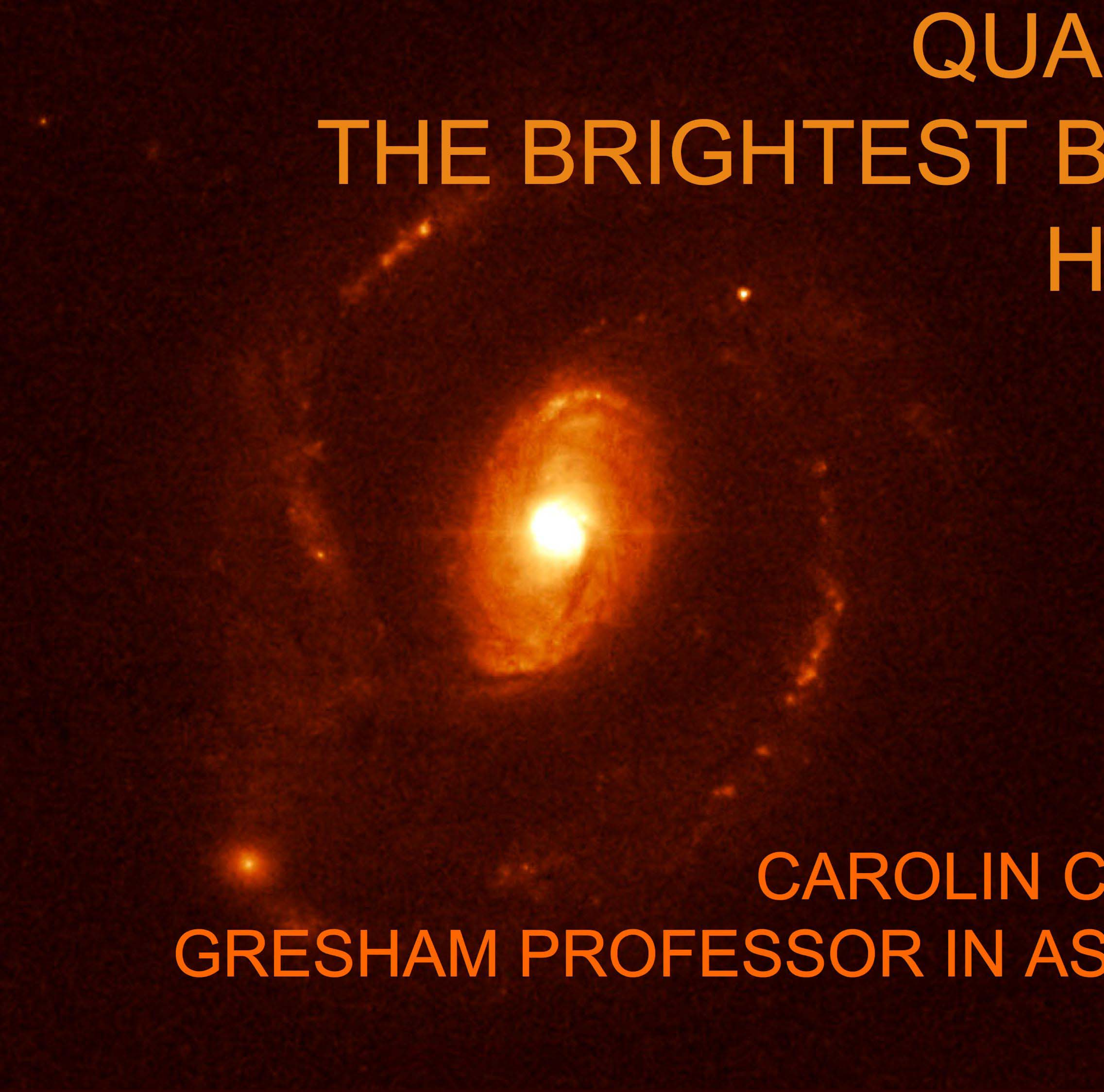
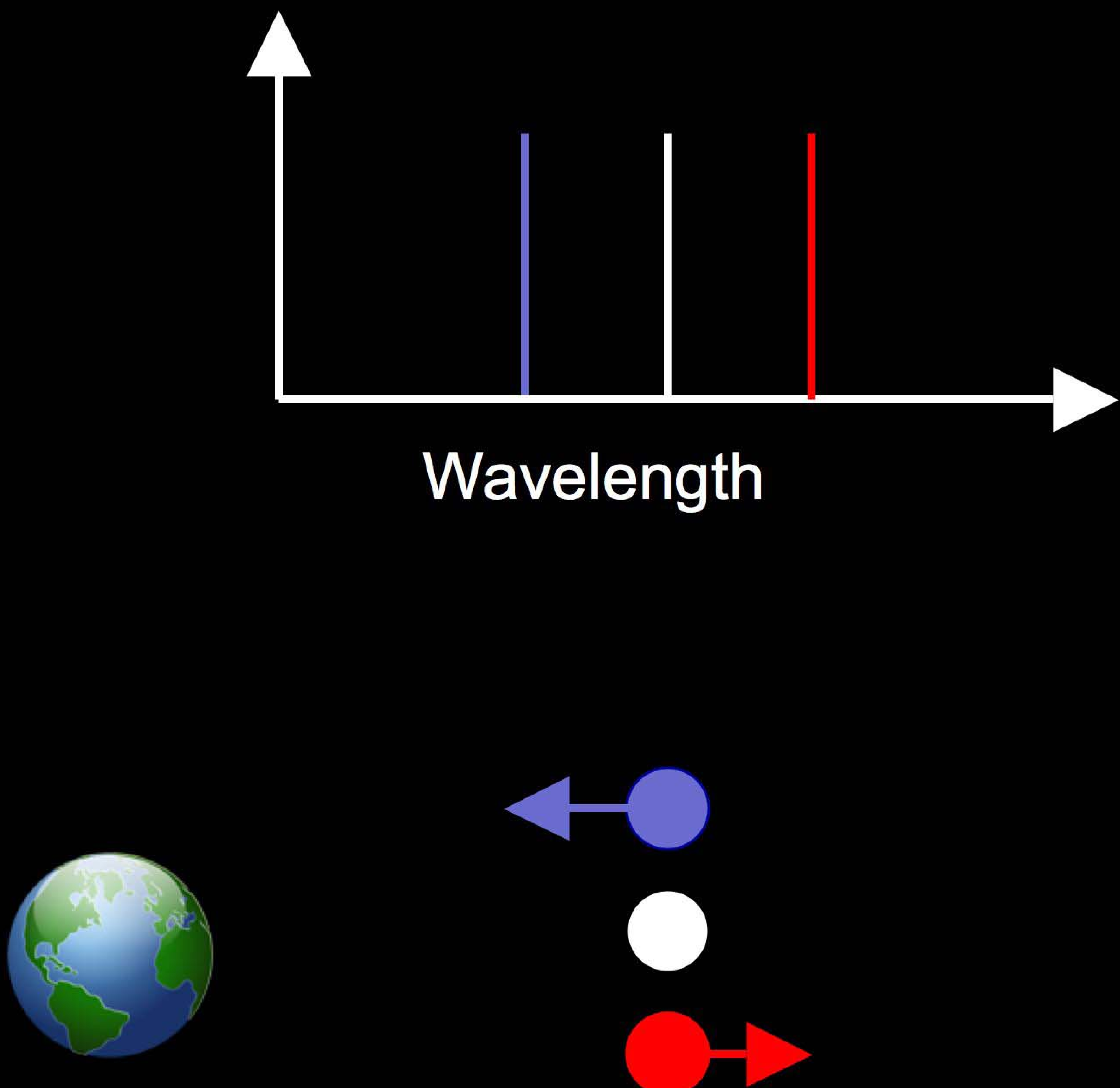
QUASARS
THE BRIGHTEST BLACK HOLES



CAROLIN CRAWFORD
GRESHAM PROFESSOR IN ASTRONOMY

NASA / ESA / ESO



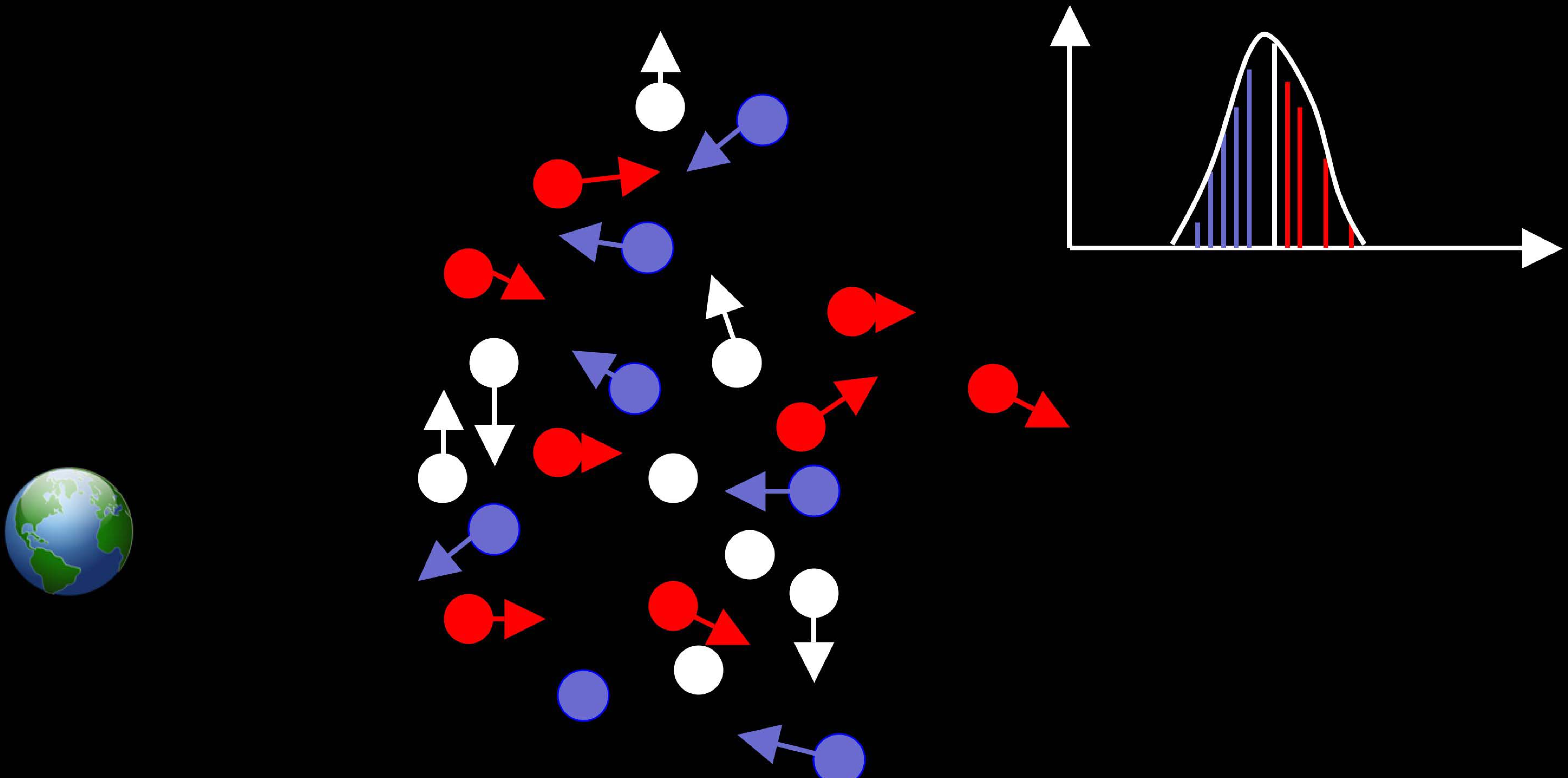
Each atom produces emission at a set of specific wavelengths

- When atom approaches observer, wavelength is shortened and line appears blueshifted

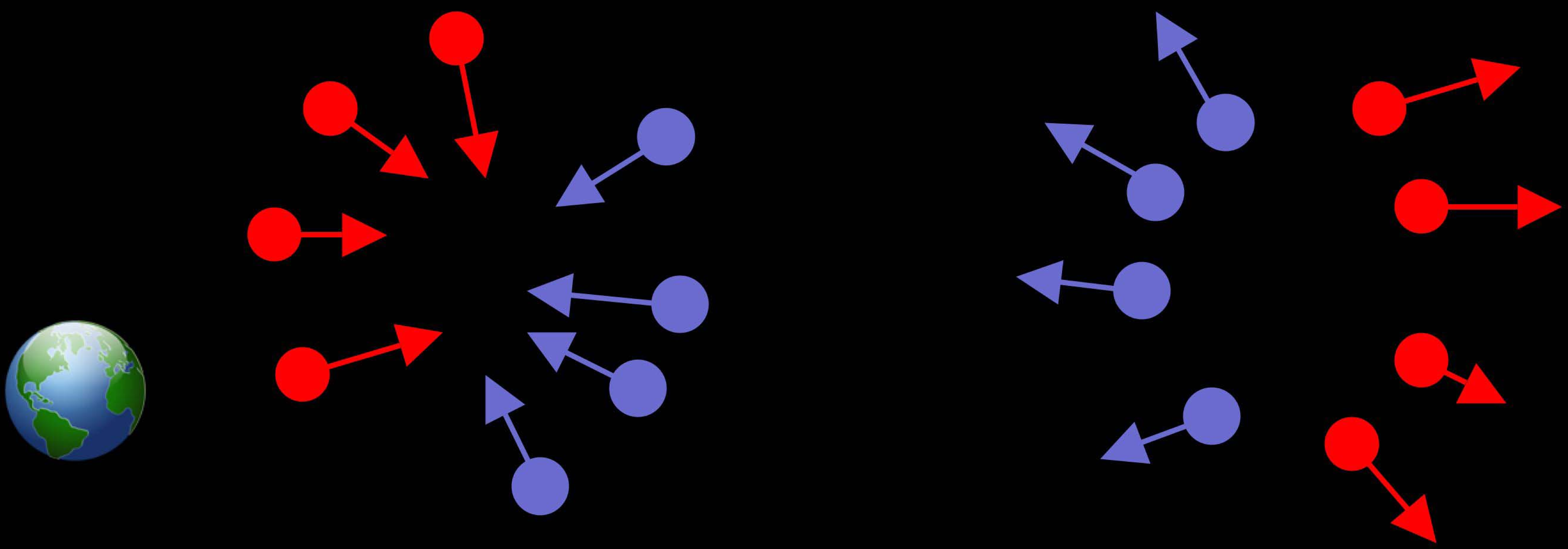
- When atom recedes from observer, wavelength is lengthened and line appears redshifted

- line broadening shows the atoms are in motion

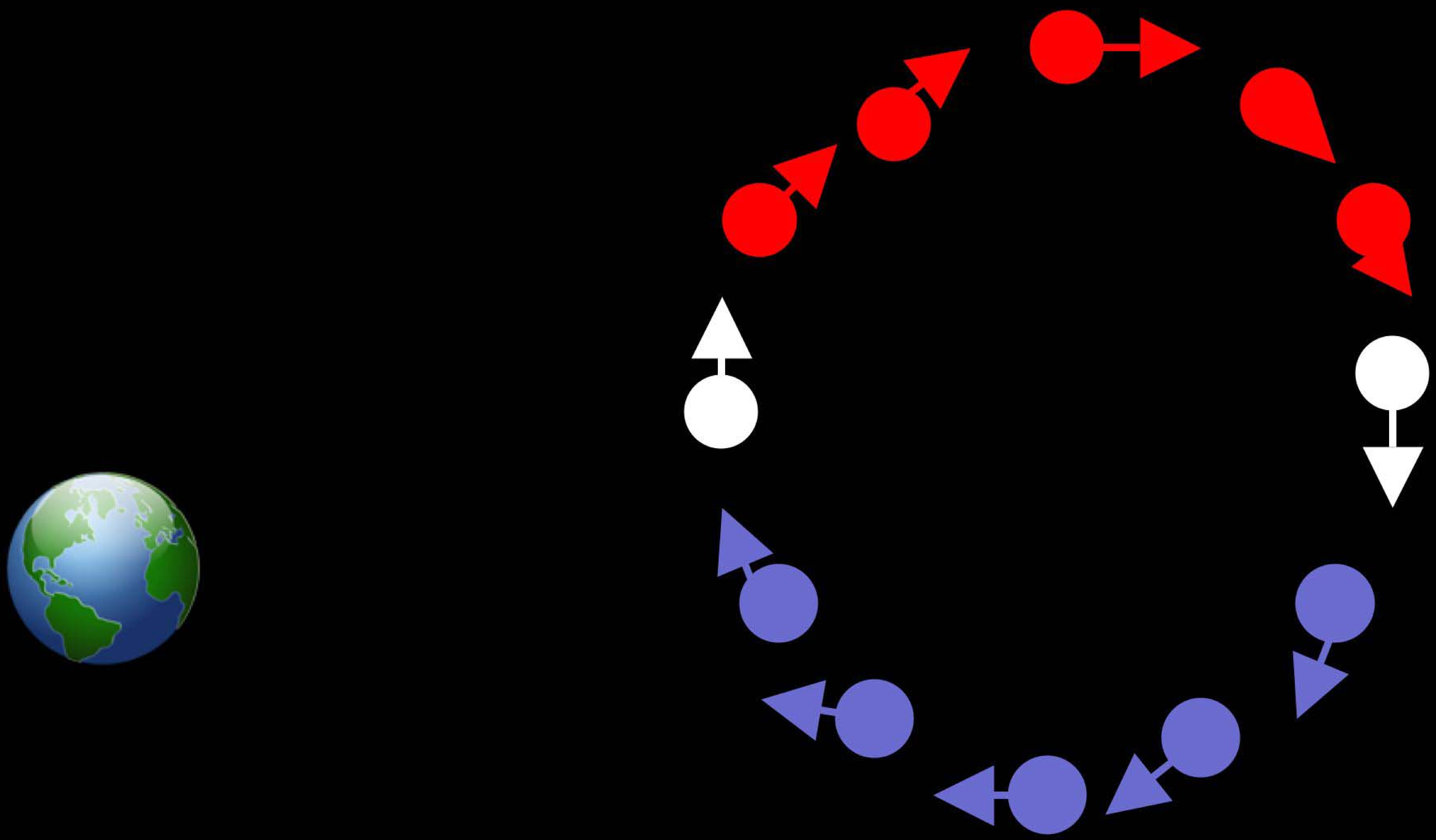
Thermal motion of atoms in the gas



Inflow or *outflow* of atoms



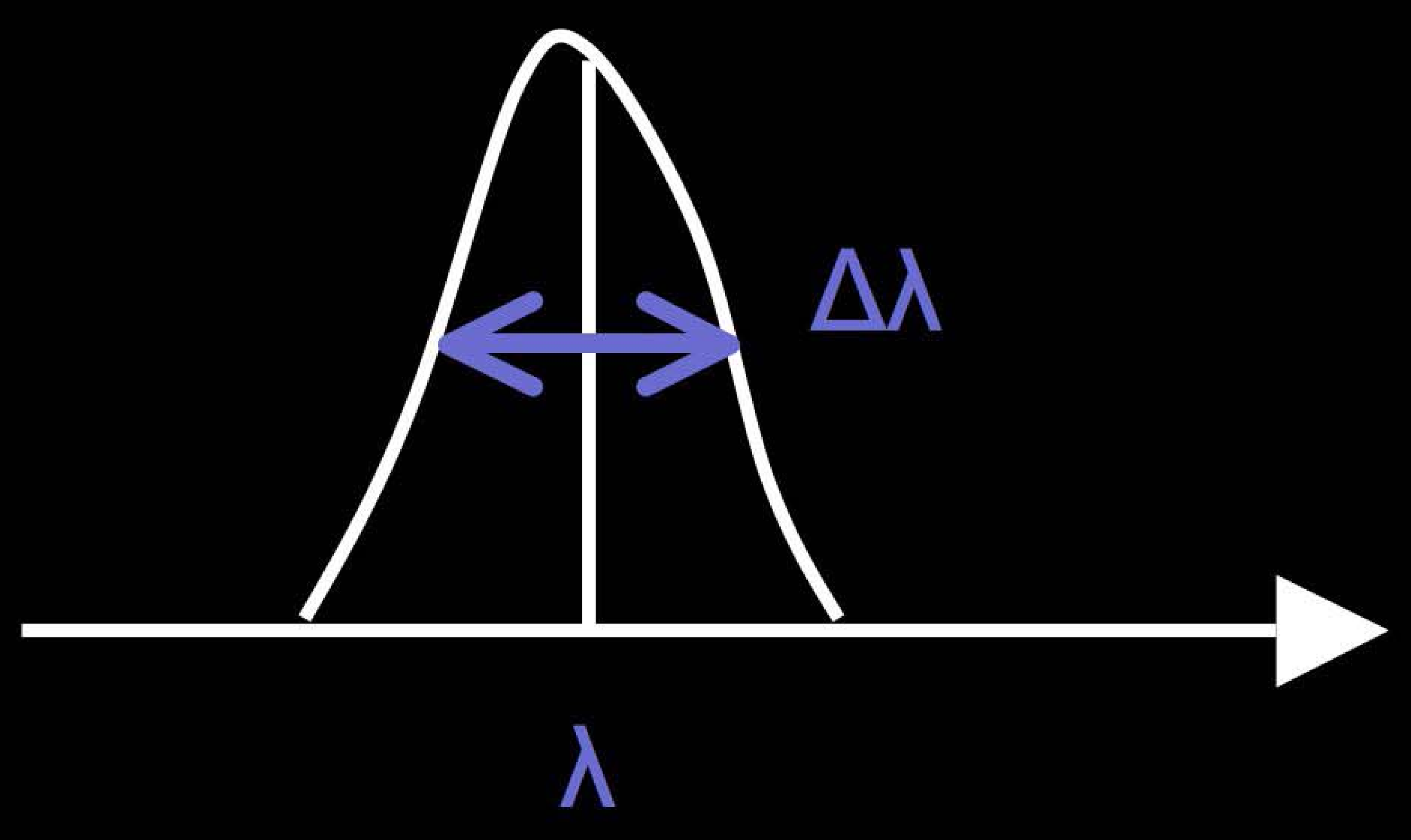
rotational motion of atoms



width of line is measured as $\Delta\lambda$

observed at central wavelength λ

c is the speed of light



$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta v}{c}$$

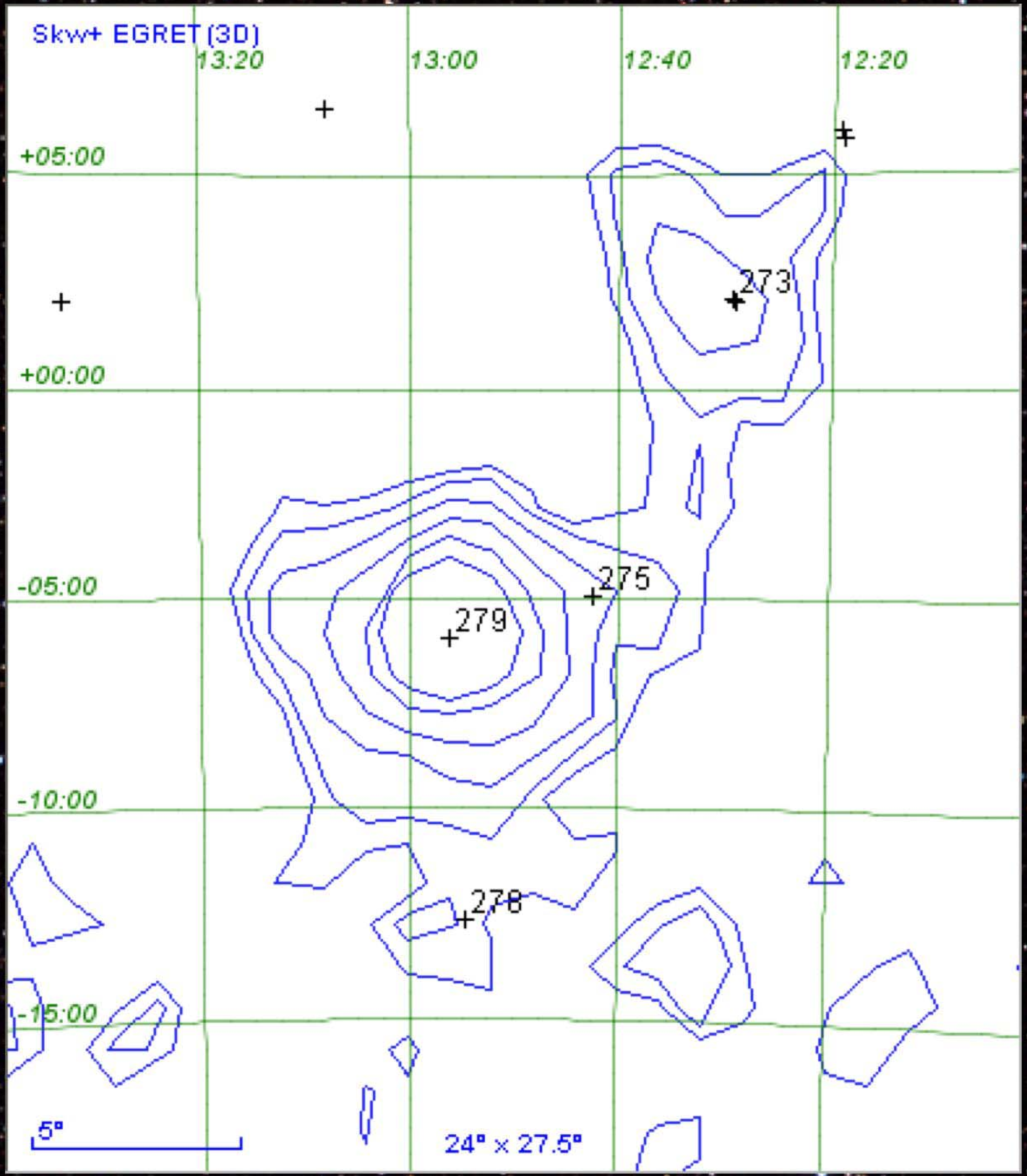
speeds of 400 km/s in the *narrow* lines

