AGN Feedback & Obscured Star Formation

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"AGN Winds in Charleston"
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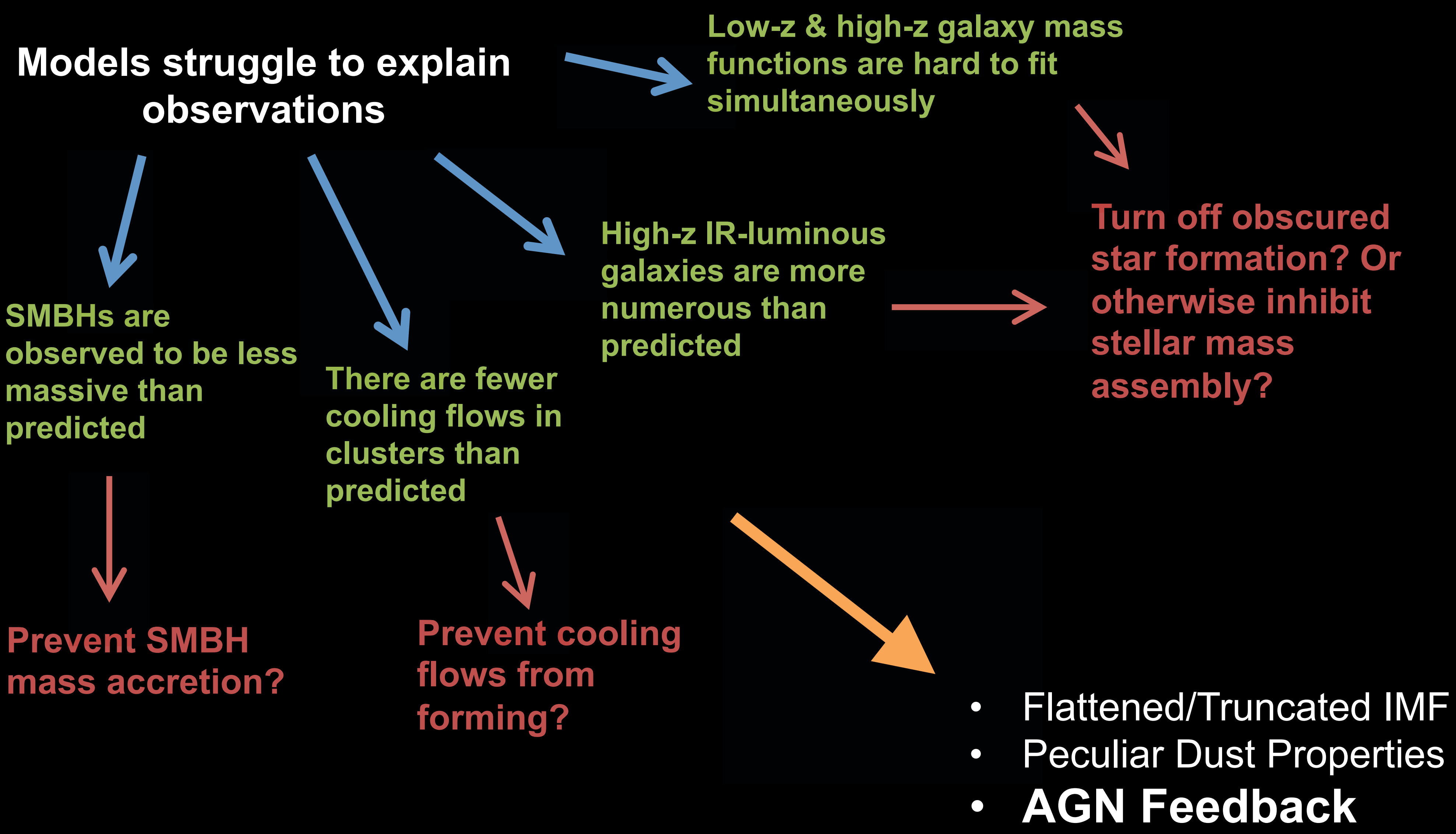
A Galaxy Evolutionists View of AGN Feedback



`Simplifying' AGN Feedback

Radiation **AND/OR** Matter

Heat ISM gas

Heat IGM gas

Expel ISM gas

Inhibit IGM gas accretion

Secondary effects

Condense all that into

Quasar Mode

Brief (~10^8 years)
Intense
Radiation from accretion disk

Radio mode

Longer (~10^9 years)
Less intense
Radio jet

Observing Feedback

Does AGN feedback affect (obscured) star formation?

How can we address this question?

- Cannot be seen `in the act', timescales are too long

- Infer from the relic properties of quiescent galaxies

- Look for evidence that an outflow has the required properties

- Show that an existing outflow may have caused a relic effect

- **Observe outflows and star formation together and see if their properties are consistent with affecting each other**

Our Work – FeLoBAL QSOs

Farrah et al 2011, ApJ submitted

FeLoBAL QSOs have the following properties:

- Broad Absorption Lines in the rest-frame UV
- Always reddened, and often IR-luminous
- Sometimes host intense, obscured starbursts

AGN-driven outflows and (sometimes) obscured star formation in the same objects

Approach:

- Take 31 SDSS selected FeLoBAL QSOs at $0.8<z<1.8$
- Measure outflow strengths and obscured star formation rates

Compare the two to each other to see if outfows terminate star formation in reddened QSOs

Method I - Outflow strengths

Fairly crude:

