



Istituto Nazionale di Astrofisica

INAF

ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

Osservatorio astronomico di Brera

Universo in fiore

I Nuclei Galattici Attivi

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INAF-Osservatorio Astronomico di Brera

8 marzo 2016

10 marzo 1946



Sommario

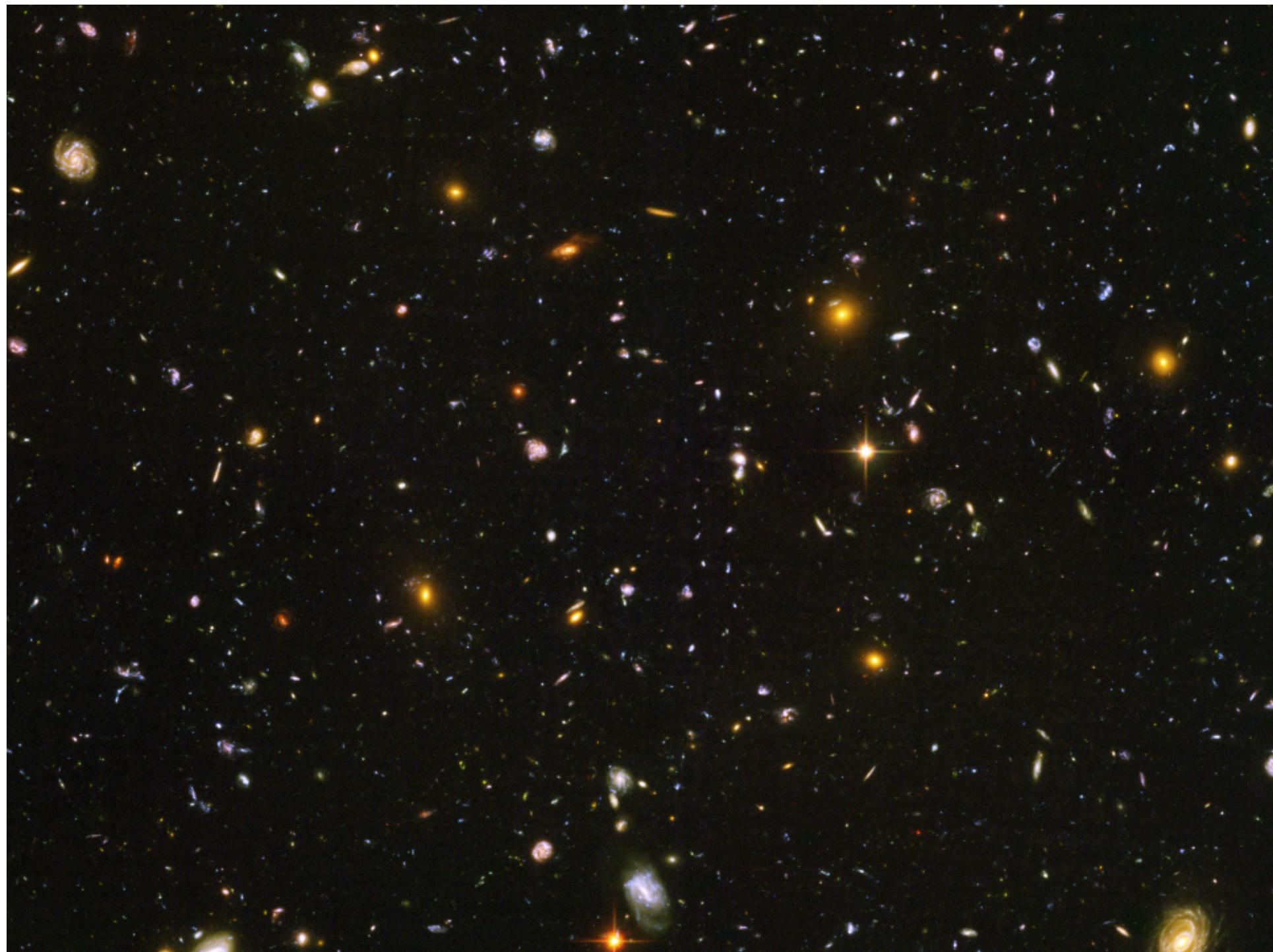
1. Un po' di storia (e ripasso)
2. Strane galassie e tassonomia
3. Proprietà degli AGN
4. Modello unificato
5. [Cosmologia]
6. Accenno a Onde Gravitazionali

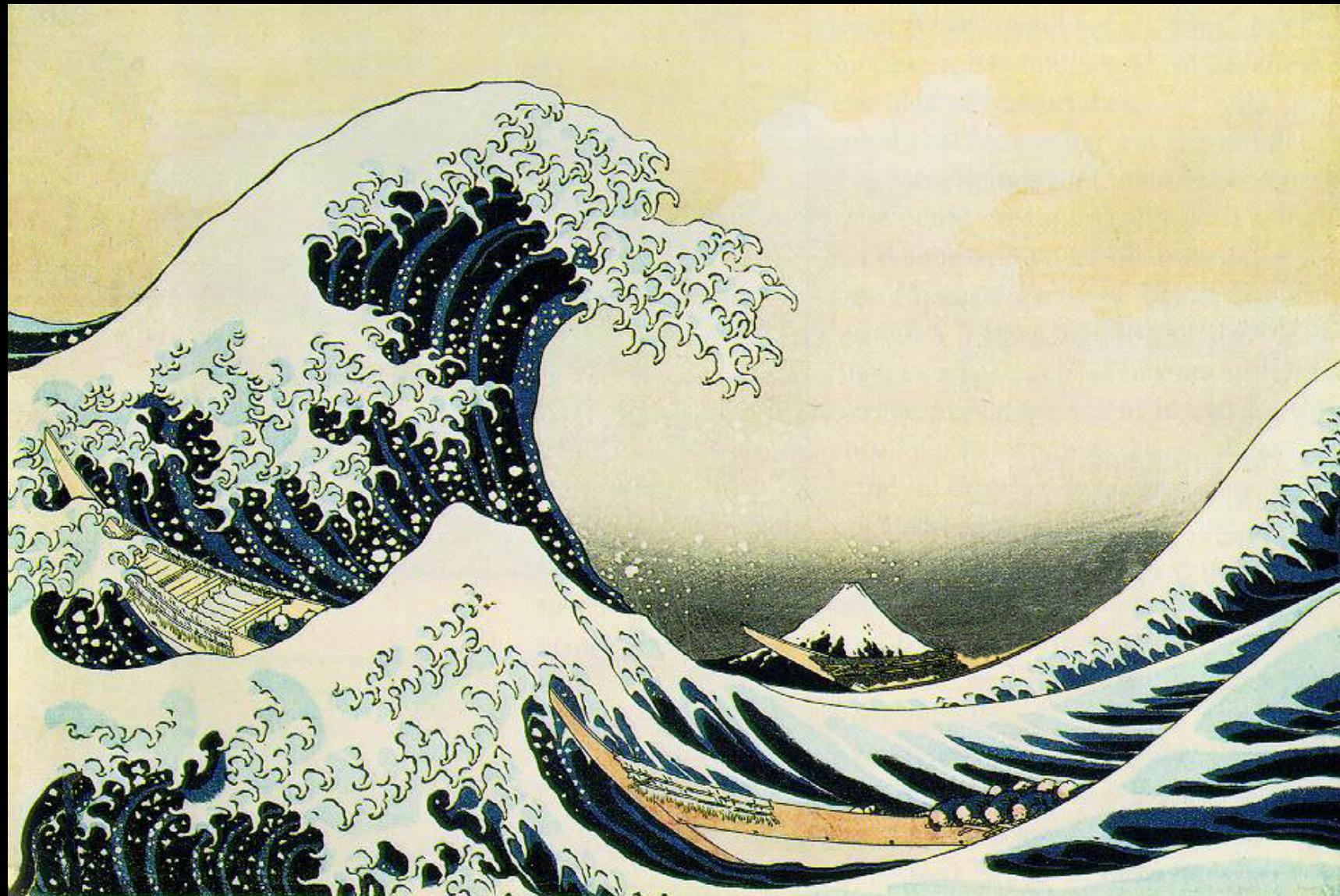
“L'unico vero viaggio verso la scoperta non consiste nella ricerca di nuovi paesaggi, ma nell'avere nuovi occhi”

Marcel Proust, *Alla ricerca del tempo perduto*

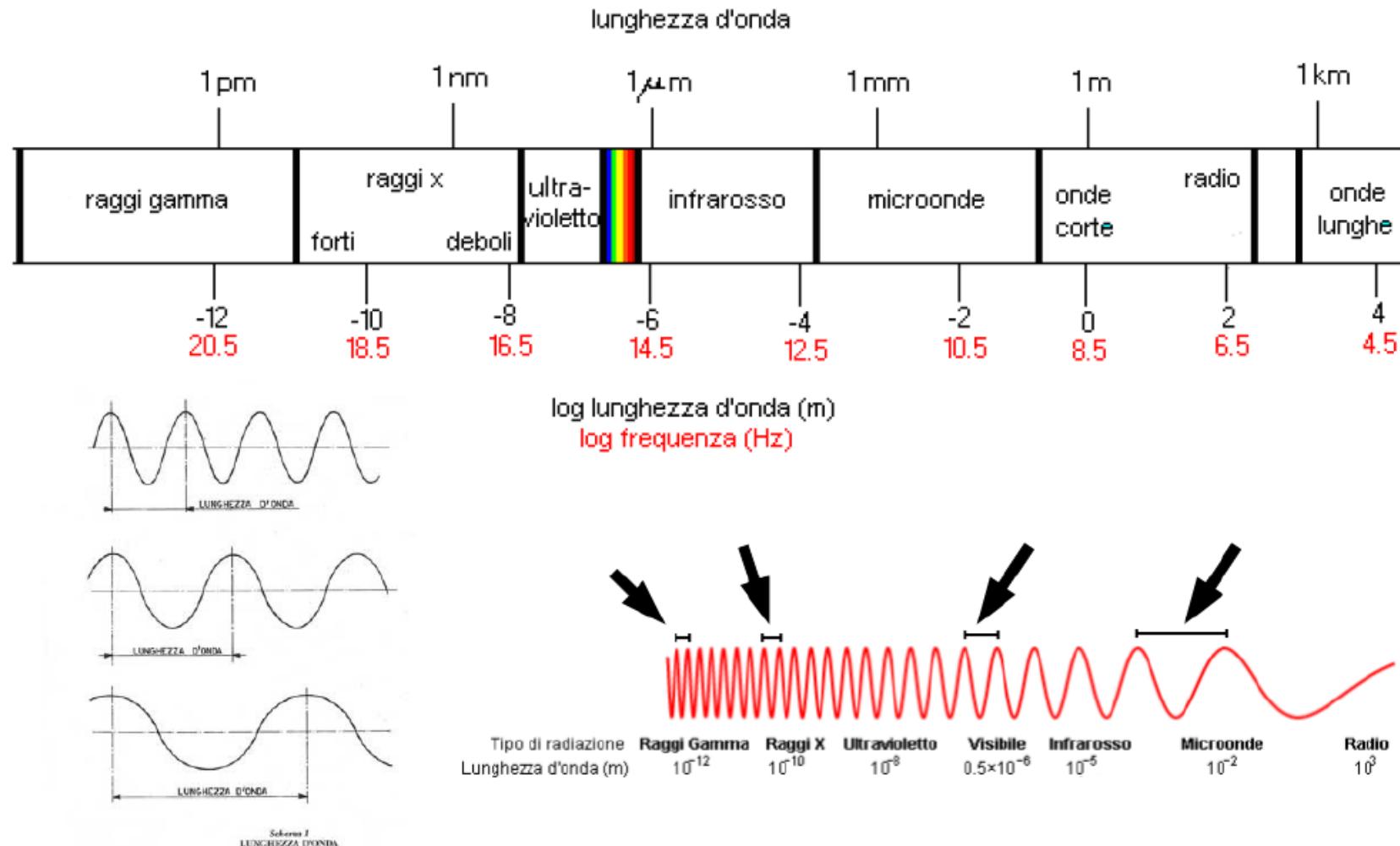
1

Un po' di ripasso





Proprietà della radiazione luce etica





$T = 12,000 \text{ K}$

$\lambda_m \approx 250 \text{ nm}$



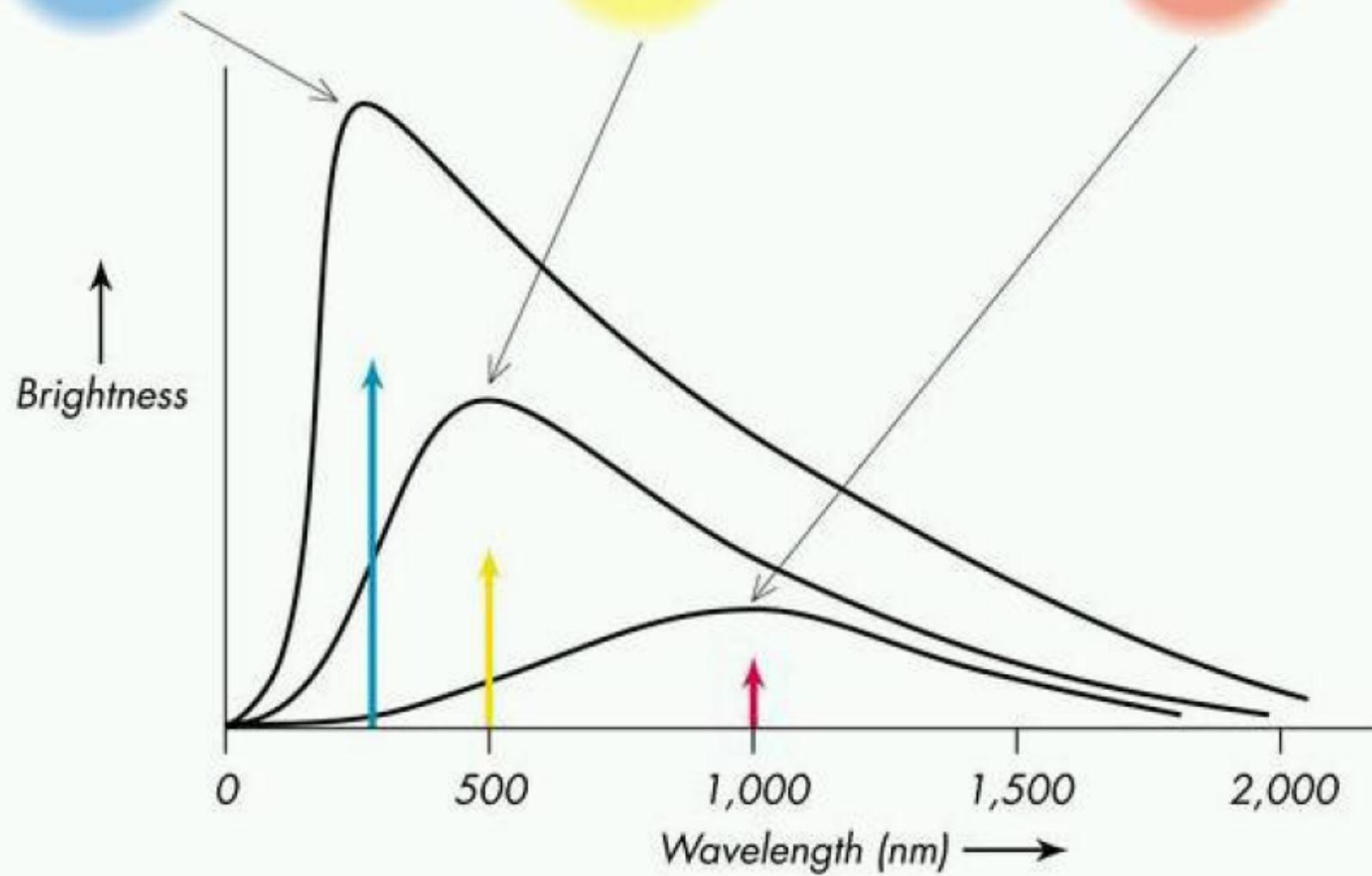
$T = 6000 \text{ K}$

$\lambda_m \approx 500 \text{ nm}$

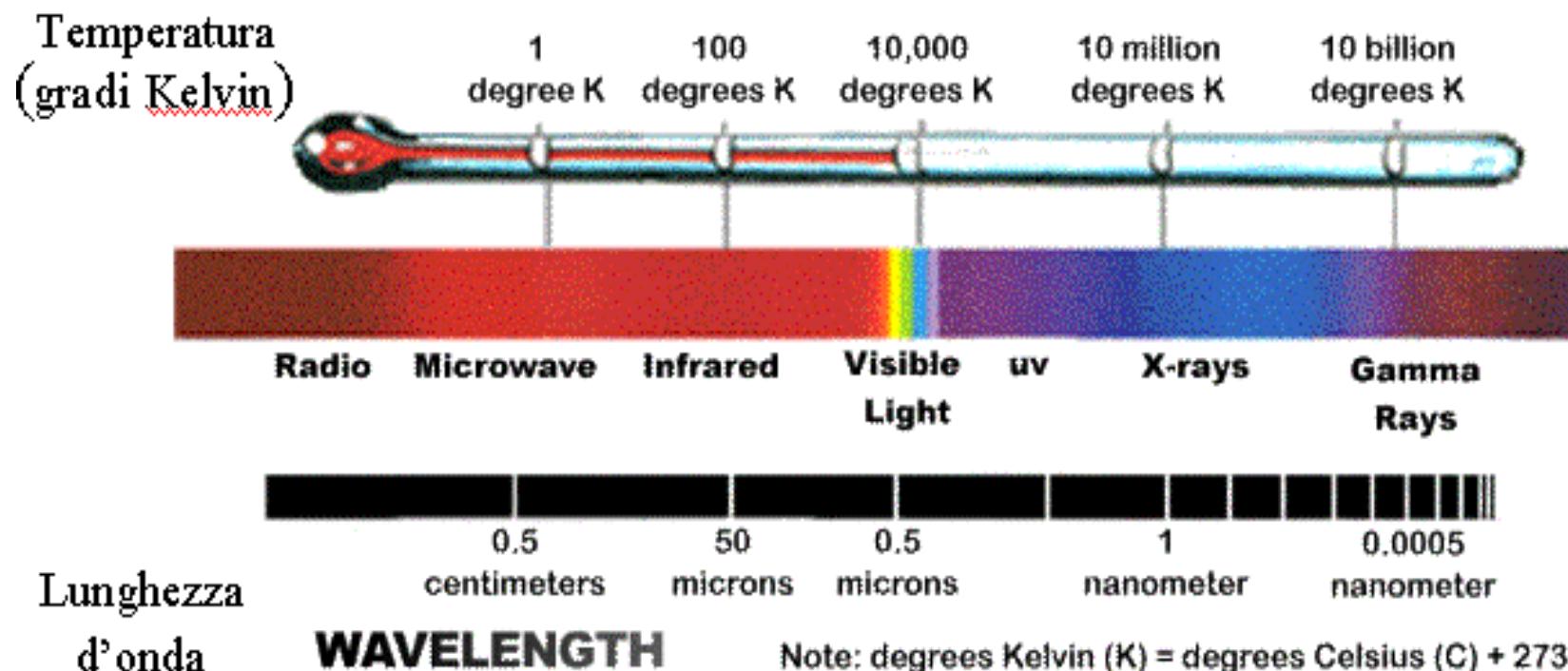


$T = 3000 \text{ K}$

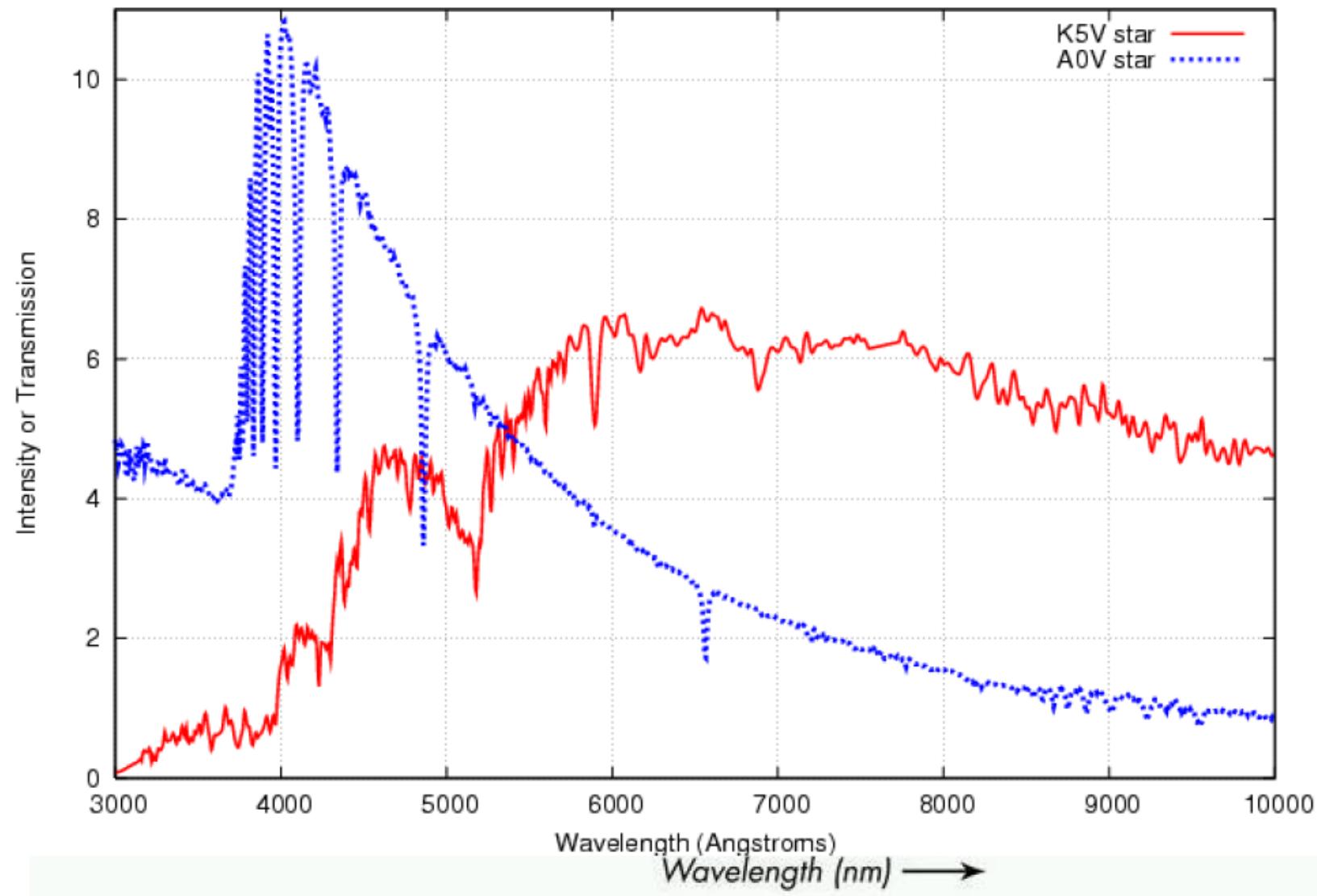
$\lambda_m \approx 1000 \text{ nm}$



Radiazione Termica



Spectra of ordinary stars



Transizioni quantizzate

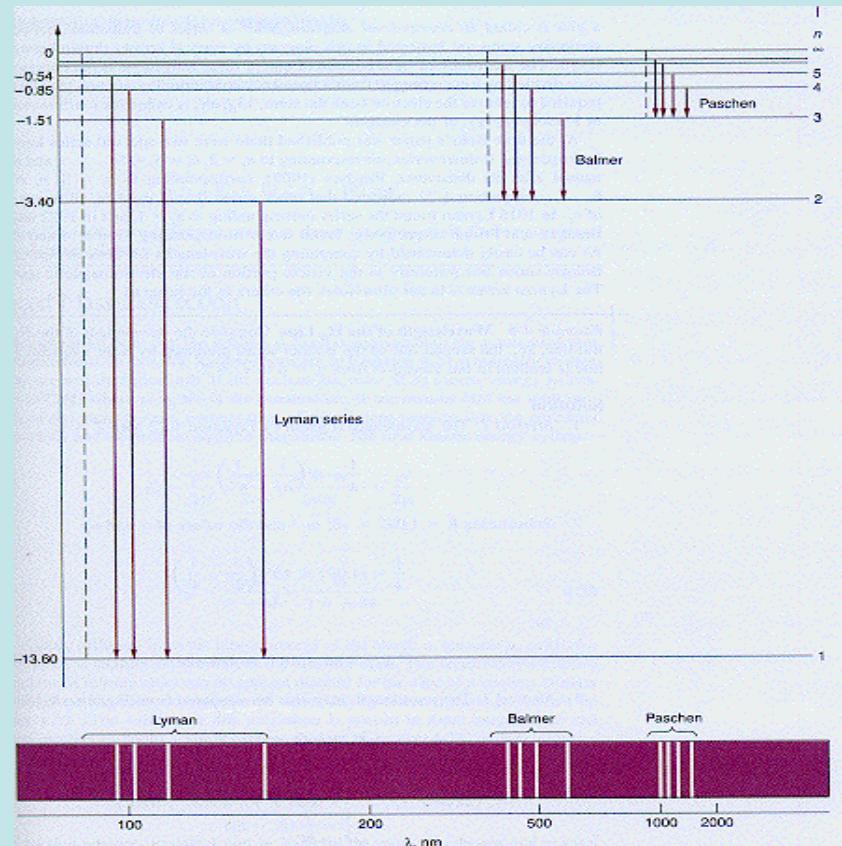
Le energie di un atomo di idrogeno seguono la legge

$$E_n = -\frac{Z^2}{n^2} \times 13.6 \text{ eV}$$

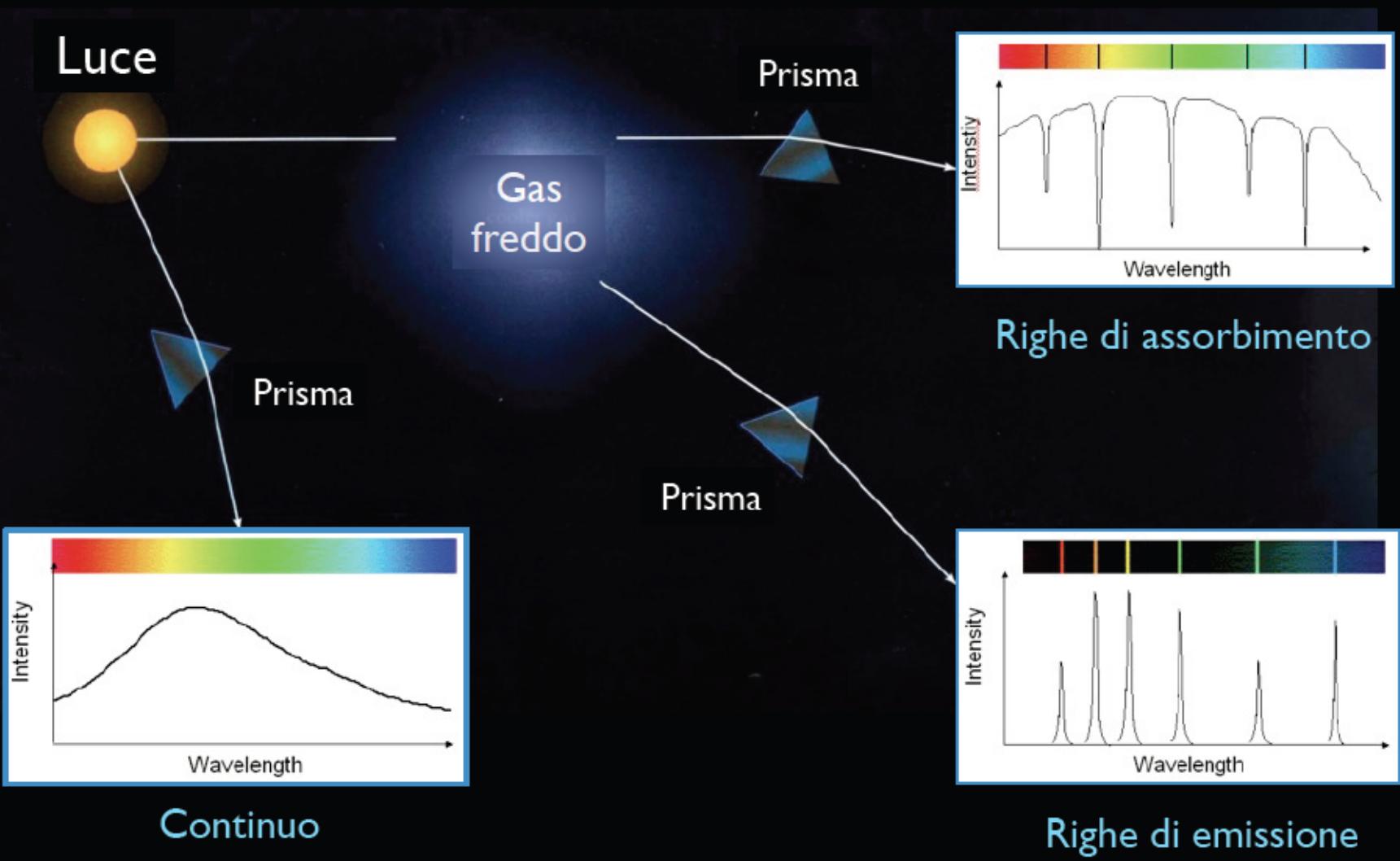
Emissione o assorbimento di fotoni tra livelli quantizzati di un atomo [o di uno ione]

Energie dei fotoni: $hf_{mn} = E_n - E_m$

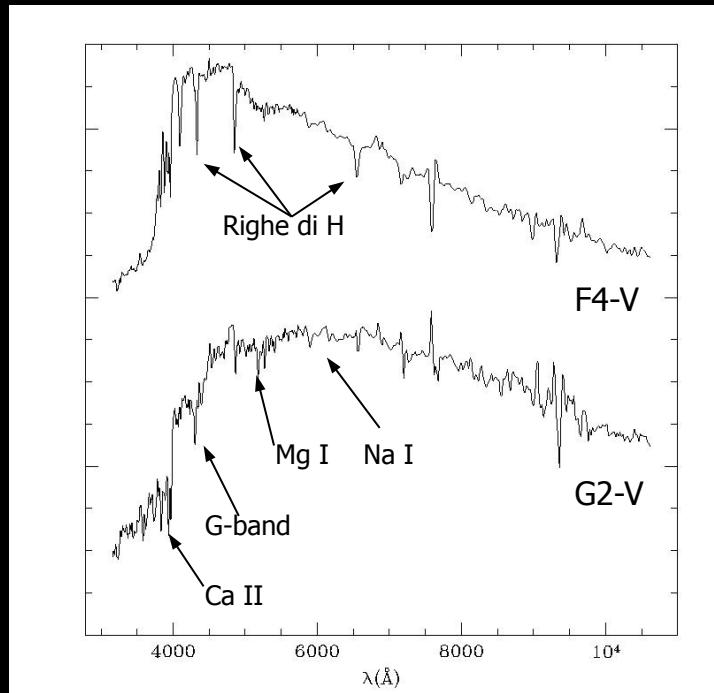
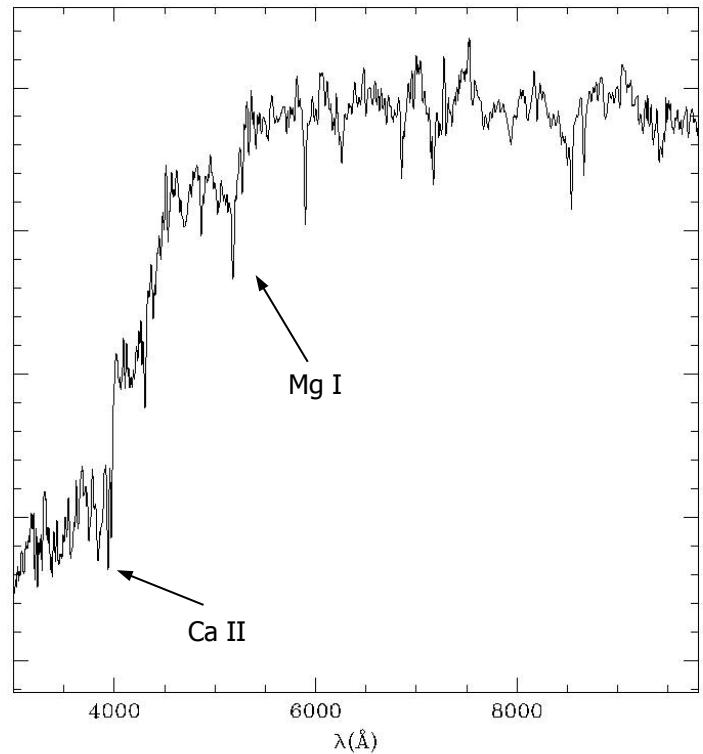
1 fotone di $f=10^{15} \text{ Hz}$ $E = 6.62 \times 10^{-19} \text{ Joule}$ lampadina: 100 joule/sec
 $\sim 10^{20}$ fotoni/sec