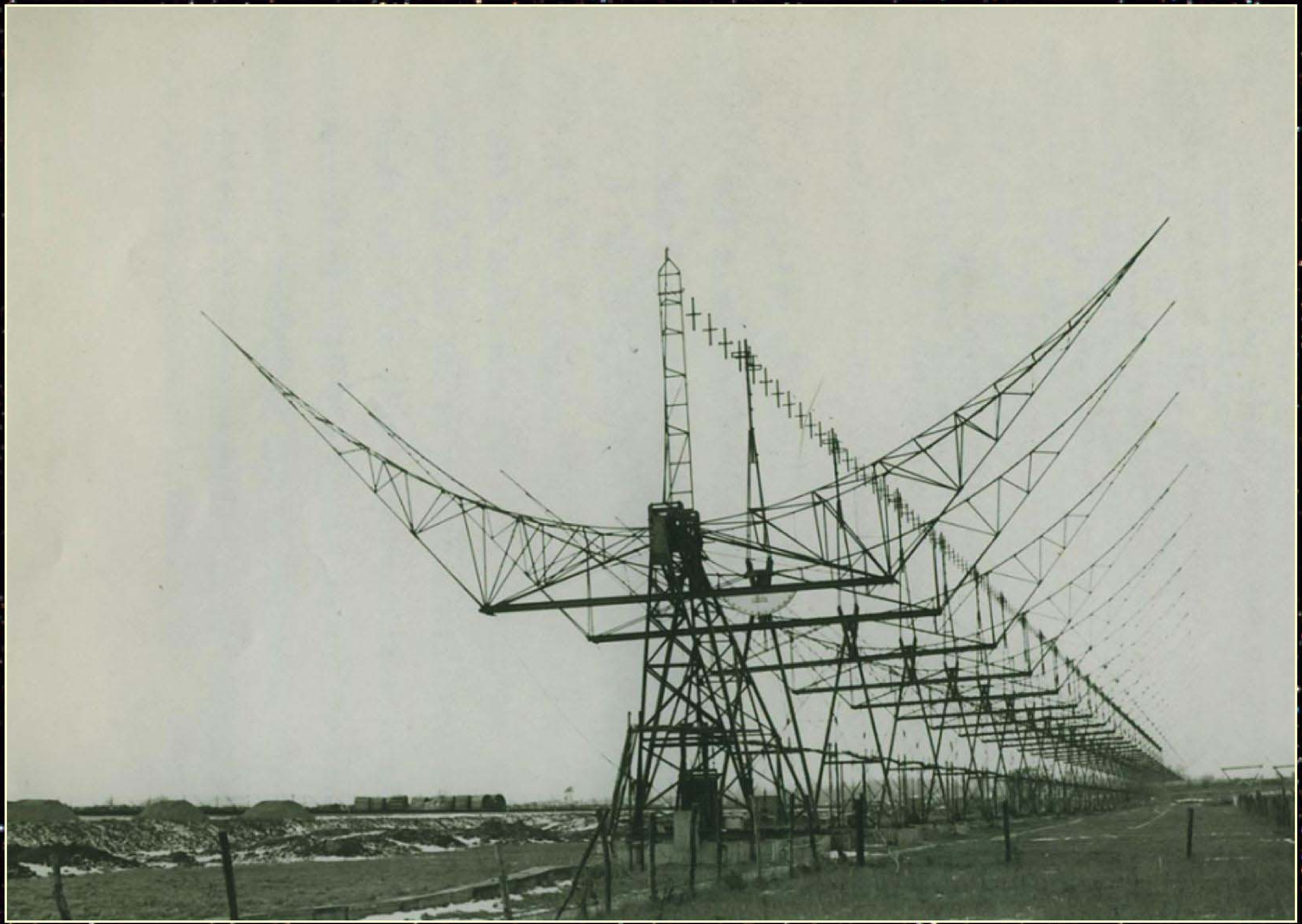
speeds of up to 10,000 km/s in the *broad* lines

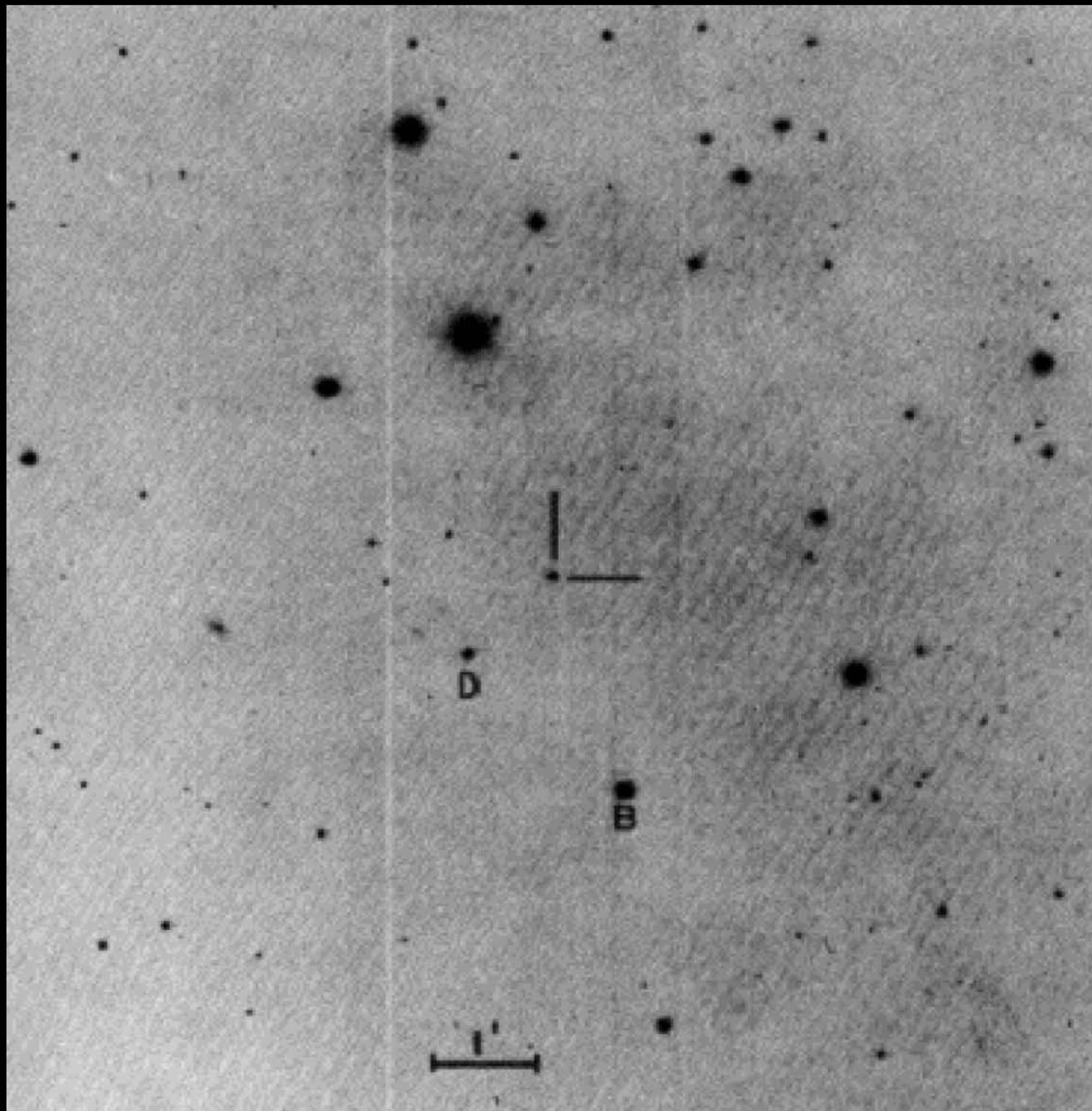
Cygnus A
radio emission

NRAO / AUI

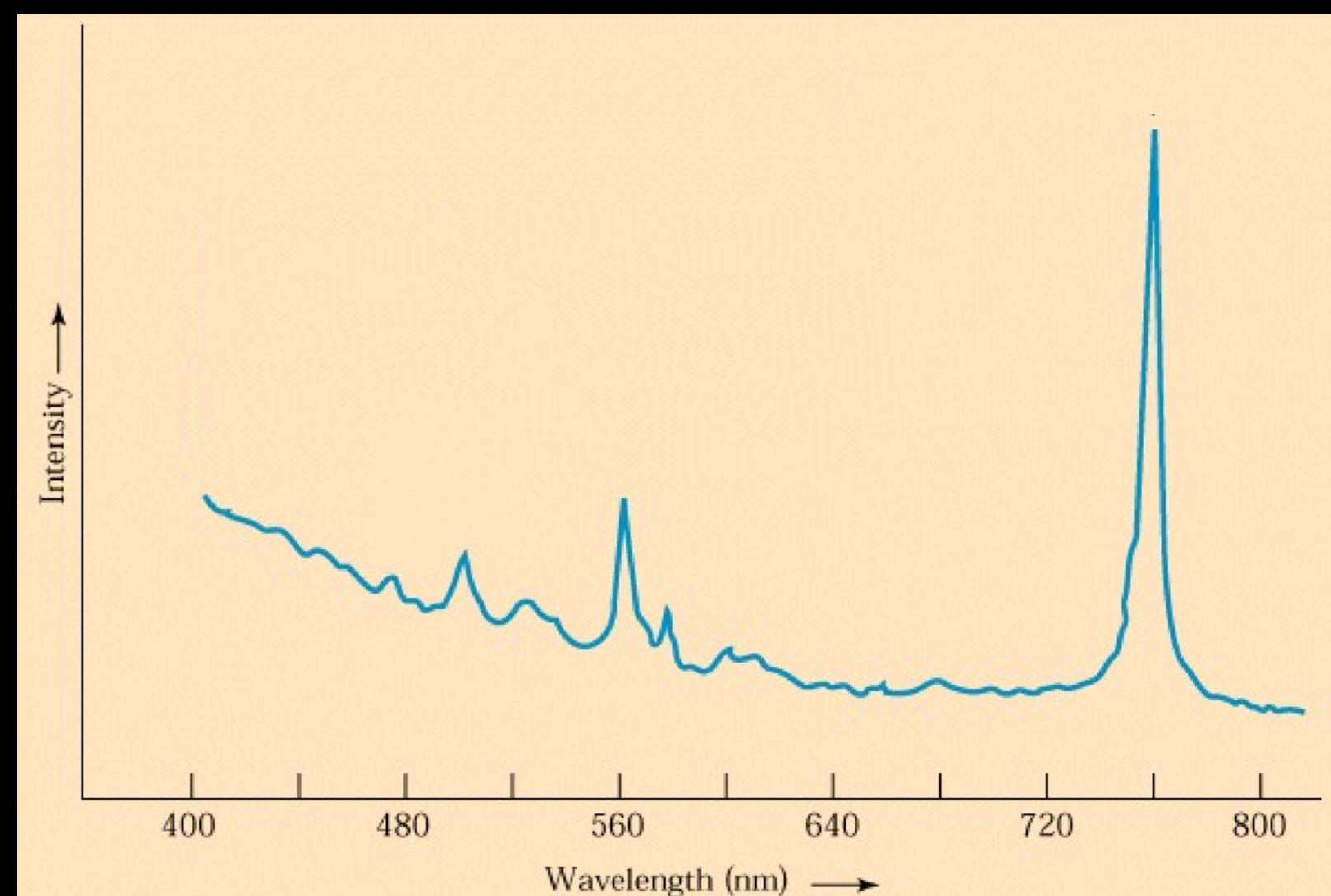

radio
visible
NRAO/AUI/NSF/NASA/ESA/HST/Perley & Cotton / Baum & O'Dea


Skw+ EGRET (3D)
13:20
13:00
12:40
12:20
+05:00
+00:00
-05:00
-10:00
-15:00
273
275
279
278
5°
24° x 27.5°