Only SDSS spectra available

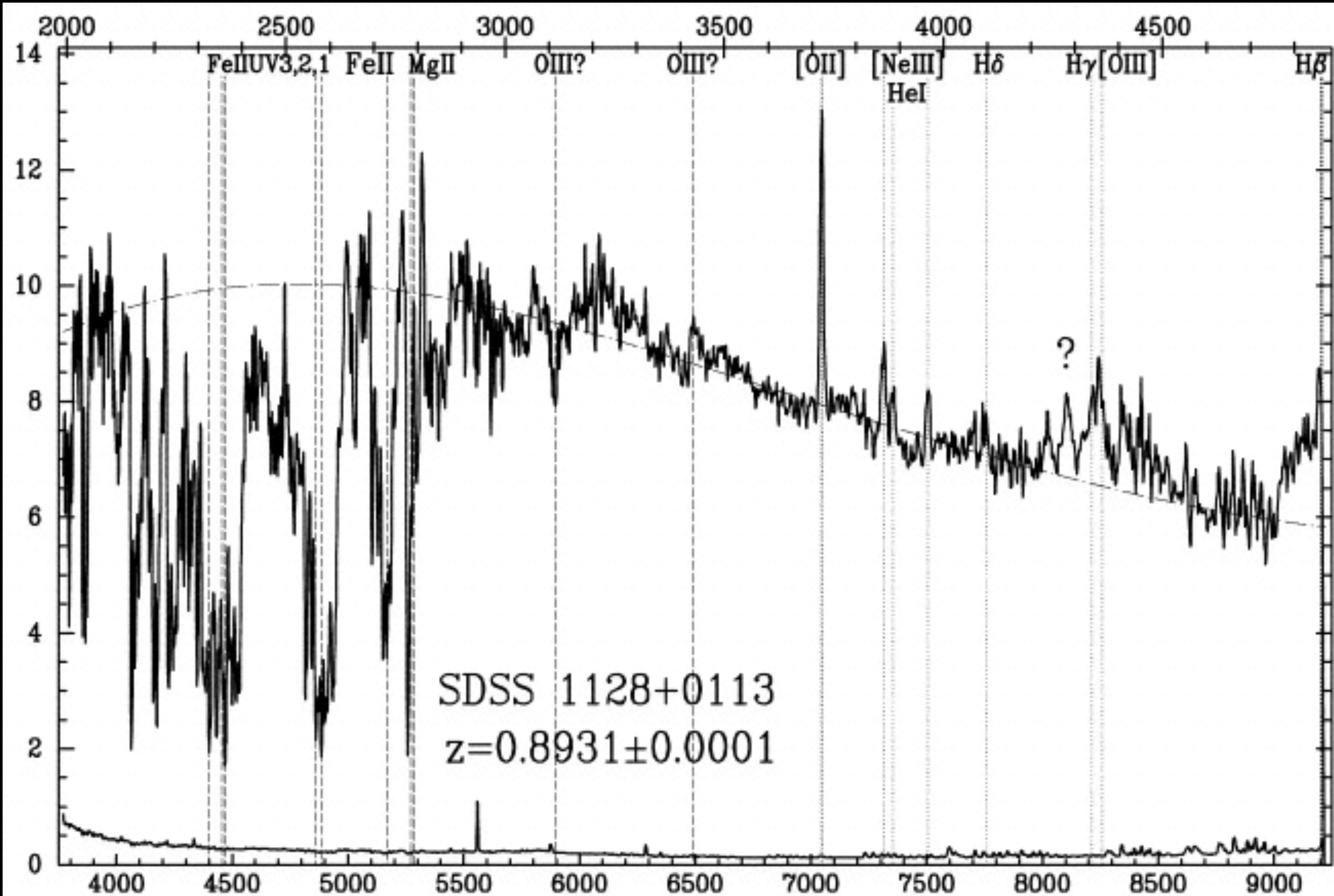
Use the SDSS spectra to measure the `Balnicity Index' (BI)
(the velocity range over which the absorption exceeds 10% of the continuum level)

Use the same species/transition for all objects
(Mg II 2799 doublet)

Even then, derived BIs are sensitive to the choice of continuum

So, measure ourselves, cross-check against independent measures in the literature

Resulting BI's are a reasonable *relative* measure of outflow strength



Hall et al 2002

Method II - Starburst/AGN Luminosities

Measure IR emission from both obscured star formation, and the AGN:

Assemble as much optical through far-IR photometry as possible
(longward of the BALs)

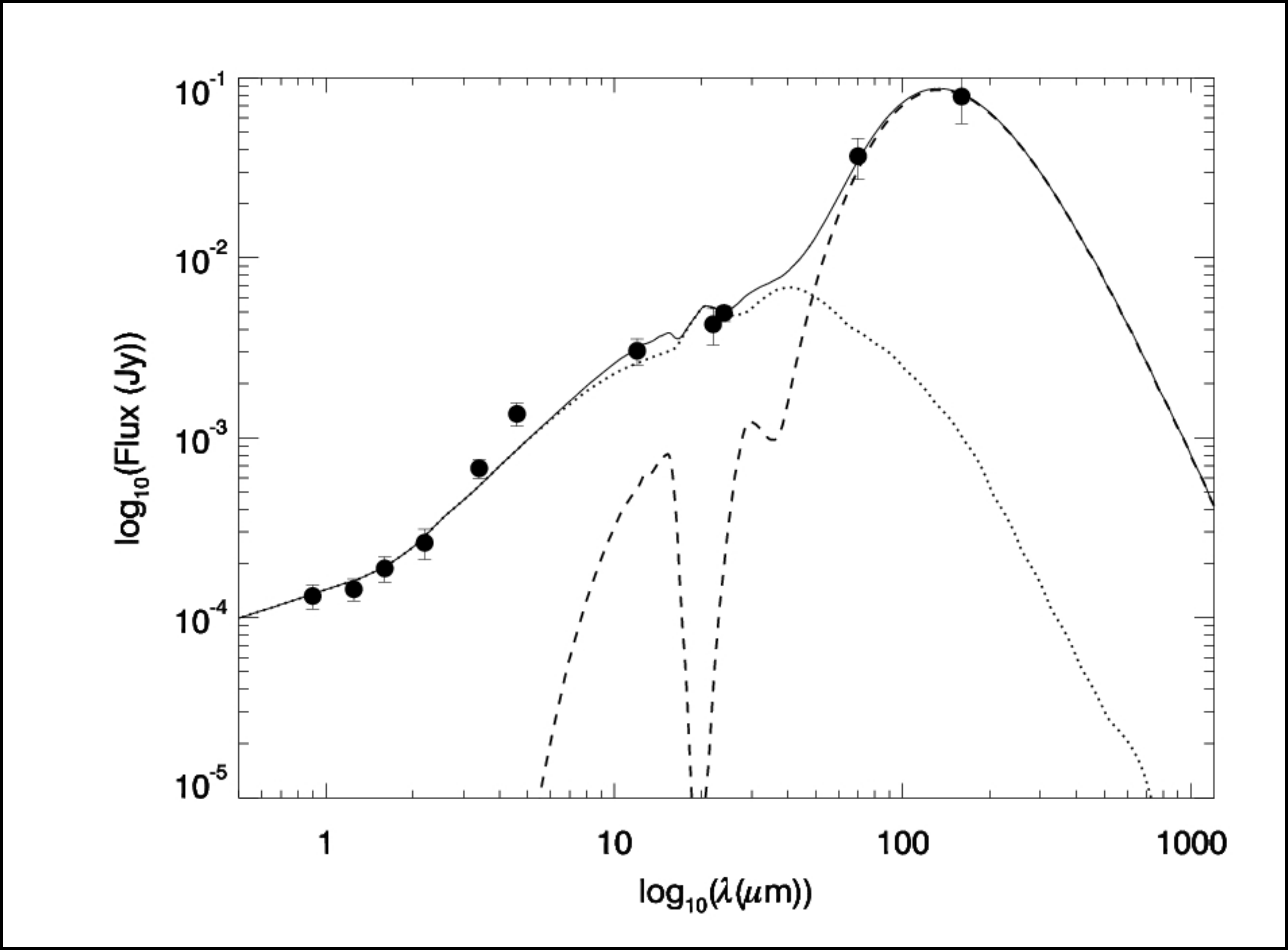
SDSS, 2MASS (or UKIDSS), WISE, Spitzer
(spans observed frame 1-160 microns, 6-14 bands per object)

