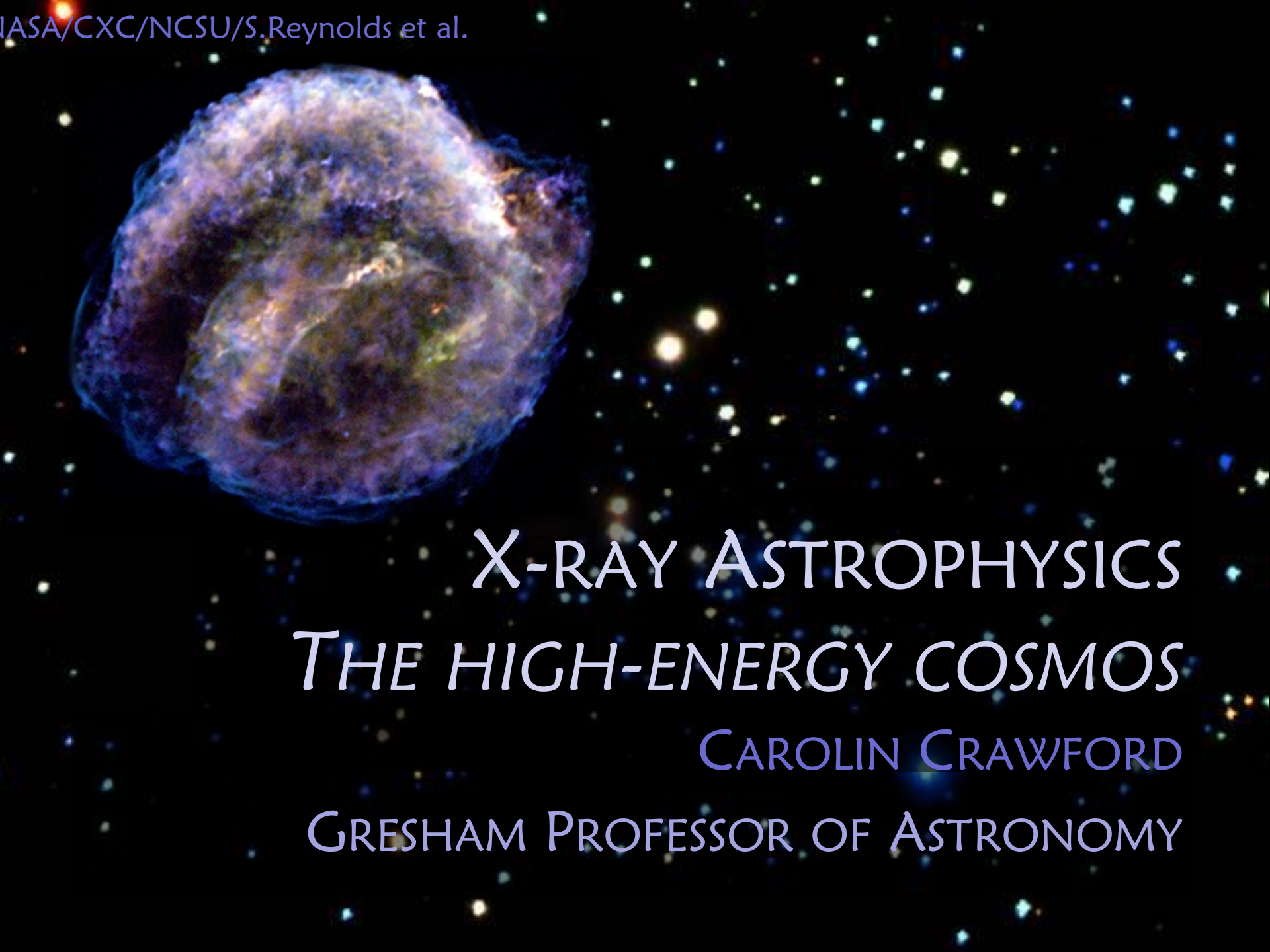


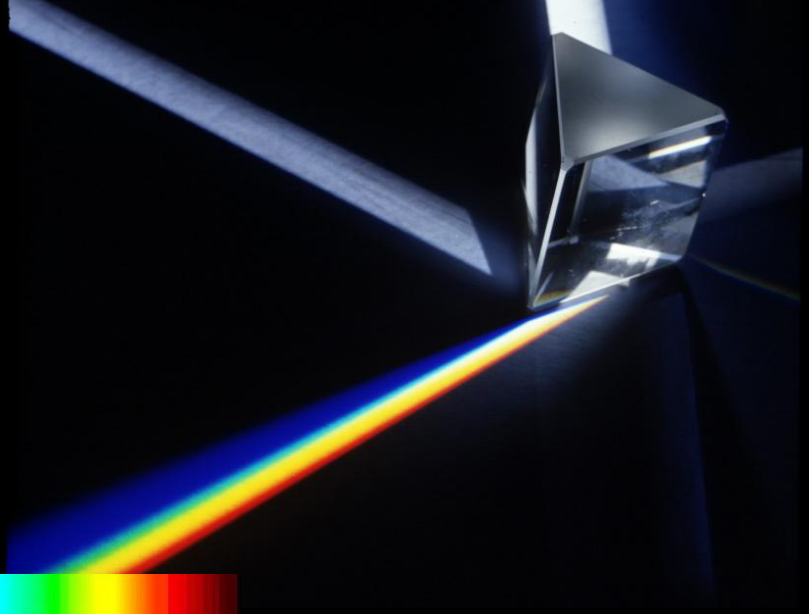
X-ray Astrophysics

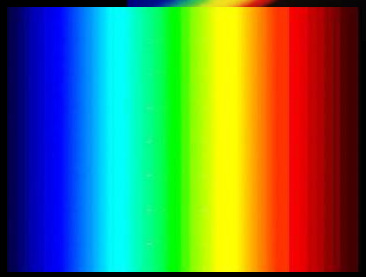
The high-energy cosmos

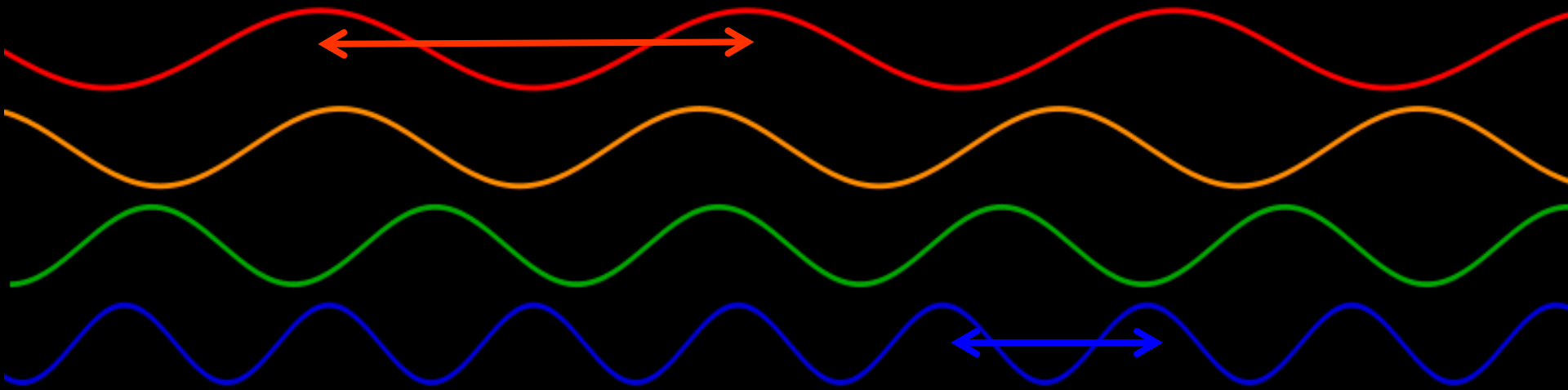
Carolin Crawford

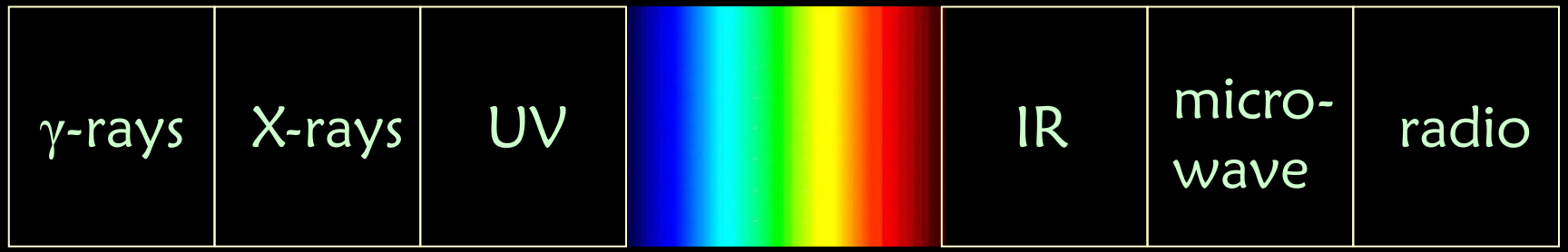
Gresham Professor of Astronomy


NASA/ESA/HST/A. Riess (STScI/JHU), L. Macri (Texas).









Short wavelength

High energy

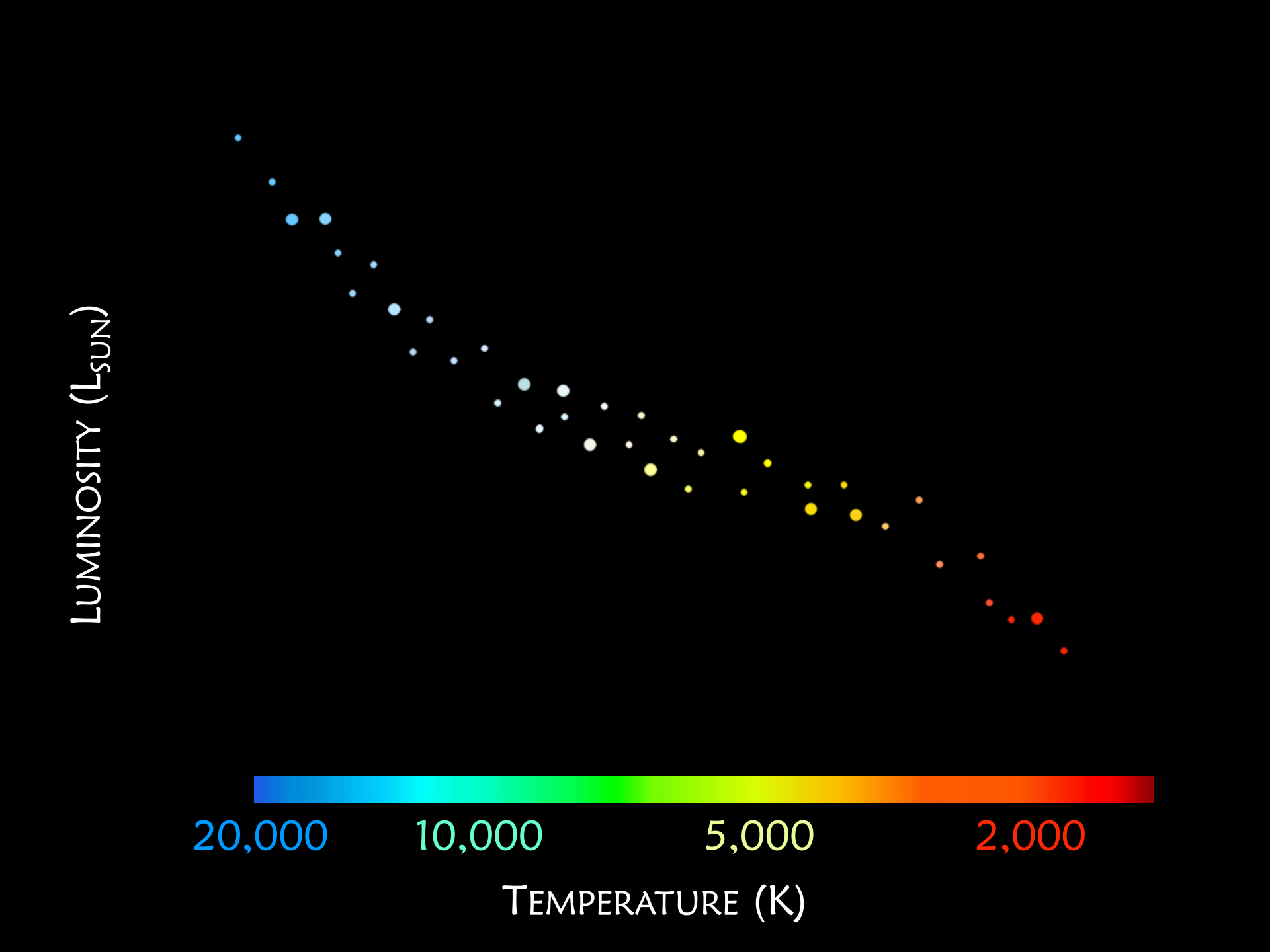
Long wavelength

Low energy

5500 3200 1750 900 K

Temperature


Roth Ritter (Dark Atmospheres)


Luminosity (L_{sun})
20,000
10,000
5,000
2,000
Temperature (K)


Roth Ritter (Dark Atmospheres)

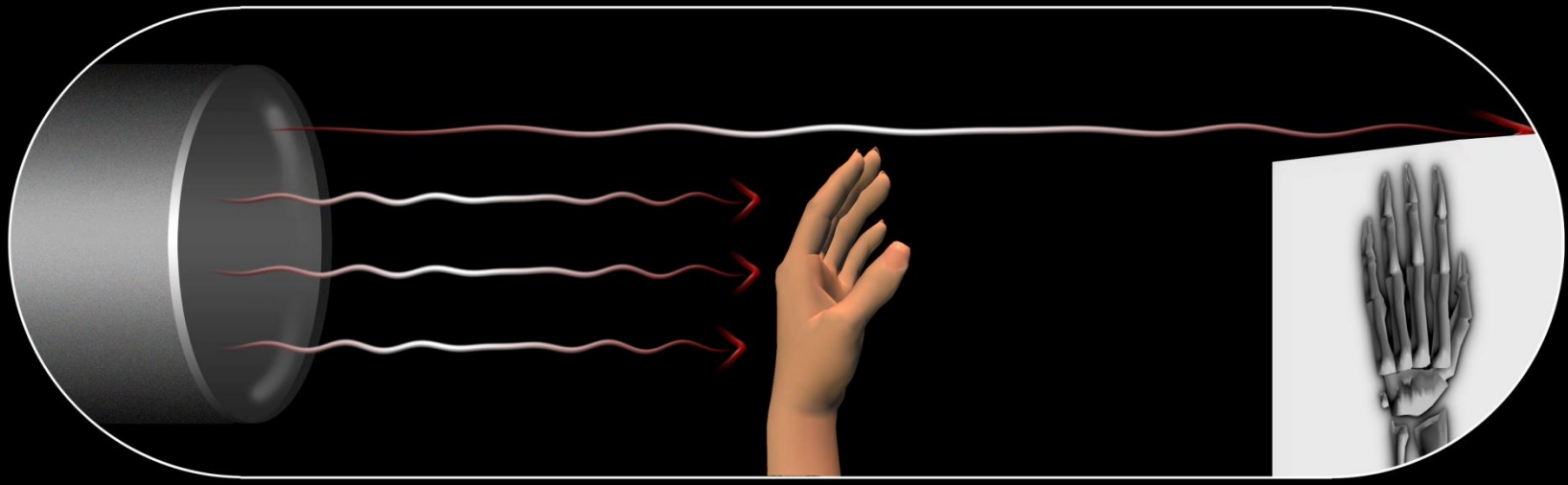
γ-rays	X-rays	UV		IR	micro-wave	radio

10 mill 1 mill 10,000 1,000 100 10 1

Temperature (K)

0 K = –273° C

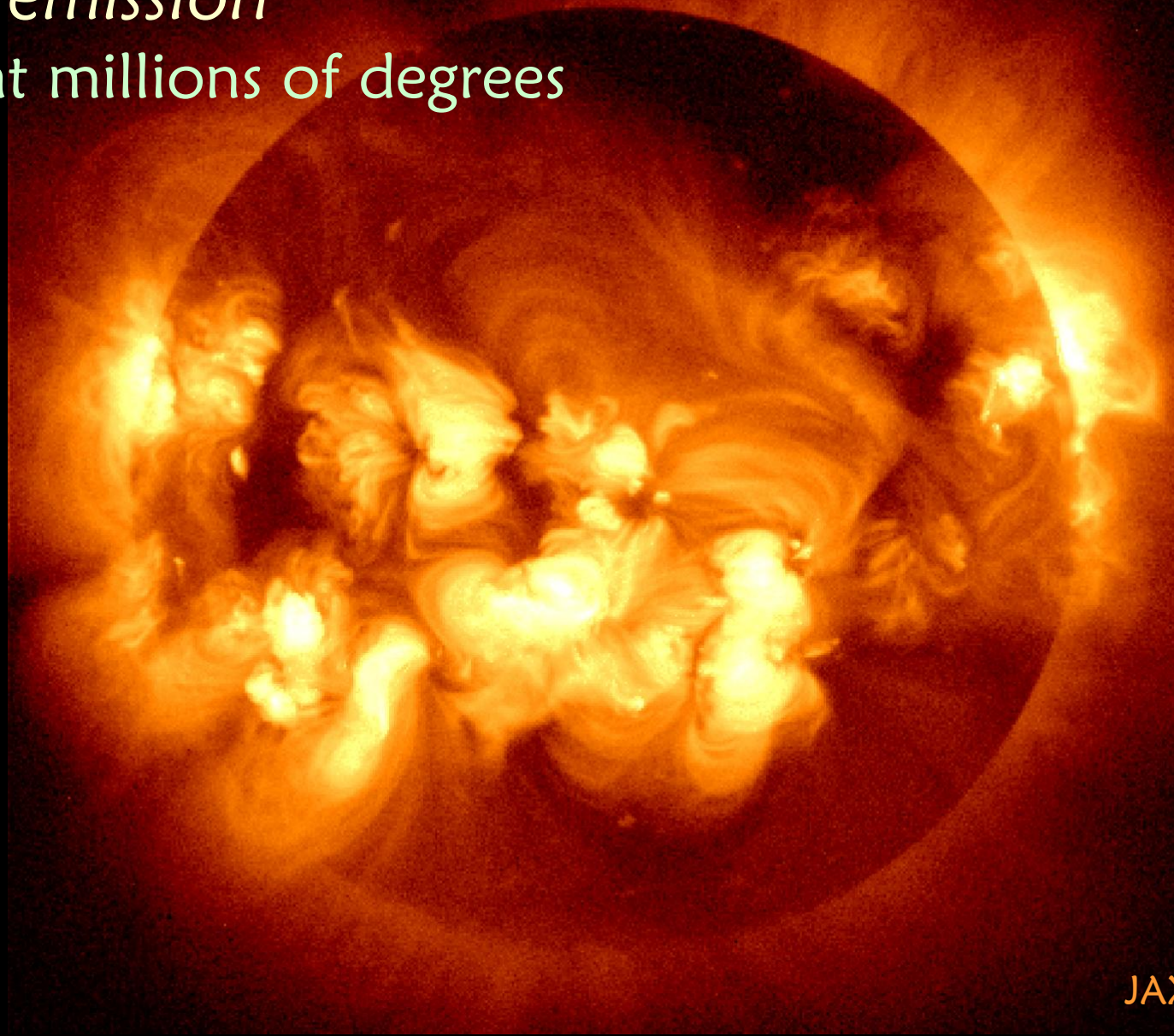
Wilhelm Röntgen (1845-1923)



