
LYNX X-RAY OBSERVATORY

*a new* GREAT OBSERVATORY

**PROVEN ARCHITECTURE**
DESIGNED *for* LONG LIFE

GIANT LEAPS
*in* SCIENCE CAPABILITY

STRONG HERITAGE
**MATURE** TECHNOLOGIES
RELIABLE COST

SCALEABLE | PARRALLIZABLE | COSTED

37,492 **SEGMENTS**

611 **MODULES**

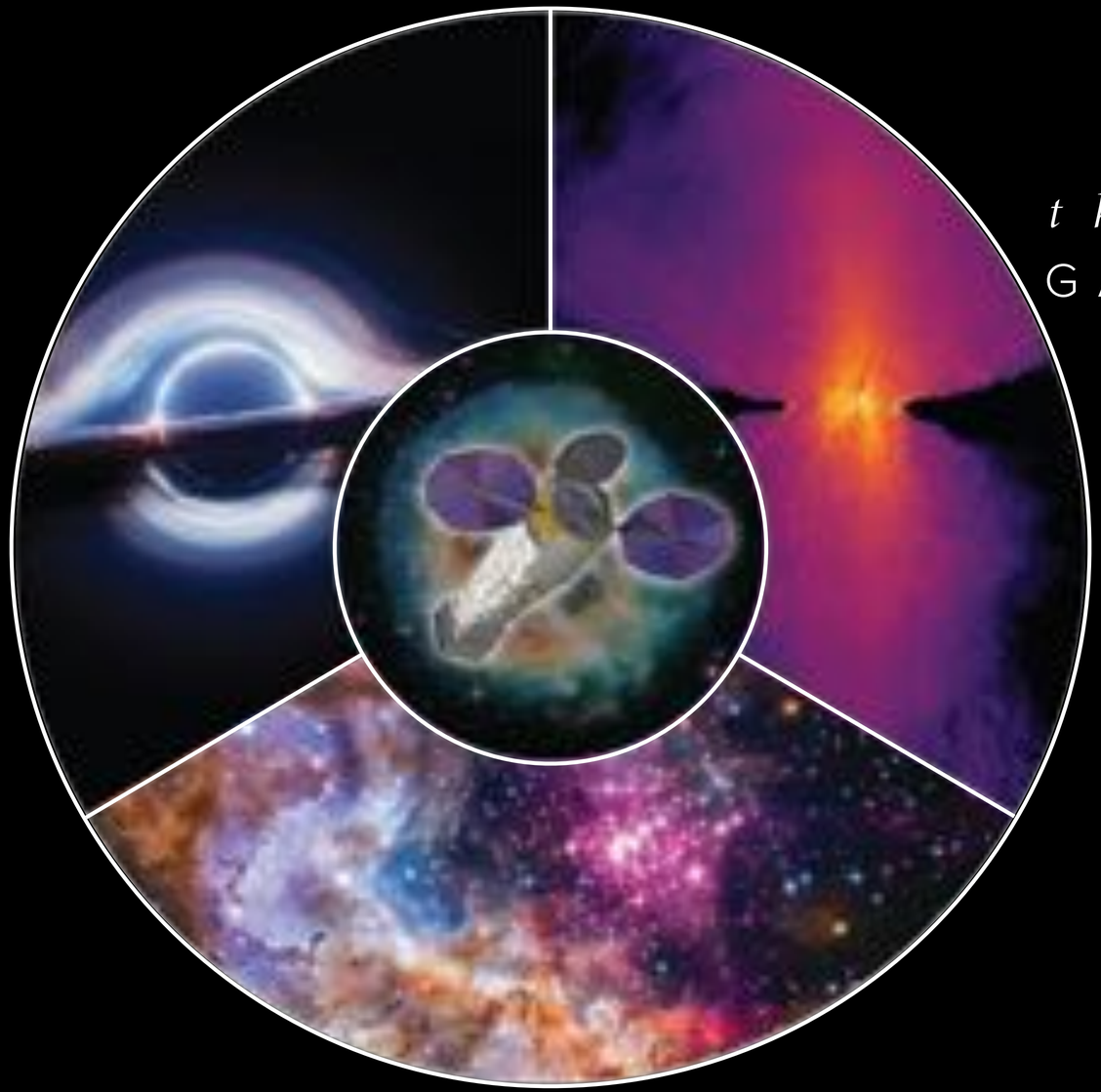
12 **META-SHELLS**

1 **ASSEMBLY**

WE **KNOW** HOW TO BUILD IT **NOW**

*a new* GREAT OBSERVATORY

*the* DAWN *of* BLACK HOLES

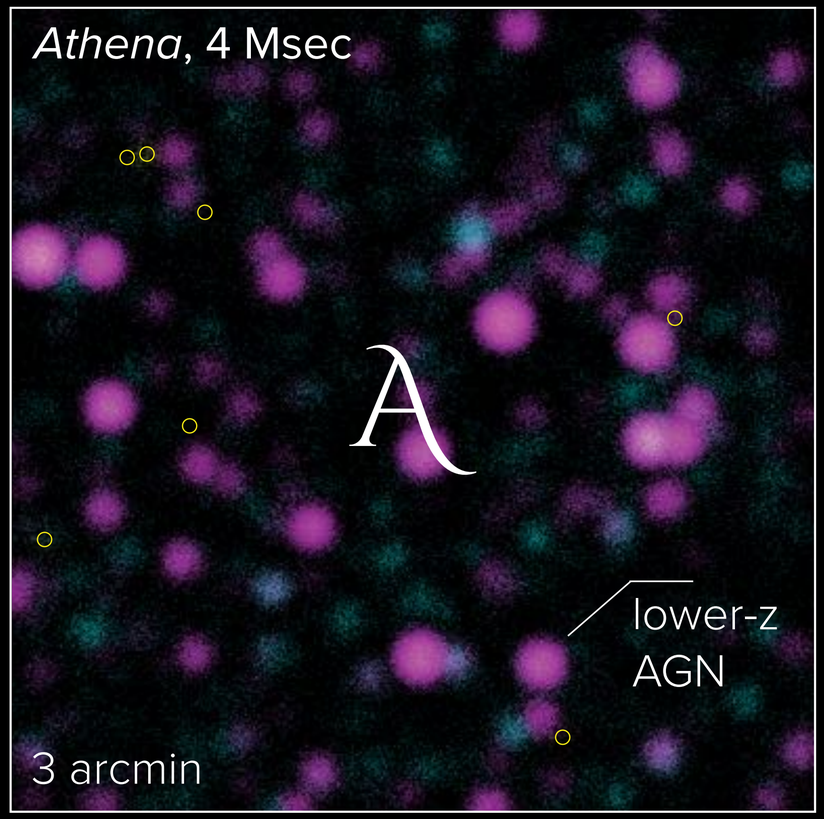


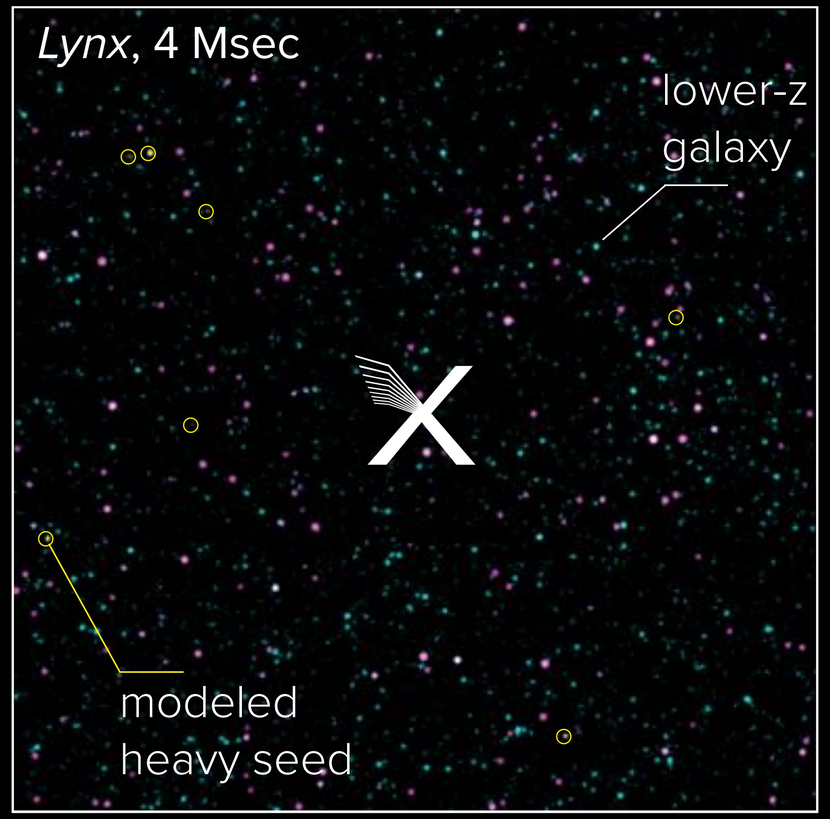
*the* DRIVERS *of* GALAXY EVOLUTION

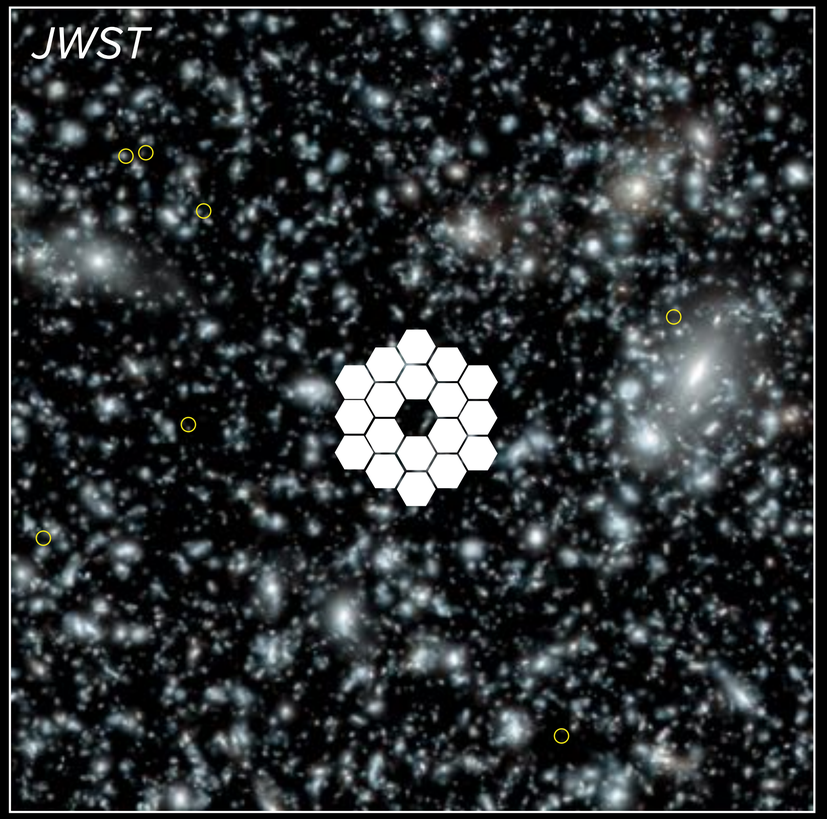
*the* ENERGETIC SIDE *of* STELLAR EVOLUTION


- Black holes define many aspects of cosmic evolution
- Were in place very early in the history of the Universe
- **What is their origin? Light seeds or heavy seeds? Did any of the massive BH form directly into $10^5$ $M_{\rm Sun}$ objects?**

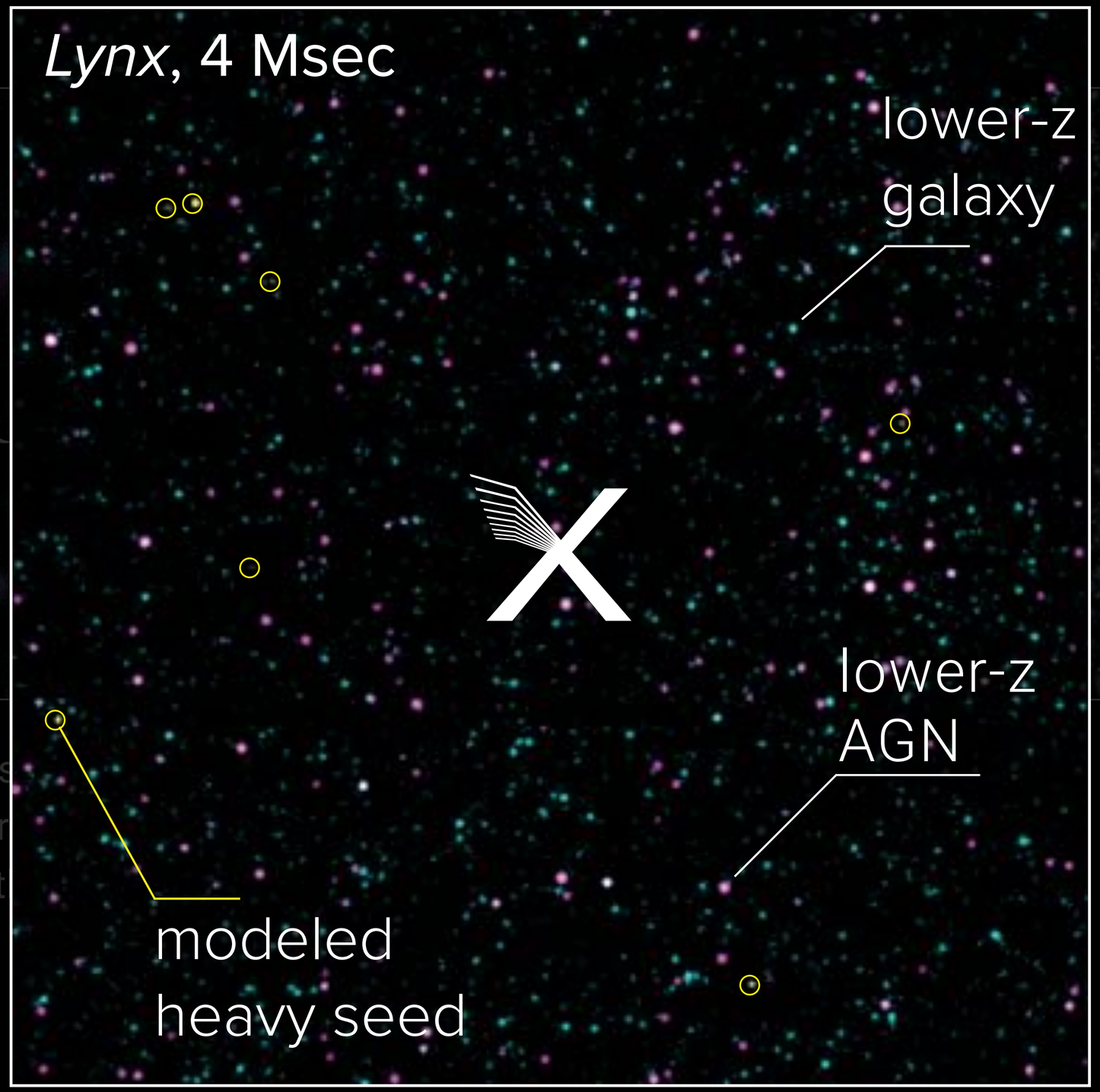
# *the* DAWN *of* BLACK HOLES




**Key observations:** surveys over ~1 deg$^2$ down to $f_X \sim 10^{-19}$ erg s$^{-1}$ cm$^{-2}$ to detect black hole seeds with $M_{BH} = 10{,}000\ M_{SUN}$ at $z = 10$




