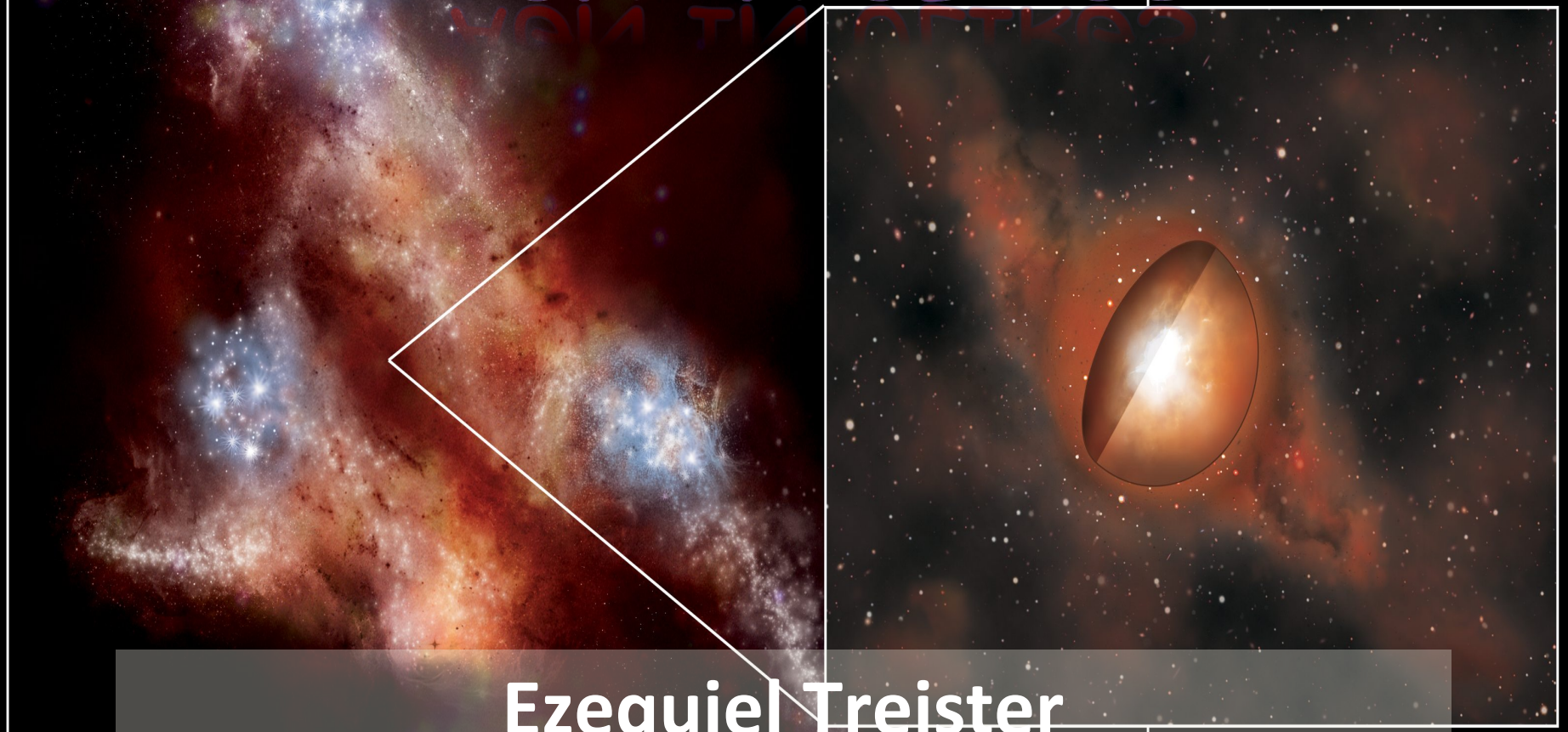
HEAVILY OBSCURED AGN IN ULIRGS

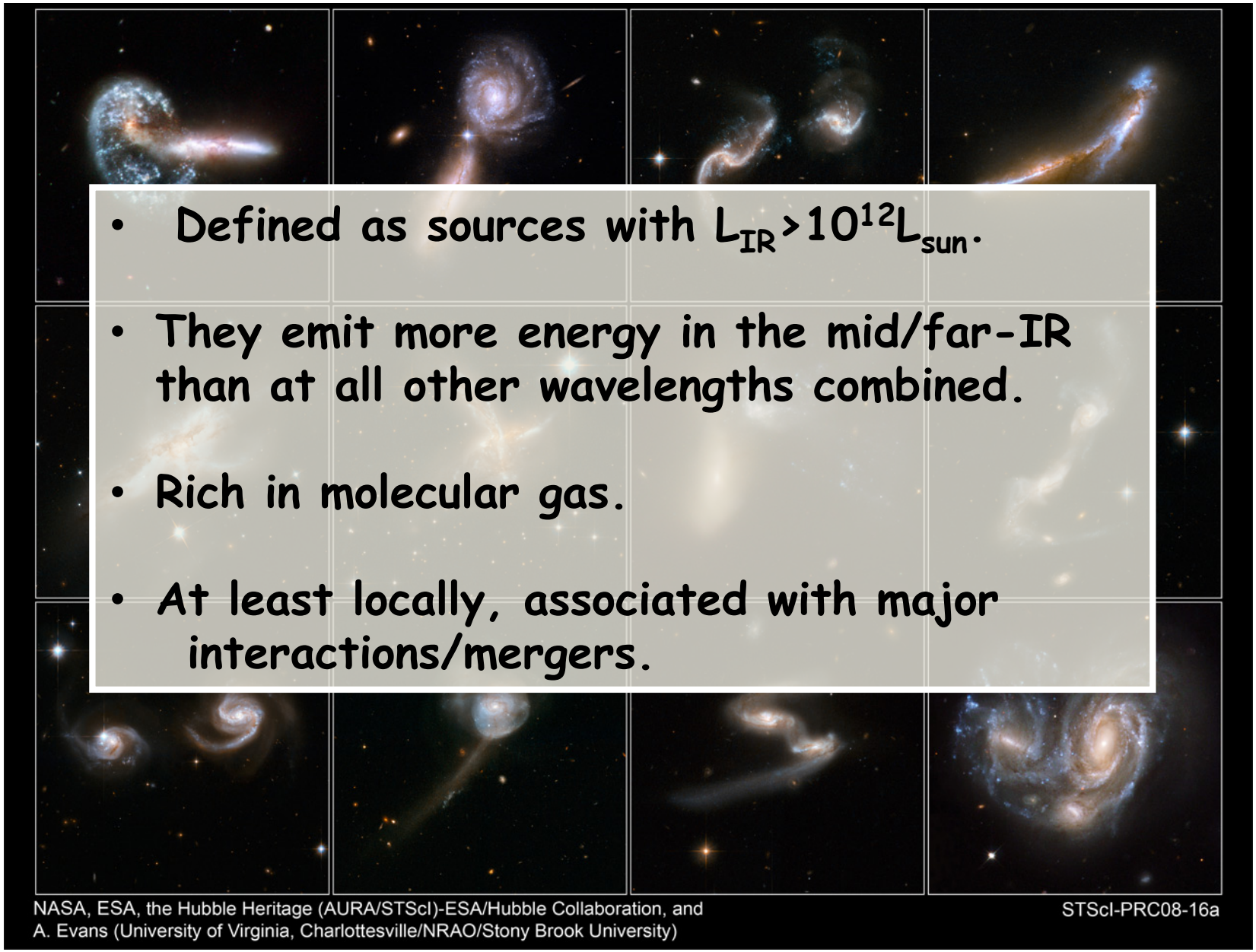


Ezequiel Treister

Einstein Fellow

Institute for Astronomy, University of Hawai'i

ULIRGs

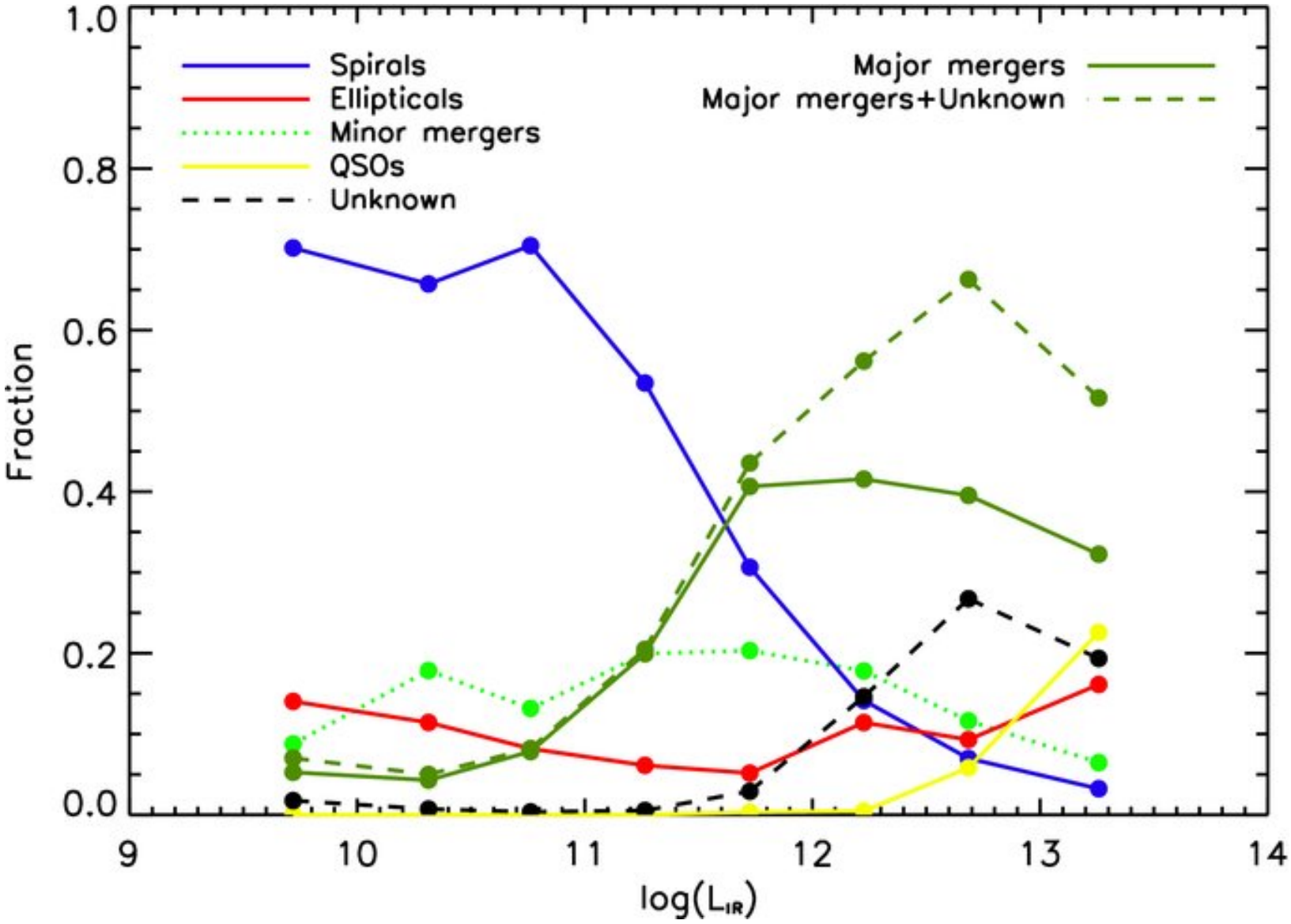


- Defined as sources with $L_{IR} > 10^{12} L_{sun}$.
- They emit more energy in the mid/far-IR than at all other wavelengths combined.
- Rich in molecular gas.
- At least locally, associated with major interactions/mergers.