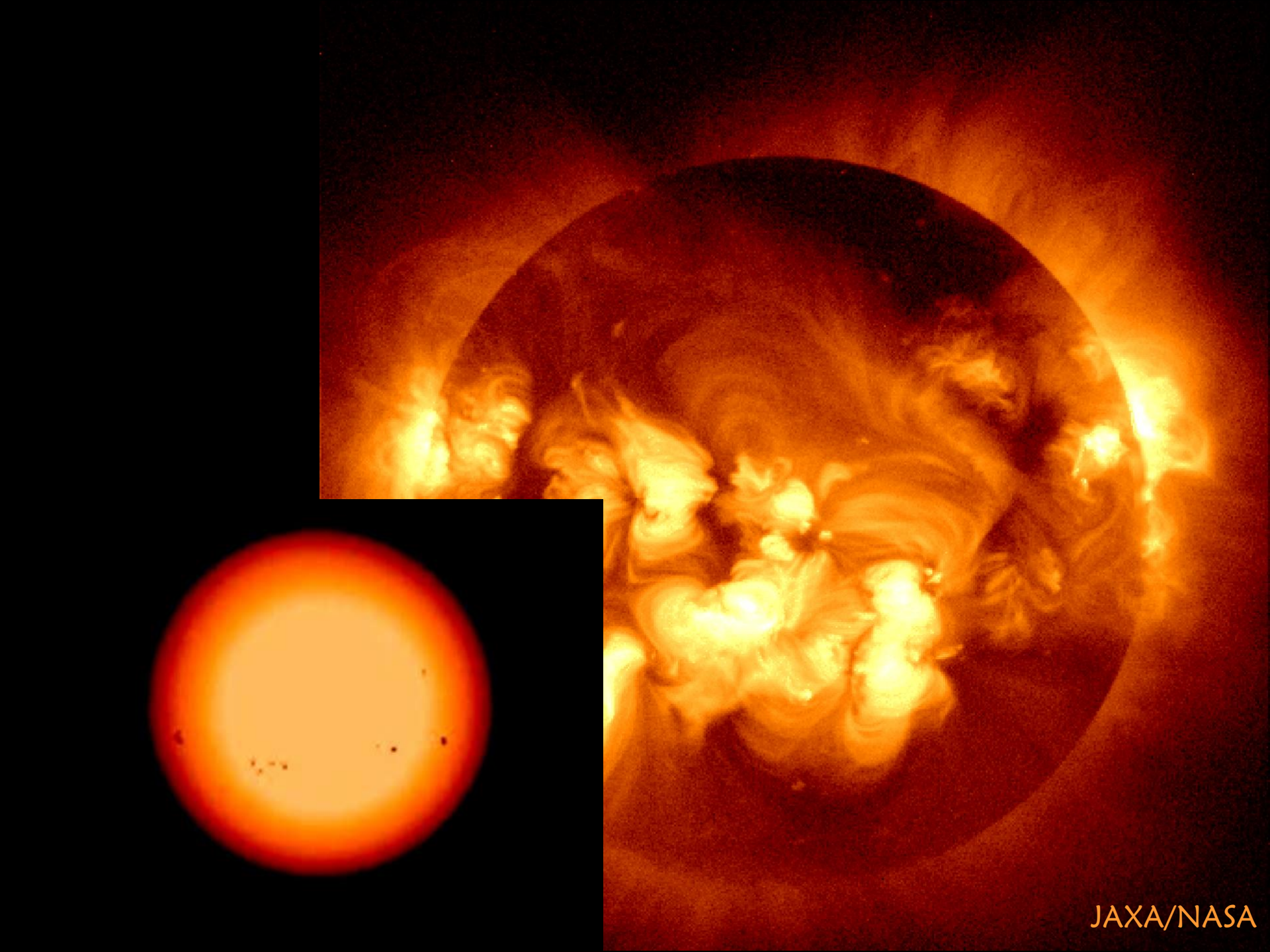
X-ray photons come from

black-body emission

- material at millions of degrees



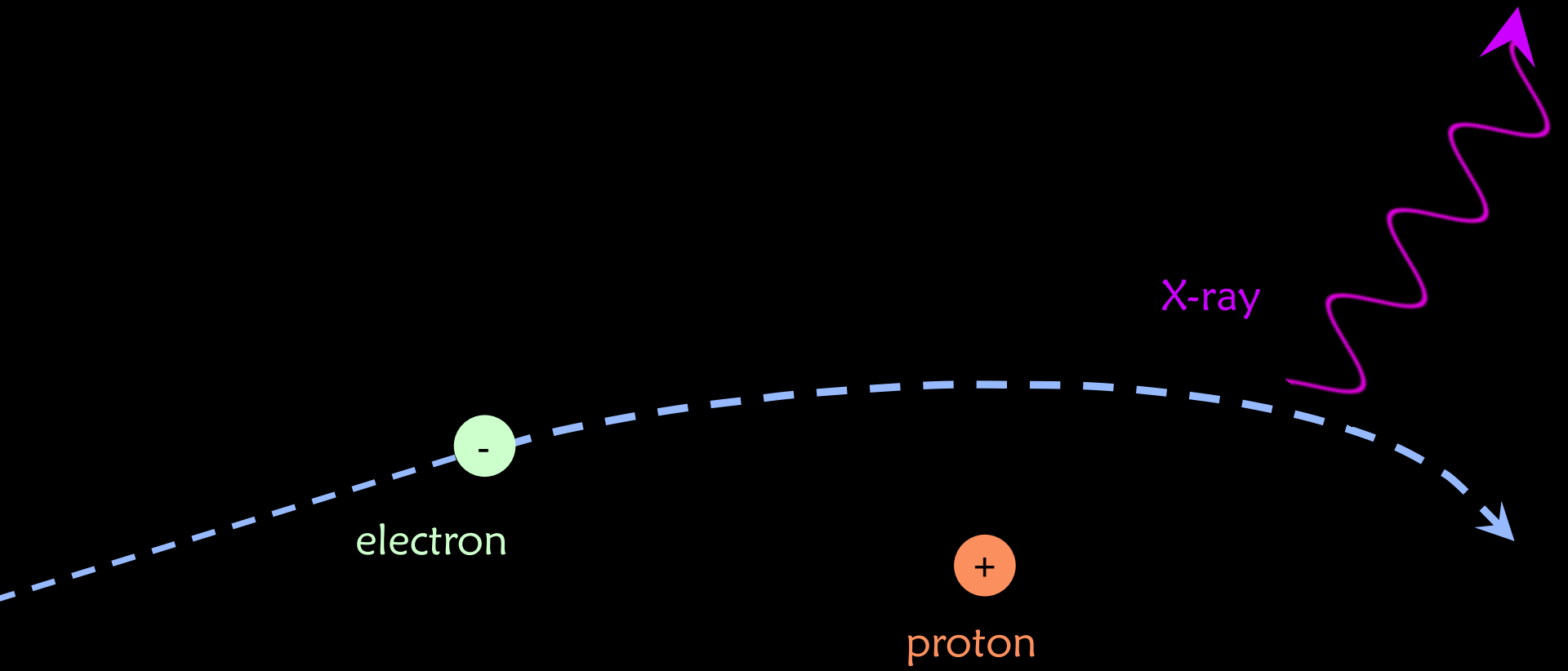
JAXA

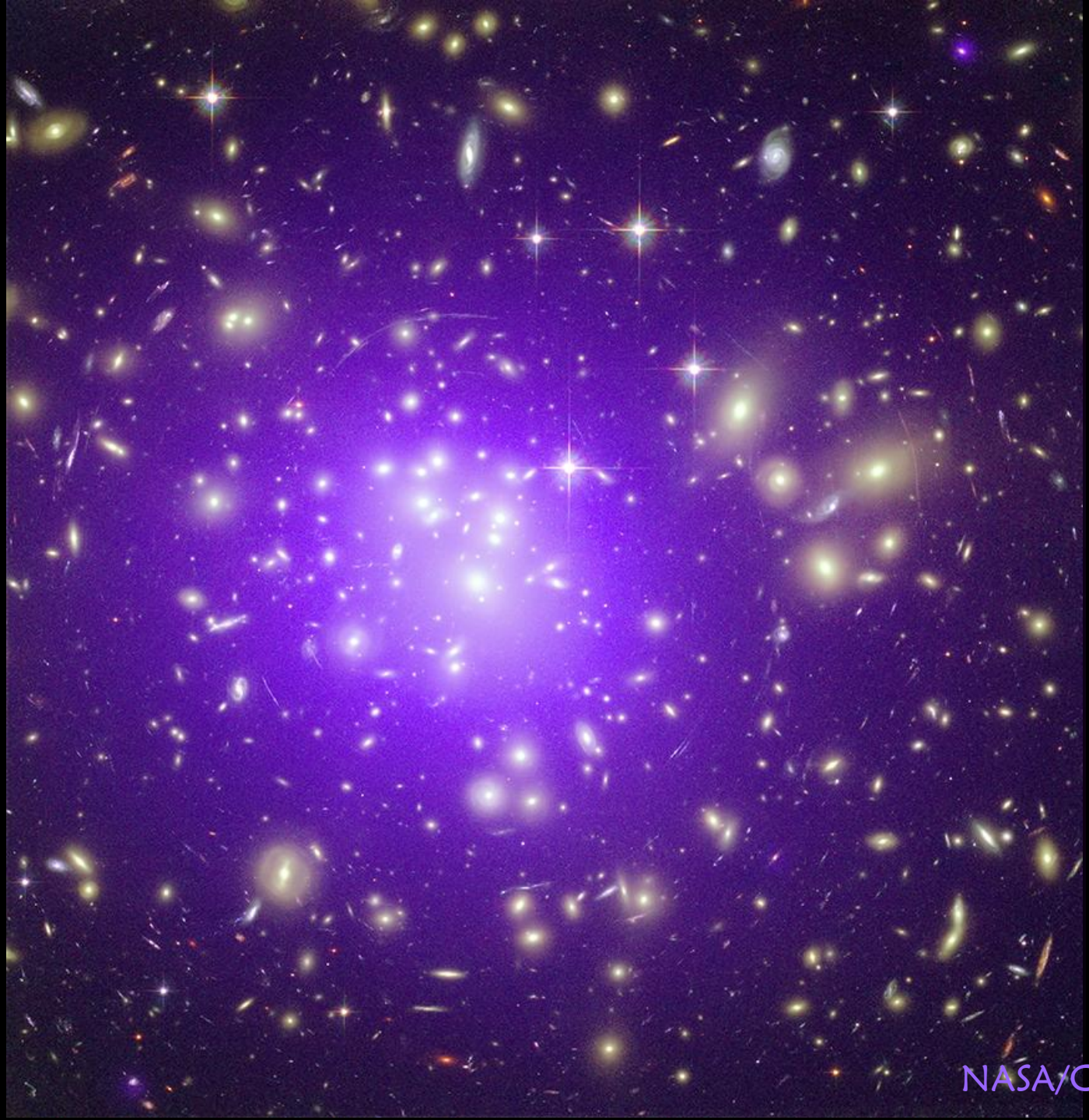

JAXA/NASA

X-ray photons come from

thermal bremsstrahlung

– electron accelerated by an electric field





optical
X-rays

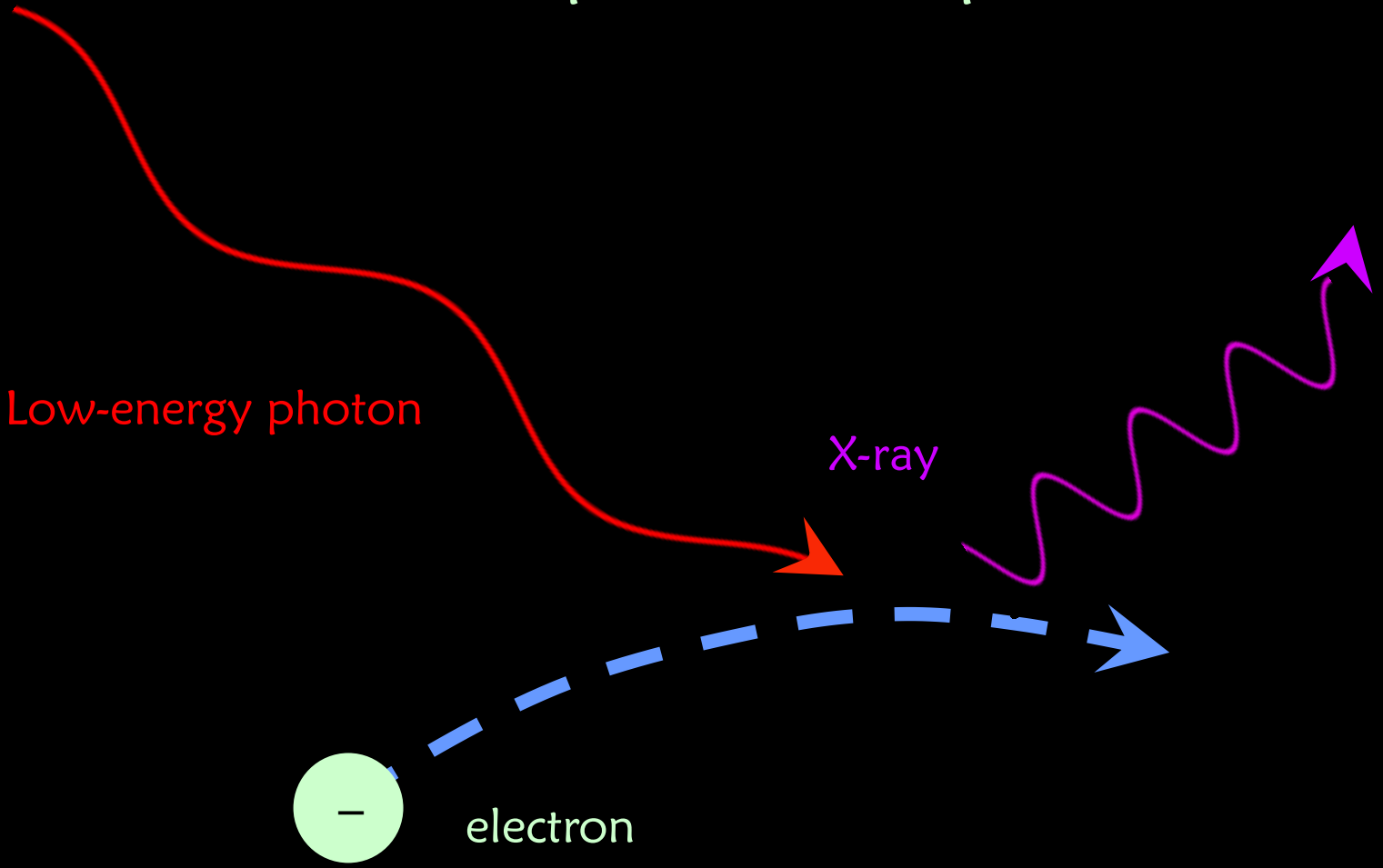
NASA/STScI

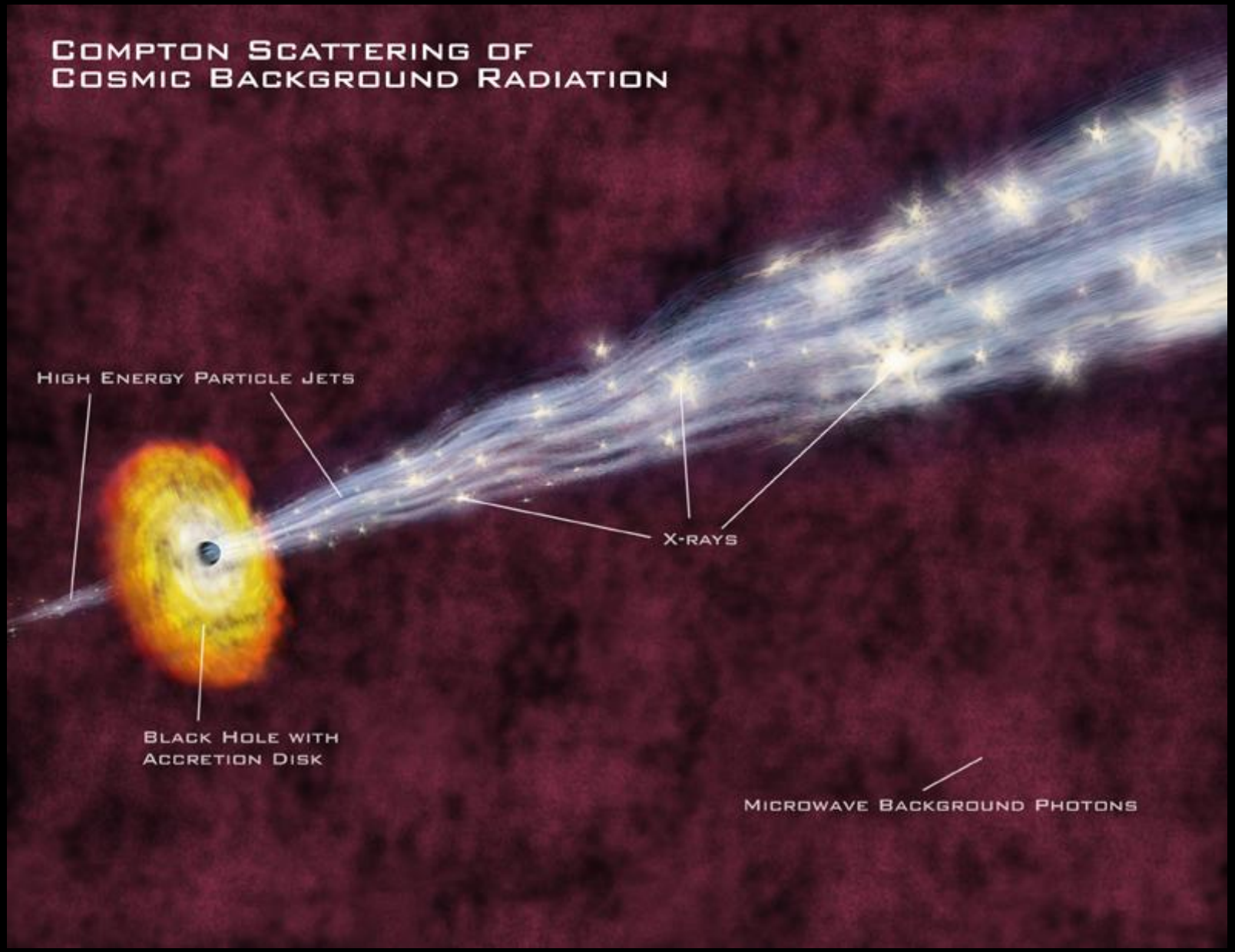
NASA/CXC/MIT/Peng et al

X-ray photons come from

Compton scattering

– collisions between photons and particles



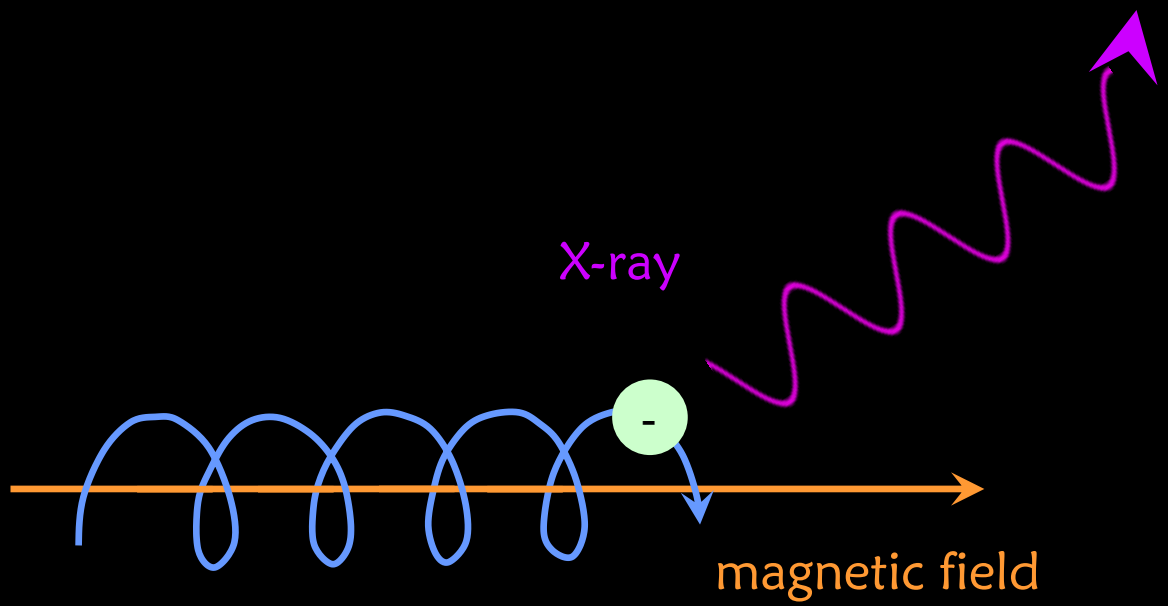

COMPTON SCATTERING OF
COSMIC BACKGROUND RADIATION
HIGH ENERGY PARTICLE JETS
X-RAYS
BLACK HOLE WITH
ACCRETION DISK
MICROWAVE BACKGROUND PHOTONS

