SPICA and ATHENA

Mat Page, MSSL-UCL

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- Key synergies between SPICA and ATHENA.
  - Black hole growth and star formation
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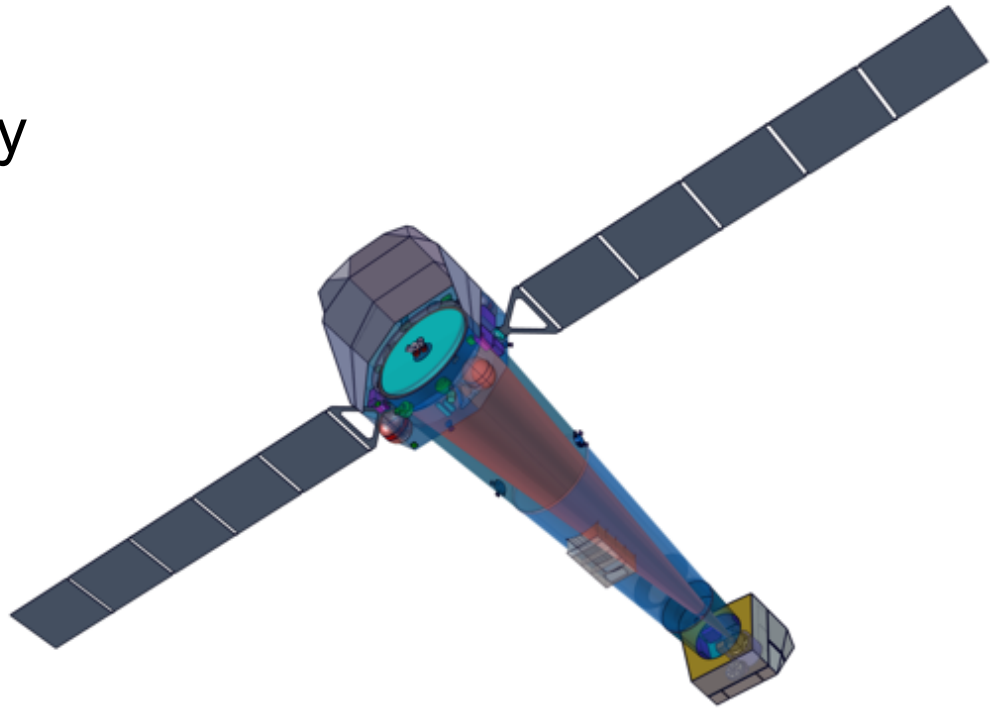
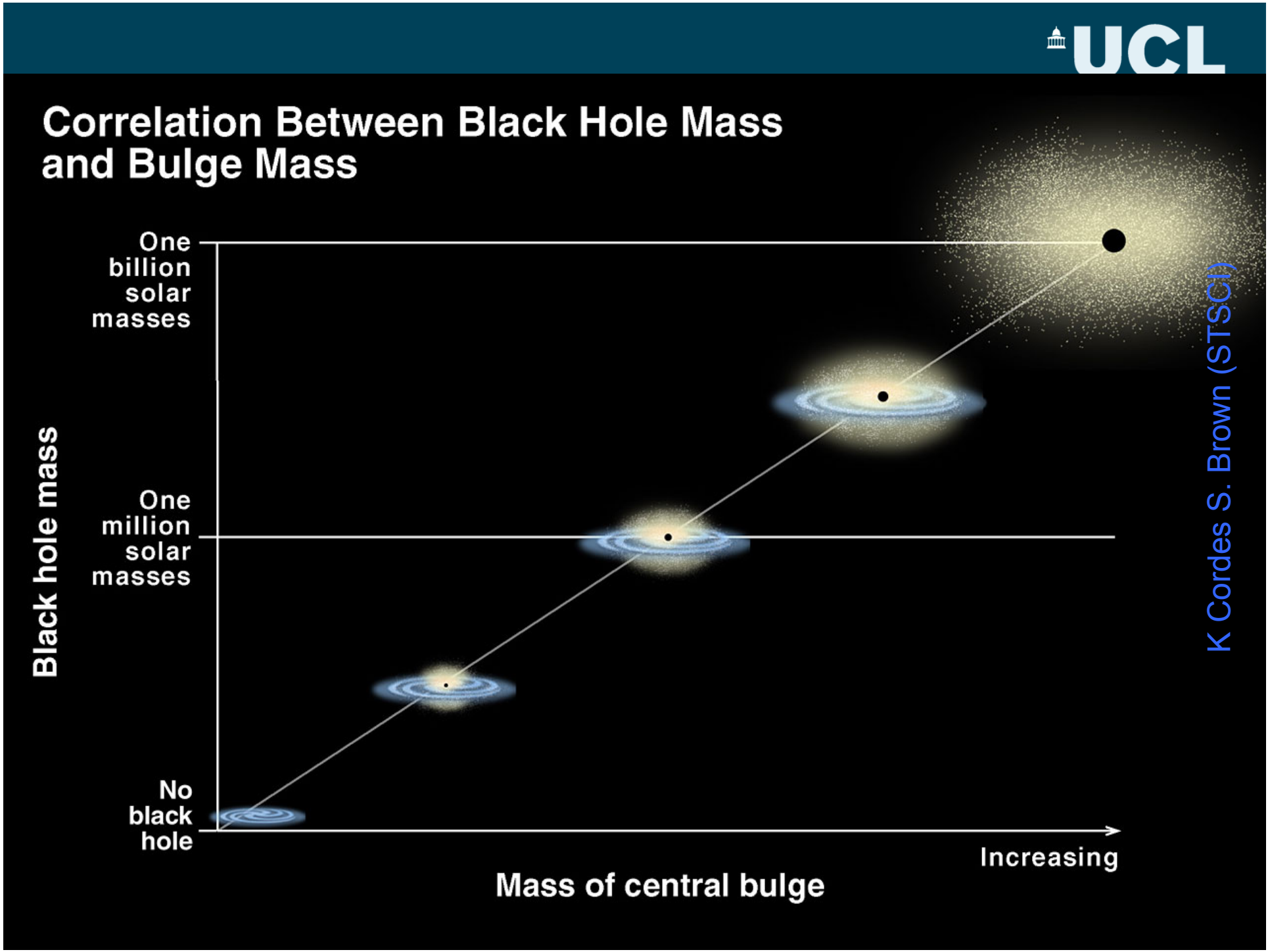
  - Hot and cold ISM.

