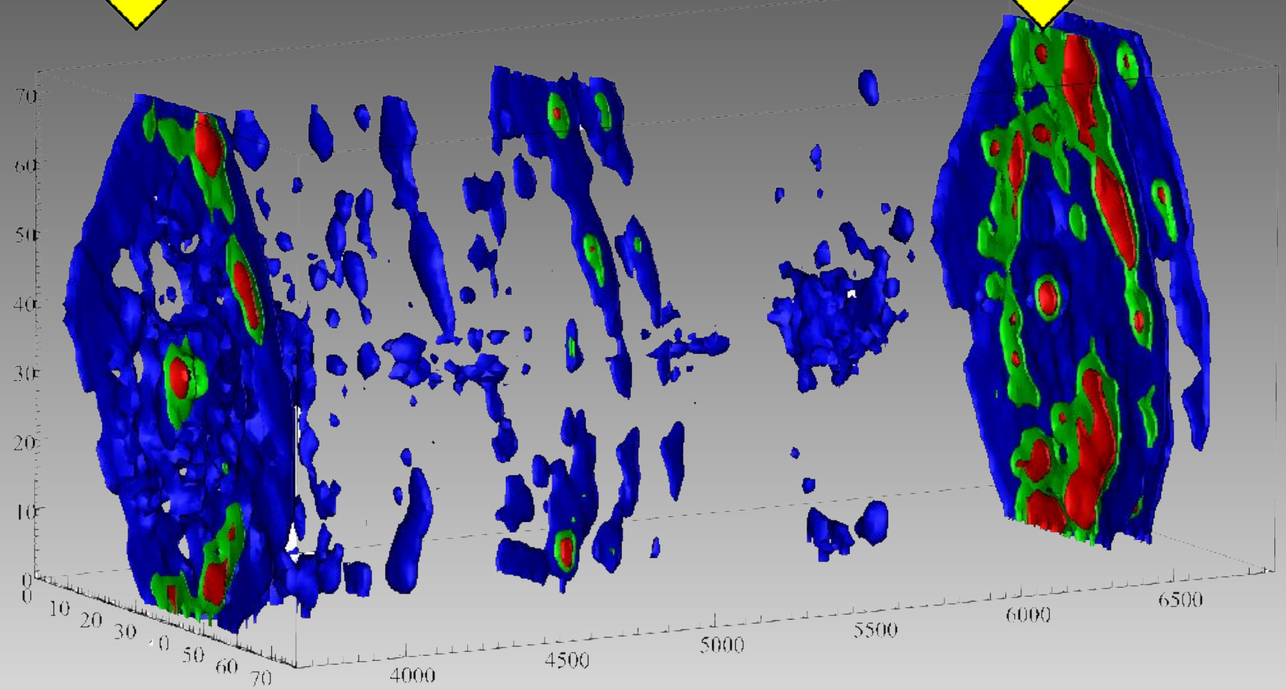
CALIFA

PCA Tomograms applied to CALIFA datacubes

(Ongoing master thesis project)



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Advisor: Roberto Cid Fernandes

GAS - UFSC BRASIL

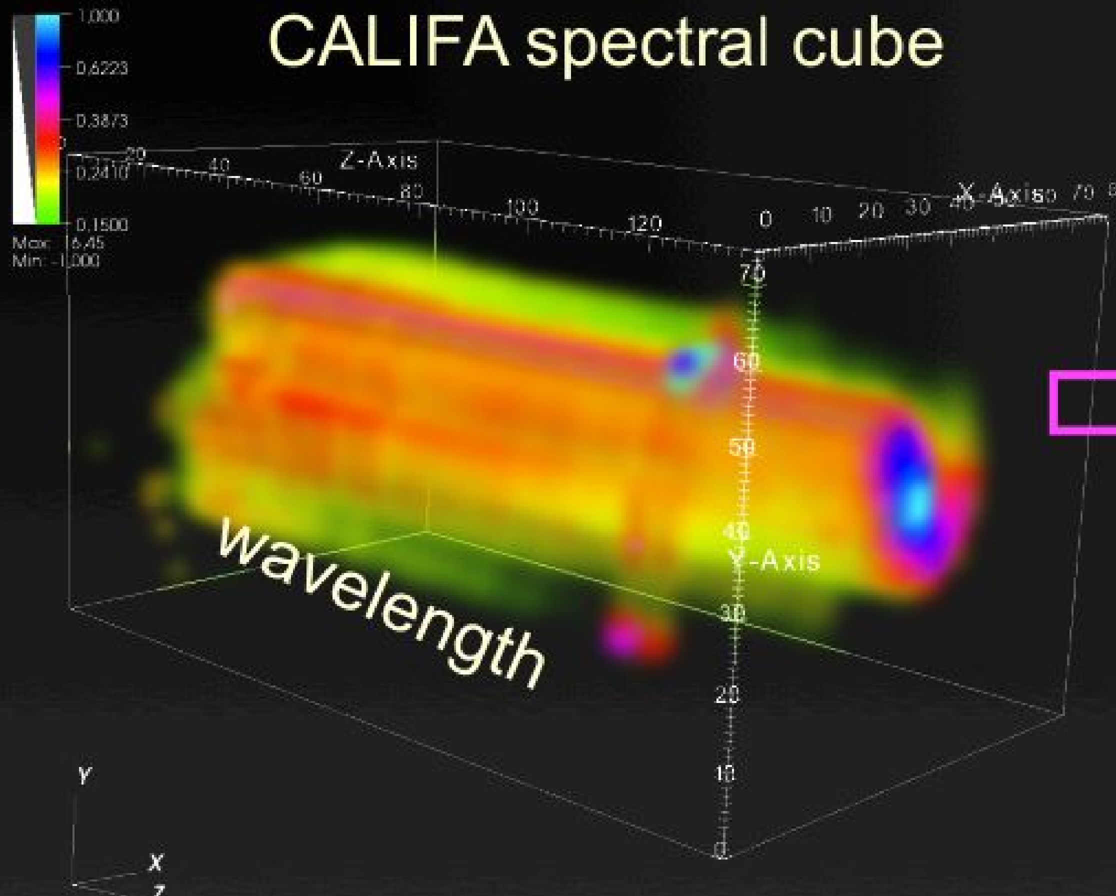
Summary

- PyCASSO
- PCA Tomography – How to...
- PCA pre-processing
- First results
- Reverse Engineering

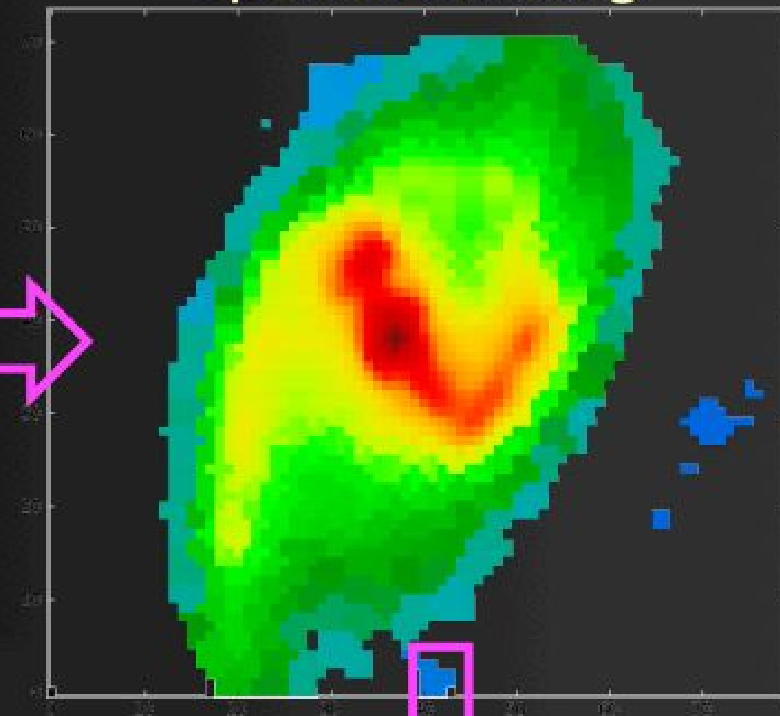
Python **CA**lifa **S**tarlight **S**ynthesis **O**rganizer

