UV Imaging of IR-Luminous Galaxy Mergers

(with an emphasis on comparative morphology)

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UV Imaging

- 1000-3500 angstroms
- Very near-UV (3000-3500 angstroms) accessible from ground using new, blue sensitive CCDs
- Shorter wavelengths require space-based observations (principally HST/STIS)

UV spectroscopy also possible, but outside scope of this talk.

UV in Context of Galaxy Mergers

•Galaxy mergers are known to trigger star formation (I.e. “starburst” phenomenon).

•Bursts are relatively short duration, and their energetics are dominated by massive young stars, whose spectral energy distributions are strongly biased towards short wavelengths.

•At highest bolometric luminosities AGN may also be important, and which also have *unreddened* SEDs weighted towards short wavelengths.

Dust

•Galaxy mergers seem mostly to be dusty. This is very important.

•In the simplest models (galaxies as light bulbs, with plane-parallel dust slabs or spheres), extinction immediately extinguishes the UV emission to undetectable levels. The high IR luminosities of many merging galaxies indicate this absorption occurs, with reradiation of the UV into the far-IR.

But Real Galaxies Aren't Light Bulbs surrounded by Dust Shells

•Dust reddens and extinguishes UV, as in slab model, and reradiates into mid/far-IR.

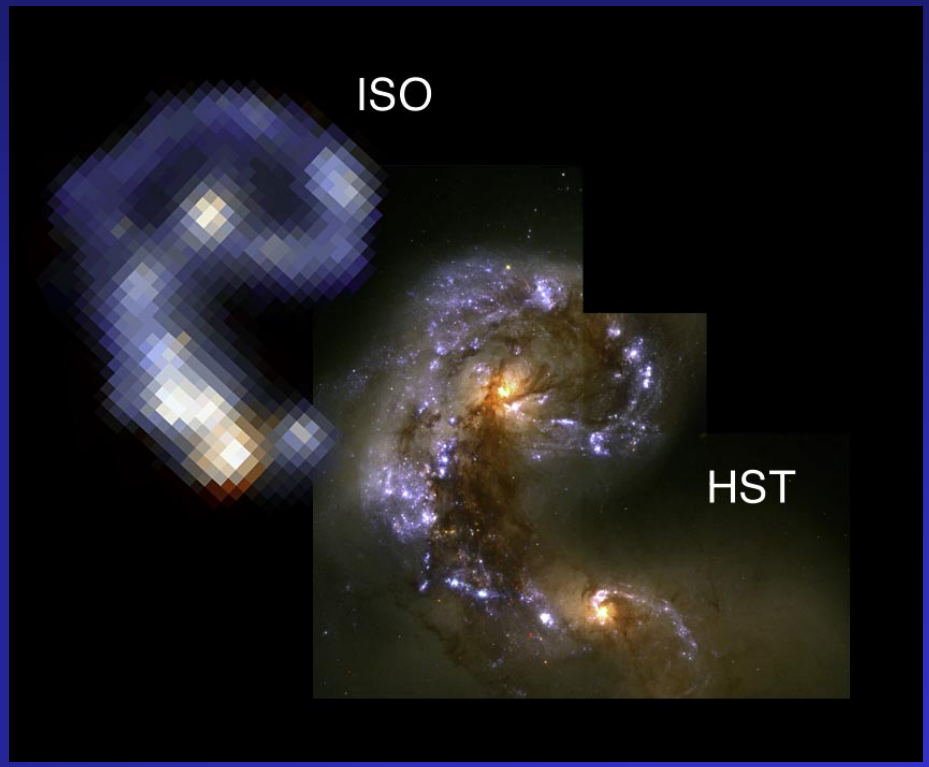
•Dust also scatters UV. Dust distributions with "holes" and "clumps" efficiently scatter UV towards the observer. It takes a lot to actually extinguish the UV.

•Furthermore, the galaxies themselves are composed of *many* emission sources, embedded in complex geometries of surrounding dust .

This last point cannot be over-emphasized.

Some Real Merging Galaxies

This is demonstrated most famously in the case of the Antennae Galaxy, where ISO observations have shown that the IR emission originates predominantly in a compact, highly obscured region physically disparate from the larger-scale systemic starburst.