What is ATHENA?

- ESA L2 mission
- Large X-ray observatory
- Silicon pore mirror
- 12 m focal length
- 2 m^2 collecting area
- Launch 2028
- Two instruments:
  - Wide field imager
  - High resolution imaging spectrometer



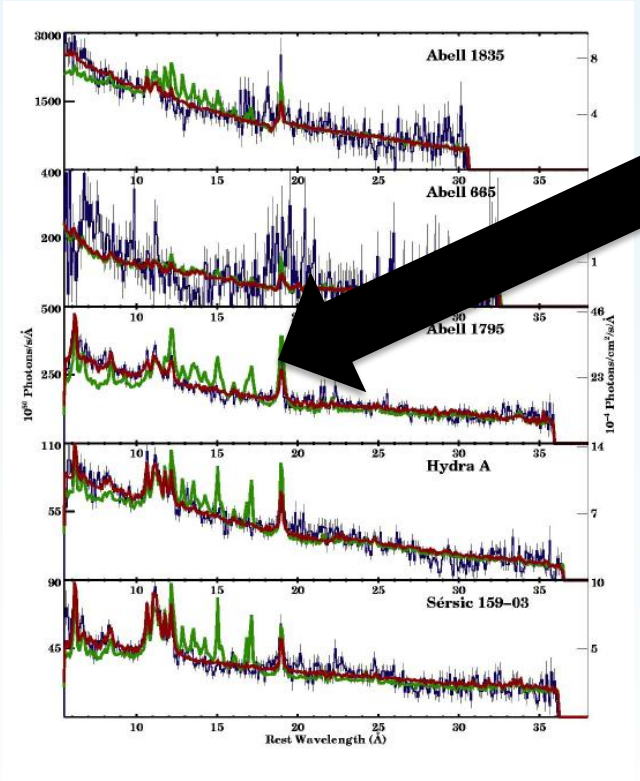
Picture courtesy:
http://www.the-athena-x-ray-observatory.eu