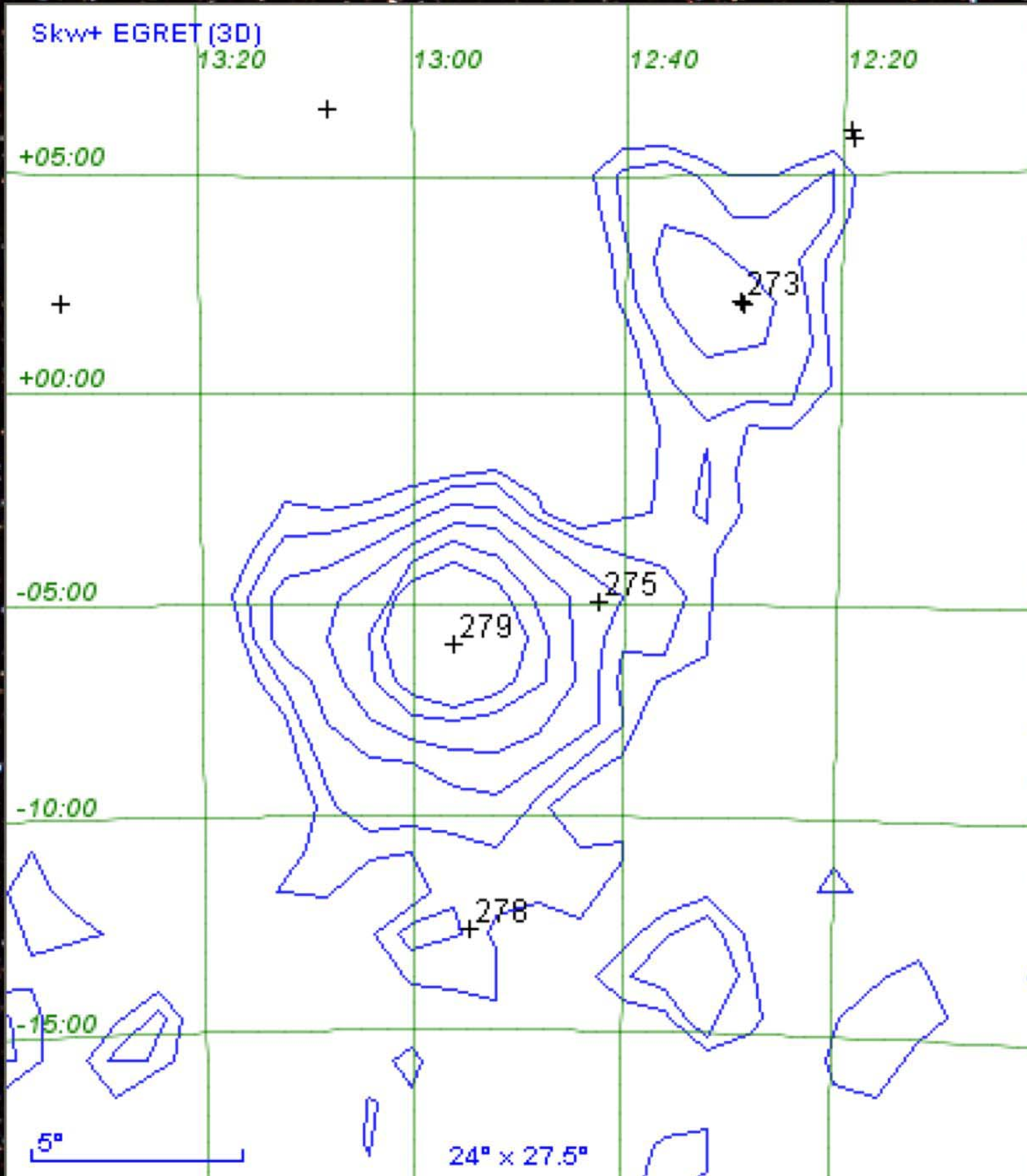




3C48



Schmidt & Mathews


Skw+ EGRET (3D)
13:20
13:00
12:40
12:20
+05:00
+00:00
-05:00
-10:00
-15:00
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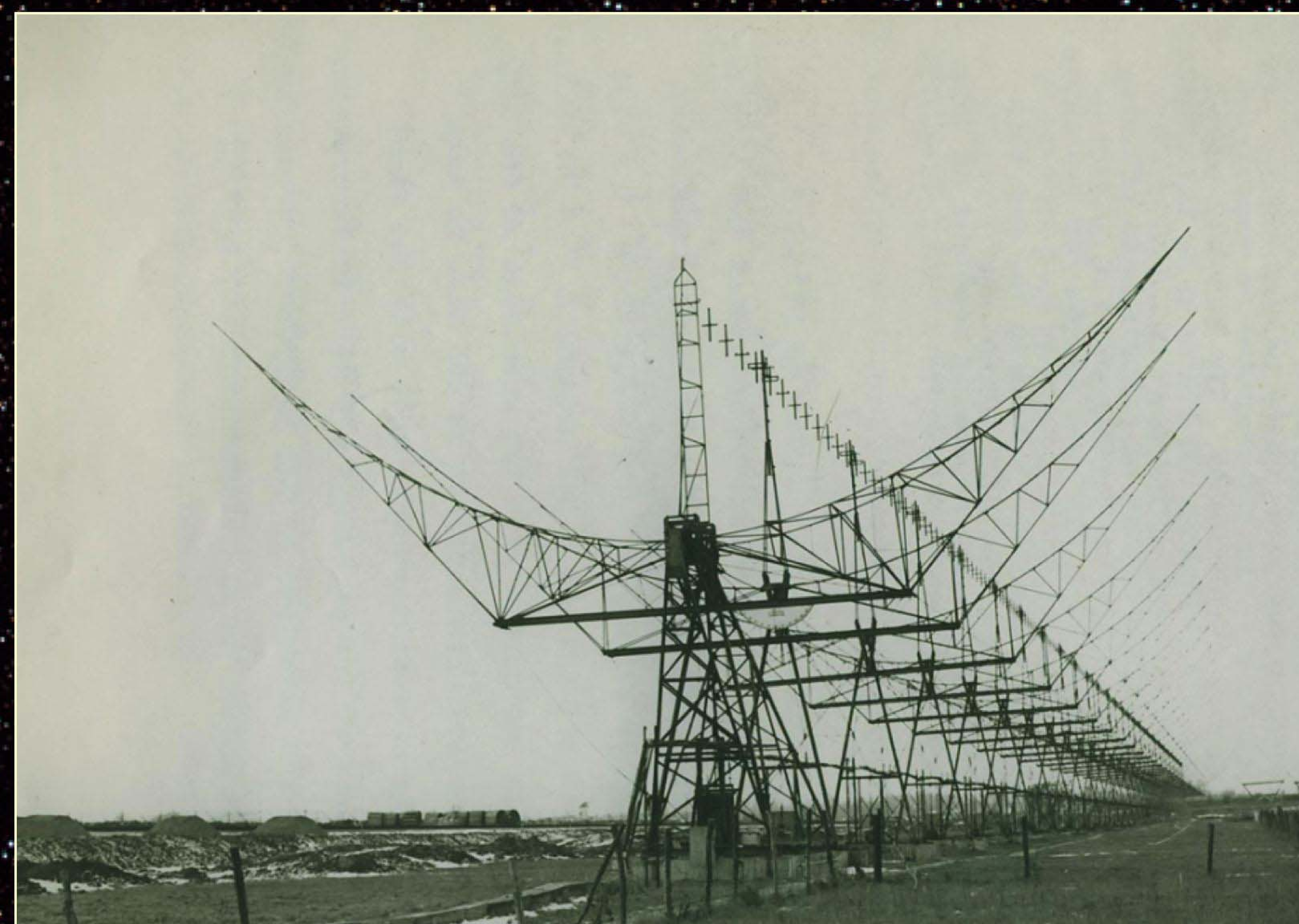
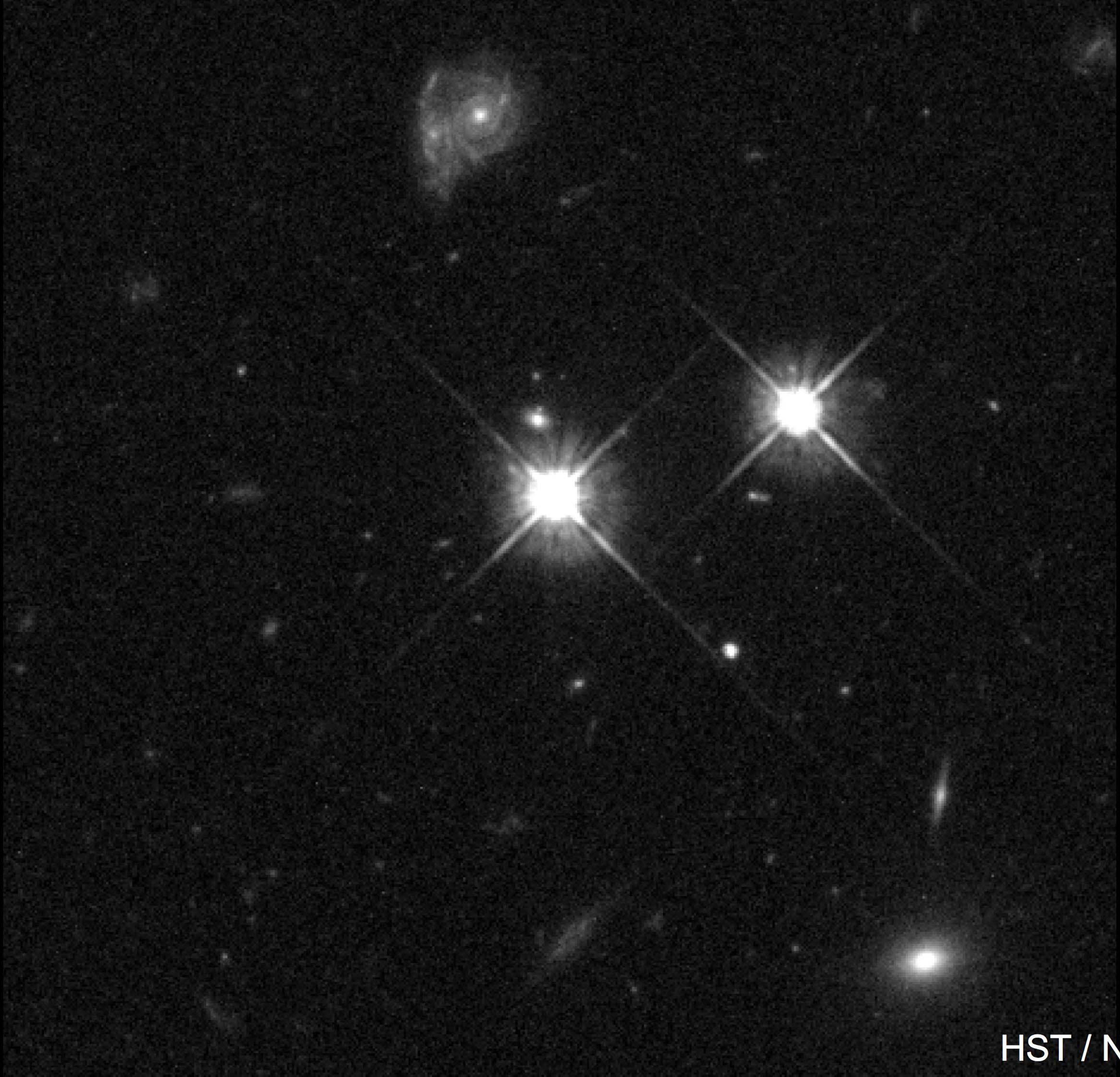
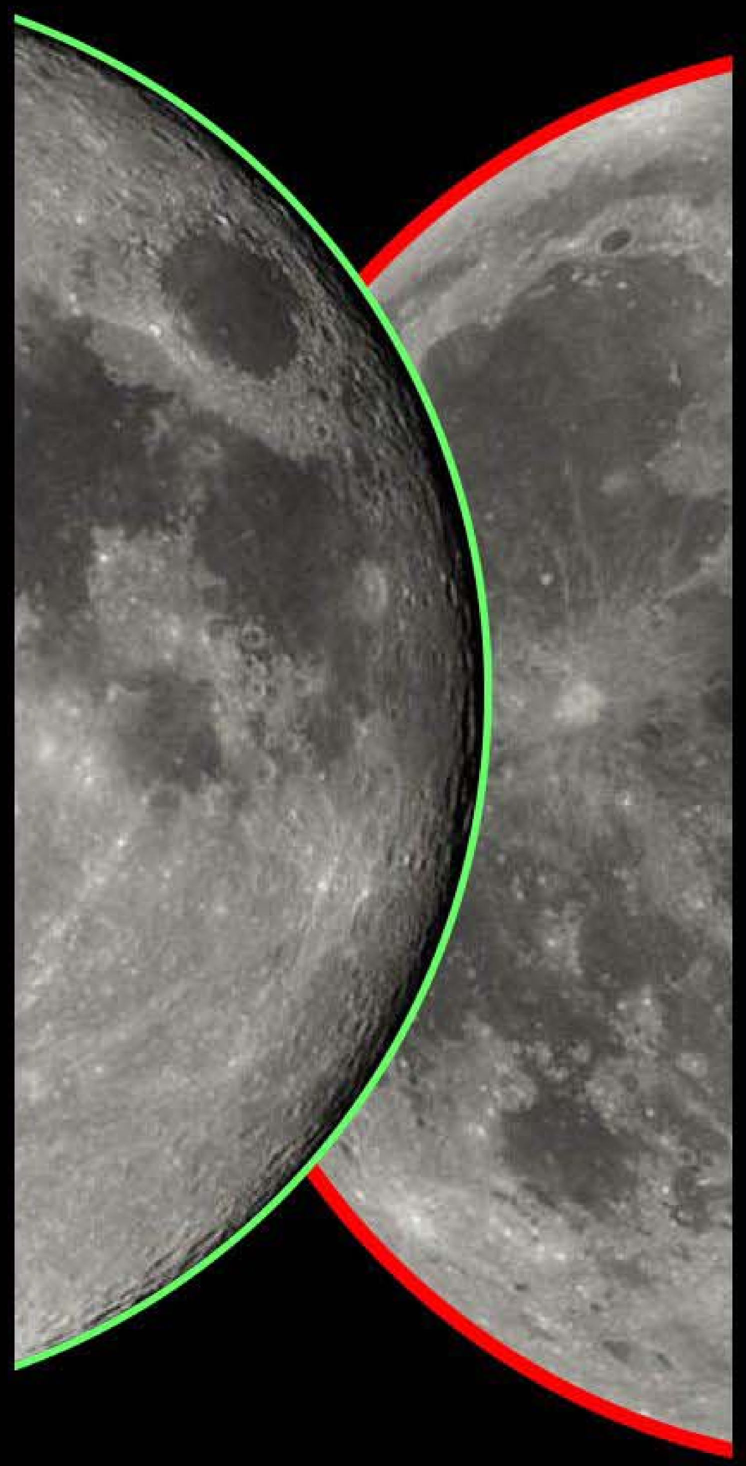
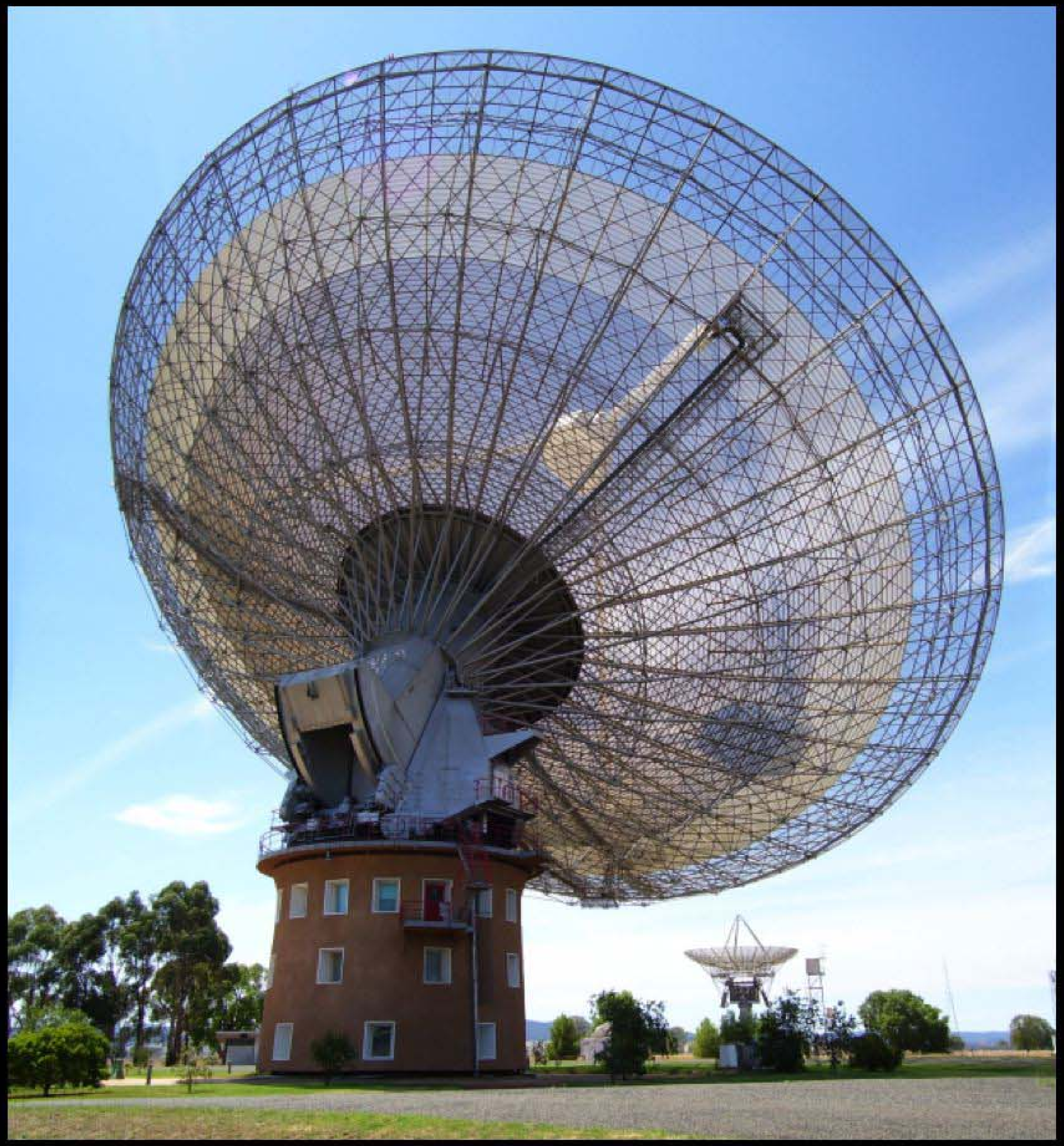