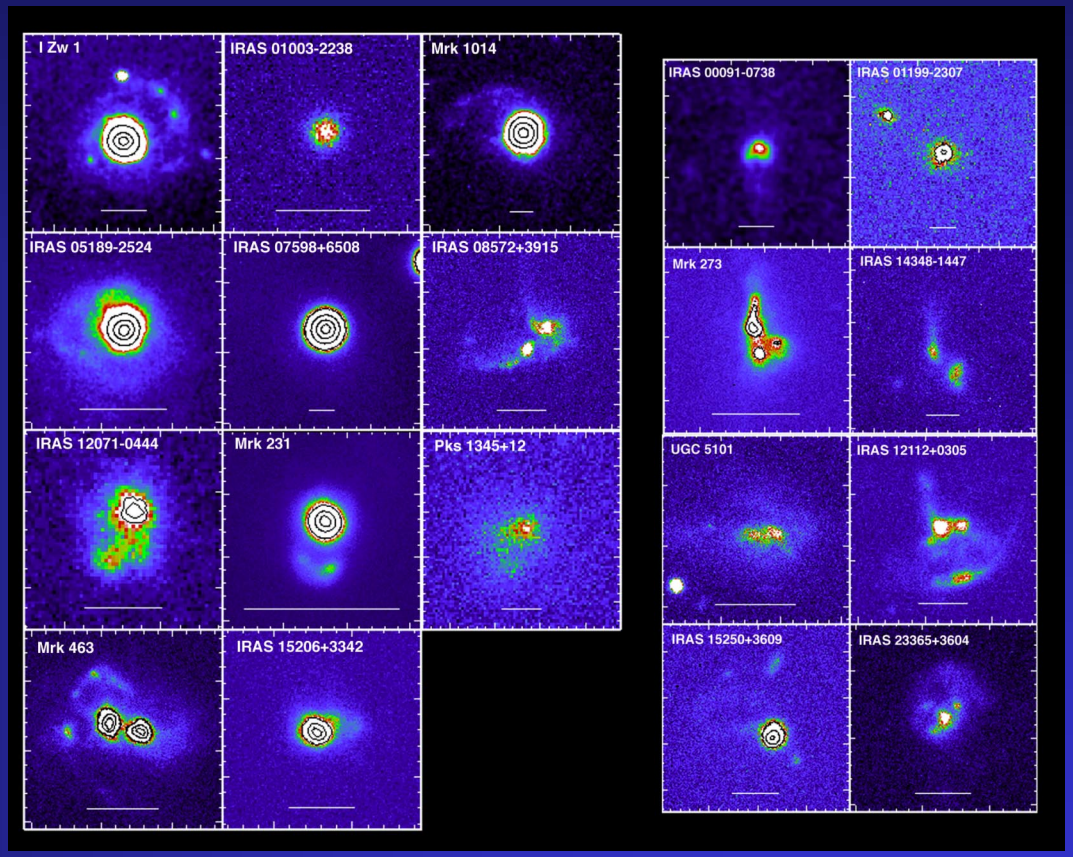


The High Luminosity End: Ultraluminous Infrared Galaxies

ULIRGs are often invoked as analogs of high redshift star-forming galaxies. They are merger systems with very high star-formation rates, making them attractive for a number of theoretical reasons.

Surace et al. (2000) directly imaged many ULIRG merger systems at 3400 A. Almost all were UV bright and extended and would be recognized as starbursts.

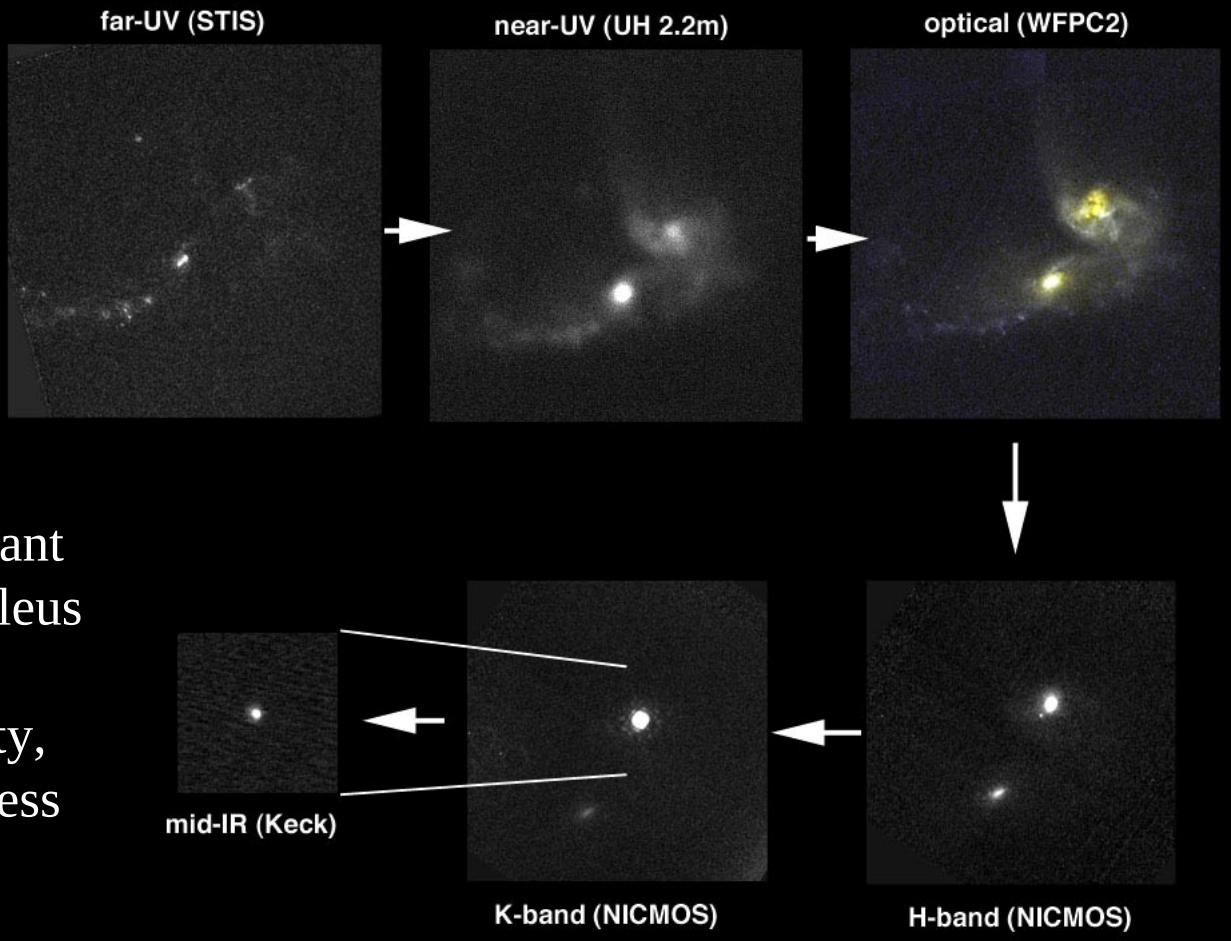
However, nothing is indicative of the quasar-like luminosities of these objects. The observed UV, even de-reddened, cannot account for more than a few % of the bolometric luminosity.