*Athena*, 4 Msec

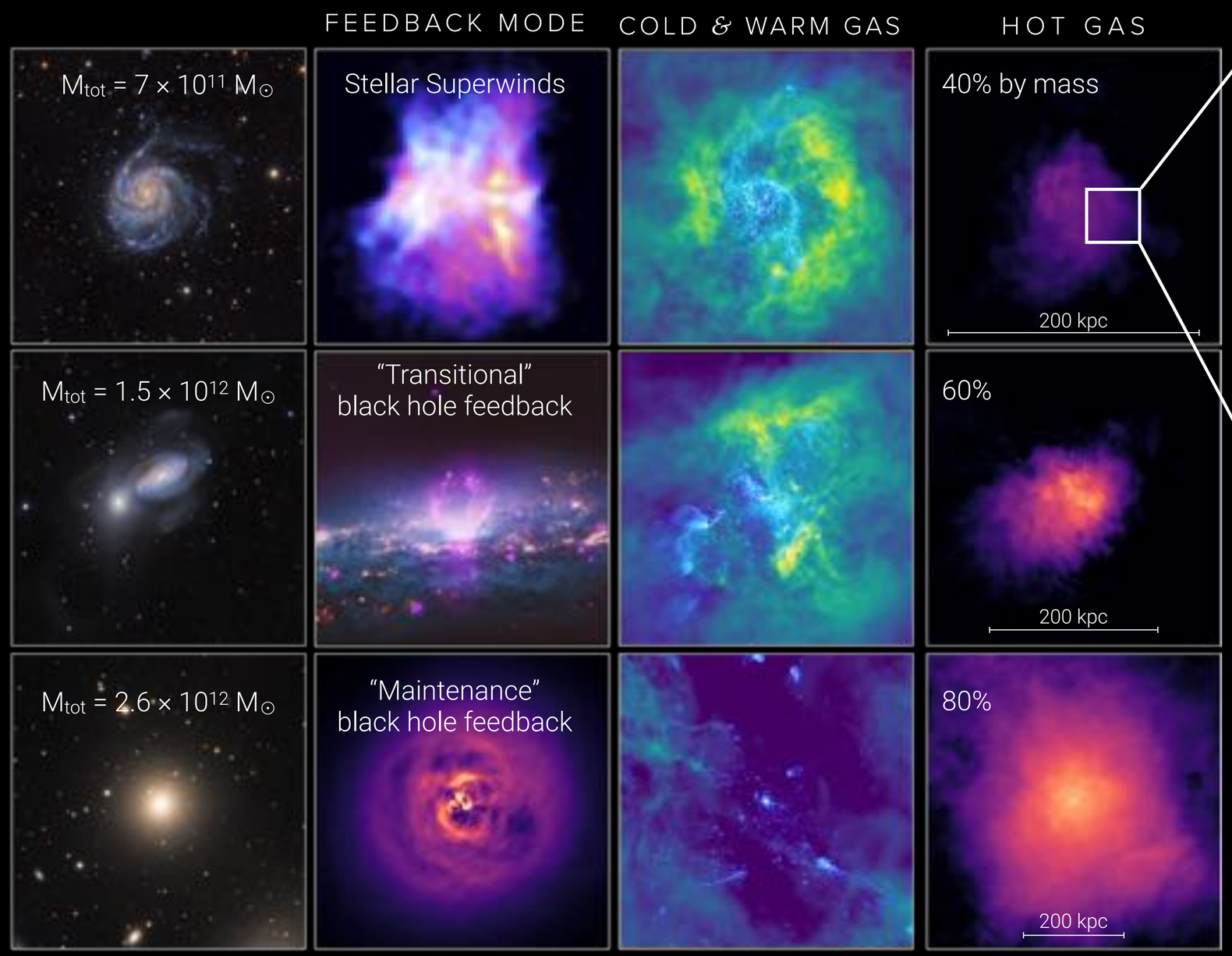
3 arcmin

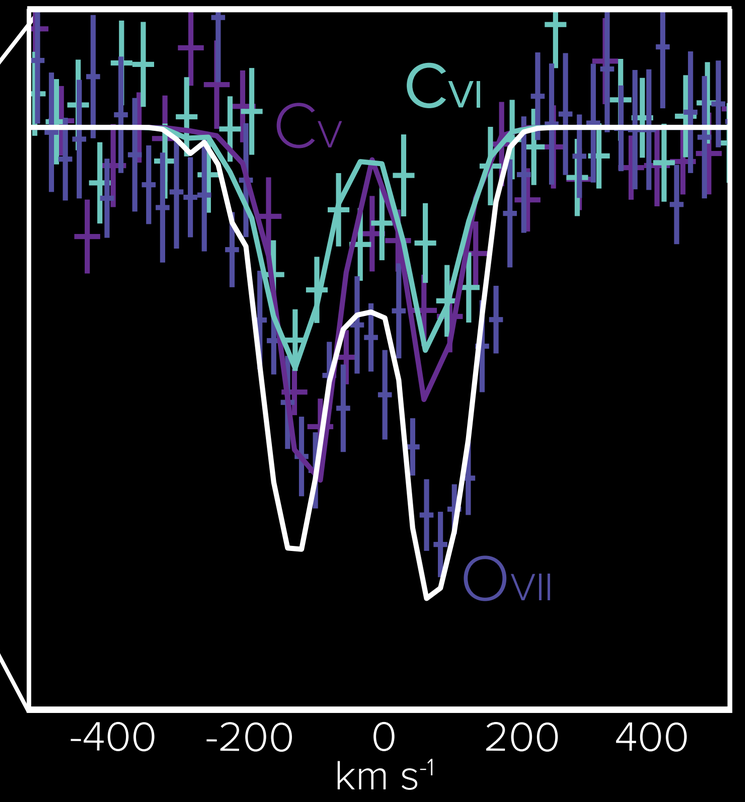
**Key observations:** s
down to $f_X \sim 10^{-19}$ er
black hole seeds wit
at $z = 10$

# *the* DRIVERS *of* GALAXY EVOLUTION

- Exquisite data available on stellar, dust, and cold gas contents of galaxies.
- Yet, there is a dearth of understanding of their exact formation mechanism
- **Main drivers are inprinted in hot CGM and in signatures of on-going feedback**

# *the* DRIVERS *of* GALAXY EVOLUTION
## *the* HOT CIRCUMGALACTIC MEDIUM



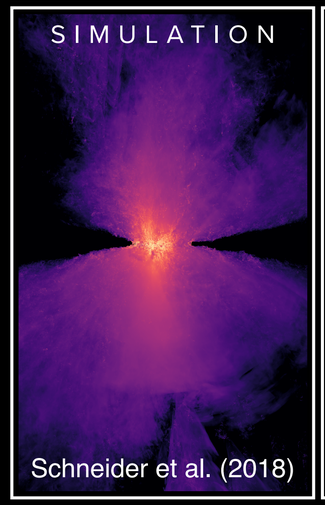



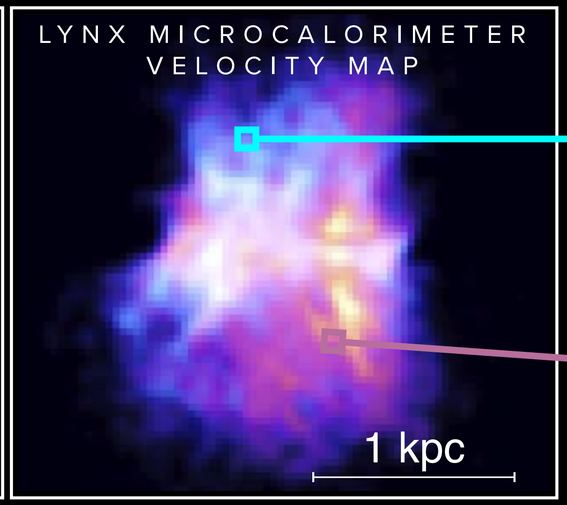

Key requirements:

- <1" PSF, $A_{eff}$ = 2 $m^2$ to map CGM in emission to ~ 0.5 $r_{200}$
- R>5000 to probe CGM in absorption beyond virial radius

# *the* DRIVERS *of* GALAXY EVOLUTION

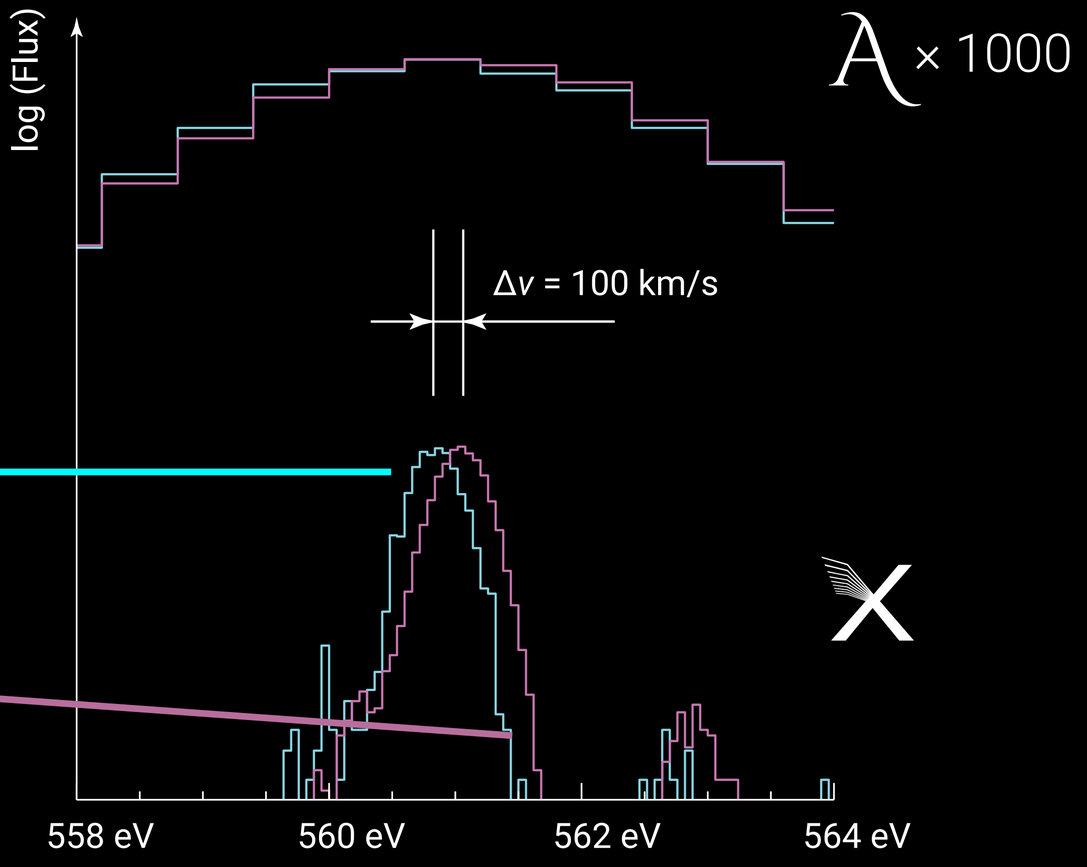
## — FEEDBACK *in* ALL MODES, *on* ALL SCALES —