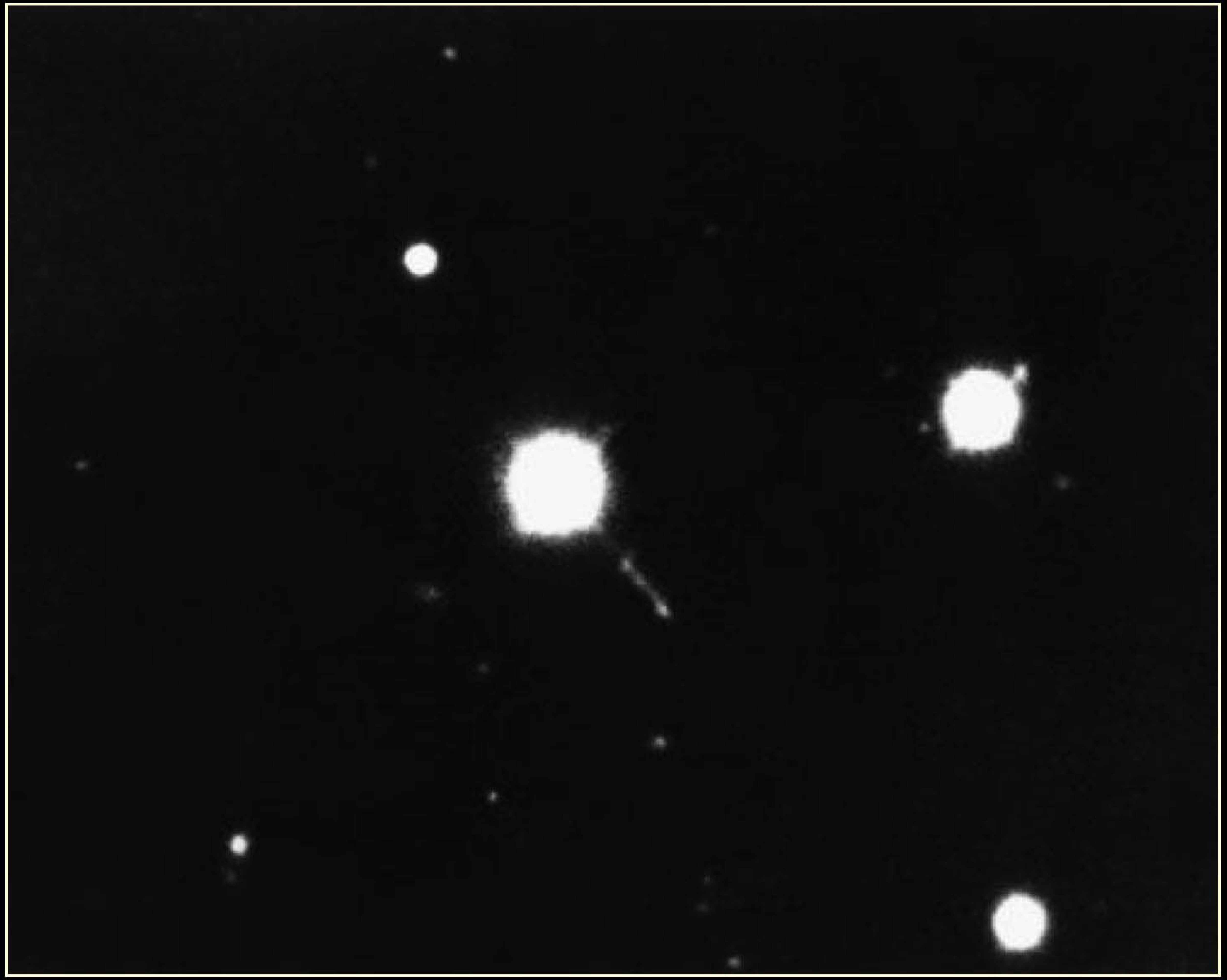
HST / NASA /C Steidel



3C273

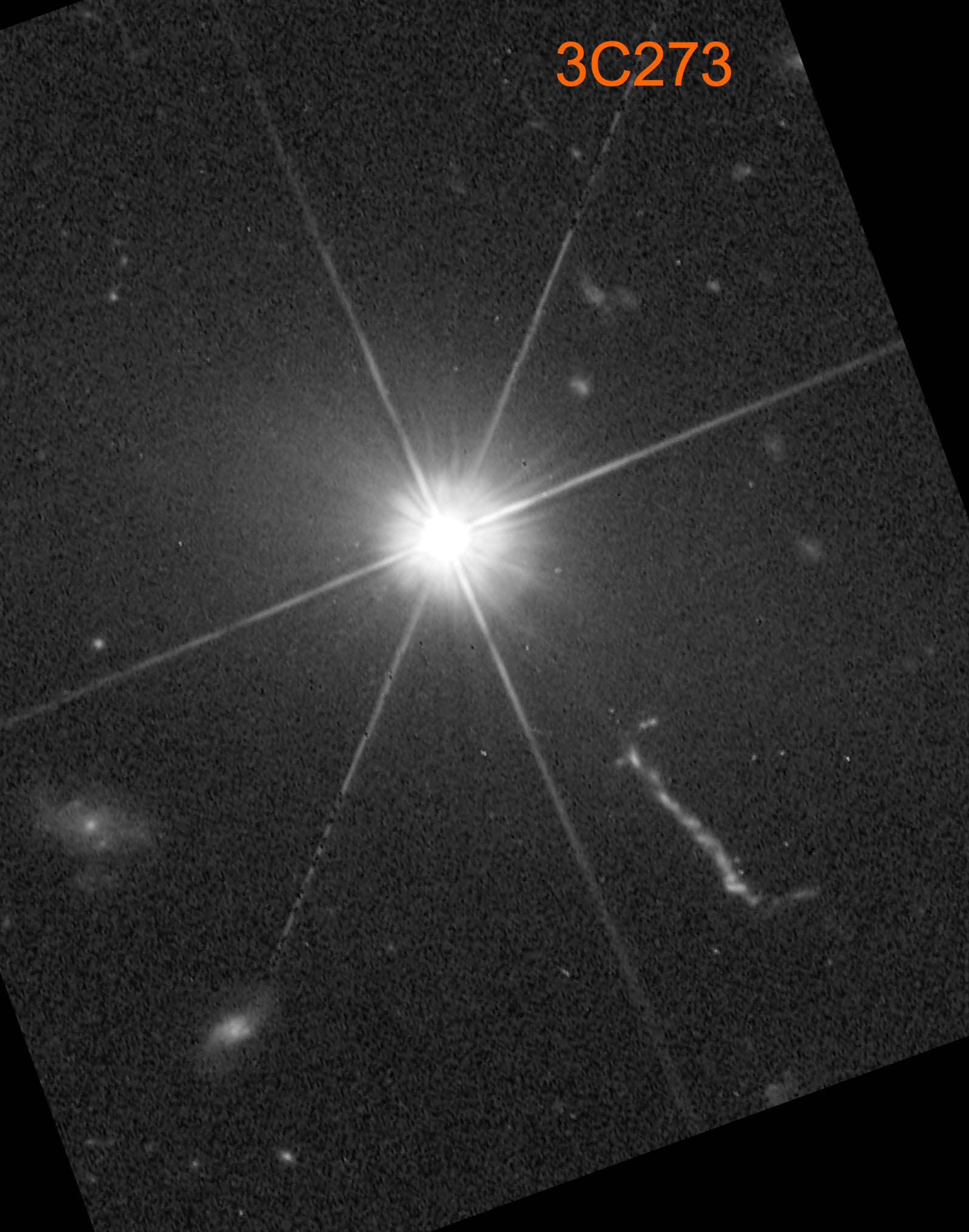


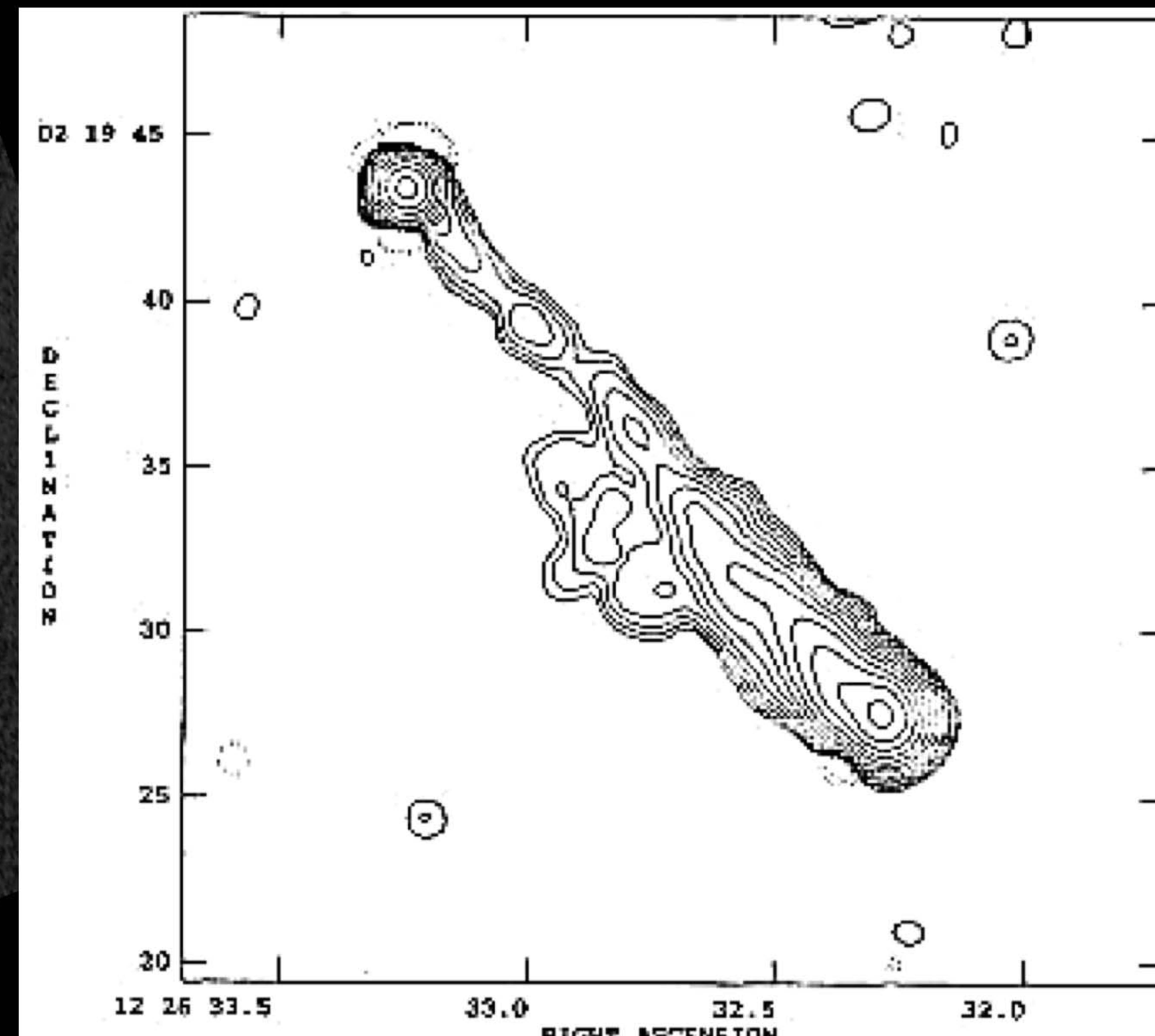
Cyril Hazard



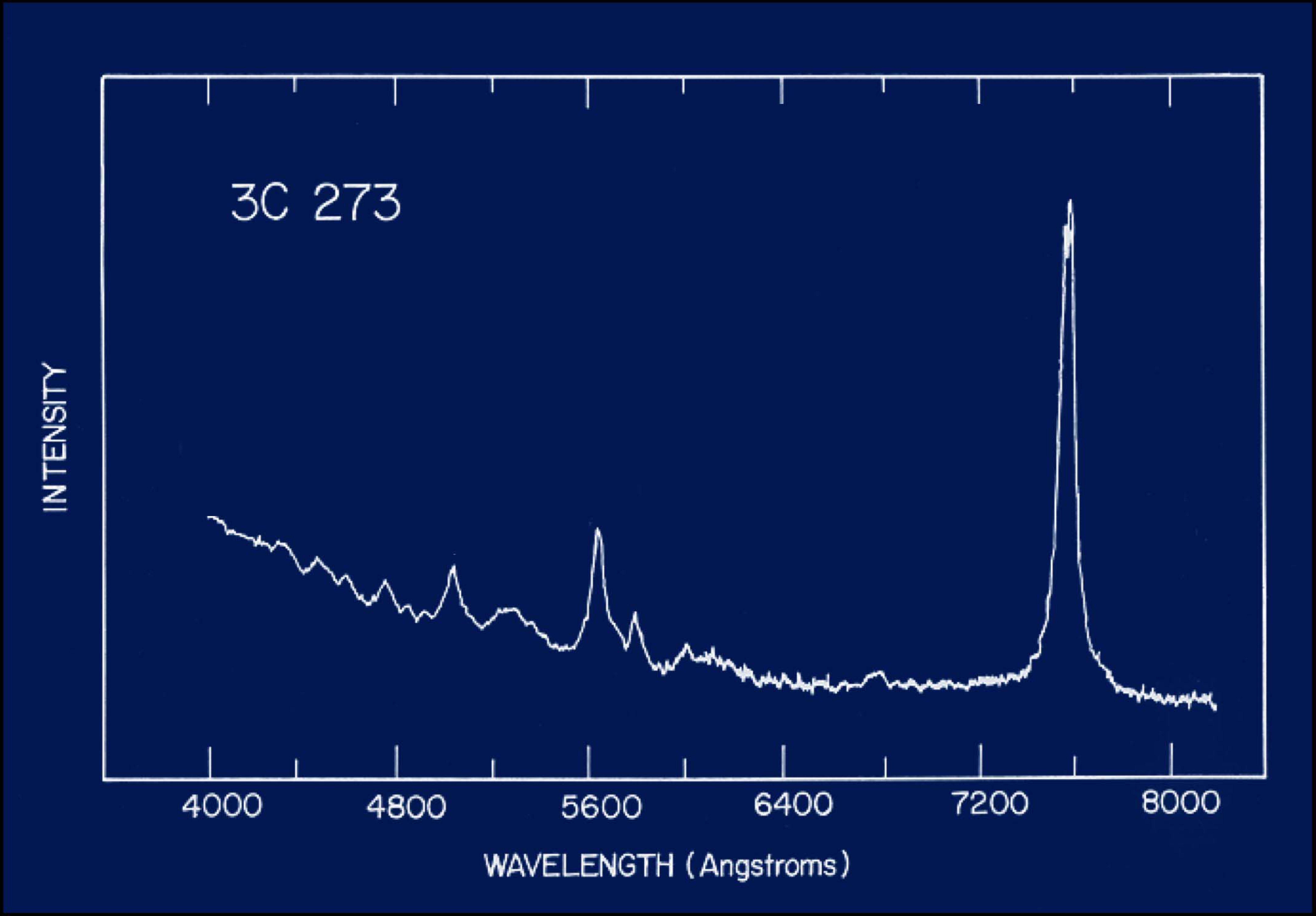
KPNO

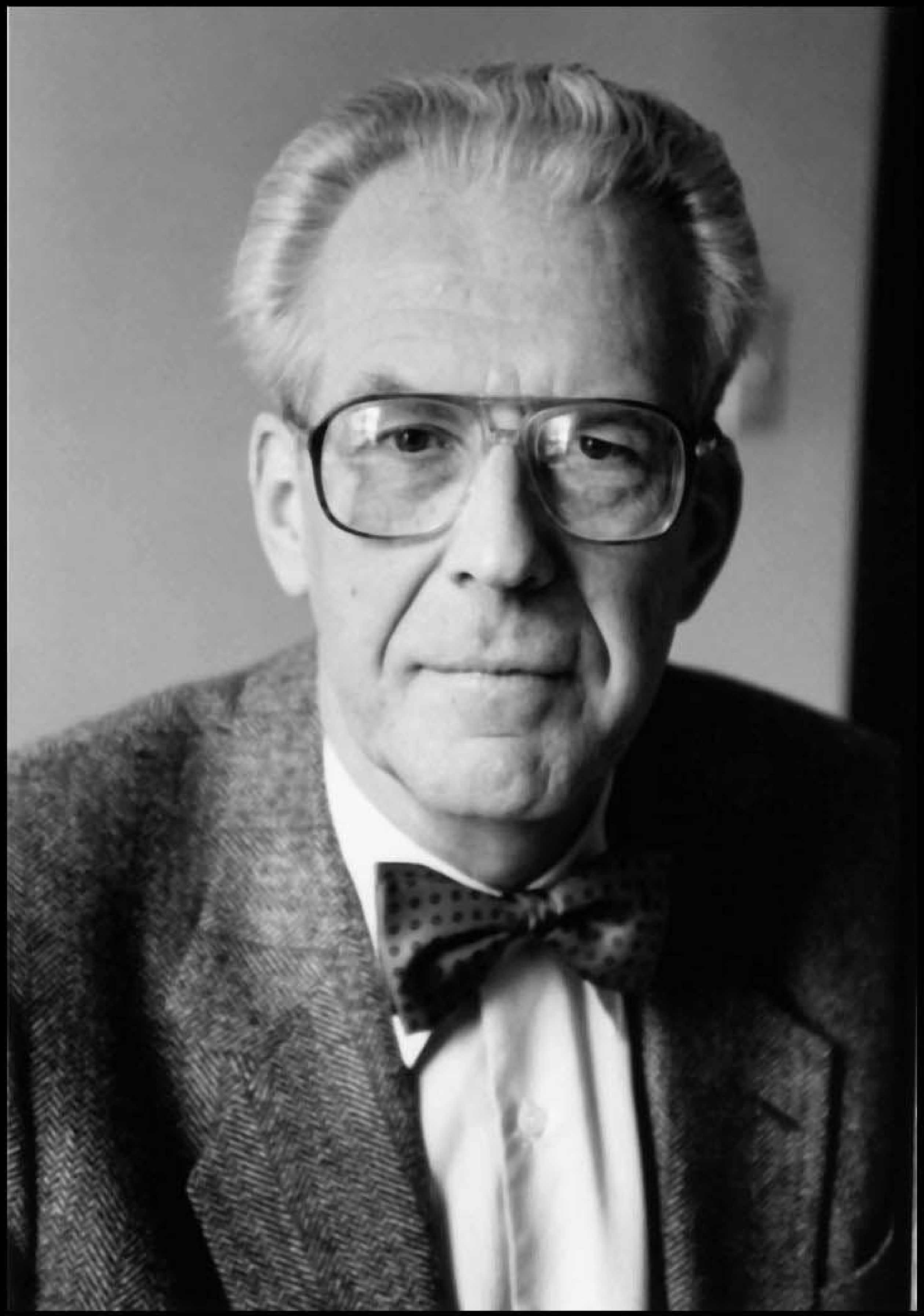
3C273



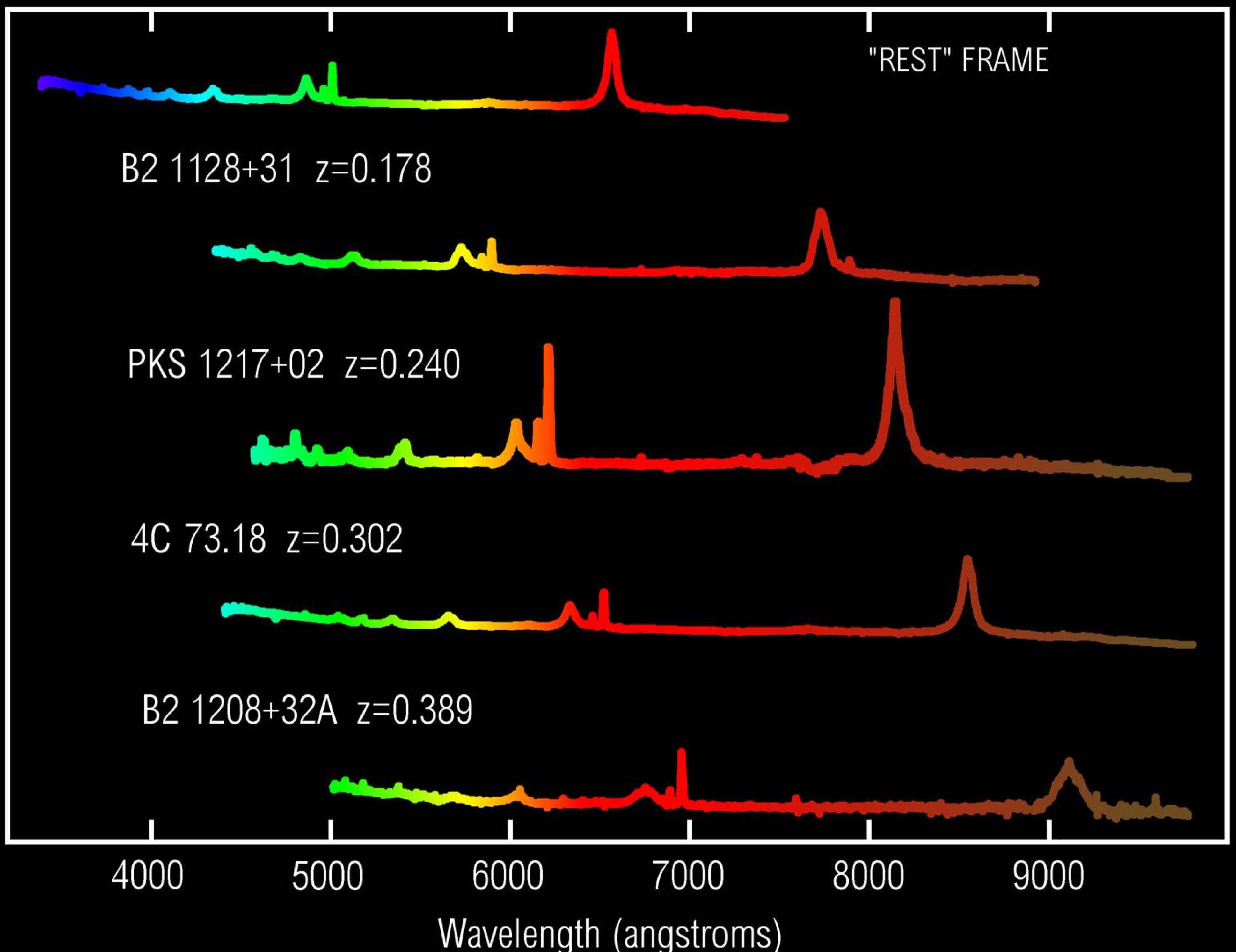


HST / NASA/ J Bahcall (IAS) / Davis et al / Merlin

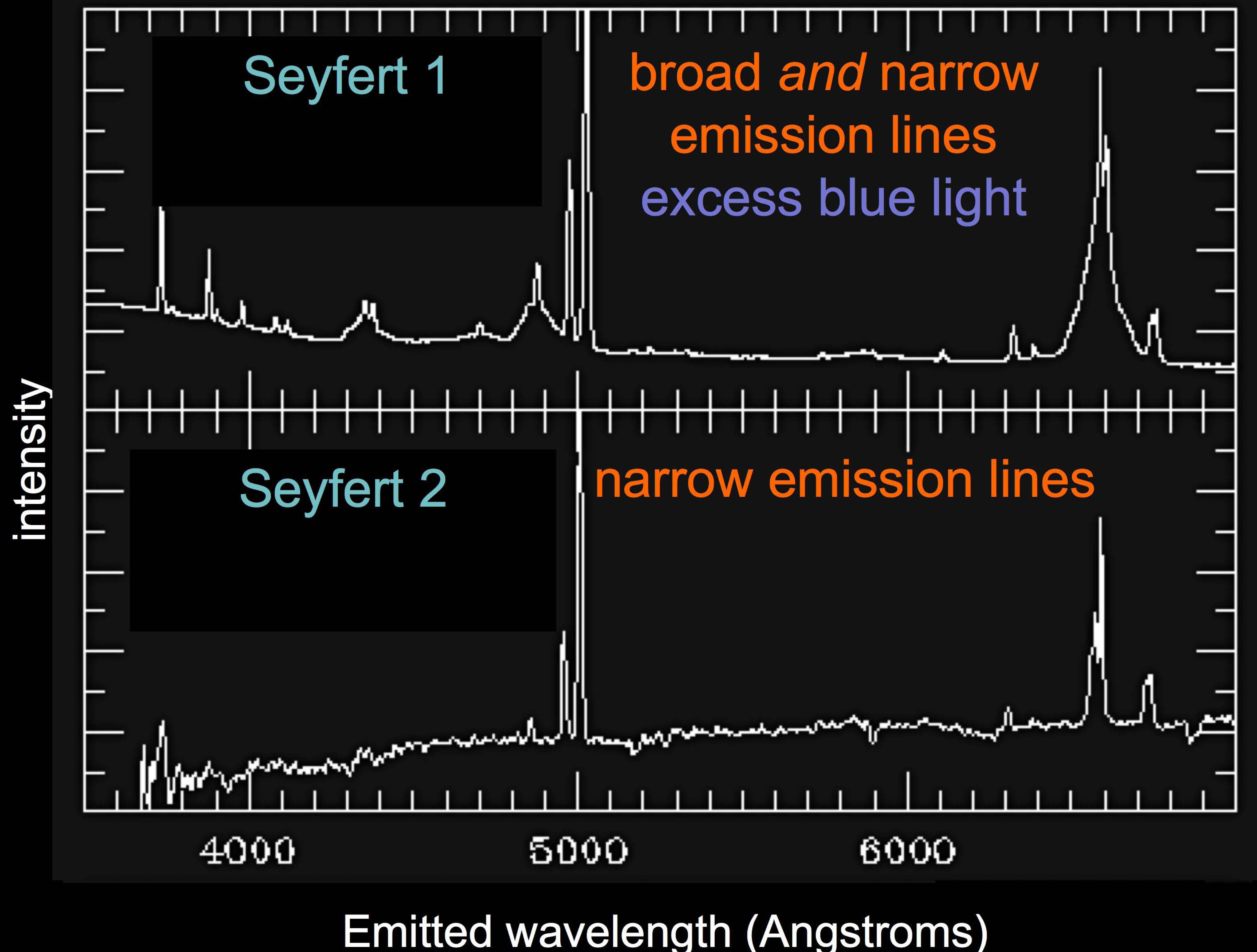




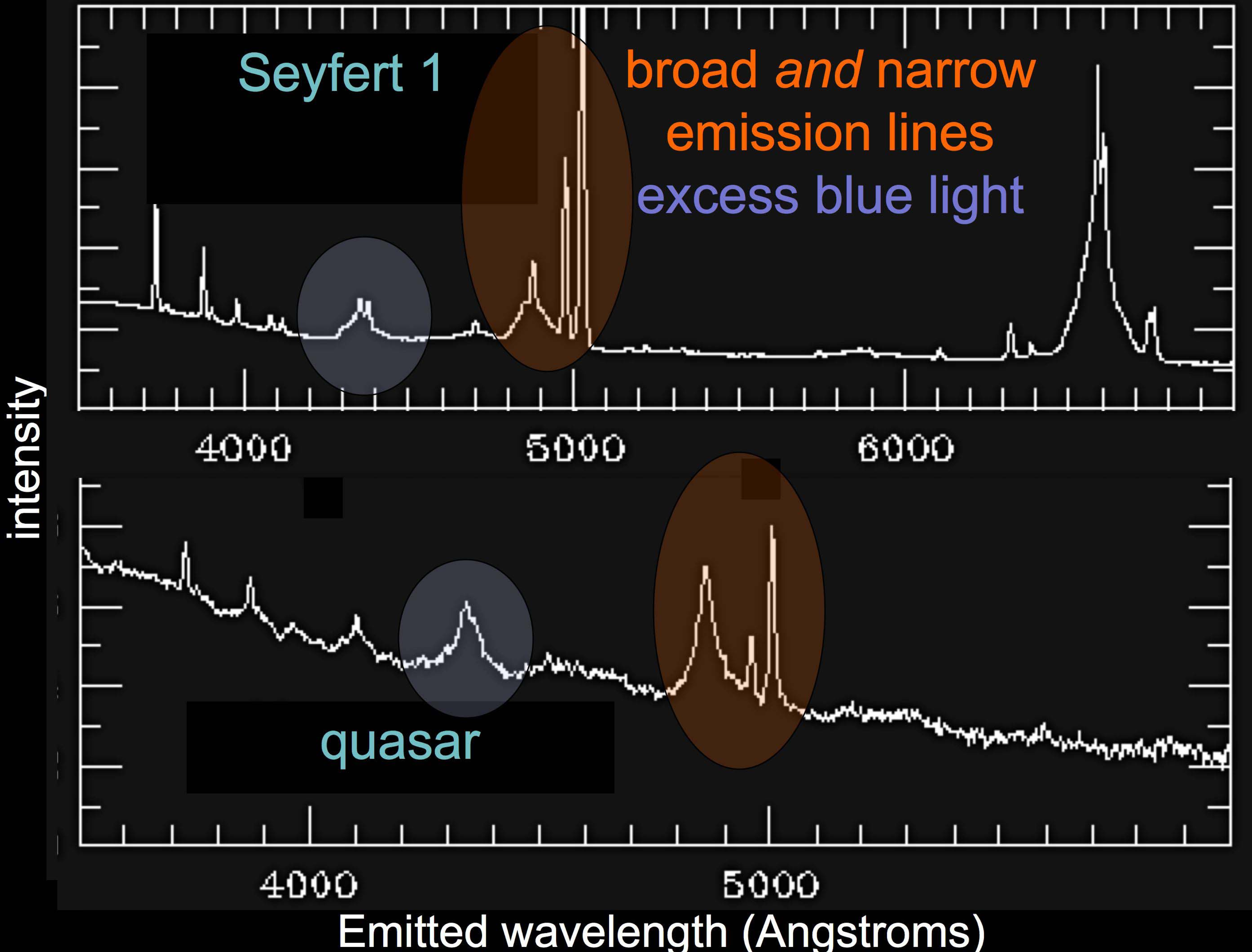
Maarten Schmidt
(1929-)



C. Pilachowski, M. Corbin /NOAO/AURA/NSF



W Keel (U of Alabama)



W Keel (U of Alabama)

HST / NASA/ J Bahcall (IAS) et al

HST / NASA/ J Bahcall (IAS) / M Disney (Wales)


NASA/ESA/HST/R Gendler

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	$\lambda/1\cdot158$	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.

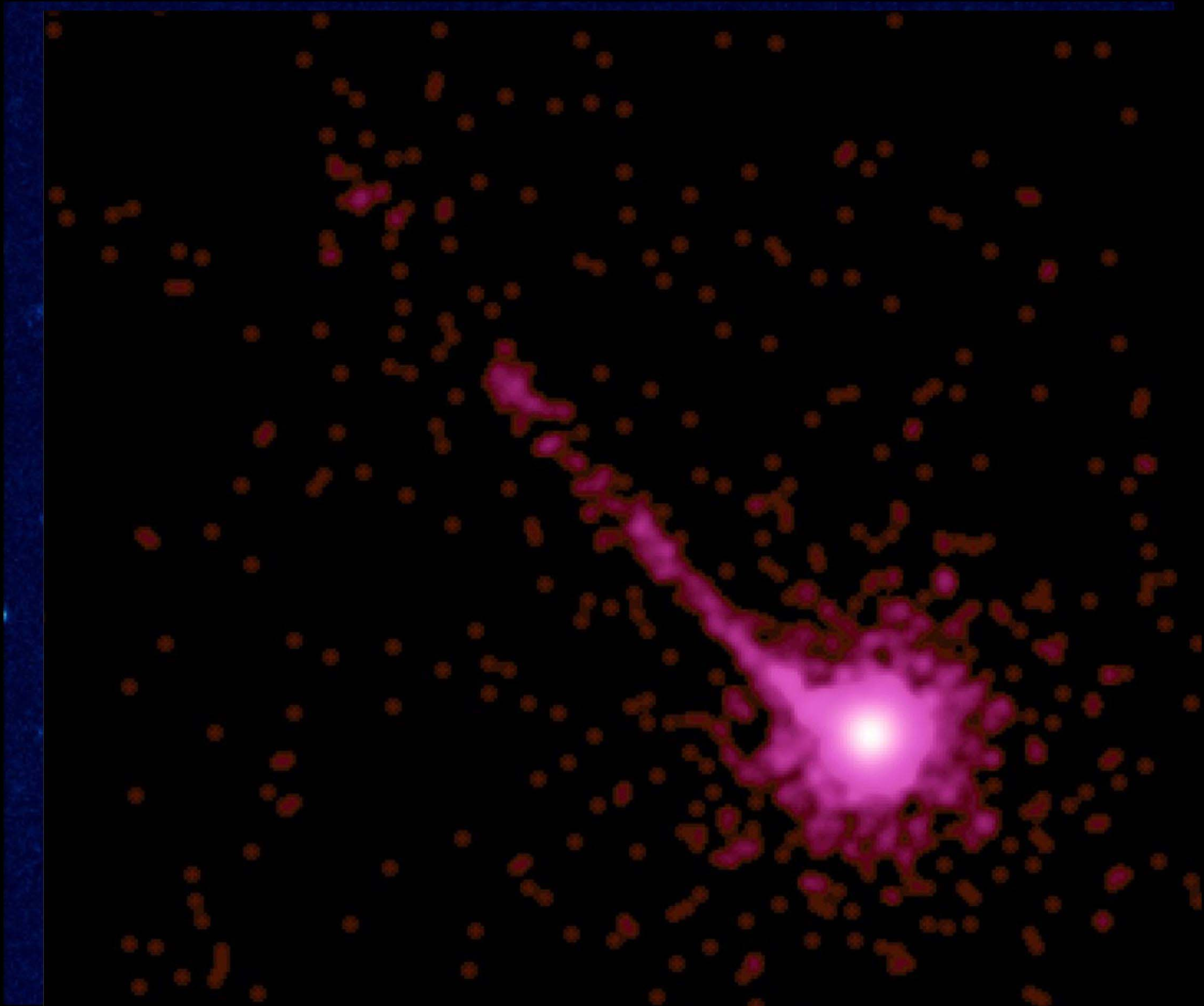
(1) The stellar object is a star with a large gravitational red-shift. Its radius would then be of the order of 10 km. Preliminary considerations show that it would be extremely difficult, if not impossible, to account for the occurrence of permitted lines and a forbidden line with the same red-shift,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