CXC/S Lee

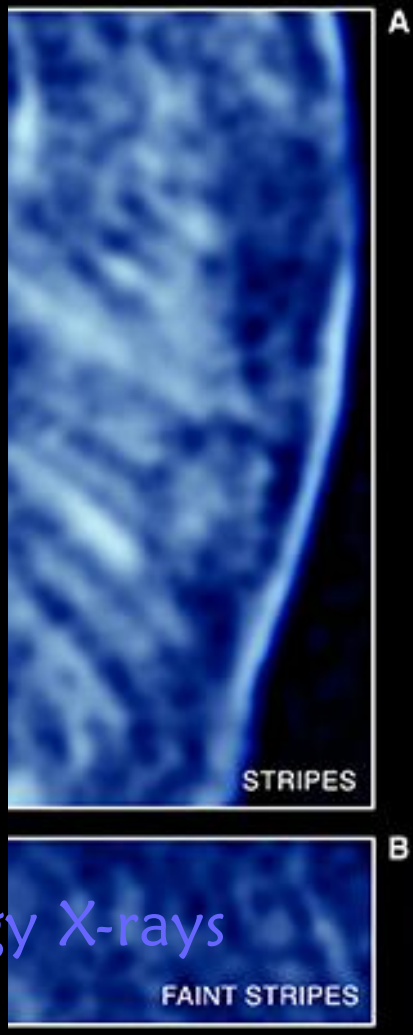
X-ray photons come from

synchrotron radiation

- charged particles spiralling along magnetic field lines



Tycho's supernova

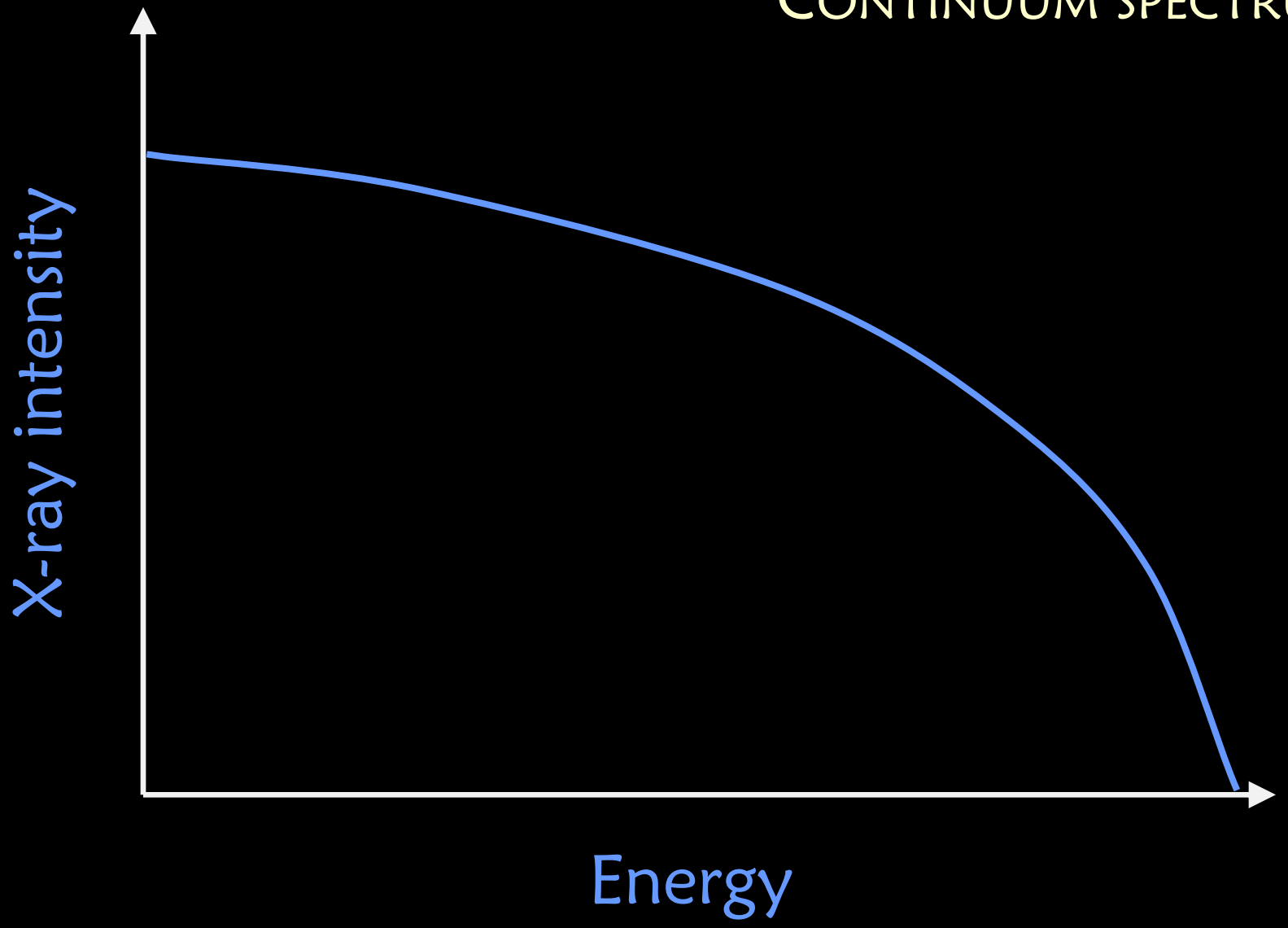


High-energy X-rays

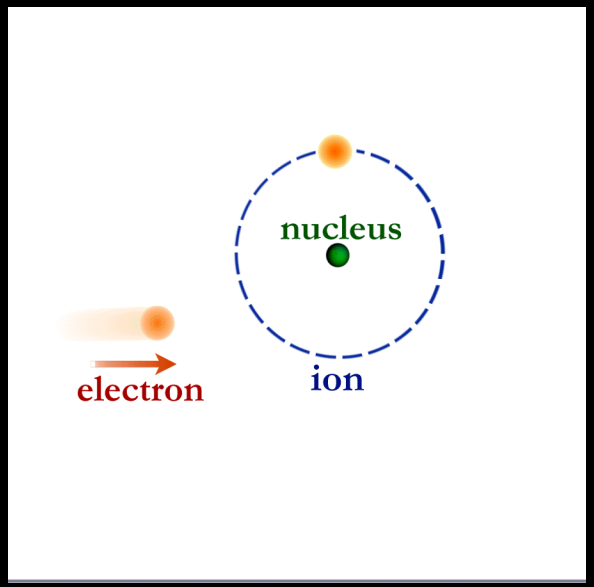
Low-energy X-rays

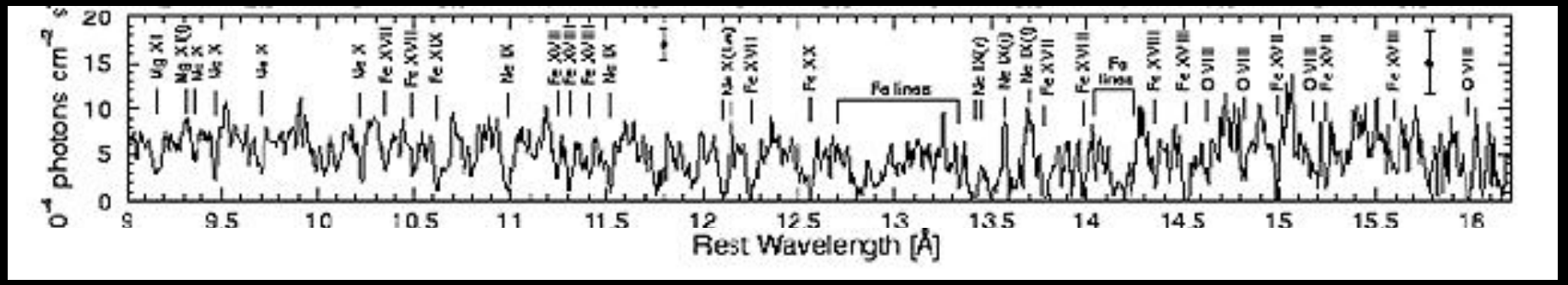
NASA/CXC/Rutgers/K.Eriksen et al

Continuum spectrum



Atomic emission



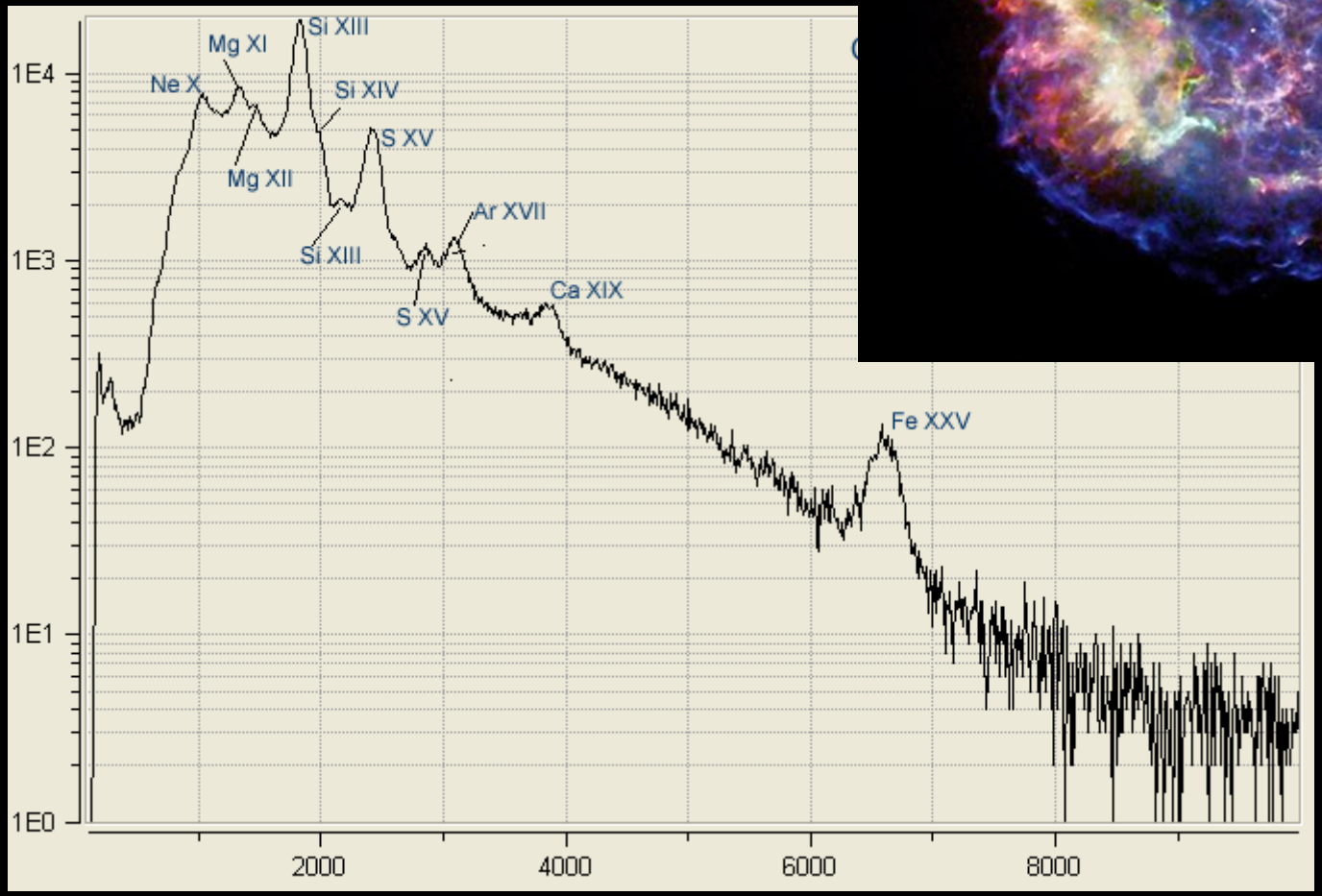


NASA/PSU

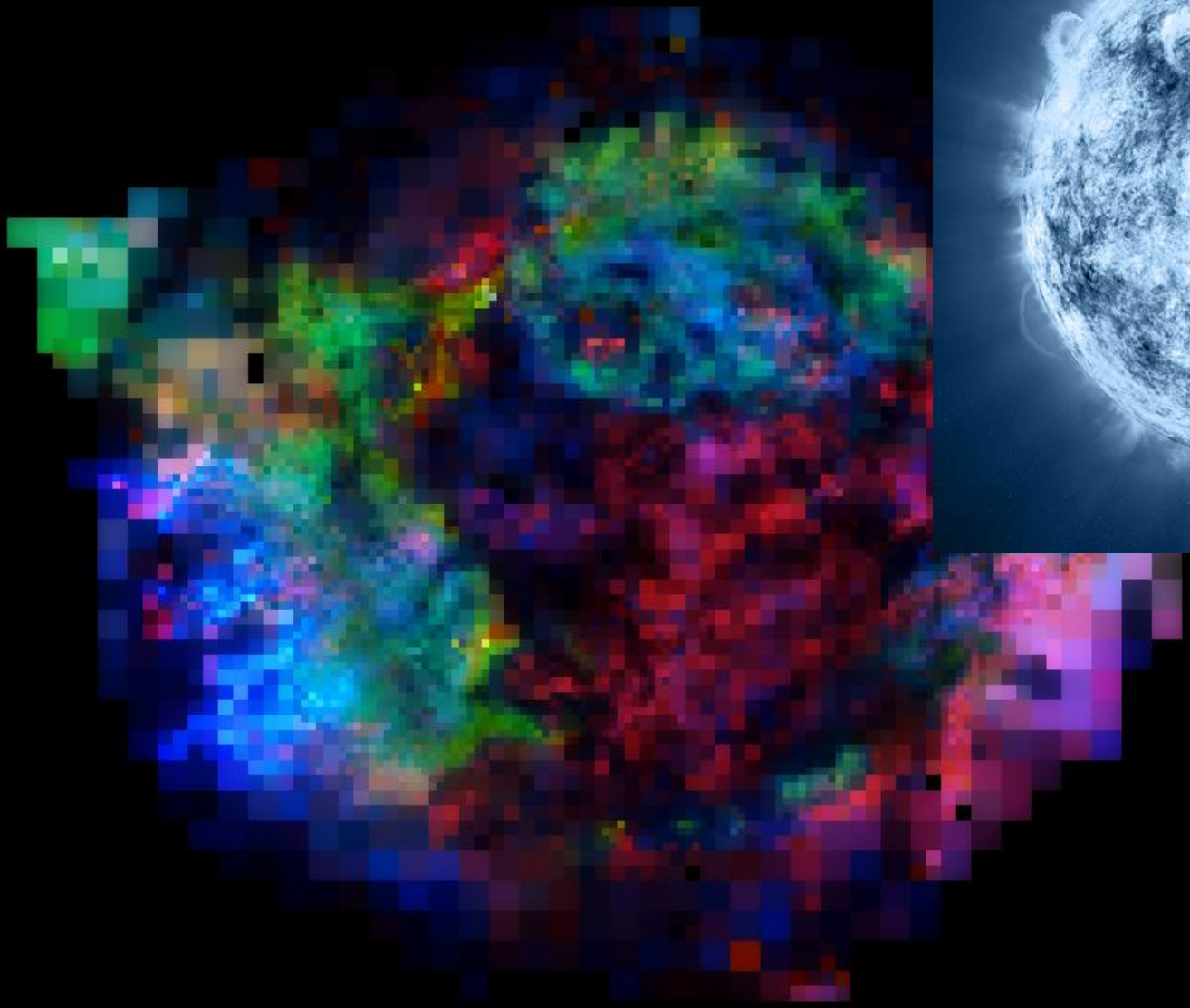
CXC/S Lee

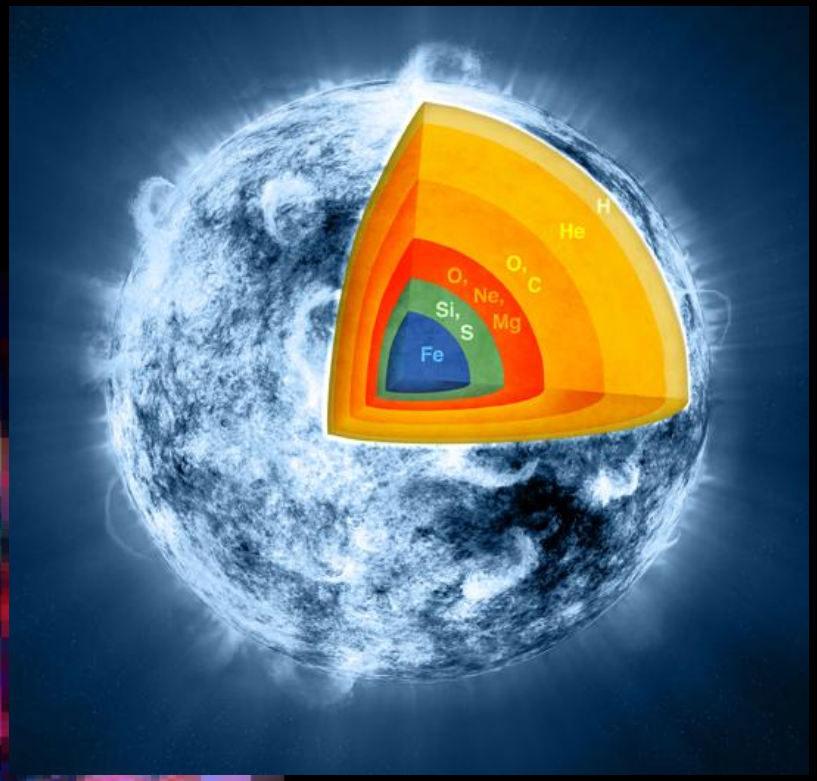
NASA/CXC/MIT/UMass Amherst/M.D.Stage et al.

