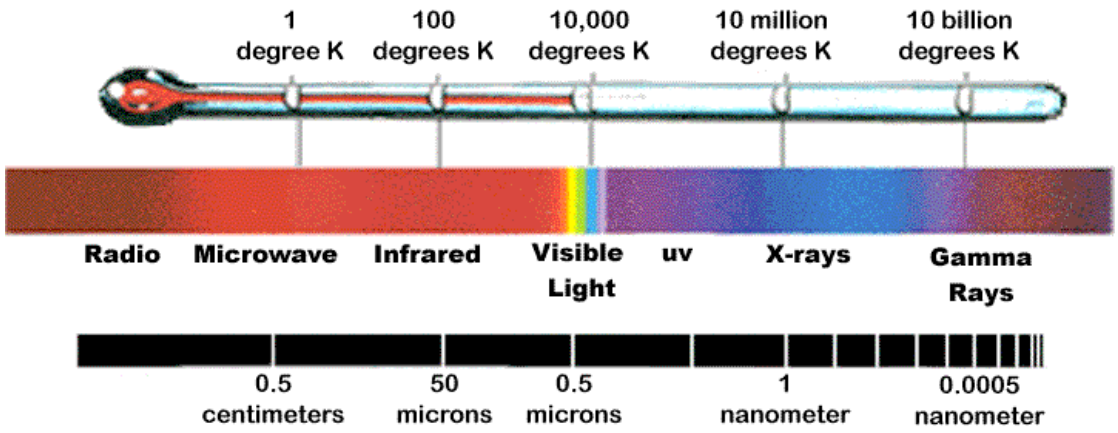
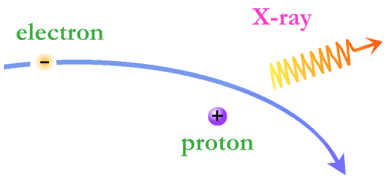
Astronomía de Rayos-X: materia bajo condiciones extremas

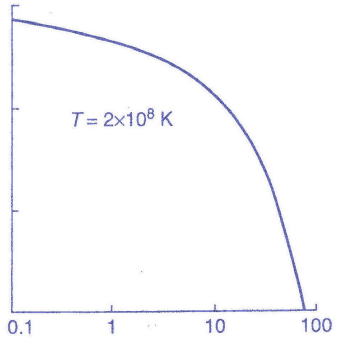


10A,1keV

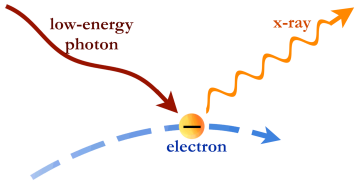
ν(Hz) 10^{10} 10^{13} 10^{15} 10^{16} 10^{18} 10^{20}



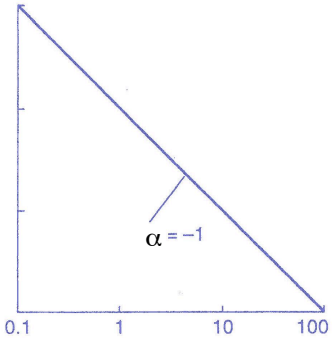
Bremsstrahlung



Energia (keV)

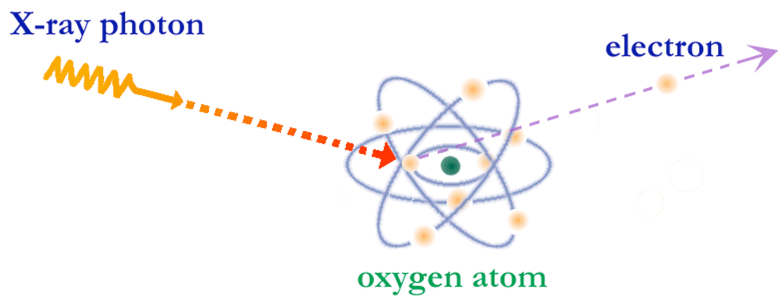


Scattering de Compton Inverso

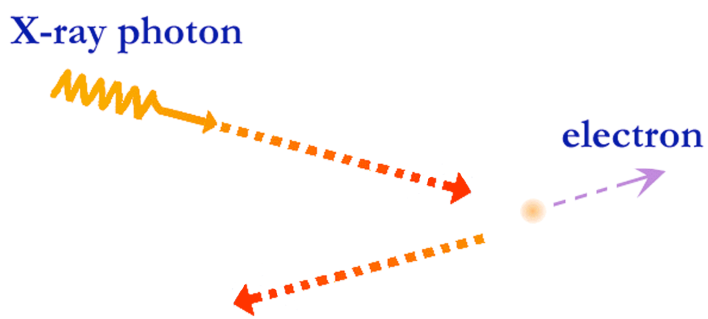


Energía (keV)

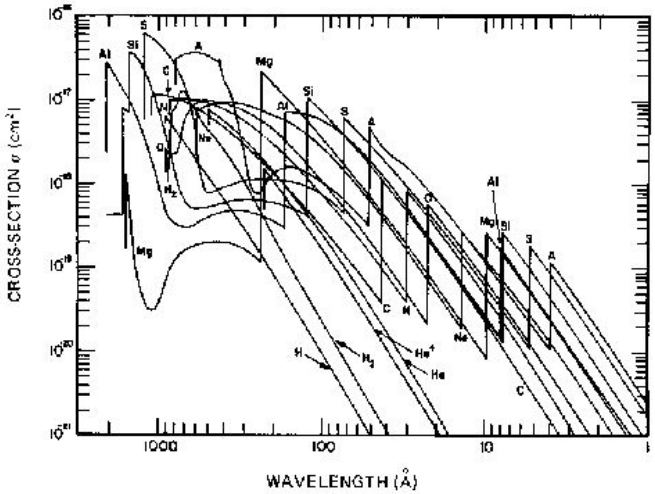
Synchrotron

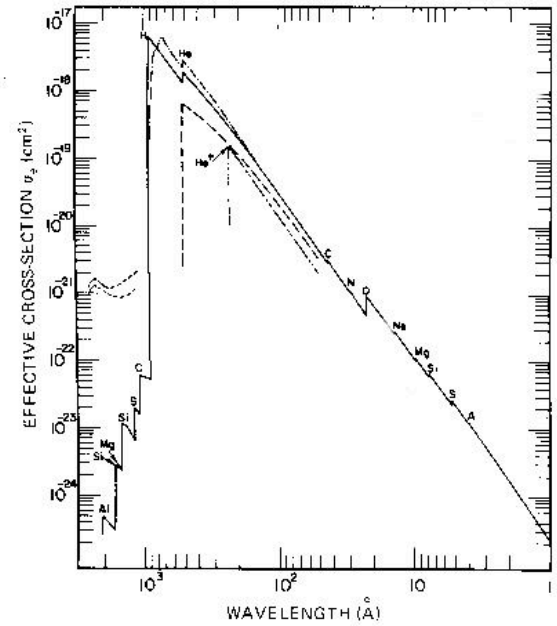


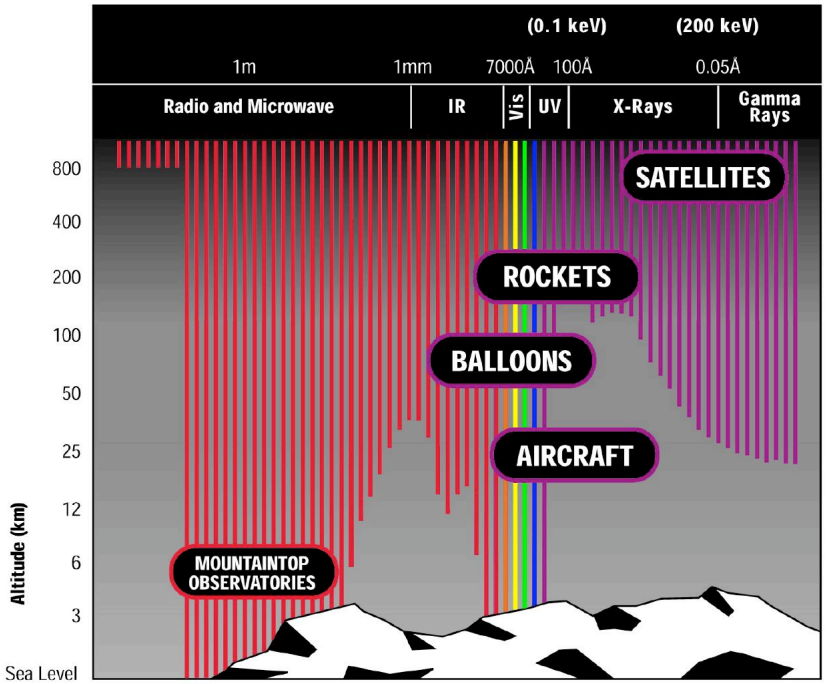
Absorción Fotoeléctrica



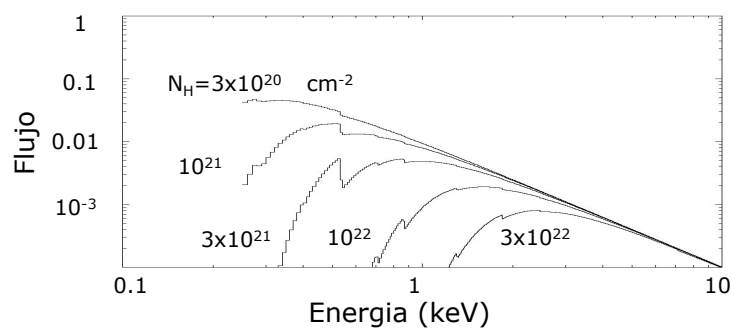
Scattering de Compton

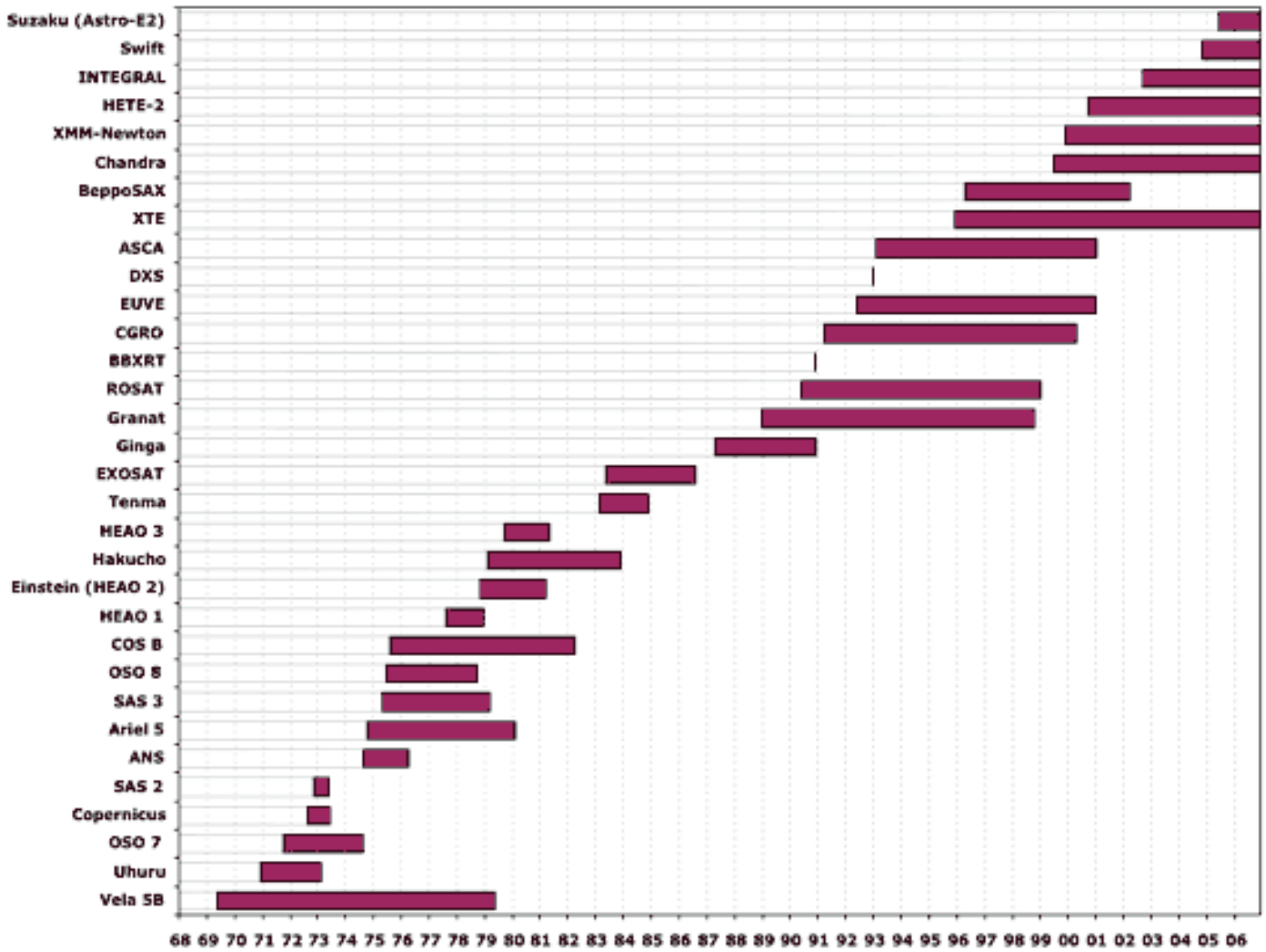

CROSS-SECTION σ (cm²)
WAVELENGTH (Å)
1000
100
10
1

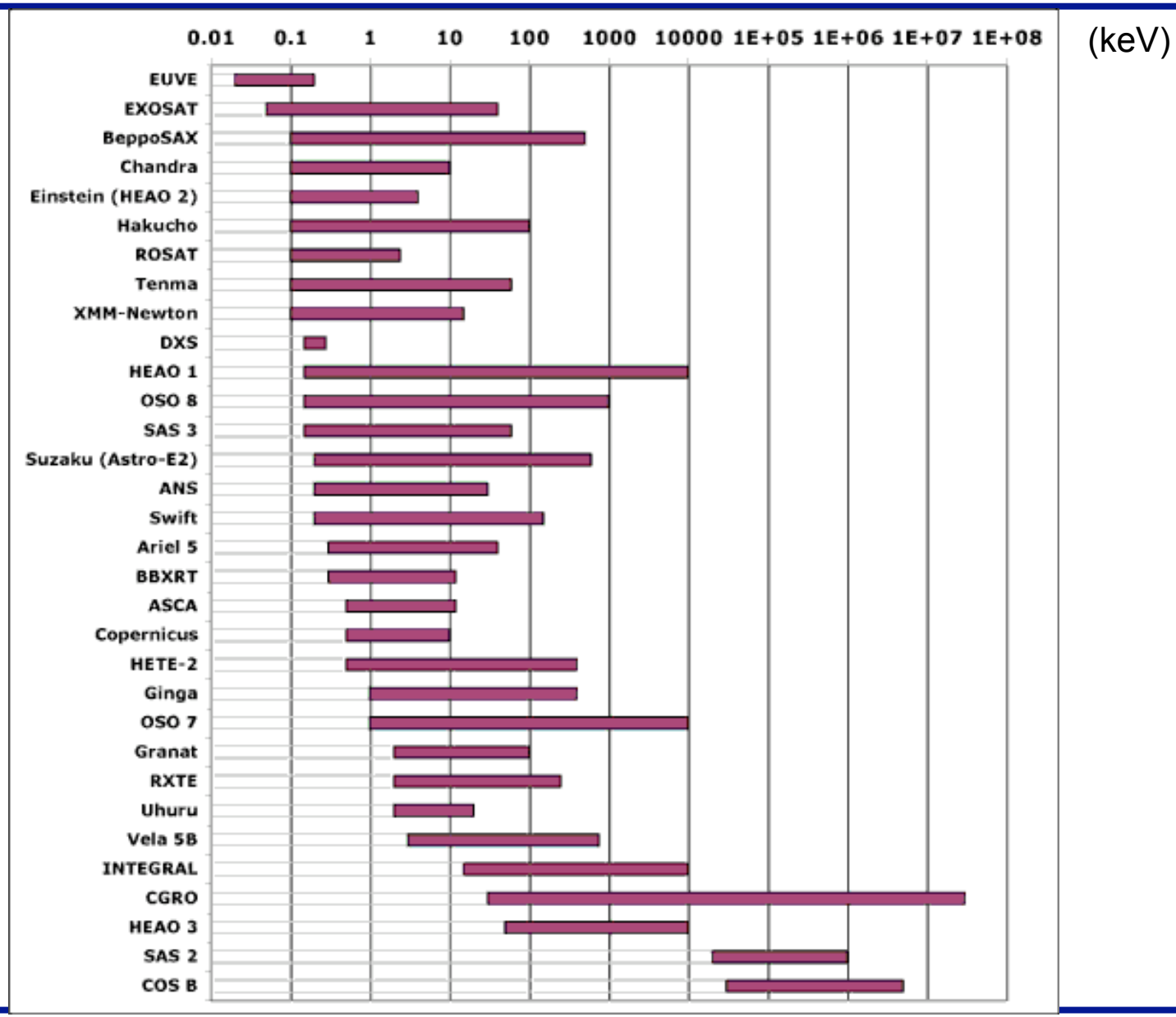

EFFECTIVE CROSS-SECTION σ₂ (cm²)
WAVELENGTH (Å)
10³
10²
10
1


(0.1 keV)
(200 keV)
1m
1mm
7000Å
100Å
0.05Å
Radio and Microwave
IR
Vis
UV
X-Rays
Gamma Rays
Altitude (km)
800
400
200
100
50
25
12
6
3
Sea Level
SATELLITES
ROCKETS
BALLOONS
AIRCRAFT
MOUNTAINTOP OBSERVATORIES

