Lecture 3

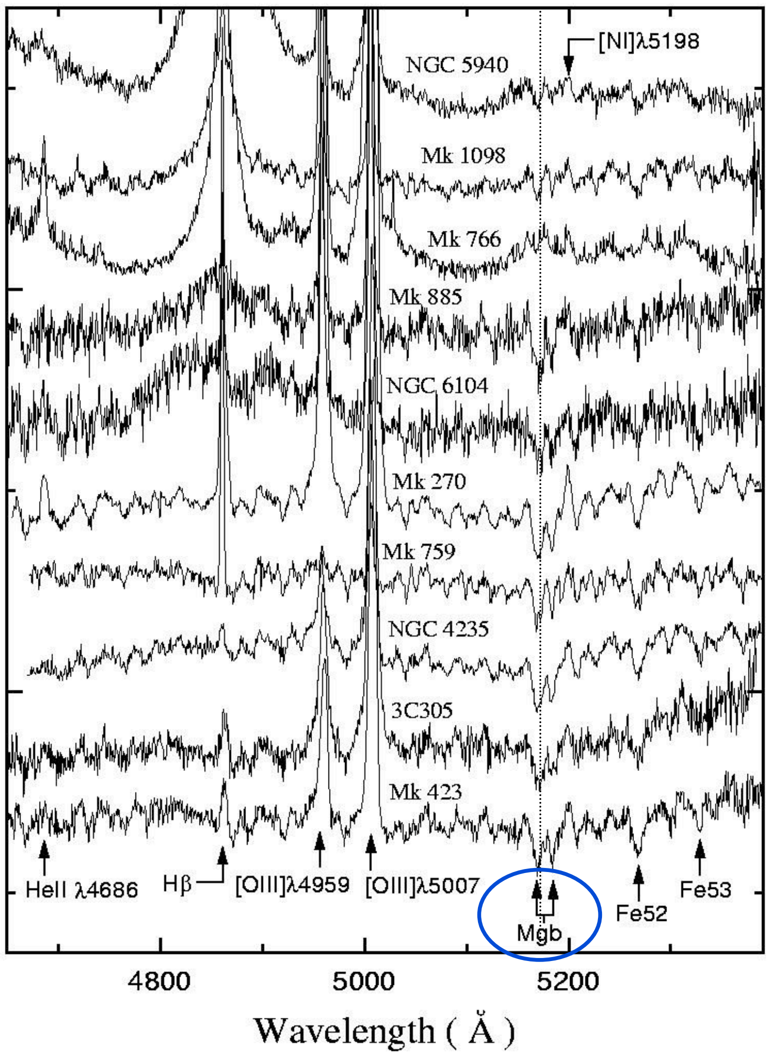
The hosts of AGN
and their environments

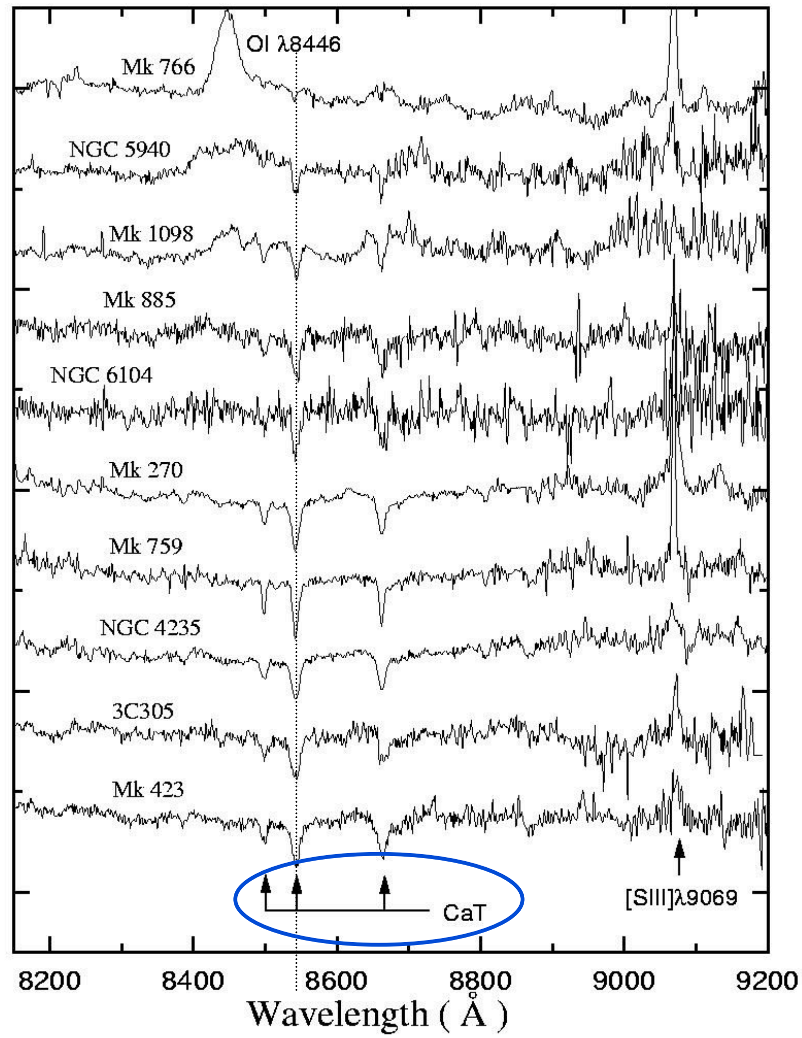
- Evidence for stars in nuclear and circumnuclear regions of AGN
- Galactic winds and supernovae
- Chemical abundances
- Host galaxies and their environments
- Connection between BH mass and galaxy mass
- AGN and galaxy formation and evolution

Itziar Aretxaga (INAOE), @CIDA, October 2007

Stars in Sy nuclei: stellar populations

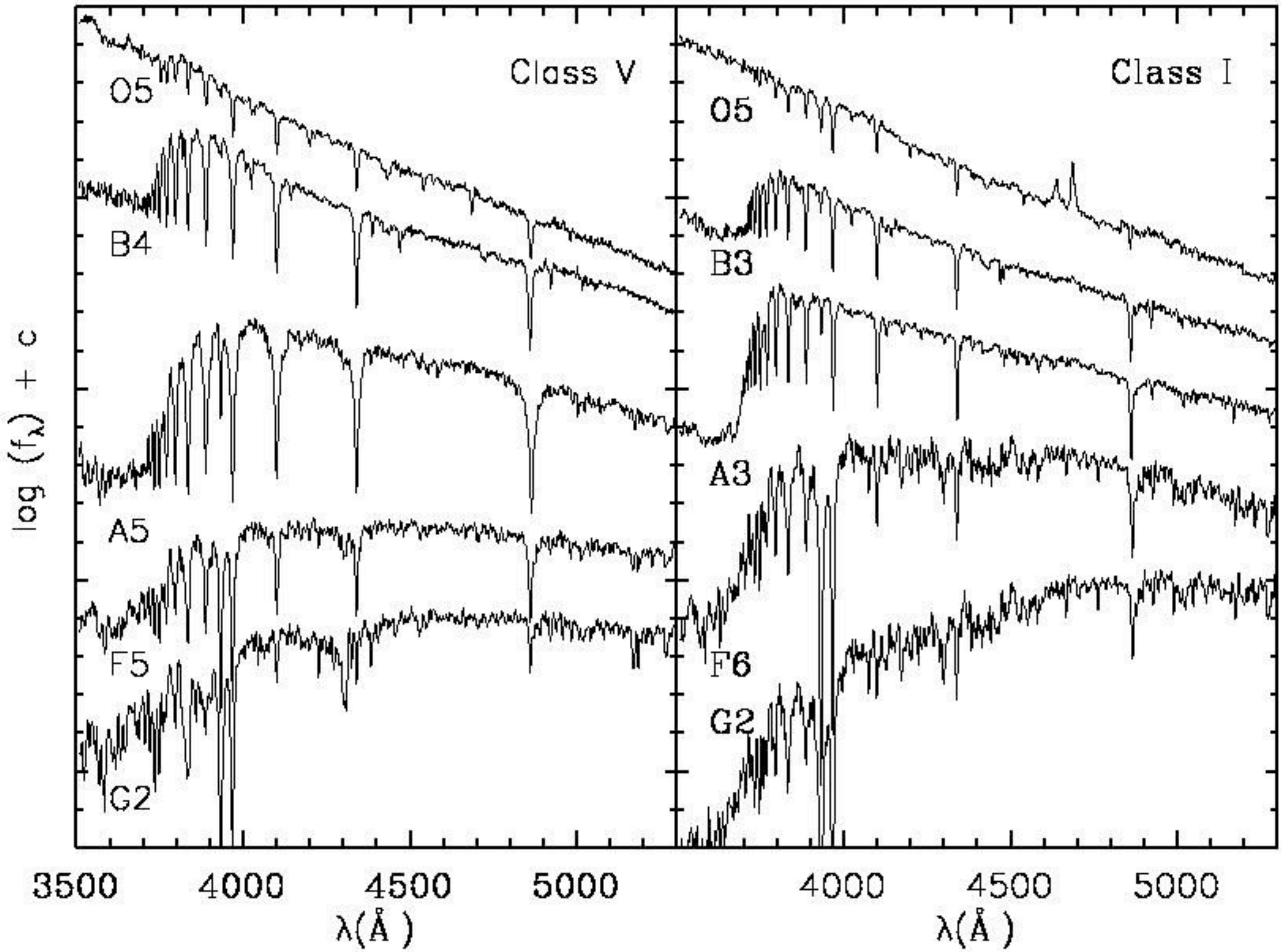
The continuum of AGN has stellar features, more evident in Sy 2s than in Sy 1s ... but is this all old bulge stellar population?





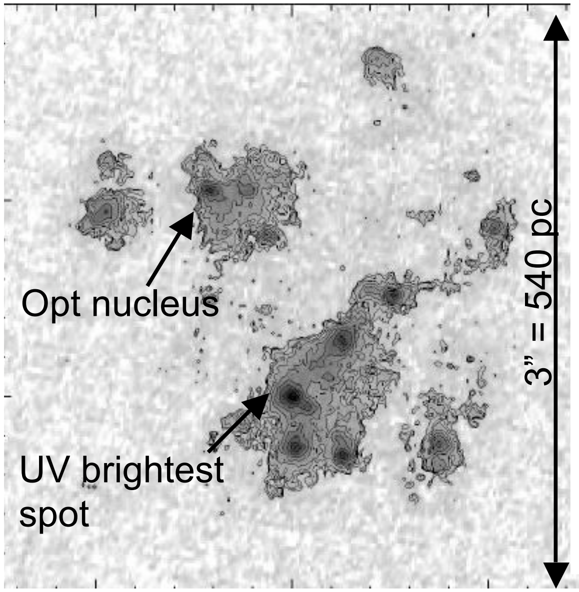
(Jiménez-Benito et al. 2000)

Stellar atmospheres: a reminder



(from Jacoby et al. 1984)

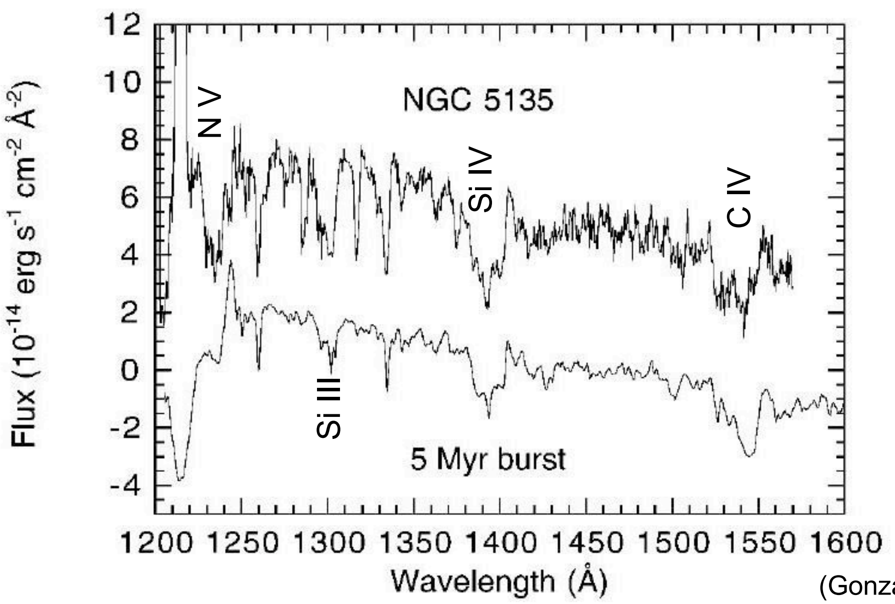
Stars in type-2 AGN: OB stars in Sy 2s

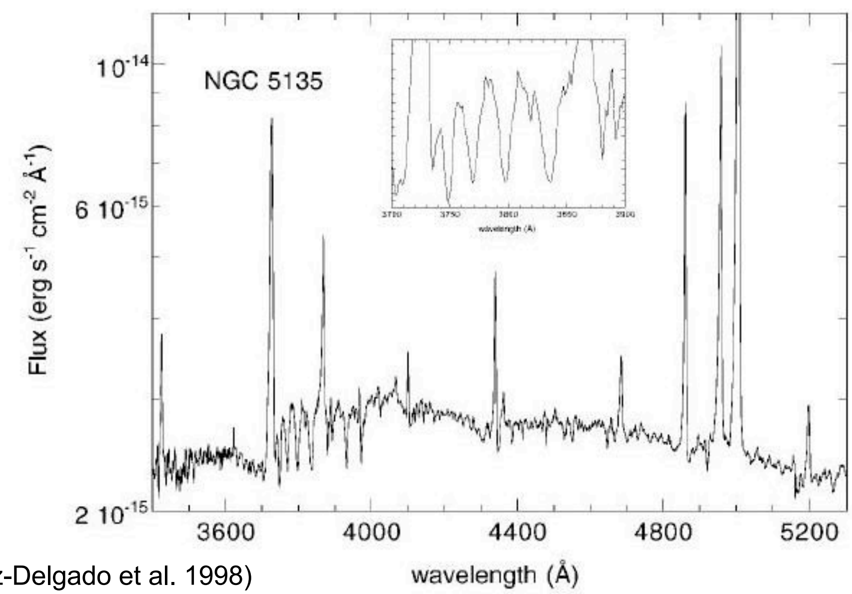


HST UV imaging and spectroscopy of 4 Sy 2s selected for being strong [O III] and 1.4GHz emitters (i.e. AGN properties) show resolved knots that are dominated by starburst features (Heckman et al. 1997, González-Delgado et al. 1998), with characteristic:

$L_{SB} \approx 10^{10} - 10^{11}\ L_{\odot}$
$M_{SB} \approx 5 \times 10^{6} - 5 \times 10^{7}\ M_{\odot}$
age ≈ 3 − 6 Myr
$Z \geq Z_{\odot}$
size ≈ 100 pc

as luminous as the hidden nucleus, which can be inferred from the N V emission lines.