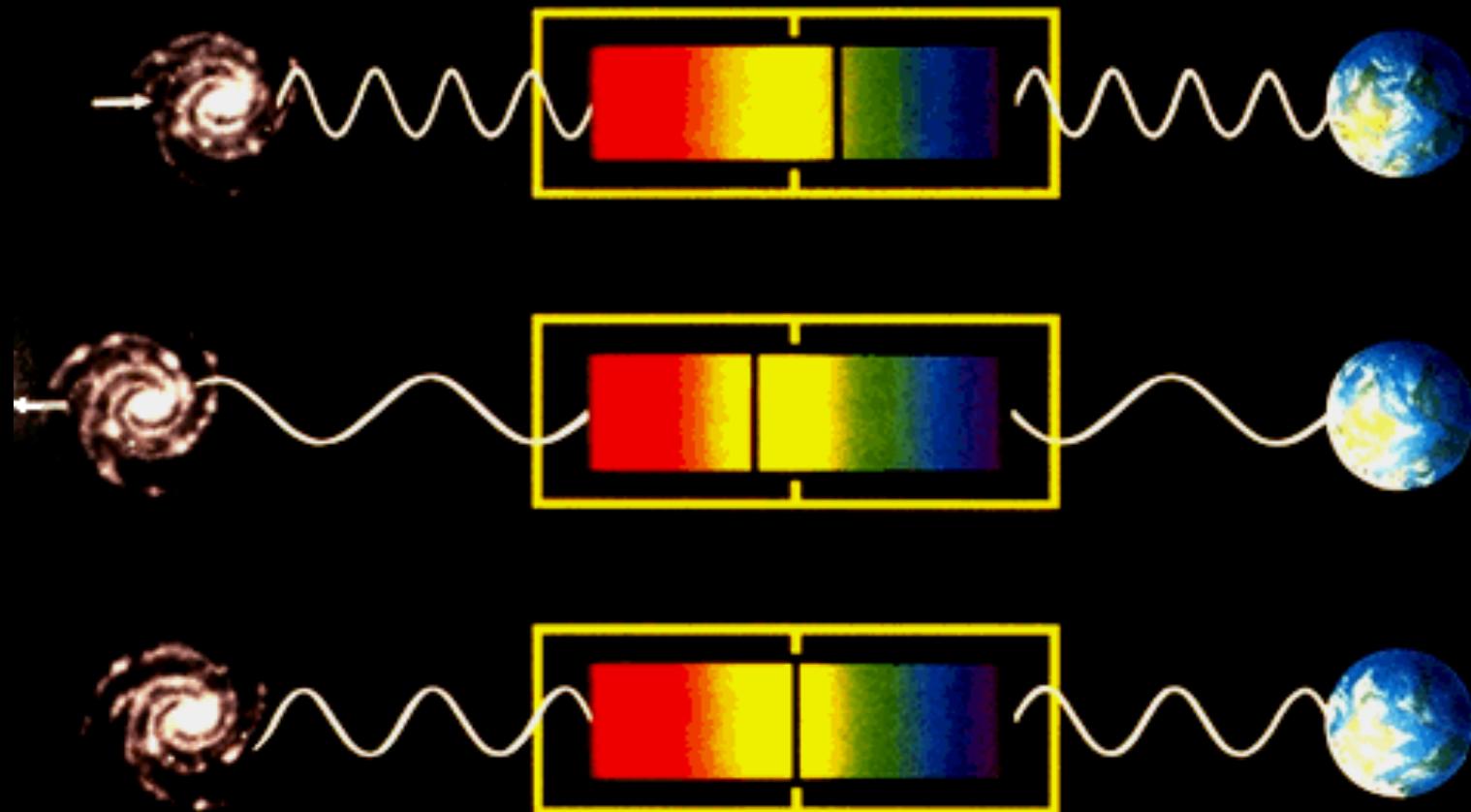
Tipi di spettro



Spettro di una galassia

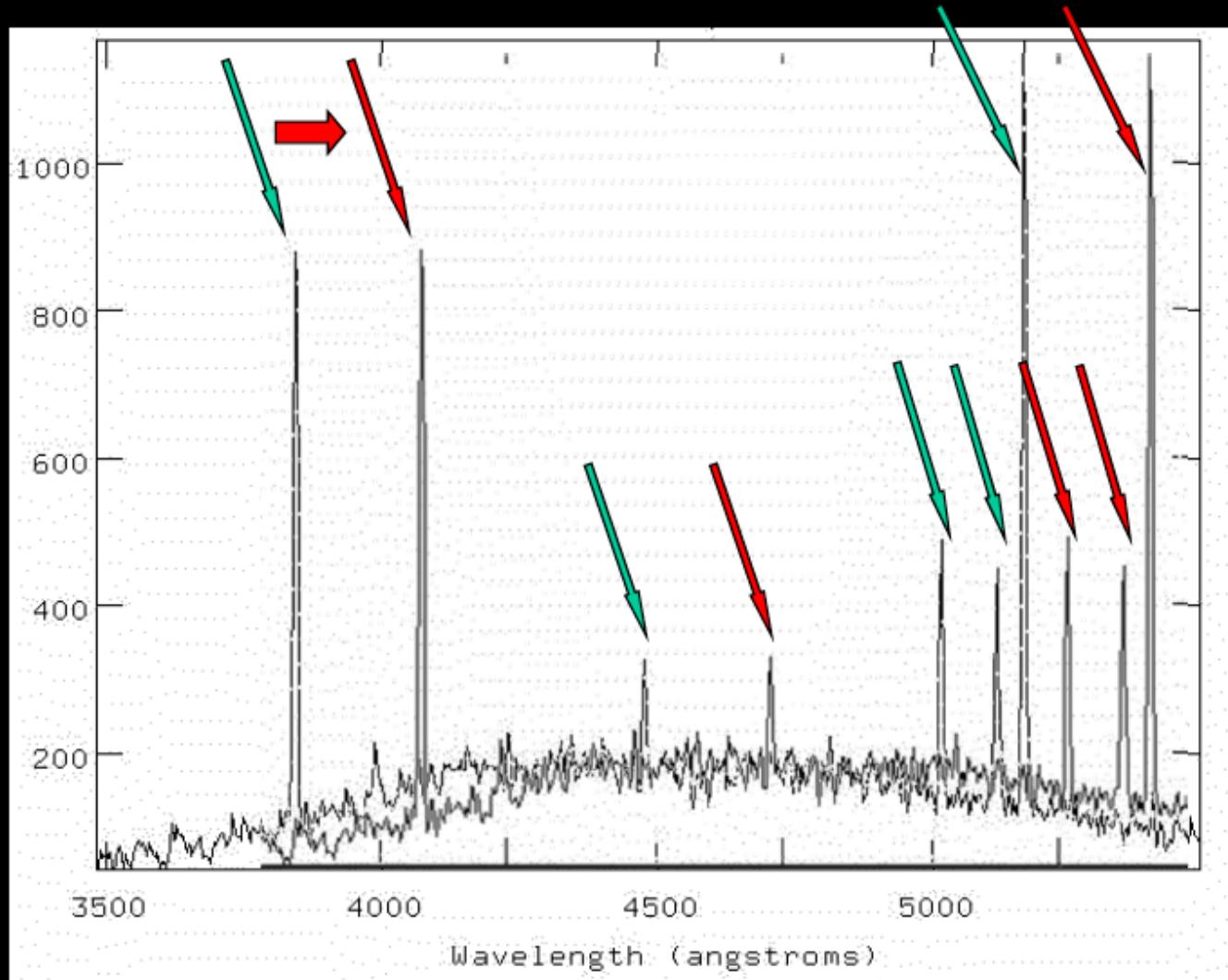


La radiazione di una stella che si avvicina alla terra è più blu

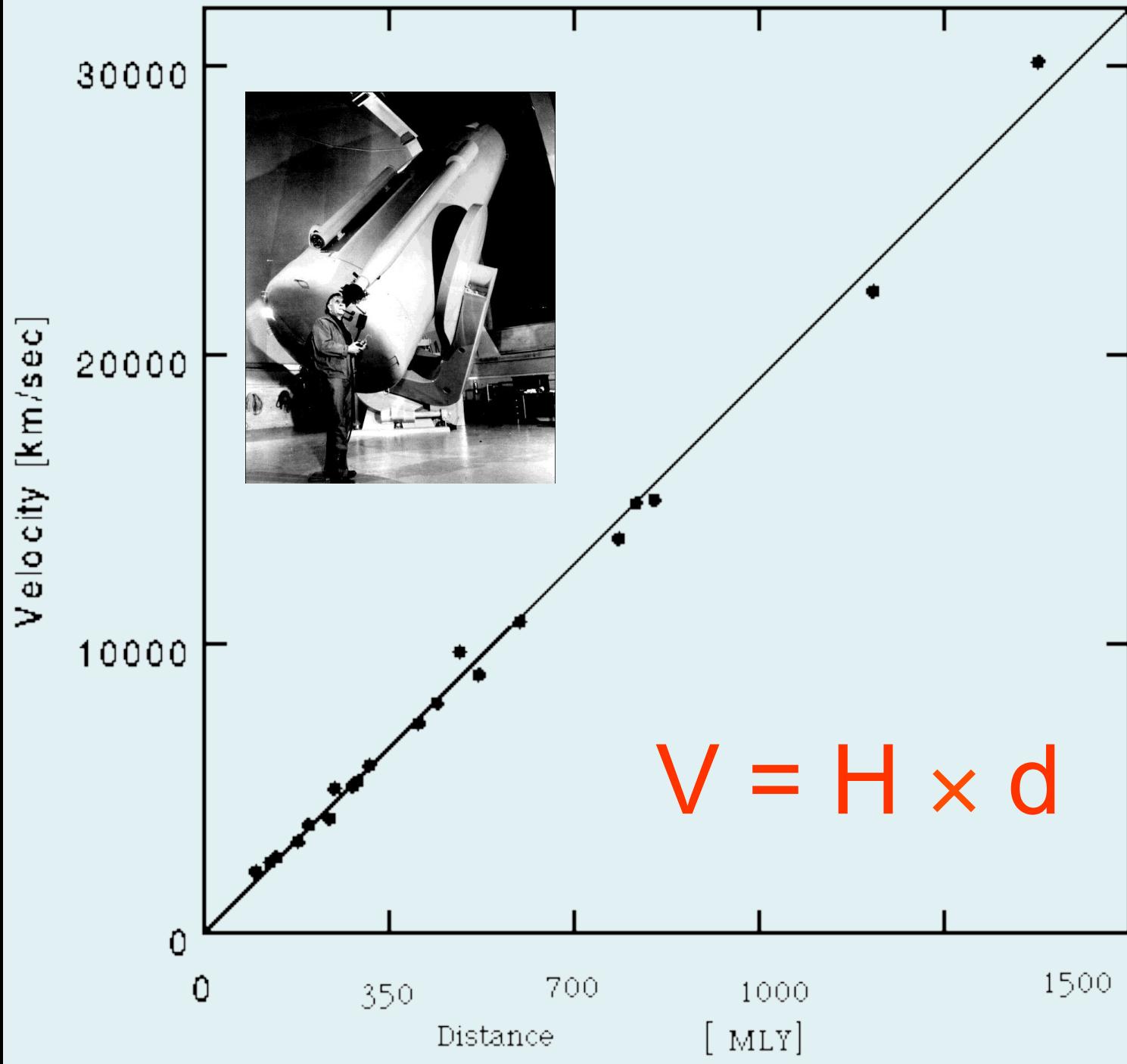


La radiazione di una stella che si allontana dalla terra è più rossa

Effetto Doppler – sorgente in allontanamento

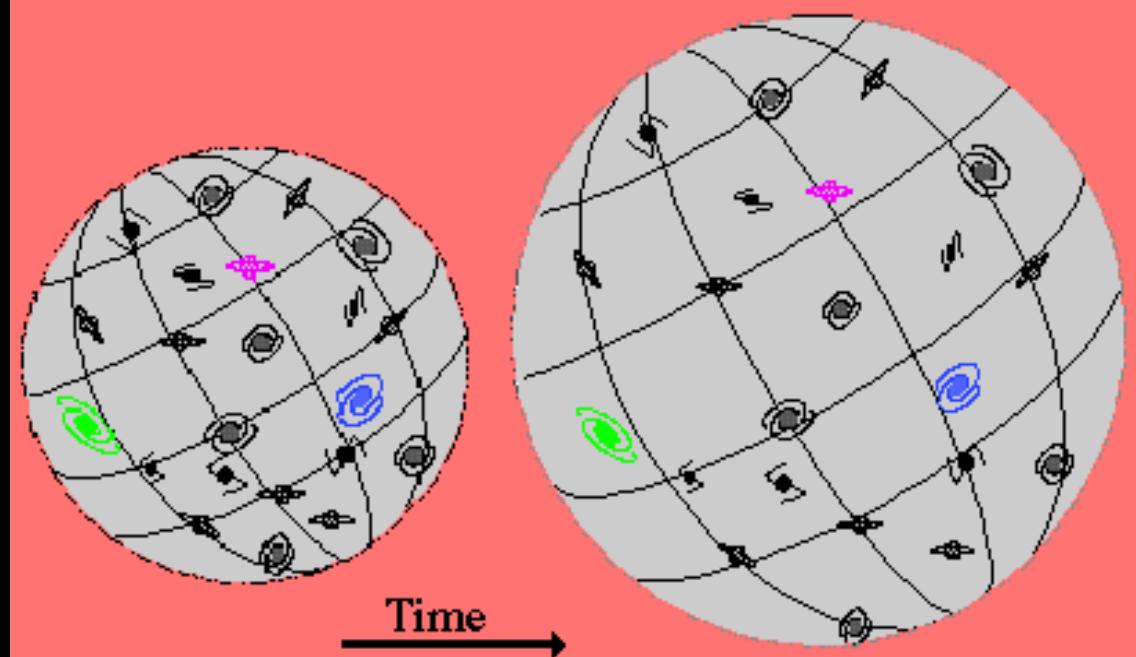


le righe si spostano quindi verso il rosso: **redshift**



Hubble elabora una **relazione tra distanza e velocità** (confermando i risultati teorici del belga Lemaître).

Gli effetti della velocità (redshift) vengono usati come misura della **distanza**.



*A RELATION BETWEEN DISTANCE AND RADIAL VELOCITY
AMONG EXTRA-GALACTIC NEBULAE*

By EDWIN HUBBLE

MOUNT WILSON OBSERVATORY, CARNEGIE INSTITUTION OF WASHINGTON

Communicated January 17, 1929

Determinations of the motion of the sun with respect to the extra-galactic nebulae have involved a K term of several hundred kilometers which appears to be variable. Explanations of this paradox have been sought in a correlation between apparent radial velocities and distances, but so far the results have not been convincing. The present paper is a re-examination of the question, based on only those nebular distances which are believed to be fairly reliable.

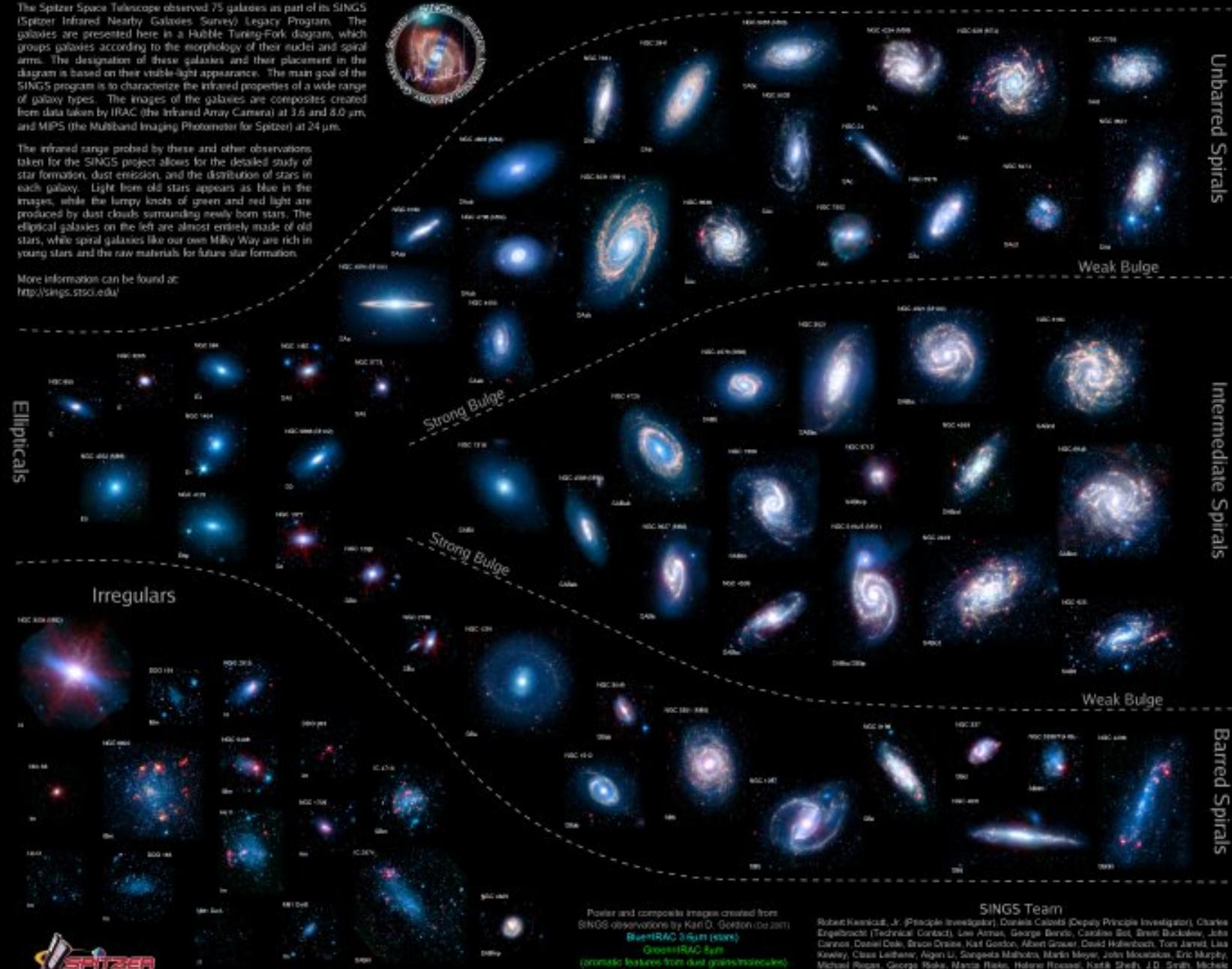
Si tratta della base osservativa che condurrà alla formulazione della teoria del **Big Bang**.

The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork

The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 μm , and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 μm .

The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.

More information can be found at:
<http://sings.stsci.edu/>



Polar and composite images created from SINGS observations by Karl D. Gordon (c. 2001)
Blue+IRAC 3.6 μm (nucleus)
Green+IRAC 8.0 μm (dust features from dust grain simulations)
Red+MIPS 24 μm (warm dust)

SINGS Team
Robert Kennicutt, Jr. (Principal Investigator), Donalea Calzetti (Deputy Principle Investigator), Charles Engelbracht (Technical Contact), Lee Armus, George Bechtel, Caroline Bell, Brett Buckalew, John Danziger, Daniel Dale, Bruce Draine, Karl Gordon, Albert Grauer, David Hollenbach, Tom Janett, Lisa Kewley, Claus Leitherer, Argon Li, Sangtae Malhotra, Martin Meyer, John Moustakas, Eric Murphy, Michael Rieger, Georgia Rule, Marica Rieke, Helene Roussel, Kartik Sheth, J.D. Smith, Michele Thornley, Pebbles Walker & George Helfer



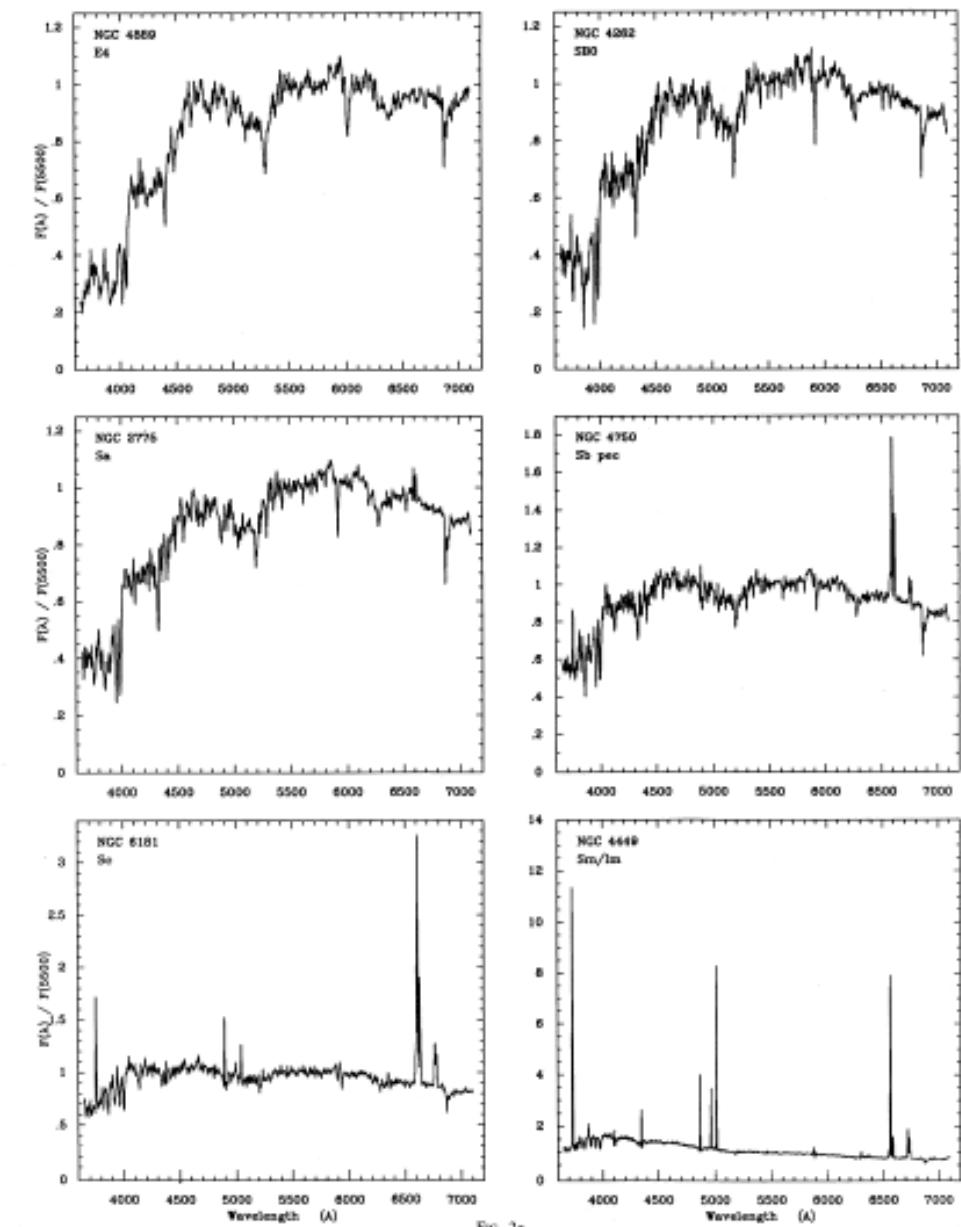
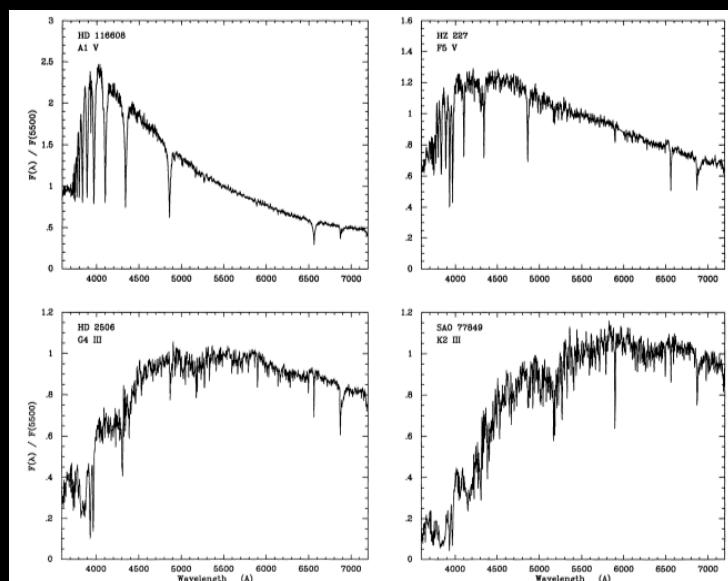


FIG. 2a

Fig. 2.—(a) The spectral Hubble sequence. Galaxies are shown in order of increasing Hubble type from top to bottom. See Table 3 for data on the galaxies. (b) Same spectra as in (a), but expanded in the blue to show the properties of the absorption-line spectra.

Spettri di galassie
in ordine di “tipo di
Hubble”

Sono la SOMMA
degli spettri stellari
Un poco “spostati”
a causa del redshift



2

Strane galassie e Tassonomia

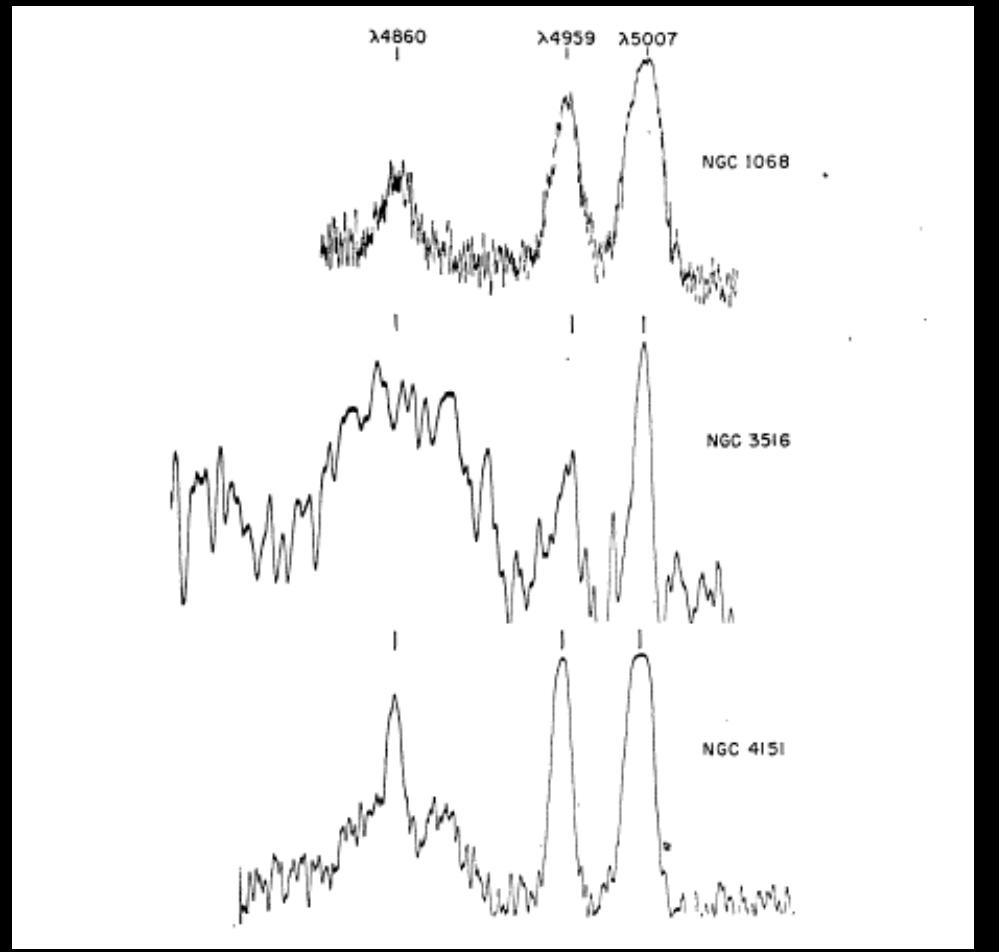
dal greco ταξις, *taxis*, "ordinamento", e νομος, *nomos*, "norma" o "regola"
è, nel suo significato più generale, la disciplina della classificazione

Nel 1943 si scoprono delle “strane” galassie: “Nuclear Emission in Spiral Nebulae” by Carl K. Seyfert

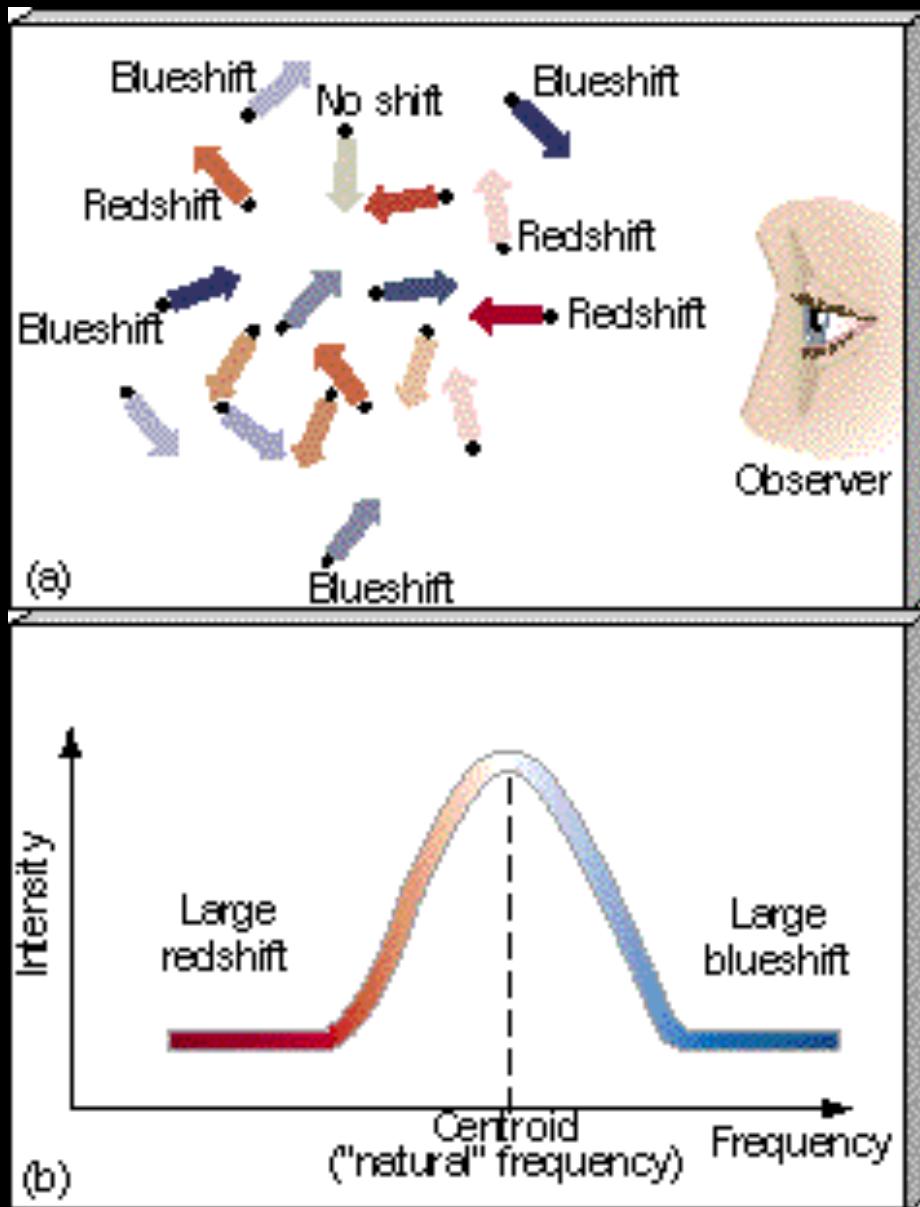


Carl Seyfert al telescopio da 24 pollici
della Vanderbilt University.
(Credit: U. Vanderbilt)

- Nucleo
- Variabilità < 1 anno
- Righe di Emissione



Spettri - righe allargate



Un diverso aspetto
dell'effetto Doppler

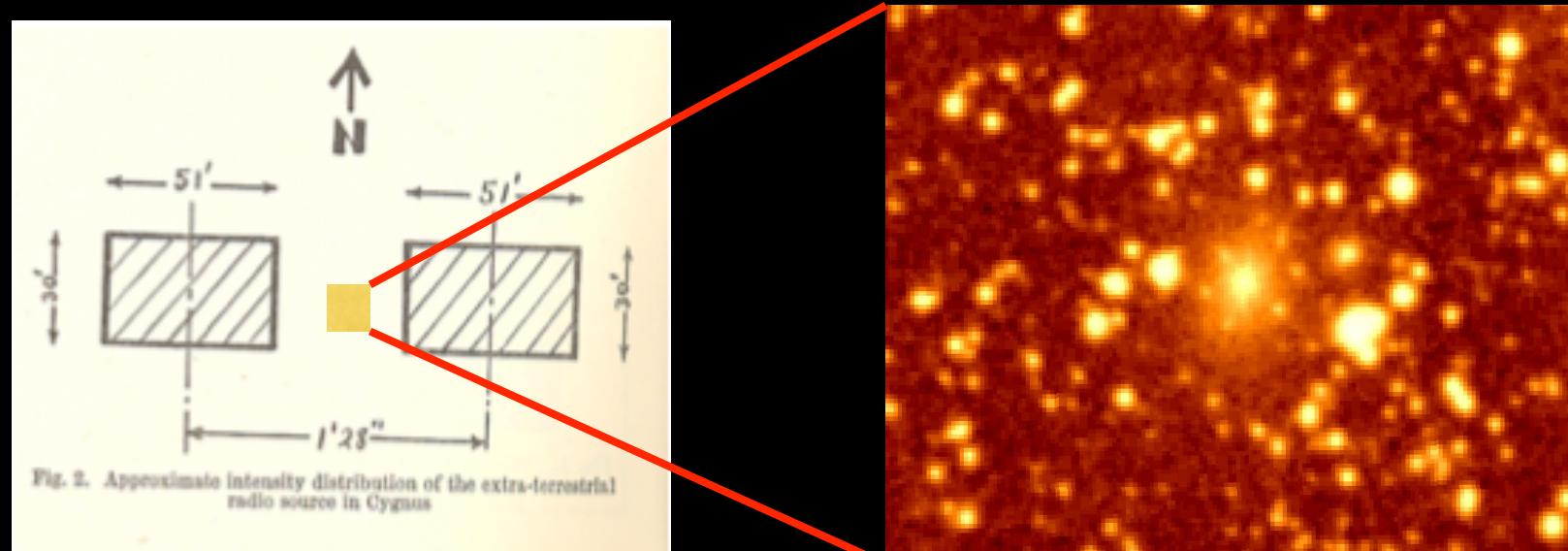
La riga si allarga a
causa del moto
degli atomi

I primi radiotelescopi



Identificazione delle radio sorgenti

- Se l'identificazione della radio sorgente è corretta, allora non c'è alcuna correlazione tra l'emissione di onde radio e la galassia



Osservazione di 3C 273

Dal 3° catalogo di Radio Sorgenti di Cambridge (Edge et al 1959)
Che contiene 471 sorgenti di onde radio (159 MHz)

Schmidt 1962: 3C 286 riga a 5170 Å° Non identificato!