Simultaneously fit radiative transfer model libraries for dusty starbursts and (un)obscured AGN

Extract best-fit total IR luminosities, and their starburst/AGN components

An Example `Best' Fit

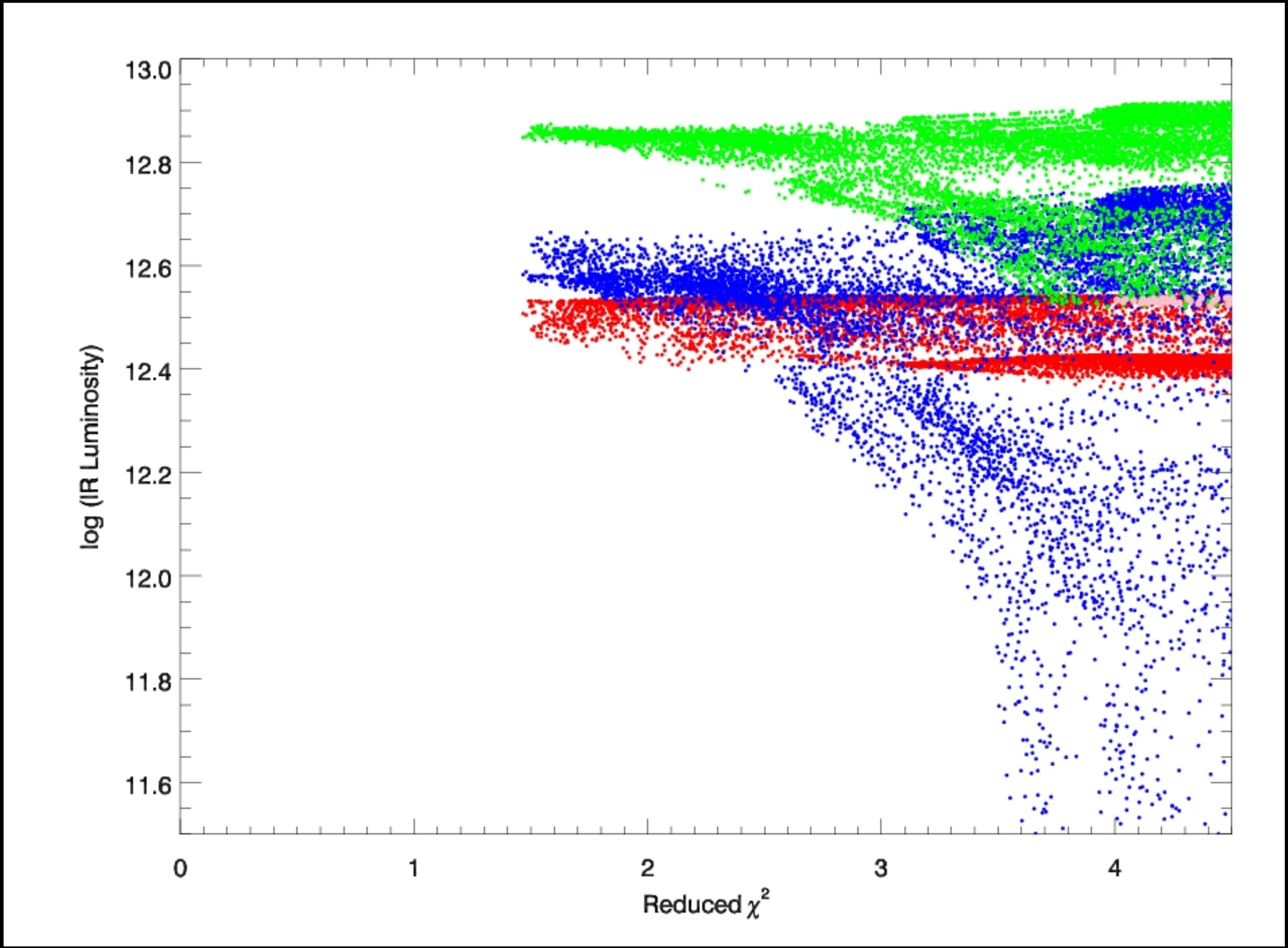
Solid – Total
Dotted – AGN
Dashed - Starburst