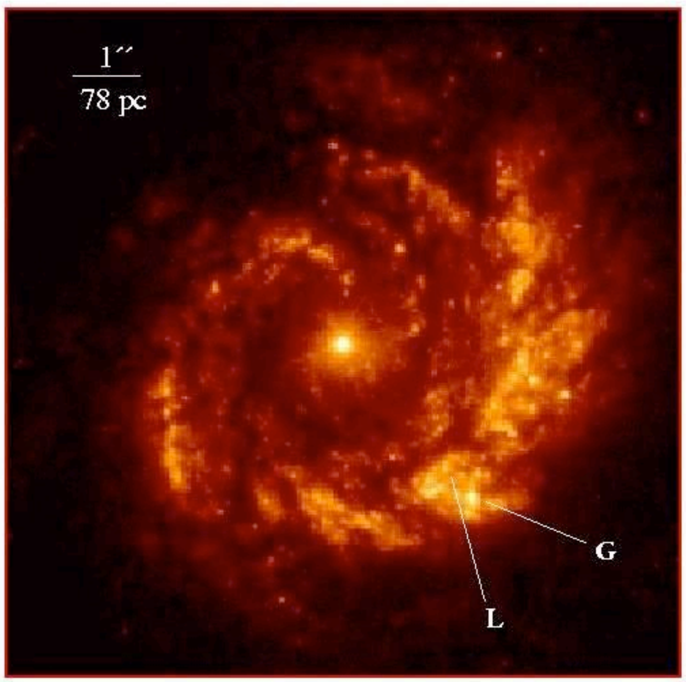
(González-Delgado et al. 1998)

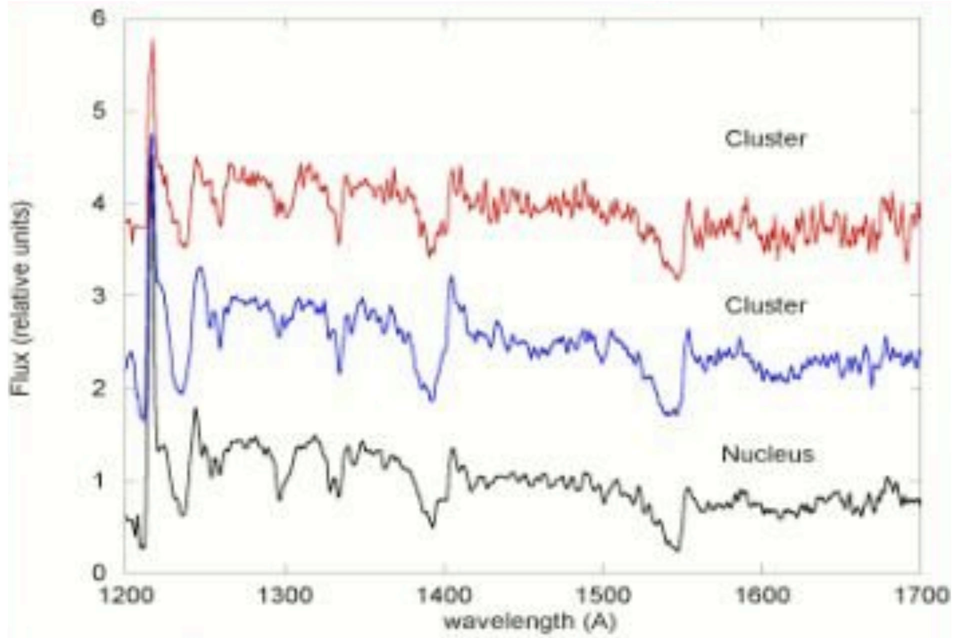
Stars in type-2 AGN: OB stars in Sy 2s

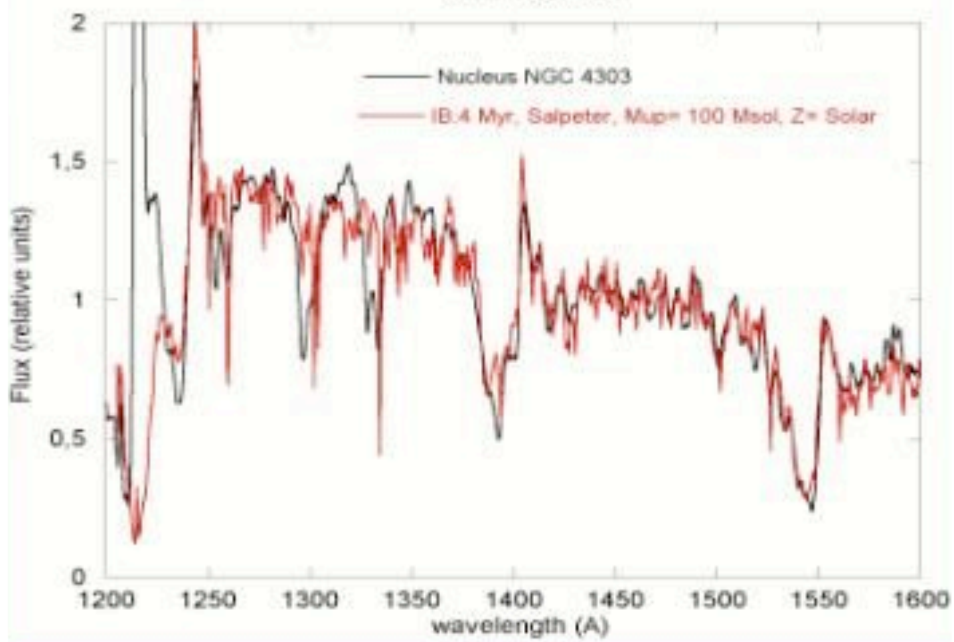
HST UV imaging and spectroscopy of NGC 4303, with dominant UV nuclear emission (Colina et al. 2002):

$L_{SB} \approx 10^8 L_\odot$
$M_{SB} \approx 5 \times 10^5 M_\odot$
age ≈ 4 Myr
$Z \geq Z_\odot$
size ≈ 3 pc

able to account for ALL the Hα emission



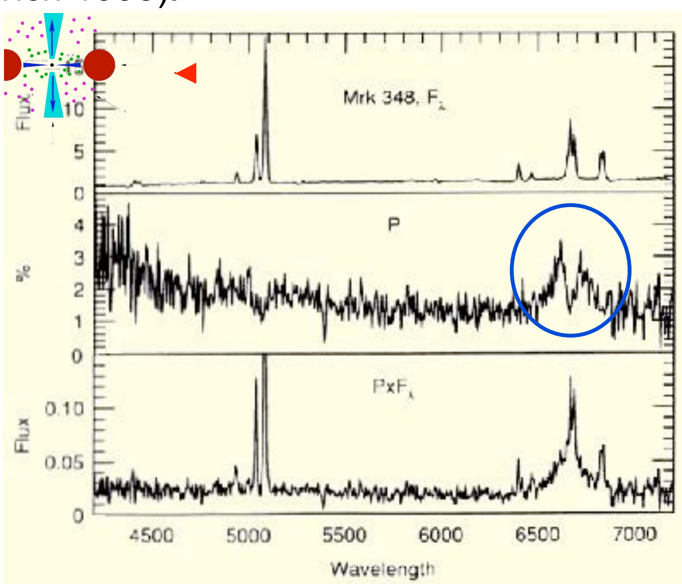


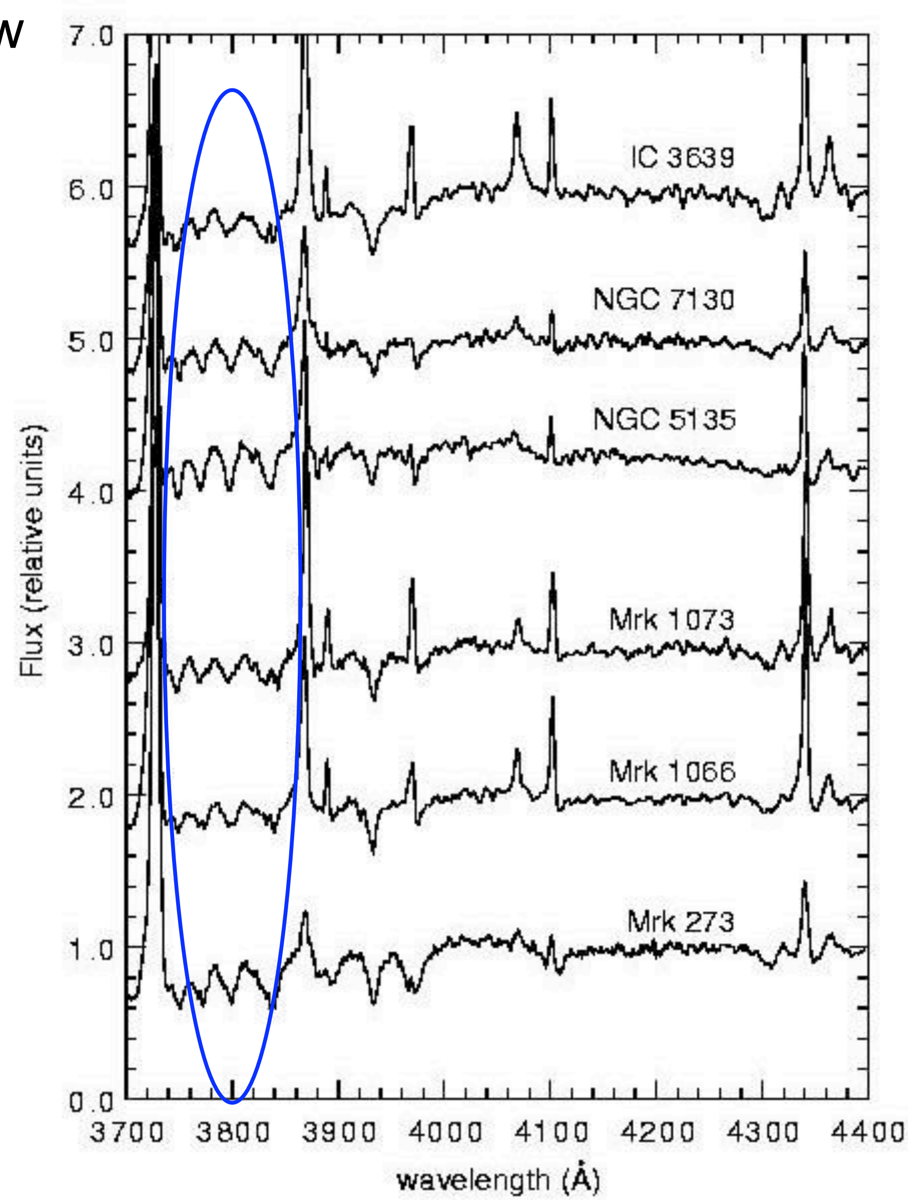


Stars in type-2 AGN: young populations

A survey of 35 Sy 2s finds that 50% show absorption lines characteristic of starburst to post-starburst ages, 5 Myr – 1 Gyr, that completely account for all the continuum emission (Schmitt et al. 1999, González-Delgado et al. 2001, Cid-Fernandes et al. 2001)

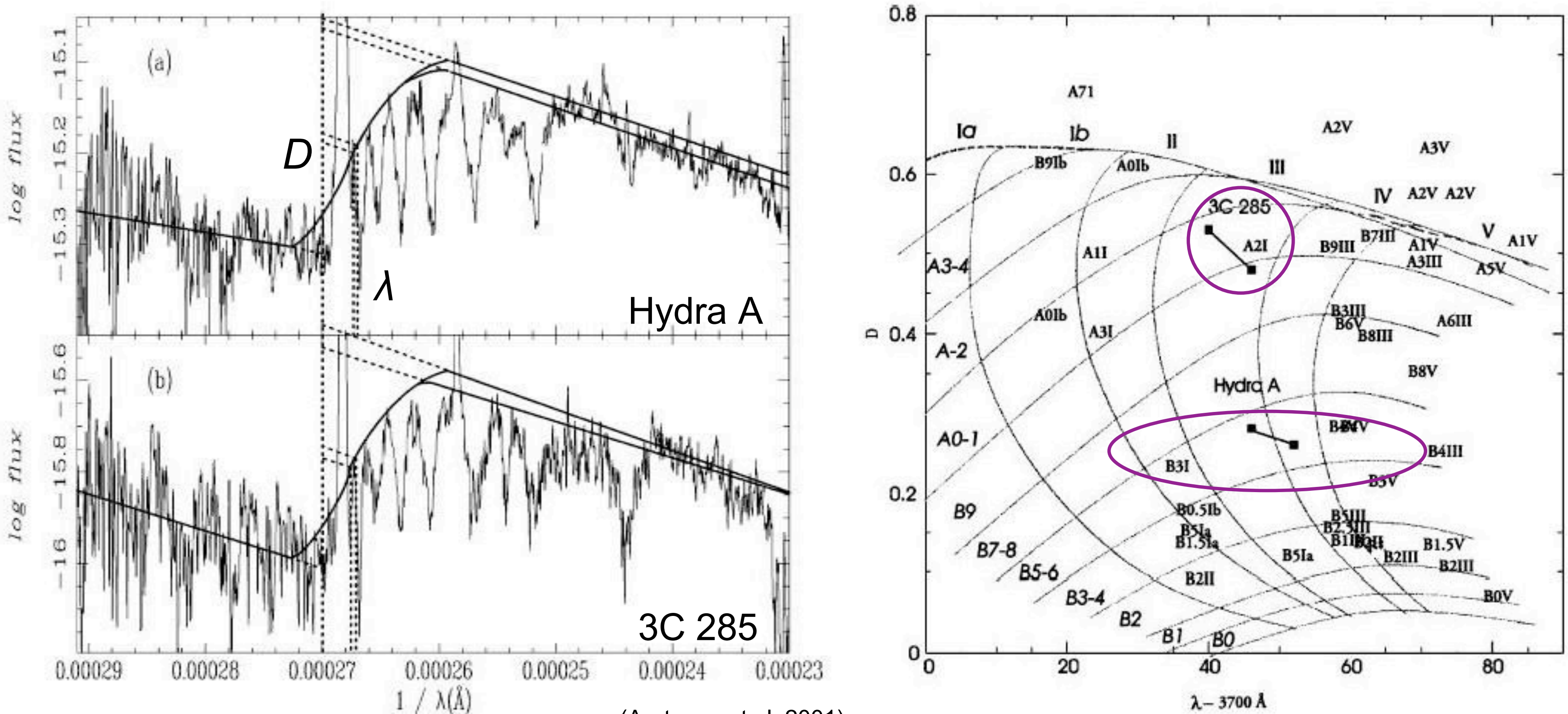
The SBs can also solve the problem of the second continuum source needed to explain the low polarization levels of the continuum of Sy 2s (Tran 1995, Cid Fernandes & Terlevich 1995).