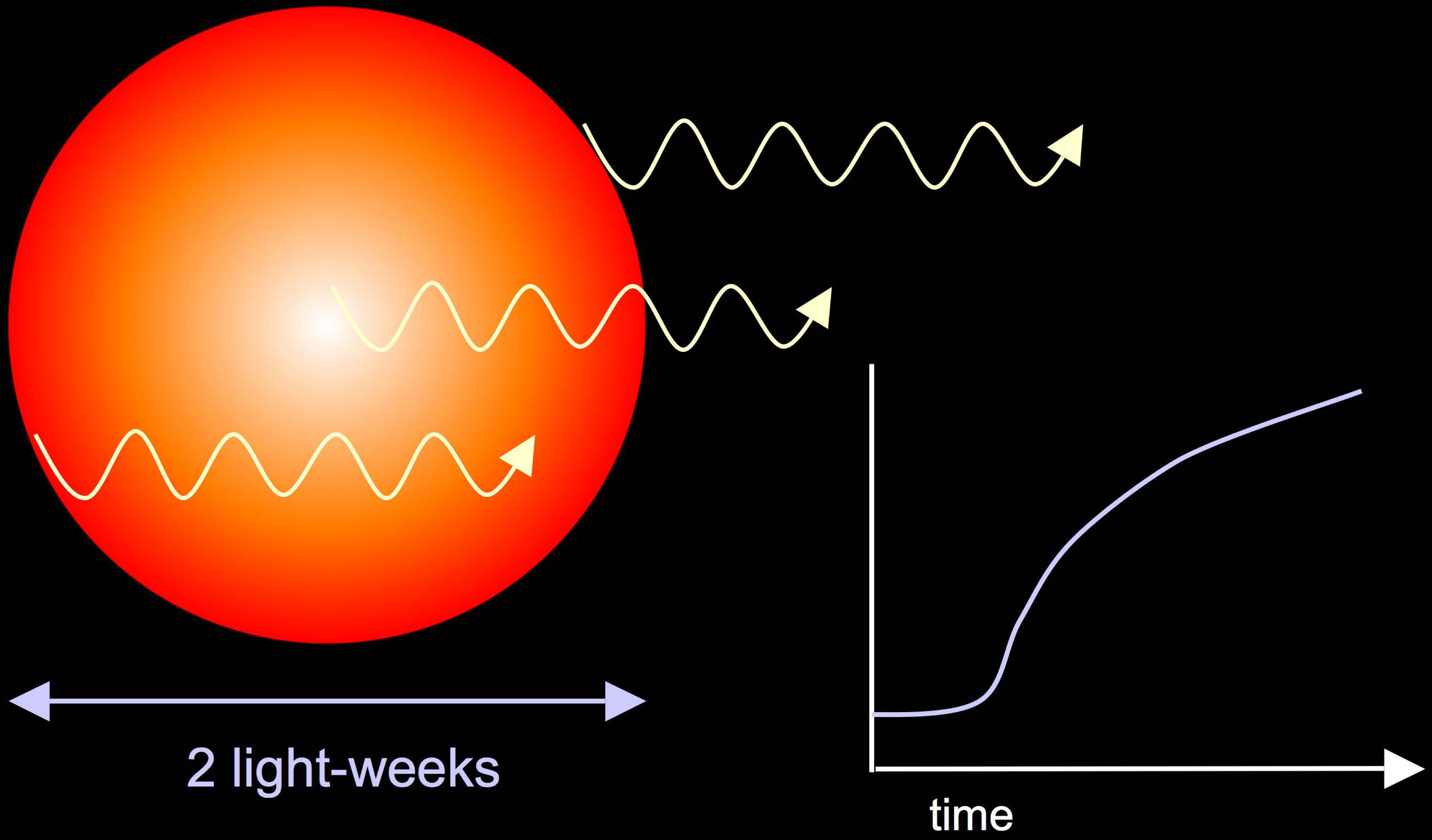
Nature

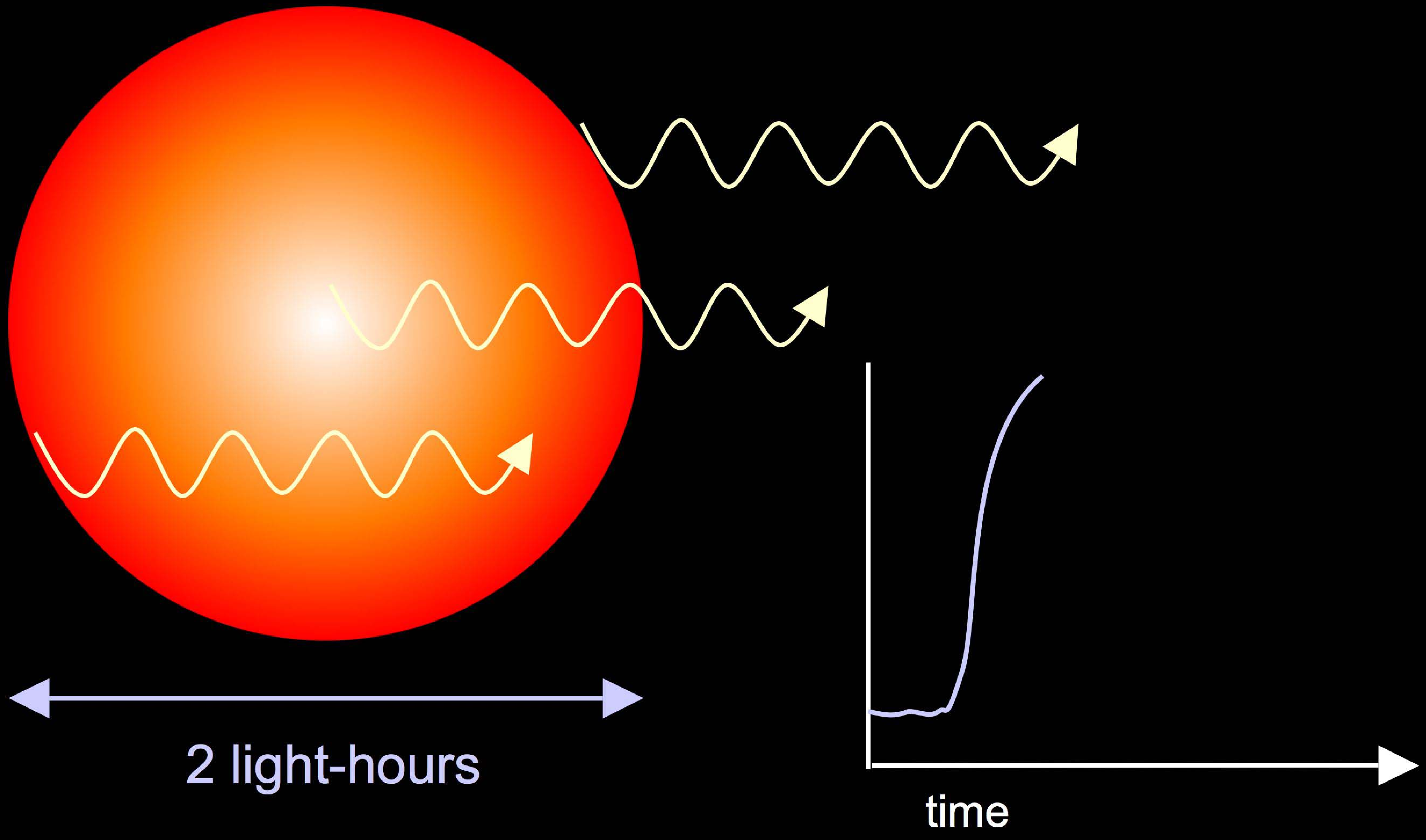


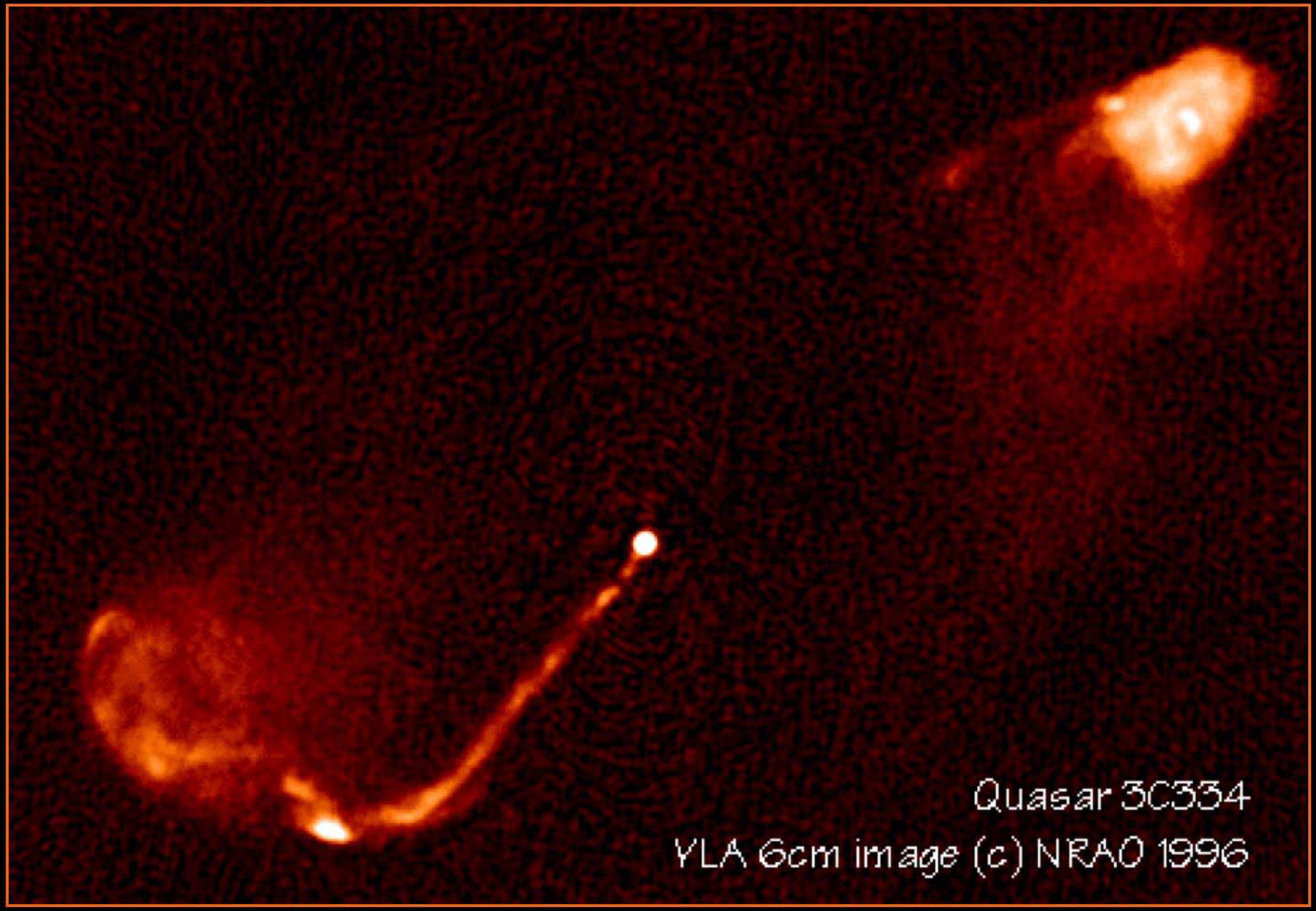
Optical X-ray

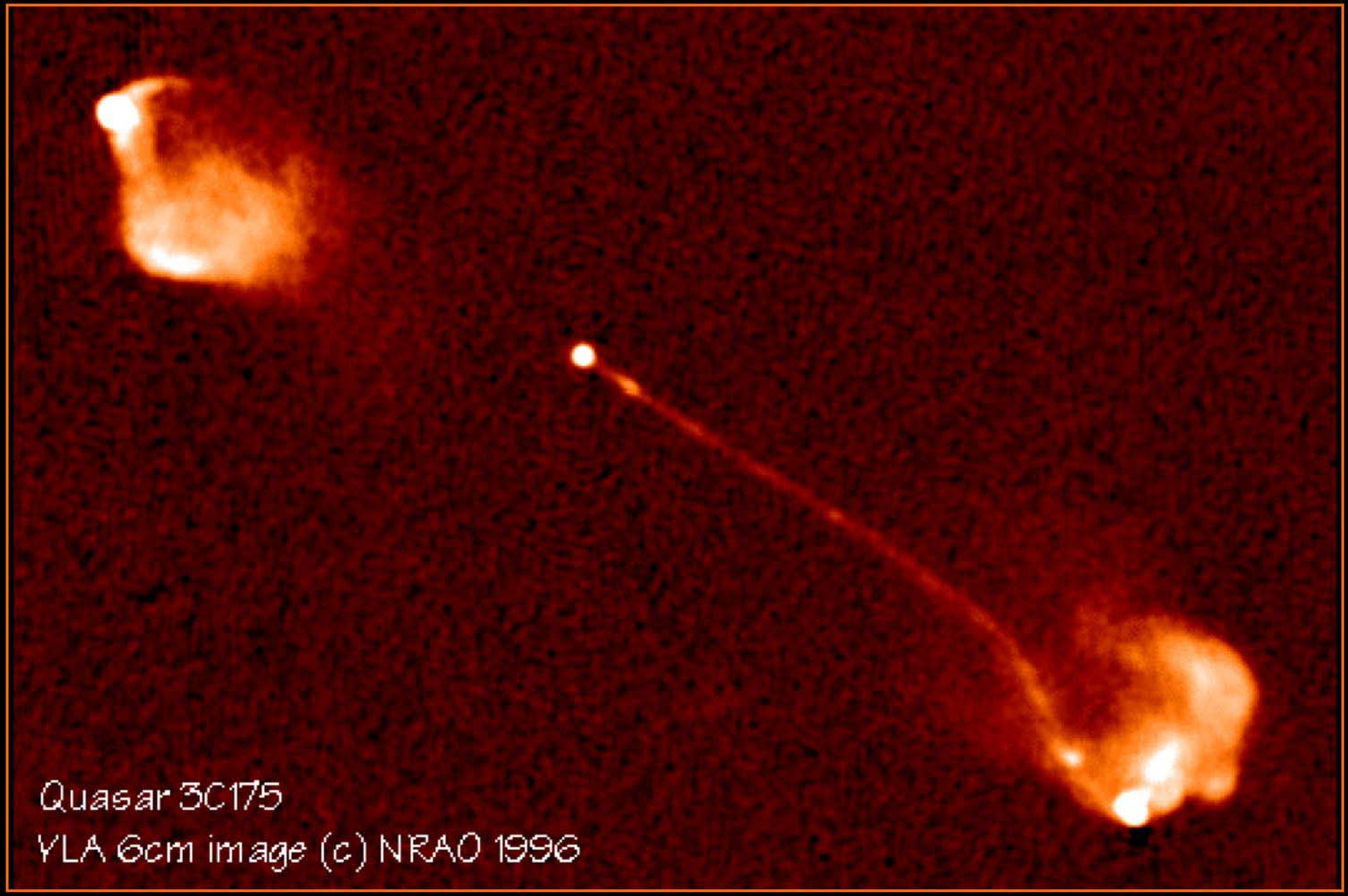
NASA/HST/CXC/CfA/A.Siemiginowska et al.

X-ray photon countrate
0
10
20
30
0
10^5
2×10^5
3×10^5
4×10^5
Time (s)
MCG-6-30-15 X-ray variability
A Fabian et al (Cambridge)

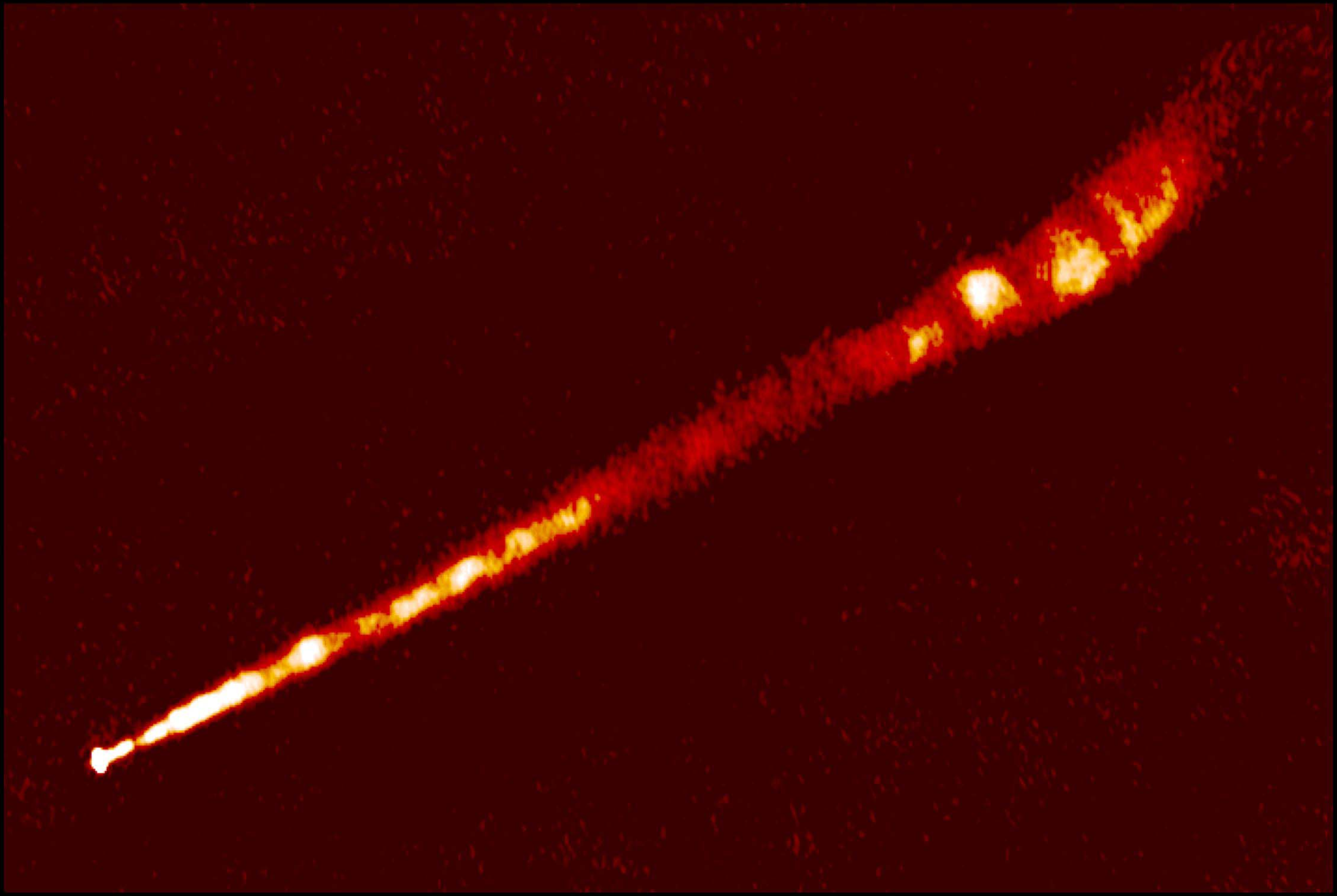

2 light-weeks
time


2 light-hours
time


Quasar 3C334
VLA 6cm image (c) NRAO 1996


Quasar 3C175
VLA 6cm image (c) NRAO 1996

NRAO/AUI/NSF



P Werner (Bristol)

so we have...

Something very very massive...

... compacted into a tiny tiny volume

Emitting lots of energetic X-ray, UV light...

...unlike the light from stars/galaxies/gas

Sometimes producing twin jets of emission extending way out of the host galaxy

Broad lines > 5,000 km/s indicating a strong gravitational field

NASA/JPL-Caltech/T Pyle (SSC)

Donald Lynden-Bell (1935-)

NASA/CXC/M Weiss

A quasar radiating at a million million x Solar luminosities

$E = mc^2$

NASA/HST/ESA


NASA / ESA

A quasar radiating at a million million x Solar luminosities

$$E = 0.1\, mc^2$$

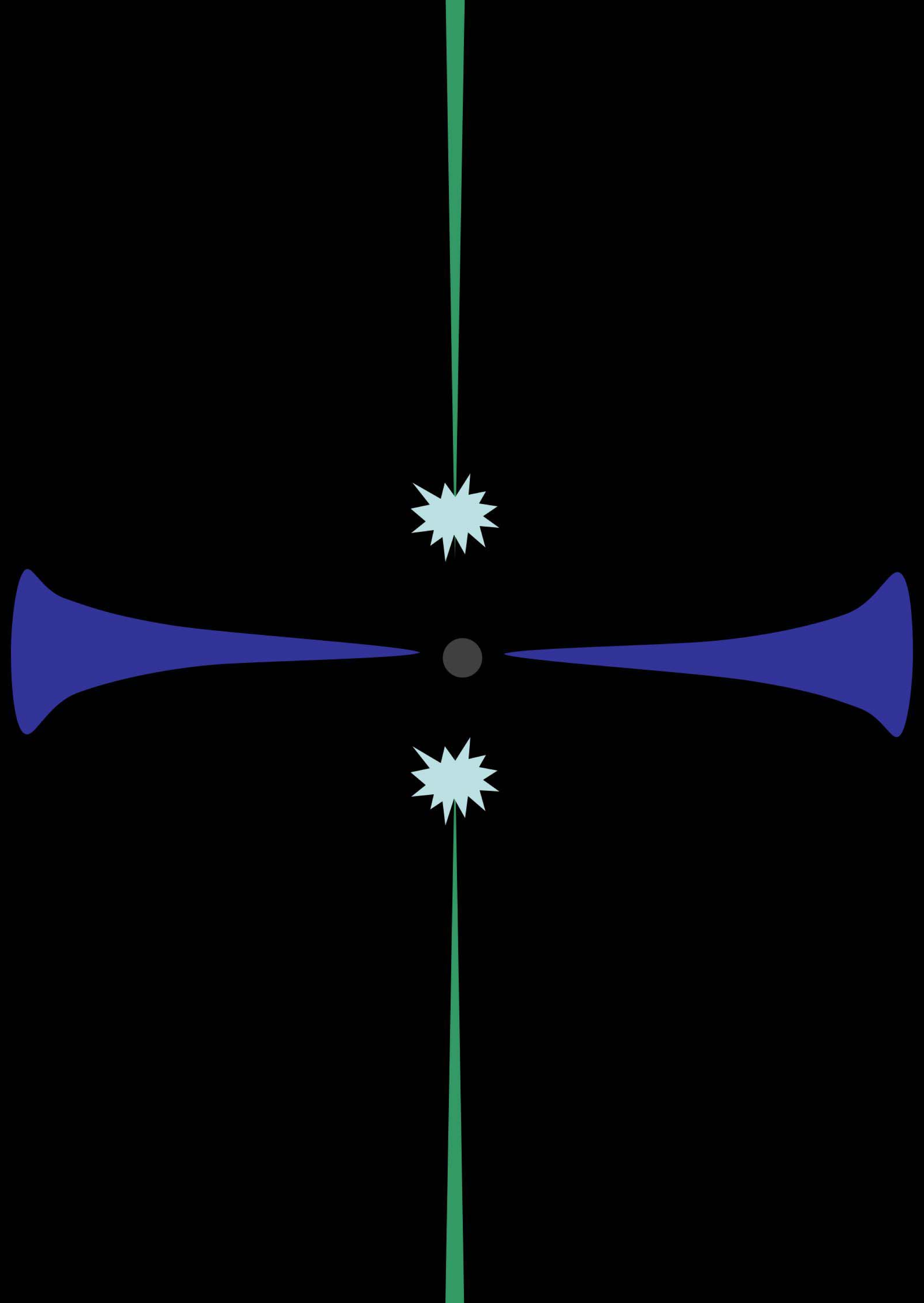
can be powered by a black hole accreting matter at the rate of about only 1 M_{sun} /year

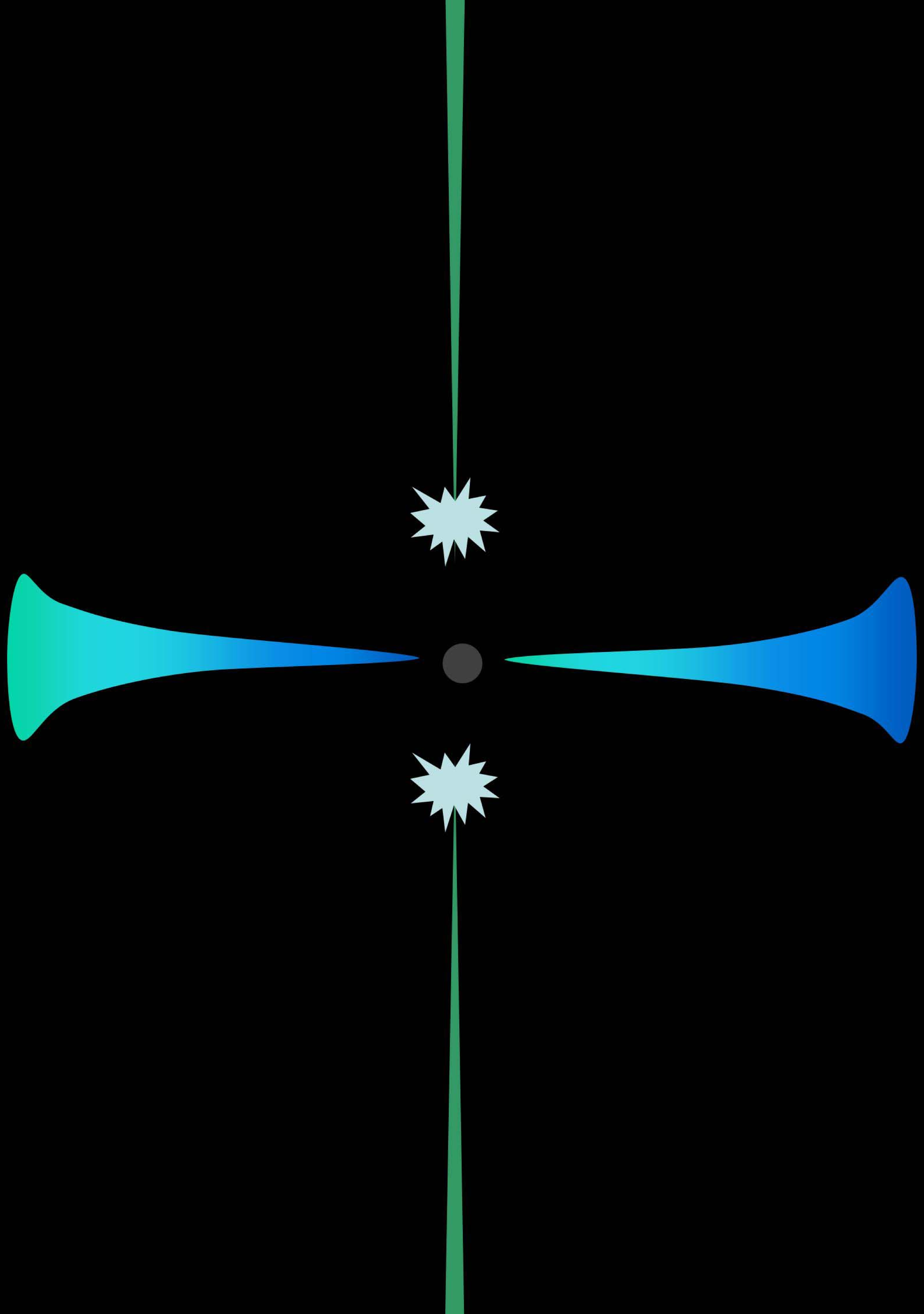
NASA/HST/ESA


A Hobart (CXC)

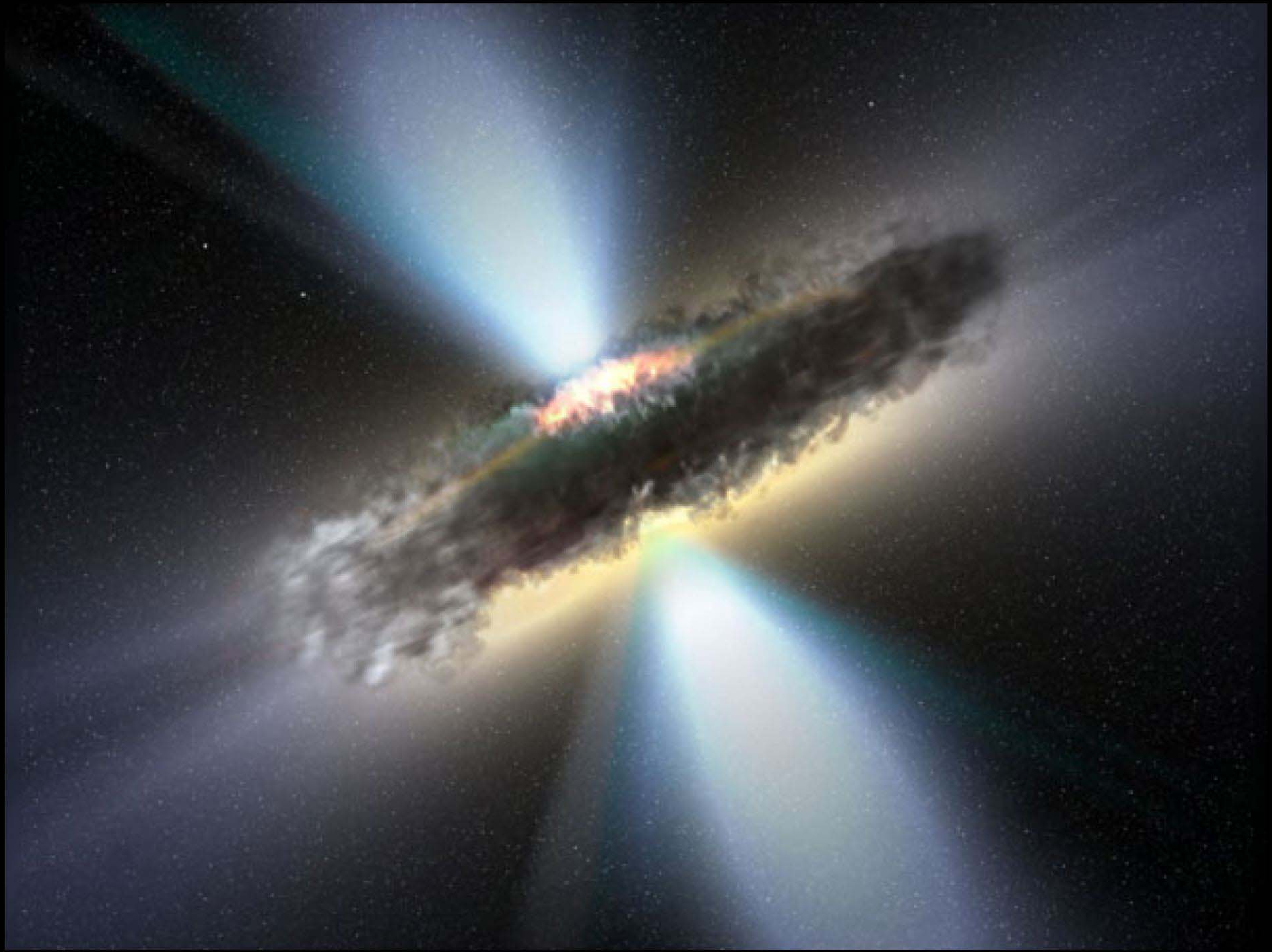
ESO/M. Kornmesser


NASA / R Hurt (JPL-Caltech)