The **PyCASSO** pipeline

CALIFA spectral cube



spatial binning

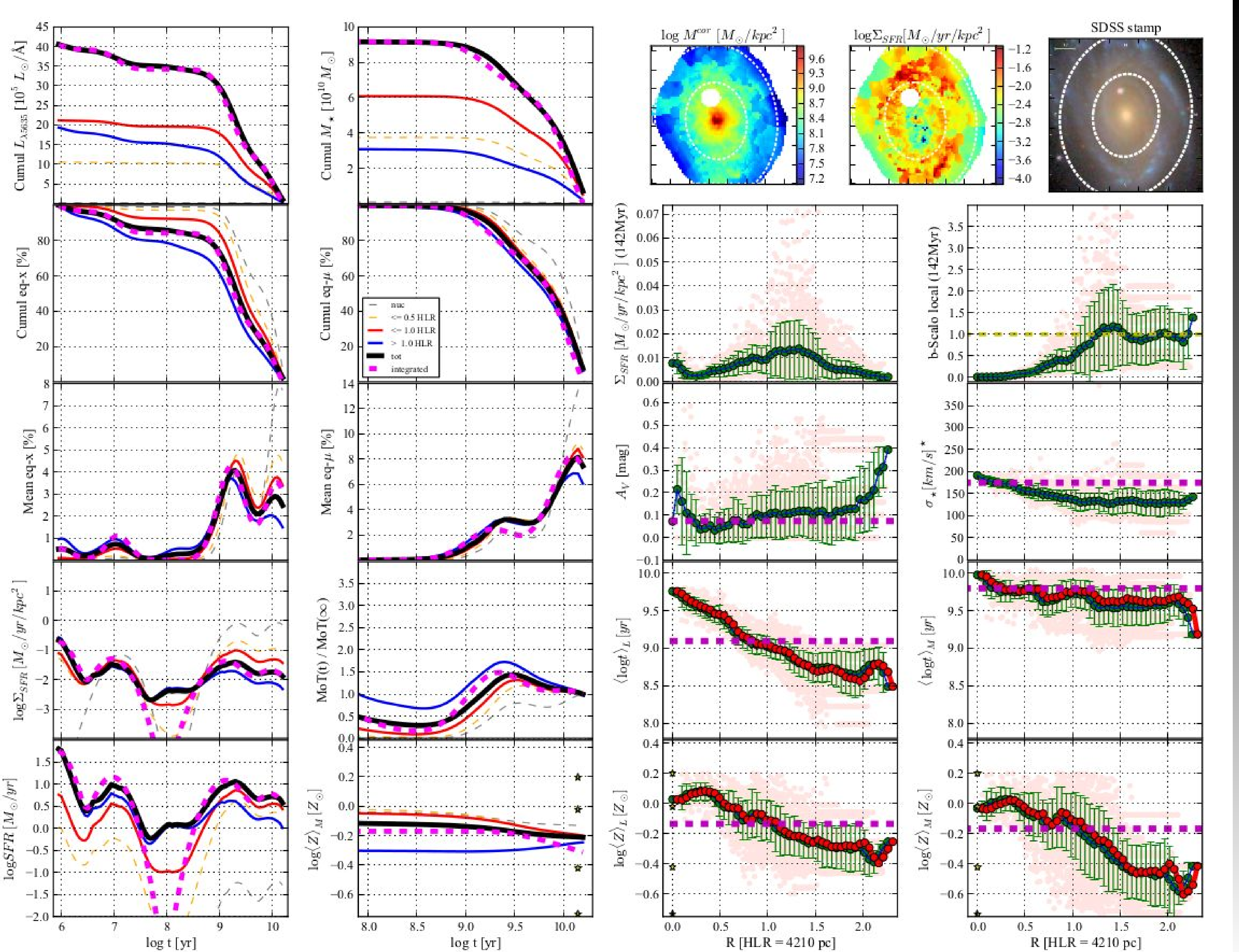


Output spectra corrected for:

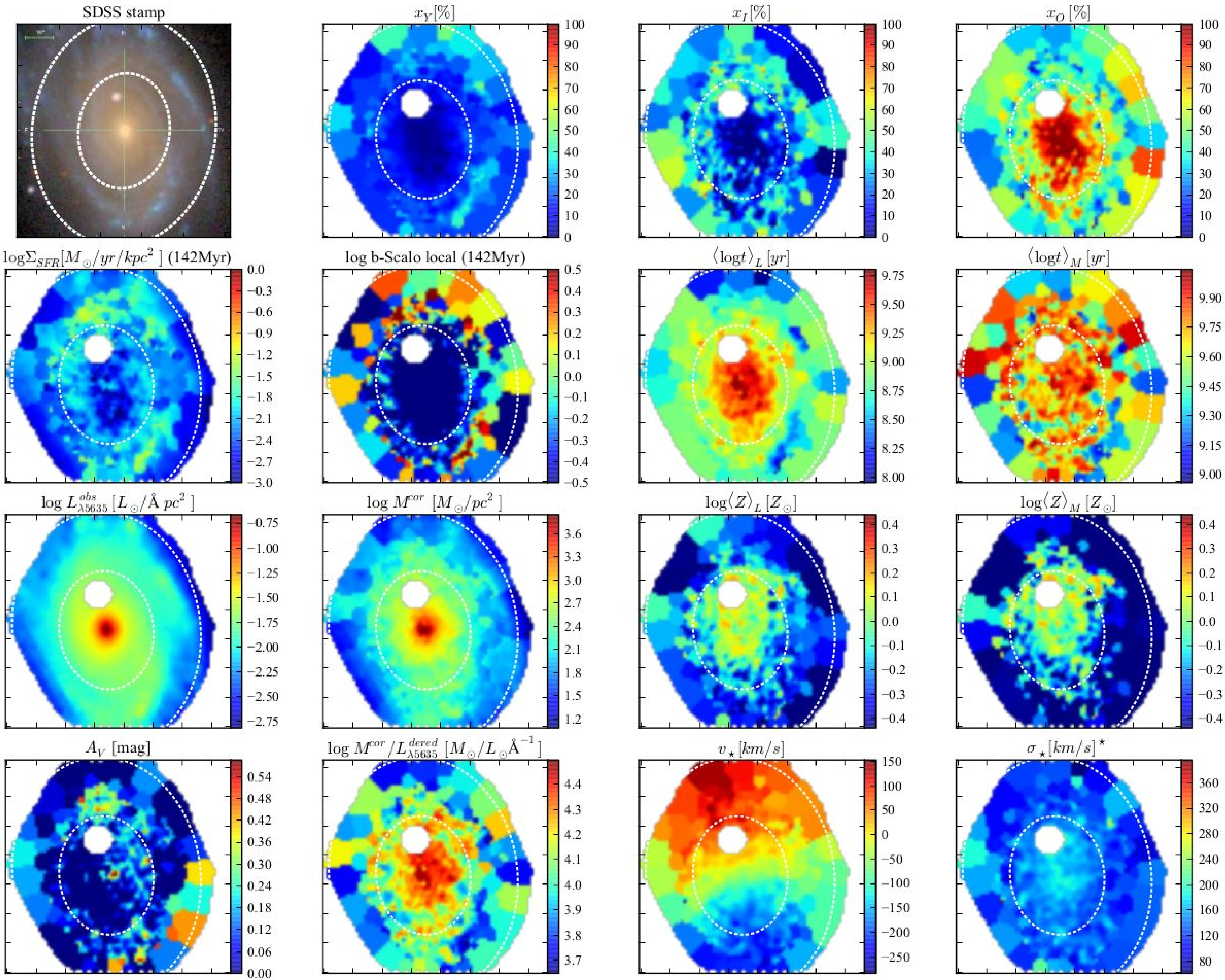
- redshift
- Galactic extinction
- etc …

STARLIGHT

M_* , v_* , σ_*, A_V,
<age>, <Z_*>, SFH, ...
as a function of x & y!!



