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Does star formation play a decisive role in active galactic nuclei fueling?

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Some AGNIFS members

Some LLAMA members

Motivation

✓ Current models and simulations of gas inflows around galaxy nuclei lead to episodes of circumnuclear SF (e.g Heckman+14, Kormendy+13, Zubovas+17 , also talk by Marc Schartmann).

✓ There is no consensus on whether AGN fueling occurs:

- simultaneously with SF (e.g. Kawakatu+08)
- during a post-starburst phase (e.g. Cid Fernandes+05, Davies+07,09)
- not associated with any recent SF (e.g. Hicks+13, Sarzi+07)

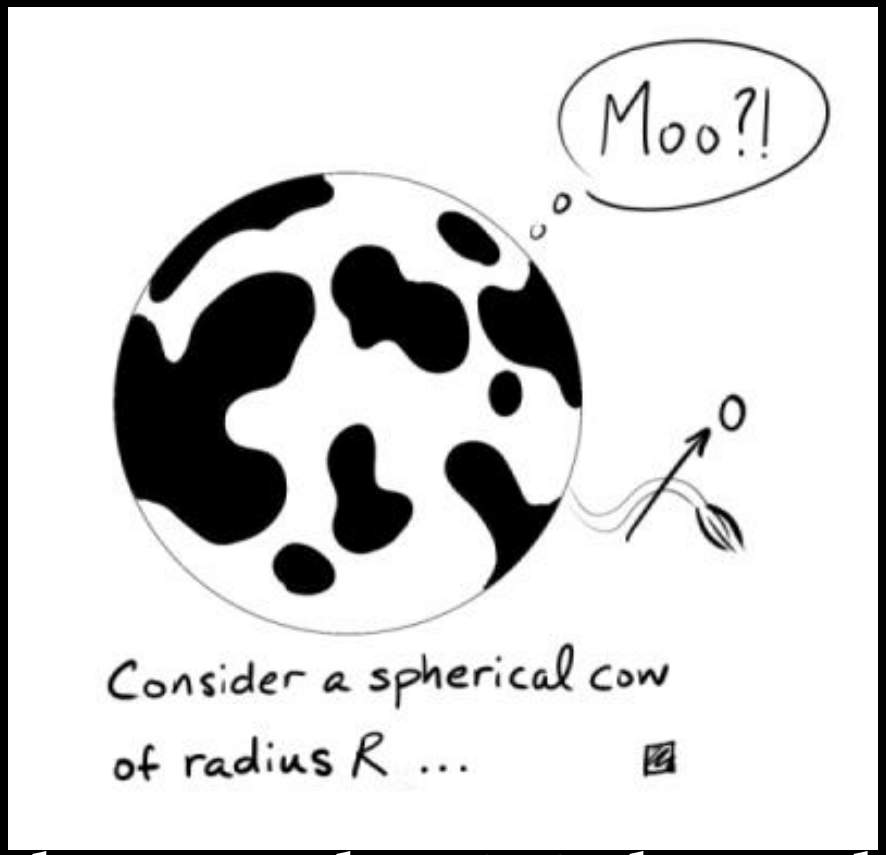
✓ A way to test for this is to access the inner pc stellar population of the AGNs hosts using NIR (0.8-2.4 μm), why?

Because it is possible to study - in a single shot - the 3 main AGN SED components in the NIR (e.g. Martin Ward's talk);

Main NIR SED components

Put here your favorite U.M. cartoon here:

My daughter likes the spherical cow model ....



The unified model for AGNs
(Antonucci & Miller, 1985)

1- Stars;
(Bulge)
2- Power Law;
(SMBH - AGN)
3- Hot Dust;
(Dust emission)

and remember it is hosted by a galaxy.

Motivation

✓ The NIR stellar content of active galaxies are still poorly known;

• Some studies based on: Brγ emission and/or 2.3μm CO bands (e.g. Rieke et al., 1980; Origlia et al., 1993; Oliva et al., 1995, Lançon et al., 2001, Davies+07);

• Some studies based on the fitting of the whole NIR spectra (e.g. Riffel+, 2007, 2008, 2009, 2010, 2011,2015, Martins +, 2010, 2013, Storchi-Bergmann +2012, Dametto+2014,2018, Dahmer-Hahn+2017,2018);

✓ It is accessible to ground based telescopes and can be used to probe obscured sources.

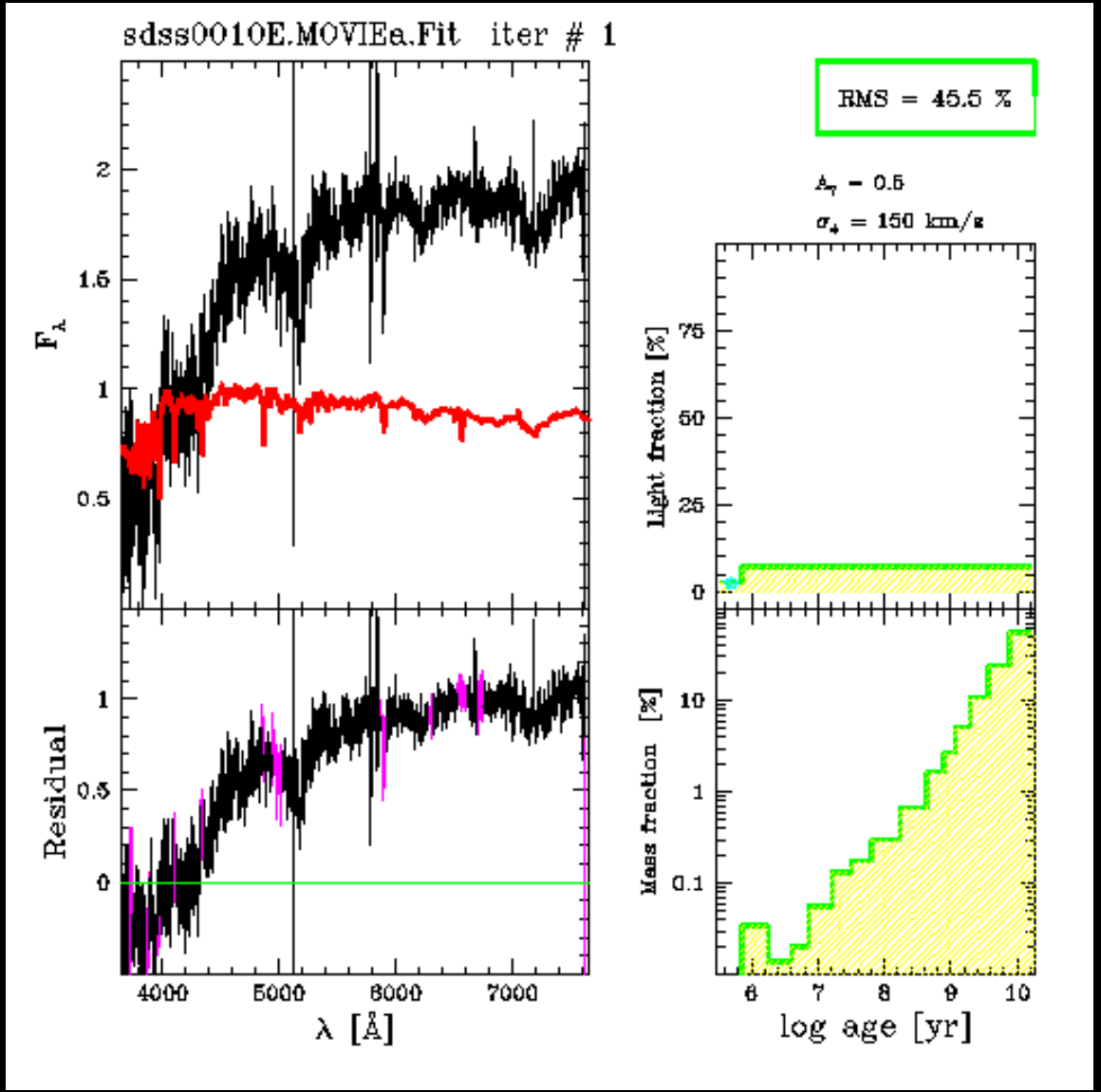
✓ The NIR host many interesting/strong stellar features (CN, CO, ZrO, TiO, among many atomic lines), that are not shined out by the AGN (at least for some type I sources) as in the optical.

Spectral Synthesis

- ✓ Synthesis code

STARLIGHT: models the whole underlying spectrum, excluding emission lines and spurious data (Cid Fernandes et al., 2004, 2005);

Courtesy of Roberto Cid Fernandes



Spectral Synthesis

- ✓ Synthesis code: STARLIGHT

- ✓ Base Set: what is used to fit the spectrum.