Observatory	XMM			Chandra				Suzaku		IXO ~~Constellation X~~		ASCA		ROSAT		RXTE
Detector	MOS	PN	RGS	ACIS	HRC	HETG	LETG	XRS	XIS	Calorimeter	Grating	SIS	GIS	PSPC	HRI	PCA
Energy (keV)	0.2-12	0.2-12	0.4-2.5	0.1-10	0.1-10	0.6-10	0.1-6	0.3-12	0.2-12	0.2-10	0.2-2	0.4-12	0.6-12	0.1-2.4	0.1-2.4	2-60
Area (cm2)																
@0.25 keV	133	460	-	30	150	-	25	-	-	3081	1235	-	-	240	40	-
@0.4 keV	360	771	44	120	50	-	12	-	-	864	2000	15	-	7	11	-
@0.6 keV	591	1061	94	345	65	-	25	-		5127	3720	35	-	70	8	-
@1.0 keV	922	1227	185	615	215	10	55	100	1600	11274	5327	230	50	210	80	-
@1.5 keV	1180	1304	160	500	162	45	105	-	-	13362	4100	300	145	180	60	-
@2.5 keV	696	779	-	320	65	20	50	-	-	7765	-	195	125	-	-	700
@6.0 keV	768	851	-	205	45	25	20	150	1000	6600	-	160	125	-	-	5000
@8.0 keV	390	557	-	45	10	7	4	-	-	4277	-	55	60	-	-	6000
@12.0 keV	19	56	-	-	-	-	-	-	-	638	-	-	-	-	-	4000
Resolution (eV)																
@0.25 keV	35	35	-	130	-	-	0.4	-	-	2	0.25	-	-	250	-	-
@0.4 keV	45	45	0.5	120	-	-	0.8	6.5	30	2	0.65	75	-	350	-	-
@1.0 keV	55	55	2.9	100	-	1.0	5.4	6.5	50	2	4.1	100	190	500	-	-
@2.5 keV	85	85	17	120	-	5.2	34	6.5	80	2	-	135	300	-	-	725
@6.0 keV	130	-	170	130	-	29	-	6.5	120	2	-	240	460	-	-	1125
@8.0 keV	150	-	190	150	-	50	-	6.5	140	2	-	265	540	-	-	1300
Angular Res	6”	6”	-	1”	<0.5”	-	-	limited	<1.5’	6”	-	1’	1’	15”	5”	1 deg
FoV	30’	30’	-	17’x17’	31’x31’	-	-	3’x3’	19’x19’	2.5’	-	22’x22’	20’x20’	114’ dia	20’x20’	1 deg



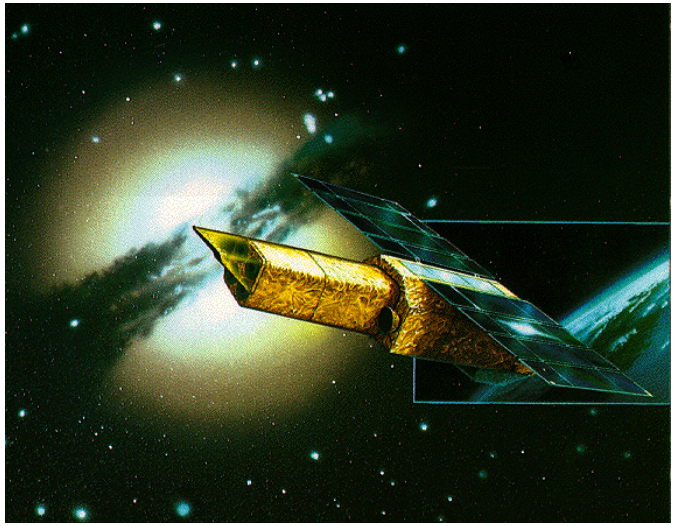

Suzaku (Astro-E2)
Swift
INTEGRAL
HETE-2
XMM-Newton
Chandra
BeppoSAX
XTE
ASCA
DXS
EUVE
CGRO
BBXRT
ROSAT
Granat
Ginga
EXOSAT
Tenma
HEAO 3
Hakucho
Einstein (HEAO 2)
HEAO 1
COS B
OSO 8
SAS 3
Ariel 5
ANS
SAS 2
Copernicus
OSO 7
Uhuru
Vela 5B
68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06

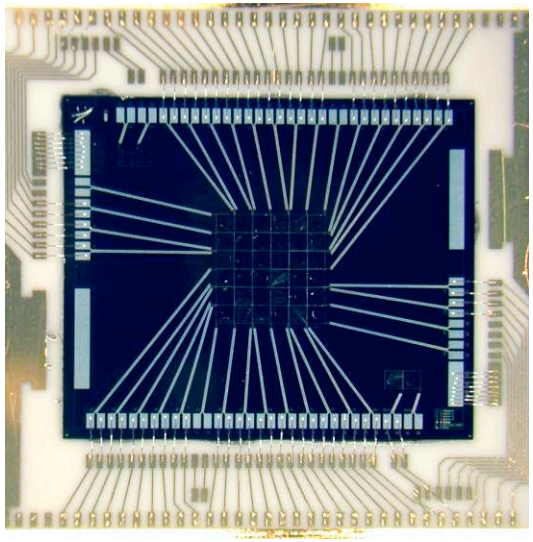

0.01
0.1
1
10
100
1000
10000
1E+05
1E+06
1E+07
1E+08
(keV)
EUVE
EXOSAT
BeppoSAX
Chandra
Einstein (HEAO 2)
Hakucho
ROSAT
Tenma
XMM-Newton
DXS
HEAO 1
OSO 8
SAS 3
Suzaku (Astro-E2)
ANS
Swift
Ariel 5
BBXRT
ASCA
Copernicus
HETE-2
Ginga
OSO 7
Granat
RXTE
Uhuru
Vela 5B
INTEGRAL
CGRO
HEAO 3
SAS 2
COS B

Chandra (ex AXAF): Julio 1999 (asc.harvard.edu)

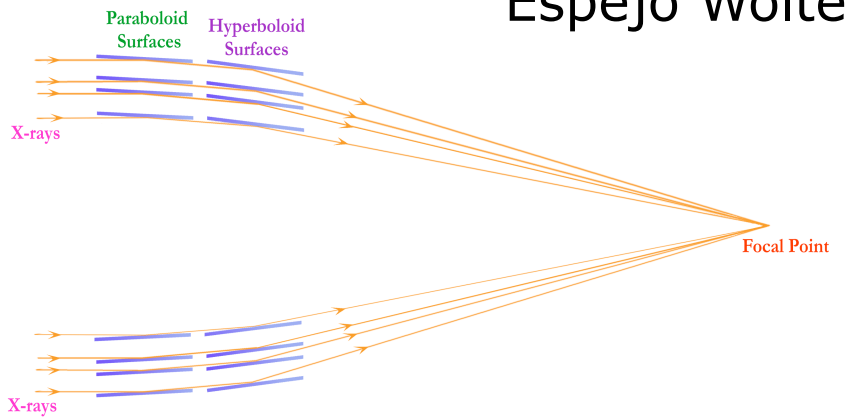
XMM-Newton: Diciembre 1999 (xmm.esac.esa.int)

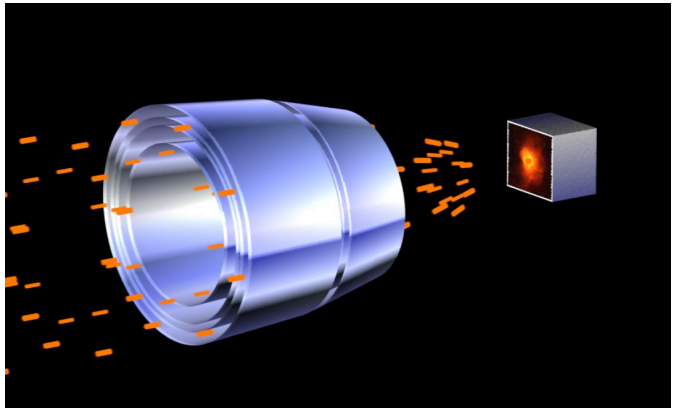
Suzaku (Astro-E2): Julio 2005 (suzaku-epo.gsfc.nasa.gov)



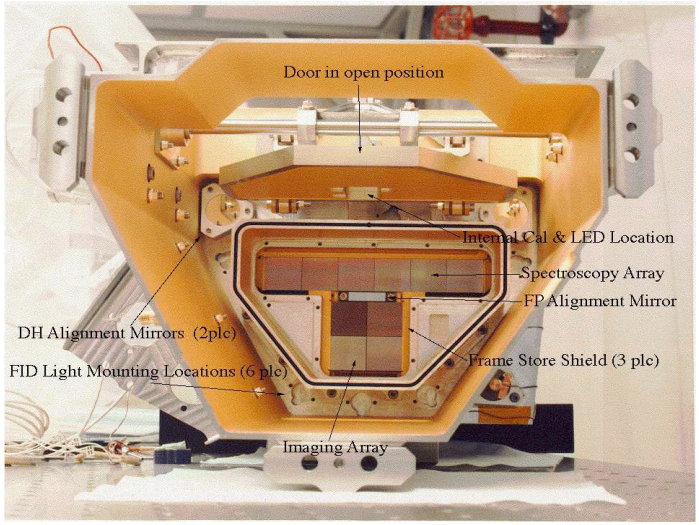


Espejo Wolter Tipo-1



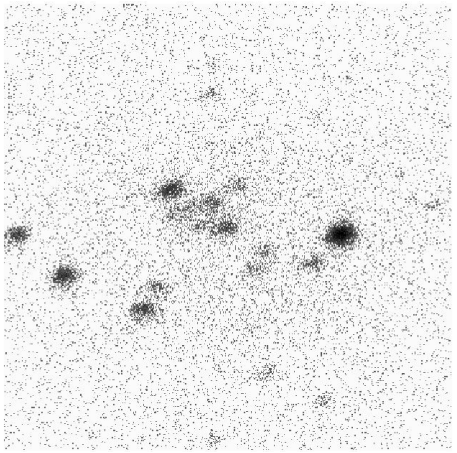


CCDs para Rayos-X

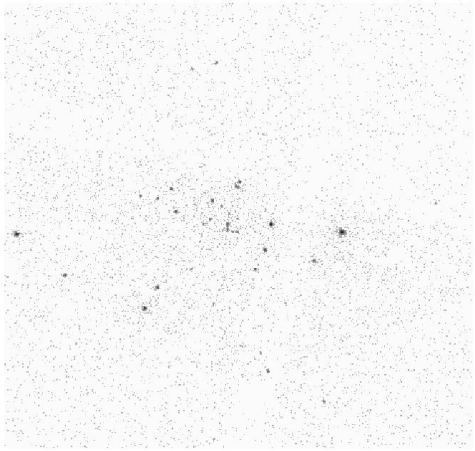


M31 - Andrómeda

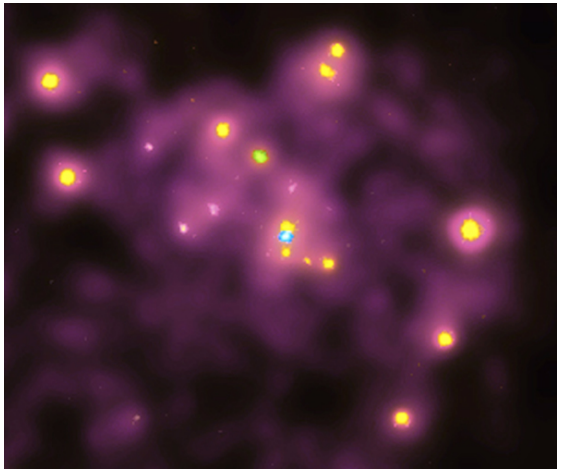
(~4′x4′)



ROSAT



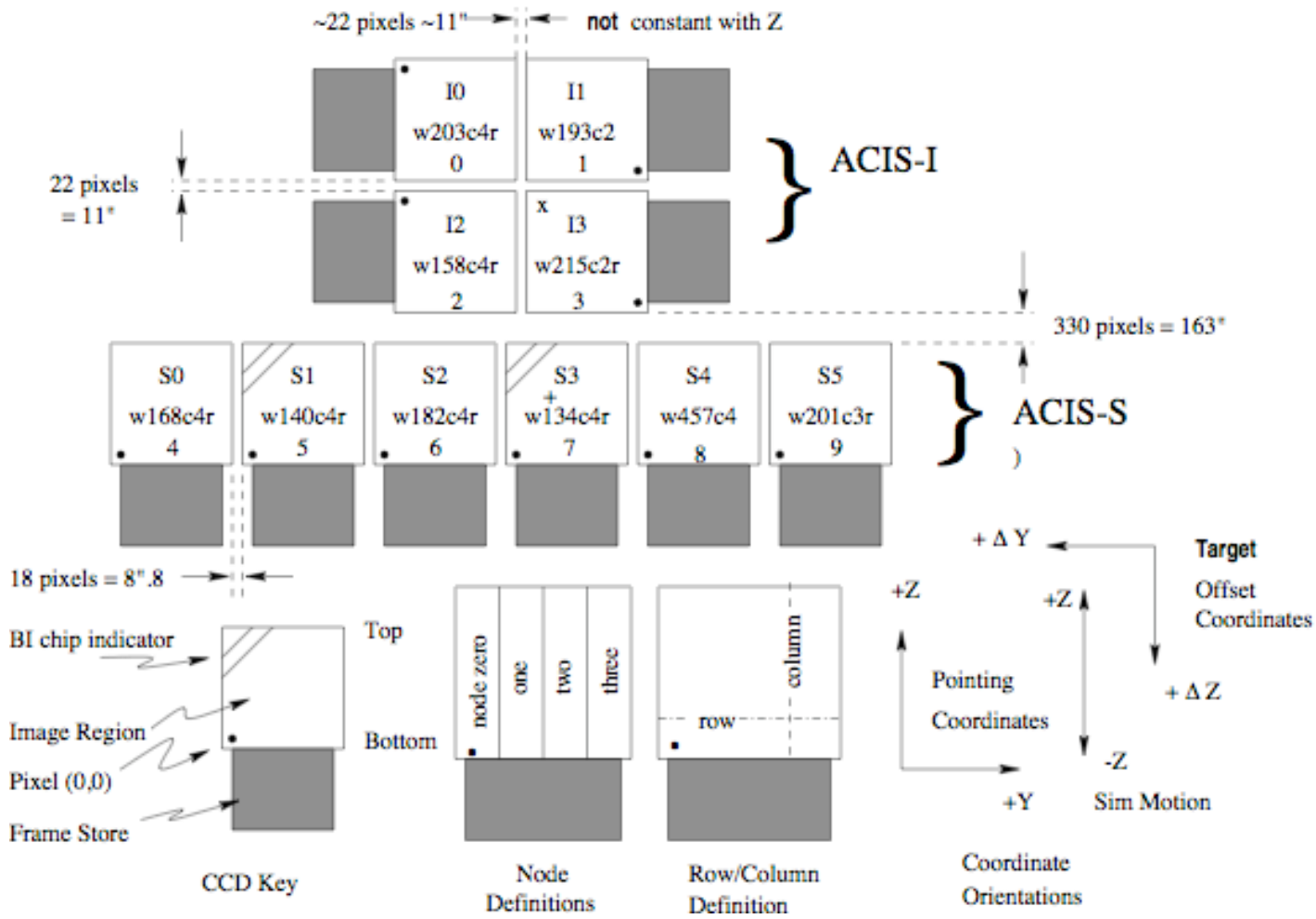
Chandra



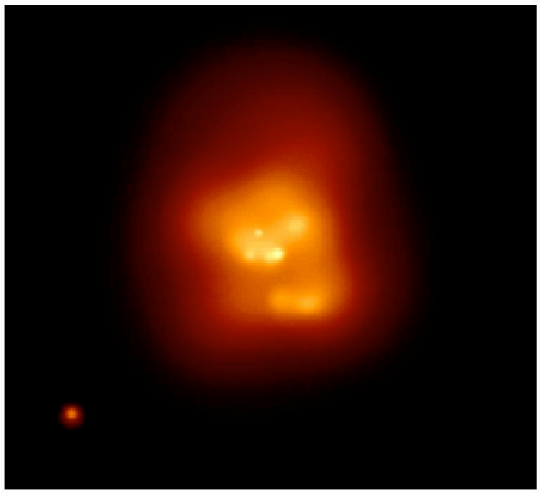
(~1′x1′)

Garcia etal 2000 ApJ 537 L23

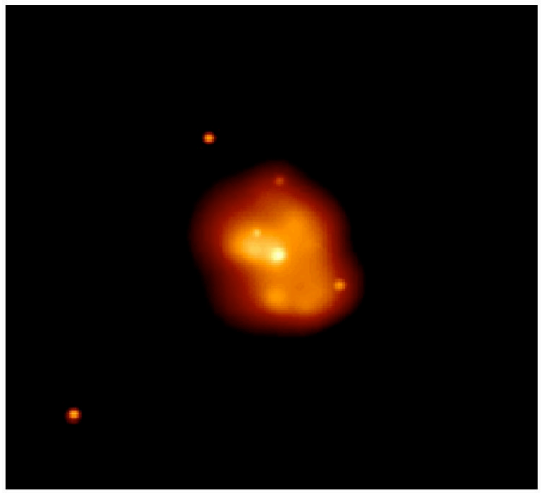
ACIS FLIGHT FOCAL PLANE



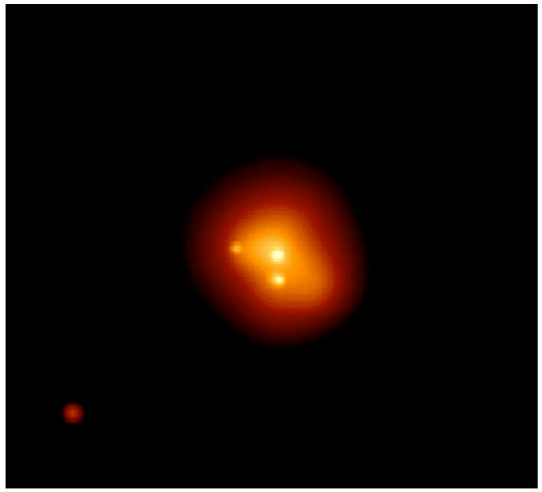
Observaciones con Chandra (~1.8’x1.4’)