NASA, ESA, the Hubble Heritage (AURA/STScI)-ESA/Hubble Collaboration, and A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)

STScI-PRC08-16a

Morphologies at z~1



Kartaltepe et al. 2010

ULIRGs "Great Debate"

Most important (open) questions at 1998 Ringber conference:

What is the source of energy?

ULIRGs follow a merger sequence from colliding disk galaxies to ellipticals.

ULIRGs are precursors of quasars.

ULIRGs are local templates of the high luminosity tail of mergers at z=1-4.

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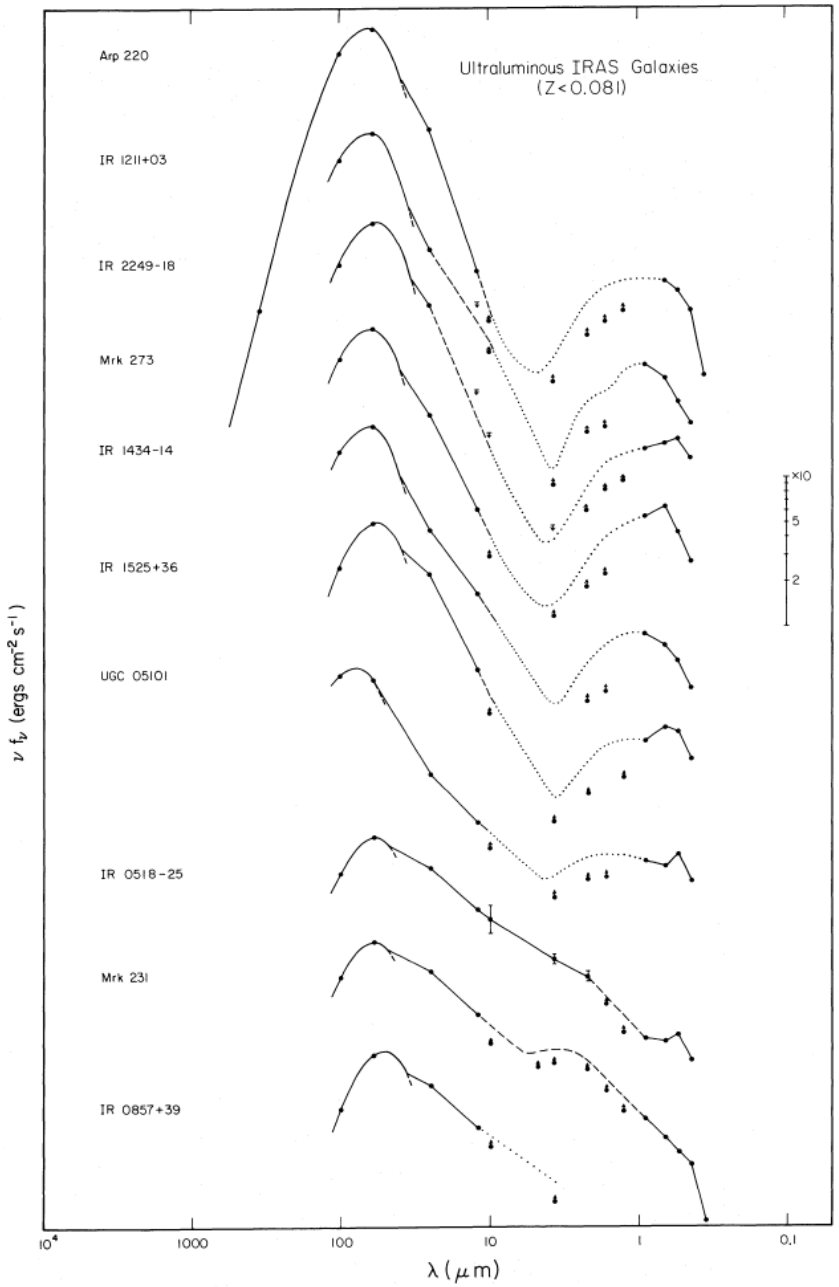
SED of Local ULIRGs



Most of the emission in the IR

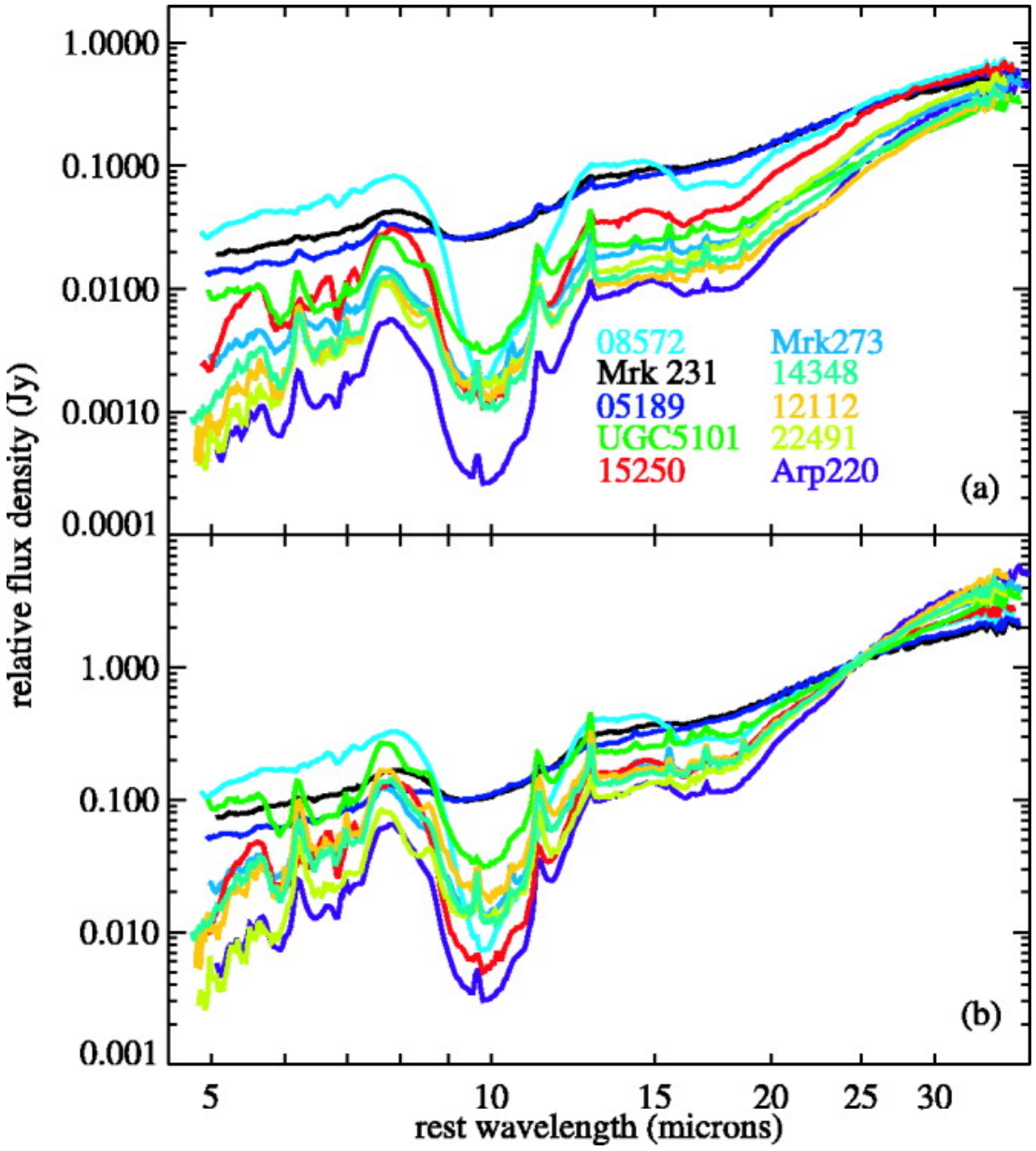
However, relatively more for the more luminous sources

Differences in spectral shape

Cold: $f_{25\mu m}/f_{60\mu m}<0.2$
Warm: $f_{25\mu m}/f_{60\mu m}>0.2$

Sanders et al. 1988

Spitzer IRS Observations



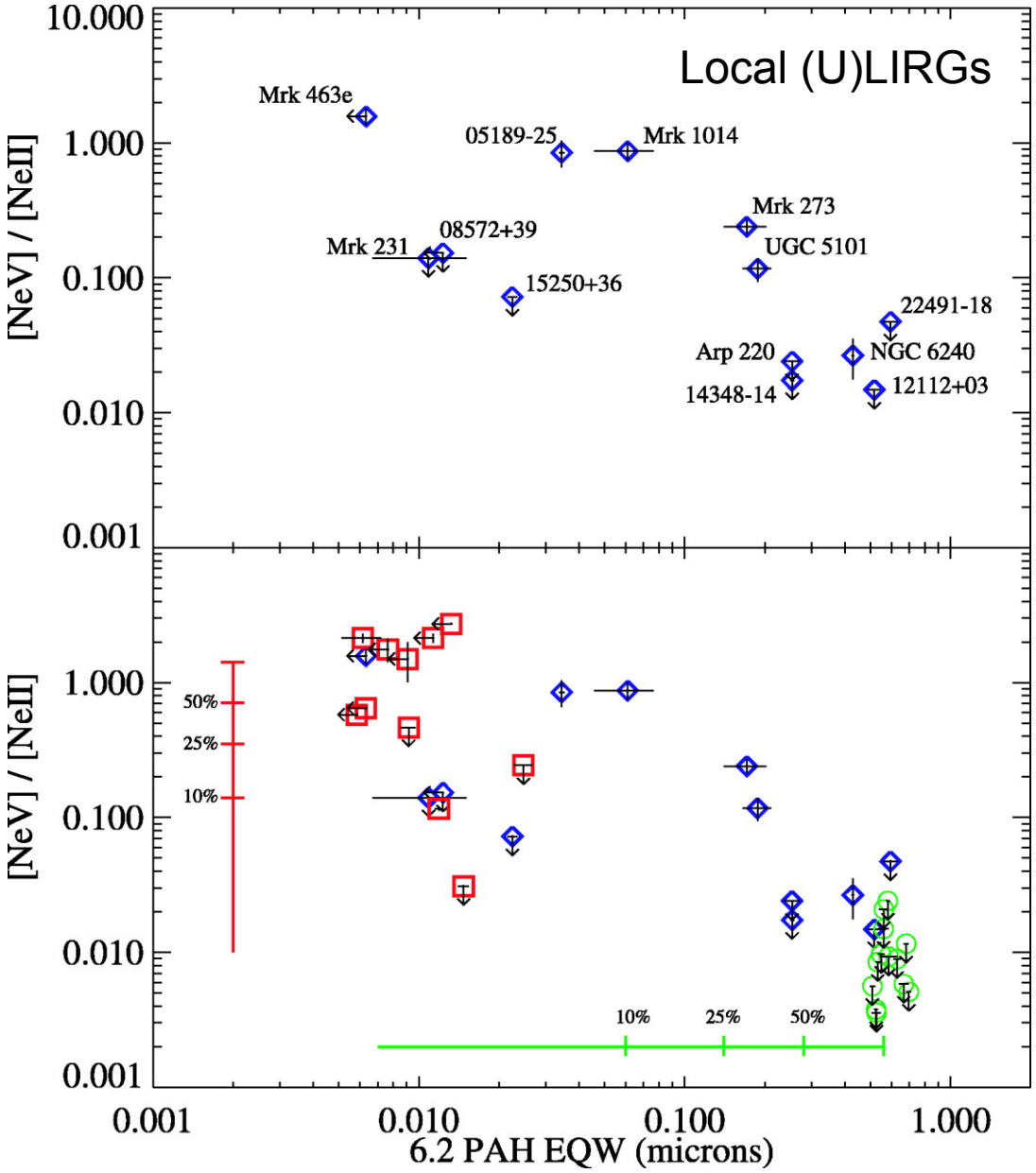
Large spread in spectral shape

PAH features present in most sources.