Cass A supernova remnant



John Kolena, Duke U





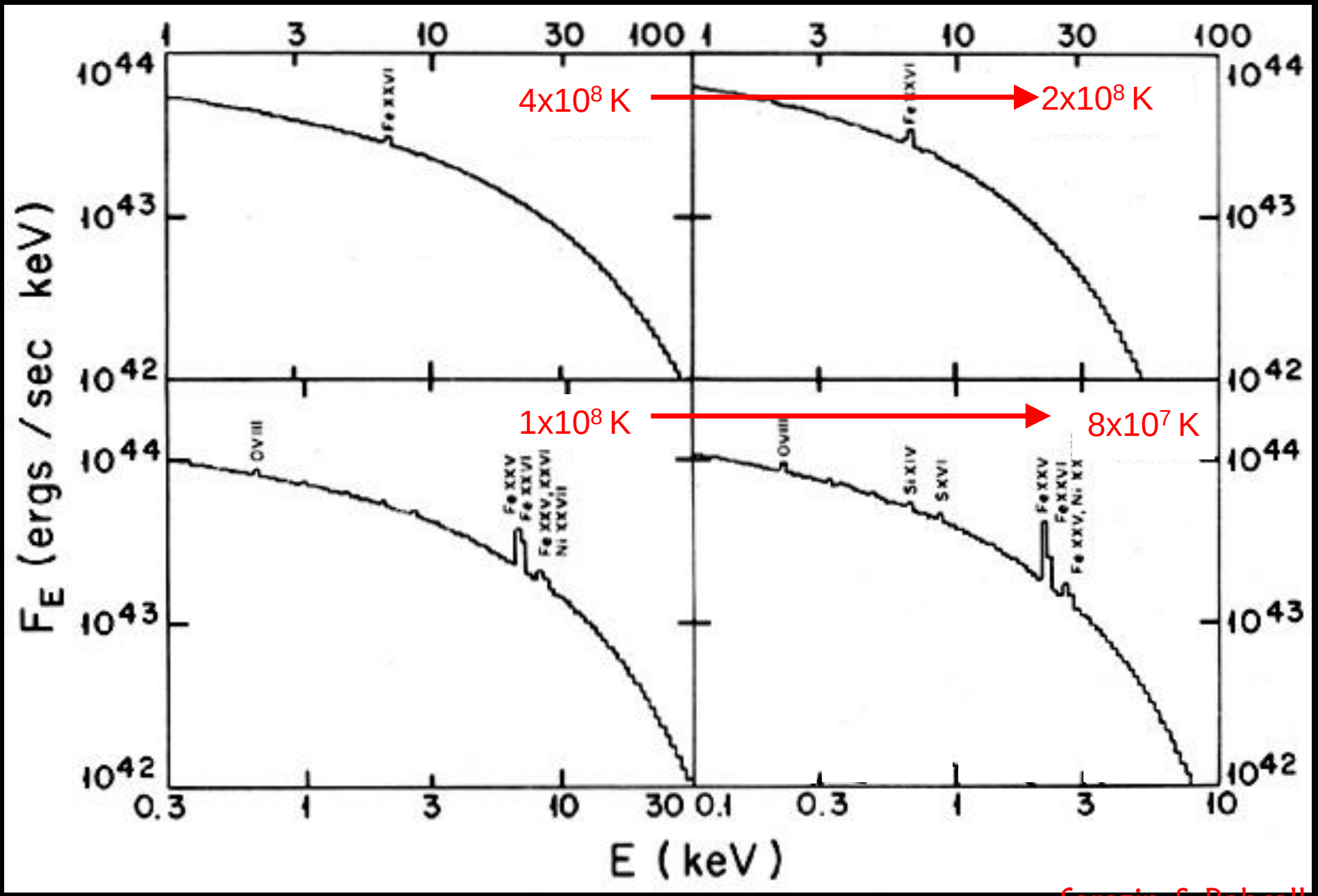
Fe

Mg, Ne, O

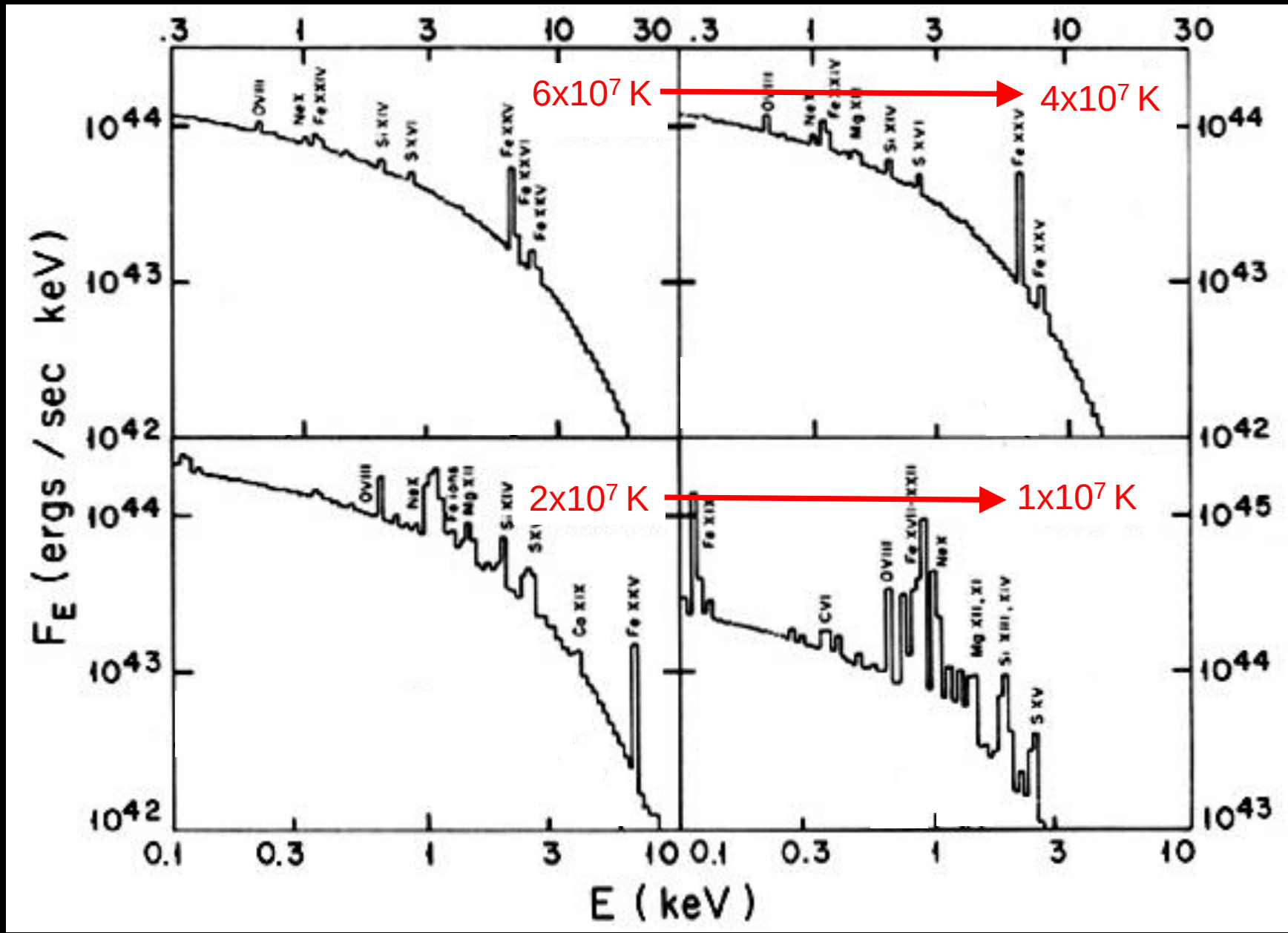
S, Si

NASA/CXC/Weiss

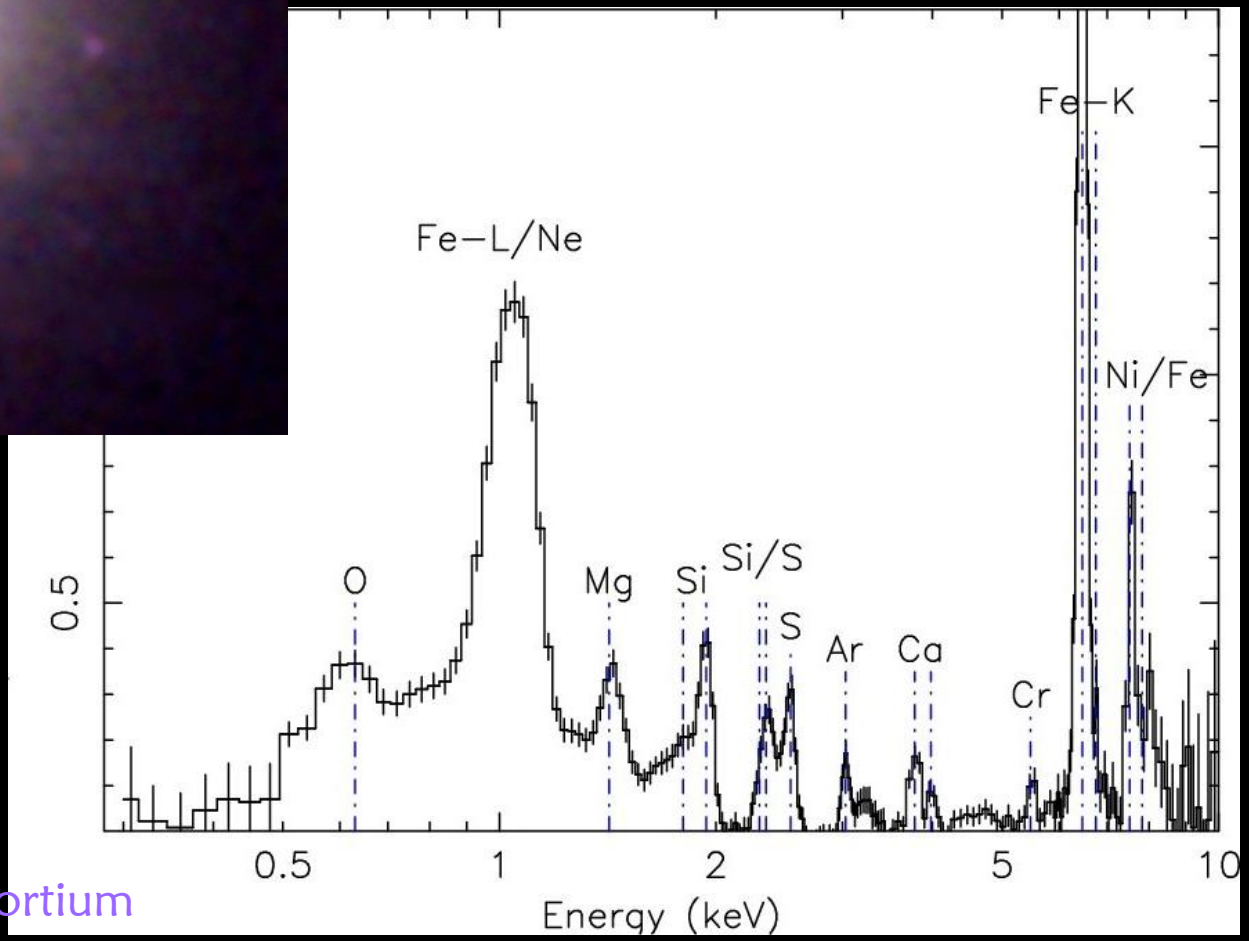
NASA/CXC/GSFC/Hwang & Laming



Sarazin & Bahcall

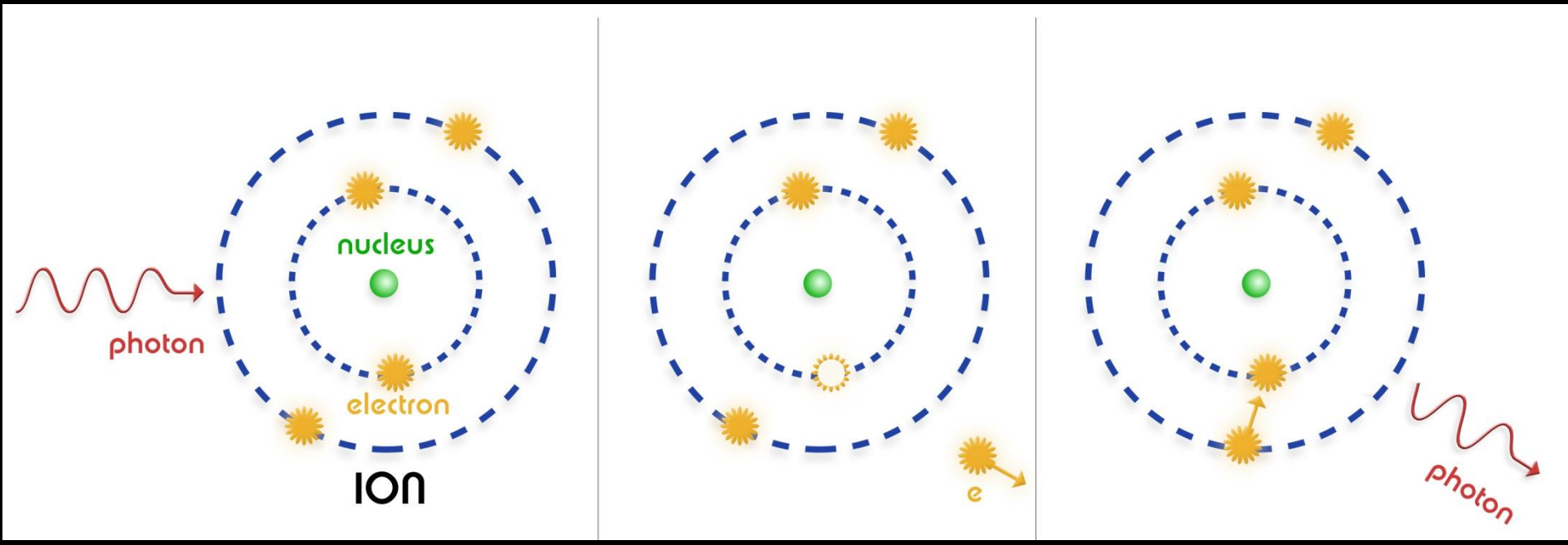


Sarazin & Bahcall

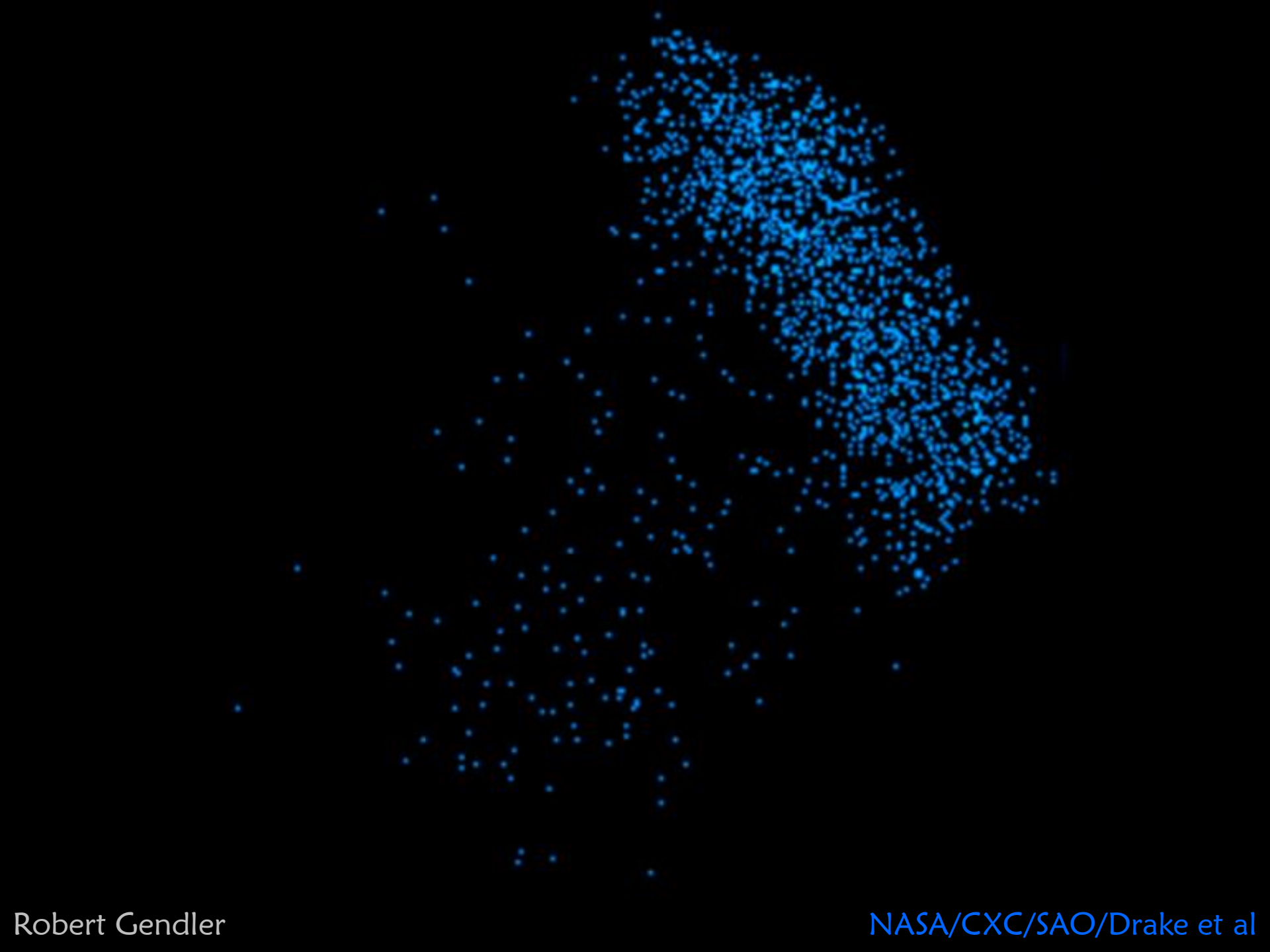


ESA/XMM-Newton EPIC consortium

FLUORESCENCE



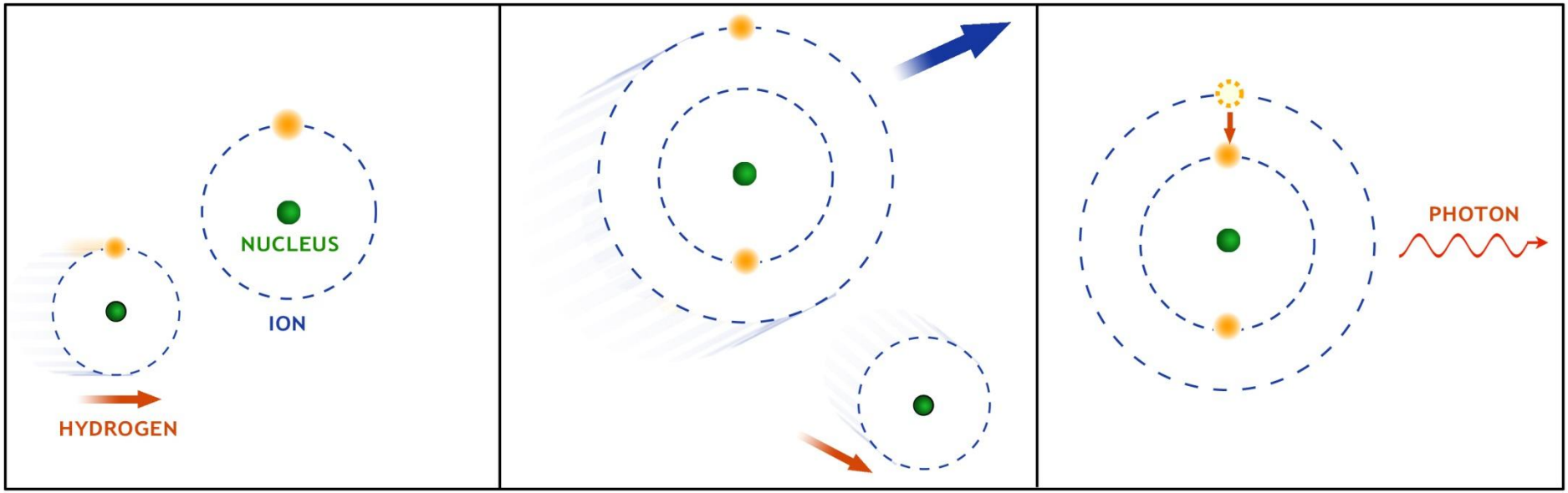
NASA/CXC/M Weiss

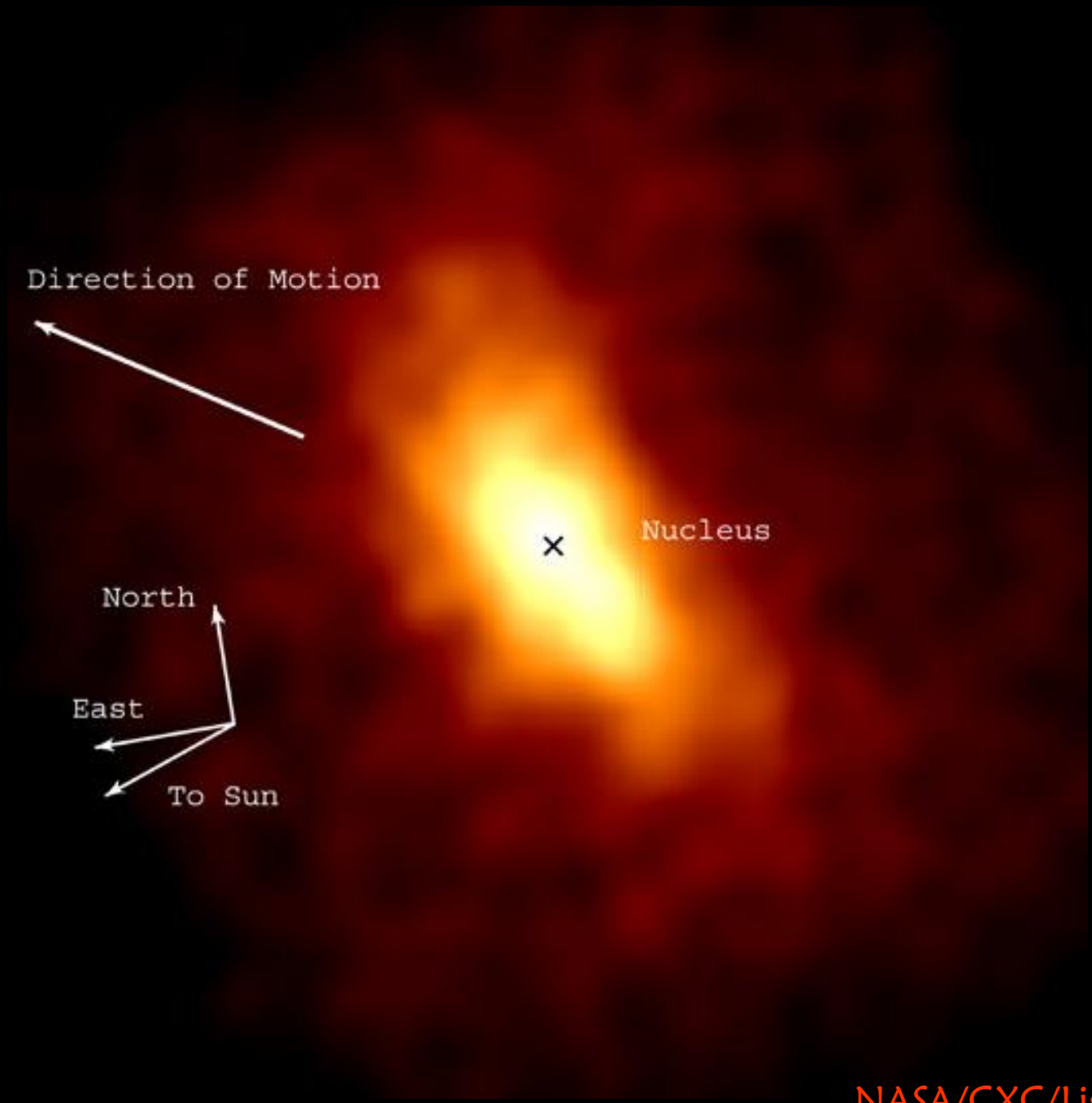


Robert Gendler

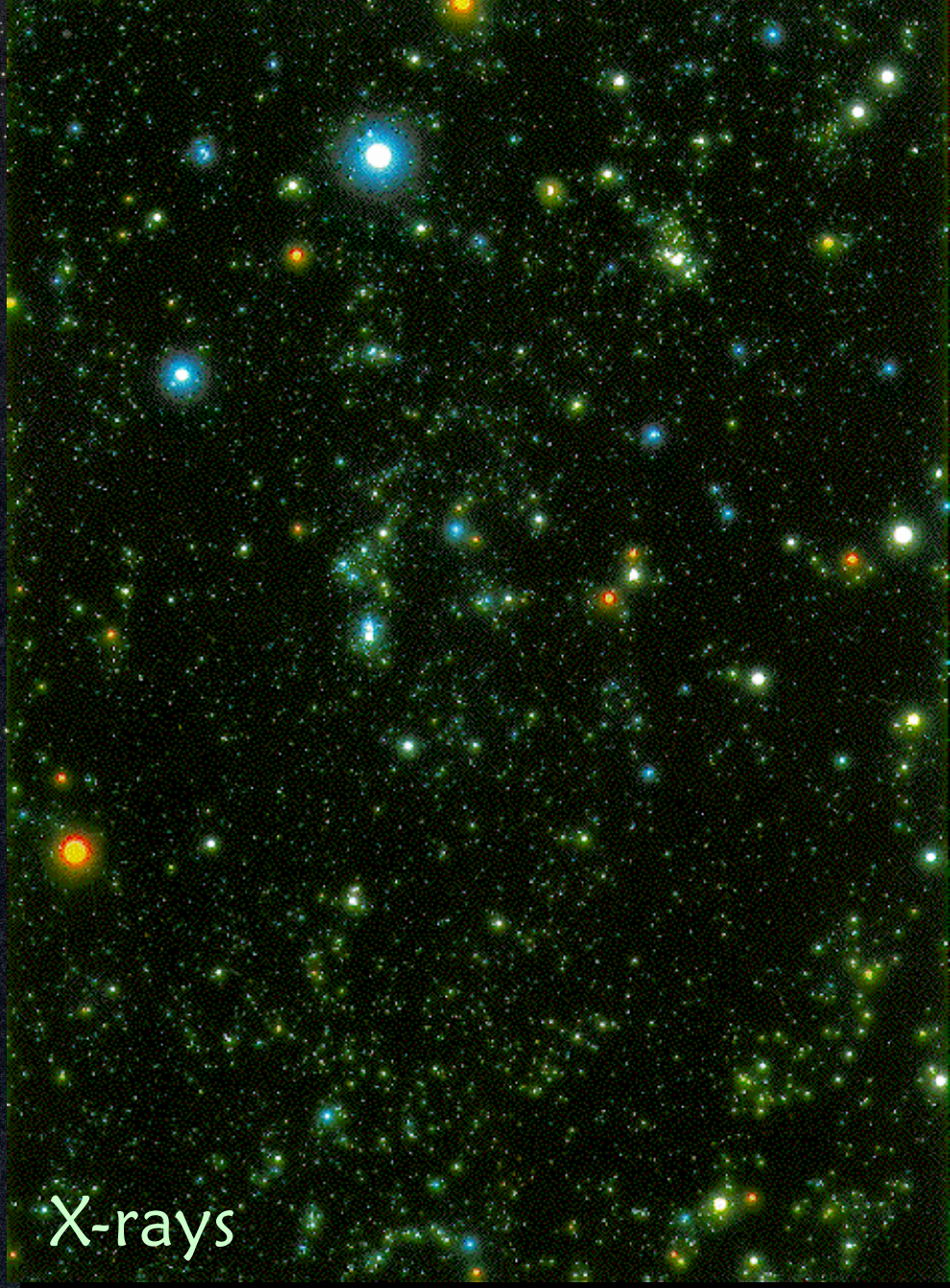
NASA/CXC/SAO/Drake et al

CHARGE EXCHANGE

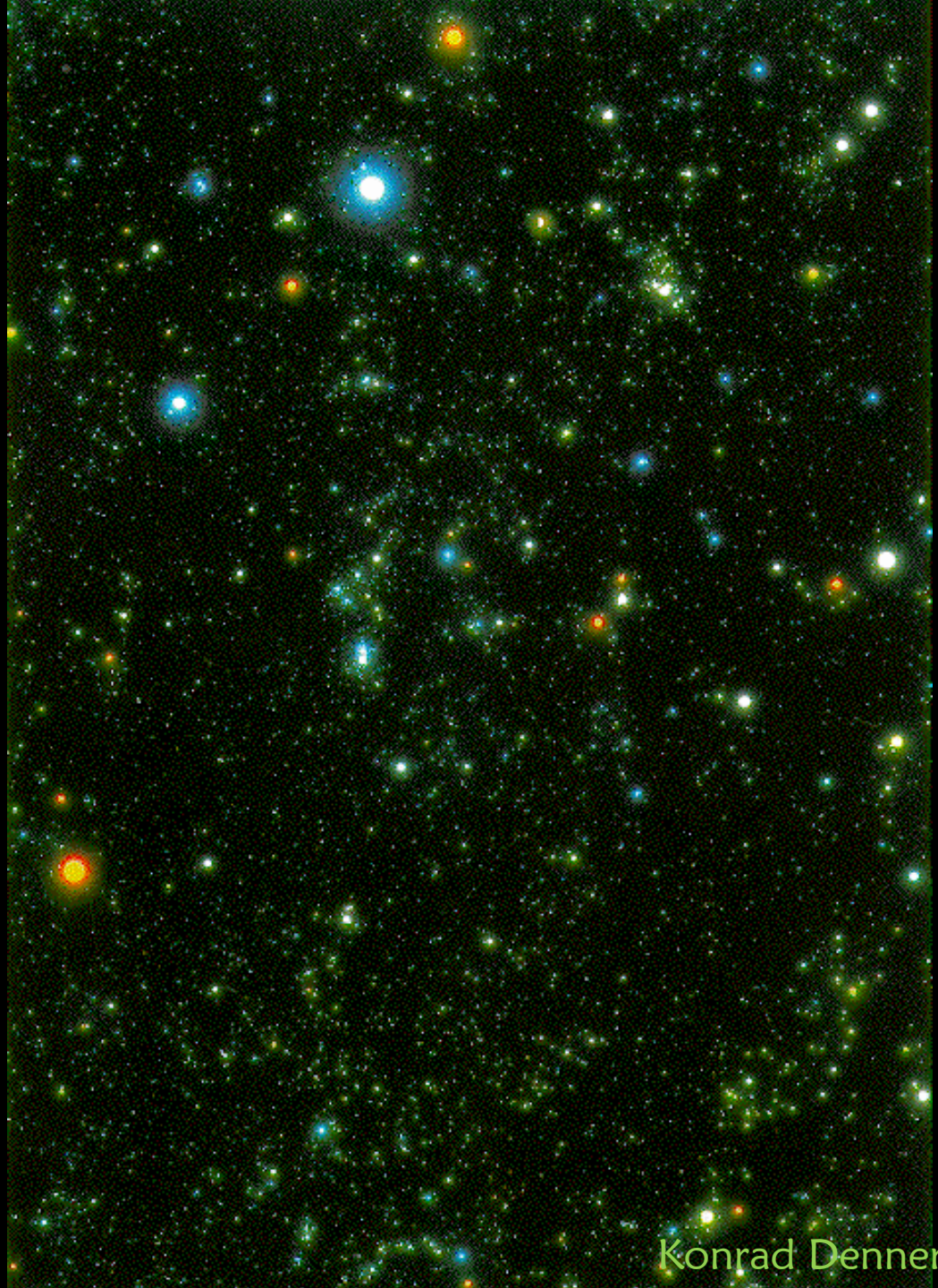




NASA/CXC/Lisse, Wolk et al



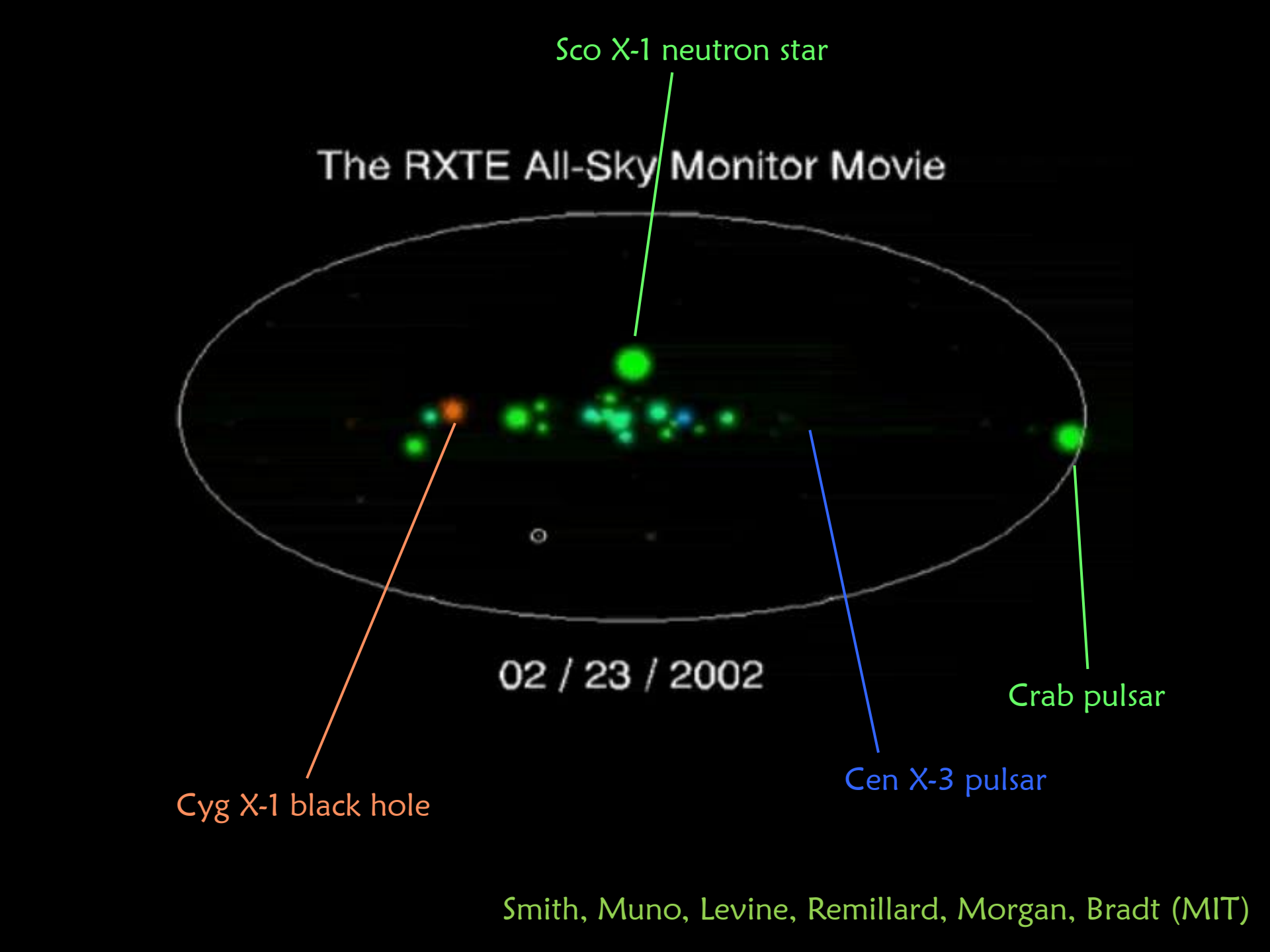
Konrad Denner & Wolfgang Voges (MPE)

