Čierne diery v kozmickej pavučine

Norbert Werner

IMAGE CREDIT: AMERICAN MUSEUM OF NATURAL HISTORY

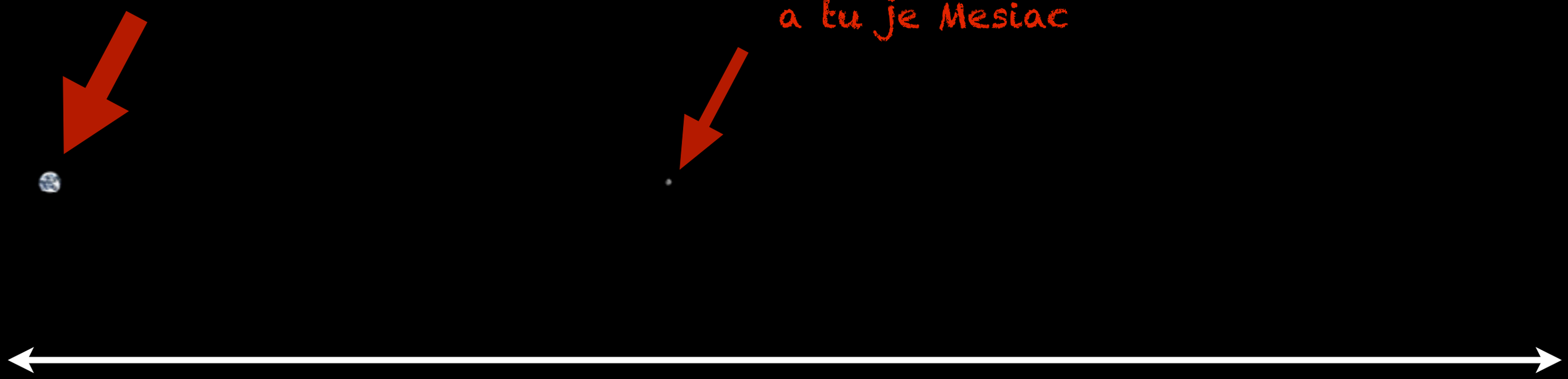
Sme tu!
Bulharská 557/4
1 km = 10³ m
Košice
OLD TOWN, KOŠICE
Mestský park
Aupark Košice
Pizza-Pizza
Hviezdoslavova
Štefánikova
Moyzesova
Štúrova
Hornád
Jantárová
Južná trieda
Alejová
Pri prachárni
Verejný cintorín
ŽELEZNÍKY
VYŠNÉ OPÁTSKE
HERINGEŠ
SLIVNÍK
FURČA
KONOPISKÁ
NAD JAZEROM
E50
E58
PR3
19
552

Sme tu!
10^7 m

NASA, Apollo 8, Bill Anders
Processing: Jim Weigang

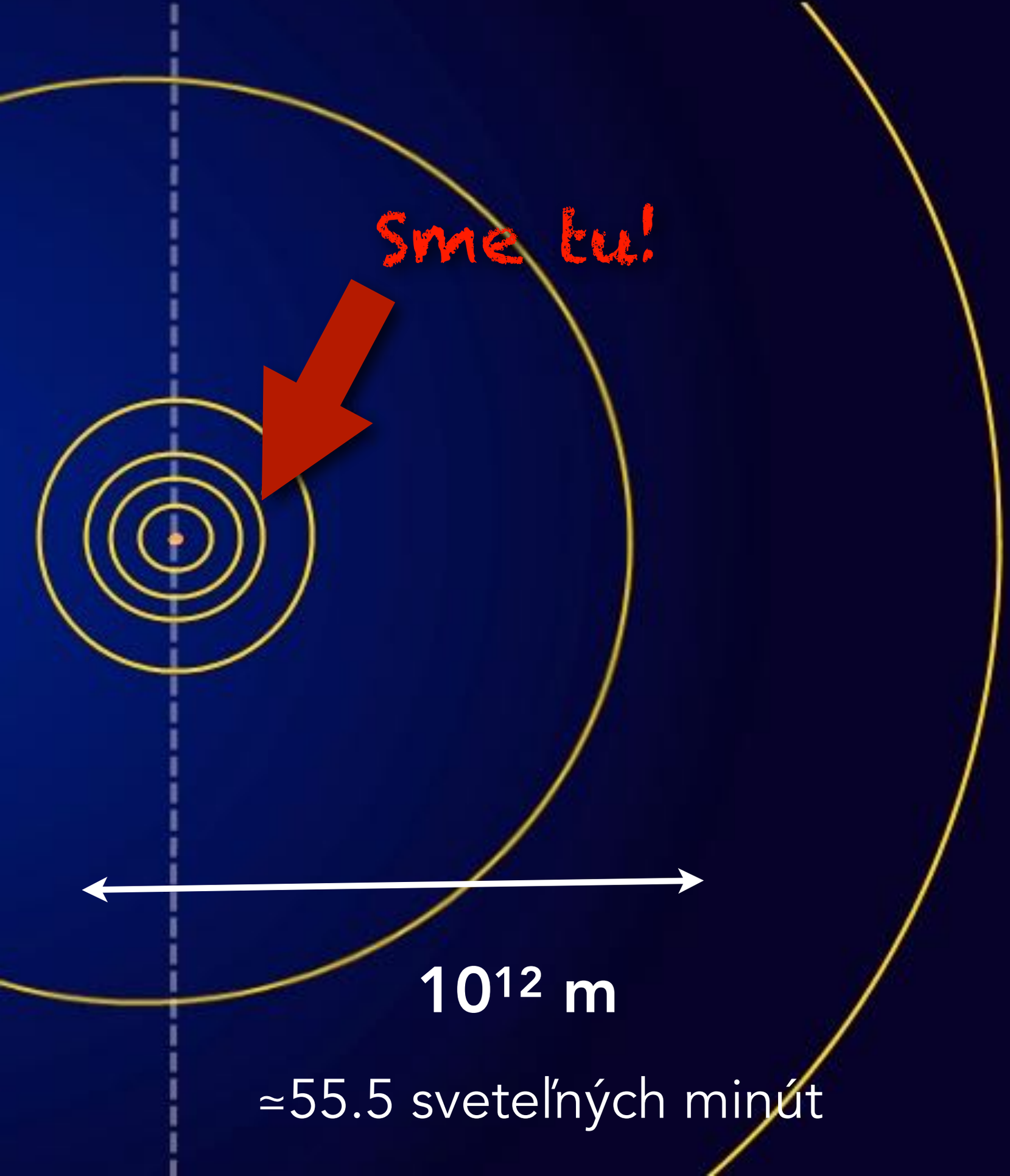
Sme tu!

a tu je Mesiac

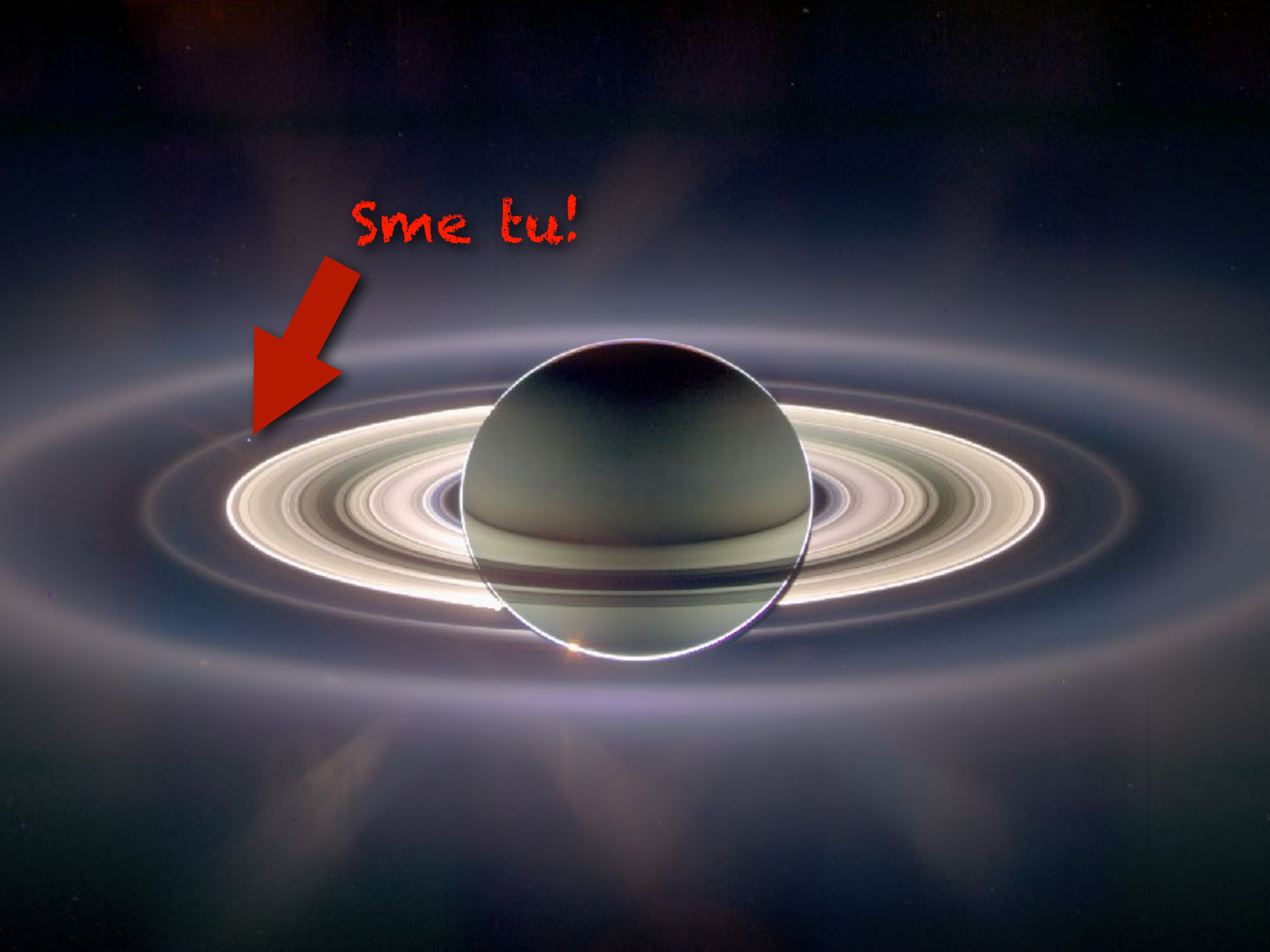


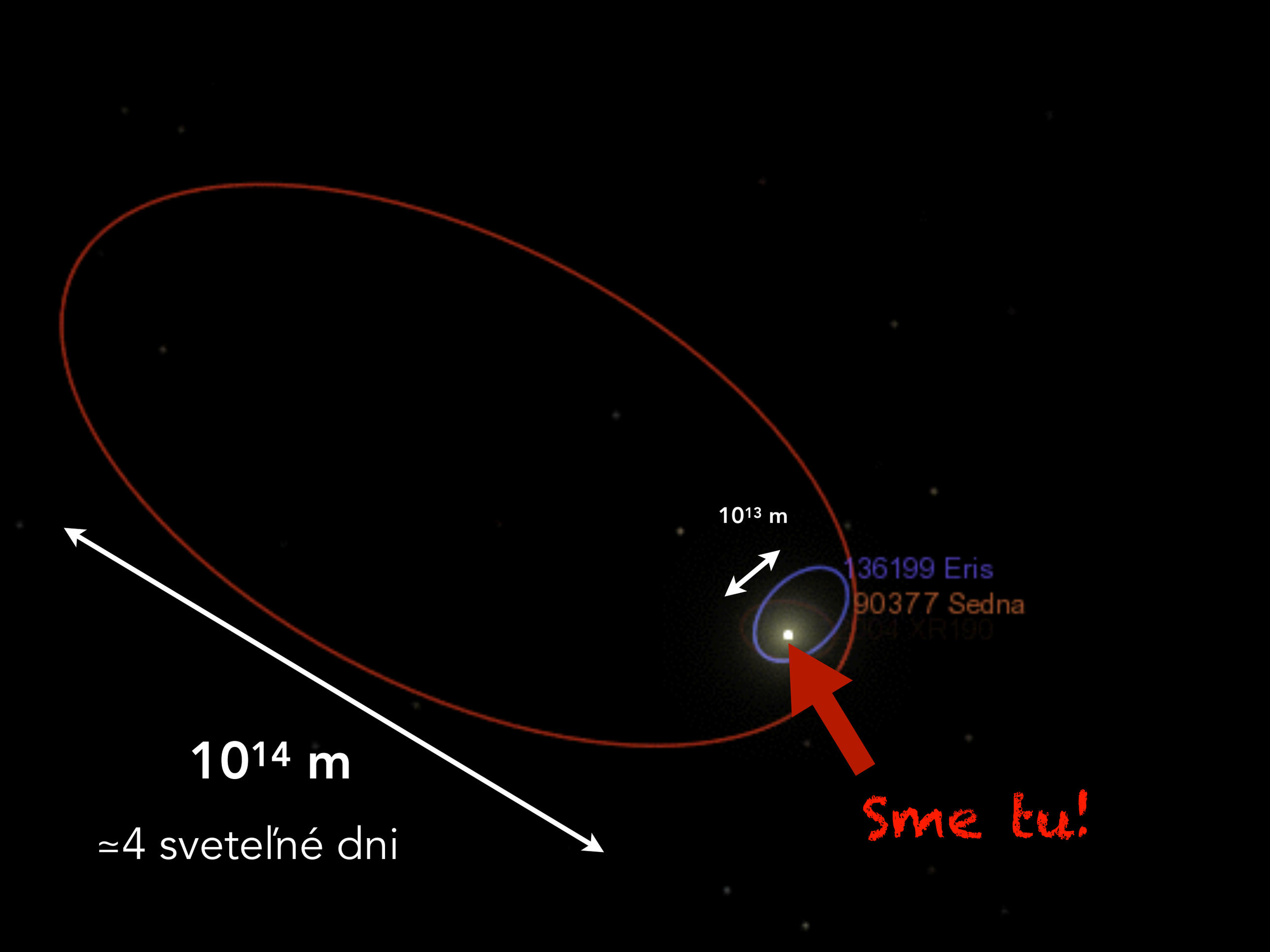
10^9 m

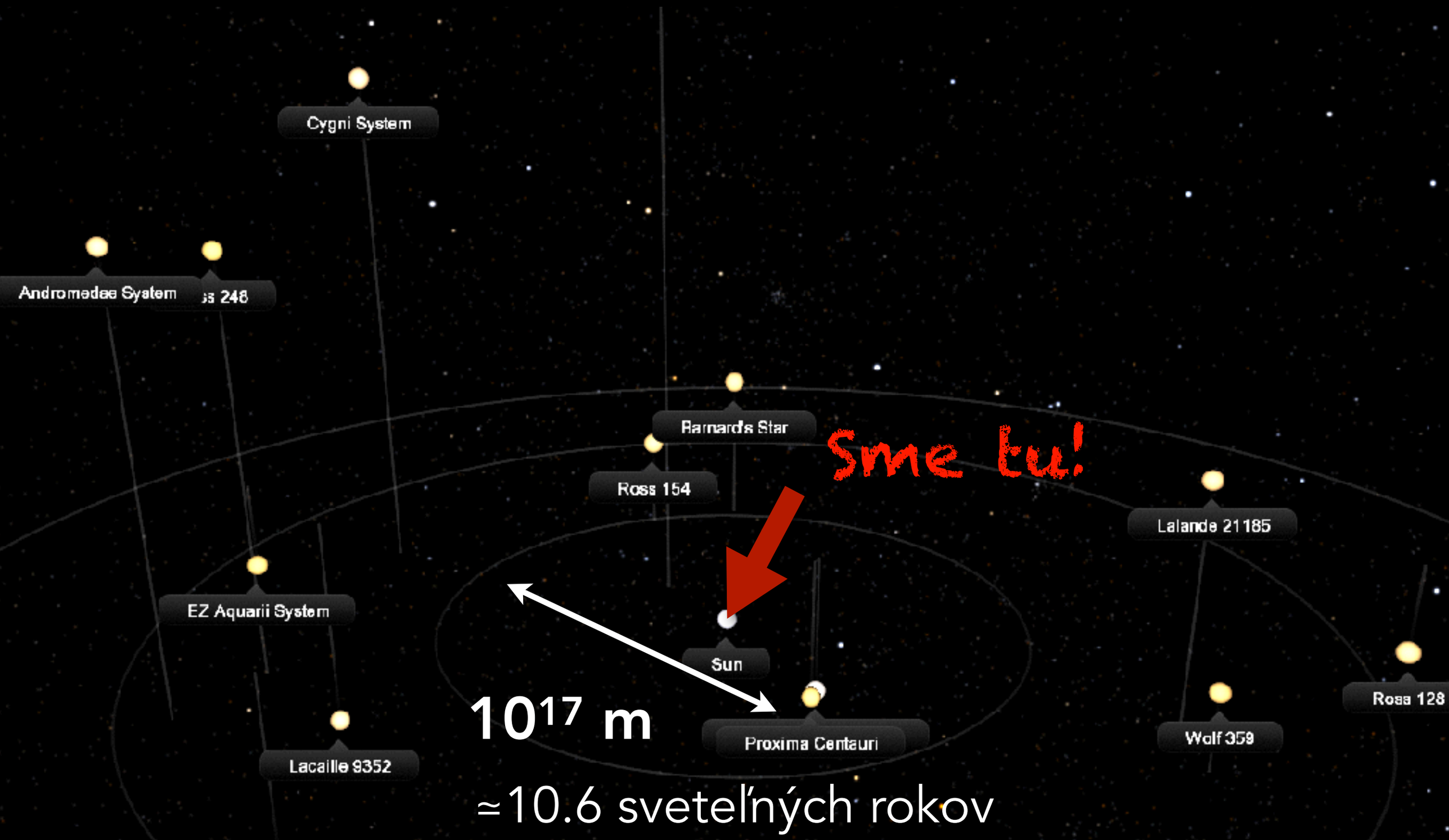
≃3.3 sveteľných sekúnd

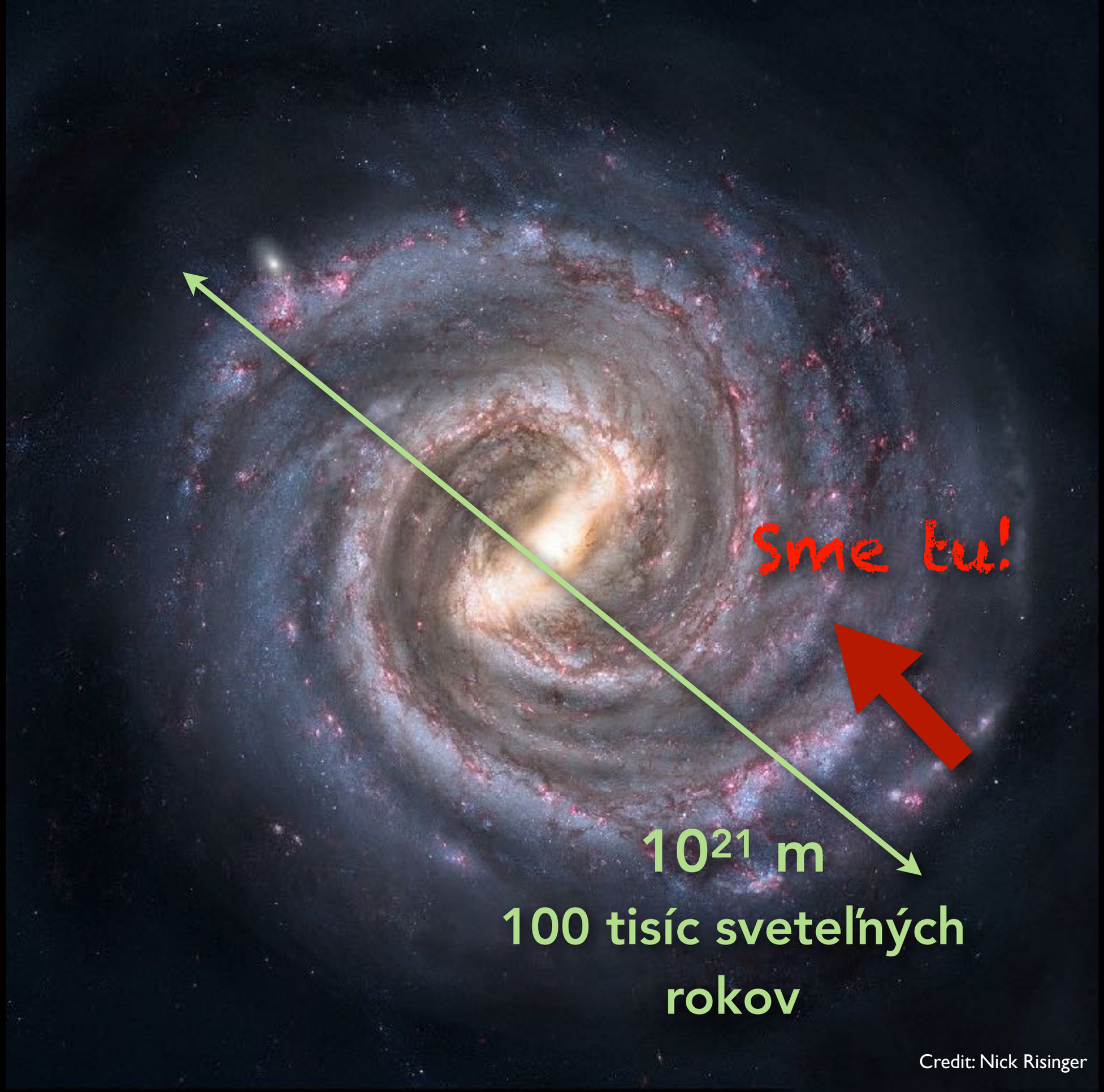


≃55.5 sveteľných minút

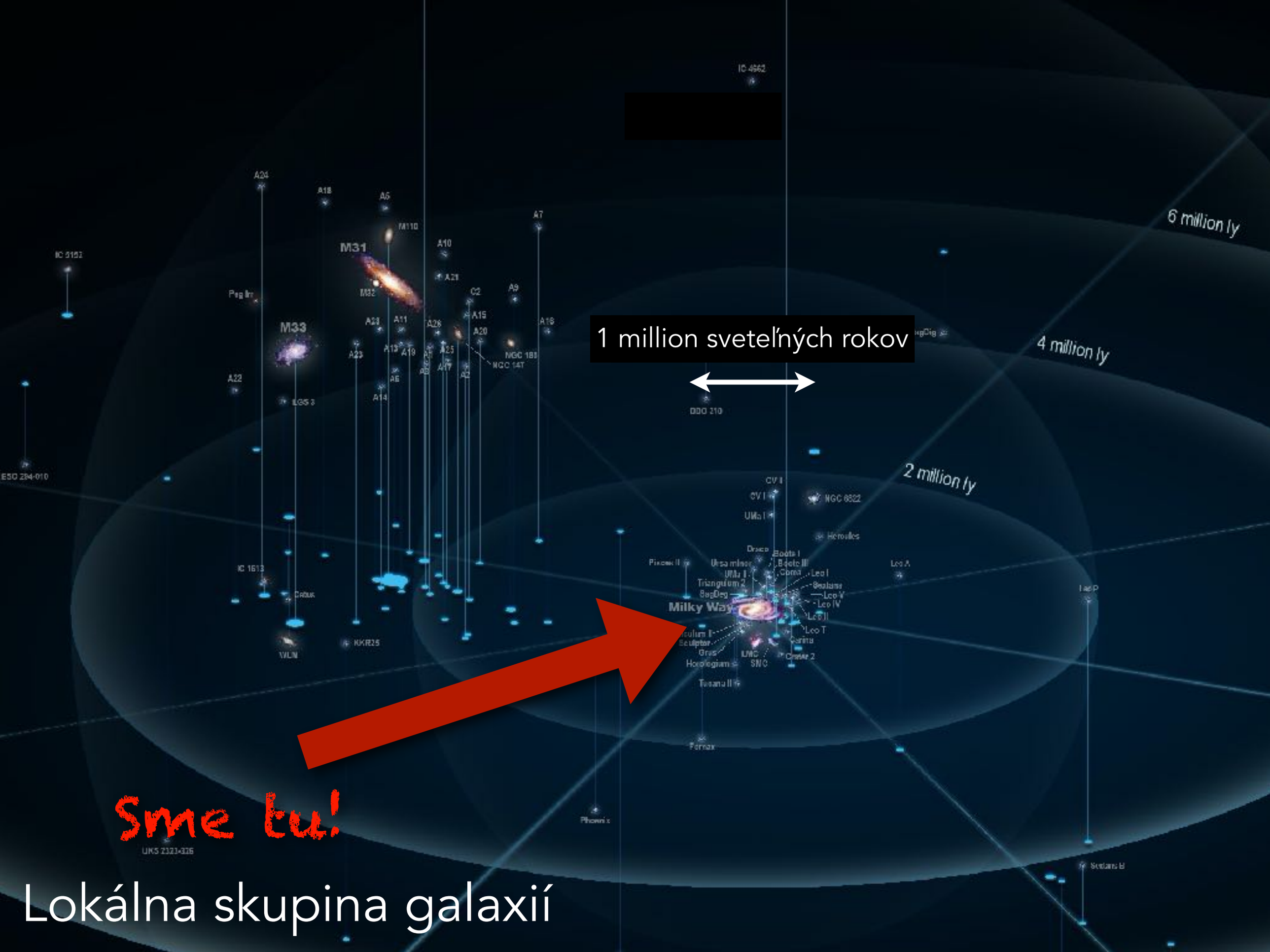

Sme tu!