0.3-1.0 keV



1.0-2.0 keV



2.0-7.0 keV

Lira etal 2002 MNRAS 330 259

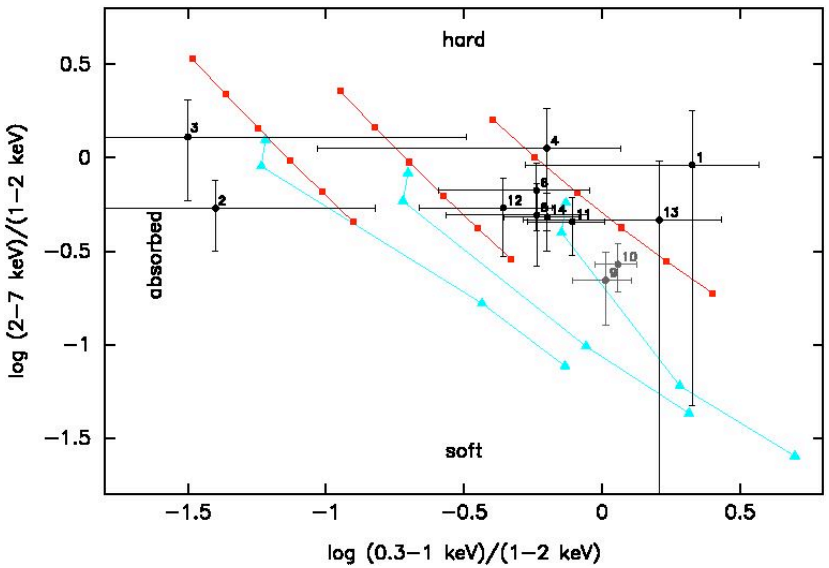
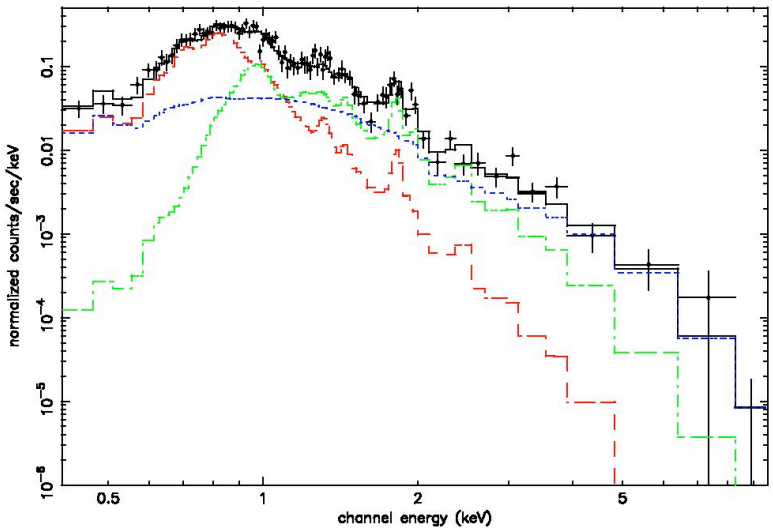
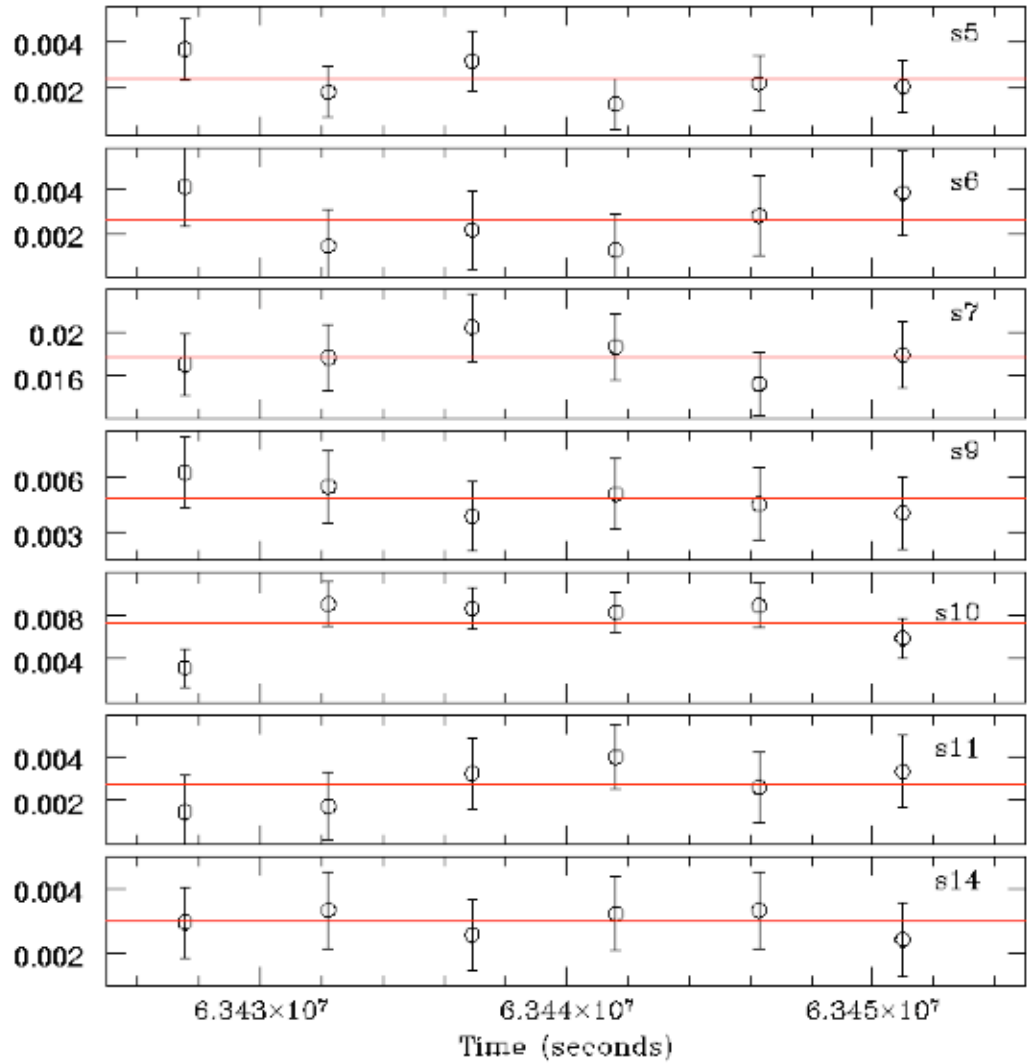


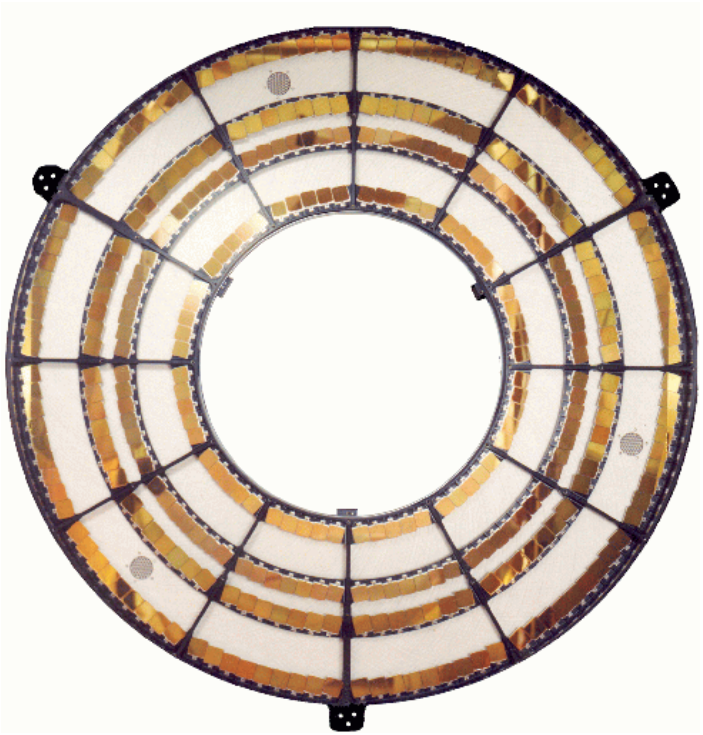
Diagrama color-color para las fuentes puntuales

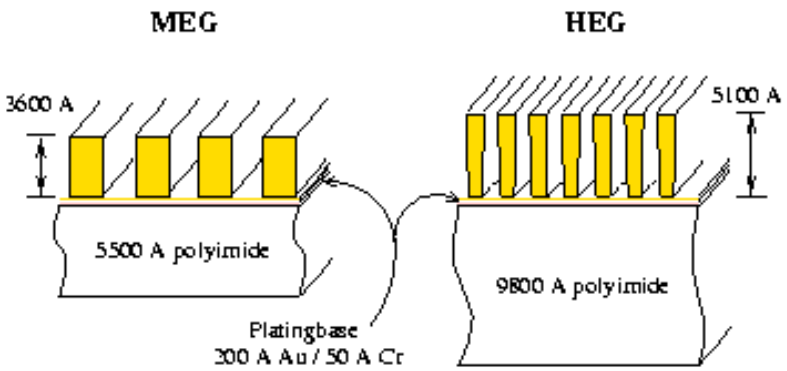


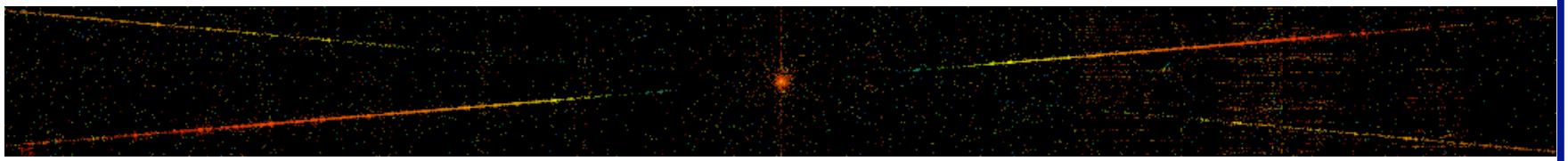
Espectro de la emisión difusa


s5
s6
s7
s9
s10
s11
s14
0.004
0.002
0.02
0.016
0.006
0.003
0.008
6.343×10⁷
6.344×10⁷
6.345×10⁷
Time (seconds)

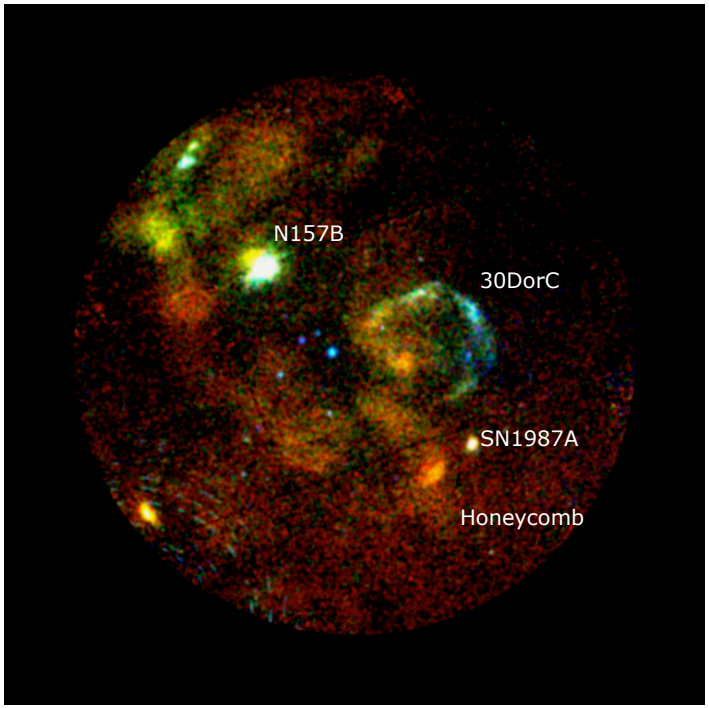
The Chandra High and Low Energy Transmition Gratings







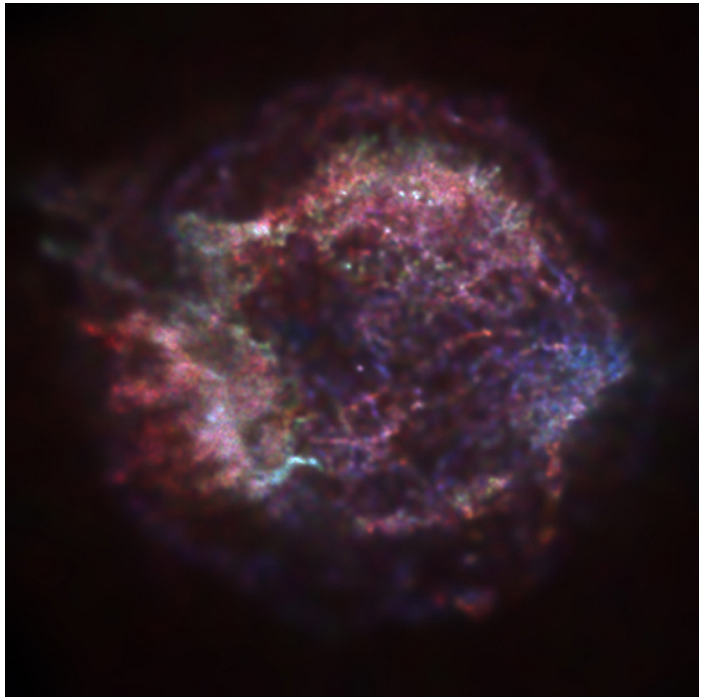
XMM-Newton



30 Dorado en la LMC
(~20'x20')

Dennerl etal 2001 A&A 365 L202

Chandra



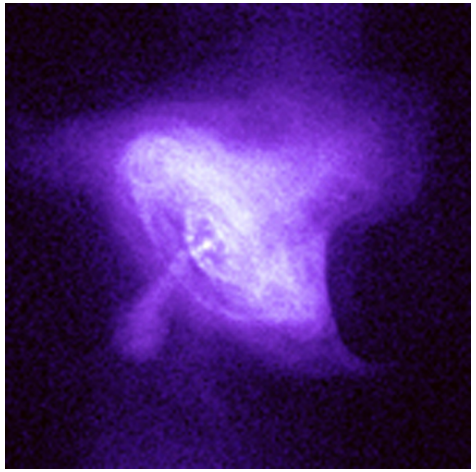
Remanente Cas A
(~8.5'x8.5')

Hwang etal 2000 ApJ 537 L119

Nebulosa del Cangrejo (Crab)

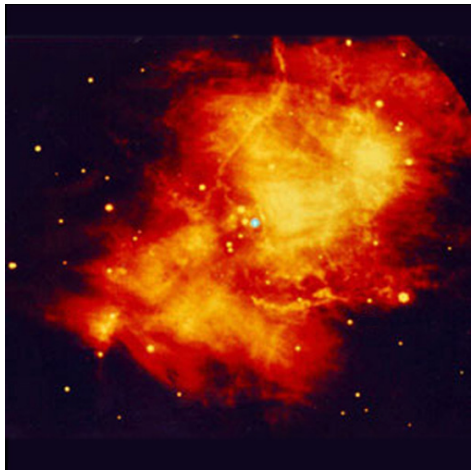
Rayos-X
(~3'x3')

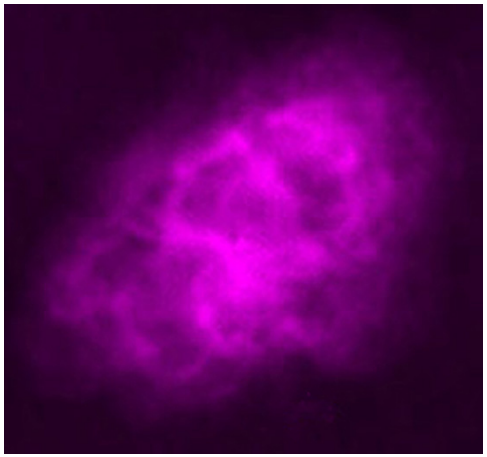
Weisskopf etal 2000
ApJ 536 L81



Optico
(~6'x6')

