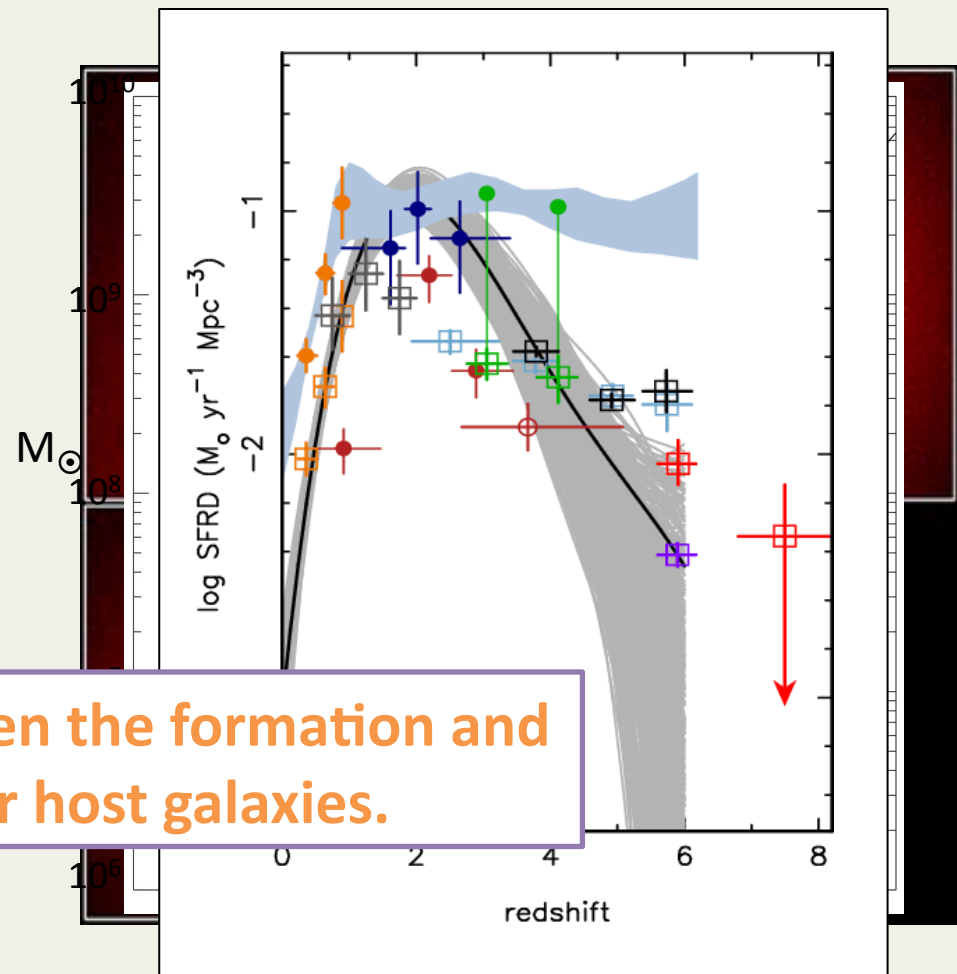# The Reddest Quasars:
A Transitional Phase in Quasar/Galaxy Co-Evolution
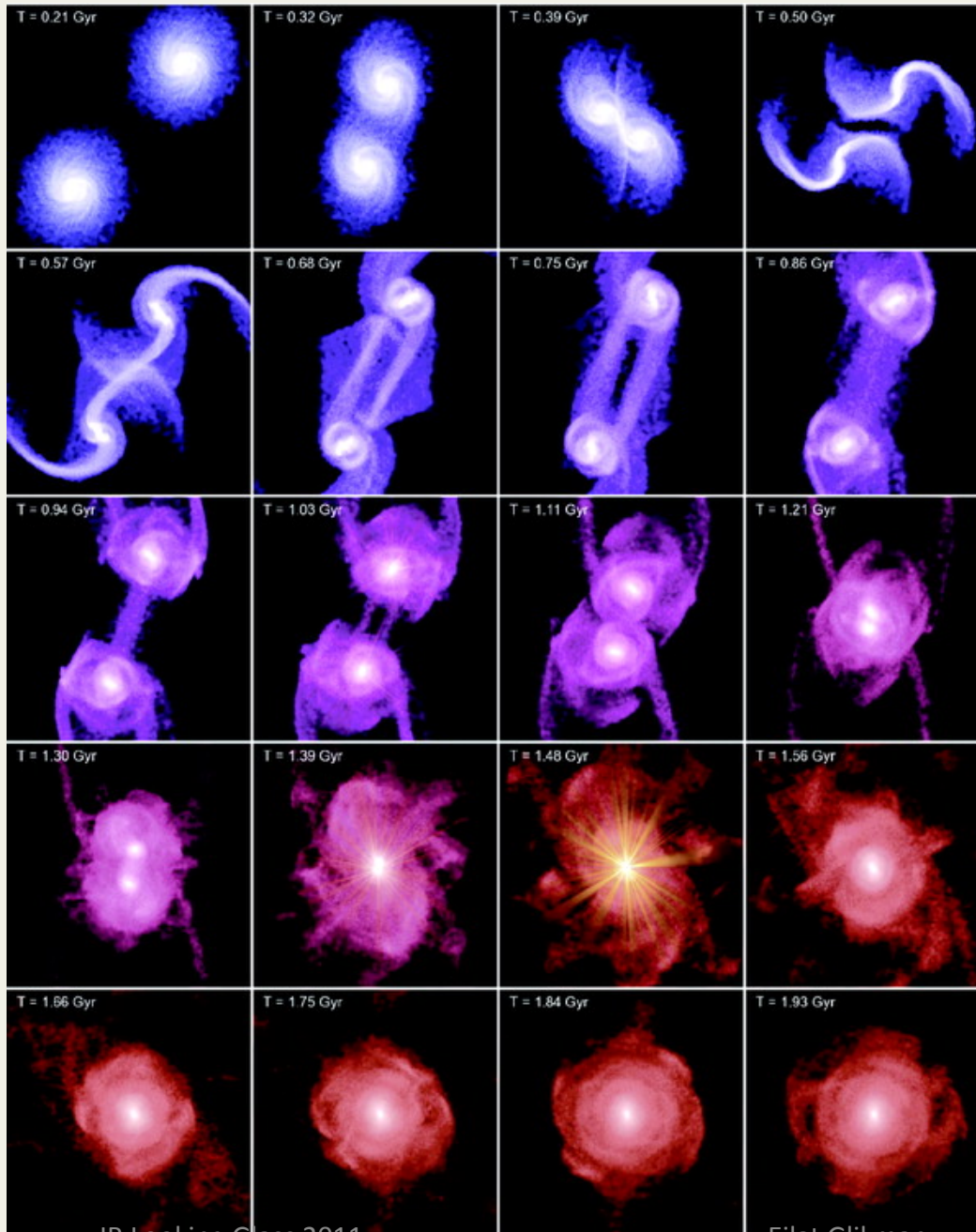
Eilat Glikman (Yale)