10^{13} m
136199 Eris
90377 Sedna
10^{14} m
≃4 sveteľné dni
Sme tu!

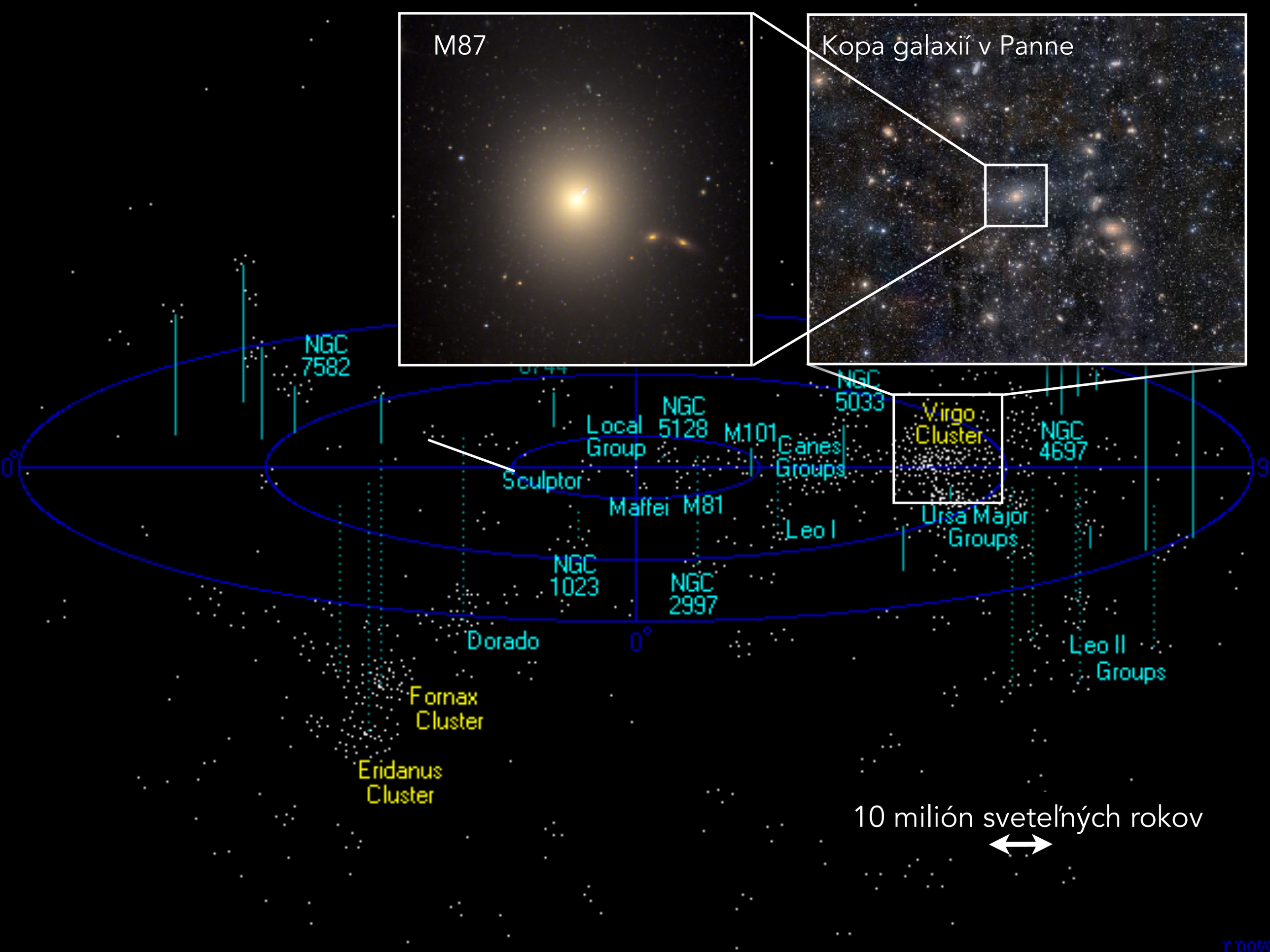

Cygni System
Andromedae System
ss 248
Barnards Star
Ross 154
Sme tu!
Lalande 21185
EZ Aquarii System
Sun
Rosa 128
Wolf 359
Proxima Centauri
Lacaille 9352
10^{17} m
≃10.6 sveteľných rokov

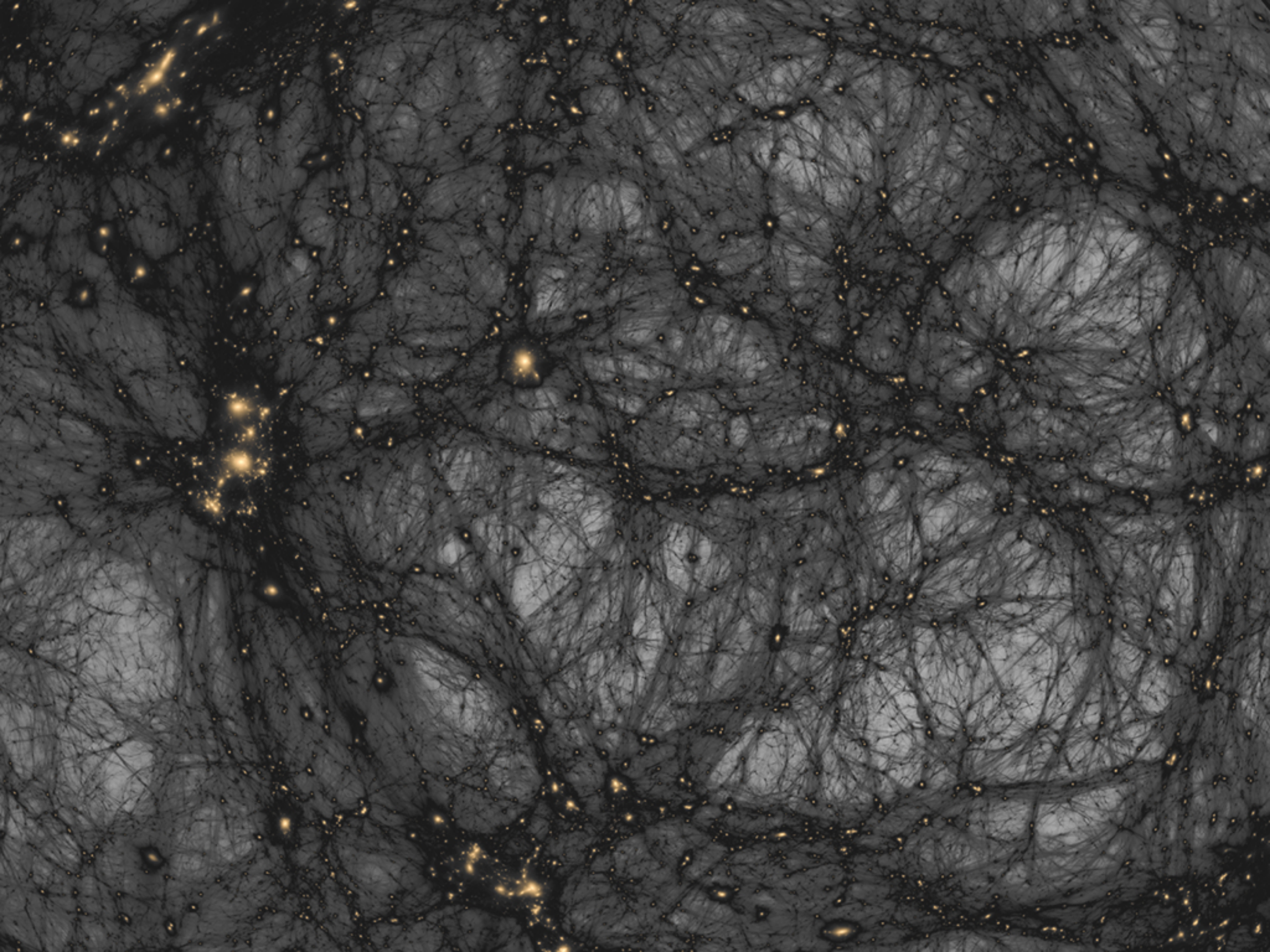


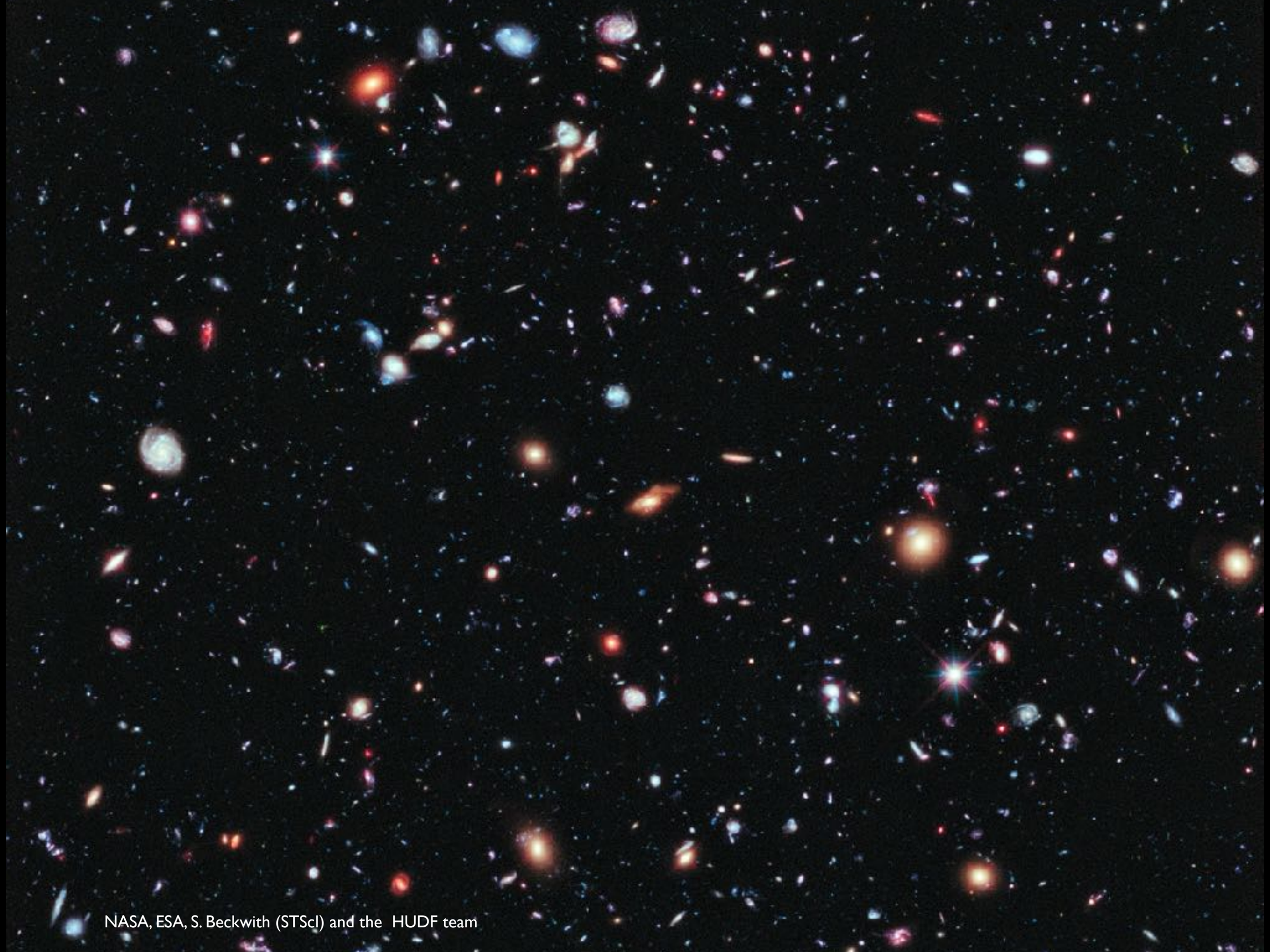
Credit: Nick Risinger



Lokálna skupina galaxií

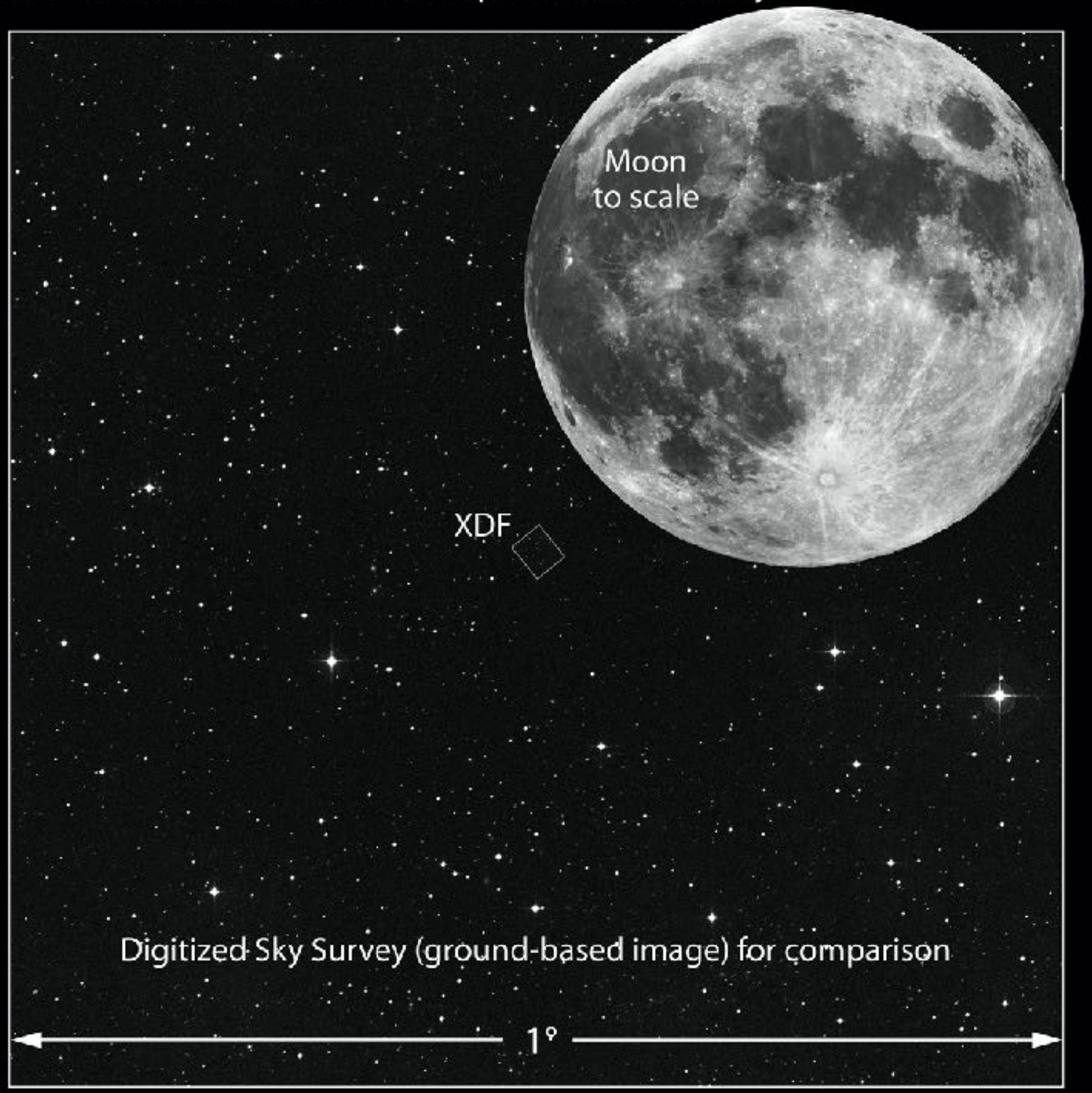

M87
Kopa galaxií v Panne
NGC 7582
NGC 5033
Virgo Cluster
NGC 4697
Local Group
NGC 5128
M101
Canes Groups
Sculptor
Maffei
M81
Leo I
Ursa Major Groups
NGC 1023
NGC 2997
Dorado
Leo II Groups
Fornax Cluster
Eridanus Cluster
10 milión sveteľných rokov