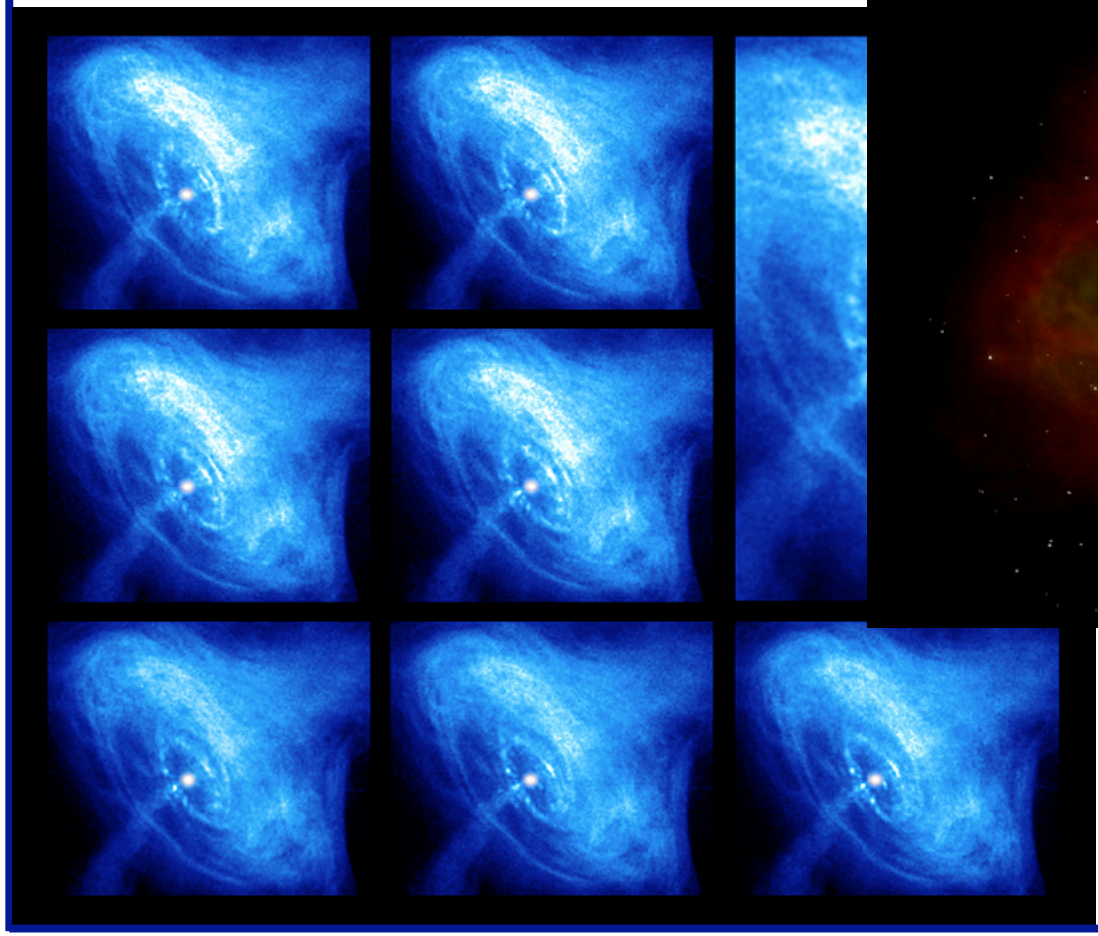
IR

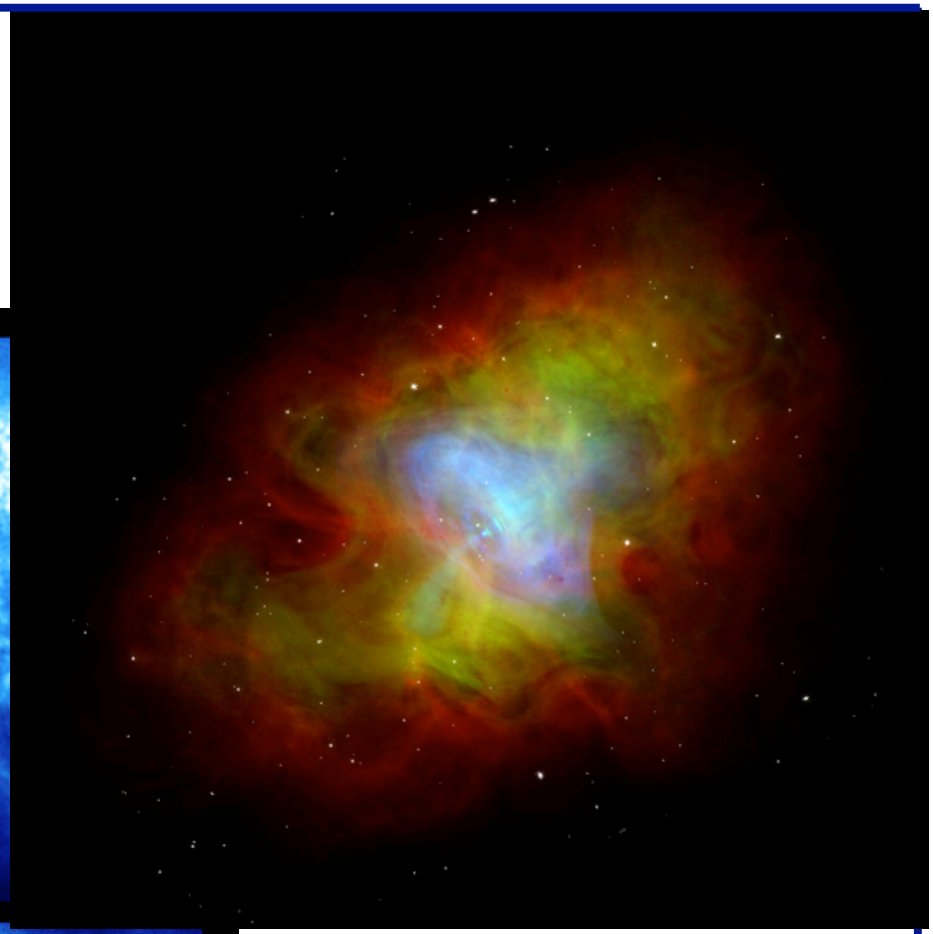




Radio

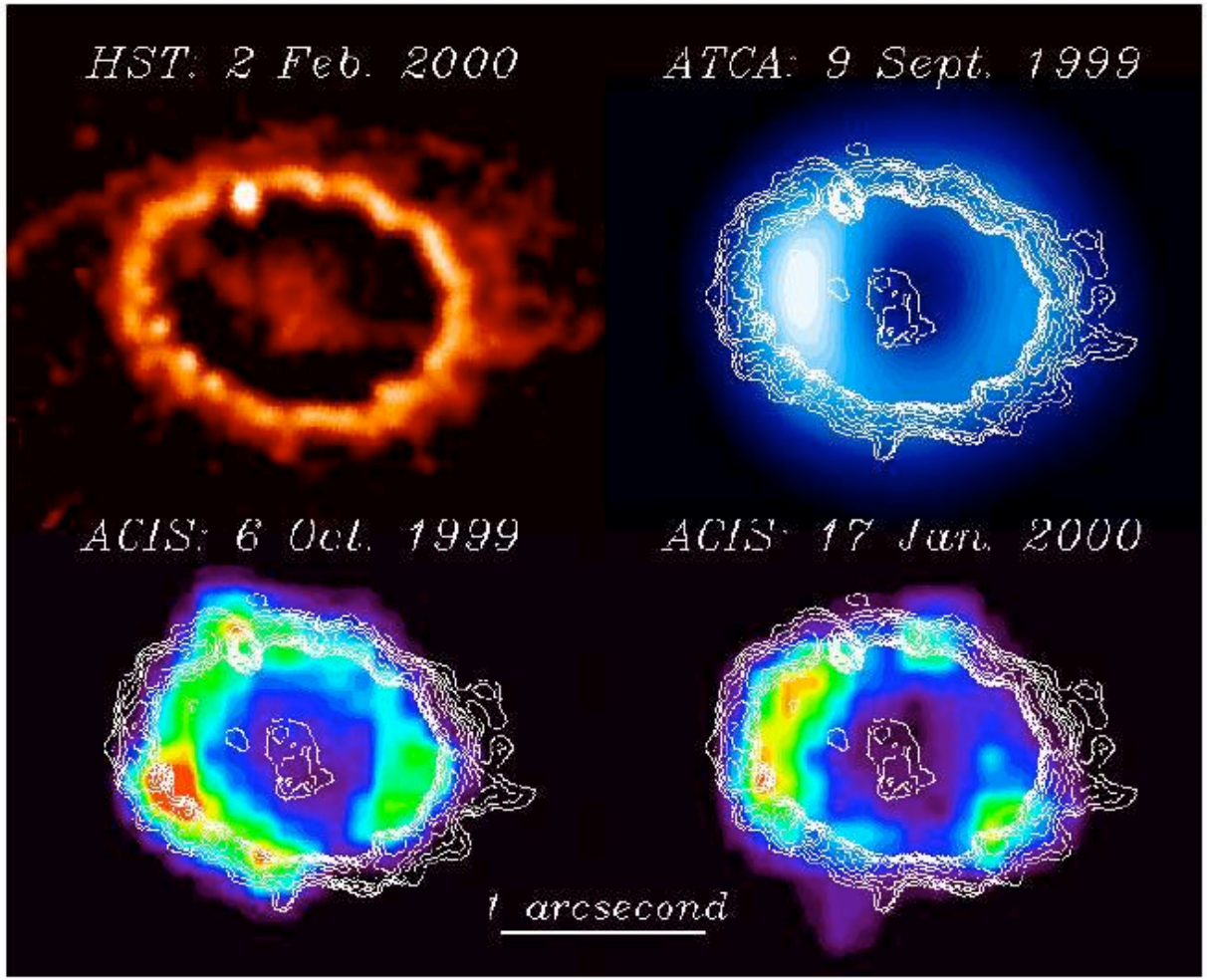
Evolution of the X-ray nebula





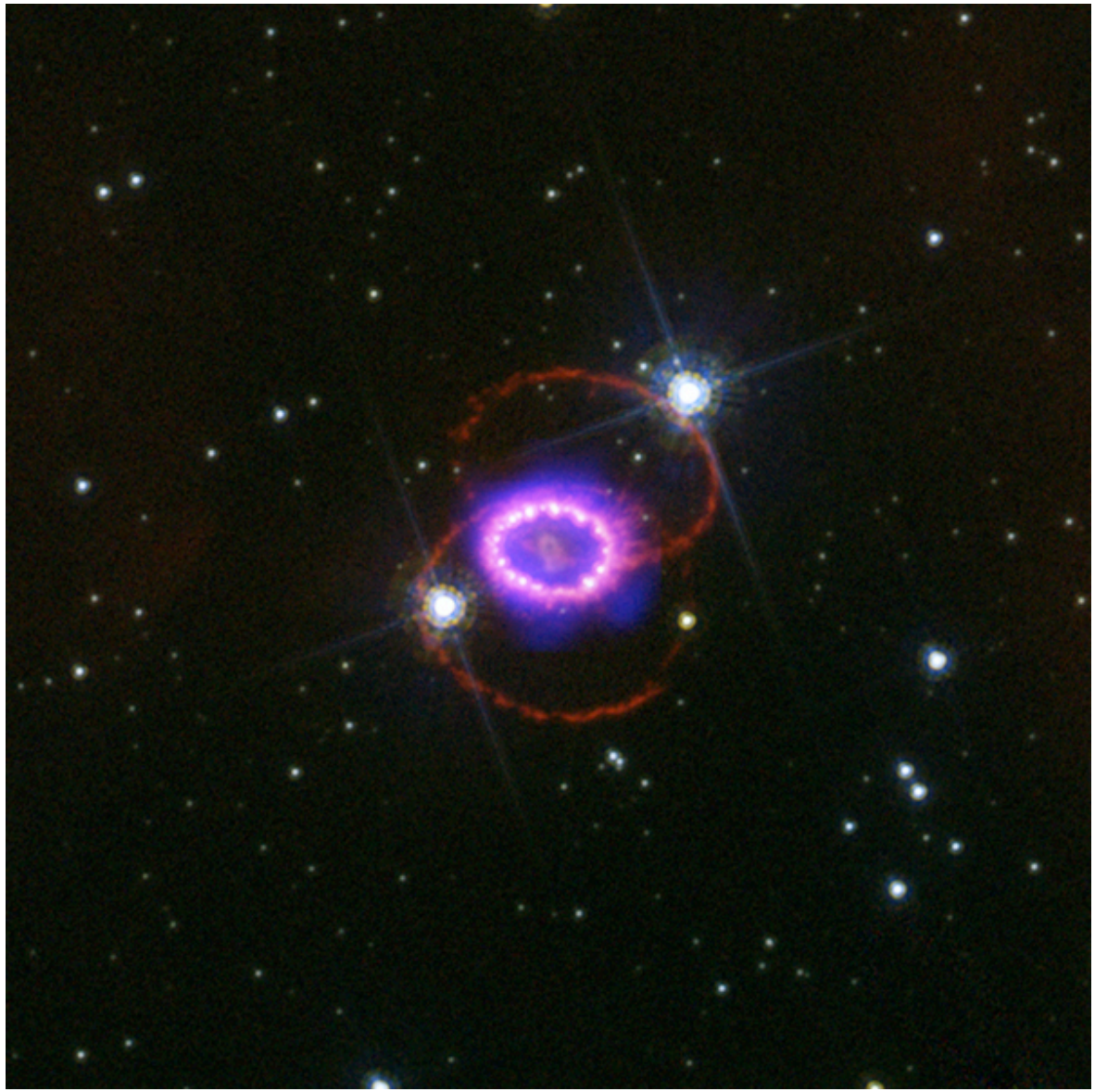
Composite image

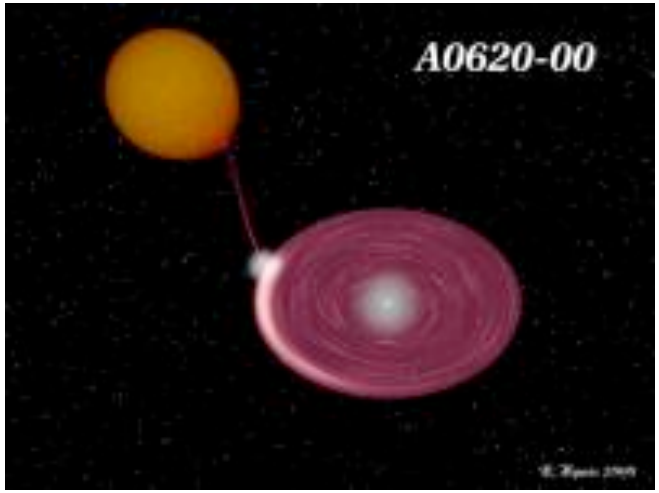
SN 1987A



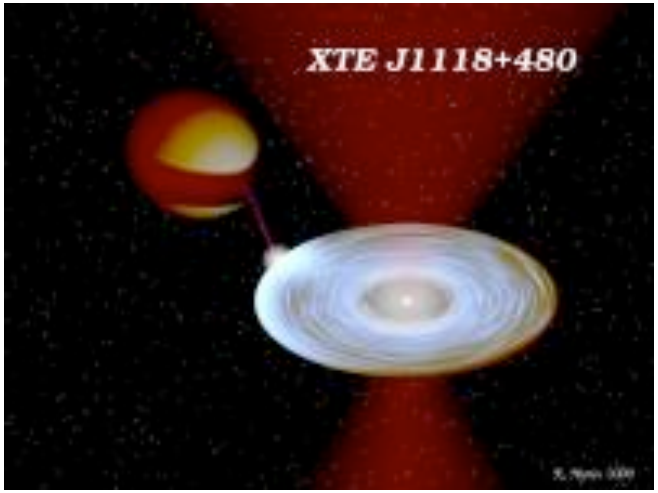
Burrows etal 2000 ApJ 543 L149

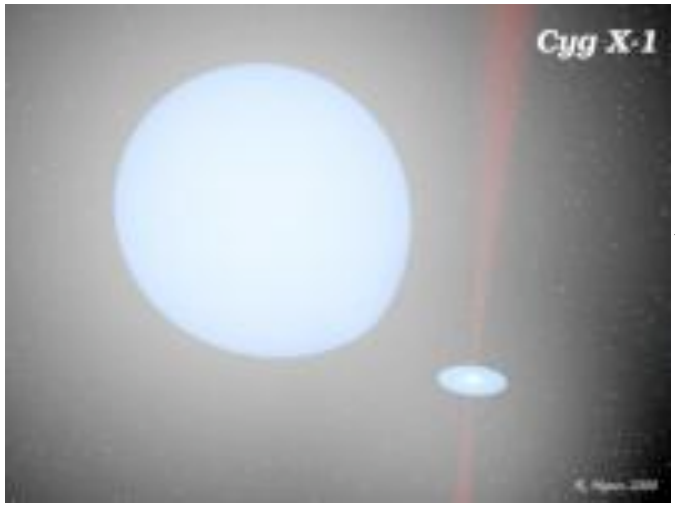
SN1987A



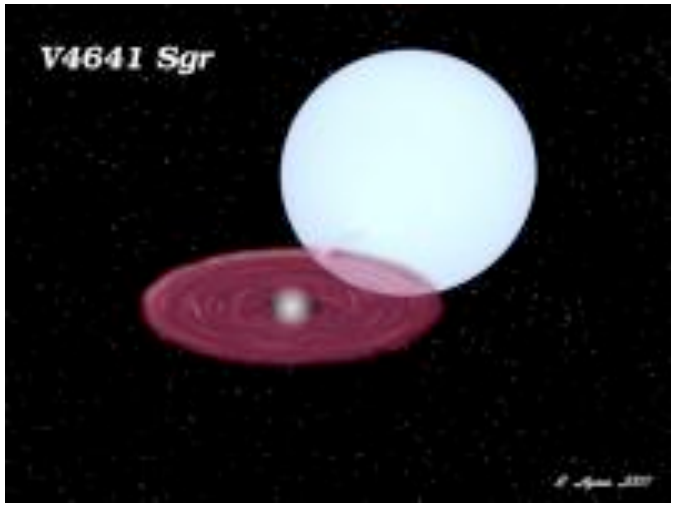


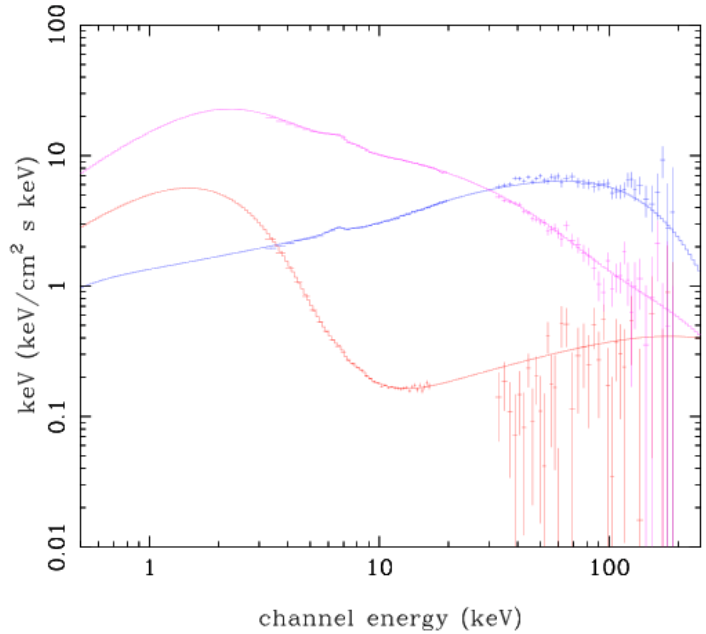
Low-mass
X-Ray Binaries

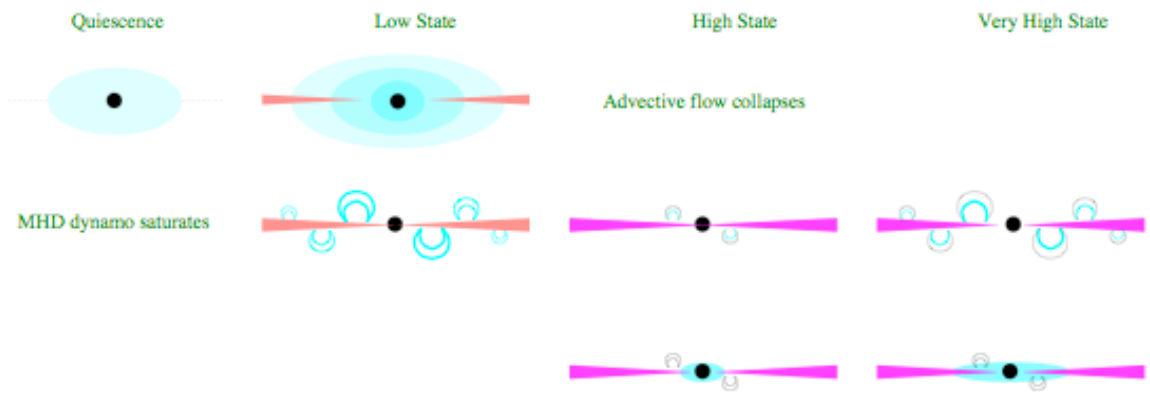




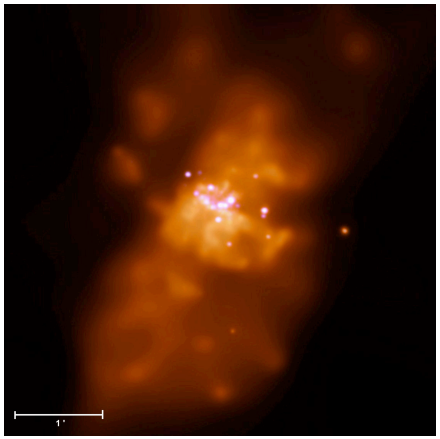
High-mass
X-Ray Binaries



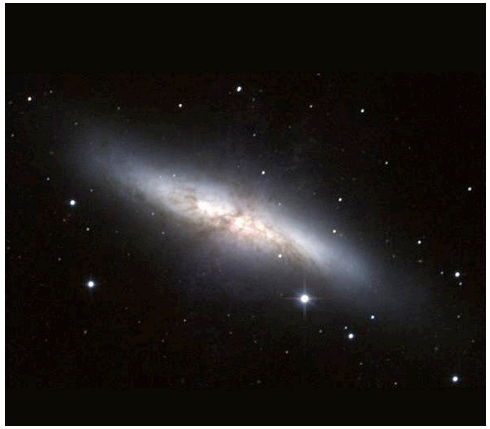

keV (keV/cm^2 s keV)
0.01
0.1
1
10
100
1
10
100
channel energy (keV)


