

The Merger-Starburst-AGN Connection in QSOs

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Background

- Galaxy interactions and mergers can fuel vigorous nuclear star formation (Toomre & Toomre 1972)
- Galaxy interactions and mergers can also fuel QSO activity (Stockton 1982)
- Circumstantial evidence connecting QSO activity with interactions and mergers:
 1. Morphological distortions in host galaxies (eg. Gehren et al, Hutchings et al, McLeod & Rieke, Boyce et al, Bahcall et al)
 2. Excess of apparent close companion galaxies (eg. Heckman et al, Bahcall et al)
 3. Extended ionized gas (Boroson et al, Stockton et al)
- No suitable control sample

Our contribution: A deep, systematic, imaging and spectroscopic study of the starburst and interaction histories of QSO hosts.

Spectroscopic Observations of Low-z QSOs

I Zw 1

PHL 909

PG 0844+349

PG 1543+489

PG 1700+518

3C 48

Mrk 1014

Mrk 231

IRAS 00275-2859

IRAS 04505-2958

IRAS 07598+6508

IRAS 14026+4341

OX 169

4C 31.63

4C 37.43

PG 1402+261

PG 1411+442

PG 1012+008

NAB 0205+02

3C 323.1

4C 61.20

PKS 2135-147

UN J1025-0040

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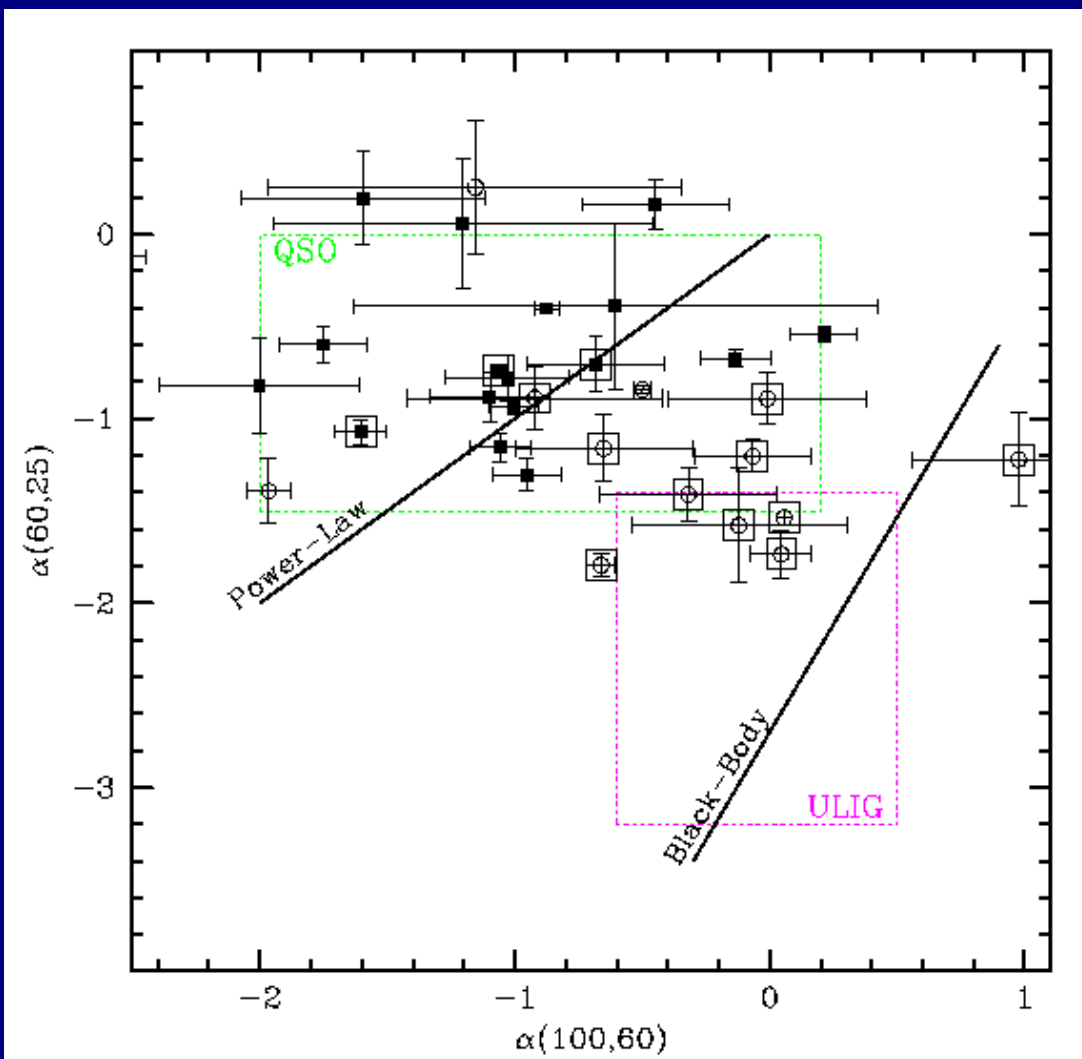
4C 61.20

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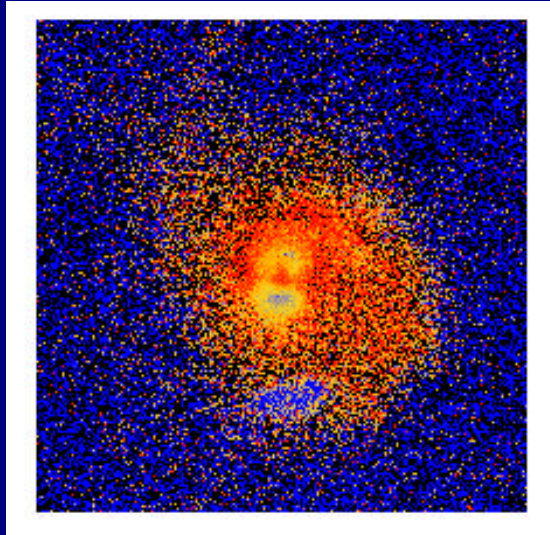
Ultraluminous Infrared Lir S 1012 LM

