Accumulated Mass of supernovae remnants:
a key for supermassive blackholes

B. Rocca-Volmerange

Institut d'Astrophysique de Paris

Université Paris-Sud, rocca@iap.fr

Collaborations Michel Fioc(IAP), Guillaume Drouart (Chalmers), Carlos De Breuck(ESO)

Colloque Chalonge, Meudon 10-12 June 2015

The context

Galaxy Evolution:
PRIMEVAL galaxies, discovered @ z> 6
a coherent link with large structures
However numerical and semi-empirical models do not agree to reproduce the Hubble sequence at z=0, mass luminosities (SED) , metals , dust and the high-z SEDs

Link to AGN growth: Supermassive Black Hole growth still debated:
disk outflows, and various positive or negative feedbacks

But no link of the AGN variability with turned off or off star formation

A new link : Galaxy evolution – the AGN growth
through the accumulated number of supernovae remnants (SNR)
along the star formation history (SFH)
An explanation for Intermediate Black holes ?

THE BEST TARGETS ARE DISTANT RADIO GALAXIES,
embedded in massive ellipticals, hosting a supermassive black hole

Outlines

The evolution of high-z ellipticals with the code Pegase.3

The best SED-fitting of two z=3.8 galaxies from UV to far-IR/submm

The puzzling age of the young burst component

From stellar black holes to supermassive black holes

From the Hubble K-z Diagram

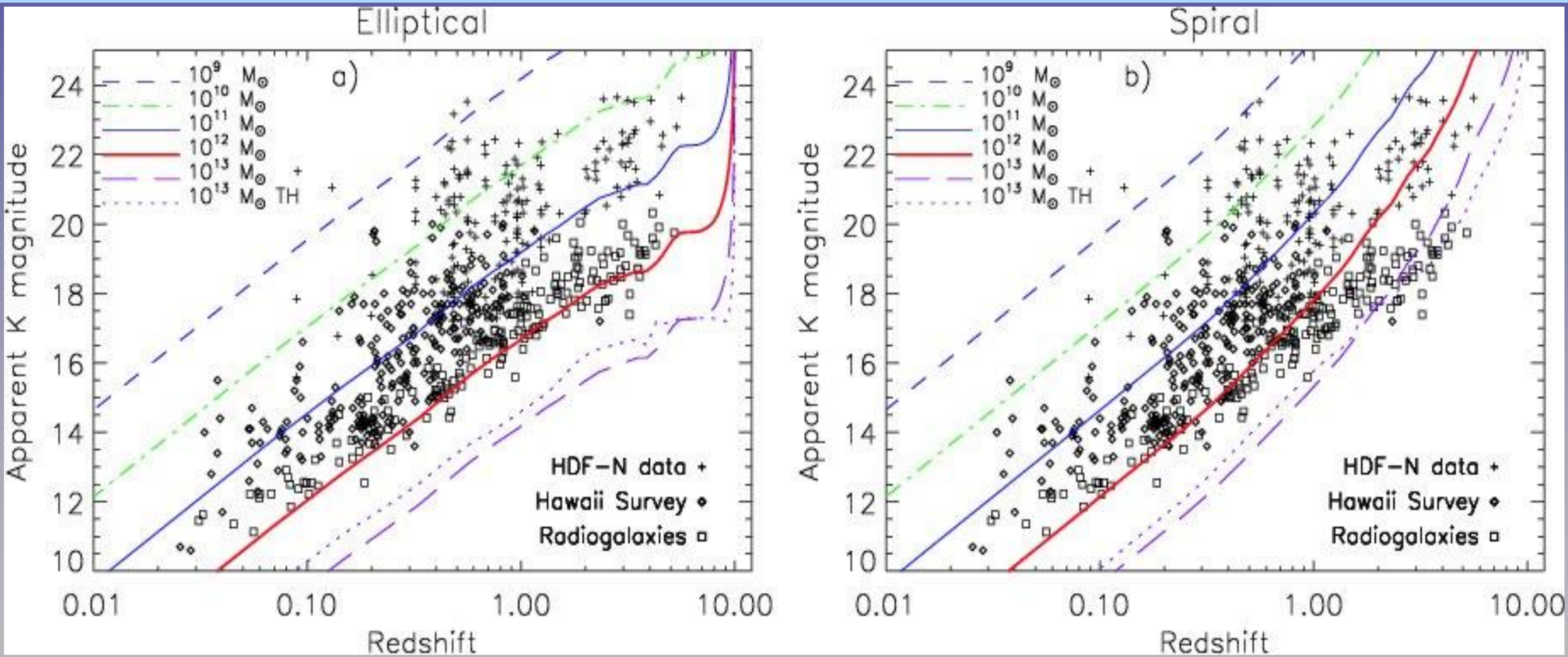
The most massive galaxies at z>4 are of elliptical (not spiral) type

They are radio, hosting a supermassive black hole

Their Baryonic Mass is 10^{12} MΘ (red line)

Hubble K diagrams

•



(Rocca-Volmerange, Le Borgne, De Breuck, Fioc, Moy, 2004, AA, 415, 931)

Redshift z

The distant radio galaxies are hosted by ellipticals
evolution of Ellipticals with the code Pegase.3

The time-scales of star formation law of ellipticals withPegase

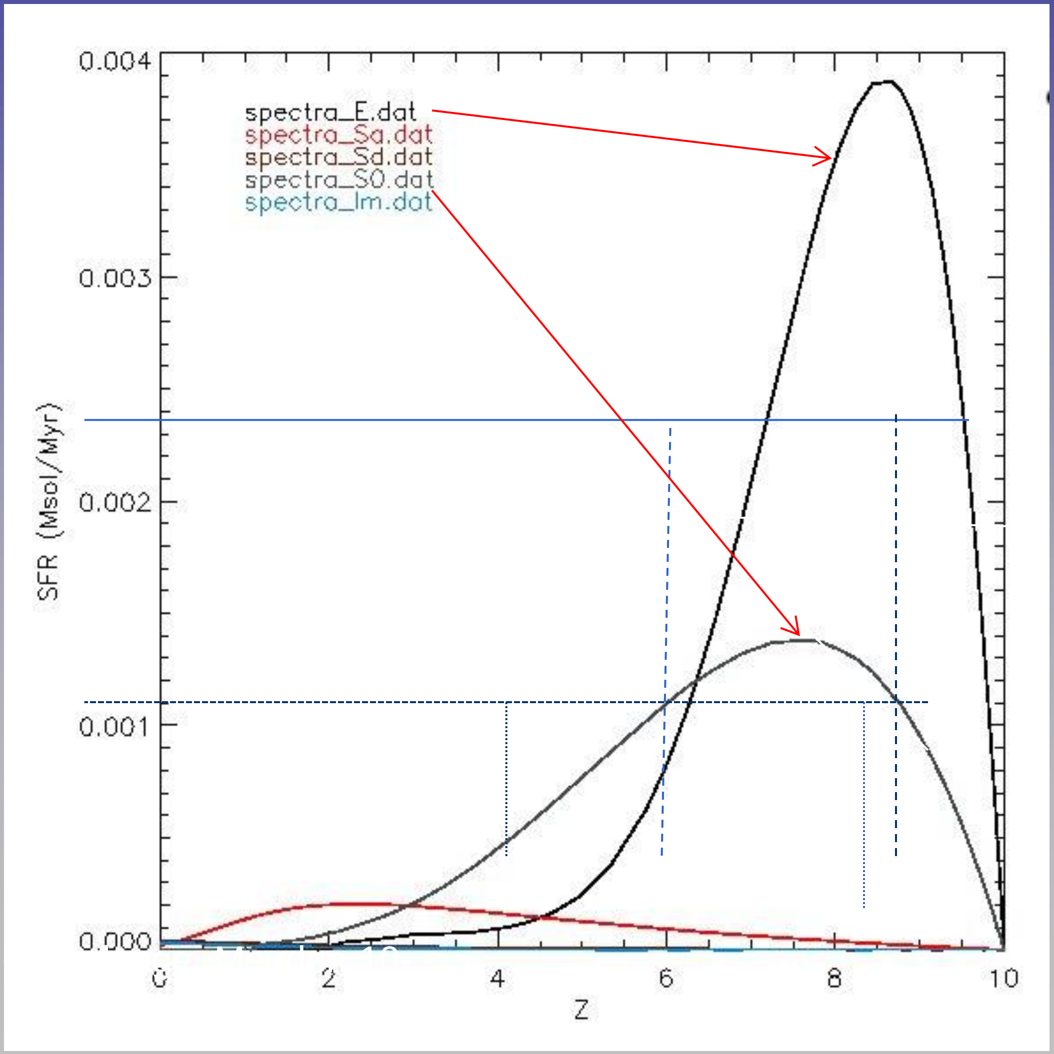
ALL these scenarios of SFR(t) by types respect the Hubble Sequence.

They fit

SEDs and colors

of galaxies at z=0

See Rocca-Volmerange et al, 2015 from
Rocca-Volmerange & Guiderdoni, 1988
Fioc's thesis, 1998
Le Borgne & RV, 2002
RV et al, 2004,



nd STELLAR EVOLUTIONARY TRACKS: L= F(Teff, e) OR ISOCHRONES (red lines) for all initial masses

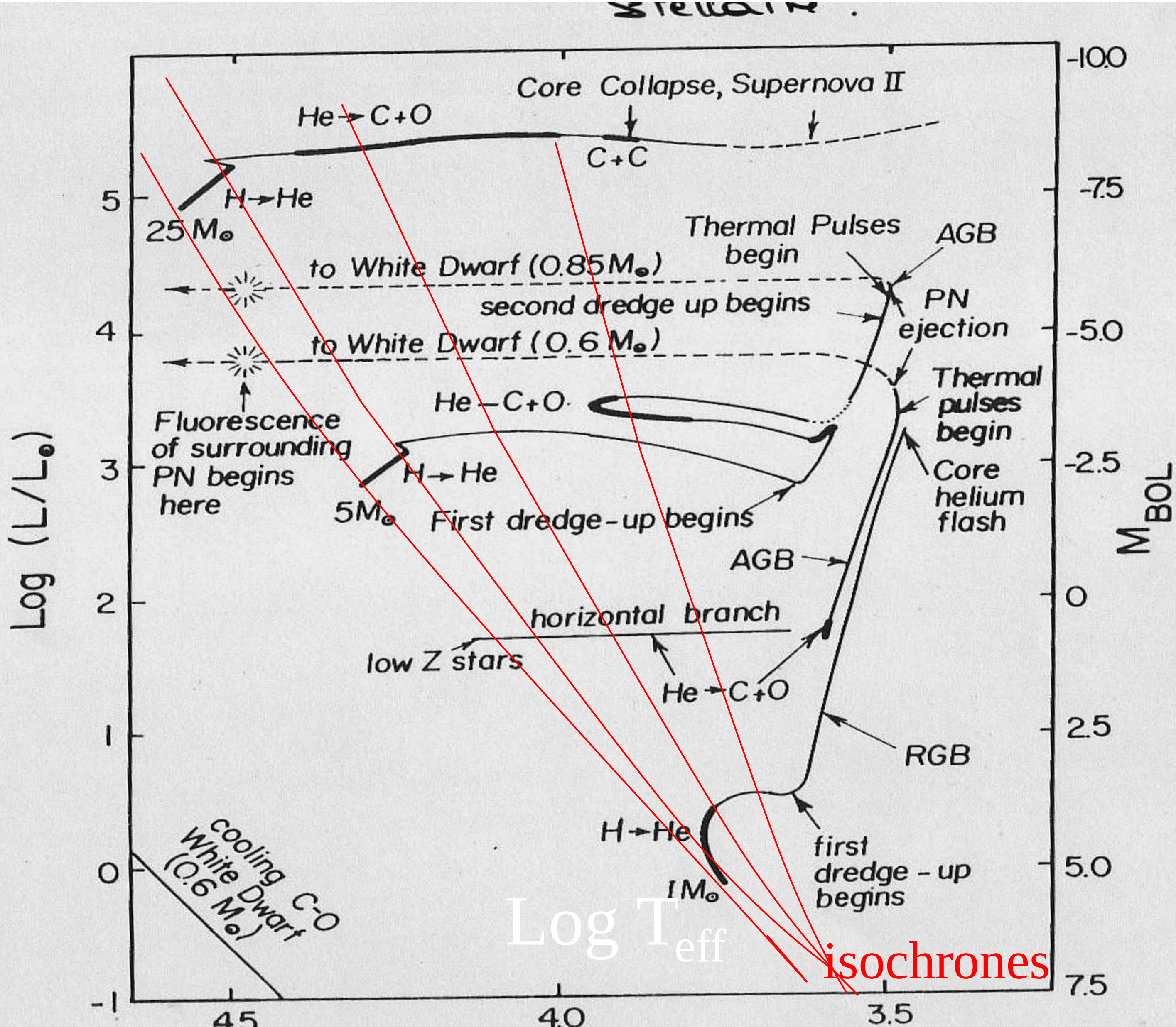
Many Groups from

Padova

Genova

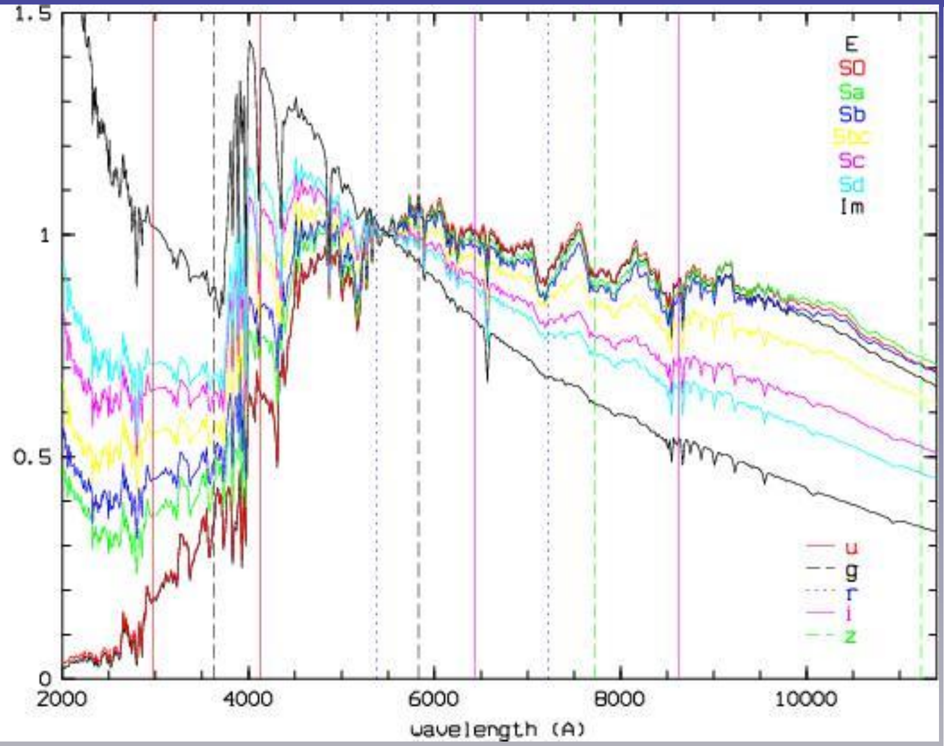
Yales

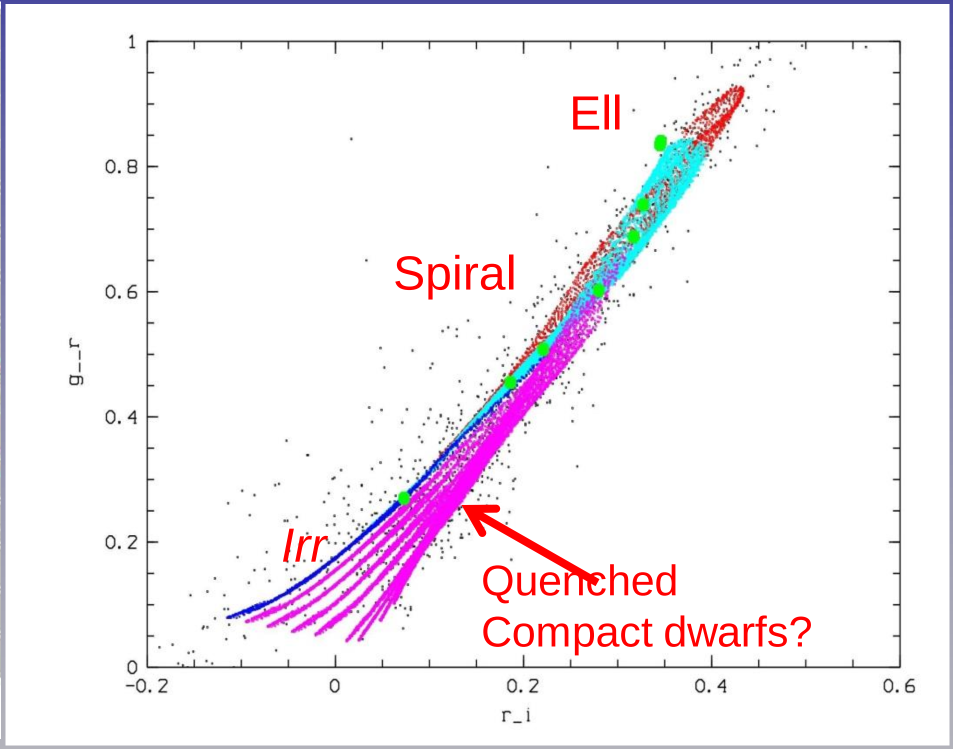
. . .



The Pegase templates fit the local z=0 SDSS.3 data

Tsalmantsa et al, 2007, 2009 (Consortium GAIA)



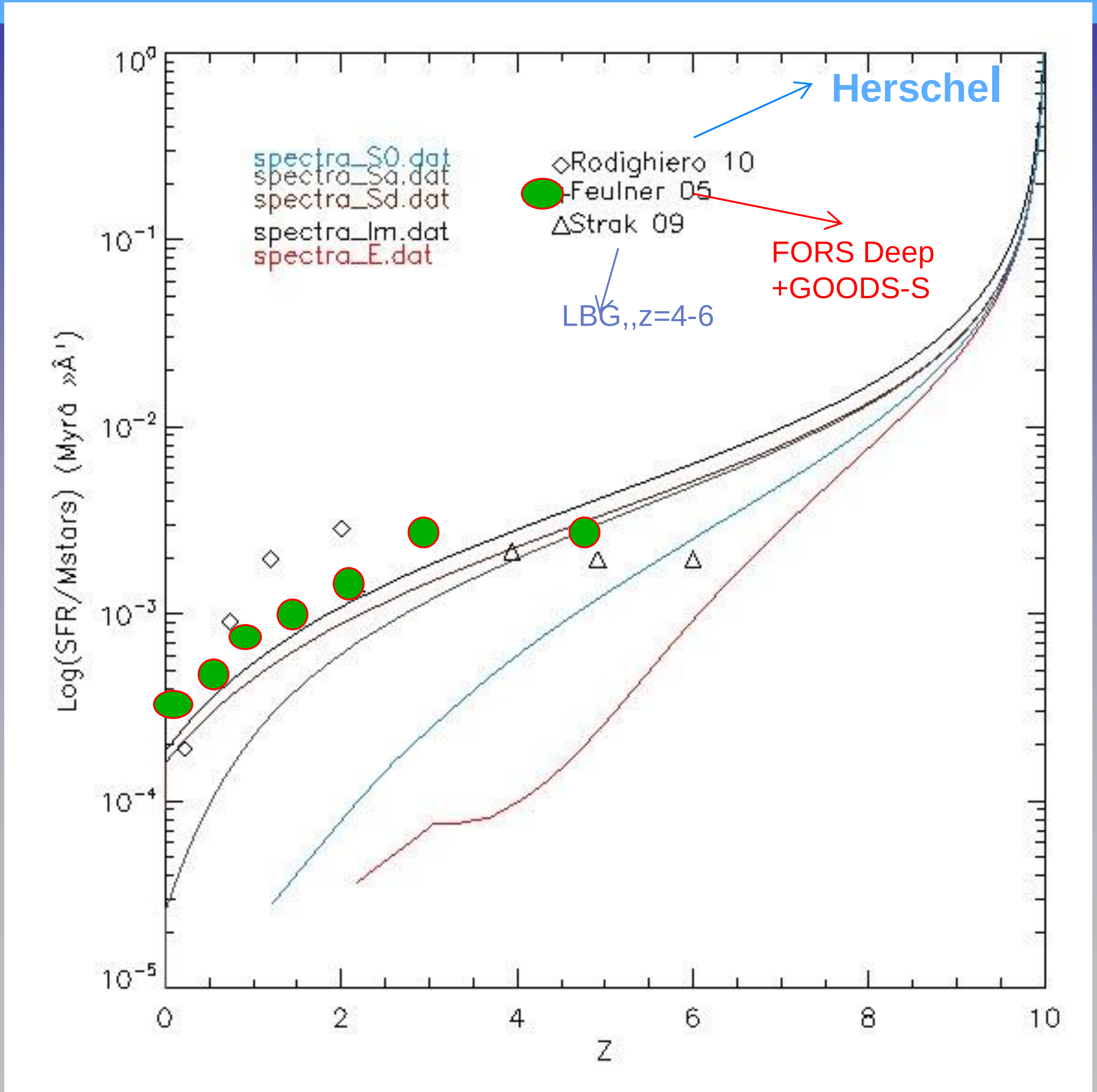


PEGASE.2 SCENARIOS ARE ALSO ROBUST IN THE UV/OPTICAL/NIR

1. Phot- z / spectro –z (Le Borgne, Rocca-Volmerange, Fioc, 2002) (code Z-PEG, http://www2.iap.fr)

2. 0<z<2 Multi-λ faint galaxy counts (Fioc & Rocca-Volmerange, 1999)

Specific star formation rate sSFR=SFR/M$_*$ versus z



PEGASE Scenarios Agree with

FORS/GOODS (optical) data of Star forming galaxies

But not with HERSCHEL (High-z)

High-z LBG/ Ellipticals Explain the flatness (see Weimann et al, 2011)