Quiescence
Low State
High State
Very High State
Advective flow collapses
MHD dynamo saturates

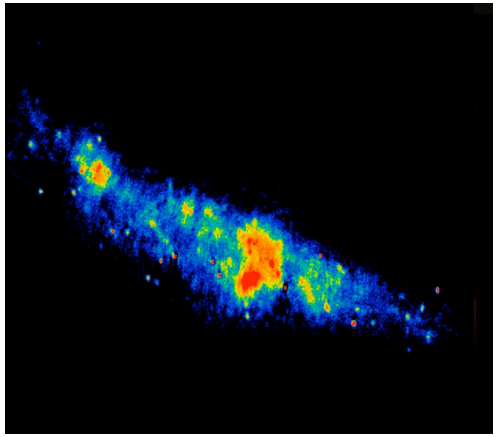
M82



Chandra

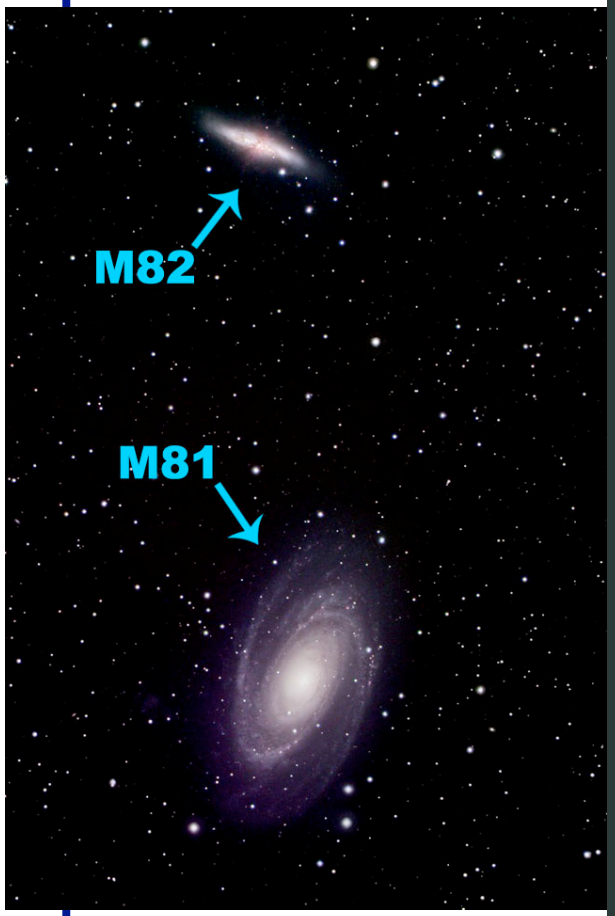


Optico



Radio

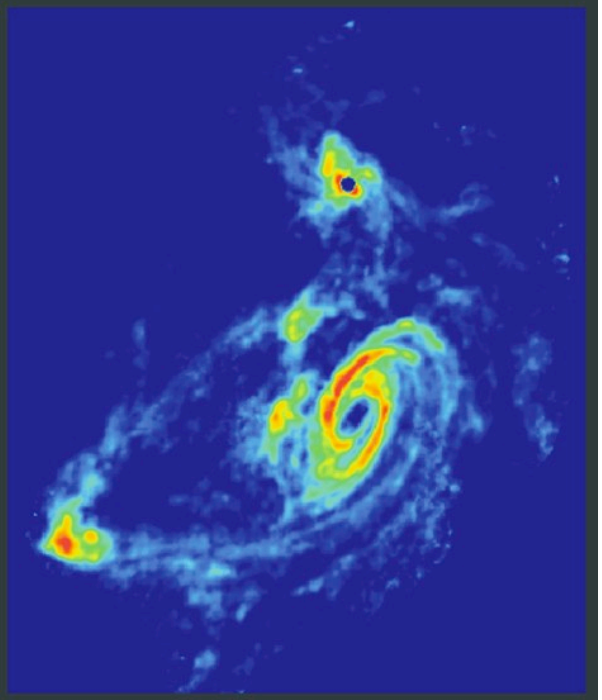
Fabbiano etal 2001



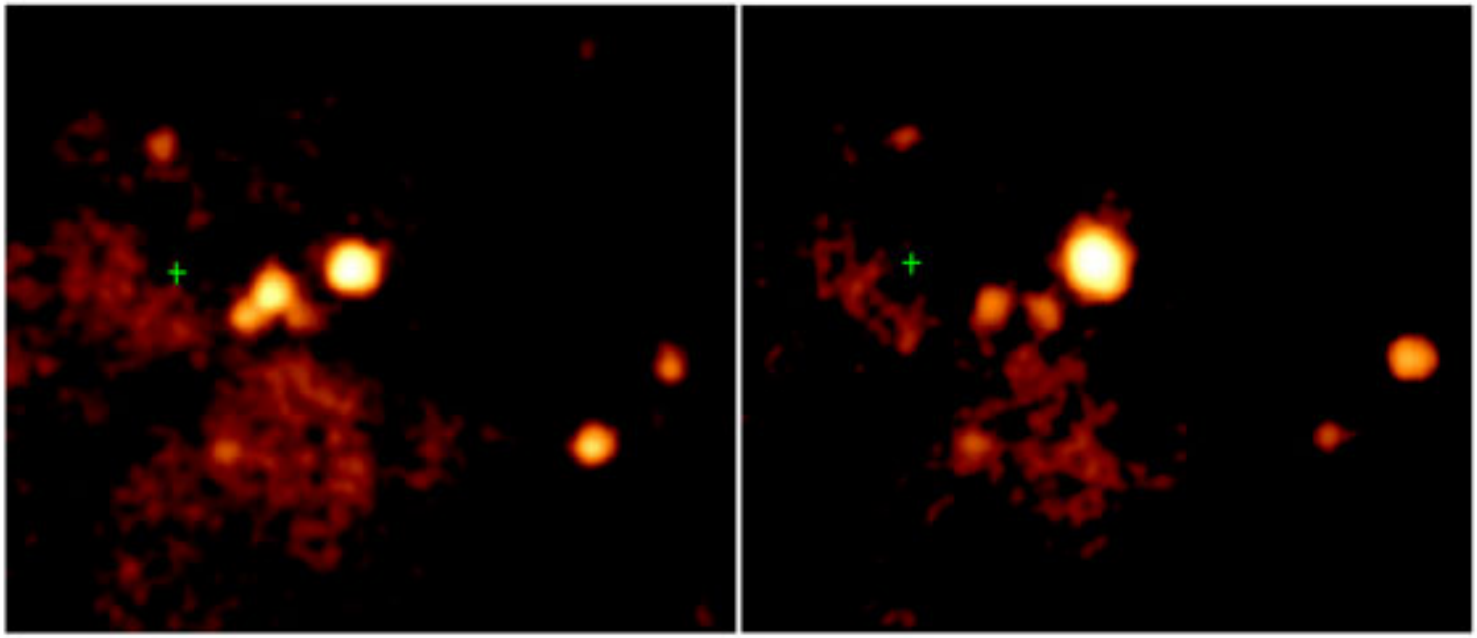
TIDAL INTERACTIONS IN M81 GROUP

Stellar Light Distribution

21 cm HI Distribution

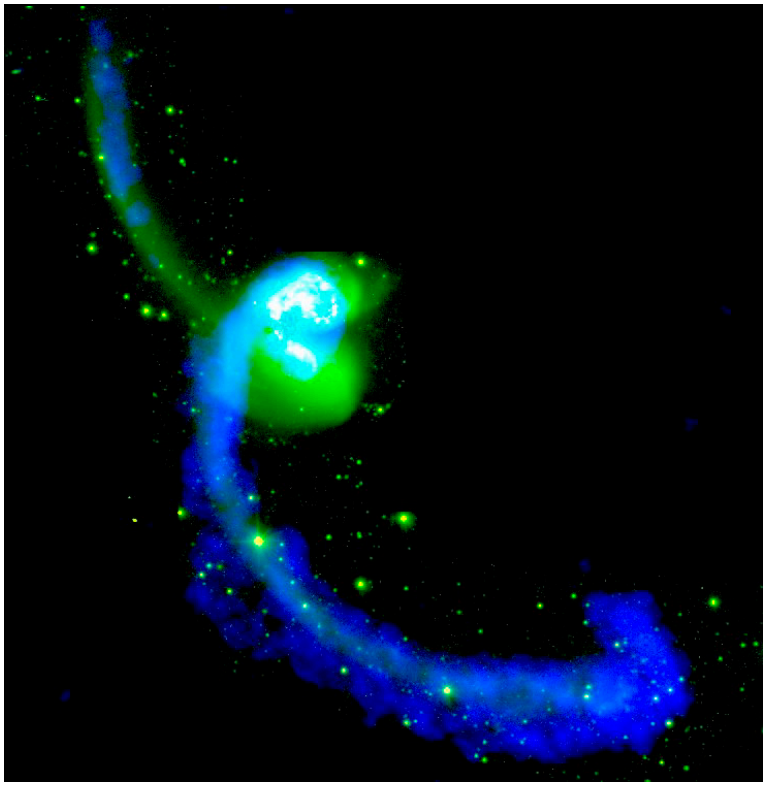


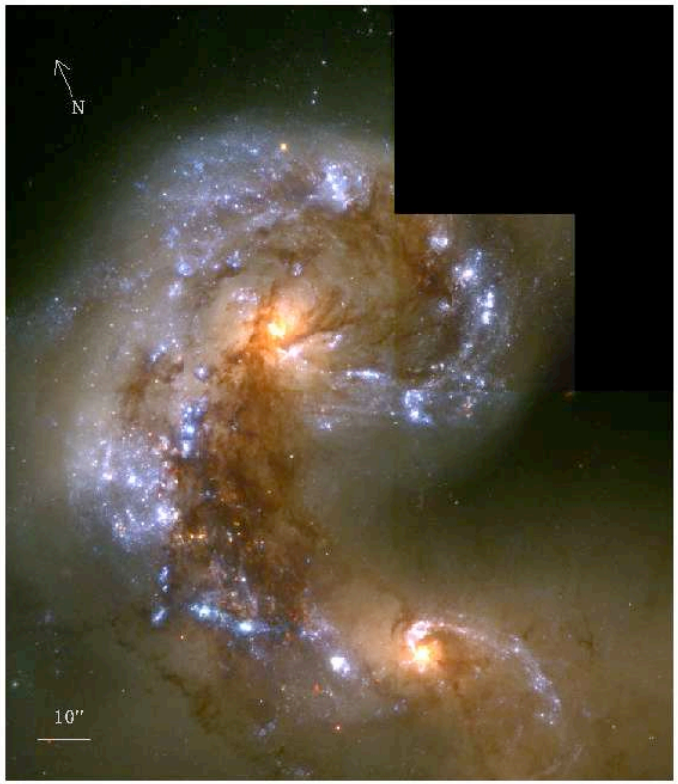
Fuente Super-Eddington in M82



Kaaret etal 2001 MNRAS 321 L29

Antennae (NGC4038/39-Arp244)

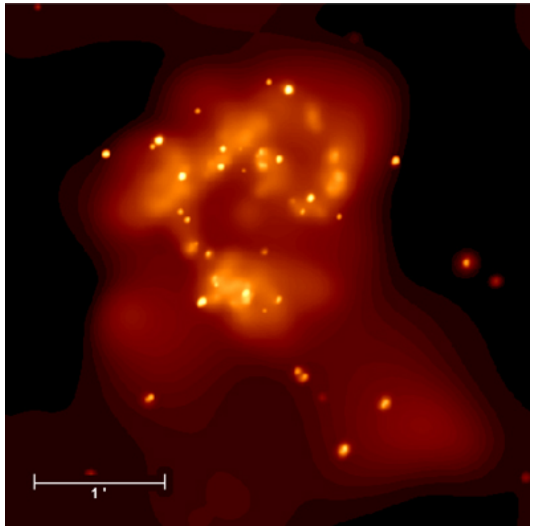


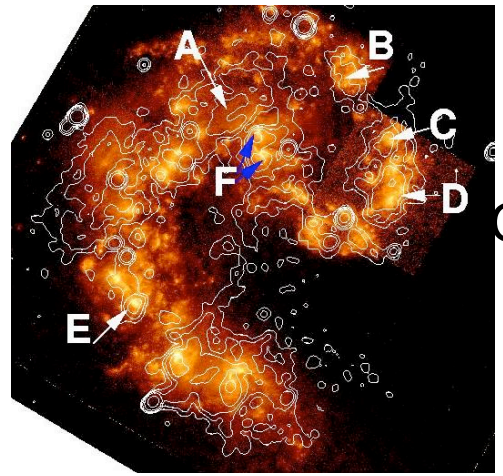


Optico (verde) + HI (azul) (~15'x15') WFPC Whitmore etal 1999 AJ 118 1551

Chandra

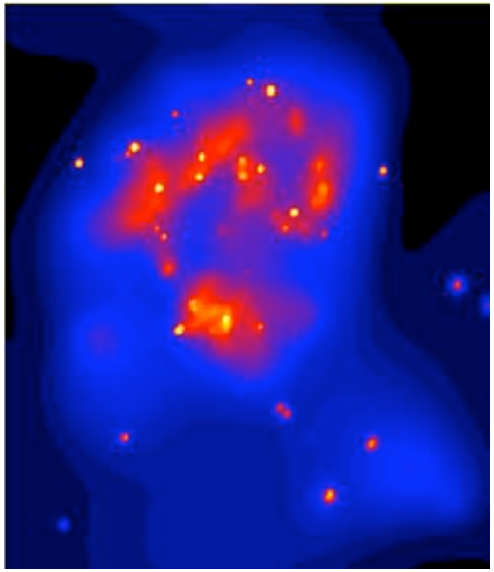
Fabbiano etal 2001

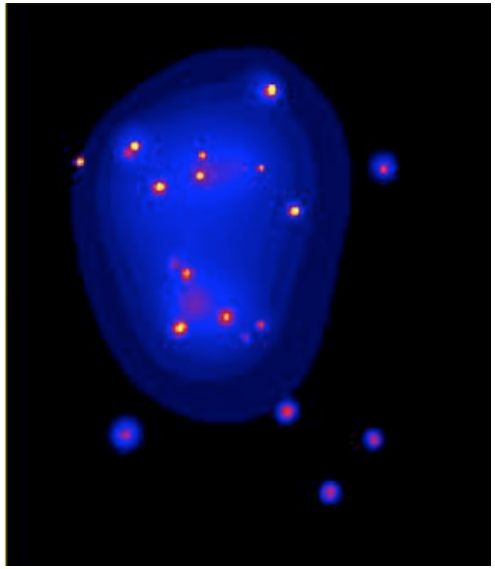




Chandra+Hα

Rayos-X
blandos
0.1-2.5 keV



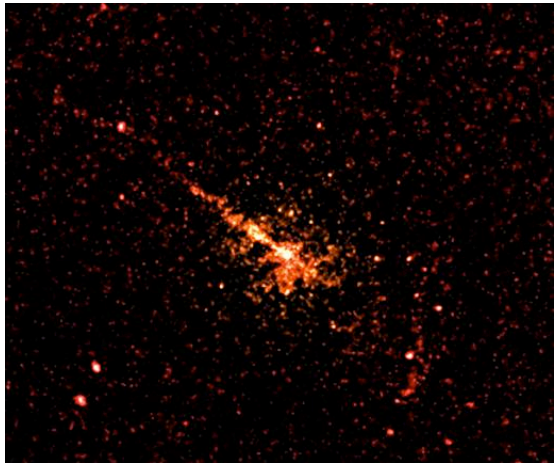


Rayos-X
duros
2.5-5 keV

Fabbiano etal 2001
Zezas etal 2001

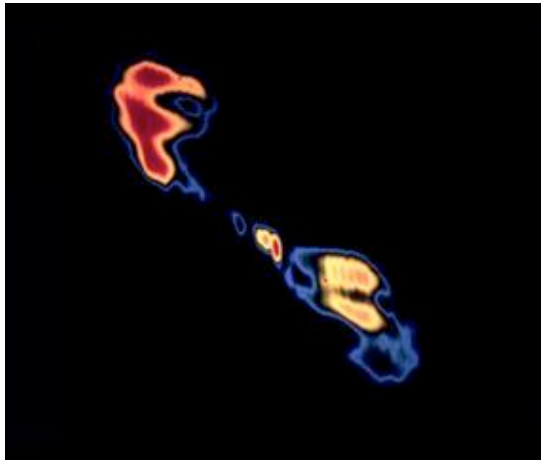
Galaxias Activas o Active Galactic Nuclei (AGN)

Centaurus-A



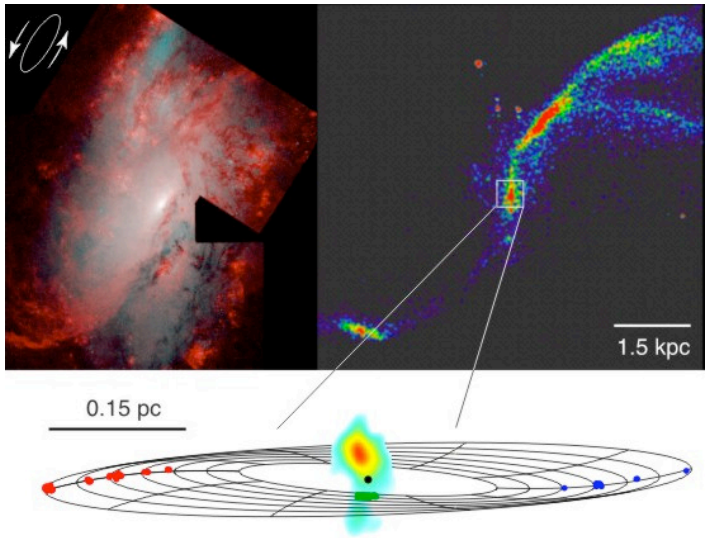
Chandra (15’x15’)