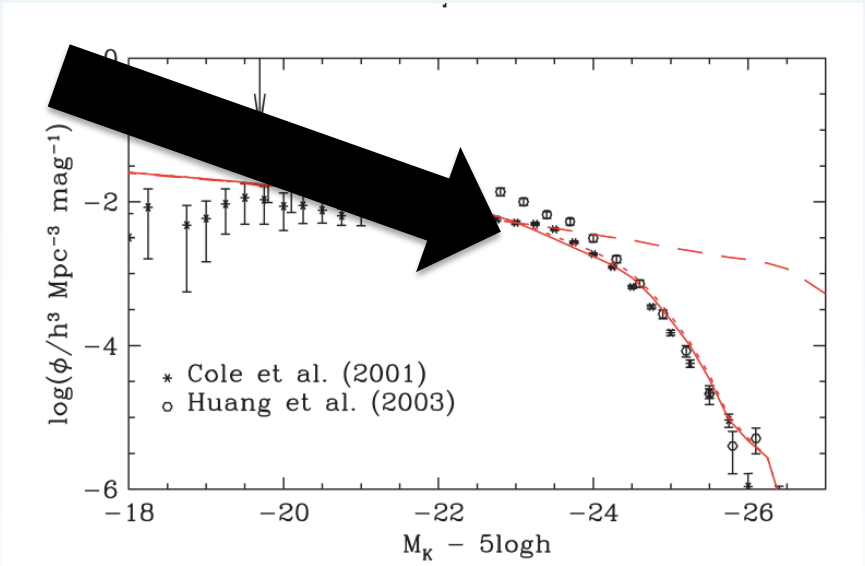

UCL
Correlation Between Black Hole Mass and Bulge Mass
One billion solar masses
One million solar masses
No black hole
Black hole mass
Increasing
Mass of central bulge
K Cordes S. Brown (STScI)

Massive black holes rule

- Nowadays we think that accreting massive black holes control the growth of all massive galaxies.

Peterson et al. 2003, ApJ, 590, 207





Bower et al. 2006, MNRAS, 370, 645

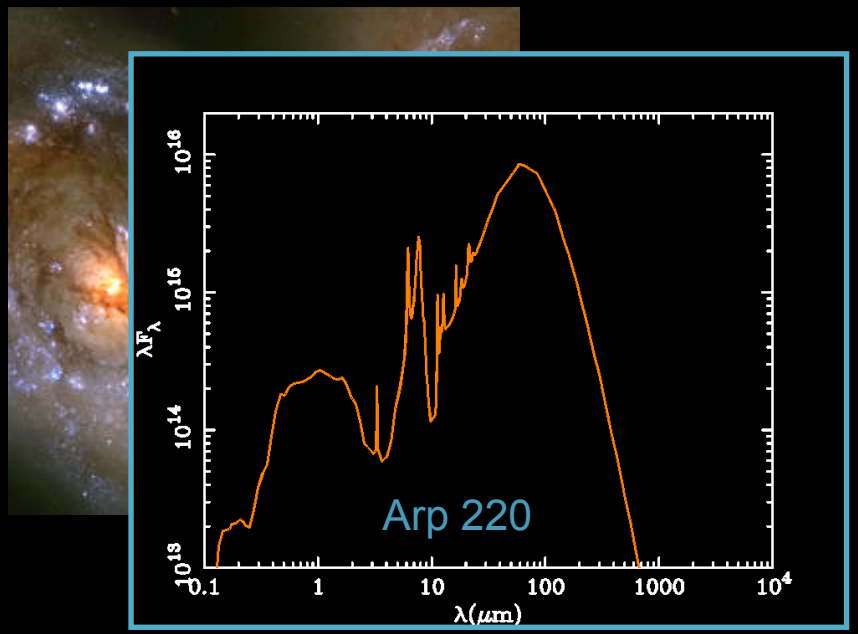
The chicken and egg question.

- Until we understand the sequence of star formation and accretion, we won't really understand black holes **or** galaxies.
- We need to measure how much accretion is happening in star forming galaxies
- And how much star formation is happening around accreting black holes.
- And we'd like to know that all the way back to the reionization era.