(González-Delgado et al. 2001)

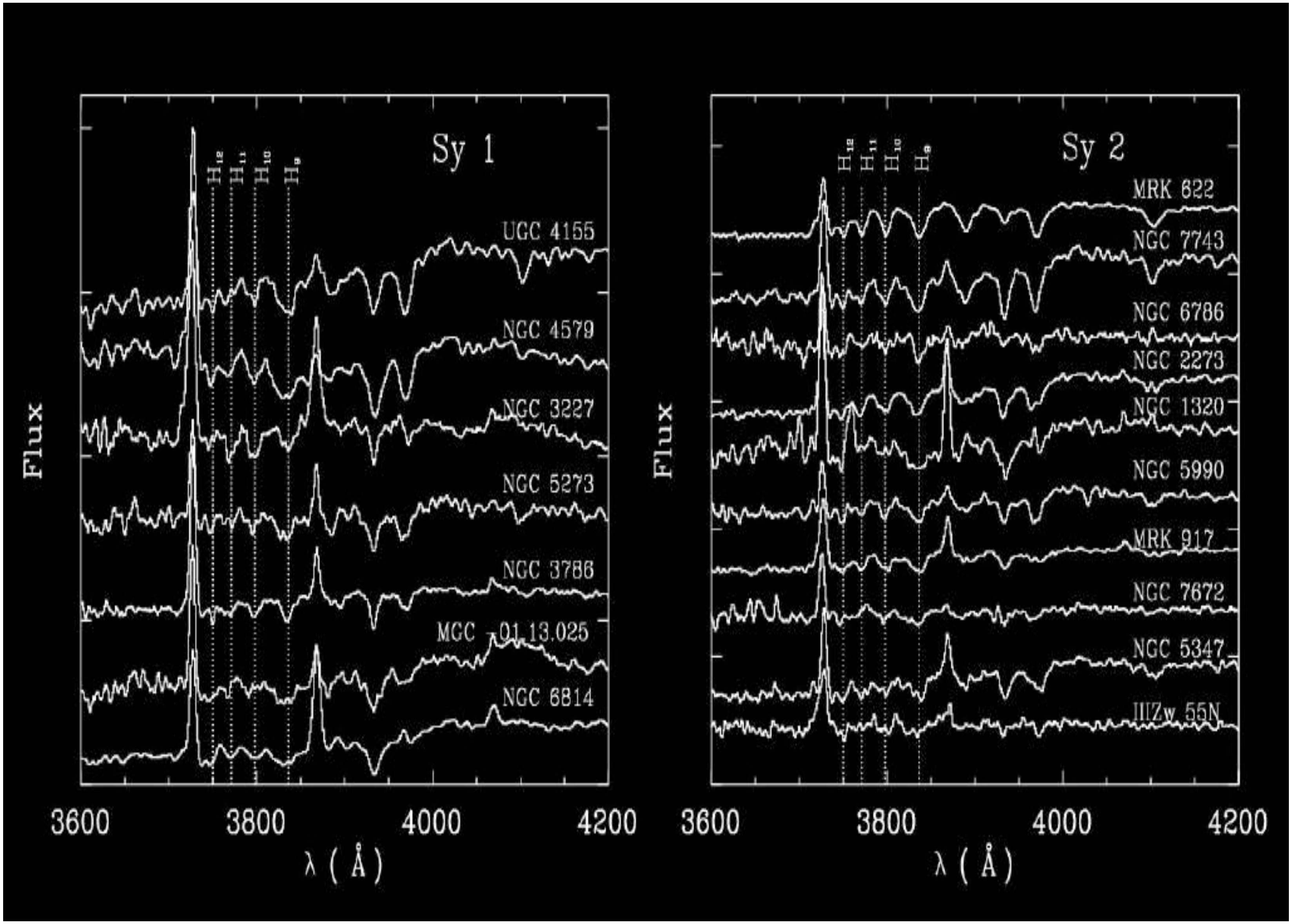
Stars in type-2 AGN: young populations



(Aretxaga et al. 2001)

2/6 radio powerful NLRGs also show continuum dominated by a young stellar cluster of 7 − 40 Myr old, the rest have <Mg Fe> vs. estimated-Hβ indices indicative of ages a few Gyr, but younger than normal E galaxy populations (Aretxaga et al. 2001). Needs statistically significant sample (see also Wills et al. 2002, Tadhunter et al. 2002).

Stars in type-1 AGN: young populations



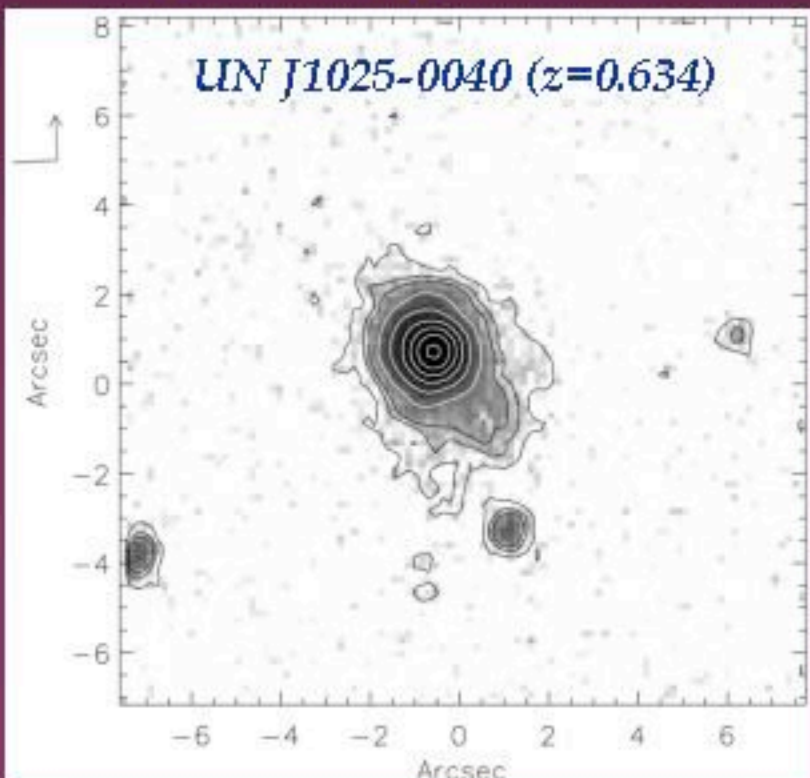
Torres-Papaqui (2005)

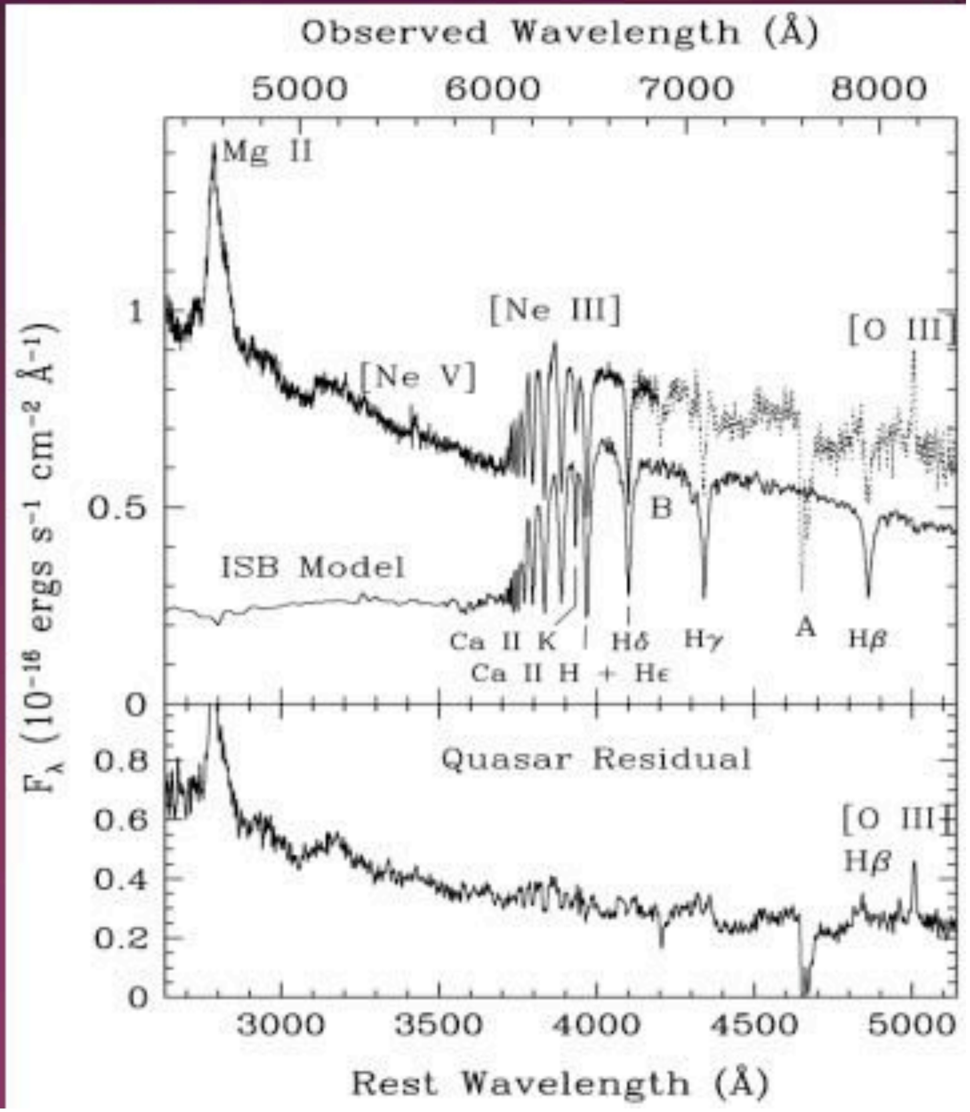
Starbursts in QSOs

A red-herring among QSOs, since most type-1 AGN show only weak absorption lines, if anything

(from Rosa González-Delgado´s web page)

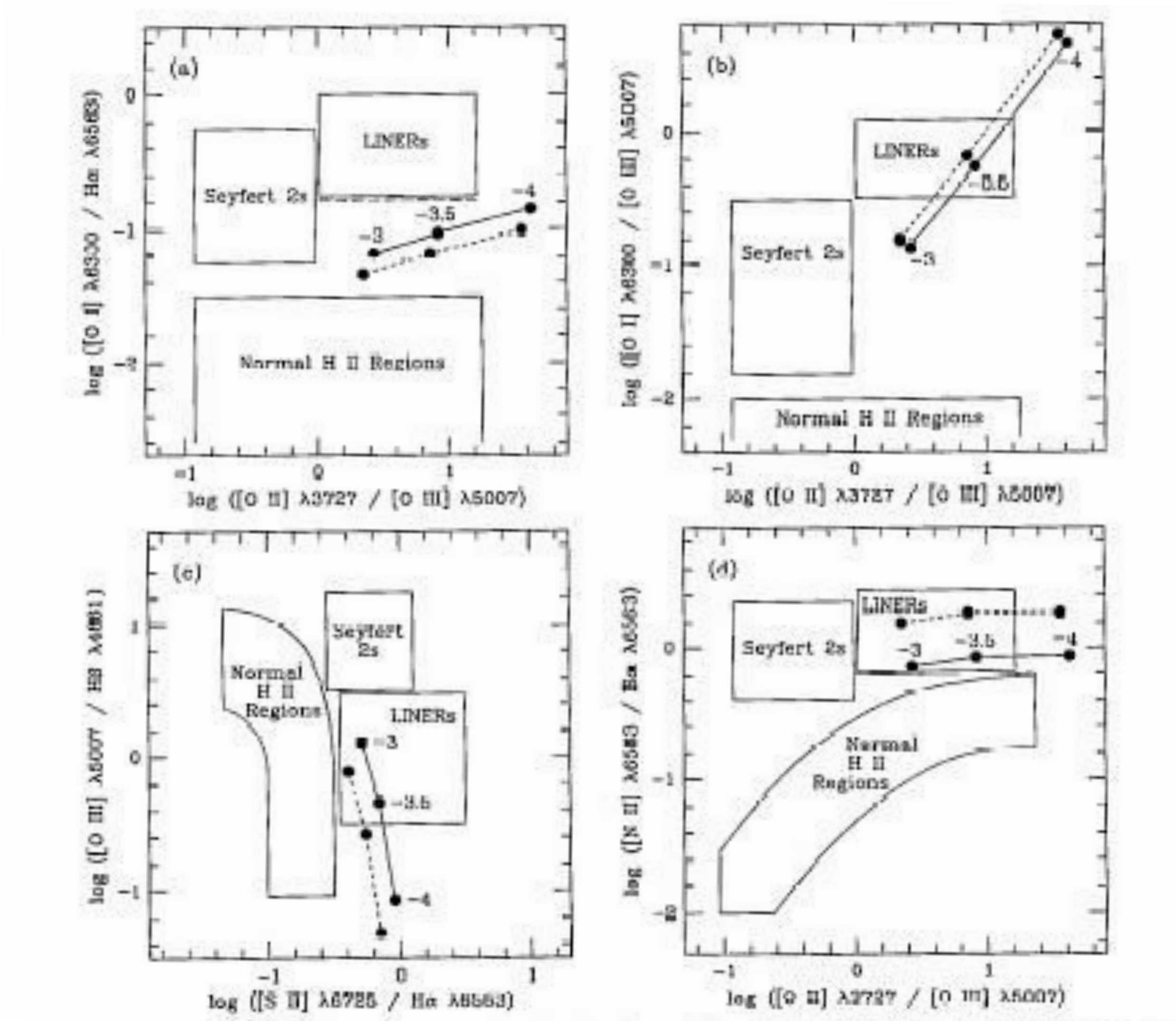
Brotherton et al (1999):
- *Starburst: 400 Myr old and 10^{11} Msol*
- *70% (K) light is unresolved and mainly emitted by the starburst*