Case Study - IRAS 08572+3915

an extended UV luminous starburst physically distinct from the primary luminosity source

Massive star formation in tidal tails, which are many kpc in length.



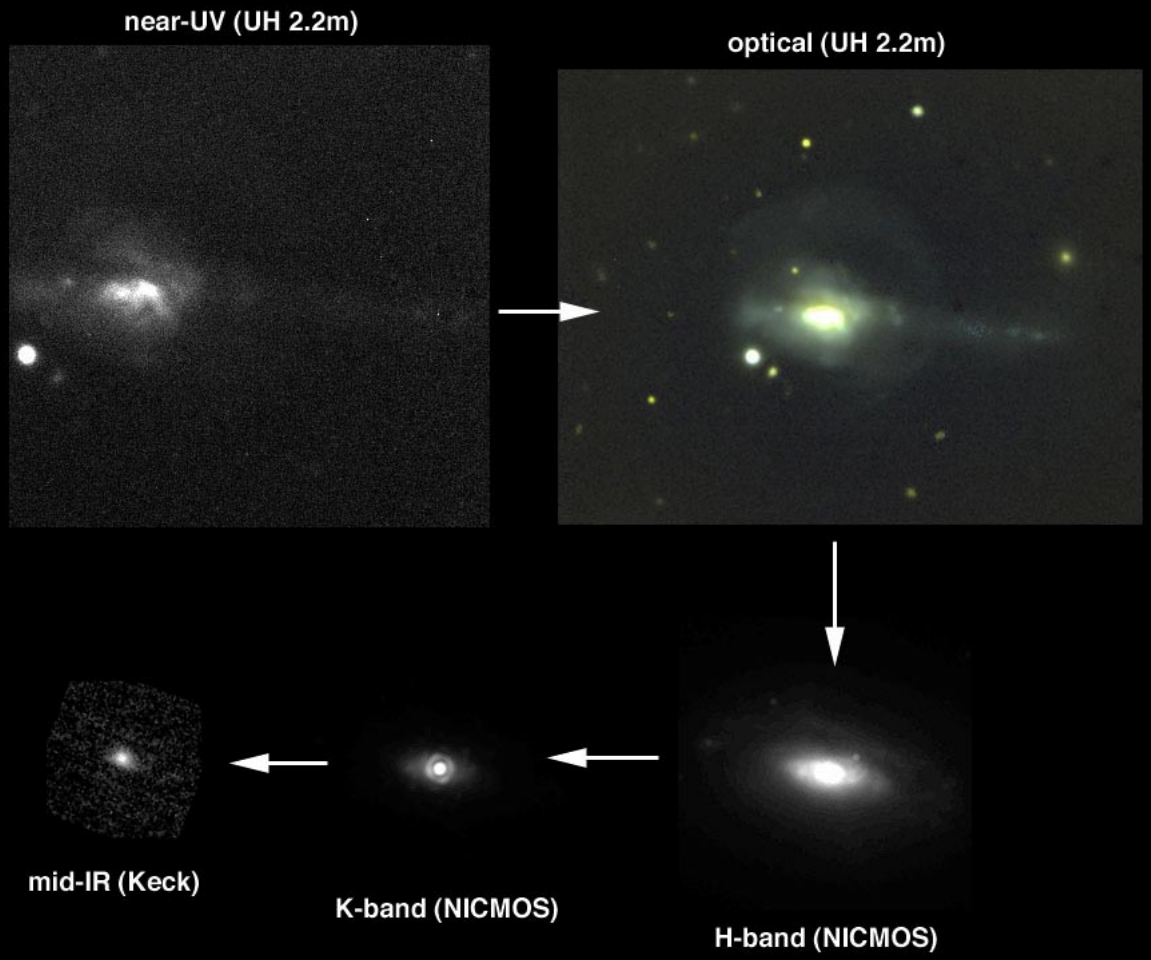
SE nucleus is dominant UV source. NW nucleus contains >80% of bolometric luminosity, but is the source of less than 5% of the UV.

Compact IR core is probably less than 100 pc in radius!