Matthews & Sandage 1963 “Radio stars” 3C 48 3C 169 e 3C 286
Hazard + 1963 occultazione lunare



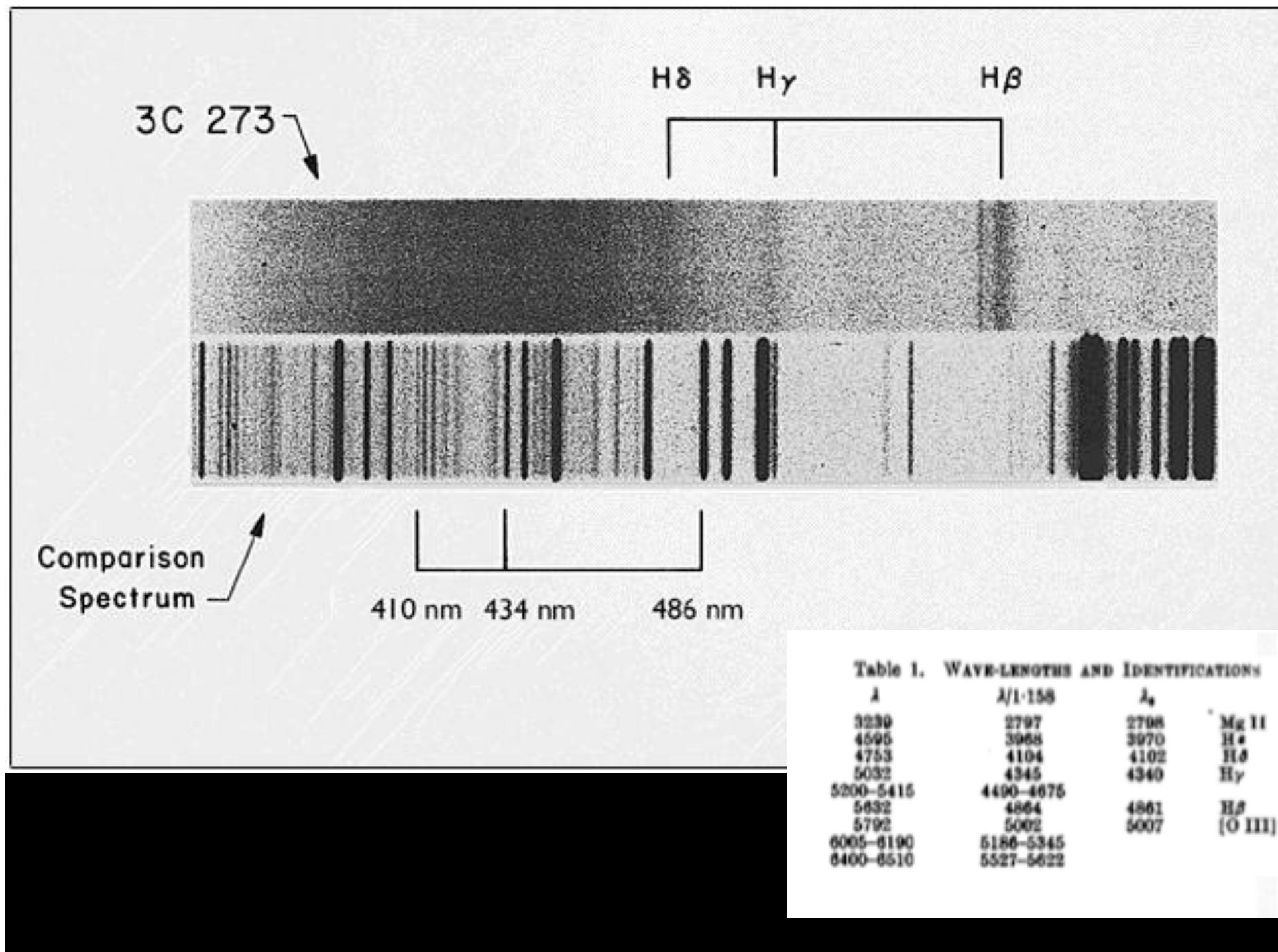
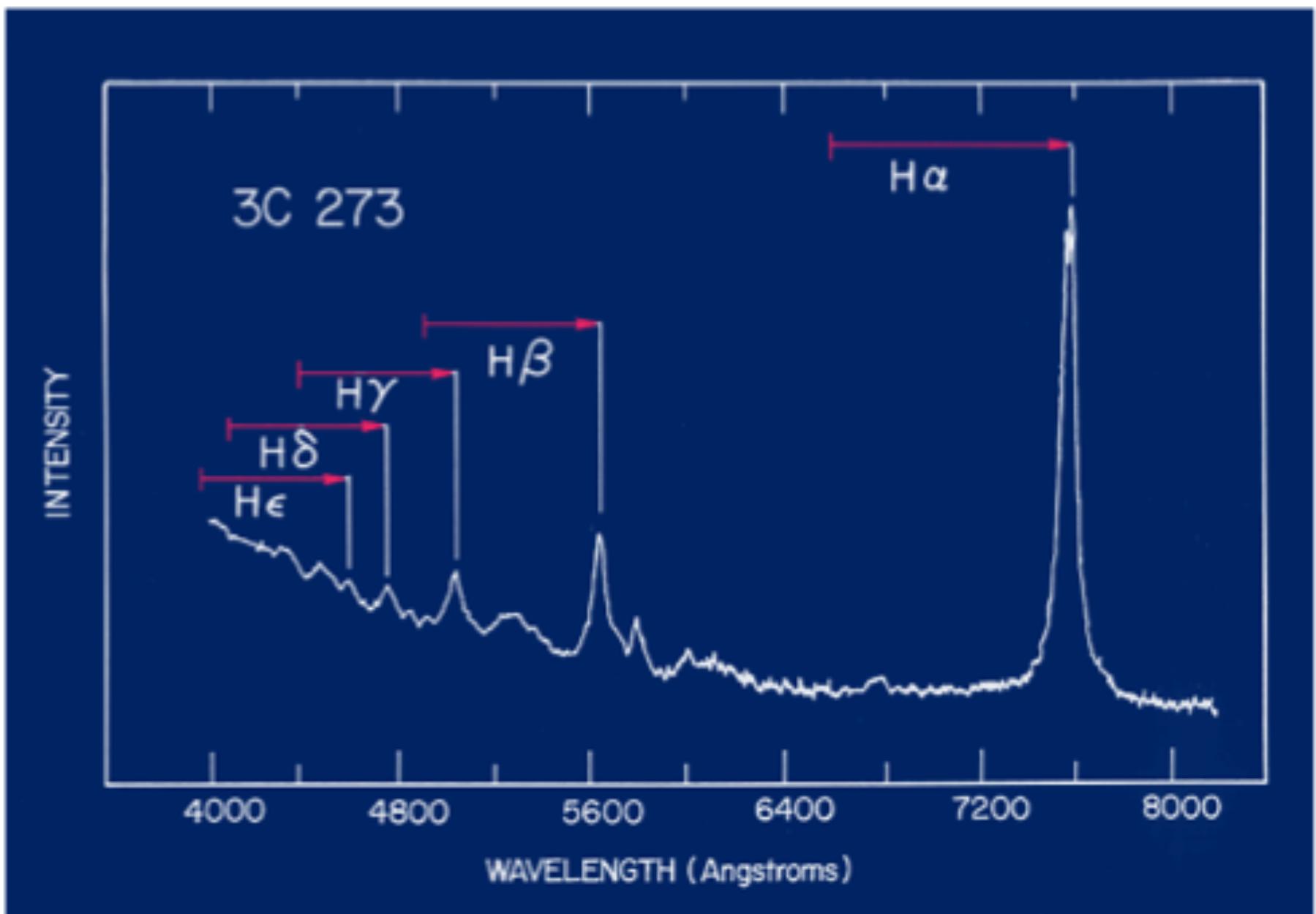


Table I. WAVE-LENGTHS AND IDENTIFICATIONS

λ	$\lambda/\text{I-158}$	λ_s	
3239	2797	2798	Mg II
4595	3968	3970	$H\epsilon$
4753	4104	4102	$H\delta$
5032	4345	4340	$H\gamma$
5200–5415	4490–4675		
5632	4864	4861	$H\beta$
5792	5002	5007	[O III]
6005–6190	5186–5345		
6400–6510	5527–5622		



QUASAR

Secondo la legge di Hubble, questo voleva dire che 3C 273 è distante dalla Terra ben 500 Mpc (~2 miliardi di anni luce) e si allontana alla velocità di 50000 km/s (1/6 di quella della luce!).

“Most direct and least objectionable”
La spiegazione più diretta e meno discutibile

1040

NATURE

March 16, 1963 VOL. 197

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

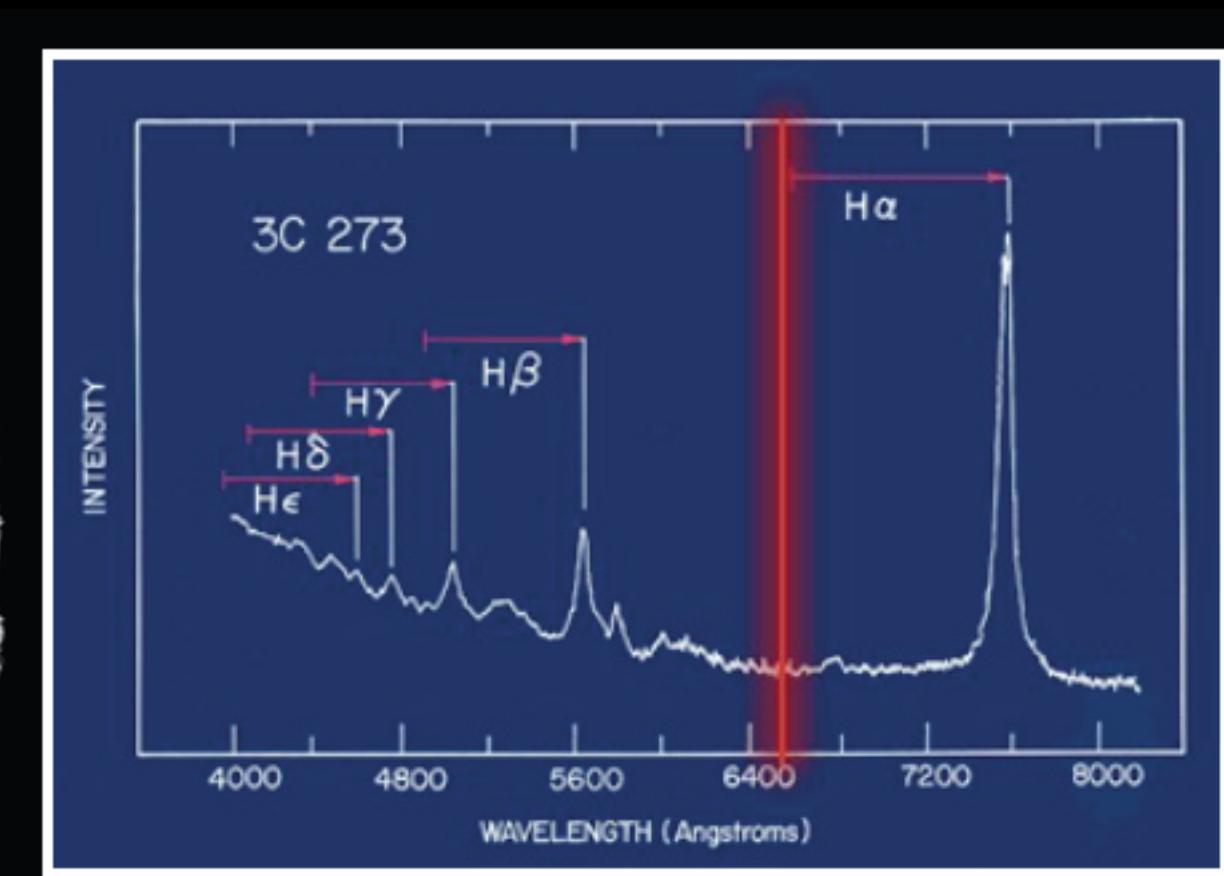
THE only objects seen on a 200-in. plate near the positions of the components of the radio source 3C 273 reported by Hazard, Mackay and Shimmins in the preceding article are a star of about thirteenth magnitude and a faint wisp or jet. The jet has a width of 1°-2° and extends away from the star in position 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.

Table I. WAVELENGTHS AND IDENTIFICATIONS

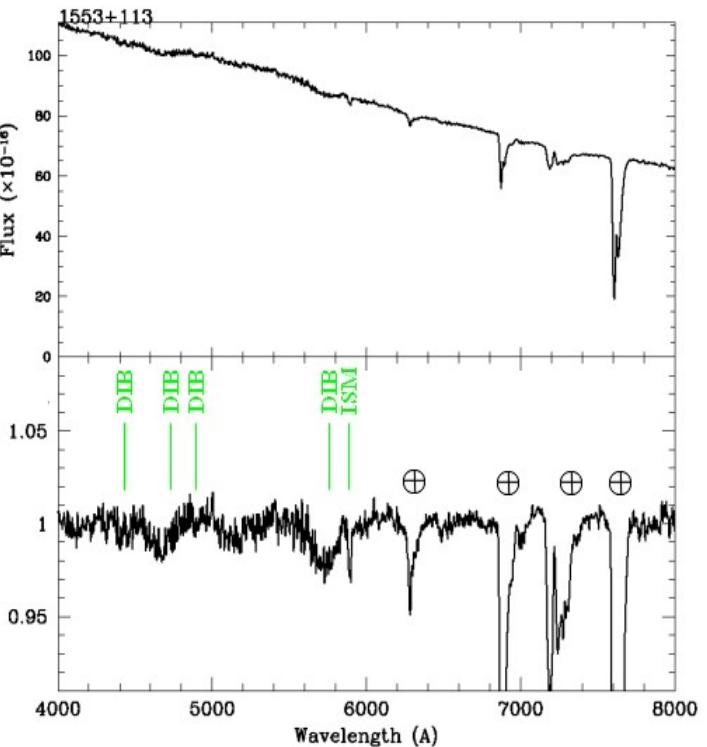
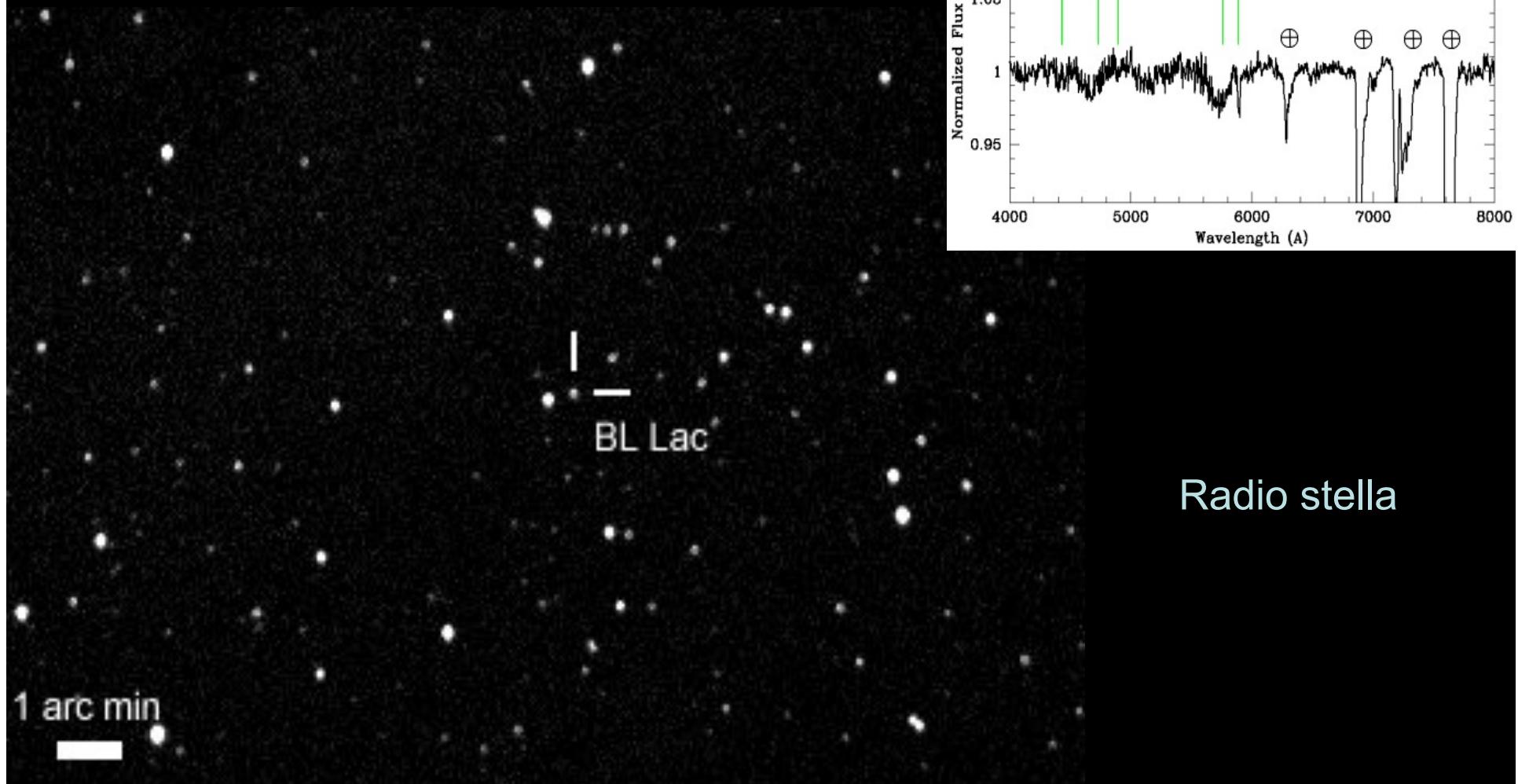
J	A2-1246	A ₄
5200-1415	4347	3787
4700	4348	3788
3900-3140	4349	3789
3400	4350	3790
3000-2400	4351	3791
2200-1400	4352	3792
1600-1100	4353	3793
1100-800	4354	3794
800	4355	3795
500	4356	3796
300	4357	3797
200	4358	3798
100	4359	3799
50	4360	3800
20	4361	3801
10	4362	3802
5	4363	3803
2	4364	3804
1	4365	3805
0.5	4366	3806
0.2	4367	3807
0.1	4368	3808
0.05	4369	3809
0.02	4370	3810
0.01	4371	3811
0.005	4372	3812
0.002	4373	3813
0.001	4374	3814
0.0005	4375	3815
0.0002	4376	3816
0.0001	4377	3817
0.00005	4378	3818
0.00002	4379	3819
0.00001	4380	3820
0.000005	4381	3821
0.000002	4382	3822
0.000001	4383	3823
0.0000005	4384	3824
0.0000002	4385	3825
0.0000001	4386	3826
0.00000005	4387	3827
0.00000002	4388	3828
0.00000001	4389	3829
0.000000005	4390	3830
0.000000002	4391	3831
0.000000001	4392	3832
0.0000000005	4393	3833
0.0000000002	4394	3834
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0.0000000000000000001	4422	3862
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0.00000000000000000002	4424	3864
0.00000000000000000001	4425	3865
0.000000000000000000005	4426	3866
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0.000000000000000000001	4428	3868
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0.0000000000000000000000000002	4448	3888
0.0000000000000000000000000001	4449	3889
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0.002	4487	3927
0.001	4488	3928
0.0005	4489	3929
0.0002	4490	3930
0.0001	4491	3931
0.005	4492	3932
0.002	4493	3933
0.001	4494	3934
0.0005	4495	3935
0.0002	4496	3936
0.0001	4497	3937
0.005	4498	3938
0.002	4499	3939
0.001	4500	3940



La luminosità di questa sorgente è 100-1000 volte maggiore di qualsiasi oggetto noto in quel momento.



Oggetti di tipo BL Lac



La ricerca continua

1967: >100 quasars identificati, spettri codificati e distanze misurate
(M. Burbidge 1967, Annual Review of Astronomy & Astrophysics)



M. Burbidge

FR I

Sey 1.8

NLXG

CSS

BLRG

QSO

HPO

LINER

BLRG

BALQSO

Sey 1

QSR

NLS1

LPO

Sey 2

BLL

Sey 1.9

OVV

FR II

3

Proprietà dei Nuclei Attivi

Proprietà

Spettri con righe di **emissione larghe**

Luminosità elevata

Morfologia peculiare – **getti**

Variabilità

Emissione RADIO

Moti **superluminali**

Proprietà

Spettri con righe di **emissione larghe**

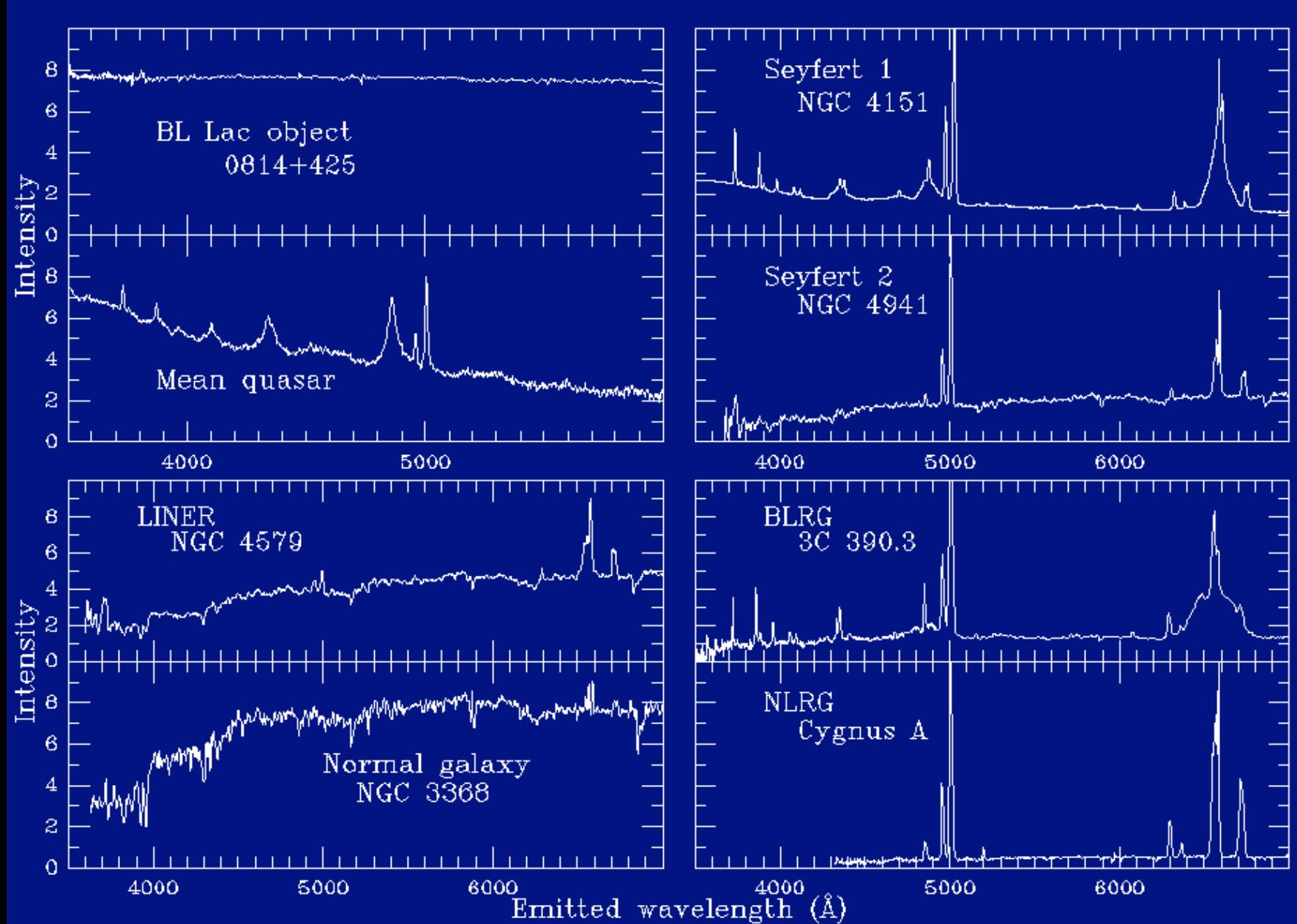
Luminosità elevata

Morfologia peculiare – getti

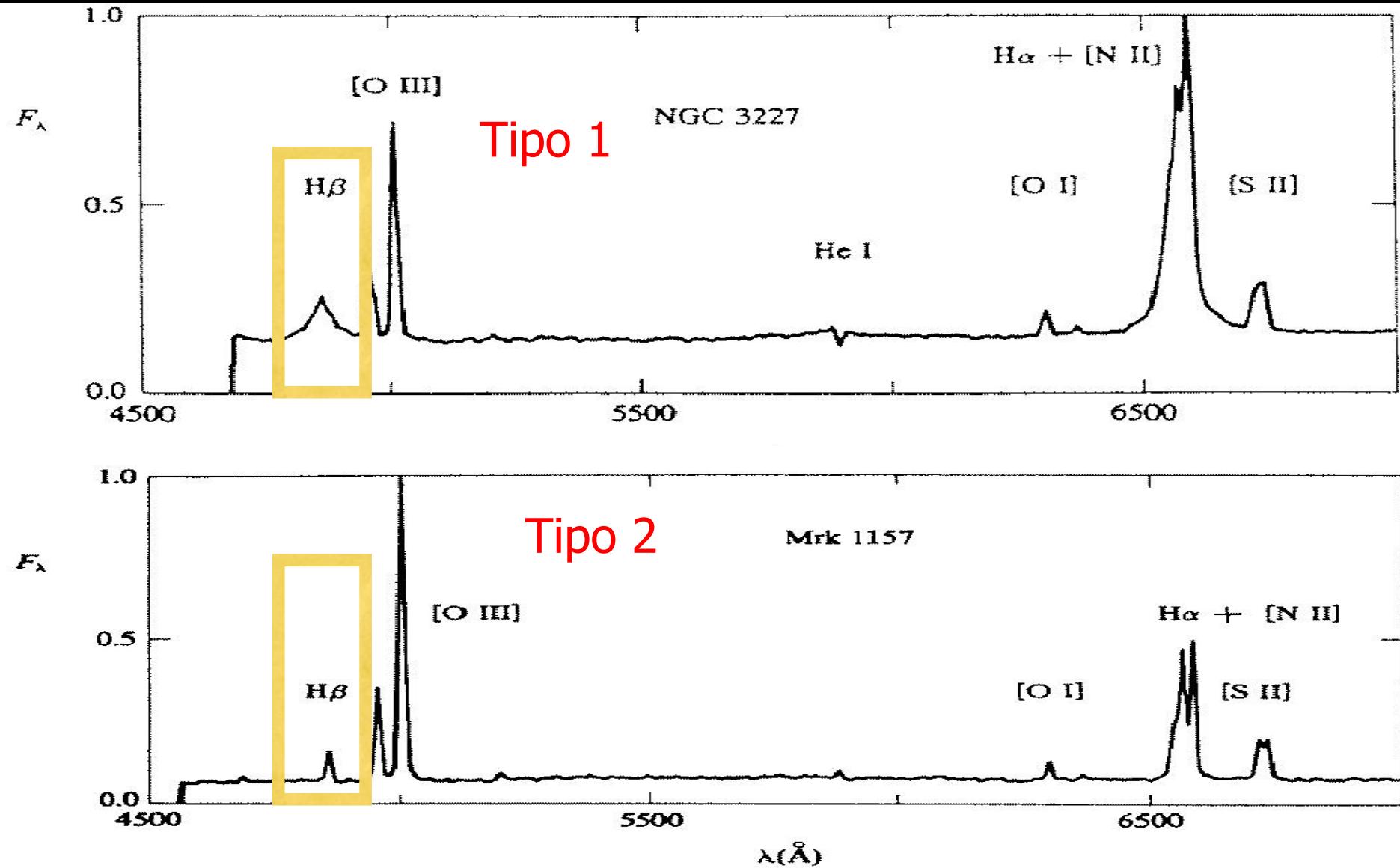
Variabilità

Emissione RADIO

Moti superluminali



Spettro di emissione



Proprietà

Spettri con righe di emissione larghe
Luminosità elevata
Morfologia peculiare – getti
Variabilità
Emissione RADIO
Moti superluminali



Quasar Host Galaxies

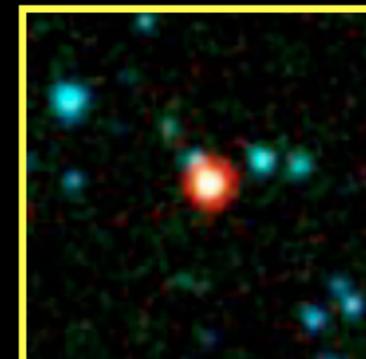
HST • WFPC2

PRC96-35a • ST Scl OPO • November 19, 1996

J. Bahcall (Institute for Advanced Study), M. Disney (University of Wales) and NASA

Produce molta energia:

Spesso di più di quella prodotta dalla galassia che lo ospita



10^{37} Watt

Energia consumata sulla Terra ogni secondo



Proprietà

Spettri con righe di emissione larghe

Luminosità elevata

Morfologia peculiare – **getti**

Variabilità

Emissione RADIO

Moti superluminali

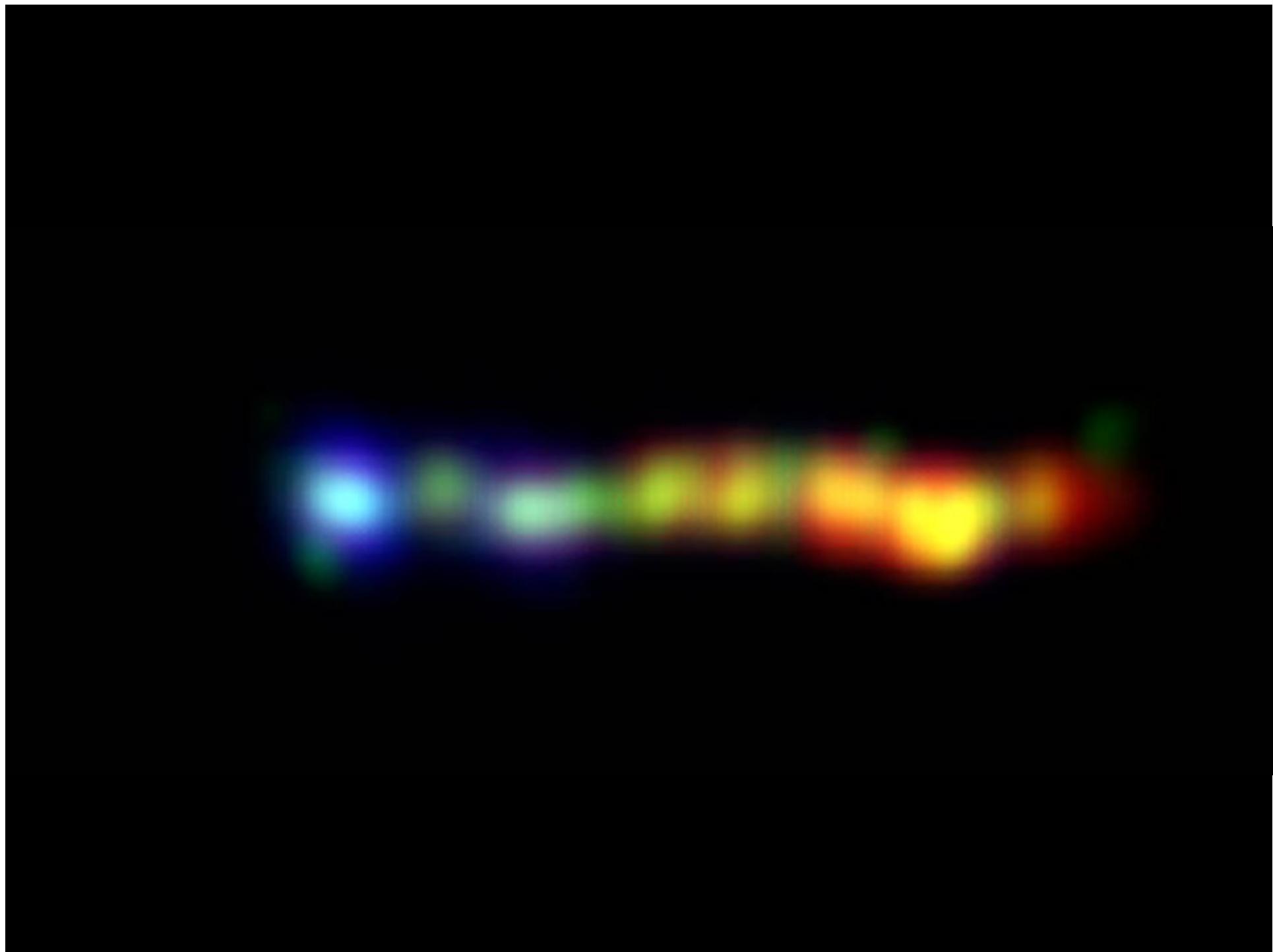
3C273

Uno dei più vicini a noi,
3 miliardi di anni luce

Pur essendo il più
brillante è mille volte
troppo debole per
essere visto ad occhio
nudo dalla Terra

La sua luminosità è
12 ordini di grandezza
(10^{12} volte maggiore di
quella del Sole)