Stellar Population (SP): EPS models of Maraston (2005, 2011). They include the empirical spectra of TP-AGB stars and, thus, are able to predict features detected in the observations (e.g Riffel et al, 2007, 2008, 2015, Ramos Almeida, 2010, Lyubenova, 2012);

Featureless continuum (FC): Power Law of the form $F_\nu \sim \nu^{-1.5}$; represents the non-thermal contribution of the AGN (e.g. Cid Fernandes et al., 2004);

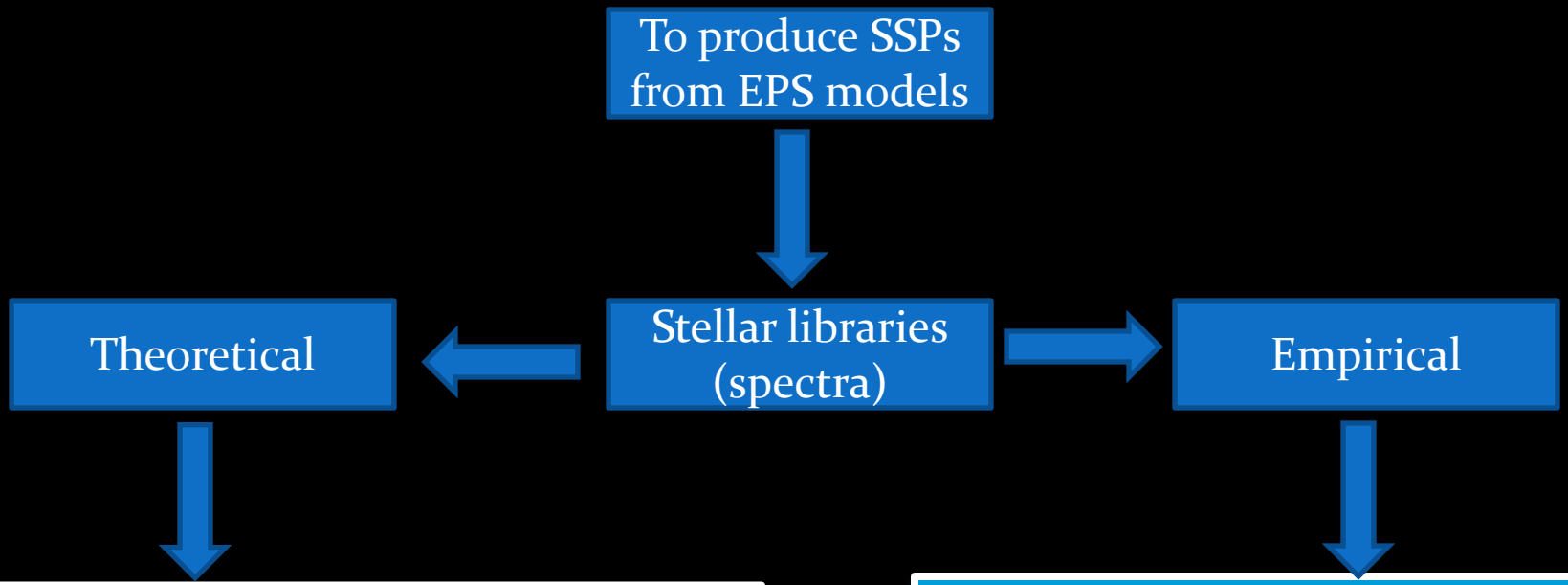
Planck distribution (BB): $700 \leq T \leq 1400$ K; to represent the hot dust.

Some issues/facts related with TP-AGB stars and galaxies stellar populations:

→These stars maybe able to dominate the emission of stellar populations with ages ~0.2 - 2 Gyr (e.g. Mouhcine & Lançon 2002; Maraston, 2005) being responsible for roughly half of the luminosity at K-band (e.g Kelson & Holden 2010) in normal galaxies.

→ The differences between the evolutionary simple stellar population (EPS) models mainly are due to the way how TP-AGB phase is treated.

Quick overview on SSPs



As result the SSP models predictions can be very different

Quick overview on SSPs

Two main 'classes'

TP-AGB 'light'
(e.g. Bruzual & Charlot, 2003)

NIR SSPs calibrated only with photometric points

Weak/no molecular features

≠

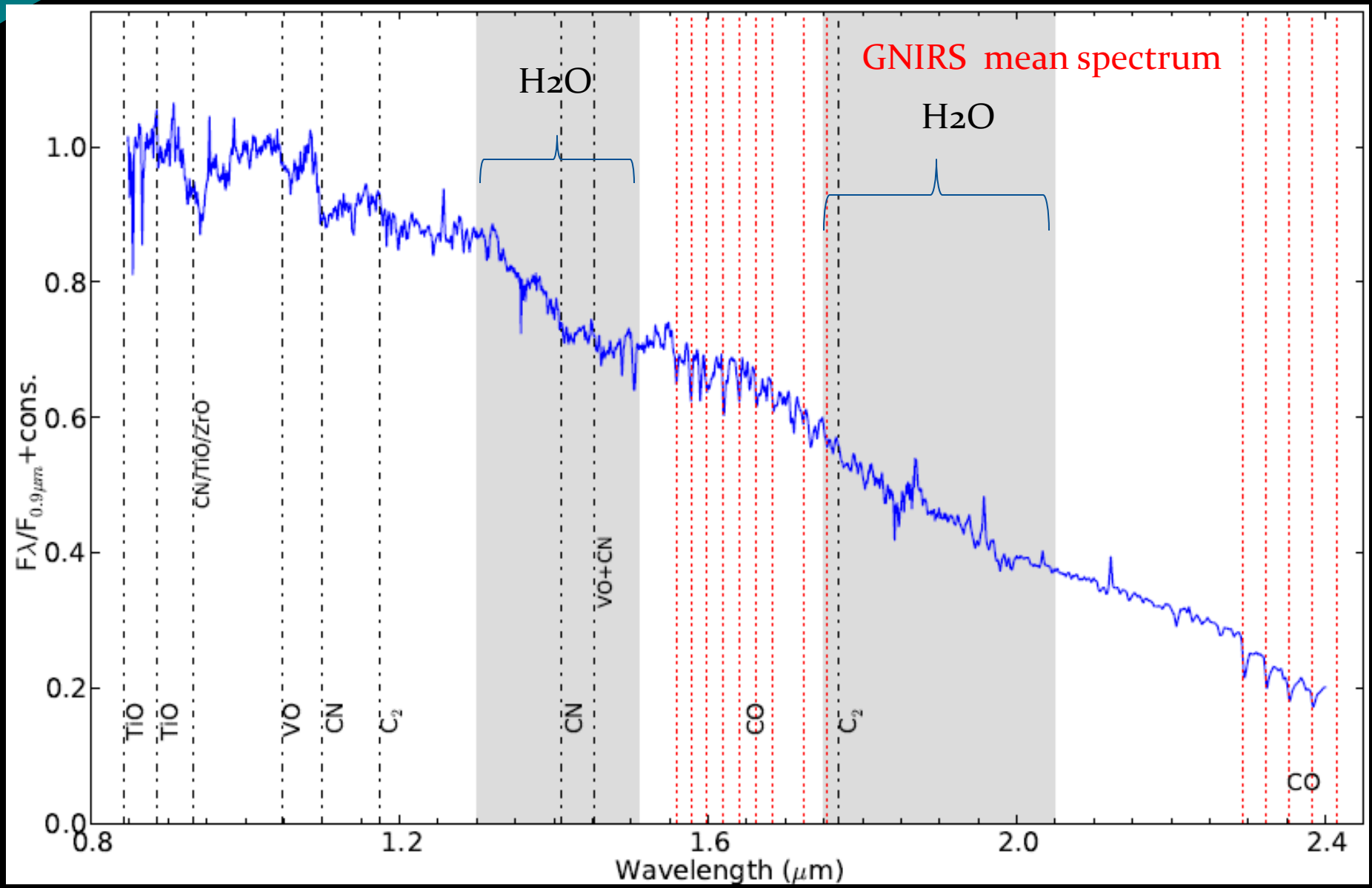
TP-AGB 'heavy'
(e.g. Maraston, 2005, 2011)

NIR SSPs calibrated with C- and O- Rich stellar spectra

Strong molecular features

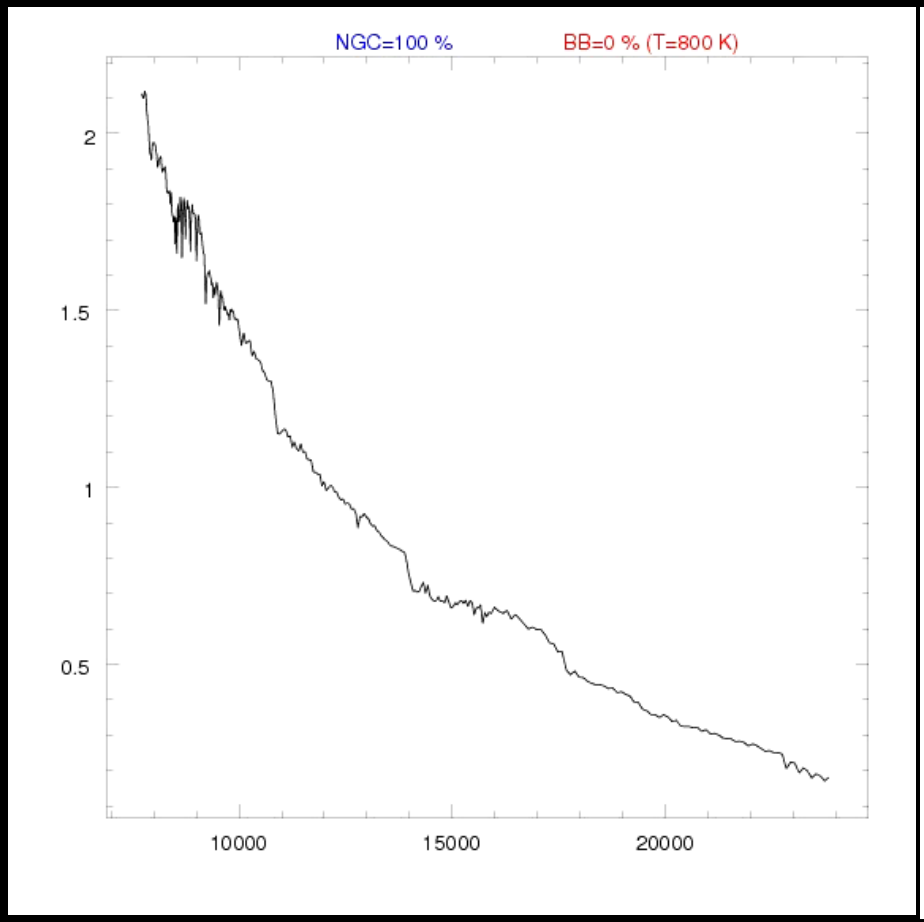
The presence (or not) of molecular features: is easy to be tested