IRAS Low-z QSOs

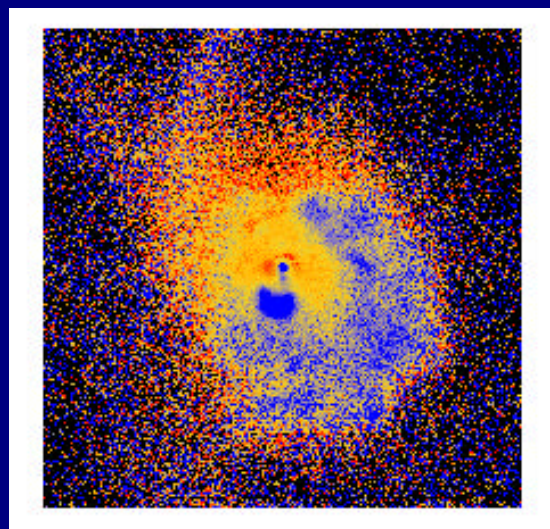
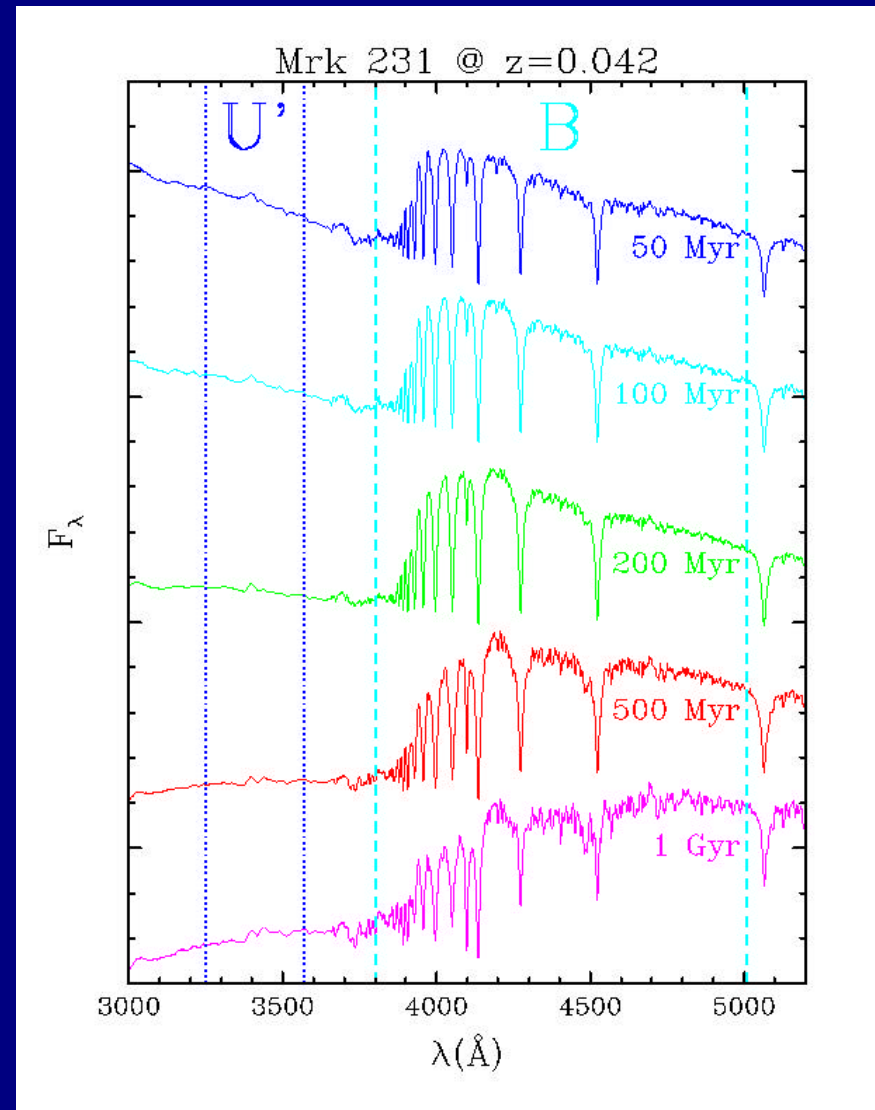