Photoionization models for AGN-like SBs

The LINER activity with weak [O I]/Hβ can be explained by normal O-type stars that ionize the surrounding medium (Filippenko & Terlevich 1992, Shields 1992), without the need of additional emission by an accretion disk.

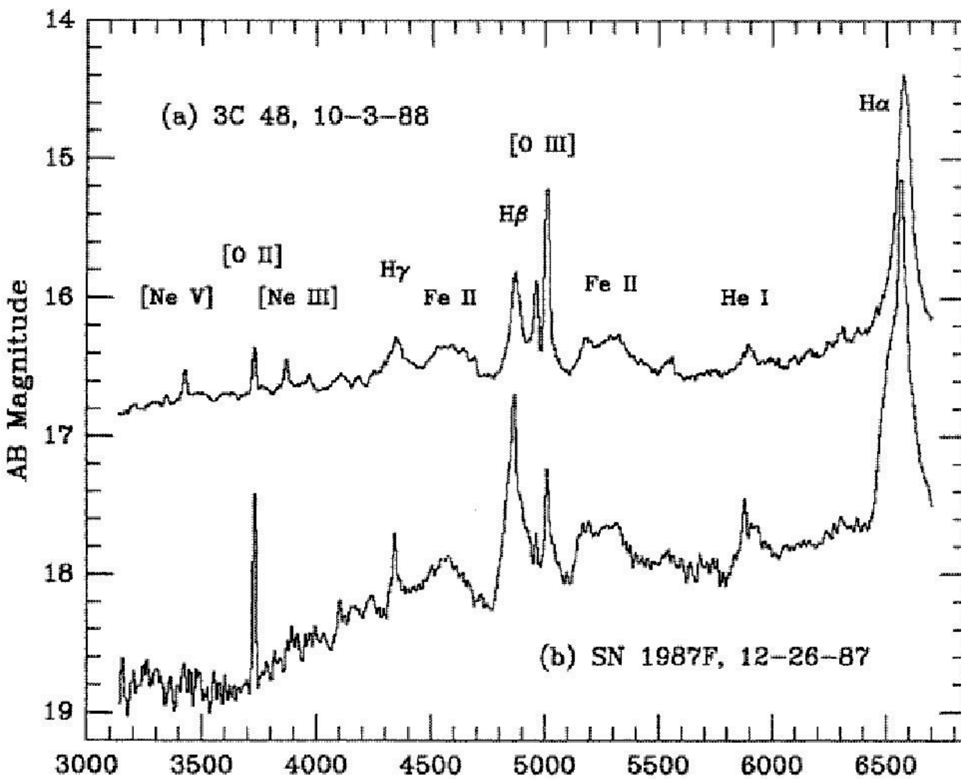


Absorption lines characteristic of young starbursts have also been found in many LINERs (Colina et al., Maoz et al.)

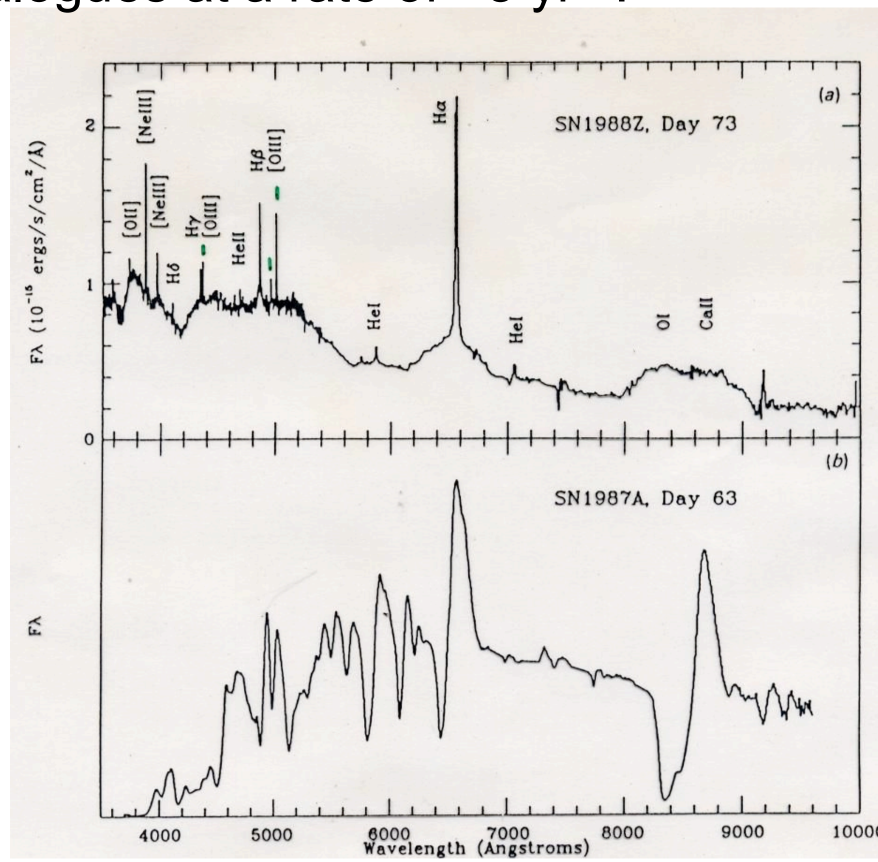
Stellar evolutionary models in the past have favoured the existence of extremely warm WR stars (warmers), but these have been disfavoured by more recent evolutionary models and also by those who proposed the idea (Terlevich 2001)

Seyfert 1 impostors: type IIn SNe

These are core-collapse SNe that resemble Seyfert 1 nuclei, but explode in the outer parts of normal galaxies. They were first discovered in 1987 (Filippenko 1989) and are collected in SN catalogues at a rate of ~8 yr^{-1}.



(Filippenko 1989)



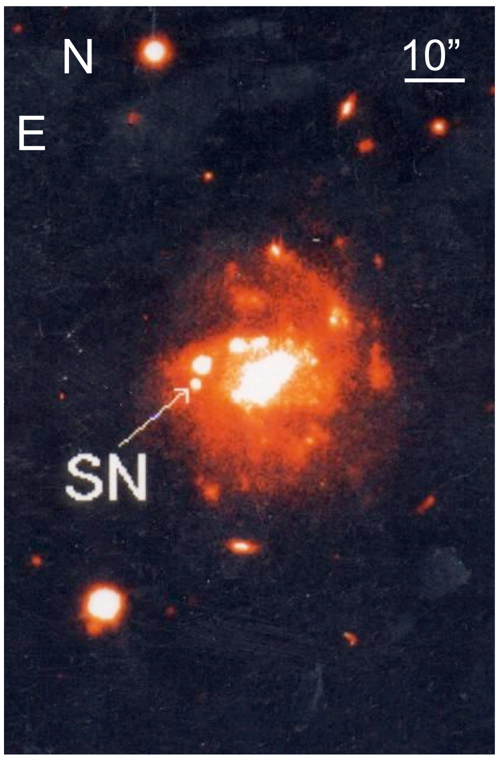
(Stathakis & Sadler 1991)

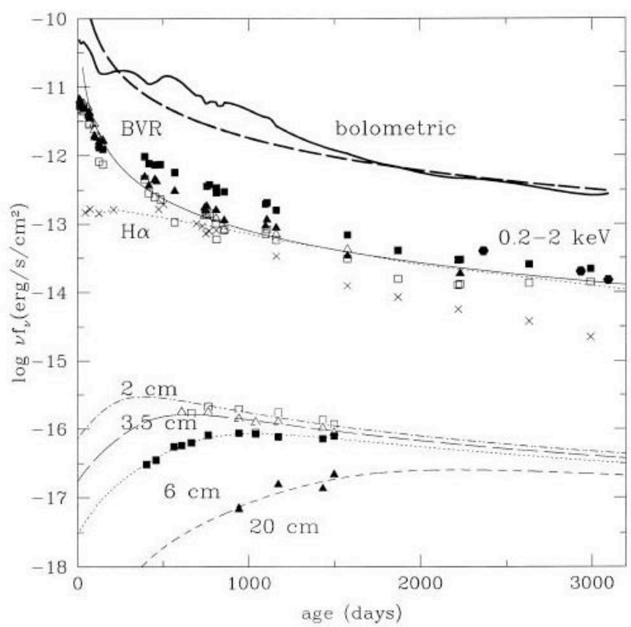
If one of these type IIn explodes in the centre of a S galaxy, this would be classified as a Seyfert 1

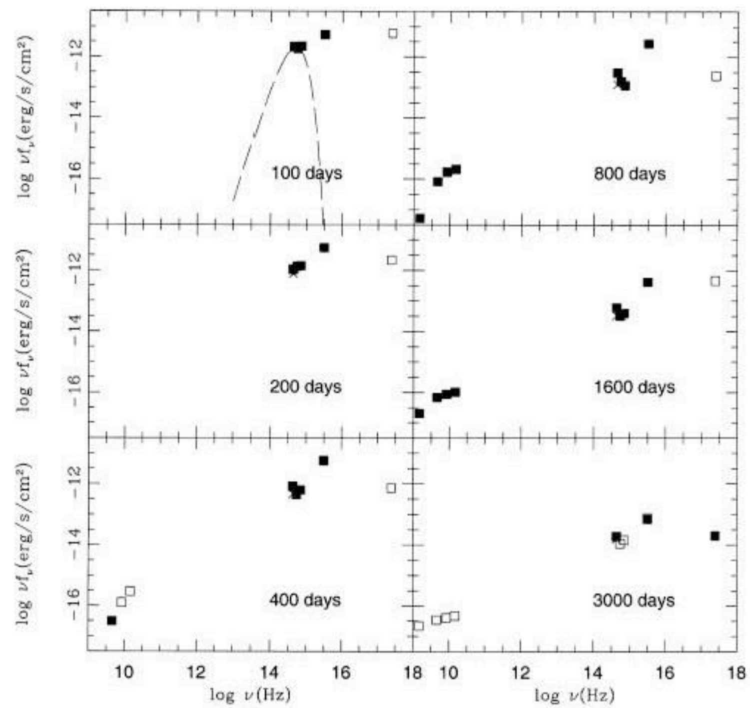
Gallery of Seyfert 1 impostors: SN 1988Z

(Stathakis & Sadler 1991, Turatto et al. 1993, Fabian & Terlevich 1996, Aretxaga et al. 1999):

- broad and variable emission lines of FWHM≈15000−2000 km s^{-1}
- coronal lines [Fe VII] − [Fe XI], [A X], [Ca V]
- slowly decaying light curve
- strong optical−UV−X radiation.
- *radiated* energies in excess of 2×10^{51} erg.
- $n_e = 4 \times 10^6 - 2 \times 10^7$ cm^{-3} for the NLR