Data from Scoville et al. (2000), Soifer et al. (2000), Meurer et al. (in prep), Surace et al. (1998, 1999)

Case Study - UGC 5101

extended burst with embedded luminosity source

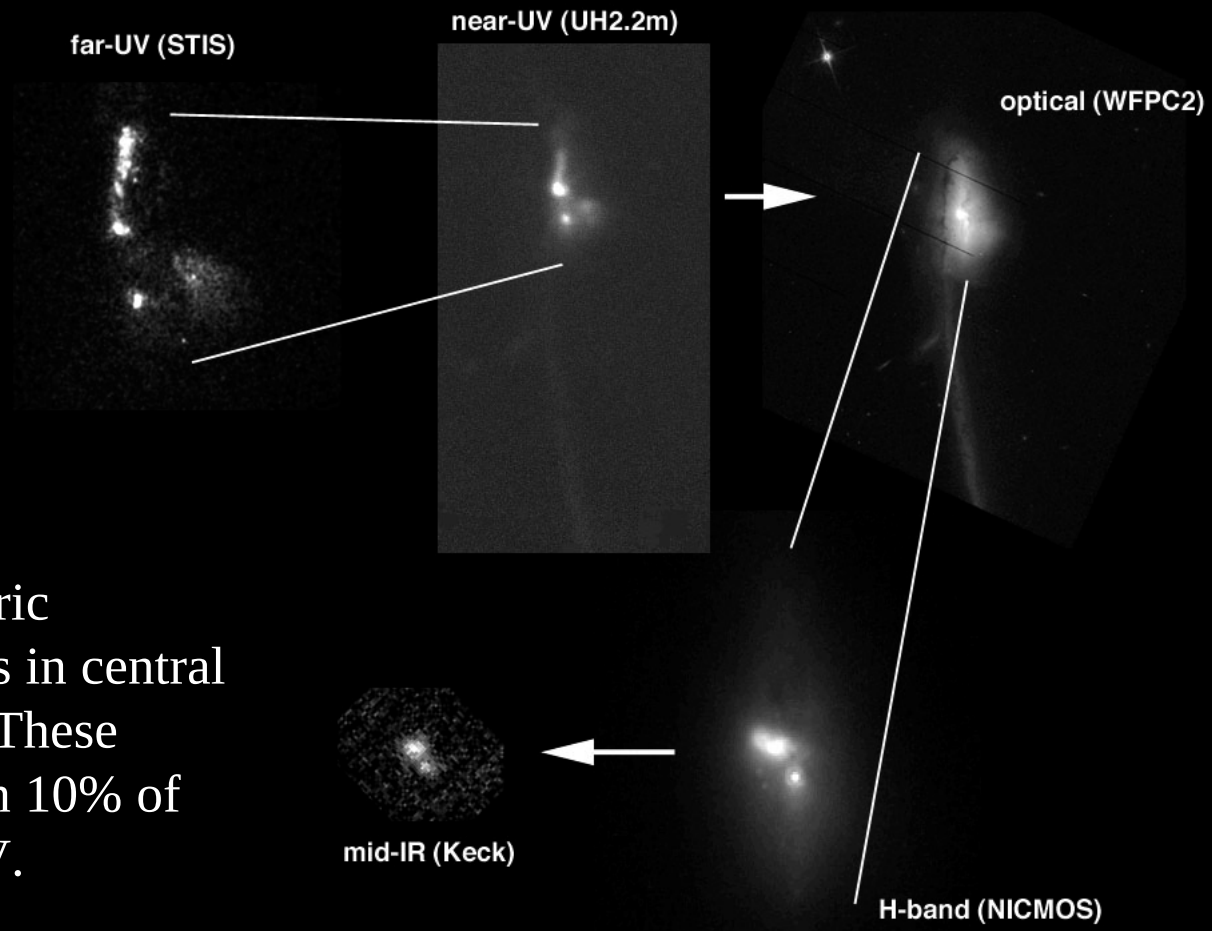


Central source provides 50% of IR, but less than 5% of UV.

Data from Surace et al. (2000), Soifer et al. (2000)