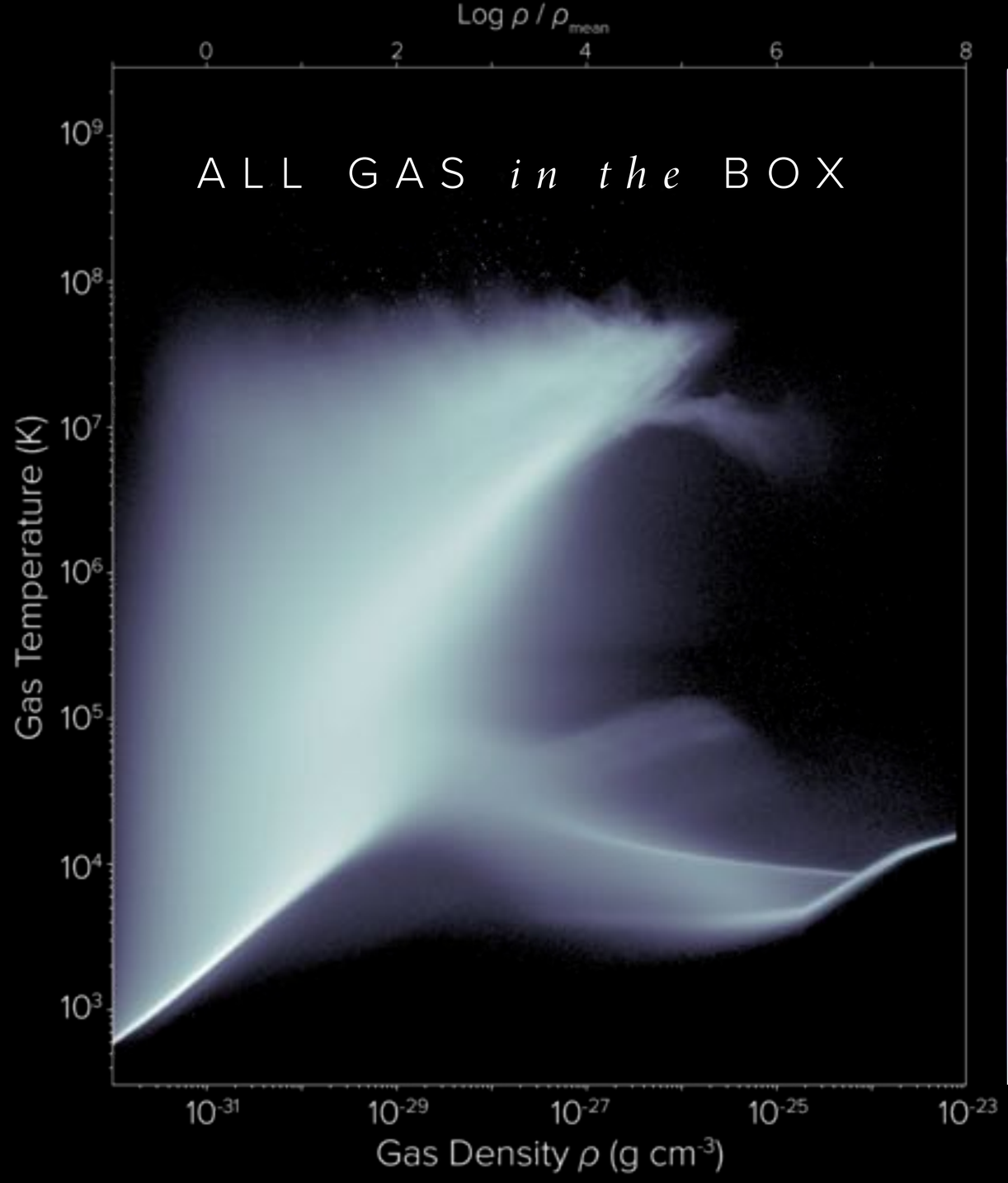




Key capabilities:

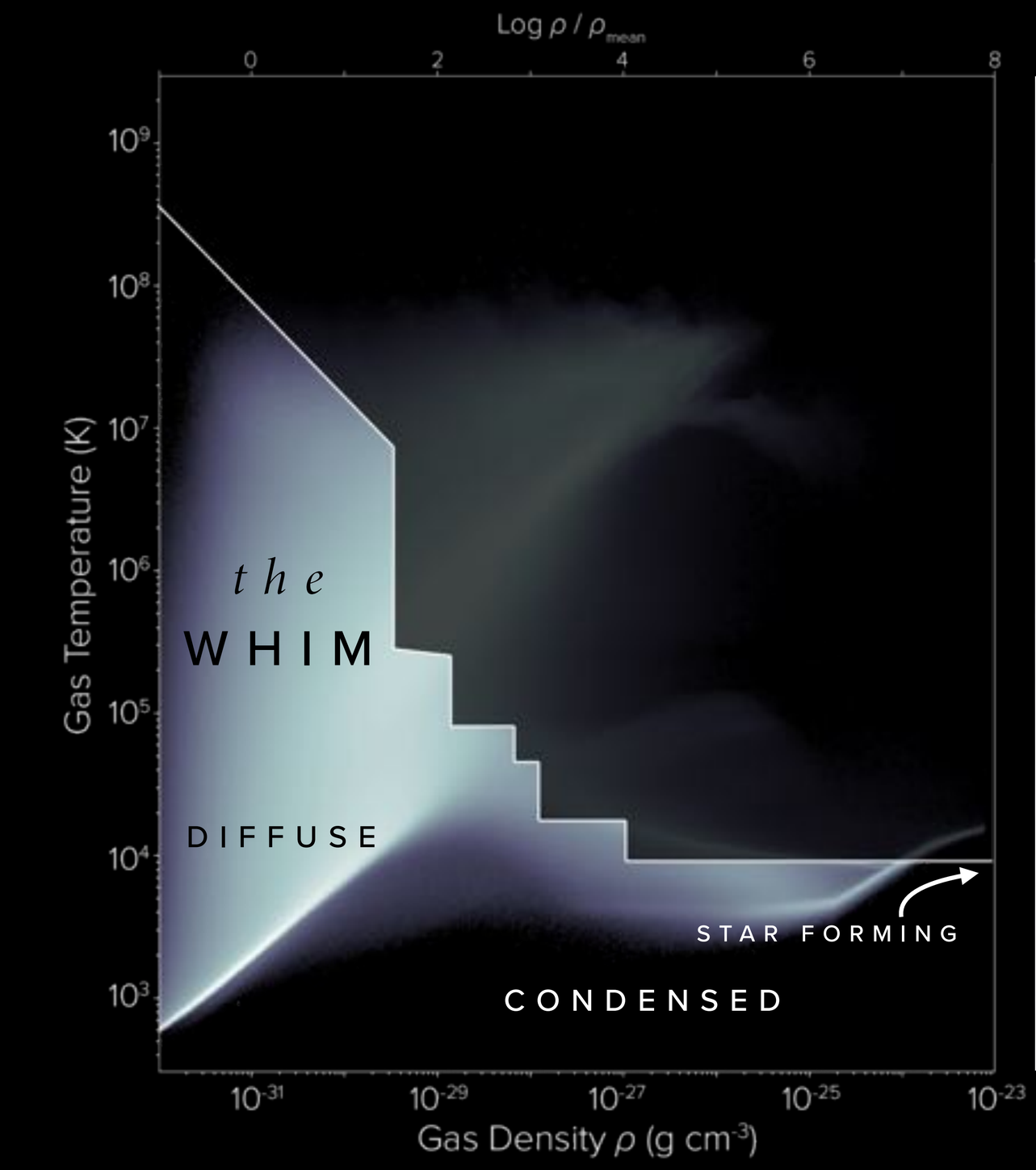
- Microcalorimeter with R=2000 at E = 0.6 keV to map velocities in ~ 100 km/s galactic outflows
- Microcalorimeter with 0.5” pixels to study AGN feedback in galaxies and clusters

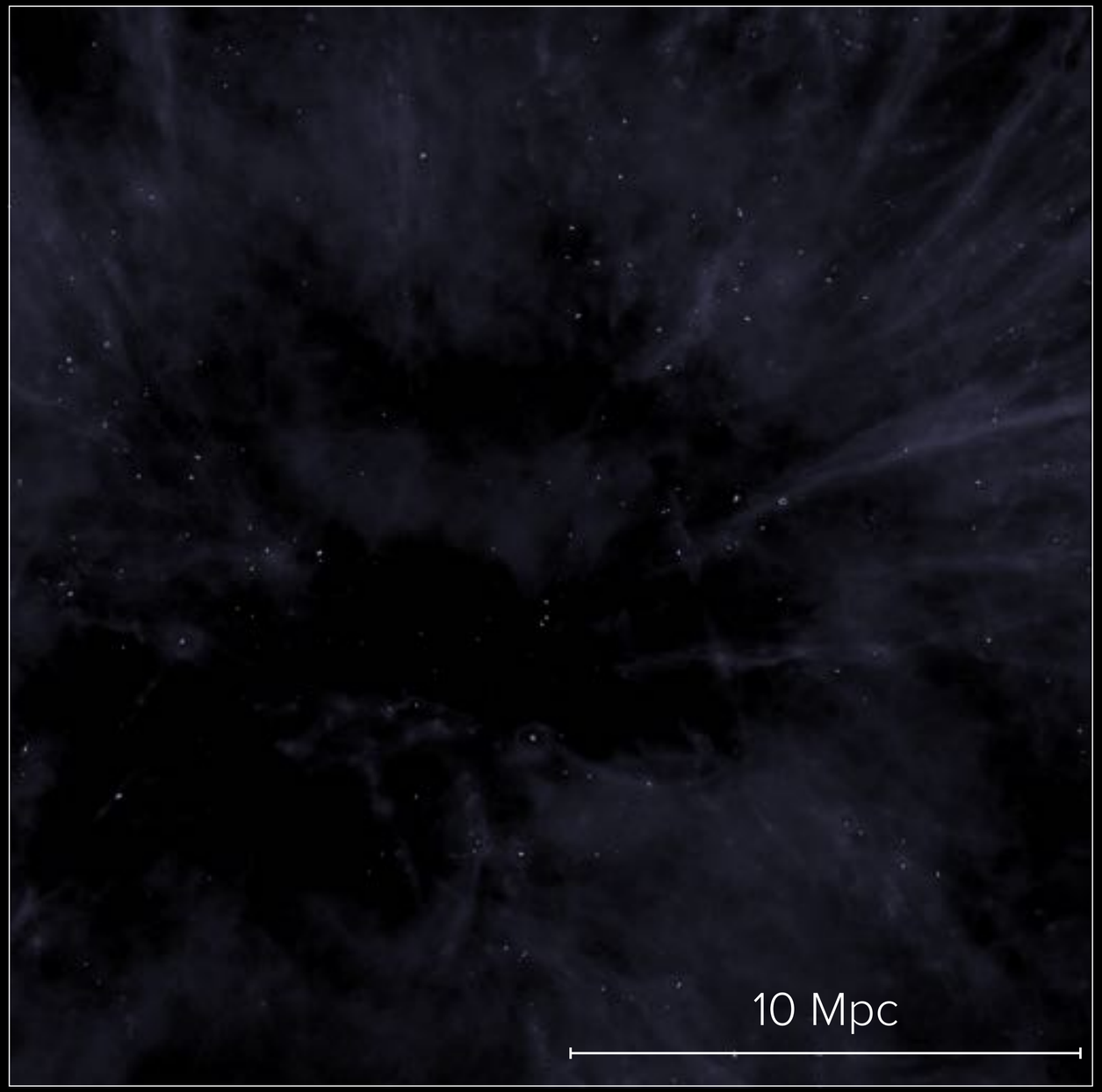


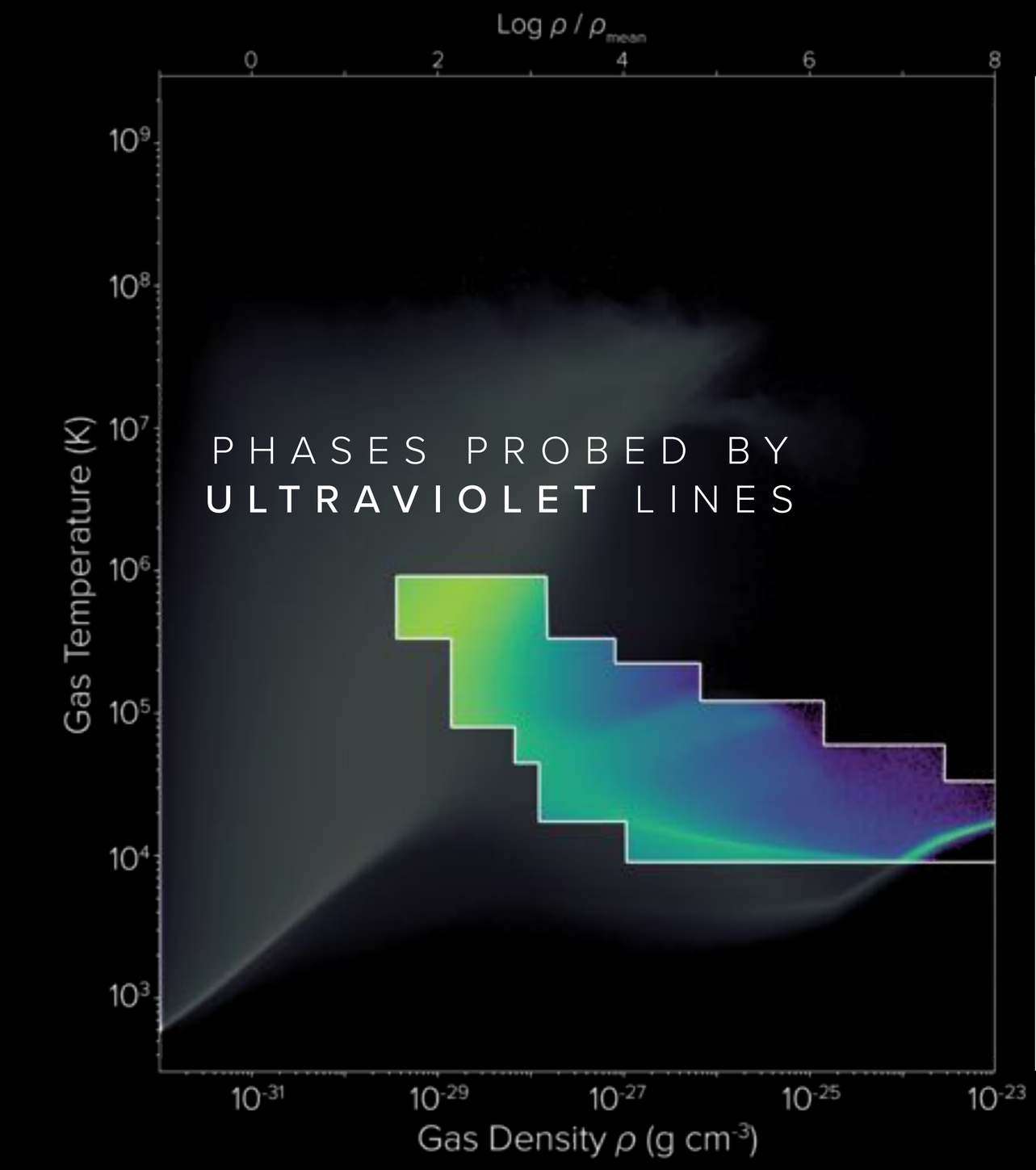

Log ρ / ρ mean
0
2
4
6
8
ALL GAS in the BOX
10^9
10^8
10^7
10^6
10^5
10^4
10^3
Gas Temperature (K)
10^-31
10^-29
10^-27
10^-25
10^-23
Gas Density ρ (g cm^-3)