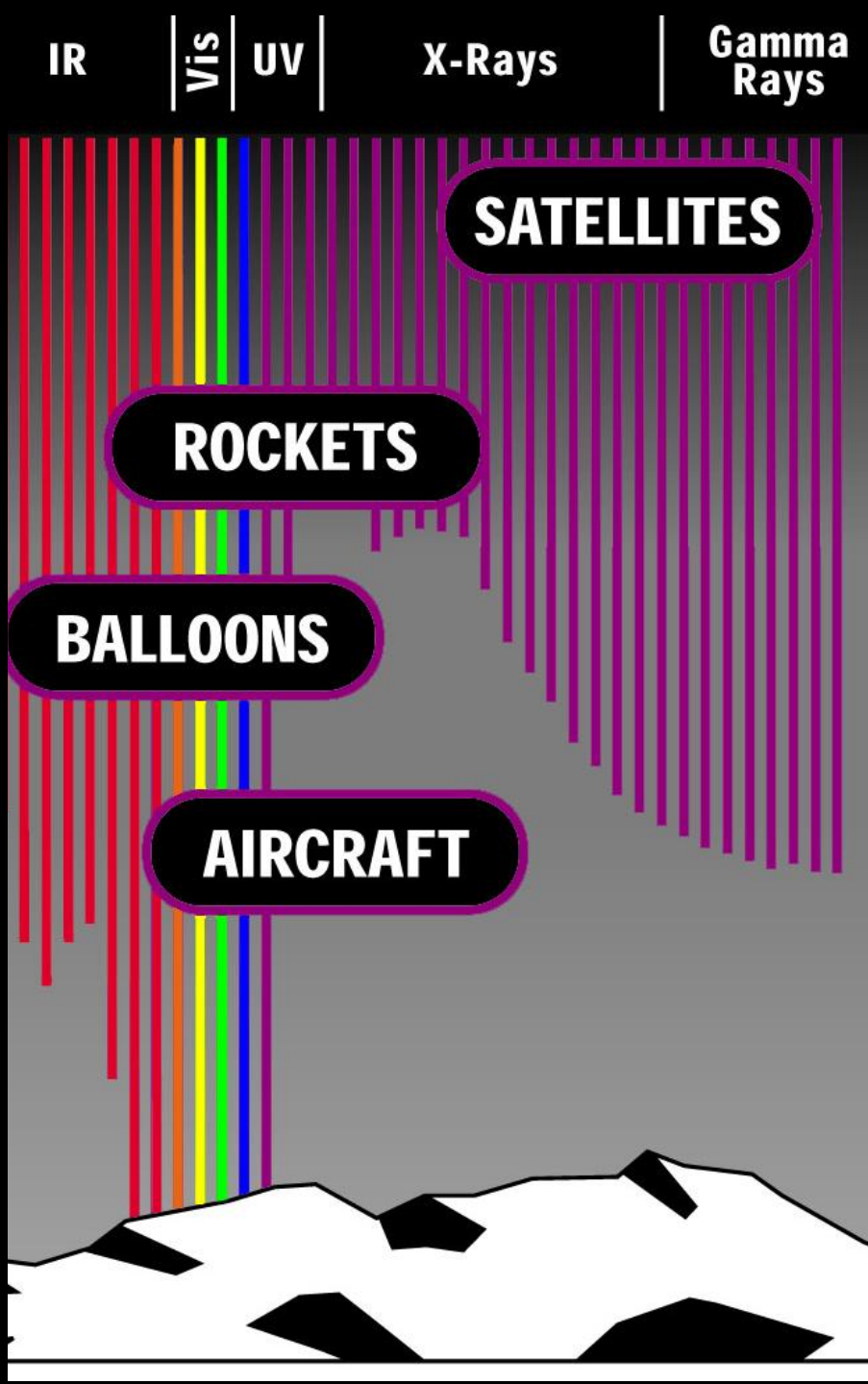


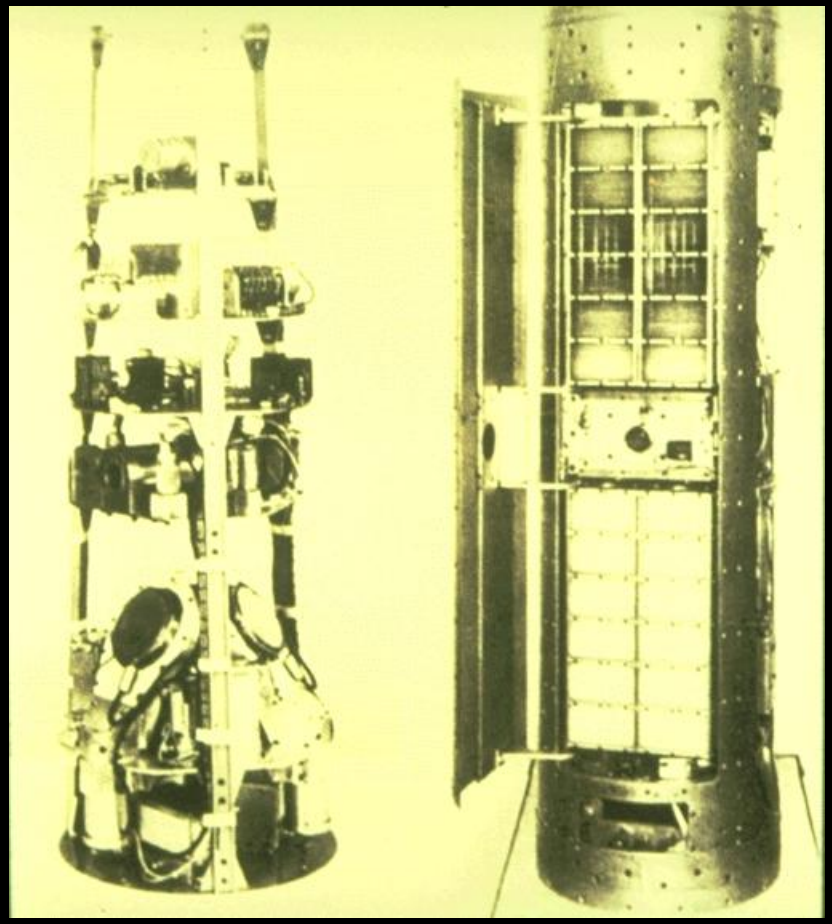
visible

X-rays

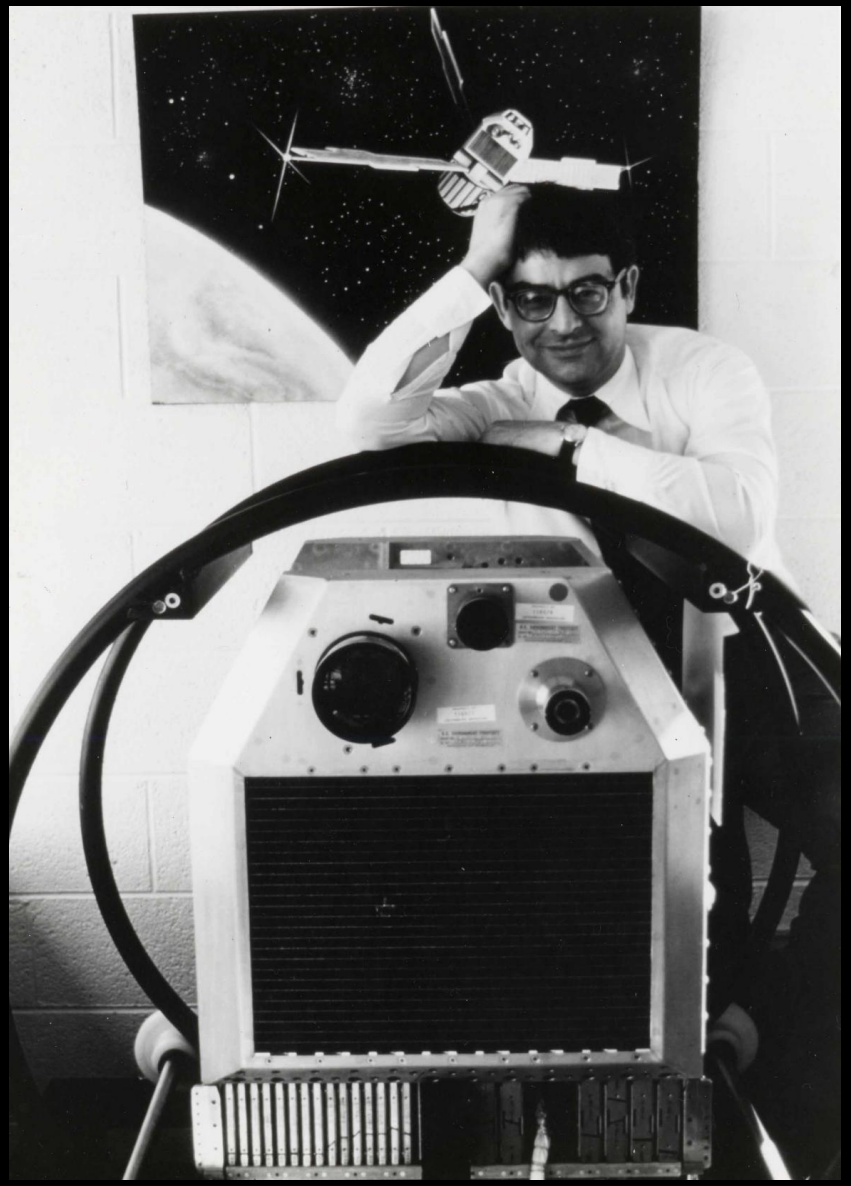
Konrad Denner & Wolfgang Voges (MPE)


Sco X-1 neutron star
The RXTE All-Sky Monitor Movie
02 / 23 / 2002
Crab pulsar
Cen X-3 pulsar
Cyg X-1 black hole
Smith, Muno, Levine, Remillard, Morgan, Bradt (MIT)


IR
Vis
UV
X-Rays
Gamma Rays
SATELLITES
ROCKETS
BALLOONS
AIRCRAFT



Riccardo Giacconi

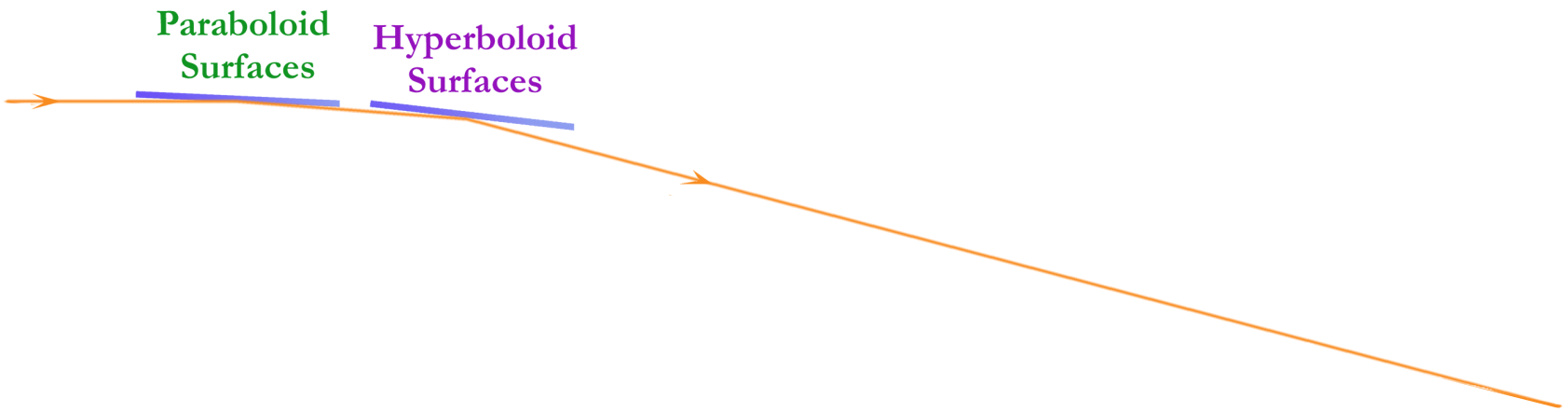


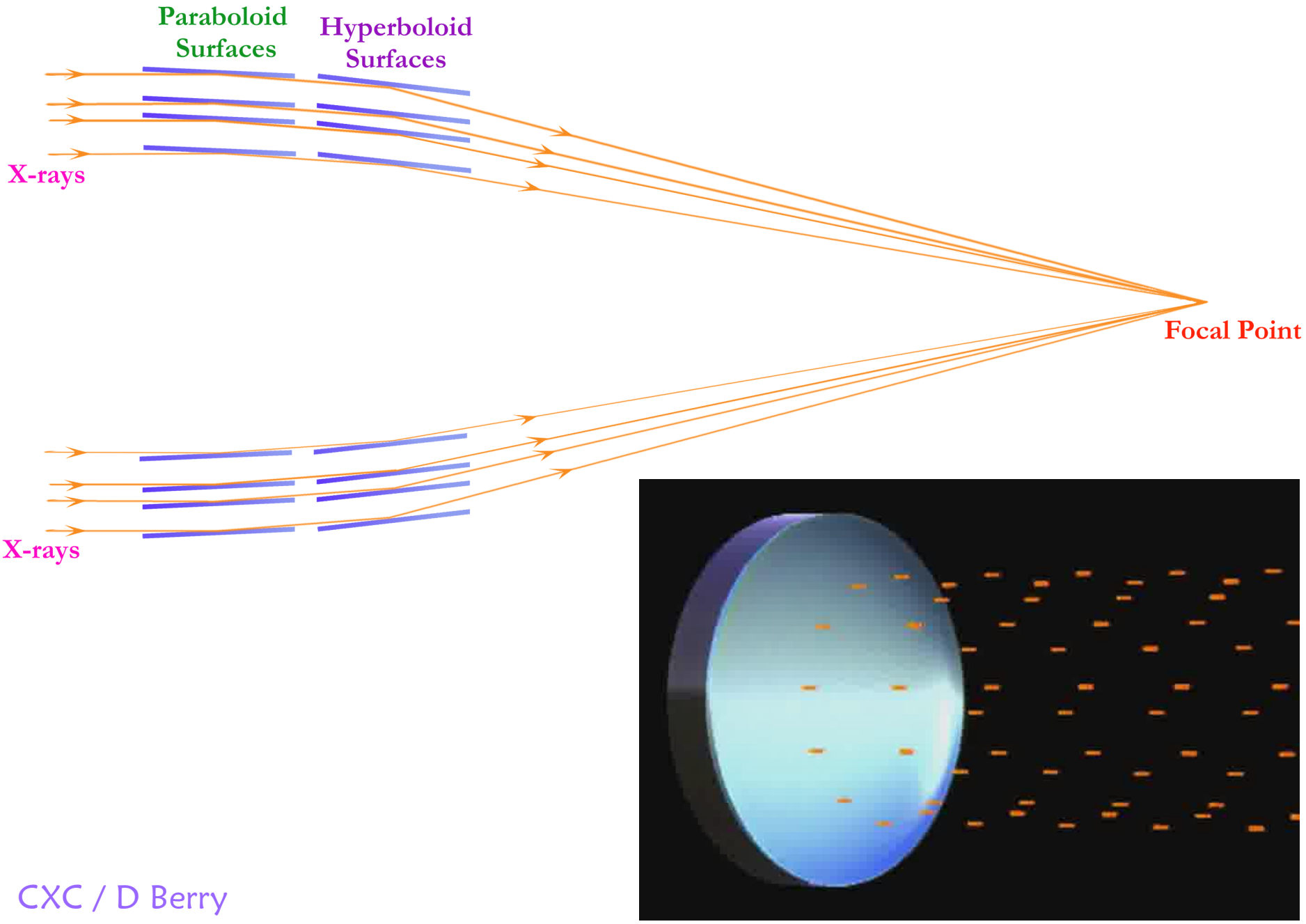
GSFC/NASA

CfA, Harvard

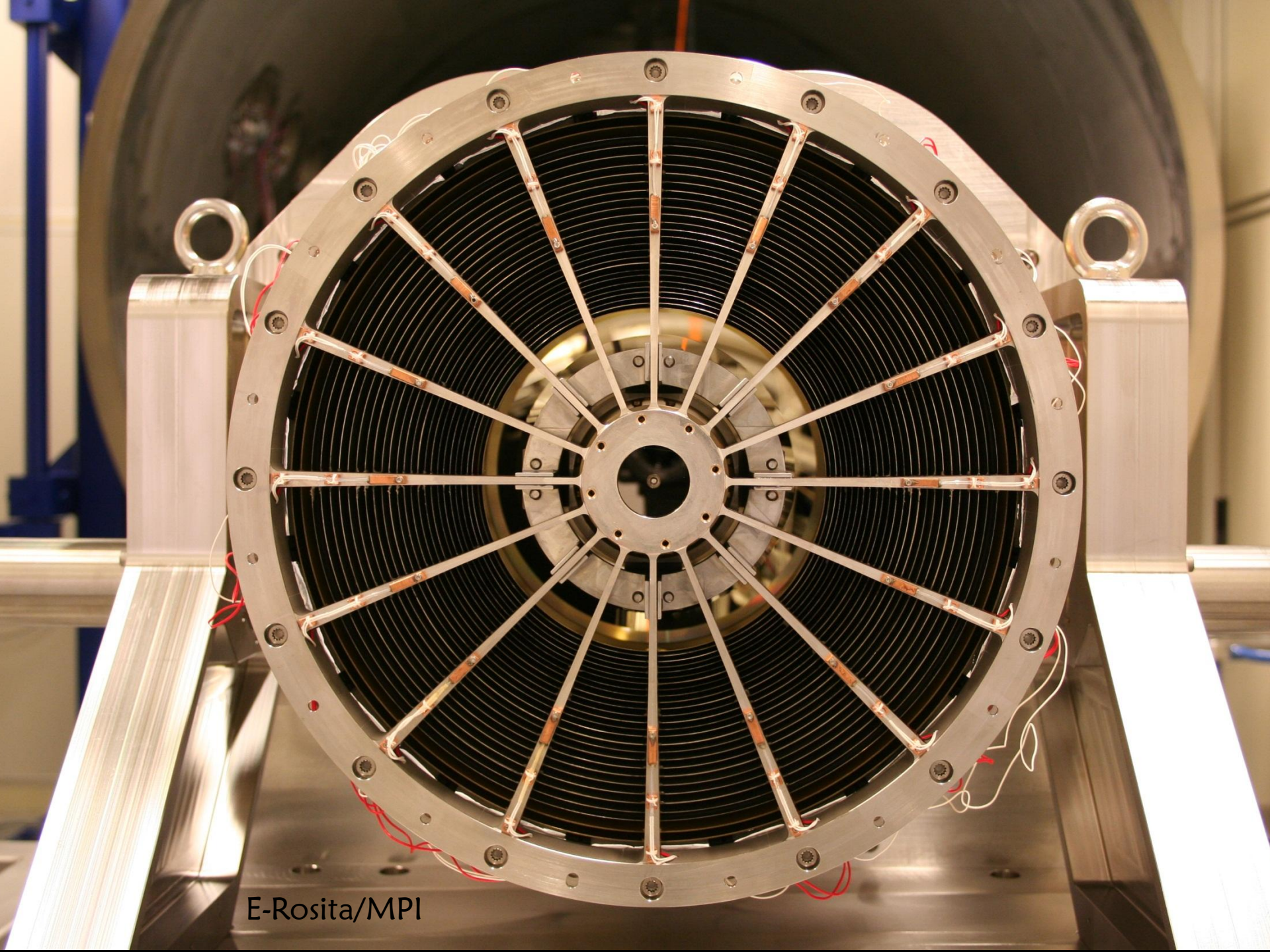
XMM-Newton
(European Space Agency)

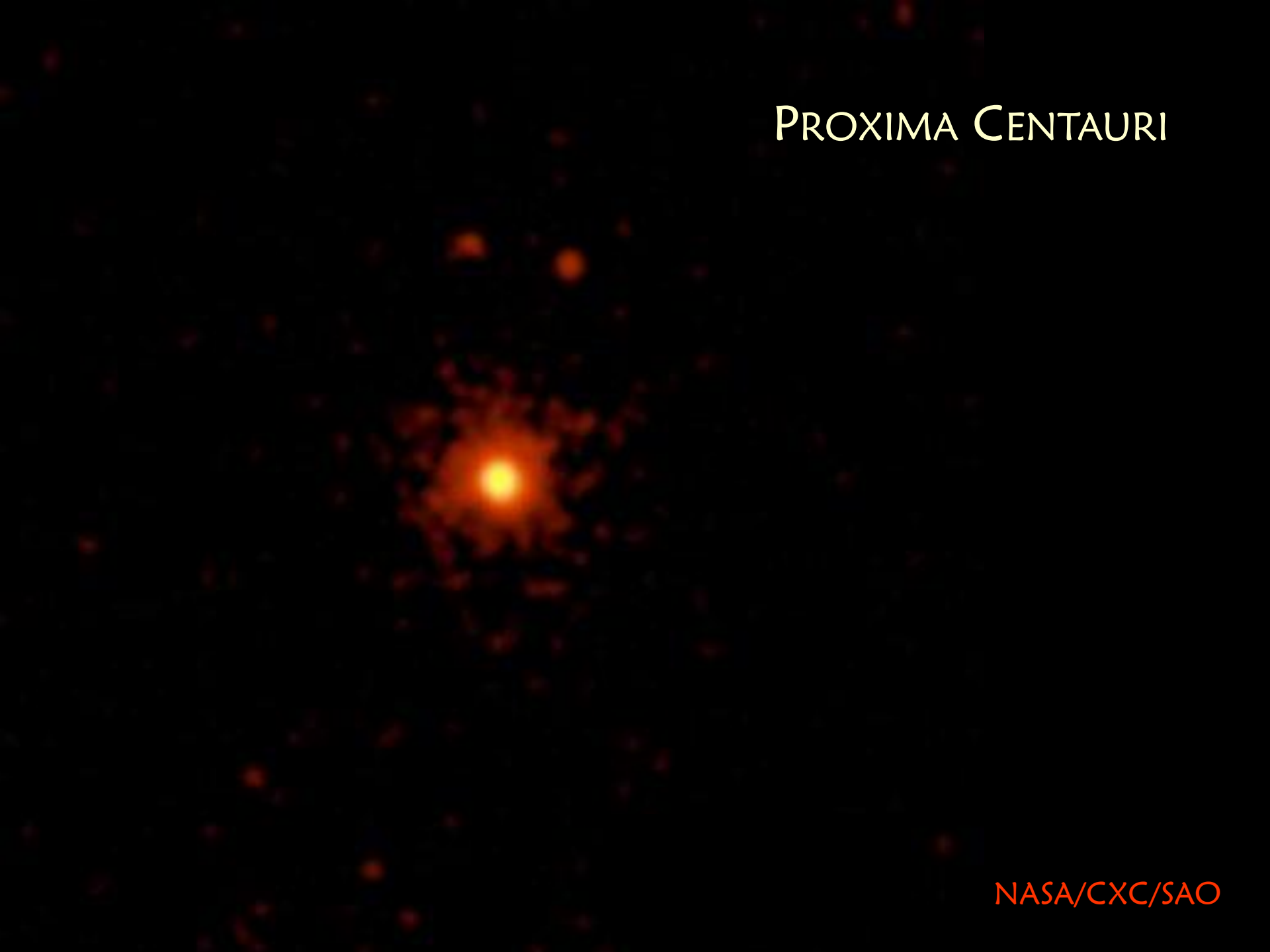
Chandra
(NASA)