But The Solution Space Is Complex

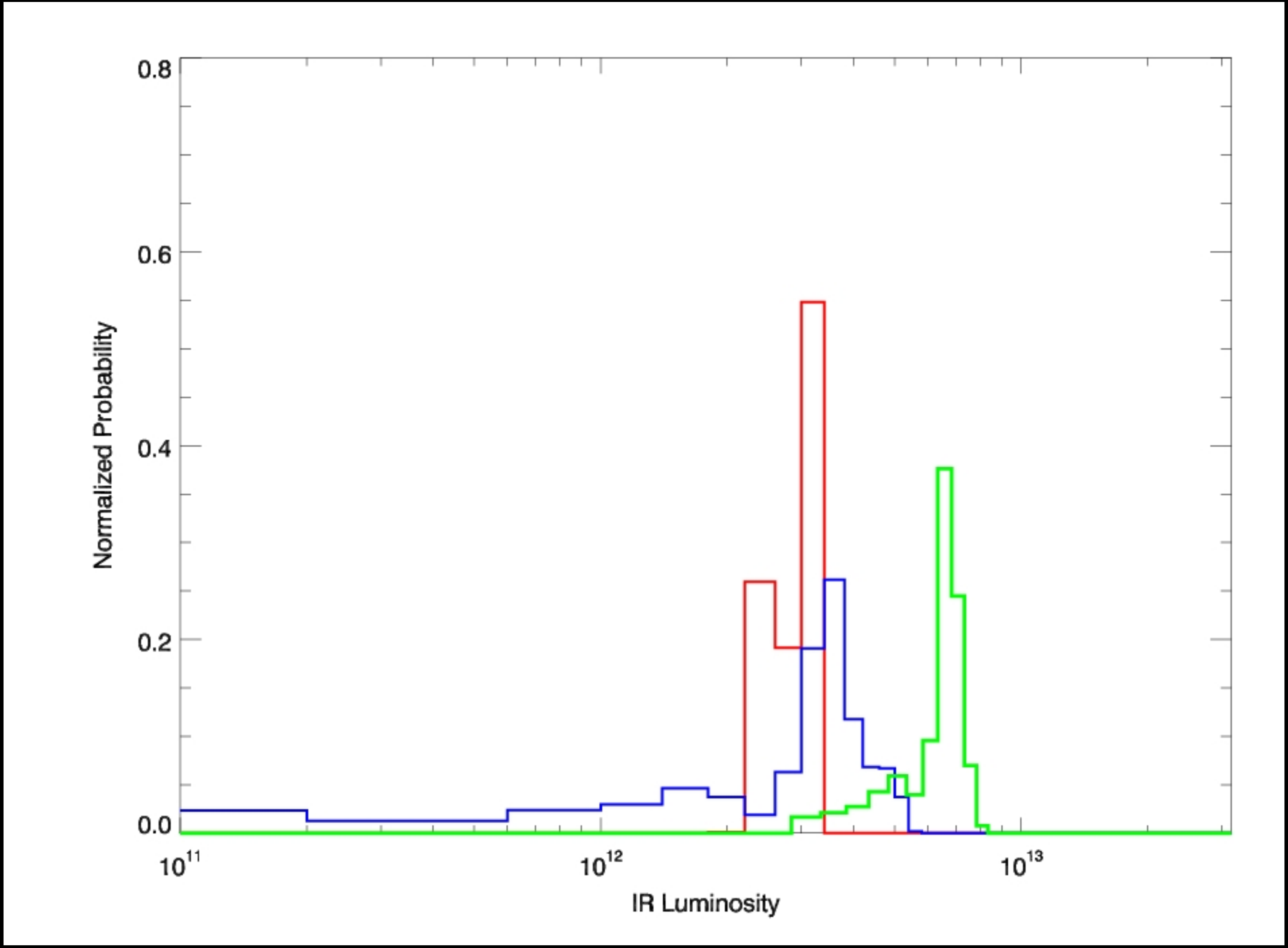
Green – Total
Red – AGN
Blue – Starburst

(one 'set' of points per fit)