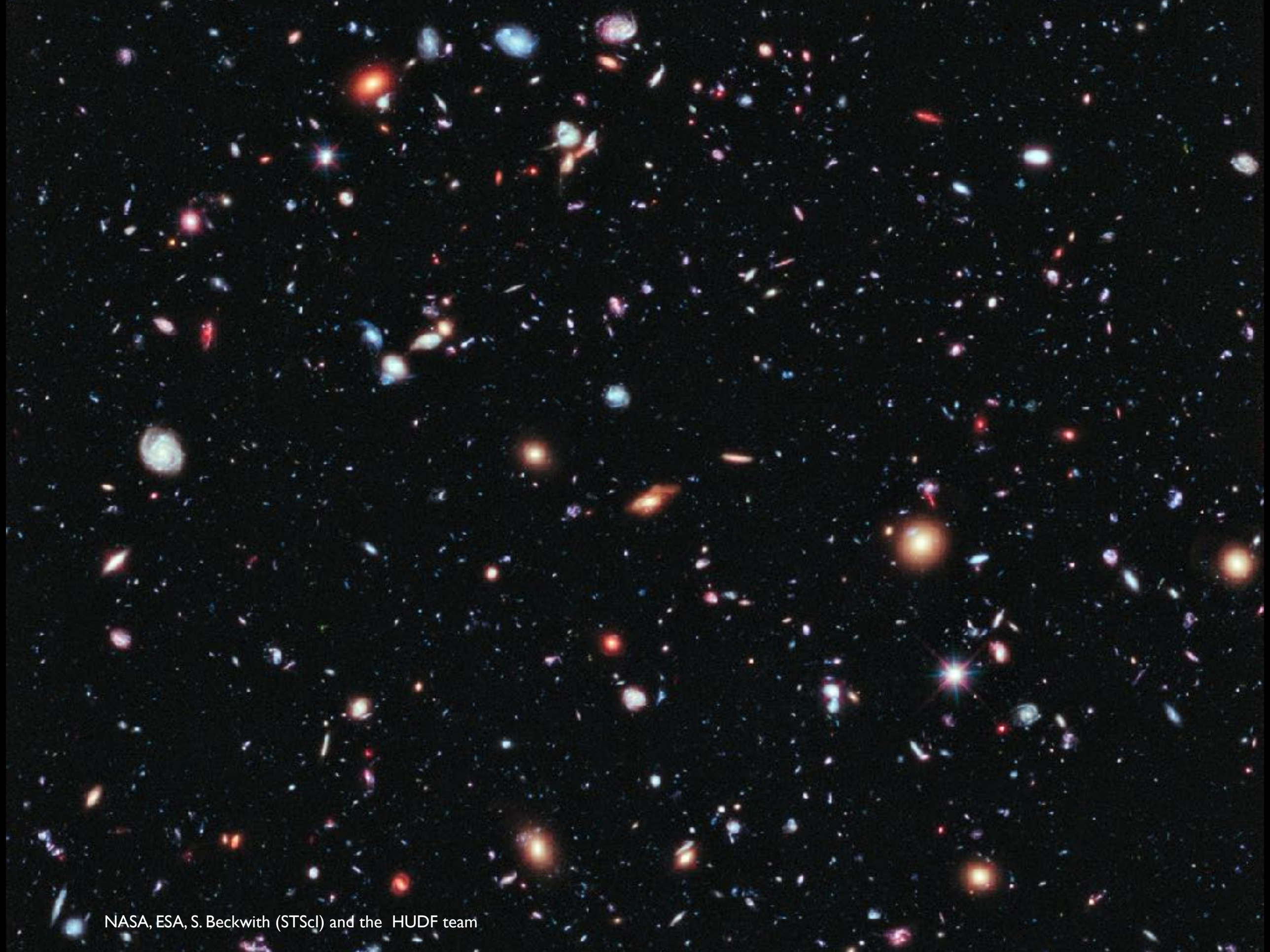




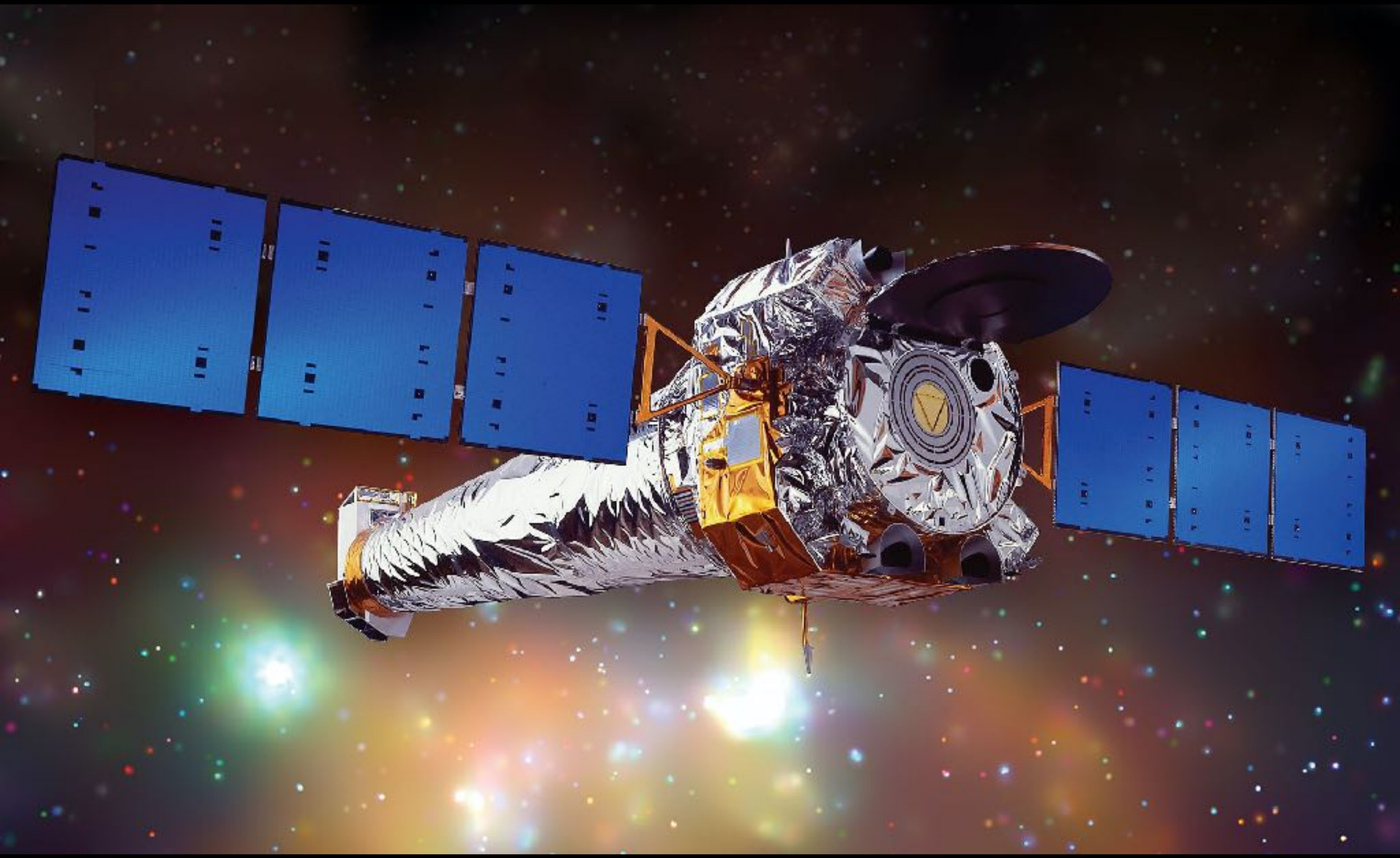
NASA, ESA, S. Beckwith (STScI) and the HUDF team

Size of Hubble eXtreme Deep Field on the Sky

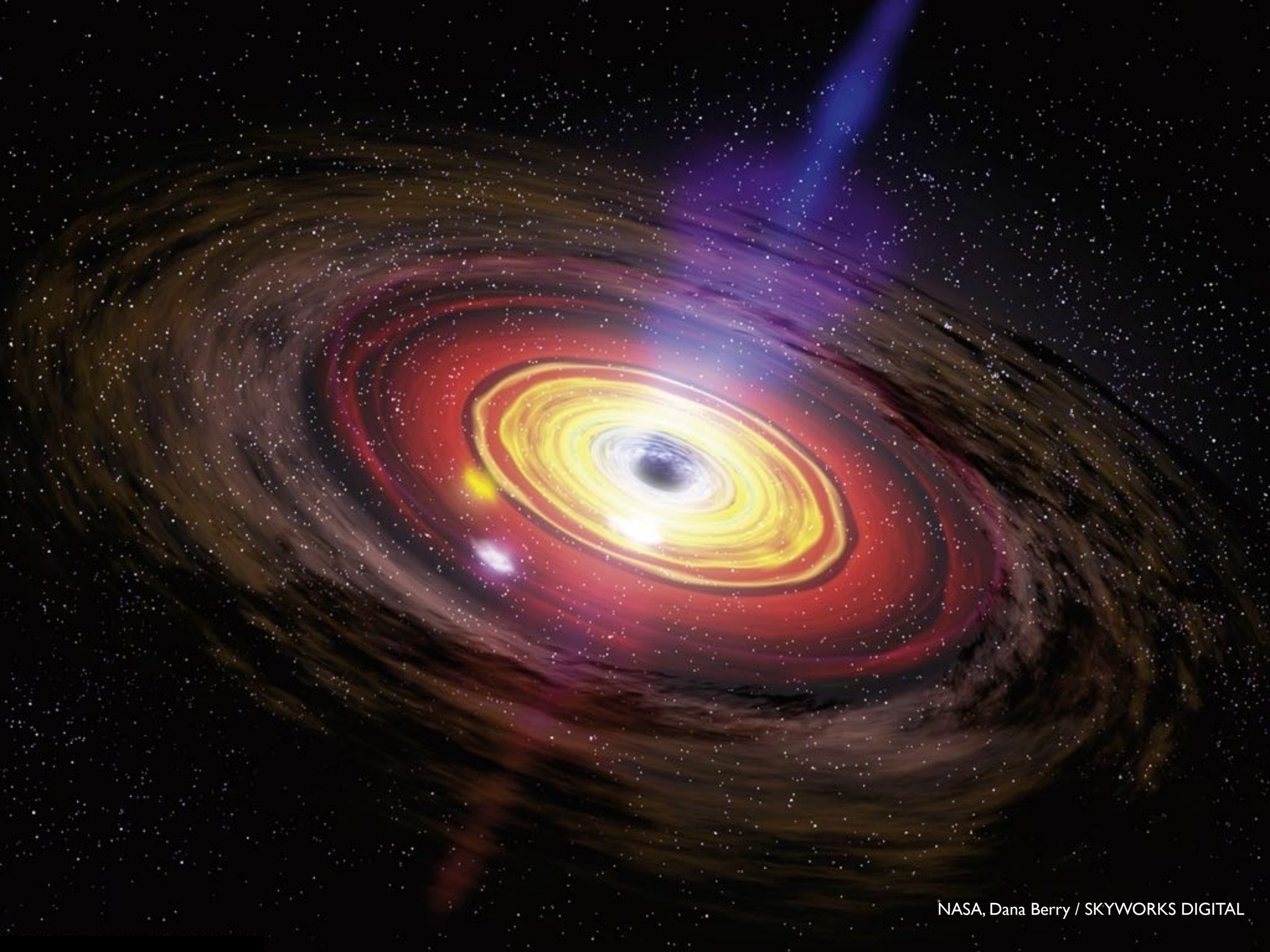




NASA, ESA, S. Beckwith (STScI) and the HUDF team

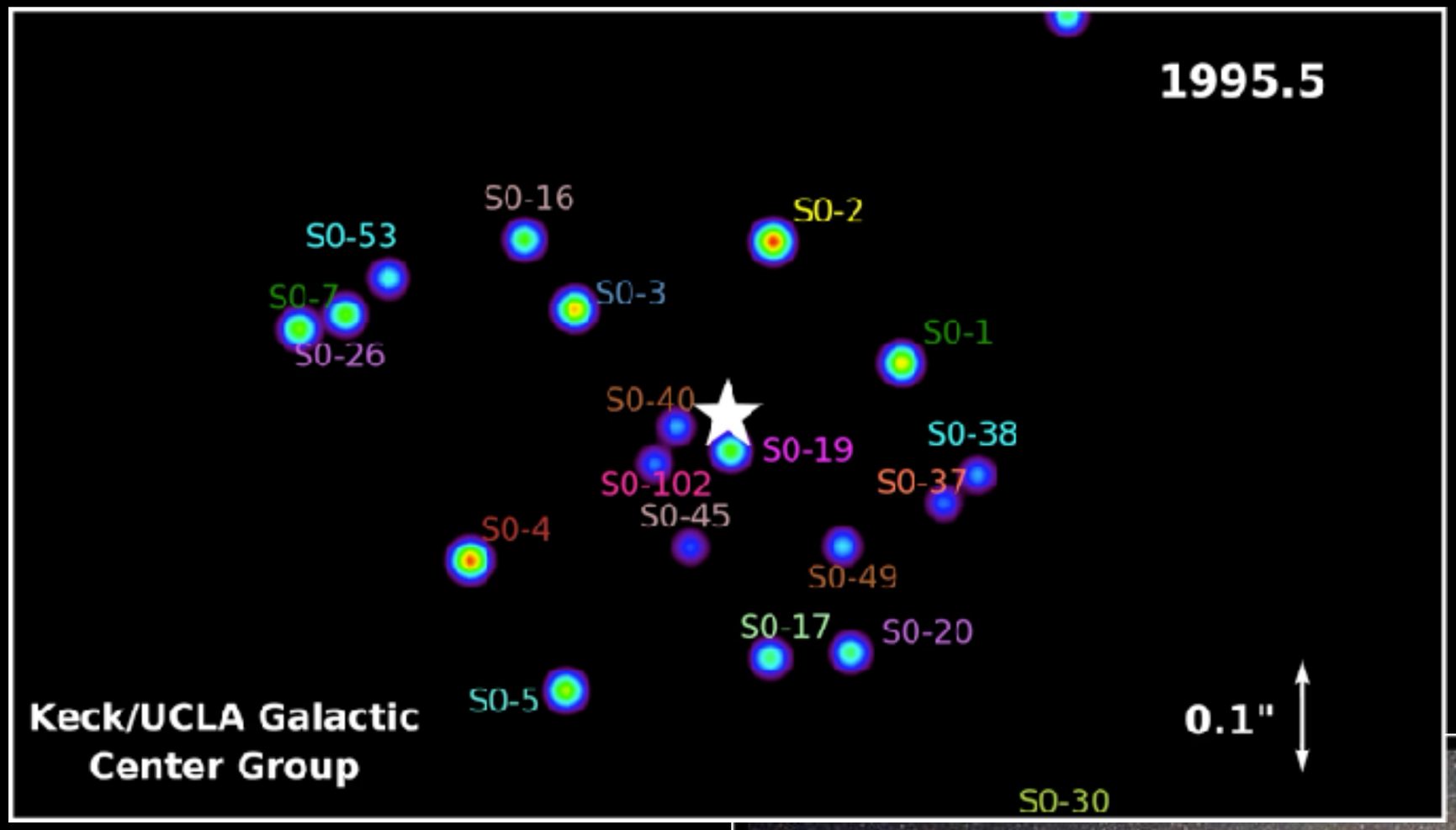


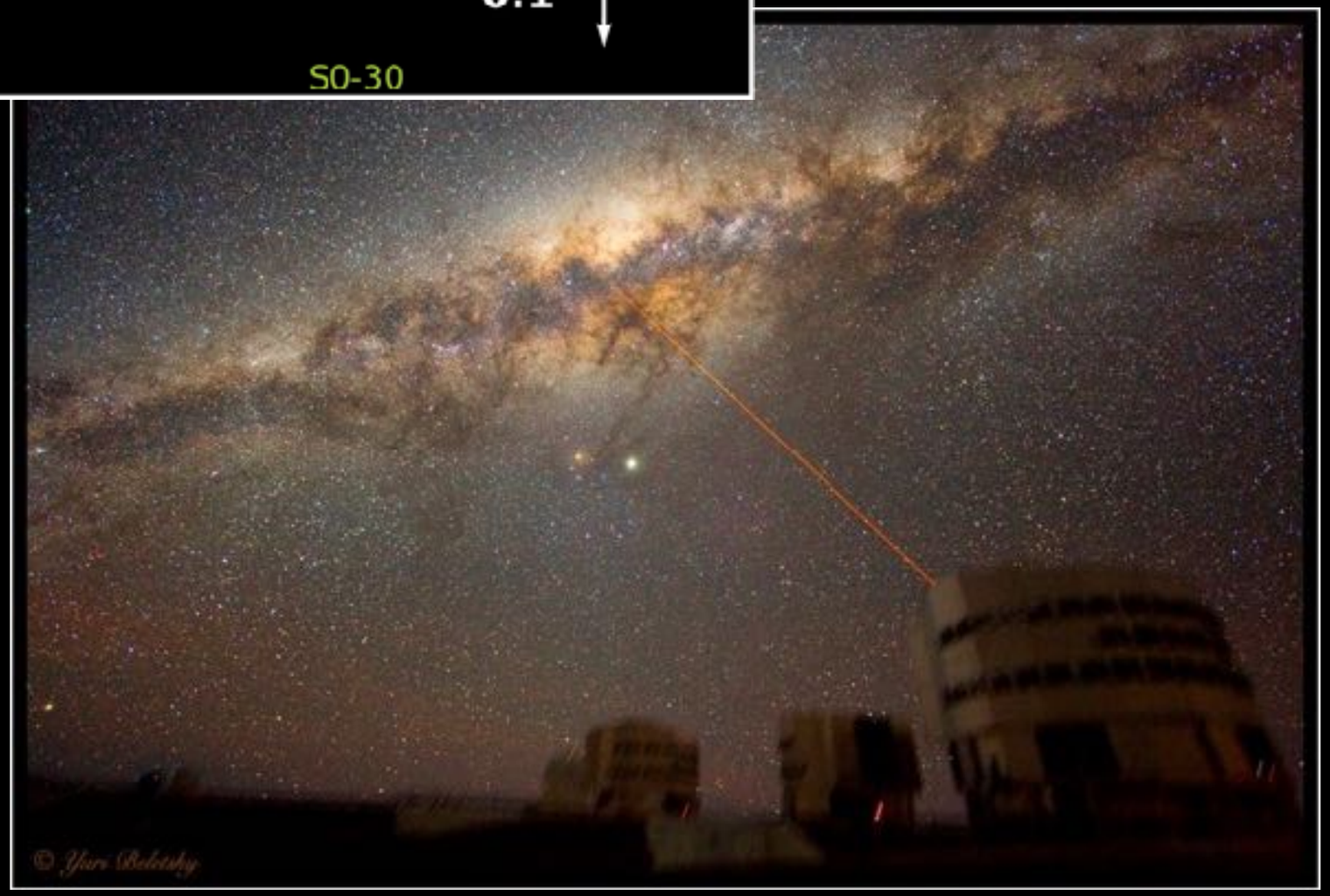
NASA, ESA, S. Beckwith (STScI) and the HUDF team



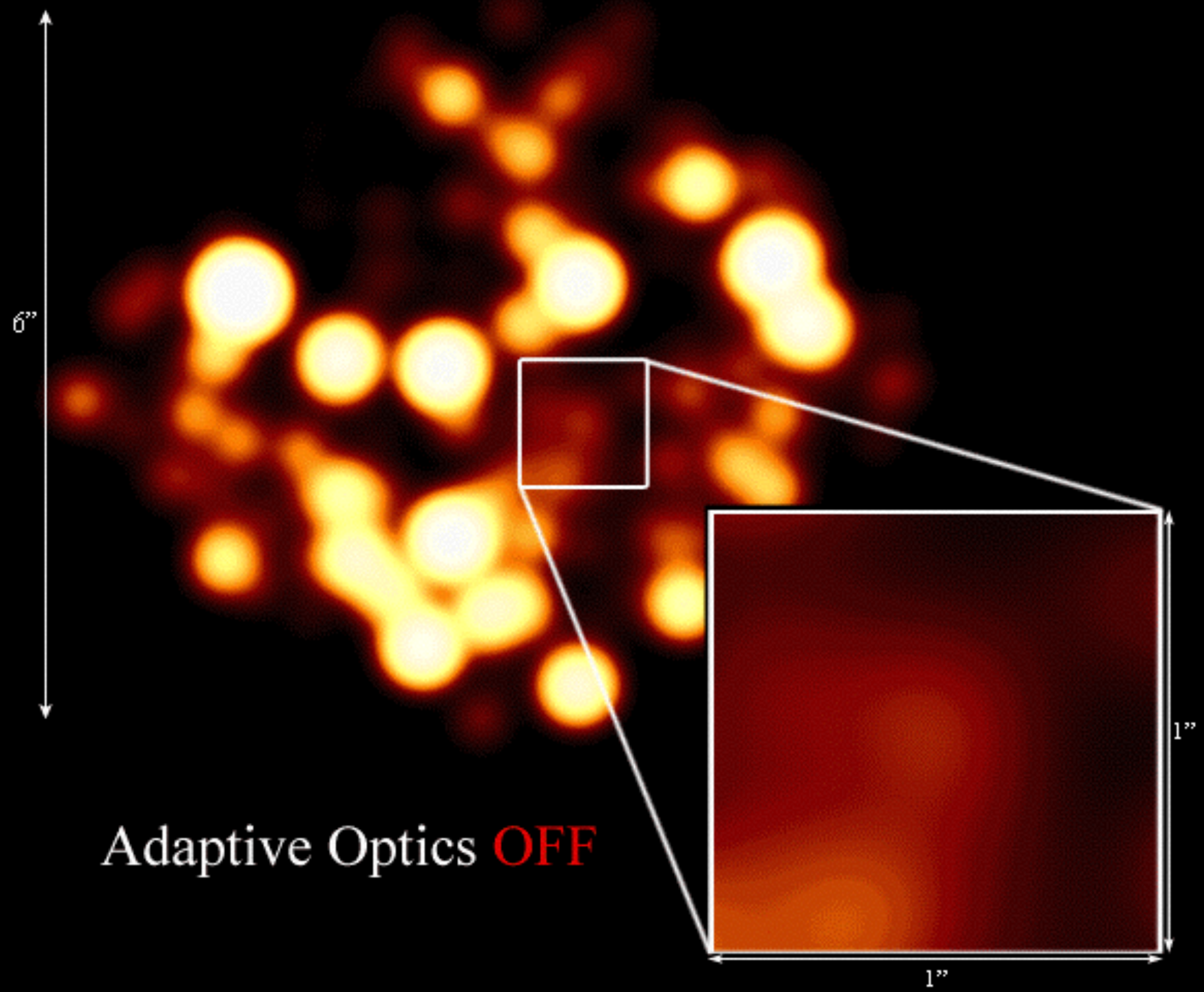
NASA, Dana Berry / SKYWORKS DIGITAL

Credit: Nick Risinger

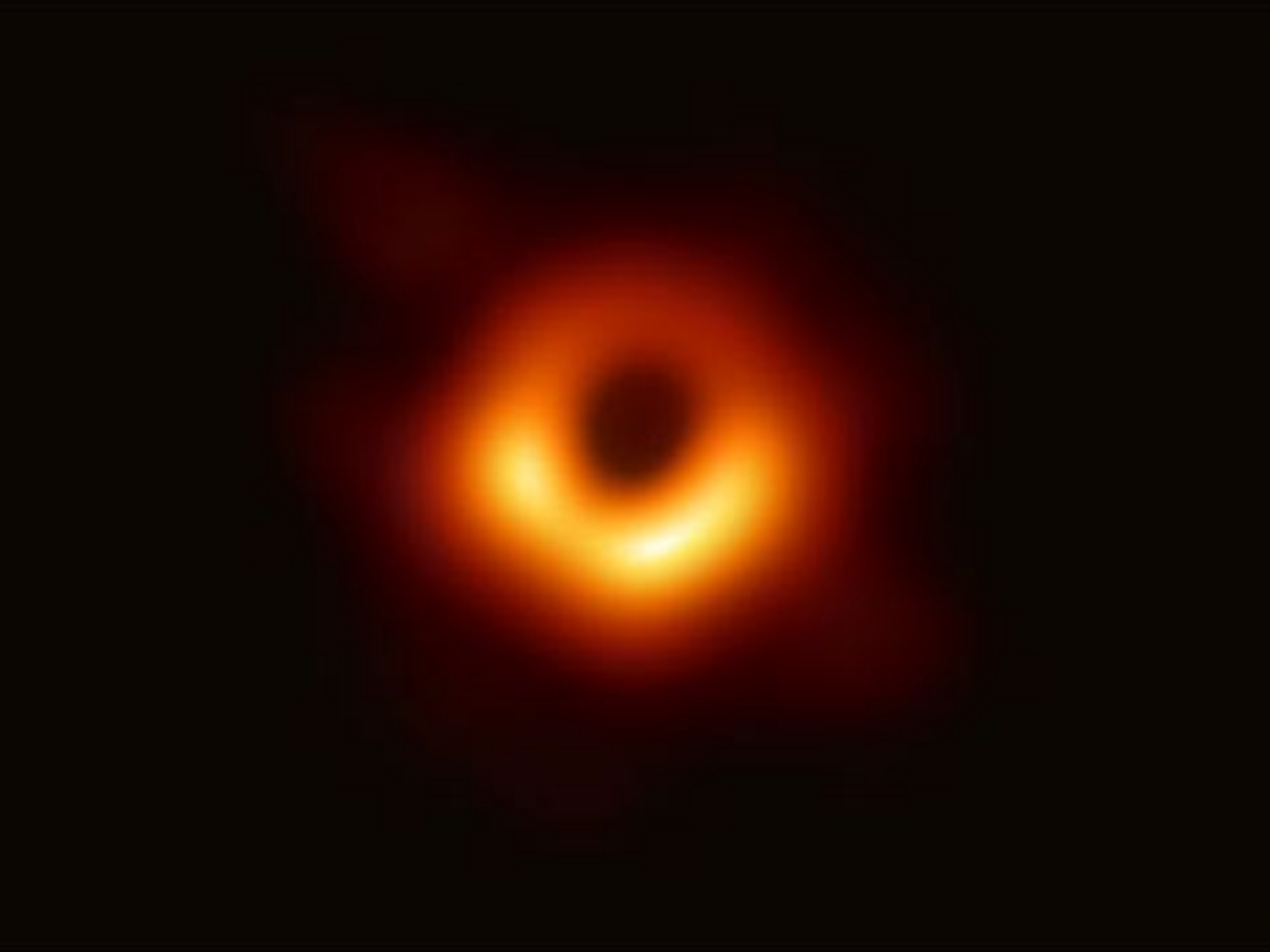

1995.5
S0-16
S0-2
S0-53
S0-3
S0-7
S0-26
S0-1
S0-40
S0-19
S0-38
S0-102
S0-37
S0-45
S0-4
S0-49
S0-17
S0-20
S0-5
0.1"
Keck/UCLA Galactic Center Group
S0-30