Range in silicate optical depth: $0.4<\tau_{9.7}<4.2$ ($7.9<A_v<78$ mags)

Armus et al. 2007

IR Diagnostics



(U)LIRGs in the IR are a mix of AGN and star formation

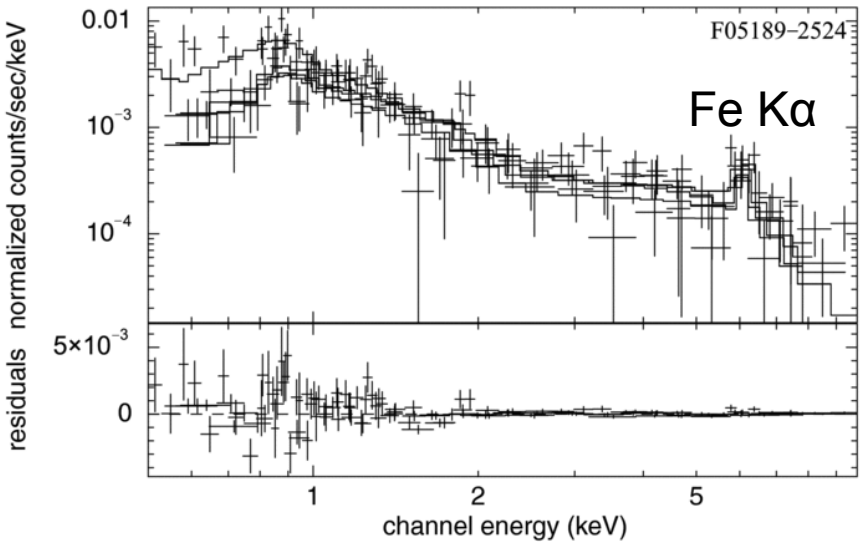
AGN

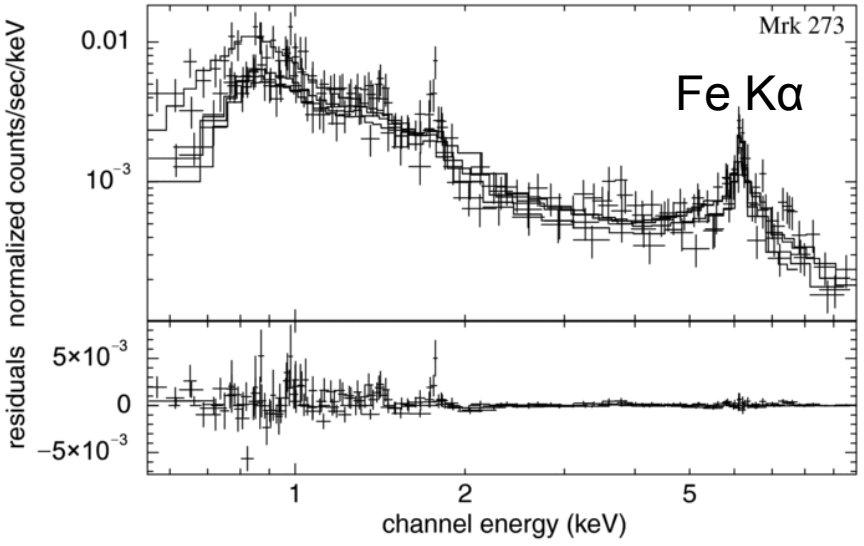
Starburst galaxies

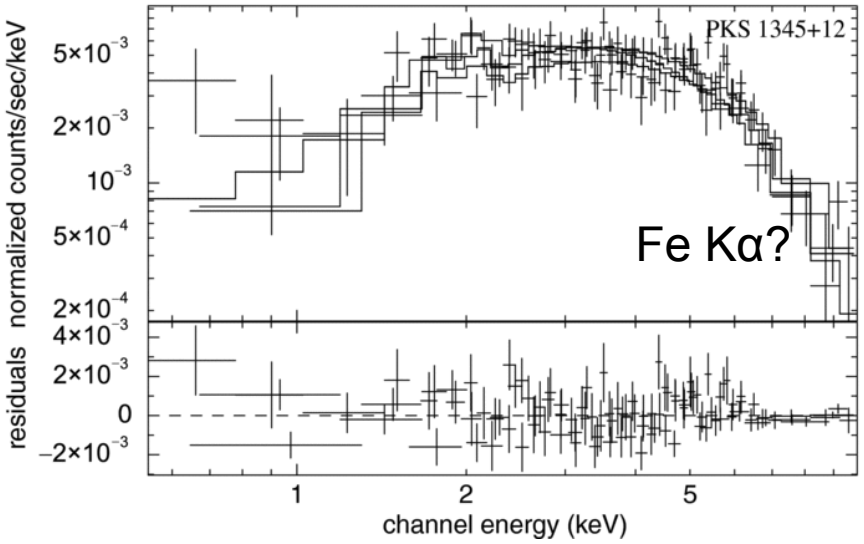
(U)LIRGs

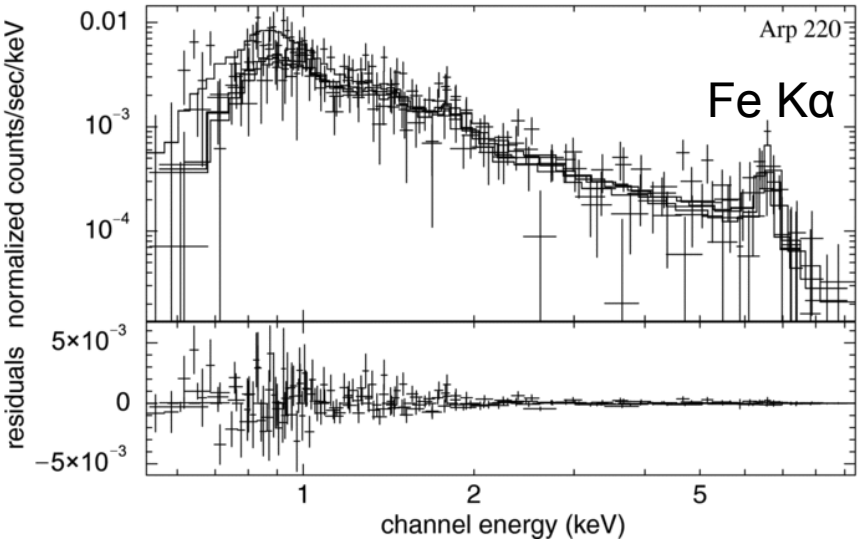
Armus et al. 2007

Suzaku X-ray Observations





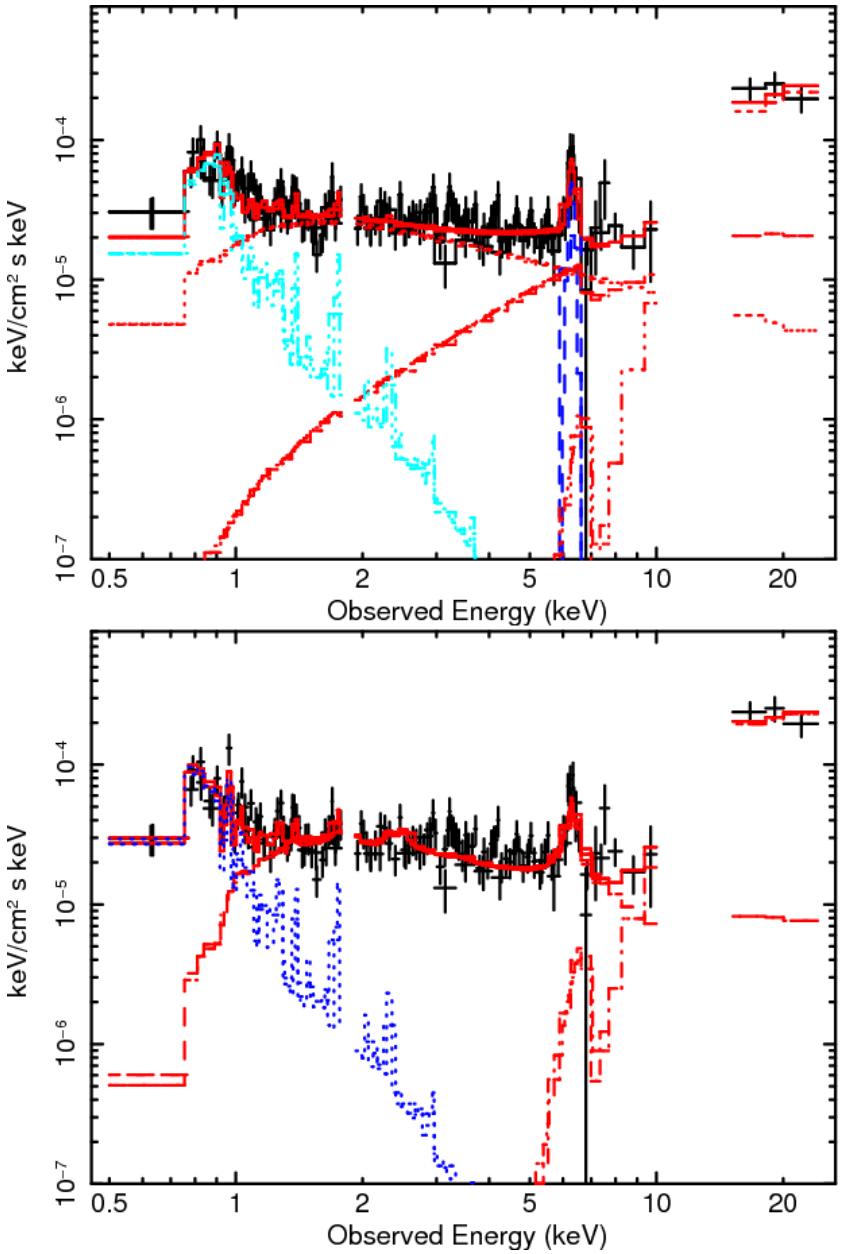




See also poster #70 by E. Nardini

Teng et al. 2009

IRAS19254-7245



Starburst component
kT~0.7 keV

Fe Kα

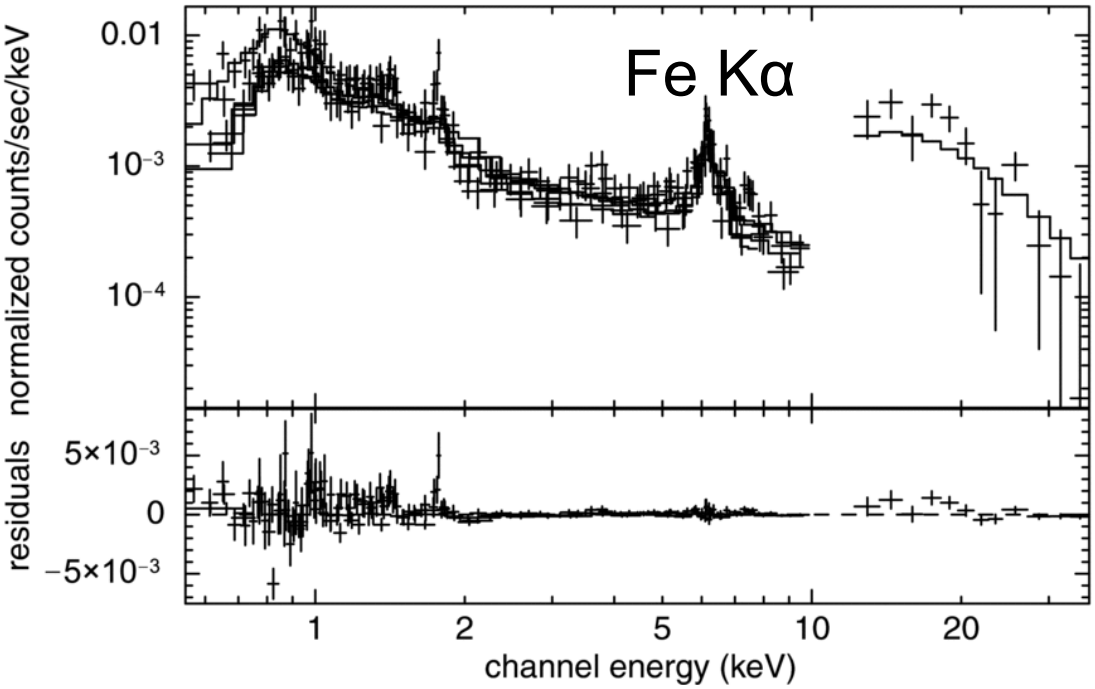
(absorbed) AGN Continuum

Starburst component

Ionized reflected component

Braito et al. 2009

Suzaku High Energy Observations of Mrk 273



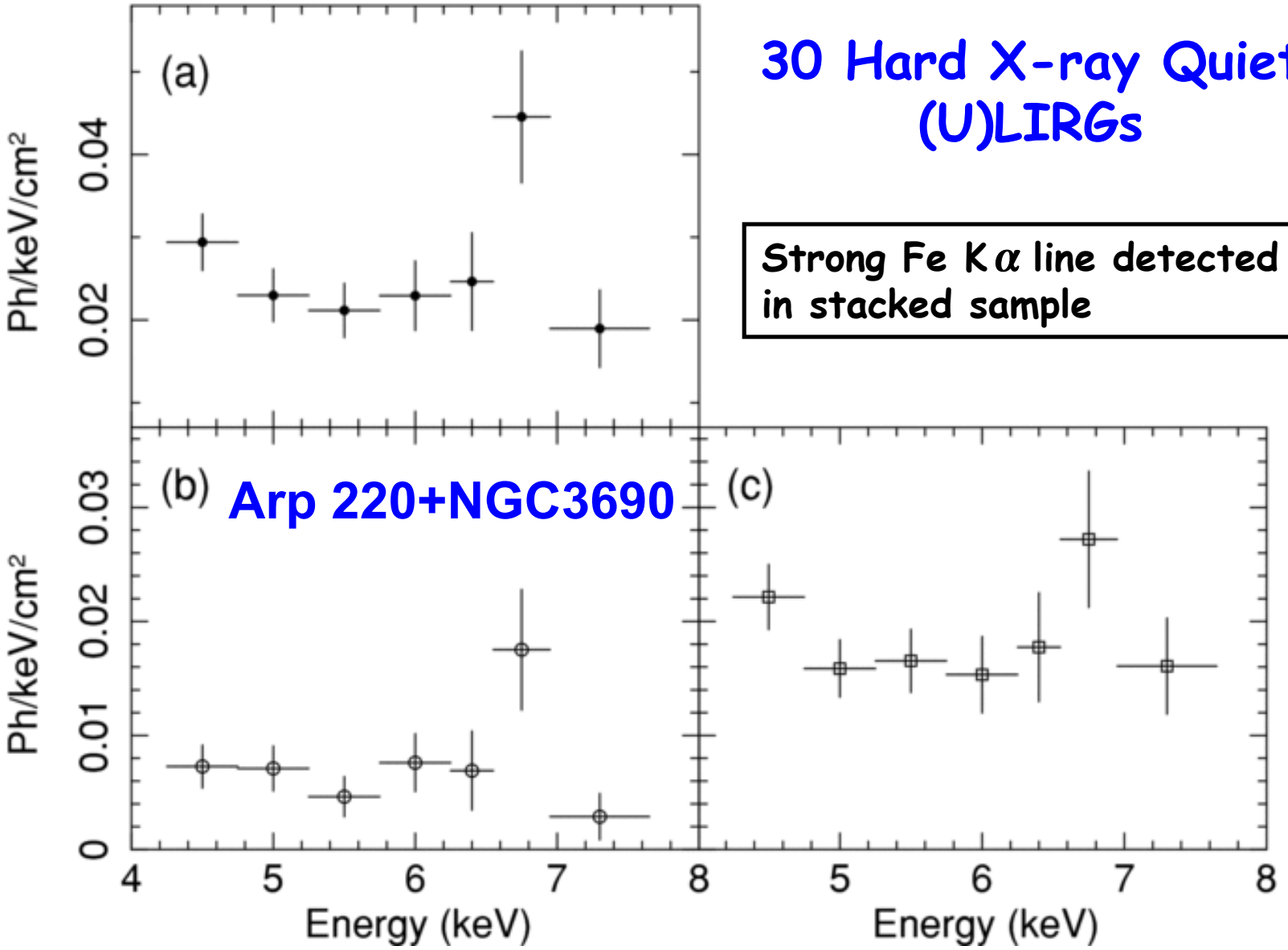
N_H~1.4x10^{24} cm^{-2} (i.e., Compton thick)