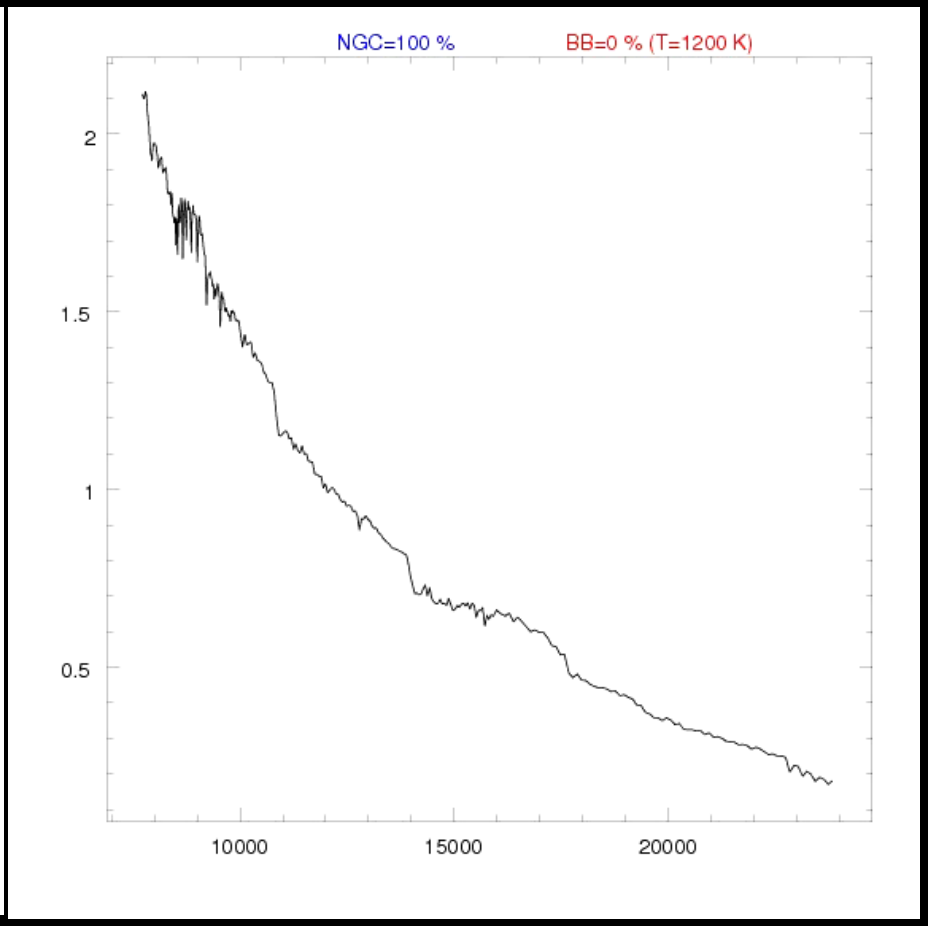
Infrared Stellar Features



Spectral Synthesis – Hot Dust

NGC 7714 + hot dust (800 K / 1200K)





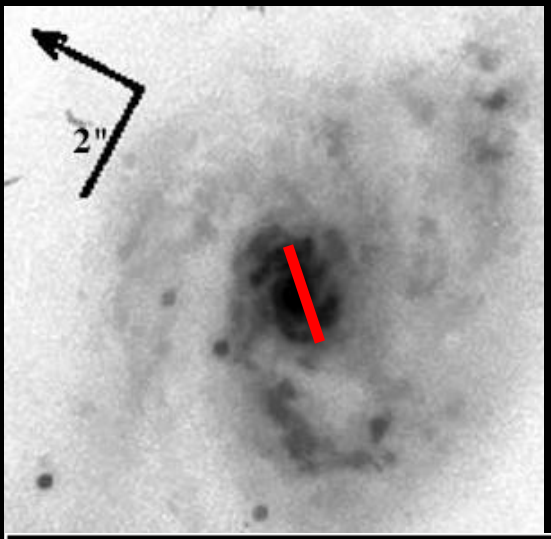
Dust effects: Dilution of absorption lines and change in spectral shape

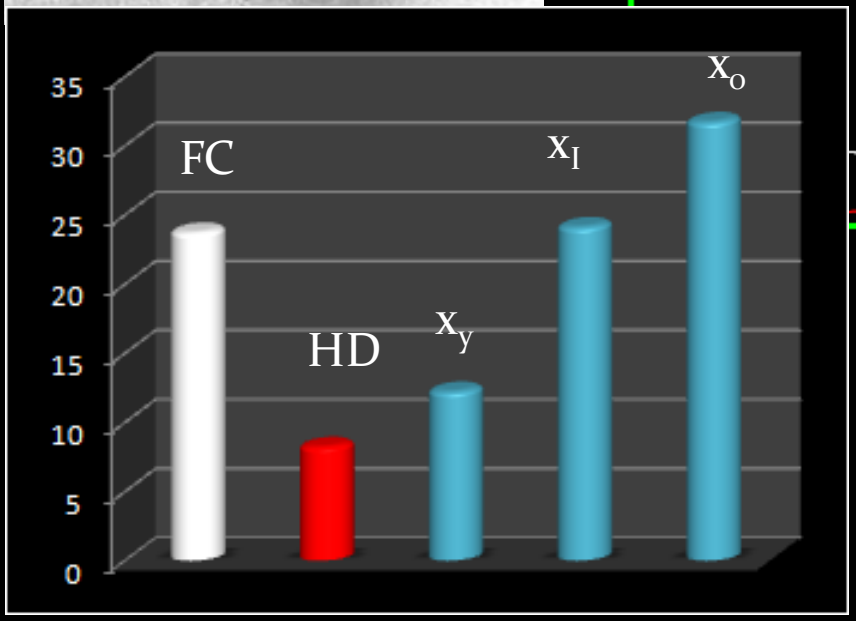
Riffel +2008, 2009, Kishimoto+2011, Burtscher+2015