© Yuri Beletsky

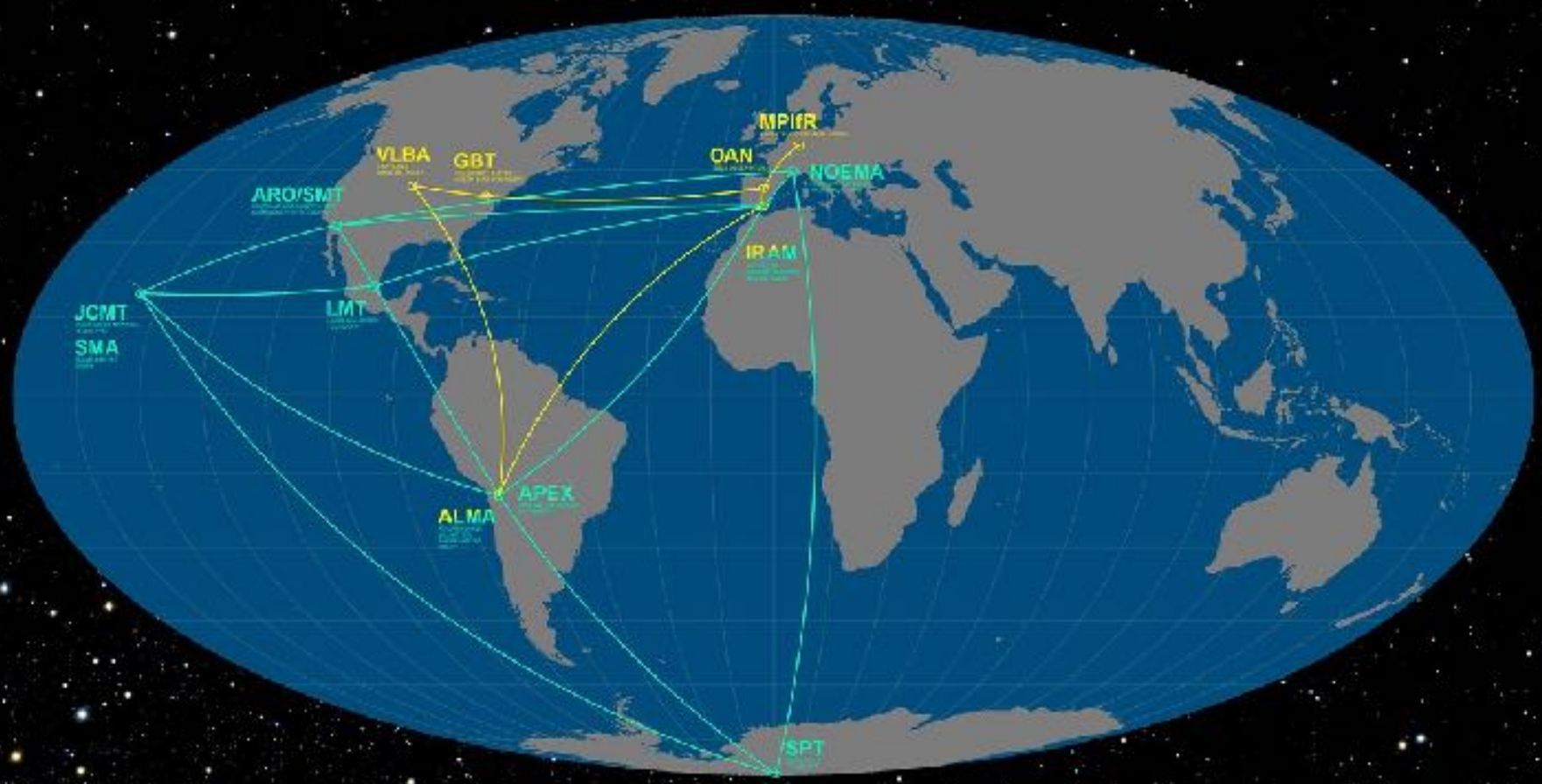
The Galactic Center at 2.2 microns

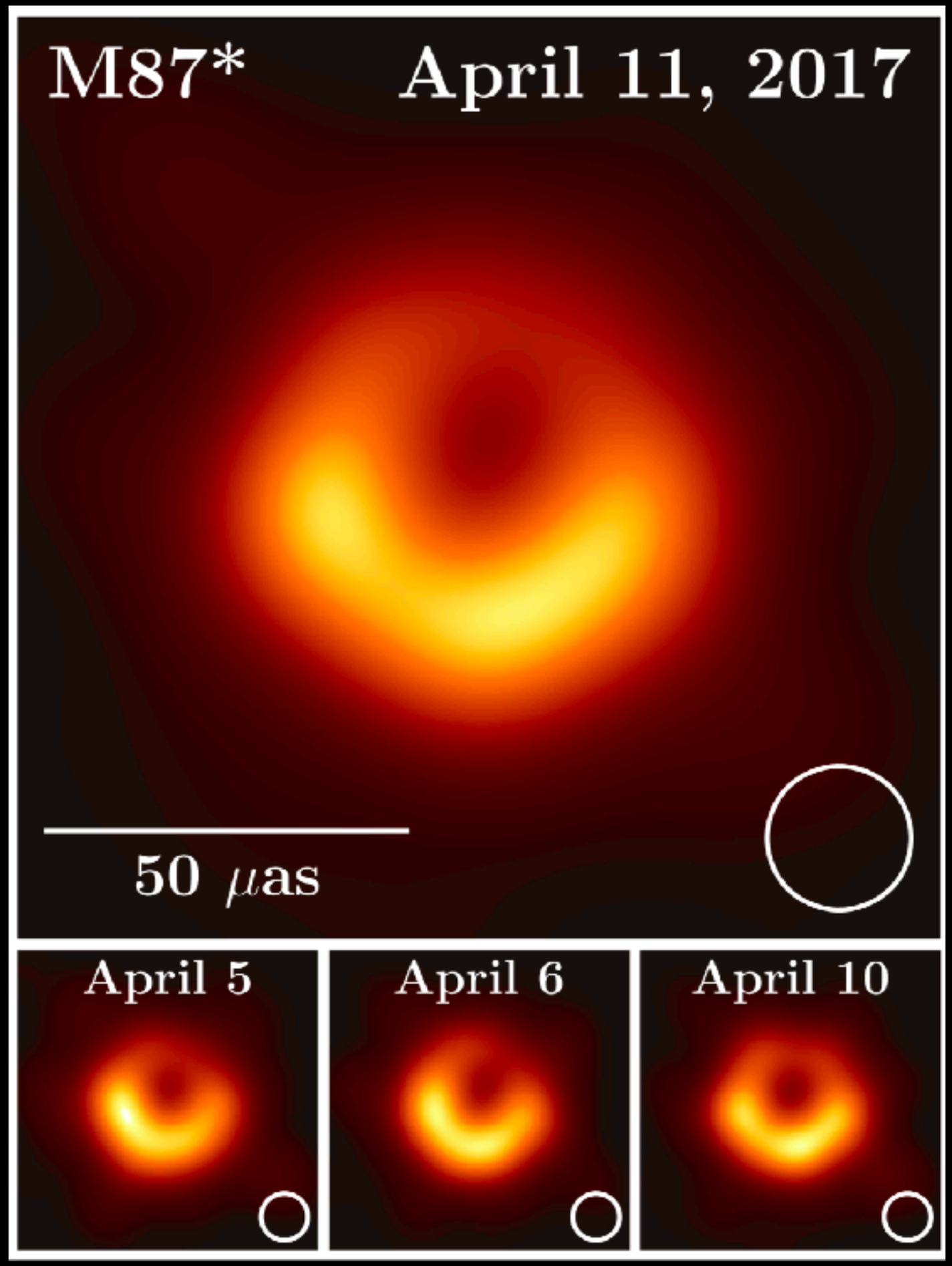


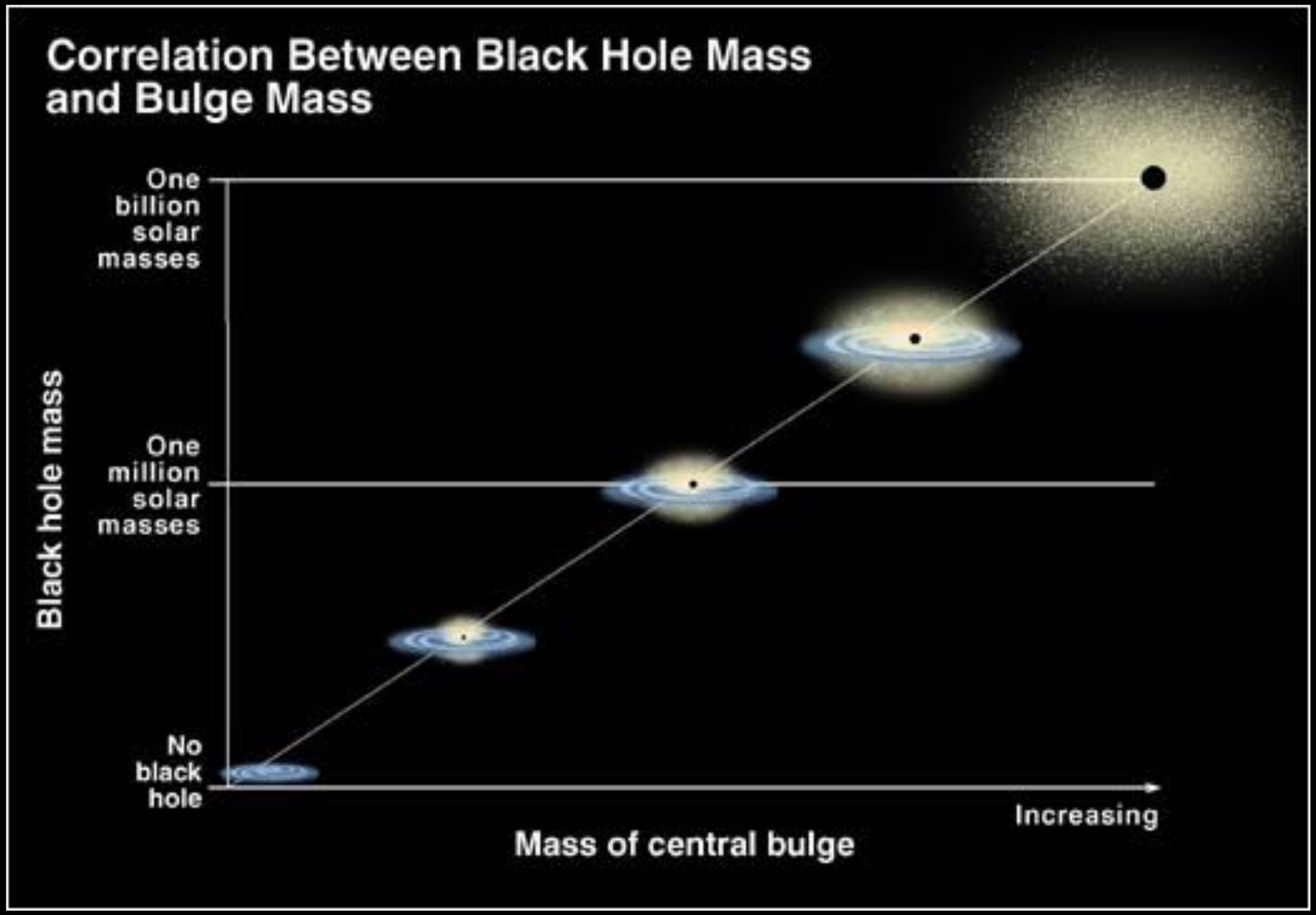
Adaptive Optics OFF



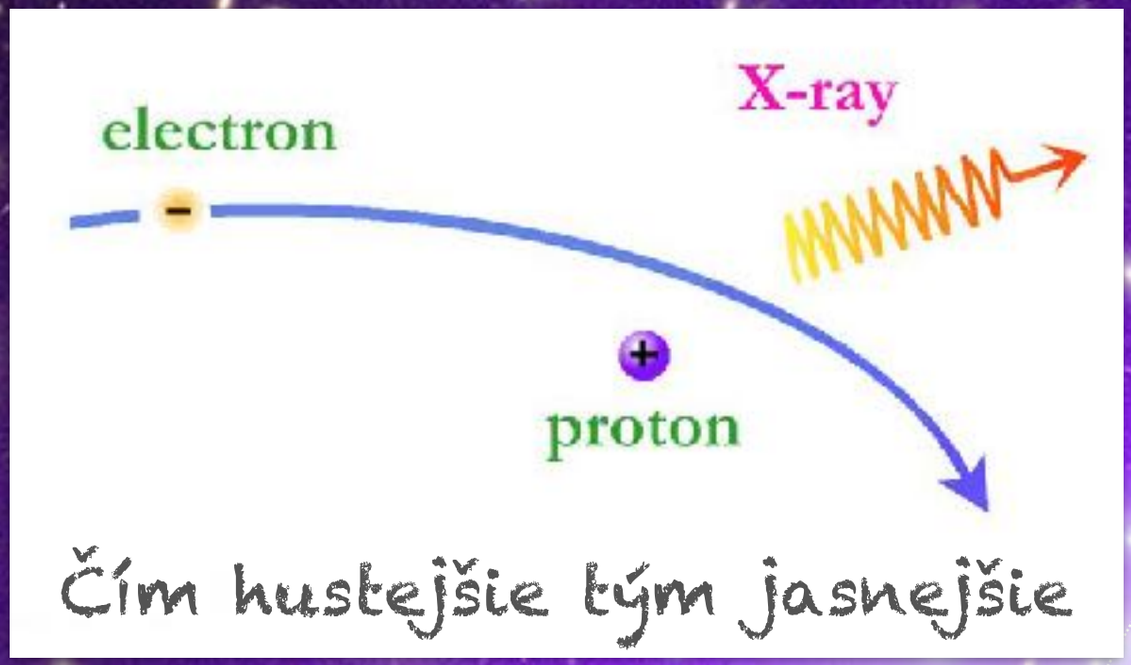
Event Horizont Telescope

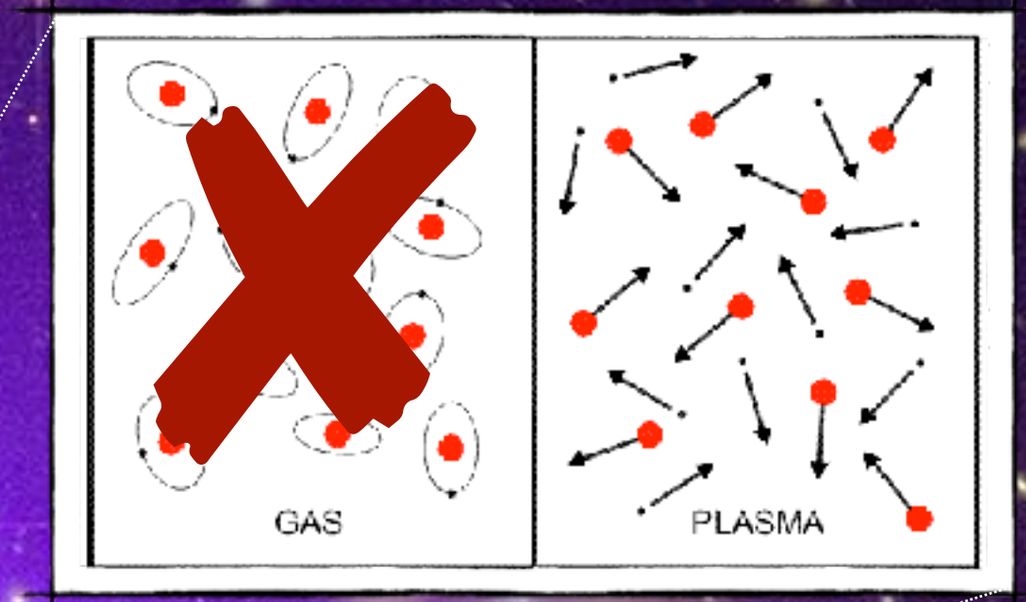



M87*
April 11, 2017
50 μas
April 5
April 6
April 10


Correlation Between Black Hole Mass and Bulge Mass
One billion solar masses
One million solar masses
No black hole
Black hole mass
Increasing
Mass of central bulge

Abell 1689 (2 899 130 981 light years)





X-rays

Optical

Plyn je skutočne horúci

(~10 - 100 milión °C)

Hviezdy,
planéty,
galaxie,...

~20%

~80%

Hviezdy, planéty, galaxie,...