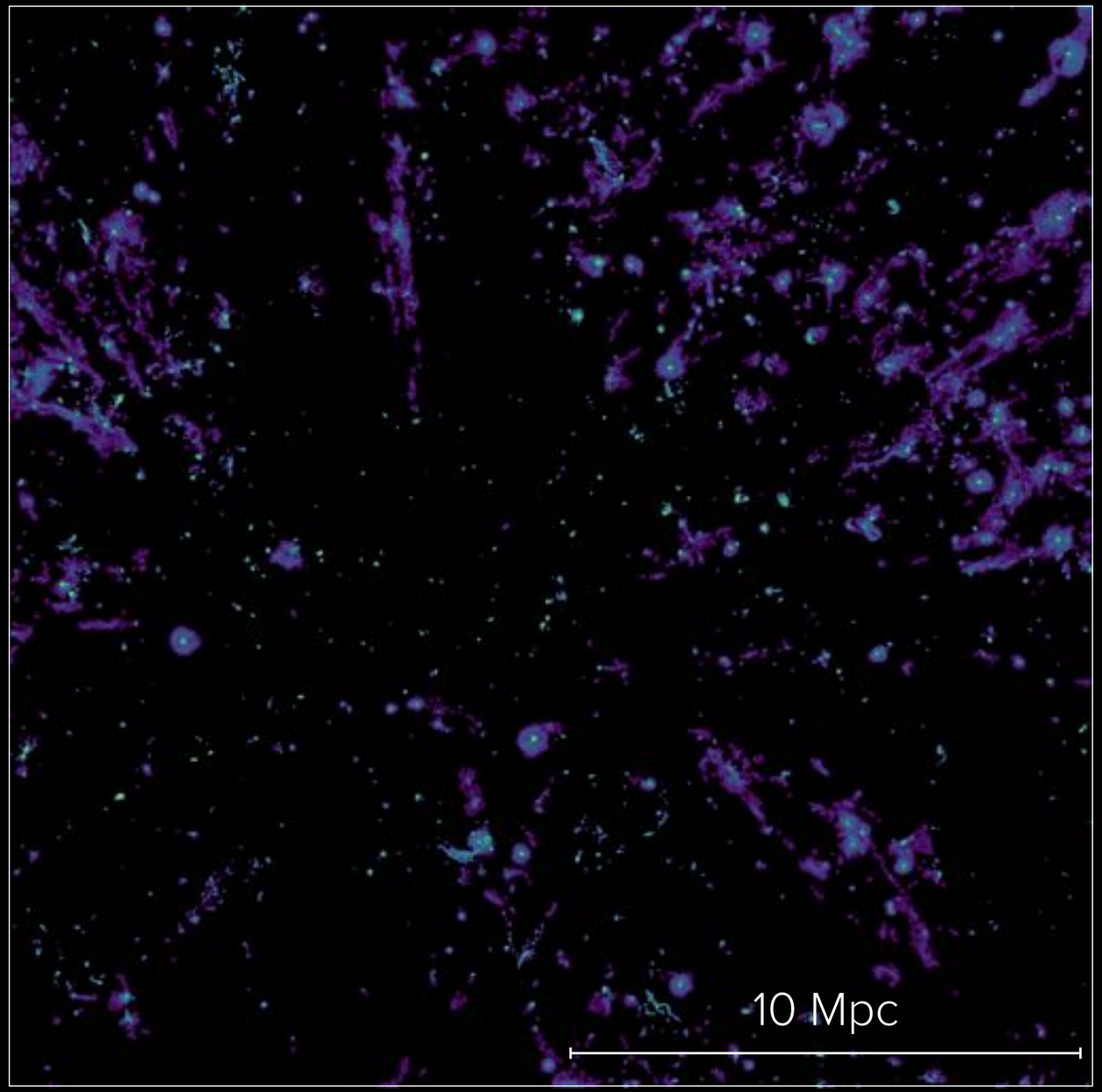
TNG**50**

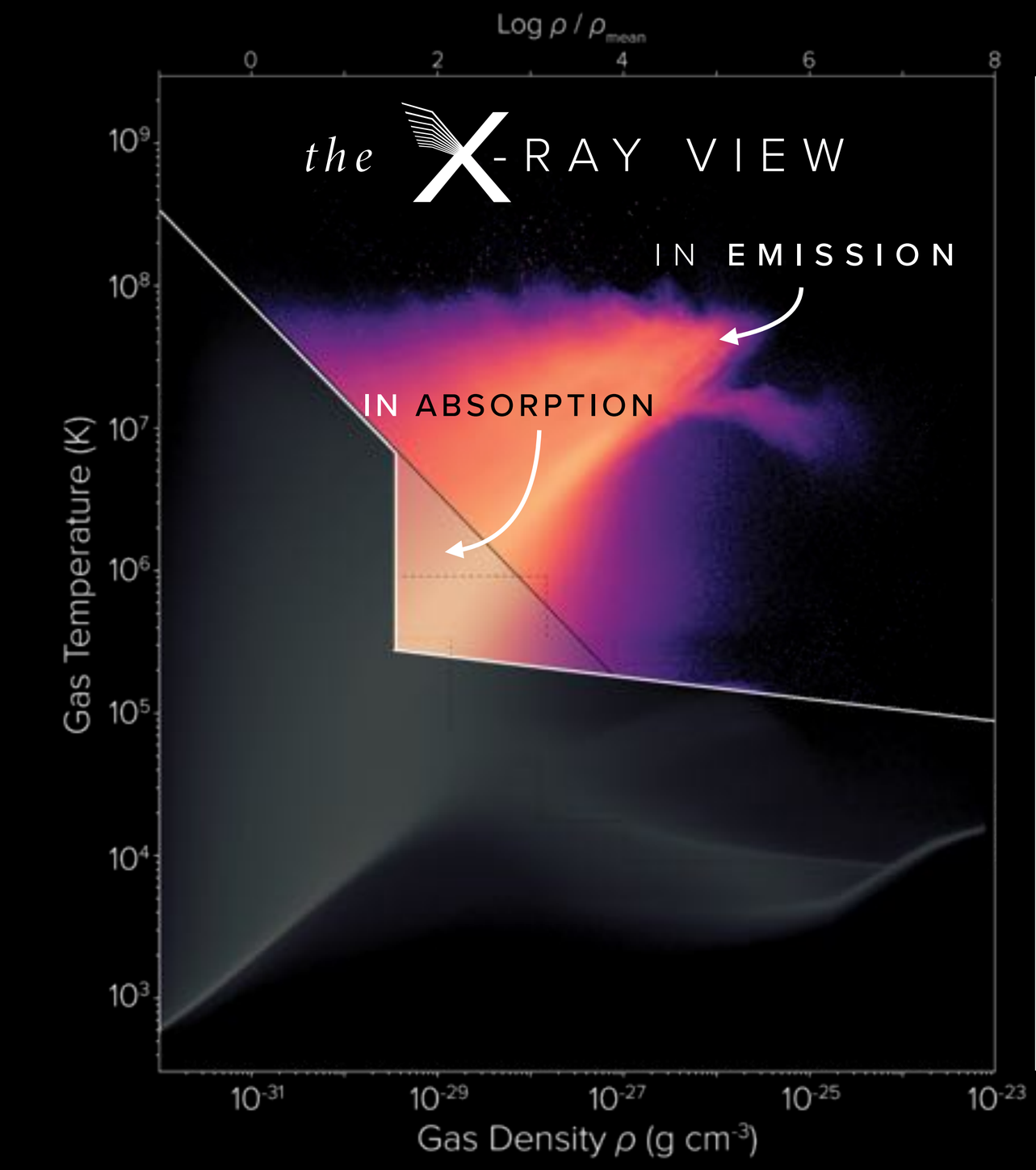

10 Mpc

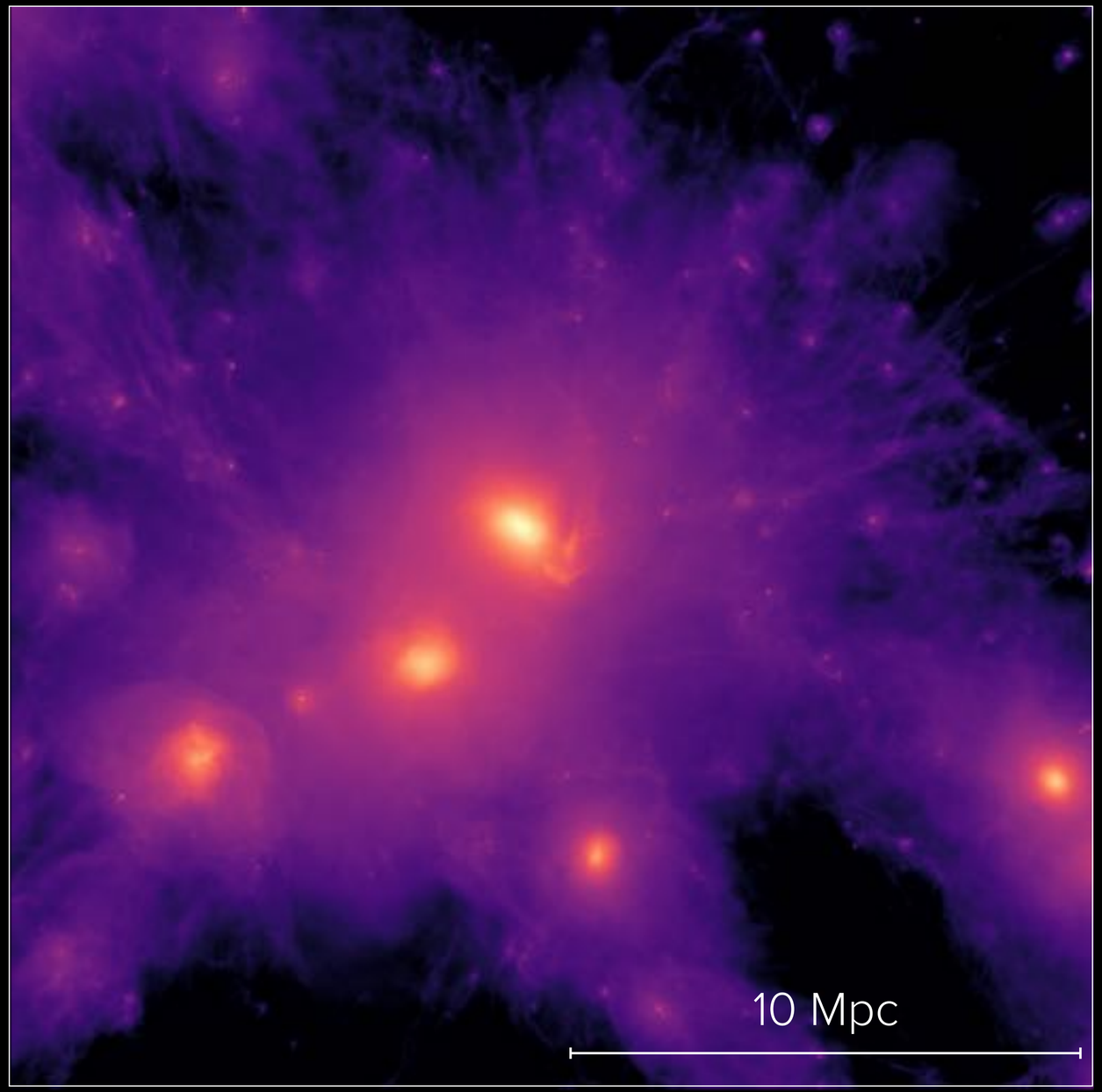

Log ρ / ρ mean
0
2
4
6
8
10^9
10^8
10^7
10^6
10^5
10^4
10^3
Gas Temperature (K)
the
WHIM
DIFFUSE
STAR FORMING
CONDENSED
10^-31
10^-29
10^-27
10^-25
10^-23
Gas Density ρ (g cm^-3)