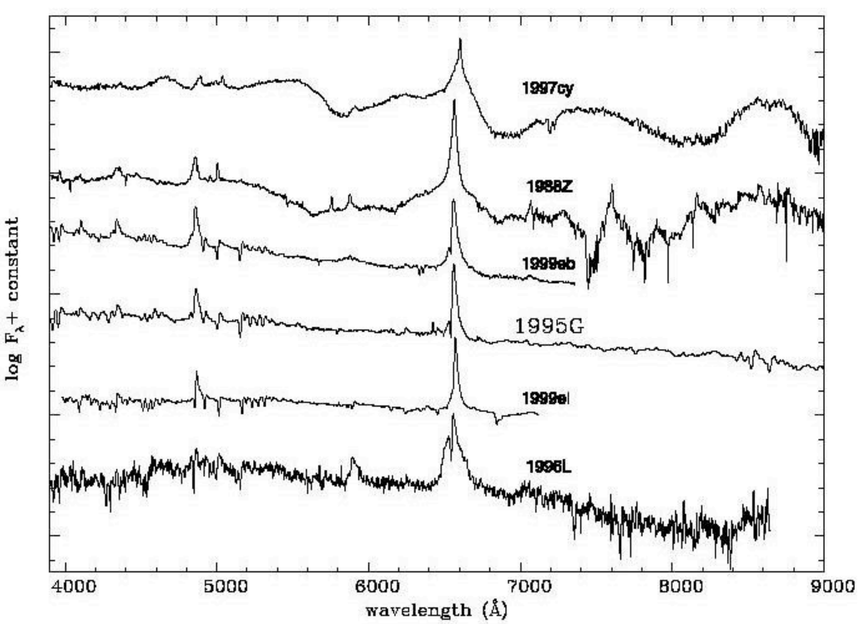


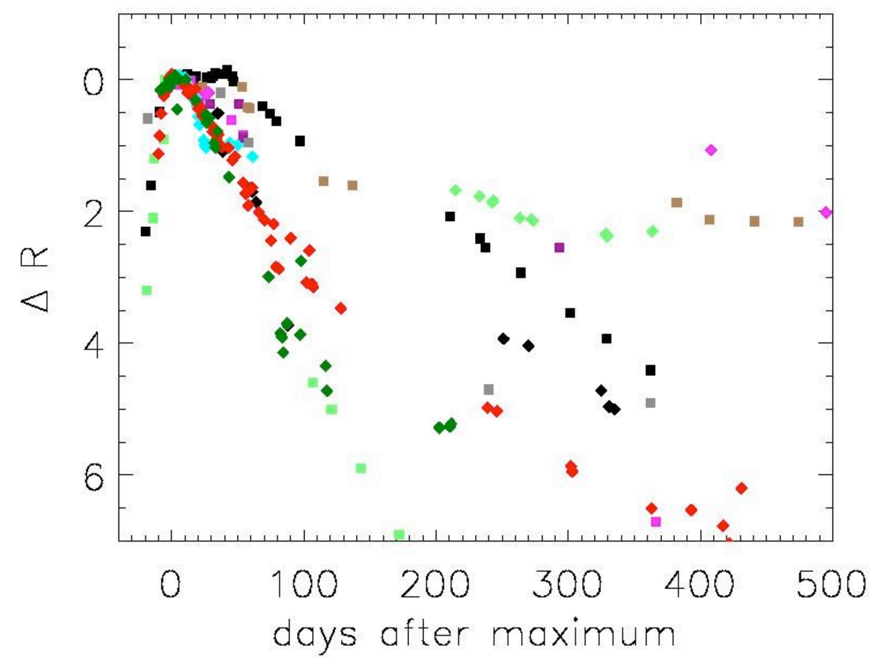
(Aretxaga et al 1999)

Seyfert 1 impostors: a summary

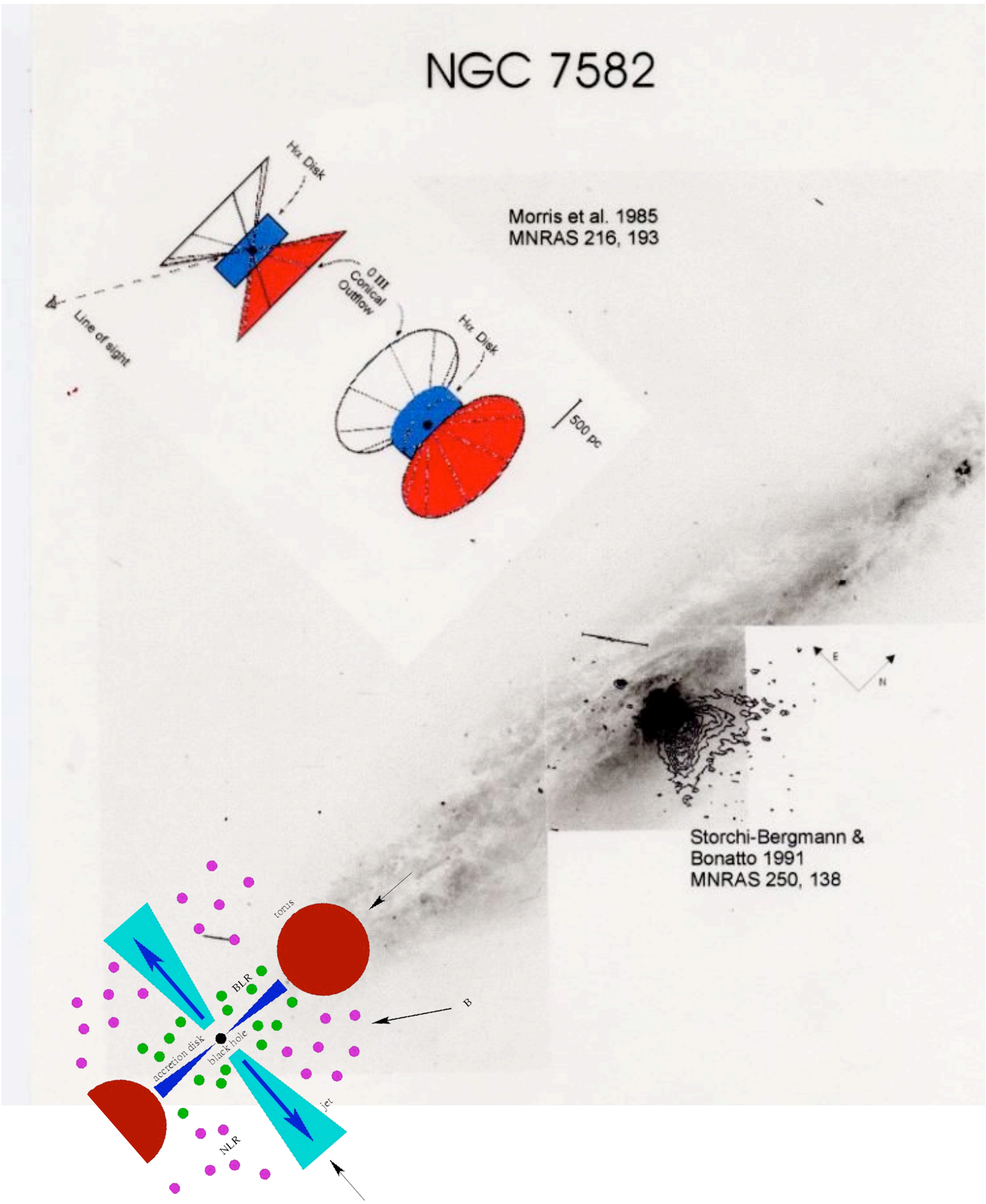
Type IIn SNe are a VERY heterogeneous class of objects (Aretxaga 2003)

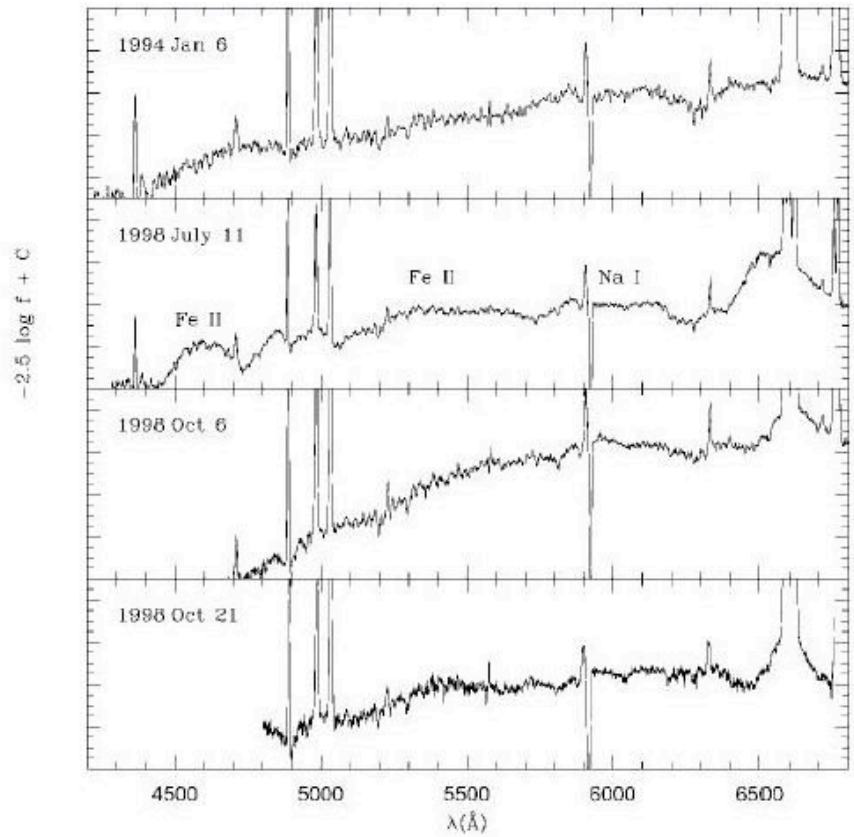
- Peak $M_V \approx -18.8$ range in the II-P class, i.e. they are not particularly over-luminous (Richardson et al. 2001)
- But, probably, some are hypernovae: 88Z, 97cy, 99E (Aretxaga et al. 1999, Turatto et al. 2000, Rigon et al. 2003), unless asymmetries are important.
- Out of a sample of 17 IIns: 40% are slow decliners, like 88Z, 30% fast decliners (II-L), like 98S, the rest 30% being intermediate
- When measured, the NLR has $n_e \approx 10^6 - 10^8$ cm^{-3}
- XR emission, coronal lines, and radio emission are common, but not universal wavelengths of radiation.





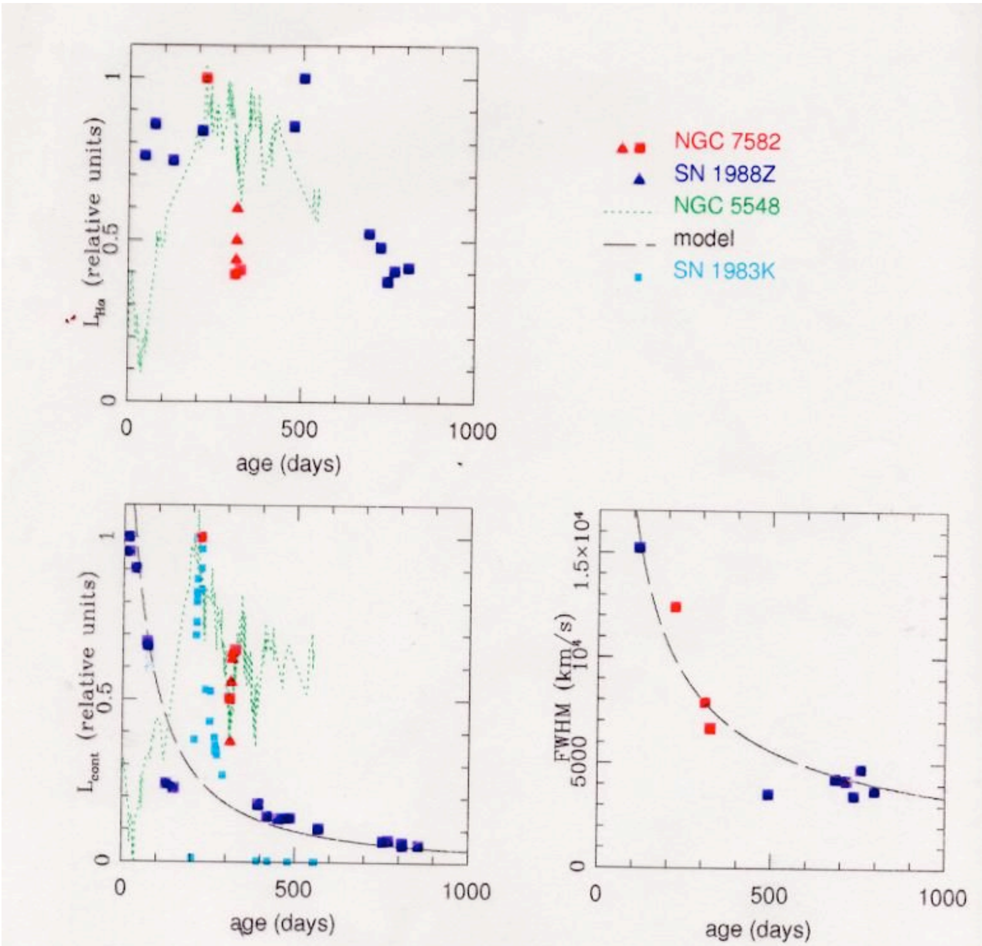
True Sy 1s or not?: NGC 7582



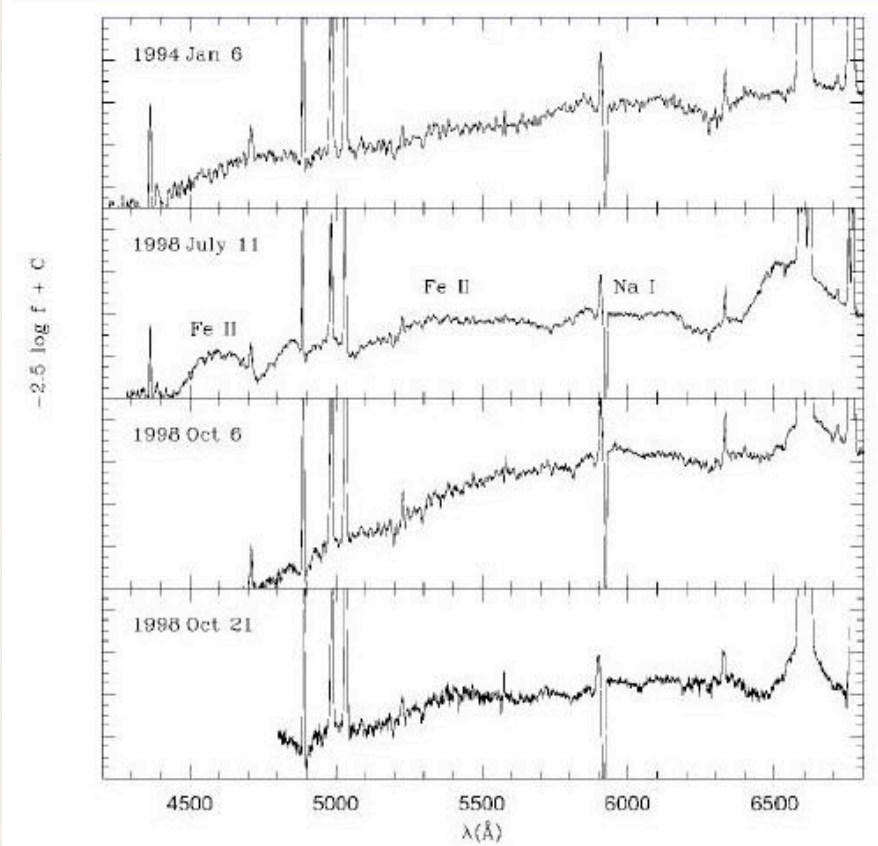


Starburst activity or hole in the torus? (Aretxaga et al. 1999)