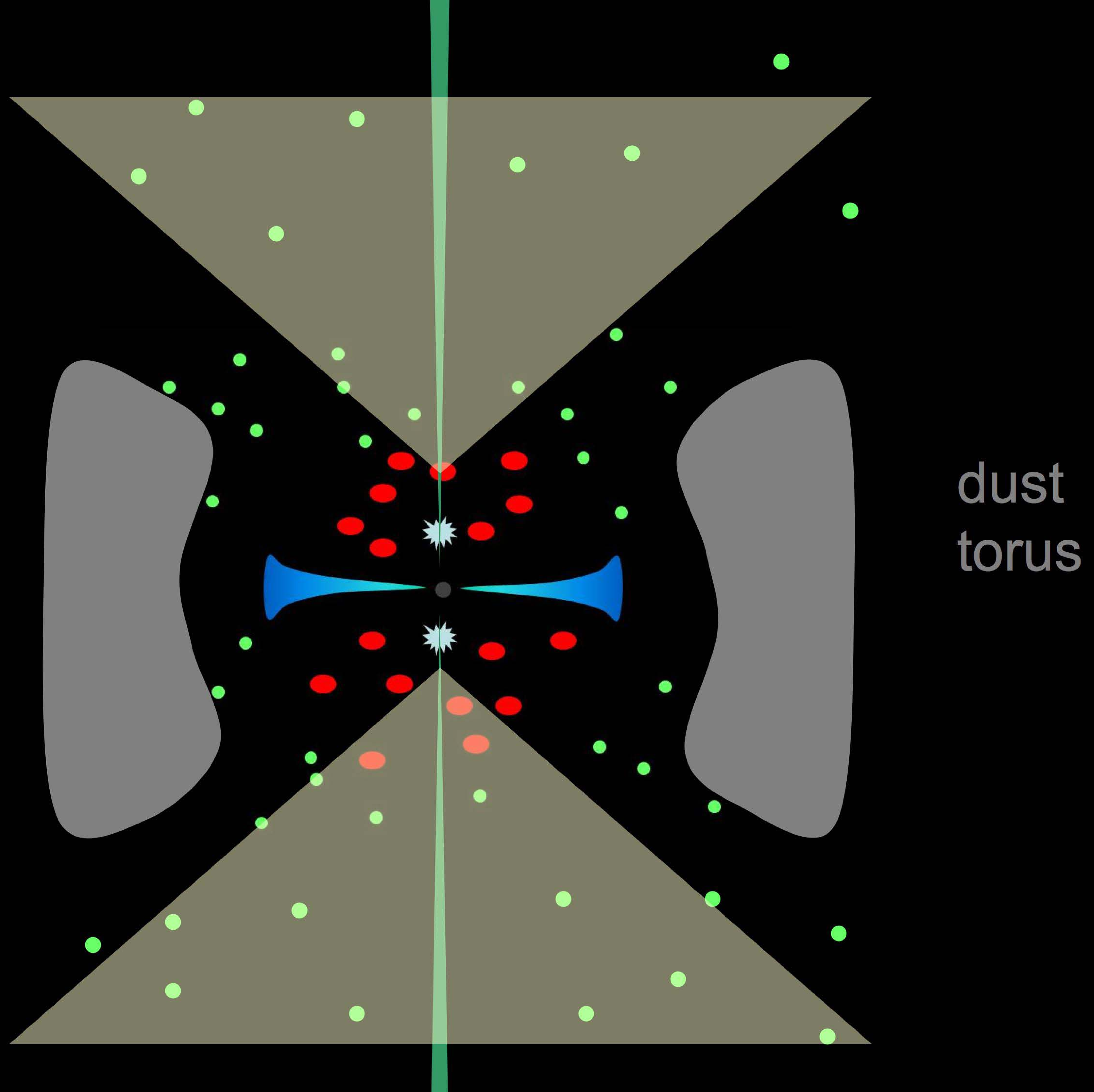



gas clouds
gas clouds



NASA/GSFC/ESA/V Beckmann

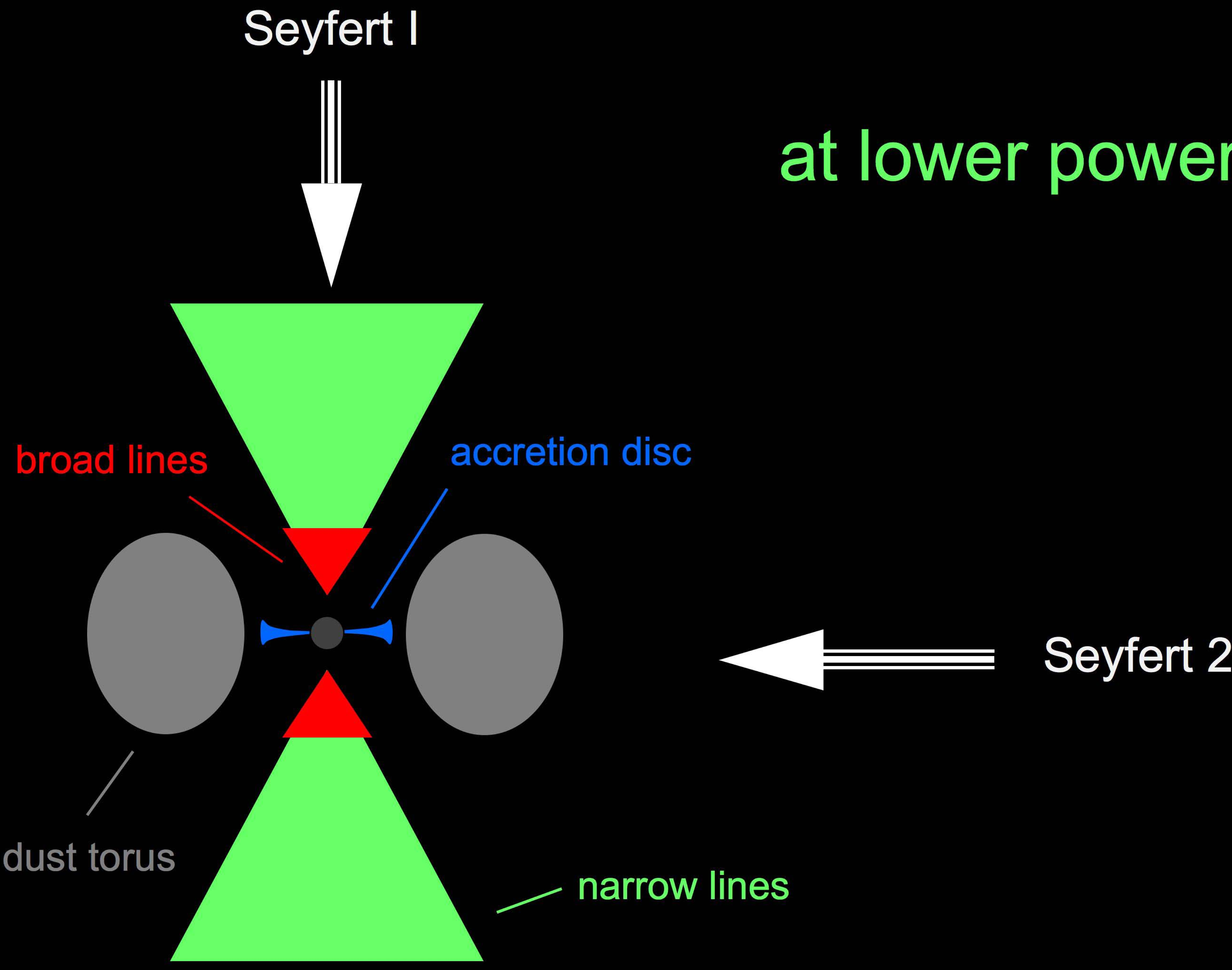
R van der Marel / van den Bosch / NASA/ ESA


dust
torus


HST / NASA / ESA


HST / NASA / A Sandage /A Wilson et al

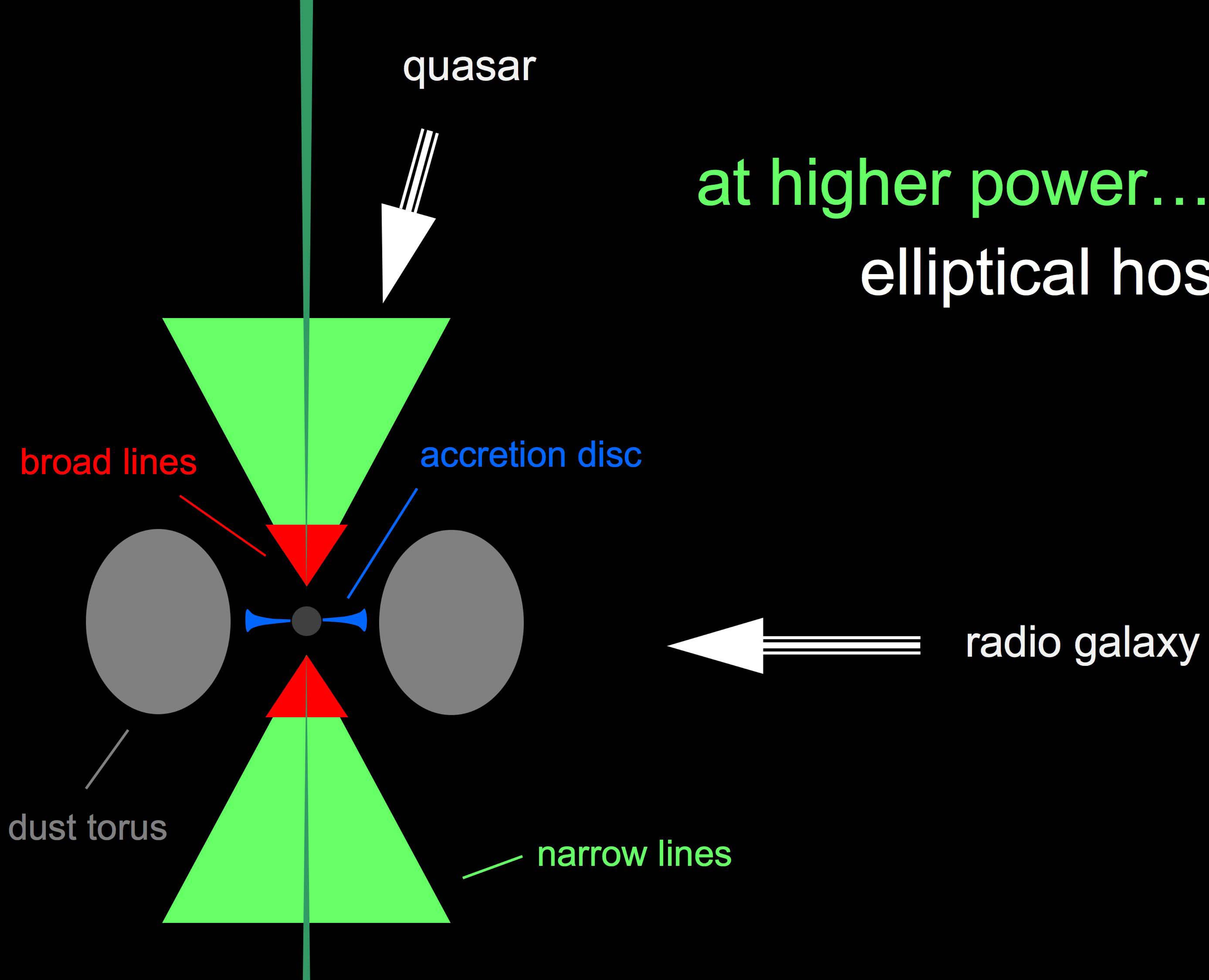
at lower power…

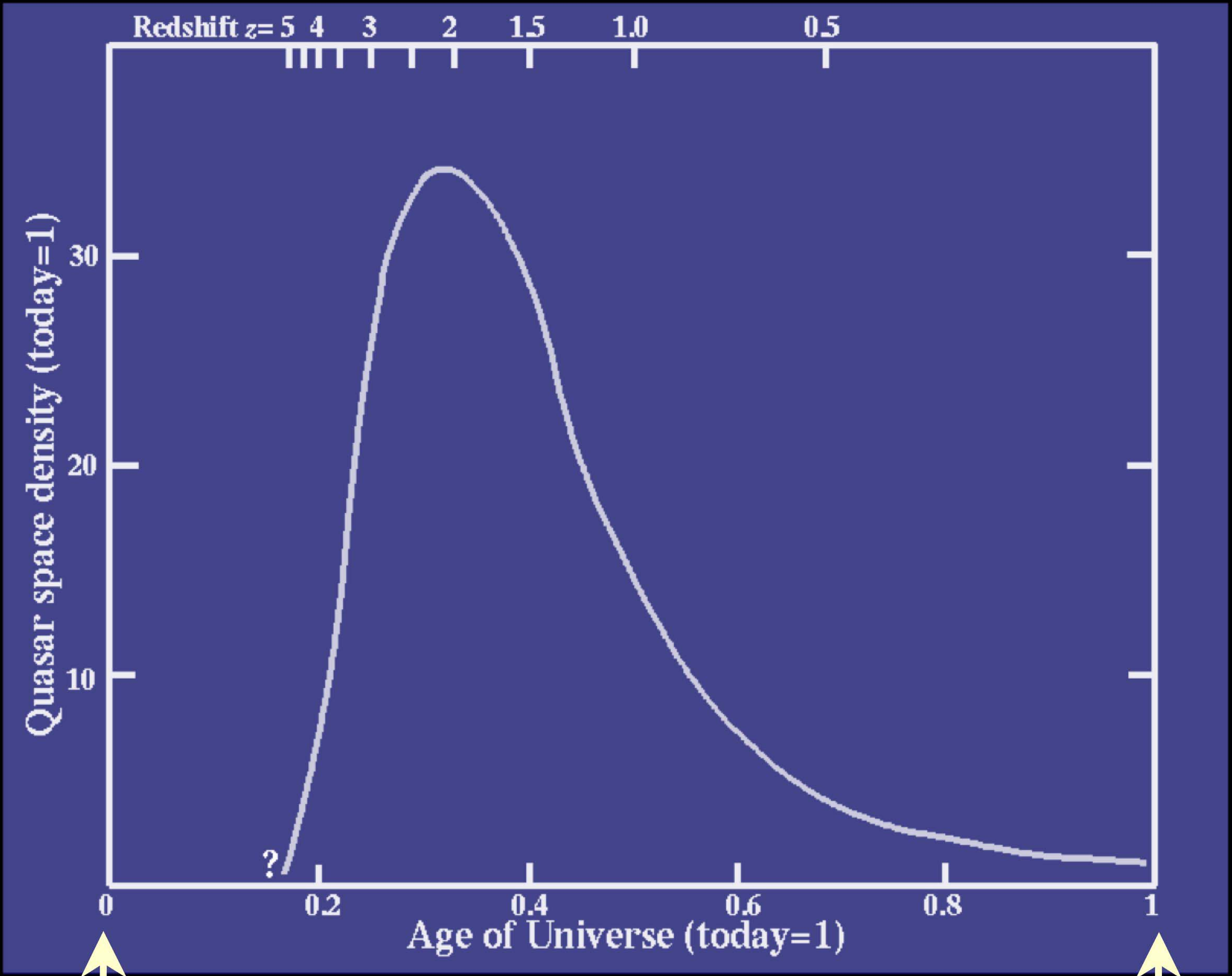


quasar
at higher power…
spiral host
broad lines
accretion disc
Seyfert 2
dust torus
narrow lines

at higher power…

elliptical host

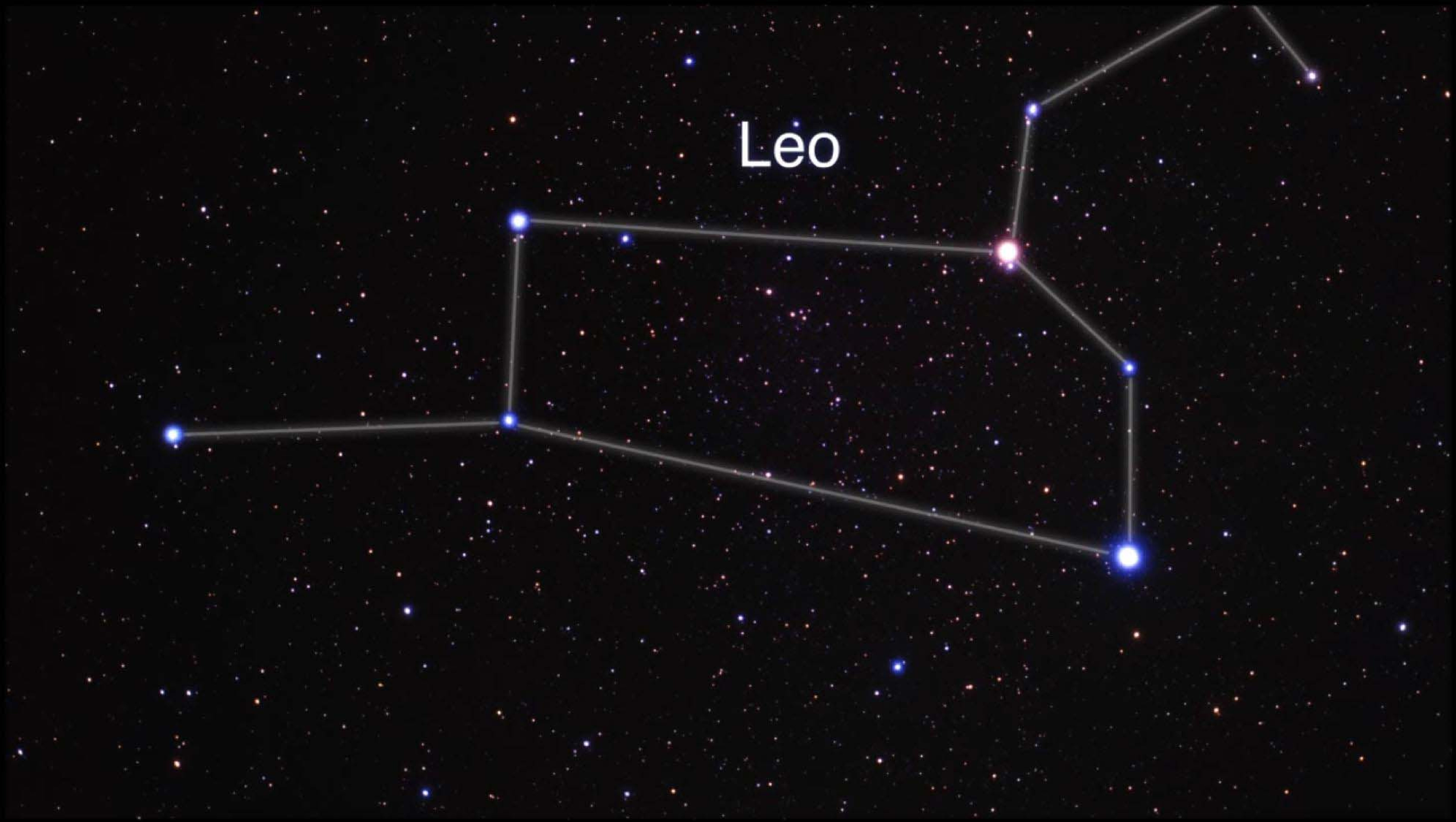




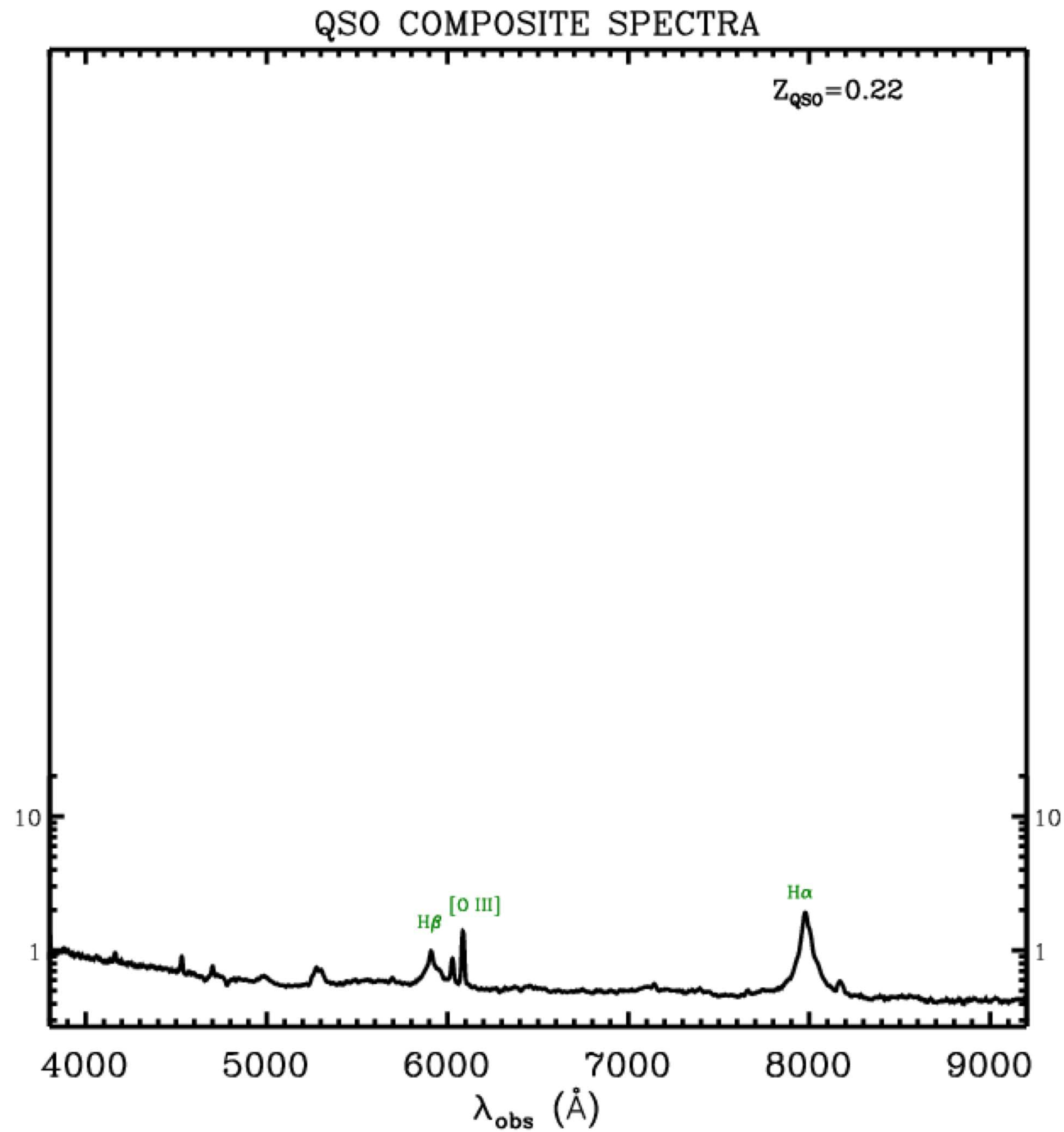
Big Bang

You are here

W Keel (U Alabama)