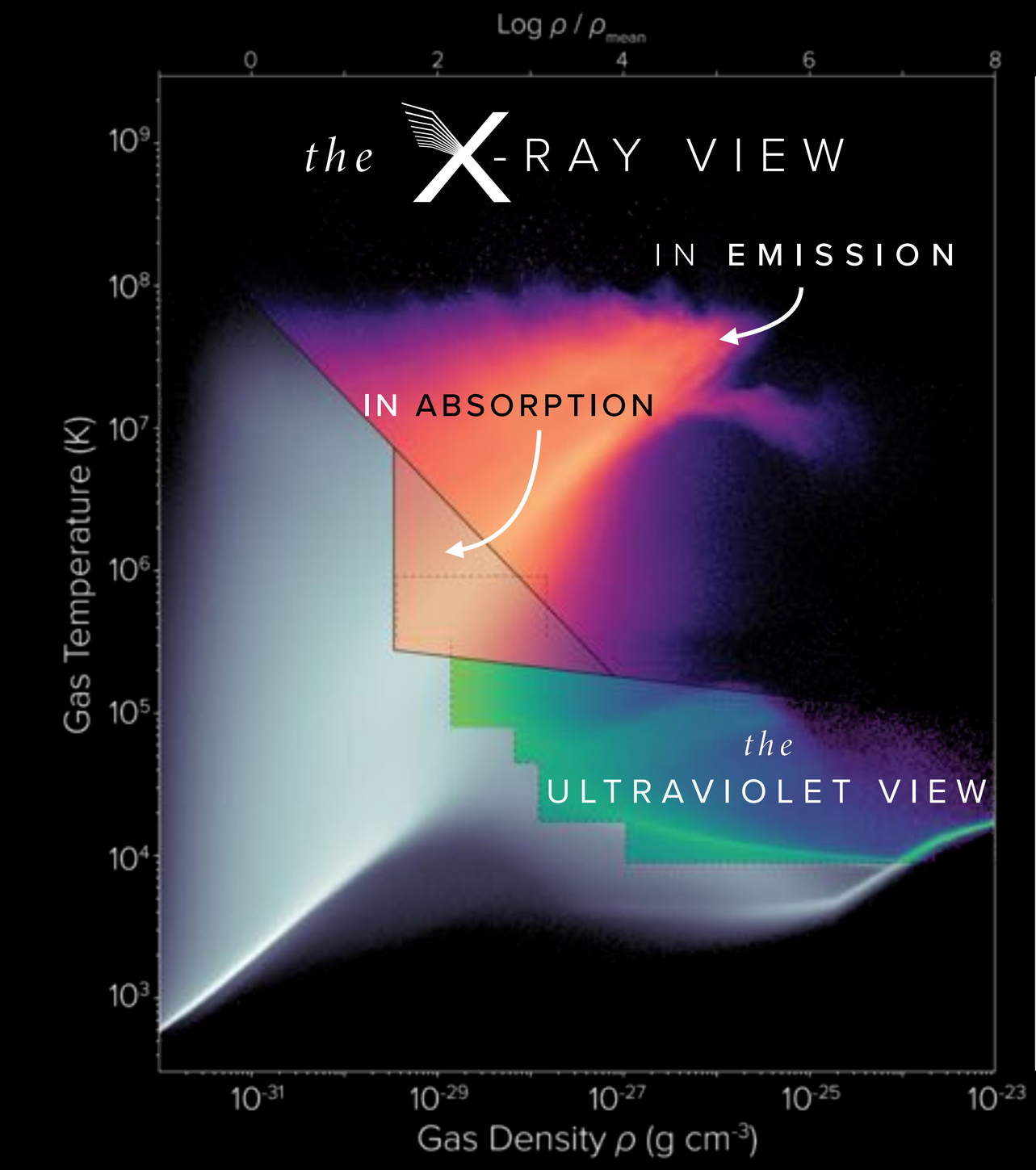

10 Mpc

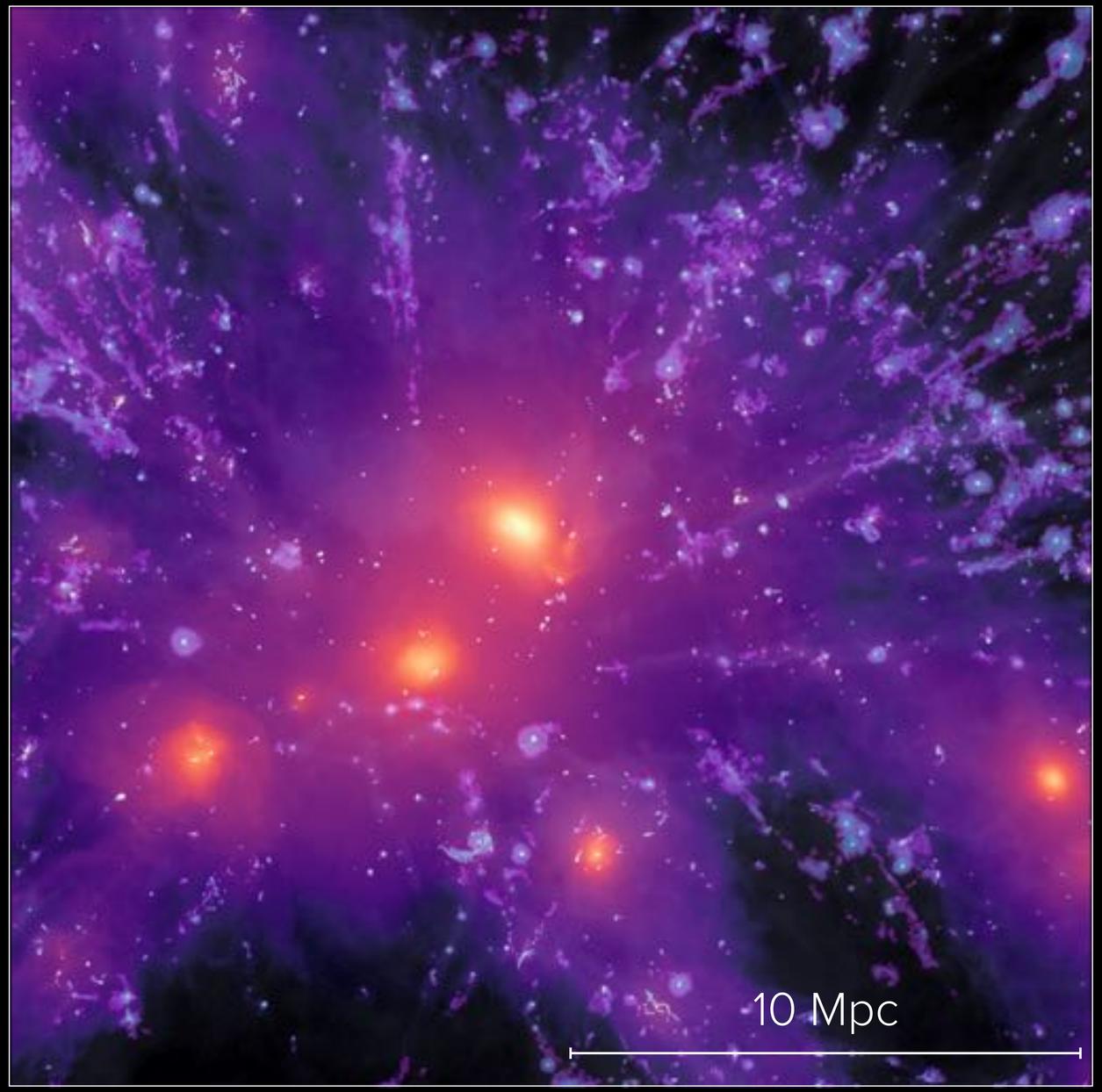

Log ρ / ρ mean
0
2
4
6
8
10^9
10^8
10^7
10^6
10^5
10^4
10^3
Gas Temperature (K)
PHASES PROBED BY
ULTRAVIOLET LINES
10^-31
10^-29
10^-27
10^-25
10^-23
Gas Density ρ (g cm^-3)

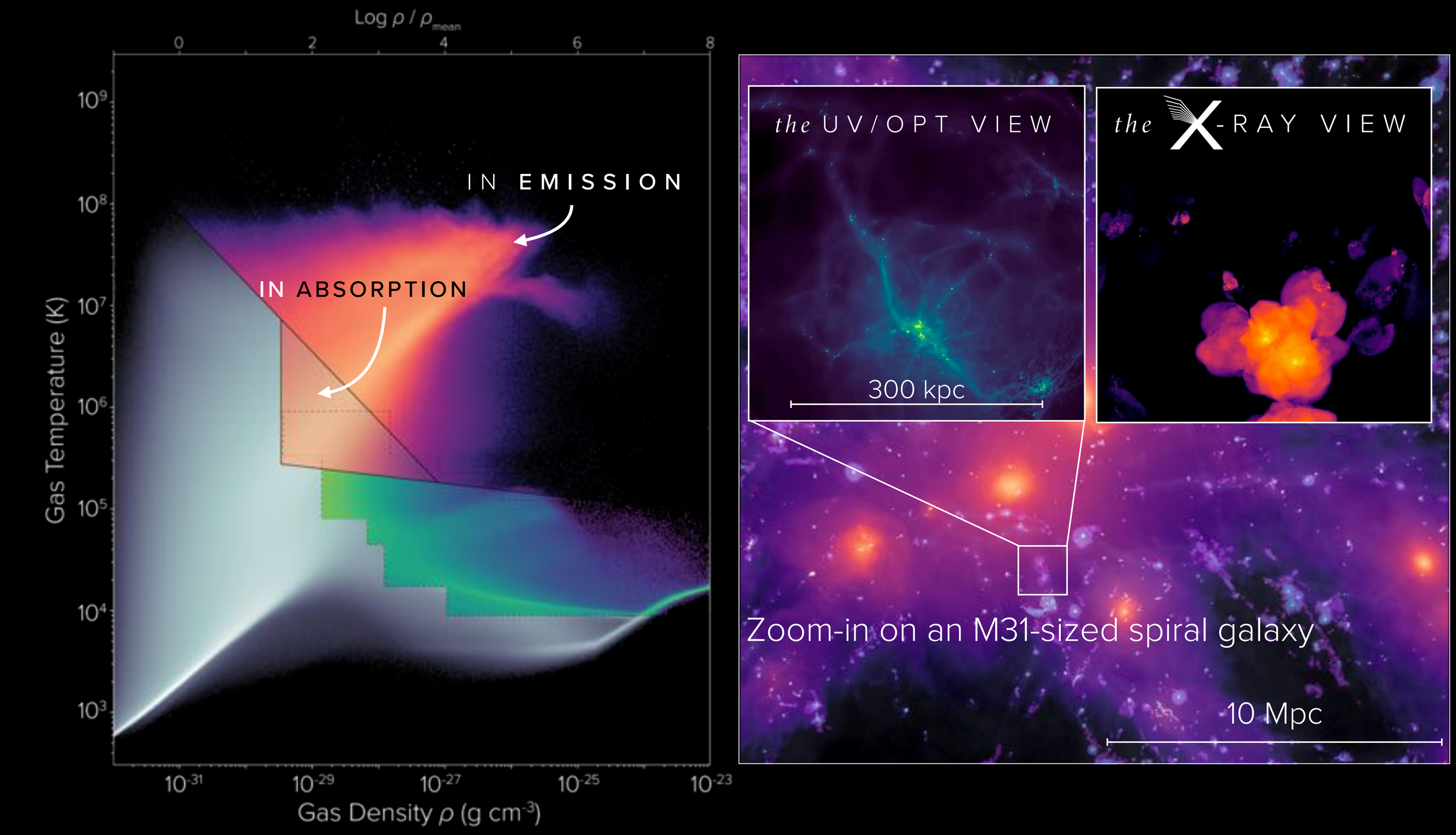

10 Mpc


Log ρ / ρmean
0
2
4
6
8
the X-RAY VIEW
IN EMISSION
IN ABSORPTION
10^9
10^8
10^7
10^6
10^5
10^4
10^3
Gas Temperature (K)
10^-31
10^-29
10^-27
10^-25
10^-23
Gas Density ρ (g cm^-3)


10 Mpc

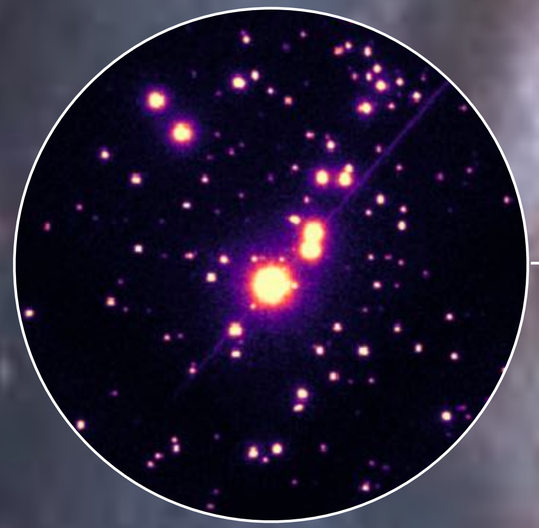

Log ρ / ρ mean
0
2
4
6
8
the X-RAY VIEW
IN EMISSION
IN ABSORPTION
the
ULTRAVIOLET VIEW
Gas Temperature (K)
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^-31
10^-29
10^-27
10^-25
10^-23
Gas Density ρ (g cm^-3)


10 Mpc


Log ρ / ρmean
0
2
4
6
8
10^9
10^8
10^7
10^6
10^5
10^4
10^3
Gas Temperature (K)
IN EMISSION
IN ABSORPTION
10^-31
10^-29
10^-27
10^-25
10^-23
Gas Density ρ (g cm^-3)
the UV/OPT VIEW
300 kpc
the X-RAY VIEW
Zoom-in on an M31-sized spiral galaxy
10 Mpc


- We are in the era of multi-messenger astronomy. Planet studies evolve to holistic assessment of habitable conditions. Leaps in data on star formation are needed to understand the galaxies and cycles of elements.
- **Science needs include observations of key high-energy processes associated with stellar birth, life, and death.**