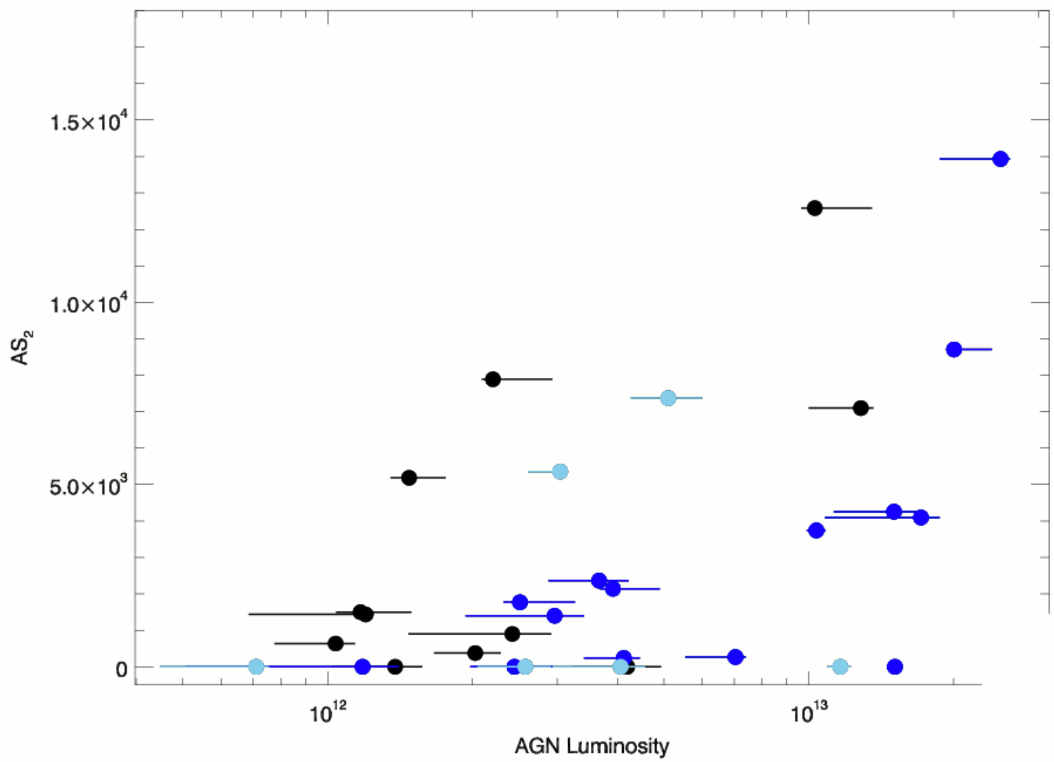


Luminosities from Probability Density Functions

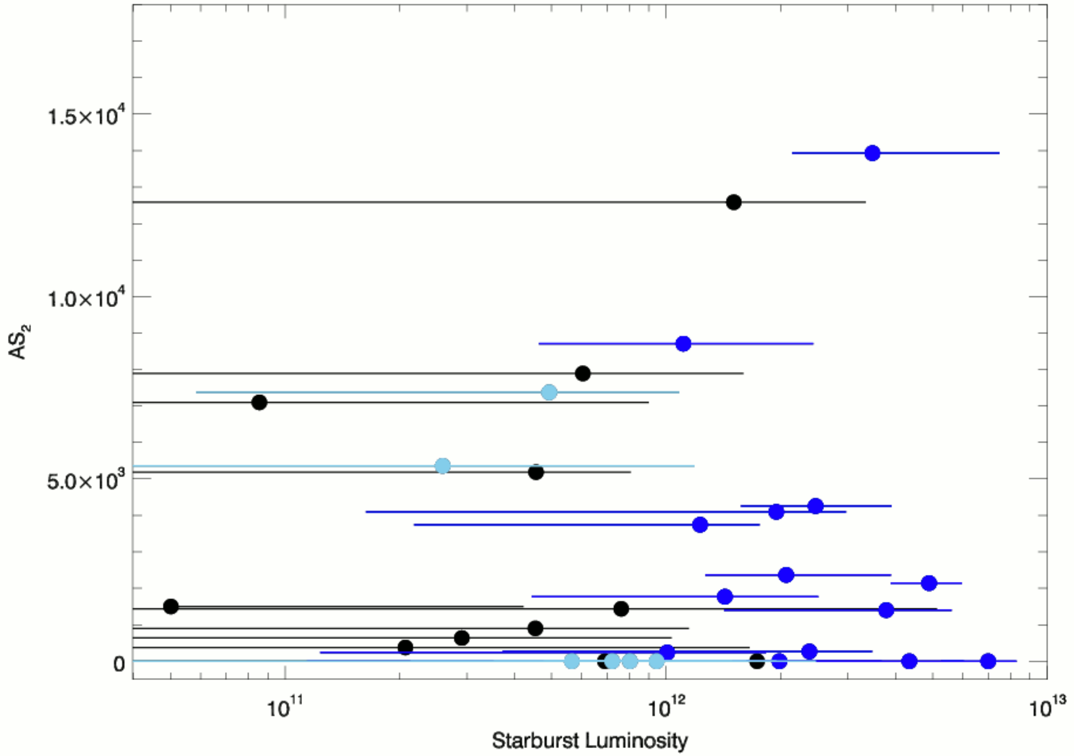
Green – Total
Red – AGN
Blue – Starburst