Horúce atmosféry

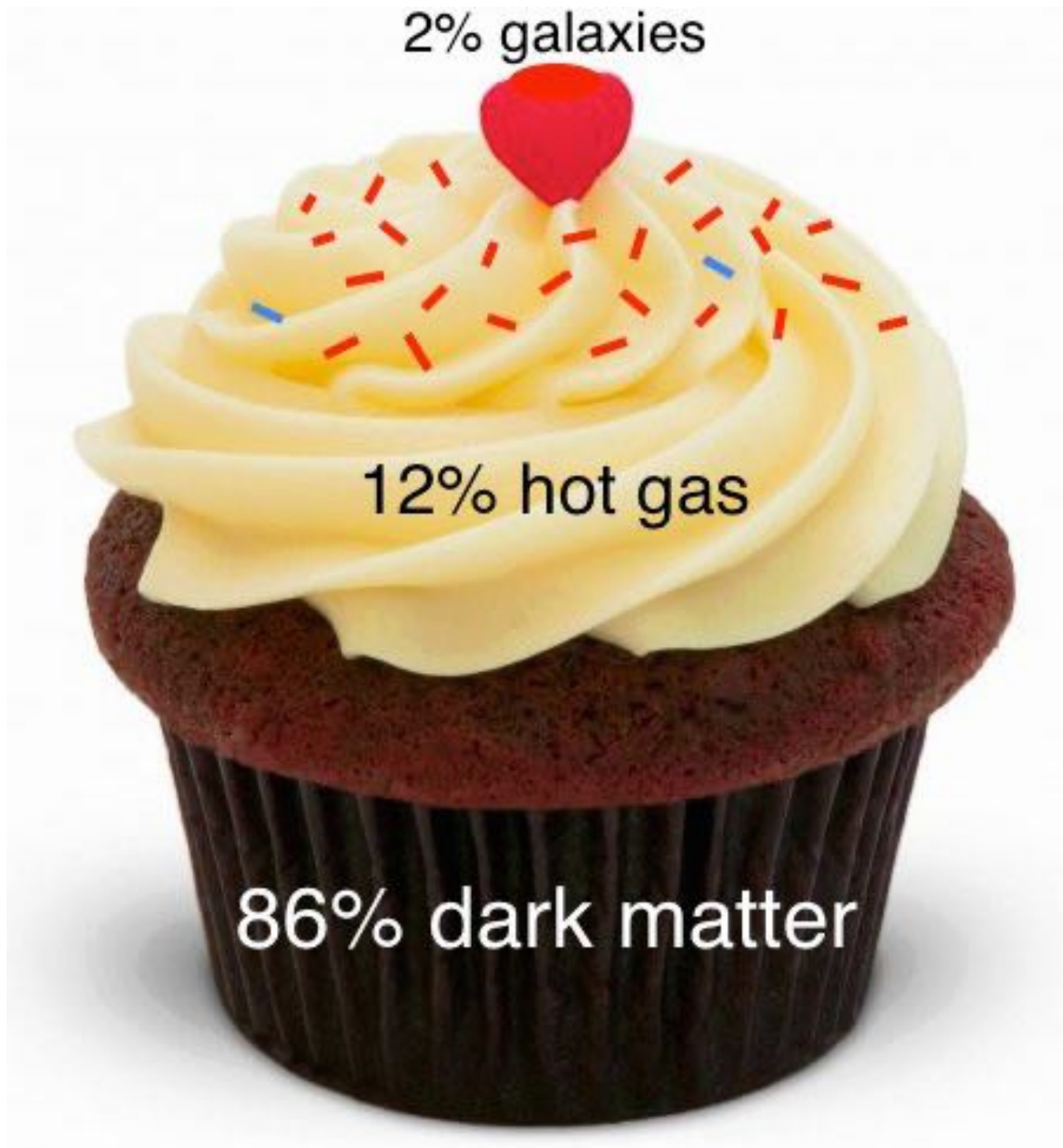
~15%

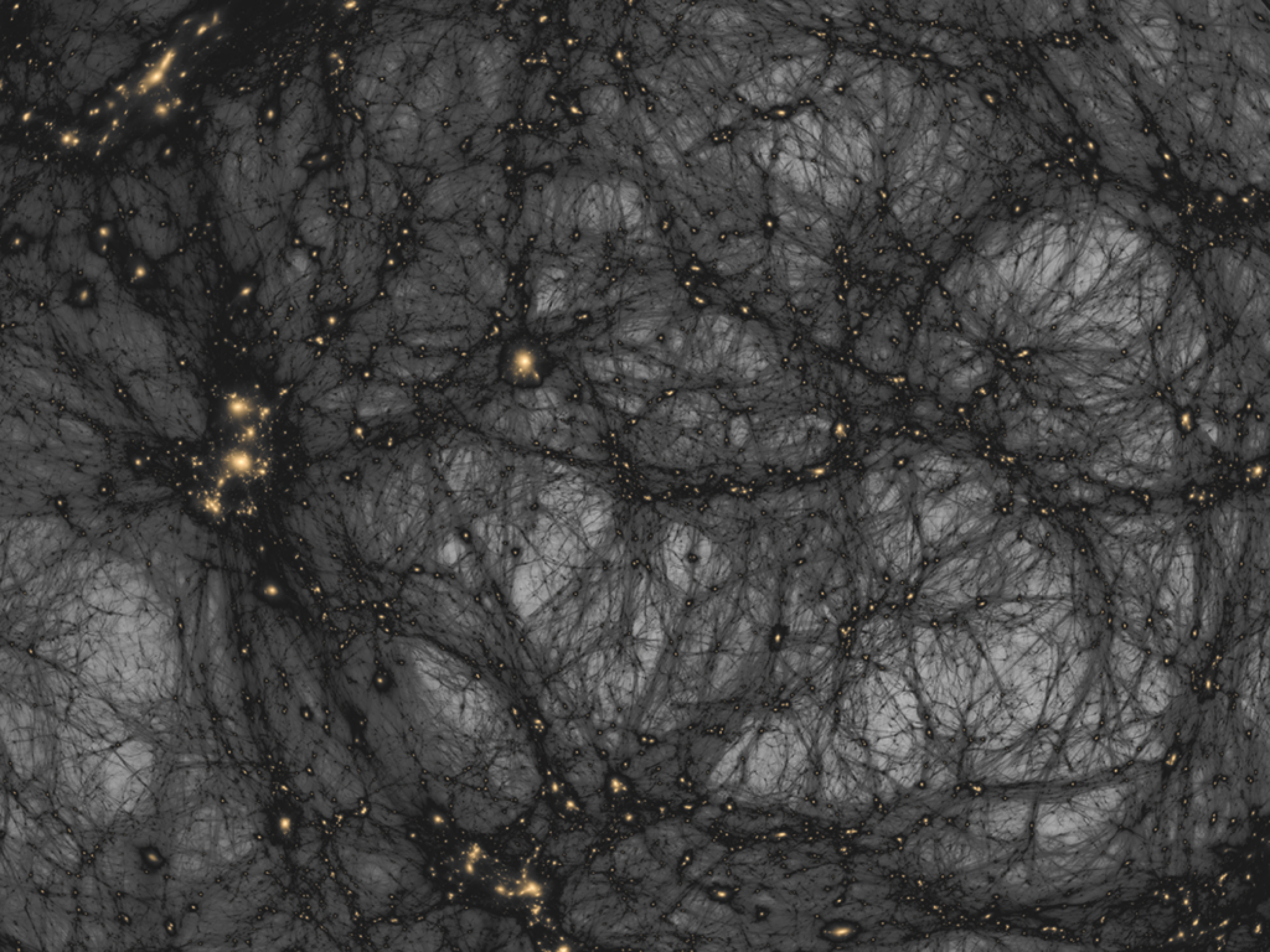
~85%

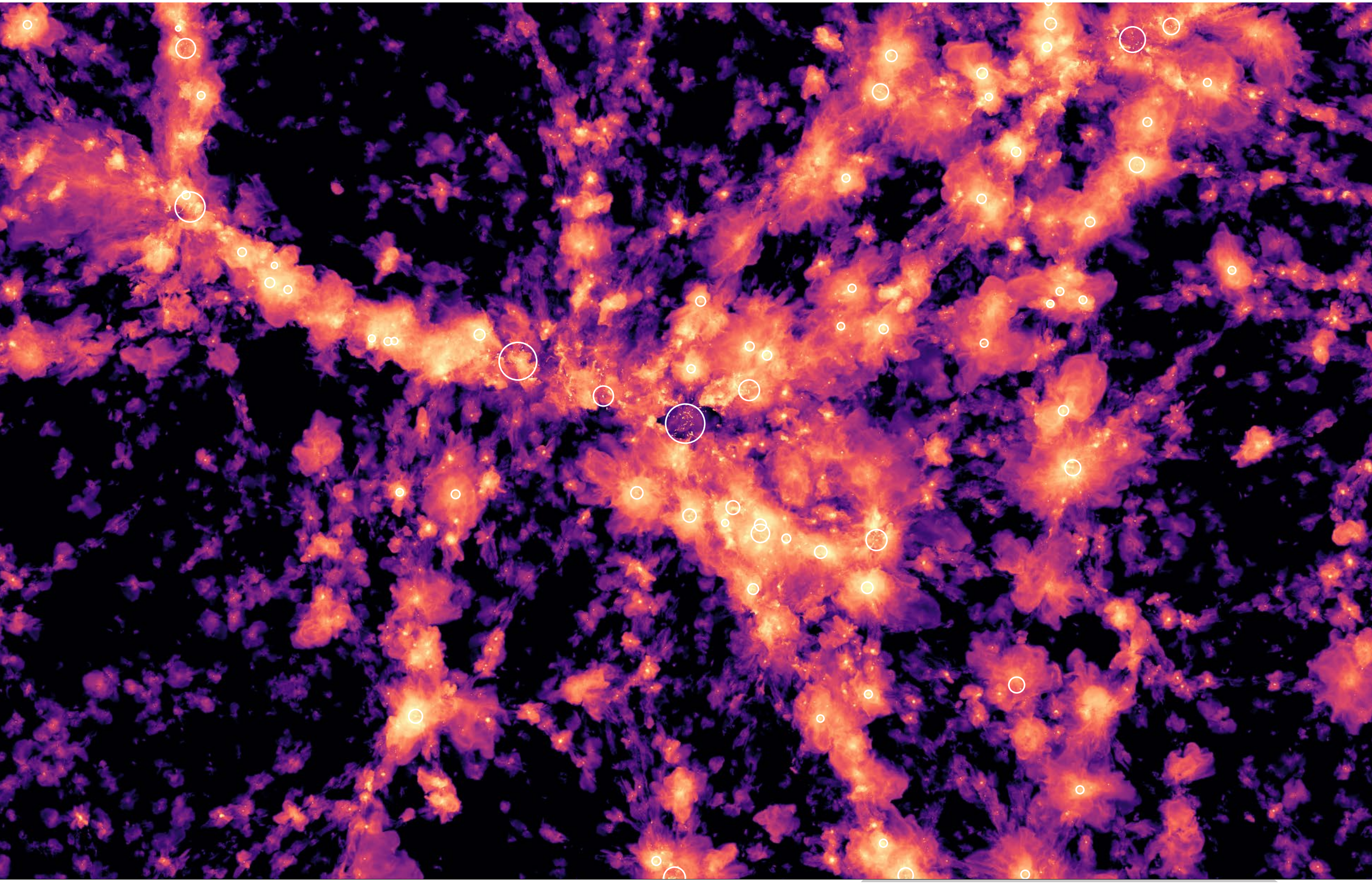
Hviezdy, planéty, galaxie,...

Horúce atmosféry

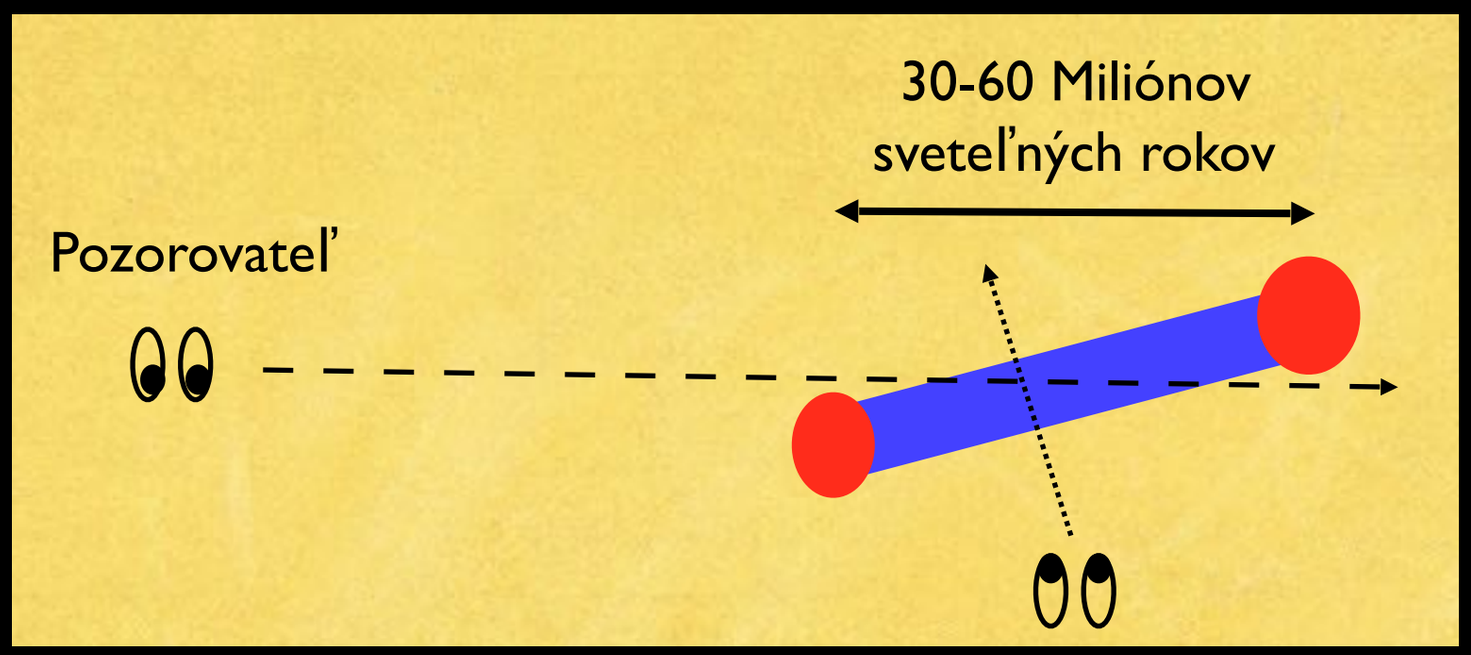
Tmavá hmota

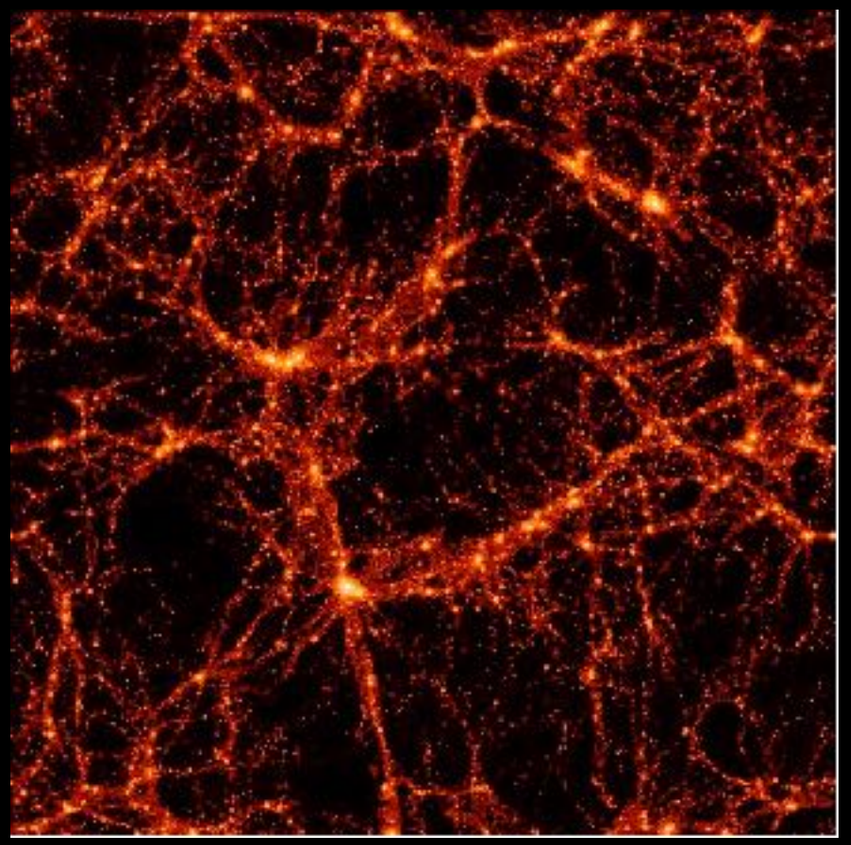

2% galaxies
12% hot gas
86% dark matter

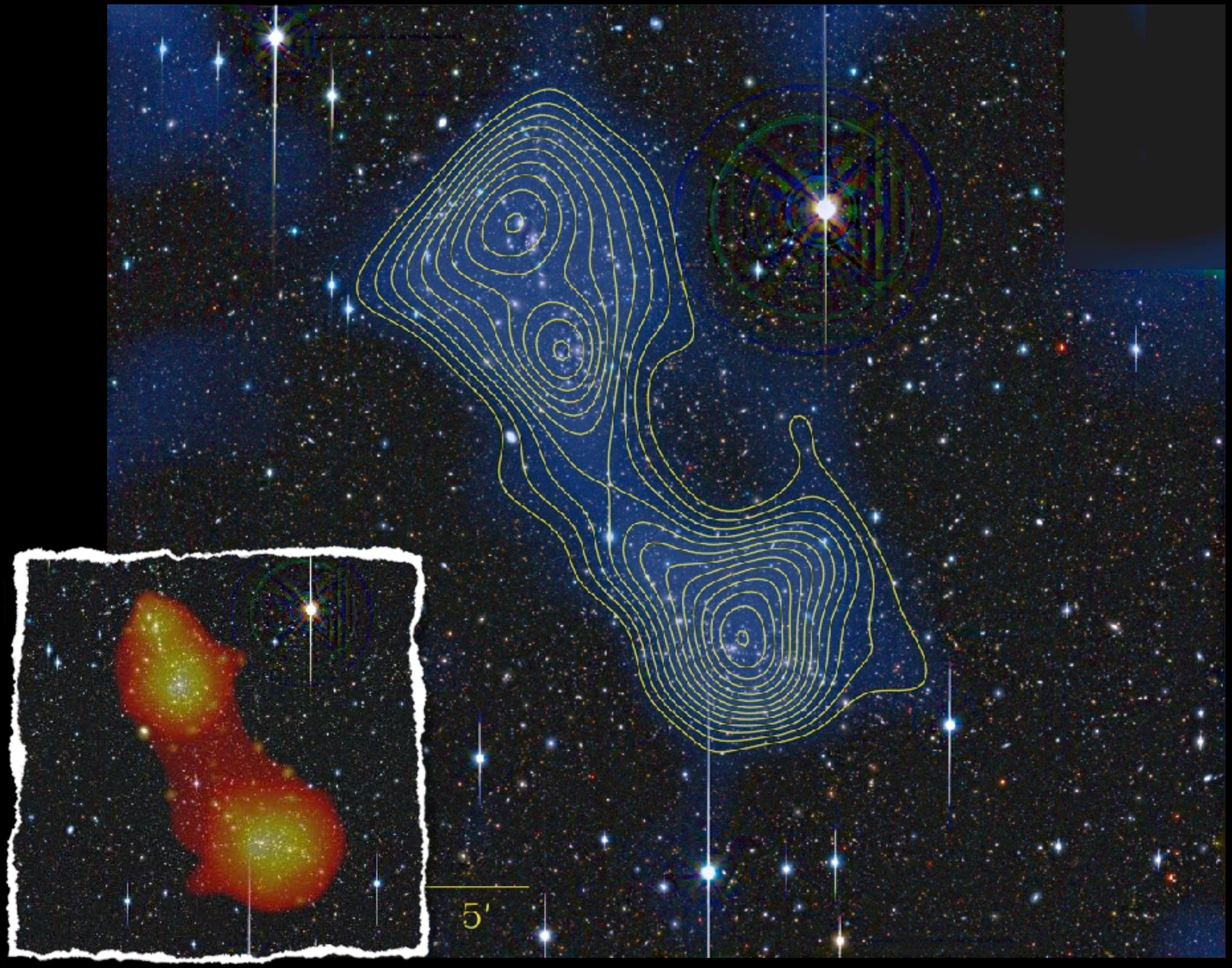


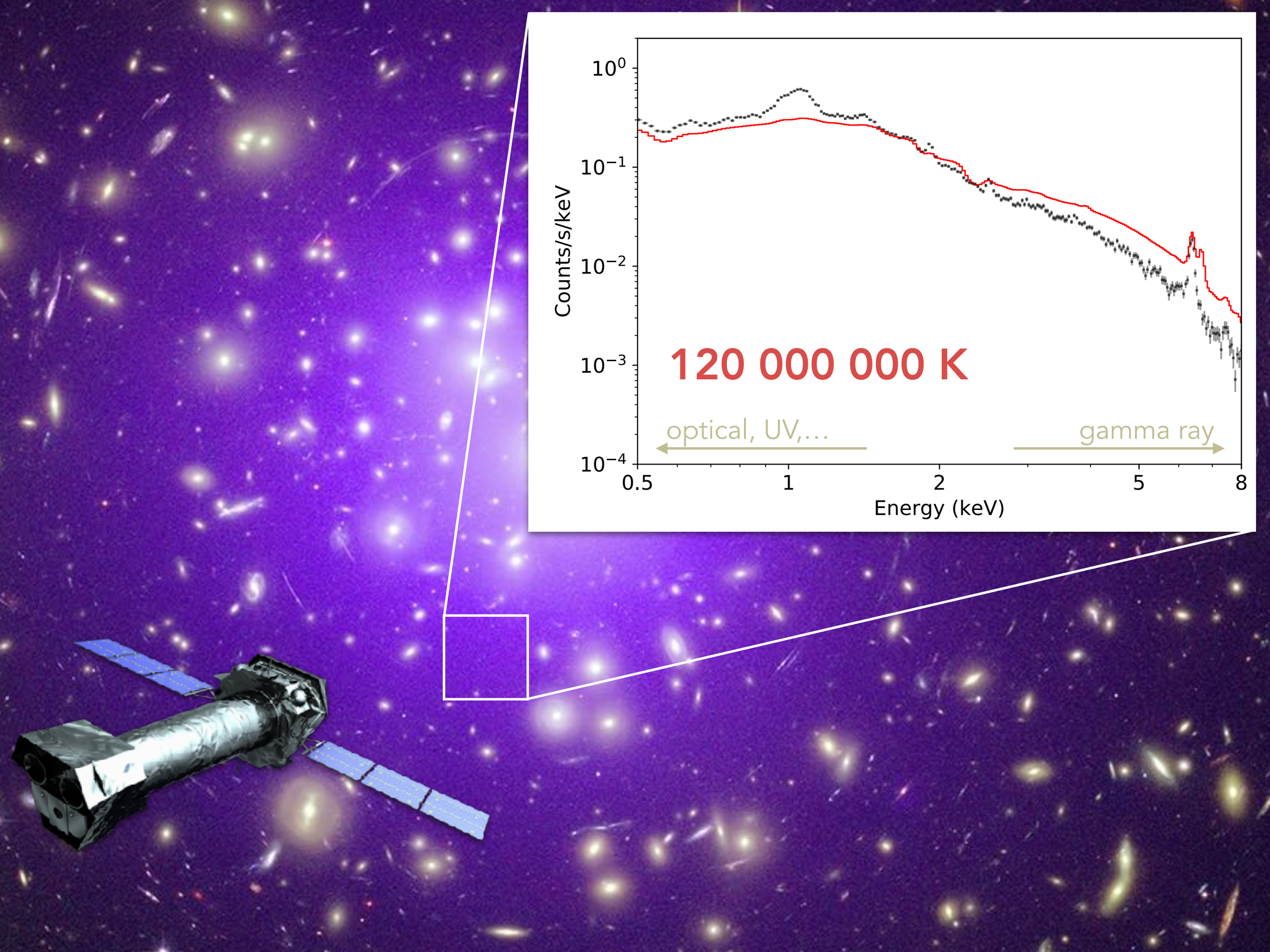


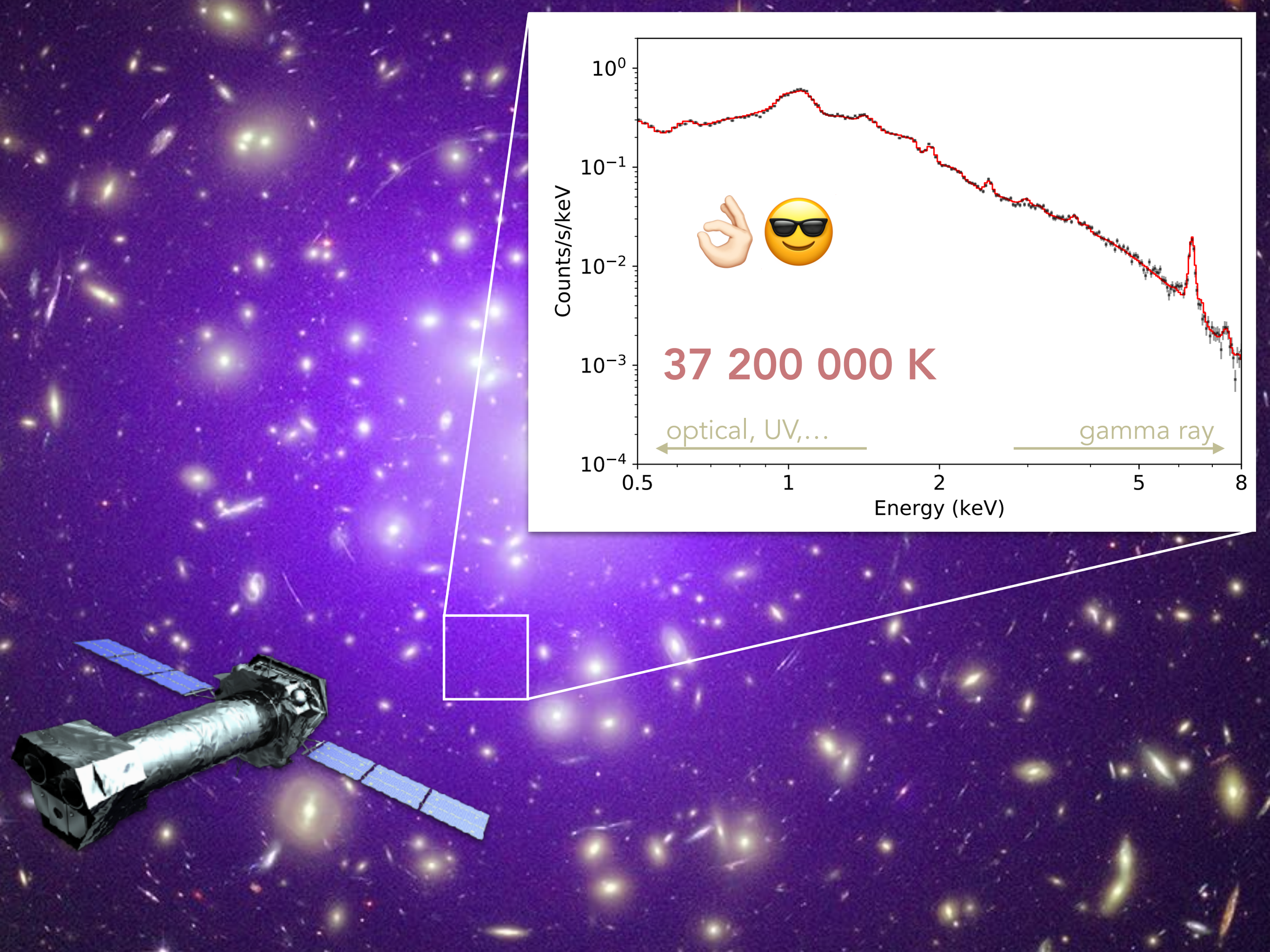
Chýbajúca normálna hmota

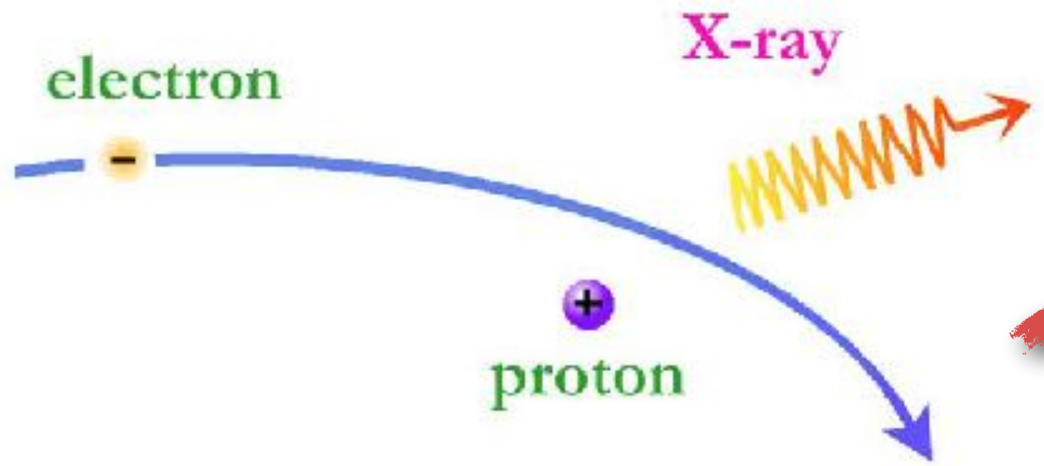





5′


Counts/s/keV
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0.5
1
2
5
8
Energy (keV)
120 000 000 K
optical, UV,...
gamma ray


Counts/s/keV
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0.5
1
2
5
8
Energy (keV)
37 200 000 K
optical, UV,...
gamma ray



Čím hustejšie tým jasnejšie

Vyžiarené unikajúce fotóny odnášajú energiu

Plyn chladne!