Case Study - Mrk 273

a nuclear starburst and a partially embedded central source

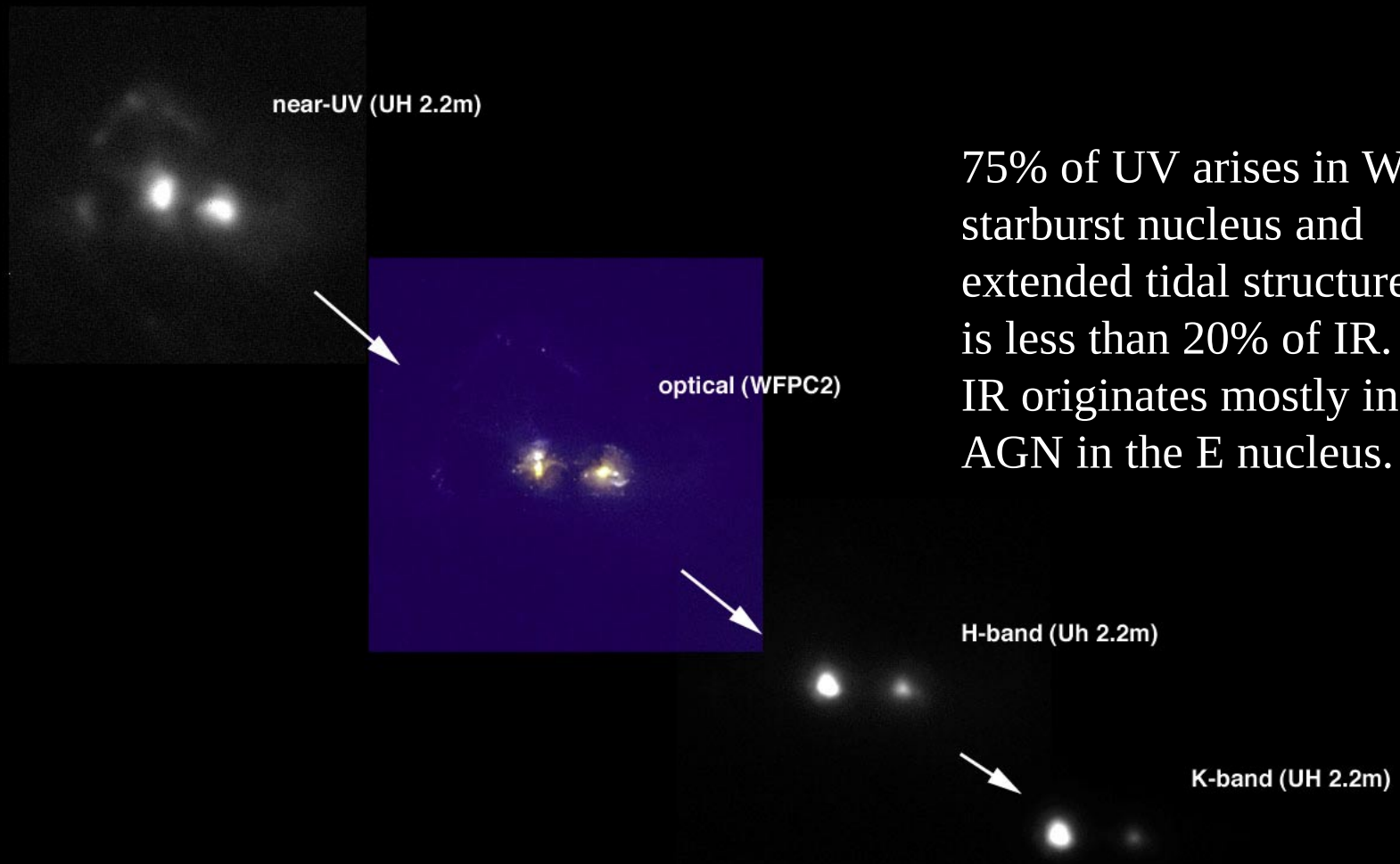


90% of bolometric luminosity arises in central pair of sources. These provide less than 10% of the observed UV.

Data from Scoville et al. (2000), Soifer et al. (2000), Meurer et al. (in prep), Surace et al. (1998, 1999)

Case Study - Mrk 463

AGN with extremely extended burst

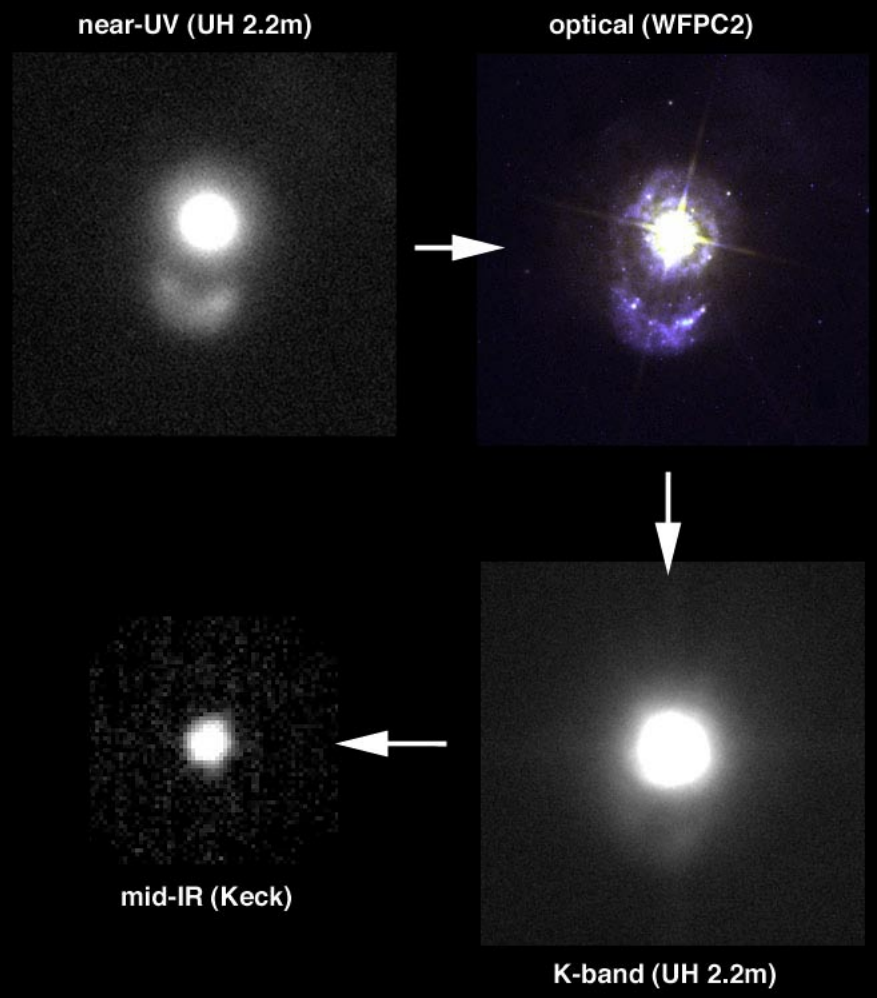


75% of UV arises in W. starburst nucleus and extended tidal structure,but is less than 20% of IR. The IR originates mostly in an AGN in the E nucleus.