True Sy 1s or not?: NGC 7582



(Aretxaga et al. 2000)

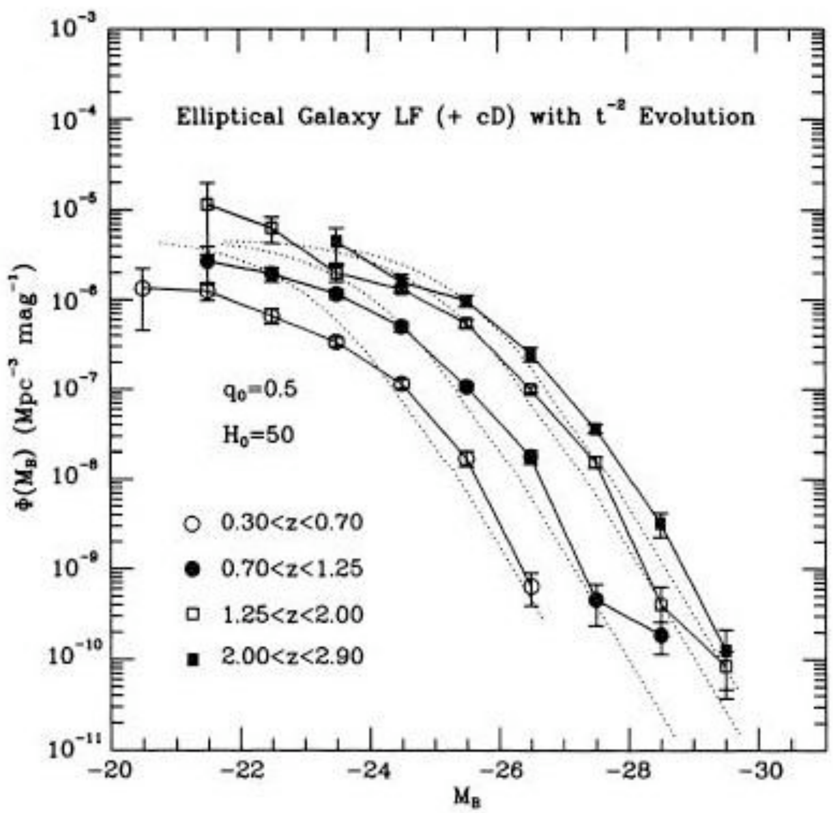


Starburst activity or hole in the torus?

Reddening variations along the line of sight (a la Goodrich) cannot explain the continuum and line variations, but a type IIn SN in the surrounding SB ring detected in extended Hα emission could do the job (Aretxaga et al. 1999, 2000)

Heretical models for QSOs: galaxy formation

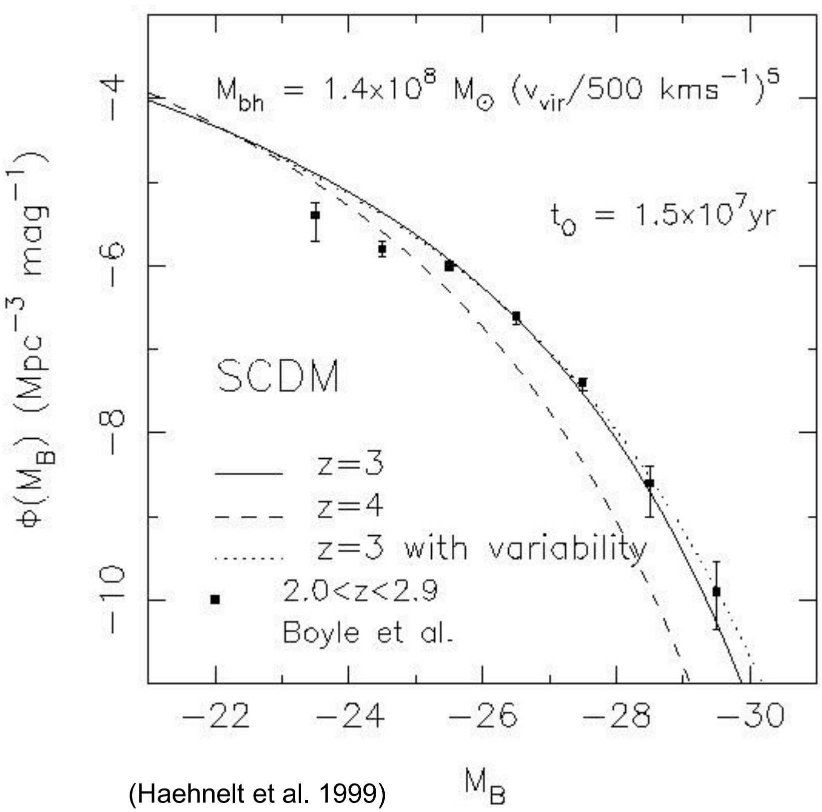
Pure SB models that try to explain the optical-UV properties of QSOs only make sense if they are, in some way, linked to the building of big spheroids, because of the huge masses required for the SBs.
A model requiring the participation of 5% of an E galaxy in a SB, from monolithic collapse approximations for galaxy formation, can reproduce the luminosities and LF evolution of QSOs (Terlevich & Boyle 1993).



The AGN role in galaxy evolution

The shape of the density evolution of UV light emitted by QSOs also has a similar shape to the density evolution of UV light emitted by field galaxies detected in deep surveys (Boyle & Terlevich 1998).

The LF evolution has also been reproduced by models of the growth of BHs and galaxies within the Press-Schechter formalism (Haehnelt et al. 1993, 1999).



(Haehnelt et al. 1999)

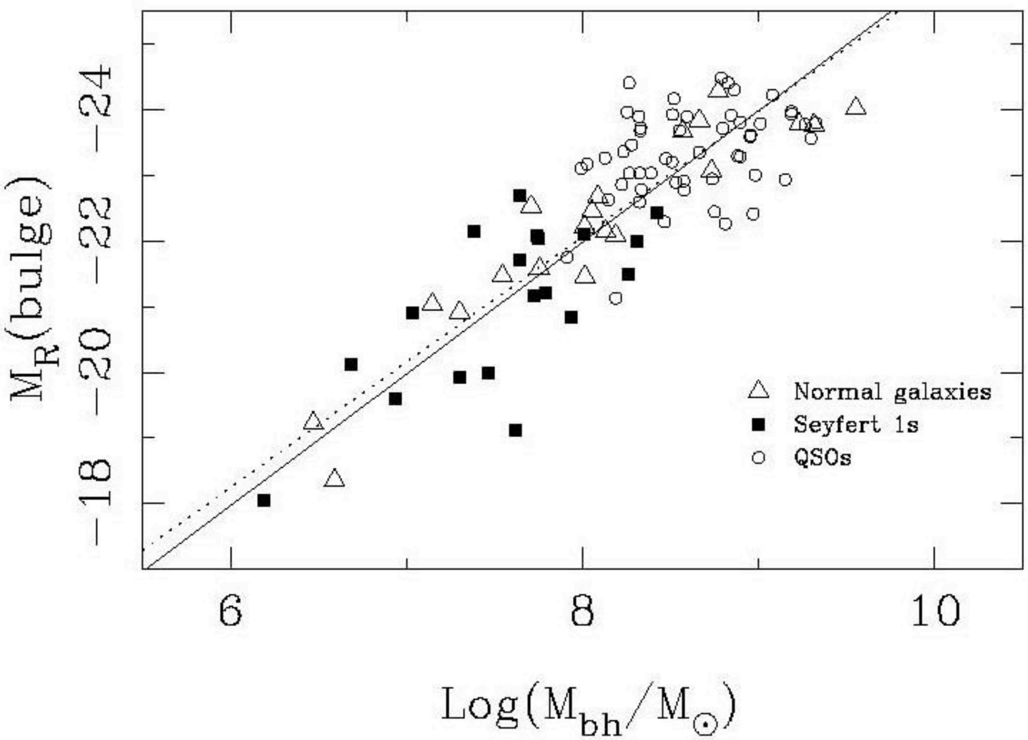
The Press-Schechter formalism is used to obtain the halo mass function $\Phi(M_{\rm halo})$ at any given epoch. This can be related to the BH mass via a BH-halo mass relationship (a la BH-bulge). Assuming a time evolution of the QSO $L(t) = L_{\rm E} \exp(-t/\tau_{\rm Q})$ the LF at z<3 can be reproduced for a range of QSO life-times:

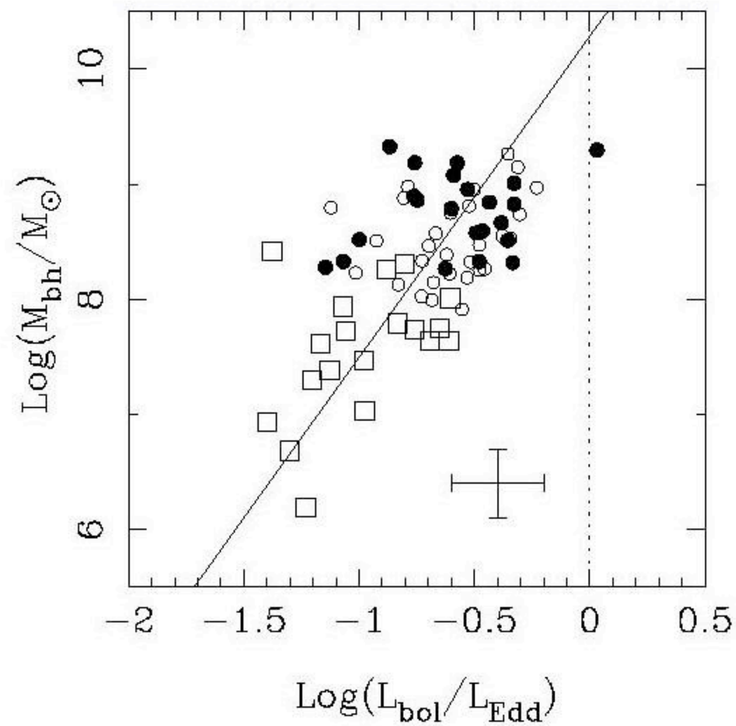
$\tau_{\rm Q} = 10^6$ yr with $M_\bullet \alpha\, M_{\rm halo}^{5/3}$ to $\tau_{\rm Q} = 10^8$ yr with $M_\bullet \alpha\, M_{\rm halo}$. However, one needs to assume $M_\bullet/M_{\rm halo}\ \alpha\ (1+z)^{5/2}$ or that the mass accretion falls by a factor of 100 (Haehnelt et al. 1999).

Low-z QSOs: BH-spheroid relation

The BH-bulge relationship found in nearby galaxies is shared by the AGN where good determinations of the BH mass are available either by reverberation (e.g. NGC 5548) or by rotational curves (e.g. NGC 4258). In a sample of 30 QSOs at 0.1 < z < 0.3, 19 Seyferts, and 18 inactive S galaxies with reliable bulge luminosities, and applying a M/L relationship, it is found that the masses of BH and bulges are linked by $\boxed{M_{\rm BH} \propto M_{\rm bulge}^{(0.95\pm0.05)}}$

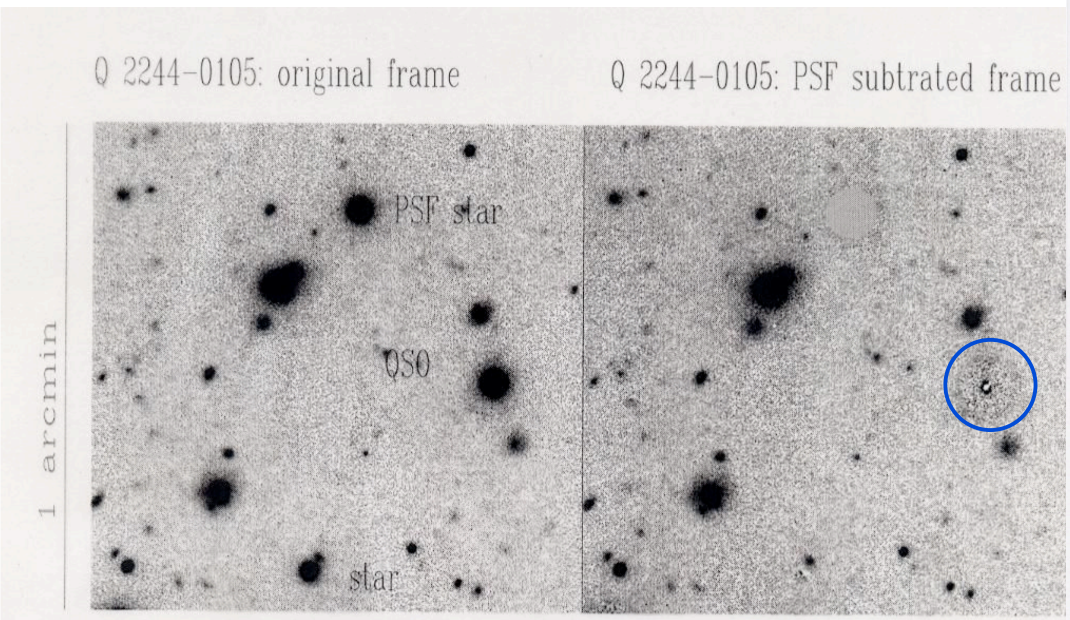
The QSO BHs are radiating at ≤10% of the Eddington limit (McLure & Dunlop 2001)