Star formation laws by types

$$SFR = \frac{p_2}{p_1}.\exp(-\frac{t}{p_1})$$

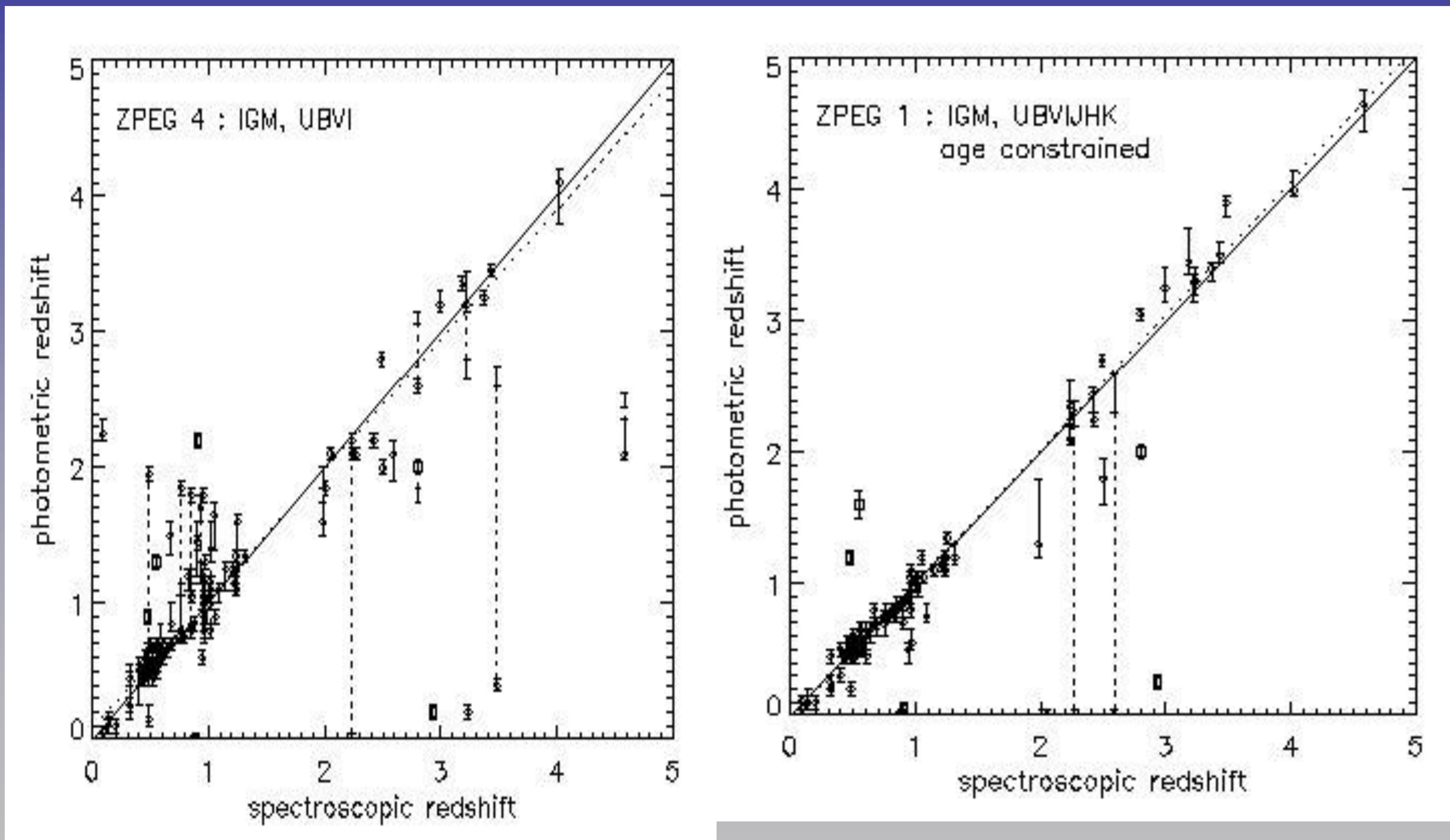
$$\mathbf{SFR = \frac{M_{gas}^{p1}}{p_2}}$$

type	P1	p2 Myr/Msun	infall	winds
Elliptical Elliptical	0.6-1.5	100-1500	Y	Y
spiral	0.8-1.5	2000-10000		N
Irr-IM	1.0-2.0	14000-20000		N

+ Starbursts (delta functions, Instantaneous SFR)

The Pegase templates also fit z<4 data

PHOTO-z / SPECTRO-z



Le Borgne & Rocca-Volmerange, 2002:
The code Z-PEG

Dust Emissions in the MID and FIR (Pegase.3)

- Coherent with the chemical evolution (O, C, Si, Fe) by types
- Grain models (Draine, 1993) (C, Si, PAHs)
- Attenuation + Radiative Transfer
- Dust Emission from N_Lyc←→ Star Formation RATE
- Spatial distribution (disk, spheroïd) 2 media: diffuse ISM and HII regions (Zubko et al, 2004 2 media
- And many possible scenarios

Fioc, Rocca-Volmerange &Dwek, near submission

Extinction Modeling

• Extinction A_λ(z) (magnitude) depends on time following dust mass, metals and gas content.

$$\tau_\lambda = \frac{\ln 10}{2{,}5} A_\lambda(Z)$$

• Optical depth

PEGASE.2

$$\tau_\lambda(Z) = \frac{\ln 10}{2{,}5} . \frac{A_\lambda}{A_V}(Z) . \frac{A_V}{E_{B-V}}(Z) . \frac{E_{B-V}}{N_H}(Z) . N_H$$

PEGASE.3

$$\tau_\lambda(Z) = \kappa_\lambda \frac{M_{dust}}{2\pi R^2}$$

Monte Carlo simulations of radiative transfer

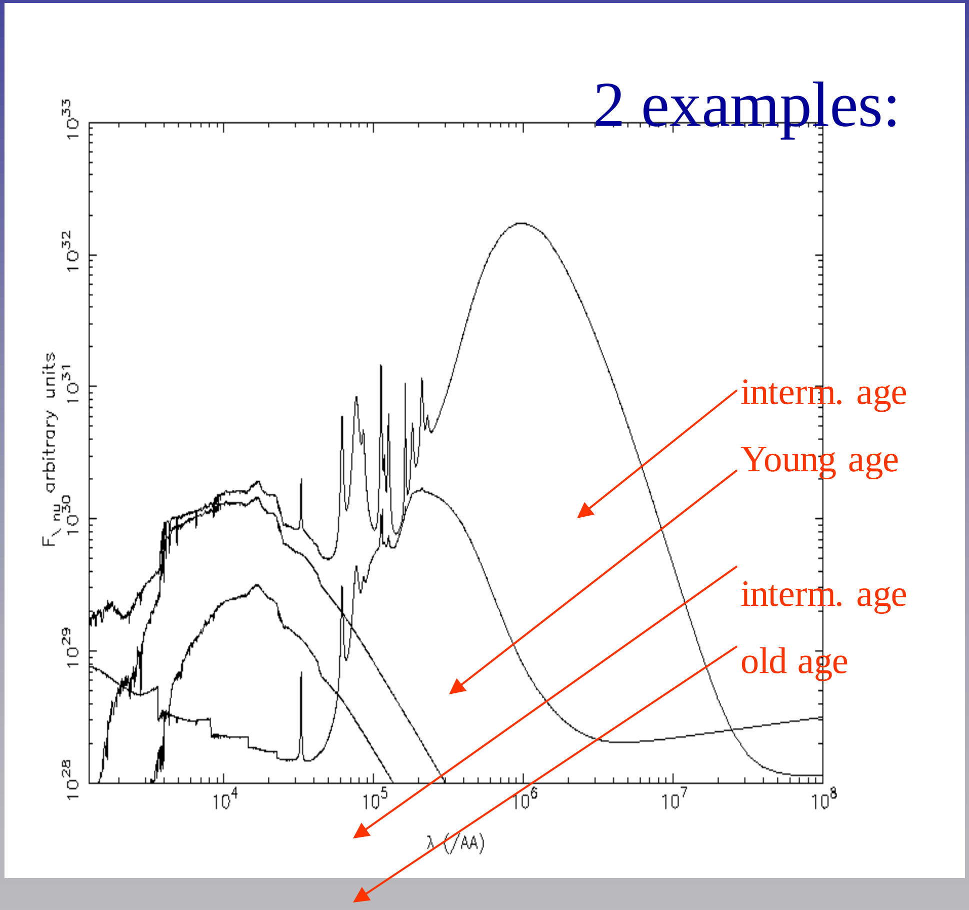
K_λ= opacity per surface unit   Bulge + disk

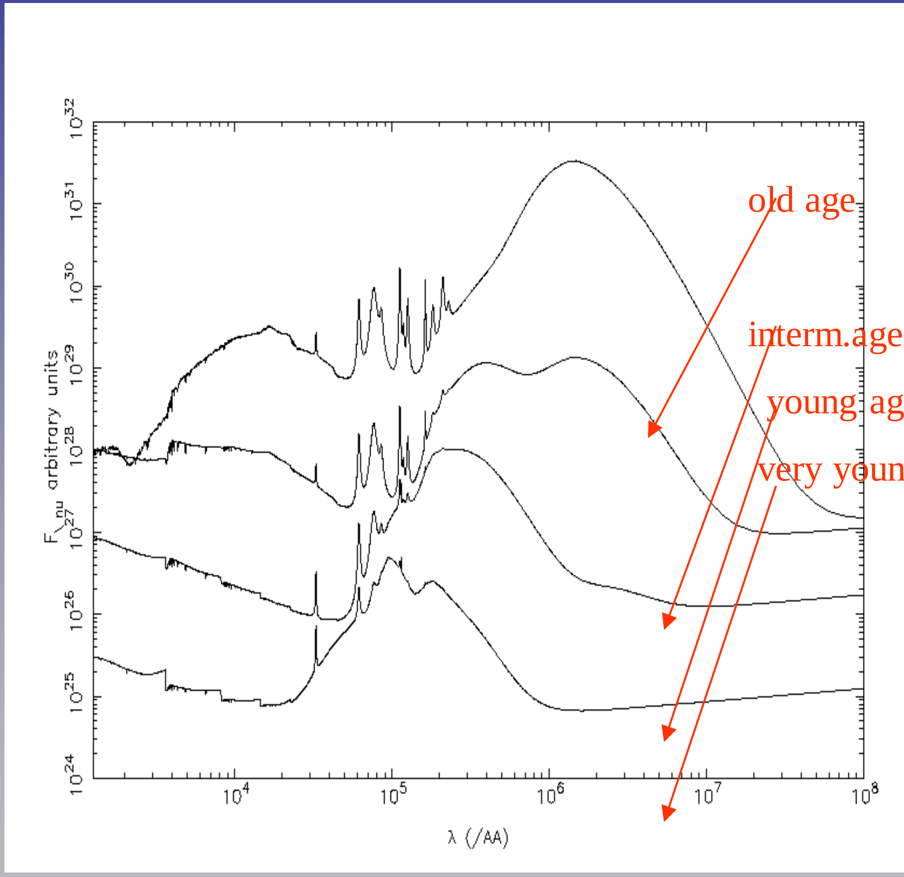
Possibility to increase the gas density

NHI = K . NHI (ISM) with K=1 to 10

Evolutionary optical-IR SEDs of PEGASE.3 by types

2 examples:

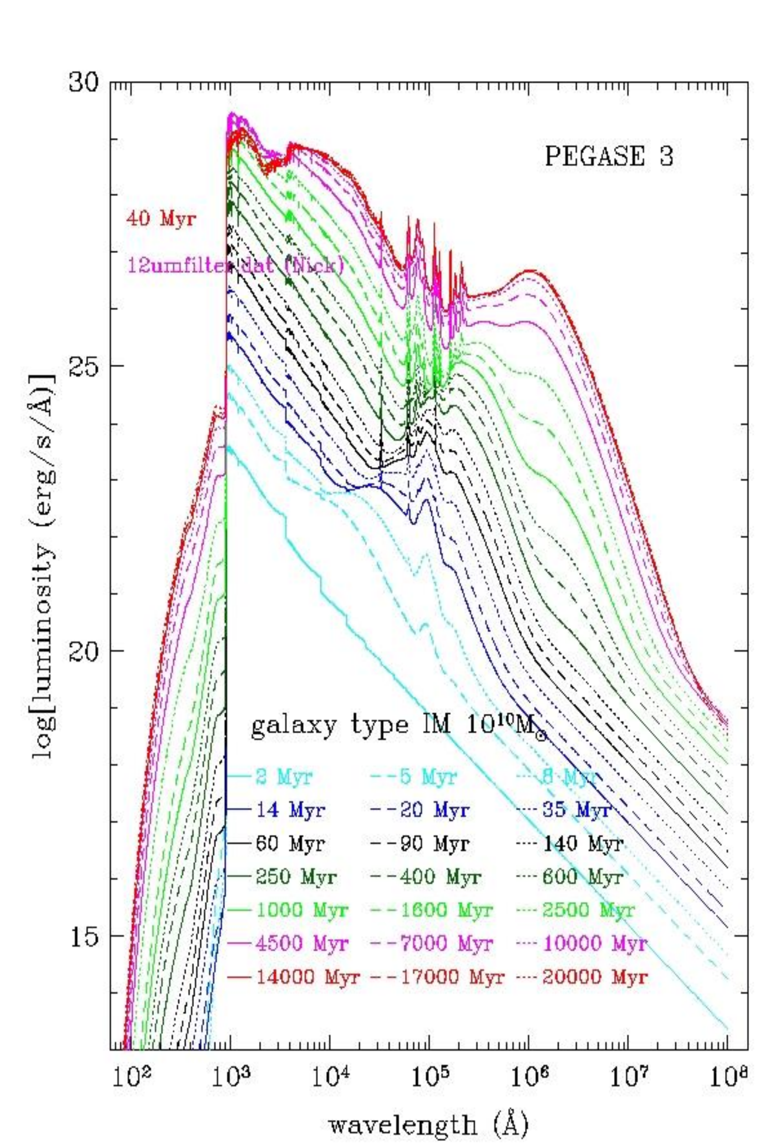




Elliptical

Spiral Sc

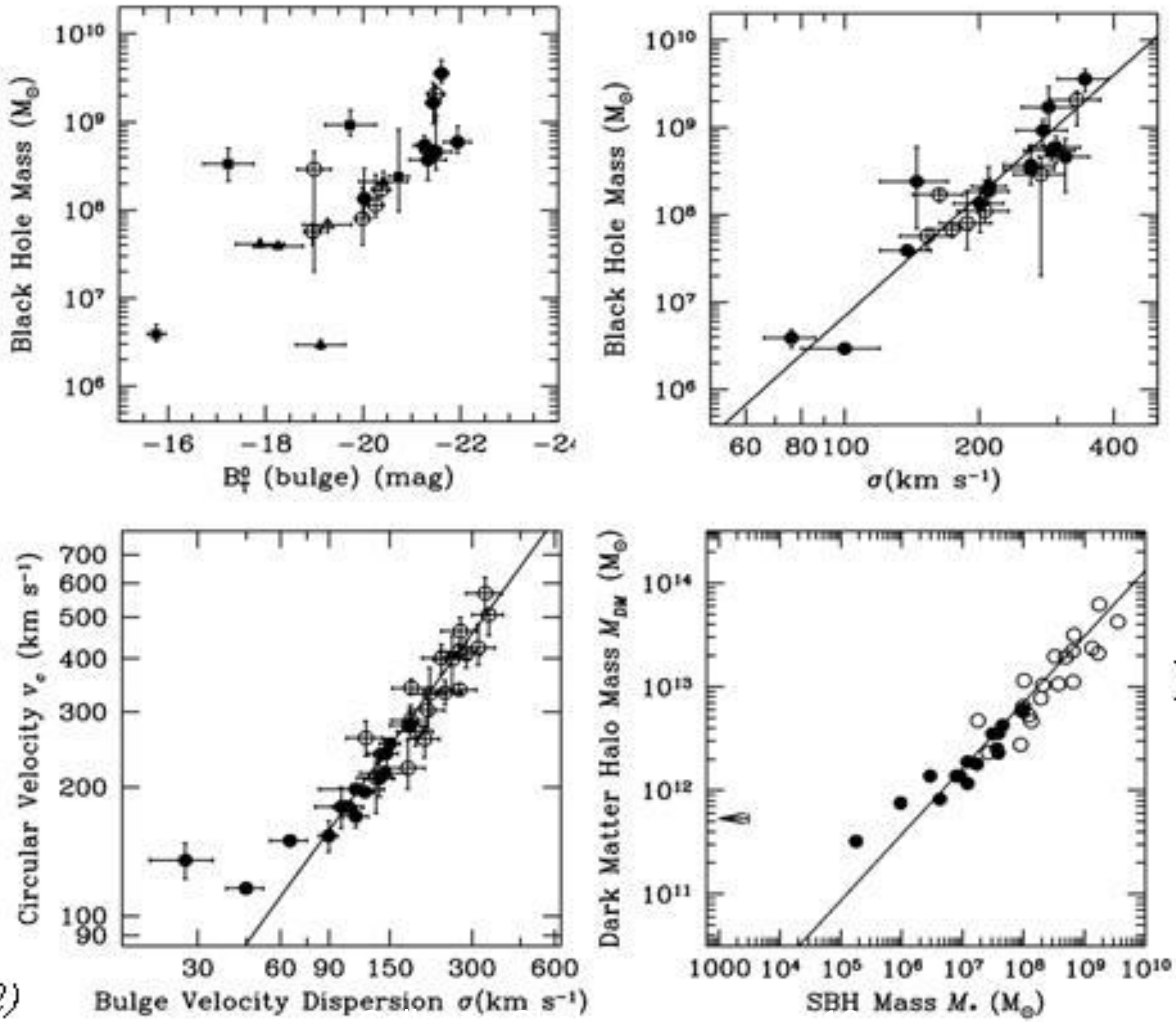
Atlas of synthetic galaxies(optical-FIR)



Statistics on SUPERMASSIVE BLACK HOLES

Fundamental Correlations Between MBHs and Their Host Galaxies

$M_\bullet \sim L_\rho^{0.9} \sim M_\rho$



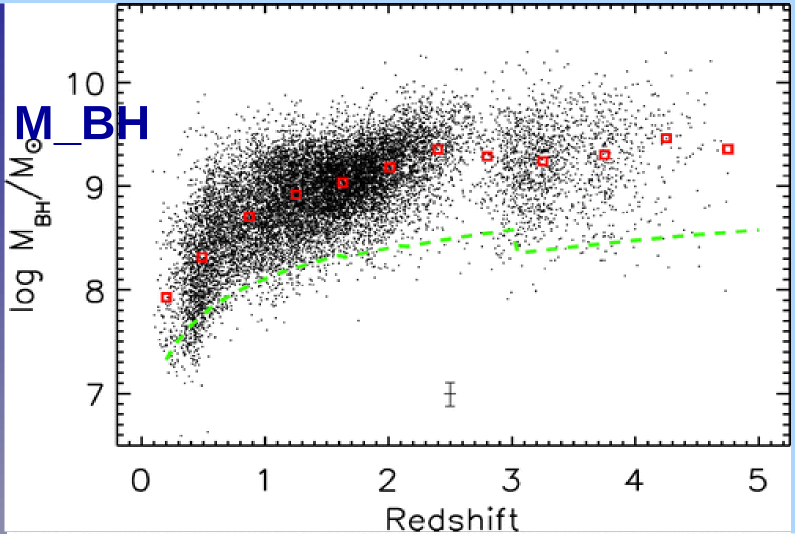
$M_\bullet \sim \sigma^{4.5}$

$M_\bullet \sim M_H^{1.6}$

(Ferrarese 2002)

From z=0 and 4
Supermassive black holes ($10^{7-9} M_\odot$)

M_BH



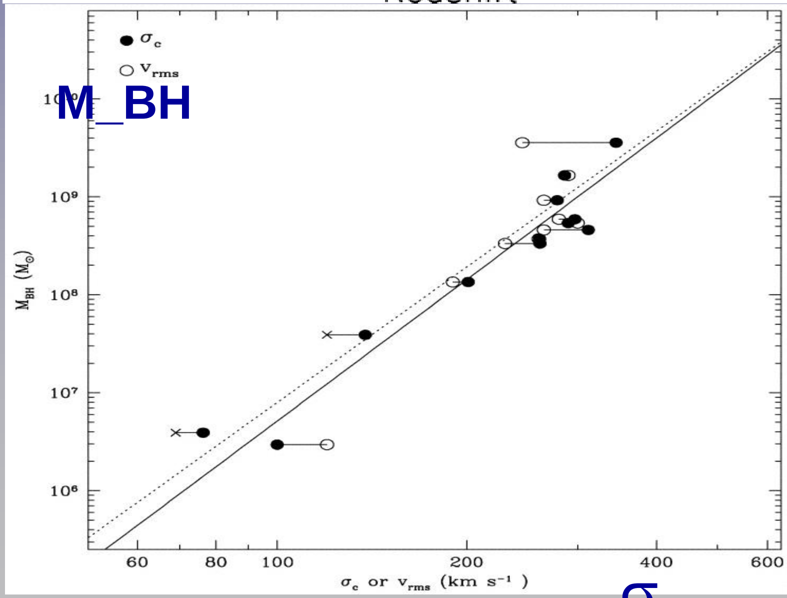
Redshift distribution of the black hole masses Of the QSOs sample f rom SDSS DR3

Vestergaard etal. 2008, ApJ, 674, L1

Relation with the Galaxy properties

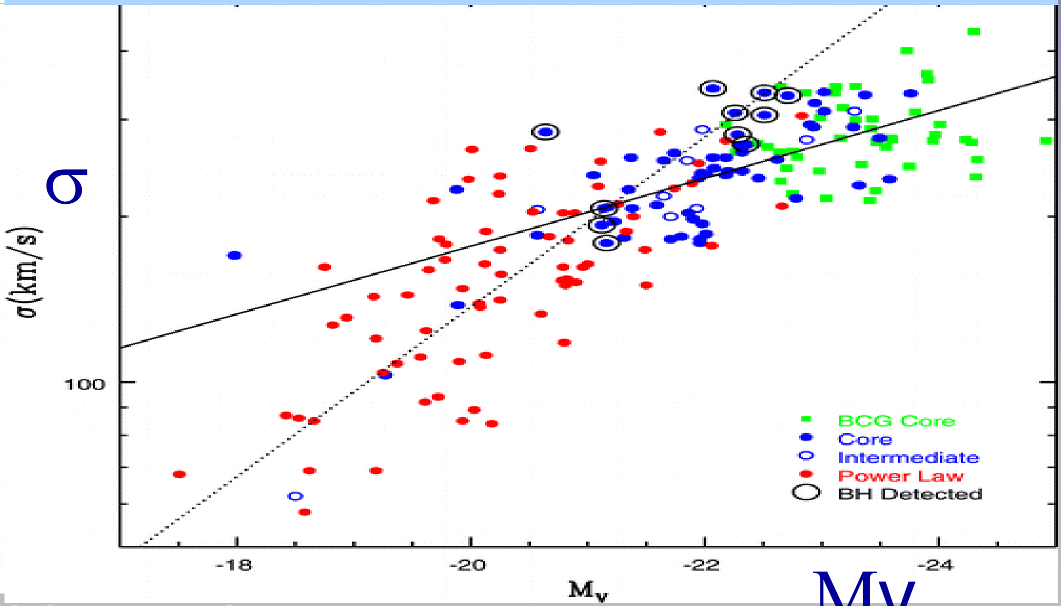
Merritt et al, 2006, Margorrian et al, 2004

M_BH



σ

σ



Mv

At z~0, a more statistical analysis for Ell-SO-Spiral galaxies
McConnell & Ma 2013

An updated sample of 72 black holes and their host galaxies,

The present revised scaling :
best-fitting power-law relations for the full galaxy sample

$$\log_{10}(M_\bullet) = 8.32 + 5.64\log_{10}(\sigma/200\ \mathrm{km\ s^{-1}}),$$
$$\log_{10}(M_\bullet) = 9.23 + 1.11\log_{10}(L/10^{11} L_\odot),$$
$$\log_{10}(M_\bullet) = 8.46 + 1.05\log_{10}((M/M_\odot)_{\mathrm{bulge}}/10^{11} M_\odot).$$

Can we connect

Star Formation law to Supermassive Black Holes?