Mark Lacy, Tanya Urrutia, S. George Djorgovski, Ashish Mahabal

Black Holes Play a Role in Galaxy Formation and Evolution

- SMBHs are ubiquitous.

- M − σ relation.

- QSOs evolve with SF.

This suggests a link between the formation and growth of SMBHs and their host galaxies.

Each panel is labeled with a time:

T = 0.21 Gyr	T = 0.32 Gyr	T = 0.39 Gyr	T = 0.50 Gyr
T = 0.57 Gyr	T = 0.68 Gyr	T = 0.75 Gyr	T = 0.86 Gyr
T = 0.94 Gyr	T = 1.03 Gyr	T = 1.11 Gyr	T = 1.21 Gyr
T = 1.30 Gyr	T = 1.39 Gyr	T = 1.48 Gyr	T = 1.56 Gyr
T = 1.66 Gyr	T = 1.75 Gyr	T = 1.84 Gyr	T = 1.93 Gyr

IR Looking Glass 2011   Eilat Glikman

Hopkins et al. (2006)

Merger-driven models of joint quasar-galaxy formation **predict an obscured quasar phase**, resulting from the large amounts of gas and dust funneled inwards during a major merger, fueling a nascent quasar.

Using Colors to Find Quasars

Glikman et al. (2006)

Warren et al. (2000)
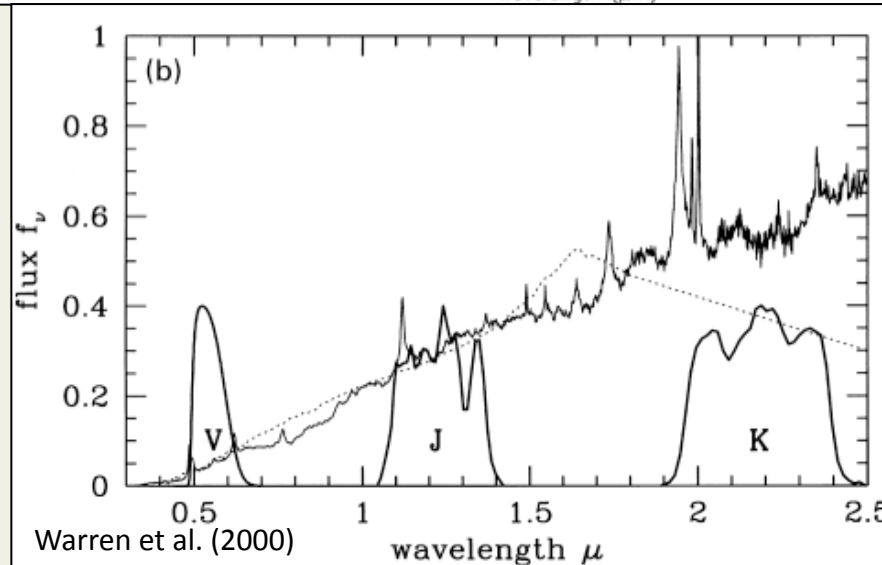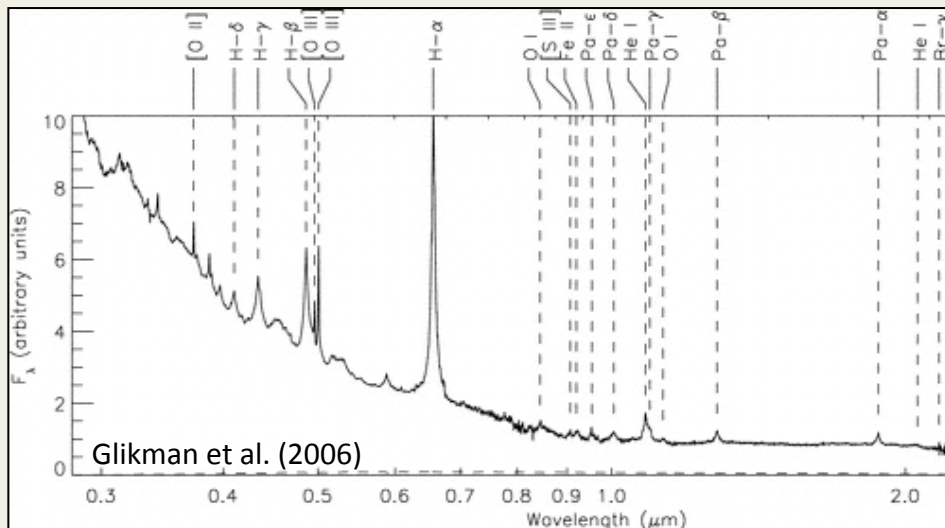
- There are >10^5 known quasars. Most are found in the optical, in searches for blue (UV excess) objects.