Color Maps

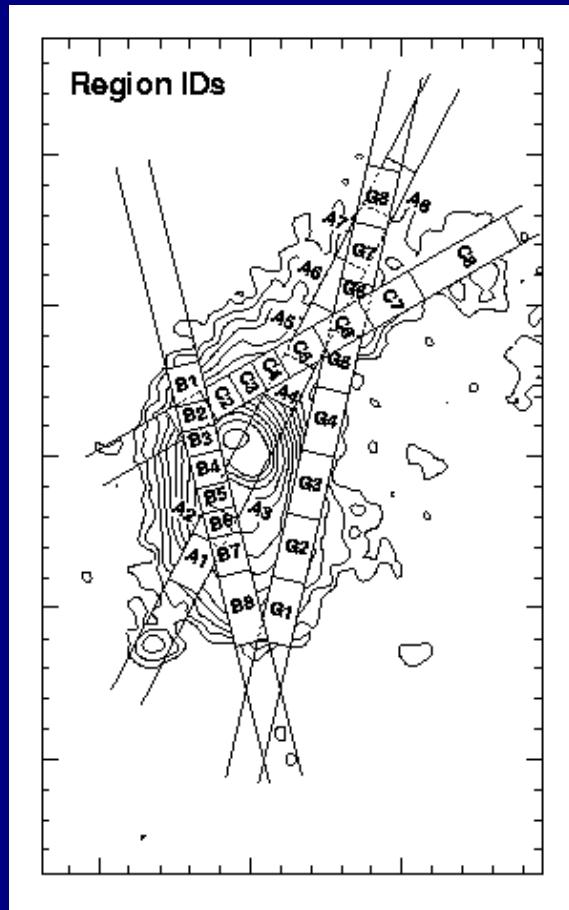
$U'-B$



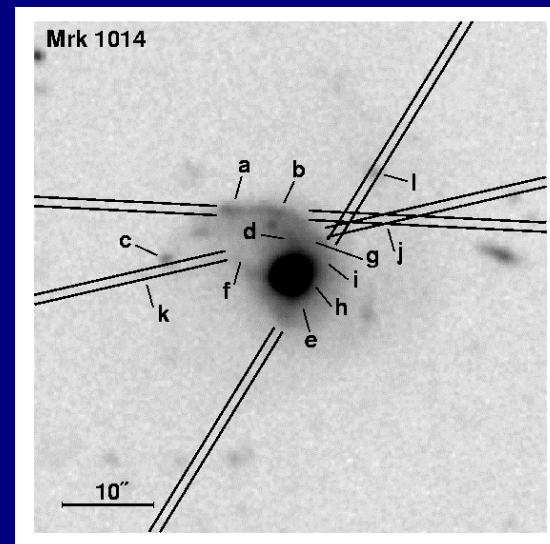
$B-V$



Spatial Resolution

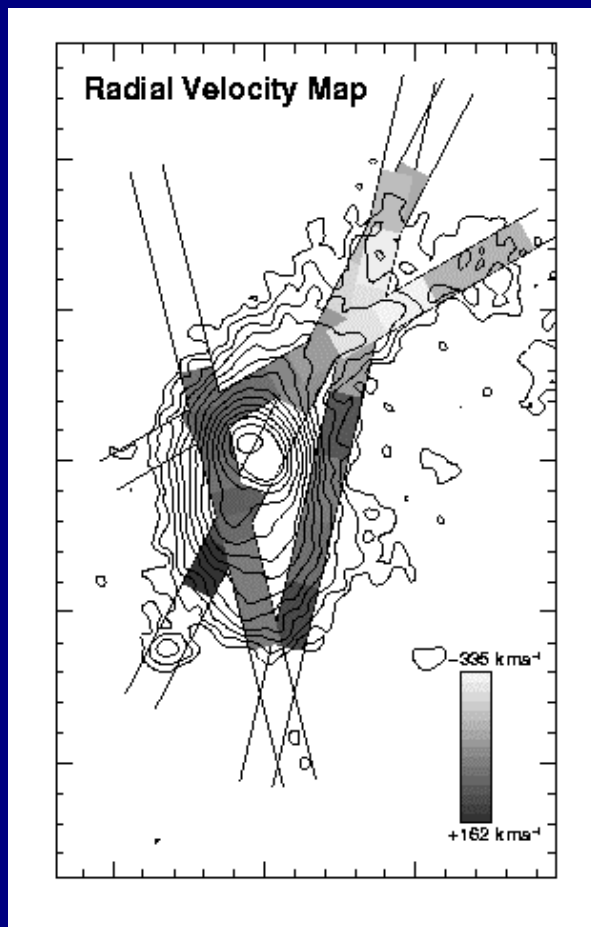
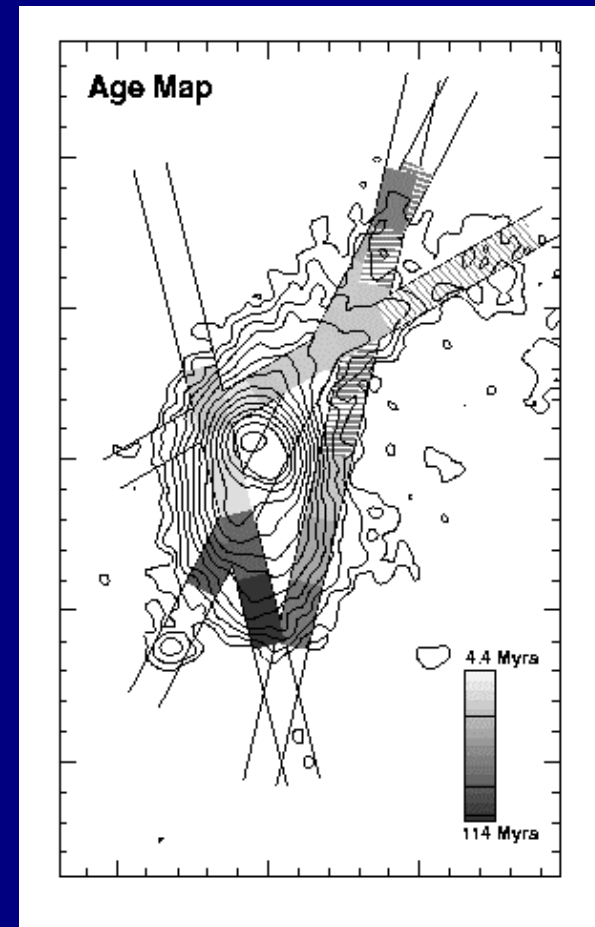


- Multiple slit positions
- Analyzed spectra from discrete regions
- QSO contamination removed