Transmitted flux ~5%

Covering fraction ~94%

Teng et al. 2009

The Chandra Perspective

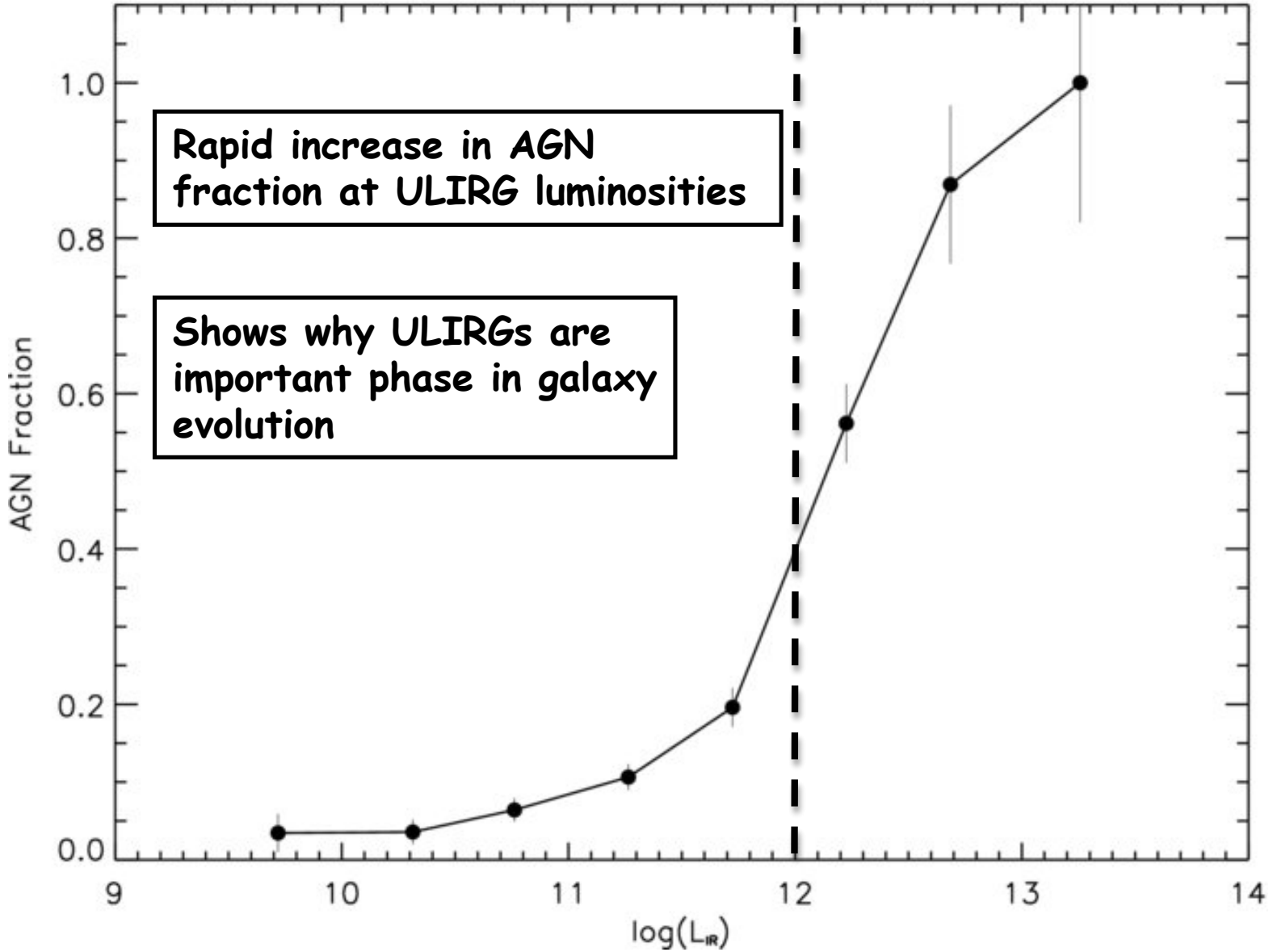


30 Hard X-ray Quiet (U)LIRGs

Strong Fe Kα line detected in stacked sample

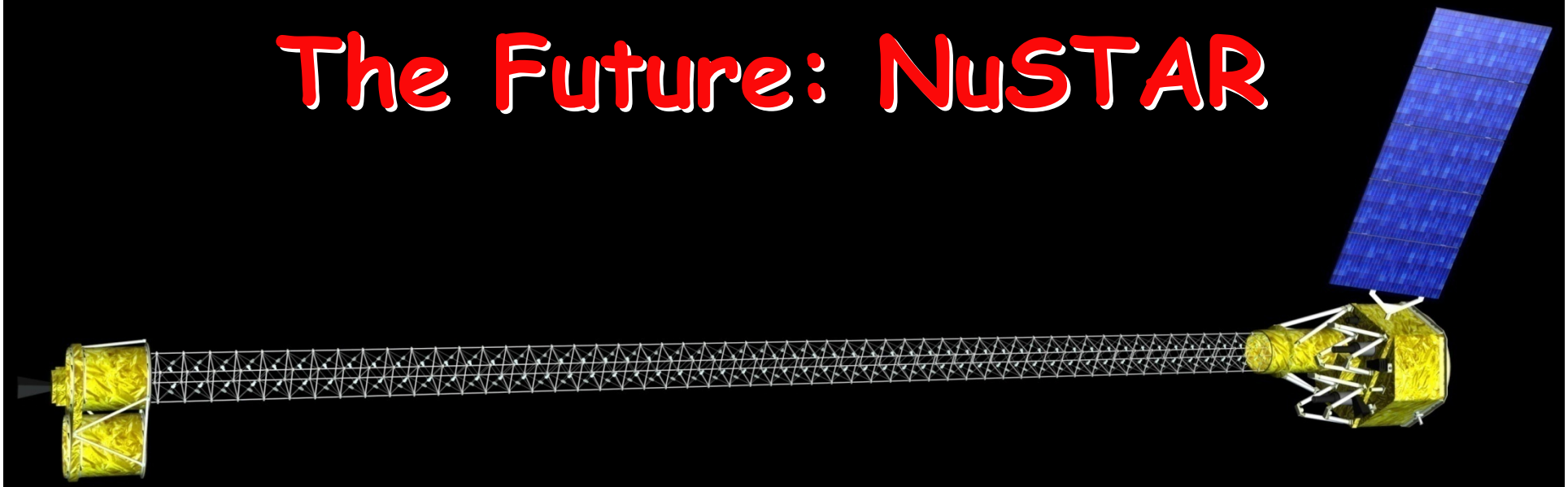
Iwasawa et al. 2009, 2011

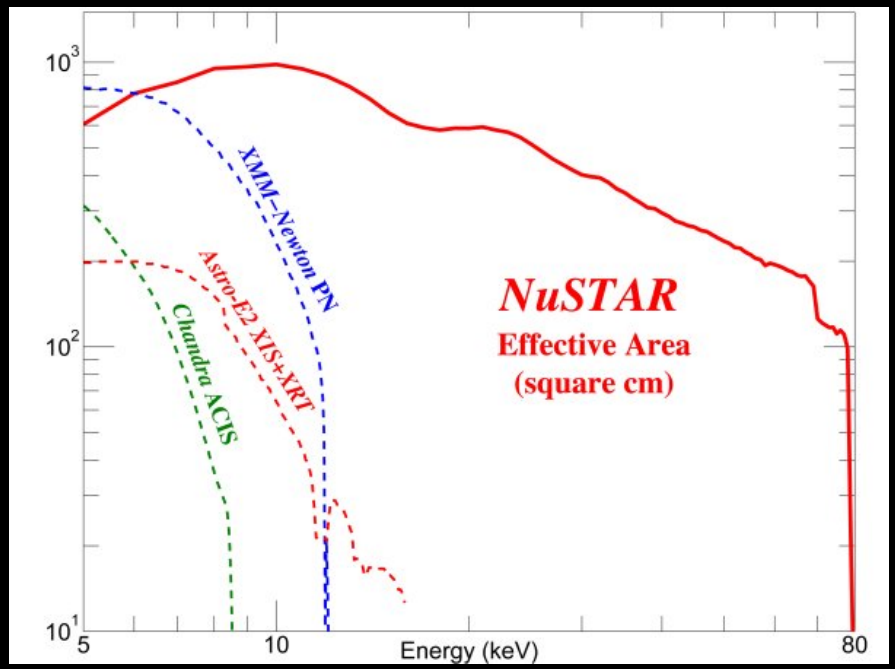
AGN Fraction vs Luminosity



Kartaltepe et al. 2010

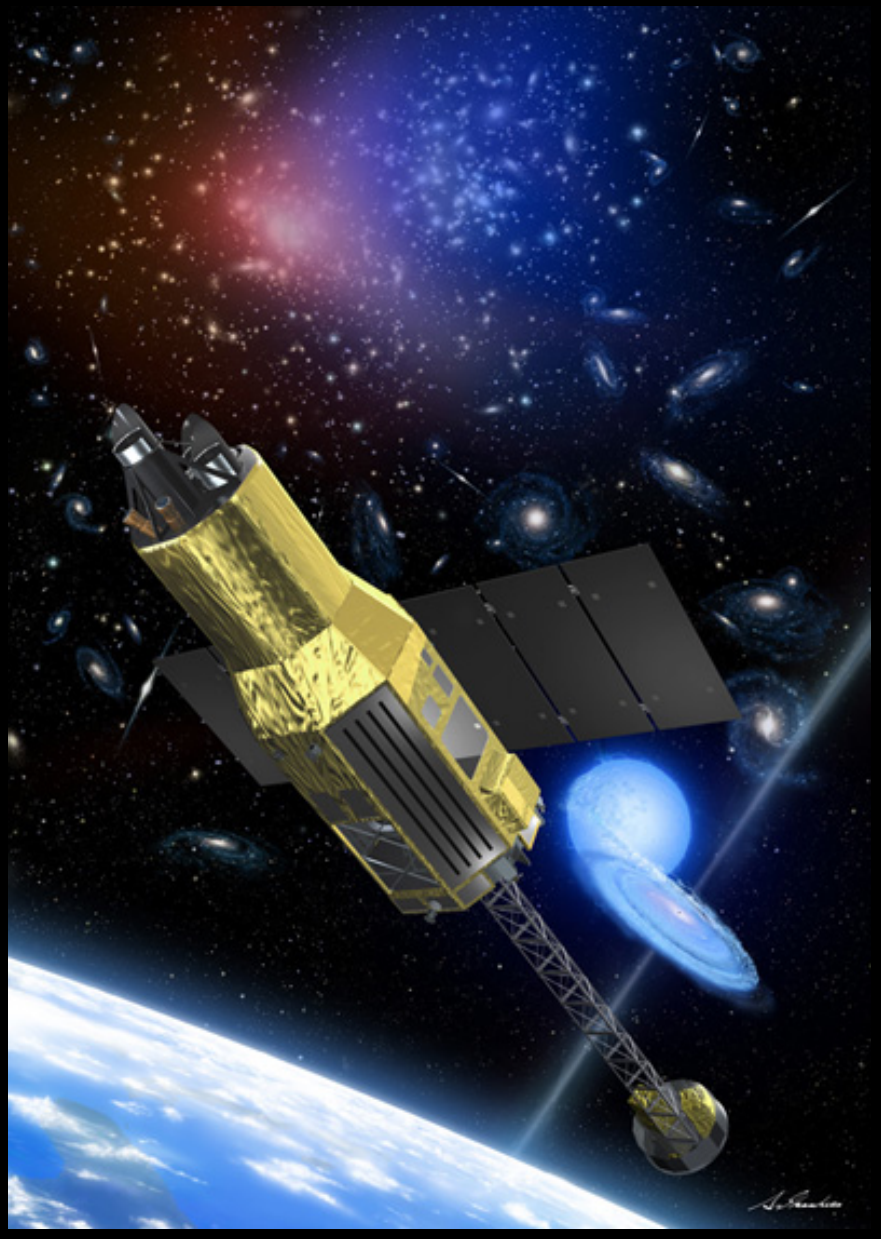
The Future: NuSTAR

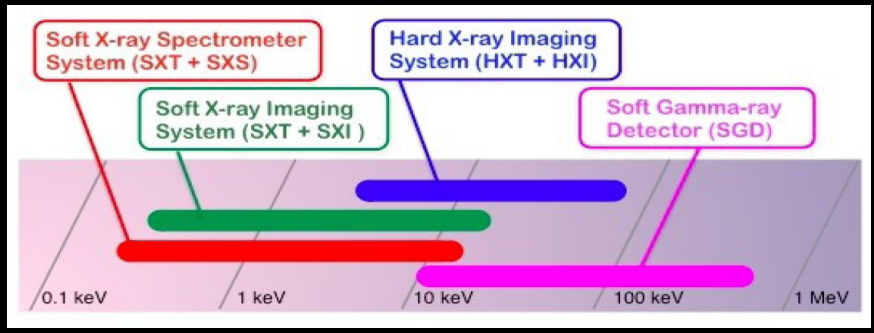


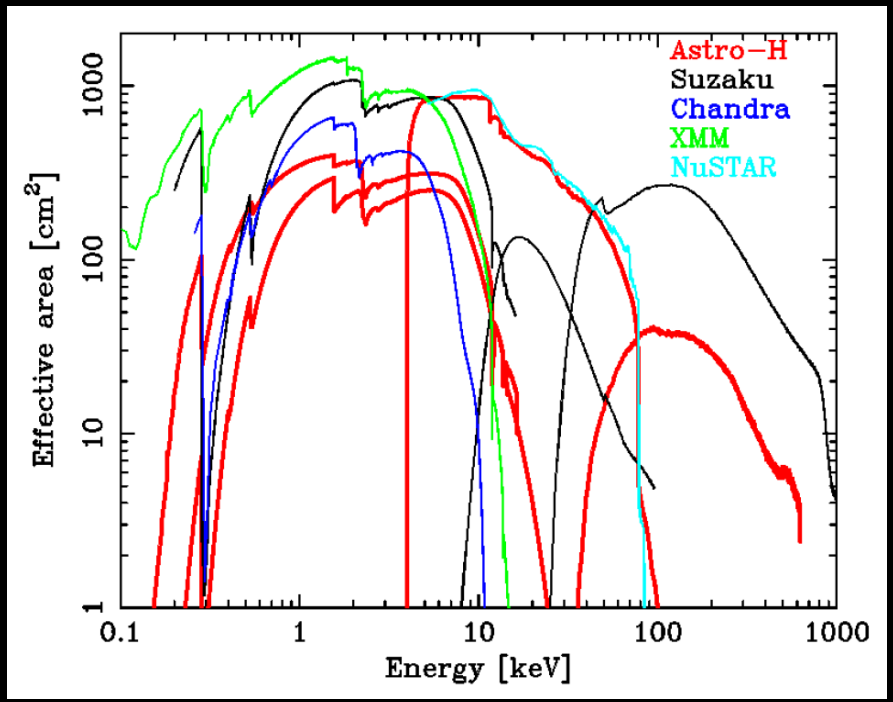


Energy Range	6-80 keV
Angular resolution	40″
Field of View	12′x12′