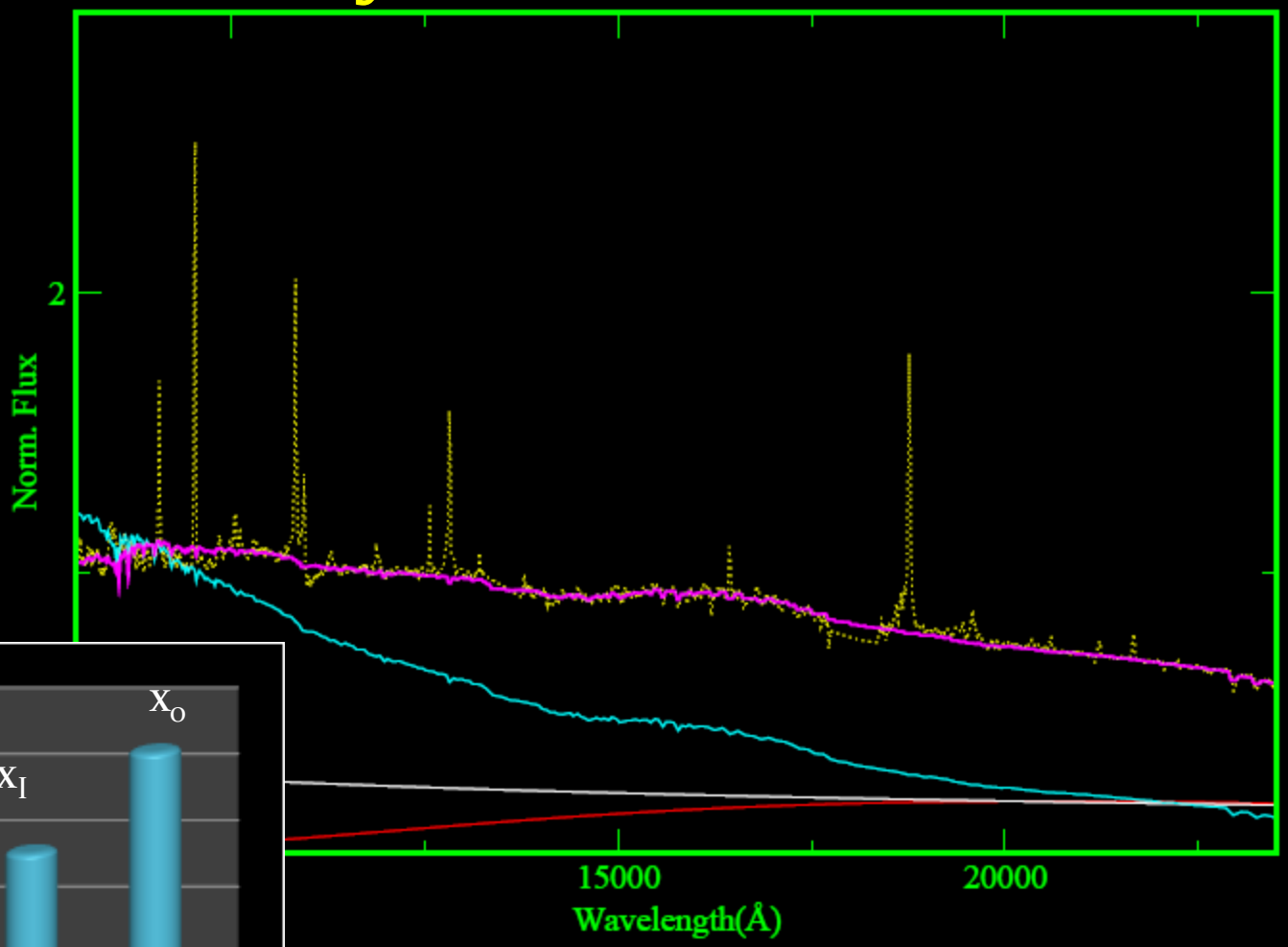
Results

Results – AGNs – Sy 1

Riffel et al., 2009





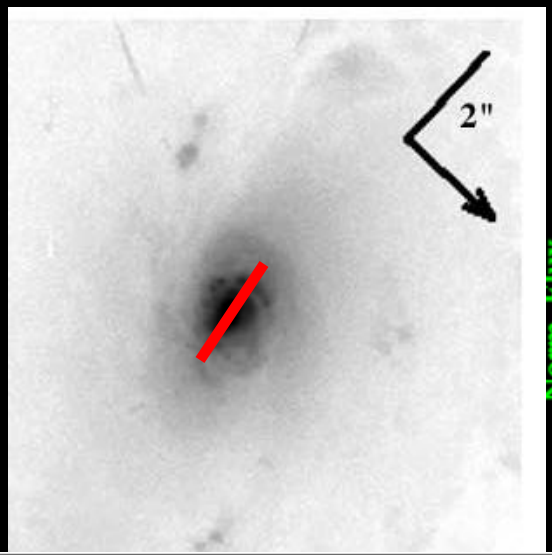


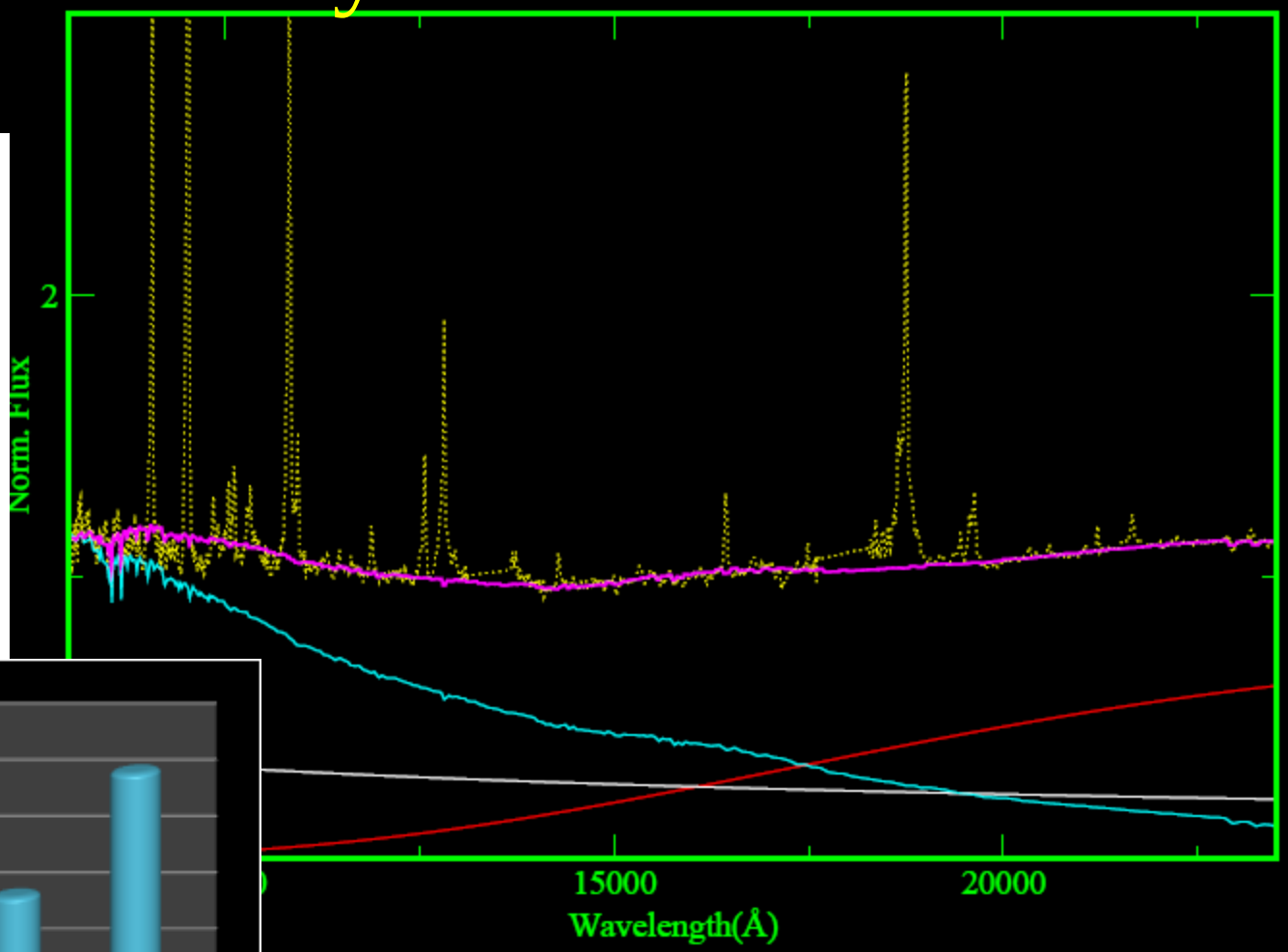
X_y = t ≤50 Myr
X_I= 100Myr ≤ t ≤ 2 Gyr
X_o= t > 2 Gyr

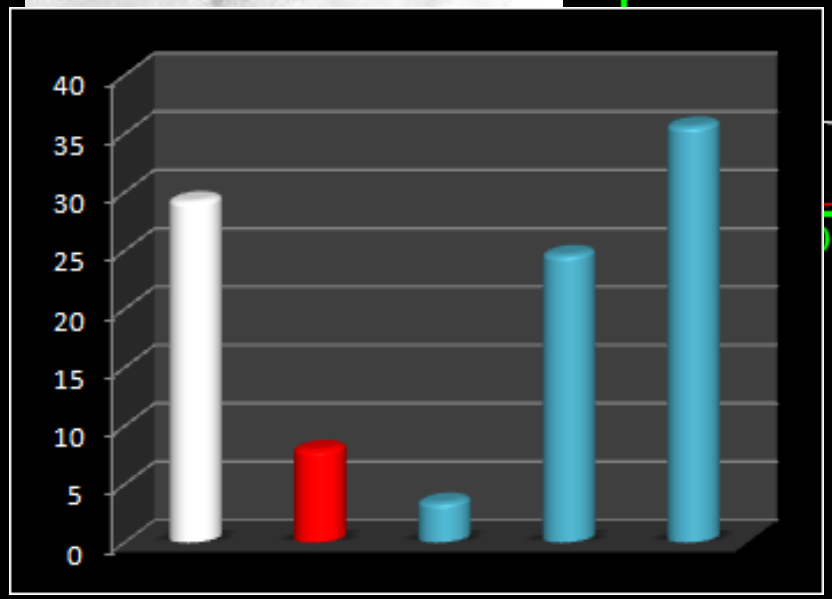
Riffel+09

Results – AGNs – Sy 2

Riffel et al., 2009





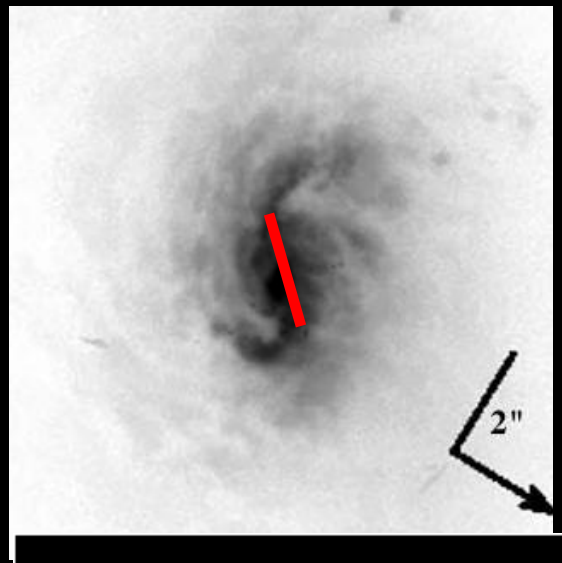


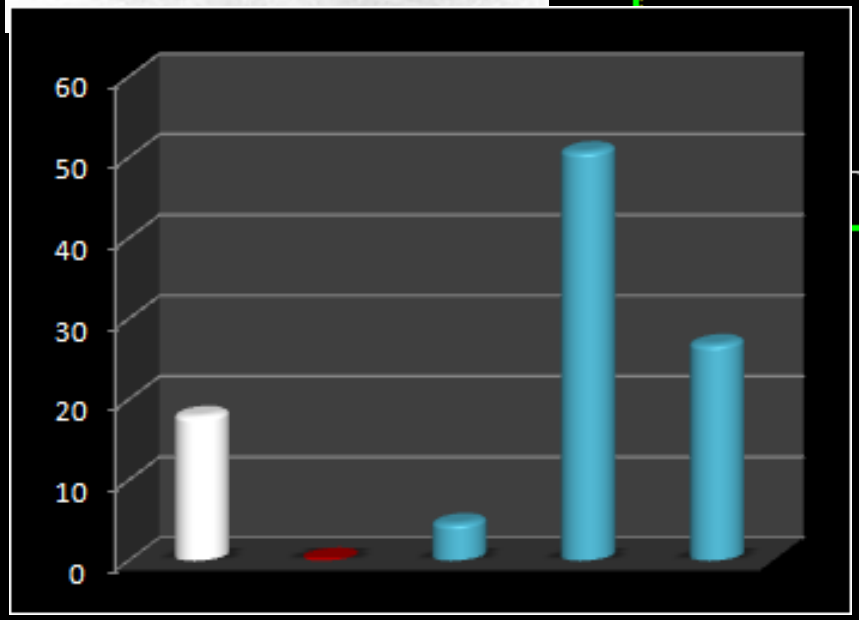
X_y = t ≤50 Myr
X_I= 100Myr ≤ t ≤ 2 Gyr
X_o= t > 2 Gyr