Cumul $L_{\lambda 5635}$ [10^5 $L_\odot$/Å]
Cumul $M_\star$ [10^{10} $M_\odot$]
log M^{cor} [$M_\odot/kpc^2$]
logΣ_{SFR}[$M_\odot/yr/kpc^2$]
SDSS stamp
Cumul eq-x [%]
Cumul eq-μ [%]
nuc
<= 0.5 HLR
<= 1.0 HLR
> 1.0 HLR
tot
integrated
Σ_{SFR} [$M_\odot/yr/kpc^2$] (142Myr)
b-Scalo local (142Myr)
Mean eq-x [%]
Mean eq-μ [%]
A_V [mag]
$\sigma_\star$[km/s]*
logΣ_{SFR} [$M_\odot/yr/kpc^2$]
MoT(t) / MoT(∞)
$\langle$logt$\rangle_L$ [yr]
$\langle$logt$\rangle_M$ [yr]
logSFR [$M_\odot/yr$]
log$\langle Z\rangle_M$ [$Z_\odot$]
log$\langle Z\rangle_L$ [$Z_\odot$]
log t [yr]
R [HLR = 4210 pc]



SDSS stamp
x_Y [%]
0 10 20 30 40 50 60 70 80 90 100
x_I [%]
0 10 20 30 40 50 60 70 80 90 100
x_O [%]
0 10 20 30 40 50 60 70 80 90 100
$\log\Sigma_{SFR}[M_\odot/yr/kpc^2]$ (142Myr)
0.0 −0.3 −0.6 −0.9 −1.2 −1.5 −1.8 −2.1 −2.4 −2.7 −3.0
log b-Scalo local (142Myr)
0.5 0.4 0.3 0.2 0.1 0.0 −0.1 −0.2 −0.3 −0.4 −0.5
$\langle \log t \rangle_L$ [yr]
9.75 9.50 9.25 9.00 8.75 8.50 8.25 8.00
$\langle \log t \rangle_M$ [yr]
9.90 9.75 9.60 9.45 9.30 9.15 9.00
$\log L^{obs}_{\lambda 5635}$ [$L_\odot$/Å pc^2]
−0.75 −1.00 −1.25 −1.50 −1.75 −2.00 −2.25 −2.50 −2.75
$\log M^{cor}$ [$M_\odot/pc^2$]
3.6 3.3 3.0 2.7 2.4 2.1 1.8 1.5 1.2
$\log\langle Z \rangle_L$ [$Z_\odot$]
0.4 0.3 0.2 0.1 0.0 −0.1 −0.2 −0.3 −0.4
$\log\langle Z \rangle_M$ [$Z_\odot$]
0.4 0.3 0.2 0.1 0.0 −0.1 −0.2 −0.3 −0.4
A_V [mag]
0.54 0.48 0.42 0.36 0.30 0.24 0.18 0.12 0.06 0.00
$\log M^{cor}/L^{dered}_{\lambda 5635}$ [$M_\odot/L_\odot$Å^{-1}]
4.4 4.3 4.2 4.1 4.0 3.9 3.8 3.7
$v_\star$ [km/s]
150 100 50 0 −50 −100 −150 −200 −250
$\sigma_\star$ [km/s]*
360 320 280 240 200 160 120 80

PCA Tomography – HOW TO:

An observed galaxy, divided into Voronoi zones or individual spaxels, can be expressed as a matrix where each row represents a zone spectrum:

$$\mathbf{F}_{z\lambda} = \begin{bmatrix} f_{z_0\lambda_0} & f_{z_0\lambda_1} & f_{z_0\lambda_2} & \cdots & f_{z_0\lambda_m} \\ f_{z_1\lambda_0} & f_{z_1\lambda_1} & f_{z_1\lambda_2} & \cdots & f_{z_1\lambda_m} \\ f_{z_2\lambda_0} & f_{z_2\lambda_1} & f_{z_2\lambda_2} & \cdots & f_{z_2\lambda_m} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ f_{z_n\lambda_0} & f_{z_n\lambda_1} & f_{z_n\lambda_2} & \cdots & f_{z_n\lambda_m} \end{bmatrix} \quad (1)$$

Zone spectrum

λ_m image

where we have n zones (spatial pixels) and m spectral pixels. One can calculate the galaxy average spectrum as:

$$\langle \mathbf{F}_\lambda \rangle = \frac{1}{n} \sum_{i=0}^{i=n} f_{z_i\lambda} \quad (2)$$

PCA Tomography – HOW TO:

Subtracting $\mathbf{F}_{z\lambda}$ from $\langle \mathbf{F}_{\lambda} \rangle$,

$$\mathbf{I}_{z\lambda} = \mathbf{F}_{z\lambda} - \langle \mathbf{F}_{\lambda} \rangle \tag{3}$$

we have a data set whose mean is zero. Now we can calculate the covariance matrix:

$$\mathbf{C}_{cov} = \frac{[\mathbf{I}_{z\lambda}]^T \cdot \mathbf{I}_{z\lambda}}{n-1} \tag{4}$$

In order to complete PCA process we find the eigenvalues (Λ_k) and eigenvectors (E_k) of the covariance matrix $\mathbf{C}_{cov}$.

Let's call $\mathbf{E}_{\lambda k}$ the matrix in which columns correspond to eigenvectors order by decreasing value of eigenvalue. Now we have the data in a new basis $(\mathbf{T})$, with uncorrelated coordinates:

$$\mathbf{T}_{zk} = \mathbf{I}_{z\lambda} \cdot \mathbf{E}_{\lambda k} \tag{5}$$

To obtain the tomogram we transform the zones to spatial coordinates: $z \rightarrow (x, y)$.

PCA Tomography: how to extract information from data cubes*

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PCA Tomograms applied to the central region of the LINER galaxy NGC 4736

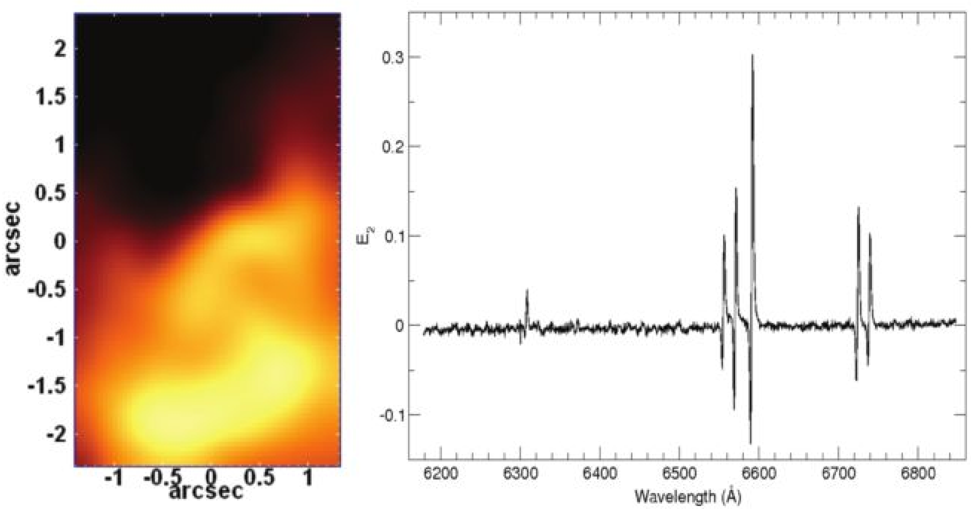


Figure A2. Tomogram of the principal component 2 and respective eigenspectrum.