*the* MILKY WAY

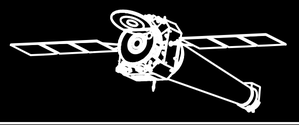


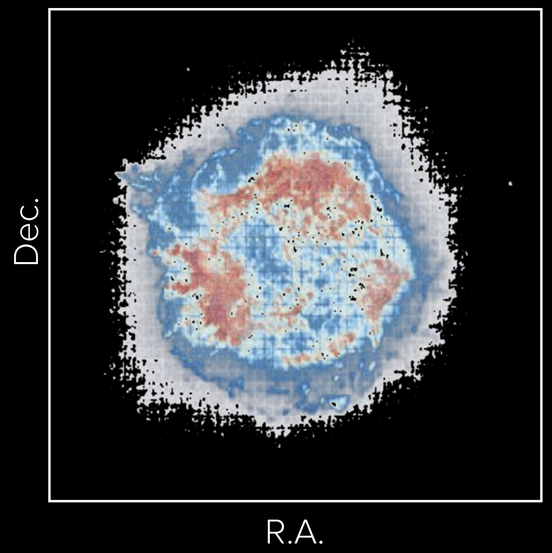


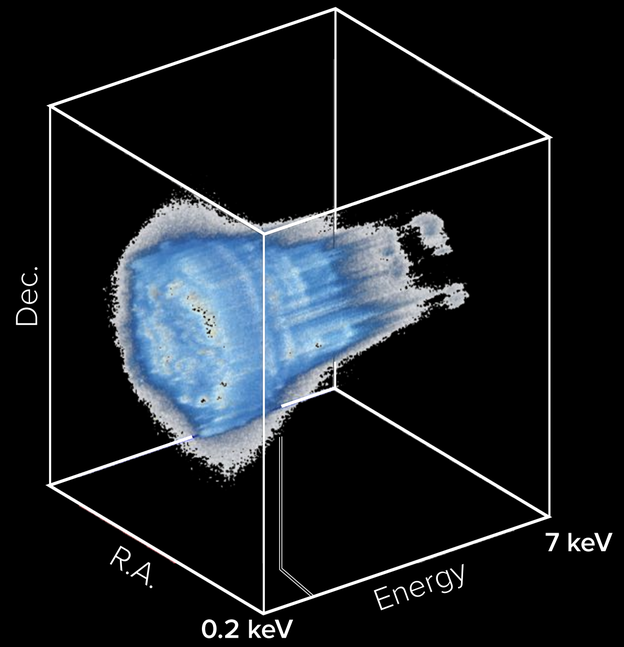

HORIZON
5 **kilo**parsecs

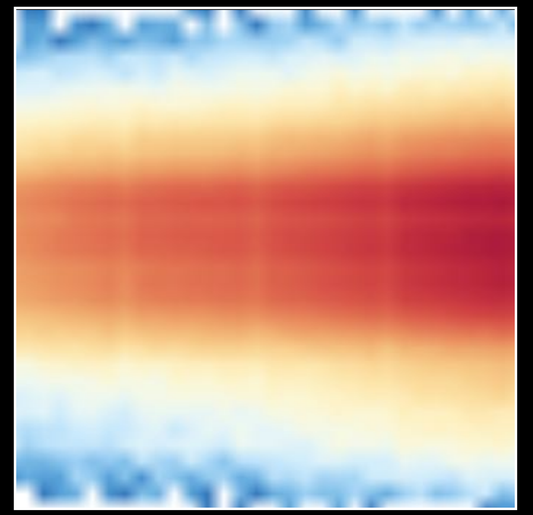
CHANDRA
HORIZON
400 parsecs

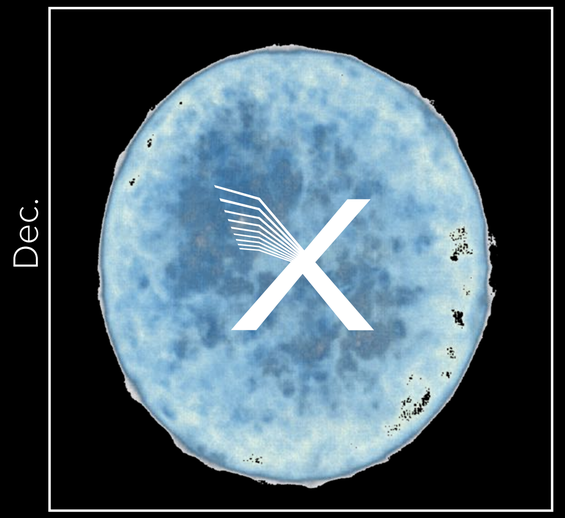
# STELLAR DEATH *in* 3D

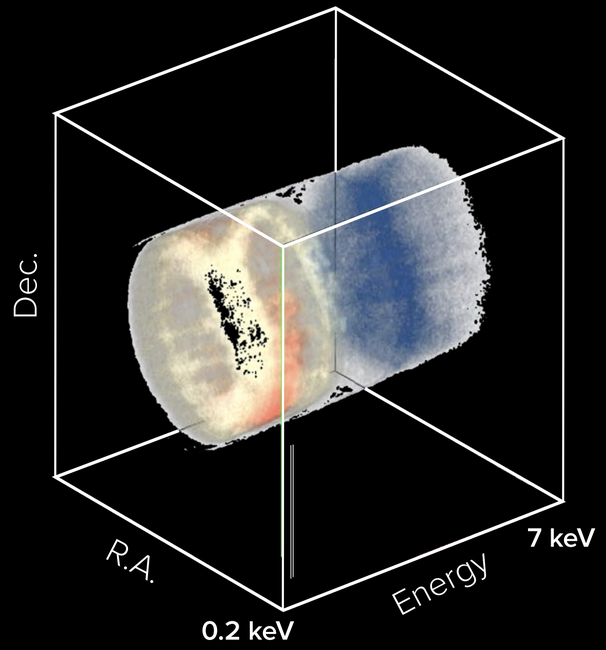


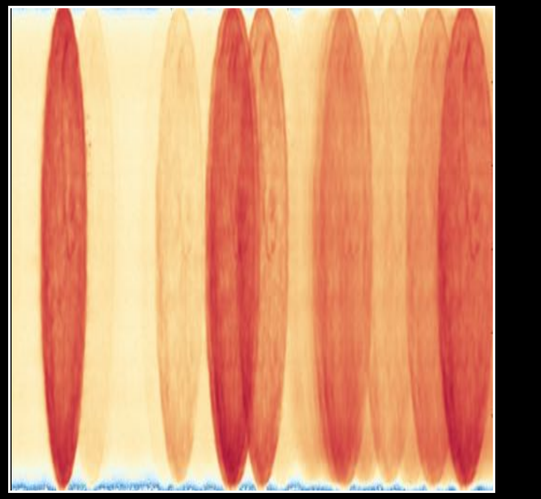


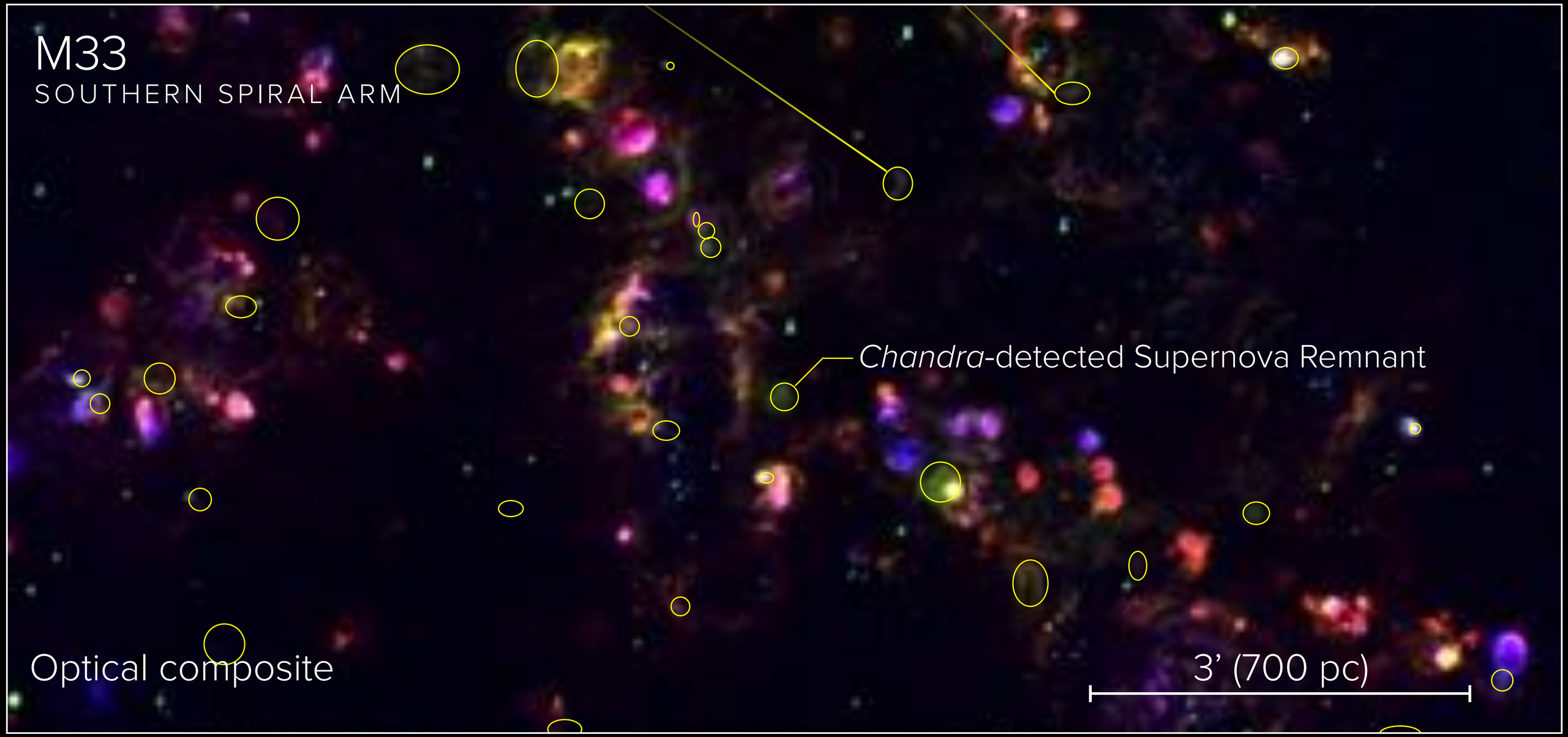



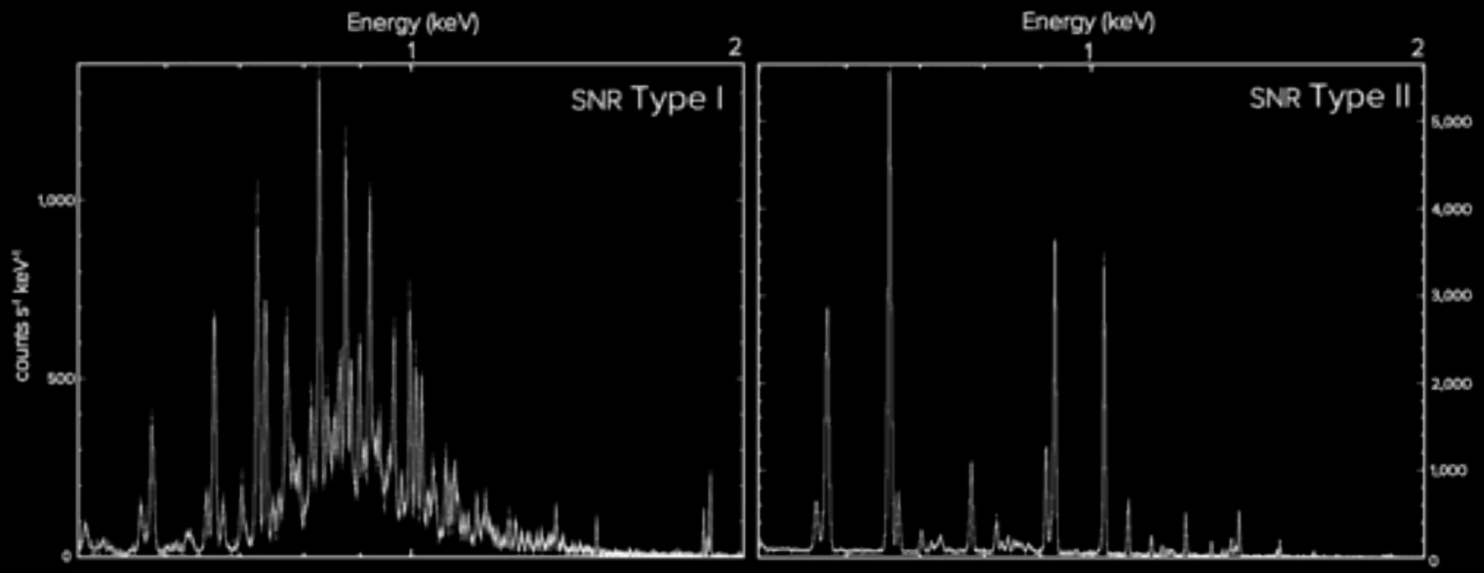



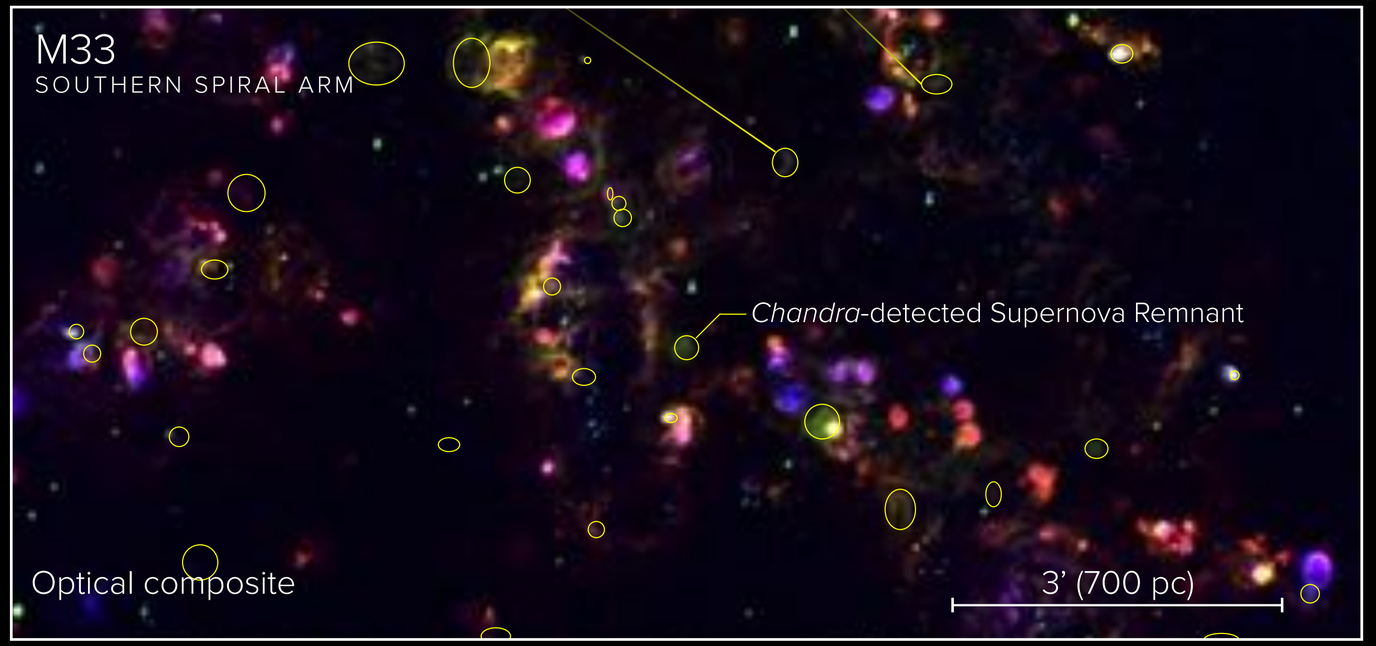
# STELLAR DEATH, EXTRAGALACTIC

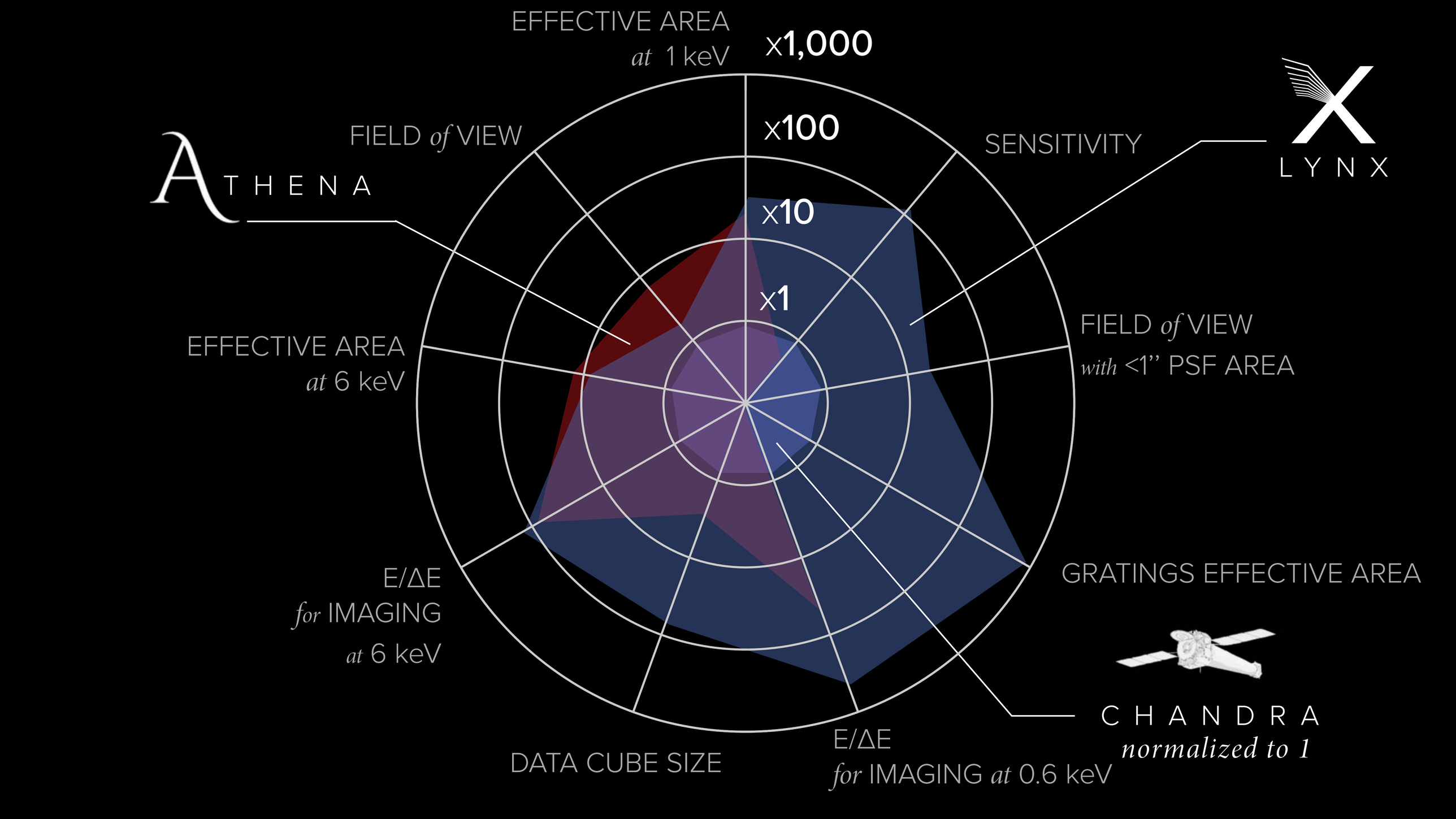


# STELLAR DEATH, EXTRAGALACTIC

- Statistical samples of SNRs (age, type, etc.)
- SN activity & relation to on-going star formation