Energy release from black holes and stars

Black holes growing by accretion are best found by X-ray emission

The most rapidly star-forming galaxies are often highly obscured, emitting the bulk of their energy in the far infrared

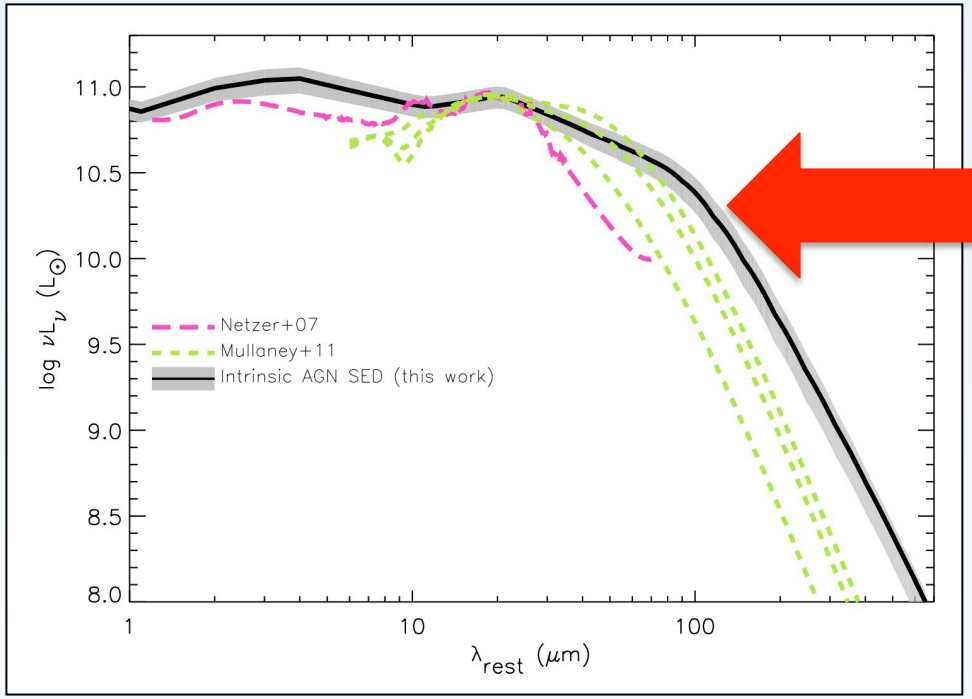


OK, but do we really need SPICA or ATHENA to do this?

YES

At least, to do it properly we do.

AGN, as well as stars, heat dust that shines in the FIR.



Symeonidis et al. 2016, MNRAS 459, 257

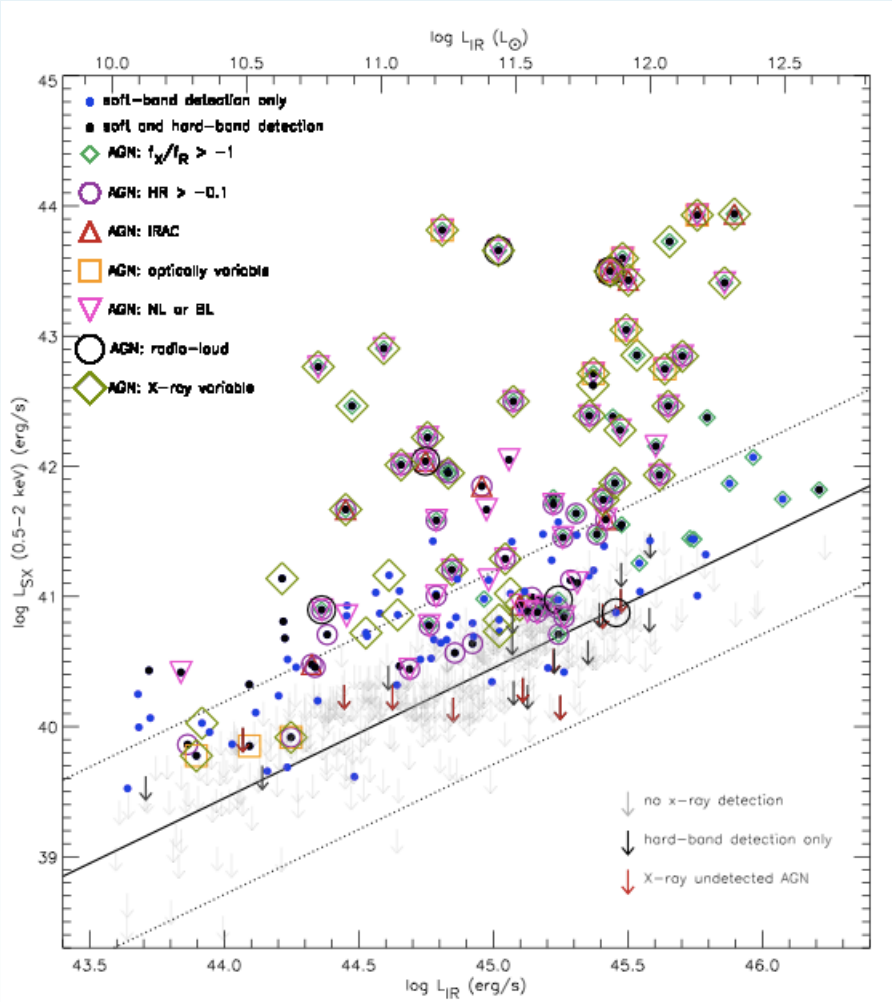
Average AGN template contains significant emission at long wavelength **from the AGN**.