The second eigenvector represents a clear map of the rotation of the emission-line gas in the FoV.

The third eigenvector represents some narrow lines ([OI], [NII] and [SII]) and a broad Hα component. Usually taken as a clear evidence for an AGN associated with an supermassive black hole.

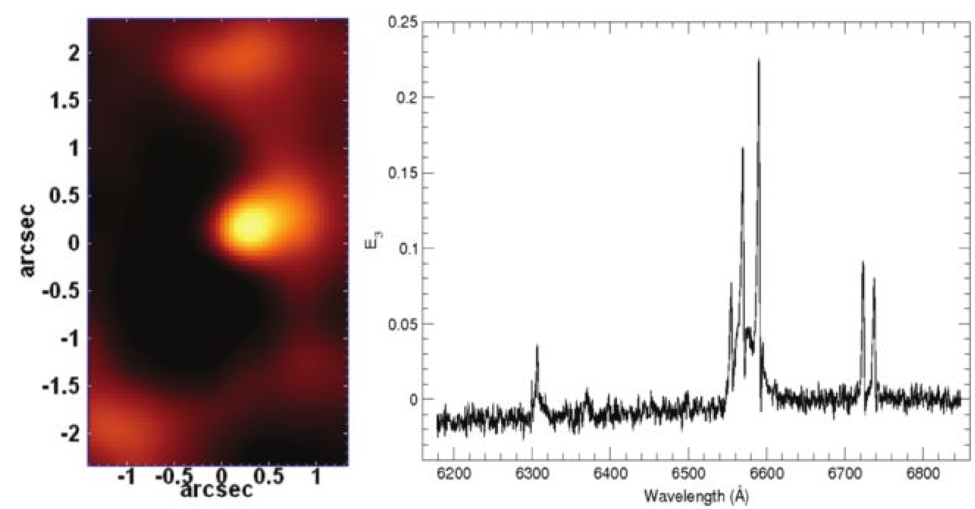


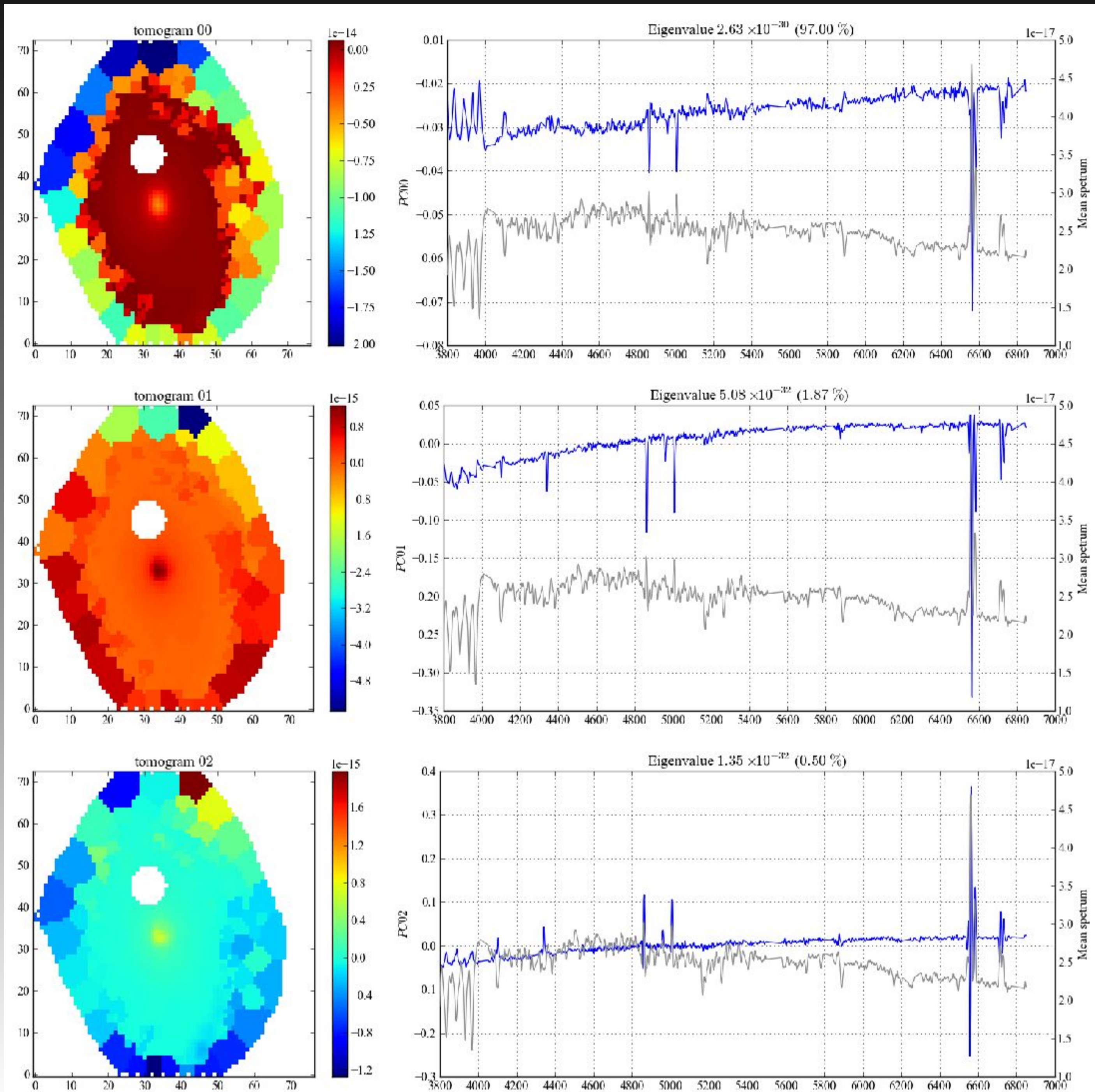
Figure A3. Tomogram of the principal component 3 and respective eigenspectrum.

PCA pre-processing

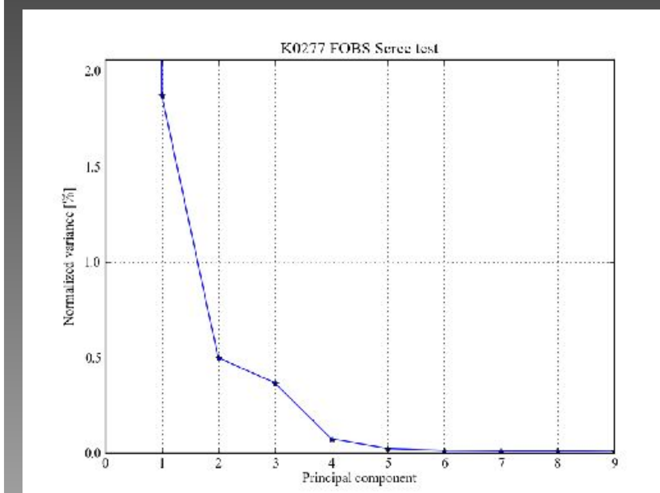
PCAble things:

- Observed fluxes (Fobs)
- Synthetic fluxes (Fsyn - STARLIGHT)
- Residual fluxes (Fobs – Fsyn)
- Spectra without kinematics
- Spectra without emission lines (stellar light)
- Line fluxes or equivalent widths
- Log(flux)
- A specific range (like [OIII]Hb and/or [NII]Hα)
- All of those above but normalized
- etc...