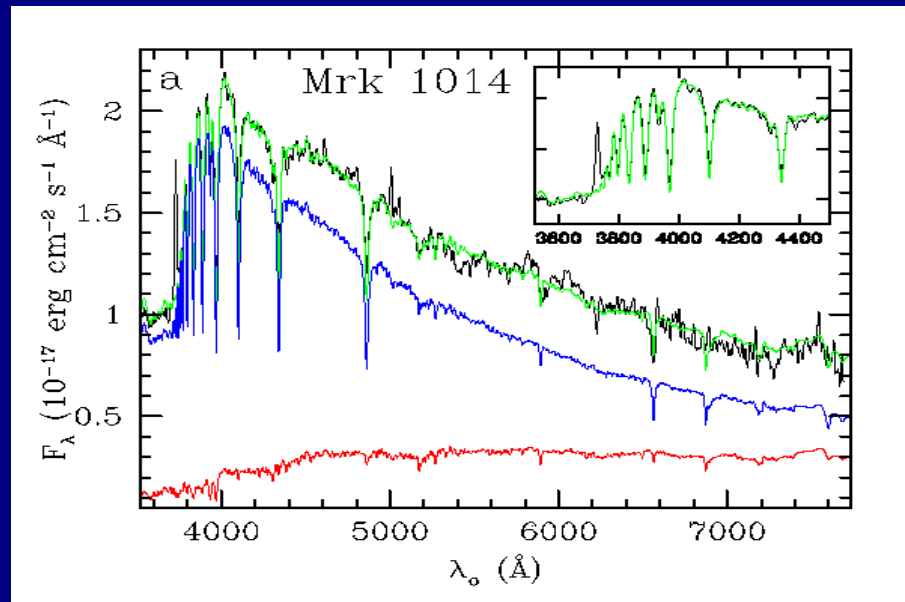
Spatial Resolution

- Velocity fields from redshifts
- Age maps from stellar populations

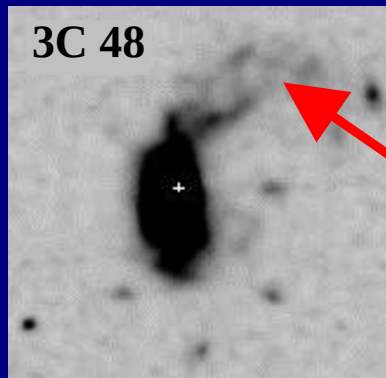
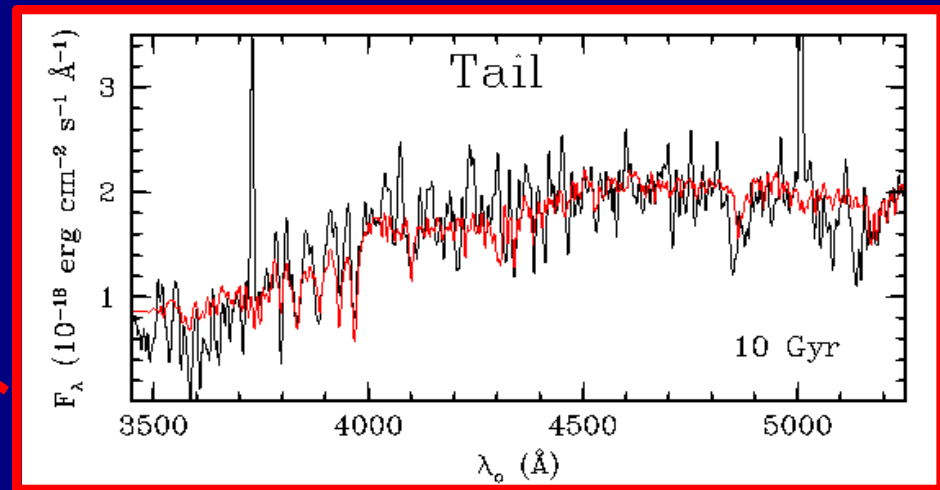


Modeling Spectra

- Two components observed in spectra:
 - Young (Balmer absorption, blue continuum)
 - Old (G-band, Ca II H & K)
- 10 Gyr-old model with exp. decreasing SFR as underlying old population + instantaneous starburst (Bruzual & Charlot)
- χ^2 fit to data with 3 free parameters: Age of starburst, scaling factors of young and old populations