- For low power AGN the submm is quite a clean star-formation measure.
- Not at all true for powerful AGN.
- We'll need SPICA diagnostics for these.

See also Symeonidis 2017, MNRAS in press: (arXiv 161007947)

Star forming galaxies produce X-rays as well as AGN.*

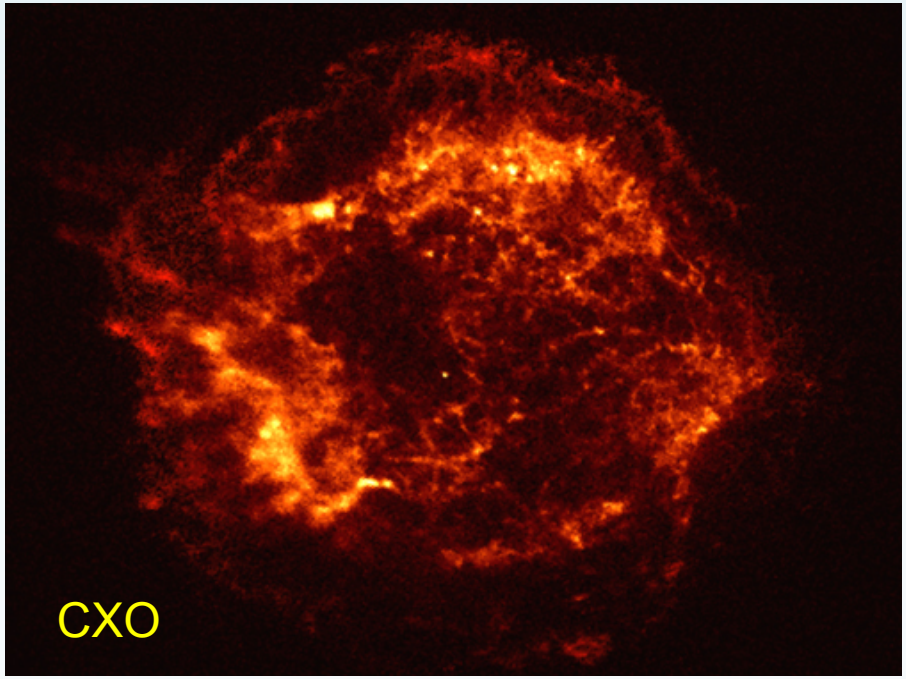
- For low-obscuration AGN X-rays are a clean measure of AGN power.
- Not true for heavily obscured AGN.
- We'll need ATHENA's big mirror and super-sensitive spectrometer to crack these.



Symeonidis et al. 2014, MNRAS 443, 3728

*In fact, star forming galaxies dominate the X-ray sky at the faintest fluxes.