Paraboloid
Surfaces
Hyperboloid
Surfaces


Paraboloid Surfaces
Hyperboloid Surfaces
X-rays
Focal Point
X-rays

CXC / D Berry

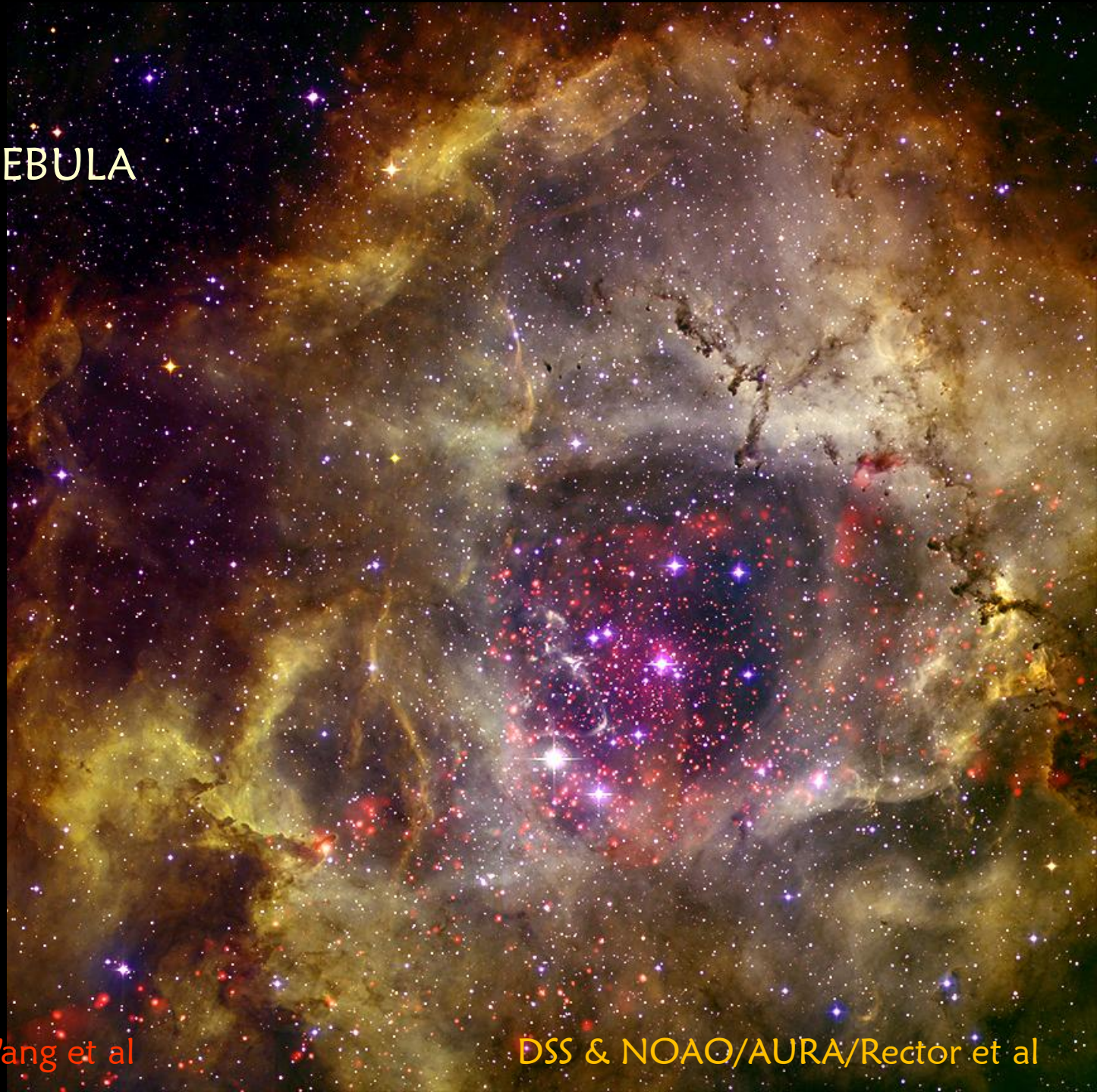

E-Rosita/MPI


Proxima Centauri
NASA/CXC/SAO

Rosette nebula

visible

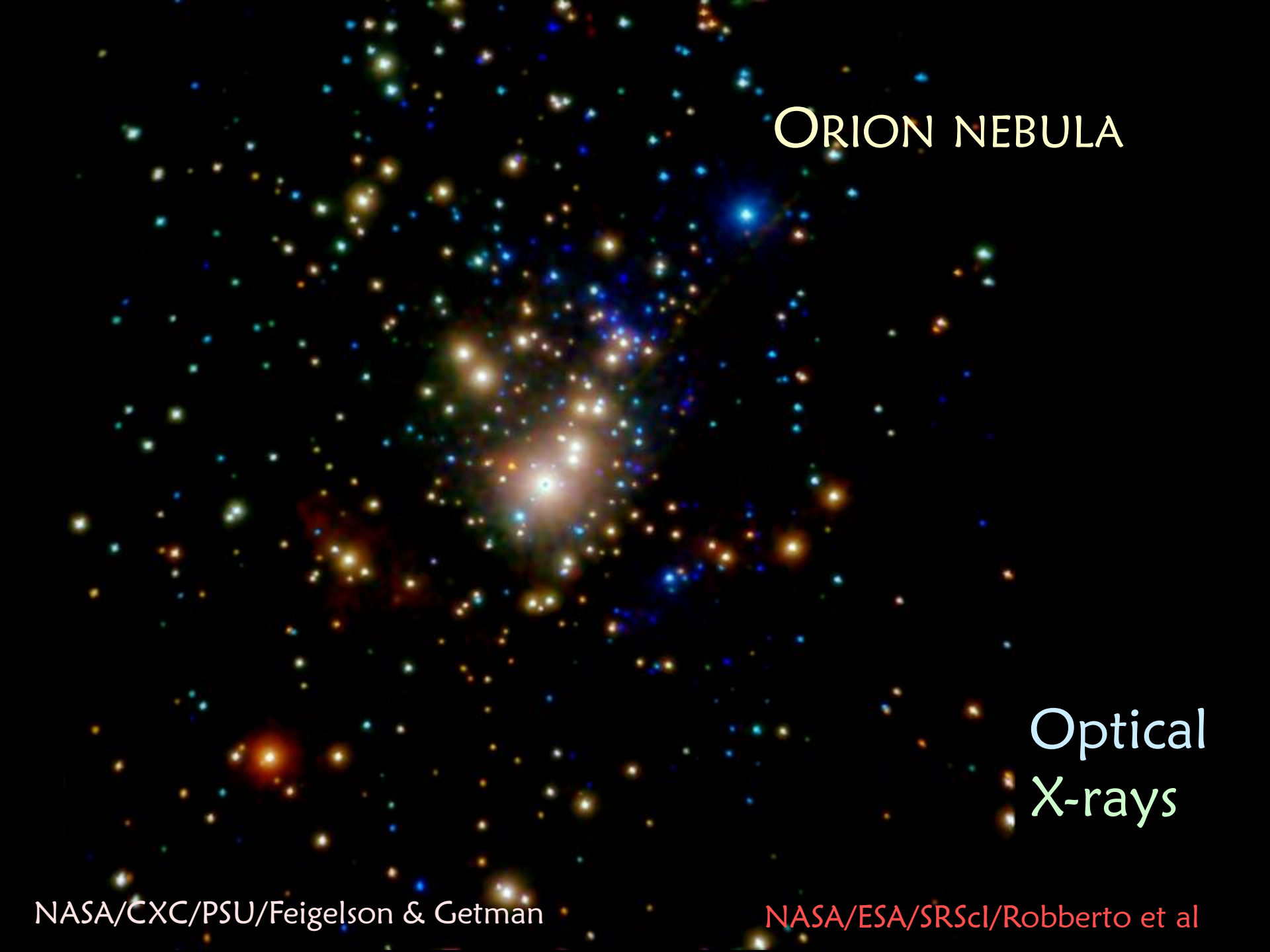
X ray



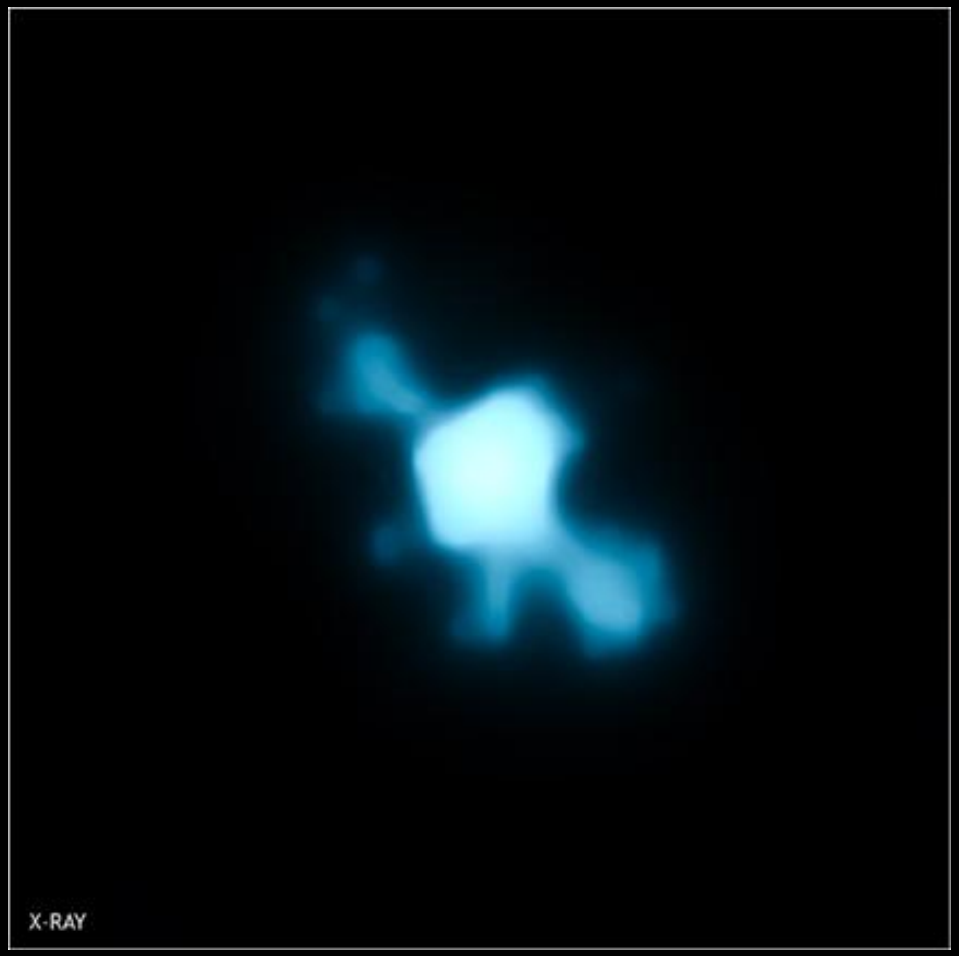
NASA/CXC/SAO/Wang et al

DSS & NOAO/AURA/Rector et al

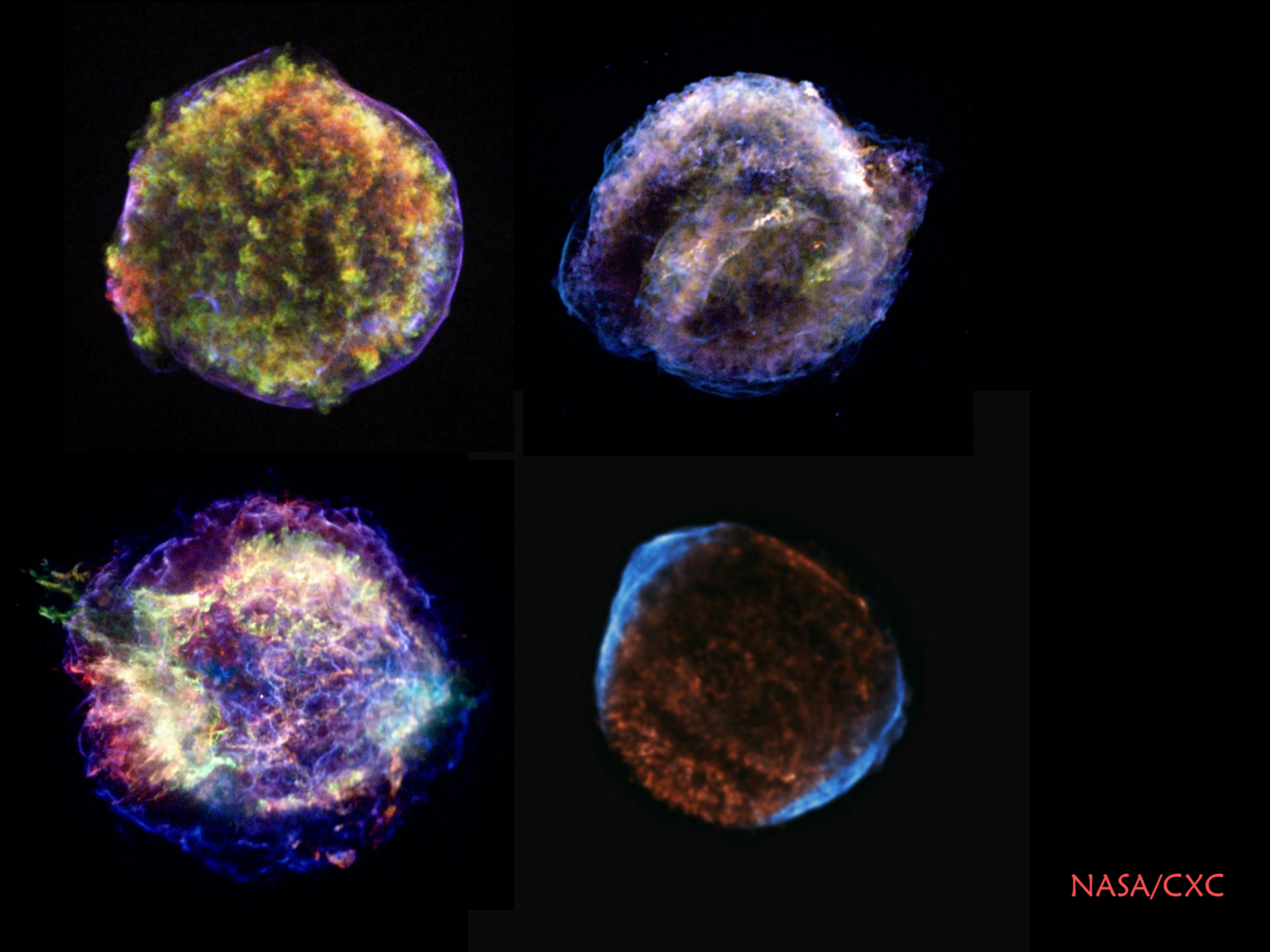

Orion nebula
NASA/ESA/SRScI/Robberto et al

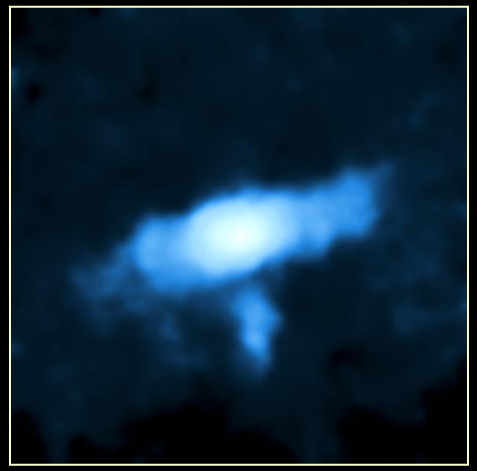

ORION NEBULA
Optical
X-rays
NASA/CXC/PSU/Feigelson & Getman
NASA/ESA/SRScI/Robberto et al

DG Tau



NASA/CXC/ETH Zuerich/M.Guedel et al.


NASA/CXC



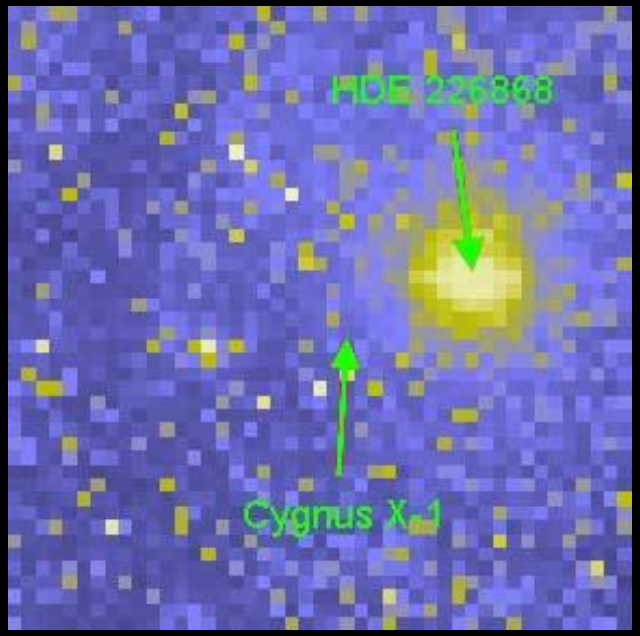
NASA/CXC/Roberts et al.