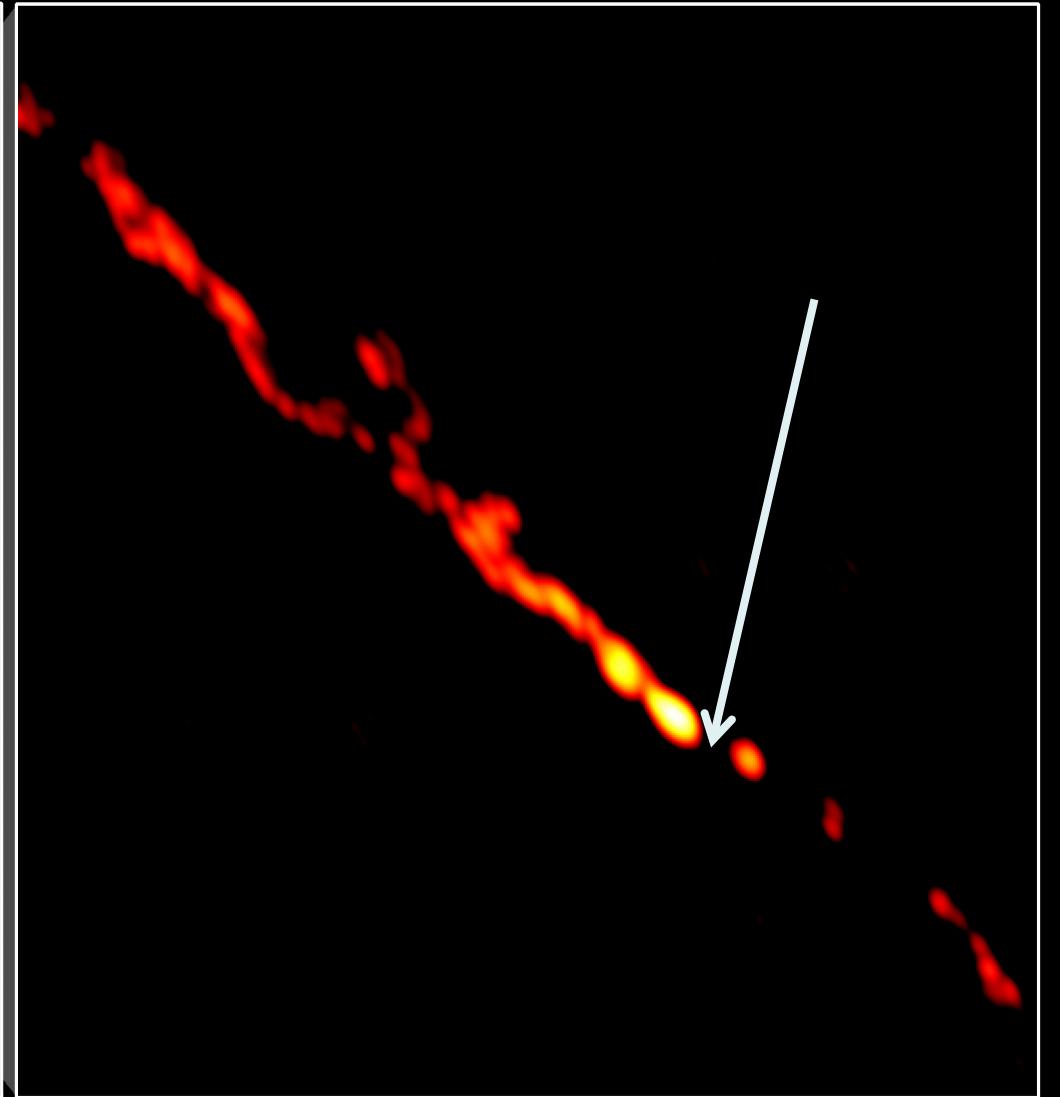




Centauro A: risultato di uno scontro



I getti interni di Centauro A



Proprietà

Spettri con righe di emissione larghe

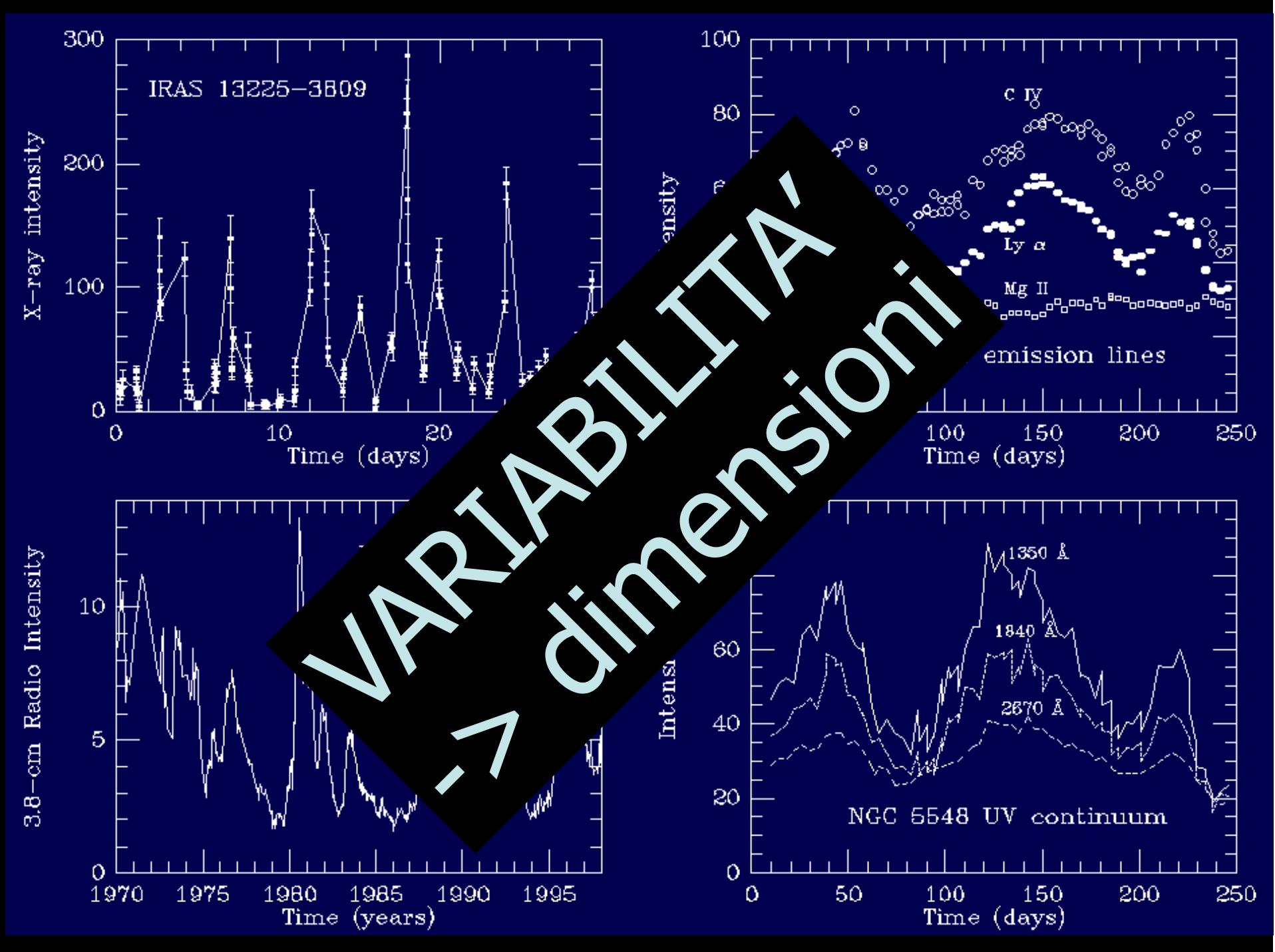
Luminosità elevata

Morfologia peculiare – getti

Variabilità

Emissione RADIO

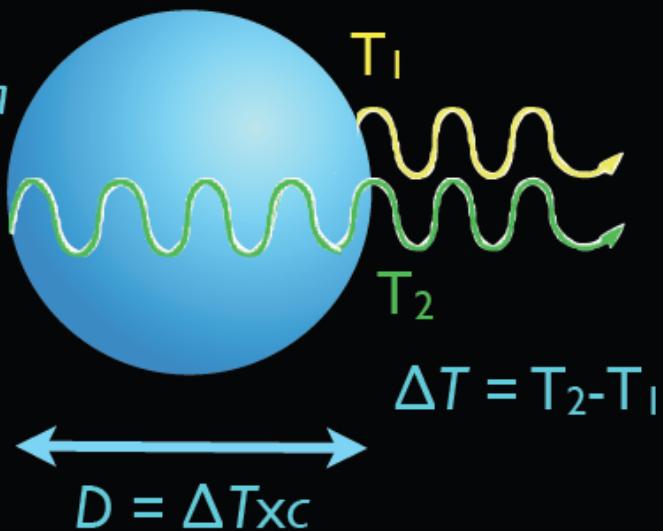
Moti superluminali



La variabilità implica una sorgente di dimensioni piccole

ΔT = tempo sul quale la
luce varia

c = velocità della luce



Proprietà

Spettri con righe di emissione larghe

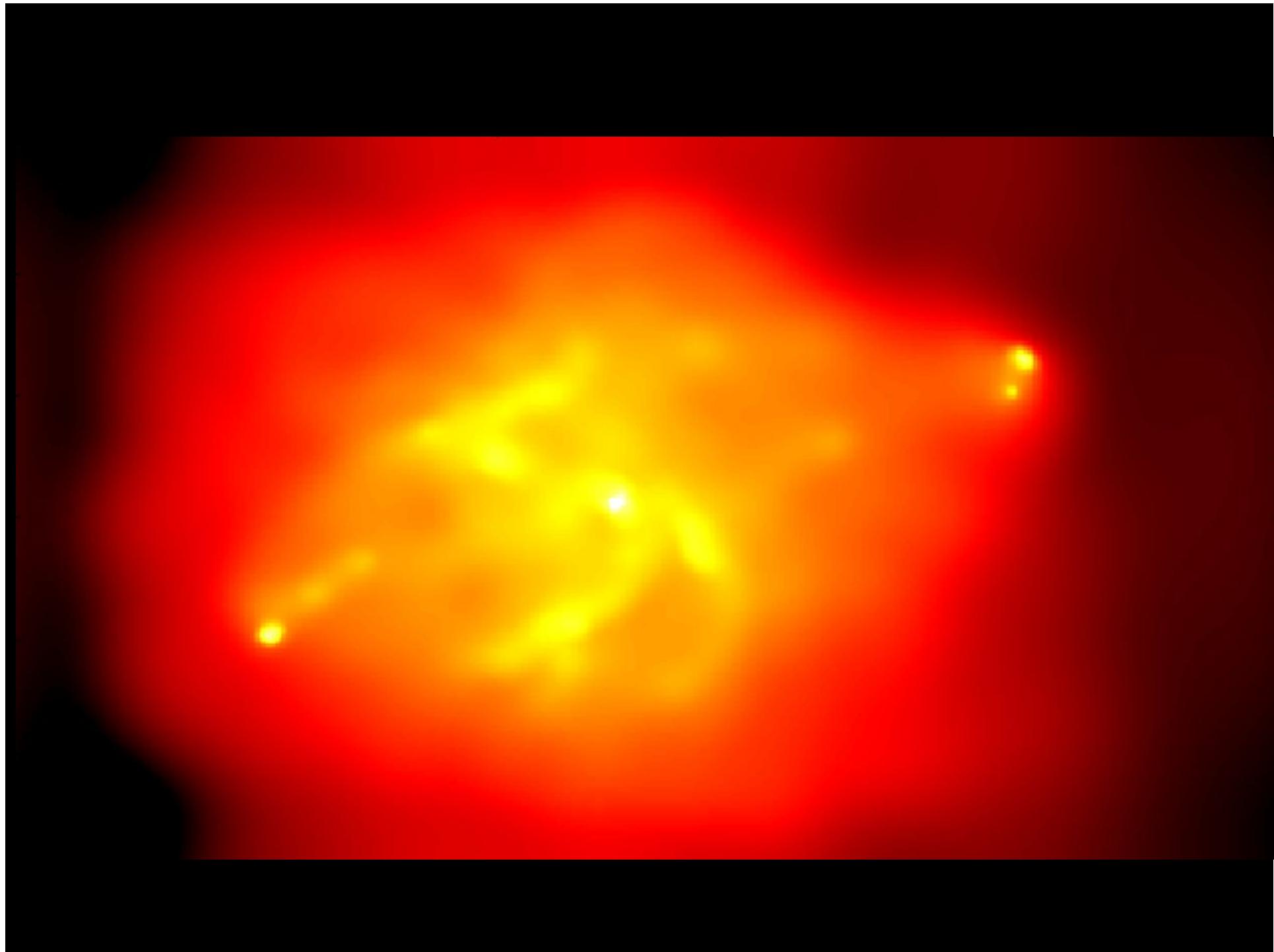
Luminosità elevata

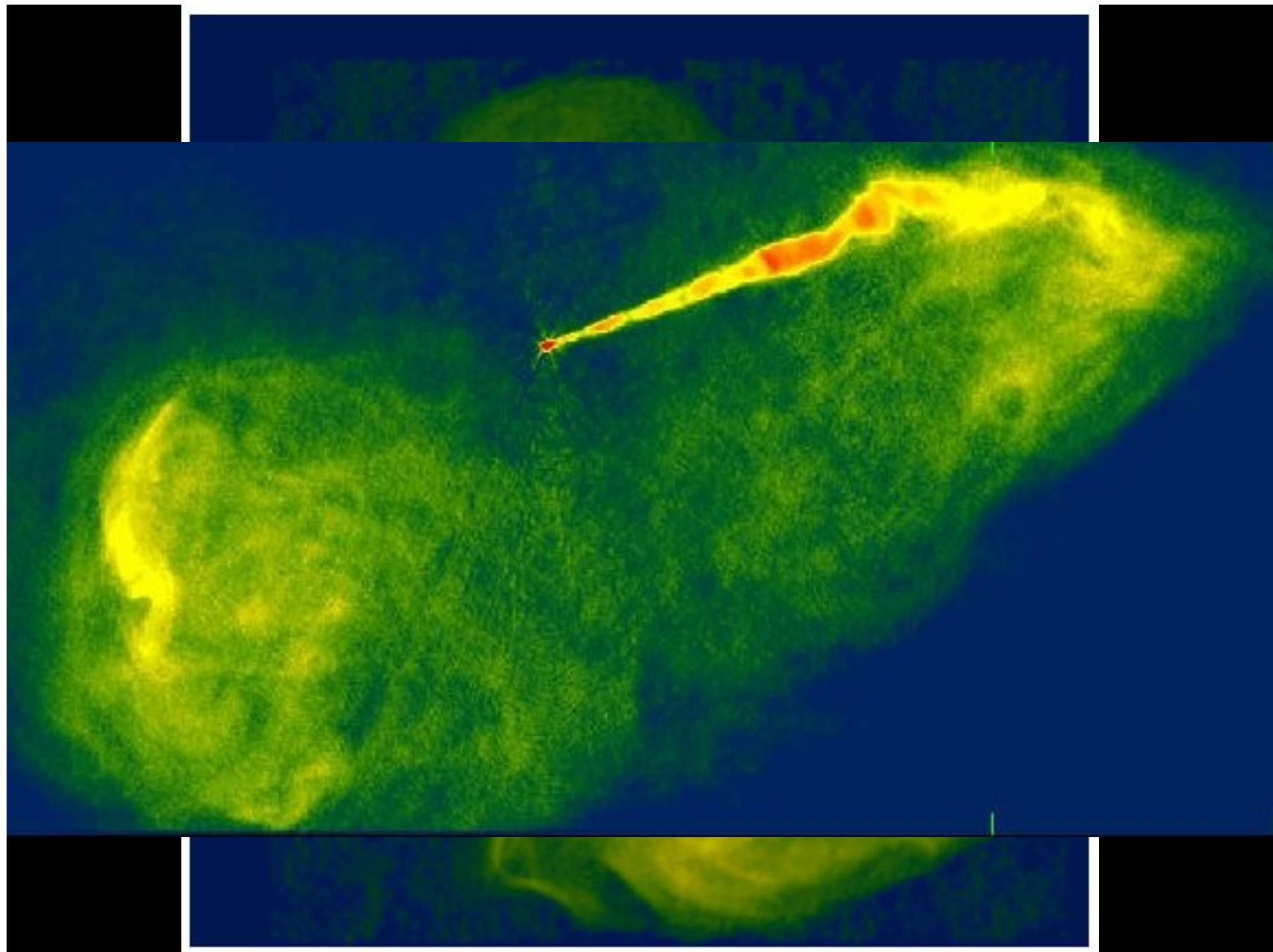
Morfologia peculiare – getti

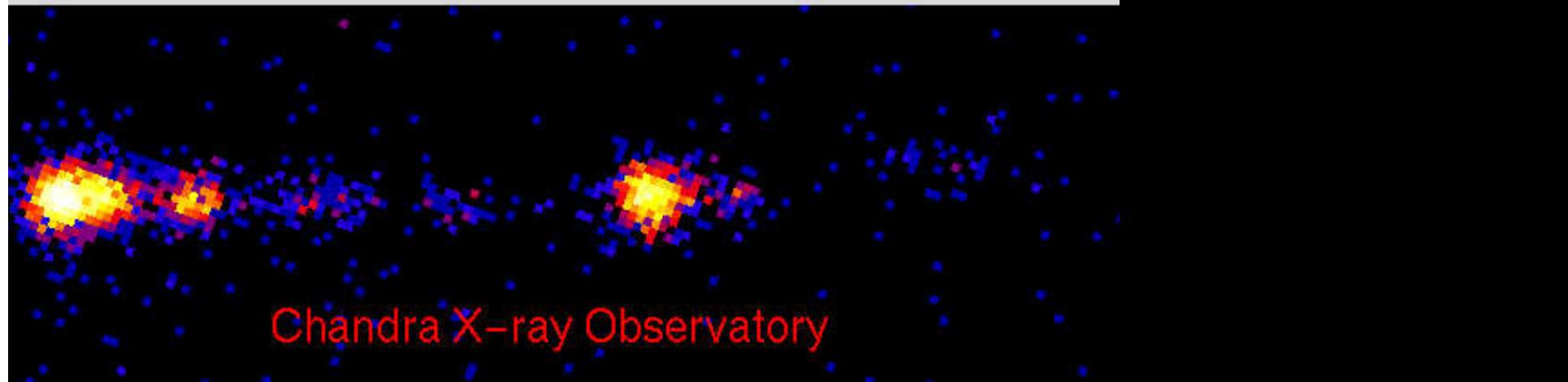
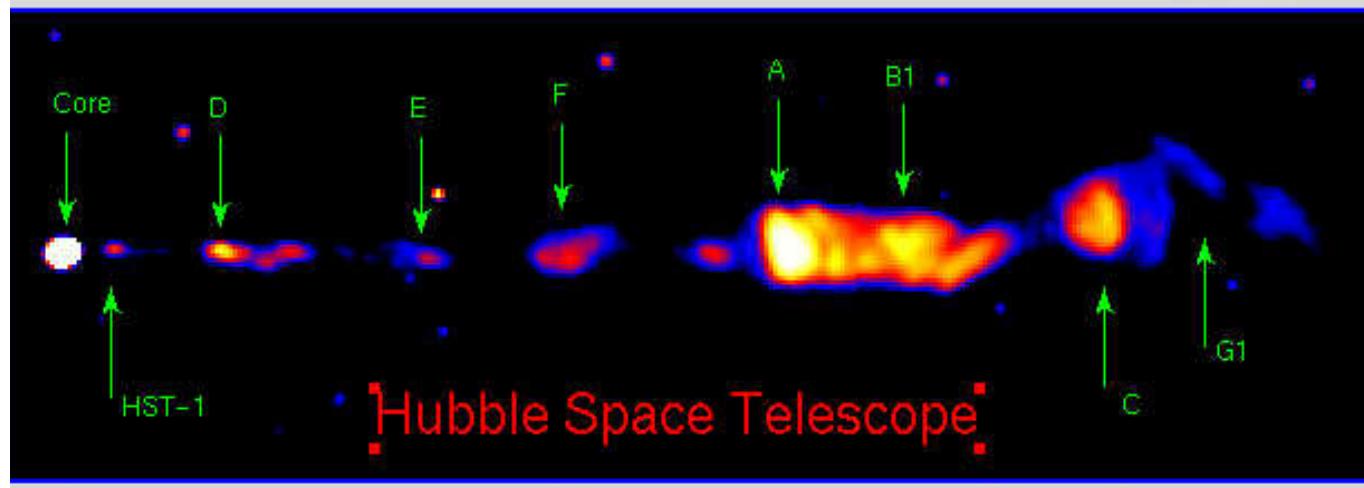
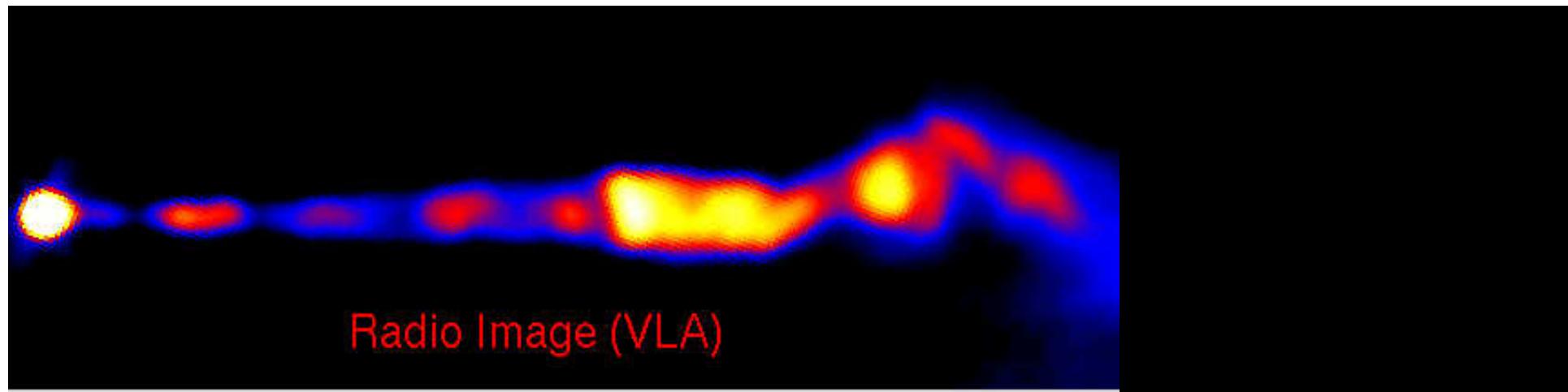
Variabilità

Emissione RADIO

Moti superluminali



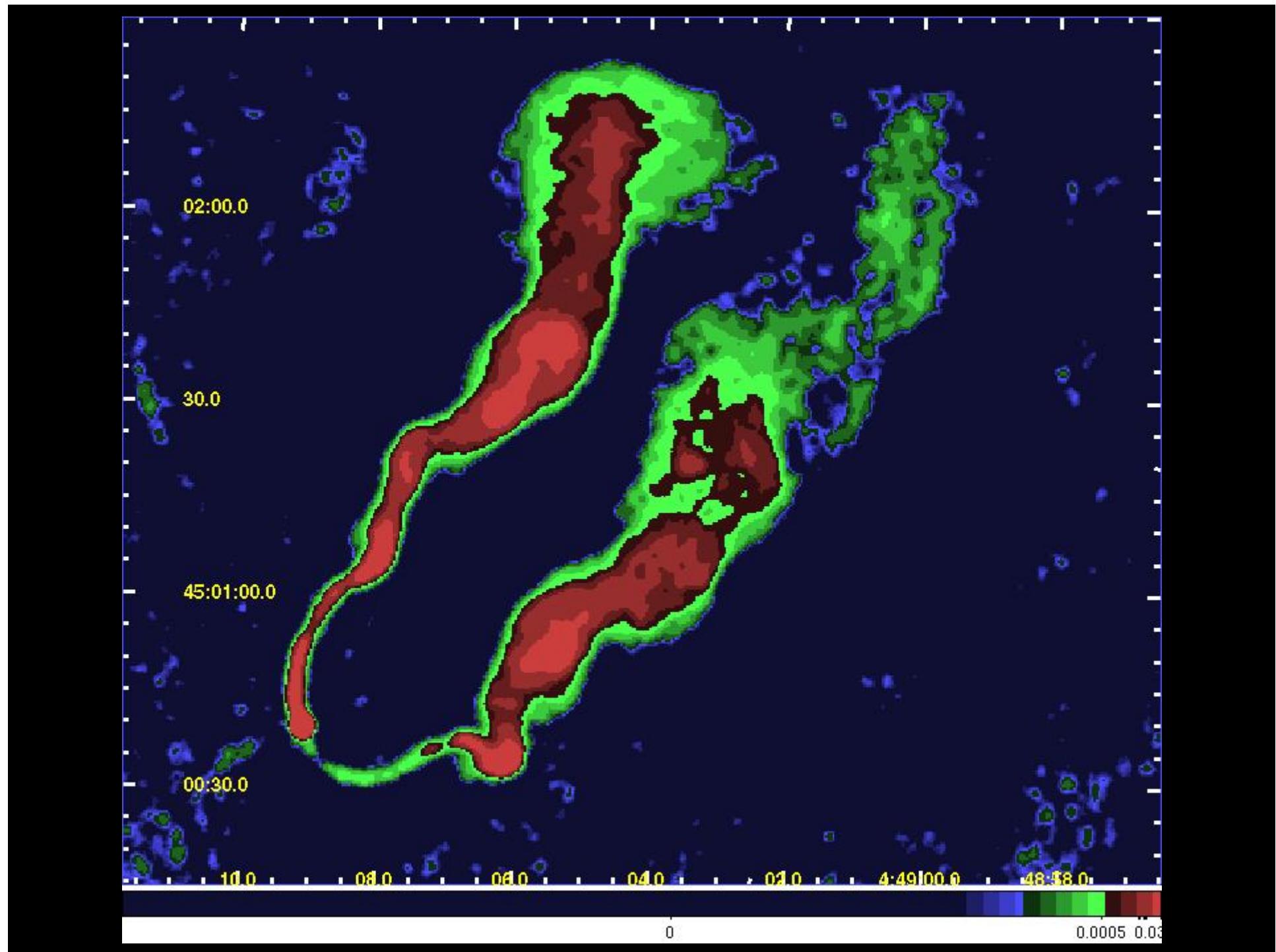


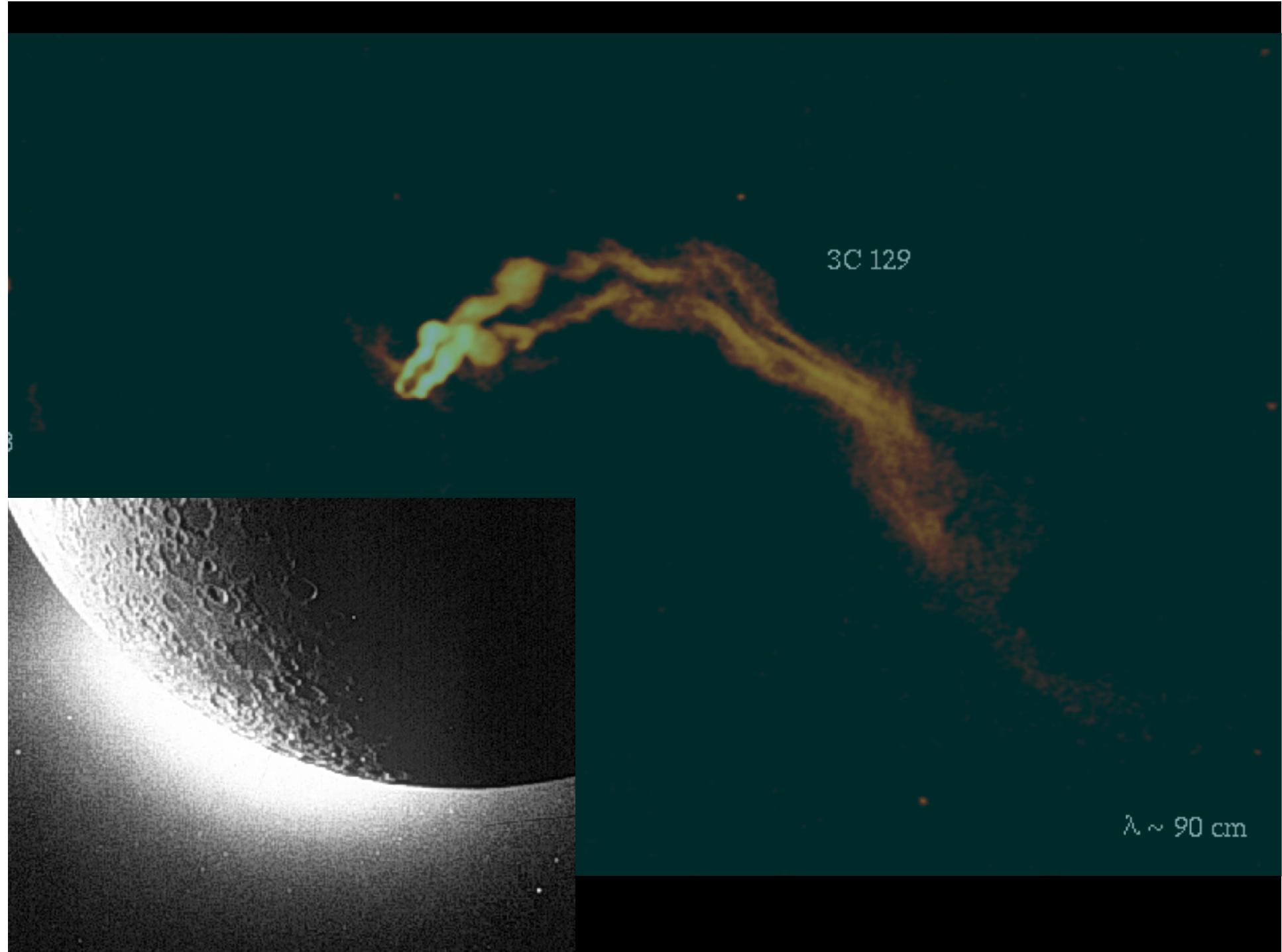


PKS2356-61 ($z = 0.1$)



Quasar
in una
galassia
ellittica

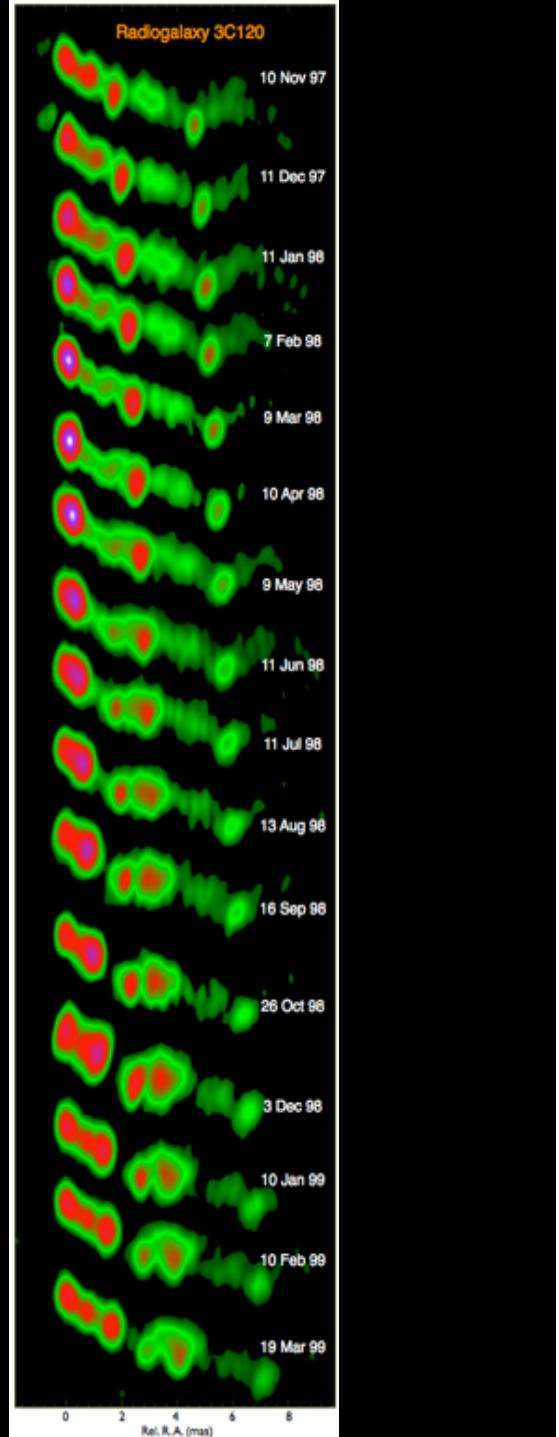
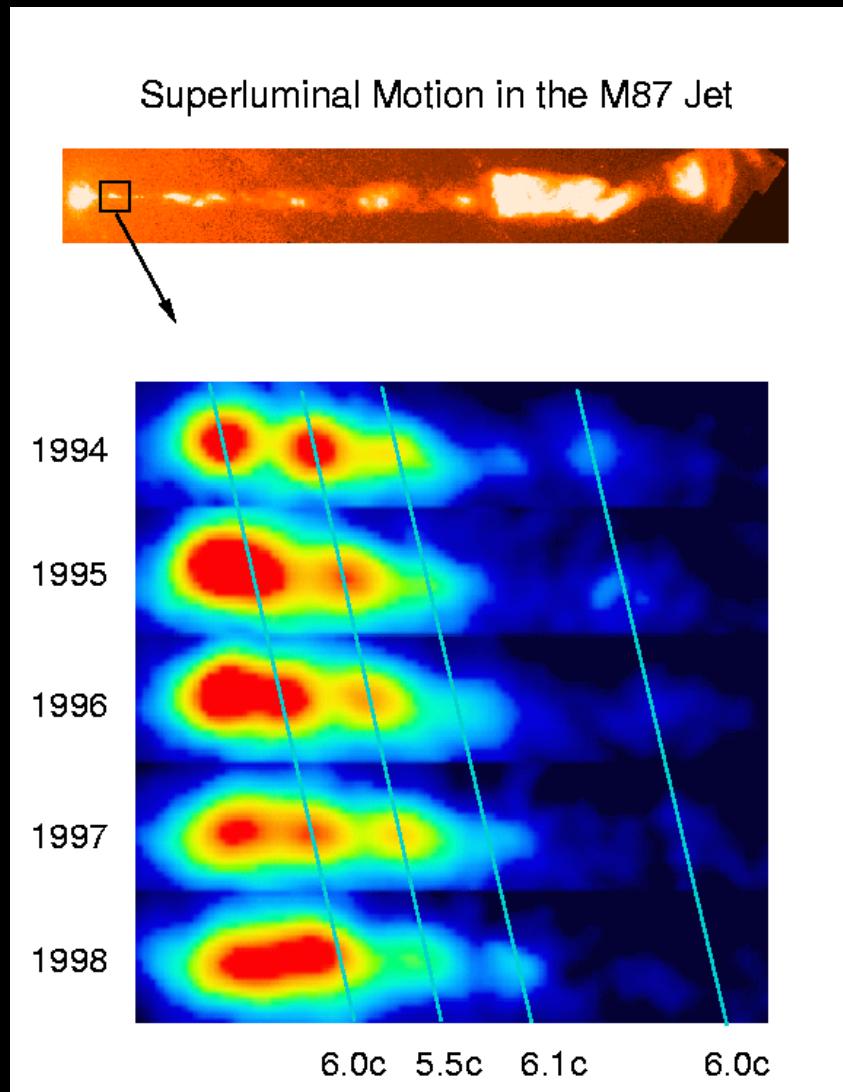




Proprietà

Spettri con righe di emissione larghe
Luminosità elevata
Morfologia peculiare – getti
Variabilità
Emissione RADIO
Moti superluminali

Moti superluminali



*VLBA 22 GHz Observations
of
3C120*

José-Luis Gómez

IAA (Spain)

Alan P. Marscher

BU (USA)

Antonio Alberdi

IAA (Spain)

Svetlana Marchenko-Jorstad

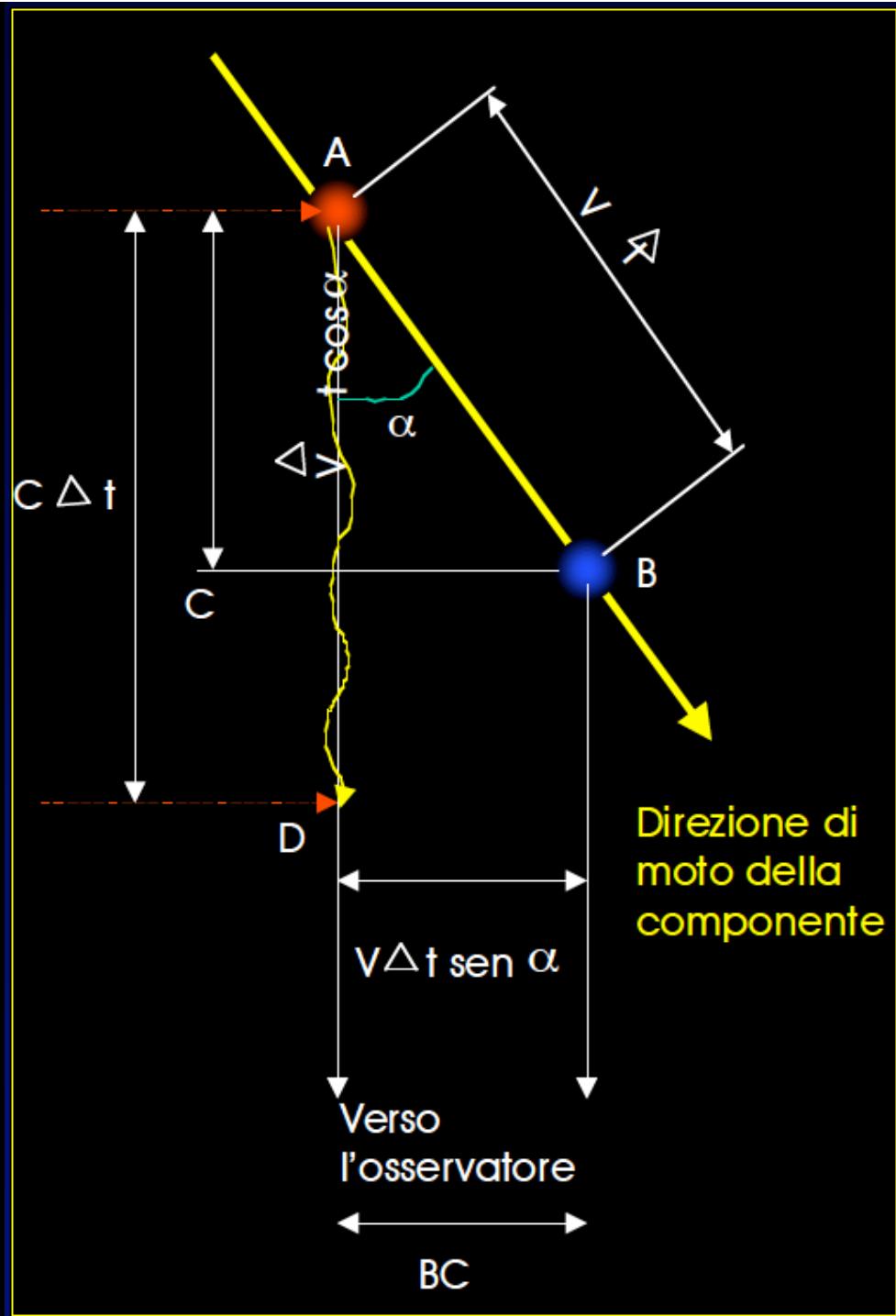
BU (USA)

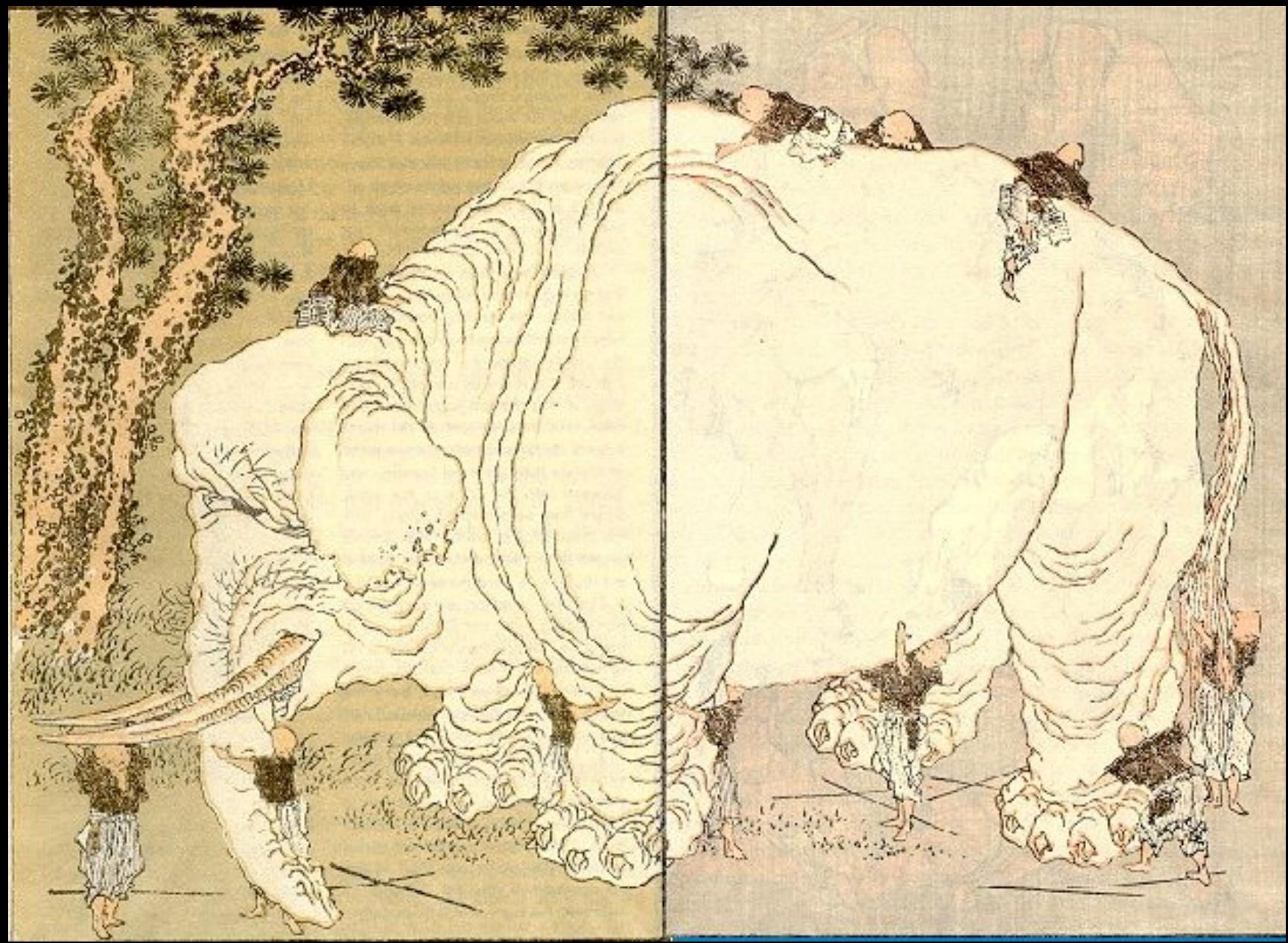
Cristina García-Miró

IAA (Spain)

Più veloce della luce!!!