Beginnings and ends of stars

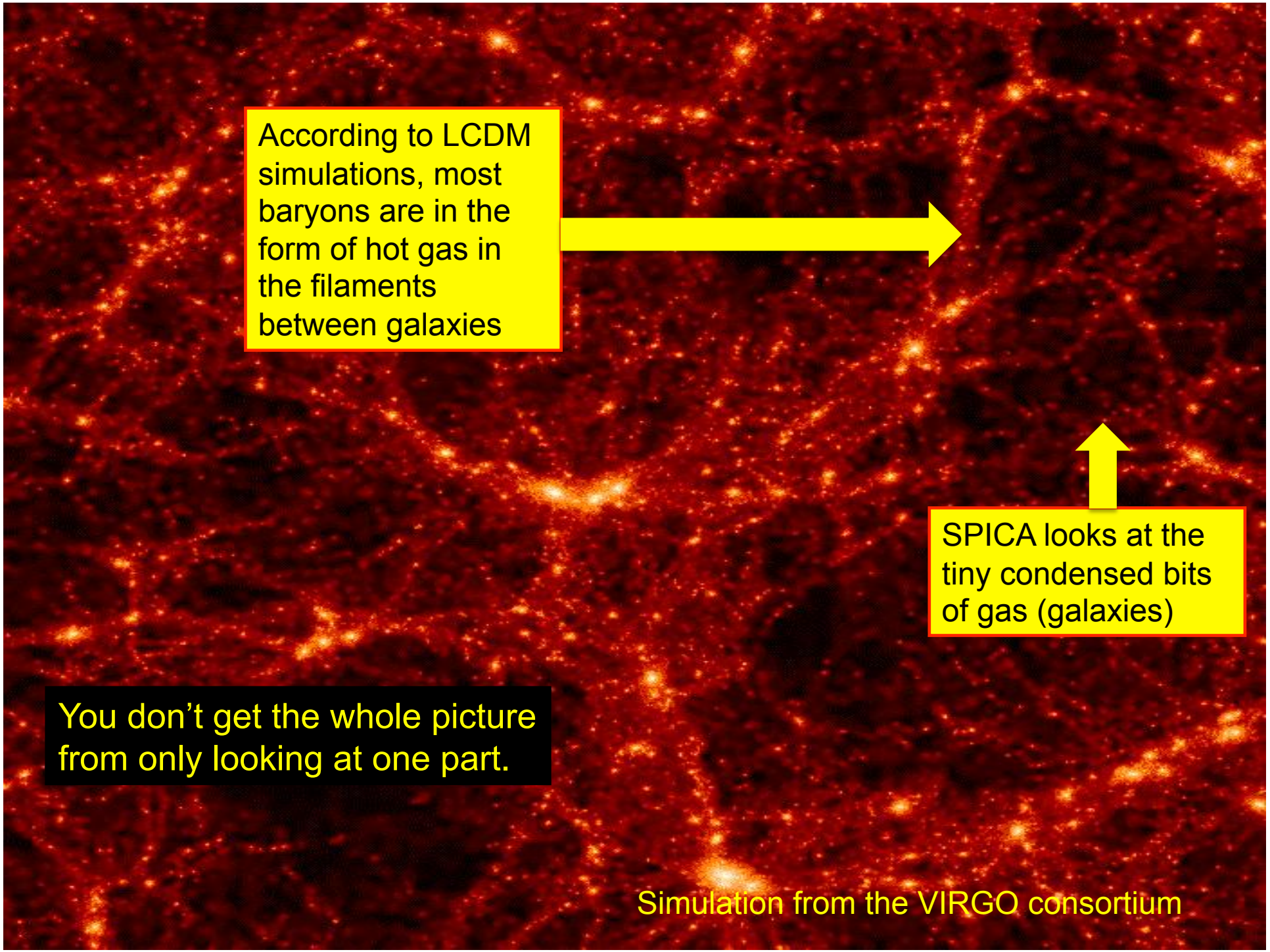


We've had centuries of optical astronomy looking at stars.
We need the **infrared** to tell us what happens before stars form.
We need **X-rays** to tell us what happens after stars die.

Hot and cold ISM

- SPICA's wavelength range is sensitive to emission from the cold phases of the ISM (dust and molecular, atomic, & low-moderate ionization gas). **Blind** to the hot phase.
- ATHENA's energy range is sensitive to emission from hot phase of ISM. **Blind** to the cool phase*.
- The "gastrophysics" of galaxy evolution follows a cycle between these phases:
- Gas falls into galaxies, forms molecular clouds, which form stars, which explode as supernovae, producing hot gas which may escape back to the intergalactic medium or may fall back and cool.

* In emission, not true for absorption


According to LCDM simulations, most baryons are in the form of hot gas in the filaments between galaxies
SPICA looks at the tiny condensed bits of gas (galaxies)
You don't get the whole picture from only looking at one part.
Simulation from the VIRGO consortium

Conclusions

- Together, SPICA and ATHENA are great tools for studying the relationship between black hole growth and star formation.
- The beginning and end points of stars, all the astrophysics related to these
- The cold and the hot interstellar medium.
- The full story of baryons.