NASA/CXC/UCSC/Lopez et al

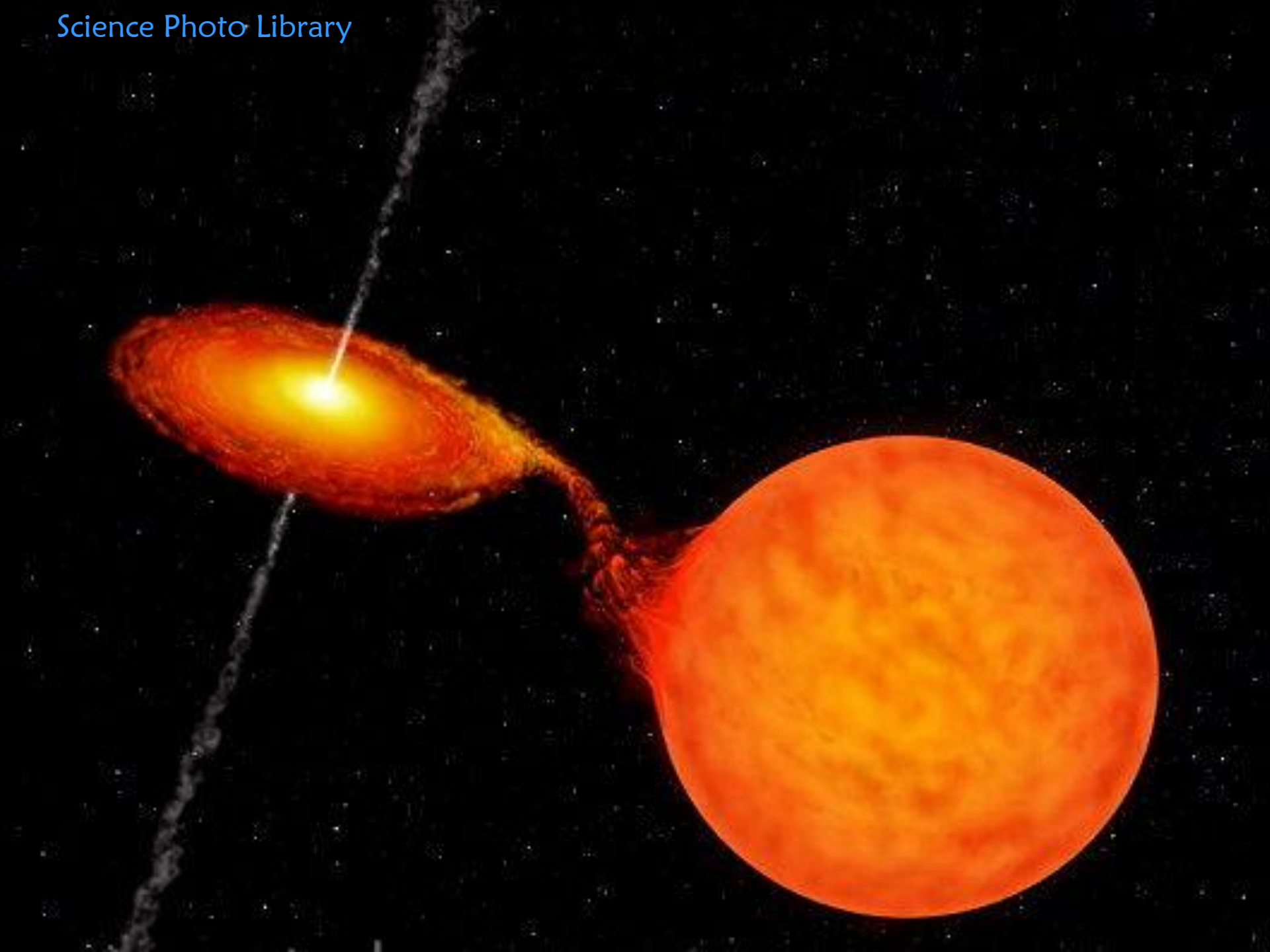
Crab Supernova

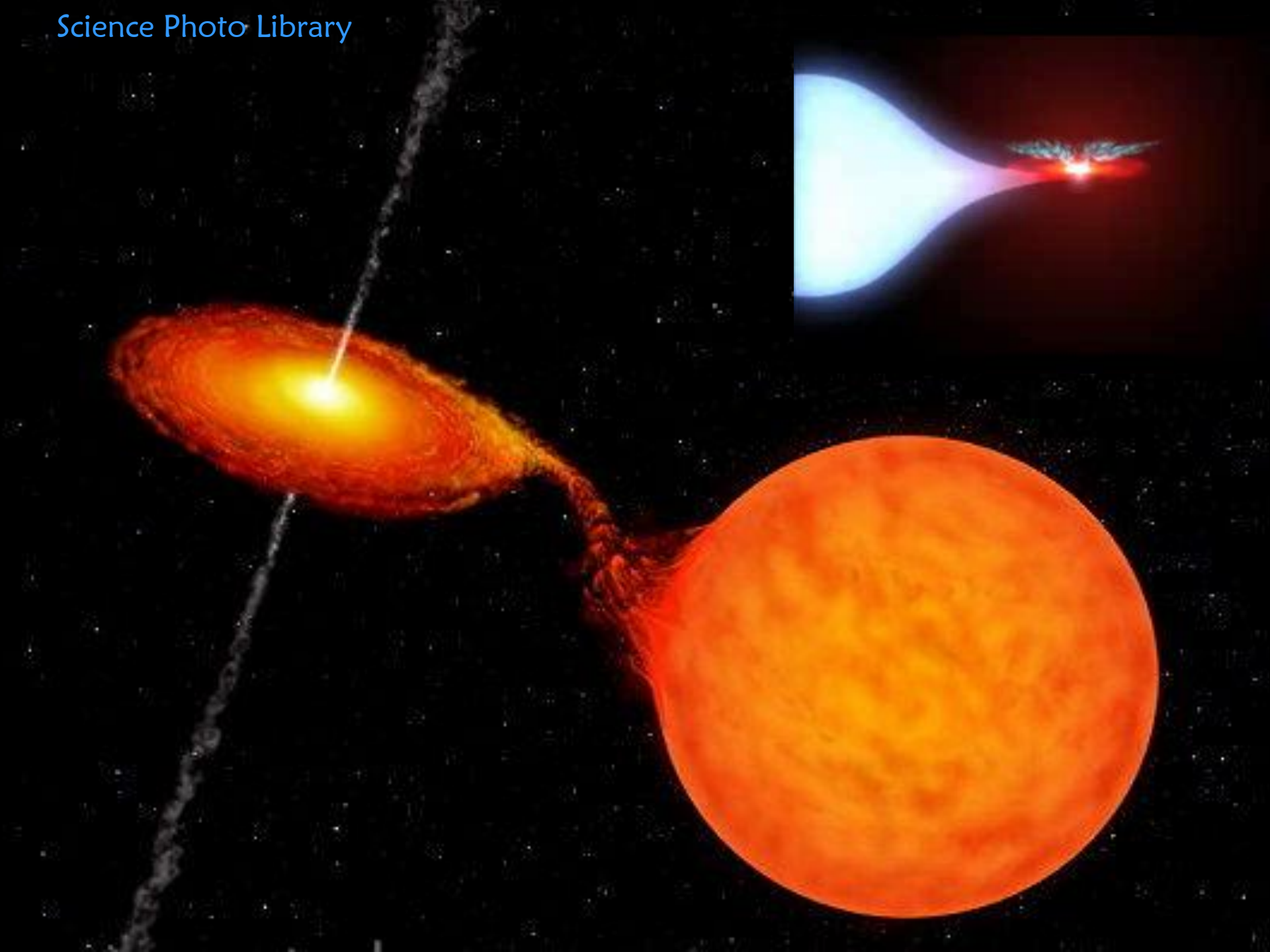
NASA/ESA/ASU/Hester & Loll

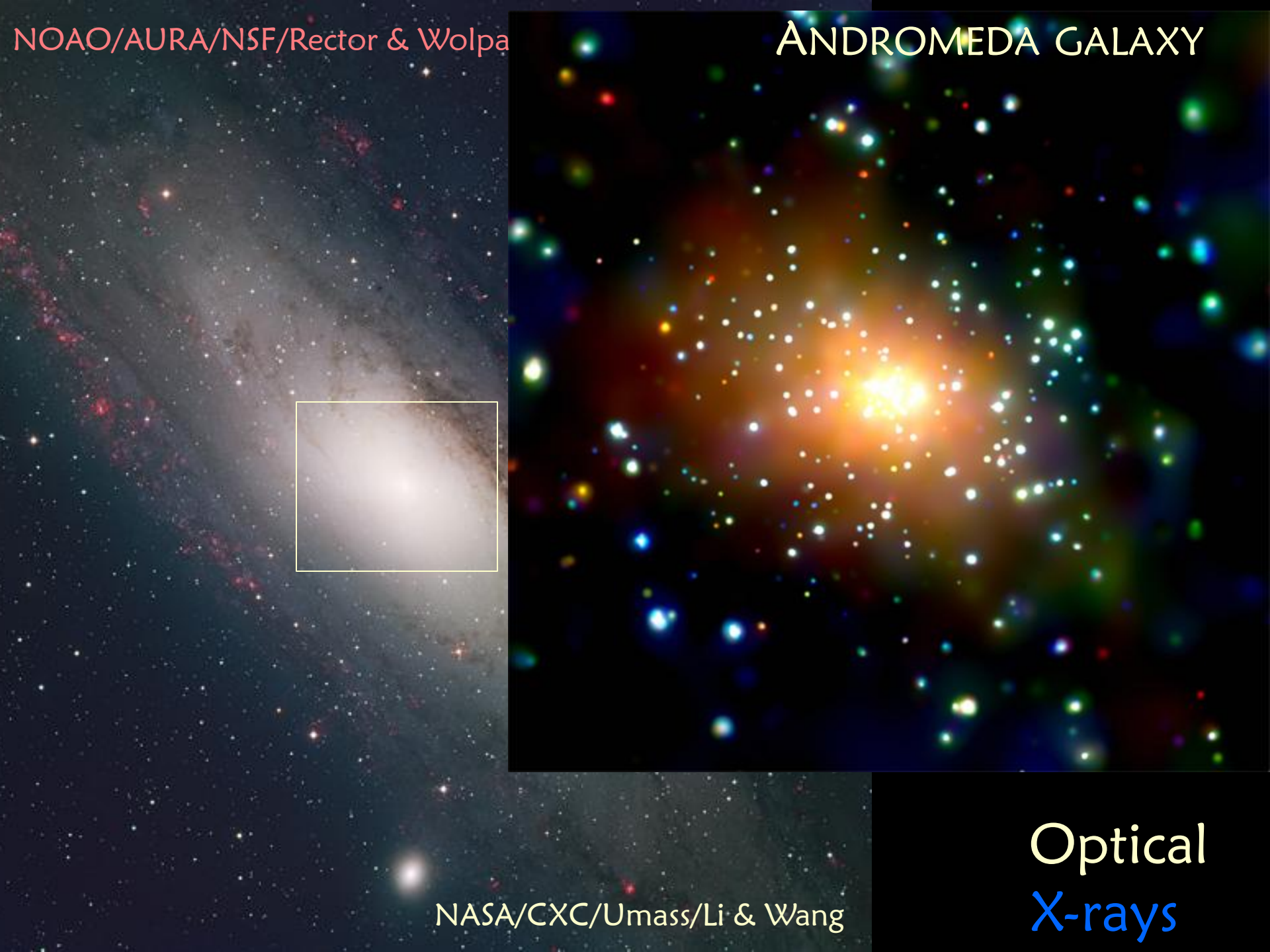
NASA/CXC/SAO/Seward et al

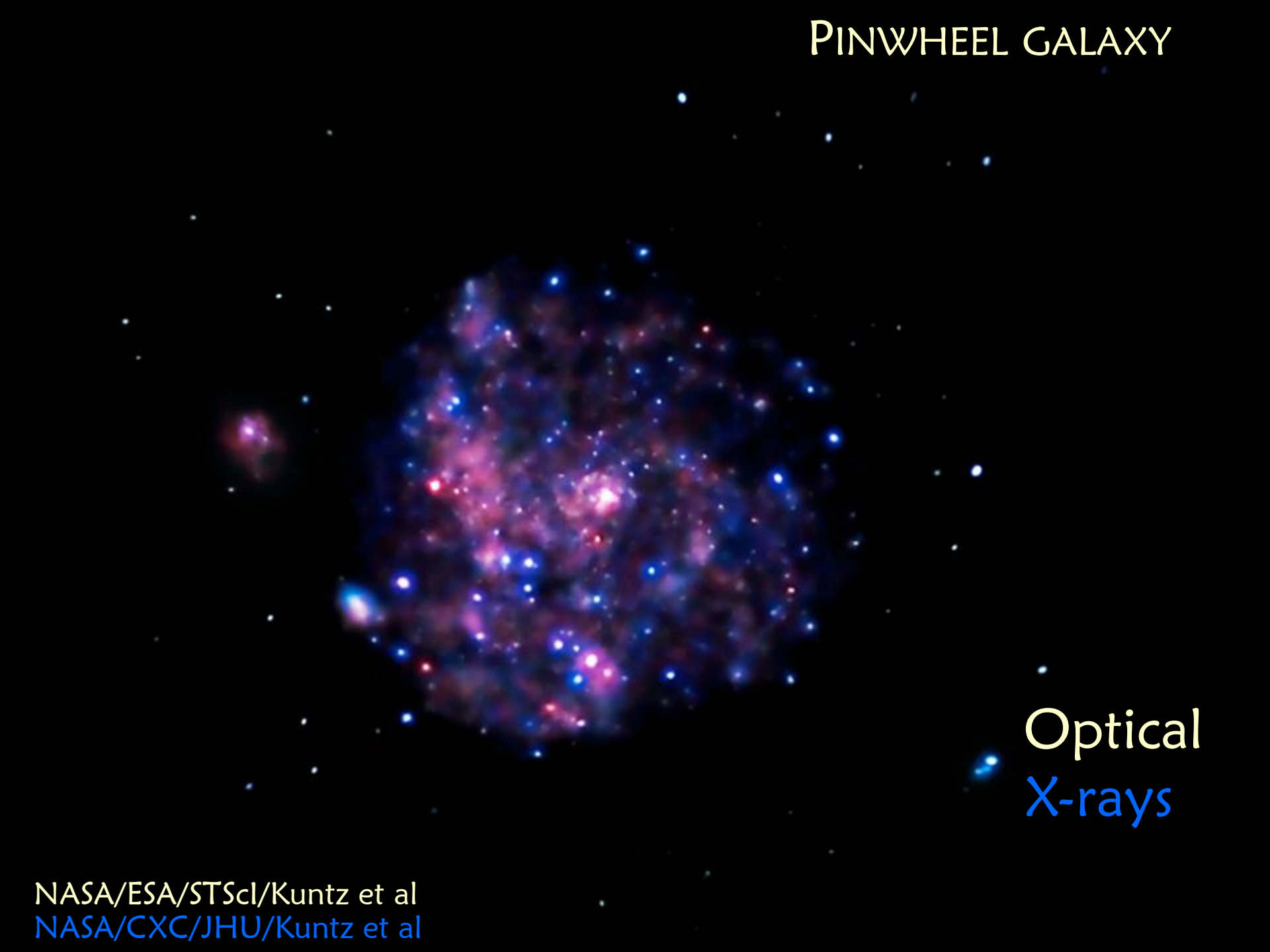


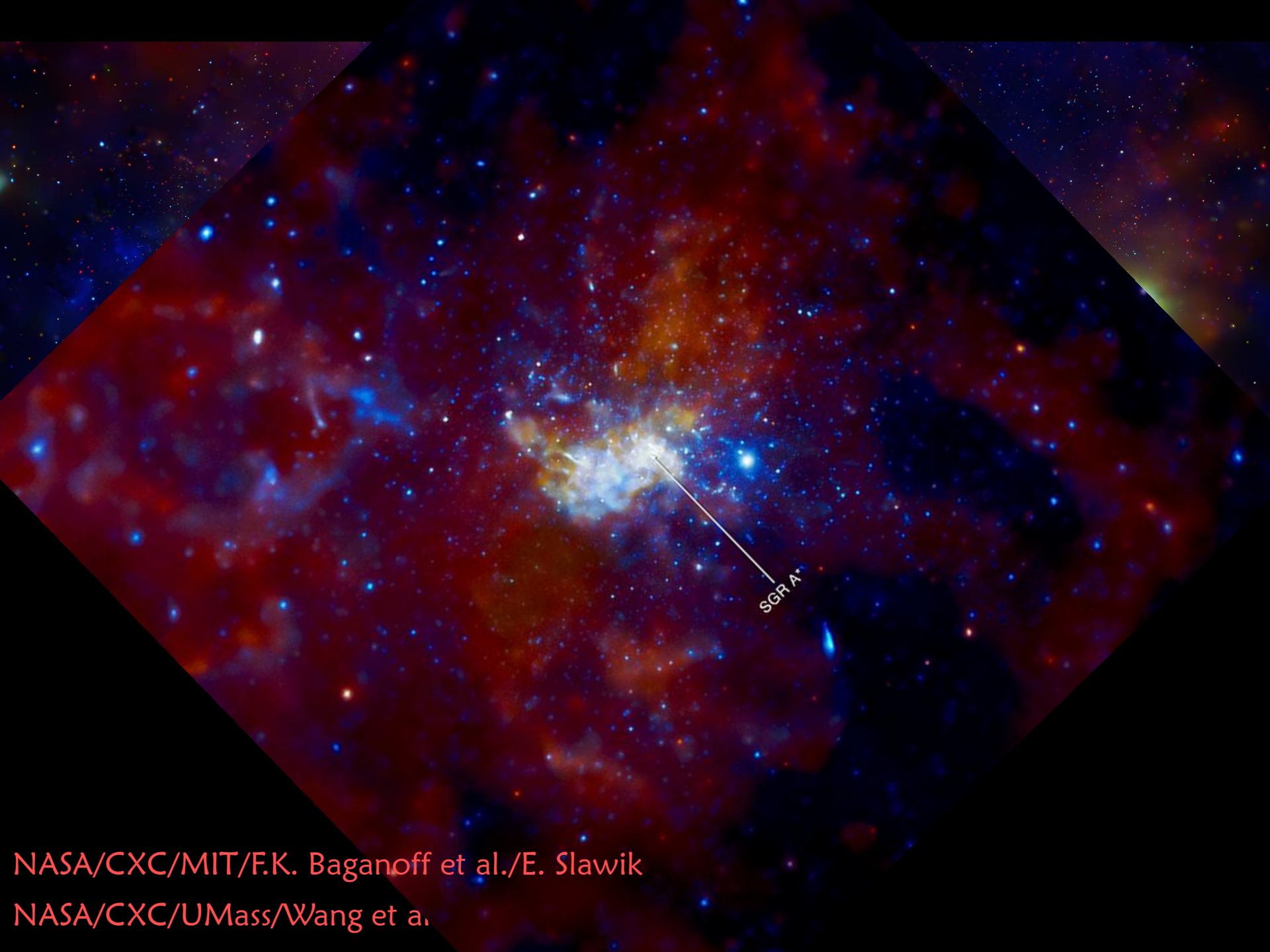
Cygnus X-1




Science Photo Library

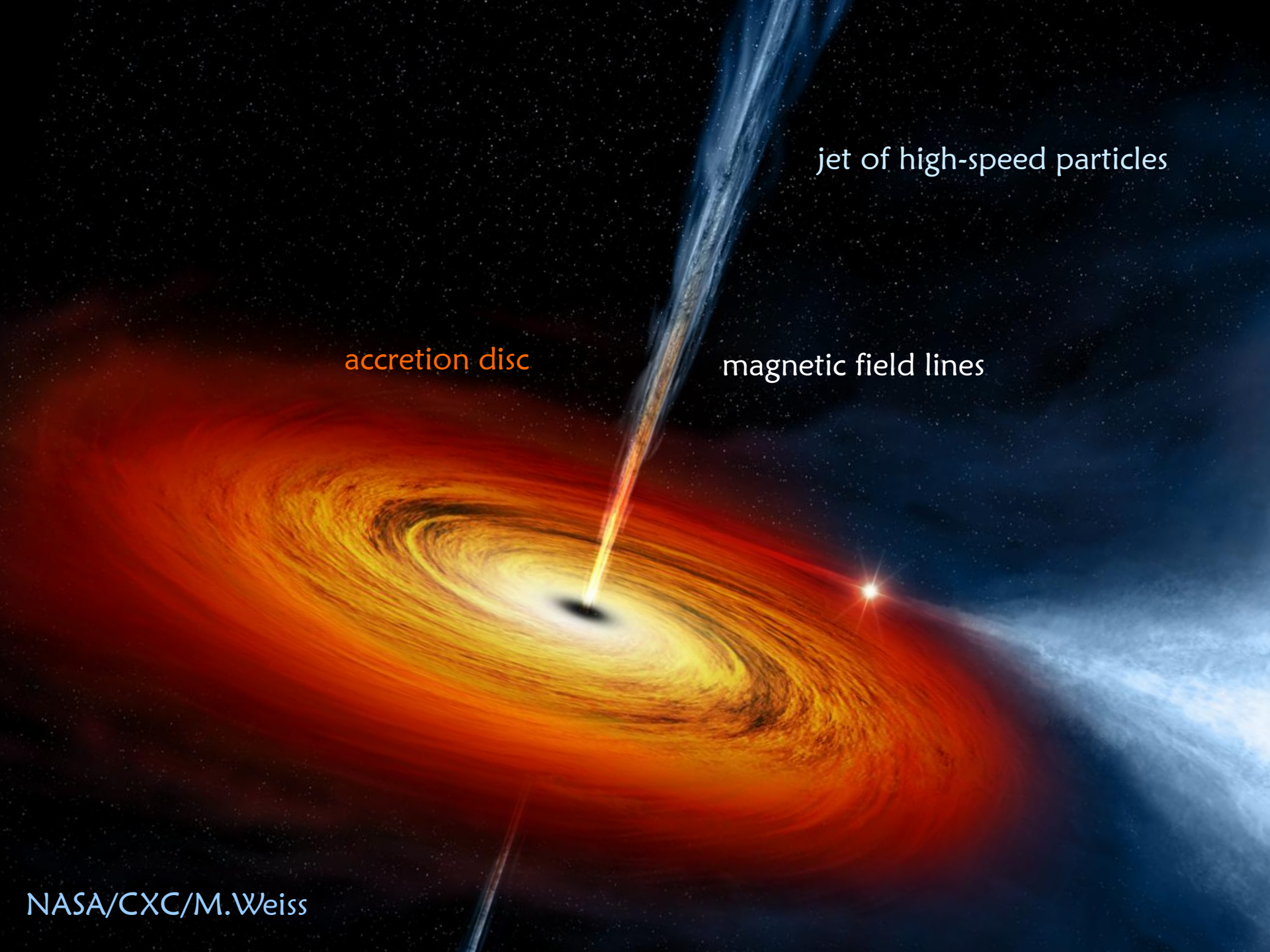

NOAO/AURA/NSF/Rector & Wolpa
ANDROMEDA GALAXY
NASA/CXC/Umass/Li & Wang
Optical
X-rays

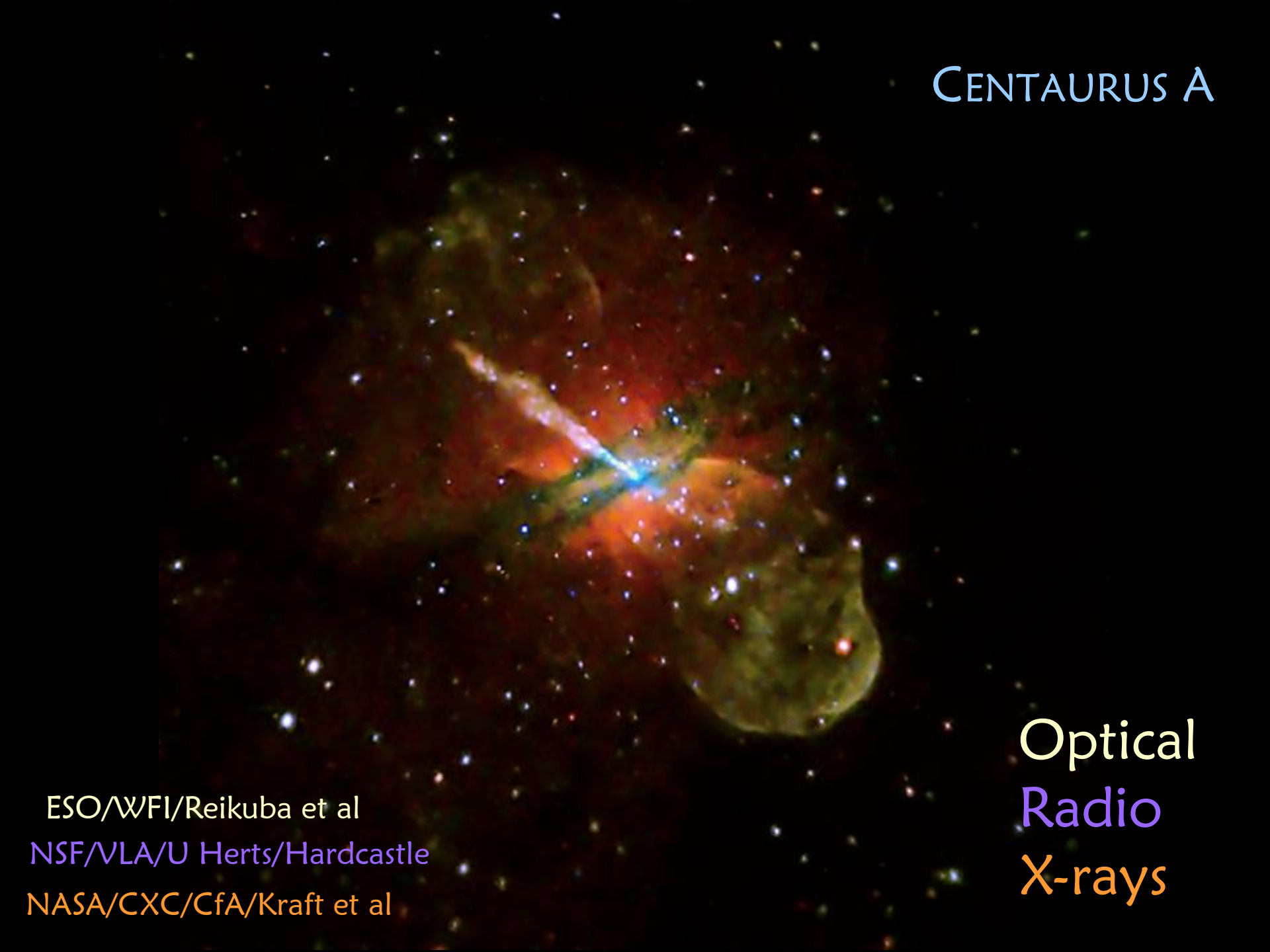

Pinwheel galaxy
Optical
X-rays
NASA/ESA/STScI/Kuntz et al
NASA/CXC/JHU/Kuntz et al

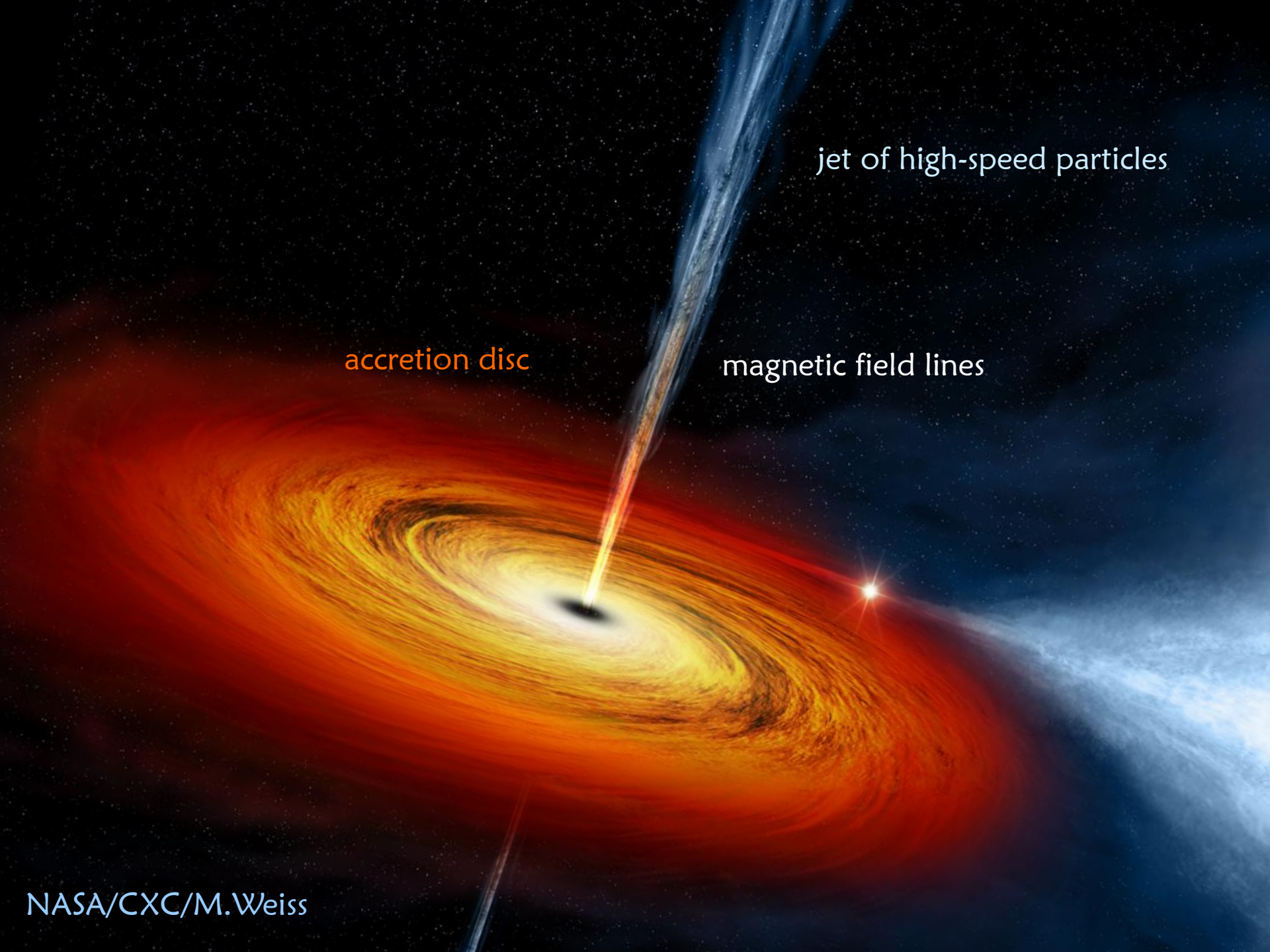


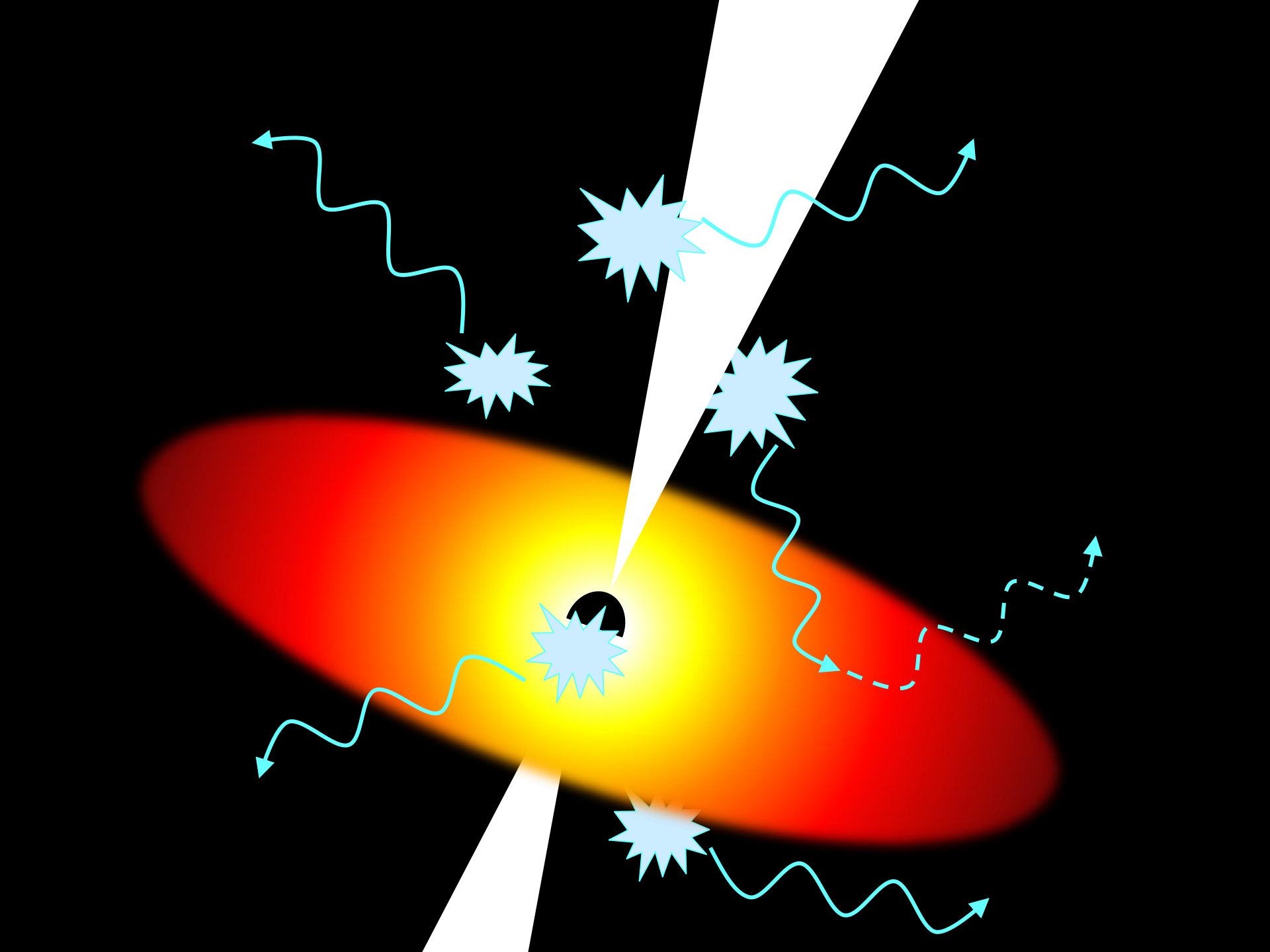
NASA/CXC/MIT/F.K. Baganoff et al./E. Slawik

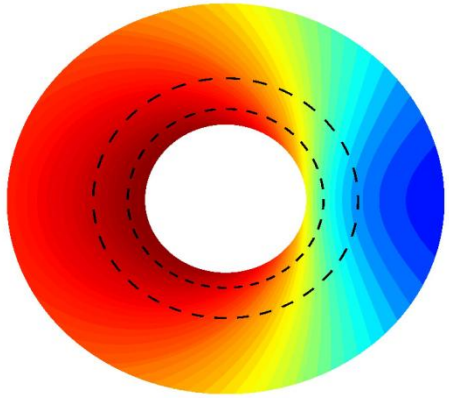
NASA/CXC/UMass/Wang et a.