ESO/A Fujii/SDSS

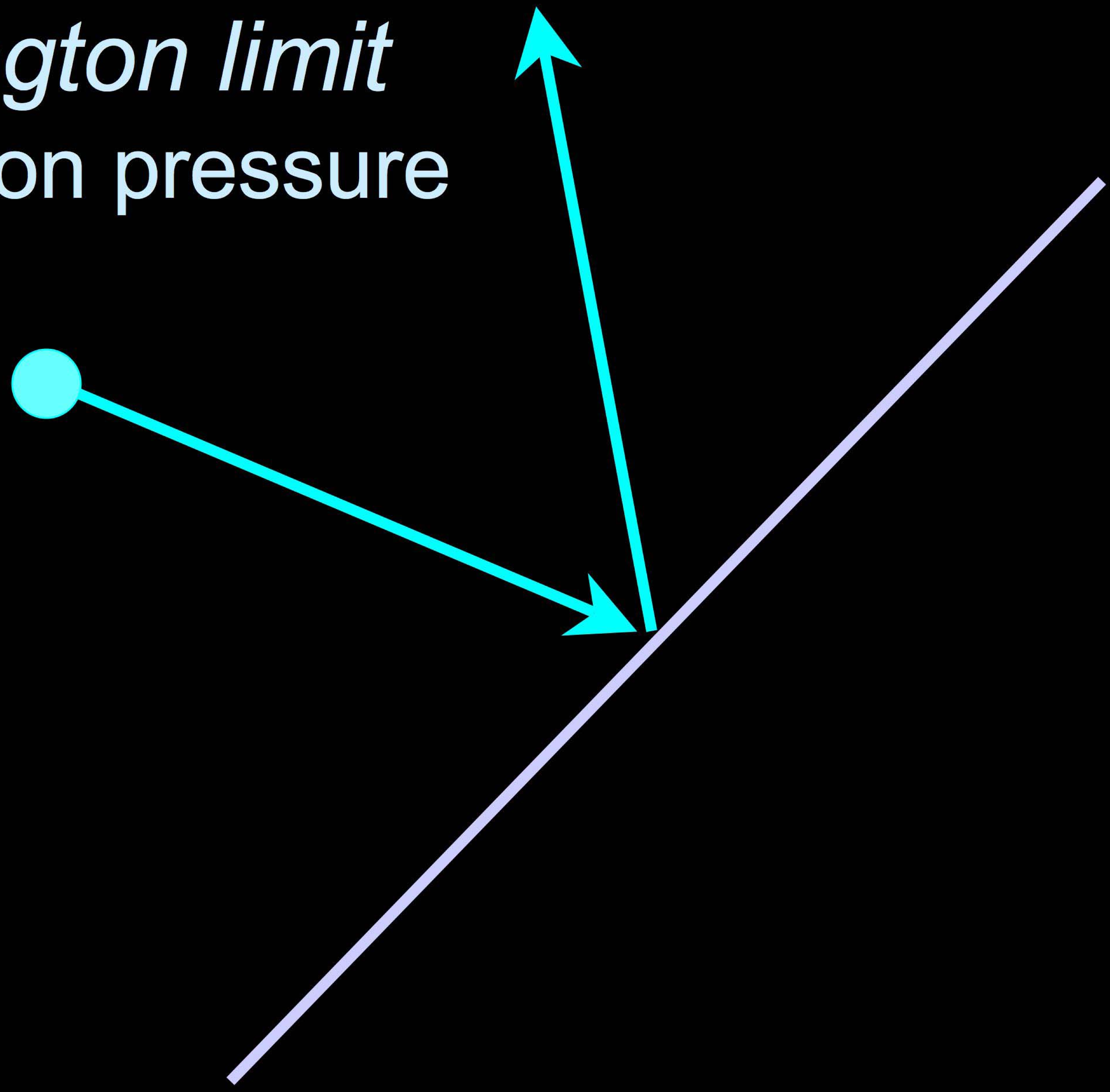

QSO COMPOSITE SPECTRA
Z_{QSO}=0.22
10
1
Hβ
[O III]
Hα
4000
5000
6000
7000
8000
9000
λ_{obs} (Å)

GB Zhu

Volunteri 2012

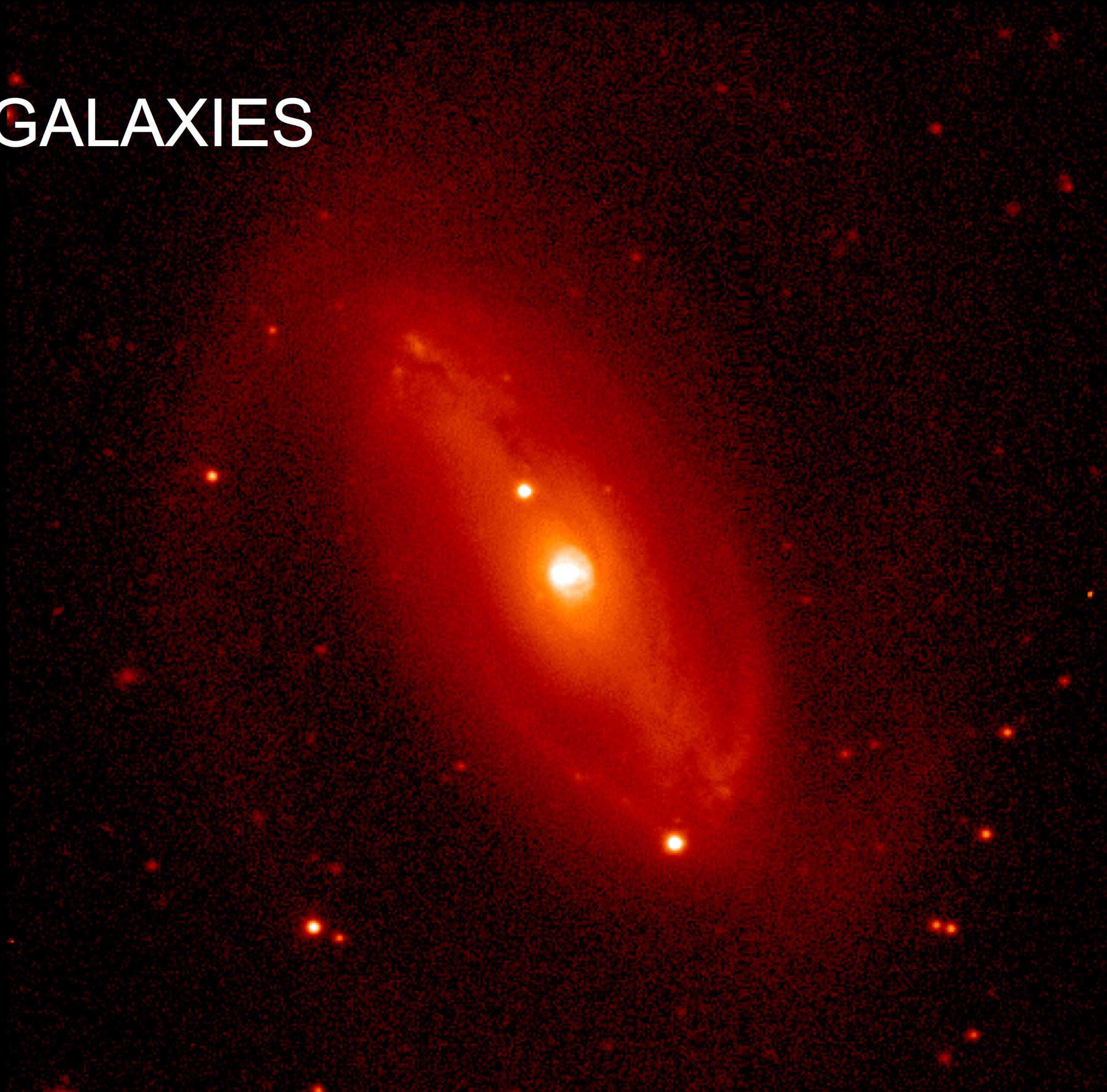
Eddington limit

radiation pressure

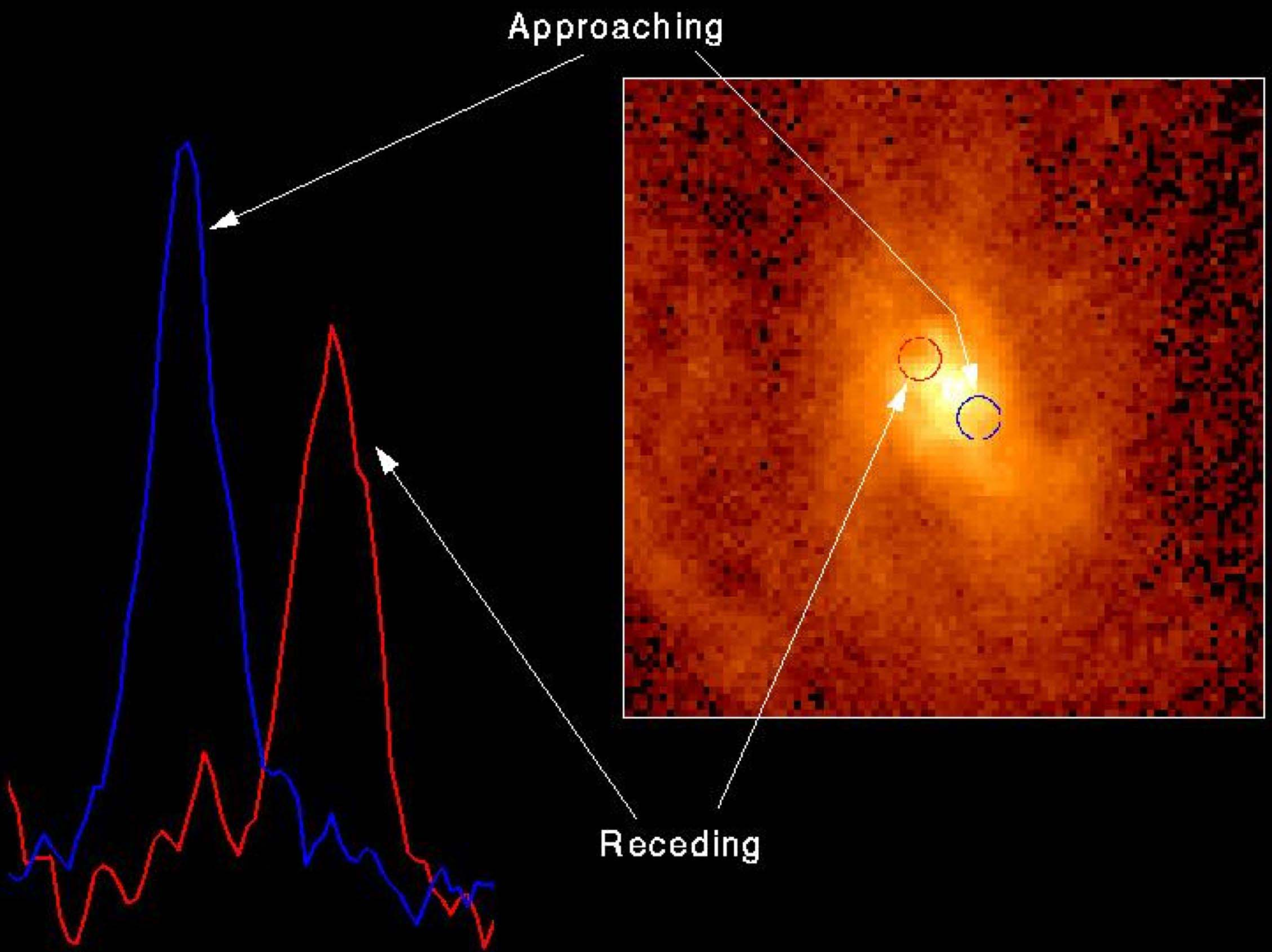


NASA/HST/ESA/ Ford et al

SEYFERT GALAXIES

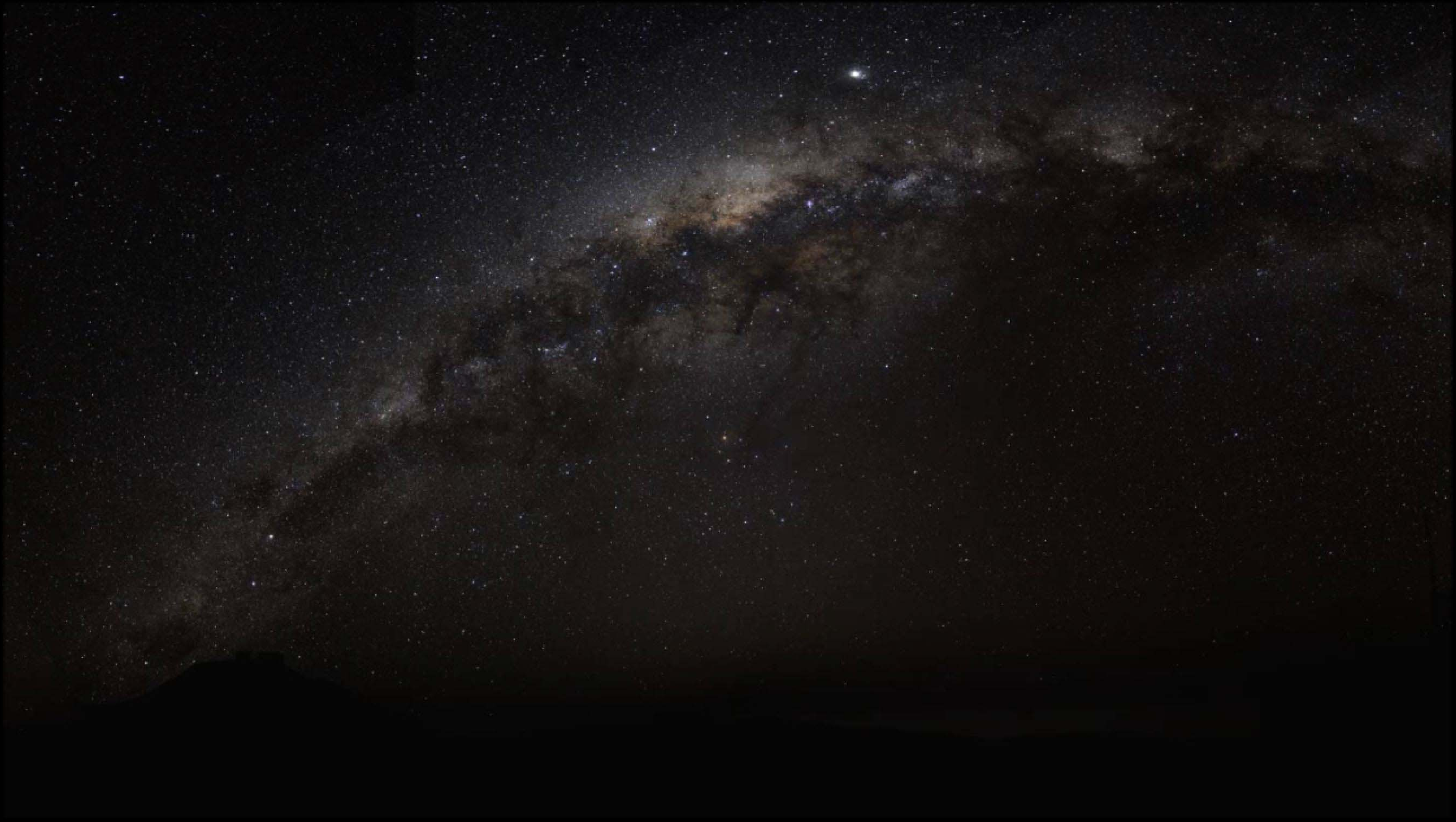


Carl Seyfert
(1911-1960)