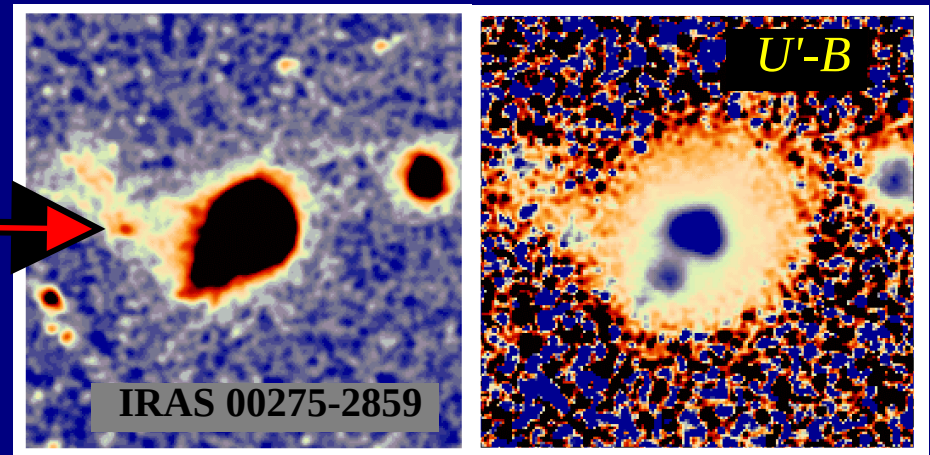


Tidal tails generally dominated by *old stars*

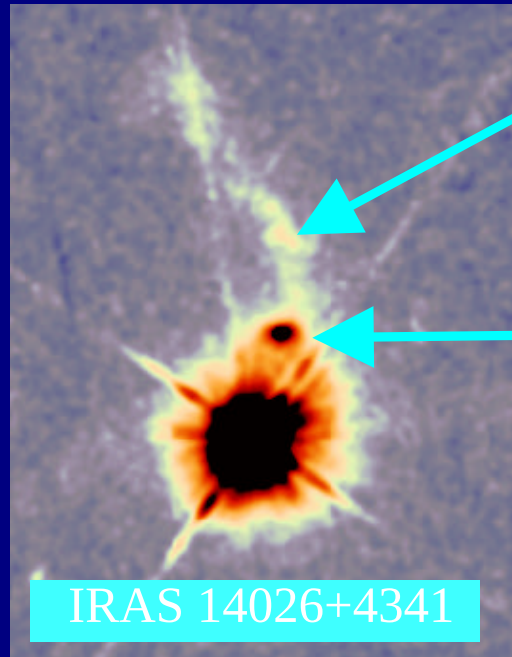


Dyn Age ~ 0.2 Gyr vs. Pop Age ~ 10 Gyr

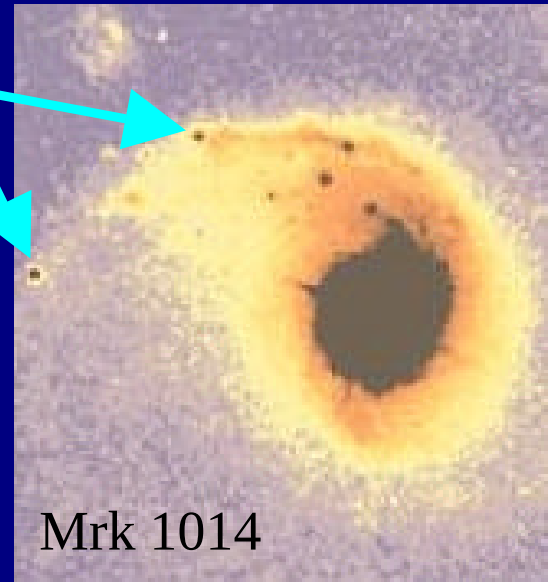
- Dynamical timescale of tail much shorter than age of stars
- Not a truncated IMF: high-mass stars in clumps within tail



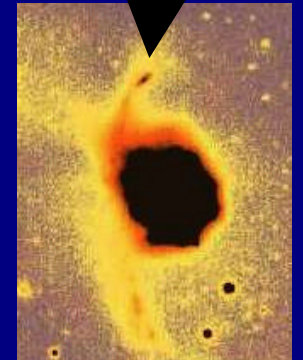
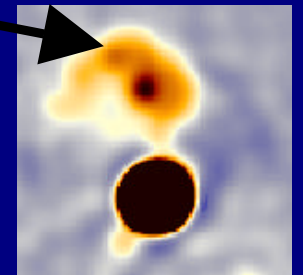
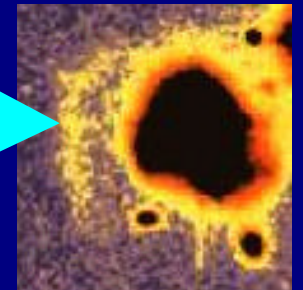
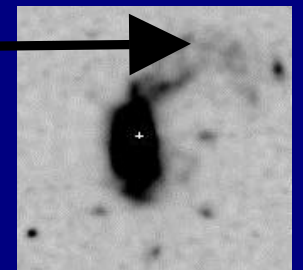
Clumps of star formation in tidal tails



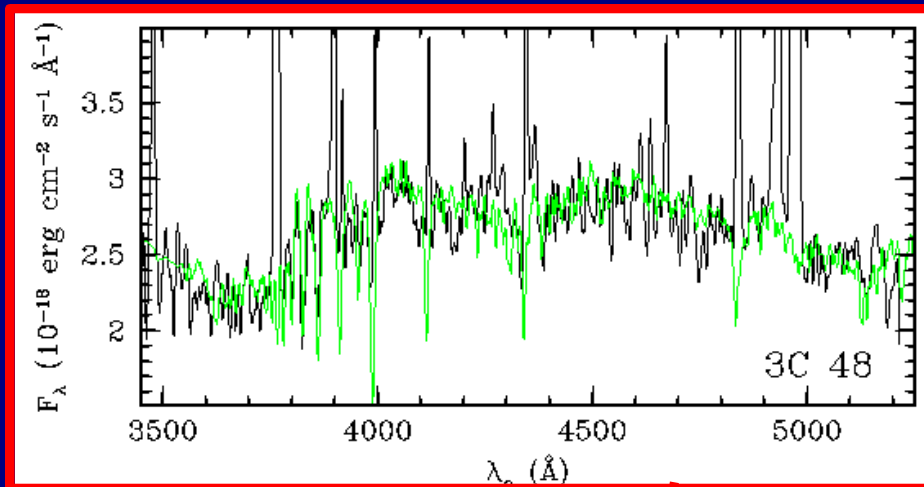
sb clumps
H II region



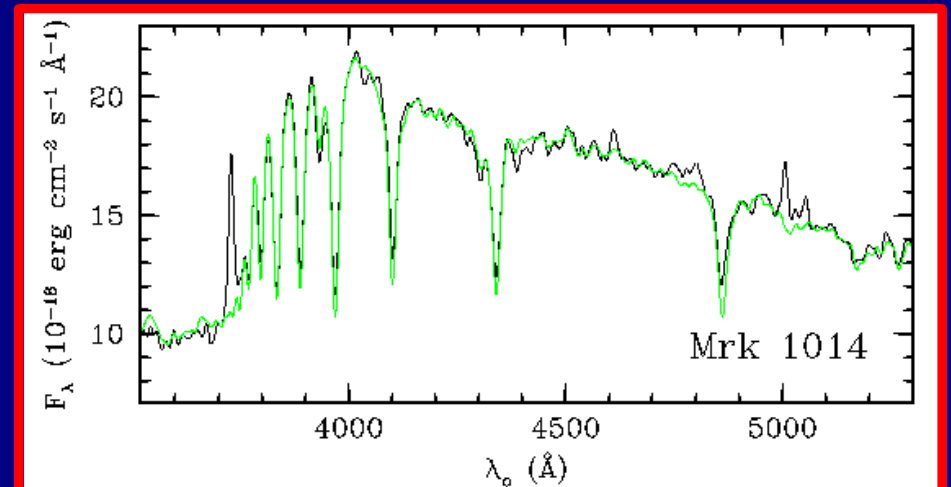
- Age of sb's R dyn. age of tail } starbursts induced after tail was initially launched.
- Similar clumps observed in nearby merging systems (eg. Schweizer & Seitzer 1998), and
- Predicted by numerical simulations (eg. Mihos & Hernquist 1996)