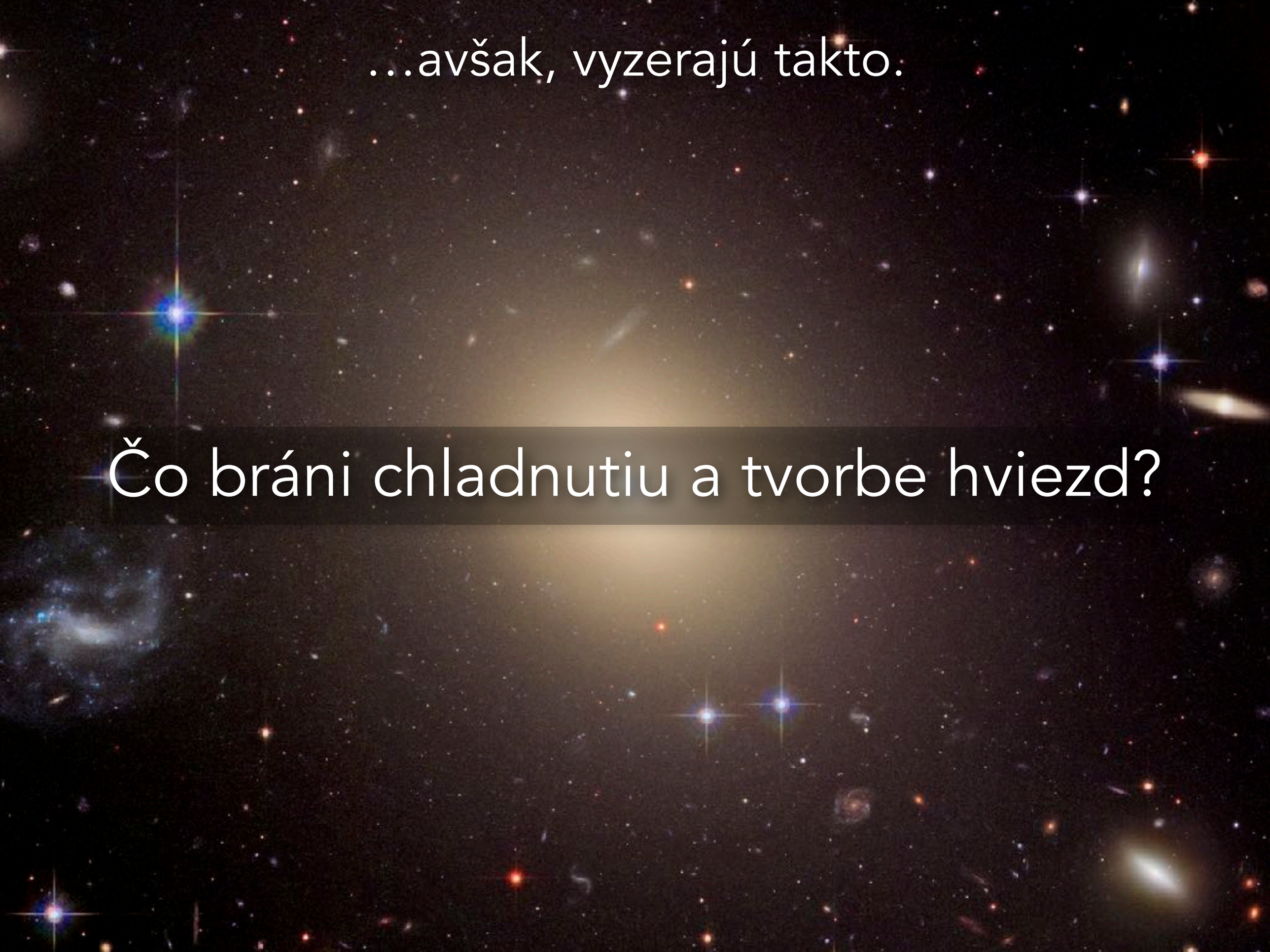
$PV = nkT$

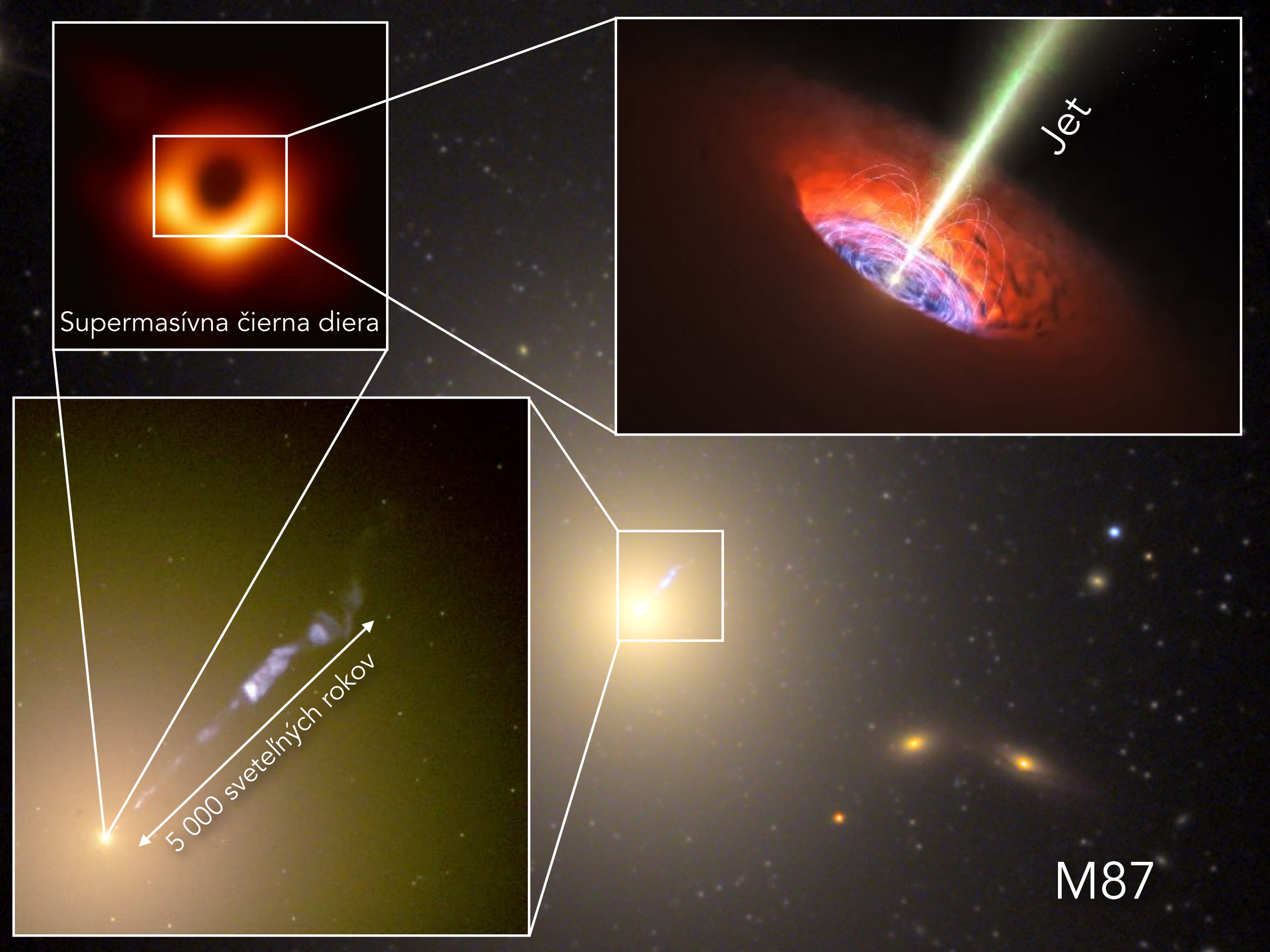
Tlak v strede kopy klesá !

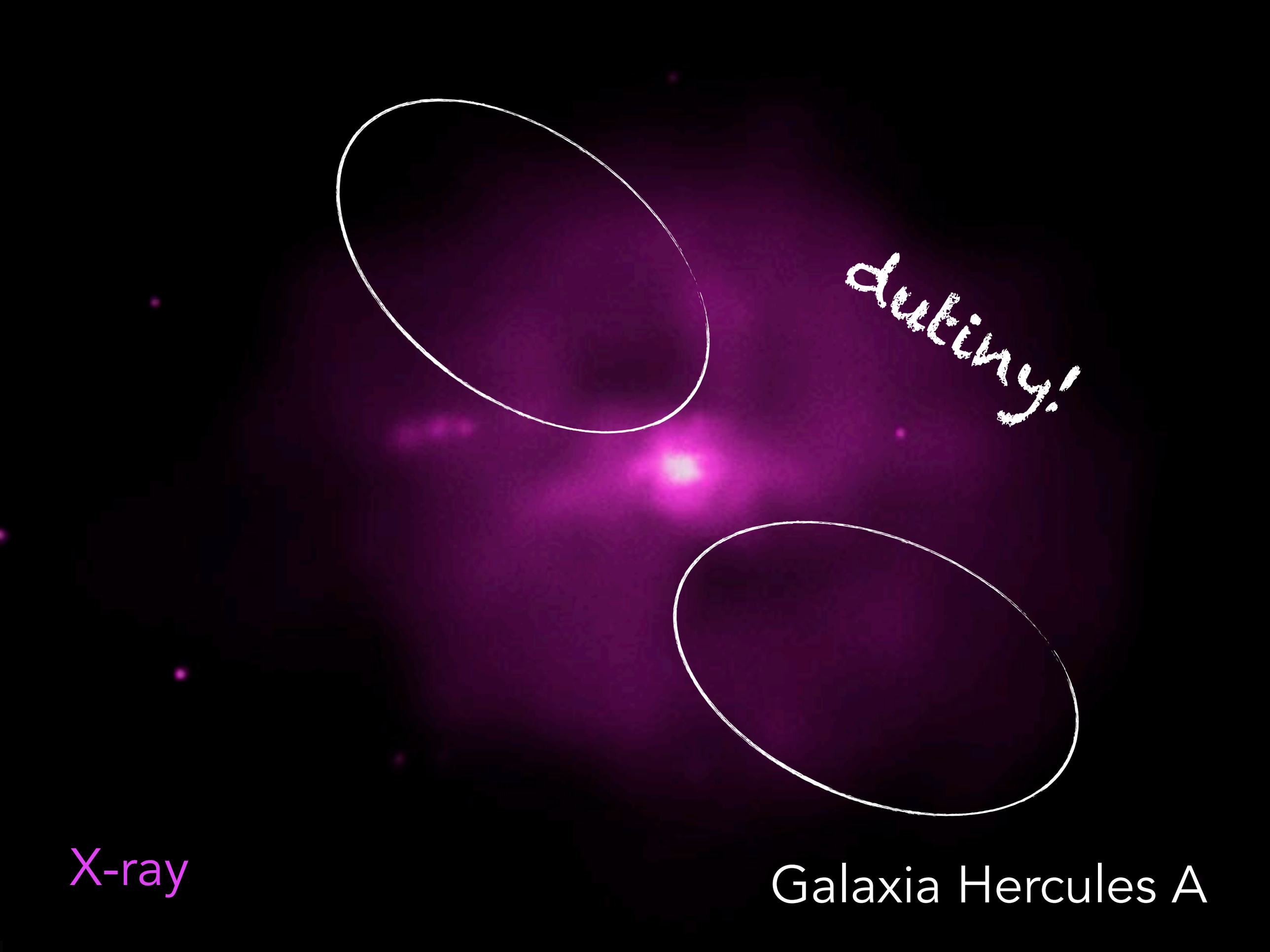
Okolitý plyn padá do stredu

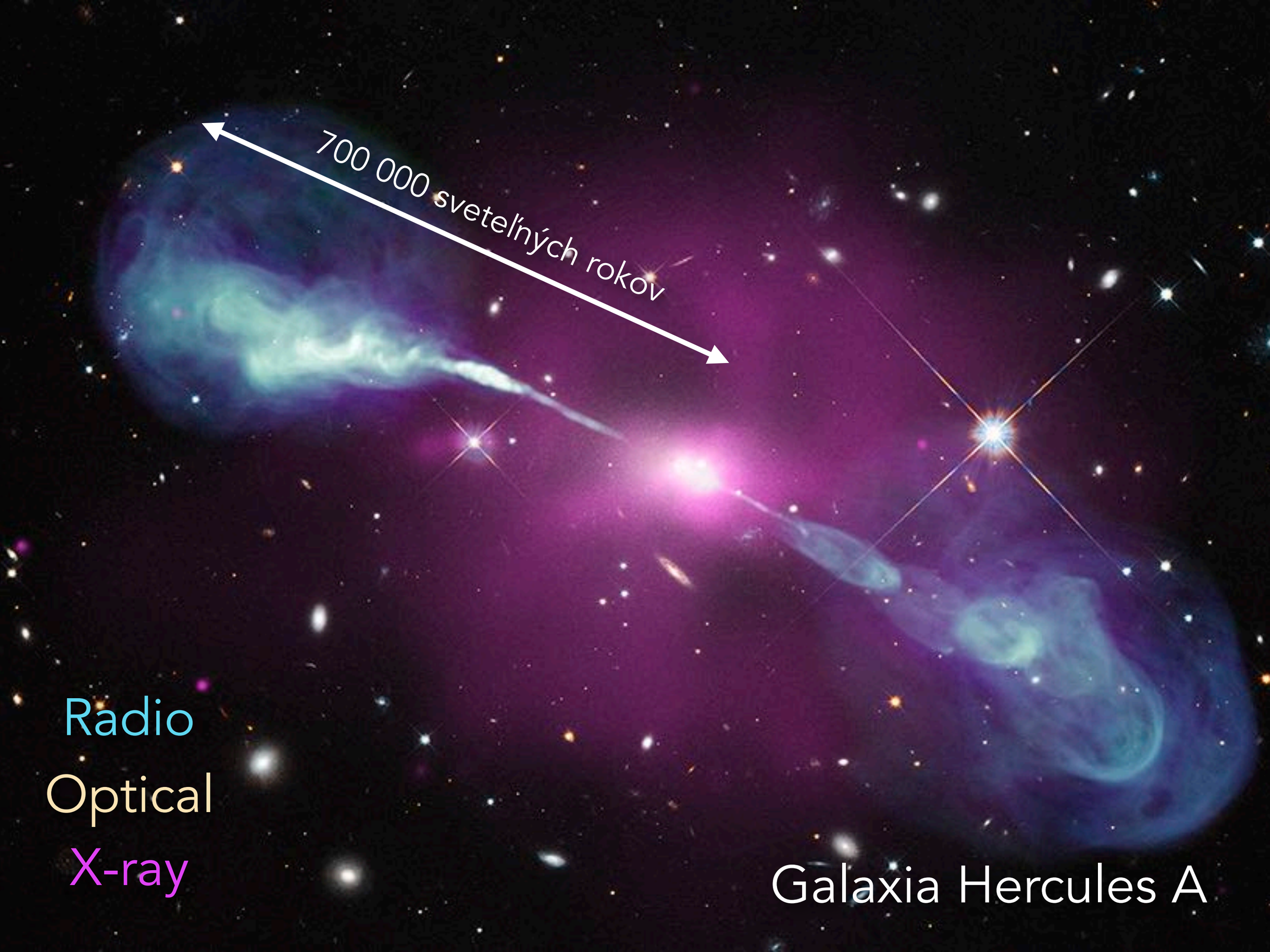
Hustota plynu sa zvyšuje!

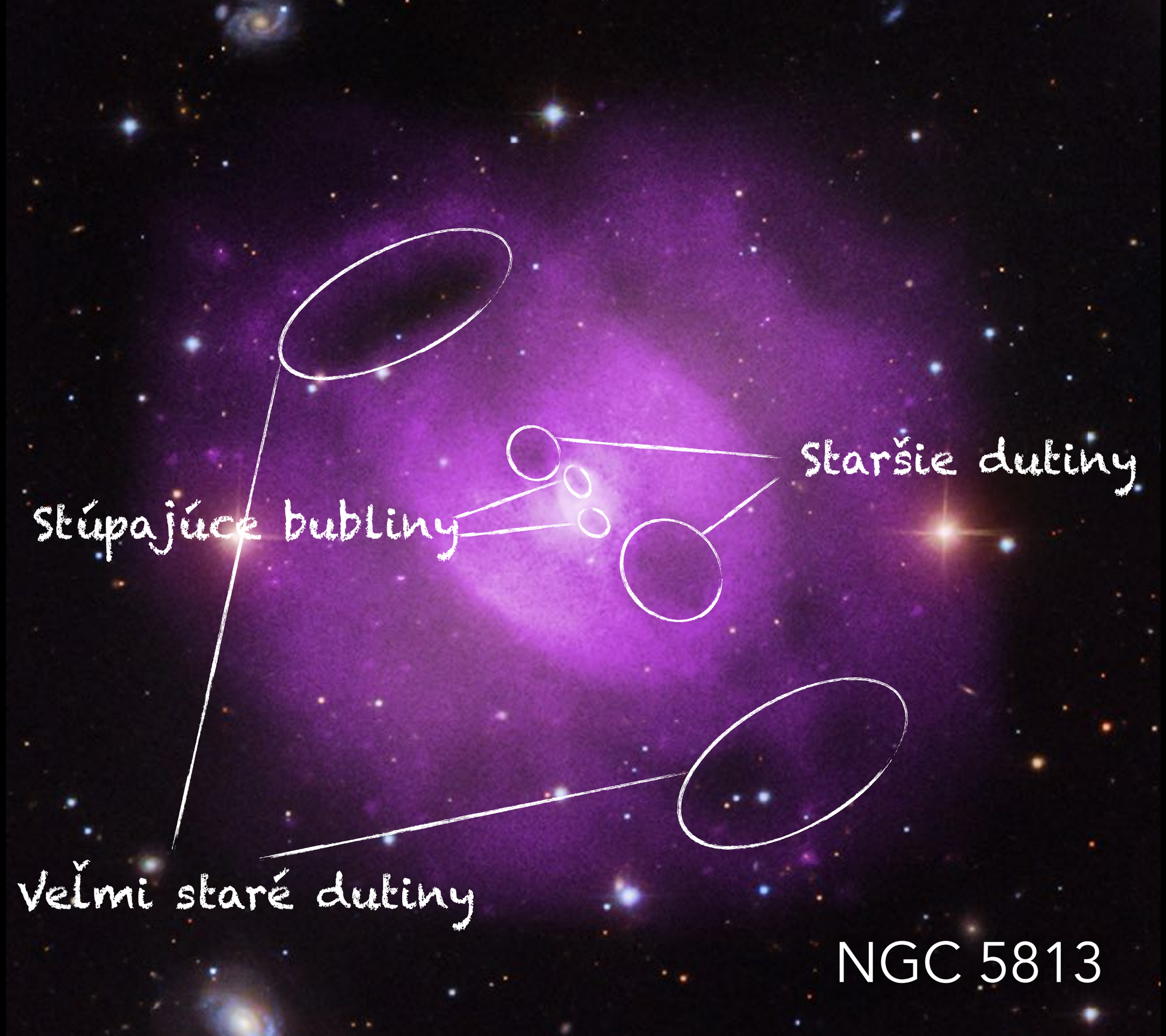
Galaxie v stredoch kôp galaxií by mali
vyzerať asi takto…


...avšak, vyzerajú takto.
Čo bráni chladnutiu a tvorbe hviezd?