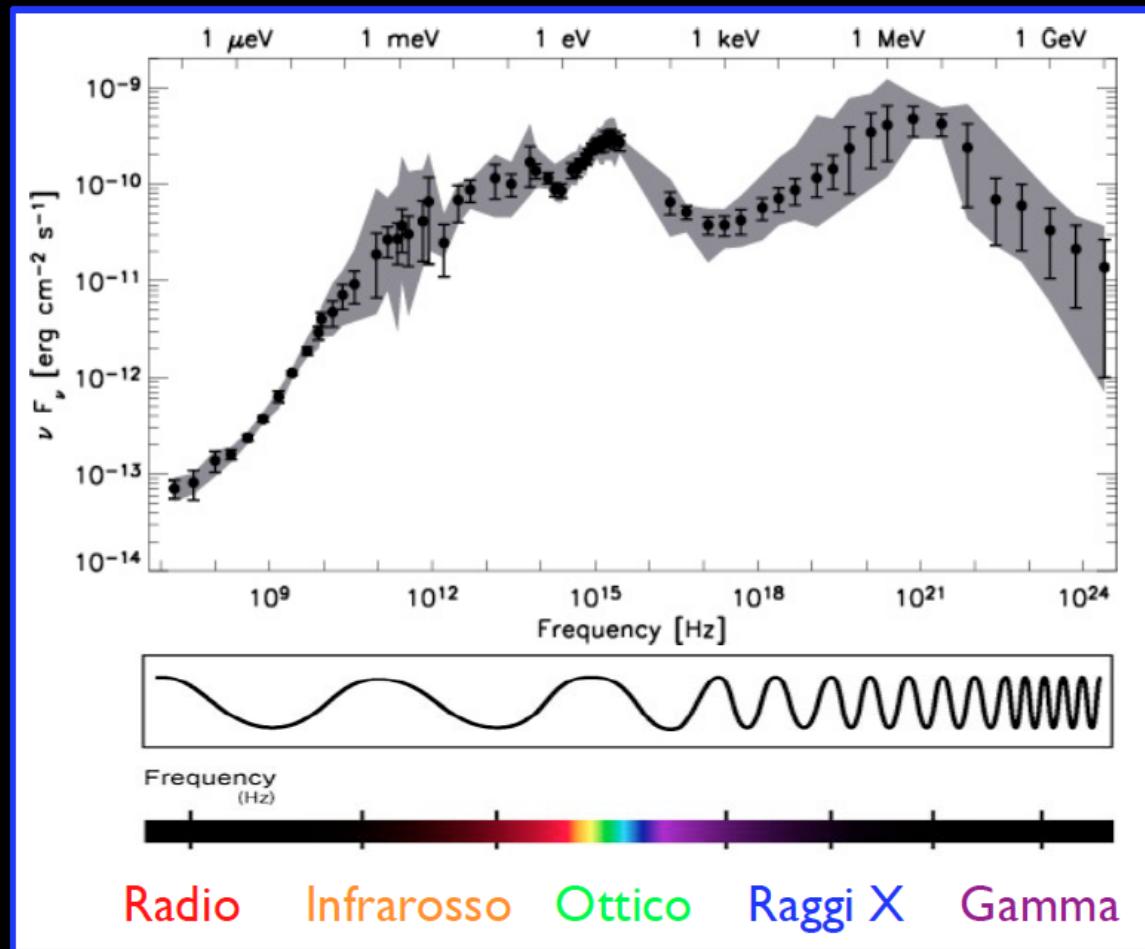
Se l'elemento B si muove a velocità vicina a quella della luce, la distanza percorsa da B nella nostra direzione è vicina a quella percorsa dal raggio di luce in A. La luce da B all'osservatore deve fare meno strada e arriva prima. Sembra che B si sia spostato rispetto ad A (nel piano del cielo) più veloce di c.





Modello Unificato

I Quasars emettono radiazione a tutte le lunghezze d'onda



AGN senza getto
≈90%

Narrow-Line Seyfert 1
Seyfert 1 e 2
LINERS 1 e 2



Galassia ospite: spirale
Raggi gamma: no!

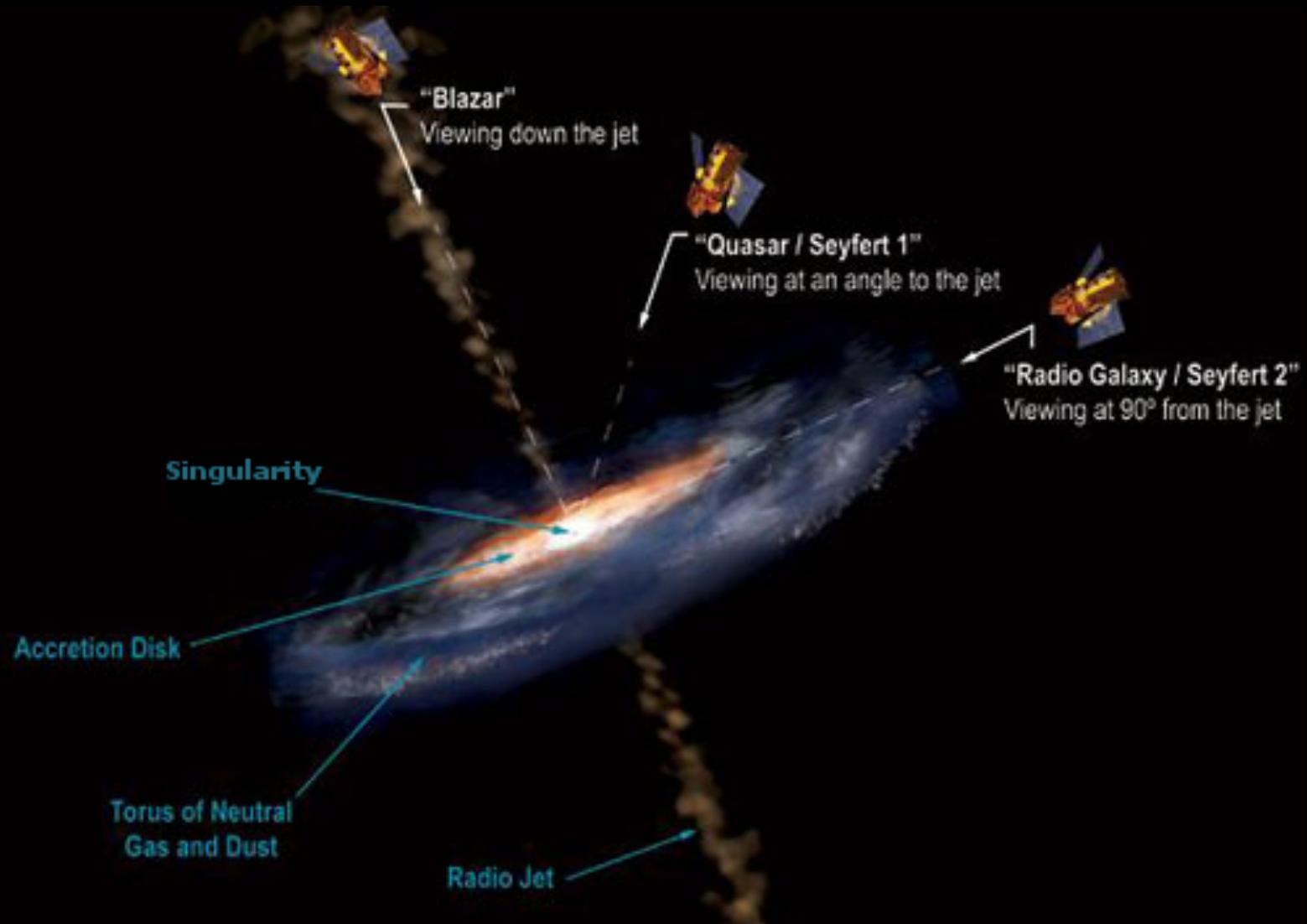
AGN con getto
≈10%

Blazars (BL Lac + Quasar)
Radiogalassie HE
Radiogalassie LE



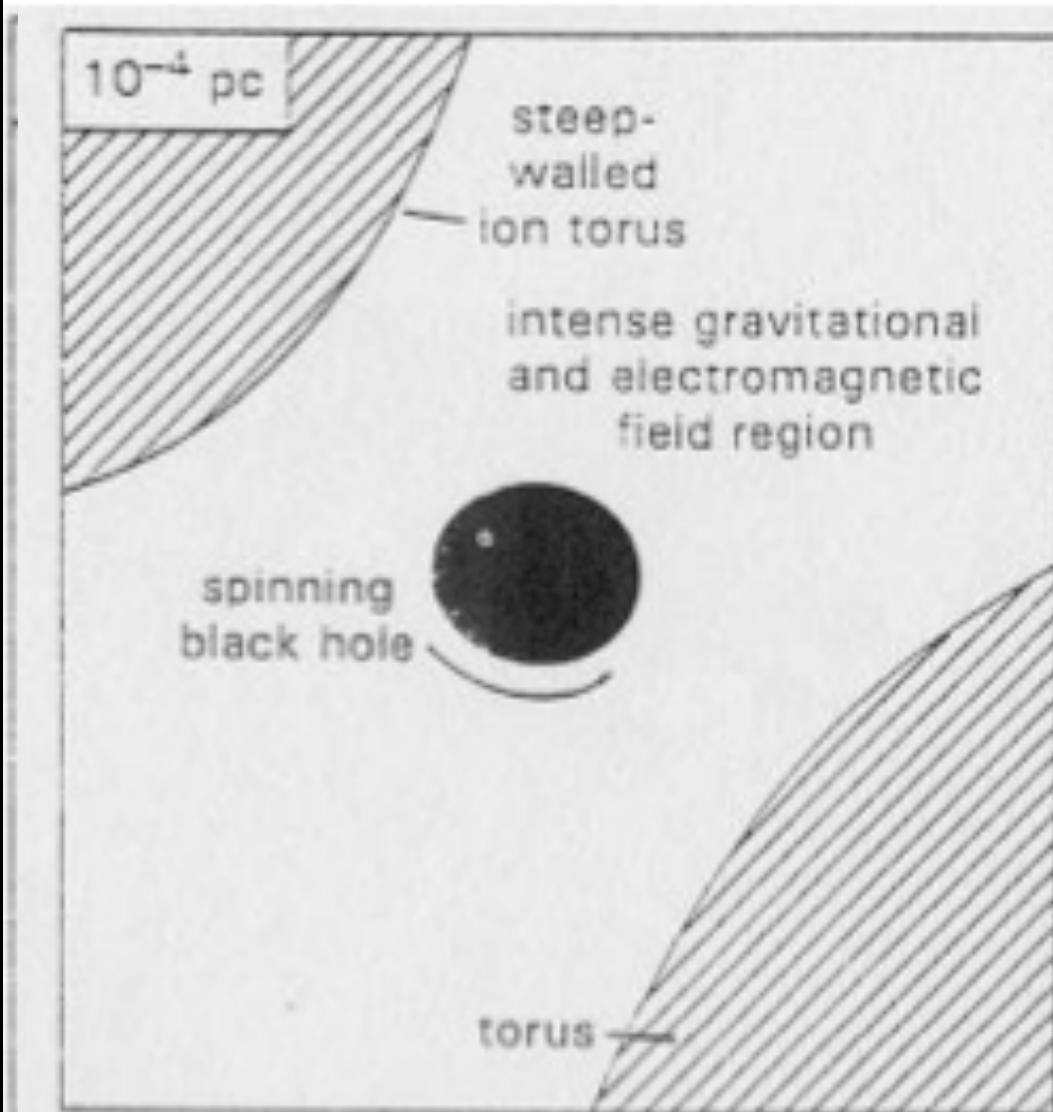
Galassia ospite: ellittica
Raggi gamma: sì!

Anche se in fase di scoperta sono state classificati molti tipi di nuclei galattici attivi, dopo un'attenta analisi (**R. Antonucci; C.M. Urry & P. Padovani**) si è visto che molte differenze potevano essere spiegate in termini di differenti punti di vista.



Diverse scale

Blandford 1990



The black hole. The Schwarzschild radius for a $10^8 M_\odot$ black hole is 2 AU (10^{-4} pc). The spin will introduce twisted magnetic field lines and particle acceleration.

Broad-Line Region (BLR)

Il gas interstellare che si trova oltre il disco, interagisce con la radiazione emessa da quest'ultimo generando delle linee di emissione.

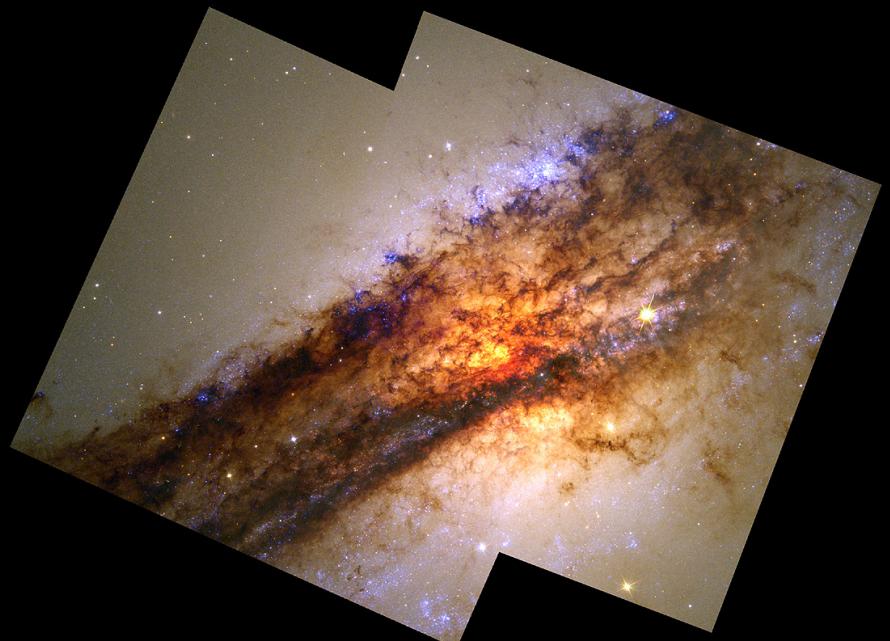
La vicinanza alla singolarità richiede che la velocità orbitale sia elevata (1000-10000 km/s) e si determina un allargamento (broadening) del profilo delle linee.

Narrow-Line Region (NLR)

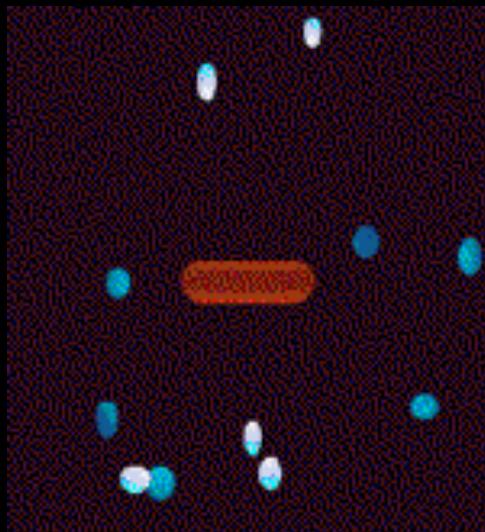
Più lontano dal disco, ma ancora in grado di interagire con la radiazione emessa da quest'ultimo, c'è un'altra regione che emette delle linee. Questa volta, essendo più lontana dalla singolarità, la velocità orbitale è inferiore (< 1000 km/s) e quindi anche l'allargamento. Le righe sono più strette (narrow).

Toro molecolare

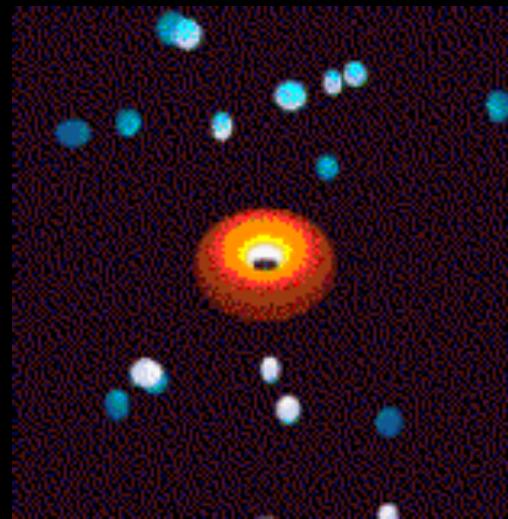
Tra le due regioni (BLR e NLR) c'è una ciambella di materiale freddo che oscura la vista diretta del nucleo o della BLR.



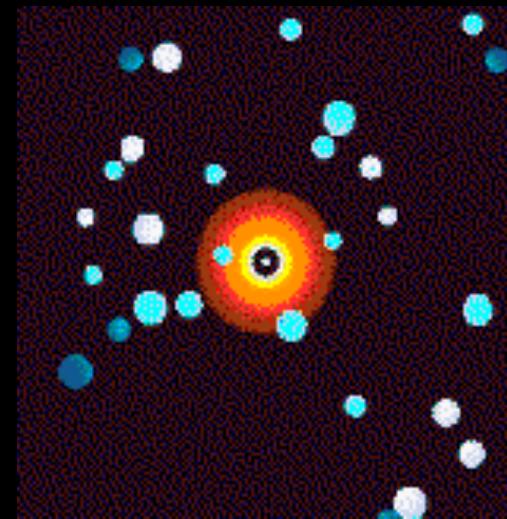
Modello Unificato BH + Disco + Toro



SY2
di fianco

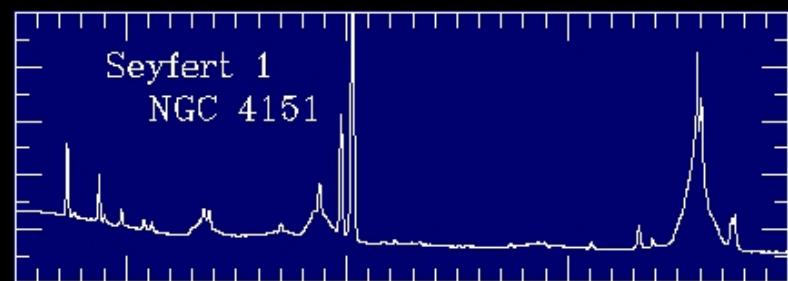
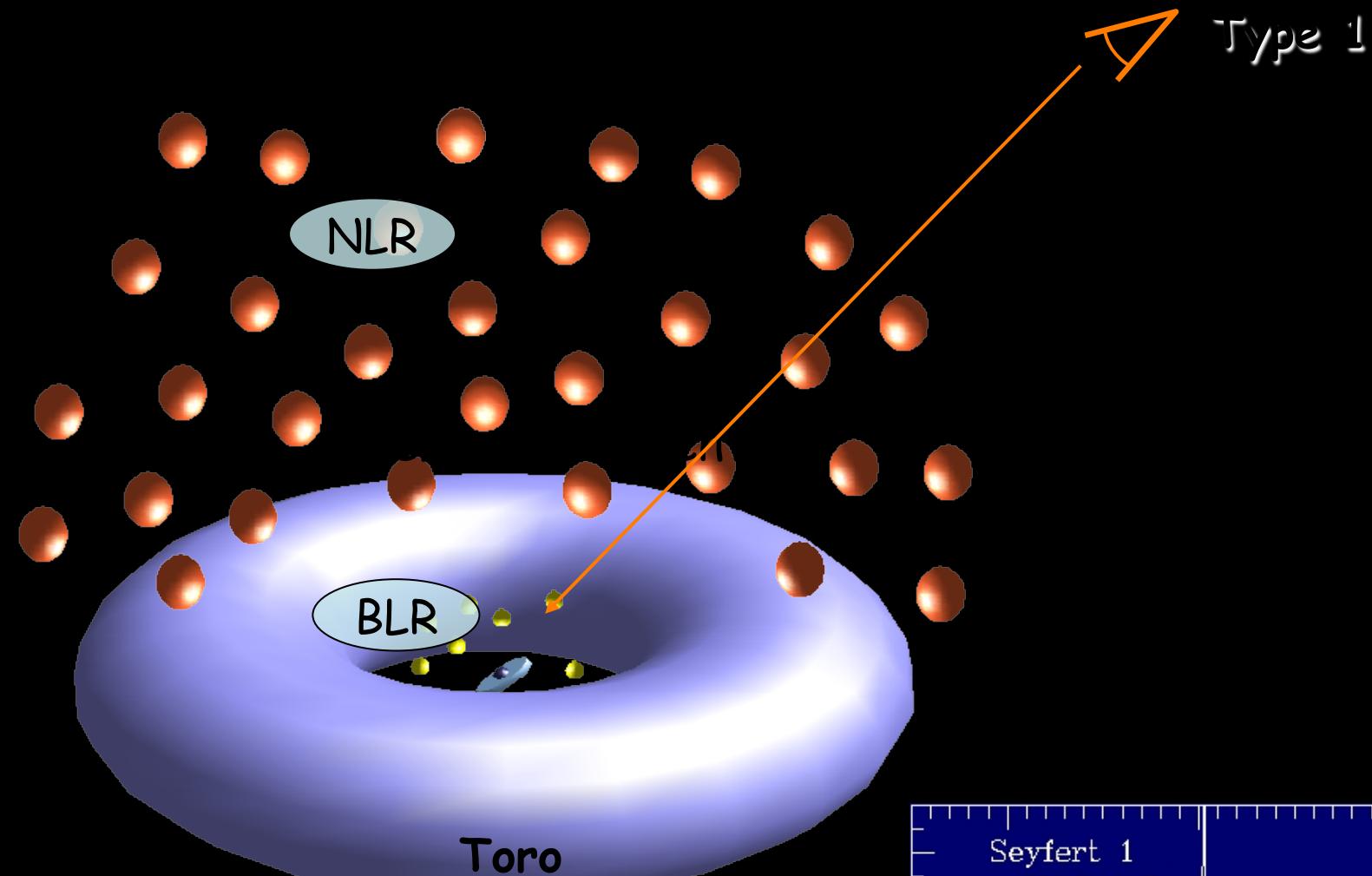


SY1
inclinato

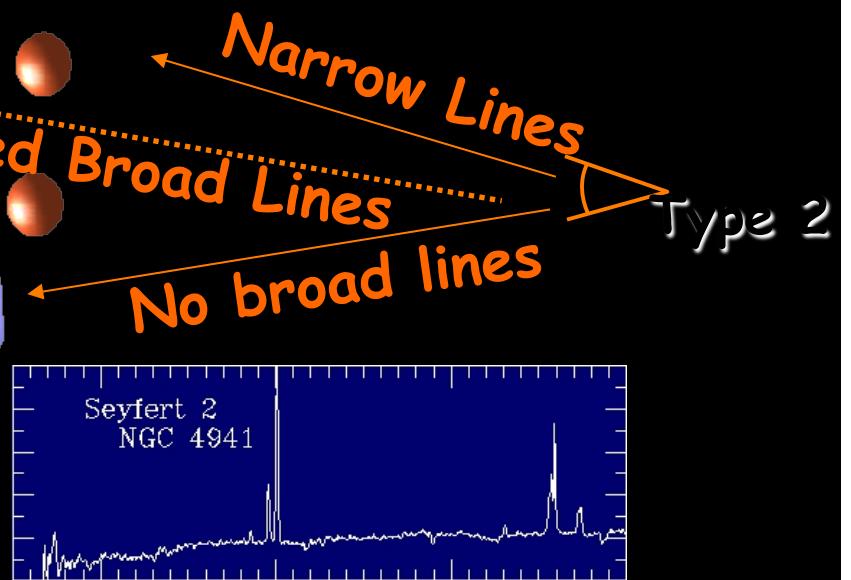
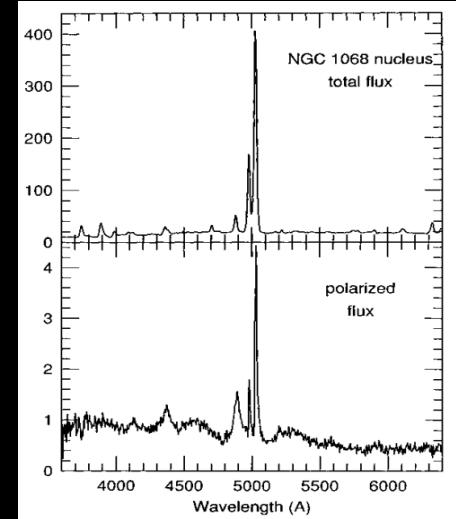
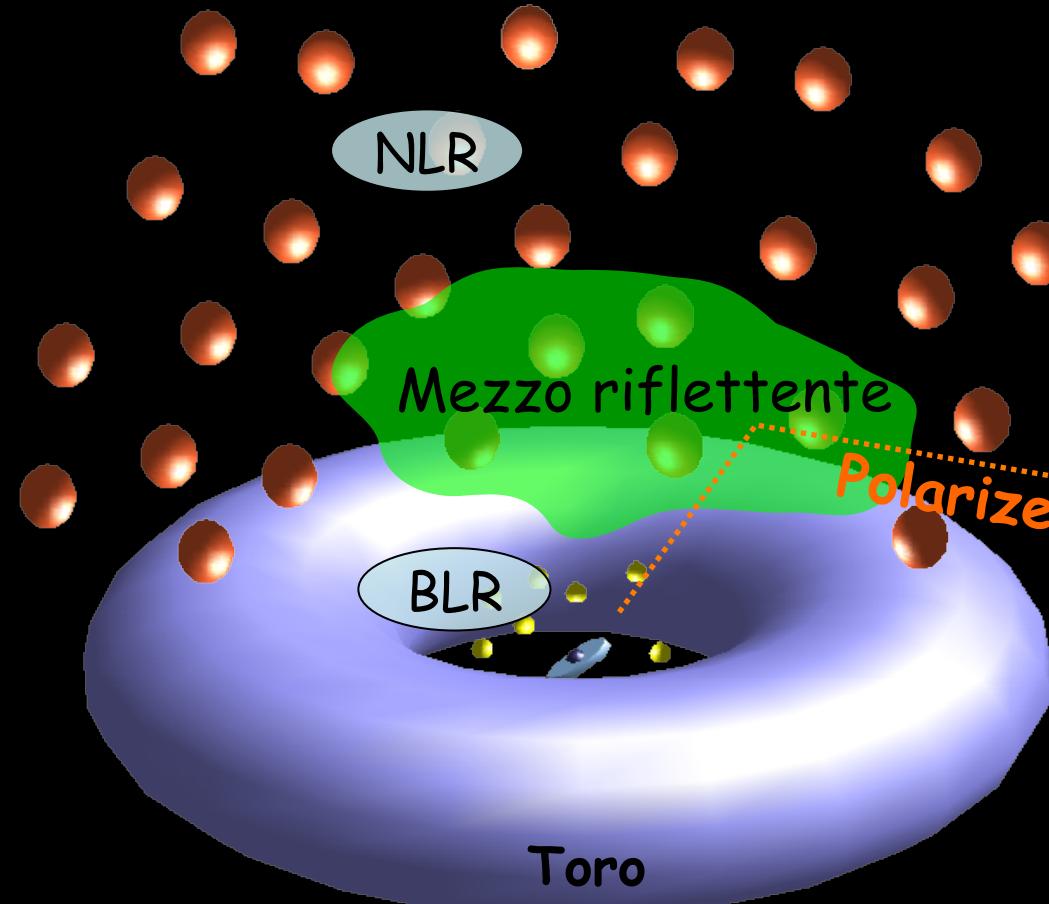


BL Lac
dritto nello scarico!