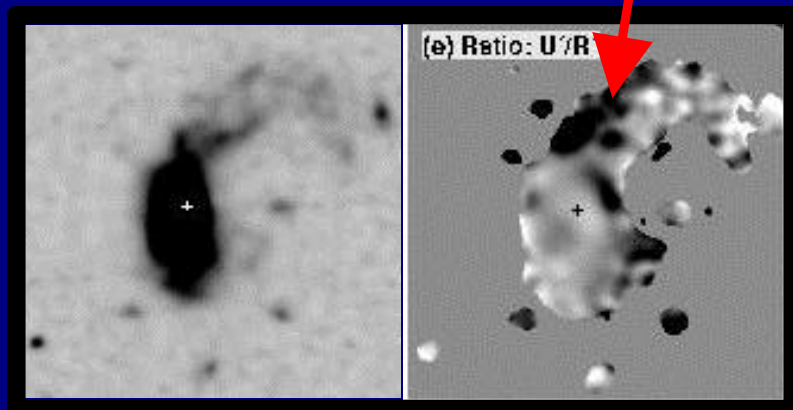
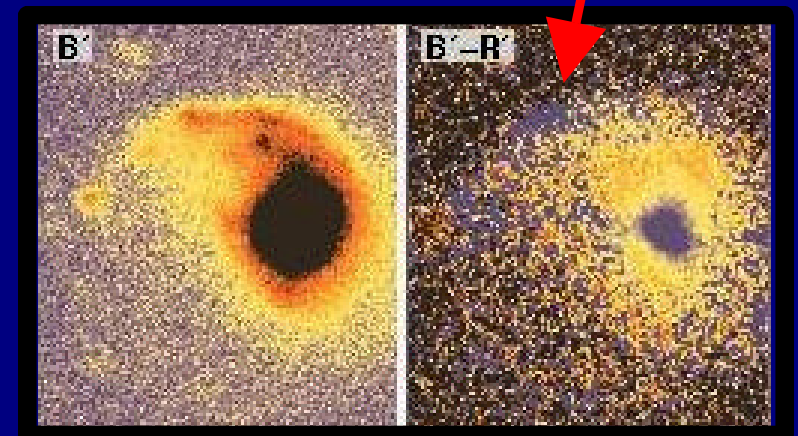
Enhanced Star Formation along Leading Edges of Tidal Tails



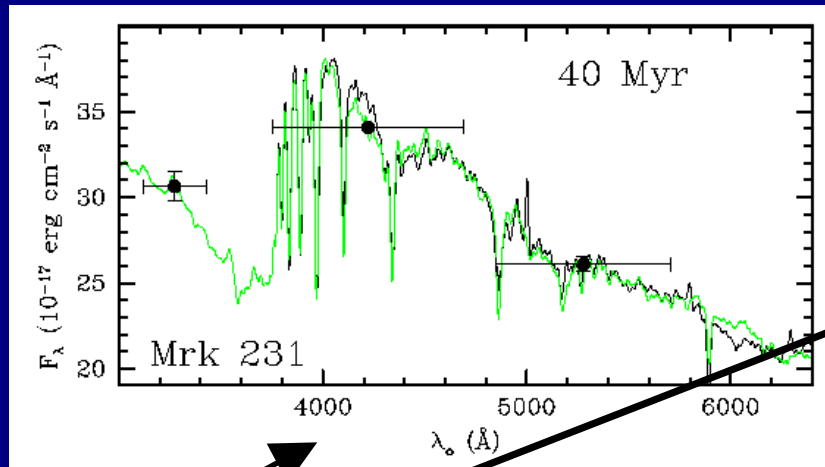
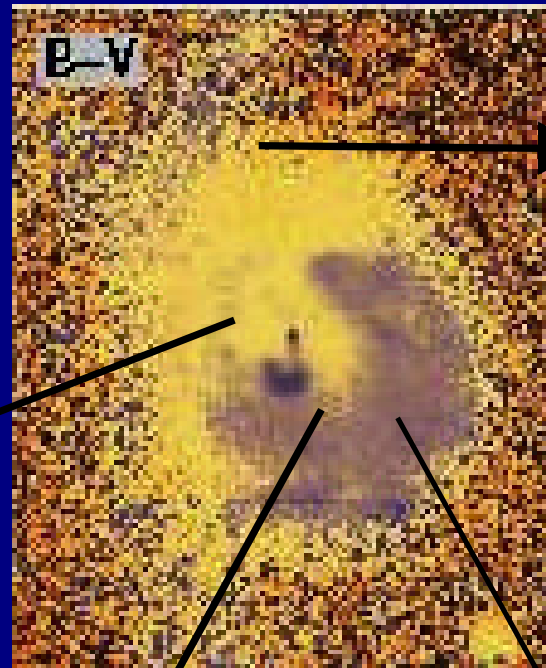
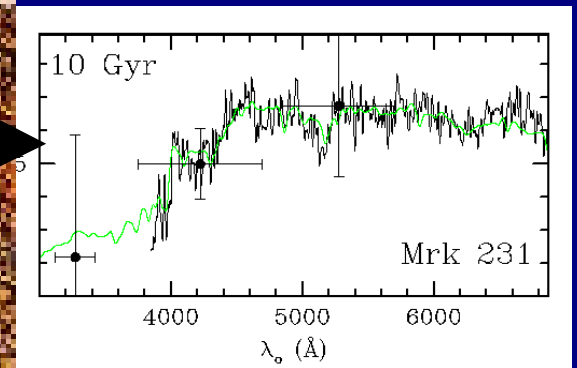
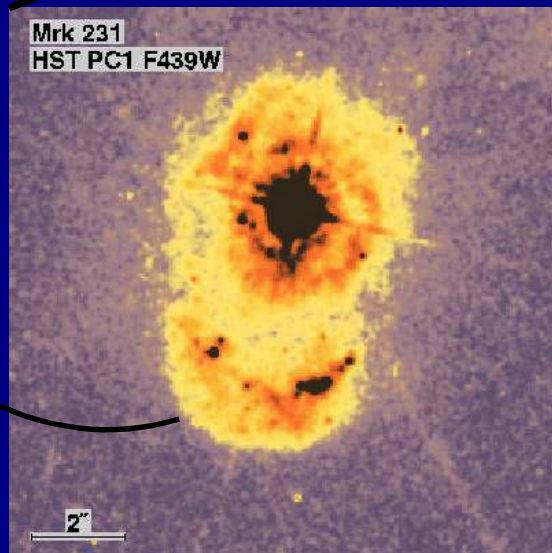
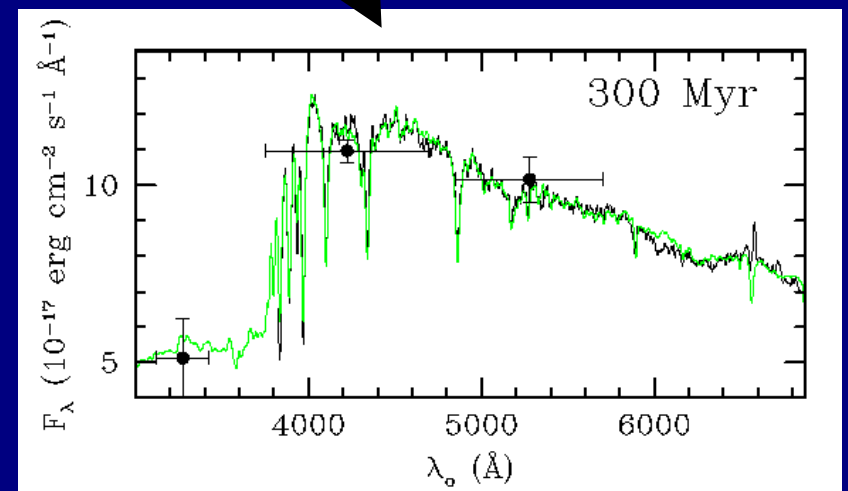
3C 48