Data from Surace et al. (1998, 1999,2000)

Case Study - Mrk 231

an AGN with a nuclear starburst

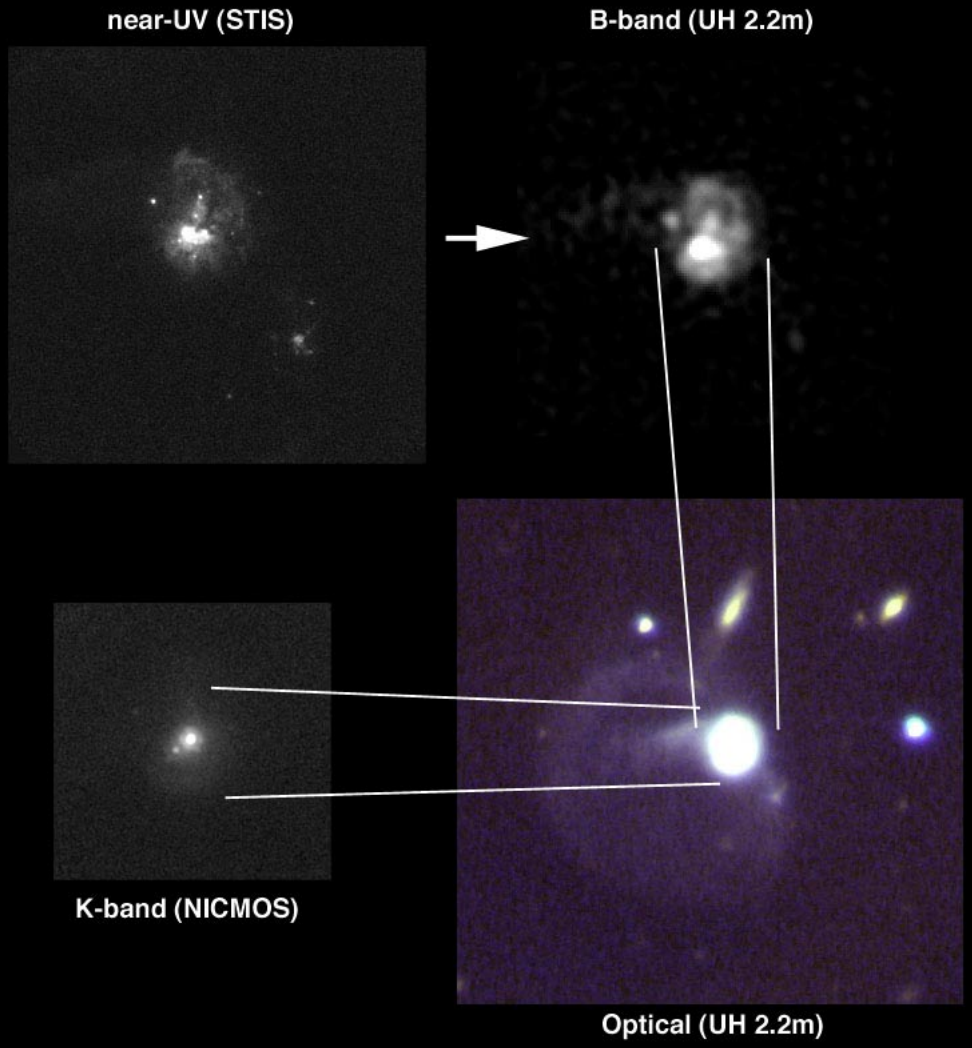


This merger system is dominated by a central AGN. 95% of the bolometric luminosity arises in the central core, and about 50% of the UV.

Data from Scoville et al. (2000), Soifer et al. (2000), Meurer et al. (in prep), Surace et al. (1998, 1999)