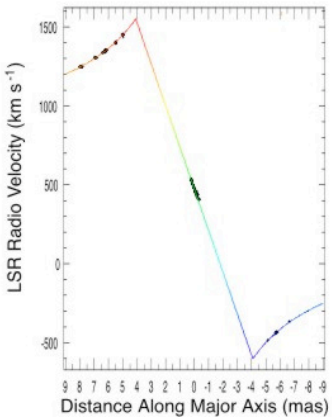
Optico (7.5’x7.5’)



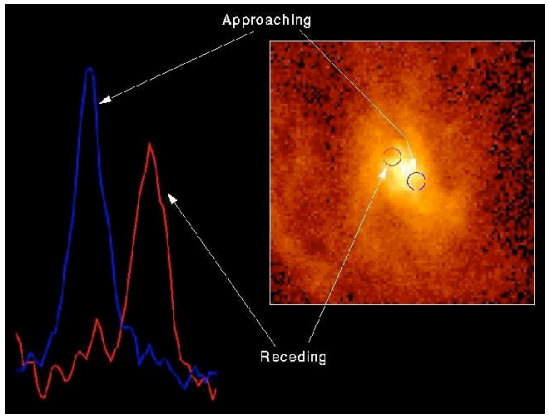
Radio (12.5’x12.5’)

Agujeros Negros en AGN



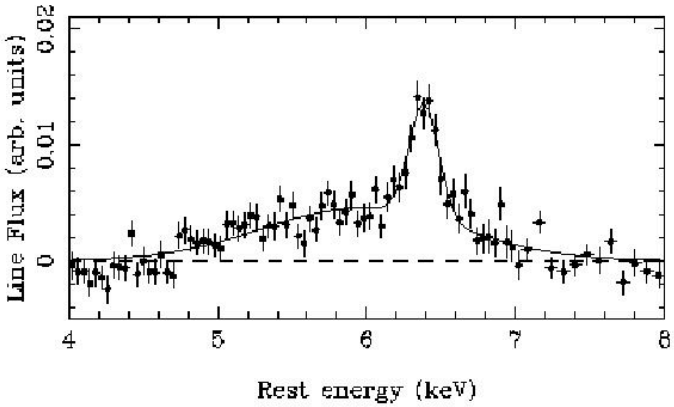


Masers en NGC4258 Miyoshi etal 1995 Nature 373 127



STScI

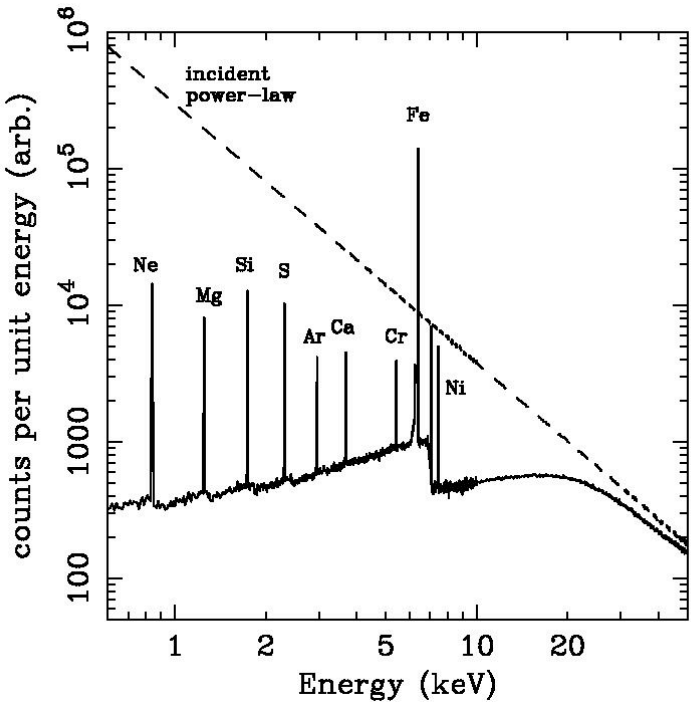
Gas en la radio galaxia M87



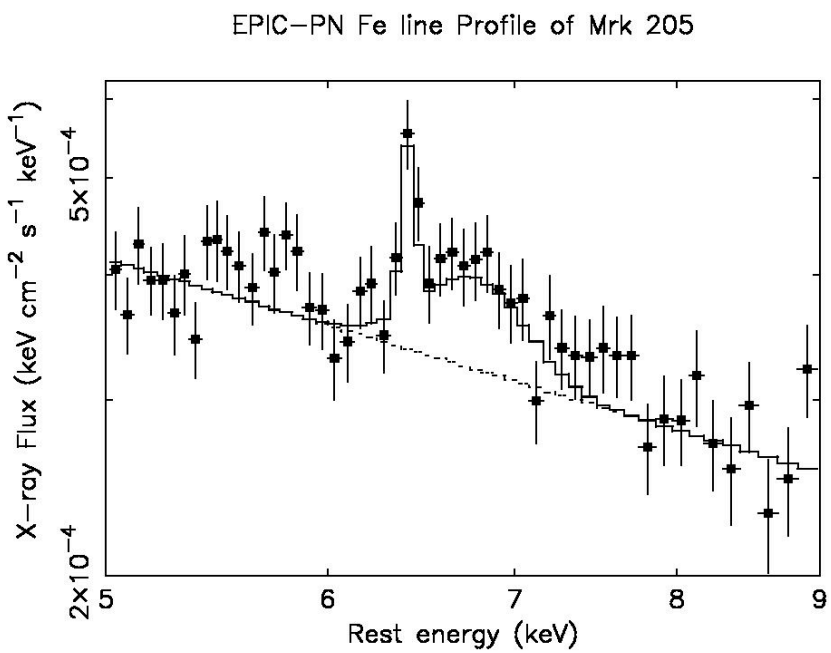
Linea del Fe en galaxias Seyfert

Nandra etal 1997 ApJ 477 602

Linea del Fe en galaxias Seyfert



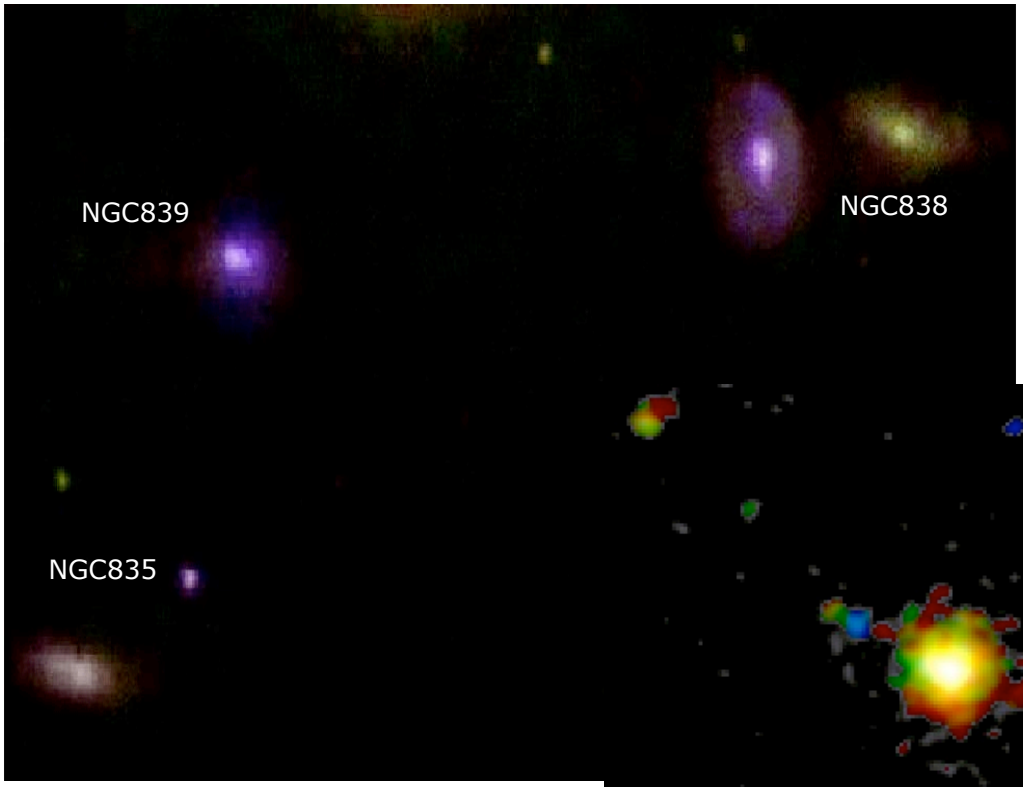
Fabian etal 2000 PASP 112 1145

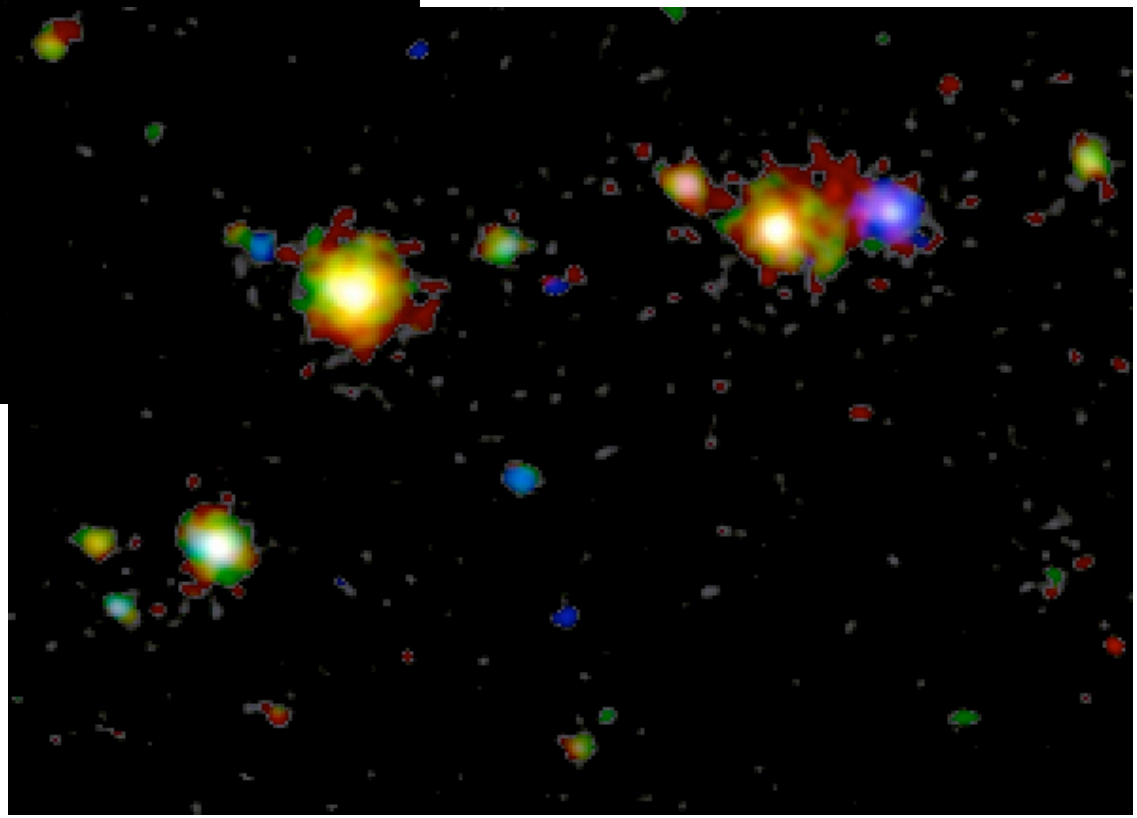


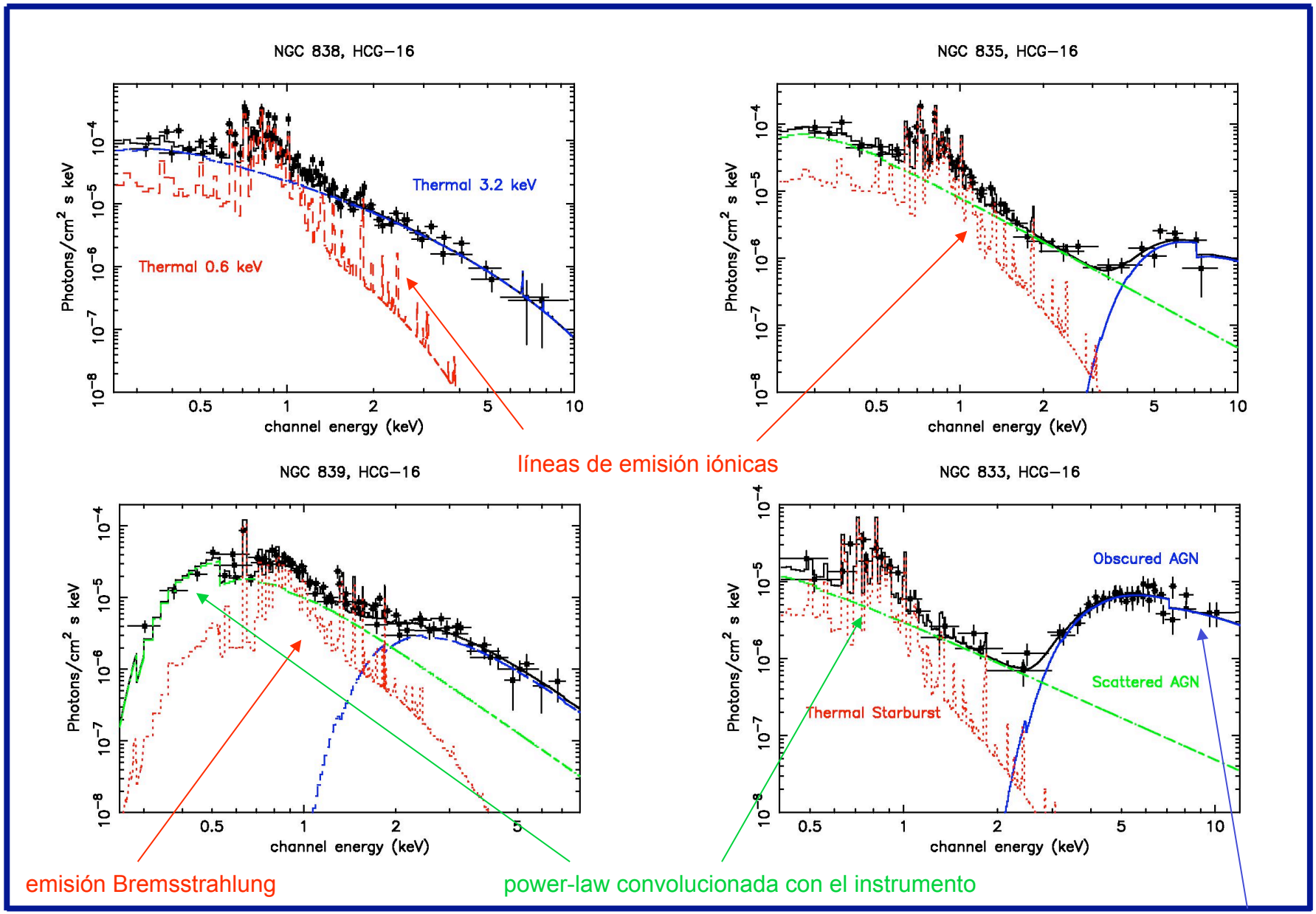
Reeves etal 2001 A&A 365 L134

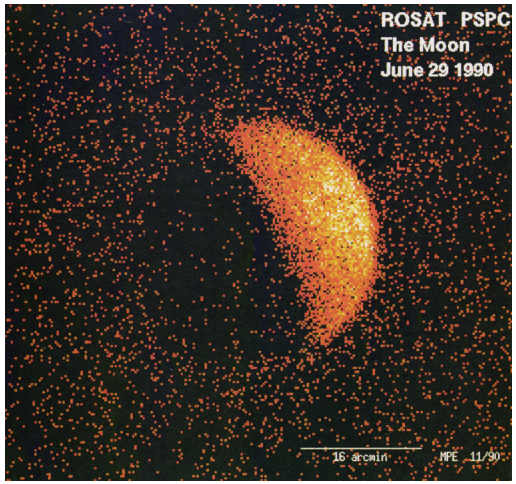
Grupo Hickson 16

Turner etal 2001 A&A365 L110

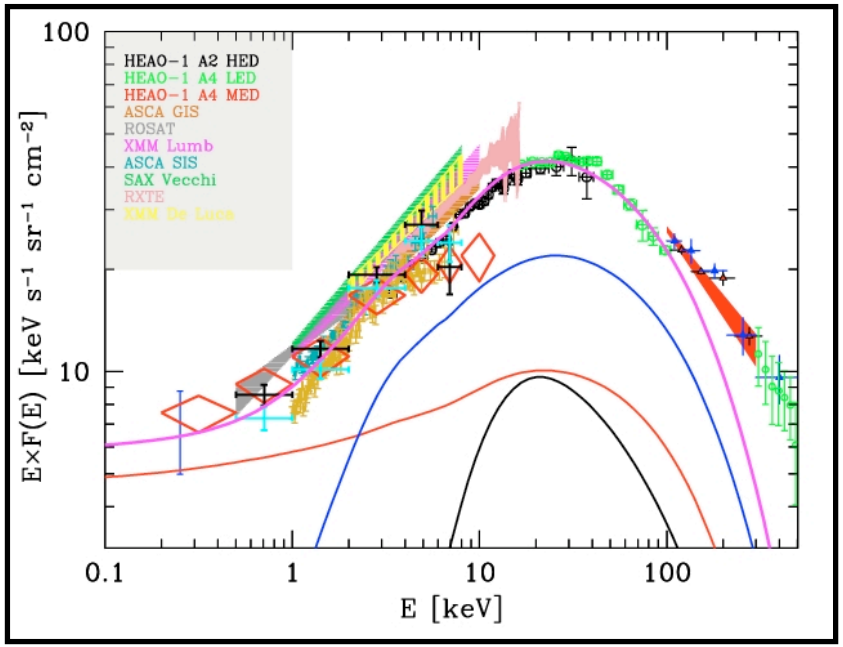


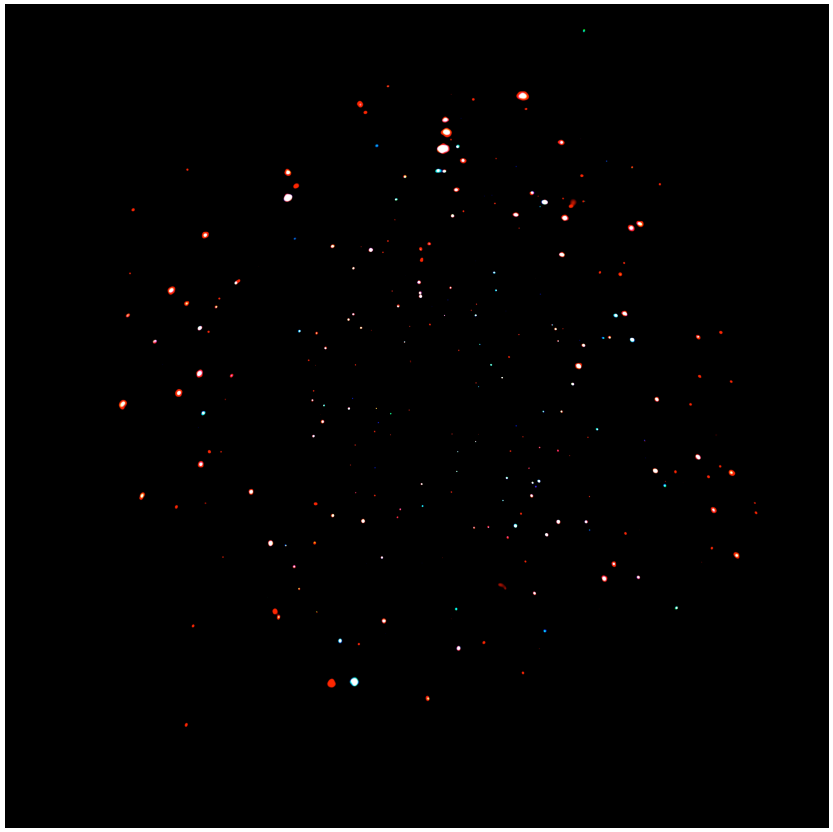



NGC 838, HCG−16
Thermal 3.2 keV
Thermal 0.6 keV
Photons/cm^2 s keV
channel energy (keV)
NGC 835, HCG−16
líneas de emisión iónicas
NGC 839, HCG−16
NGC 833, HCG−16
Obscured AGN
Scattered AGN
Thermal Starburst
emisión Bremsstrahlung
power-law convolucionada con el instrumento
power-law detrás de una columna de ~10^{23} cm^{-2}