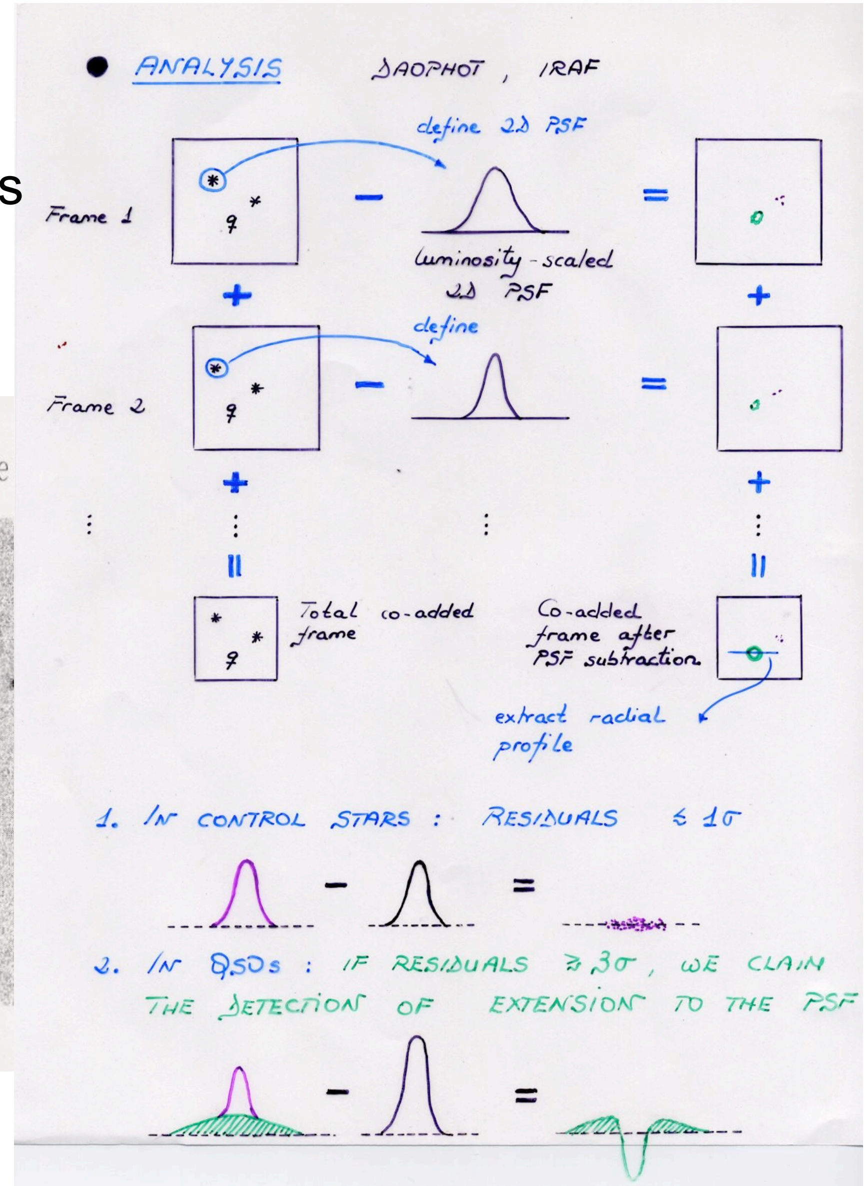


QSO hosts at high-z: giant blue galaxies?

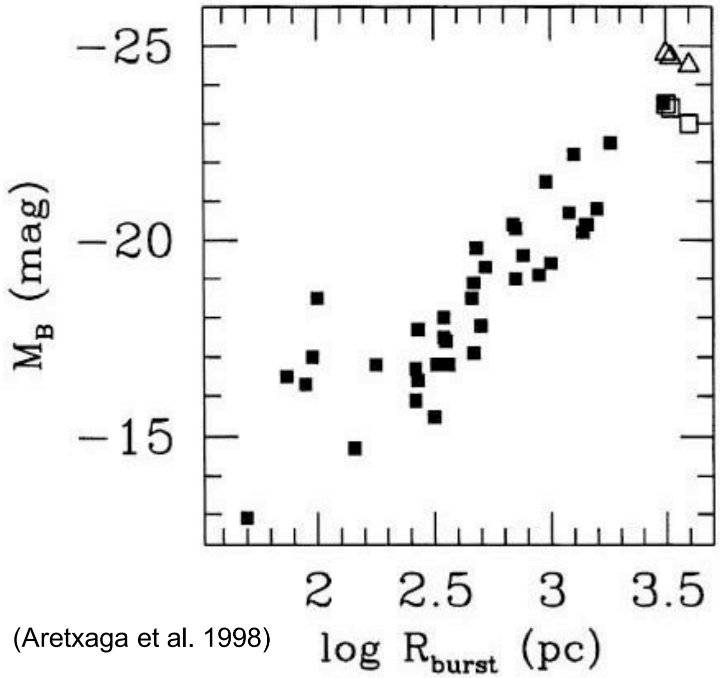
The host galaxies of z≈2−3 RL and RQ QSOs have been detected at observer-frame optical and NIR bands, which correspond to UV−optical rest-frame bands (Lehnert et al. 1992, Aretxaga et al. 1995, 1998, Ridgway et al. 2001).



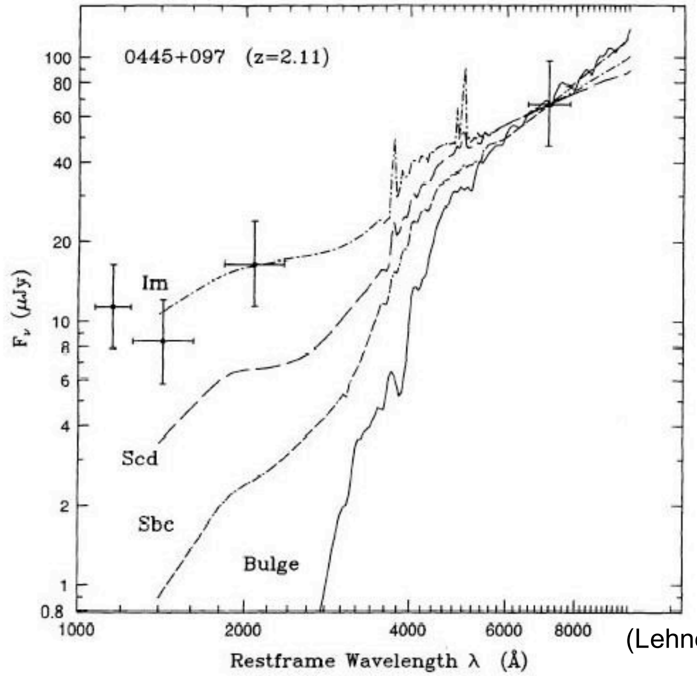
(Aretxaga et al. 1995)



QSO hosts at high-z: giant blue galaxies?



(Aretxaga et al. 1998)

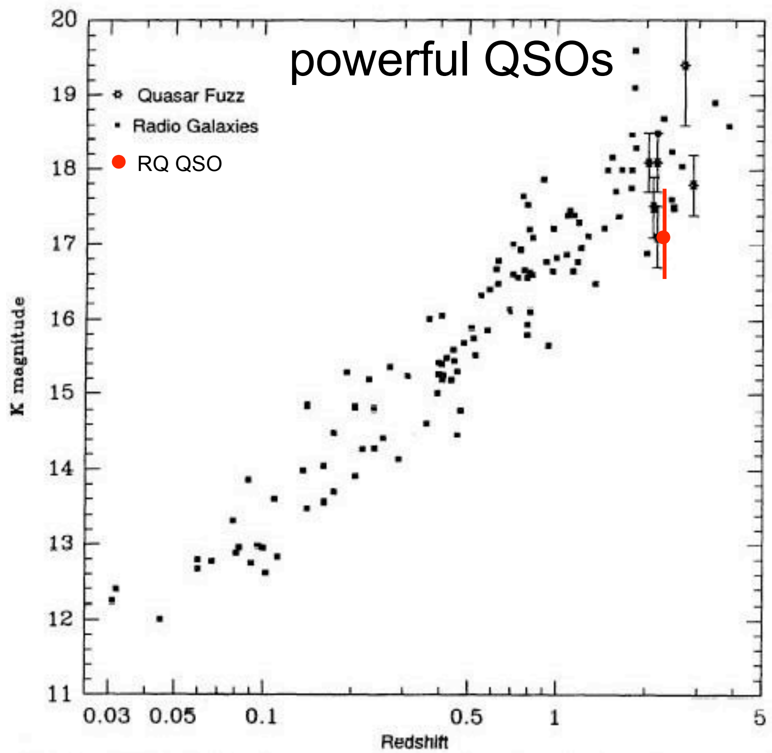


(Lehnert et al. 1992)

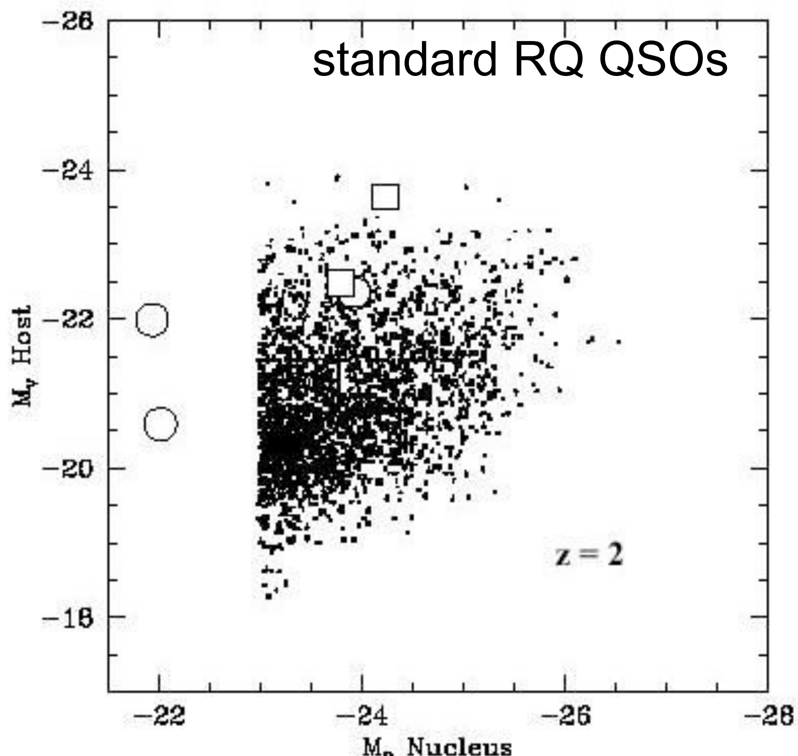
The hosts of luminous z=2−2.5 QSOs are big (FWHM=1 arcsec ≈ 4 kpc for RQs) and UV bright: L_{host}=5−12% L_{QSO} for RQ to RL QSOs, respectively (Lehnert et al. 1992, Aretxaga et al. 1998), but the samples are still painfully small. The light is probably not scattered from the nucleus, since the colours are redder than the nuclear light. The SED of one of the RL QSOs, which has been detected in 4 pass-bands, looks like that of a Magellanic irregular. The UV light implies SFR > 200 $M_\odot$/ yr, so we probably are witnessing the formation of the spheroid.

QSO hosts at high-z: the building of spheroids

K-band imaging reveals that powerful z≈2–3 RL QSOs (sample of 6, Lehnert et al. 1992) and RQ QSOs (sample of 1, Aretxaga et al. 1998) follow the same magnitude-relationship as first-rank cluster members. The luminosities are above $3L_*$. These probably become luminous E galaxies. Typical RQ QSOs (sample of 5) seem to be L_* galaxies with a range $0.2-4\ L_*$ (Ridgway et al. 2001). Its nuclear-to-host luminosity is reproduced by semi-analytical galaxy+BH formation scenarios (Ridgway et al. 2001).