Flux Limit	~2×10^{-14} in 1 Msec
Launch Date	**February 2012**
PI	Fiona Harrison

The Future: ASTRO-H







http://astro-h.isas.jaxa.jp

NuSTAR

NuSTAR will be ~100x more sensitive than Suzaku/HXD at high energies.

Several ULIRGs will be observed by NuSTAR
Exact target list TBD. Exp. times ~100 ksec.

Main goals:
-Confirm presence of AGN at high energies
-Measure AGN bolometric luminosity
-Constrain amount of obscuration
-Look for variability in AGN component

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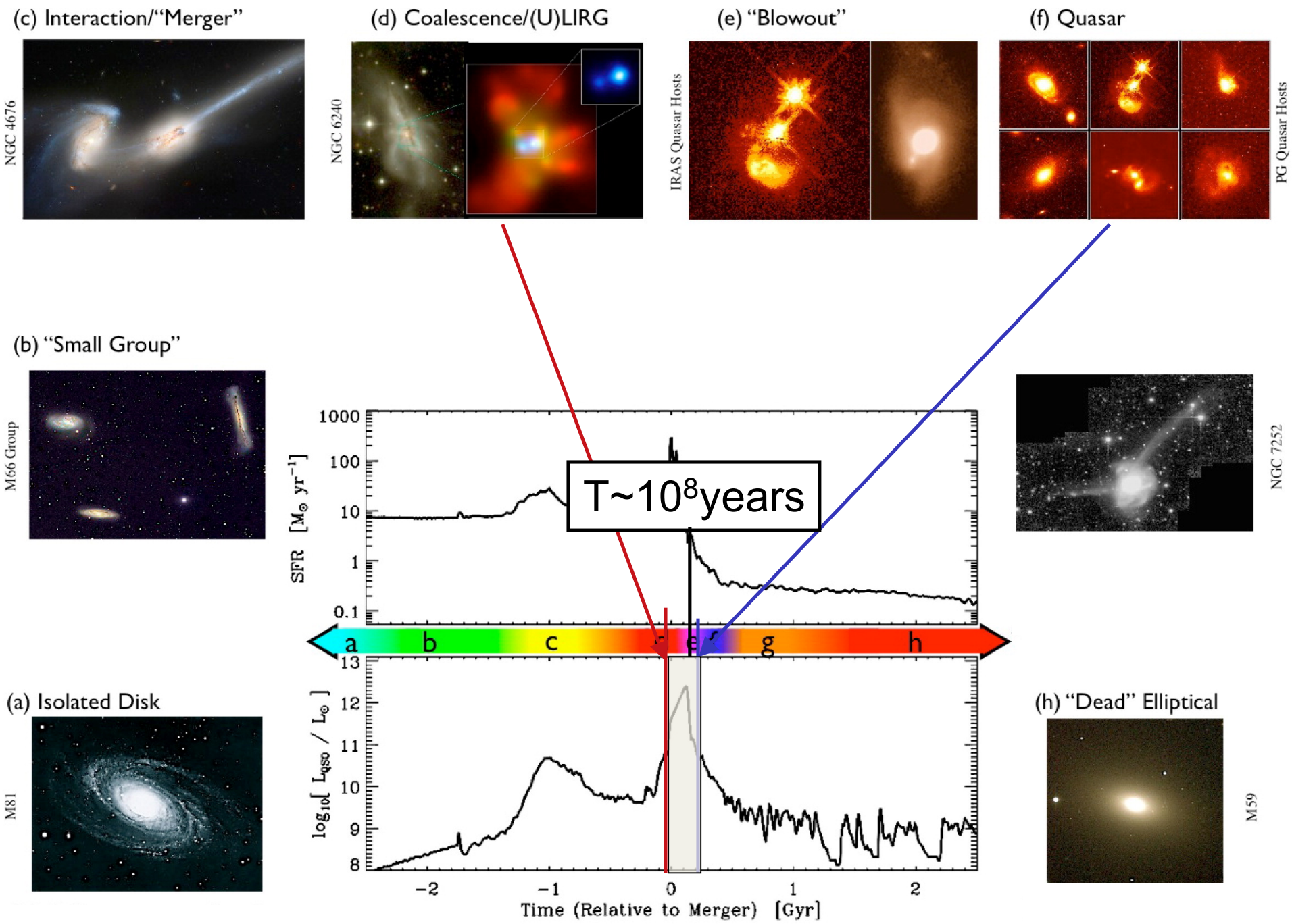
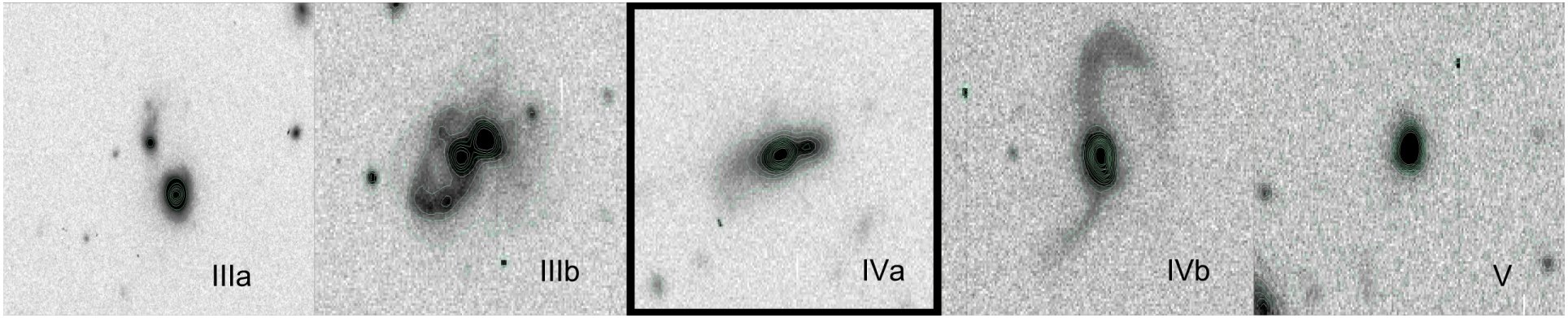