El fondo de Rayos-X: AGNs no resueltos

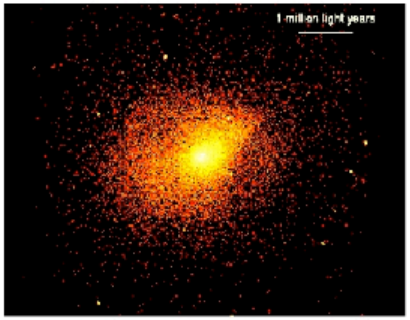




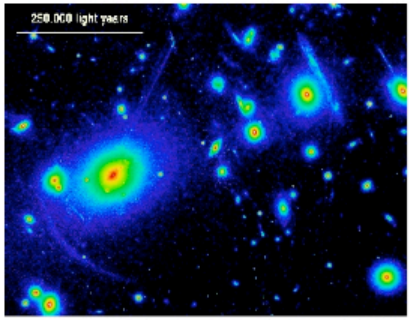
2 Ms CDFS (~600 fuentes)

Cumulos de Galaxias

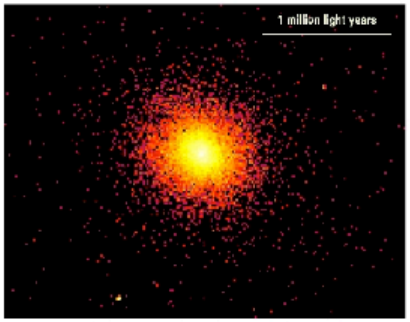
Hasta un 90% de los bariones estan en la forma de gas a varios millones de grados.



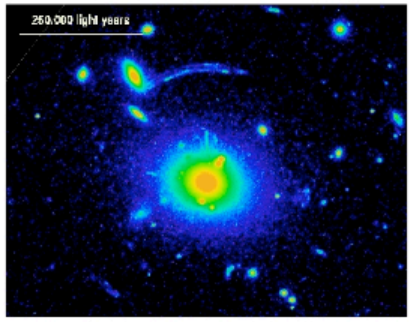
Abell 2390: Chandra (ACIS)



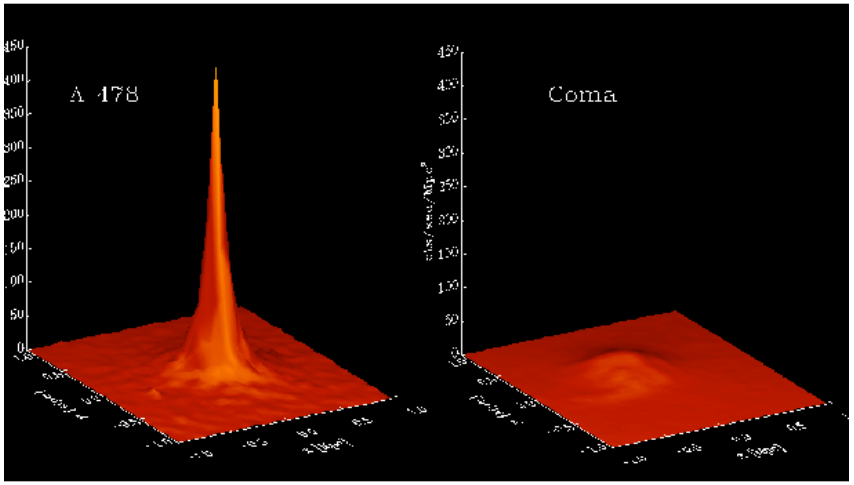
Abell 2390: HST (WFPC2)

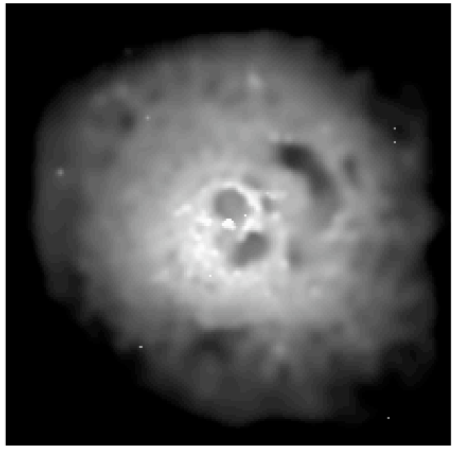


MS2137.3-2353: Chandra (ACIS)

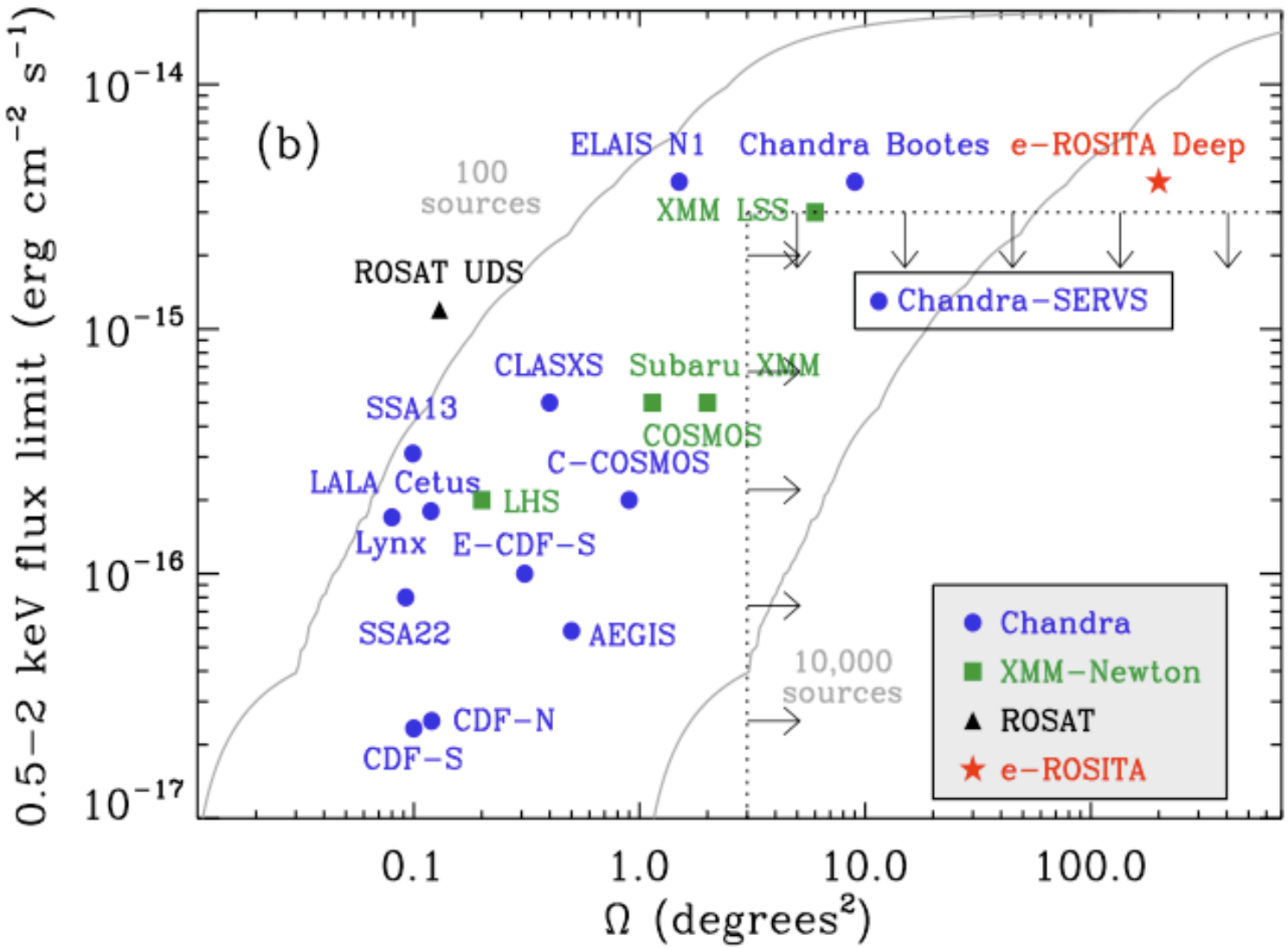


MS2137.3-2353: HST (WFPC2)