First results - CALIFA 277 (NGC2916)



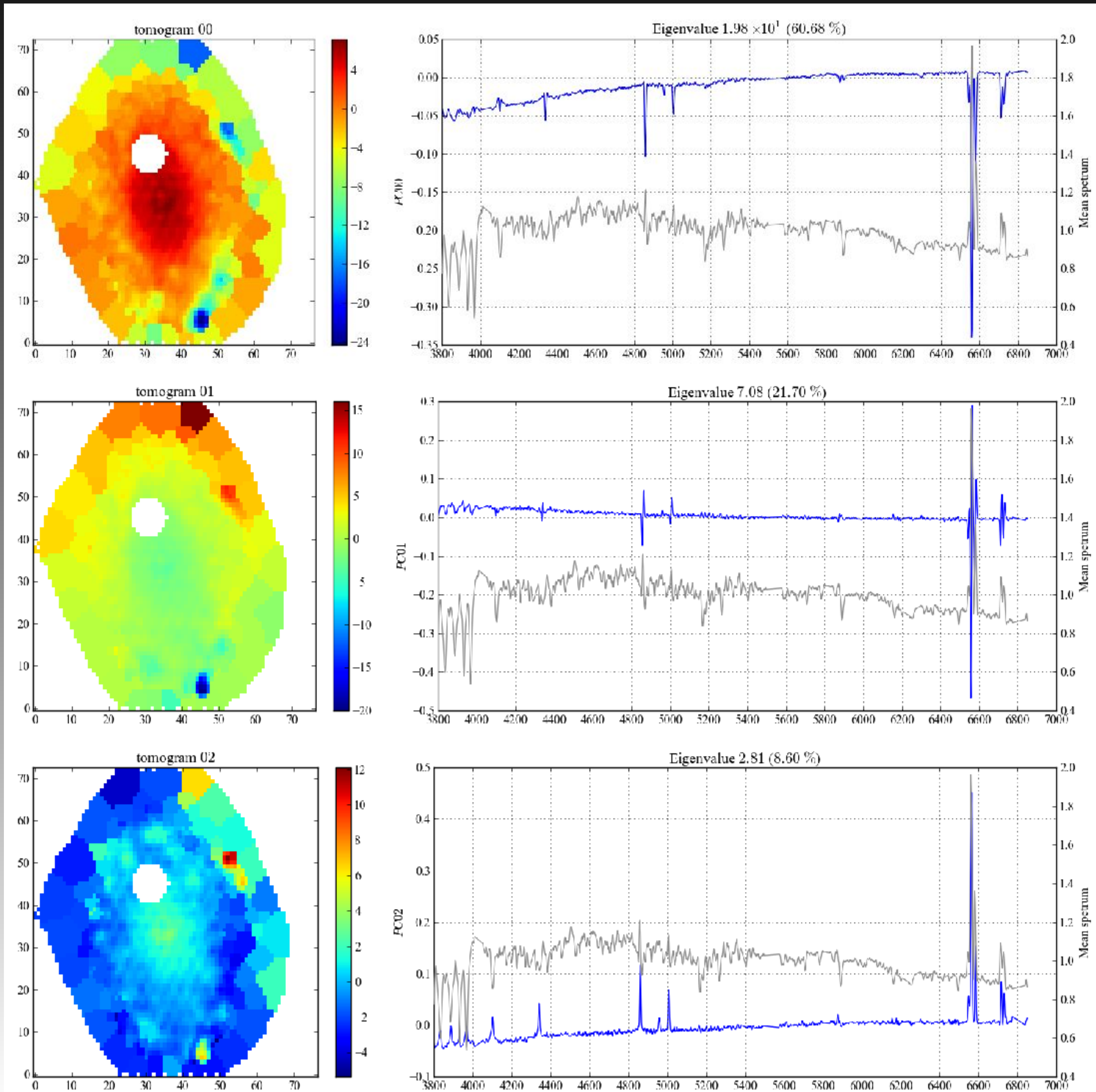
PCA Tomograms



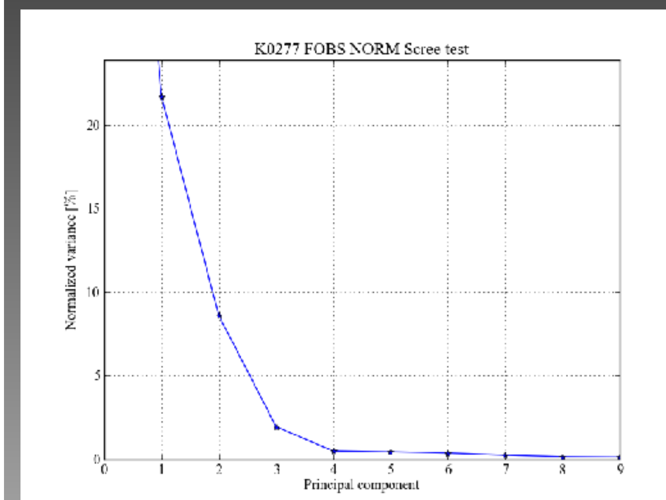
Scree test

Observed Flux

First results - CALIFA 277 (NGC2916)