Hopkins et al. (2008)

Evolutionary Sequence

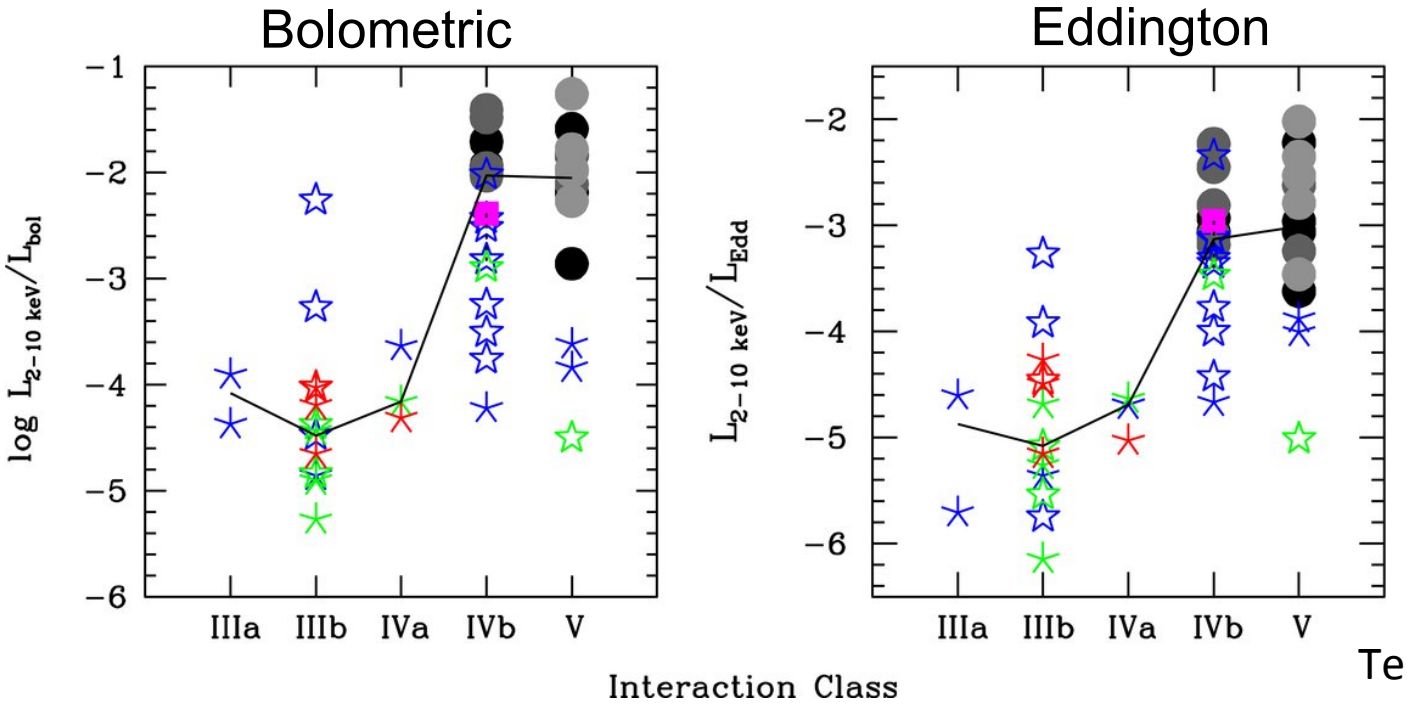


pre-merger

diffuse merger

compact merger

old merger



Teng et al. 2010

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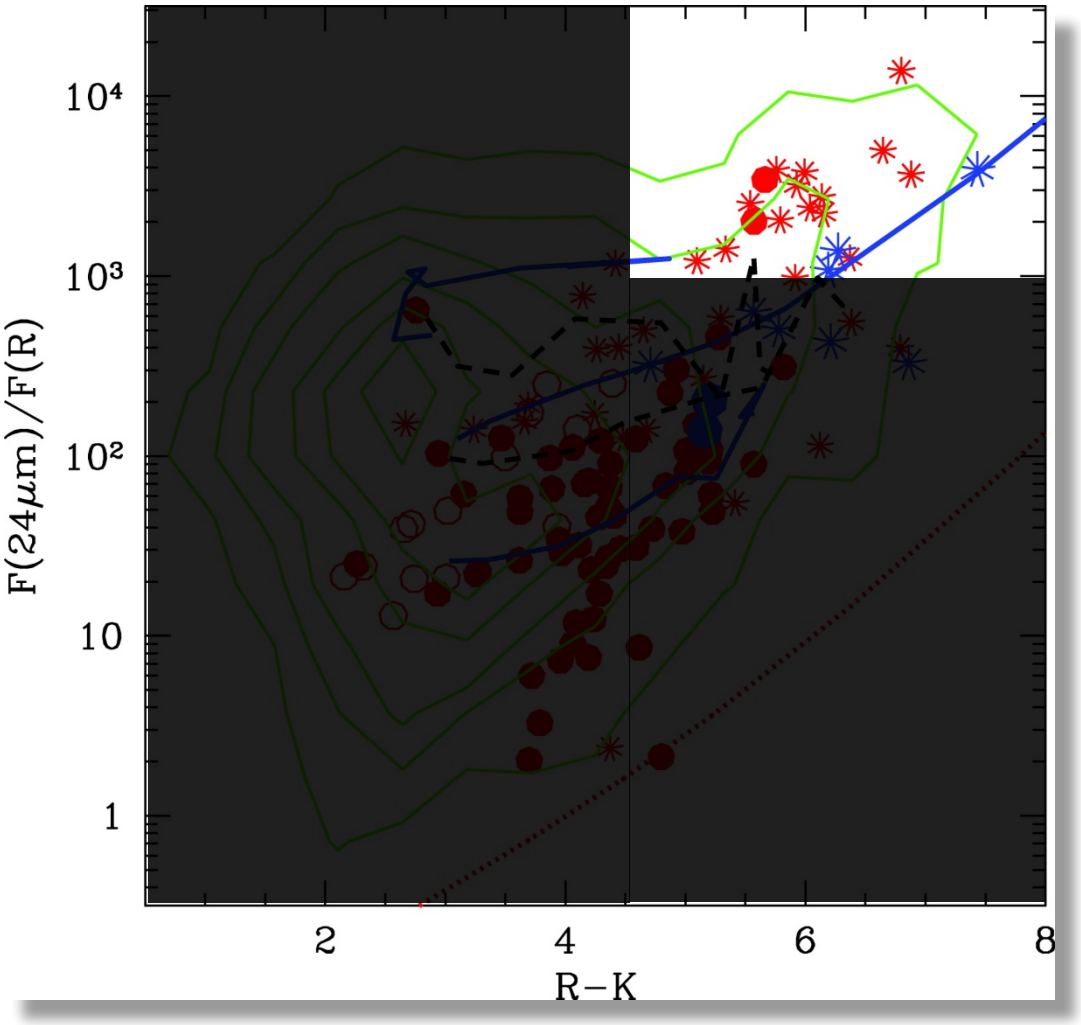
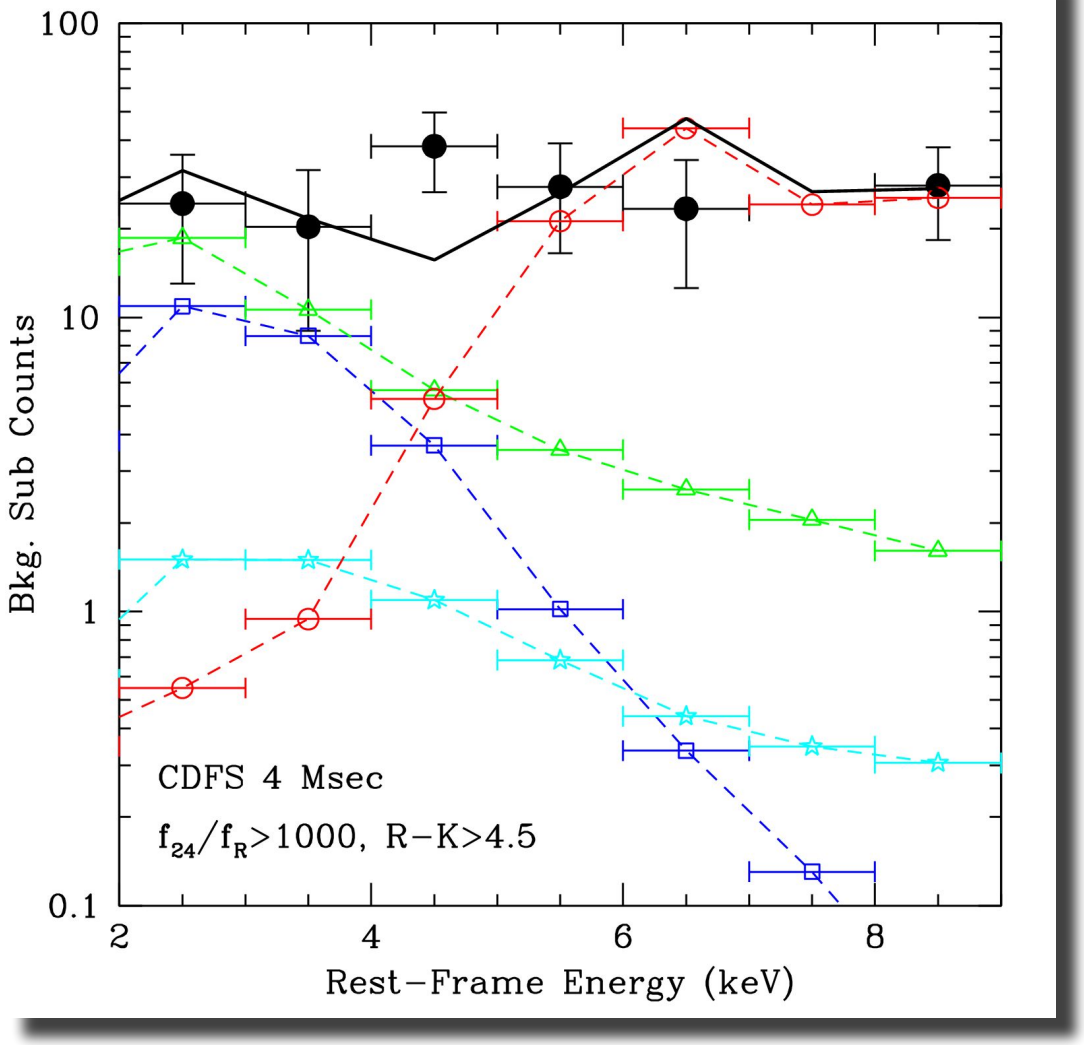
Mid-IR Excess Sources at z~1-3



This technique selects mostly high luminosity, heavily obscured AGN (quasars).