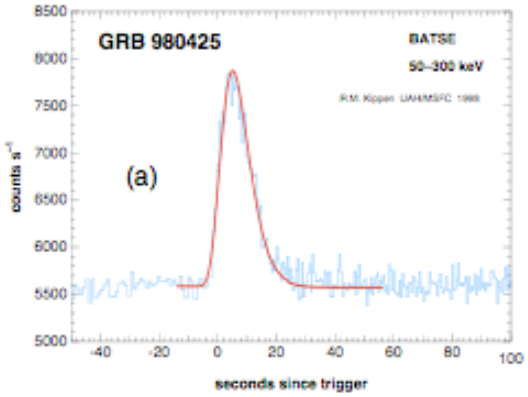


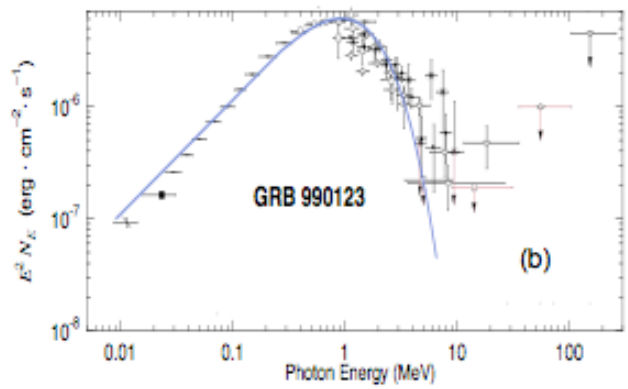


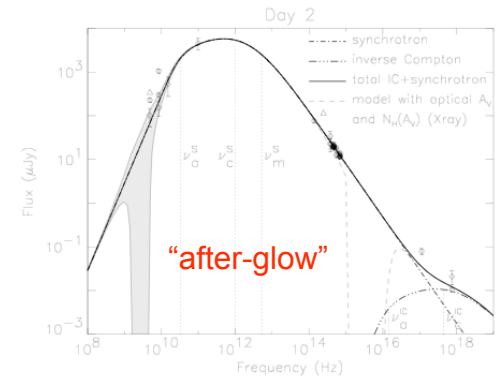
Surveys en Rayos-X

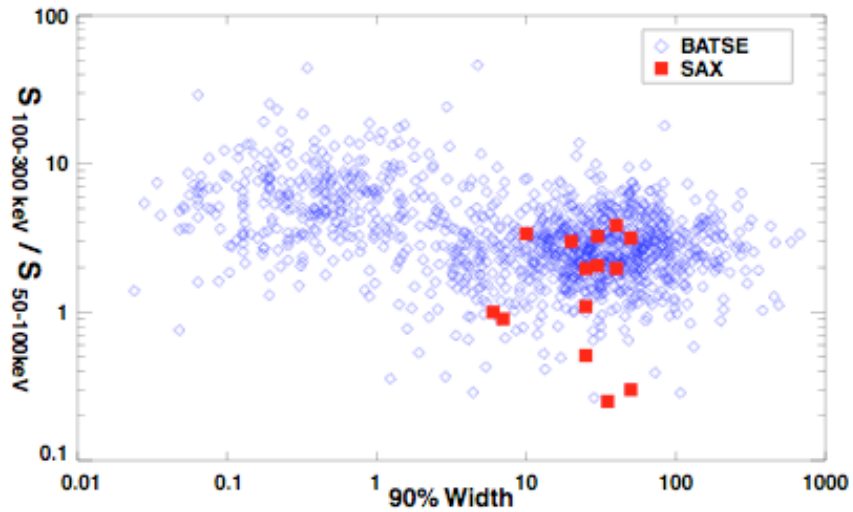


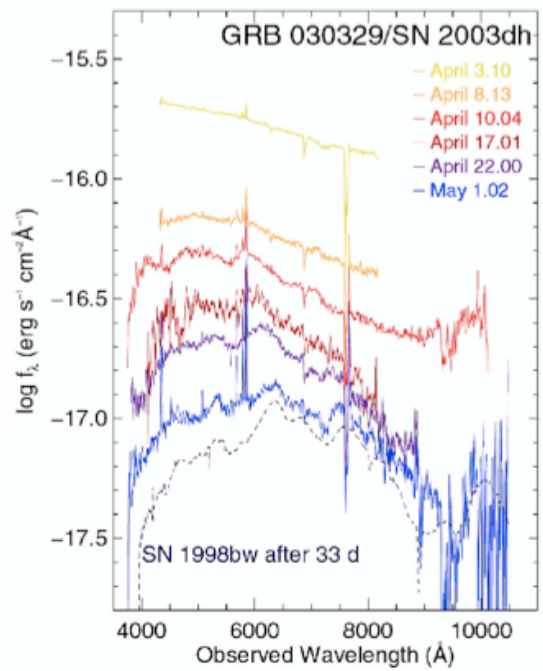
Gamma Ray Bursts





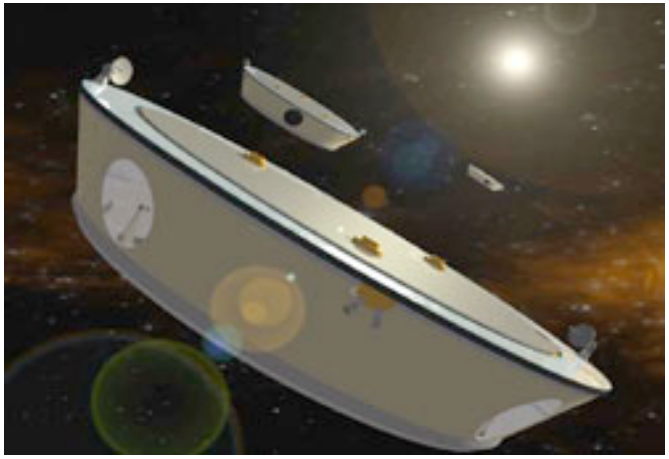




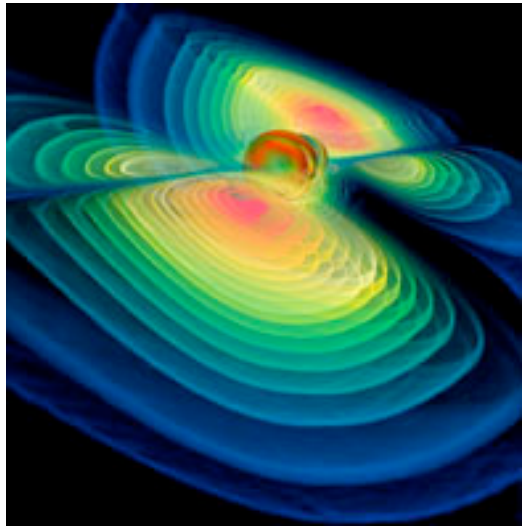


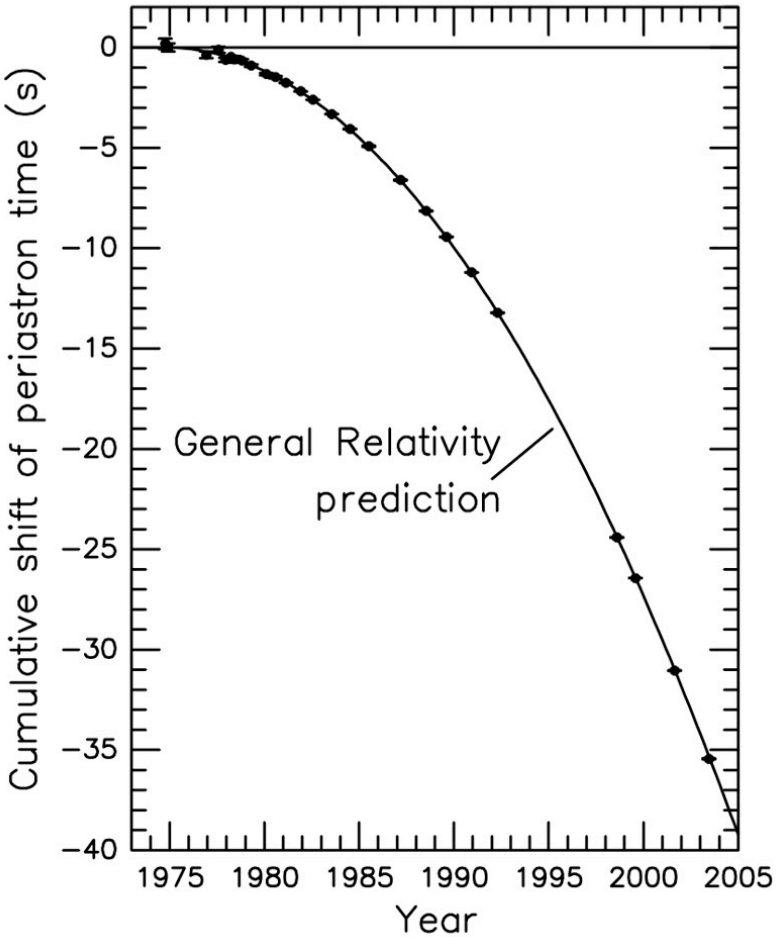
Swift: Noviembre 2004

LISA: Laser Interferometer Space Antenna

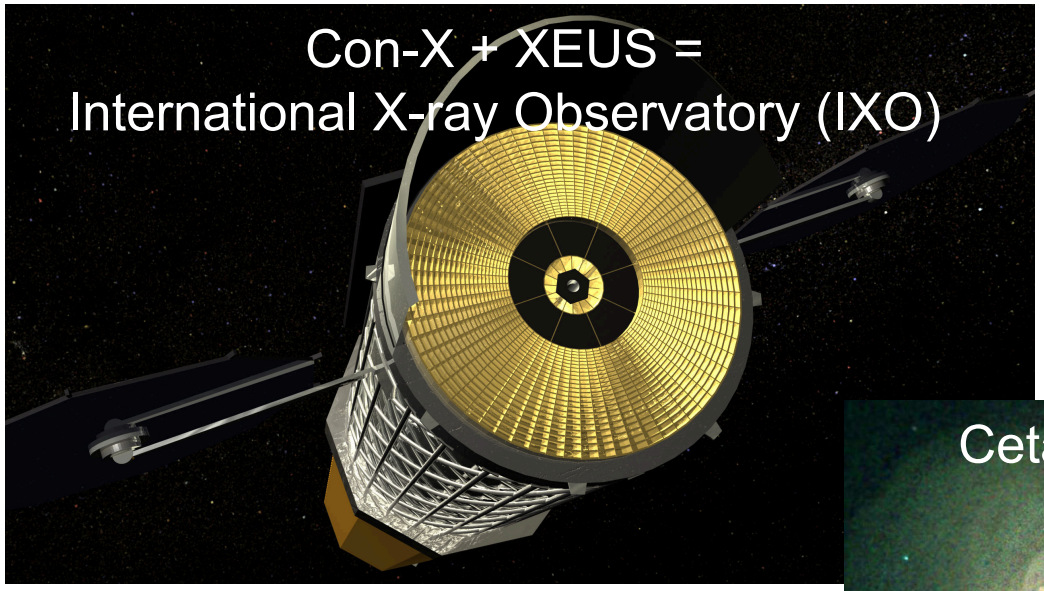


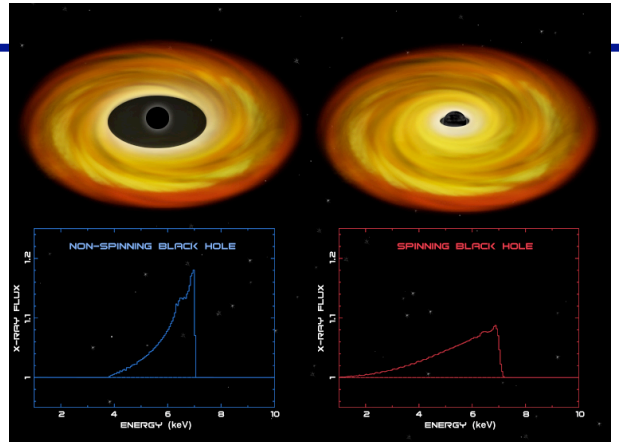
3 naves a 5×10^6 km conectadas por la emisión de un laser IR

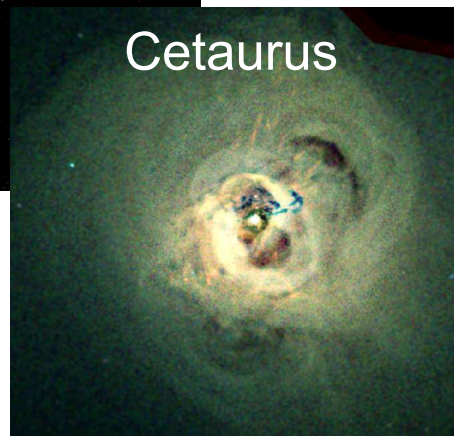


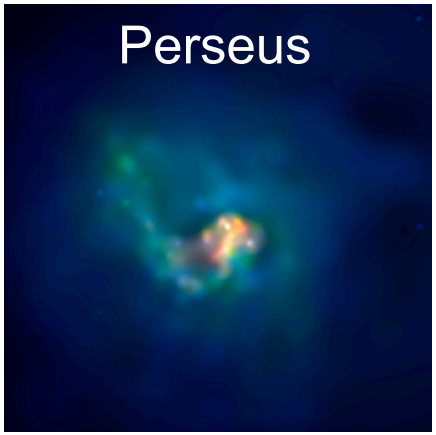


Weisberg & Taylor 1974:
binary pulsar PSR1913+16





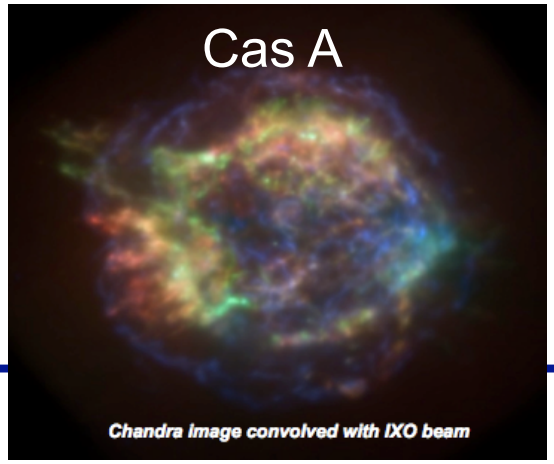




Black Holes

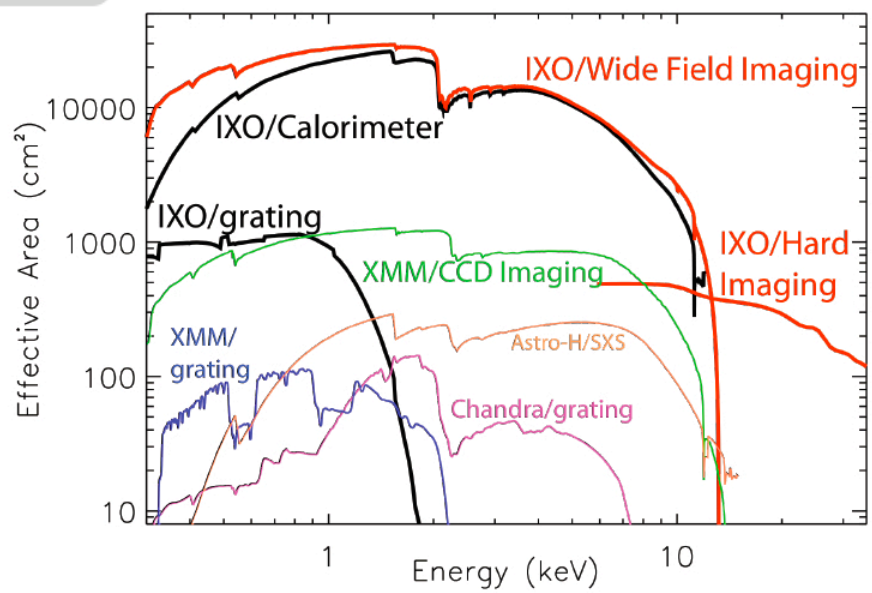
Cúmulos de Galaxias & Feedback

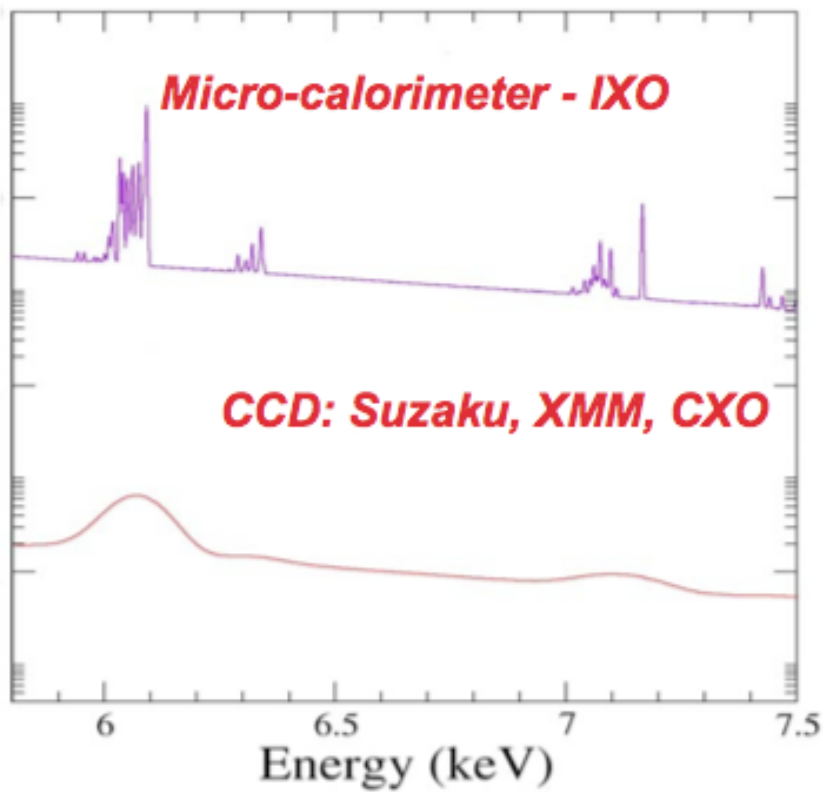
Generación de metales y energía

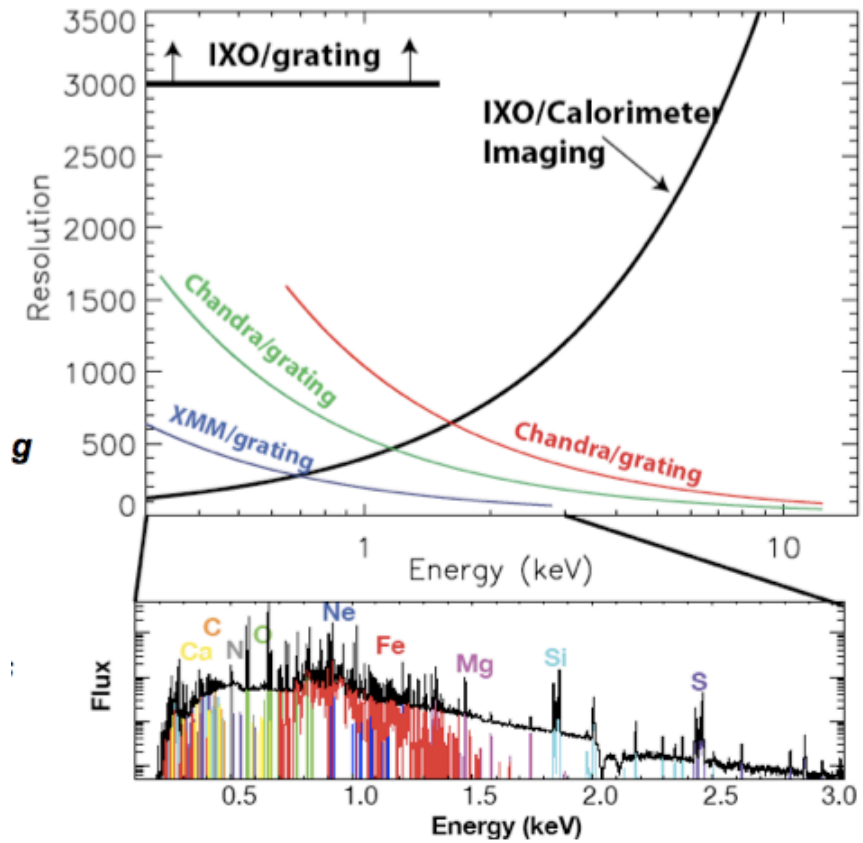


science performance requirements

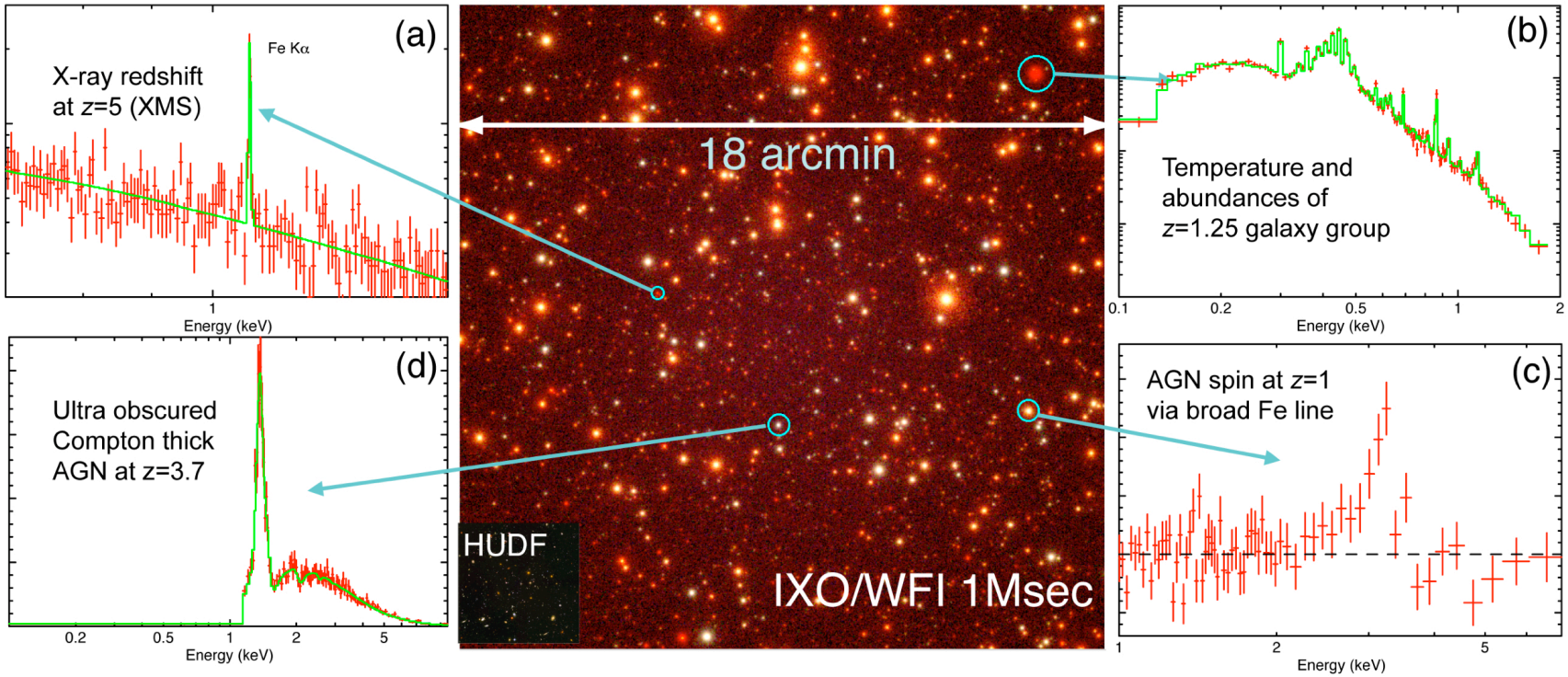
Parameter	Requirement	Science Drivers	Instruments
Mirror Effective Area	3 m^2 @1.25 keV 0.65 m^2 @ 6 keV 0.015 m^2 @ 30 keV	Black Hole Evolution Strong gravity Strong gravity	
Spectral Resolution (FWHM), FOV, bandpass	ΔE = 2.5 eV, 2 arcmin, 0.3 – 7 keV ΔE = 10 eV, 5 arcmin, 0.3 – 7 keV ΔE =150 eV, 18 arcmin, 0.1– 15 keV $E/\Delta E$ = 3000, point src, 0.3 – 1 keV	Galaxy Cluster Evolution Cosmic Feedback Black Hole Evolution Cosmic Web	XMS XMS WFI/HXI XGS
Angular Resolution	5 arcsec HPD, 0.3 – 7 keV 5 arcsec HPD, 0.3 – 7 keV 30 arcsec HPD, 7.0 – 40 keV	Cosmic feedback, Black Hole Evolution Strong Gravity	XMS WFI/HXI WFI/HXI
Count Rate	10^6 cps with < 10% deadtime	Neutron Star Equation of State	HTRS
Polarimetry	1% MDP, 100 ksec, 5×10^{-12} cgs (2–6 keV)	Strong Gravity	XPOL




Micro-calorimeter - IXO
CCD: Suzaku, XMM, CXO
6
6.5
7
7.5
Energy (keV)


IXO/grating
IXO/Calorimeter Imaging
Chandra/grating
XMM/grating
Chandra/grating
Resolution
3500
3000
2500
2000
1500
1000
500
0
1
10
Energy (keV)
Flux
C
Ca
N
O
Ne
Fe
Mg
Si
S
0.5
1.0
1.5
2.0
2.5
3.0
Energy (keV)

AGNs con IXO


(a)
Fe Kα
X-ray redshift
at z=5 (XMS)
1
Energy (keV)
(b)
Temperature and
abundances of
z=1.25 galaxy group
0.1
0.2
0.5
1
2
Energy (keV)
18 arcmin
HUDF
IXO/WFI 1Msec
(d)
Ultra obscured
Compton thick
AGN at z=3.7
0.2
0.5
1
2
5
Energy (keV)
(c)
AGN spin at z=1
via broad Fe line
1
2
5
Energy (keV)