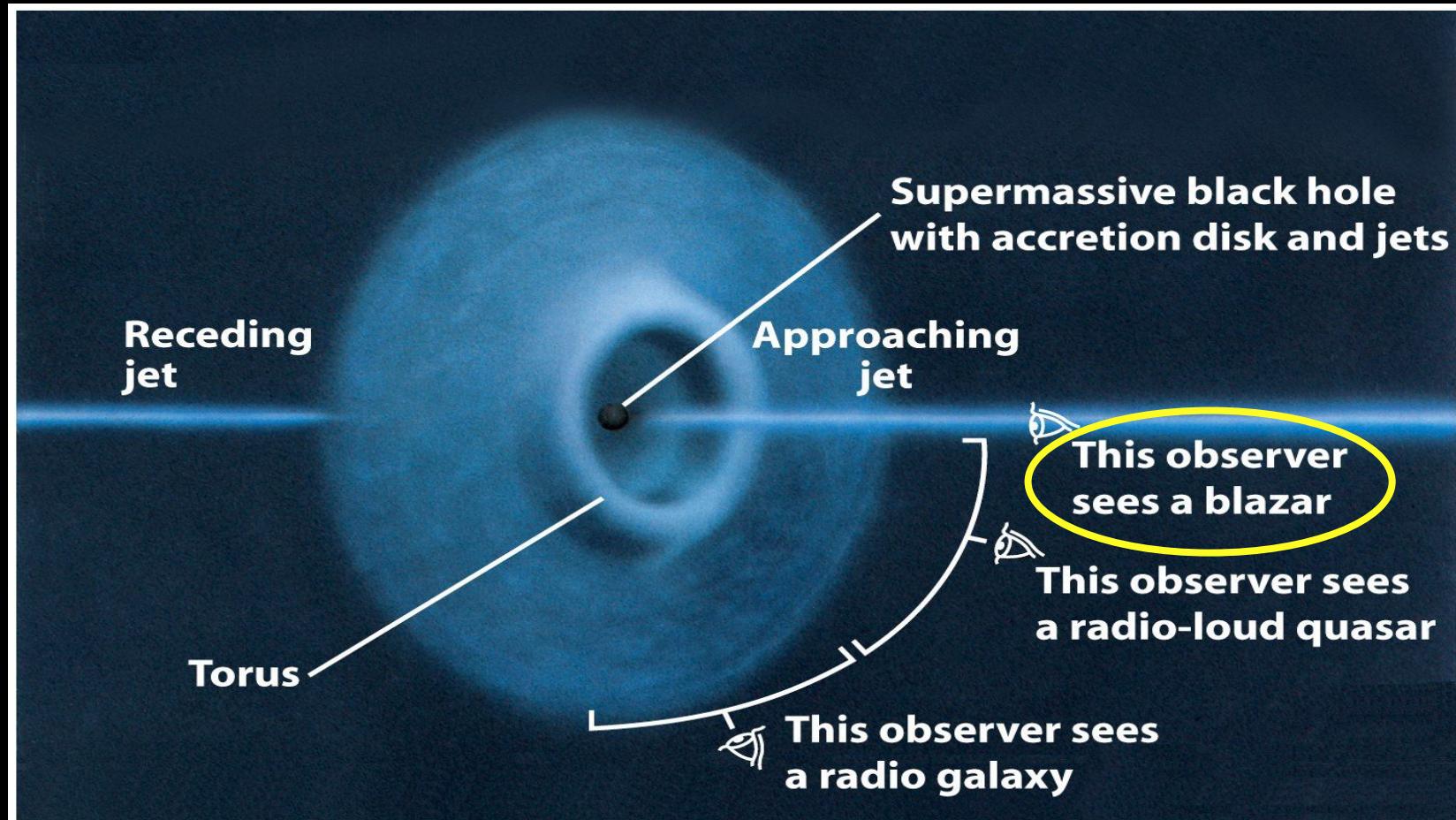
Il Modello Unificato



Il Modello Unificato



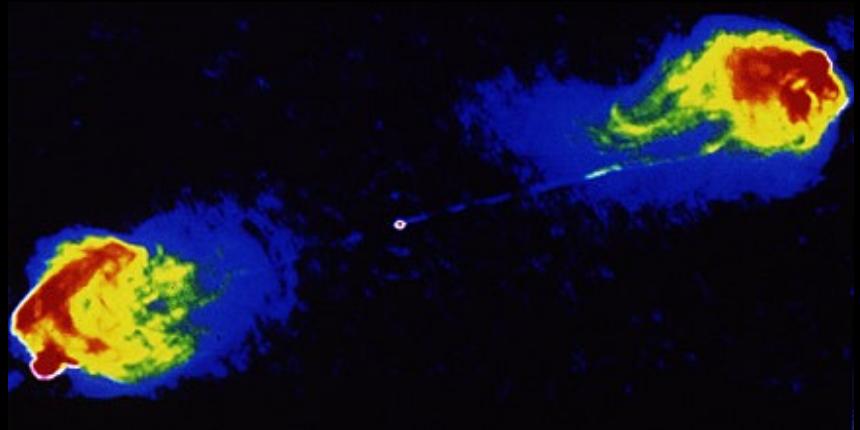
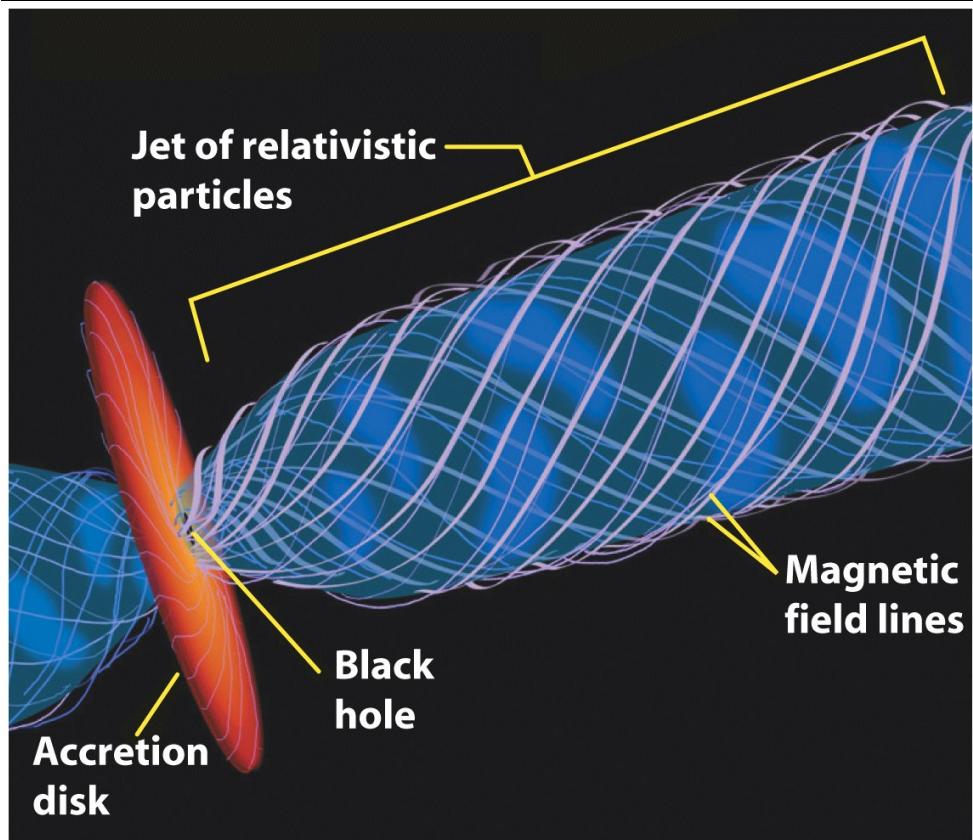
Getti extragalattici:



Courtesy: Ski Antonucci

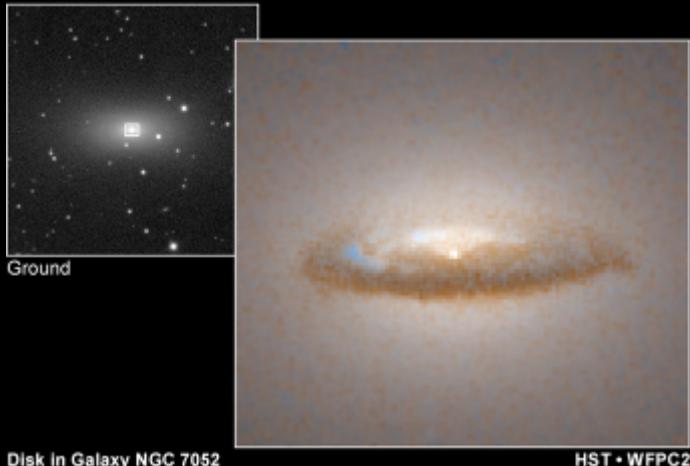
La magia dei getti relativistici

L'energia cinetica dei getti può essere anche maggiore di quella emessa dal nucleo attivo sotto forma di radiazione

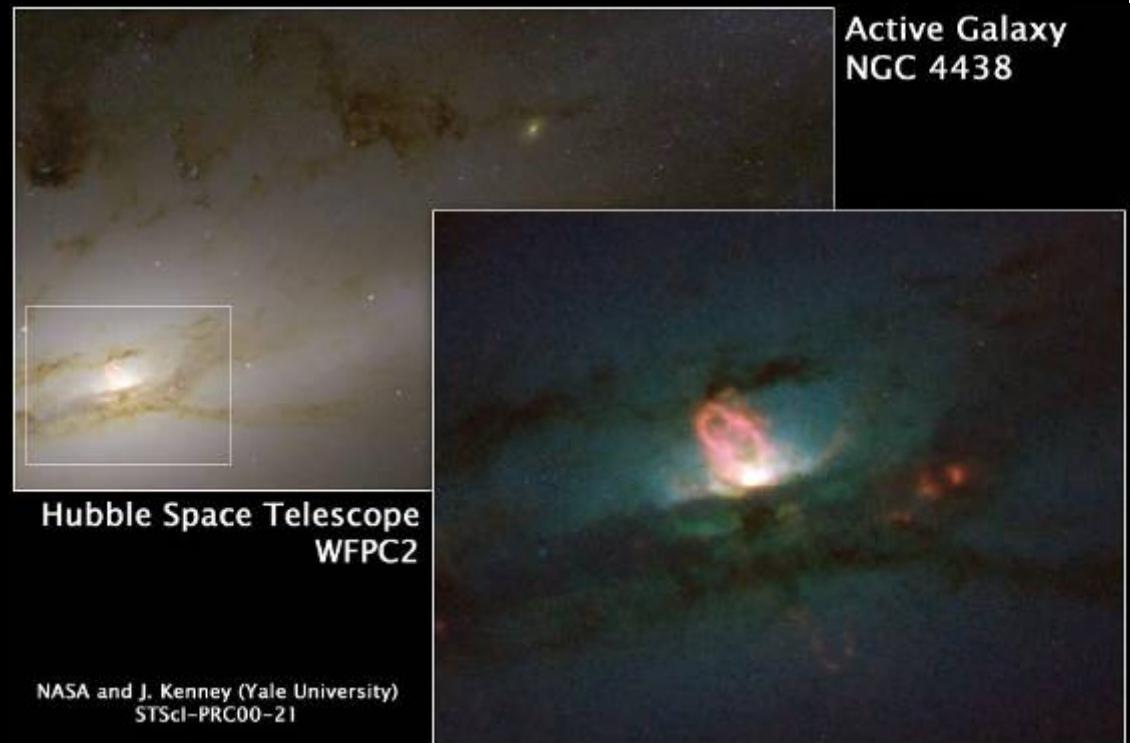


L'energia nei lobi di Cygno A equivale all'annichilazione ($E=mc^2$!) di
10000000000000000000000000000000000 kg...
1 kg equivale a una bomba H di 100
Megatoni

Al centro di una grande galassia



HST • WFPC2



NASA and J. Kenney (Yale University)
STScI-PRC00-21

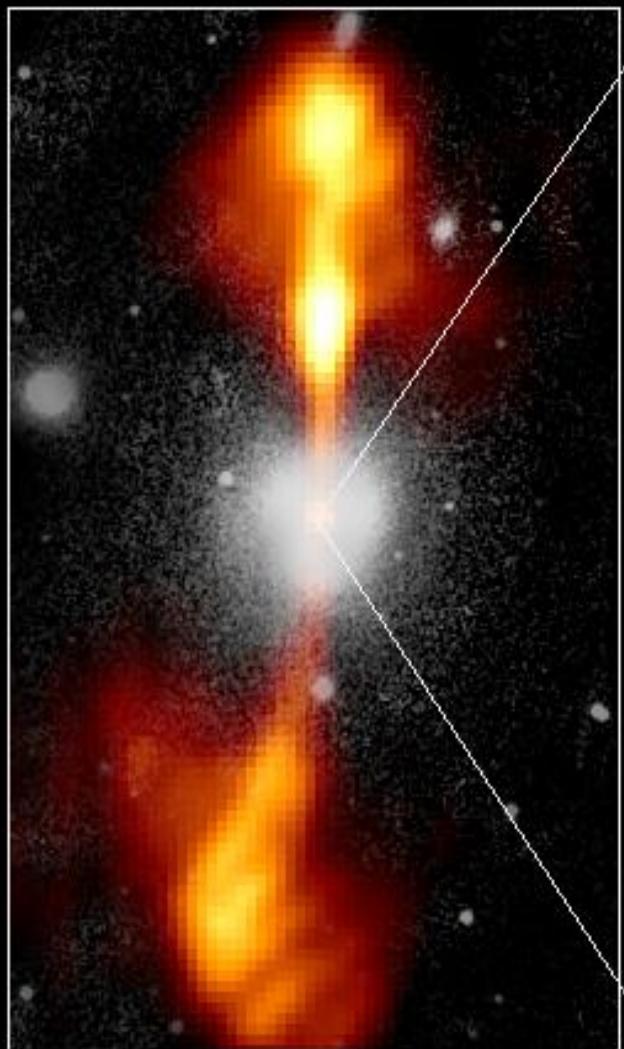
<http://hubblesite.org/newscenter/archive/releases/exotic/black-hole/1998/22/results/20/> and

http://hubblesite.org/newscenter/archive/releases/exotic/black%20hole/2000/21/image/a/format/web_print/results/20/

Hubble Space Telescope

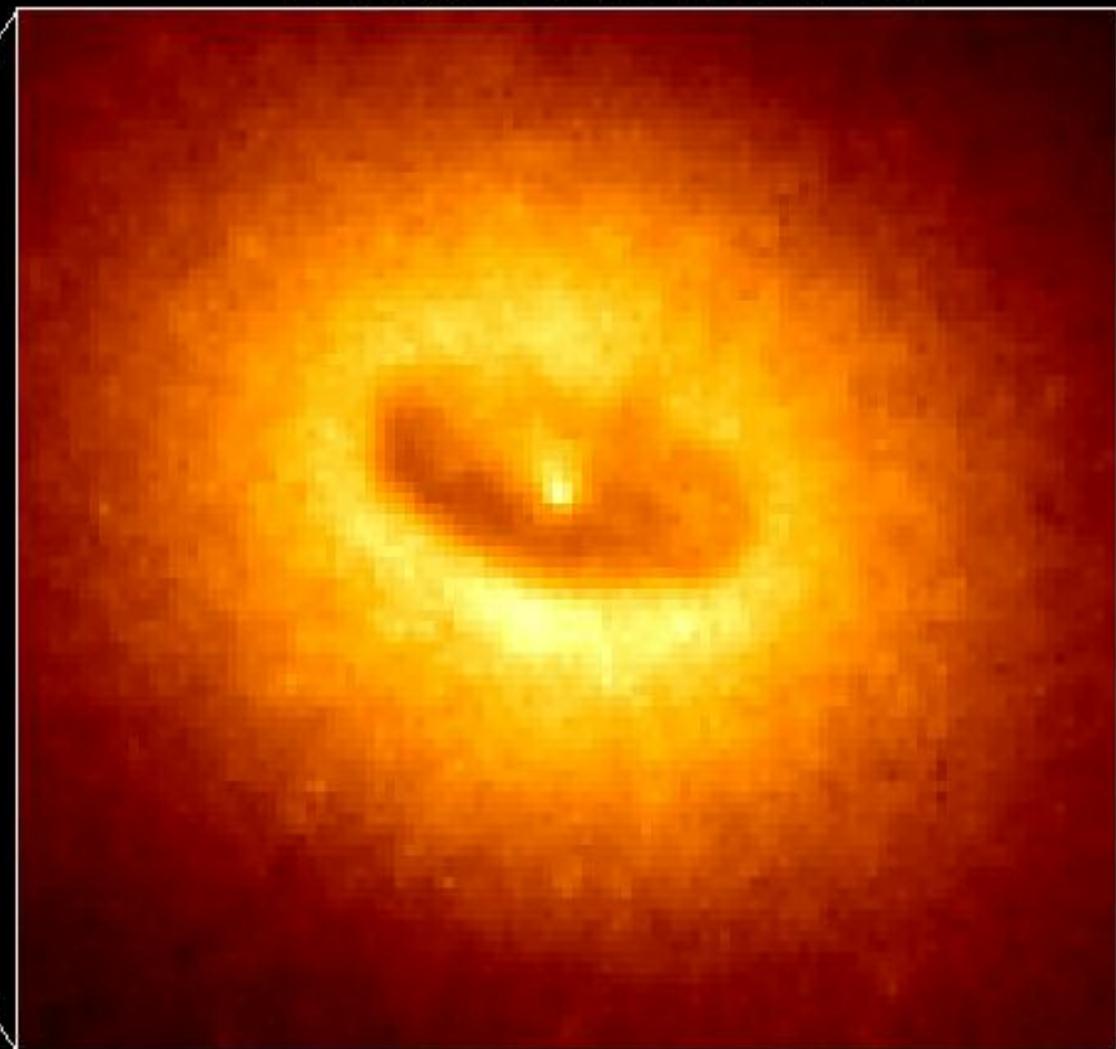
Wide Field / Planetary Camera

Ground-Based Optical/Radio Image



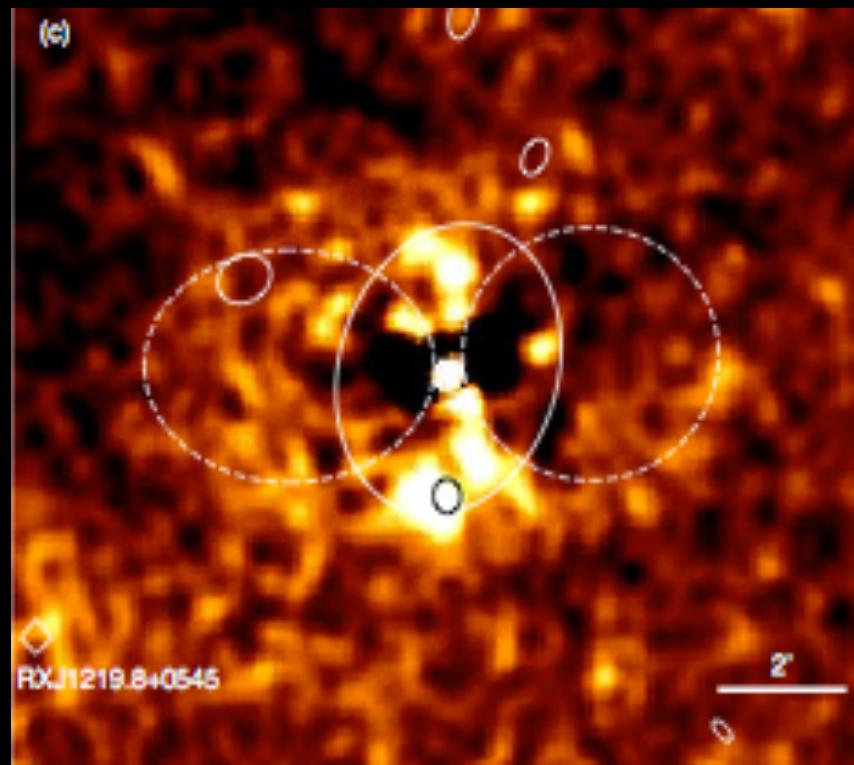
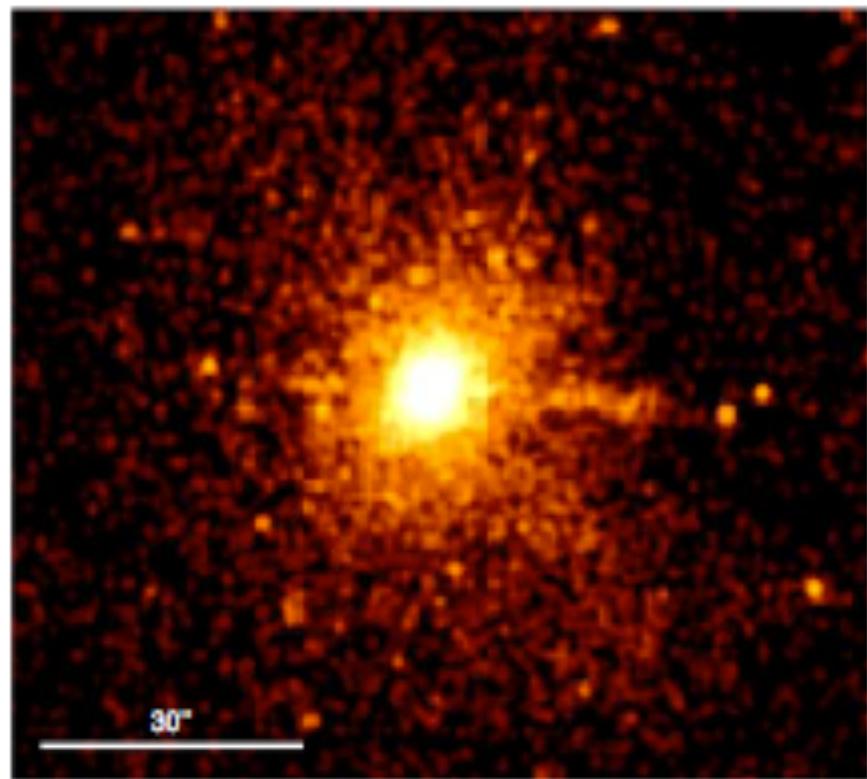
380 Arc Seconds

HST Image of a Gas and Dust Disk



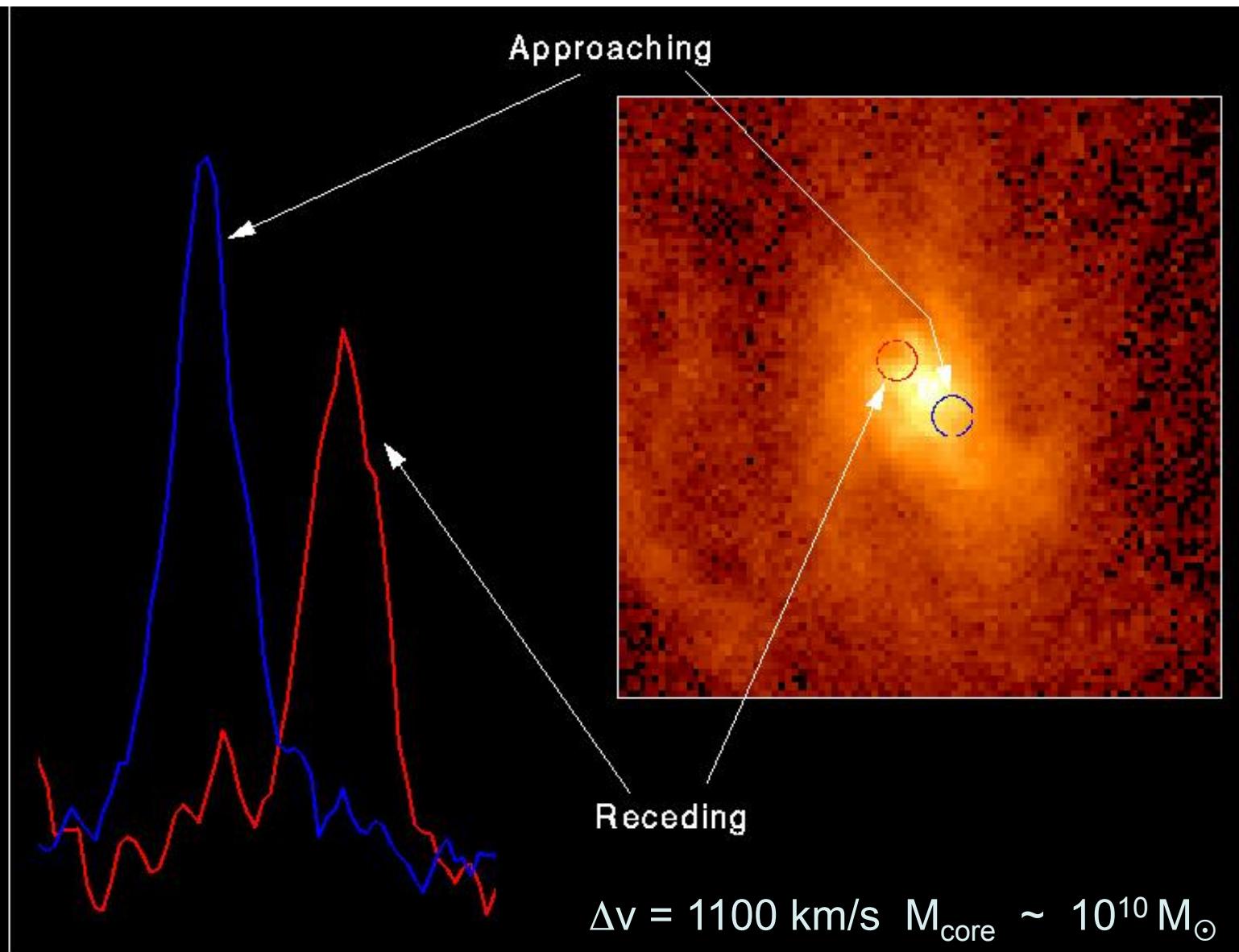
1.7 Arc Seconds

NGC 4261

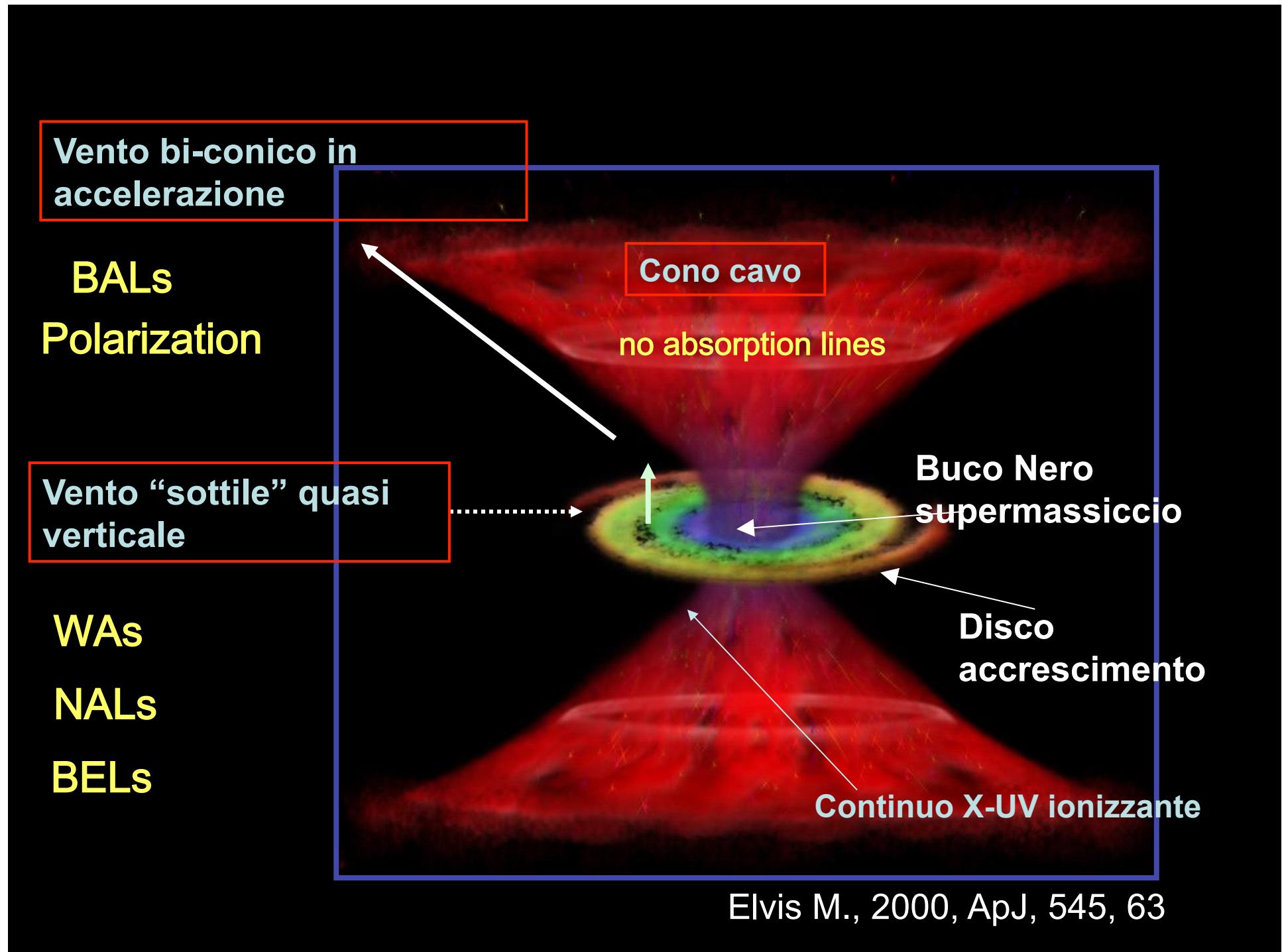


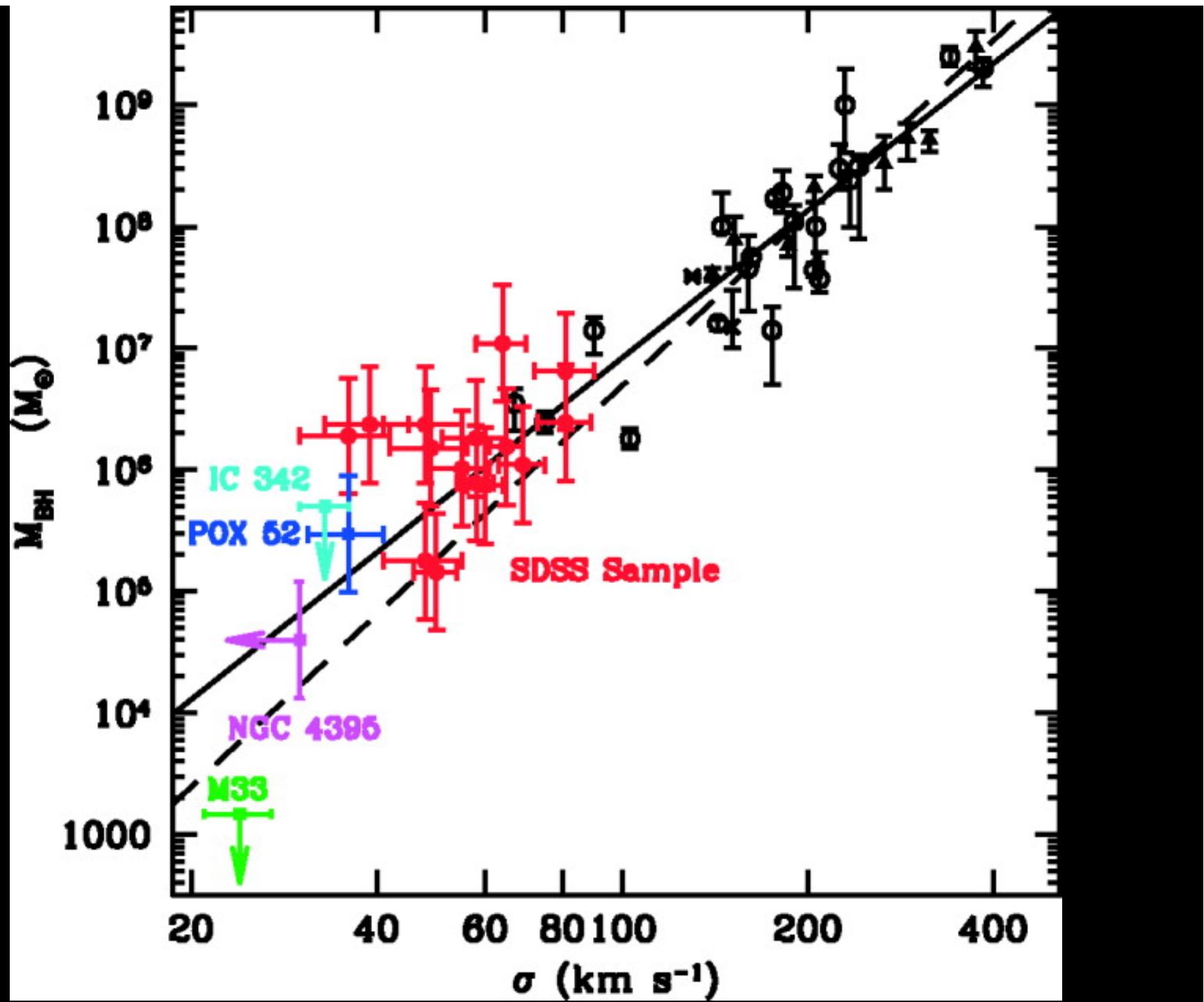
- Immagini Chandra O'Sullivan et al

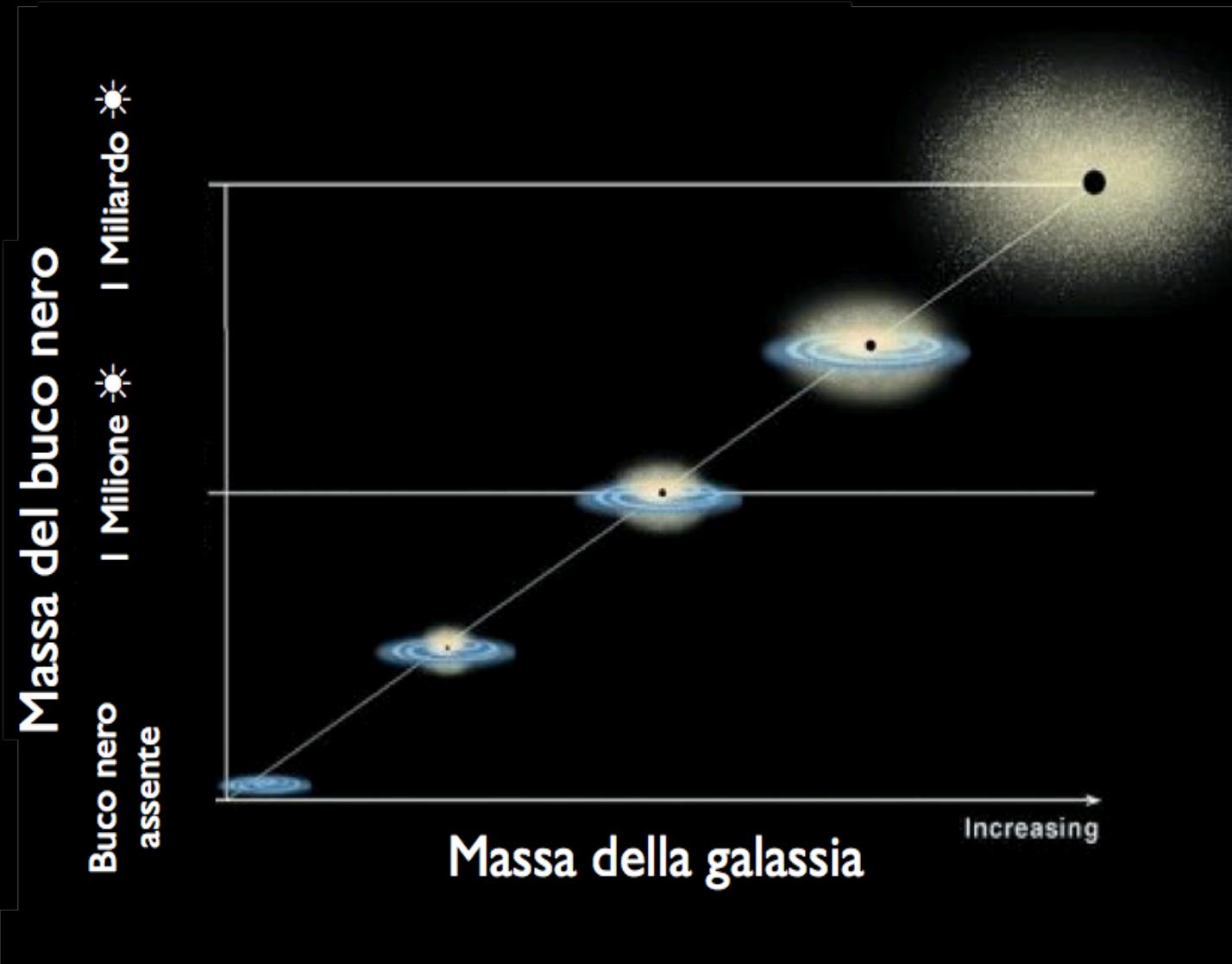
Spettro del disco di gas nella galassia attiva M87



Hubble Space Telescope • Faint Object Spectrograph







La Via Lattea

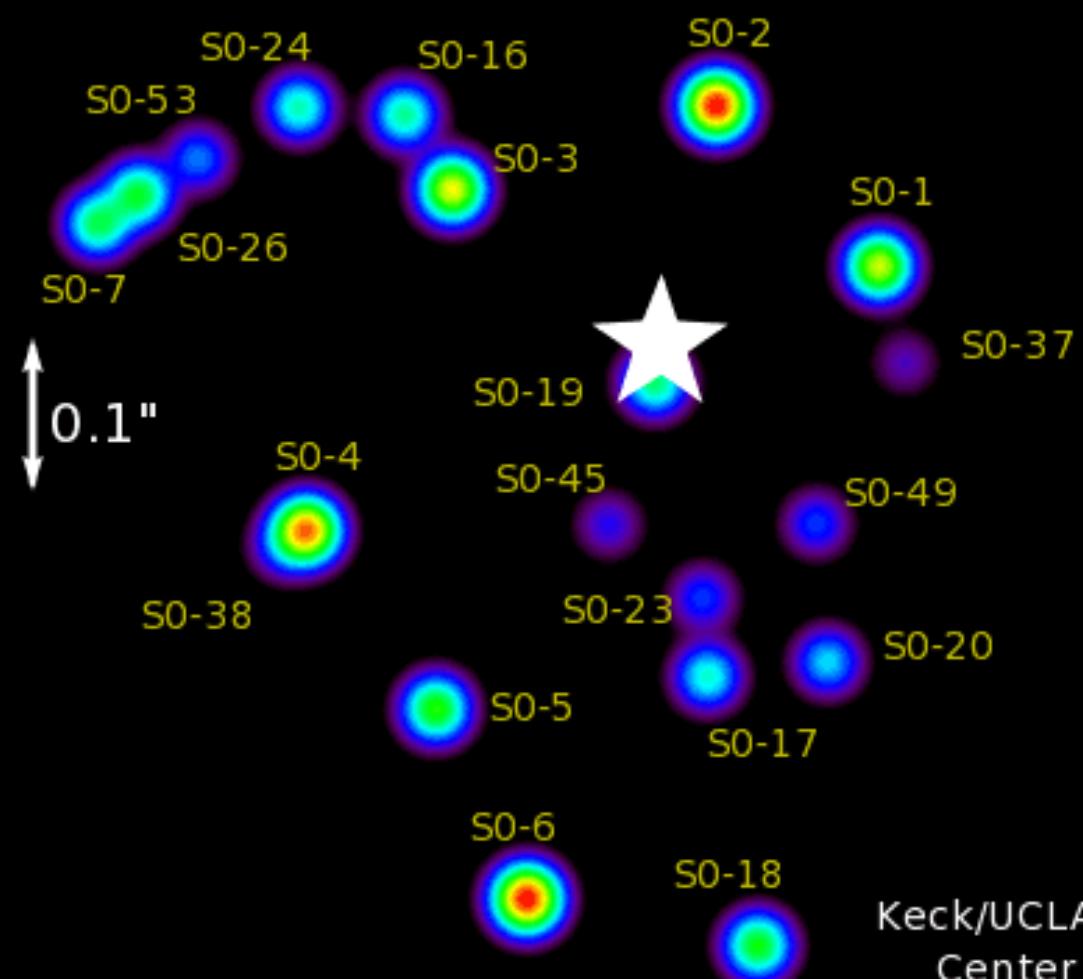


Outer Arm
Perseus Arm
Orion Arm
Carina Arm
Crux Arm

Norma Arm
24Kpc Arm
Sagittarius Arm
Scutum Arm

UNSC Space
Covenant Space

1995.5



Keck/UCLA Galactic
Center Group

Massa del Buco Nero

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$p^2 = \frac{4\pi^2}{GM} r^3$$

3^a legge di Keplero

$$M =$$

4 milioni di volte la
massa del Sole

Ma cosa sono perciò gli AGN?