- Flux-limited optically-selected quasar samples are biased against dust-obscured objects.

- A few magnitudes of extinction will leave only the most luminous objects in a flux-limited sample.

Pilot Project:
Example: F2M013435.6-093103

Radio

Near-Infrared

Optical – photographic plate

Optical - Sloan Digital Sky Survey
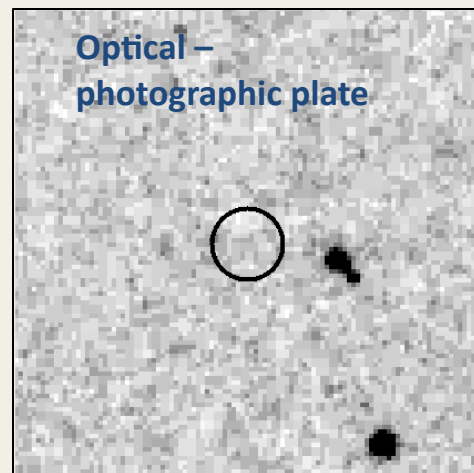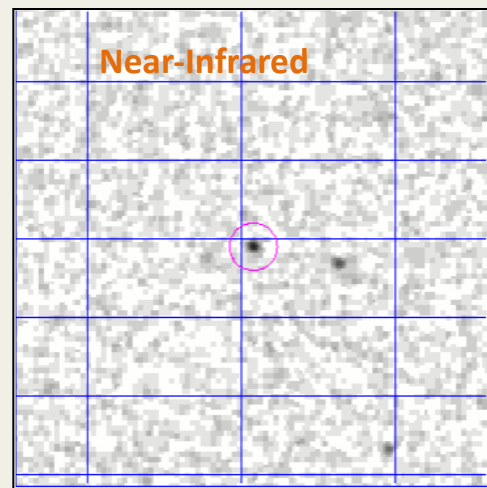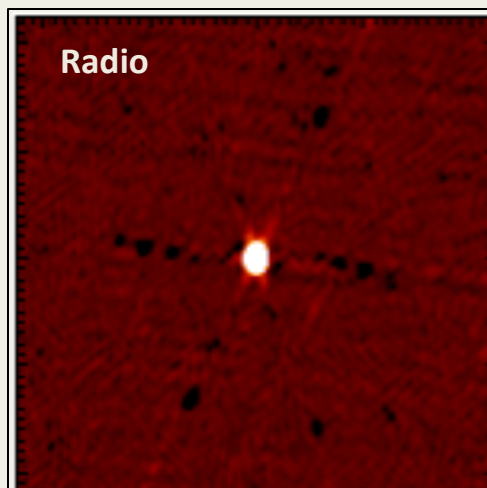
Find obscured quasars: Radio + near-IR, no optical

FIRST flux density, S_{20cm} >1 mJy

2MASS detection within 2" of FIRST position
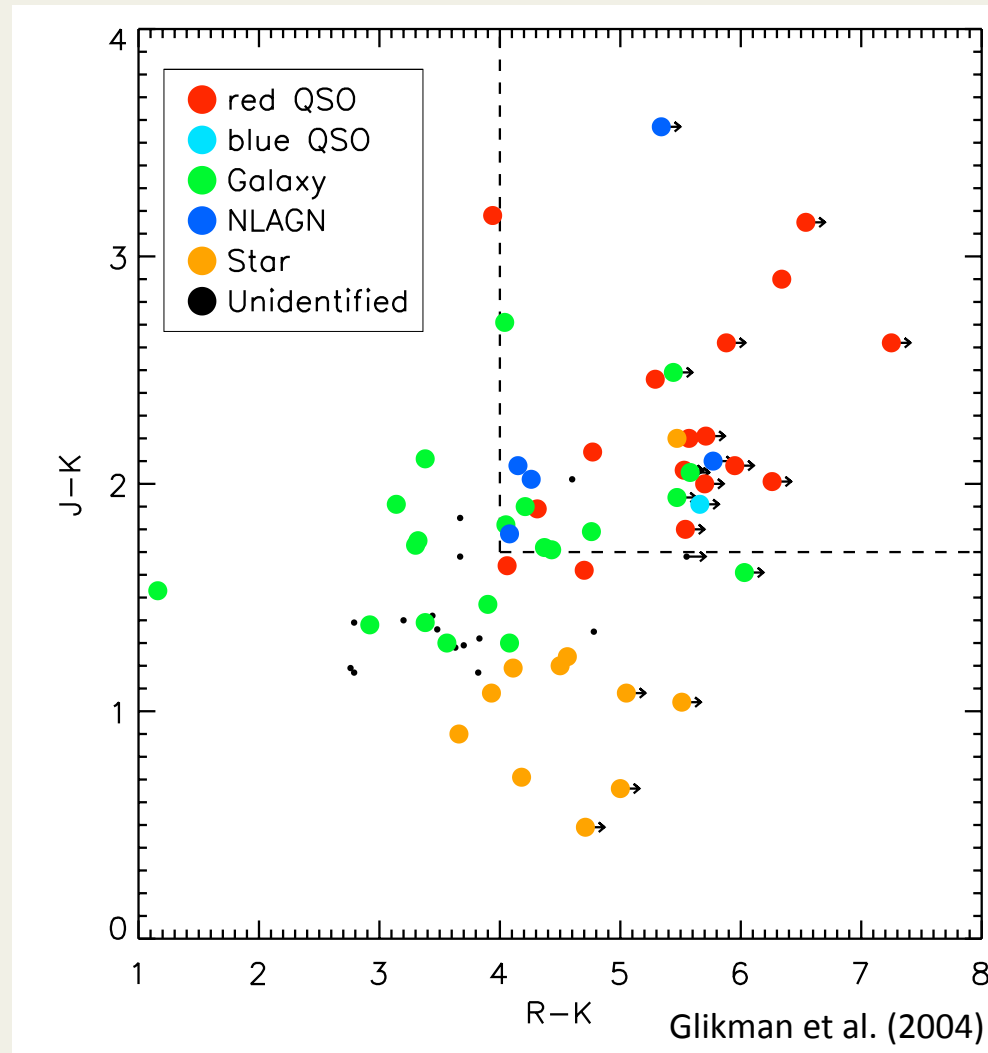
No optical counterpart in APM scans of POSS-I plates (R>20, B>21.5).