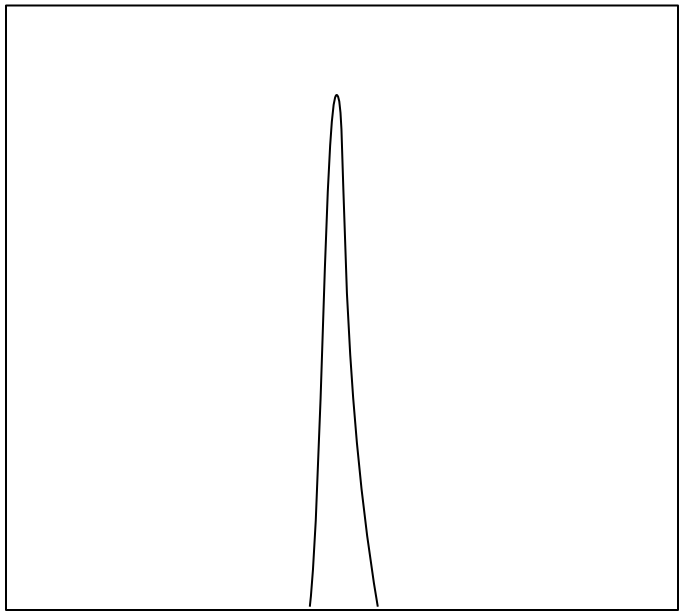

jet of high-speed particles
accretion disc
magnetic field lines
NASA/CXC/M.Weiss


CENTAURUS A
ESO/WFI/Reikuba et al
NSF/VLA/U Herts/Hardcastle
NASA/CXC/CfA/Kraft et al
Optical
Radio
X-rays


jet of high-speed particles
accretion disc
magnetic field lines
NASA/CXC/M.Weiss





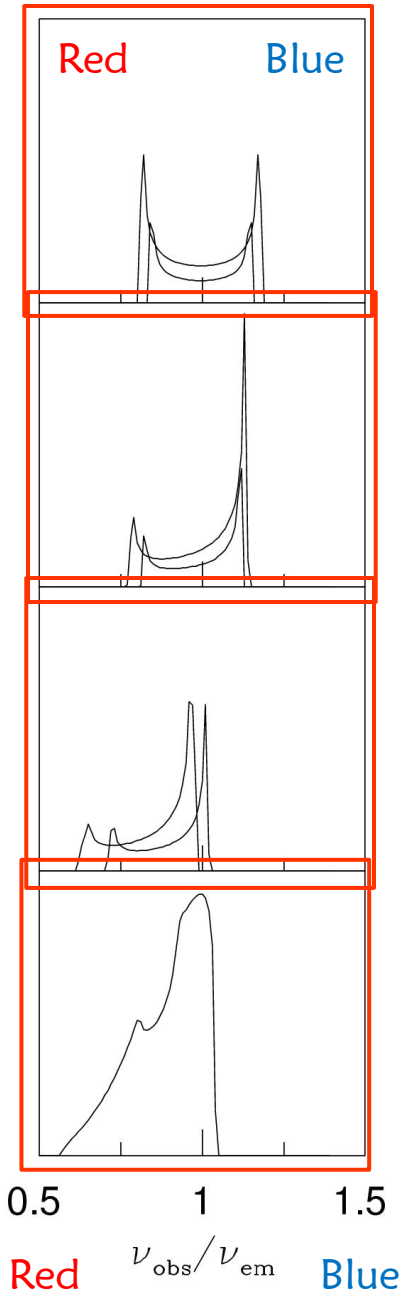


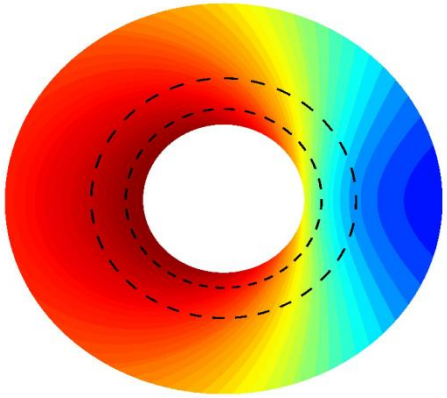
Red Energy Blue

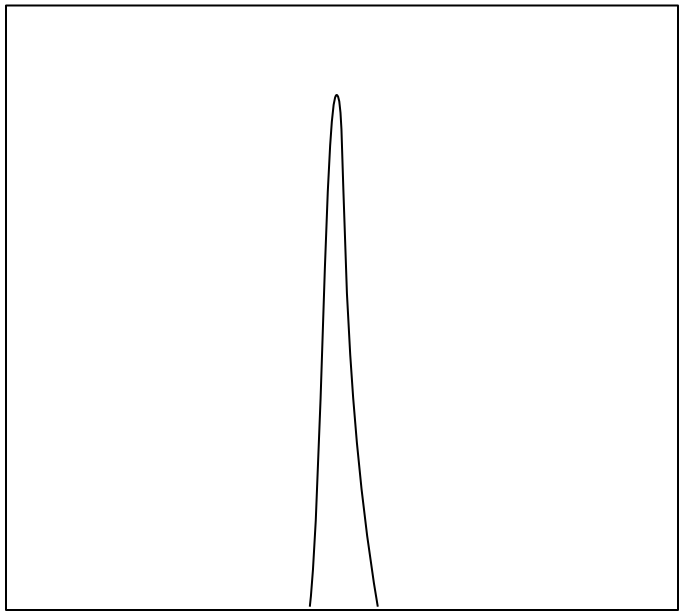
Andy Fabian

Newtonian

Doppler shift

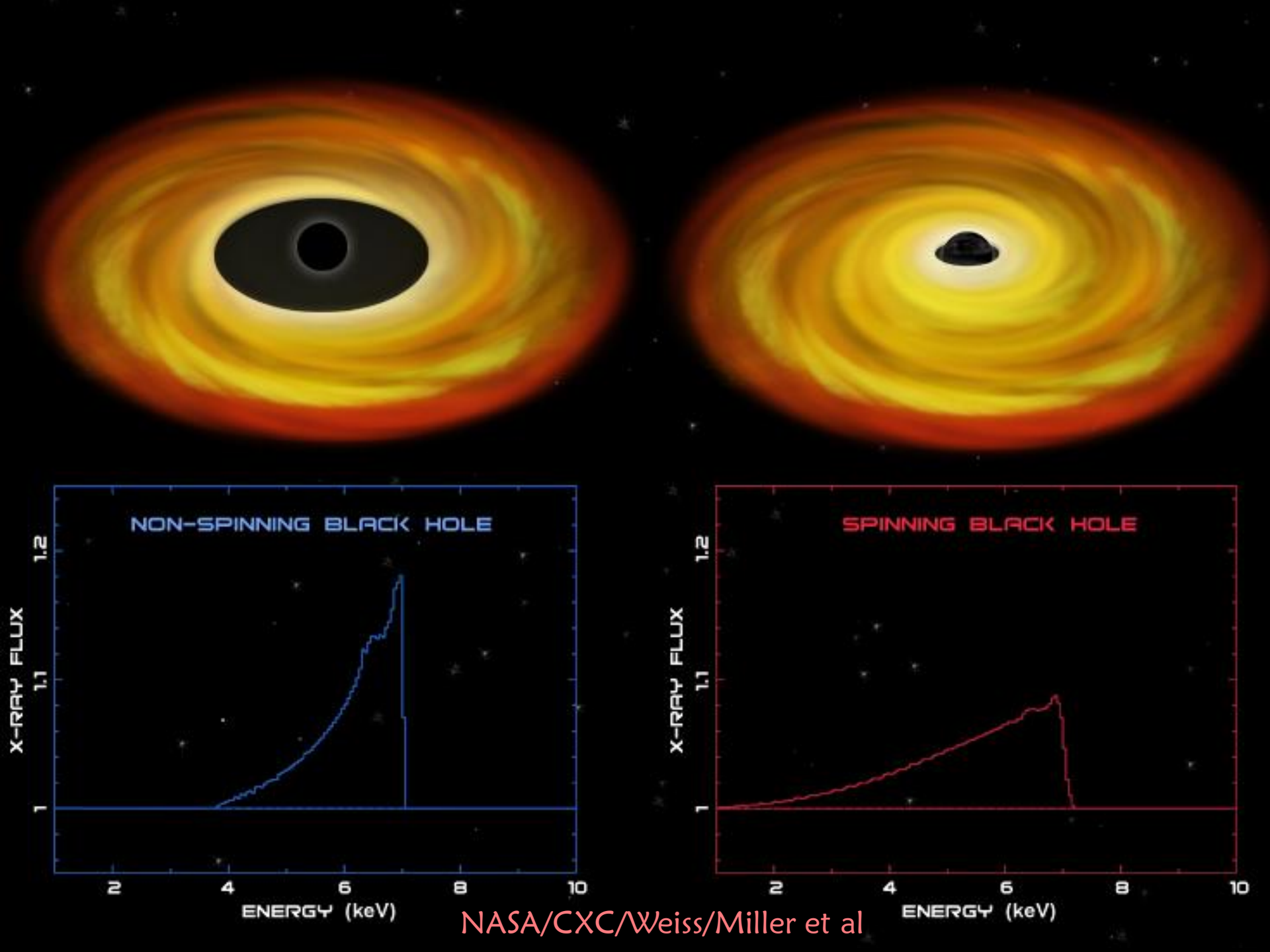




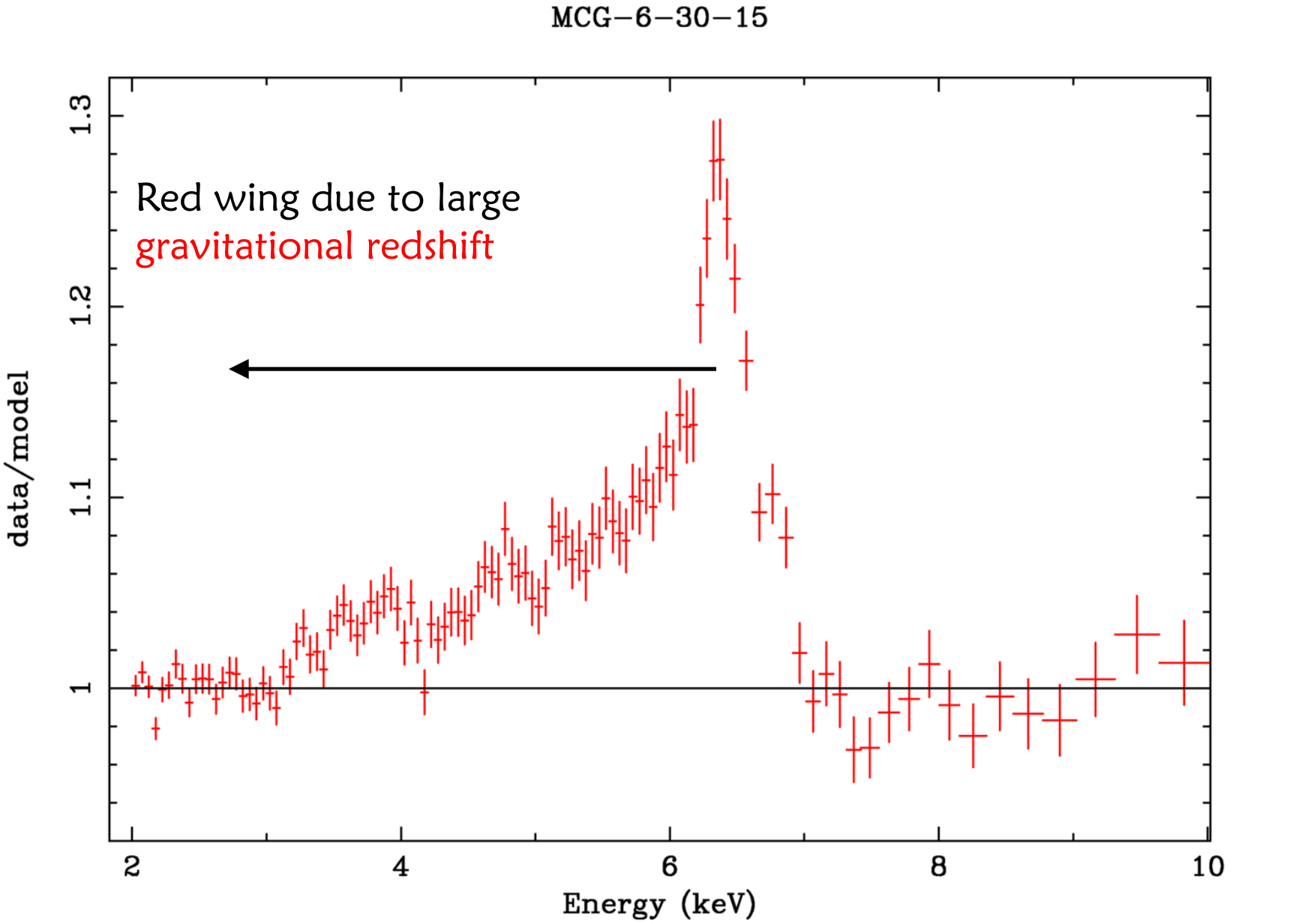


Red Energy Blue

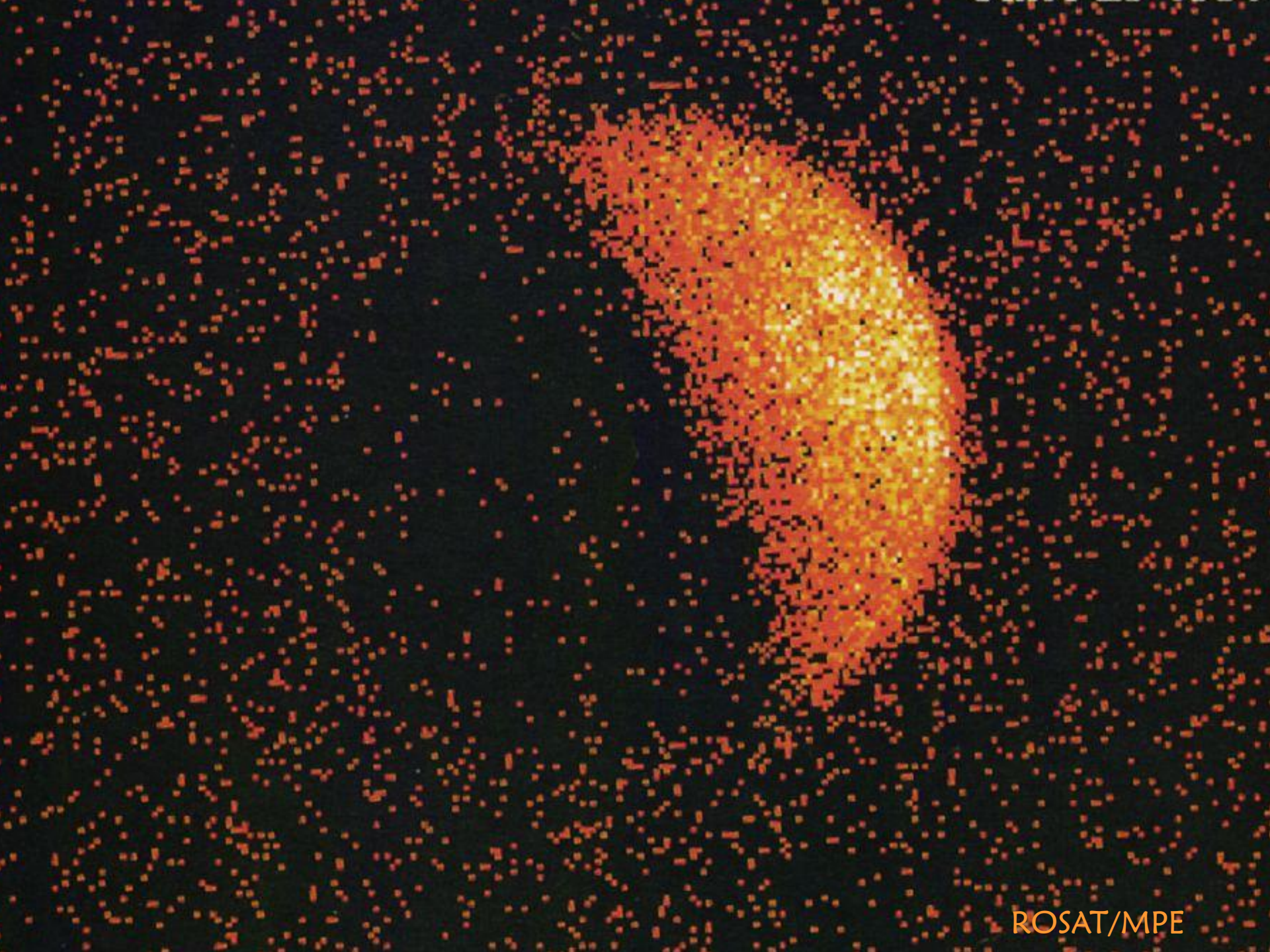
Andy Fabian

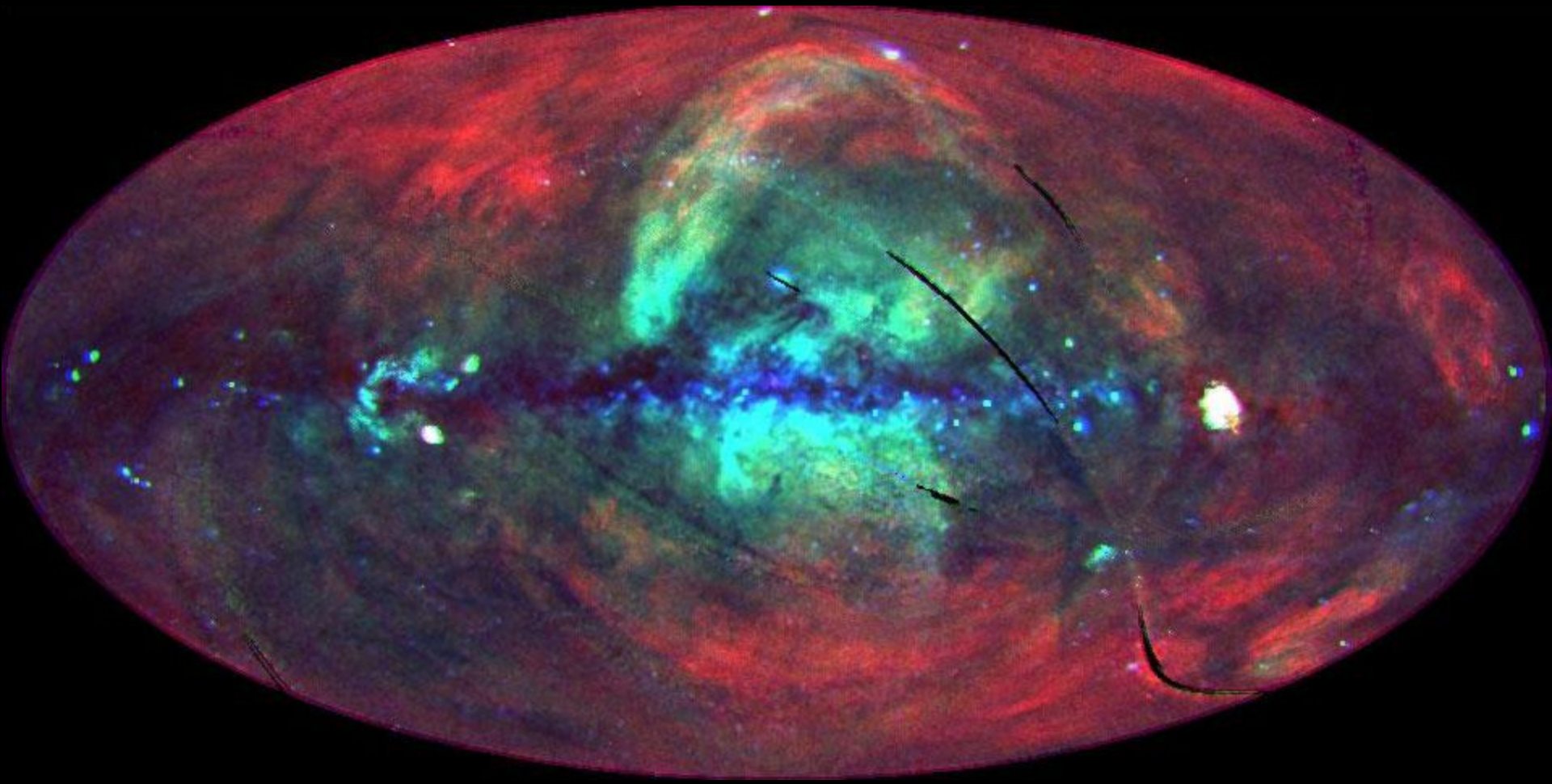


NASA/CXC/Weiss/Miller et al

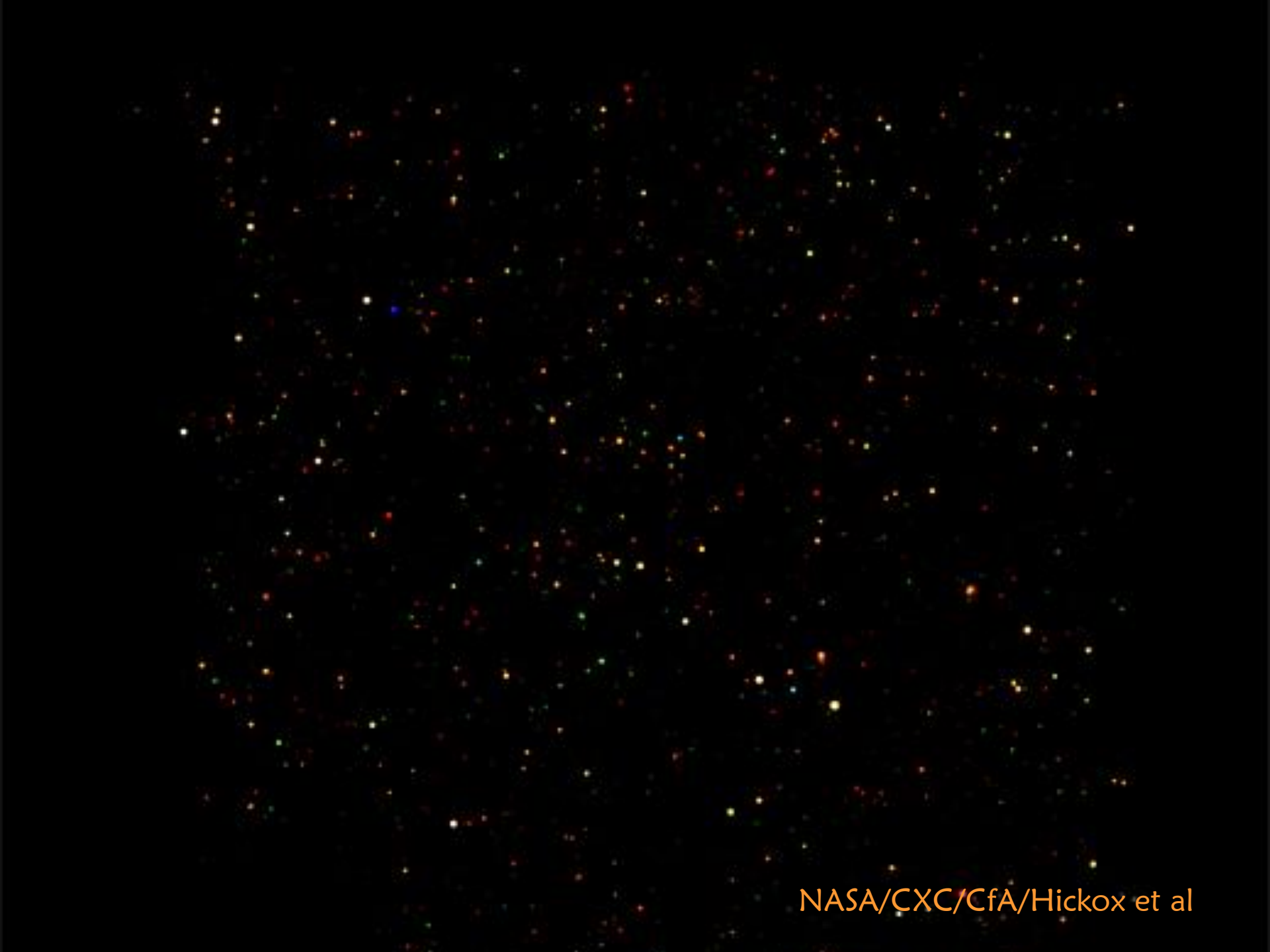

MCG−6−30−15
Red wing due to large
gravitational redshift
data/model
1
1.1
1.2
1.3
2
4
6
8
10
Energy (keV)

Andy Fabian


ROSAT/MPE



ROSAT/MPE


NASA/CXC/CfA/Hickox et al

Atmospheric Phenomena
5th December 2012 1pm

B Starling