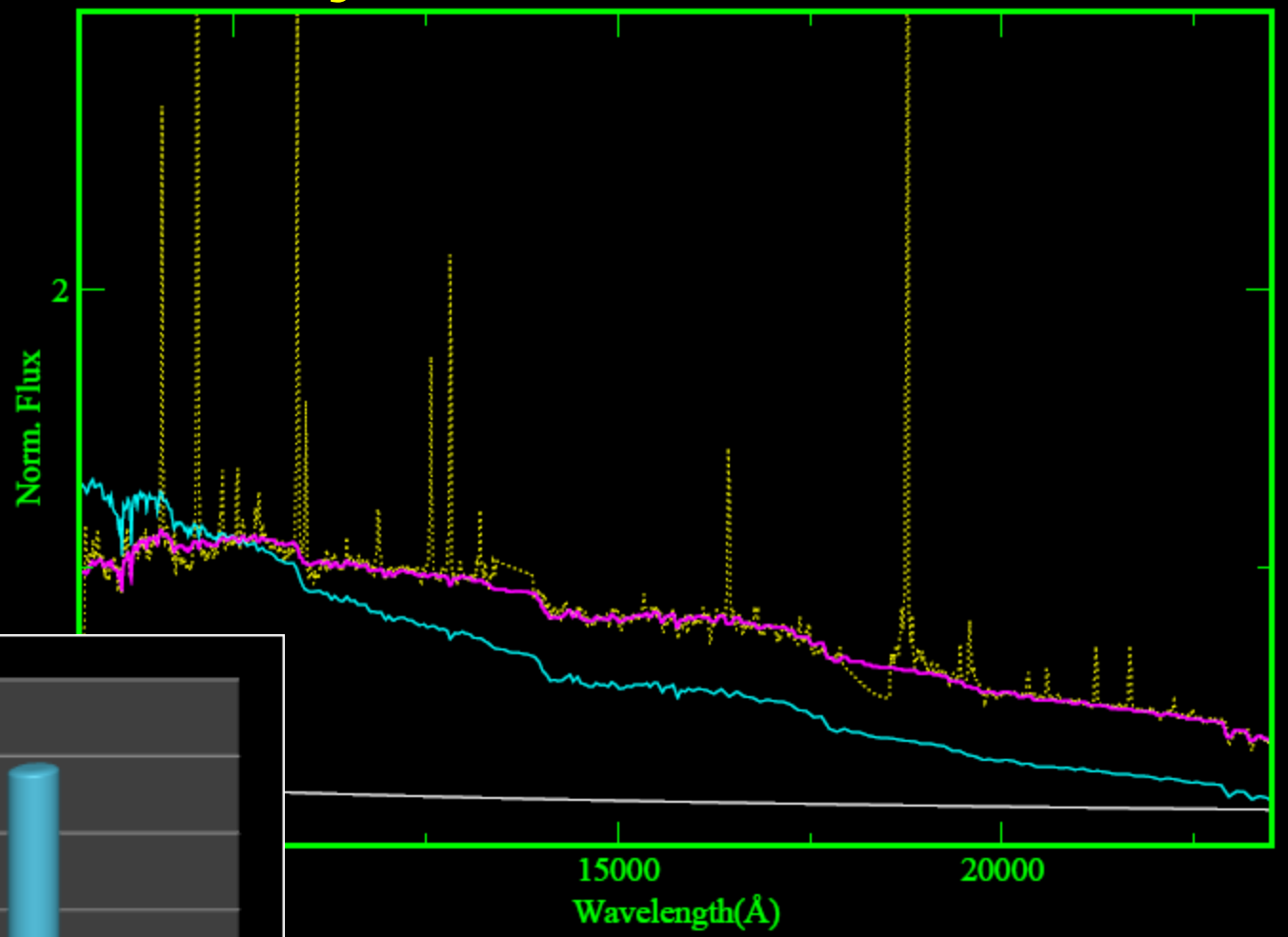
Riffel+09

Results – AGNs – Sy 2

Riffel et al., 2009







X_y = t ≤50 Myr
X_I= 100Myr ≤ t ≤ 2 Gyr
X_o= t > 2 Gyr

Riffel+09

From our long-slit studies we concluded

✓ The simultaneous fitting of SP, FC and hot dust components allows a proper analysis of each one of them;

✓ A substantial fraction (~40%) of an intermediate age (~1 Gyr) stellar population is detected in the inner pc of Seyfert galaxies (in agreement with Davies+07).

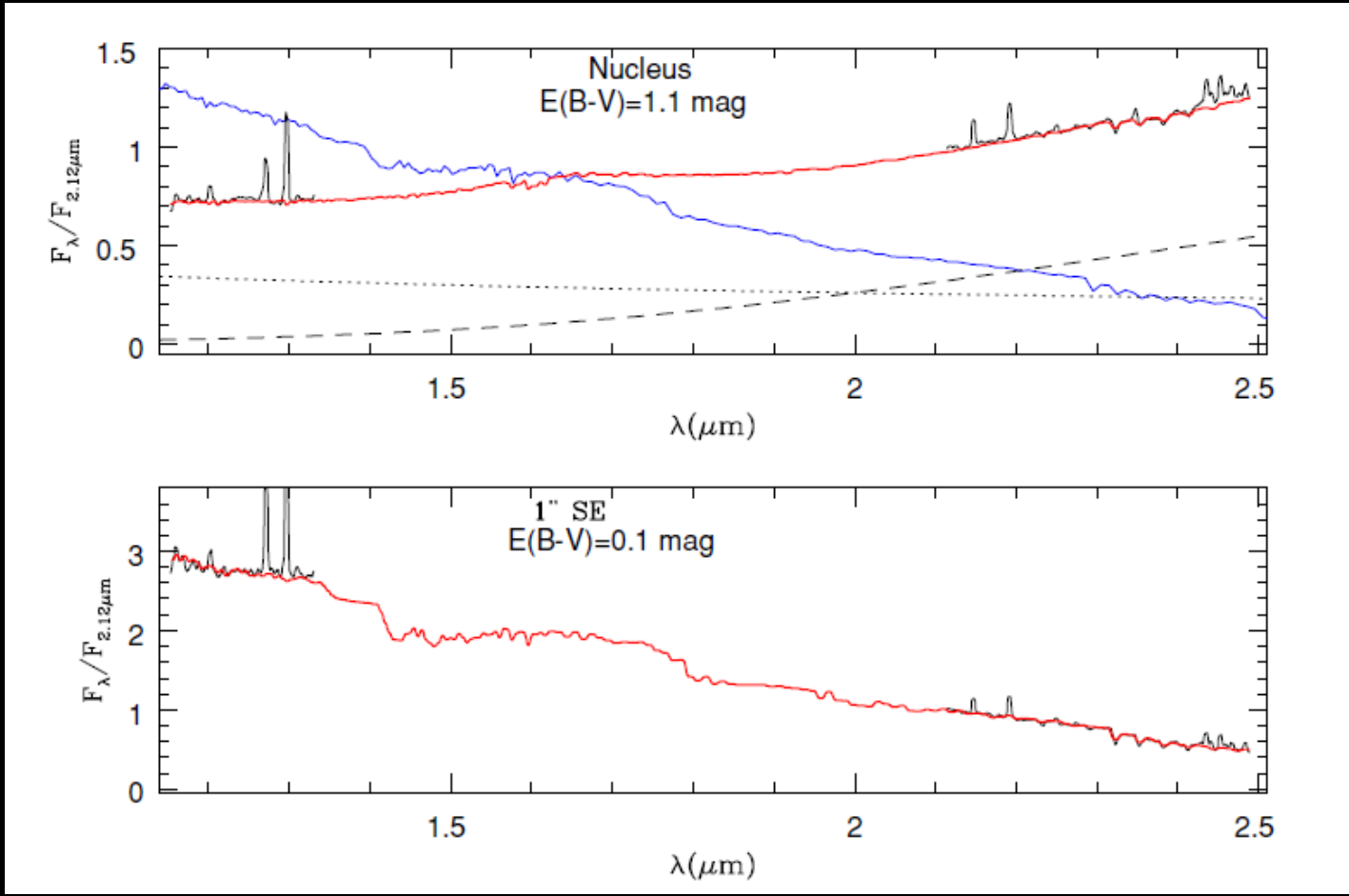
✓Hot dust is necessary to explain the excess observed in the K-band spectra of almost all Sy 1 sources and in ~25% of the Sy2;

Resolving the galaxies stellar populations in space and time….. let's IFU them!

Mapping the inner few parsecs using IFUs.