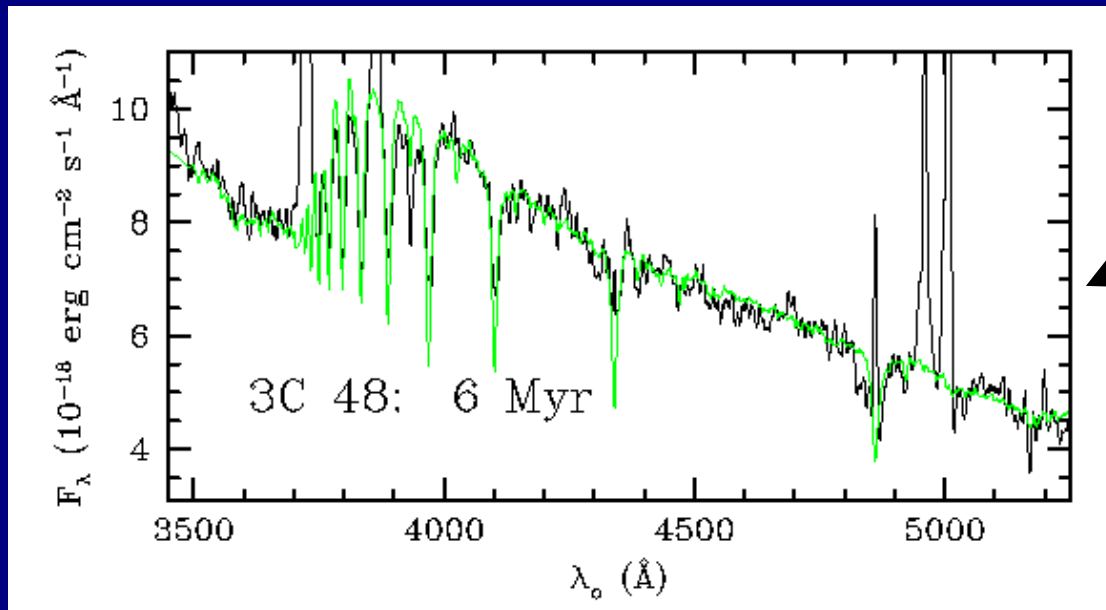
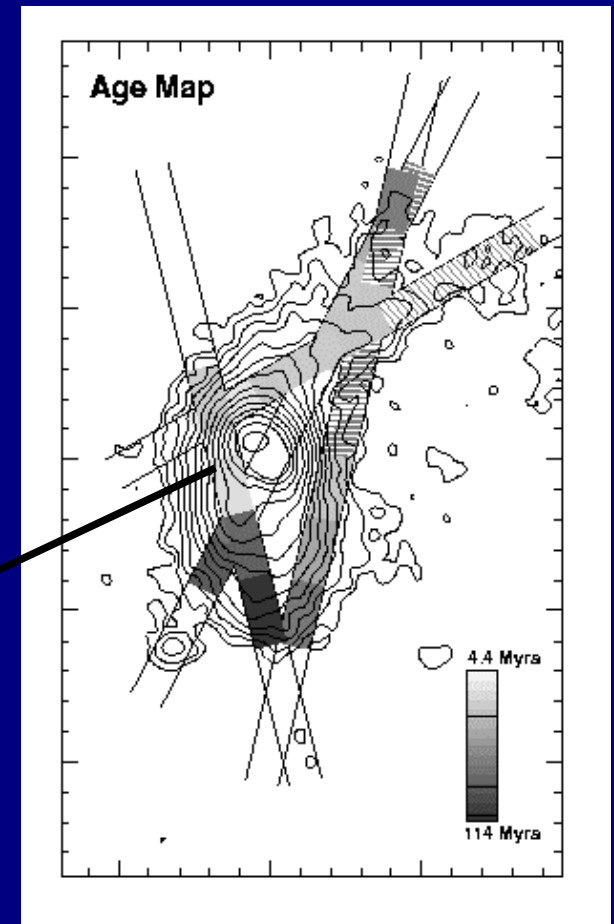
Mrk 1014