NASA/HST/ESA/ Ford et al

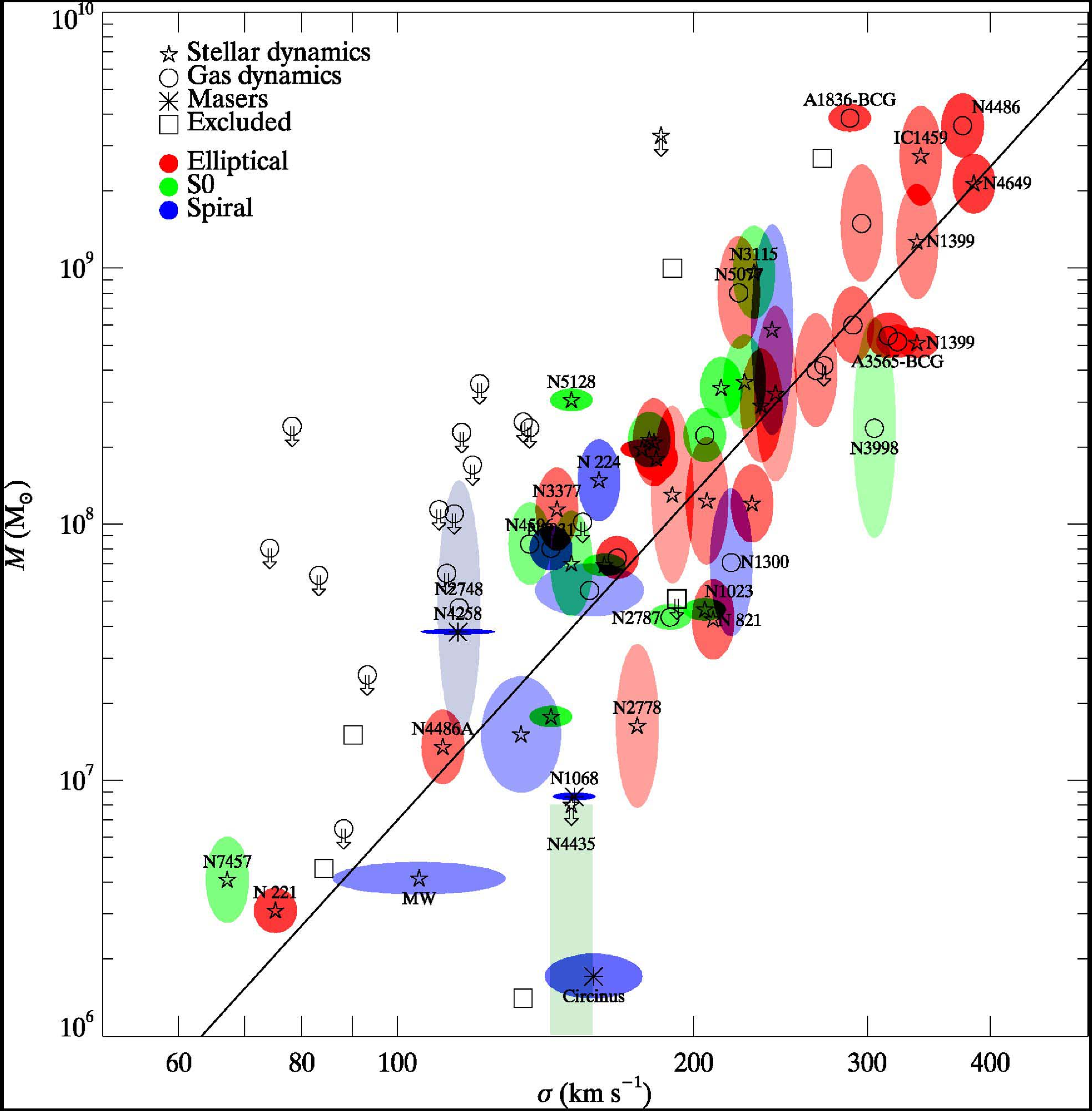
NASA/HST/ESA



ESO

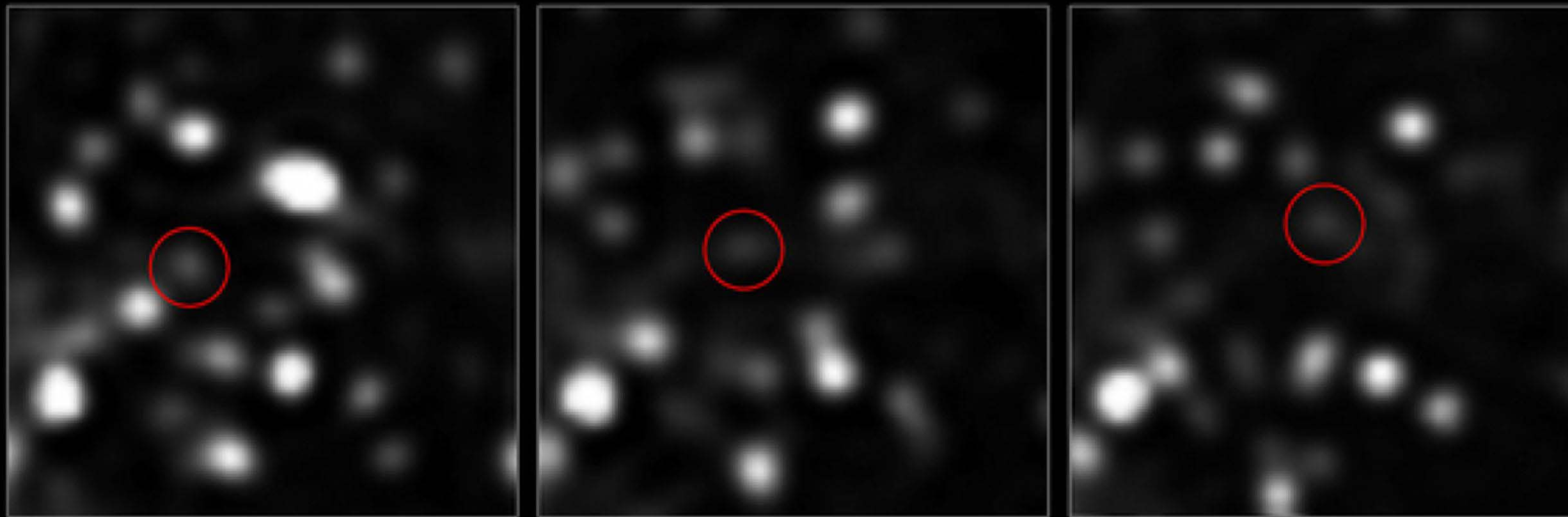

L Comolli

Mass of black hole



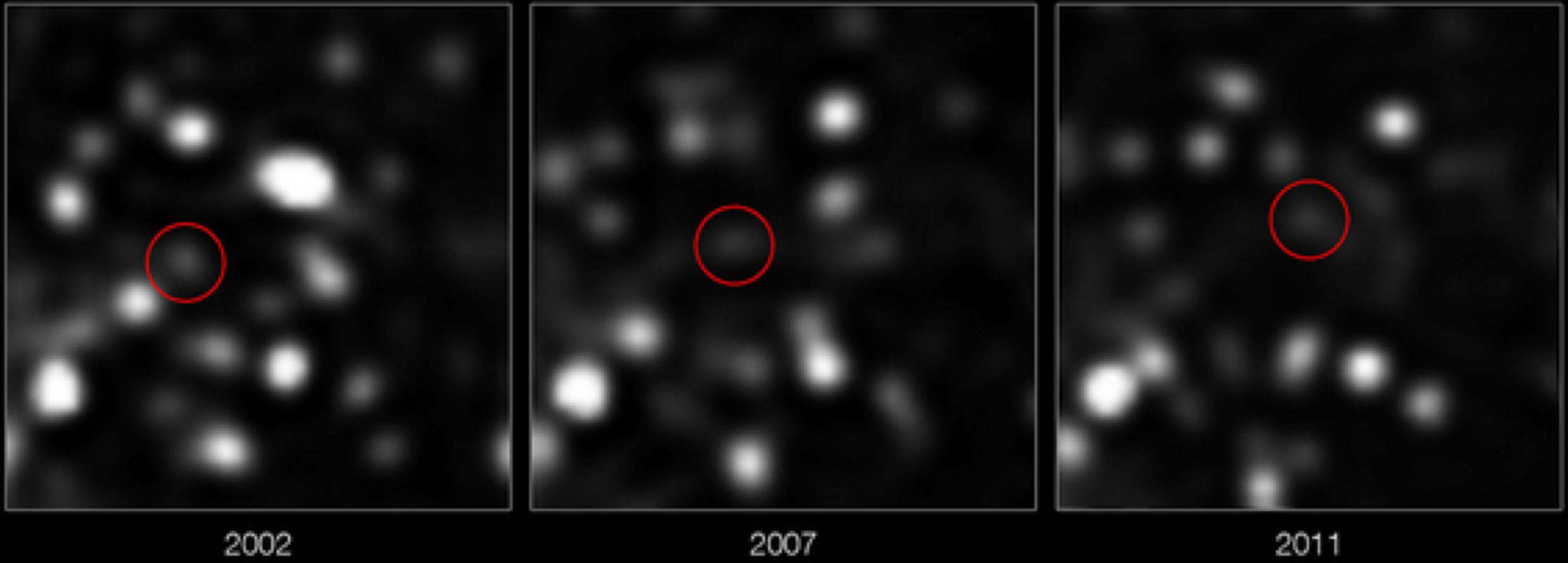
Mass of host galaxy

Gultekin et al

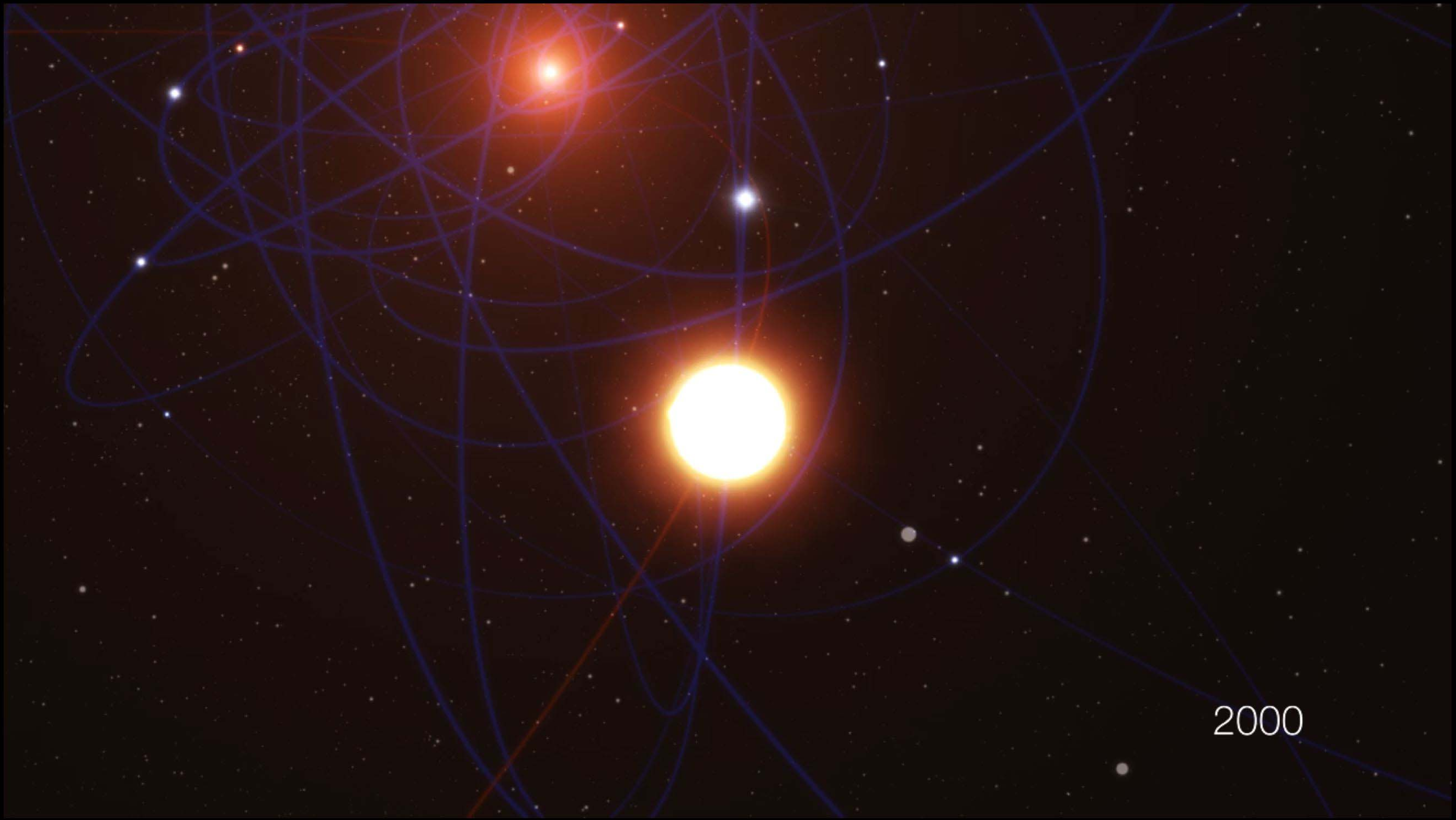


2002 2007 2011

ESO / VLT



ESO / VLT



ESO / S Gillessen / MPE / M Schartmann / L Calcada cloud velocity

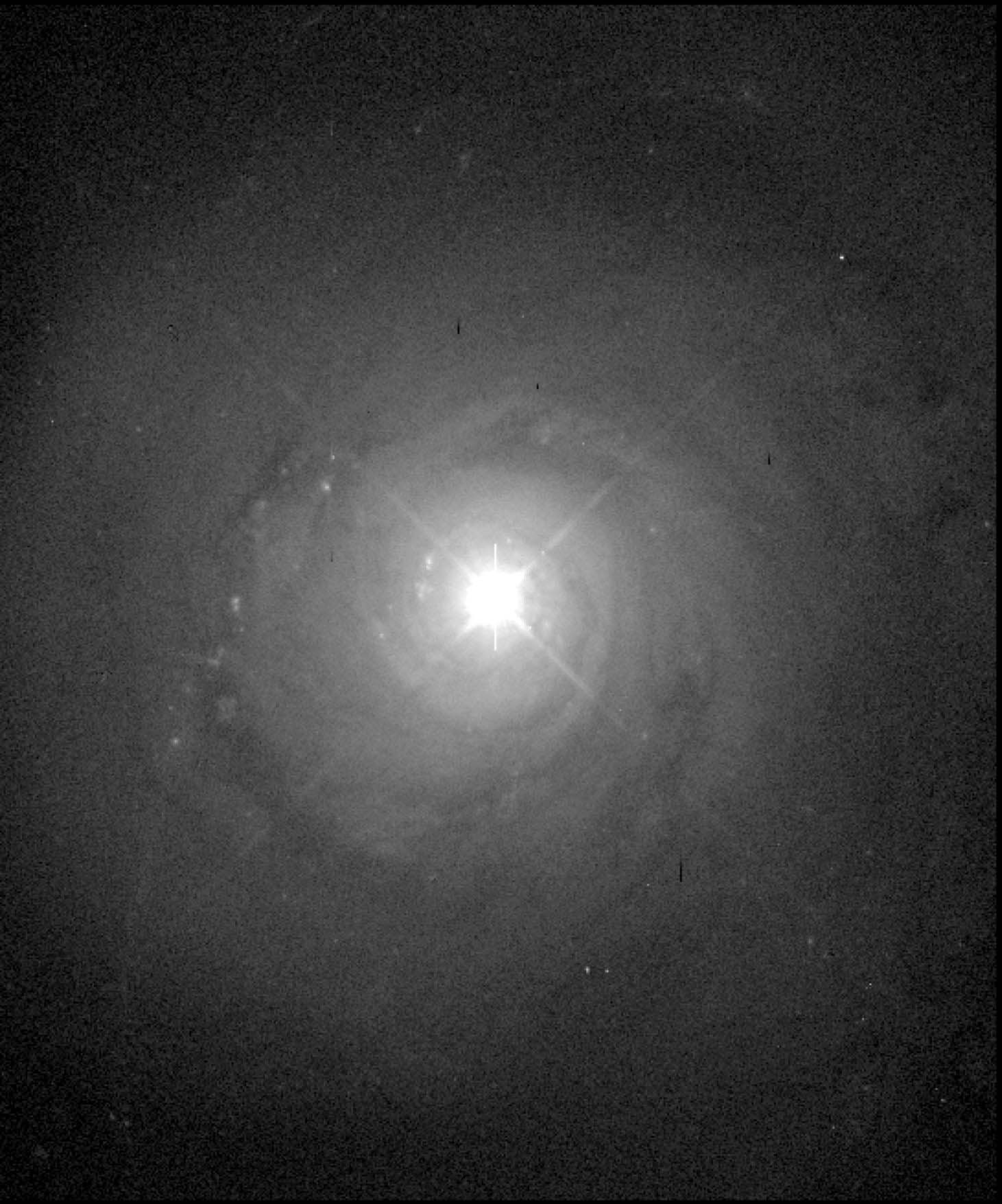
extent of cloud

ESO / S Gillessen

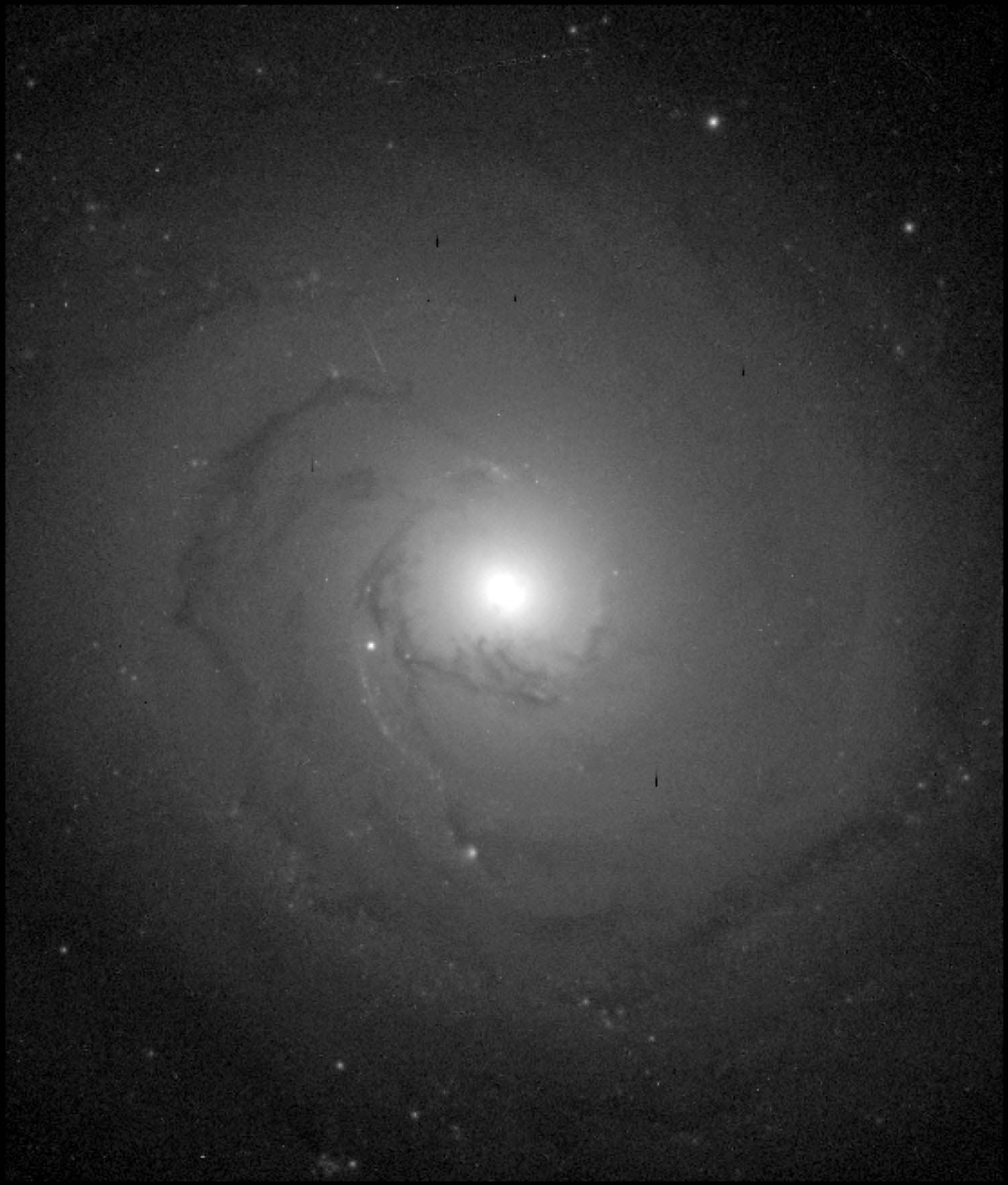
WED 20TH NOVEMBER 1PM

COMETS

ESA/NASA/HST



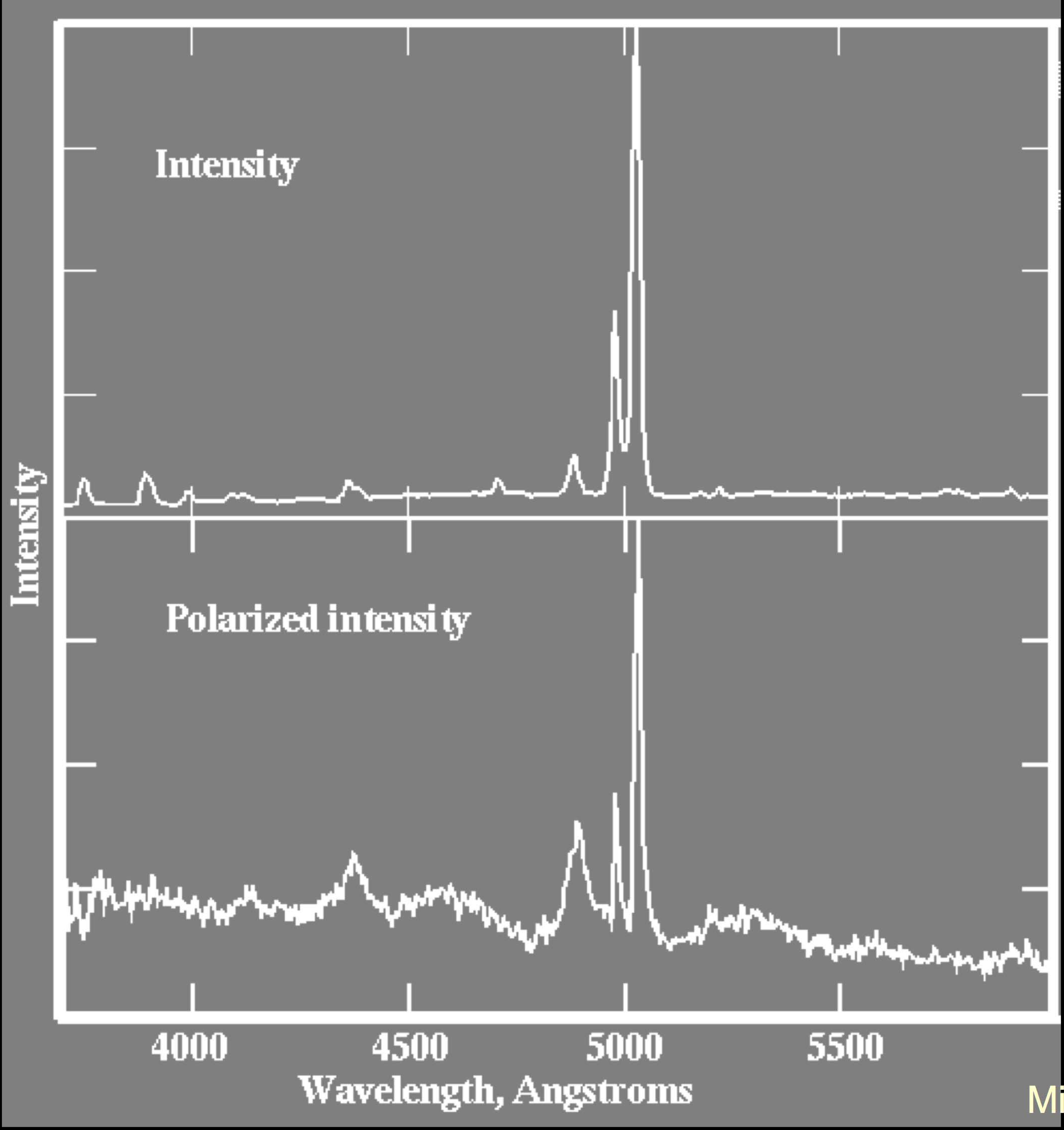
NGC5548
Seyfert galaxy



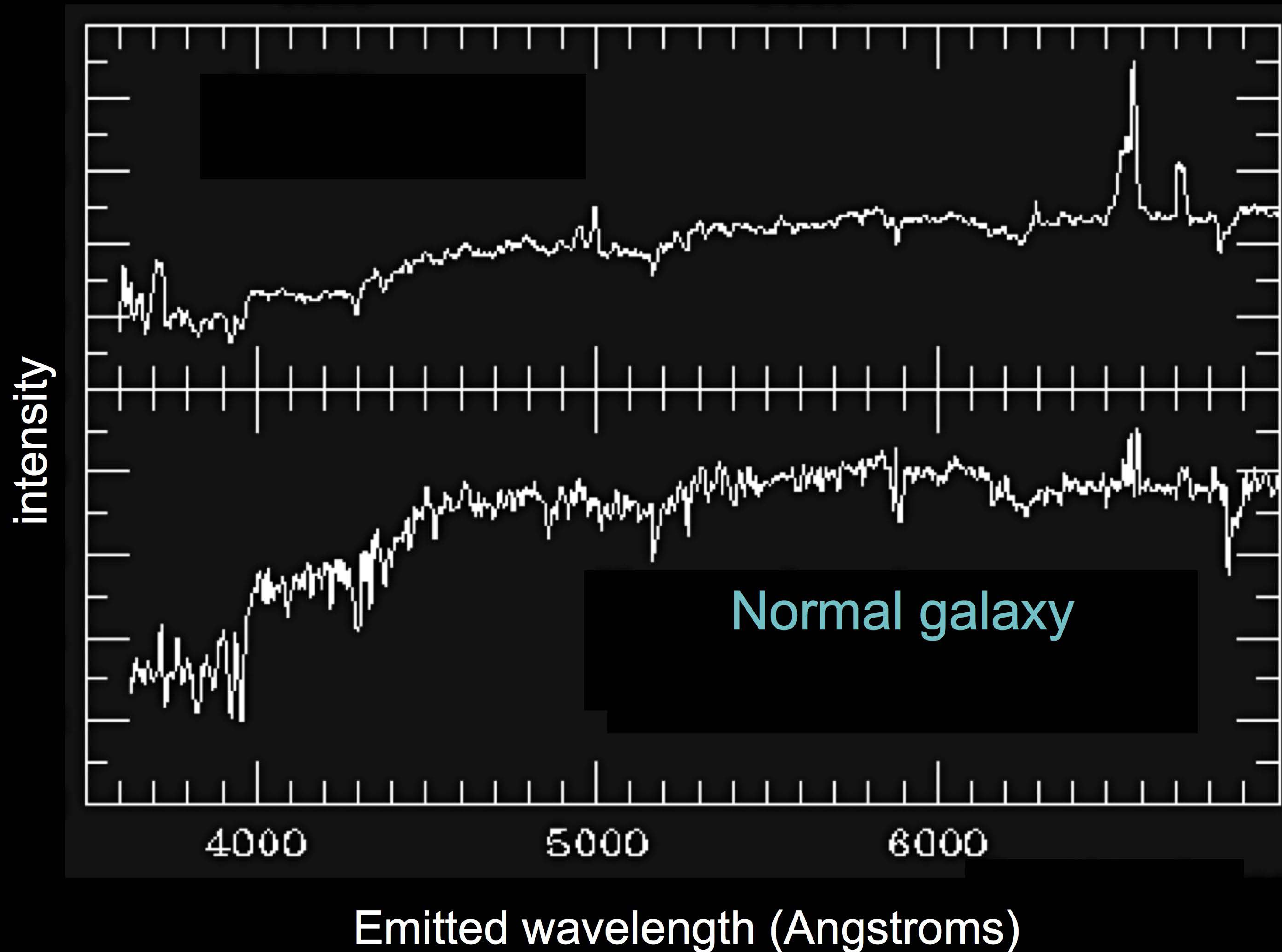
NGC3277
ordinary spiral galaxy

W Keel (U of Alabama)

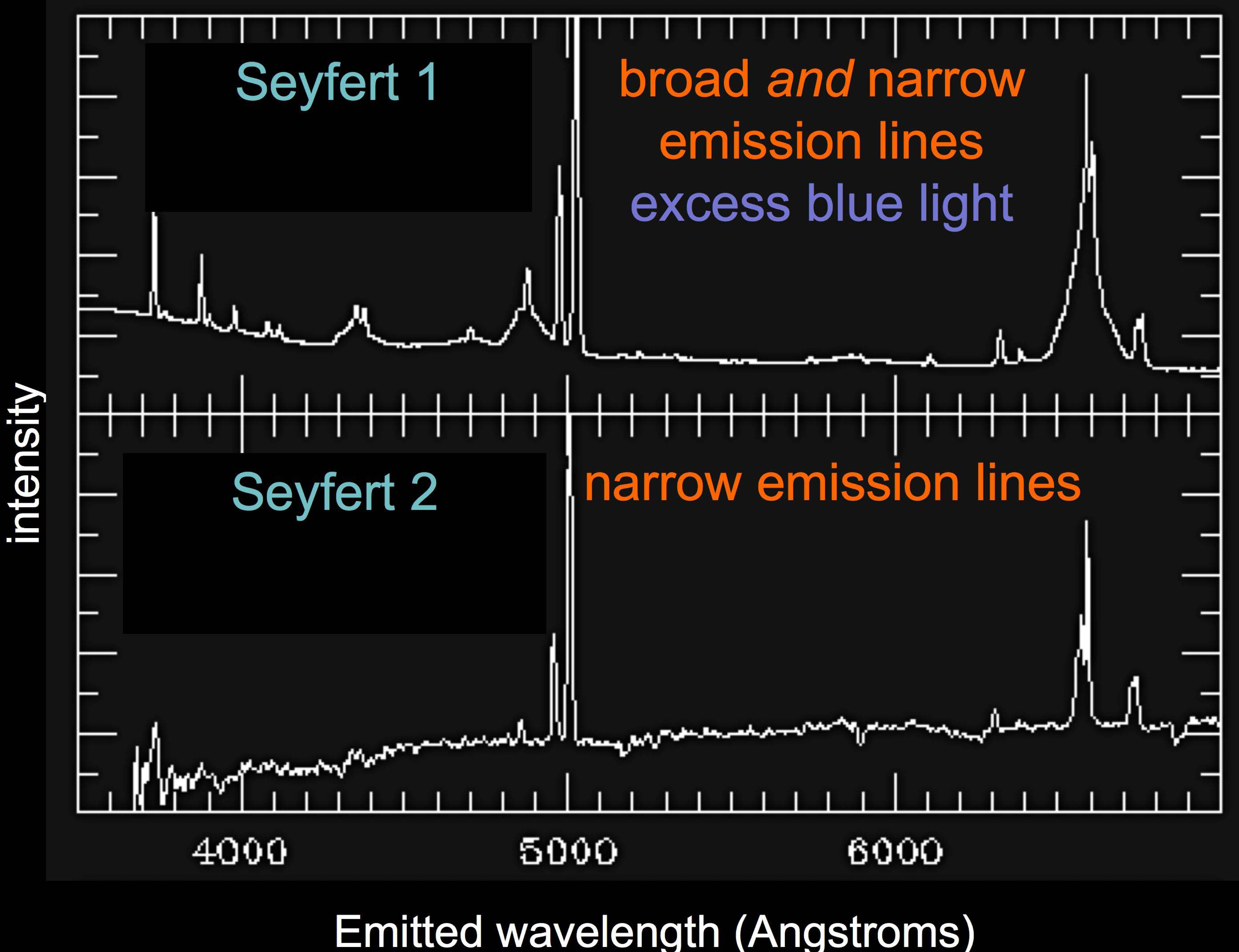
ESO/UKIDSS/SDSS



Miller et al 1991



W Keel (U of Alabama)



W Keel (U of Alabama)