Outflow Strength vs. AGN & Starburst Luminosities

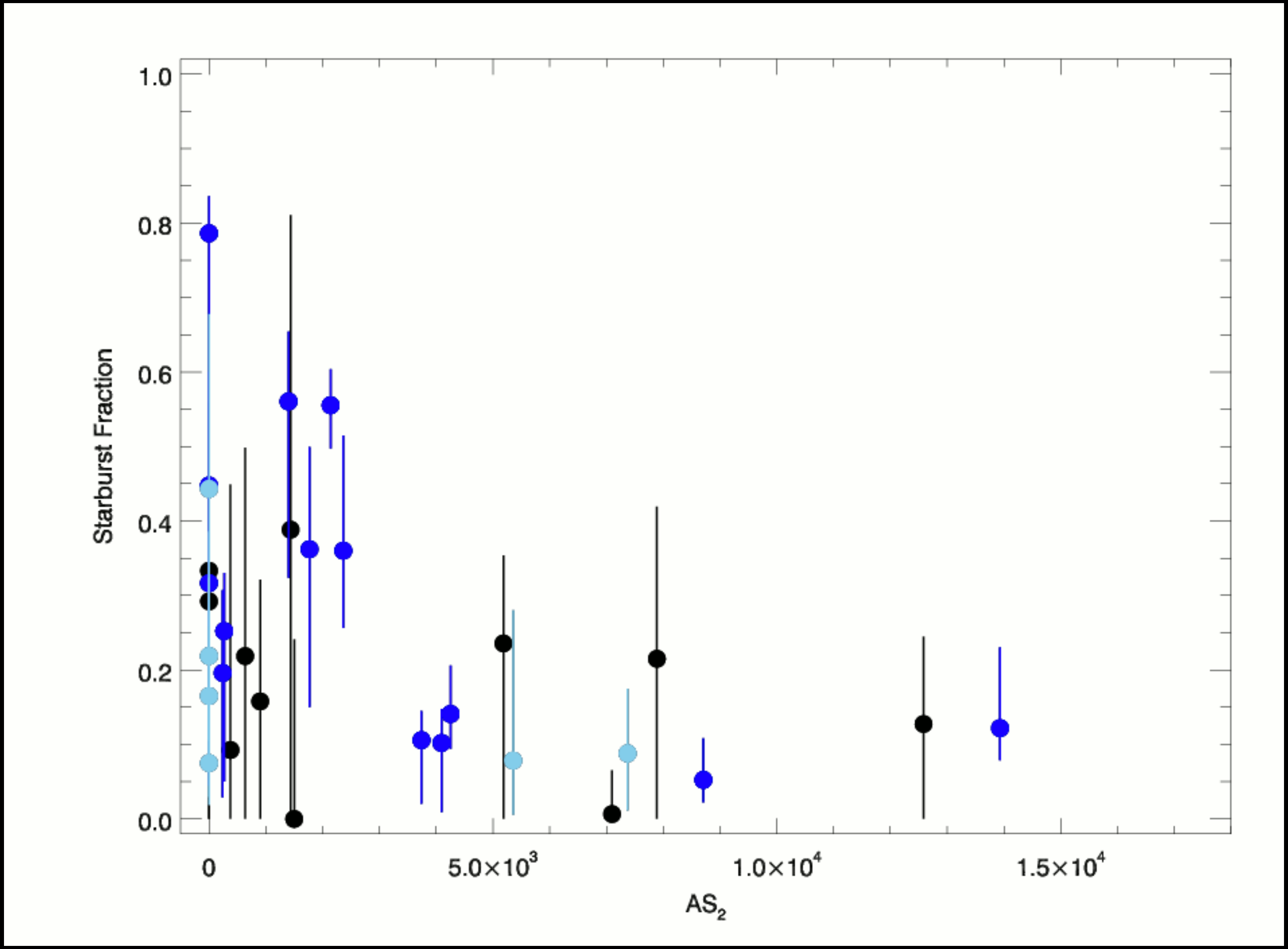


Black - undetected starburst
Light Blue - <10^{12} L_{sun} Starburst
Dark Blue - >10^{12} L_{sun} Starburst



No obvious correlations in either case

Outflow Strength vs. Starburst Contribution



At P(Starburst)>25%
All objects have BI<3500km s^{-1}

At P(Starburst)<25%
The distribution appears random

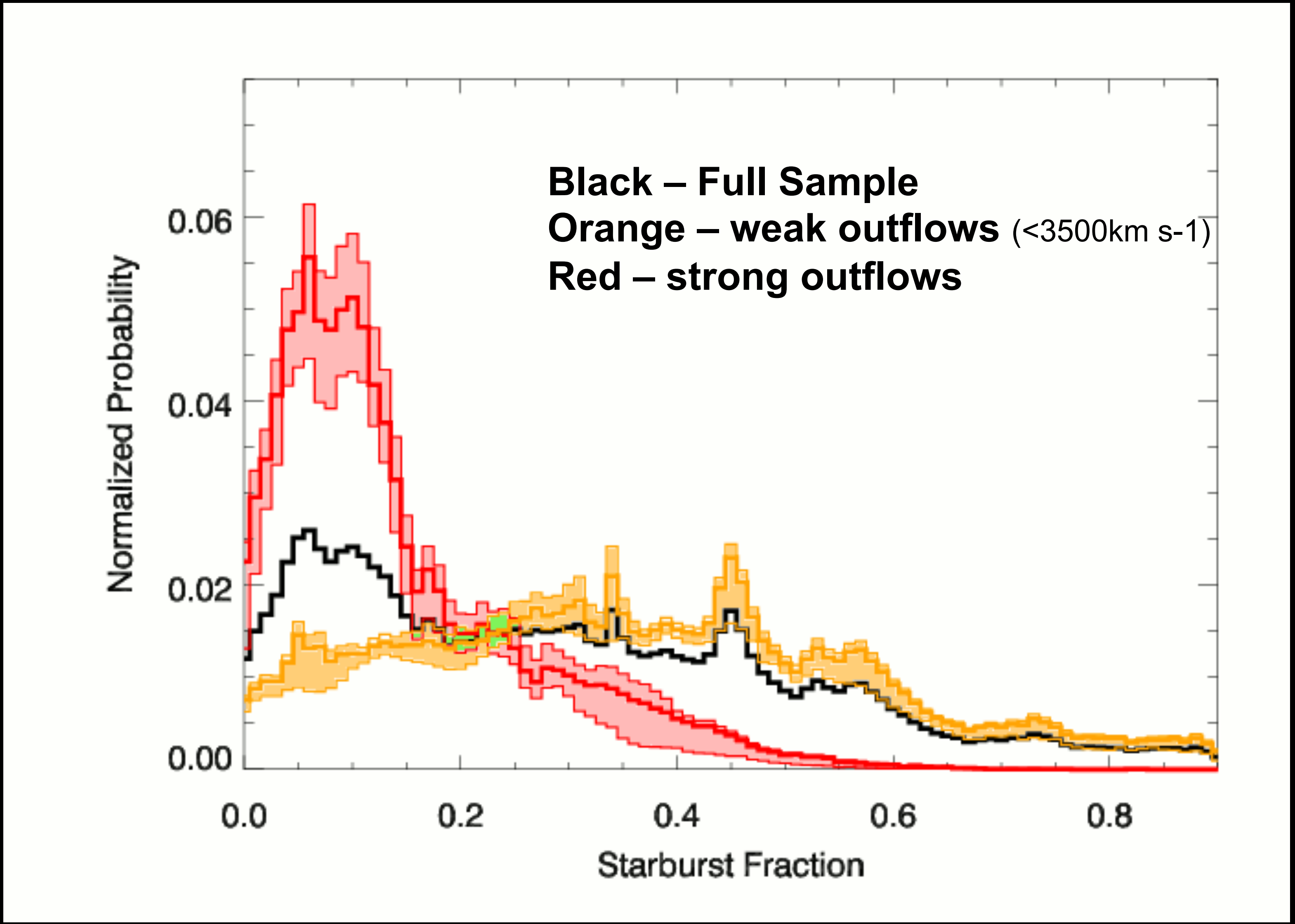
Lower starburst contribution at BI>3500 km s^{-1}? → **But from this plot, significance of detection is only 99%**

Starburst Contribution with ALL the information in the PDFs

All Objects:
P(Starburst>25%):
51% +/- 5%

Weak Outflows:
P(Starburst>25%):
63% +/- 4%

Strong Outflows:
P(Starburst>25%):
18% +/- 5%



Weak Outflows means a greater chance of seeing a large starburst *contribution* than strong outflows

What could cause this?