➔ Radio galaxies are the best templates

Two selected Radiogalaxies
4C41.17 and TN J2007-1316 (z=3.8)

- **Faint AGN contribution**
- **Evidences of stellar populations**
- **Continuous flux-calibrated SEDs from**

❖ **Optical (UV rest-frame)**

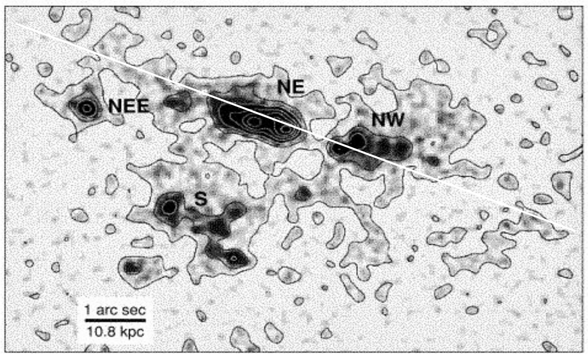
❖ **Spitzer (K-band rest-frame)**

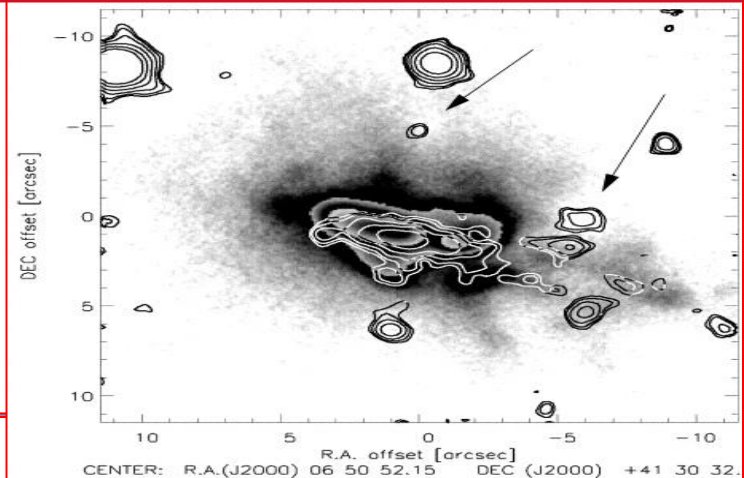
❖ **Herschel and submm** **(cold grain peak rest-frame)**

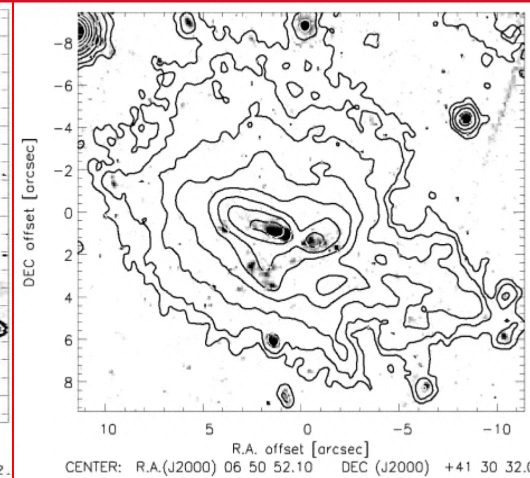
- **Negligeable synchrotron emission**

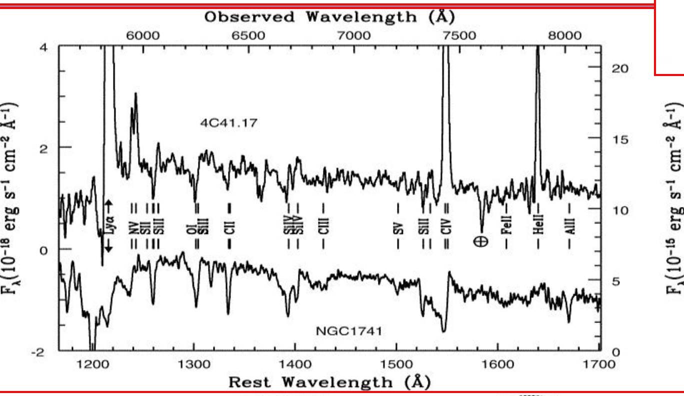
High-z radio galaxies and Giant Lyα Clouds

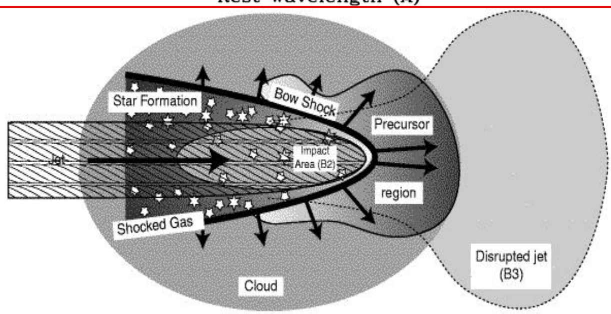
The template distant radio galaxy 4C41.17 (z=3.8)





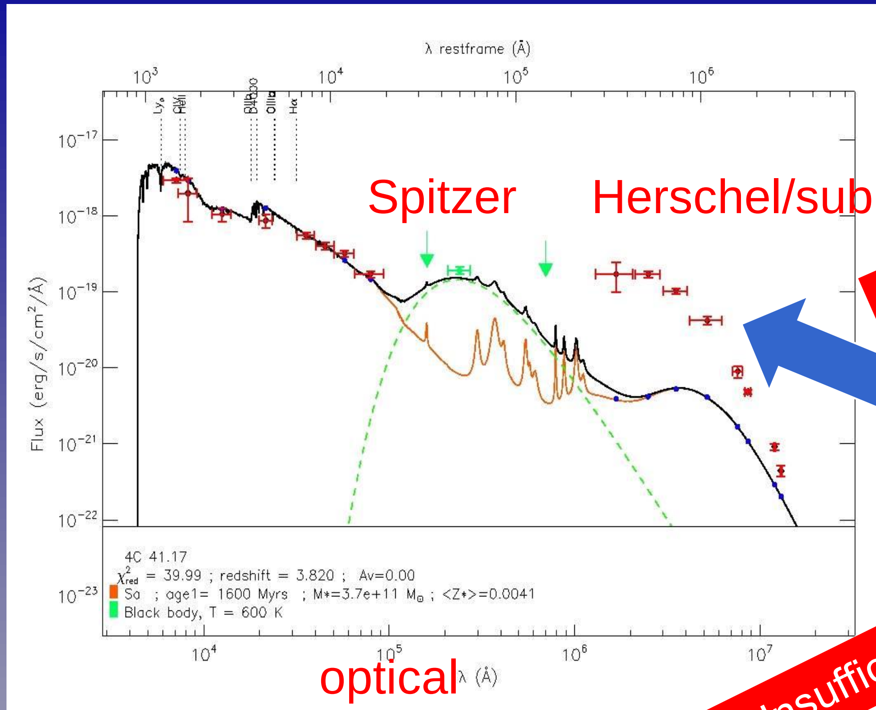


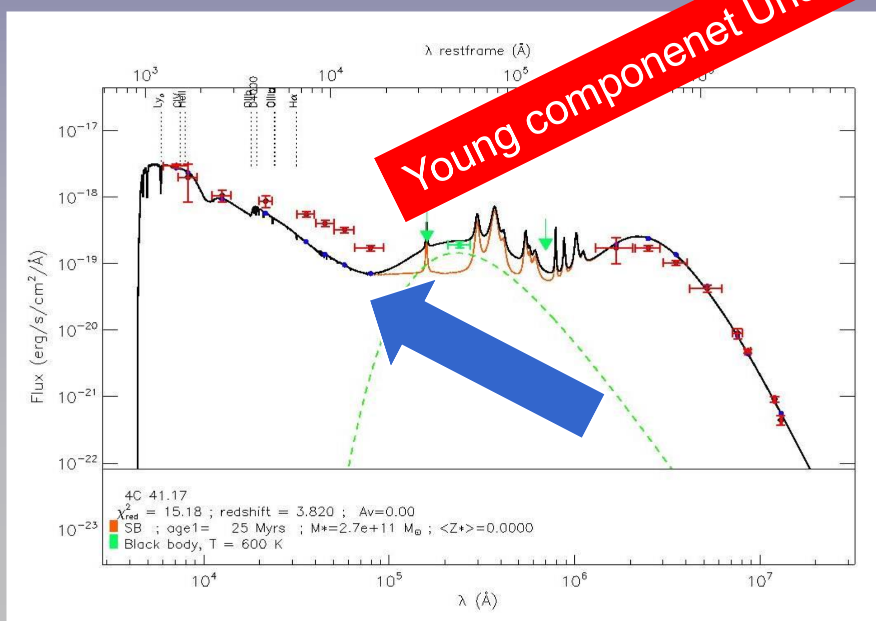




- **Huge Lyα Clouds of 100-200 kpc of ionized gas (cocoon)** (Dey et al, 1997, Van Breugel et al, 1999, Reuland et al, 2003).
- HIGH-z RADIO GALAXIES are hosted by MASSIVE ELLIPTICALS

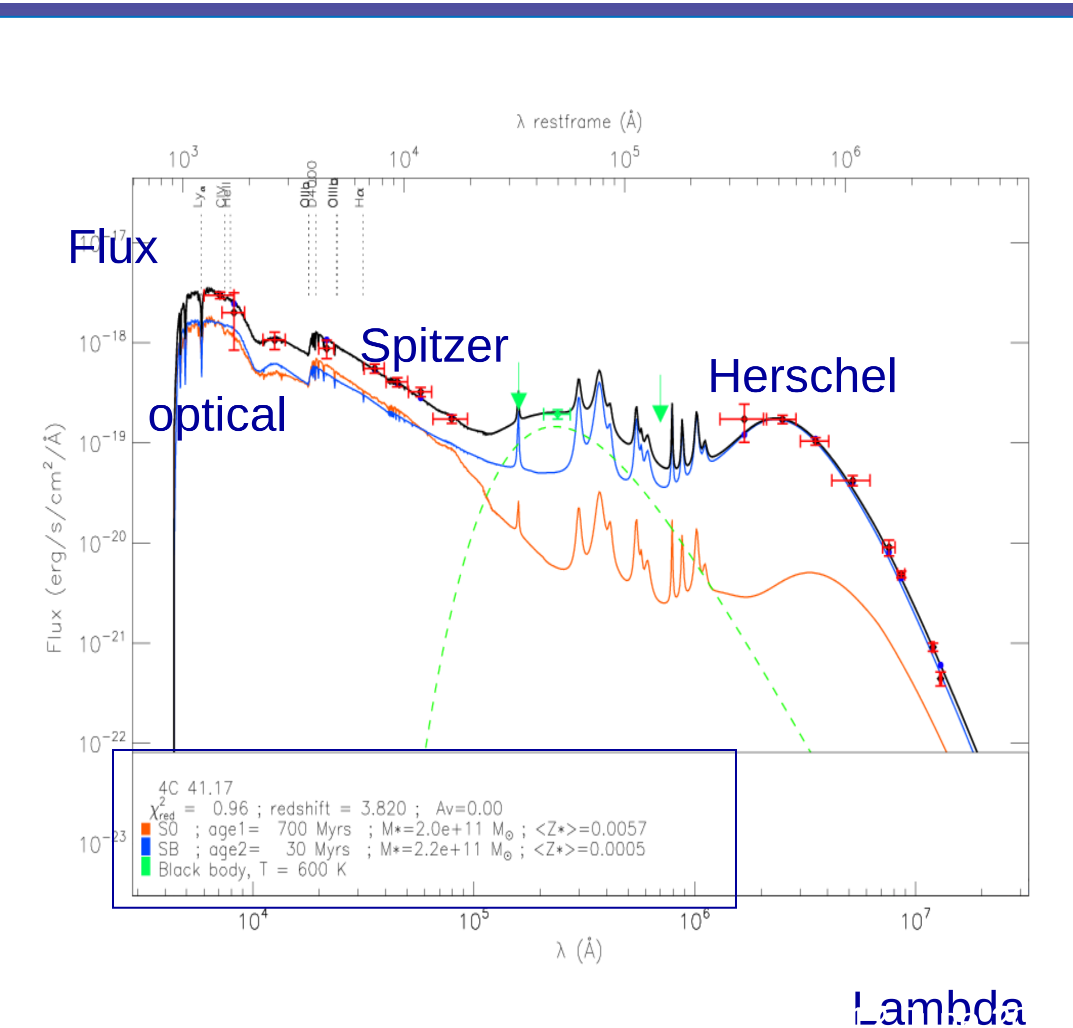
- **Stellar lines are detected along the radio axis (Dey et al, 1997), as WR starbursts**
- Star formation along the radio jet and south-East component, Bicknell et al, 2000





Rocca-Volmerange et al, 2013

The z=3.8 radio galaxy 4C41.17 with HERSCHEL, SPITZER and optical SED of a massive starburst in the evolved (~1Gyr) galaxy by spectral evolutive synthesis with the code Pegase.3



Rocca-Volmerange, Drouart, Fioc And the HeRGé group., MNRAS, 2013

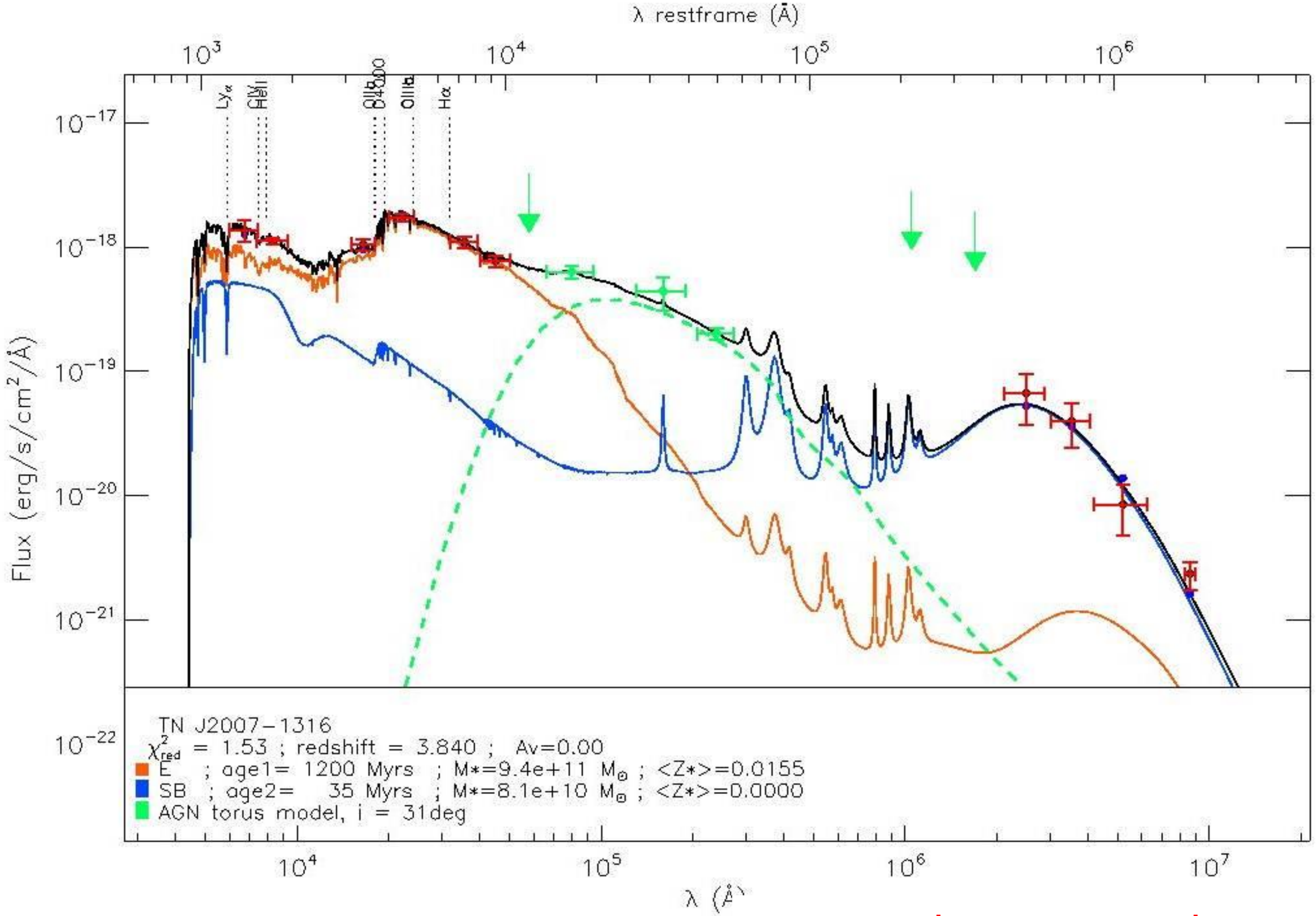
Observations (red)

Total fit with 3 components : Black line

- **Massive starburst at 30Myrs** (blue)
- **Evolved early type at 700Myrs** (orange)
- **Simple AGN model** (dashed green)

Procedure : in the observer frame, template libraries by types, Khi2 min.

Confirmed for TN J2007-1316 (z=3.8)
Two stellar components: Starburst at age 35Myrs (blue) + SO/Elliptical at age 1200Myrs(blue) +AGN



Rocca-Volmerange et al, 2013

Projet HeRGE

N. Seymour, C. De Breuck, D. Stern,
… G. Drouart, B. Rocca-Volmerange.
+ 33 co-authors, 2010, 2012)

- **He**rschel **R**adio **G**alaxy **E**volution Project
- 71 powerful (L_3GHz>10^26WHz) radio galaxies at 1<z<5.2
- From Ultra Steep Spectrum radio sample (alpha < -1.3, De Breuck et al., 2000)
- ***Spitzer***, ***Herschel***, SCUBA(JCMT) and LABOCA(APEX)
- *HST*, VLT, Keck, Palomar, VLA, **ALMA**

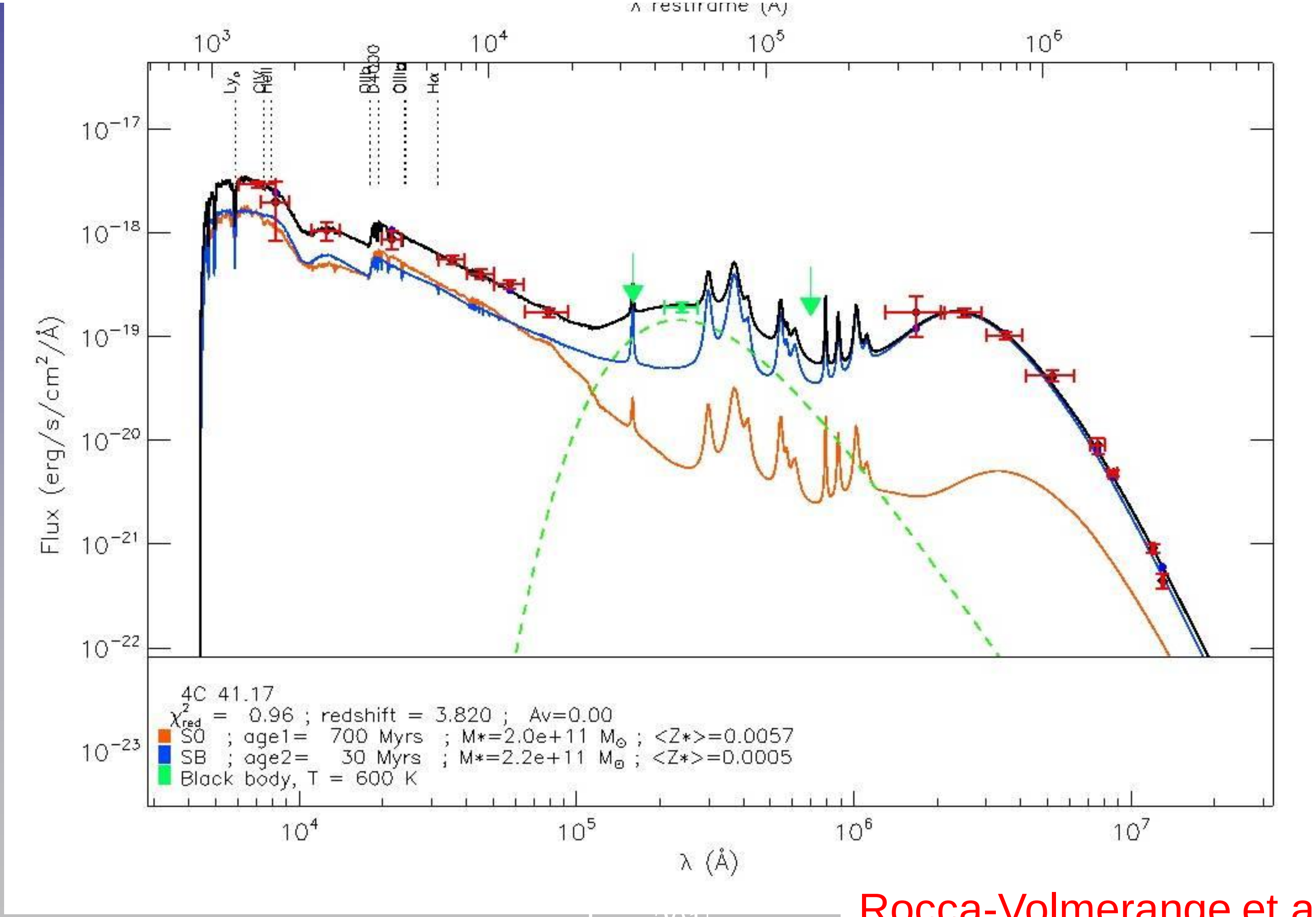
Articles: Drouart et al., in prep

Wylezalek et al., 2013; Seymour et al., 2012; Ivison et al., 2012; De Breuck et al., 2010; Seymour et al., 2007 …

and team members: M. Lehnert, N. Nesvadba, D. Stern, M. Haas, J. Vernet…

See Drouart's talk of the meeting

The best fit of 4C41.17: sum of Two Stellar Populations: Starburst at age 30Myrs + Elliptical at age 700Myrs
The AGN (600K) is not significantly constraining
Excellent $\chi 2=0.96$, huge masses 10 ^11 M_0, low Z



Rocca-Volmerange et al, 2013

Two star formation time-scales:

- **Instantaneous ~1-Myr → SF episode revealed by dust from SN and AGB stars**

- **Cumulative ~1 Gyr → possible sum of SF episodes , the envelop is a model → SFR law.**

- **Star formation initiates at z_{for} = 10 or more,**
- **z_{for} < 4 is unlikely for the most massive RG**

- **Evidences of a cumulative sum of SF episodes**

- **But No evidence of hierarchical merging down to z=0**

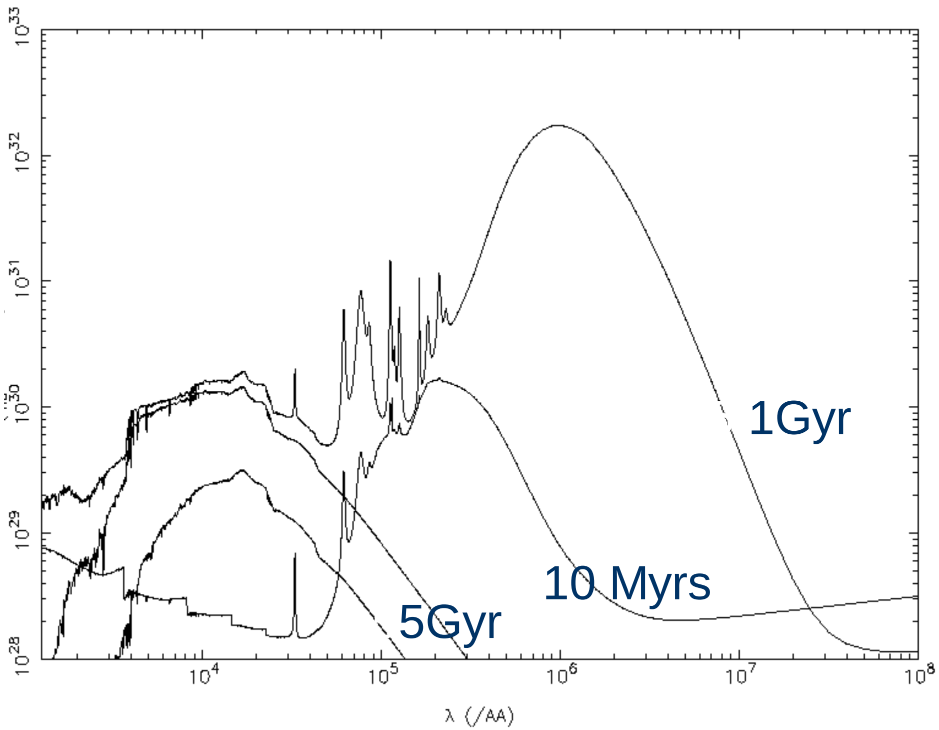
But why the age of 30Myrs of the most recent episode ?