Starburst Regions in Main Body of Galaxy



Strongest and youngest starbursts concentrated towards central regions



Summary - ULIR QSOs

- All objects are major mergers, mostly of disk galaxies
- Host galaxies have interaction-induced post-sb pops with ages < 300 Myr
- In many cases, major starburst activity delayed until more advanced stages of merger, indicating presence of stabilizing mechanism
- Strongest and youngest sb's concentrated towards centers of hosts
- Concentration of material towards nucleus likely to have triggered both central starbursts and QSO activity

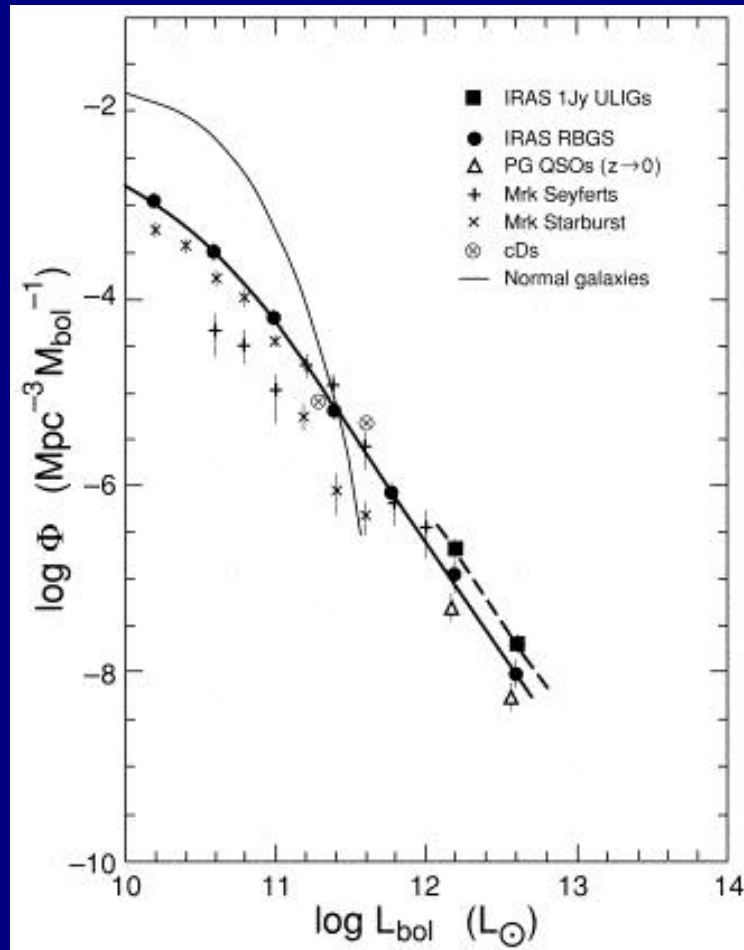
Were starbursts triggered by interaction? Yes.

Were QSOs fueled during interaction? Yes. But,

Was the QSO activity a result of the merger?

Or, did a galaxy already hosting a QSO happen to merge with another galaxy (and rejuvenate the QSO)?

QSOs and ULIGs: Chance Overlap?



Space Densities (Φ)

Galaxies: $3D10^{-3} \text{ Mpc}^{-3}$

ULIGs: $1.7D10^{-7} \text{ Mpc}^{-3}$

QSOs: $2.2D10^{-7} \text{ Mpc}^{-3}$

Kim & Sanders 1998, ApJS, 119, 41

QSOs and ULIGs: Chance Overlap?

Fraction of ULIGs: 5.6×10^{-5}

Fraction of QSOs: 7.3×10^{-5}

Probability that both occur *by chance* in any given otherwise normal galaxy: 4.1×10^{-9}

Expected number in integrated comoving volume to $z = 0.4$:
 $(3 \times 10^{-3} \text{ galaxies Mpc}^{-3}) \times (8 \times 10^9 \text{ Mpc}^3) \times (4.1 \times 10^{-9}) = 9.8 \times 10^{-2} \text{ galaxies}$

In contrast, we have **eight** objects that are both bona fide QSOs and *bona fide* ULIGs

1 QSO and ULIG phenomena are physically related in these objects

1 At least some QSOs can be unambiguously traced back to a merger and an ultraluminous IR phase.

Where do we go from here?

**It is established that low- z ULIR QSOs are ignited through mergers.
But how is this subsample related to the majority of QSOs?**

- **Look for natural descendants among non-ULIR, IRAS QSOs:**

- a) Aging starbursts

- b) Aging signs of interaction

PHL 909, PG 0844+349, and more.

- **Find the IR-quiet counterpart to IRAS QSOs by exploring other properties.**

Also:

- Detailed models to exploit data (spatial distribution and time history of star formation in hosts)
- Companion galaxies: problems with timescales.

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Low
Ionization
BALs



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Close
Companions



"Starburst
Quasar"