This object turned out to be a high-redshift, gravitationally lensed quasar (Gregg et al. 2002, Hall et al. 2002, Glikman et al. 2004)
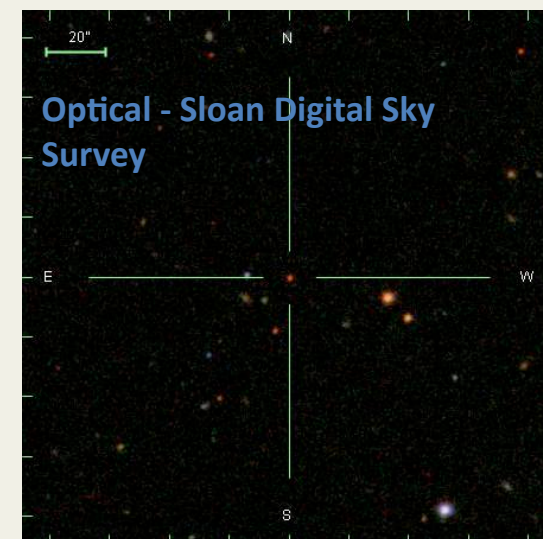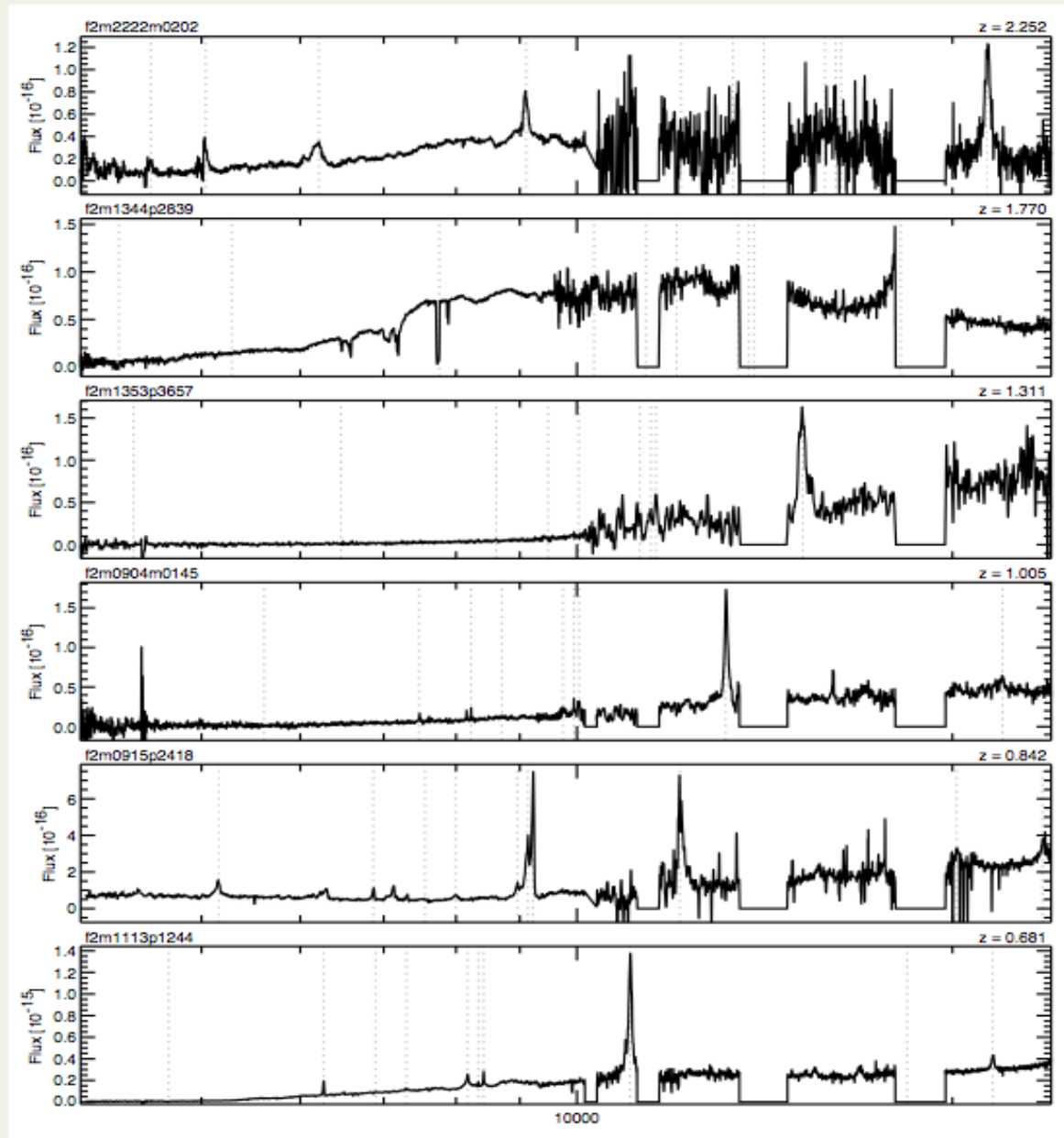
Results from our Pilot Program

- 69 candidates over 2716 deg^2.