Supermasívna čierna diera
Jet
5 000 svetelných rokov
M87


dutiny!
X-ray
Galaxia Hercules A

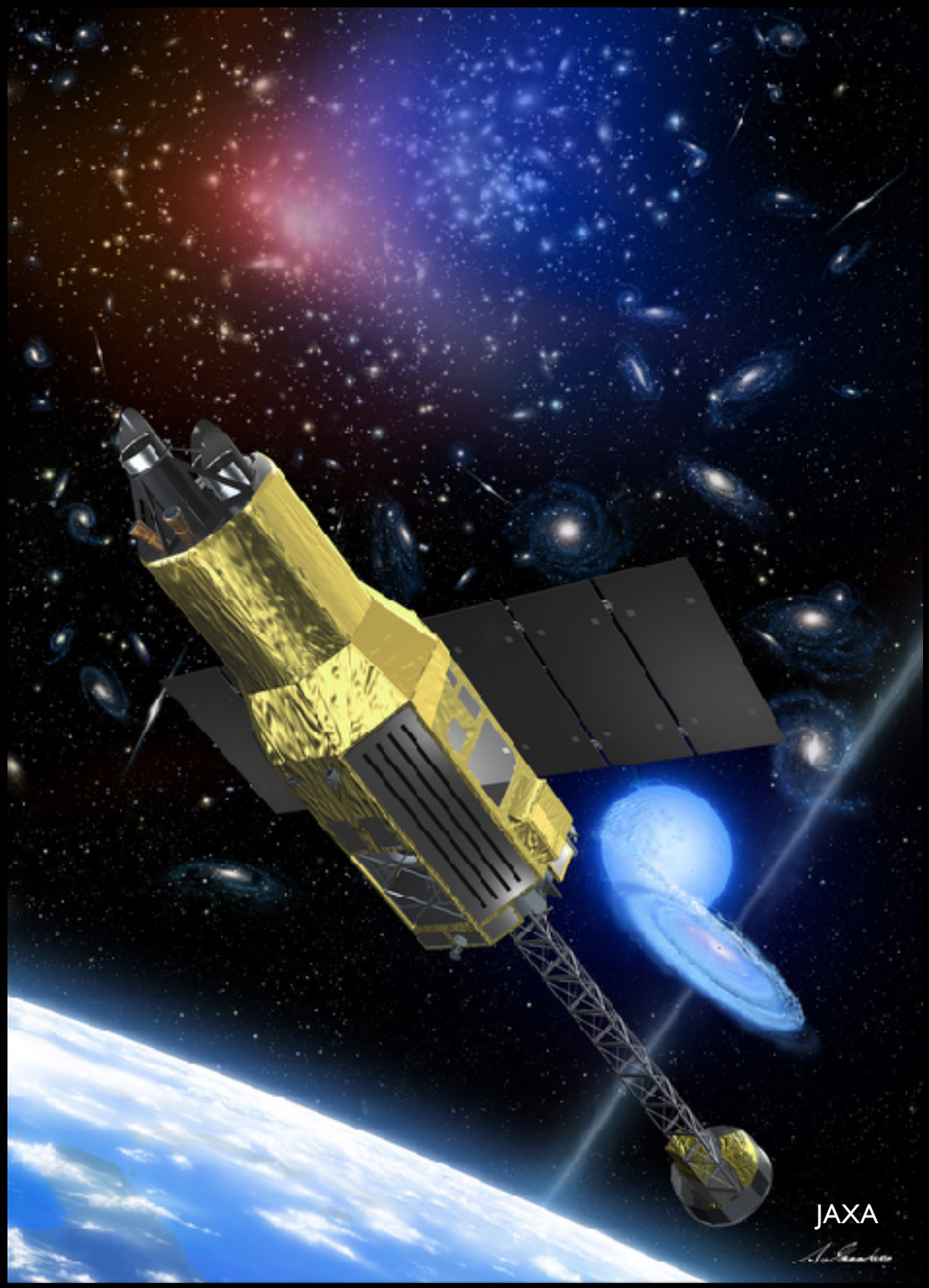

700 000 svetelných rokov
Radio
Optical
X-ray
Galaxia Hercules A


Staršie dutiny
Stúpajúce bubliny
Veľmi staré dutiny
NGC 5813

Kopa galaxií v Perzeovi

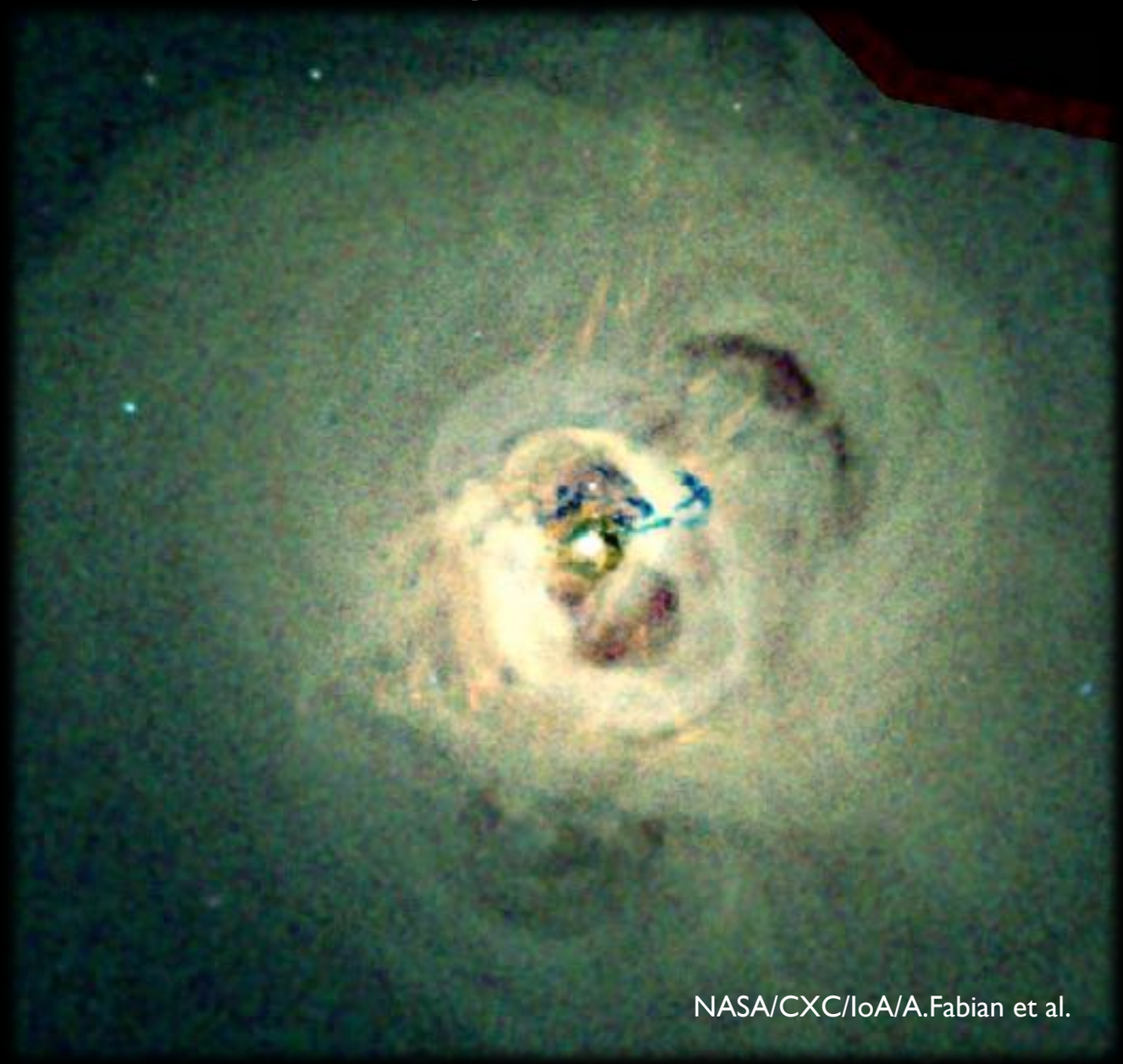
Tanegashima, Japan
JAXA

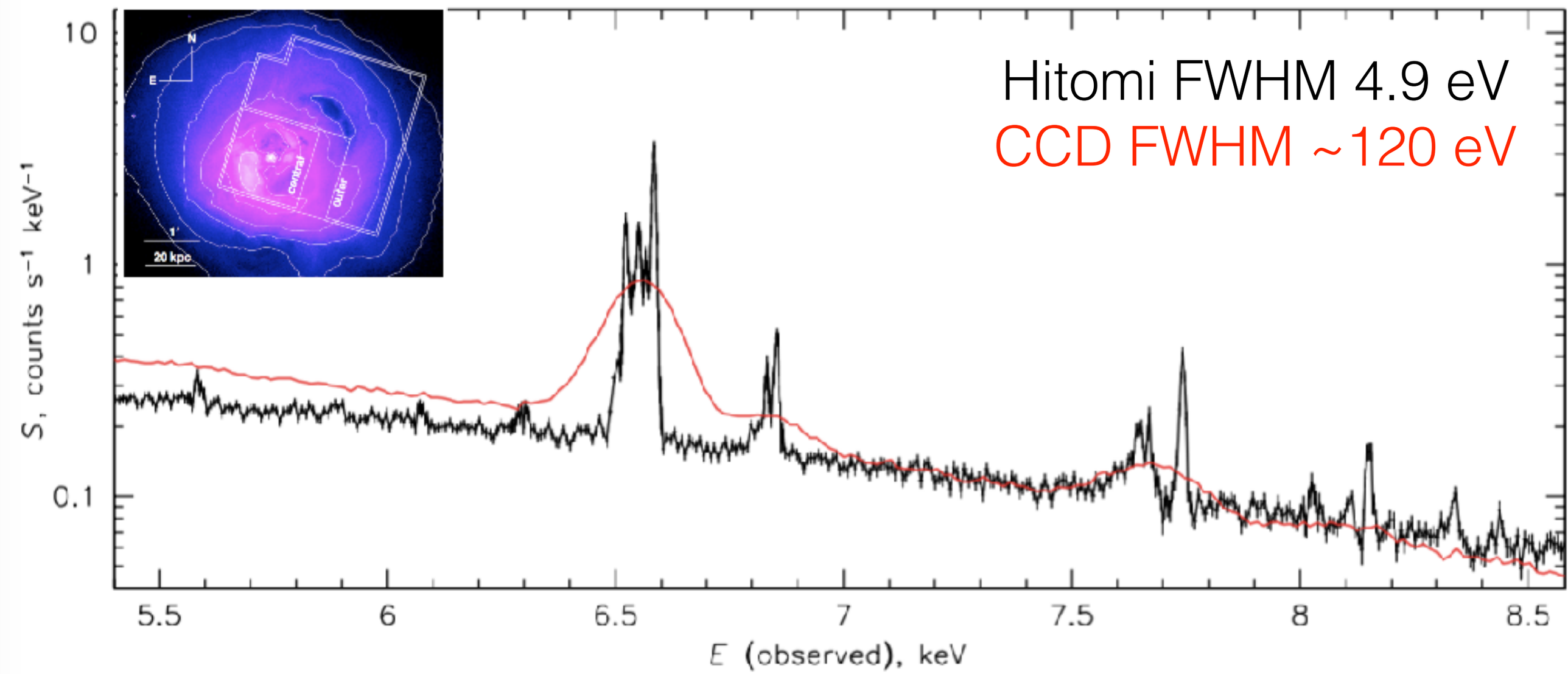
Feb 17 - Mar 26, 2016



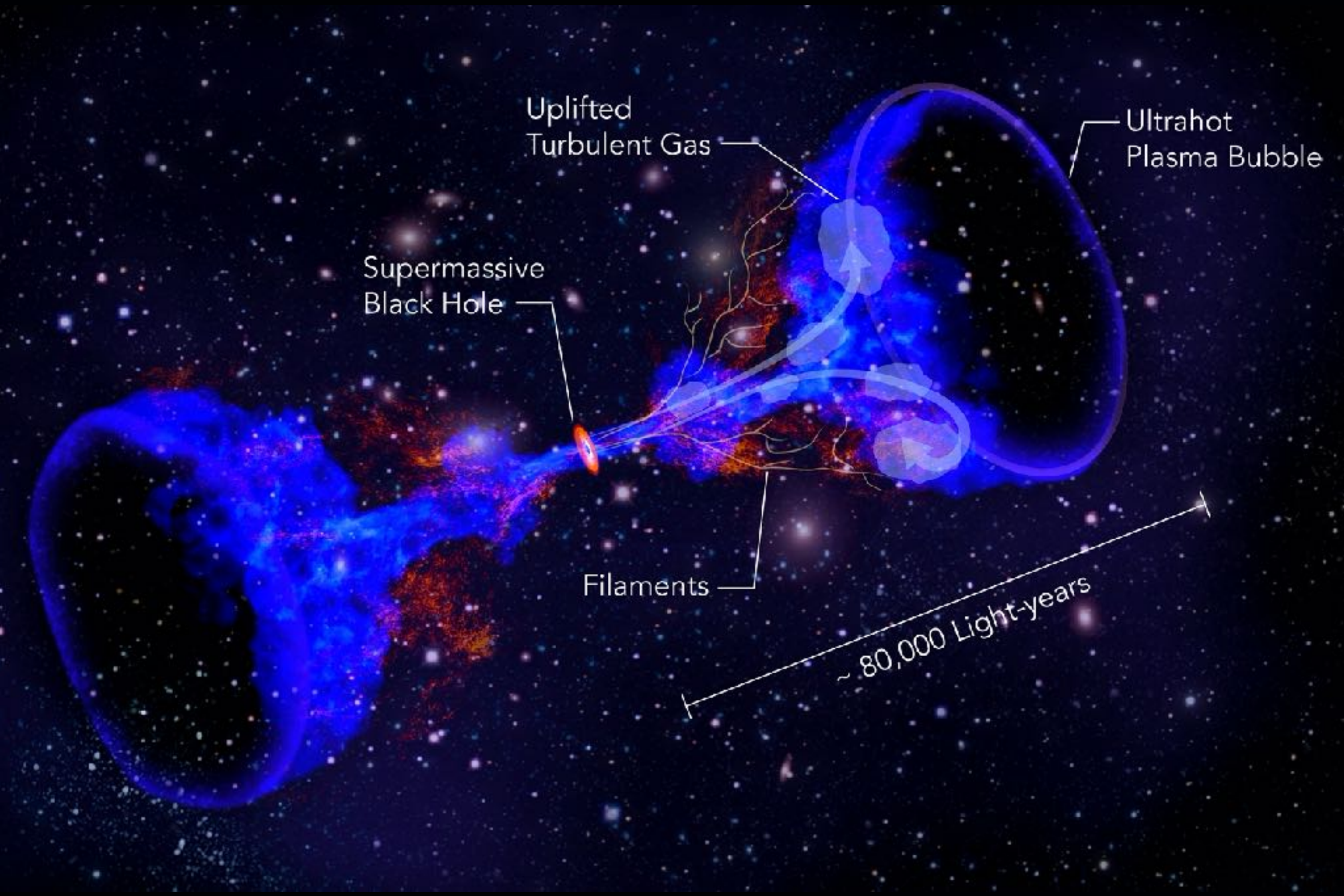
Kopa galaxií v Perzeovi

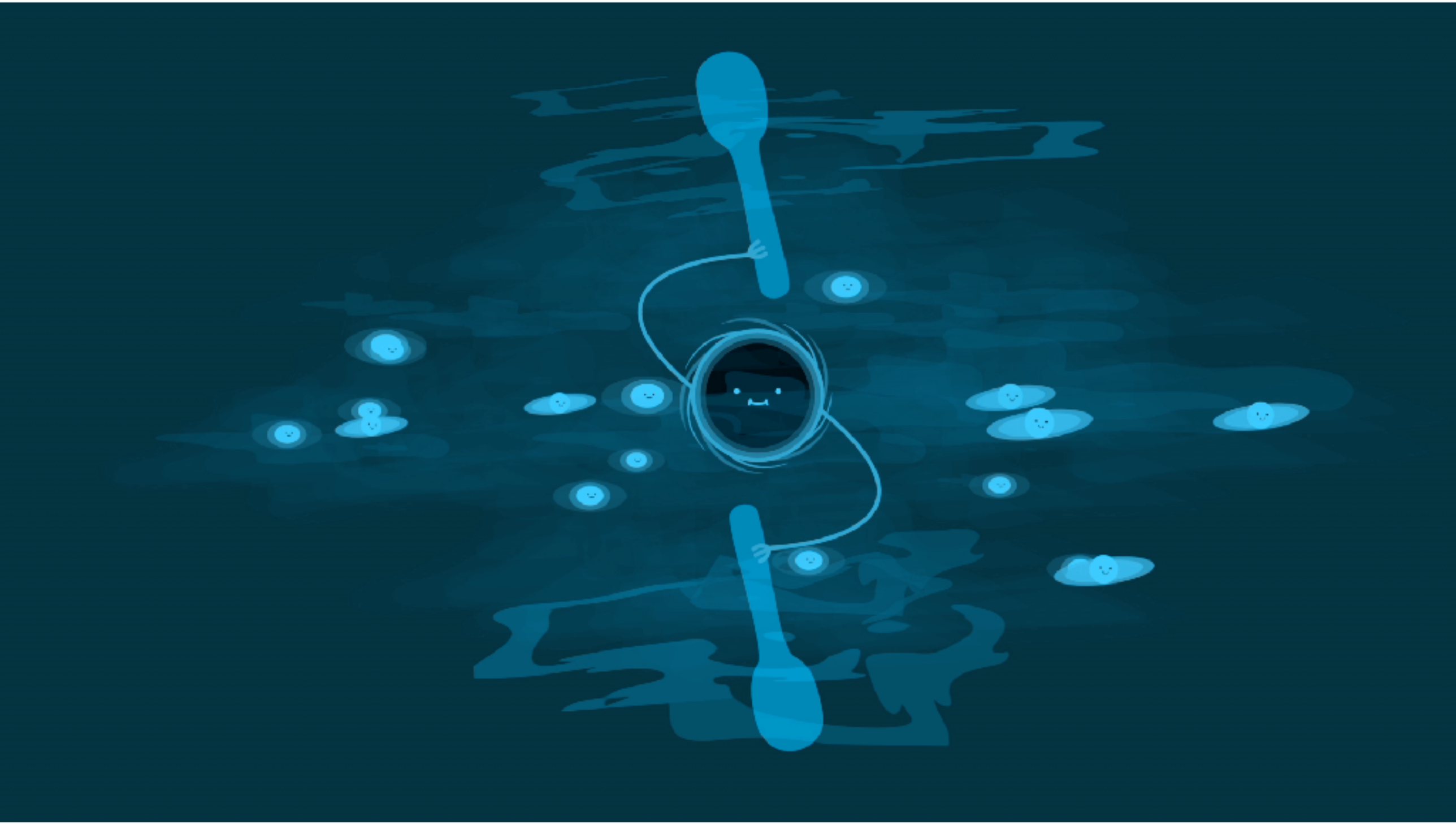
3 dni pozorovania



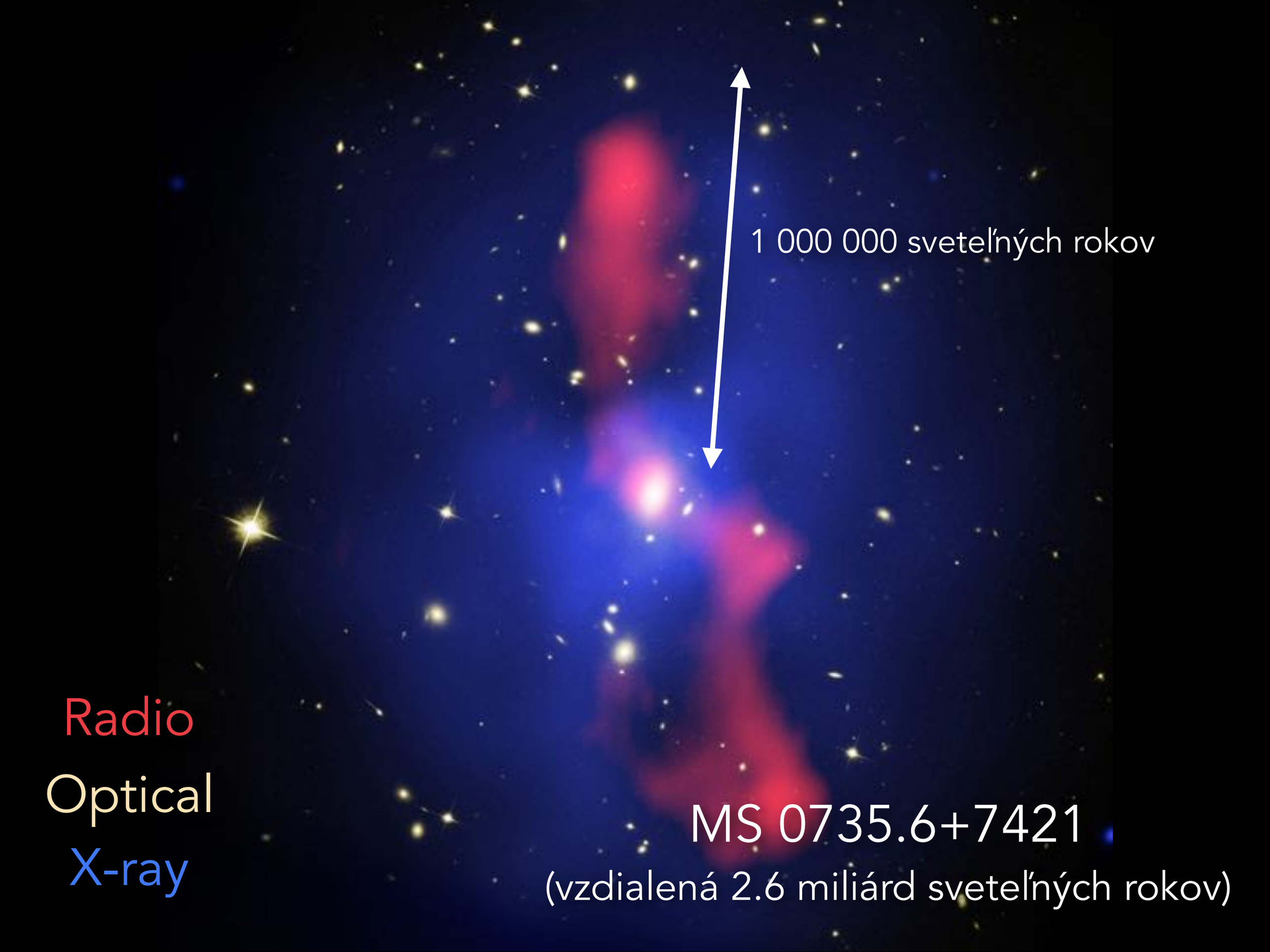


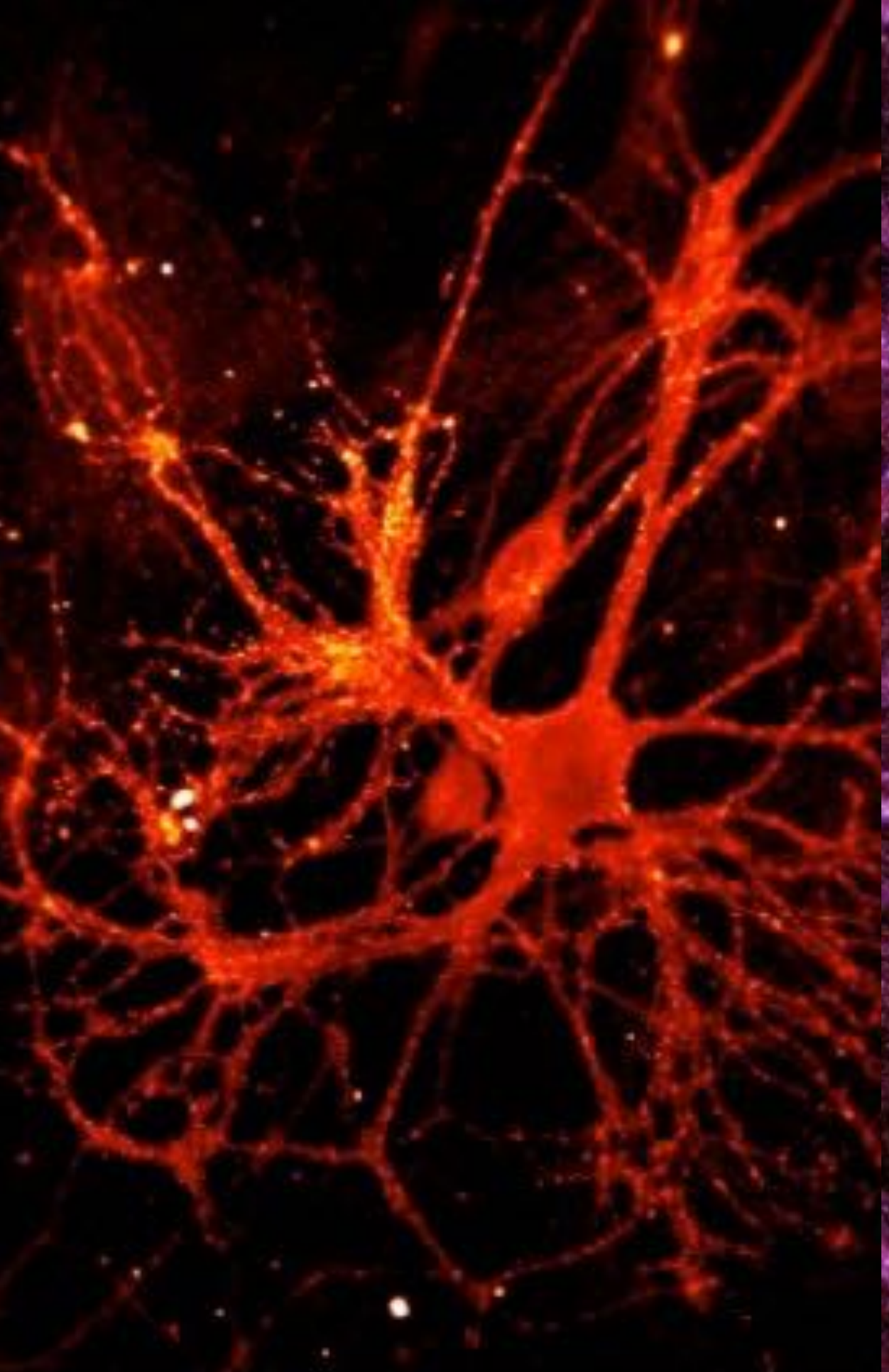
Hitomi collaboration, Nature, 2016