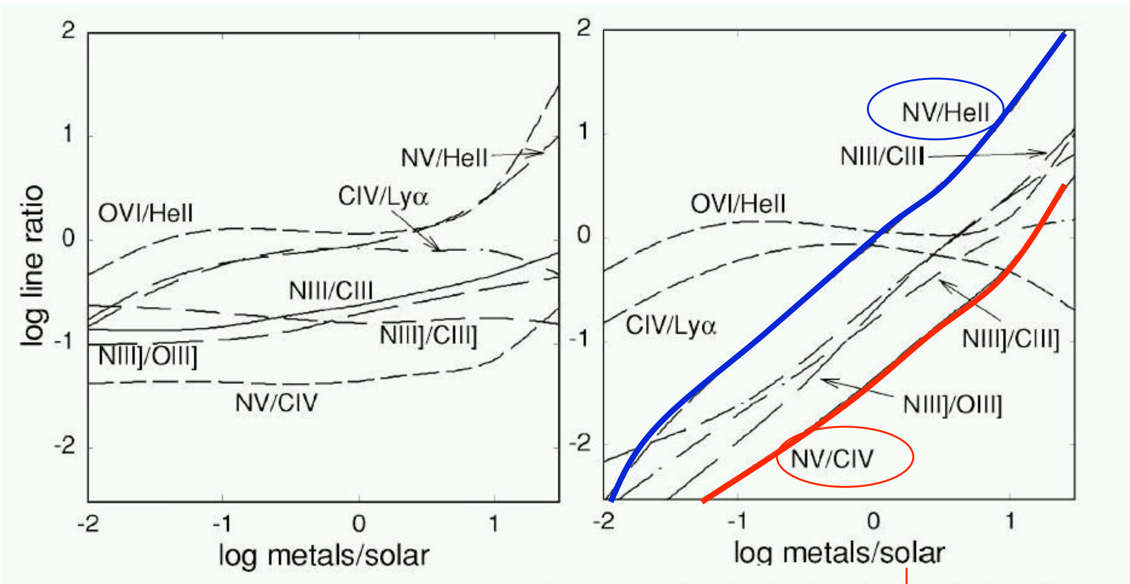
(Lehenrt et al. 1992, Aretxaga et al. 1998)



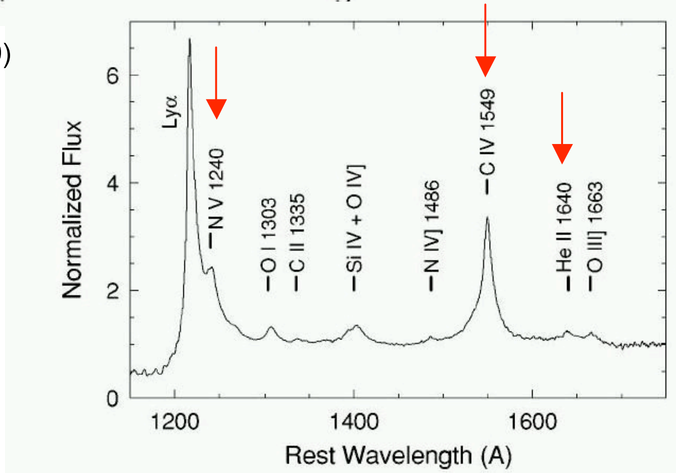
(Ridgway et al. 2001, comparison with Kauffman & Haehnelt 2000)

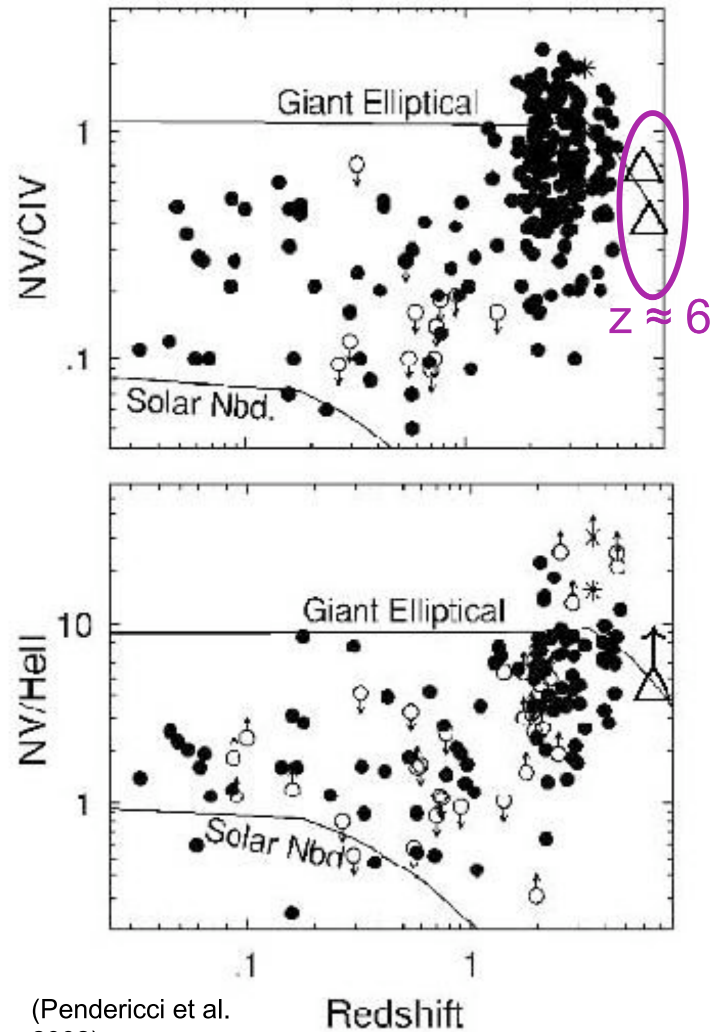
QSO hosts at high-z: the building of spheroids

Photoionization modeling of the BLR in high-z QSOs implies that the metallicities of the gas orbiting the engine are typically oversolar (Hamann & Ferland 1993, …,1999), and this picture extens up to the z≈6 (Pendericci et al. 2002).



(Hamann & Ferland 1999)

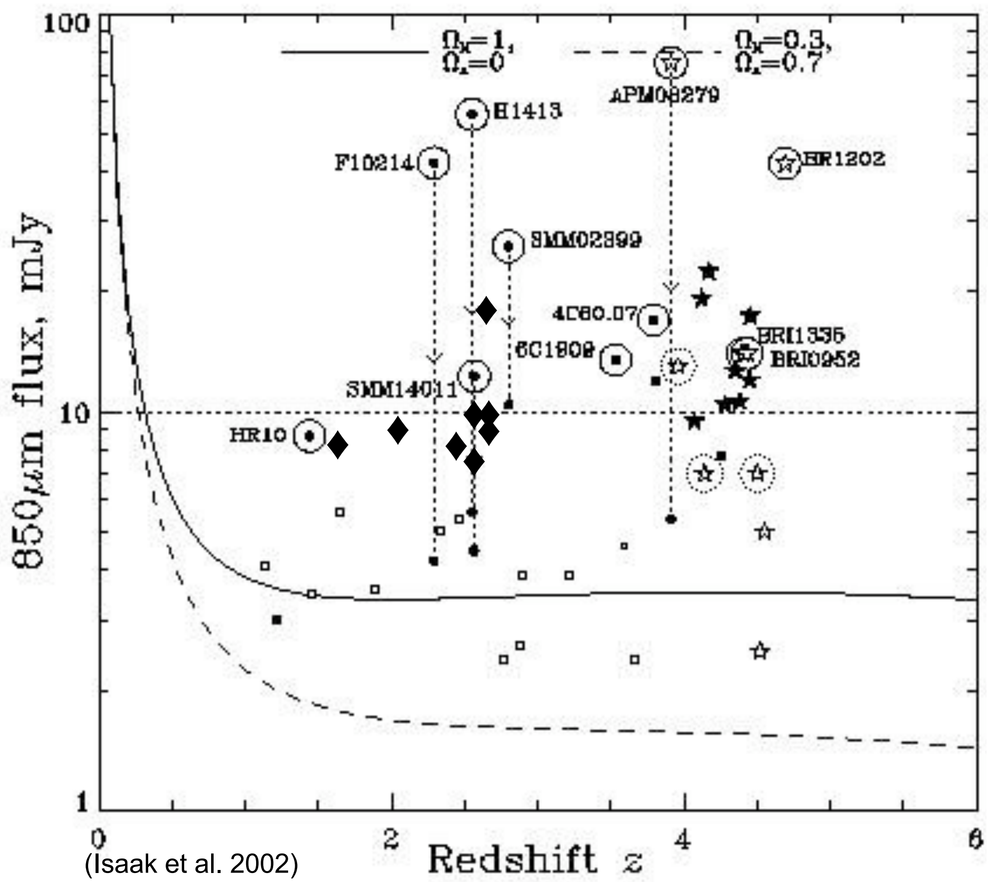




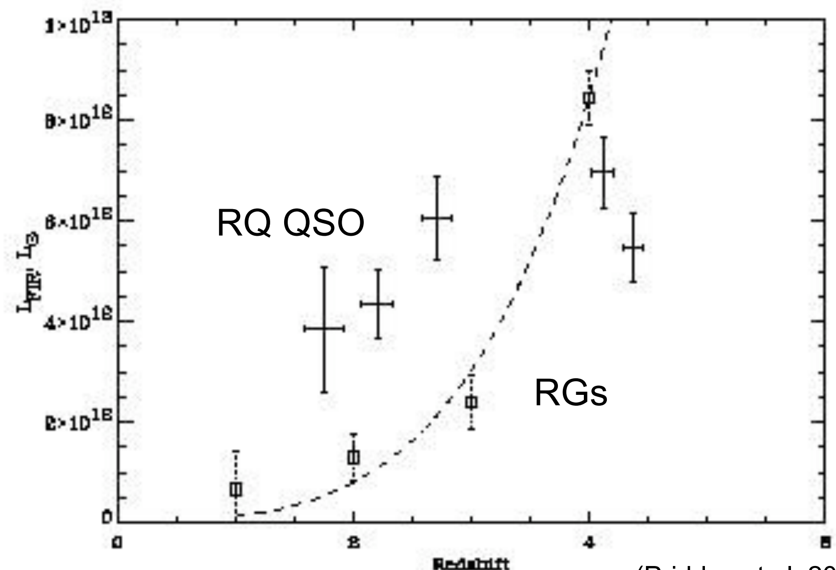
(Pendericci et al. 2002)

QSO hosts at high-z: the building of spheroids

Intense sub-mm/mm thermal emission has been detected in high-z AGN, implying large masses of dust are present early on (Isaak et al.1994, McMahon et al.1994) The FIR luminosities of typical RQ QSOs are L_{FIR}=1.1–2.6 x $10^{13} L_\odot$, which translates into dust masses of M_D=0.8–2.0 $M_\odot$ and SFR=1100–2600 $M_\odot yr^{-1}$ (assuming all UV heating is due to star formation). No evolution is inferred for RQ QSOs (Priddey et al. 2003), but a strong $(1+z)^{3–4}$ evolution is inferred for RGs (Archibald et al. 2001). However, the selection criteria and survey depths are not matched.



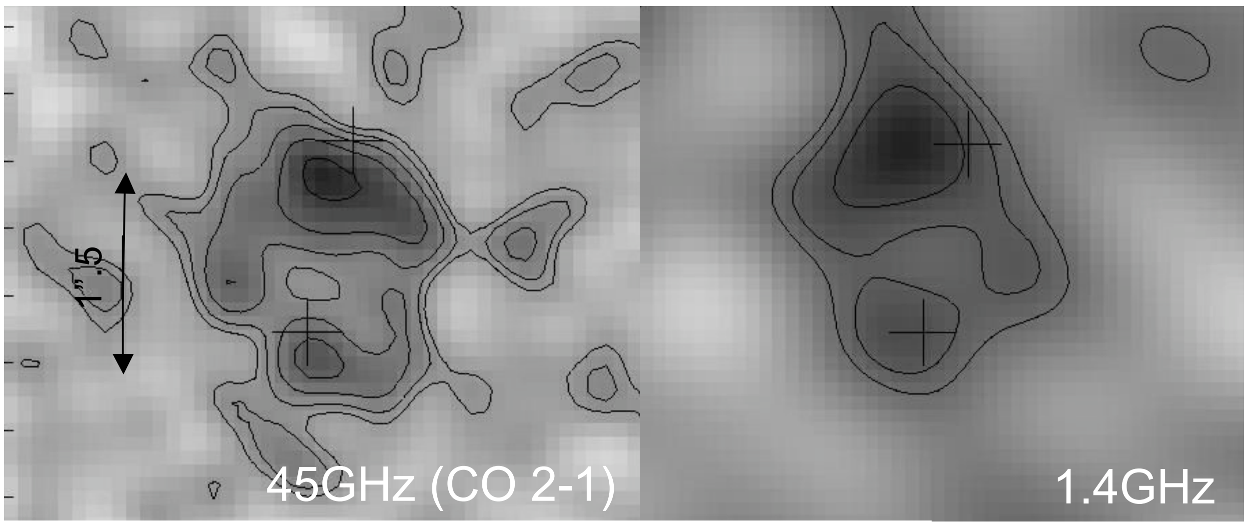
(Isaak et al. 2002)



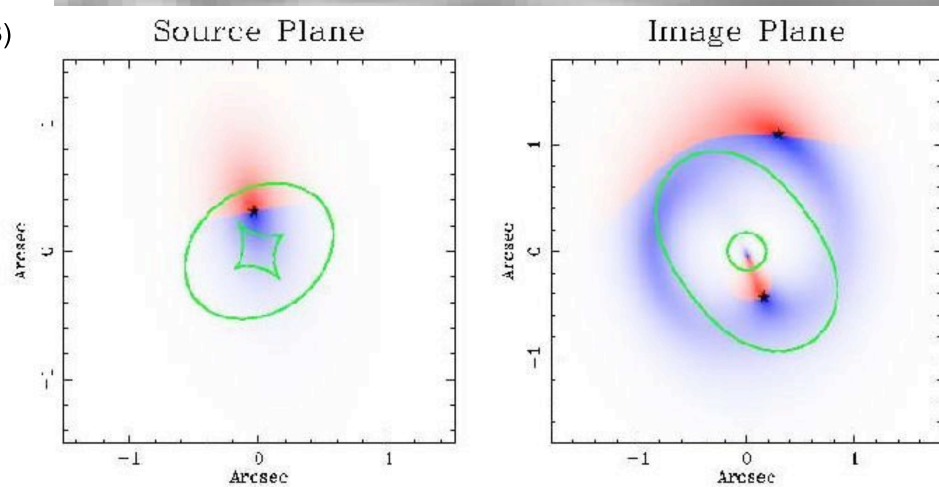
(Priddey et al. 2003)

QSO hosts at high-z: the building of spheroids

Follow-up CO interferometry of the dusty QSOs imply that they contain large reservois of molecular gas $M \geq 10^{10}\ M_{\odot}$ at $z \approx 4$ (Omont et al. 2001). This emission may have been resolved in a high-z QSO (Carilli et al. 2003).



(Carilli et al. 2003)



$z = 4.11$

$M_{gas} = 2 \times 10^{11}\ M_{\odot}$

$r \approx 2$ kpc

SFR $\approx 900\ M_{\odot}$/yr

Active Galactic Nuclei

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Bibliography:

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- “Quasars and Active Galactic Nuclei”, A. Kembhavi & J. Narlikar, 1999, Cambridge University Press.
- “Advanced Lectures on the Starburst−AGN Connection”, 2001, Eds. I. Aretxaga, D. Kunth & R. Mújica, Word Scientific. With reviews by B.P. Peterson, R. Goodrich, H. Netzer, S. Collin, F. Combes, R.J. Terlevich & B.J. Boyle.
- A compilation of useful reviews can be found in Level 5 @ IPAC, and the rest of the references can be found in papers listed in ADS or astro-ph

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