- 54 identifications using optical and/or near-infrared spectroscopy.

- 17 red quasars.

Glikman et al. (2004)

Expanded Survey:

- 394 candidates over 9033 deg^2
- 304 spectroscopic identifications.

- **118 red quasars**

Glikman et al. (2007)
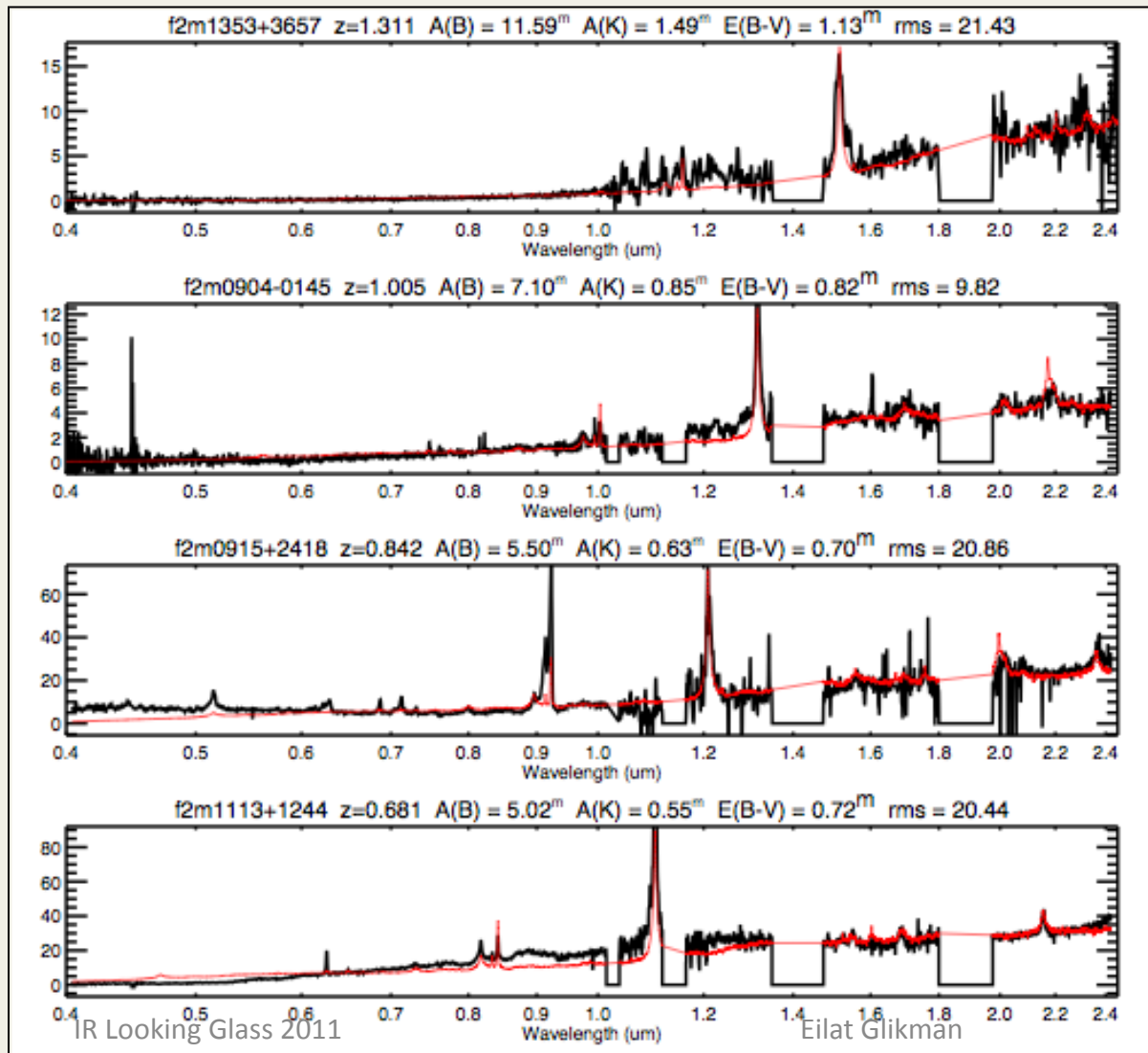Glikman et al. (2011) in prep

De-reddening the spectra
Determining the intrinsic brightness:

We fit a reddened quasar template to our red quasar spectra applying an exponential reddening law to the composite.