MRK 1066

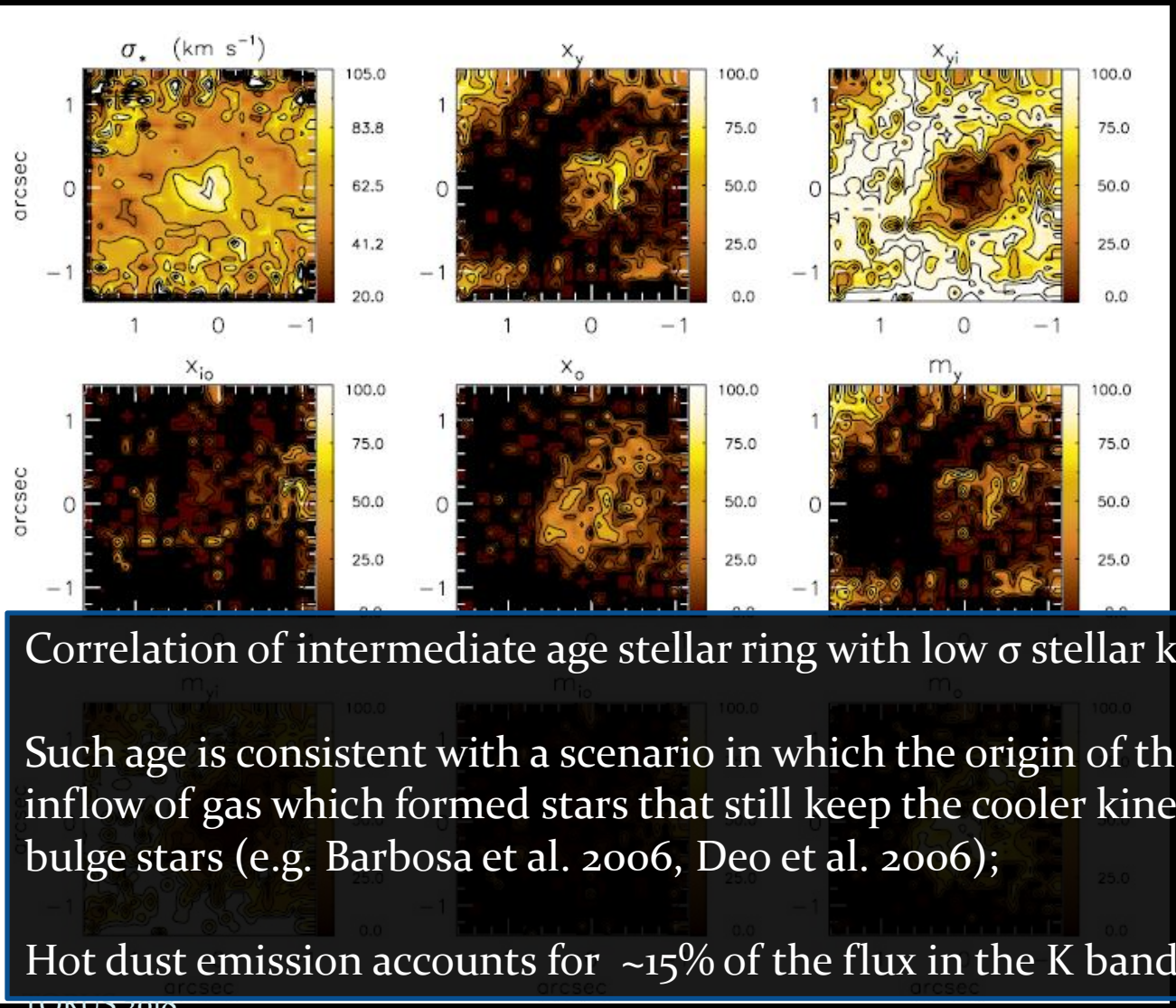
Lesson 1: Spatial resolution matters!



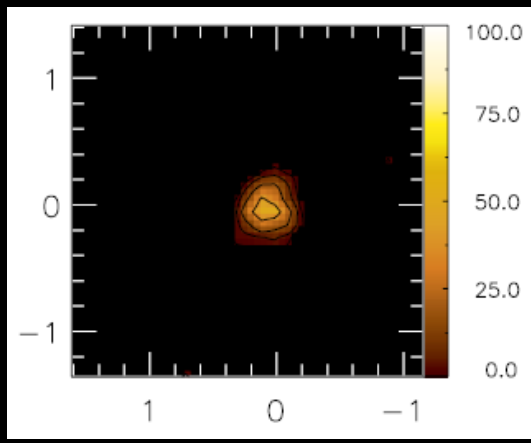
Riffel+2010

Mapping the inner few parsecs using IFUs.

MRK 1066 (inner 300pc with 35pc of spatial resolution)



Unresolved Hot dust emission



Correlation of intermediate age stellar ring with low σ stellar kinematics;

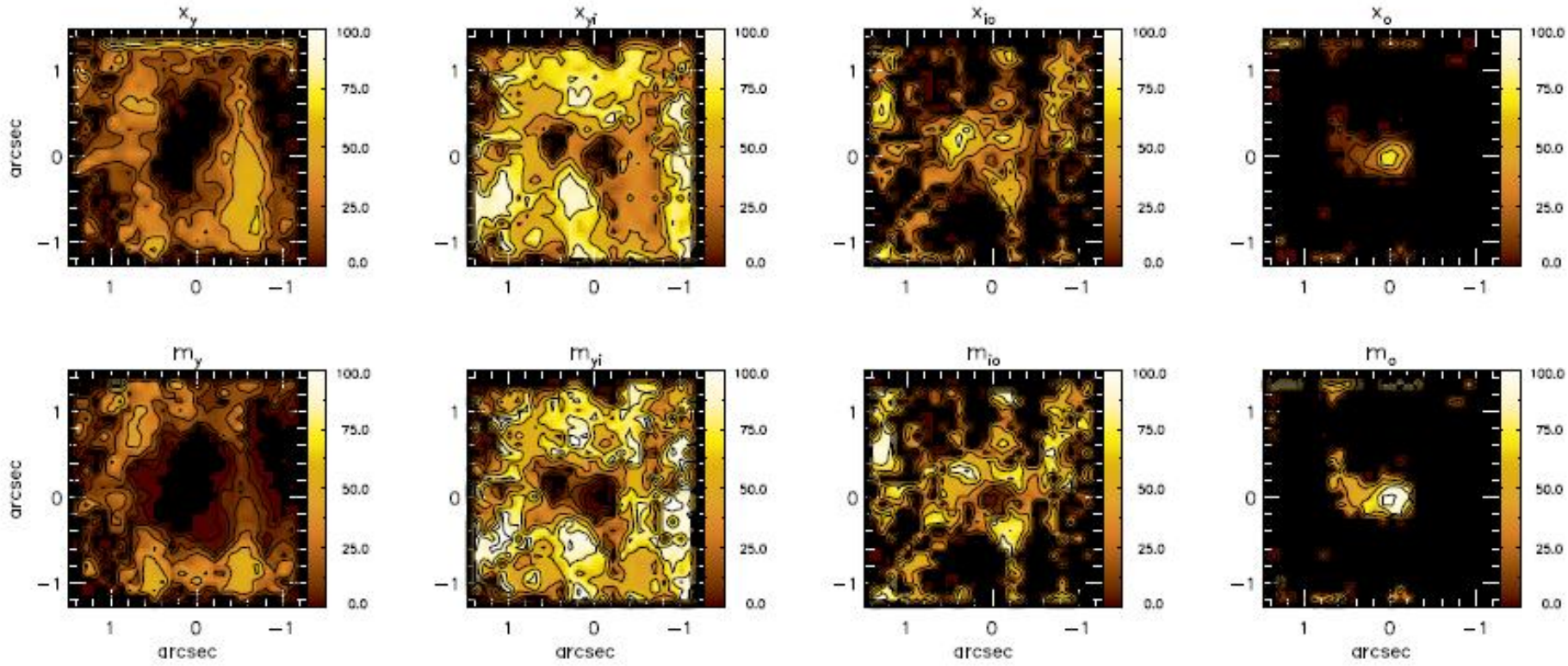
Such age is consistent with a scenario in which the origin of the low σ rings is an inflow of gas which formed stars that still keep the cooler kinematics compared to bulge stars (e.g. Barbosa et al. 2006, Deo et al. 2006);

Hot dust emission accounts for ~15% of the flux in the K band.

Riffel+2010

Mapping the inner few parsecs using IFUs.

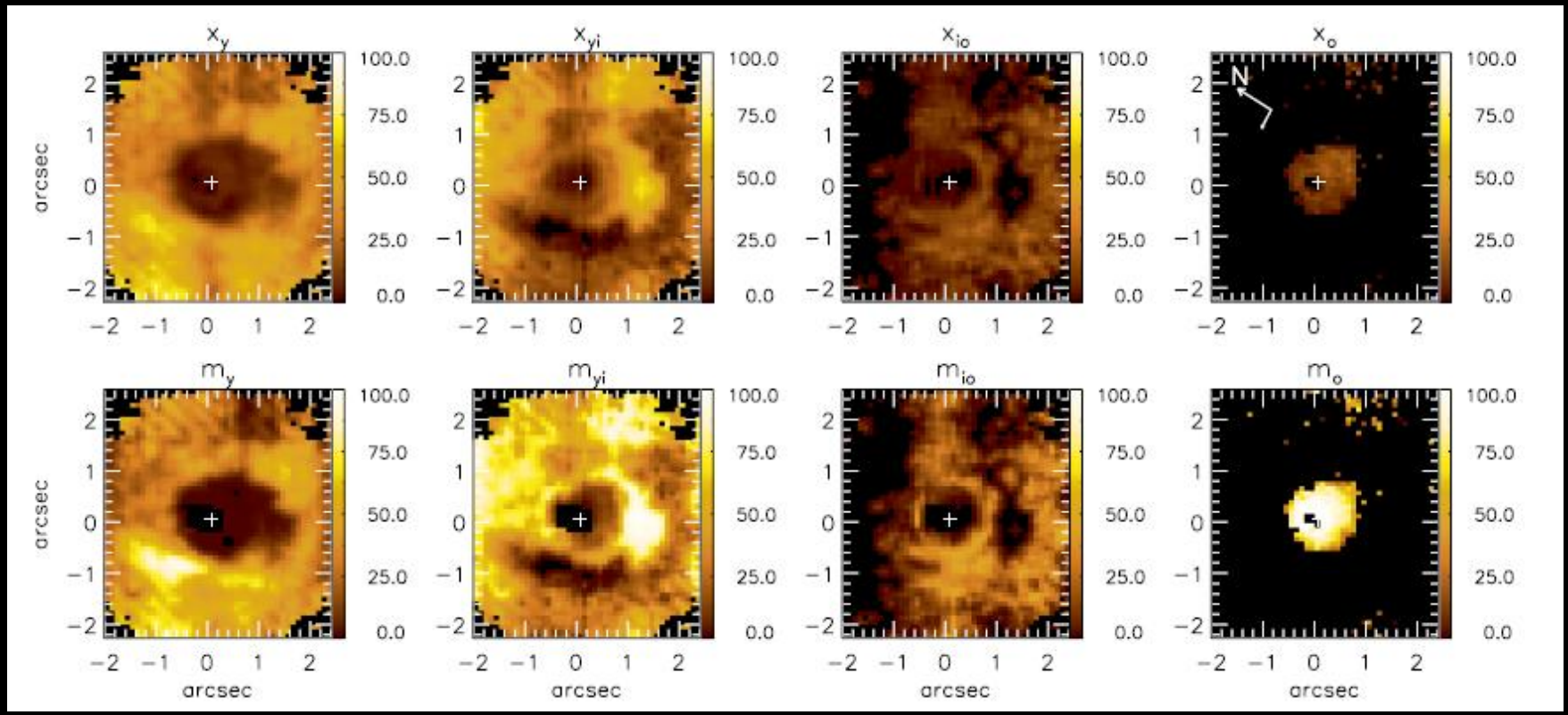
MRK 1157(inner 400pc with 35pc of spatial resolution)



Similar results as for Mrk 1166 but no hot dust or feature less was detected.