The huge Infrared emission requires Supernovae ➔

metal ejecta to form Grains of Dust

+

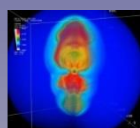
Still UV young stars
(heating photons)



At any age of SSP or galaxy (Σ (SSPs))

0Myr

30 Myrs



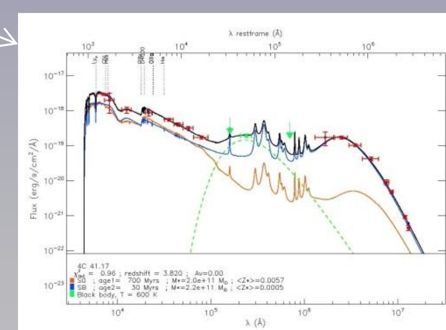
Galaxy age

Exploded SN

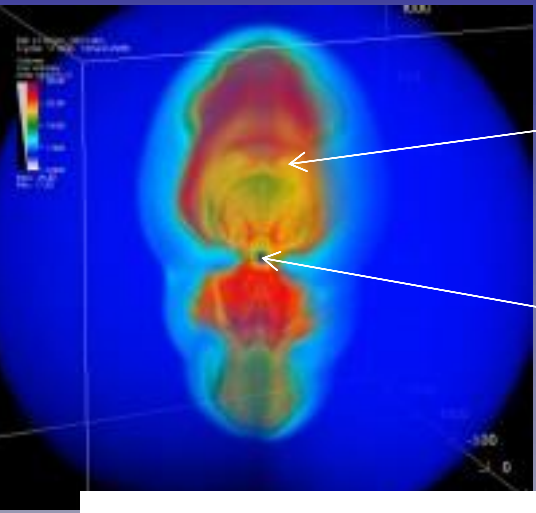
M (SNR)

+ Ejecta ➔ Z

SED



Mass of SNRs from exploded supernovae for SSP and Galaxy (sum of SSPs)



Metal ejecta (from yields)

Stellar black hole (or neutron star) $M_{BH/NS}$ | =SNR

$m_{BH/NS}$ = $m_{presupernova}$ - m_{ejecta} (including winds)

$\Phi\ (m_{presupernova})$: from IMF and stellar evolution

= M_{SNR} for SSP ➔

for sum of SSPs M^{Gal}_{SNR}

Ages, Stellar mass and SNR mass after calibration on data of 4C41.17 and TN J2007-1316

Rocca-Volmerange et al., 2015, ApjL, 803, L8

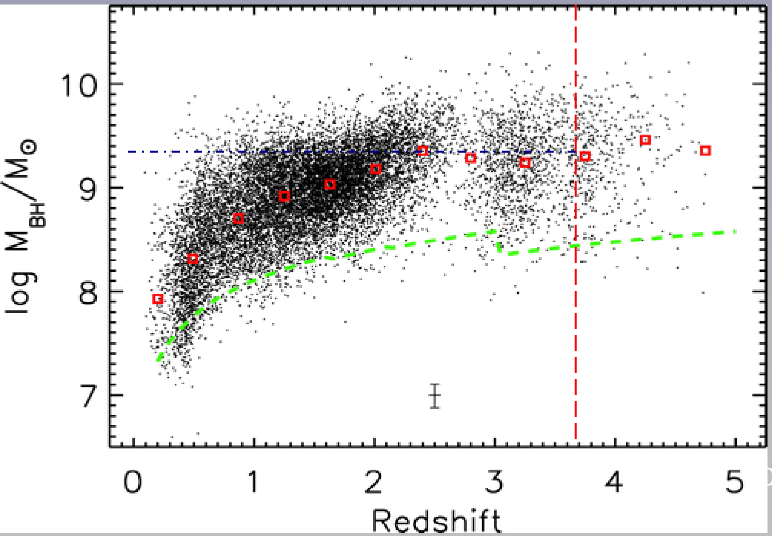
Galaxy component	Age in Myr	Stellar mass (10+11 Msun)	SNR Mass (10+9 Msun)	SNR/ Star mass ratio	Z
4C41.17/Burst	**30**	2.2	**8.5**	0.004	0.0005
4C41.17 SO	700	8.1	**4.3**	0.042	0.0057
TNJ2007-1316/Burst	**35**	2.0	**3.4**	0.002	0.0001
TNJ2007/Ell	1200	9.4	**19.0**	0.020	0.0155

Stellar masses (~$10^{12}M_0$) and SNR masses (10^9M_0)
Similar ratio (10^3) in local galaxies

SNR mass of SSP and old population @ z=3.8 = several 10 (+9) Msun

Rocca-Volmerange et al, 2015, ApJ, 803, L8

Is COMPARABLE with



M $_{SMBH}$ = 10 (+9.3) Msun at z=3.8 from SDSS3, Vestergaard et al, 1998

From Ha / VLT
M $_{SMBH}$ ~ 10 (+9) Msun à z~ 2.5
Nesvadba et al, 2011

How stellar black hole mass

resulting from past SN explosions

might explain the growth of

supermassive black hole mass

Possible transfer of SNRs from explosion site to the central supermassive black hole by dynamical friction

= loosing angular momentum

= migration inwards to the core

The dynamical friction time scale

$$t_{fric} = \frac{19}{lnL} Gyr(\frac{ri}{5kpc})2 \frac{\sigma}{200km\ s-1} 10^8 Mo/M(SNR)$$

= 0.095 Gyr << 1Gyr Hubble time

For ri=0.25kpc, MSNR=2 10^7, σ=400km s−1

Binney & Tremaine, 2008

- Low signatures of stellar black holes
  The catalogue of SNR in the Milky WAY= ~300 SNRs…

- Stellar BH are in agreement with luminous stars (SEDs)
- And Metallicity, issued from the same star formation history

- No direct relation of starburst with the variability of AGN

- Possible numerical simulations to form elliptical and dense bulges (van Dokkum et al, 2013, 2014)

What is the scale of star forming?
SF regions, Bubbles, clumps, …

At z=4

The question of Angular resolution Is essential 4-5 ¨ for SDSS3

0.1 ¨ for VLA…

Future/Current works

Statistics M_{SMBH} / σ, or L_V or M_{bulge}
(McConnell&Ma, 2013 and references therein)

Details on dynamical friction and stellar statistics
(Binney & Tremaine, 1998)

Galaxy evolution models
No evidence of major mergers,
hierarchical merging
But occasionnally

Intermediate black hole masses?

THE TOOL BOX **PEGASE**

PEGASE.2 (www2.iap.fr/pegase) 8 spectral types (Ell→Irr) for evolutionary SED synthesis with Metals, Dust and Geometrical Effects (Fioc & Rocca-Volmerange, 1997, 1999)

free access

free access

CODE Z-PEG

Photometric redshifts

(Le Borgne & Rocca-Volmerange, 2002)

NEB-PEG

Nebular emission

PEGASE+CLOUDY +MAPPINGSIII

(Moy & Rocca-V, 2001, 2002)

PEGASE-HR (R= 10000),

High spectral resolution with ELODIE library

Le Borgne, Rocca-Volmerange B., Lançon A. , Prugniel P. , Soubiran C. , 2004,

PEGASE.3 from UV to Far-IR

(evolution + grains) Fioc, Rocca-Volmerange,Dwek, README ready

X-Rays-Optical-IR

D. Le Borgne, PhD thesis , 2003,

Comparison SNR mass and supermassive black hole mass

SNR mass of SSP and old population @ z=3.8
= several 10 (+9) Msun

From SDSS3, M $_{SMBH}$ = 10 (+9.3) Msun at z=3.8,
Ferrarese et al, 1998

From Ha / VLT M $_{SMBH}$ ~ 10 (+9) Msun à z~ 2.5
Nesvadba et al, 2011

Rocca-Volmerange eta l, 2015, ApJ, 803, L8

SMBH growth at z=4 by accretion of SNRs

- Low signatures of stellar black holes
- The catalogue of SNR in the Milky WAY= ~300 SNRs…

- Dynamical Friction at z=3.8
- = loosing angular momentum
- = migration inward to the core

- Followed by Numerical simulations for galaxies
- To form elliptical and bulges (van Dokkum et al, 2013, 2014)
- galaxies (see talk Bournaud)
- Grandes structures

A model of Galaxy EvolutionPEGASE.3
The coherent evolution of :

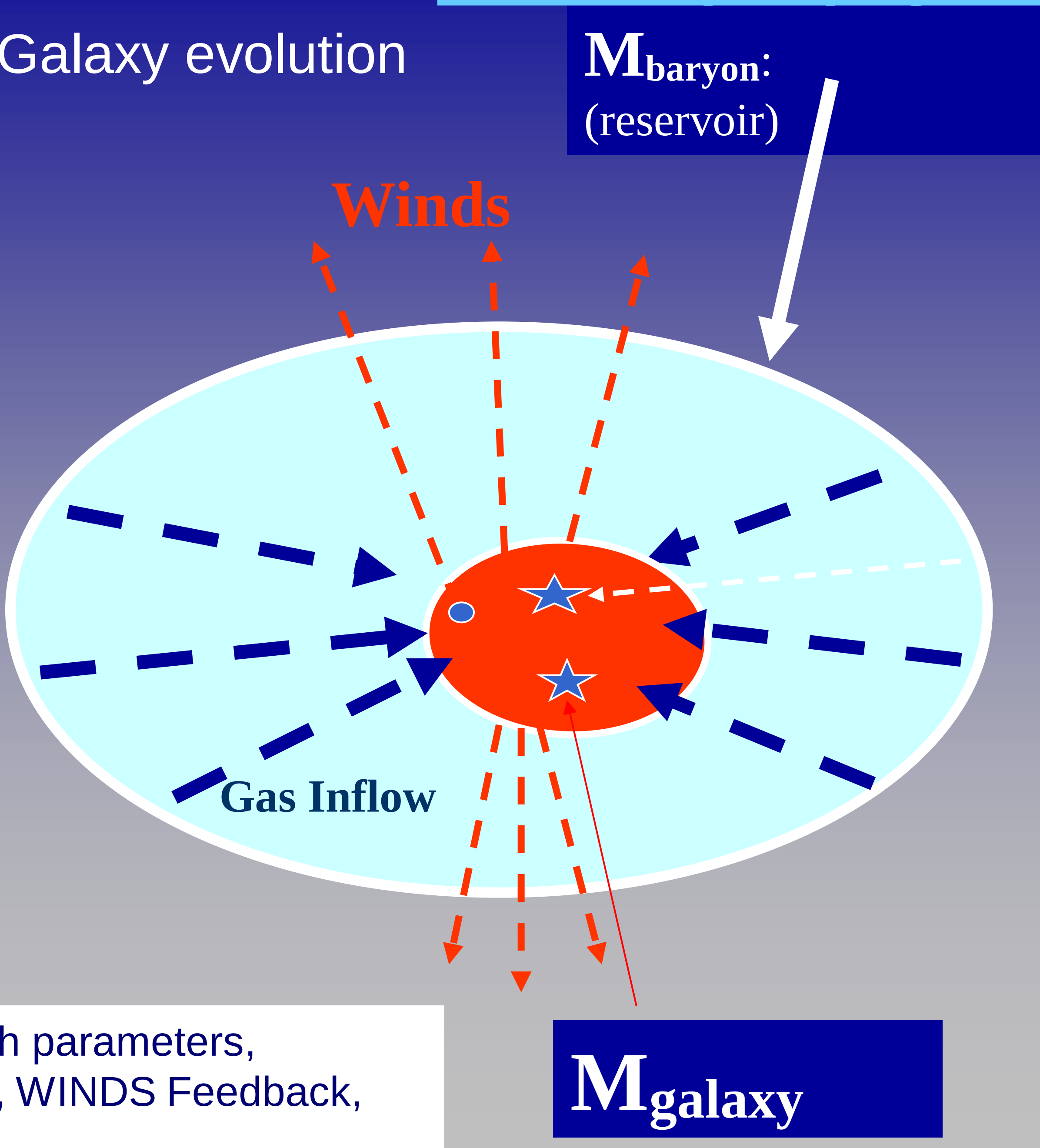
- Mass
- Gas (ionized, neutral and molecular)
- Stars (from UV to NIR)

and

- Dust (attenuation, emission,

www2.iap.fr/pegase

PEGASE model of Galaxy evolution



Scenarios by type:
Four Parameters

- **Star Formation law SFR(t)**
- **Inflow time-scale**
- **Extragalactic winds**
- **IMF**
- **+ RADIATIVE TRANSFER Dust absorption and emission**

MAIN QUESTIONS:: mass growth parameters,
Star formation laws , Quenching, WINDS Feedback,
Metal-enrichment,

The method based on continuous Pegase scenarios as a modulated sum of SSPs

1.To build libraries of reference templates from z=0 to high z

2. Analysis in the situ frame (observer frame) :Cosmology + evolution

- **Distance**
- **Evolution and expansion corrections to the cosmic time t (z)**

➡ **Luminosity/ Mass ratio L/M (lambda,z)**

3.Mass estimates by calibrating the predicted L/M on observations

➡ **Stellar masses , and consequences (metal, dust , ionized gas)**

3.4 Stellar Libraries

Characterized by several properties

- Spectral resolution 20A (low) → 0.5A (high) →
- Theoretical (Kurucz; 1993) or observationnal (Elodie, OHP)
- Wavelength range : UV, optical, NIR (K)
- Complete Coverage of HR diagram
- Effect of Metallicity

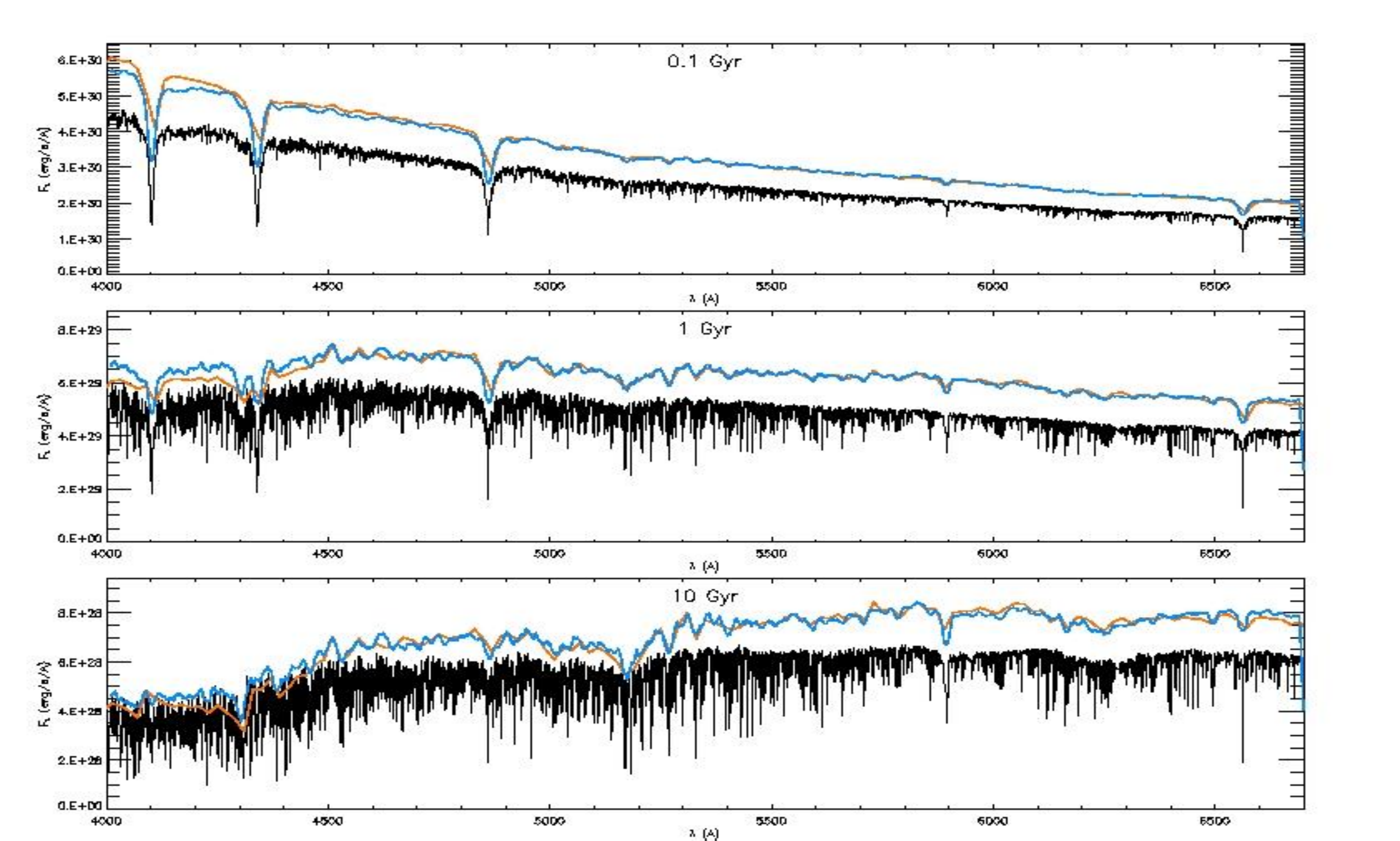
Quality of stellar spectra = Quality of SEDs

2 European schools: Padova, Geneva

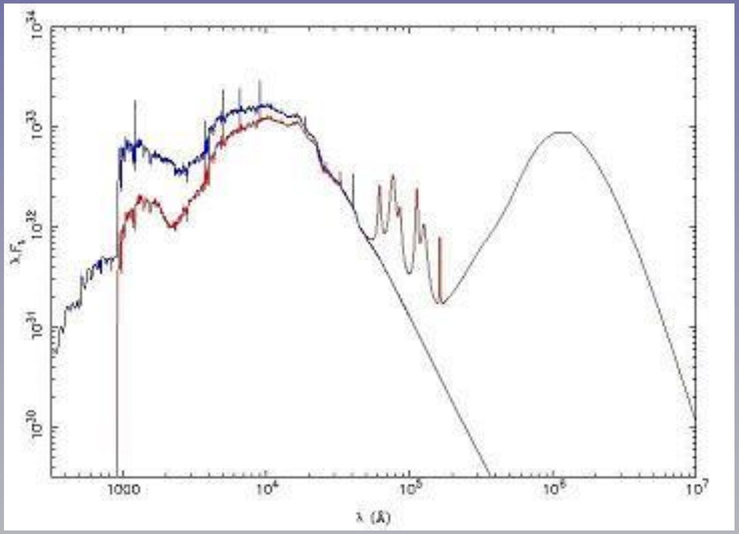
For AGB: Lançon et al, 2000

Several stellar libraries :

- BaSel (Lejeune et al, 2002) 20A/bin, theoretical
- Munari et al, 2005, 1A/bin, theoretical (Kurucz)
- ELODIE dans PEGASE_HR (Le Borgne et al, 2004)



FROM UV Extinction ➔ to IR Emission



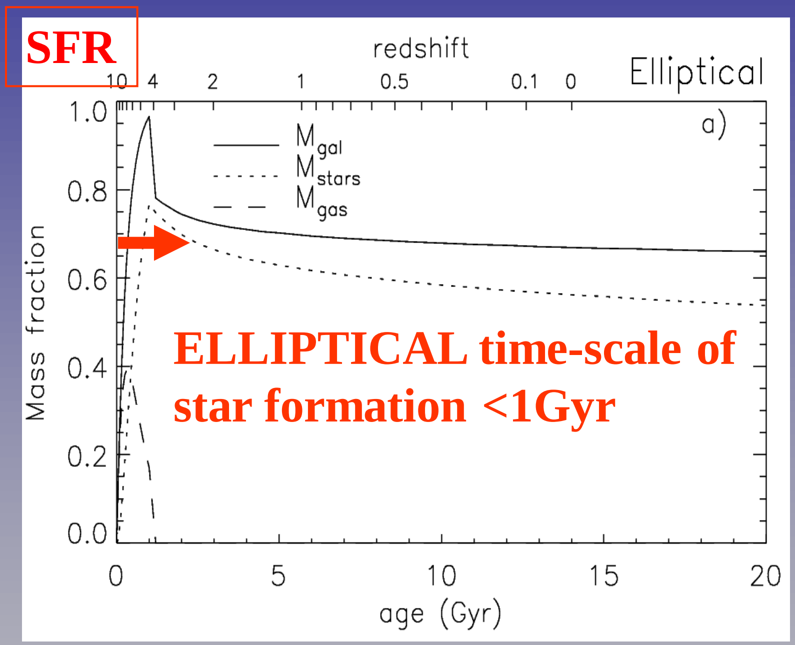
Synthetic spectra
With and without
Dust extinction

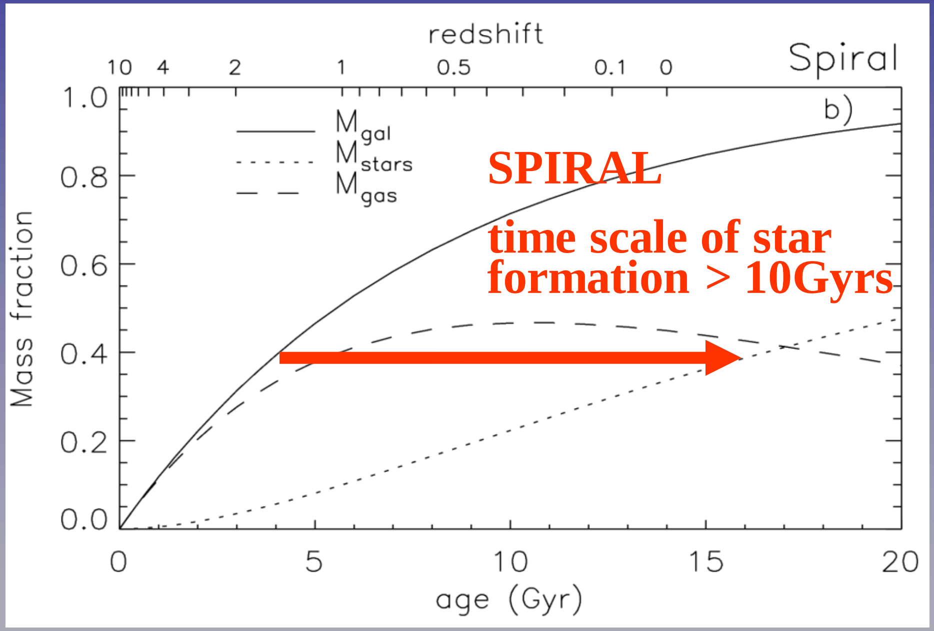
The main parameter is the Star formation time-scale inducing the M_{stars} evolution:

2 different scales

Elliptical/ bulges **Spiral/disks**

:





- SFR law is regulated by accretion/infall (a few 100 Myr)
- Extra galactic winds (1 to 3 Gyr)

Mid-IR and Far-IR emission

B. T. Draine

dy, Einstein Drive, Princeton, NJ 08540 USA
, Princeton University, Princeton, NJ 08540 USA)
raine@astro.princeton.edu

ewed
s sili-
AHs)
ction
istri-

light,
e ex-
ysical
differ
tinc-
ssion

n the
emis-
car-
istri-
dust
Milky
adia-
rared
vered
n fea-
ately
ture.