$$F = F_0 e^{-k(\lambda)\mathrm{E}(B-V)/1.086}$$
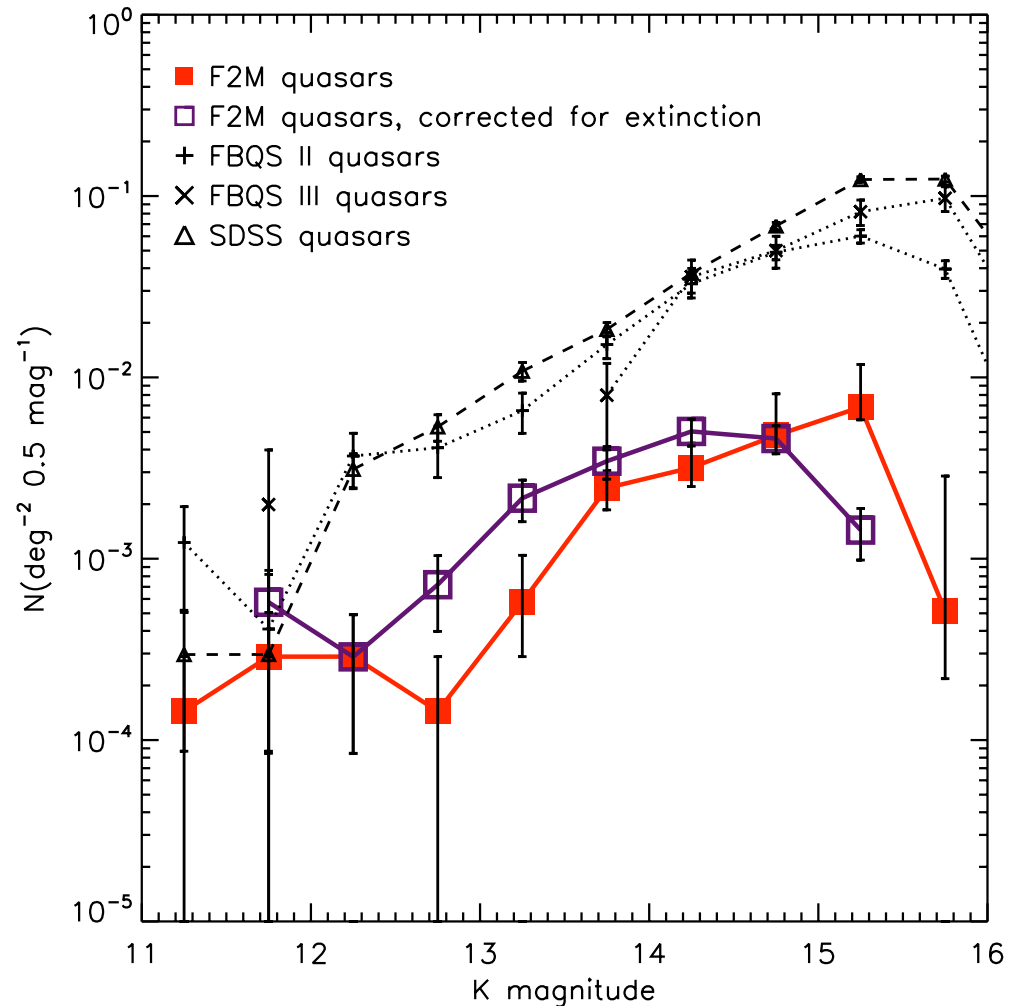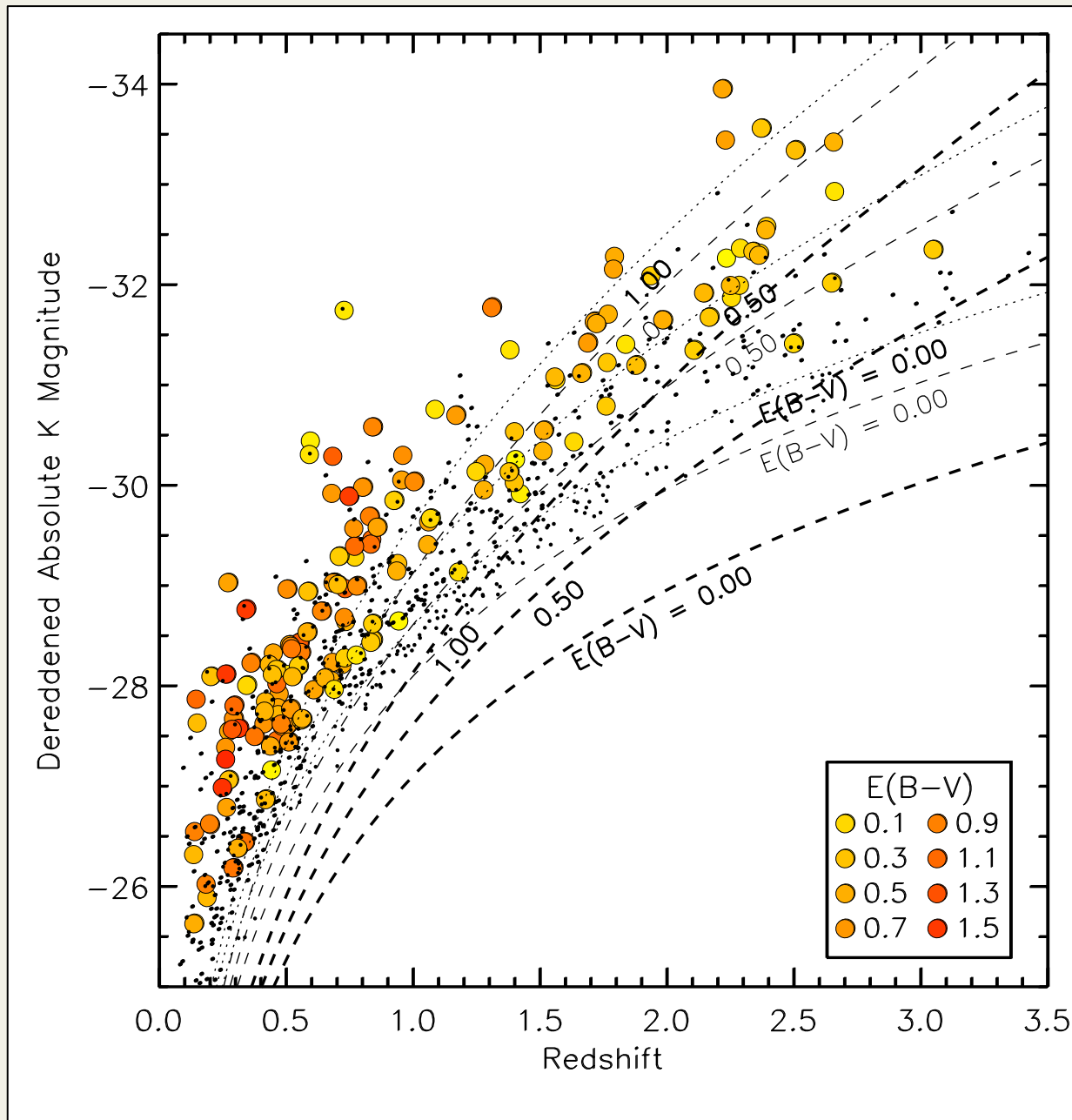
SMC reddening law.