Sono galassie ad alto/altissimo z

Hanno distanze cosmologiche ($>10^9$ LYs) che fanno sembrare questi oggetti, che hanno brillanze intrinseche enormi, delle deboli stelle

Dai dati X tale potenza ($\sim 10^{47}$ erg/sec) è confermata, risultando circa 10 trilioni maggiore di quella emessa dal Sole per un oggetto di diametro pari a quello del Sistema Solare.

Si nutrono del materiale circostante, da 1 Sole alla settimana a 1 Sole all'anno

Una piccola frazione presenta getti ed emissione radio collimata

Abbiamo visto che:

- Le galassie sono sede di fenomeni “violentî”
- La causa è la caduta di materia per gravità verso la regione centrale

Resta da capire:

- Come si estrae l'energia dal buco nero per trasmetterla ai getti?
- Se ogni galassia attiva ha un buco nero centrale, perché solo alcune hanno getti radio?
- Perché non ce ne sono vicini a noi?
- ...

Cosmologia →

Cosmologia

I Quasars: sonde cosmologiche

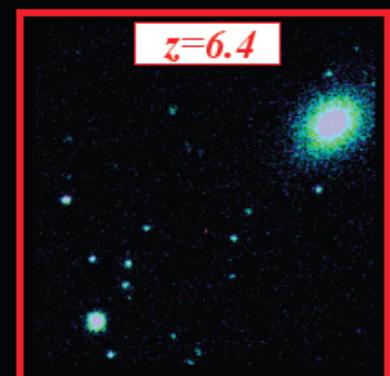
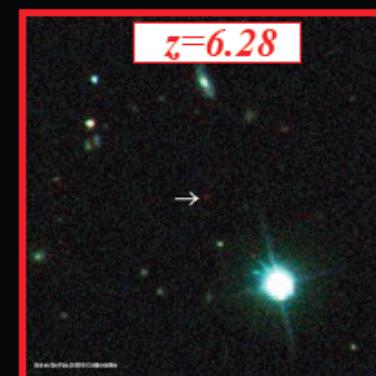
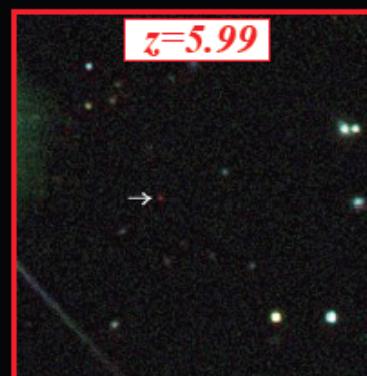
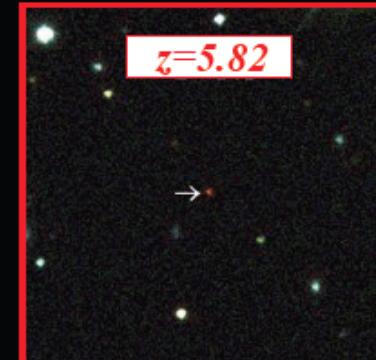
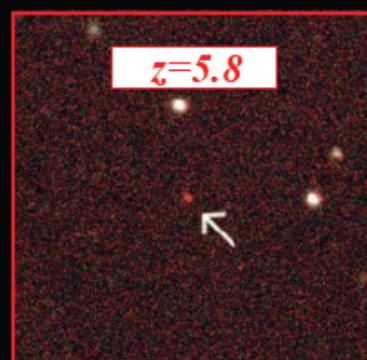
L'elevata luminosità ed apparenza puntiforme offrono la possibilità di usare i quasars come strumenti per sondare l'universo lontano.

I Quasars sono tra gli oggetti più distanti che riusciamo a vedere.

$z \approx 6$



*Età dell'universo \approx
1 miliardo di anni*

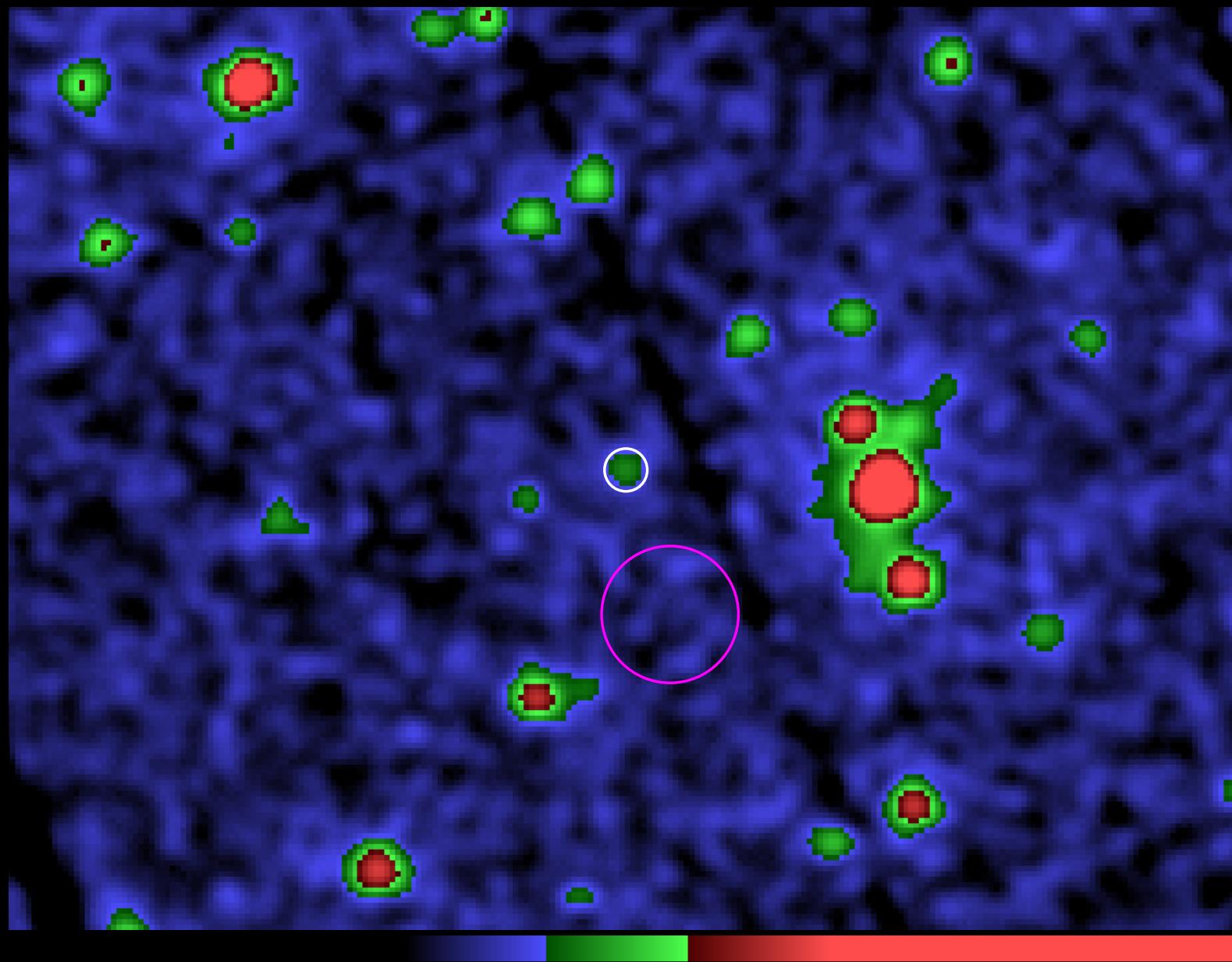


Il quasar più distante

La luce emessa ha impiegato circa
12.9 miliardi di anni per raggiungerci.



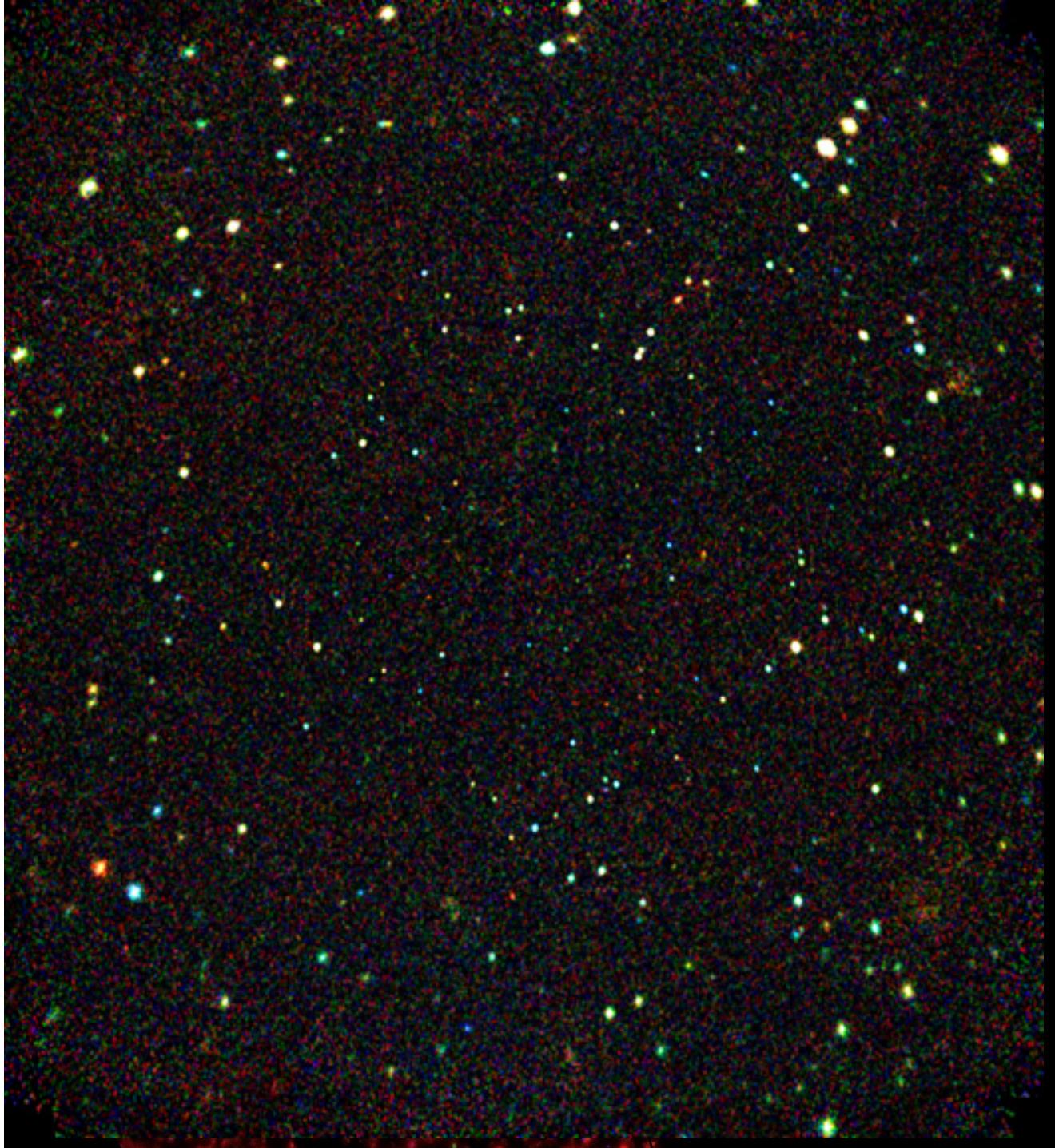
$z=7.1$ cioè 770 milioni di anni dopo il Big Bang



ULAS J1120+0641

GN-z11



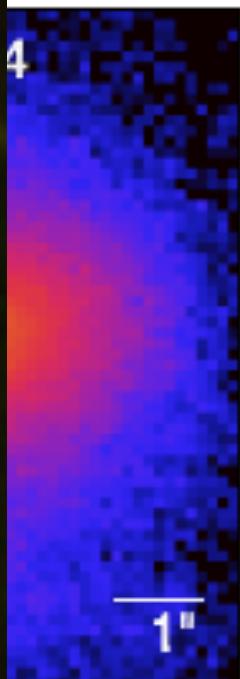
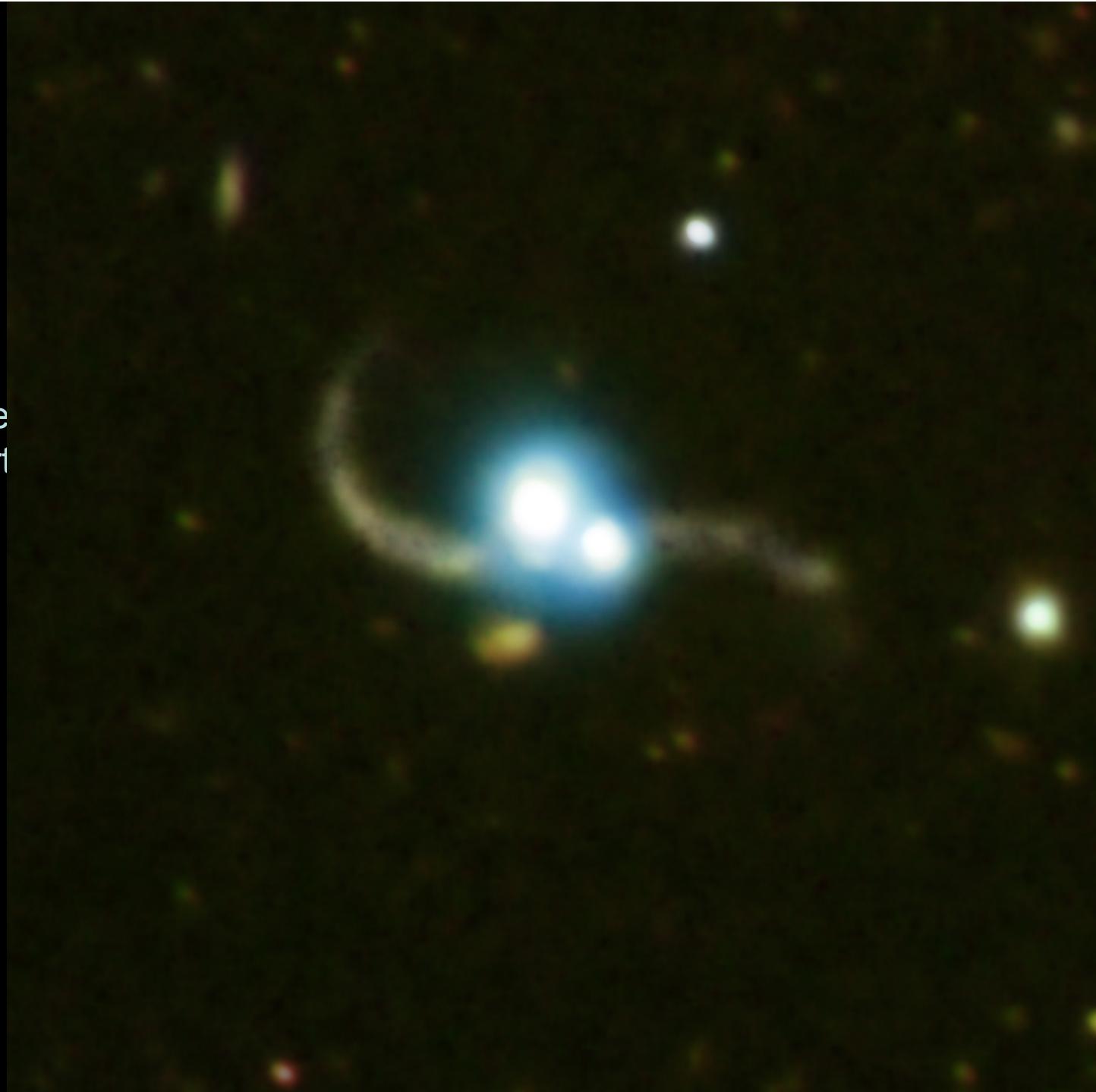


Le profondità del
cosmo con XMM-
Newton e Chandra

La maggioranza di
queste sorgenti
sono quasar (AGN)
l'80% circa del
“fondo cosmico” in
raggi X

Le onde gravitazionali

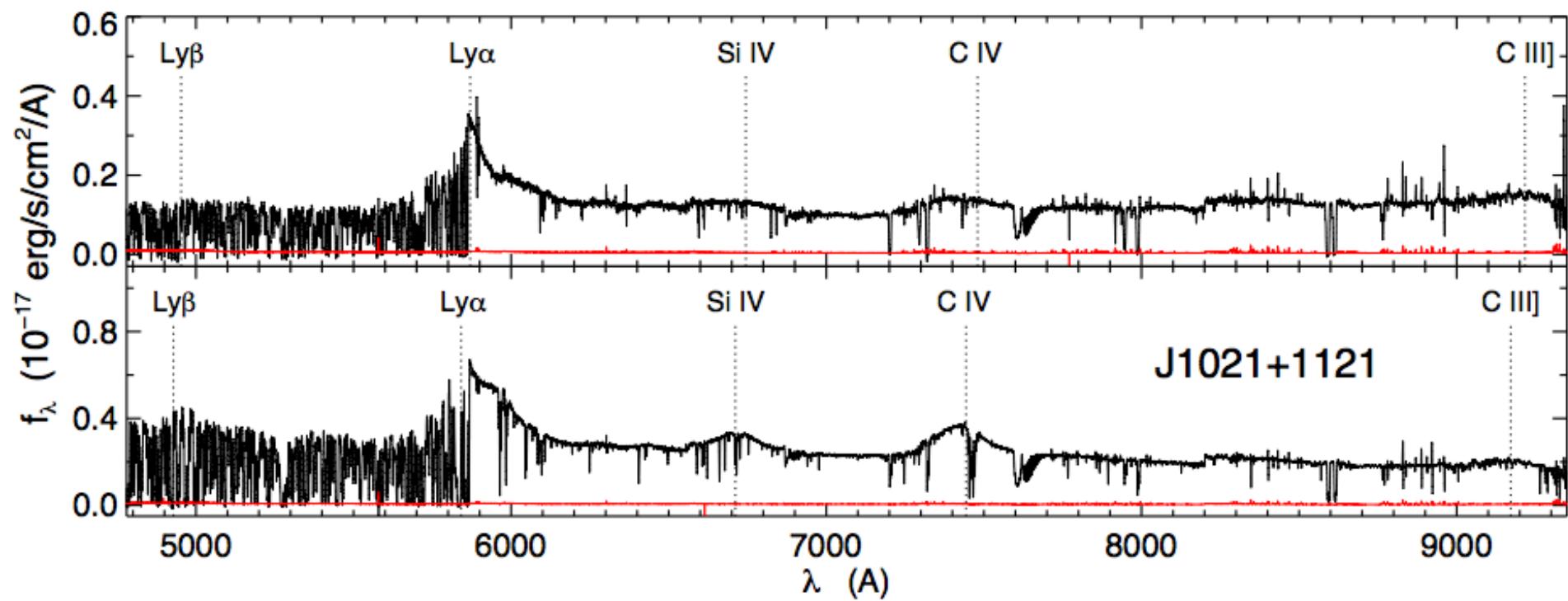
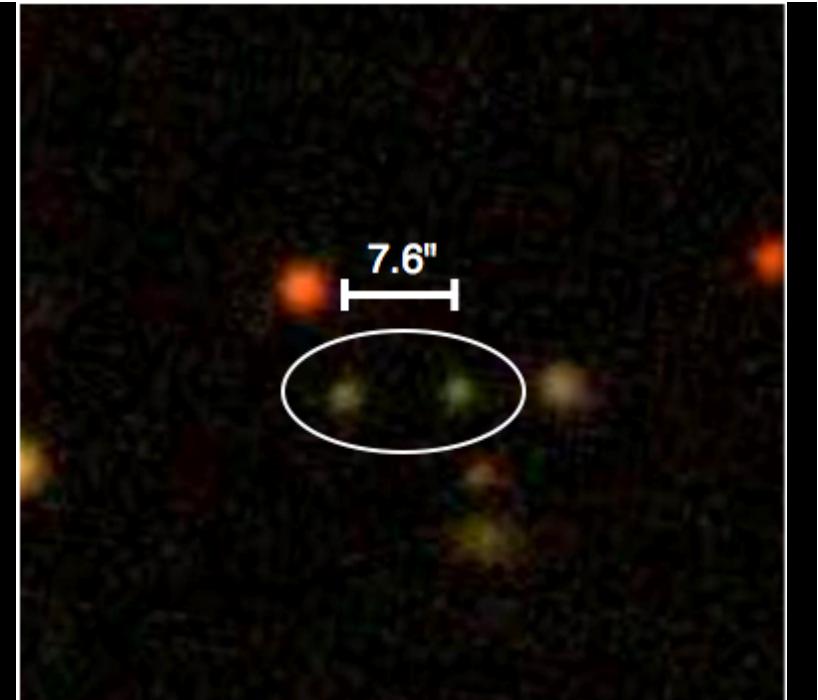
4
galassie
di Seferi
con
Doppio
Nucleo
in IR



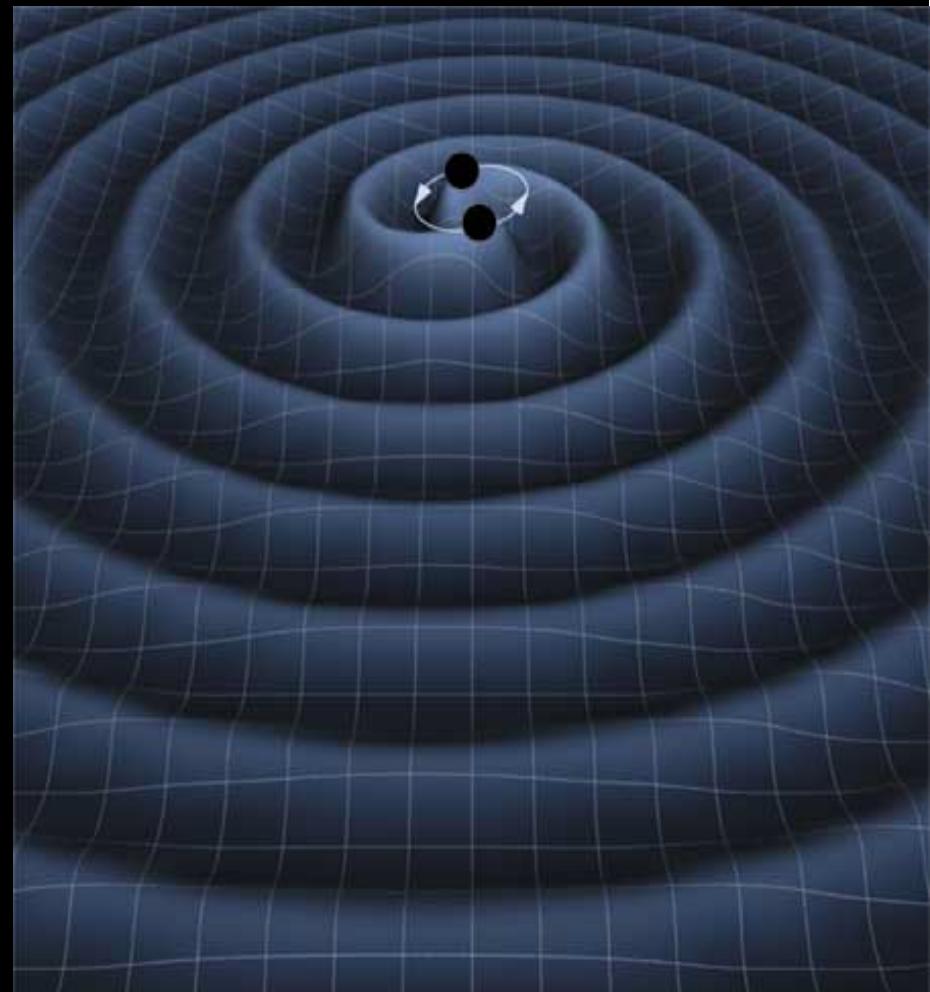
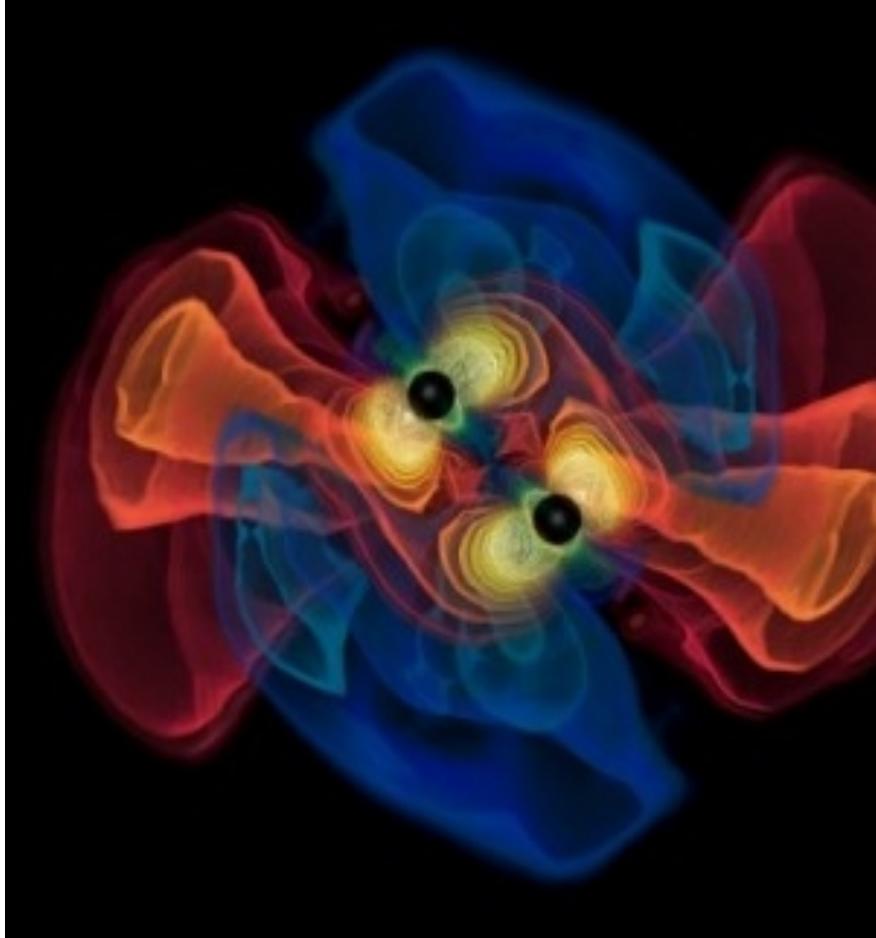
06

0"

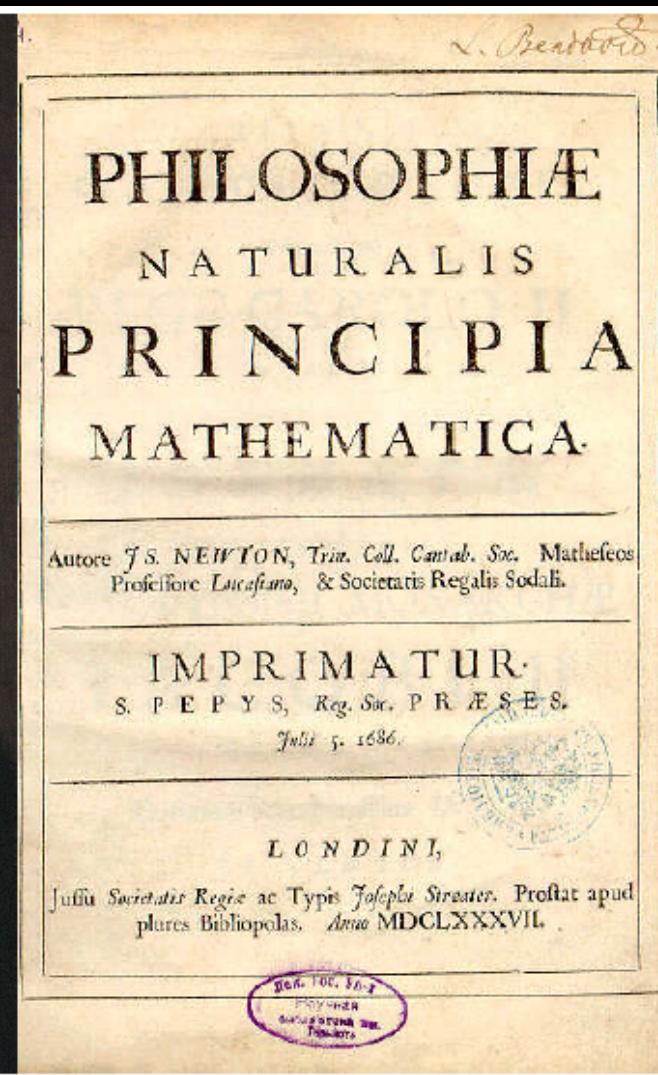
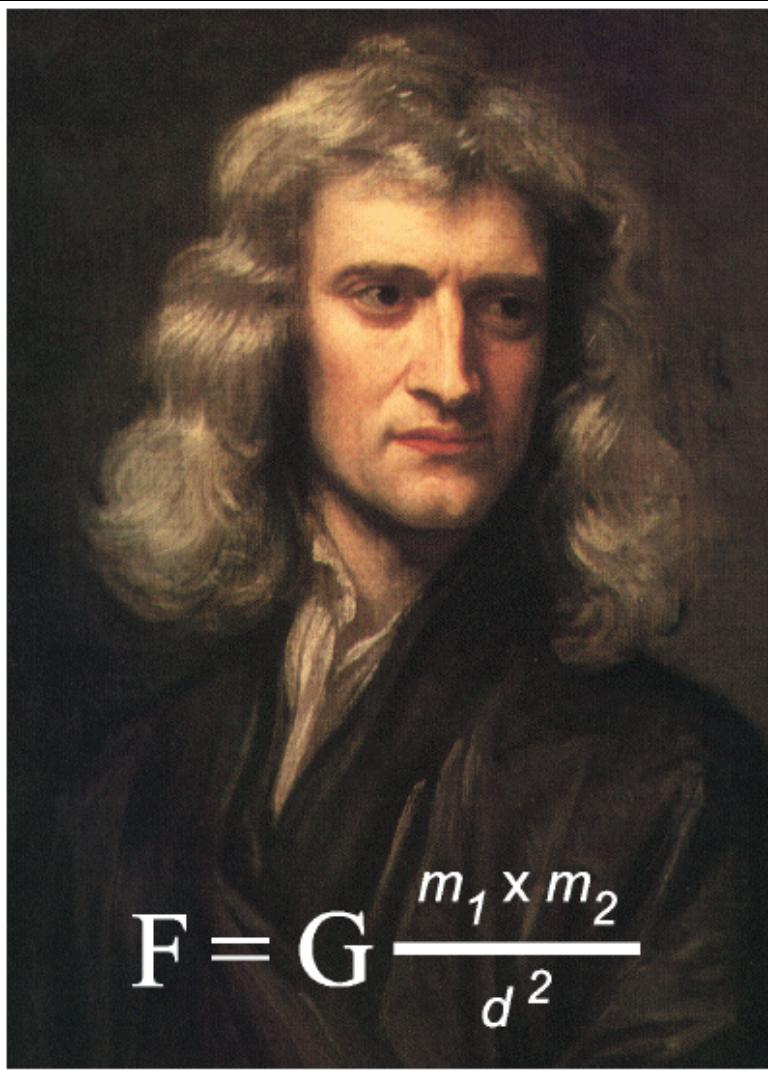
Coppia di quasar a $z=3.8$,
40 kpc
27 coppie a $z > 2.9$



Onde Gravitazionali



La forza di gravità

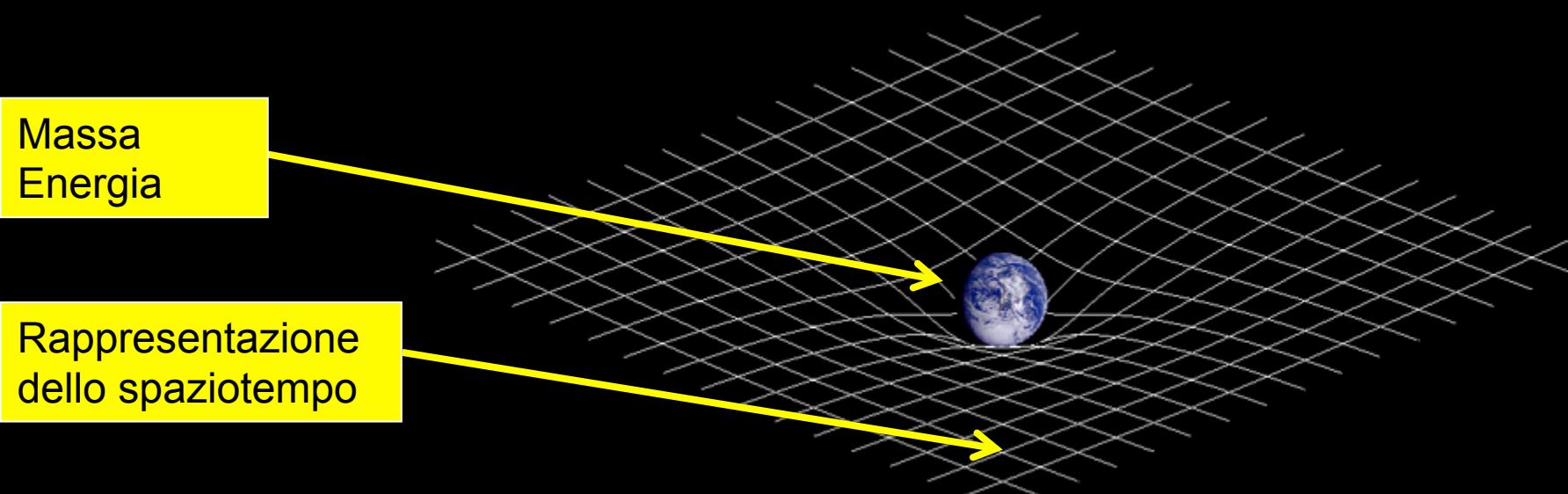
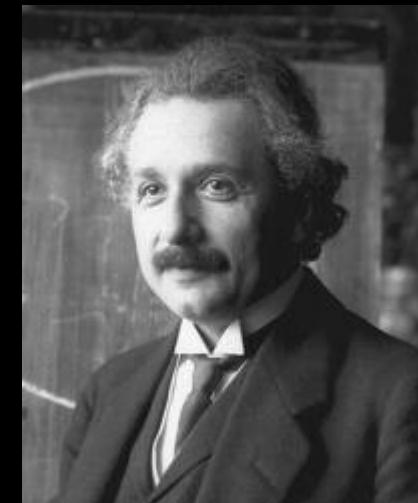


La Gravità di Einstein

La Relatività Generale è una teoria geometrica della Gravità proposta da Albert Einstein nel 1915

La Relatività Generale comprende la Relatività Speciale e la Teoria Newtoniana della Gravitazione.