Case Study - IRAS 15250+3609

an extended circumnuclear starburst

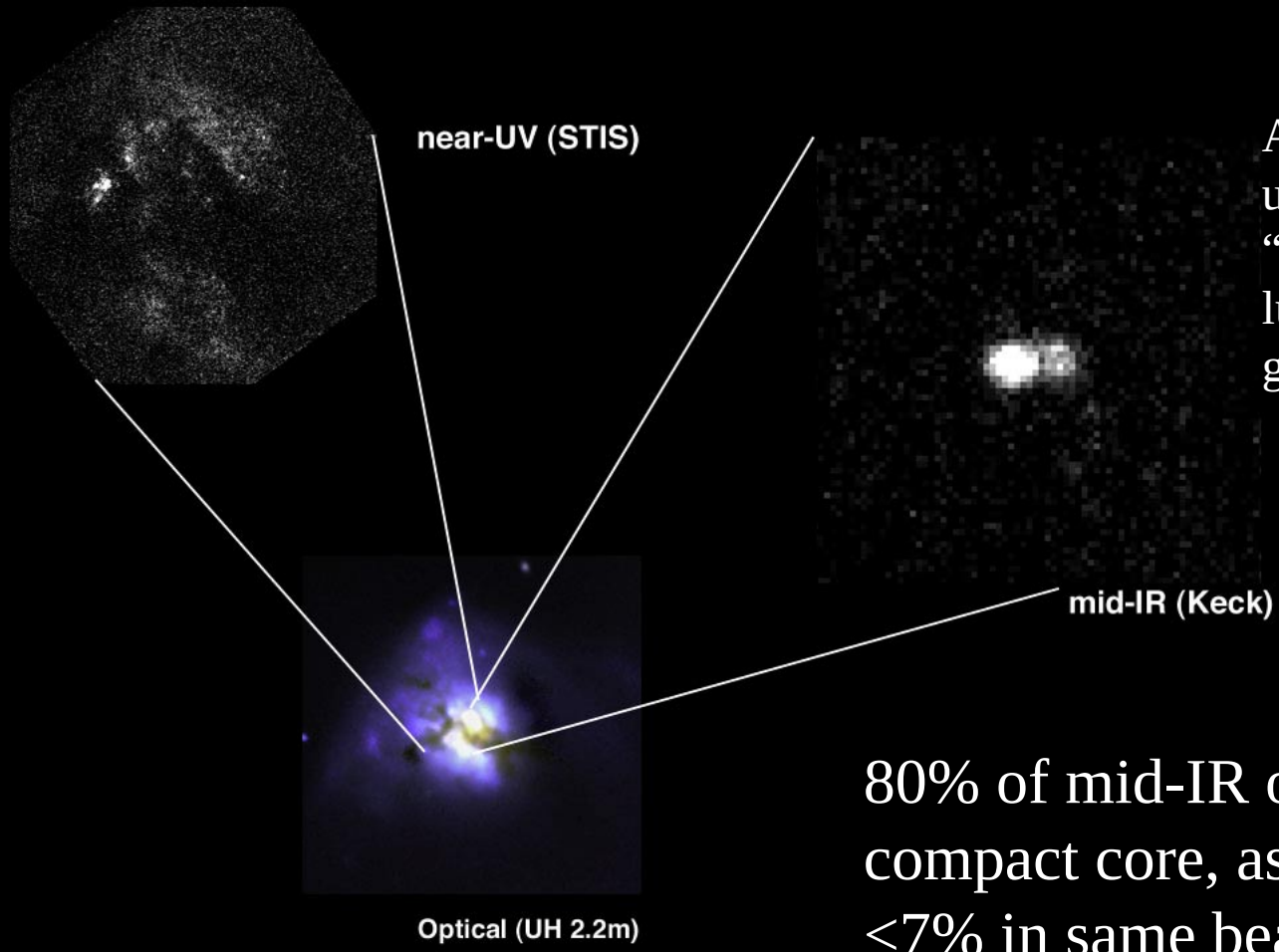


Dominant central object contributes between 40-50% both to UV and IR.

Data from Scoville et al. (2000), Soifer et al. (2000), Meurer et al. (in prep), Surace et al. (1998, 1999)

Case Study - Arp 220

a heavily obscured merger



Arp 220 is commonly used as the "prototypical" high-luminosity merging galaxy.

80% of mid-IR originates in compact core, as opposed to <7% in same beam in far-UV.

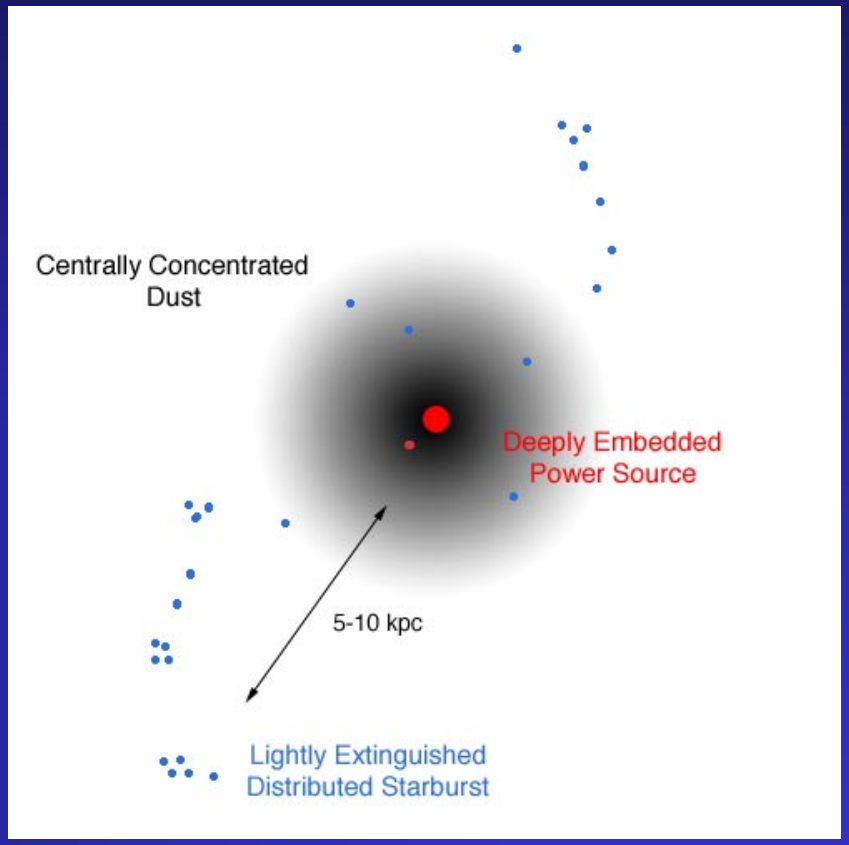
Data from Scoville et al. (2000), Soifer et al. (2000), Meurer et al. (in prep)

What This Means for IR-Luminous Mergers

•UV luminous systemic starbursts extended over many kpc. Star formation is ongoing in most systems. UV and optical are almost identical, indicating little extinction. There is some evidence for patterns in the ages of these star-forming regions.

•***But***, most of the bolometric luminosity arises in a supercompact (<100pc) region, which is very deeply embedded and contributes little to the UV.

•This indicates a multicomponent emitter model with a centrally concentrated dust distribution, widespread star formation, some of which is unobscured, and a deeply embedded "monster" (AGN or super compact starburst).