Eilat Glikman

Space Density of Red Quasars

Space density of quasars on the sky of F2M red quasars compared with optically-selected quasars (FBQS).

Observed: F2M quasars make up **10 ± 1 %** in flux limited samples.

Extinction Corrected: F2M quasars make up

19.2 ± 2.6% of radio-selected quasars with K ≤ 14.5.

• At all redshifts, red quasars are the most luminous objects.

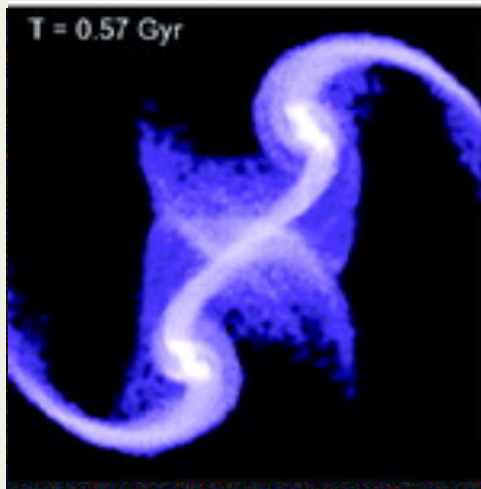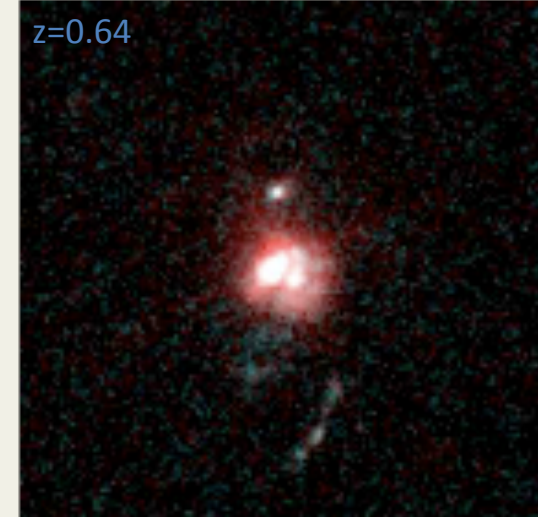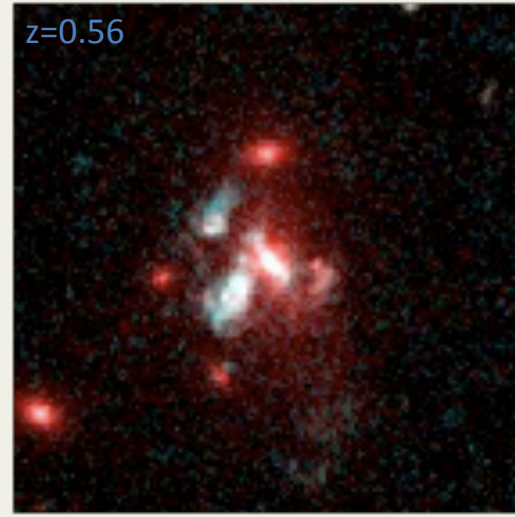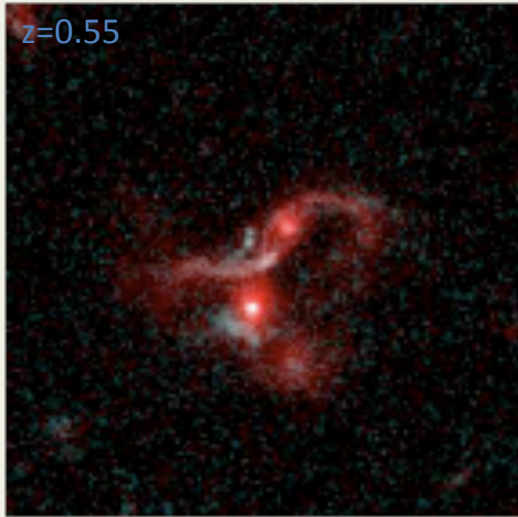→ Opposite direction for Type I/II quasars which goes the other way!

→ Not reddened by nuclear obscuration.

→ **Red quasars are an evolutionary *phase***

• No highly reddened objects at high redshift.