Feedback!

One obvious cause:

The AGN-driven outflow inhibits star formation

Three `unlikely' causes:

The star formation inhibits the AGN-driven outflow

Observation bias: strong starbursts cause Mg II troughs to *appear* weak

Starburst UV continua much weaker than AGN ones in most circumstances

Not likely

Selection bias: QSOs with strong Mg II absorption and strong starbursts drop out of the SDSS QSO selection

No obvious effect that could cause this

Not likely

But…

THERE IS ONE OTHER OBVIOUS CAUSE

In IR-luminous galaxies, starburst & AGN luminosities can (crudely) correlate with each other

The peak IR luminosity of the AGN may `lag' the peak luminosity of the starburst by 10-100Myr

So, assuming:

- The above statements are true
- Outflow strength correlates with the *infrared* luminosity of the AGN

Then we could observe an anticorrelation between starburst contribution and outflow strength but where the outflow does not actually affect the starburst

Can we test this?

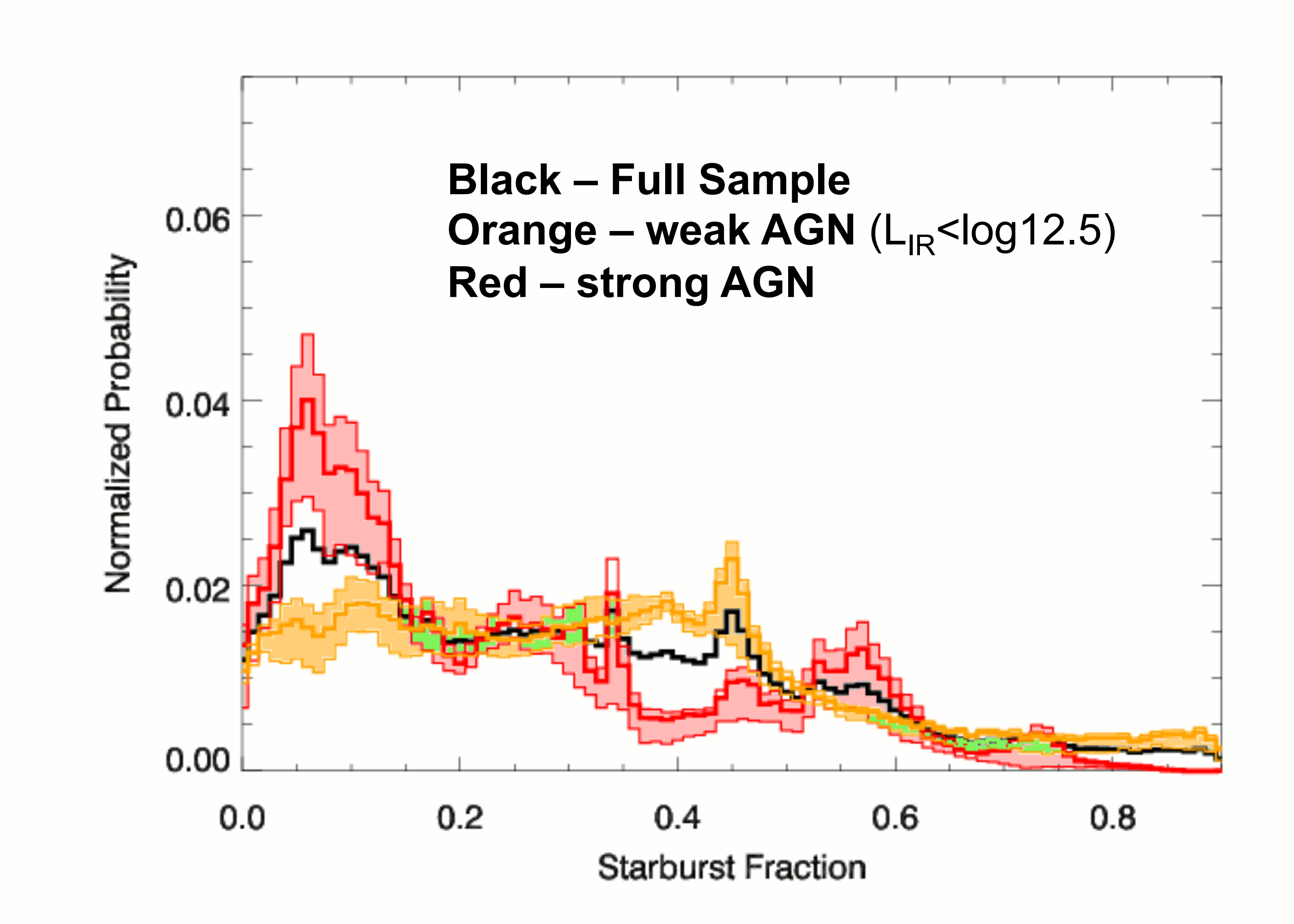
If this is true, then starburst contribution PDFs for subsamples divided on AGN luminosity should show an equal or bigger difference than the subsamples divided on outflow strength