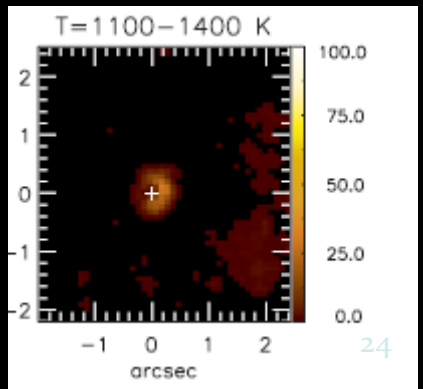
Mapping the inner few parsecs using IFUs.

NGC 1068 (inner 180 pc with 8pc of spatial resolution) Storchi-Bergmann+12



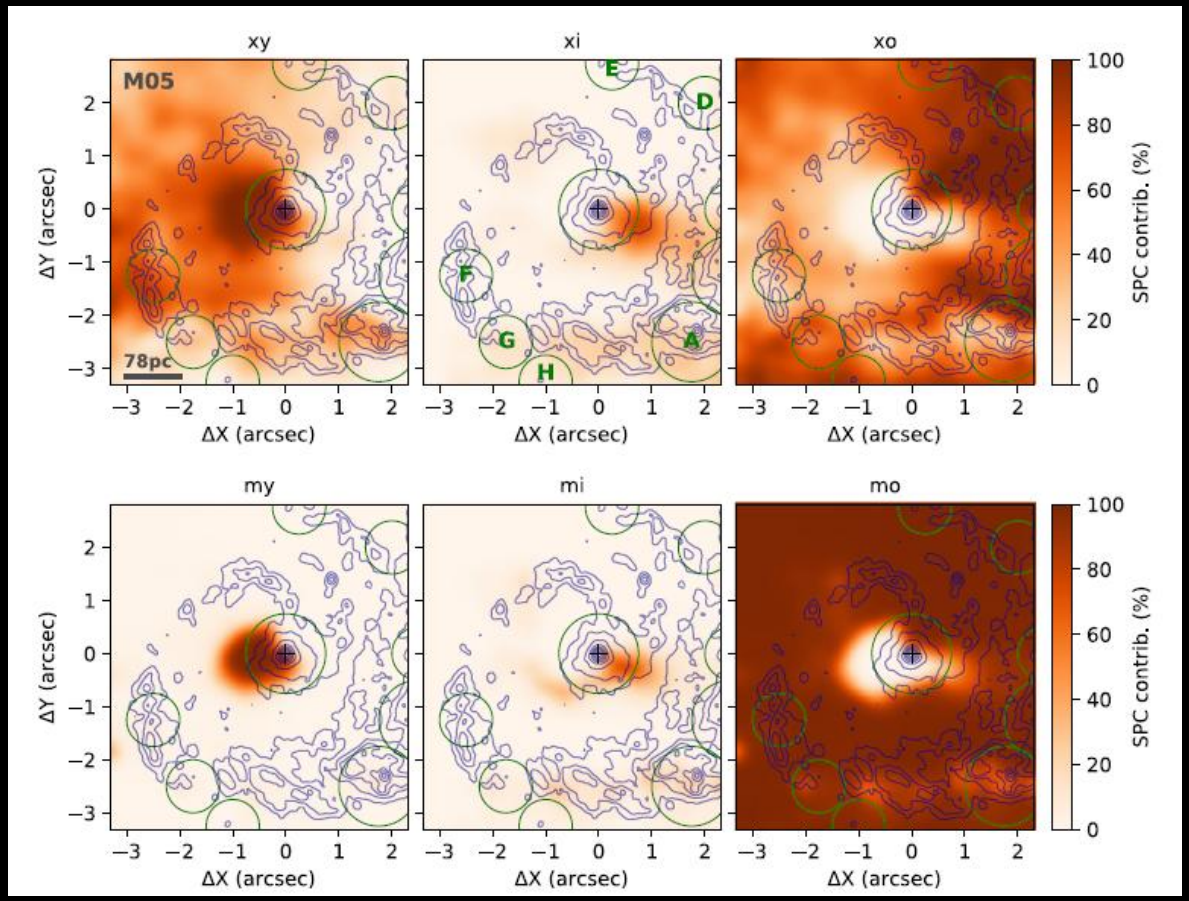
Correlation of young SP with molecular hydrogen emission gas (link with H_2 and SF?)

Correlation of intermediate age stellar ring with low σ stellar kinematics.



Mapping the inner few parsecs using IFUs.

NGC 4303 (inner 250 pc with ~70 pc of spatial resolution) – SINFONI (Dametto+18)

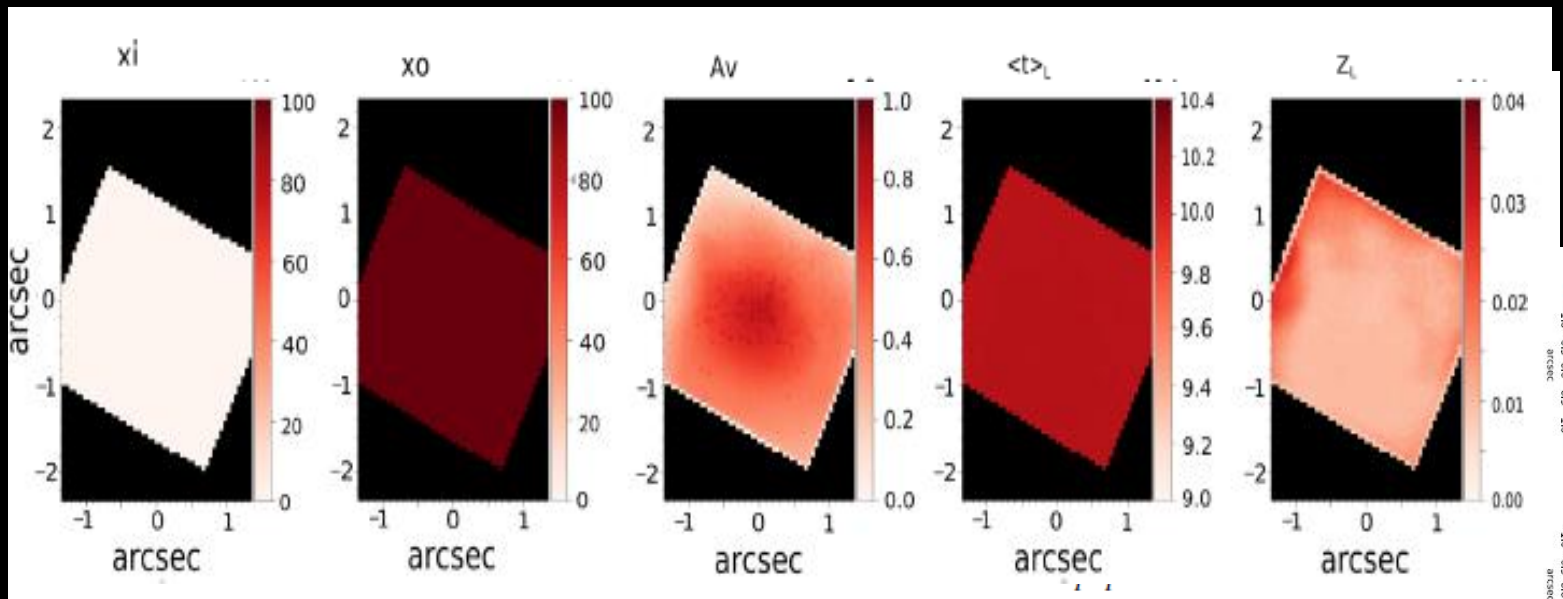


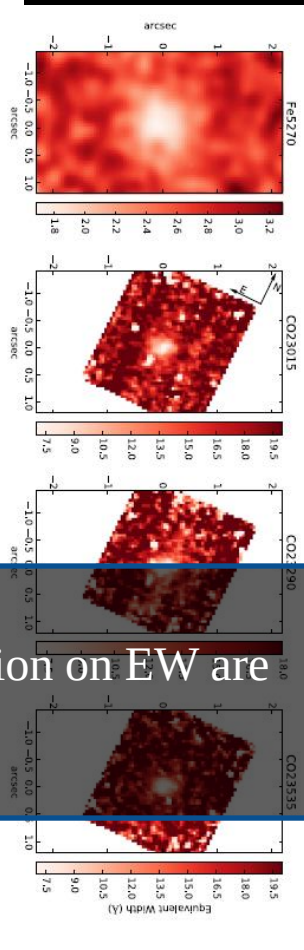
This is a LINER/SB galaxy: there is a good correlation of the young stellar population component with Br γ emission.

No hot dust or featureless component detected

Mapping the inner few parsecs using IFUs.