La gravità è descritta come una proprietà geometrica dello spaziotempo.





Curvatura dello spazio

“La materia dice allo spazio come curvarsi, lo spazio dice alla materia come muoversi.” (J.A. Wheeler)

La curvatura dello spazio-tempo viene descritta matematicamente dalla geometria non euclidea studiata per primo da Bernhard Riemann a metà dell'Ottocento.

688 Sitzung der physikalisch-mathematischen Klasse vom 22. Juni 1916

Näherungsweise Integration der Feldgleichungen der Gravitation.

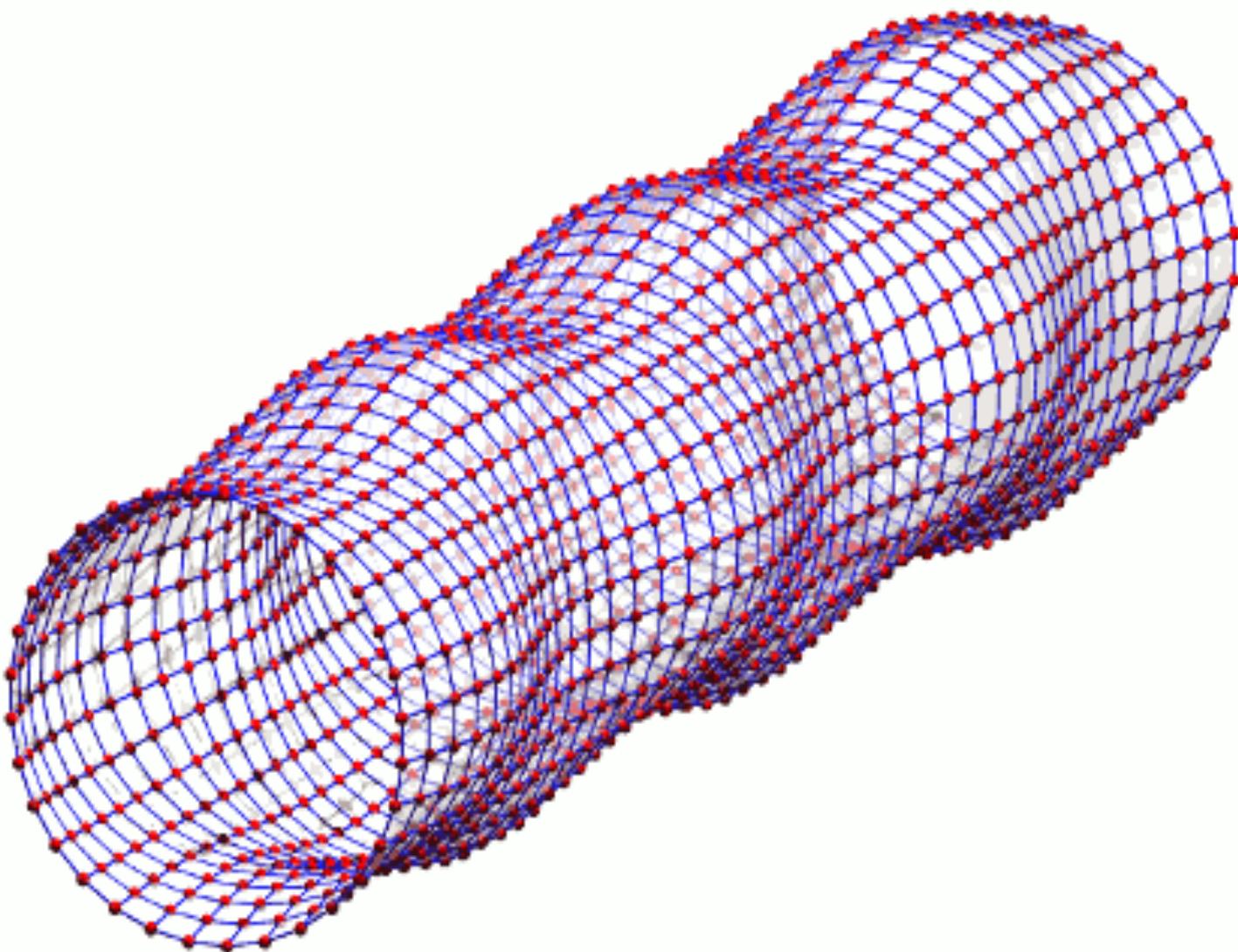
Von A. EINSTEIN.

Über Gravitationswellen.

Von A. EINSTEIN.

(Vorgelegt am 31. Januar 1918 [s. oben S. 79].)

Die wichtige Frage, wie die Ausbreitung der Gravitationsfelder erfolgt, ist schon vor anderthalb Jahren in einer Akademiearbeit von mir behandelt worden¹. Da aber meine damalige Darstellung des Gegen-



www.einstein-online.info

Una ricerca condotta a livello internazionale



GEO600 (British-German)
Hannover, Germany



LIGO (USA)
Hanford, WA and Livingston, LA



KAGRA (Japan)
Kamioka

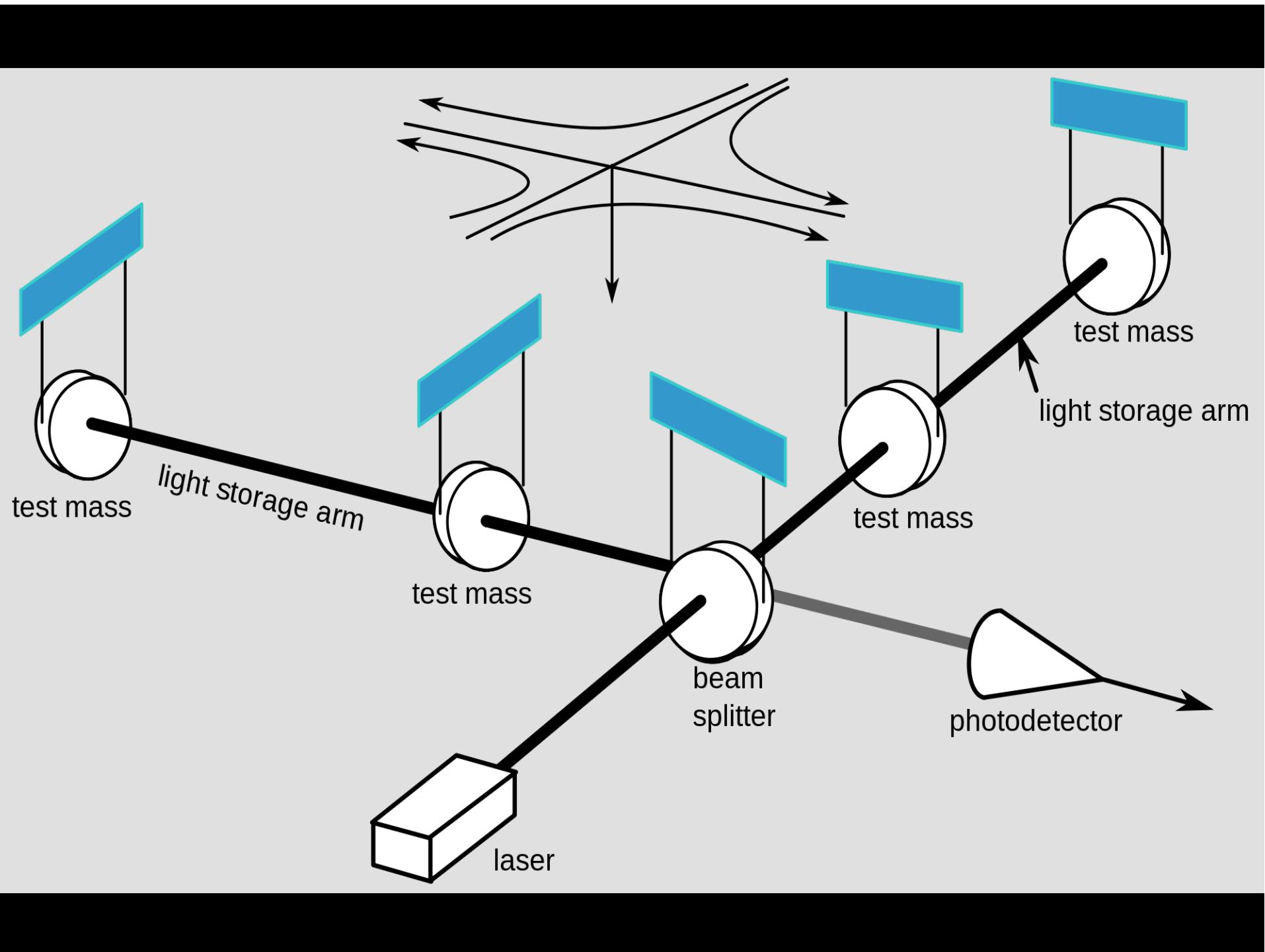


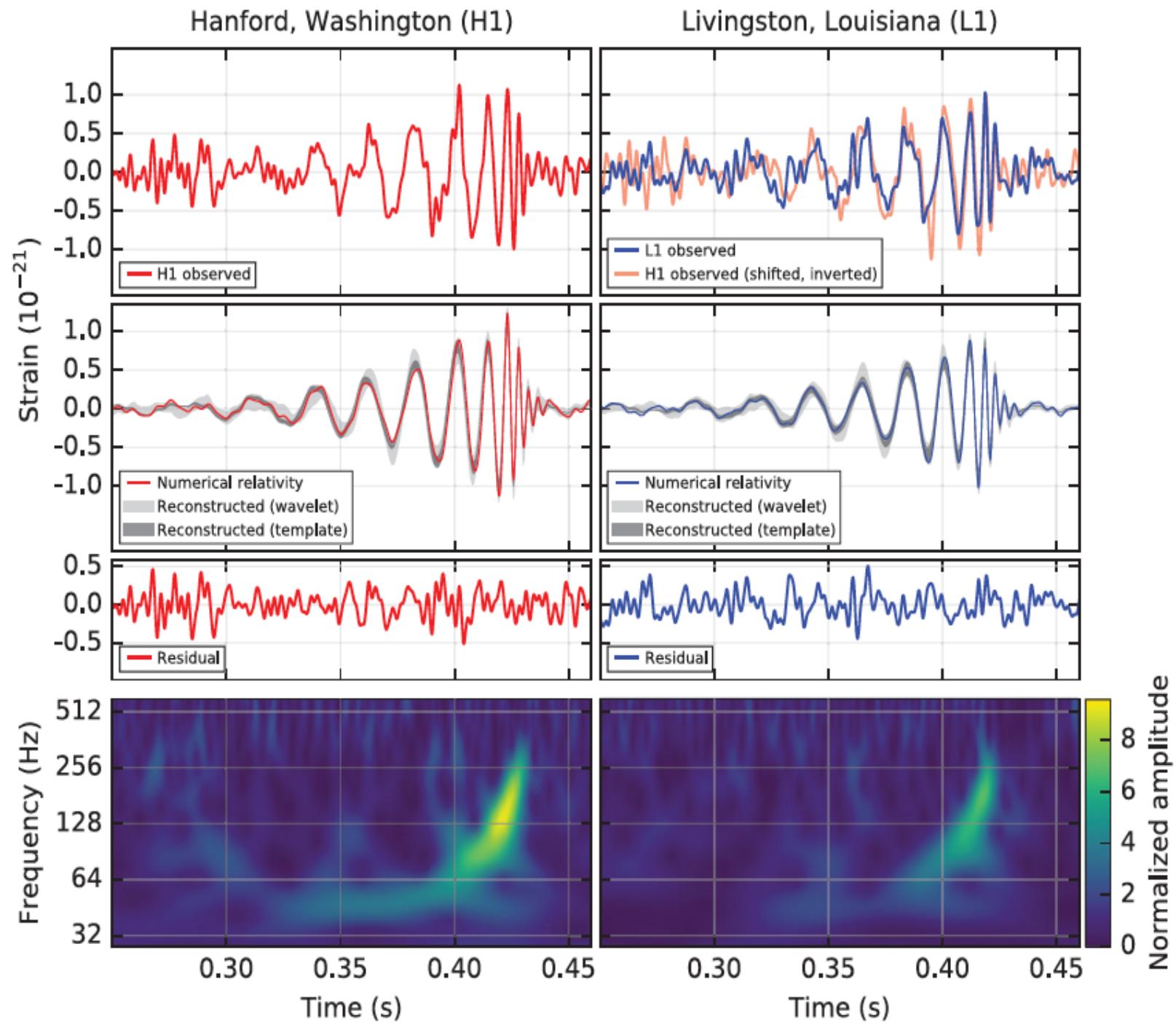
INDIGO (India),
R&D activity for a 4km Interferometer



VIRGO (French-Italian)
Cascina, Italy

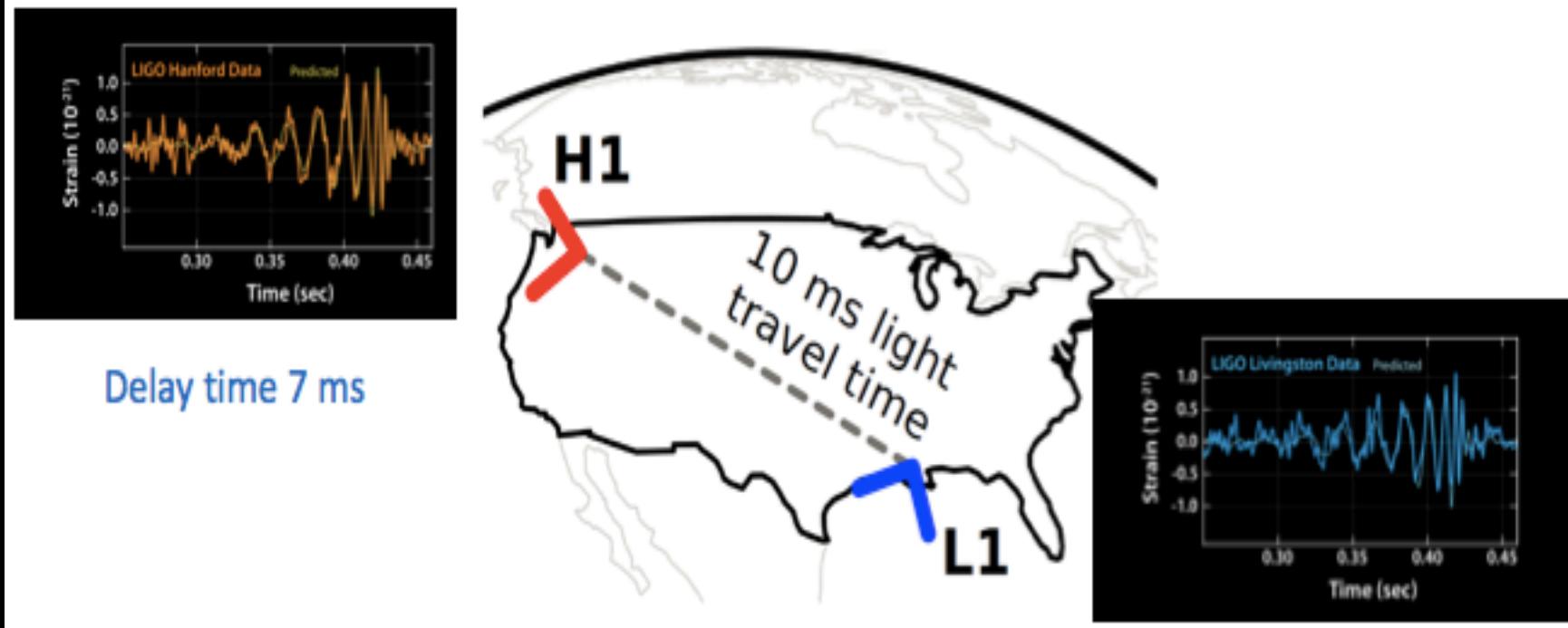
43





GW150914 the chronology

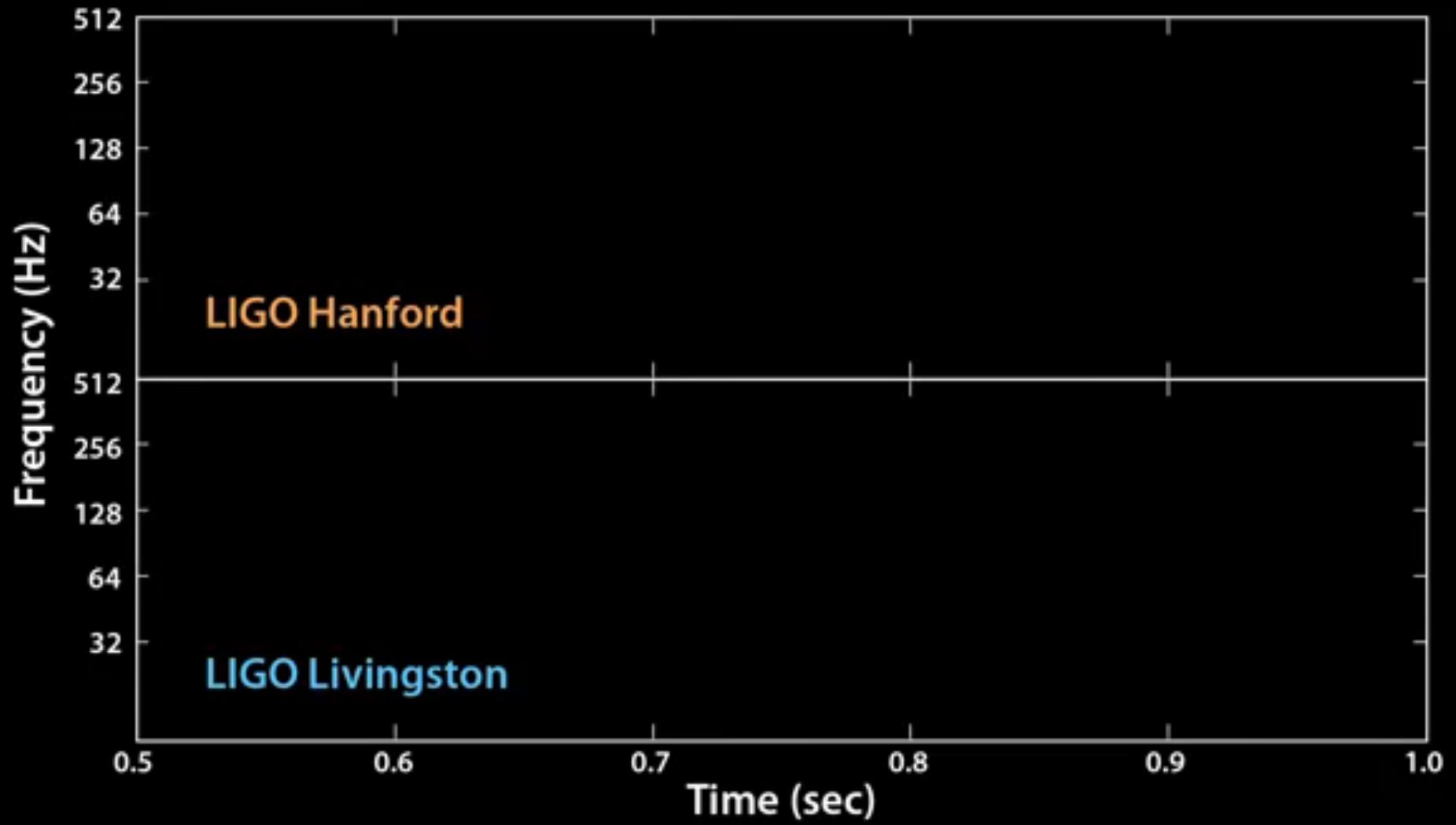
- First Observation run **O1**: Sept 2015 - Jan 2016
- September 14, 2015 UTC: 09:50:45

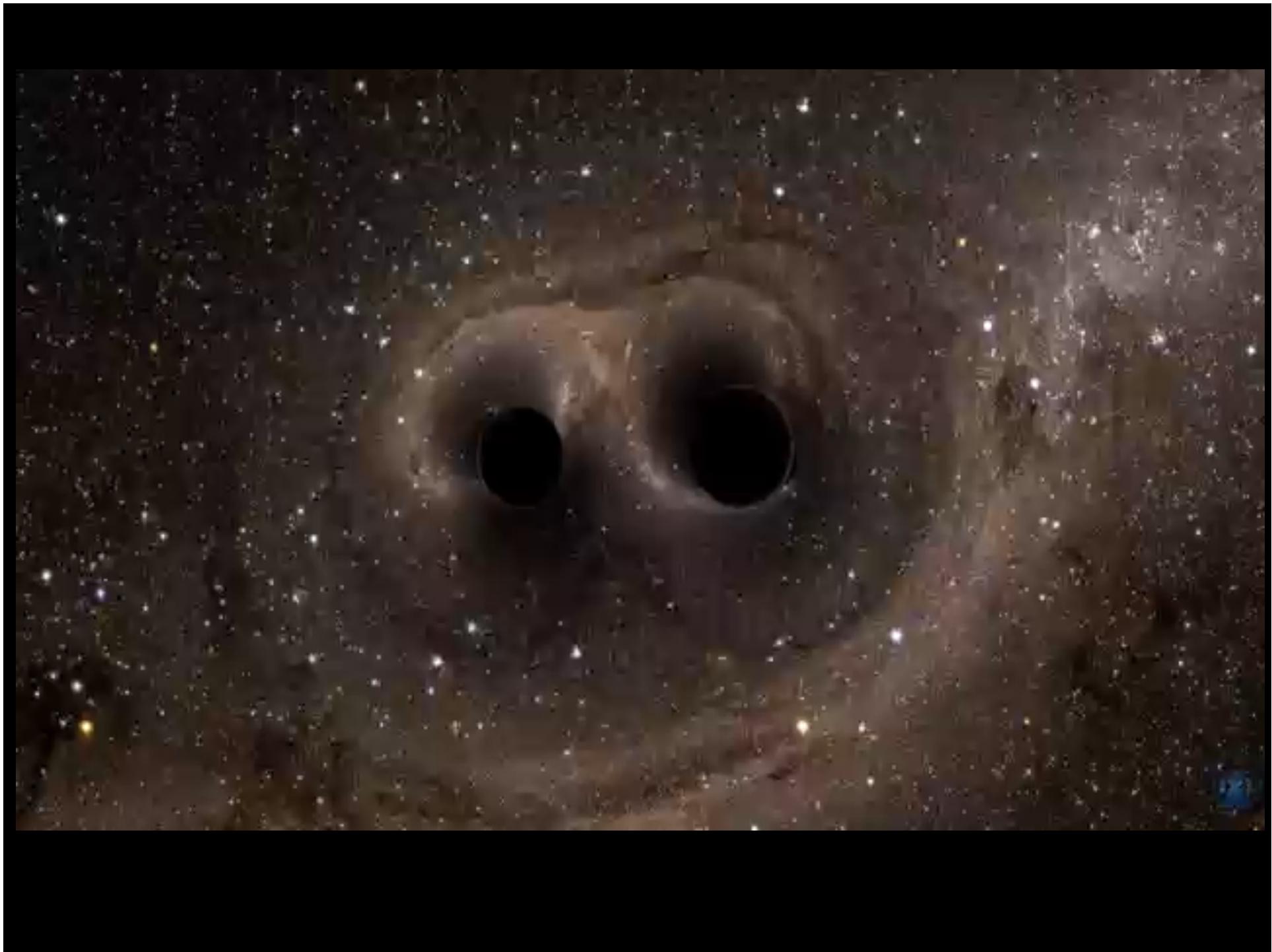


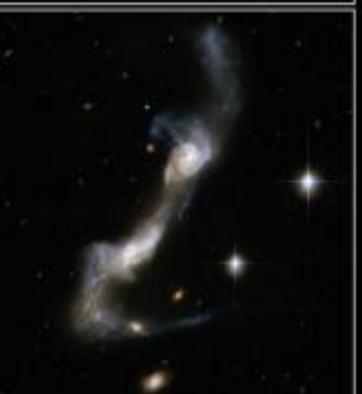




Scale of Effect Vastly Exaggerated









Observation of Gravitational Waves from a Binary Black Hole Merger

B. P. Abbott *et al.**

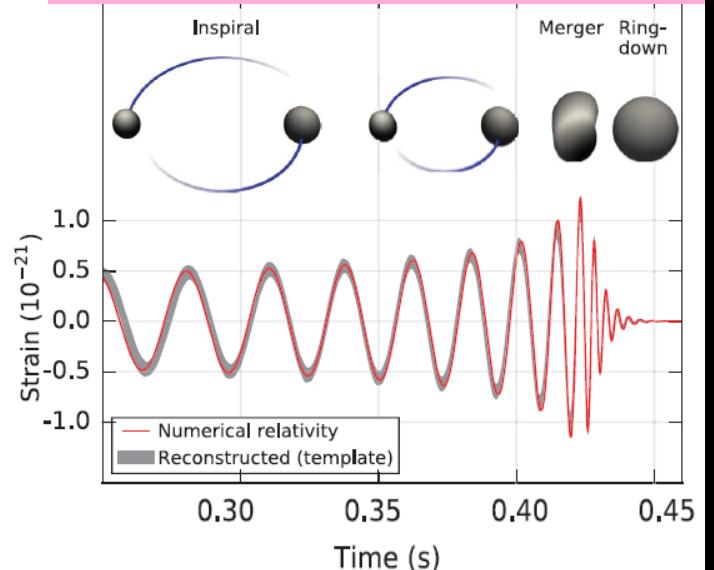
(LIGO Scientific Collaboration and Virgo Collaboration)

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- I rivelatori di LIGO (Laser Interferometer Gravitational-Wave Observatory) hanno osservato onde gravitazionali dalla coalescenza di due buchi neri di masse stellari.
- La forma d'onda rivelata è in accordo con le predizioni della relatività generale per la coalescenza di una coppia di buchi neri e l'assestamento del buco nero risultante.
- Questa osservazione dimostra l'esistenza di sistemi binari di buchi neri di masse stellari.
- Questa è la prima rivelazione diretta di onde gravitazionali e la prima osservazione di un sistema binario di buchi neri coalescenti.



11 Febbraio Press Conference



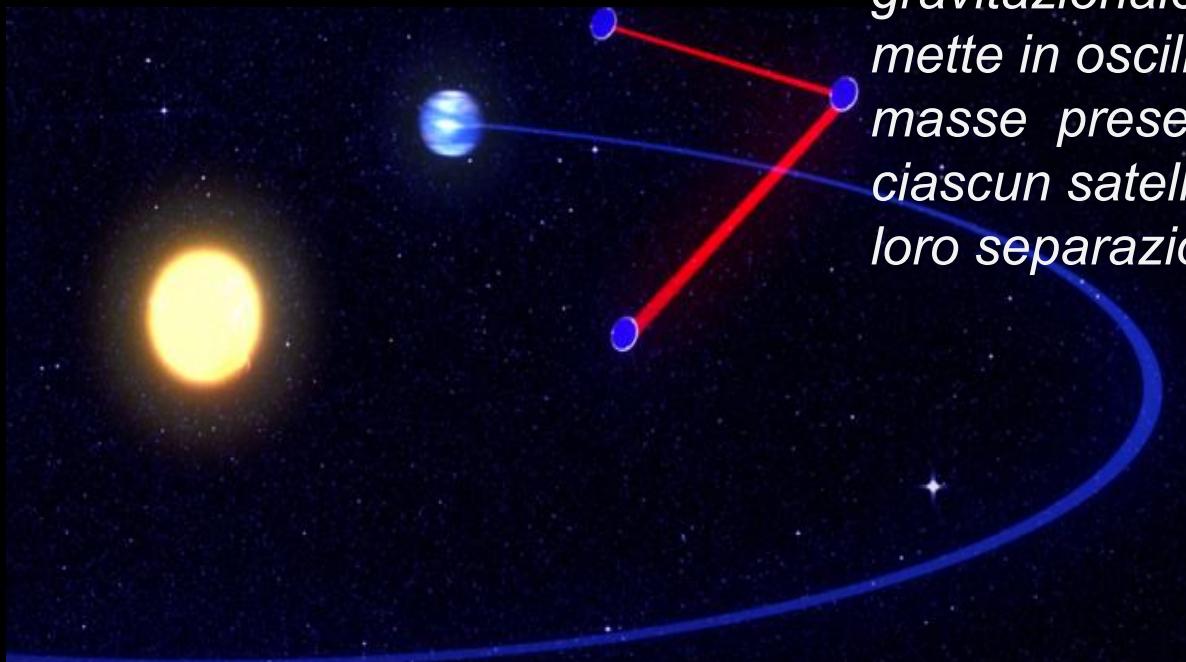
EGO - Virgo



L'Interferometro italo-francese
VIRGO (Cascina, Pisa) per la
rivelazione delle Onde
Gravitazionali



eLISA

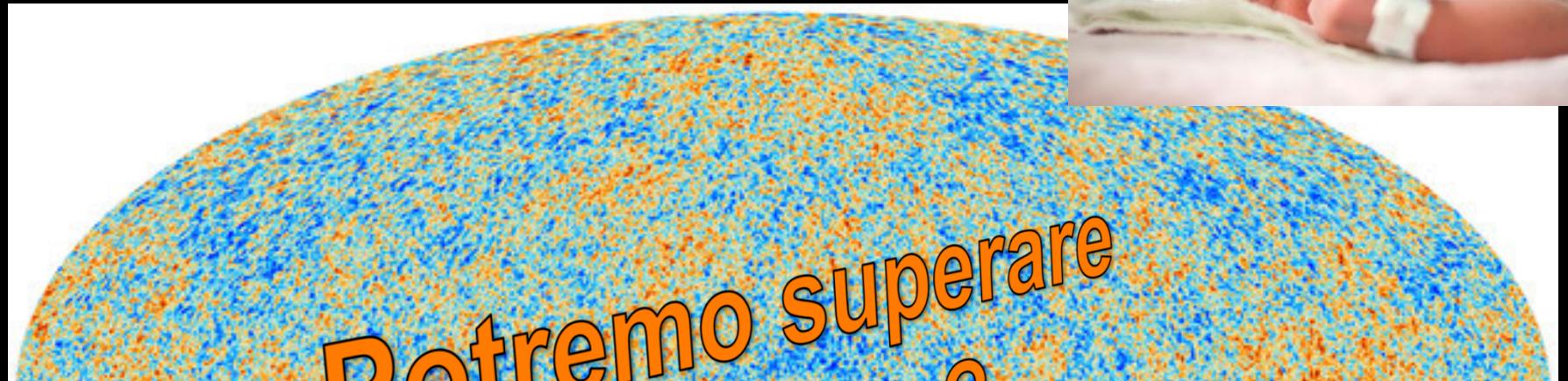


eLISA: The Mission

eLISA è un interferometro spaziale che sarà costituito da tre satelliti posti ai vertici di un ideale triangolo equilatero, ciascuno alla distanza di un milione di chilometri l'uno dall'altro e tutti in movimento su un'orbita eliocentrica. Un'onda gravitazionale, al suo passaggio, mette in oscillazione piccole masse presenti all'interno di ciascun satellite, variando così la loro separazione relativa. .

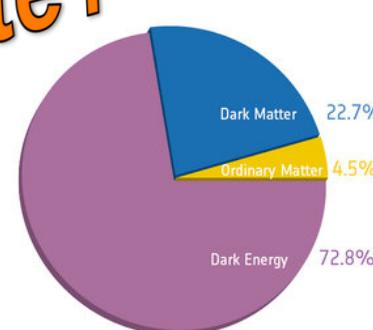
I nuovi risultati di PLANCK

L'Universo a 380 000 anni

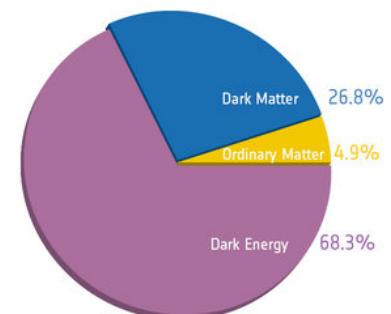


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YEARS OF RITA**

From a home lab to the Italian Senate, by way of nerve growth factor — Rita Levi-Montalcini is a scientist like no other. Alison Abbott meets the first Nobel prizewinner set to reach her hundredth birthday.



Before Planck



After Planck