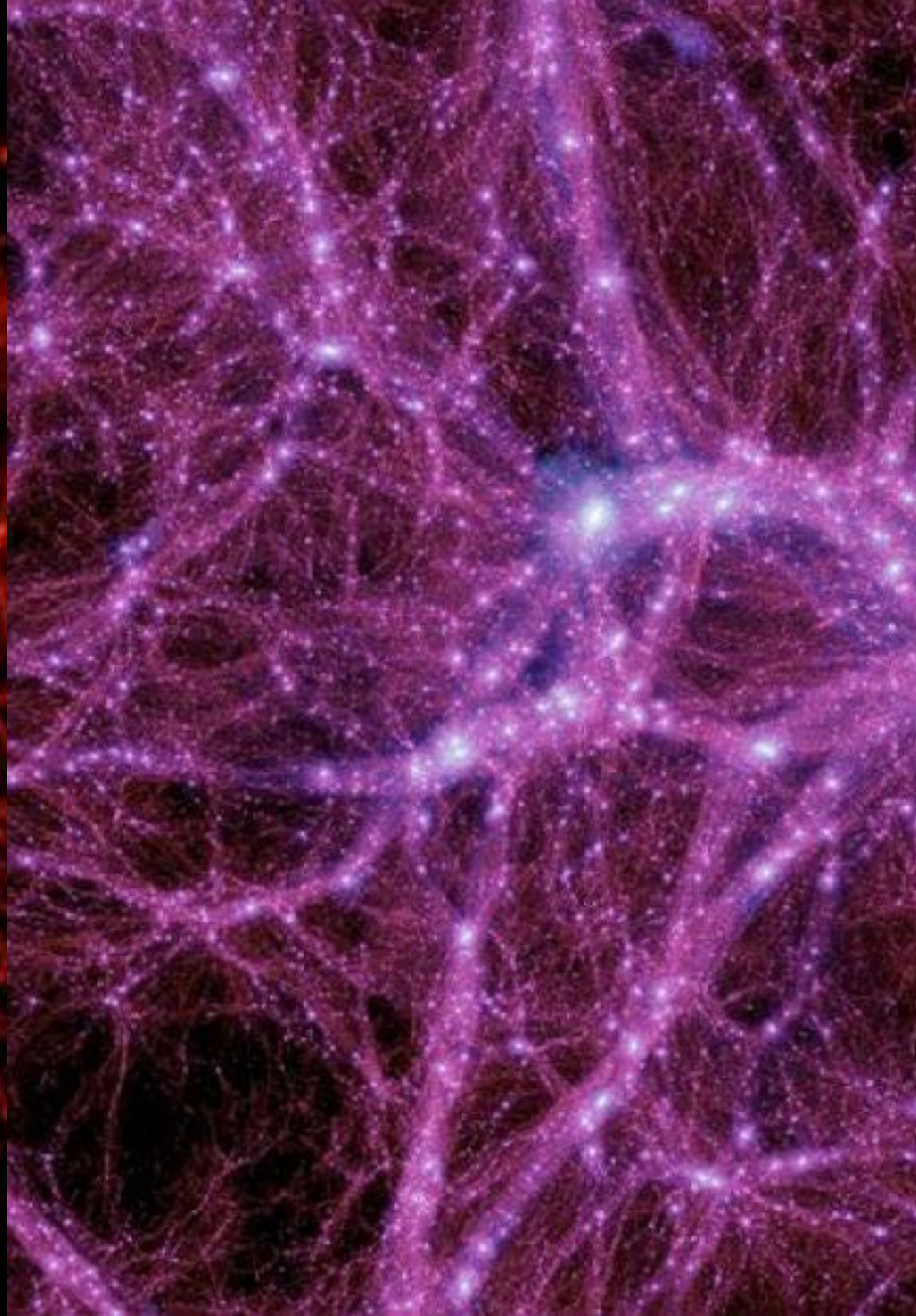

Uplifted
Turbulent Gas
Ultrahot
Plasma Bubble
Supermassive
Black Hole
Filaments
~ 80,000 Light-years



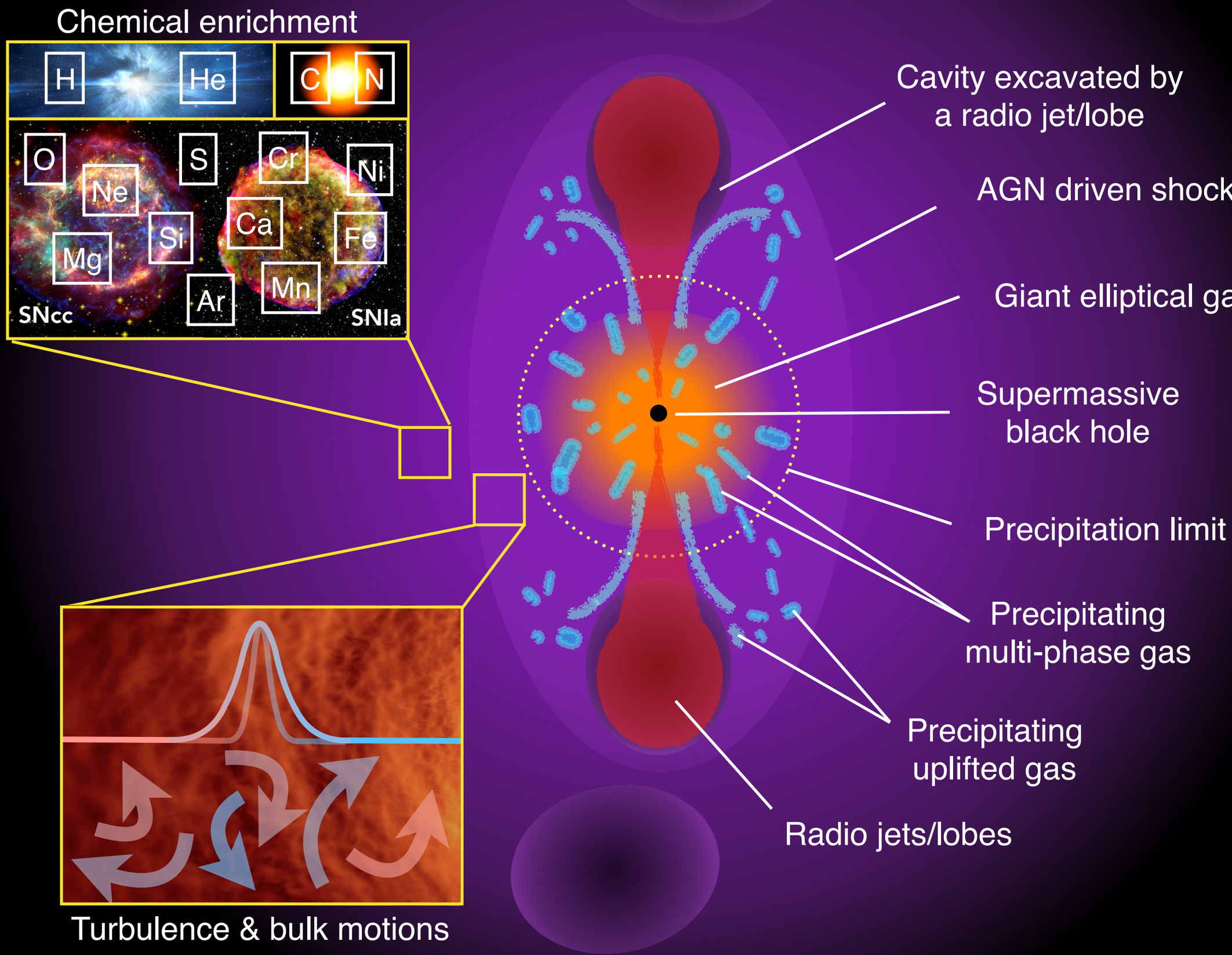
dutiny!
Radio
Optical
X-ray
MS 0735.6+7421 (2.6 billion light years)


1 000 000 sveteľných rokov
Radio
Optical
X-ray
MS 0735.6+7421
(vzdialená 2.6 miliárd sveteľných rokov)

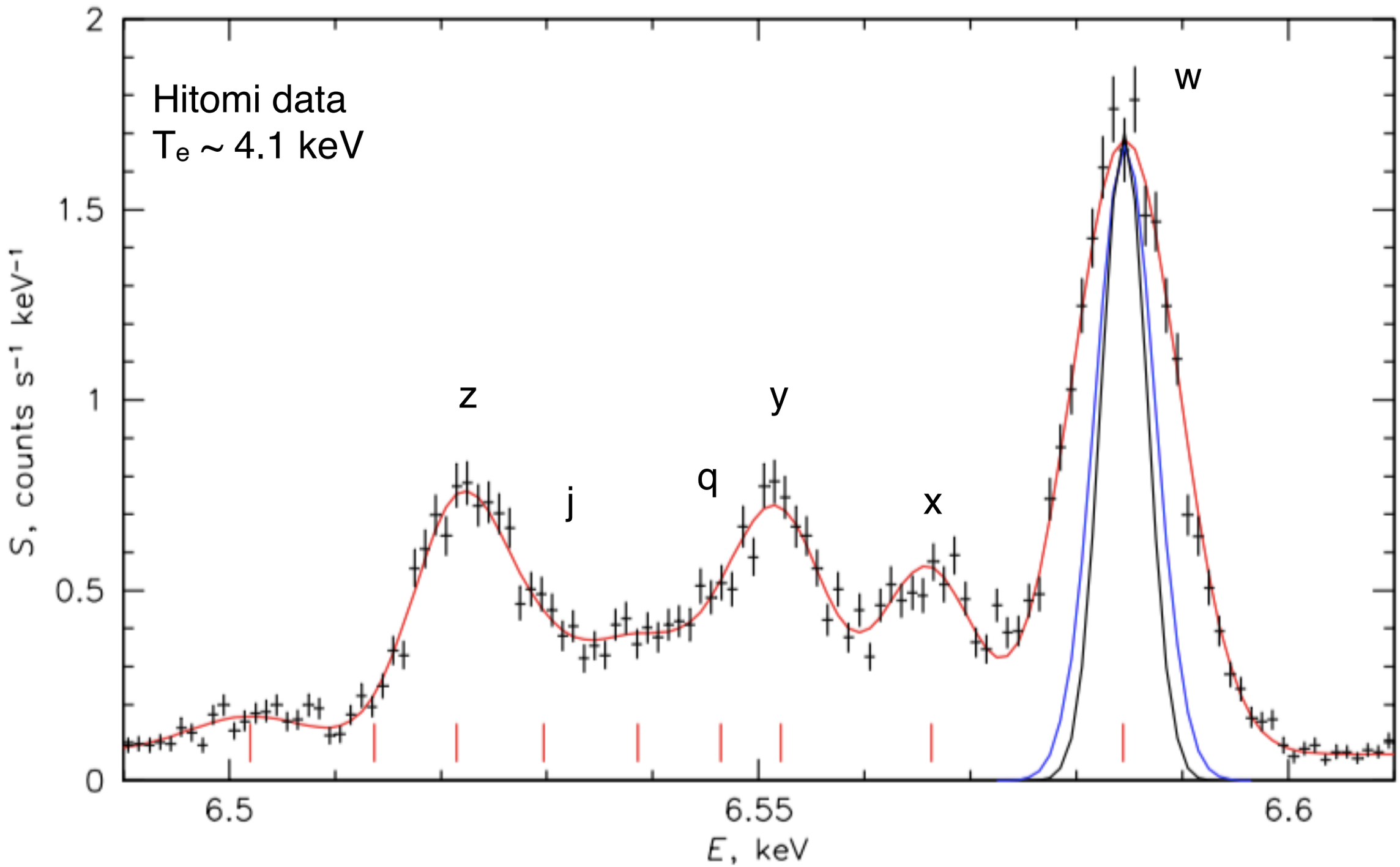




Hot Atmosphere

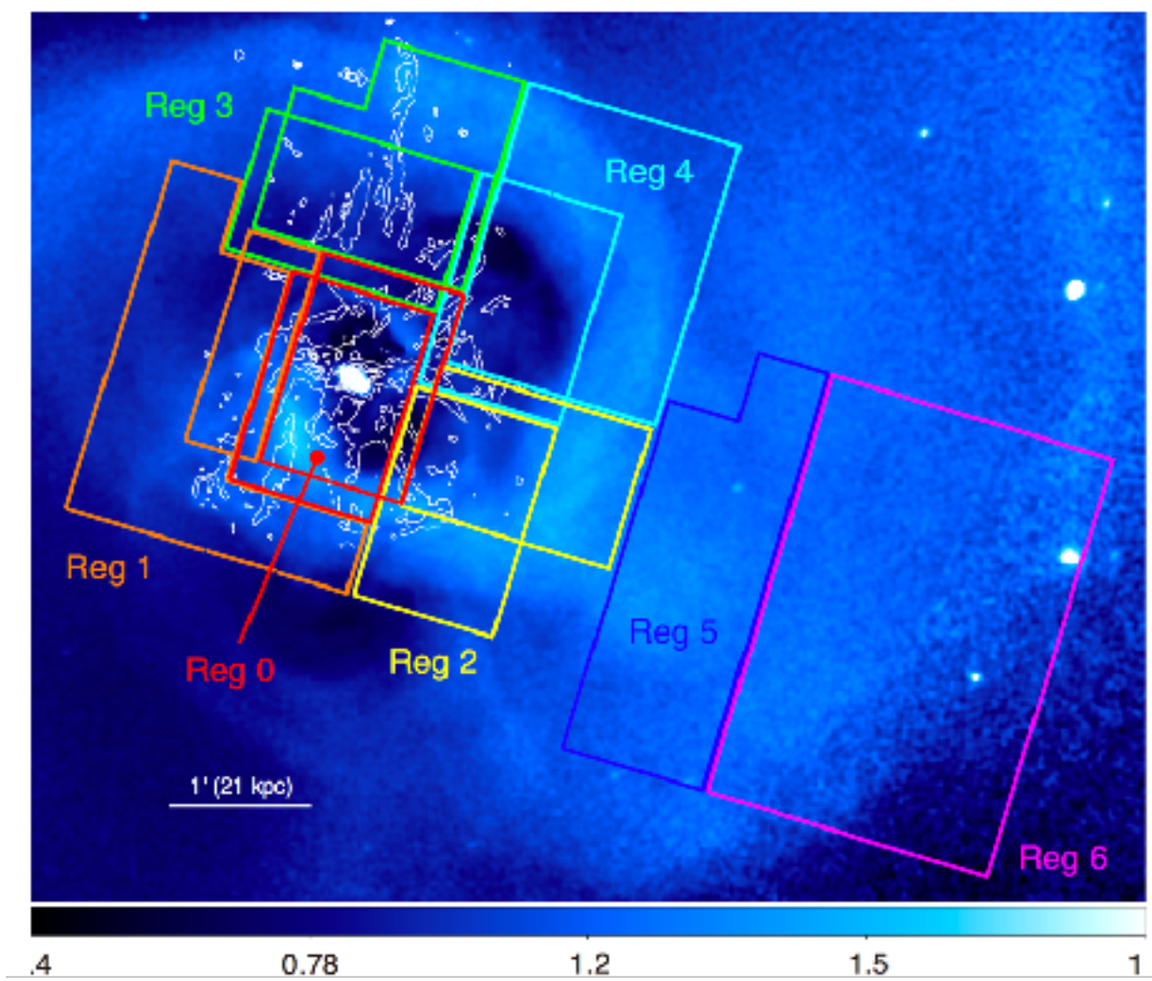


Fe XXV Heα

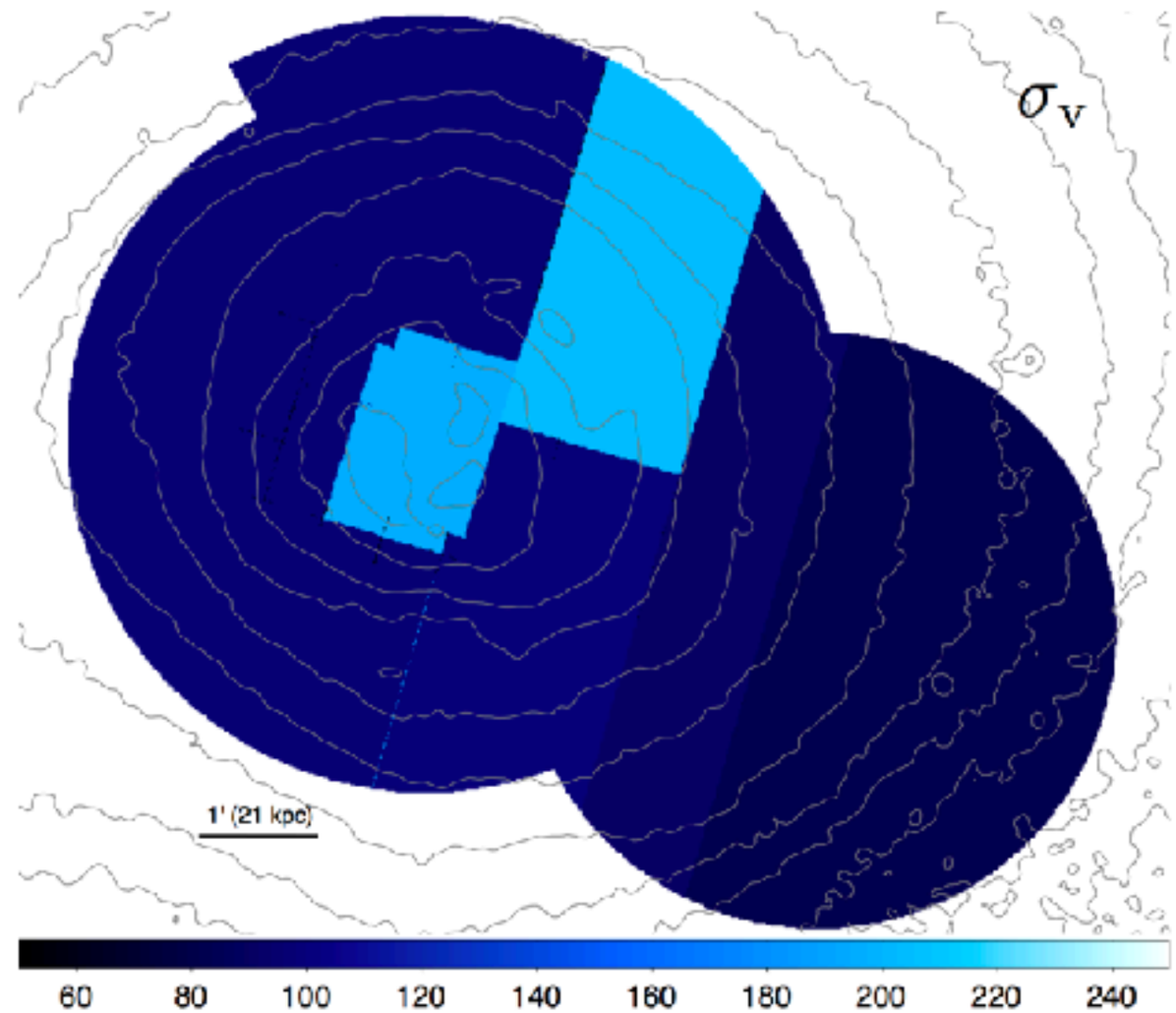


Hitomi collaboration, Nature, 2016

First Direct Velocity Measurements



line broadening



[km/s]

$E_{turb}/E_{therm} \sim 2\text{–}6\%$

Hitomi collaboration, PASJ 2018