Fiore et al. 2008, Treister et al. 2009

Rest-frame X-ray Stacking

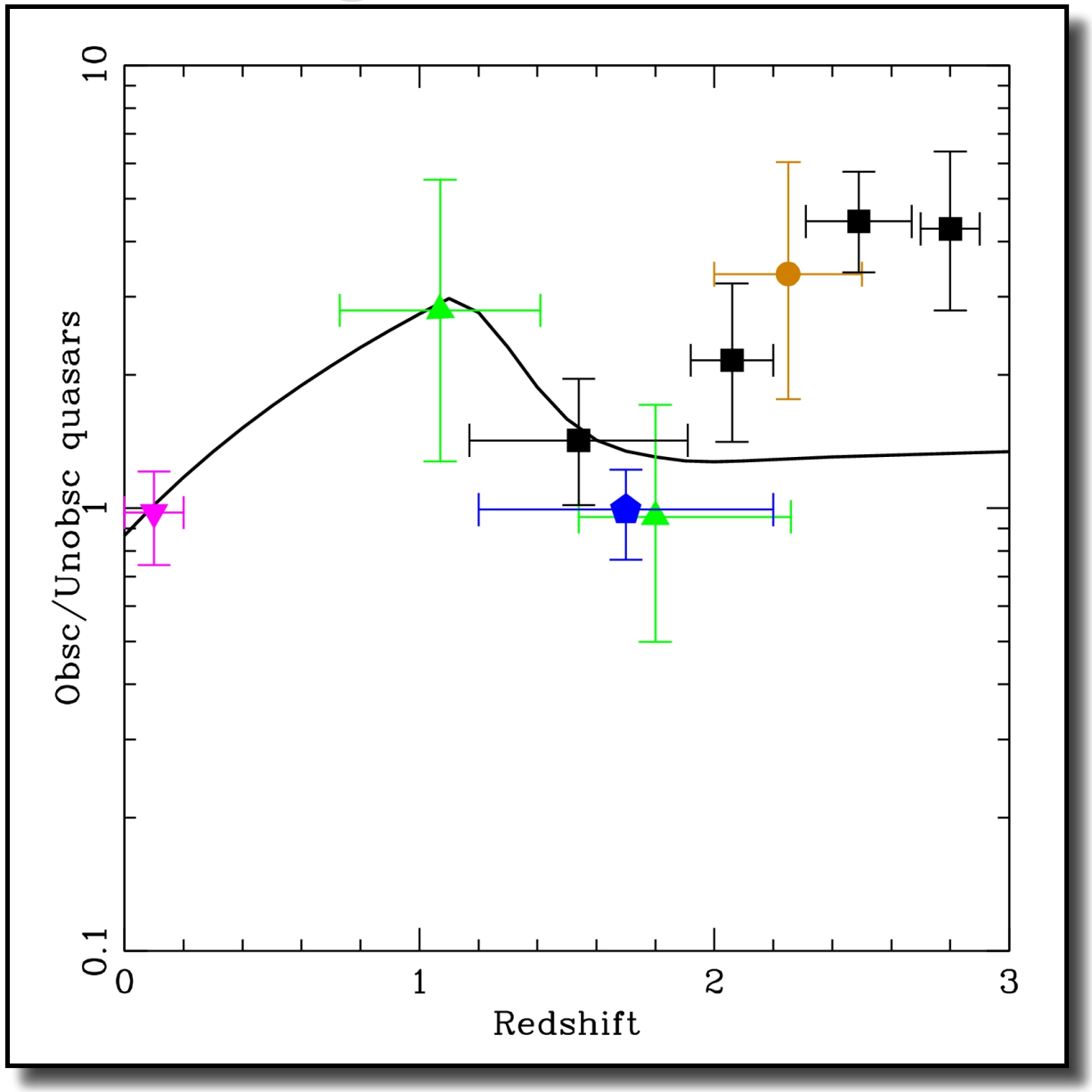


$N_H=10^{24}cm^{-2}$ $\Gamma=1.9$
$\Gamma=1.9$ (reflected)
Thermal kT=0.7 keV
HMXBs

Combination of heavily-obscured AGN and star-formation

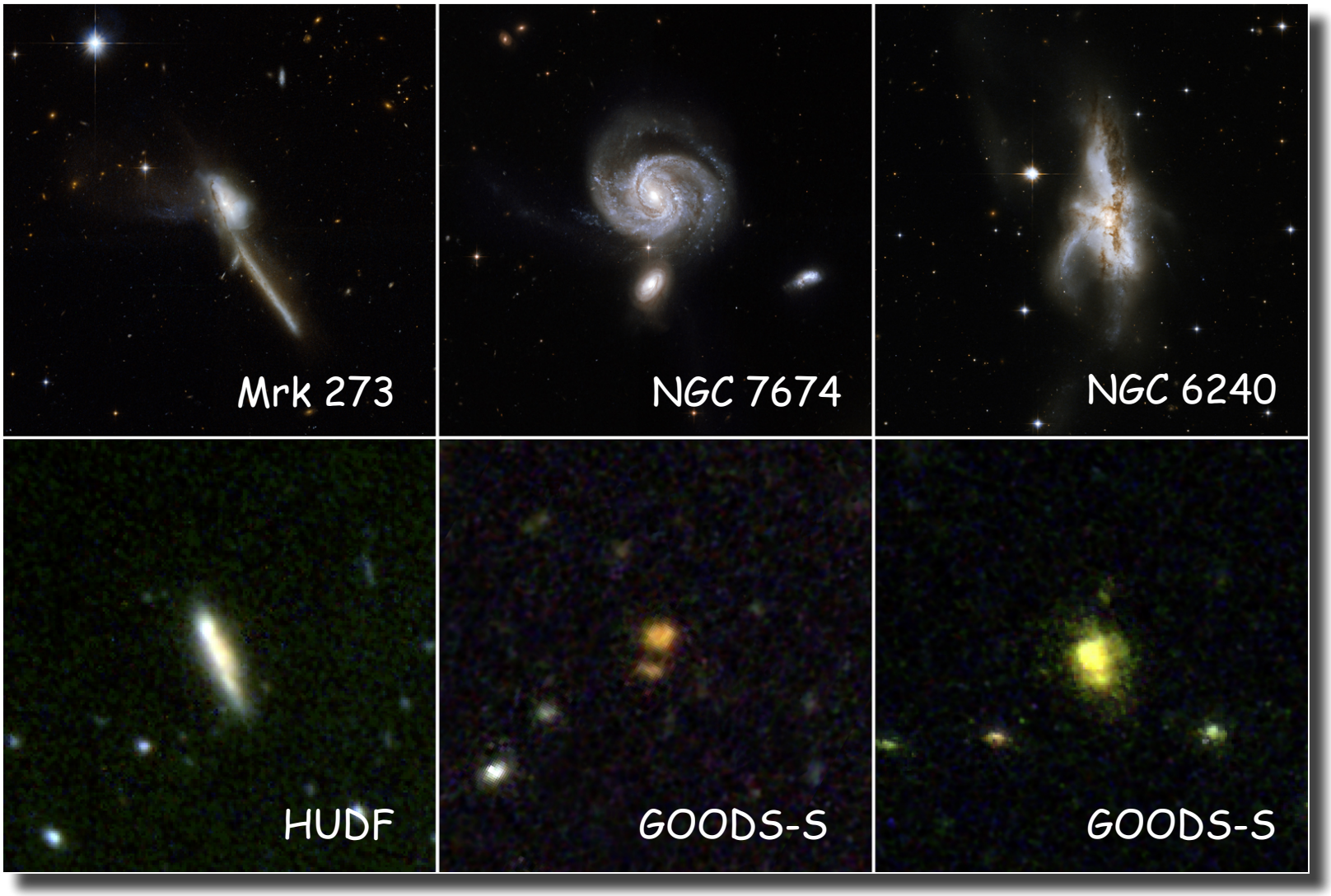
Treister et al. 2009

The Merger-Quasar Connection



Treister et al. 2010

Morphologies

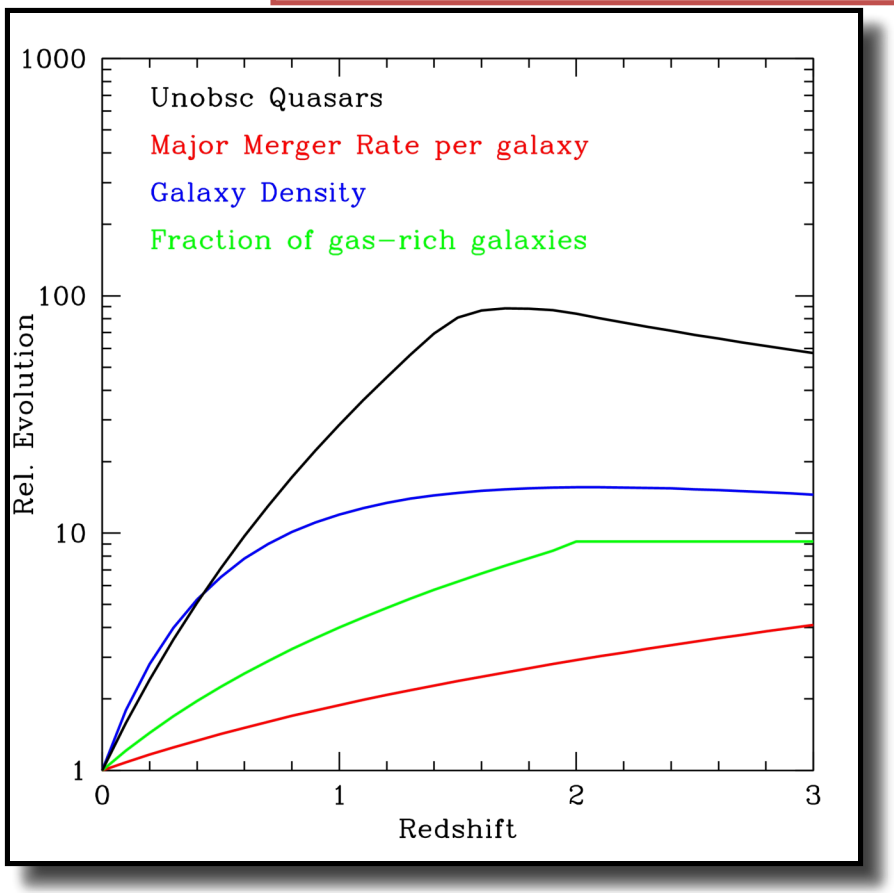


Treister et al. 2010

Merger-Quasar Connection

Obscured quasars are the product of the merger of two massive gas-rich galaxies. After a time Δt the quasar becomes unobscured

$$\frac{N_{obsc}}{N_{Unobsc}}(z) = \frac{\Delta t \frac{d^2\,merger}{dtdN} N_{gal}(> M_{\min}(z)) f_{gas}(z)}{N_{Unobsc}(z)}$$