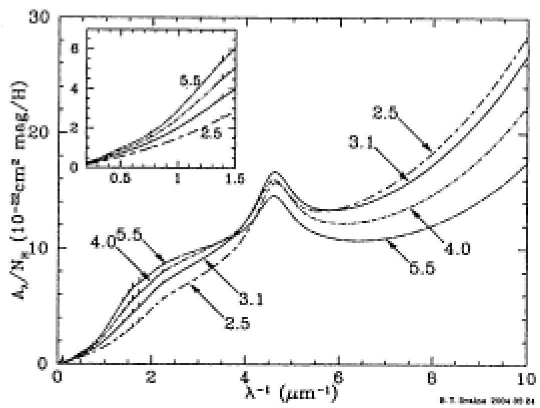


Figure 1. The interstellar extinction per H nu cleon, on sightlines with different values of R_V = $A_V/E(B-V)$. The shapes of the extinction laws ar from the parameterization of Fitzpatrick (1999), plu diffuse interstellar bands. The normalization rela tive to H is from Draine (2003a). Figure taken fron Draine (2003a).

through development of models to compare to the ob servations. The models are constrained by the law of physics and by increasingly informative observa tions.

2. EXTINCTION CONSTRAINTS

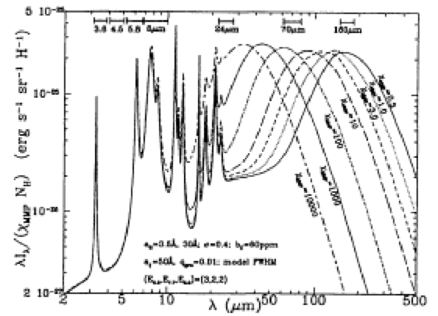


Figure 3. IR spectra emission (scaled by the starlight intensity) for dust model illuminated by χ_{MMP} times the local interstellar radiation field of Mathis, Mezger, & Panagia (1983) (see text). The IRAC and MIPS bands are indicated. From Li & Draine (2001).

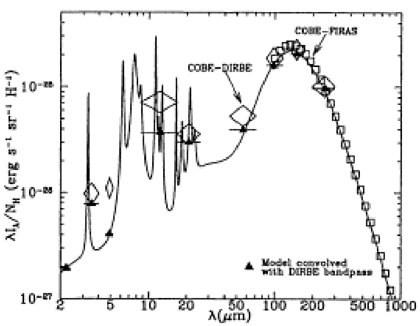


Figure 4. Infrared emission calculated by Li & Draine (2001) for dust at high galactic latitudes heated by diffuse starlight. Squares: COBE-FIRAS (Finkbeiner et al. 1999). Diamonds: COBE-DIRBE (Arendt et al. 1998). From Draine (2003a).

for the thermal energy would be E. It is therefore

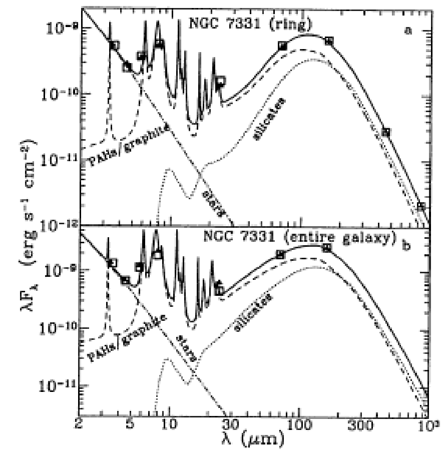


Figure 5. Photometry of NGC 7331 (square symbols) compared with the sum of model starlight plus emission calculated for the Li & Draine (2001) model of carbonaceous grains and silicate grains, illuminated by a distribution of radiation fields. Triangles show model convolved with the Spitzer filters. Figure from Regan et al. (2004).

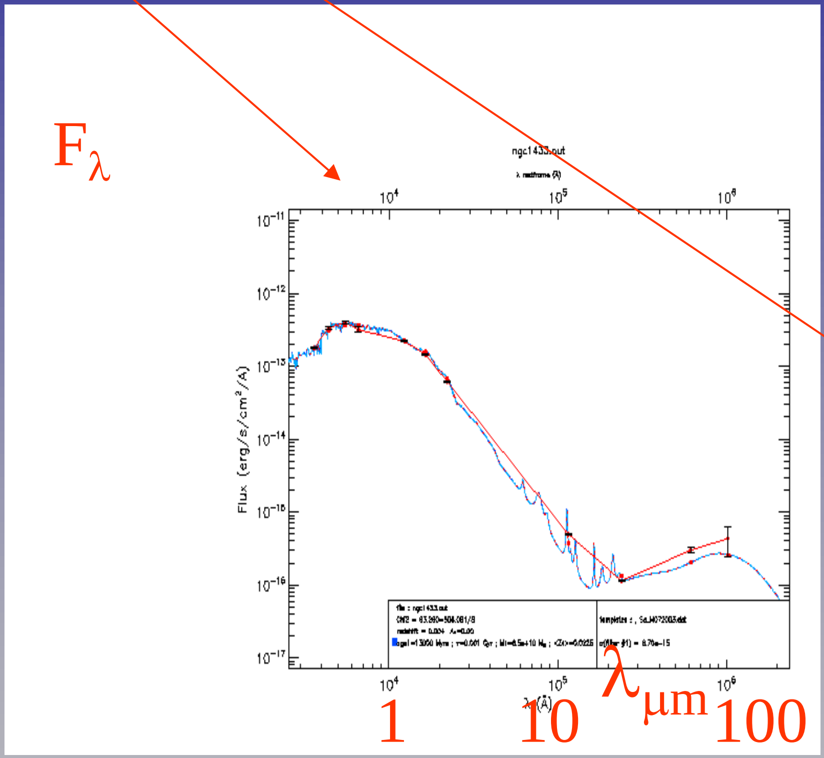
5. IR AND FIR OBSERVATIONS

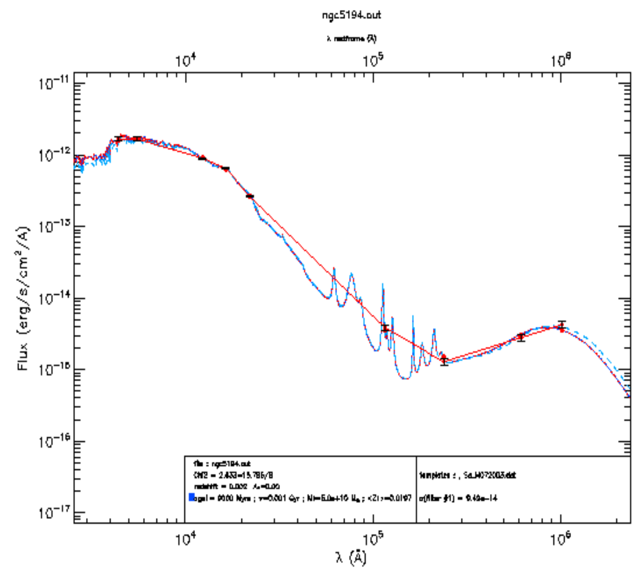
As part of the SINGS Legacy Project (Kennicutt et al. 2003), Spitzer Space Telescope recently imaged the Sb galaxy NGC 7331 in 7 bands (Regan et al. 2004), and measured the emission from (a) the star-forming ring (with radius r = 4 kpc) and interior, and (b) from the entire galaxy. Figure 5 compares the photometry of NGC 7331 with a combination of starlight (dominant at short wavelengths) and emission from the dust model illuminated by a power-law distribution of starlight intensities ranging from $\chi = 0.3$ to 10^4. By suitable choice of the starlight distribution, and the total dust mass, excellent agreement is obtained. Within $r = 4$ kpc the dust mass is $M_d \approx 4 \times 10^7 M_\odot$; for the entire galaxy the dust mass is found to be $M_d \approx 3 \times 10^8 M_\odot$.

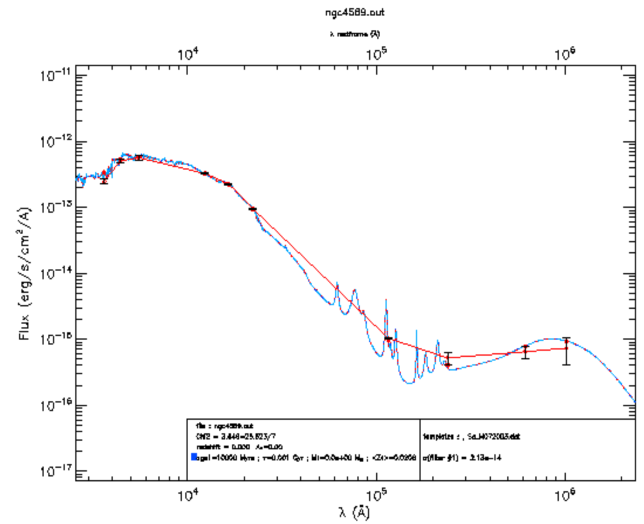
Assuming a gas:dust mass ratio of 150:1, the implied

Comparison of normal SEDs for early-type galaxies to models from PEGASE.3

(NGC4569, NGC5194, NGC1433)

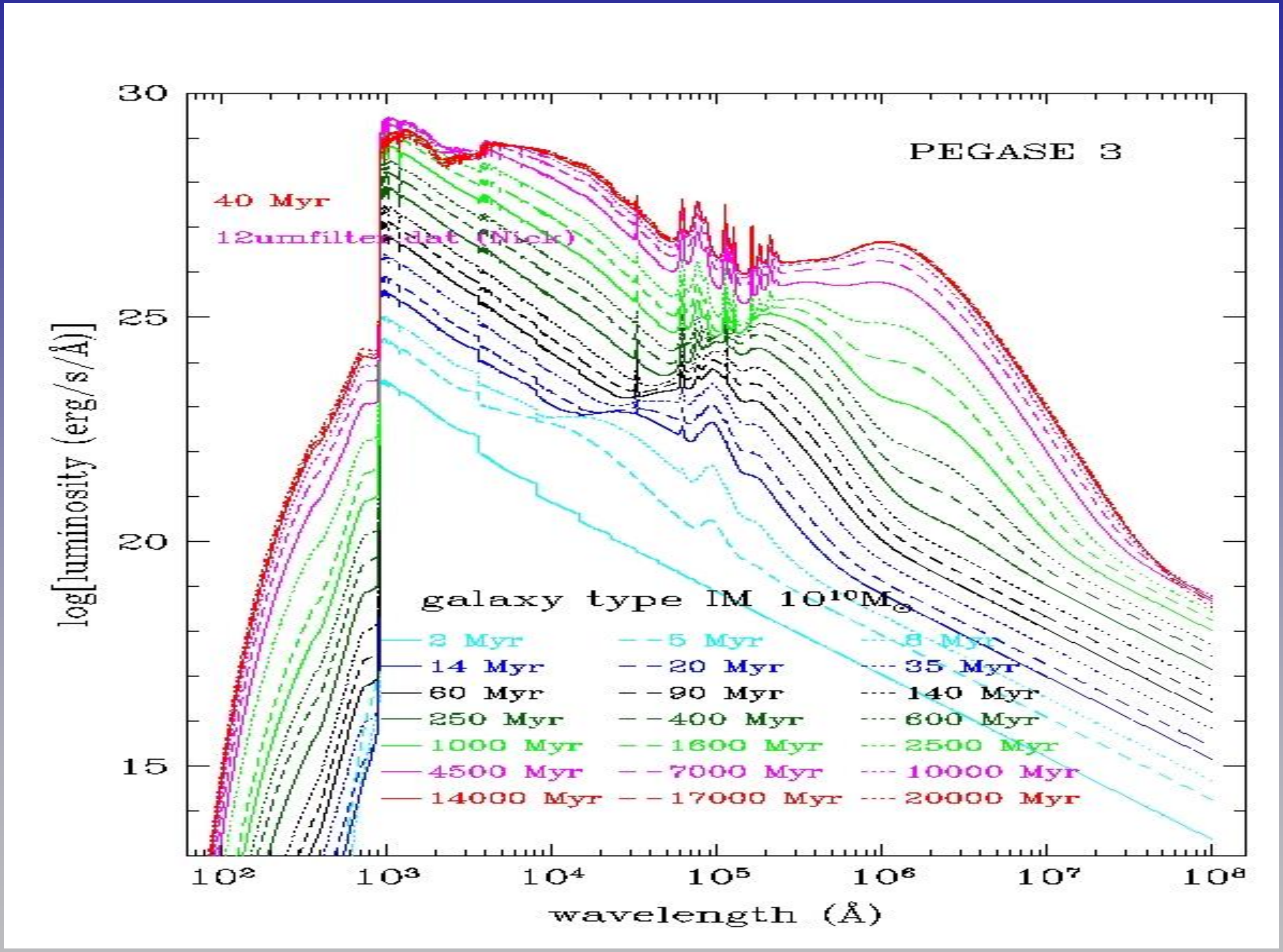




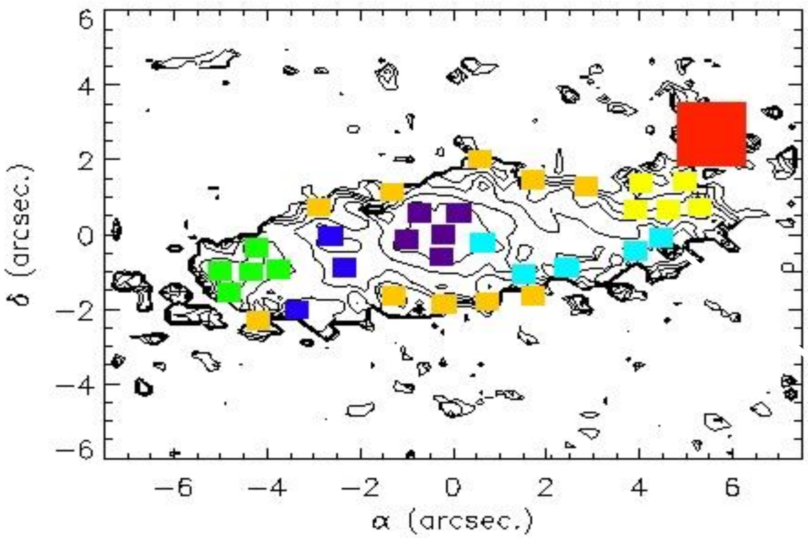


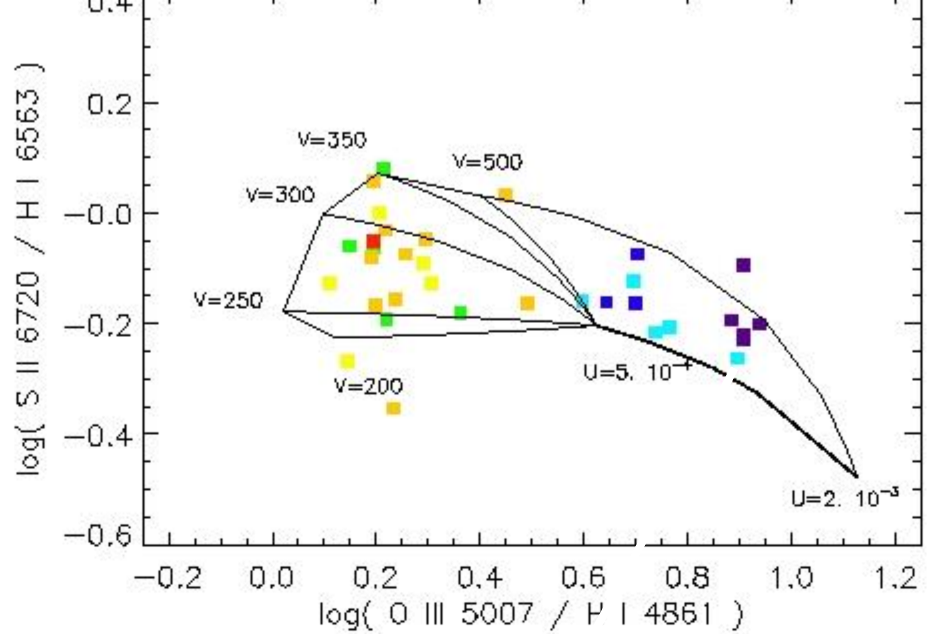
Collaboration with J. Masegosa, I. Marques, Granada

Libraries of synthetic galaxies(optical-FIR)



Fioc, Rocca-Volmerange, Dwek , near of submission to the community





3C171/OASIS:Interpreted with a coupled model (Moy & Rocca,2002): Shocks + AGN Photoionization

- Central and intermediate zones (High U): AGN Photoionization
- Hot spots, boundaries and plume (Low U): Shocks + AGN phot.

One exception are the light blue points of High U, far from AGN :

Star Formation?

We select 2 radiogalaxies at z=3.8 4C41.17 and TN J2007-1316

from the HERGE sample

- Faint AGN contribution
- Evidences of stellar populations
- Continuous flux-calibrated SEDs from

❖ Optical (UV rest-frame)

❖ Spitzer (K-band rest-frame)

❖ Herschel and submm (cold grain peak rest-frame)

❖ negligeable synchrotron emission

❖ Corrections of apertures, flux calibrations to build, etc

THE OPTICAL-SPITZER-HERSCHEL-SUBMM SED at z

Stellar populations

The early –type population is dominant in the NIR (1-2 mu) (Spitzer)

The starburst is essential the far-IR/submm emission (Herschel)

Both have essential role in the optical
HST

The 2 previous galaxies are selected for their low AGN activity

The analysis is completed with the large sample of Hergé with more powerful AGN (see G. Drouart t's talk), based on the

two stellar components + a variety of AGN models

Similar analyses are proceeded with 3CRR → 6C

Stellar mass and SNR mass of 4C41.17 and TN J2007-1316

Rocca-Volmerange et al., 2013, MNRAS
Rocca-Volmerange et al., 2015, ApJ, 803, L8

Galaxy component	Stellar mass (10+11 Msun)	SNR Mass (10+9 Msun)	SNR/ Star mass ratio	Z
4C41.17/Burst	2.2	8.5	0.004	0.0005
4C41.17 SO	8.1	4.3	0.042	0.0057
TNJ2007-1316/Burst	2.0	3.4	0.002	[illegible]0001
TNJ2 007/E	9.4	19.0	0.020	0.0155

COMPARABLE MASS
TO
SUPERMASSIVE
BLACK HOLE MASSES

Conclusions 2 about STARBURST-AGN

STARBURST is of 30-35 Myr old, not instantaneous

WHY? The Far-IR max emission requires a delay to metal-enrich the ISM due SNII ejecta

The AGN models Fritz (no clumpy dust) and
ARPEGE from Herge (Drouart et al, 2015, near submission)
And about 3CRR? (Podigachoski, Barthel,Rocca-Volmerange, Drouart et al,)

Conclusions 3

Supermassive blackholes form at z>4 from accretion of most
of SNRs proceded along the star formation histories

Models of ellipticals forming ellipsoids are
compatible with observed core masses

Future: Confirmation by luminosity functions of galaxies and AGNs ,
High energy contribution (X and Gamma), physics of AGNs,
dust torus evolution(LF of active galaxies (EUCLID)

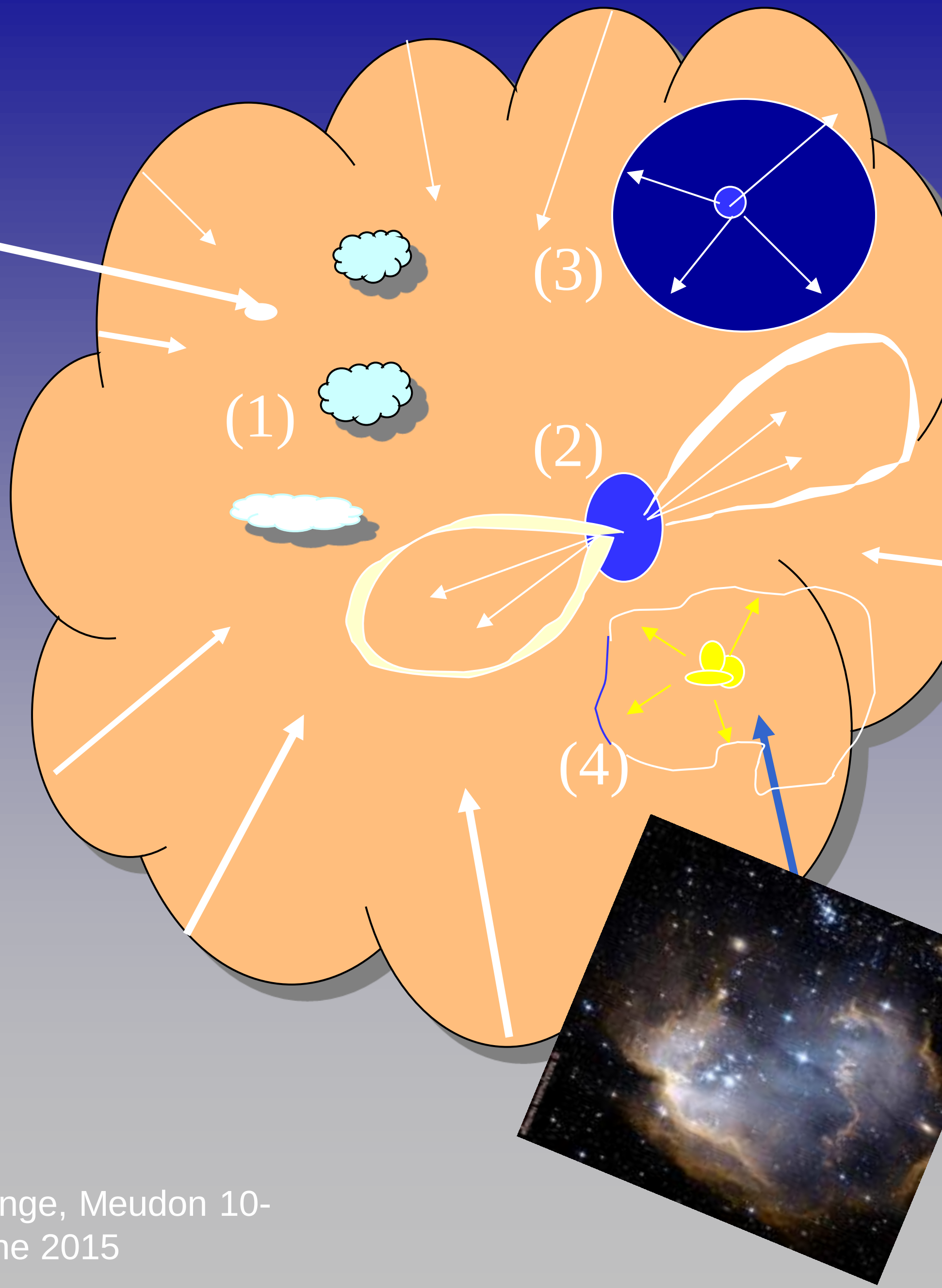
Scheme of star formation
in a molecular cloud (H2, CO,..)