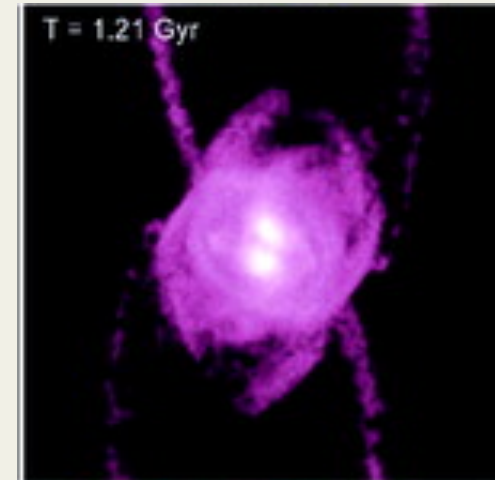→the result of K-correction and 2MASS flux limit.

Red Quasar Host Morphologies

- 13 HST images were obtained with ACS.
- All the images reveal a nearby companion.
- 11 show interacting or disrupted morphologies.

Urrutia et al. (2008)

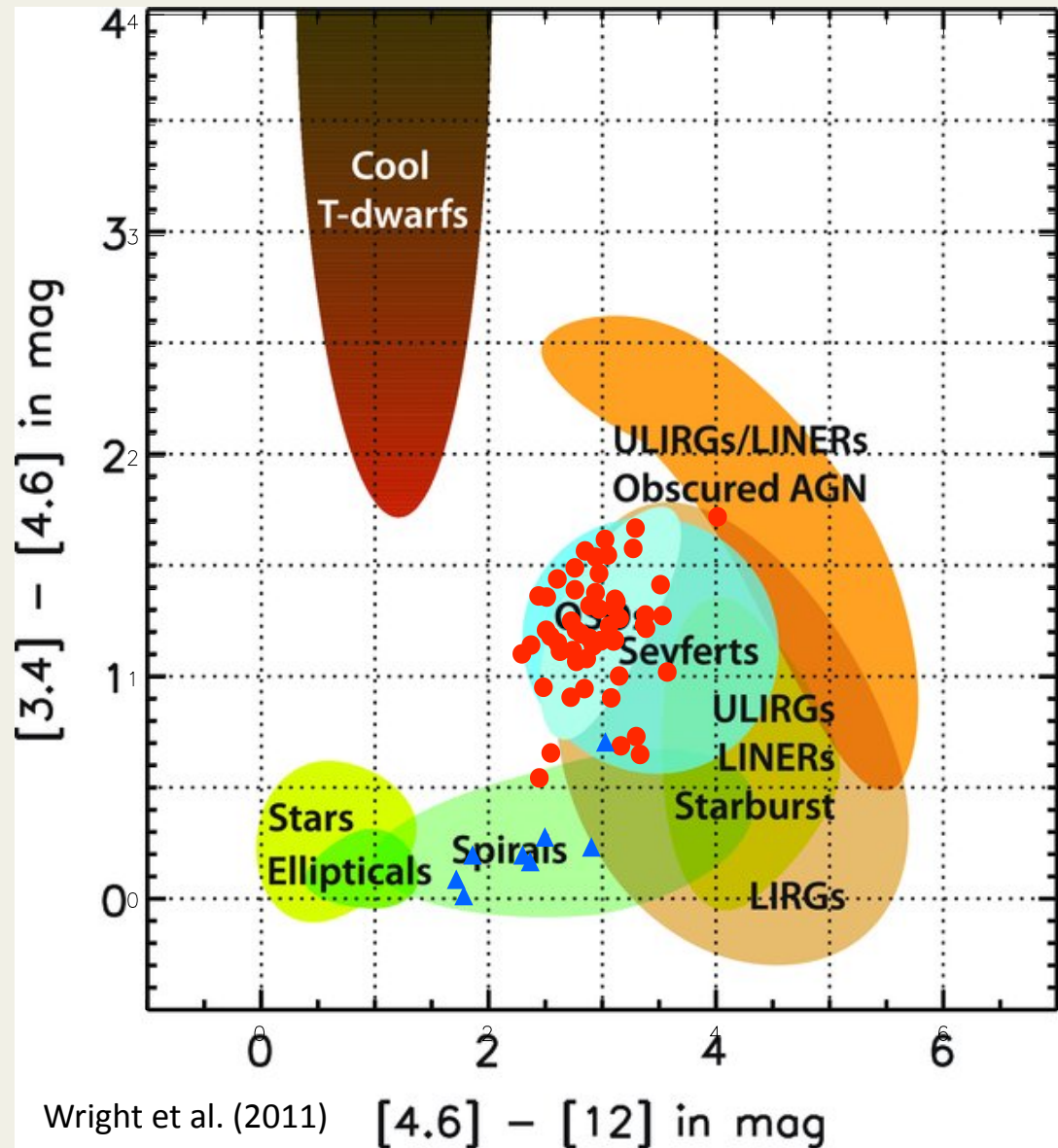- Continuing imaging program with WIYN telescope.

Eilat Glikman

Hopkins et al. (2006) simulations

Red Quasars in WISE

55 Red Quasars

8 Galaxies

• Red quasars live with all other quasars in WISE color-color space

• Can easily separate quasars from galaxies (and stars) to produce complete quasar samples.

Wright et al. (2011)

Summary and Conclusions

- Identified a population of dust-obscured red quasars whose fraction is ~20% of the total quasar population.

- They are the **most luminous** sources at every redshift.

- They reside in highly disturbed, interacting hosts.

- Reddened quasars are revealing an emergent phase where the heavily obscured quasar is shedding its cocoon of dust prior to becoming a "normal" blue quasar.

- Based on the fraction of objects in this phase, the duty cycle is ~20% as long as the unobscured quasar phase, **a few million years.**

Eilat Glikman