Treister et al. 2010

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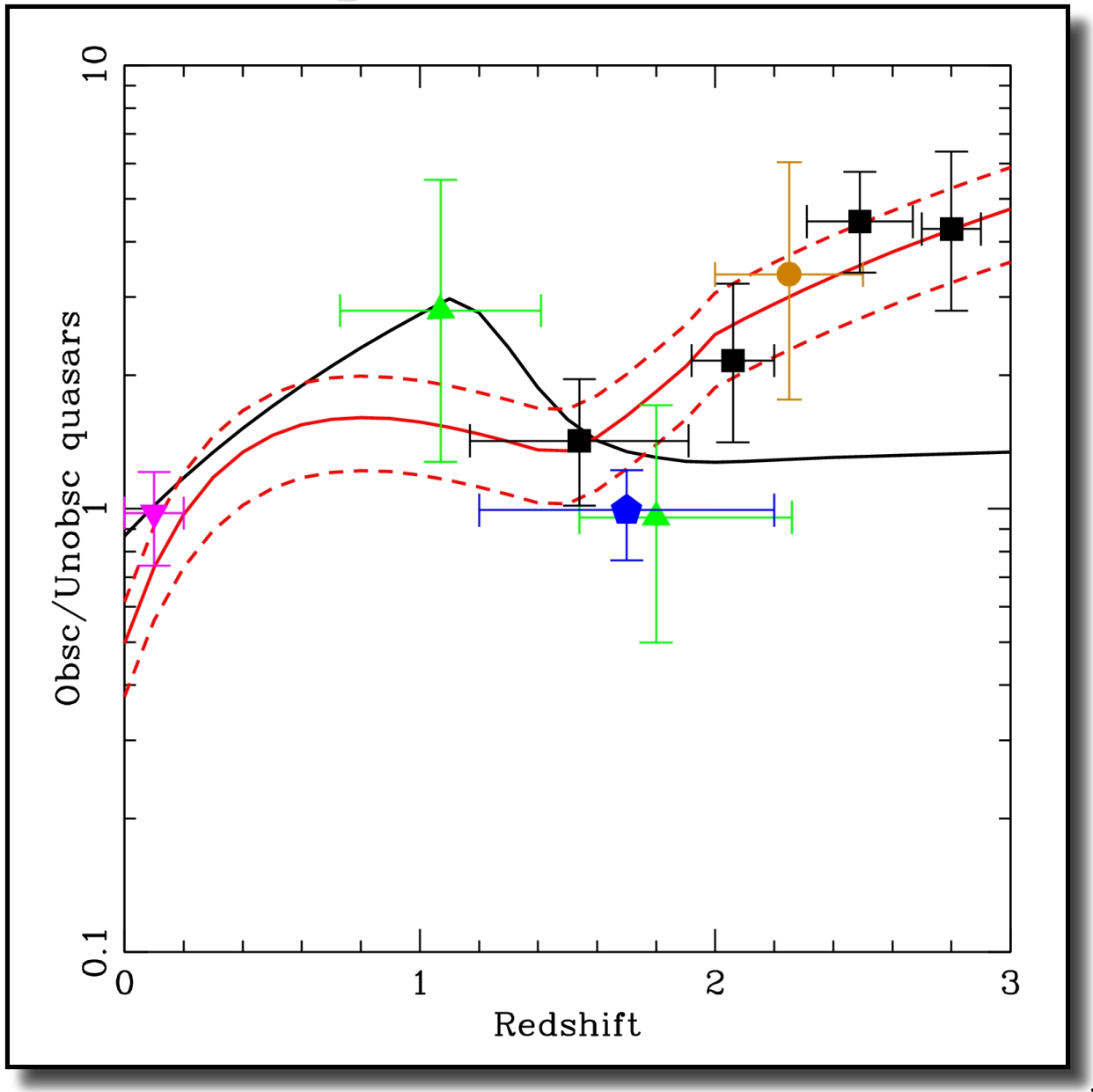

Treister et al. 2010

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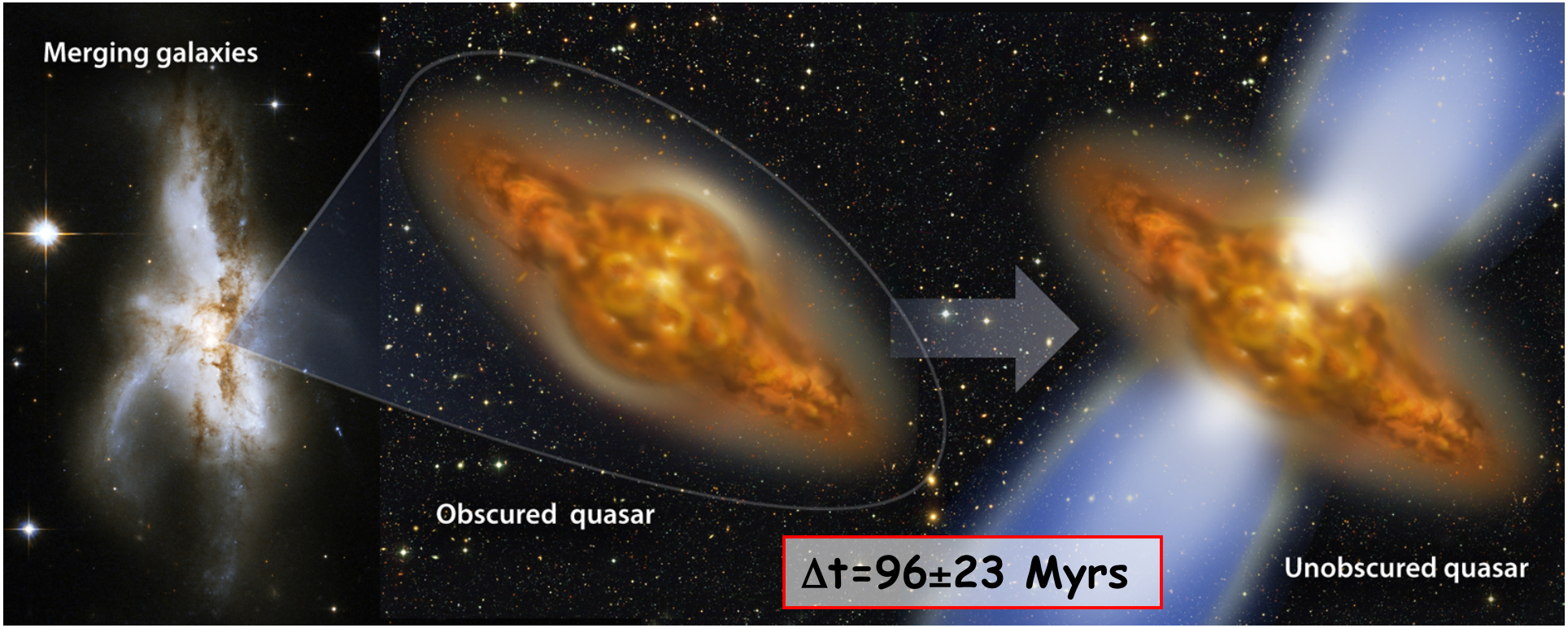

The obscured phase represents ~30% of total accretion onto supermassive black holes

Quasars outflows can get rid of most of the surrounding material

Treister et al. 2010

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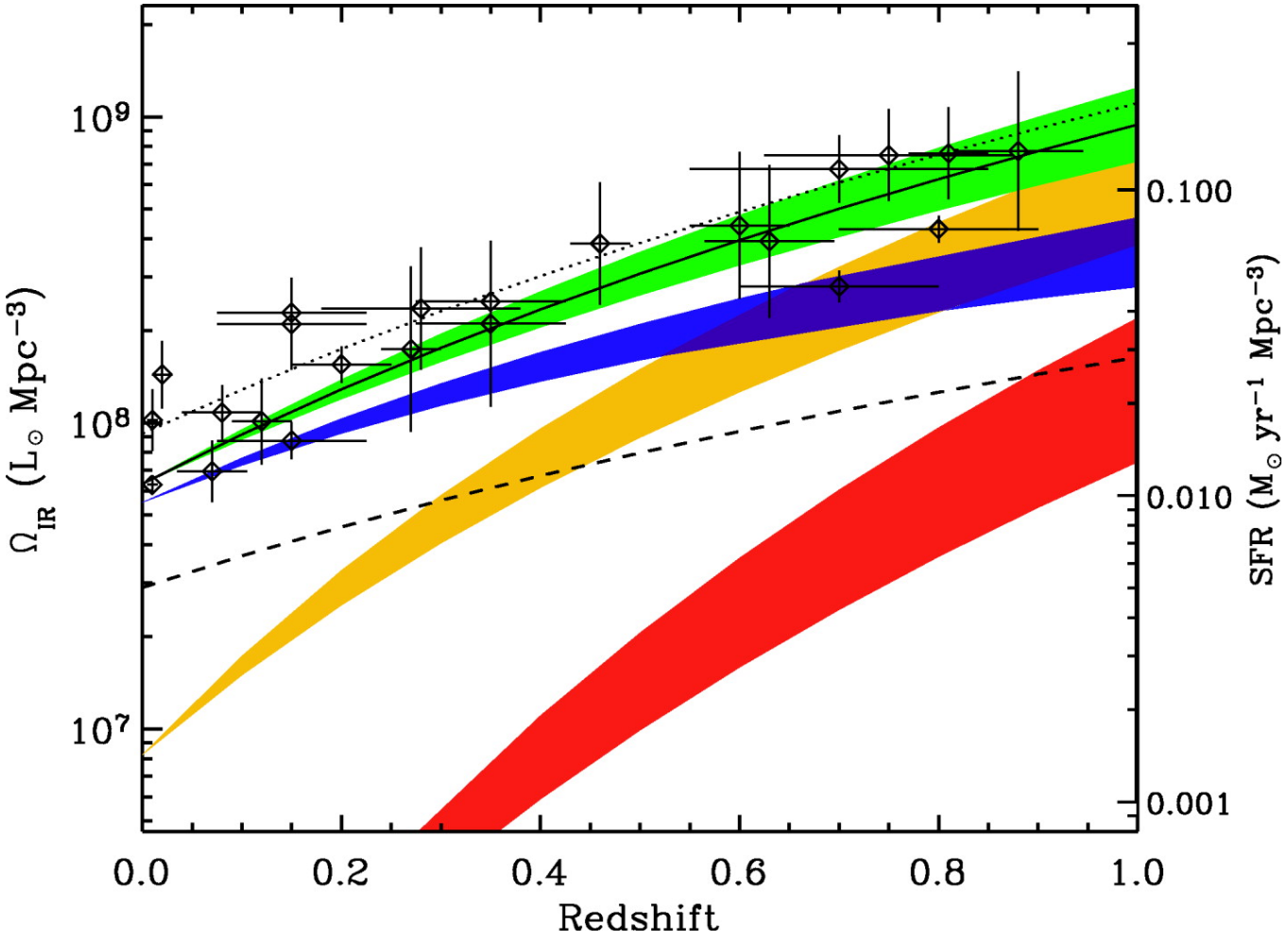
Cosmological Relevance



All galaxies

$L_{IR}<10^{11}\ L_{sun}$

$L_{IR}>10^{11}\ L_{sun}$

$L_{IR}>10^{12}\ L_{sun}$

Le Floc'h et al. 2005

ULIRGS: What do we know

What is the source of energy?

A combination of AGN and star formation

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The Future

When in merger an AGN is triggered?

NuSTAR and Astro-H observations of ULIRGs across merger sequence

What is the fraction of dual (binary) AGN?

What is the molecular gas doing during the merger?

ALMA!