(1) Cold dense cores

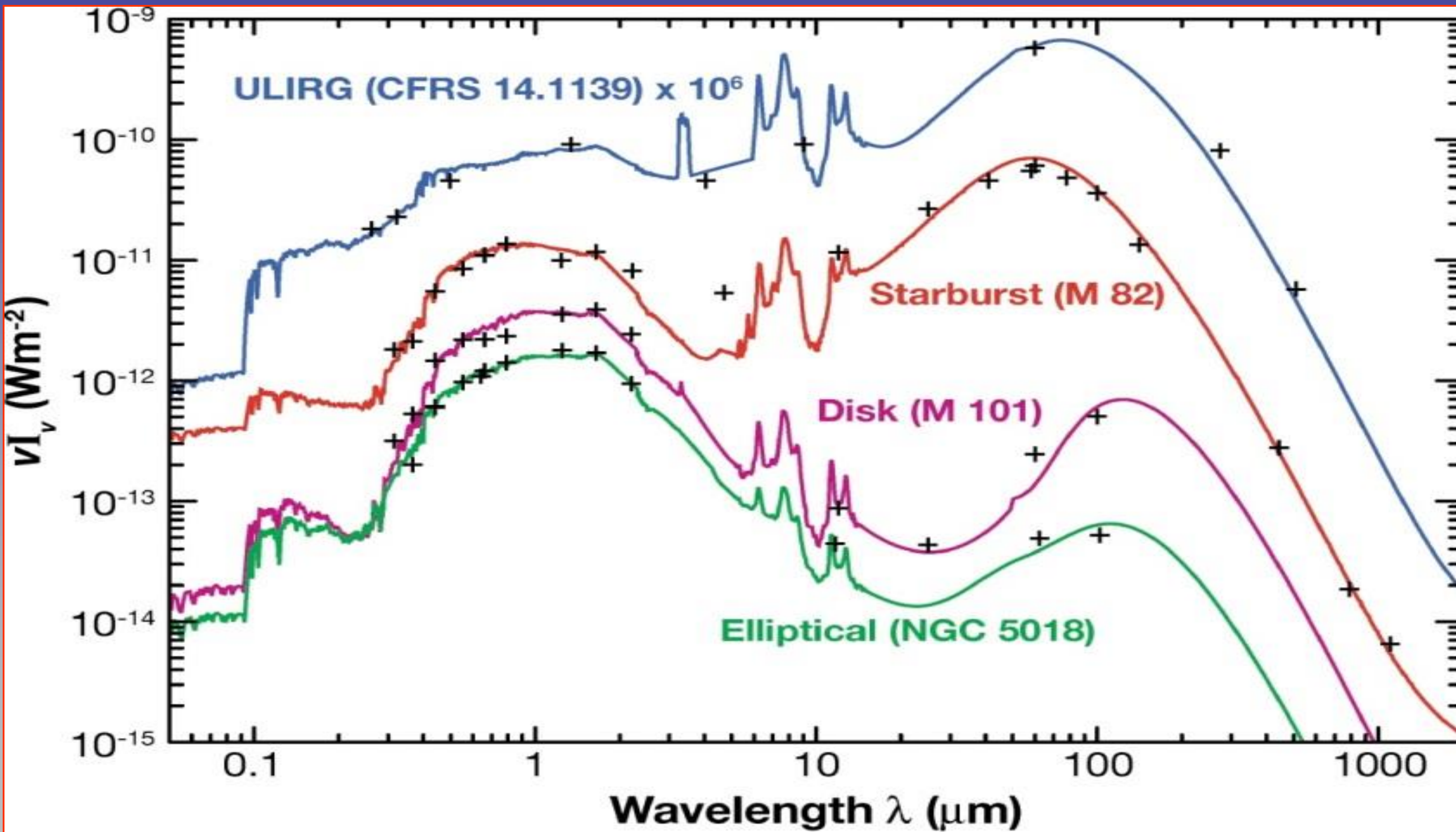
(2) Nuclear reactions triggering young star and bipolar fluxes

(3) UV photon Emission. de Photons
UV ionizing and winds from young stars
= HII REGION HII

(4) Stars in clouds
Molecular, Bok Globule



BUT Highz galaxies
Hubble sequence + ULIRGs



Lagache, G et al. 2005
Annu. Rev. Astron. Astrophys. 43: 727–68

At all z, apparent magnitudes

$$m_\lambda(z,t_{obs}) = M_\lambda(z=0,t_0) + k_\lambda(z) + e_\lambda(z) + (m-M)_{bol} + A_\lambda$$

Rocca-Volmerange & Guiderdoni, 1988, AA

k- (expansion) corrections

$$k^i_\lambda(z) = M^i_\lambda(z,t_0) - M^i_\lambda(0,t_0)$$

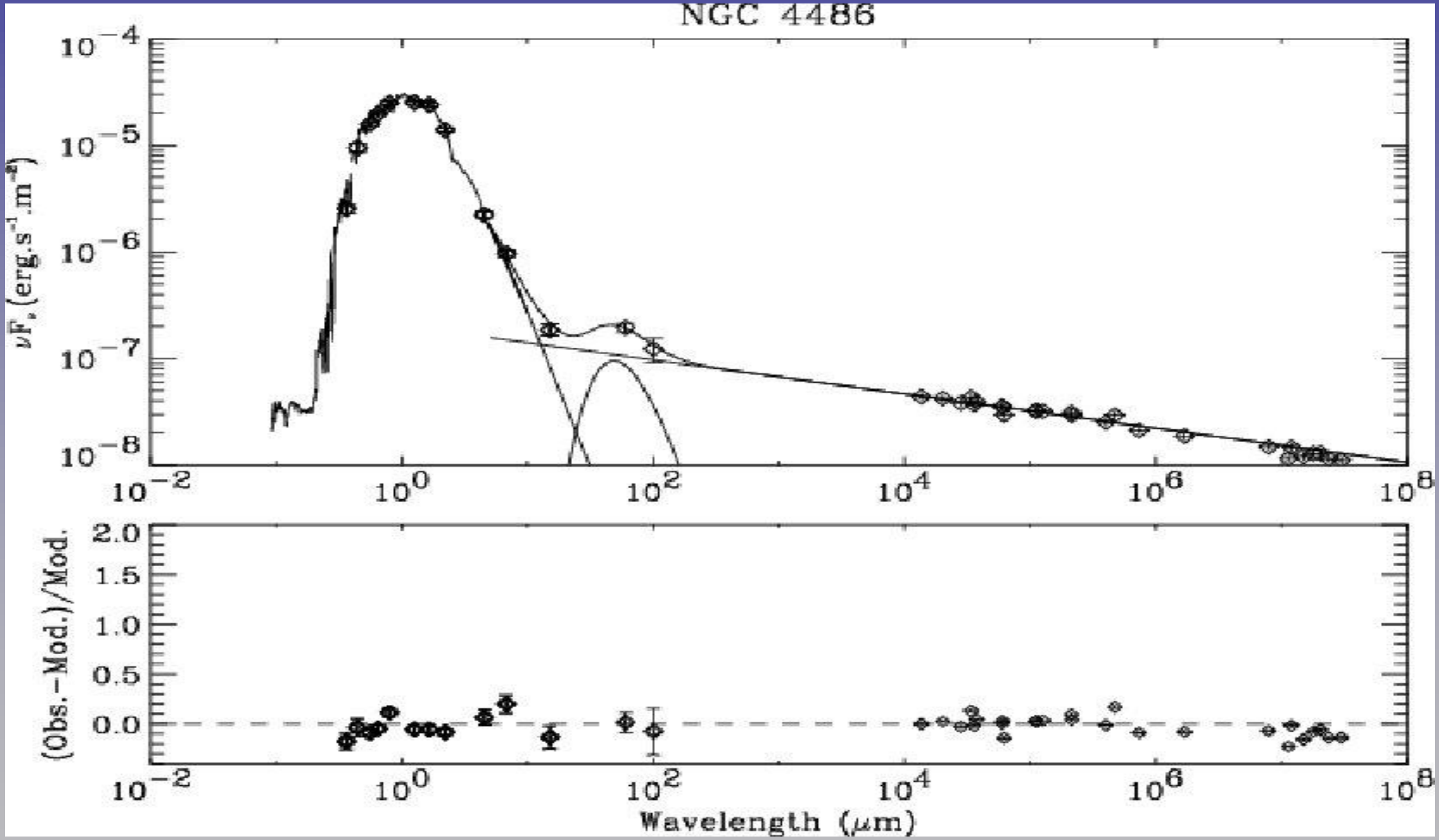
e-(evolution) corrections

$$e^i_\lambda(z) = M^i_\lambda(z,t_z) - M^i_\lambda(z,t_0)$$

Computed with F^i_λ=synthetic flux from library models through the pass-band of the filter λ **Rocca-Volmerange & Guiderdoni, 1988, AA**

THE CASE OF ELLIPTICALS

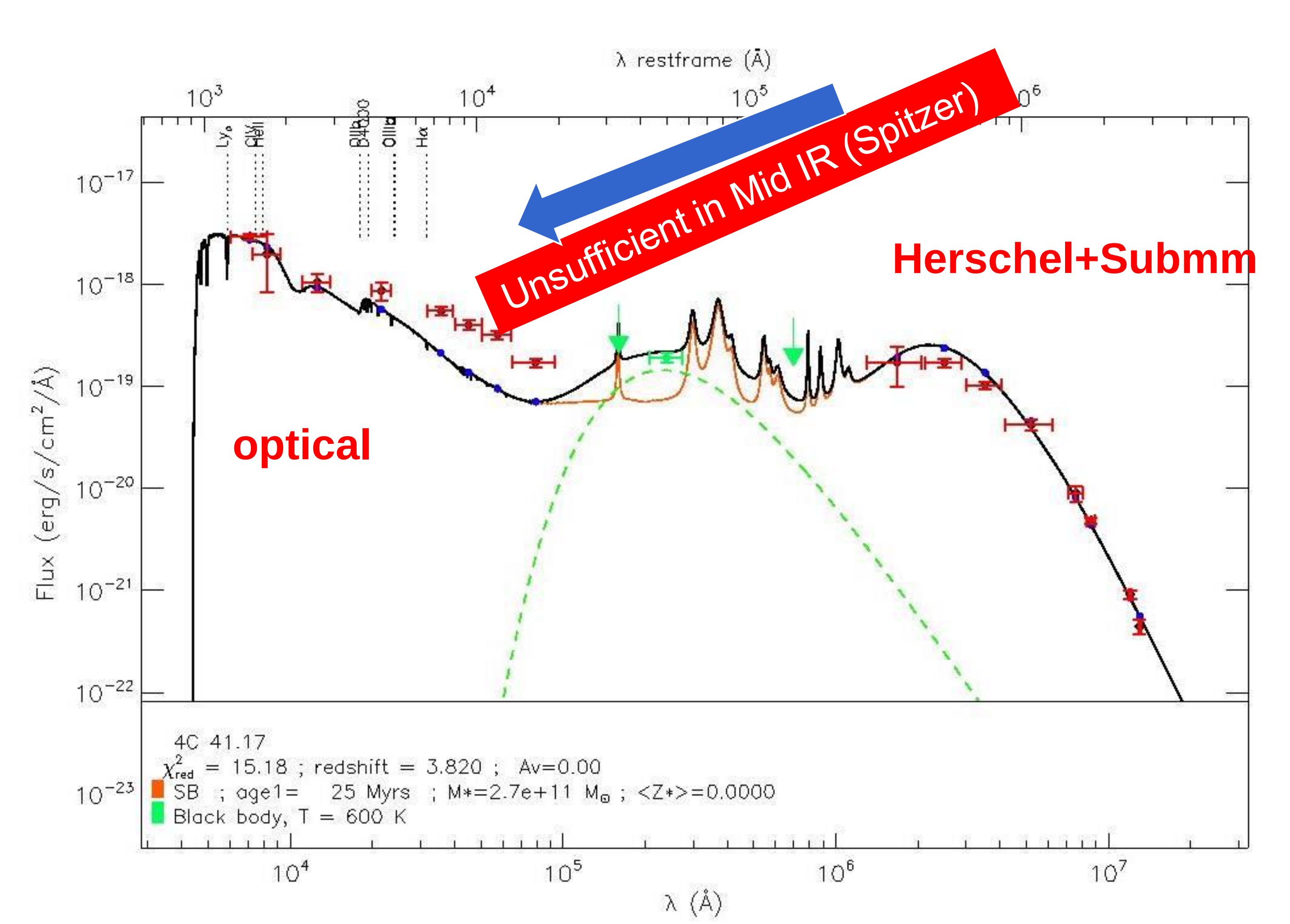
Local massive ellipticals dominated by the 1mu peak, faint in the far Infrared



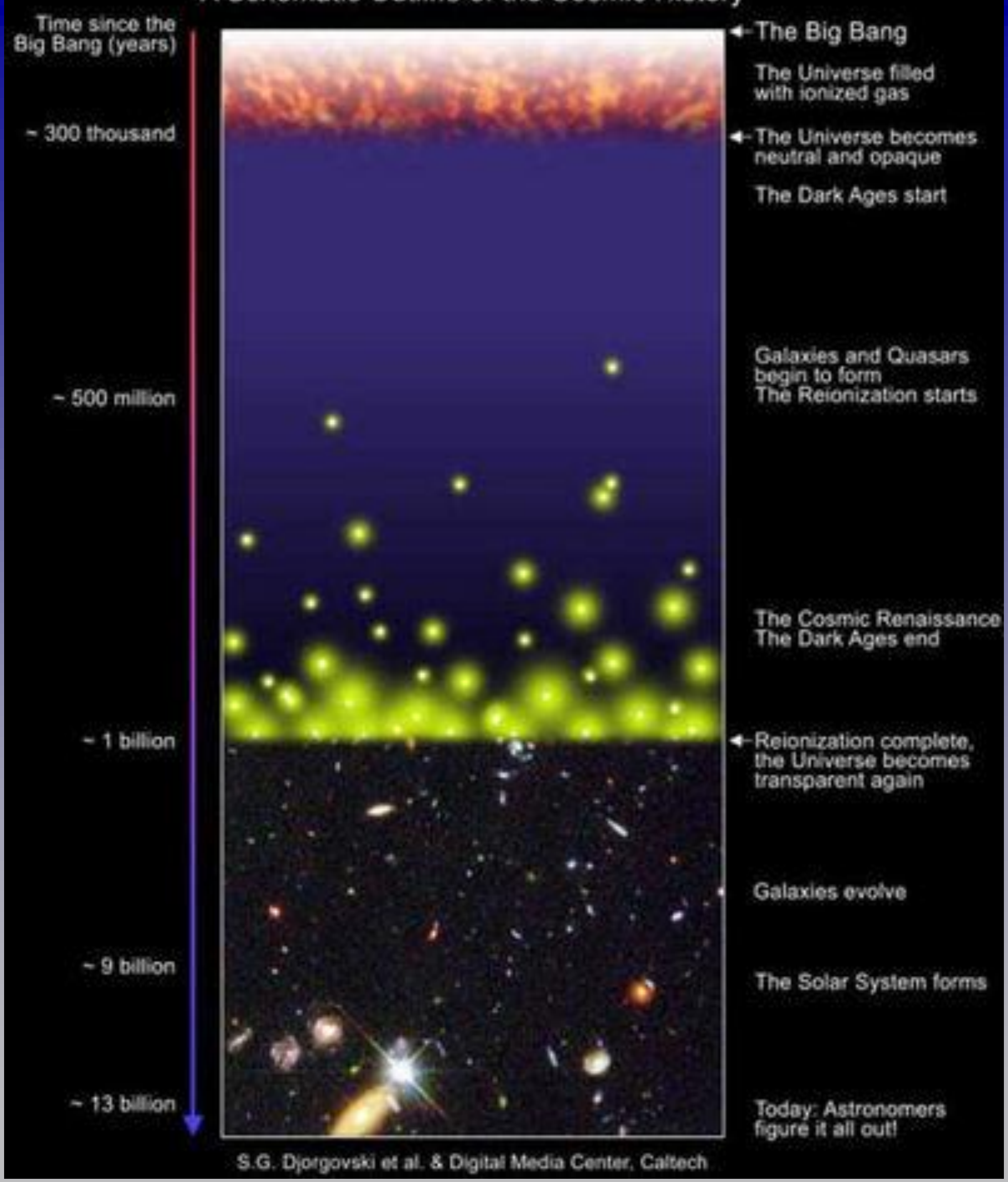
Xilouris et al., 2003,Temi et al, 2004

Raleigh-Jeans distribution of the K-M stellar population
Minor peaks @ 50K and 20K

4C41.17 @ z=3.8
One starburst component
25Myr + AGN

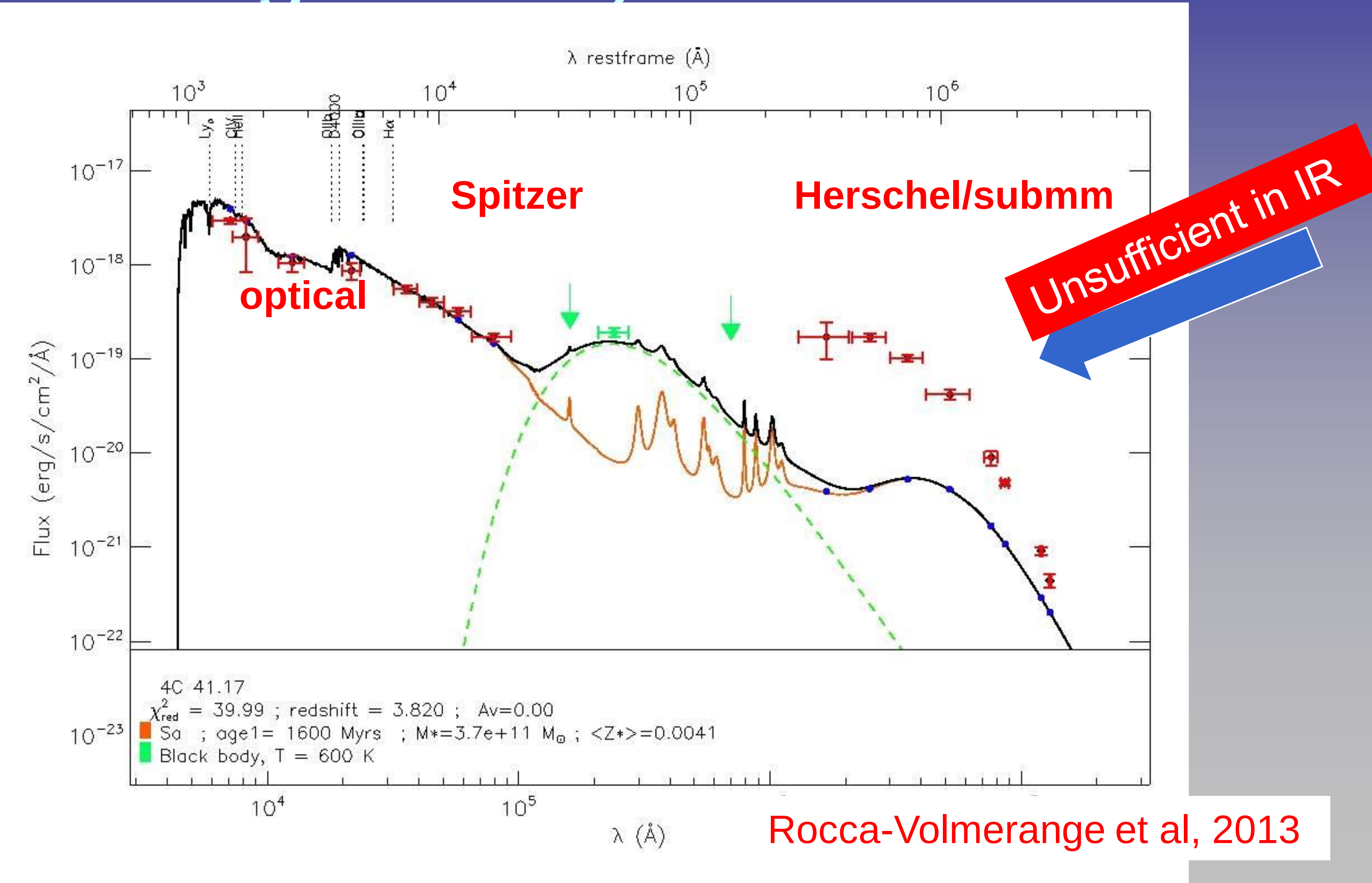


Cosmology pattern



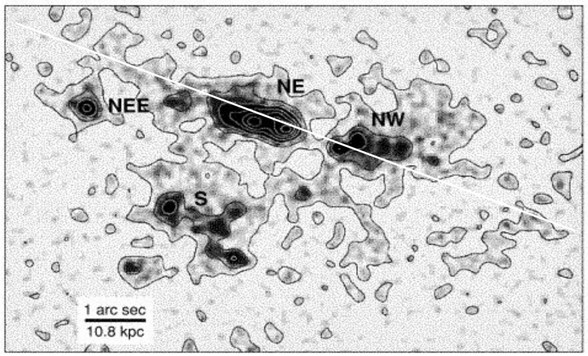
z	Cosmic time
5	**1.2 Gyr**
2	**3.5 Gyr**
1	**6.1 Gyr**
0	**14.5 Gyr**