NGC 1052 (inner 320pc with ~70 pc of spatial resolution) – GMOS + NIFS (Dahmer-Hahn+18)





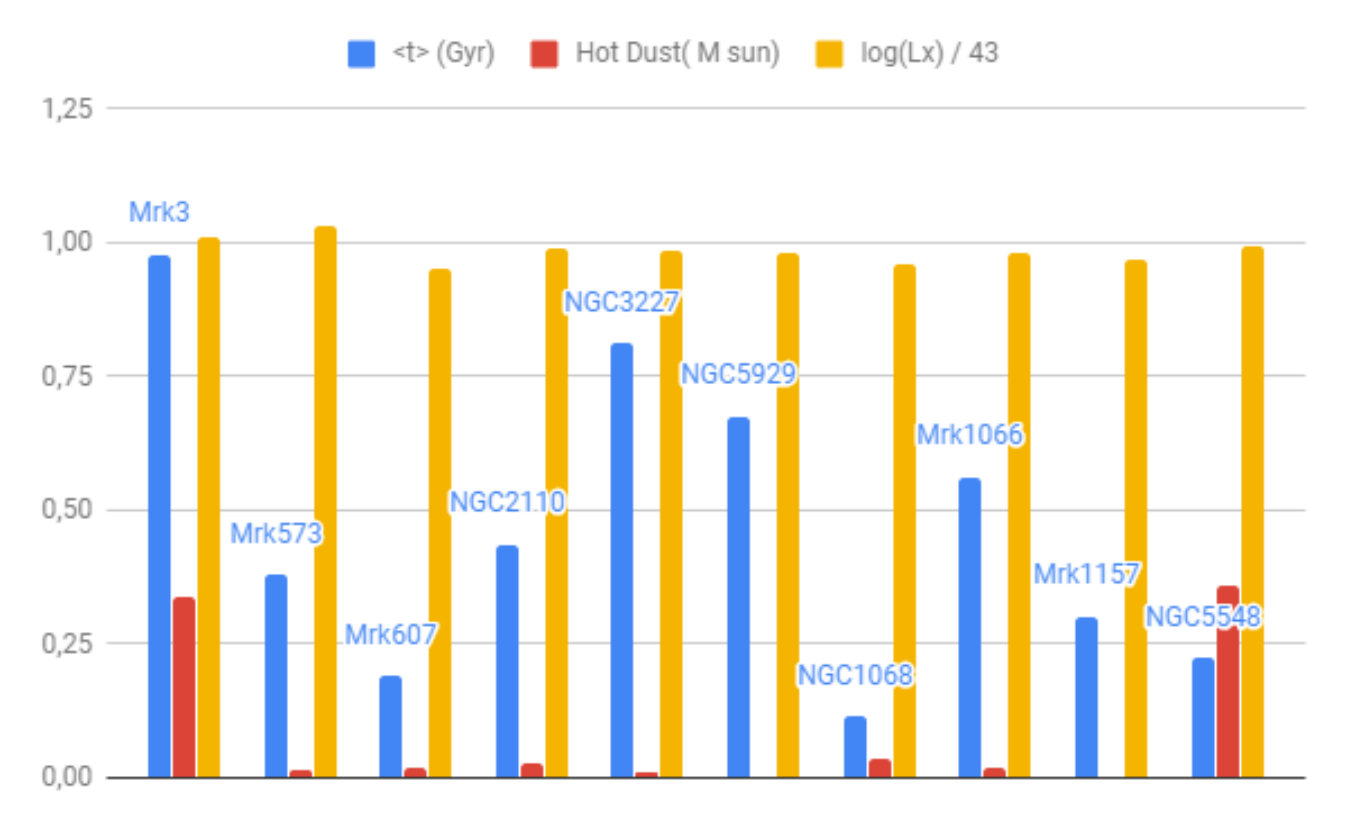
This is a LINER/Sy2 galaxy (only used SSPs with t > ~ 1Gyr)

No hot dust or featureless component directly detected, however sings of dilution on EW are found.

This is the first SP fit from optical to NIR on a datacube.

Mapping the inner few parsecs using IFUs.

Preliminary results



$$\langle \log t_\star \rangle_{\mathrm{L}} = \sum_{j=1}^{N_\star} x_j \log t_j$$

$$M_{HD} \approxeq \frac{4\pi}{3} a^3 N_{HD} \rho_{\mathrm{gr}} \mathrm{kg}$$

$$N_{HD} \approxeq \frac{L_{\nu,ir,HD}}{L^{gr}_{\nu,ir}}$$

$$L^{gr}_{\nu,ir} = 4\pi^2 a^2 Q_\nu B_\nu(T_{gr})$$

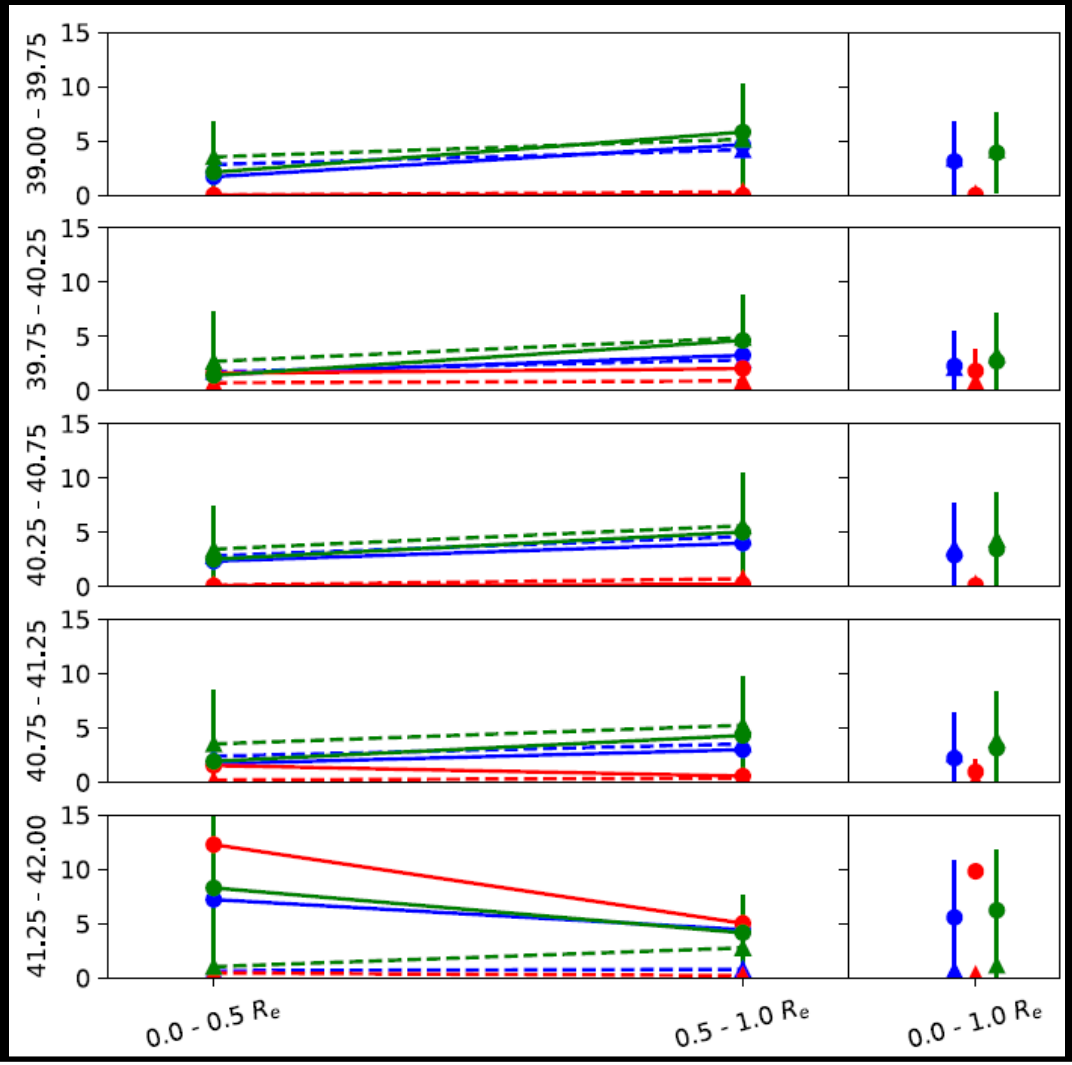
(e.g. Barvanis 1987)

Inner regions dominated by young to intermediate age (in agreement with results of Davies+07)

Hot dust (near to sublimation) detected in almost all sources (90% of Sy2s).

All galaxies with nearly the same Luminosity [log(Lx) ~ 43]

MaNGA (62 AGN with controls – Mallmann+18)



The most luminous AGN seems to have been triggered by a recent supply of gas that has also triggered recent star formation (*t ≤40 Myr)* in their central regions.

Or recent cessation of star formation (?).

Green: late-type AGN, red: early-type AGN and blue for all the AGN.
Solid lines AGNs and dashed control galaxies.

Summary & Conclusions

✓ The simultaneous fitting of SP, FC and hot dust components allows a proper analysis of each one of them;

✓ A substantial fraction (~40%) of an intermediate age (~1 Gyr) stellar population is detected in the inner pc of Seyfert galaxies.

✓Hot dust is necessary to explain the excess observed in the K-band spectra of almost all Sy1 sources and in ~25/90% (LS/IFU) of the Sy2;

✓Spatial resolution is very important do detect all the components.

✓ There seems to be a correlation of young to intermediate age stellar populations with low σ stellar kinematics.

✓ TP-AGB 'heavy' models do better reproduce the NIR features detected in active galaxies (are they a source for the dust observed in the AGNs?)

✓ Luminosity seems to be a hidden and very important parameter (see Davies +15)

✓ A

t.

LLAMA (PI Ric) and Gemini NIFS (PI Thaisa) surveys may help to answer the title question. So far the answer is NO! Stay tuned for new results.

Thanks