- Sensitive XRB studies beyond the Local Group

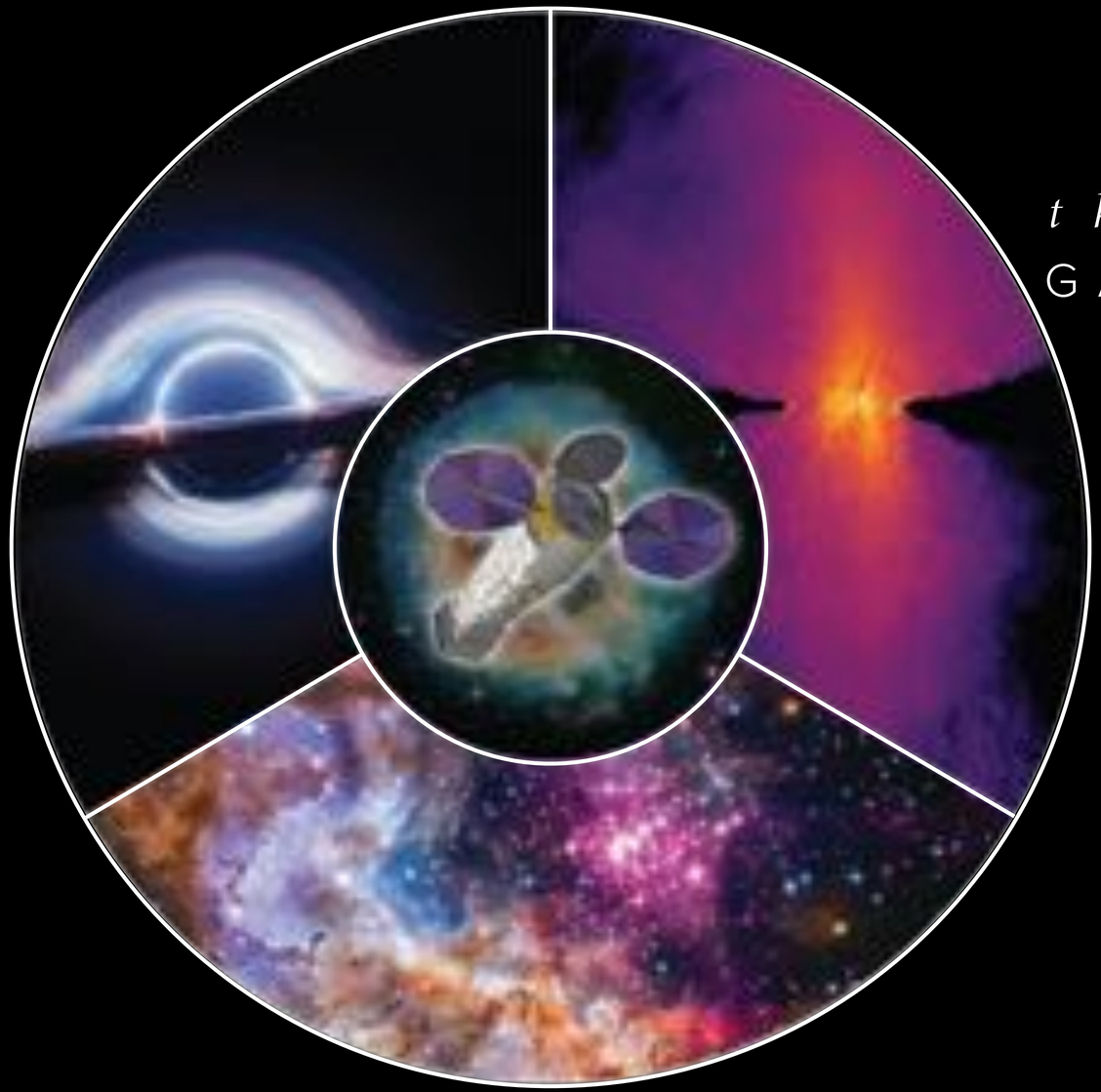



EFFECTIVE AREA
at 1 keV
x1,000
x100
x10
x1
SENSITIVITY
LYNX
FIELD of VIEW
ATHENA
FIELD of VIEW
with <1'' PSF AREA
EFFECTIVE AREA
at 6 keV
GRATINGS EFFECTIVE AREA
E/ΔE
for IMAGING
at 6 keV
CHANDRA
normalized to 1
E/ΔE
for IMAGING at 0.6 keV
DATA CUBE SIZE

*a new* GREAT OBSERVATORY

*the* DAWN *of* BLACK HOLES



*the* DRIVERS *of* GALAXY EVOLUTION

*the* ENERGETIC SIDE *of* STELLAR EVOLUTION

# *the* IMPACT *of* LYNX SCIENCE

## CRITICAL ADVANCES *in*

Cosmic Dawn, Galaxy Formation, Black Holes, Origin of Elements

## MAJOR IMPACT *on*

Cosmology, Resolved Stellar Populations, Solar System Observations, Multi-Messenger Astronomy