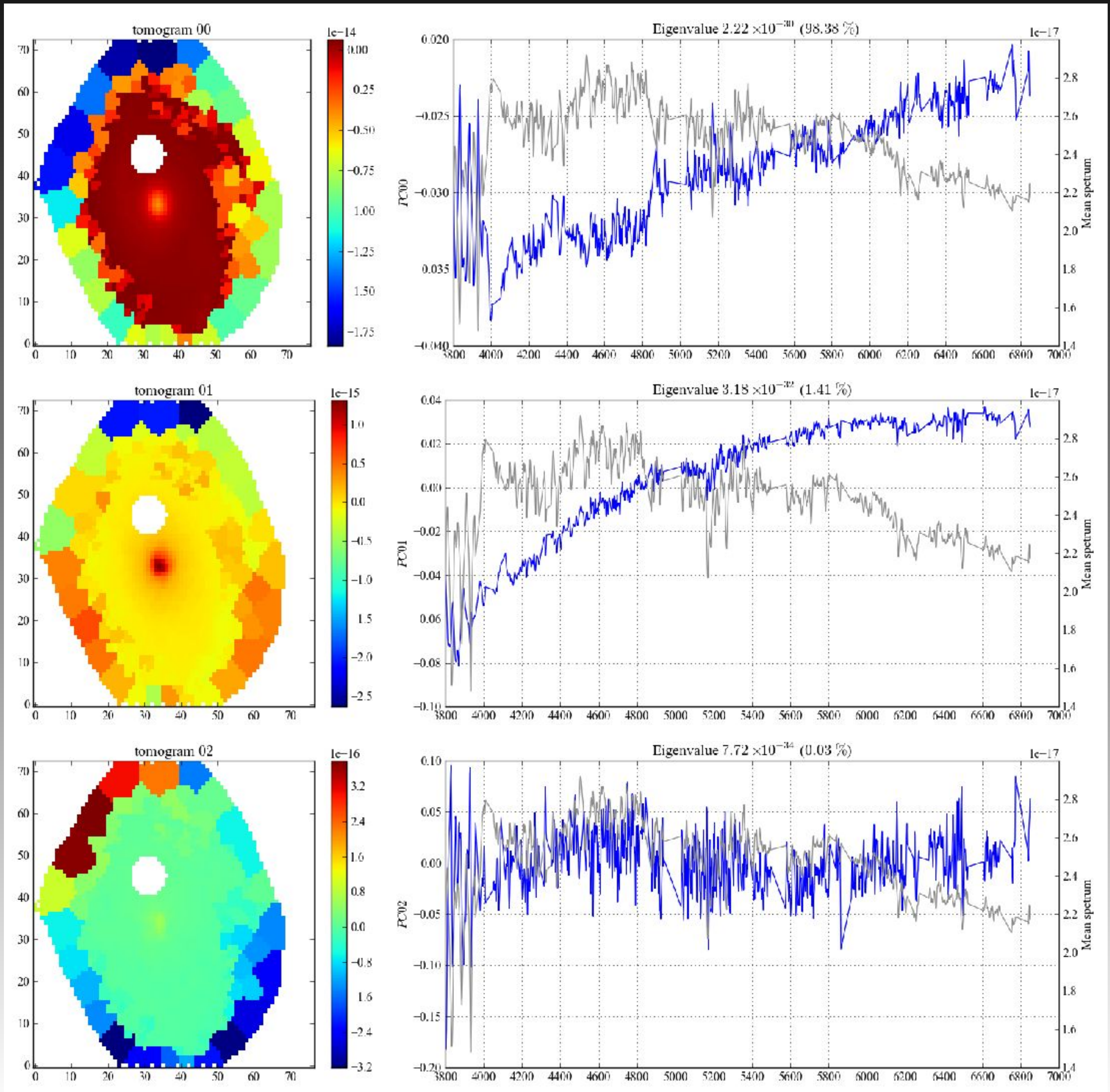
PCA Tomograms



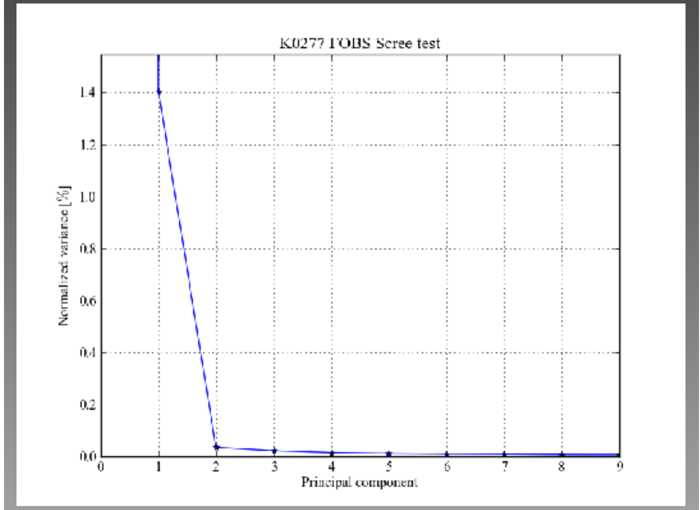
Scree test

Normalized observed flux

First results - CALIFA 277 (NGC2916)



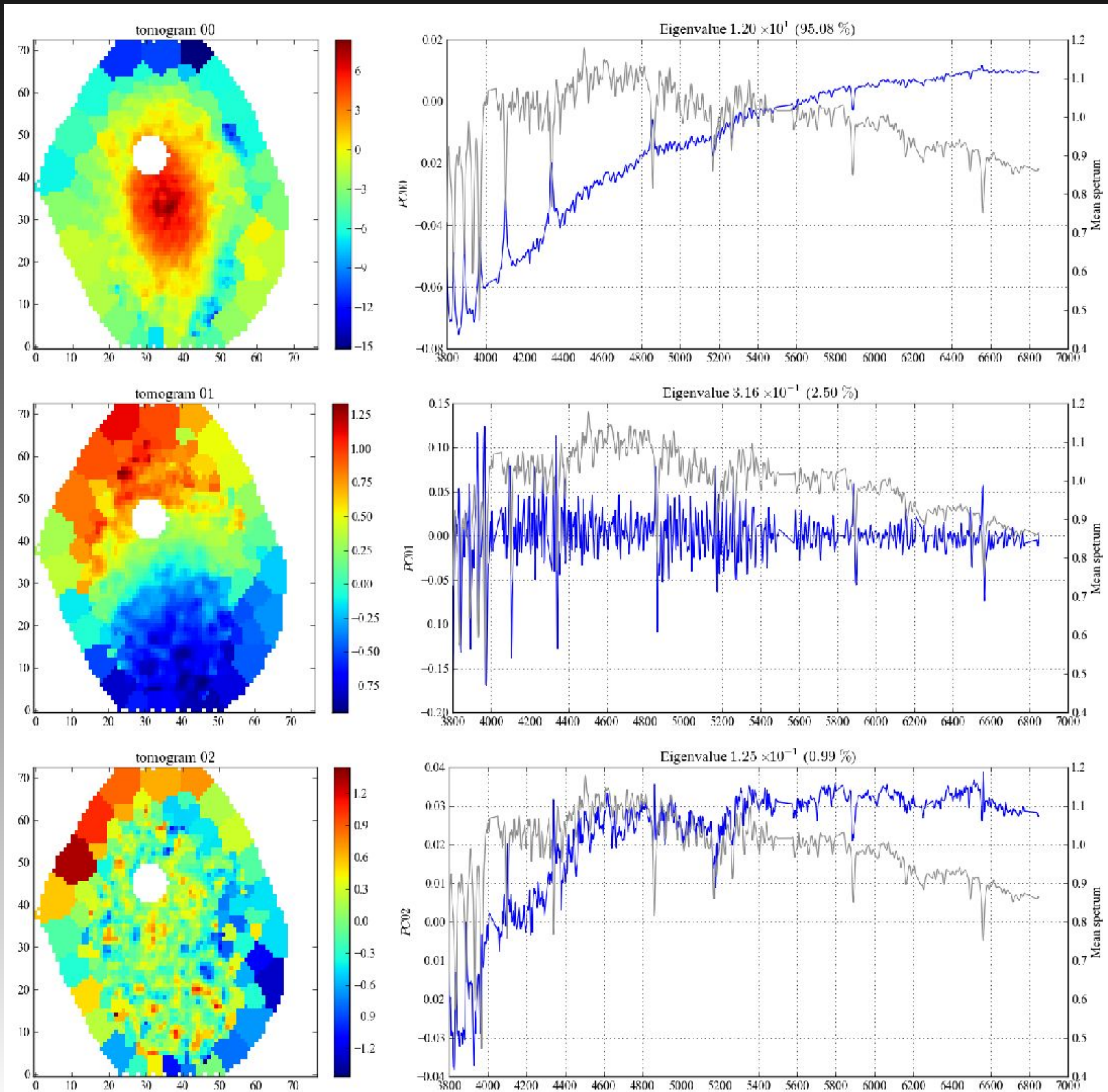
PCA Tomograms



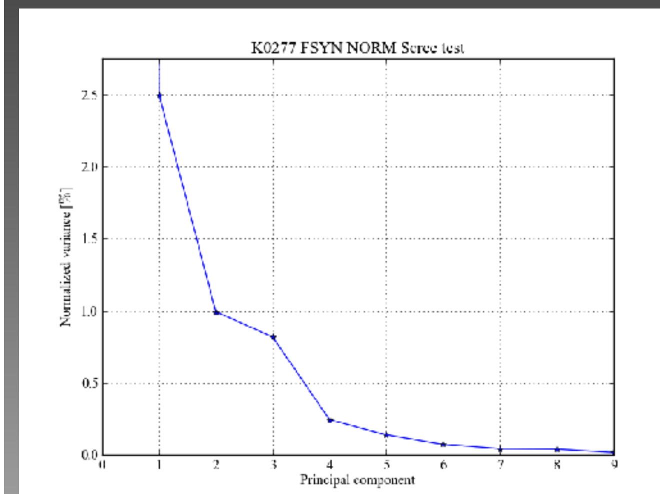
Scree test

Observed flux without emission lines

First results - CALIFA 277 (NGC2916)