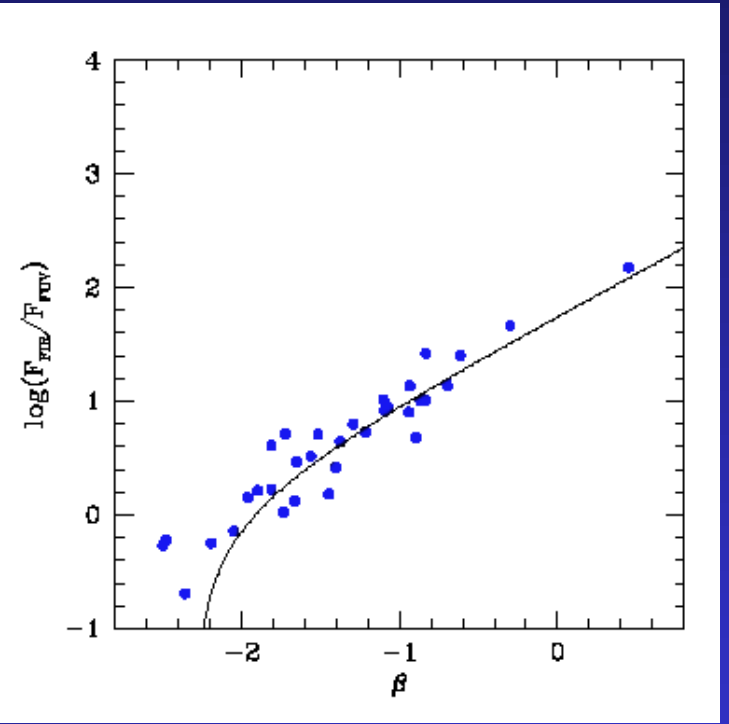
The UV Tells Us What In Terms of Galactic/Cosmic Evolution?

- That there is on-going star formation in the nuclear regions and often in the tidal features. Perhaps the presence of these young stars can be correlated with the merger dynamics.
- Nothing about the source of the majority of the energy production. Highest luminosity local systems (ULIRGs) have highly obscured sources of the majority of their bolometric luminosity.
- A multi-component emission model means that high luminosity mergers will be luminous at UV wavelengths, but there is no expected physical link between UV and bolometric (I.e. far-IR) luminosity.

UV color/IR-excess

(and there's no link between observed IR and UV in ULIRGs)

This can be directly demonstrated. At right is the relation between far-IR emission and UV emission as a function of UV color found by Meurer.



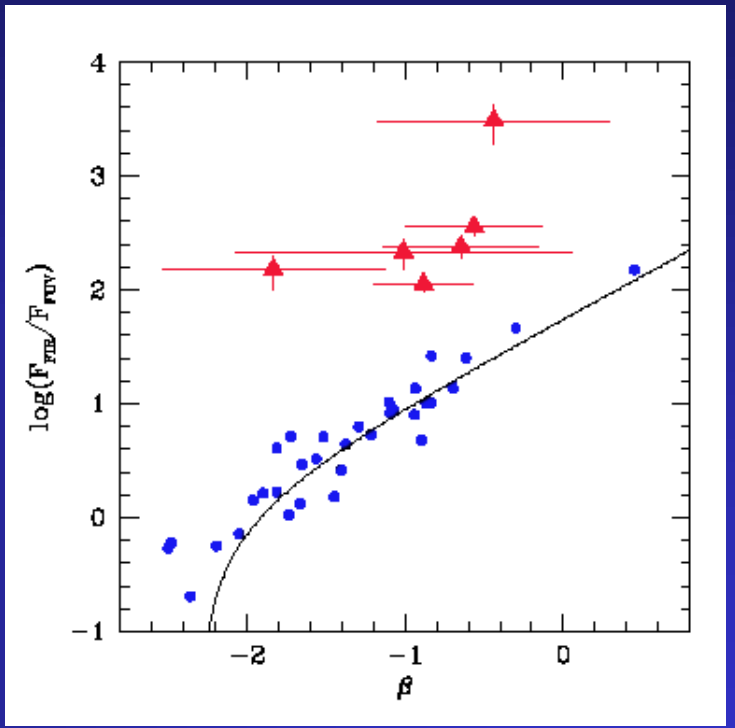
Meurer et al. 2000

UV color/IR-excess

(and there's no link between observed IR and UV)

This can be directly demonstrated. At right is the relation between far-IR emission and UV emission as a function of UV color found by Meurer.

Highest luminosity mergers (ULIRGs) do not follow this relation. They are as bright in the UV as other starbursts, but have much greater IR luminosities. The scatter in infrared to UV excess is nearly 2 orders of magnitude.



Meurer et al. 2000

Can the UV Measure the high-Z Star Formation Rate?

•ULIRGs are commonly invoked as analogs of high redshift systems. They are the only objects known with star-formation rates approaching that of high-redshift systems such as sub-mm galaxies.

•In particular, Arp 220 is commonly invoked as a "template". But if you use Arp 220 as a template, be prepared to accept the additional consequences. Namely, the UV cannot be more than a minimum star-formation tracer. The uncertainty in bolometric luminosity in using the UV will be factors of 10 or more.

•There is a possibility that the high redshift systems do have some correlation between IR and UV. If such a correlation exists at high redshift, it's causation may be via a third hidden parameter, such as interaction geometry or age, or maybe they're just completely structurally different. In this case the high redshift systems are fundamentally unlike the low-redshift systems. High resolution imaging (with HST) should be able to tell.