Starburst Contribution - by AGN luminosity

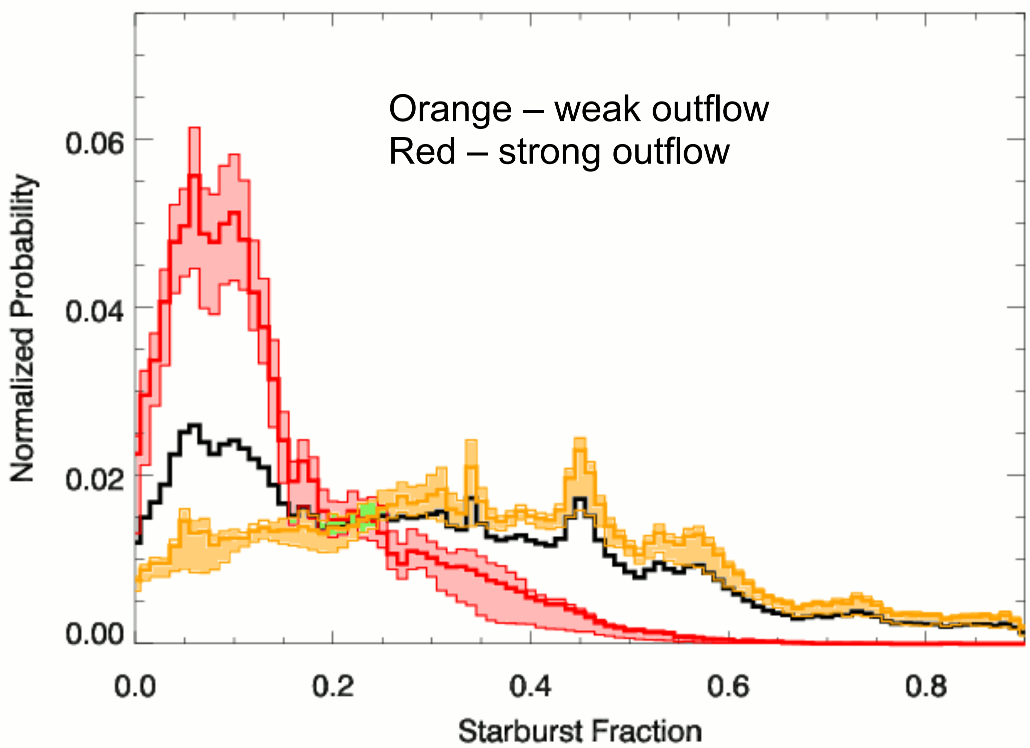
Adopt a (semiarbitrary) boundary of L_{IR}=log12.5 that divides the sample in half:

Faint AGN:
P(Starburst>25%):
58% +/- 5%

Bright AGN:
P(Starburst>25%):
40% +/- 9%



Faint AGN means at best a marginally greater chance of seeing a large starburst contribution than a bright AGN



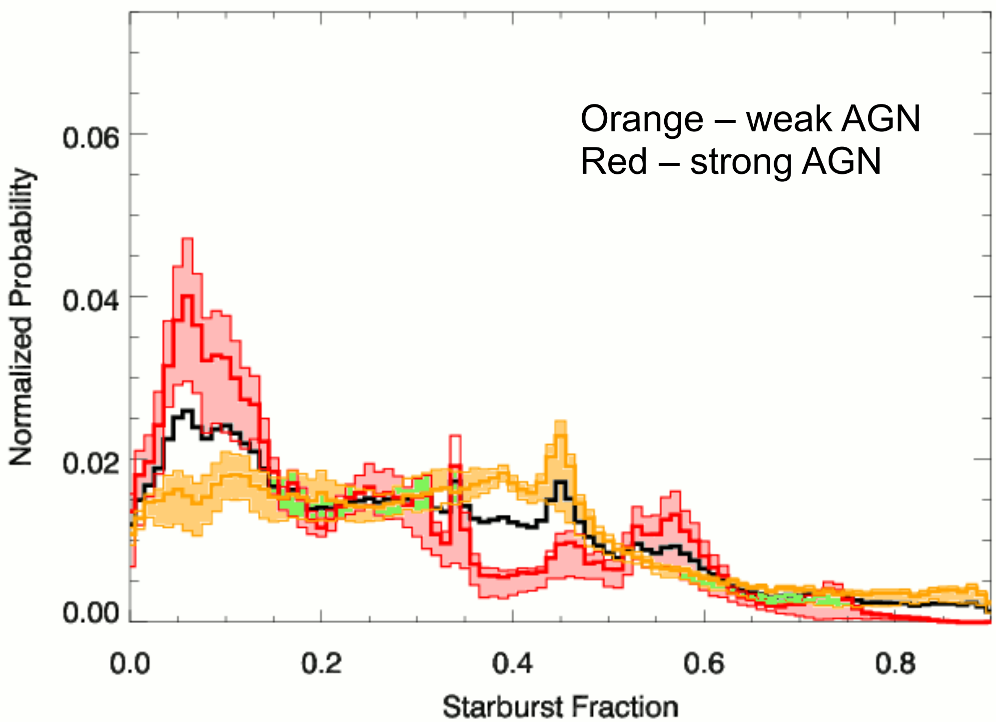
P(Starburst) > 25%

Weak Outflows: 63% +/- 4%
Strong Outflows: 18% +/- 5%

Weak AGN: 59% +/- 5%
Strong AGN: 40% +/- 8%

It's (probably) not a symptom of a brightening AGN

(especially as computing P(Starburst>50%) gives an even clearer difference)



Caveats

Our outflow strengths are measured crudely – We'd really like higher quality optical spectra. Compare different species, construct outflow models…

We have no far-IR data – observations longward of 200 microns, especially with Herschel, would give a factor of ~3 increase in accuracy on starburst luminosities, sensitivity to fainter starbursts, and set our results on a much firmer footing

BALs can vary – probably not by enough to explain our result, but we have not yet quantified the required degree of `conspiracy'

Sensitivity to model templates – do our results depend on the starburst & AGN template sets used in the infrared?

Independent observational checks – e.g. emerging radio jets

Other BAL classes – do we see this in LoBALs? HiBALs? NAL QSOs? QSOs with Pcygni profiles in emission?

Conclusions

Models and observations of galaxy assembly face differences that are irreconcilable without invoking one or more `exotic' solutions

One of these solutions is AGN feedback, which involves a luminous AGN acting to curtail star formation and further SMBH accretion

Based on observing radiatively driven outflows and obscured star formation in the same objects and comparing their properties, we propose that:

Radiatively driven outflows from an AGN can act to dramatically curtail star formation in the host galaxy

The magnitude of this effect (probably) cannot be deduced from the IR luminosity of the AGN