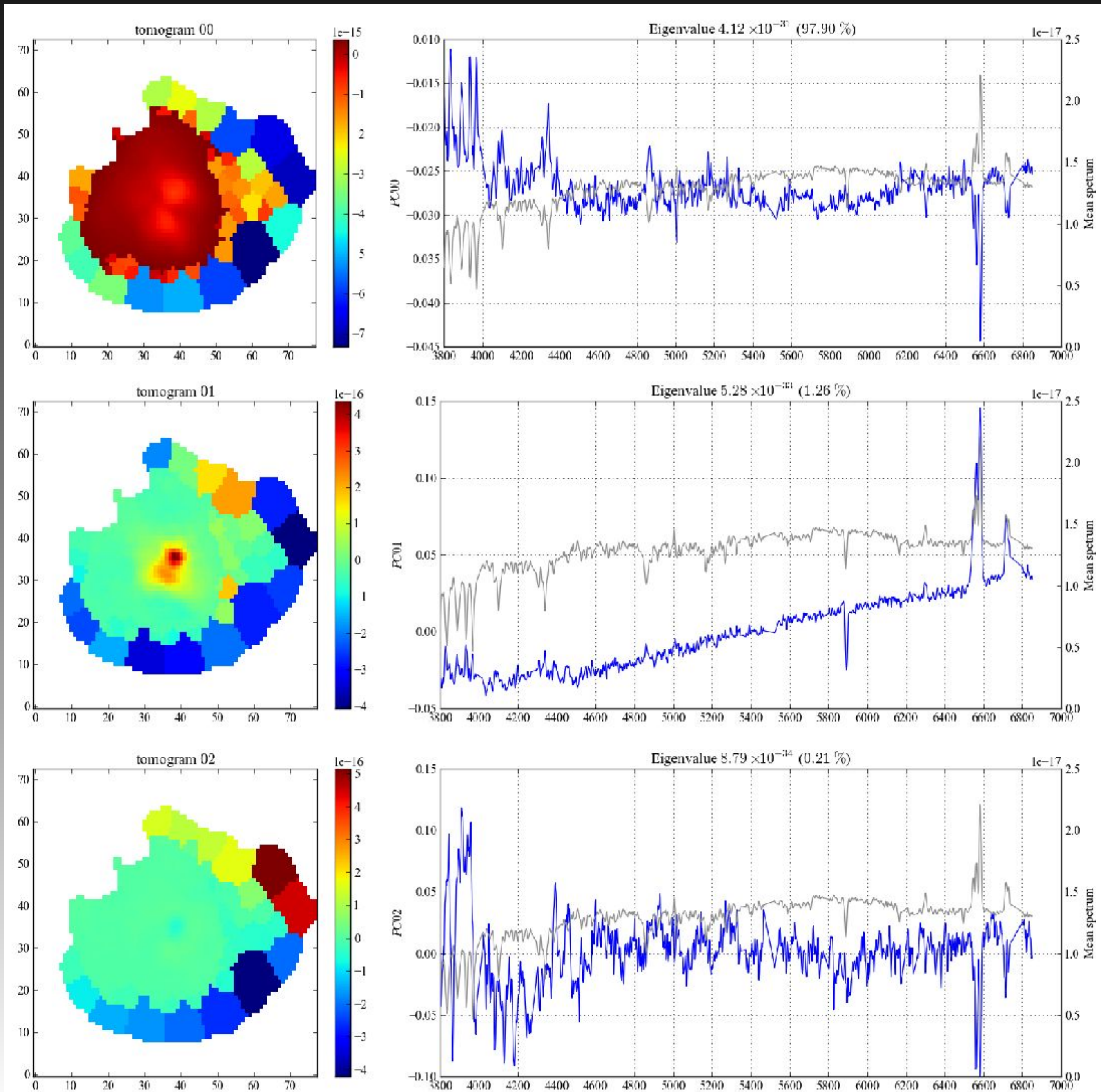
PCA Tomograms



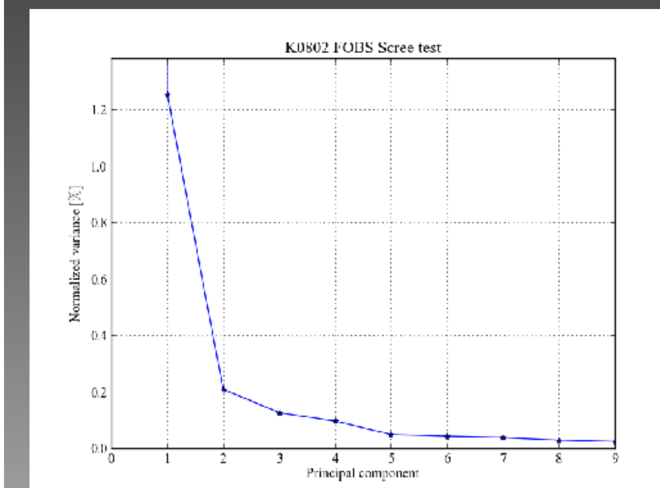
Scree test

Normalized synthetic flux

First results - CALIFA 802 (Arp220)