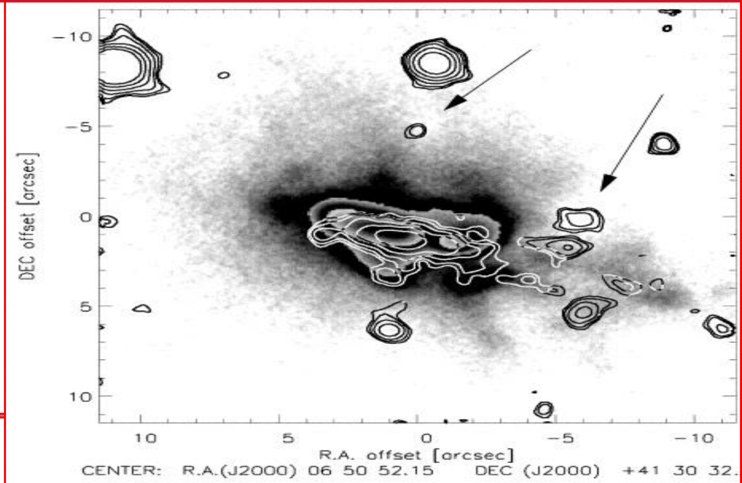
4C41.17 : One early type component Sa age 1.6Gyr + AGN

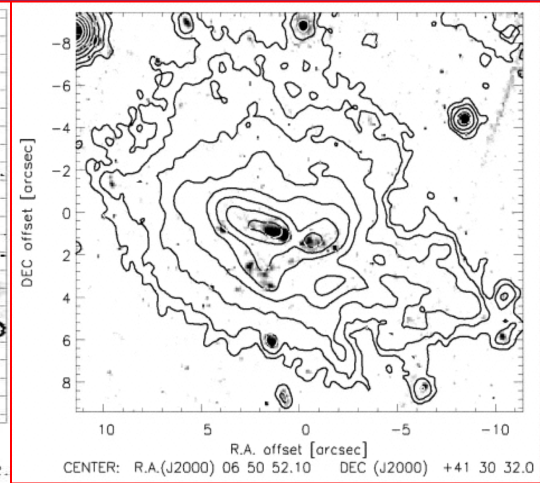


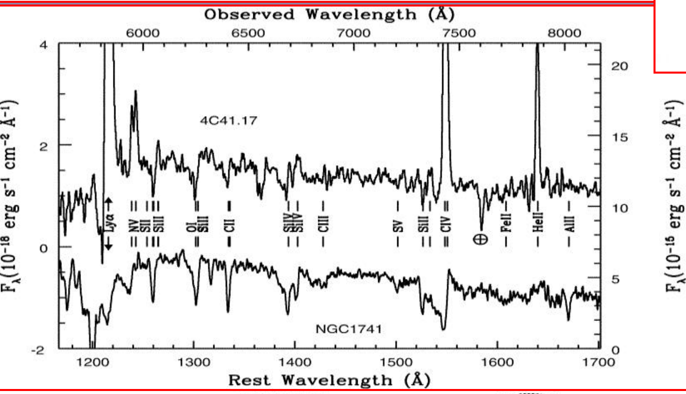
Rocca-Volmerange et al, 2013

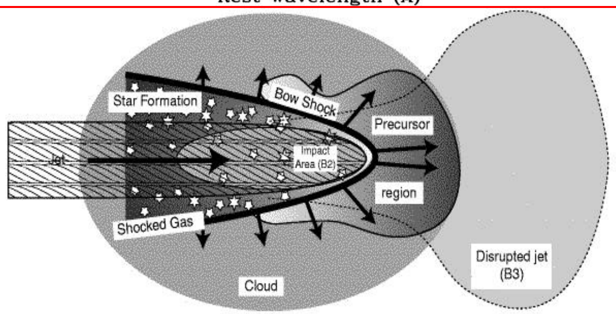
The template distant radio galaxy 4C41.17 (z=3.8)











▪Huge Lyα Clouds of 100-200 kpc of ionized gas (cocoon) (Dey et al, 1997, Van Breugel et al, 1999, Reuland et al, 2003).

▪HIGH-z RADIO GALAXIES are hosted by **MASSIVE ELLIPTICALS** (van Breugel et al, 1998, Penterricci et al, 2001)

Stellar lines are detected along the radio axis (Dey et al, 1997), as WR starbursts

▪**Star formation along the radio jet** and south-East component, Bicknell et al, 2000

TWO stellar COMPONENTS are required for 4C41.17

Starburst at 30Myrs + Elliptical at 700Myrs +AGN (600K)

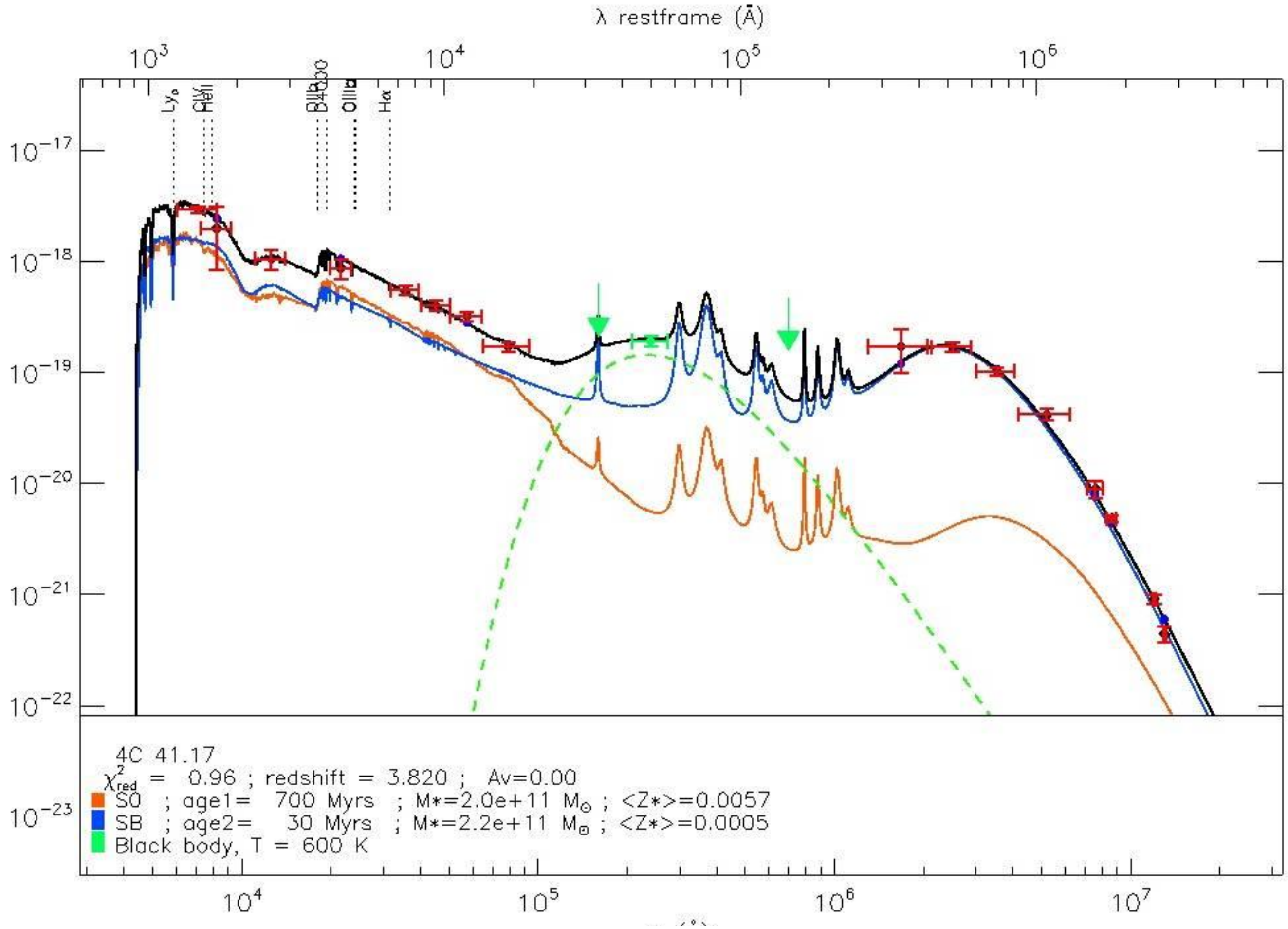
Excellent $\chi2=0.96$, huge masses 10 ^11 M₀, low Z

Observations (red points from Hergé)

Starburst :dark blue

Evolved : orange

AGN model : green Dashed, Pier& Krolik model



Rocca-Volmerange et al, 2013, MNRAS, 429, 2780

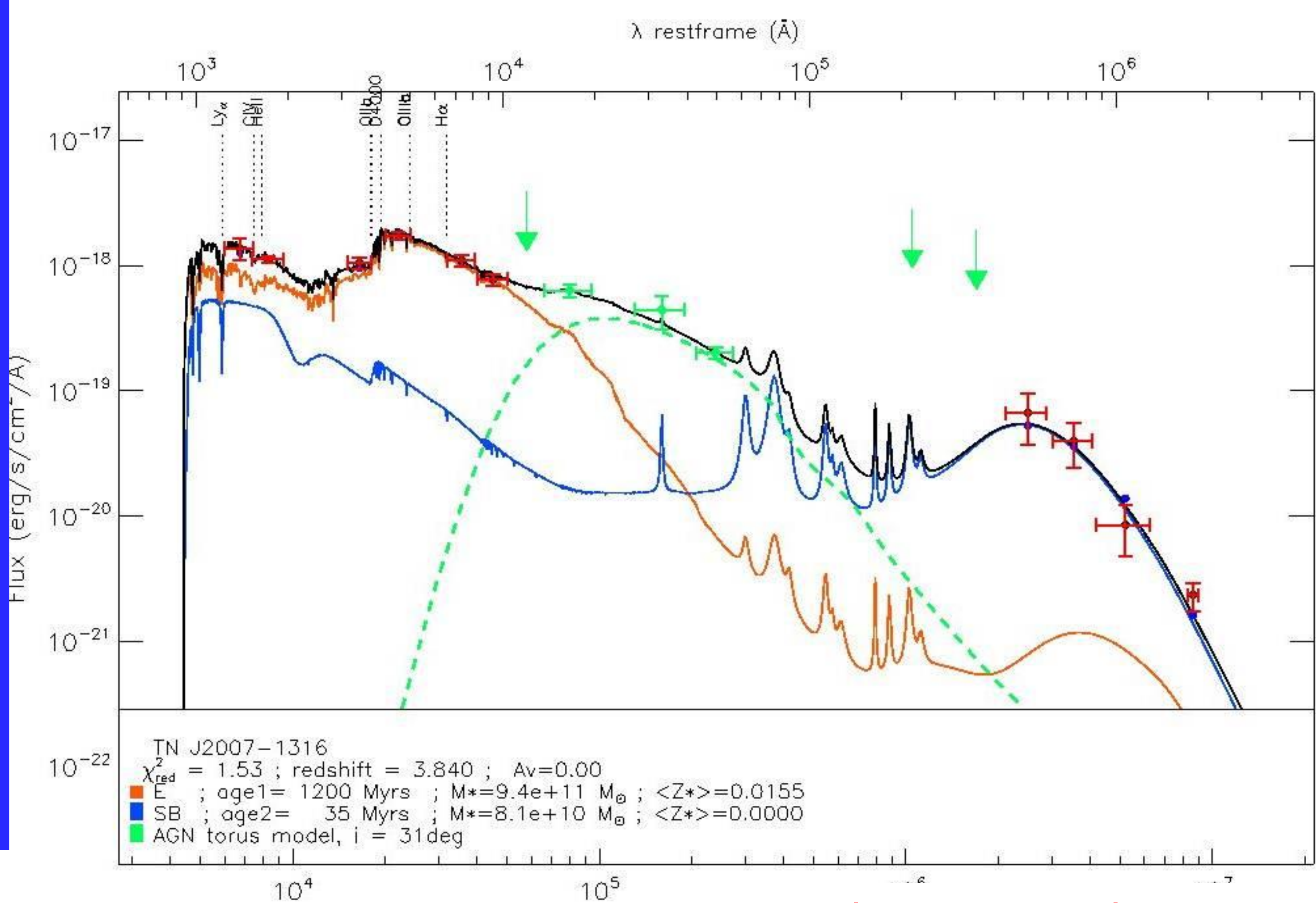
TN J2007-1316 (z=3.8) Two stellar components:
+ SO/Elliptical at age 1200Myrs
Starburst at age 35Myrs

AGN model
Pier & Krolik
(dashed green)

Old Elliptical
At 1.2 Gyr
(red line)

A starburst
At 35 Myrs
(dark blue)

Green arrows :
Superior limits



Rocca-Volmerange et al, 2013

2d conclusion

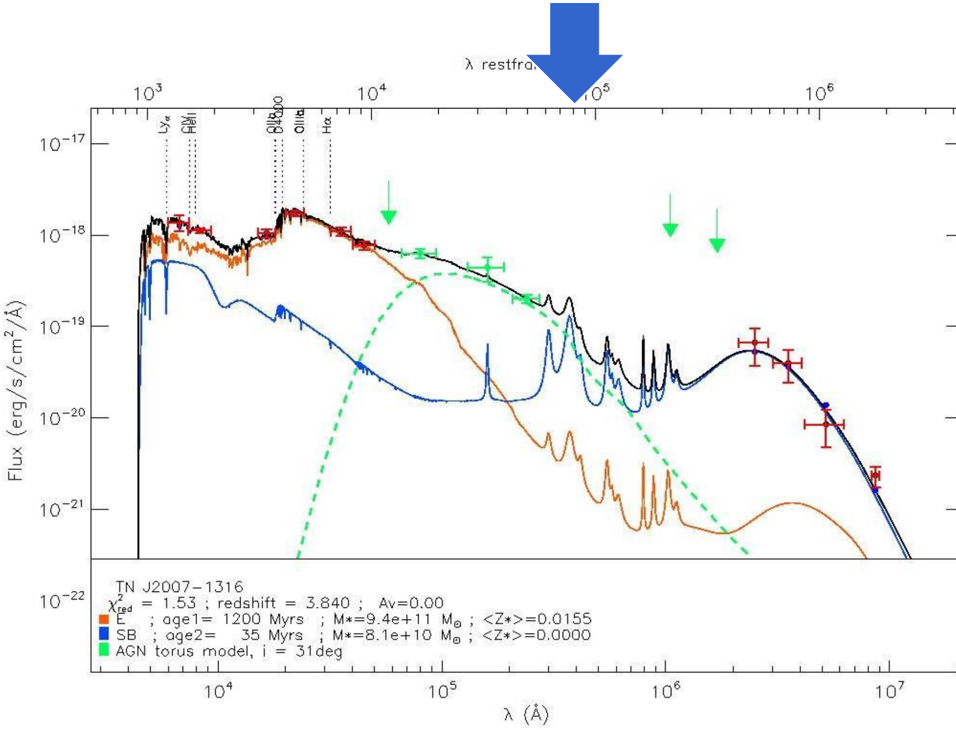
Starburst (optical + FIR) + old evolved (mid-IR)

- **Both are highly massive**

- **Medium density**
- **10^{22-23} part/cm2 (x10 NHI ISM)**

- **Low Z metallicity**

- **MERGING**
- **or jet cloud INTERACTION**



Primeval galaxies : Conclusion

Early-type population (1μ m peak) at z= 3.8

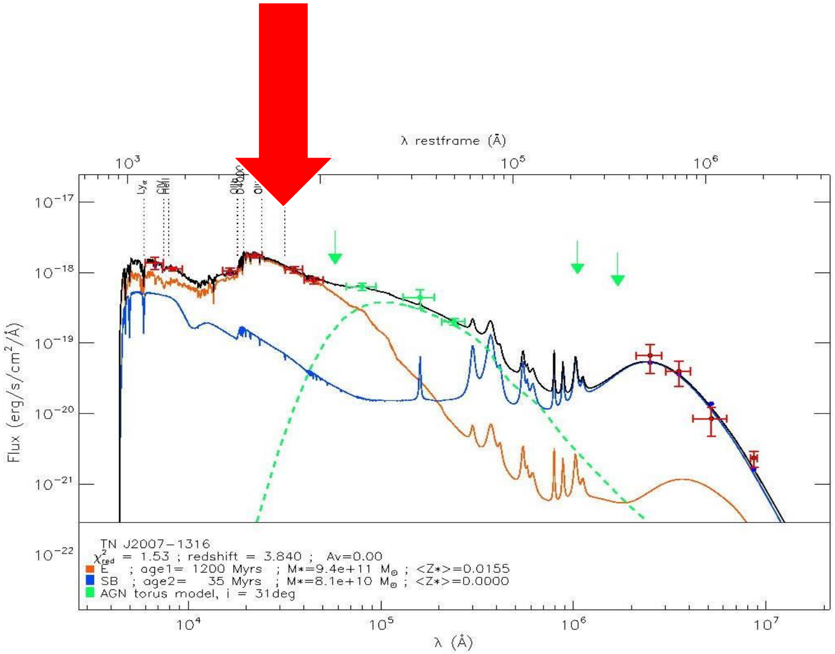
discovered in Spitzer data

already discovered in K-z diagram

(RV et al, 2004)
10^12 M0 stellar masses

And

In the red sequences of clusters

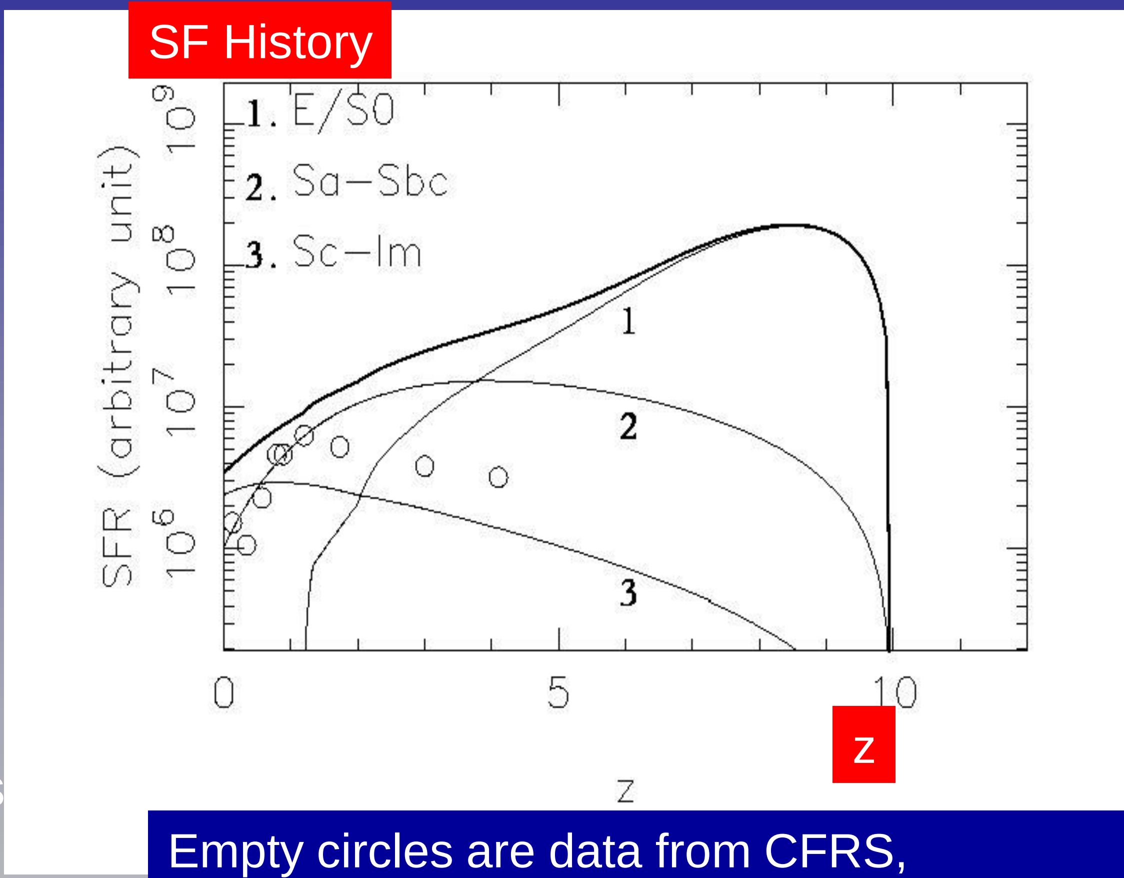


Metallicity Z is O.OO5, compatible with early-type scenarios.

Consequences on cosmic SF history

(1) The star formation history is dominated by ellipticals at early epochs (z=10 or more).