## SIGNIFICANT IMPACT *on*

Planets, Protoplanetary Disks, Very High Energy Astrophysics

*the* HOT *and*
ENERGETIC UNIVERSE

ATHENA

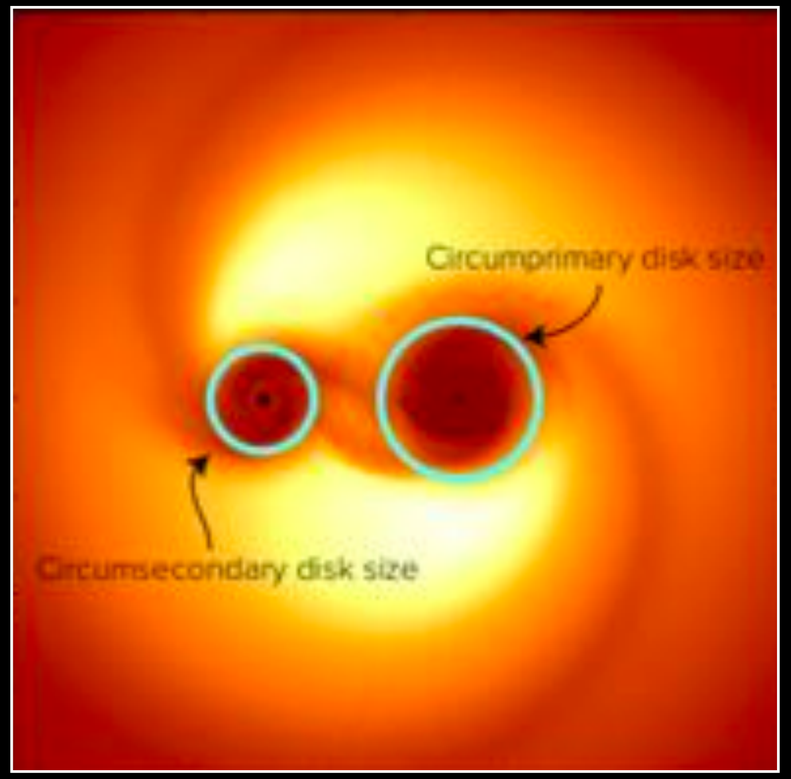
BLACK HOLE
DAWN

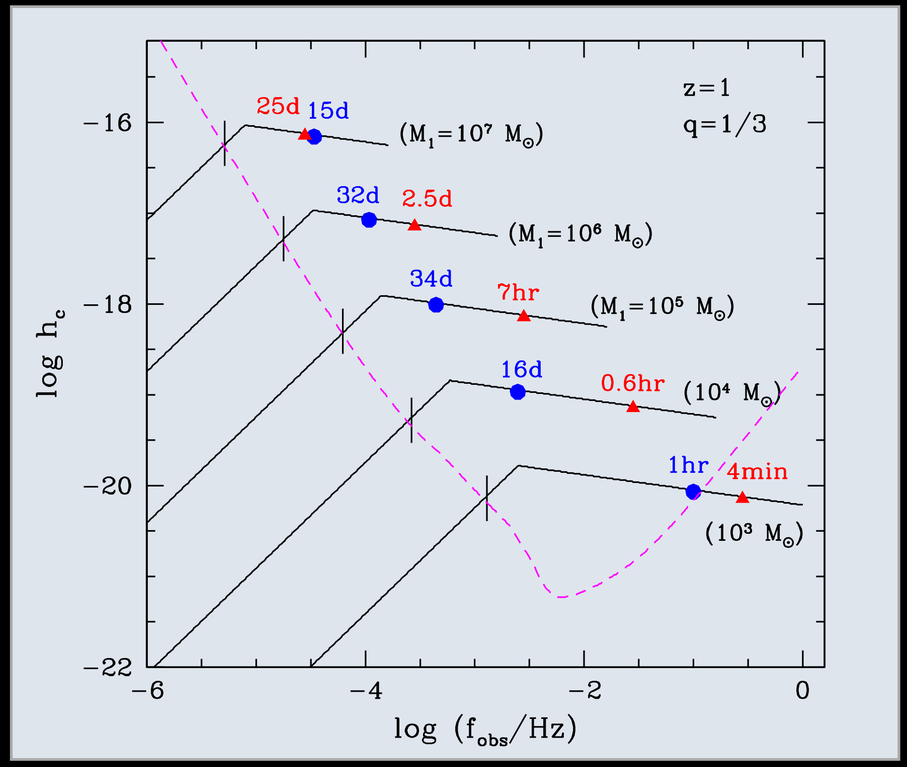
LYNX

*the* ENERGETIC SIDE
*of* STELLAR EVOLUTION

DRIVERS *of*
GALAXY EVOLUTION

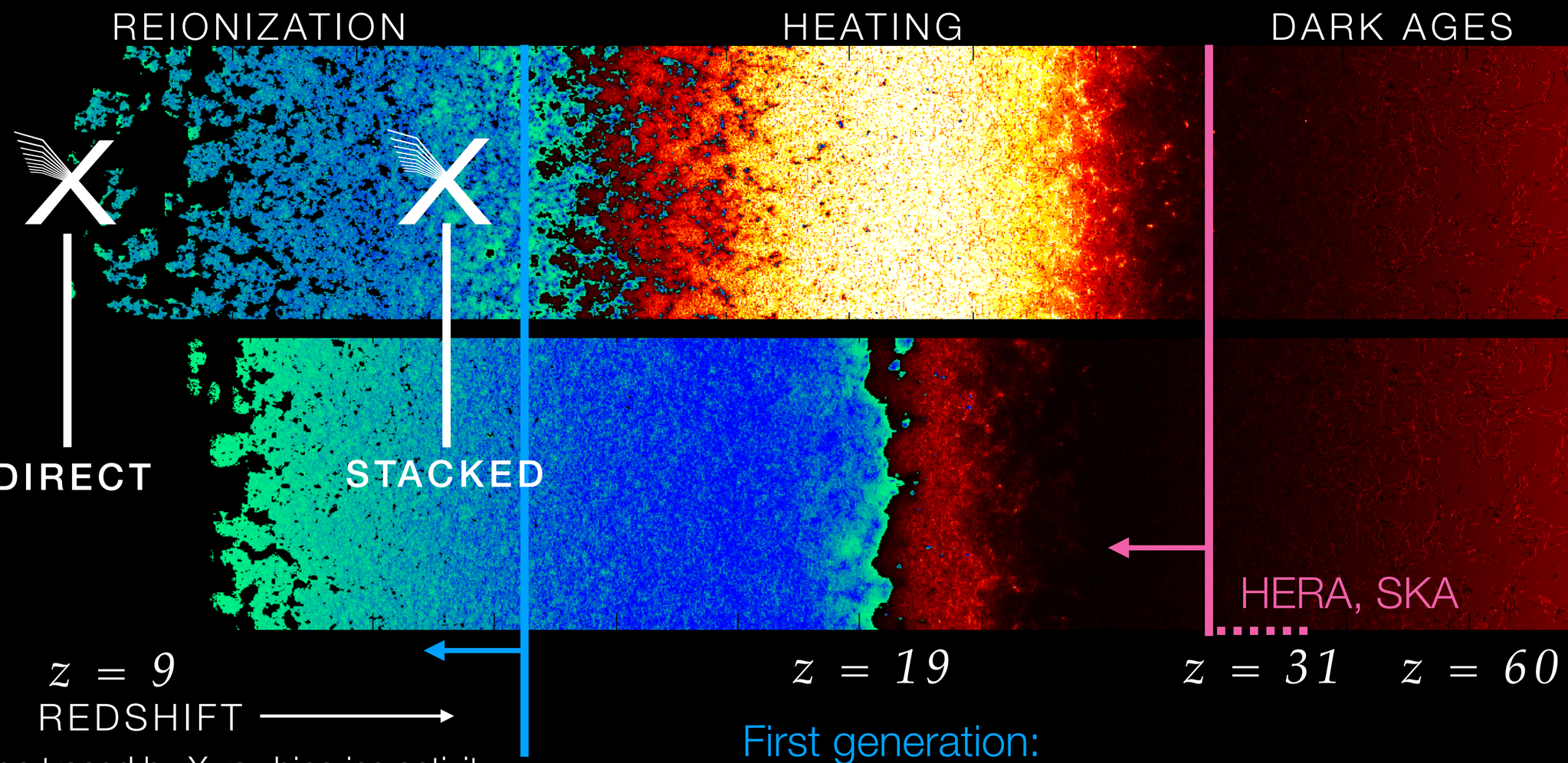
# LYNX DISCOVERY SCIENCE
# TIME DOMAIN & MULTI-MESSENGER ASTRONOMY




- *Lynx* can respond to a subset of ToOs within 3 hours of trigger
- Will rely on extreme sensitivity, sharp angular resolution & spectroscopic capabilities:
  - X-ray chirp signal from merging supermassive black holes
  - Followup of LIGO A+ events
  - Prompt spectroscopy of gamma-ray burst afterglows

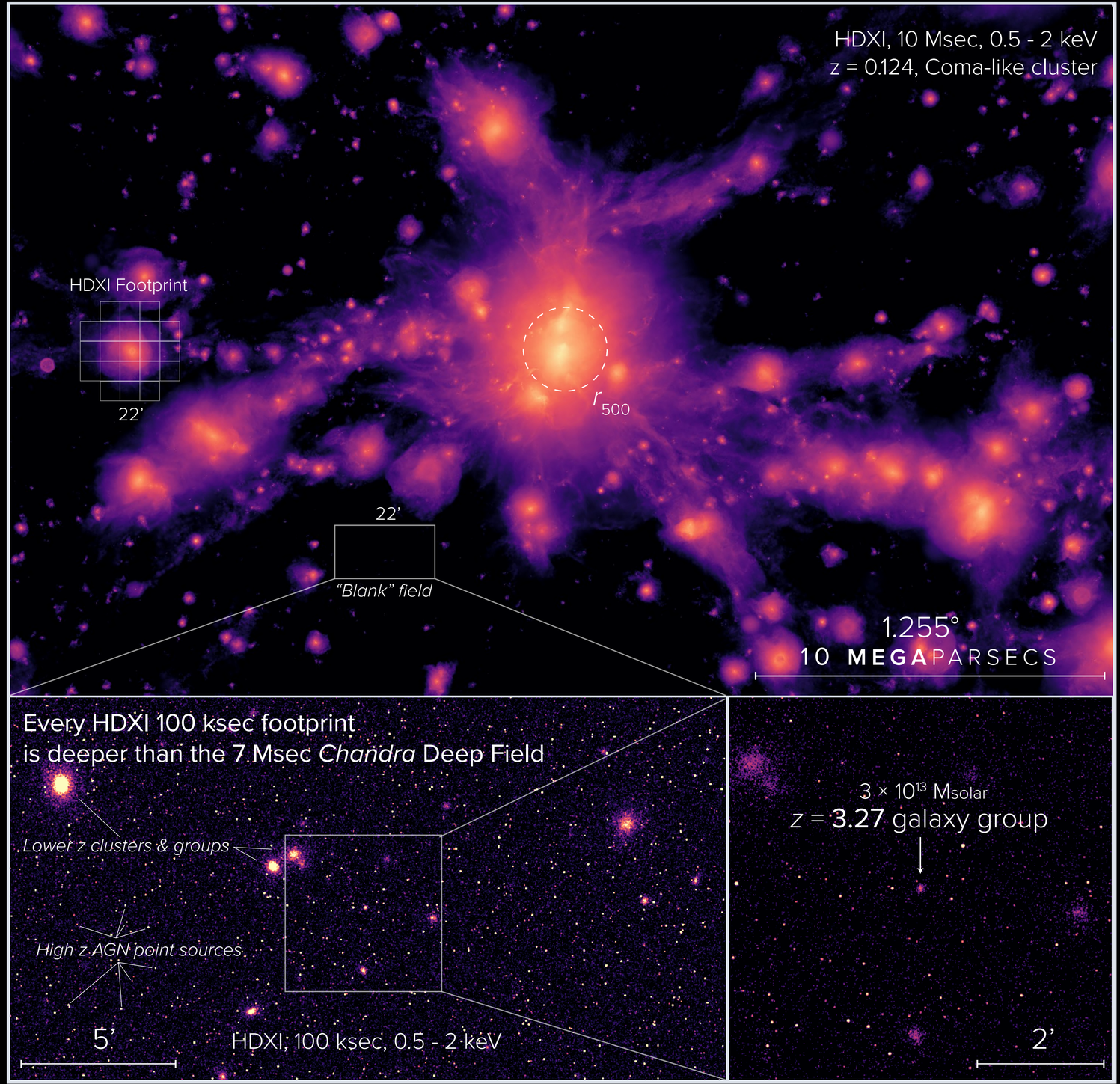
# LYNX DISCOVERY SCIENCE
# COSMIC DAWN *& the* EPOCH *of* REIONIZATION




- High-redshift star formation traced by X-ray binaries activity
- Extrapolation of XRB populations to the Epoch of Reionization
- Cross-correlation with 21cm signals

# LYNX DISCOVERY SCIENCE
## *the* LEGACY FIELD

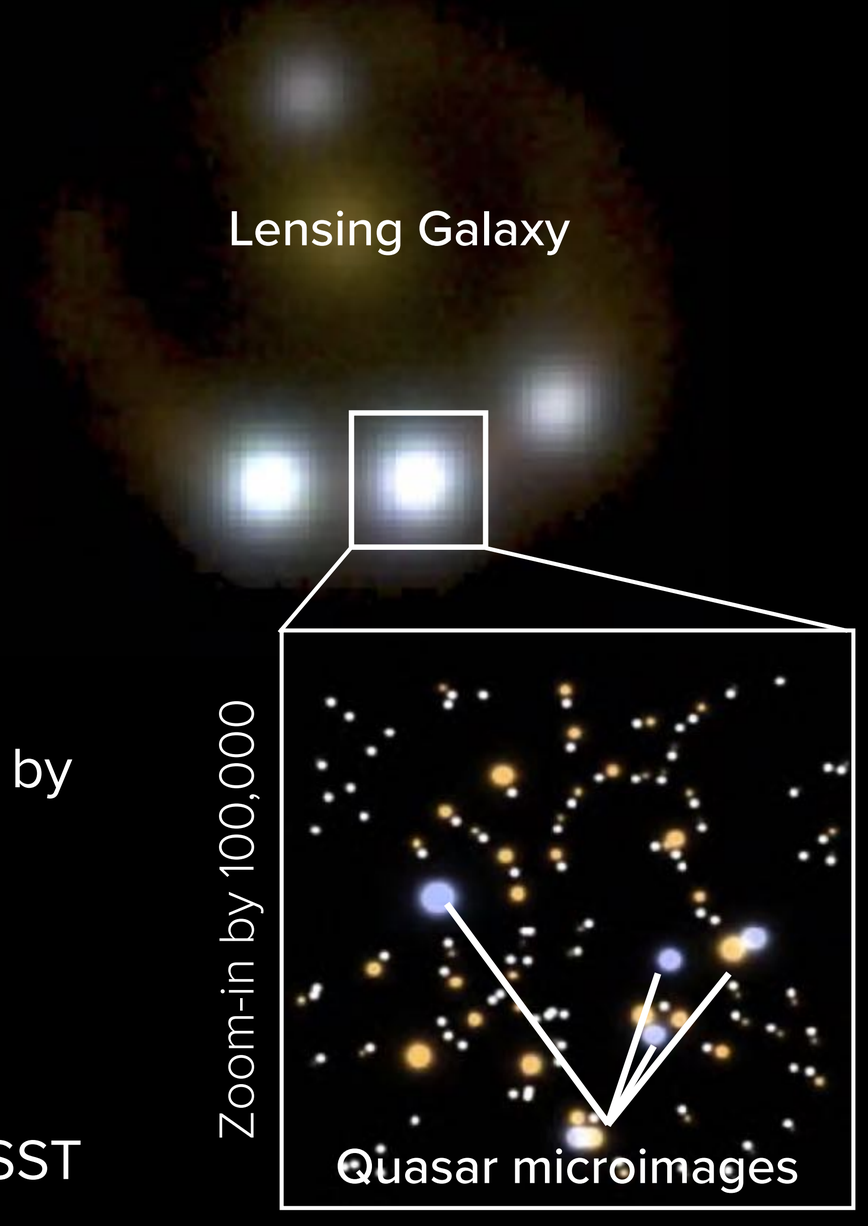
- AGN Surveys
- LSS
- Cosmology
- Galaxy Evolution
- Cosmic Web



# LYNX DISCOVERY SCIENCE
# *the* STELLAR IMF *via* QUASAR MICROLENSING

Nobody ever measures the stellar mass. That is not a measurable thing; it's an inferred quantity. You measure light, OK? You can measure light in many bands, but you infer stellar mass. Everybody seems to agree on certain assumptions that are completely unproven.

Carlos Frenk, 2017 May 15 (44:48)




Order-of-magnitude variations in brighness when stellar field shifts by 10s of μas.

Macrolensing gives full mass

Microlensing gives mass in stars

*Chandra* results: $M^*/L = 1.2 \pm 0.6$ Salpeter ⟶ exquisite post-LSST