(2) **Rapid increase of SF for spirals 0<z<1** , comparable
To CFRS results
(Le Fevre et al, 1998):
CFRS is selected on Sa spirals



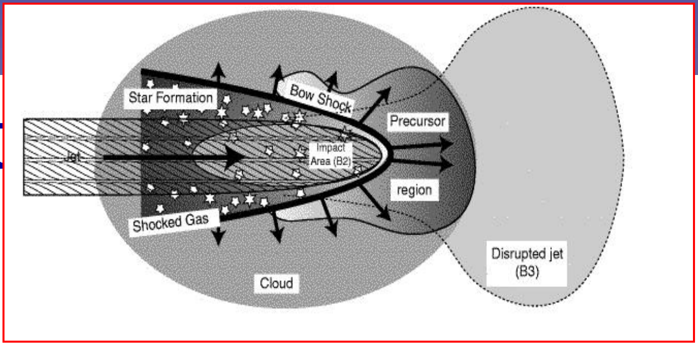
Empty circles are data from CFRS,
Deep survey selected on Spiral Sa galaxies

(3) Dwarfs contribute to SFH at low z

These sources are not ULIRGs induced by galaxies in interaction. All are compatble with deep UV-optical-NIR counts

Star formation by Merging or jet_cloud interaction

- Issued from jet-cloud int



(Bicknell et al, 2000)

The formed stellar mass Is too huge to form in a so narrow zone

- The most likely process is a gas-rich merging of mass ratio ~1 to 1/10, triggering an extremely short starburst in a dense medium

The intense star formation rate is >10^4 M0/yr during 1 Myr

So short time scale would correspond to the short time scale of the embedded super massive black hole

Synthetic synthesis method

-LIBRARIES OF STARBURSTS at all ages, various IMF,

-LIBRARIES OF ELLIPTICALS, SPIRALS and IRREGULARS

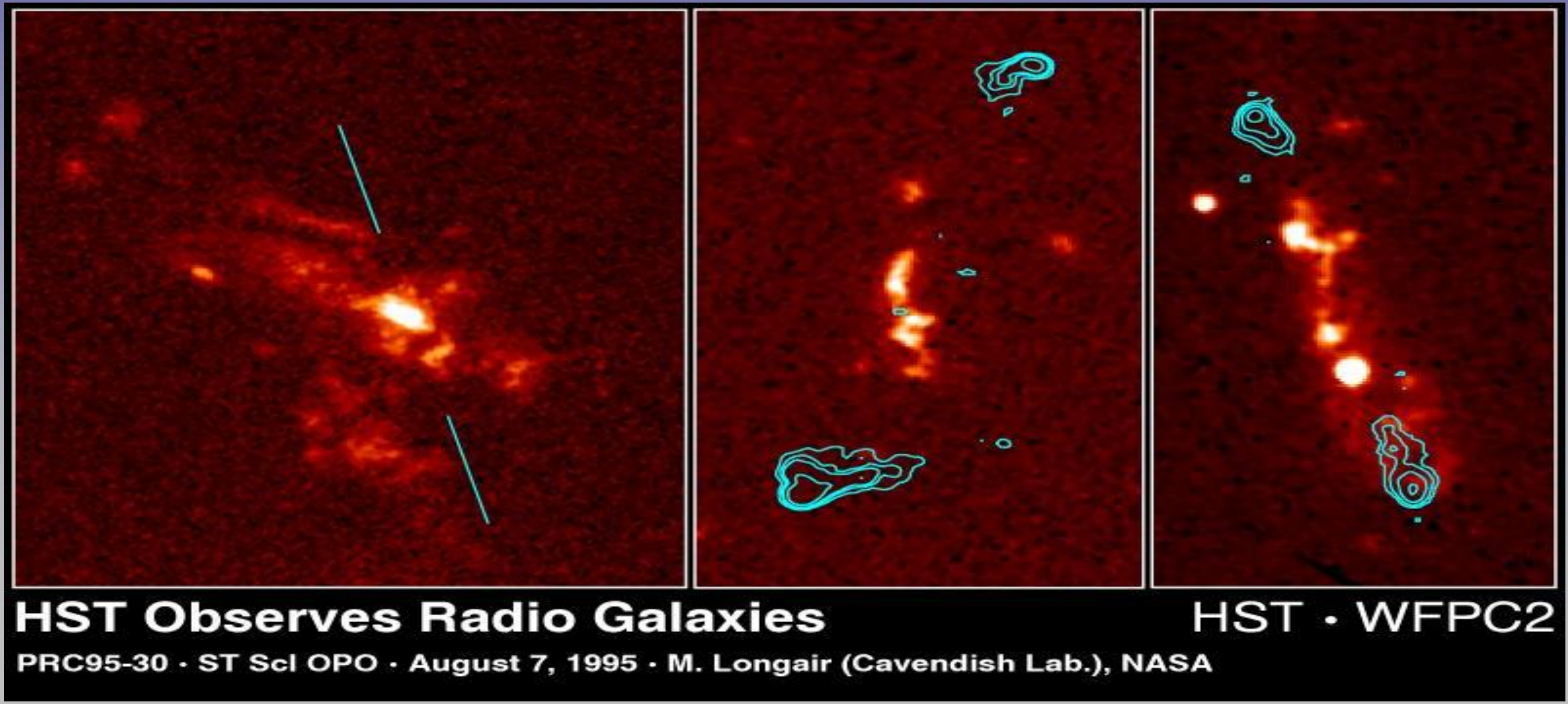
- **A $\chi 2$ minimization method on the global coverage of the SEDs**

- **A selection of 2 radio galaxies at the same z=3.8**
- **Faint radio power**
- **Evidence of star formation**
- **Observations Herschel + Spitzer + K and optical**
- **Calibration and aperture checked**

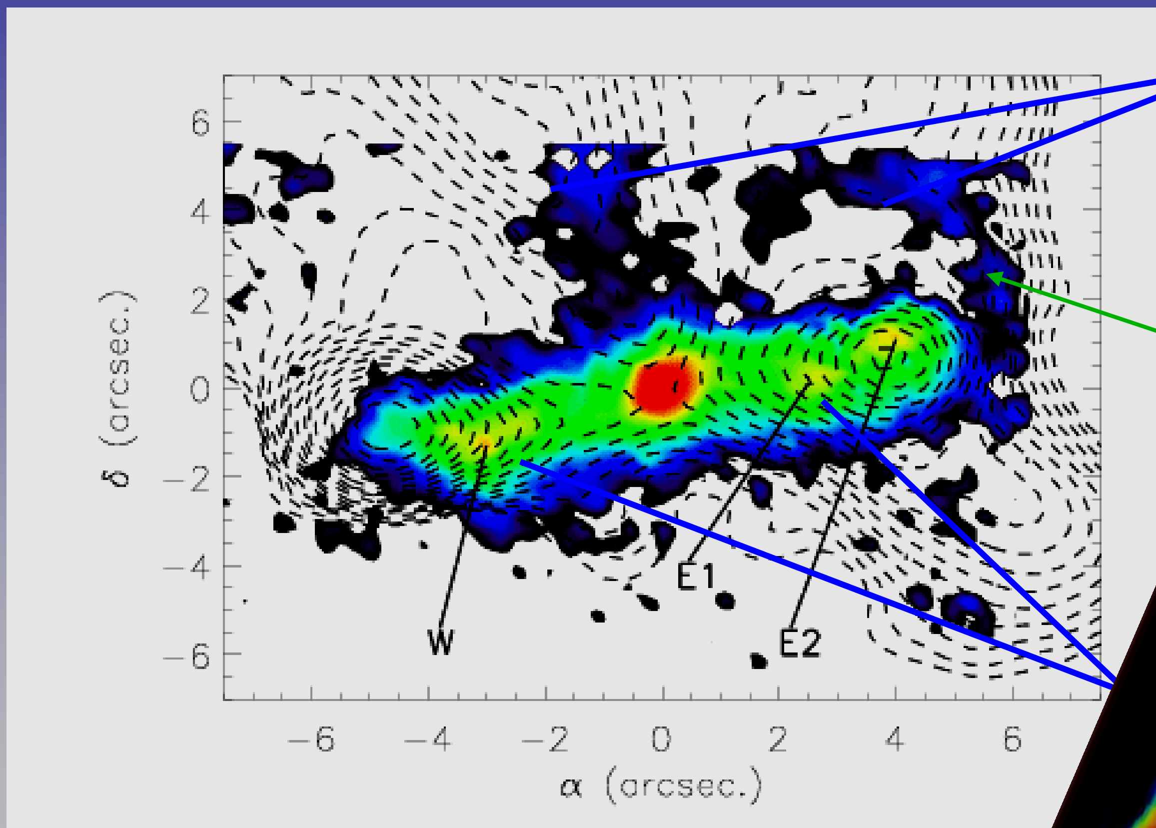
OUTPUTs: $\chi 2$ minimum, types, ages and masses of the 2 components

Moreover high-z radio galaxies (hosted by ellipticals) reveal activity of star formation

- Powerful , ultra distant 1<z<7,
- STELLAR, nebular and AGN emissions



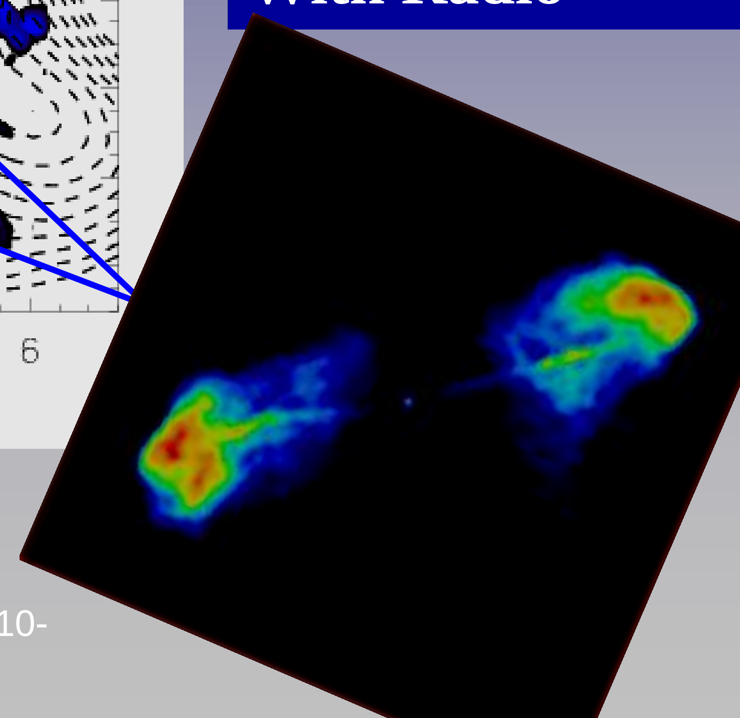
Extension of the Hα cocoon
Of the FR-II radio galaxy 3C171 (z=0.286)



Sharp Emission a
cocoon boundarie

Narrow coupling

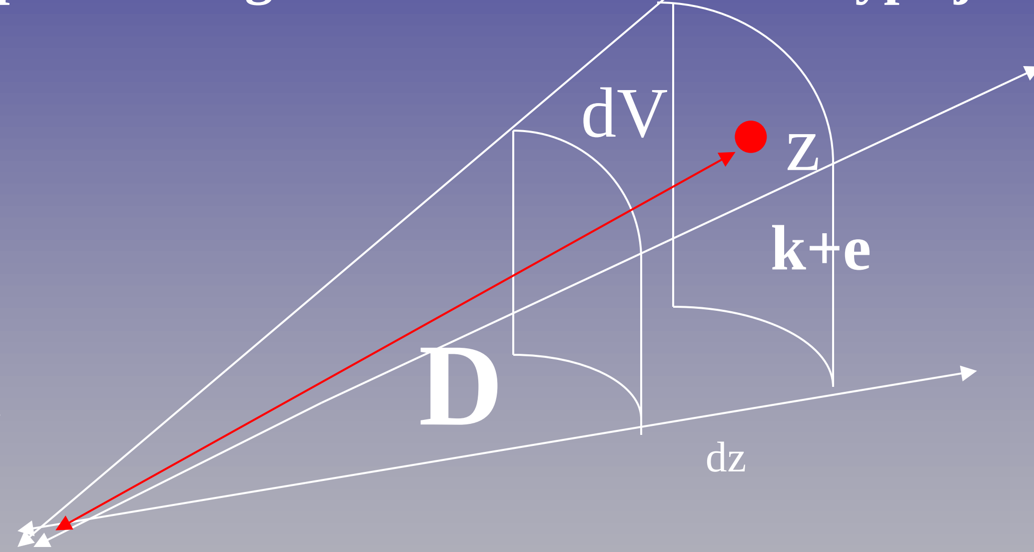
With Radio



Modélisation des comptages

$$d^2 A_j(m_\lambda, z) = \Phi_j(M^j{}_\lambda(z))(1+z)^3 \frac{dV}{dz} dm_\lambda dz$$

Galaxy Number density by apparent magnitude mλ and z bin of type j



$$\Phi_j(M^j{}_\lambda(z))$$

z=0 luminosity function by type j for filter λ

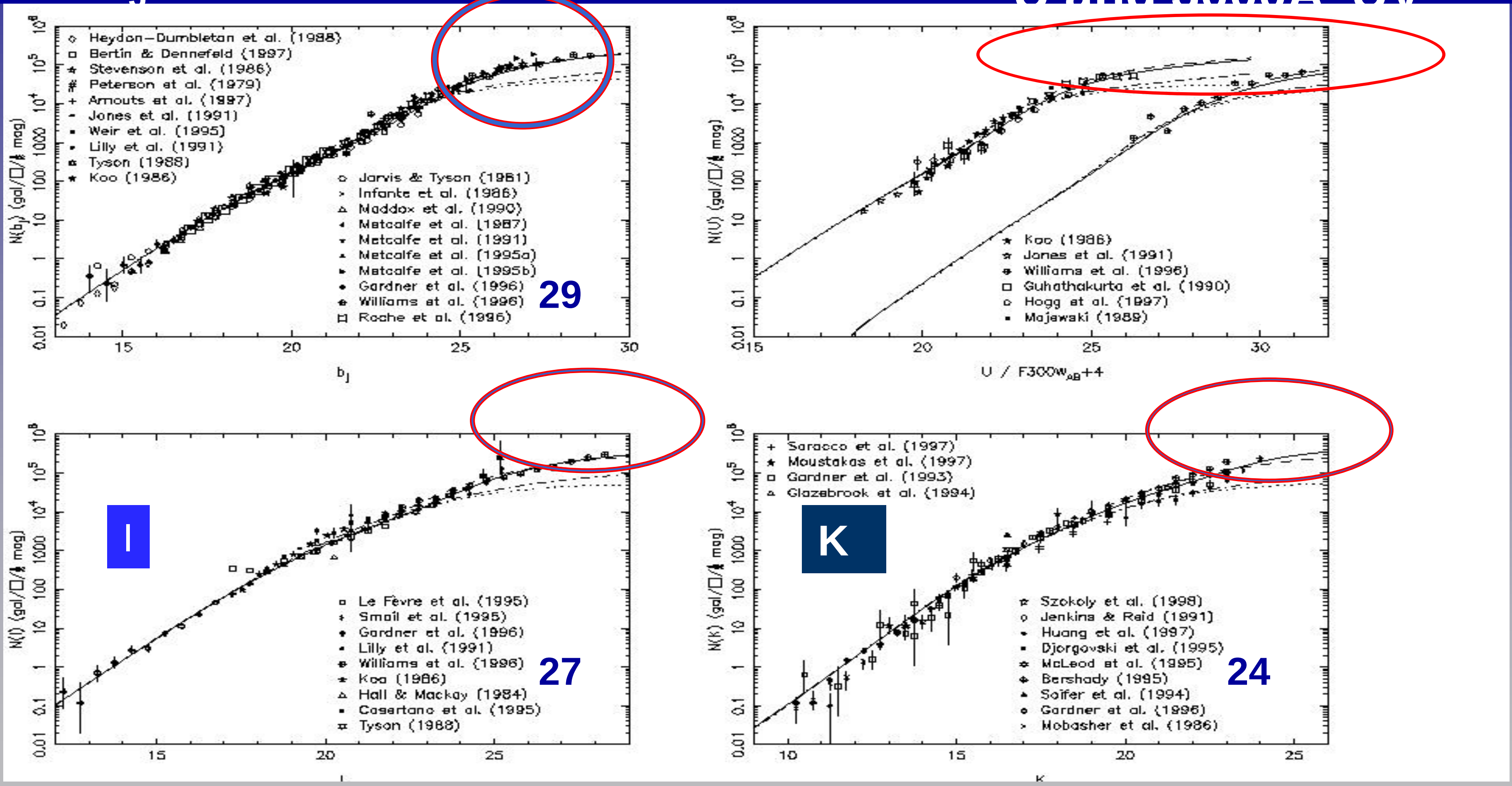
$$m^j{}_\lambda(z) = M^j{}_\lambda(z=0,t_0) + k^j{}_\lambda(z) + e^j{}_\lambda(z) + (m-M)$$

k- and e- corrections are computed from synthetic spectra for all scenarii and all z

Multi-lambda modeling faint galaxy counts: UV—OPTICAL--NIR with evolution scenarios by types

Fioc and Rocca-Volmerange, 1999, AA,344,393

b_J BLUE **U and 3000A UV**

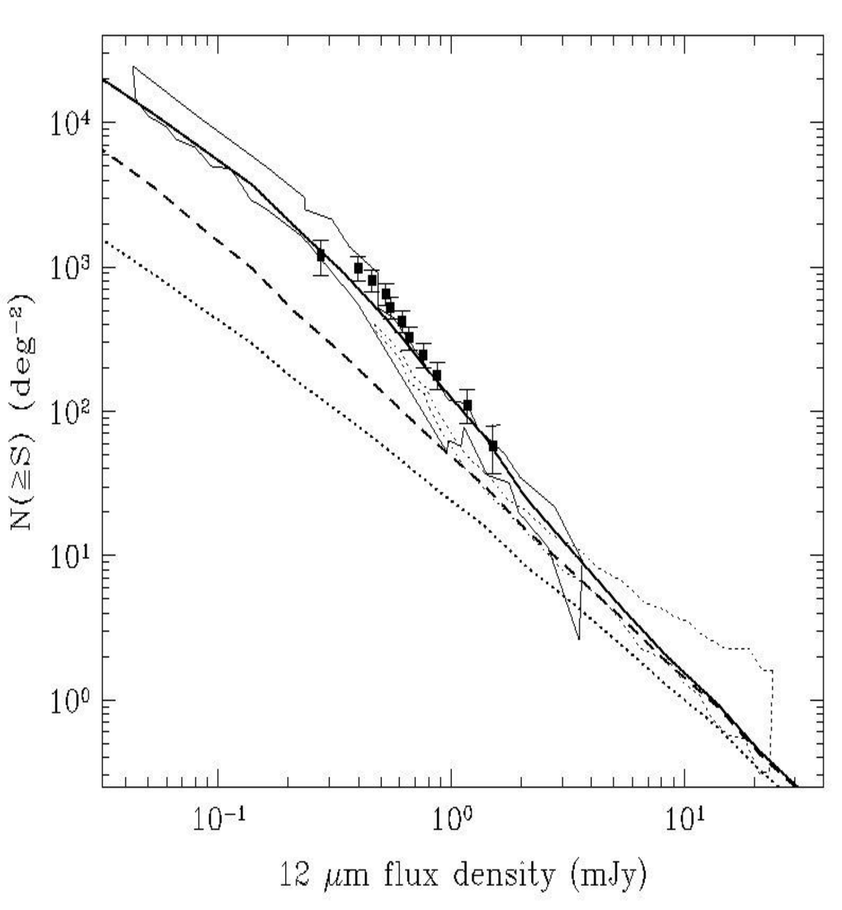


Galaxy population fractions : ELLIPTICAL (26%) :Sa+Sb+Sbc (24%) Sc+Sd+Im (50%)

Confirmed by 9% of IR Ultraluminous Ellipticals (RG and/or AGNs?) to explain the typical IR bump ,all other galaxies are normal Hubble Sequence galaxies

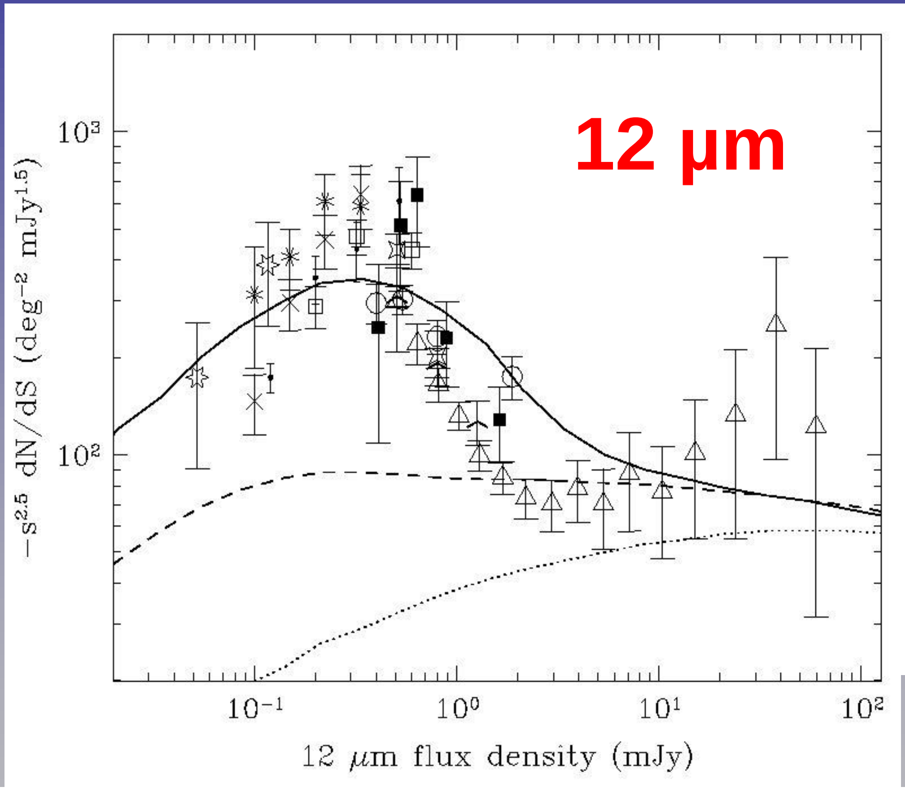
Model: Rocca-Volmerange, de Lapparent, Seymour, 2007

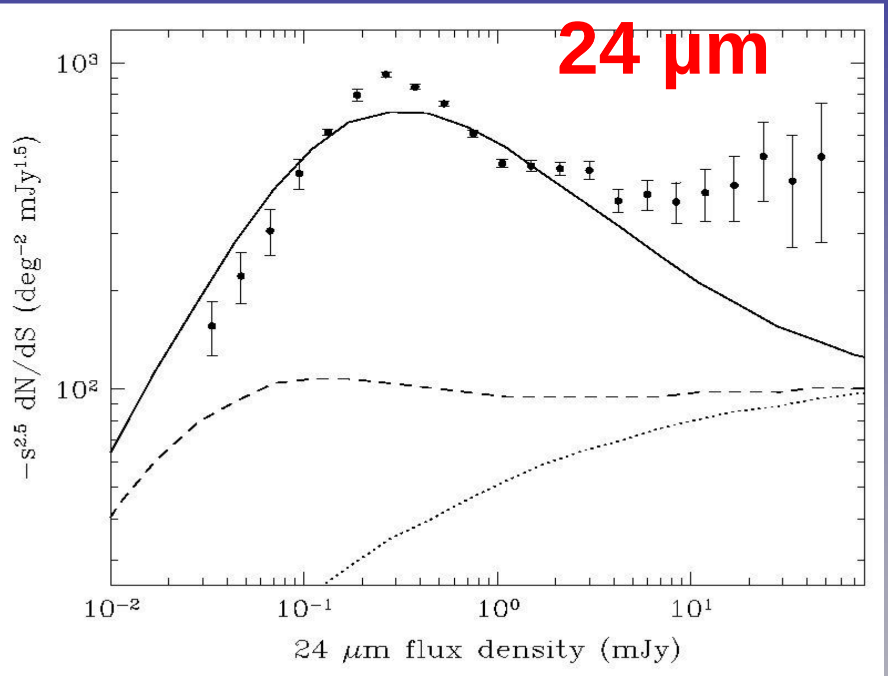
Number Fraction	Type	Magnitude M*
9%	**ultra-bright ellipticals**	**Normal -2.5**
15%	normal ellipticals	model color IRAS LF
24%	Early Spirals	//
50%	Late Spirals	// IRAS LF



Full line: k+e corrections, dashed line: k- corrections, dot line: comoving v

The galaxy population IR excess 12-15 and 24 um discovered in the ISO and Spitzer faint counts is due to 9% of IR Ultra-Luminous massive





(Rocca-Volmerange, Seymour, de Lapparent , 2007, AA)

Full line: expansion + k + e corrections,
dashed line: expansion + k- corrections,
Dotted line: expansion Standard Cosmology (Ω_M=0.3, Ω_Δ=0.7)

And Evolution of self-gravitating gas cloud with dissipation
Rees & Ostriker, 1977

2 time-scales are in competition

$$t_{ff} = \frac{1}{\sqrt{G\rho}}$$

- the free_fall time scale (dynamics)

- the cooling time scale (radiation)

$$t_{cooling} = \frac{1}{\rho\Lambda(T_G)}$$

fonction $\Lambda(T_G)$ is the cooling function depending on atomic properties

2 régimes are possible. They depend on the cooling function

$t_{ff} > t_{cooling}$ cloud fragmentation

$t_{ff} < t_{cooling}$ quasi-static evolution of the cloud

Conclusions

Evolutionary synthesis: in the observer's frame:

- (cosmology + active and passive evolution)
- Local templates + distance + k+ e corrections

Hubble Sequence types + Starburst Evolutions

Radio galaxies are the most distant and massive galaxies
Confirmation of massive early type galaxy hosts
In the K-z diagram (Rocca-Volmerange et al, 2004)
And the fragmentation limit 10^12 M0