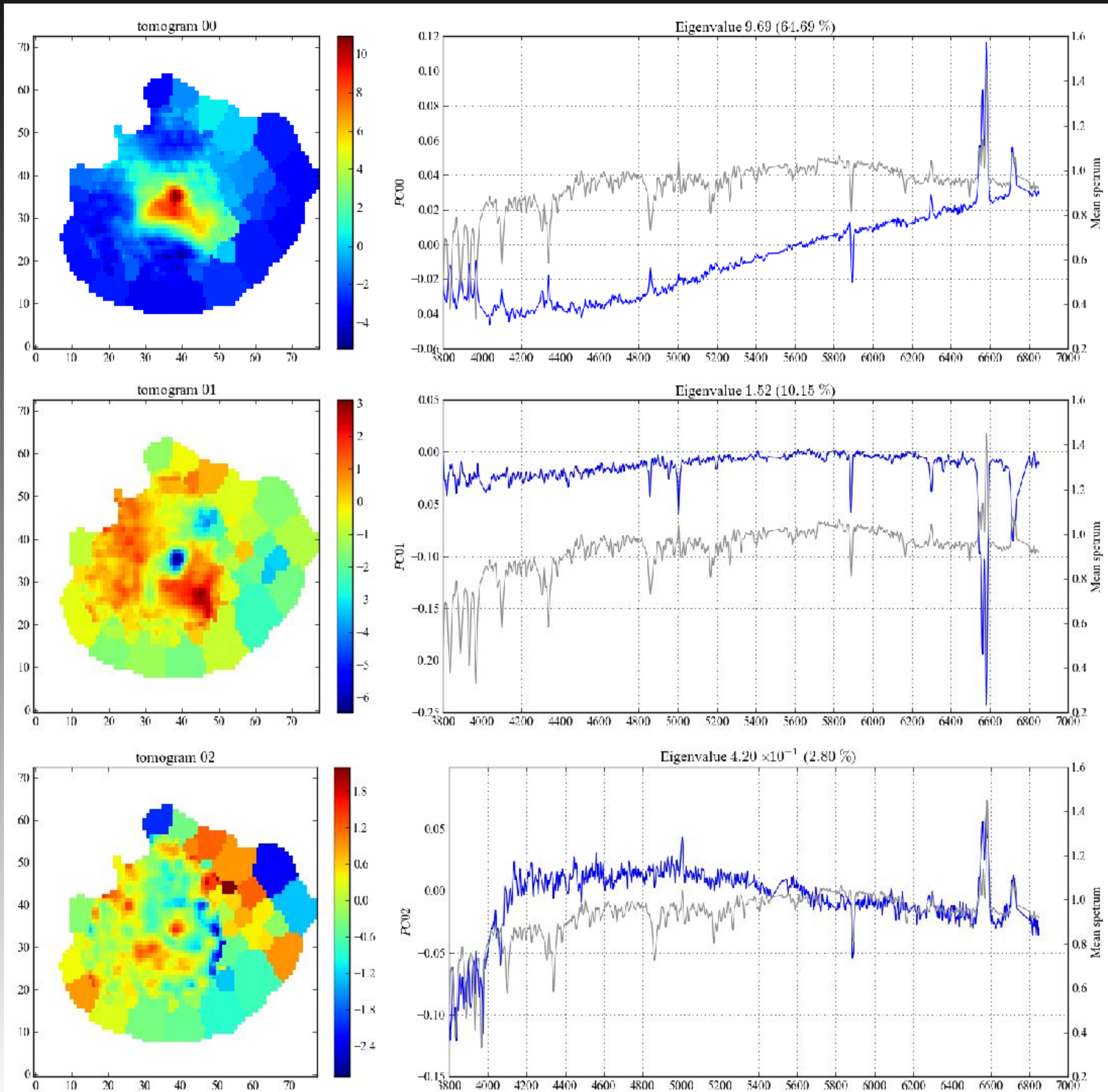
PCA Tomograms



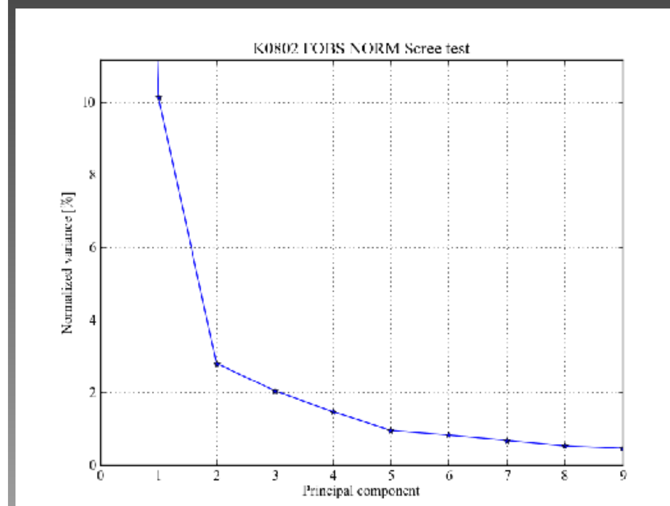
Scree test

Observed flux

First results - CALIFA 802 (Arp220)



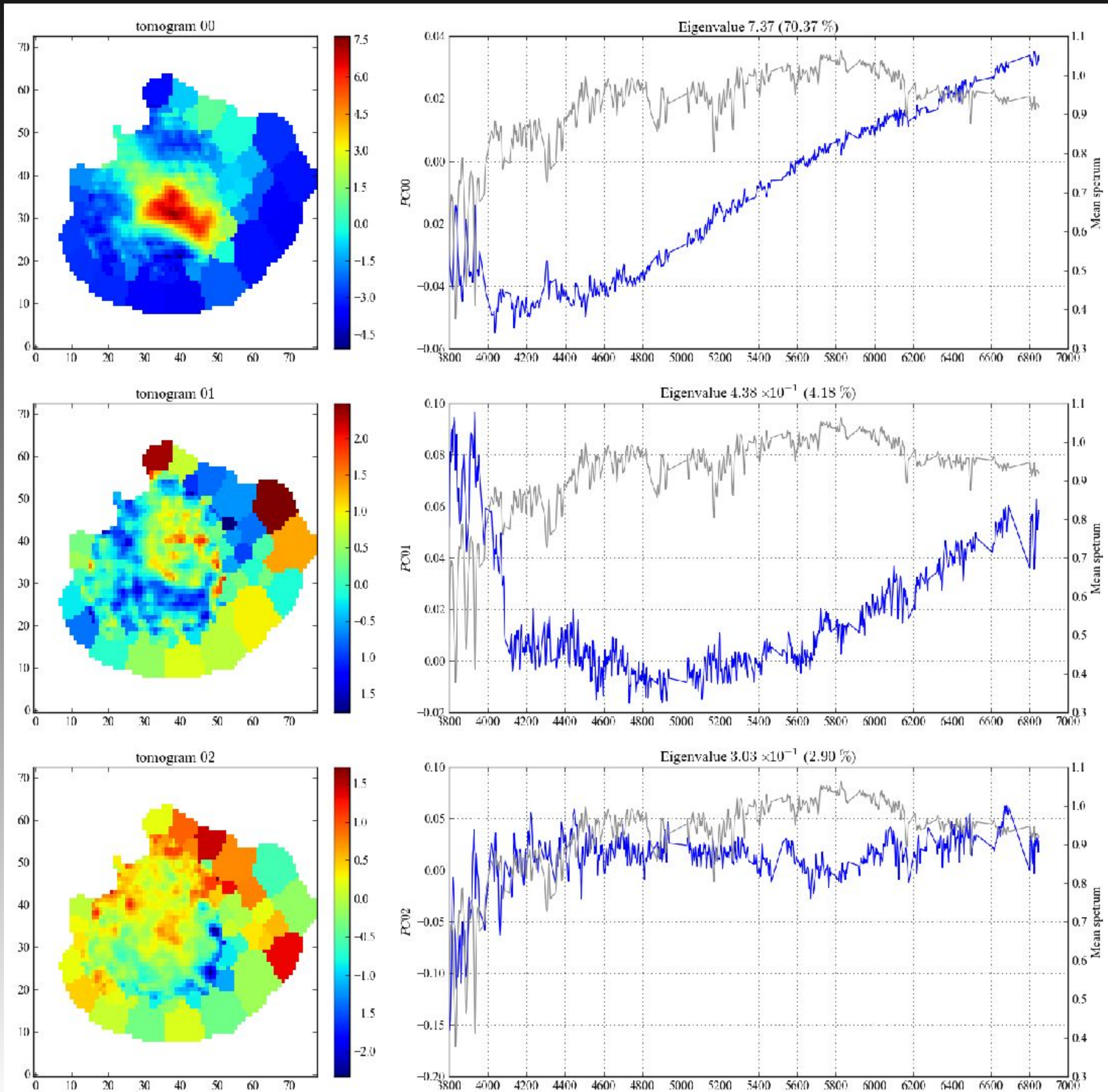
PCA Tomograms



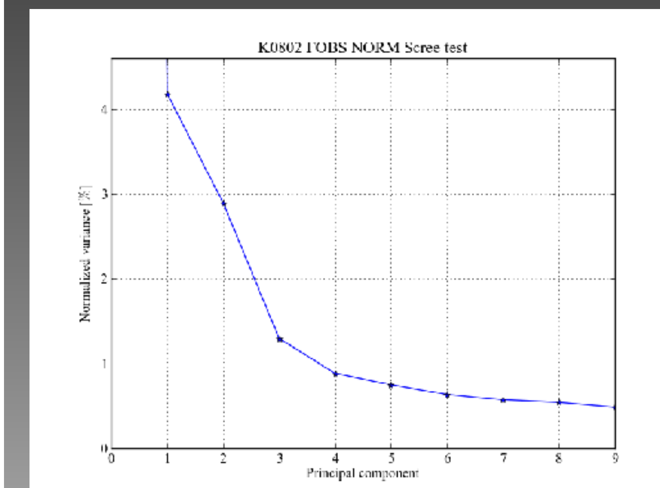
Scree test

Normalized observed flux

First results - CALIFA 802 (Arp220)



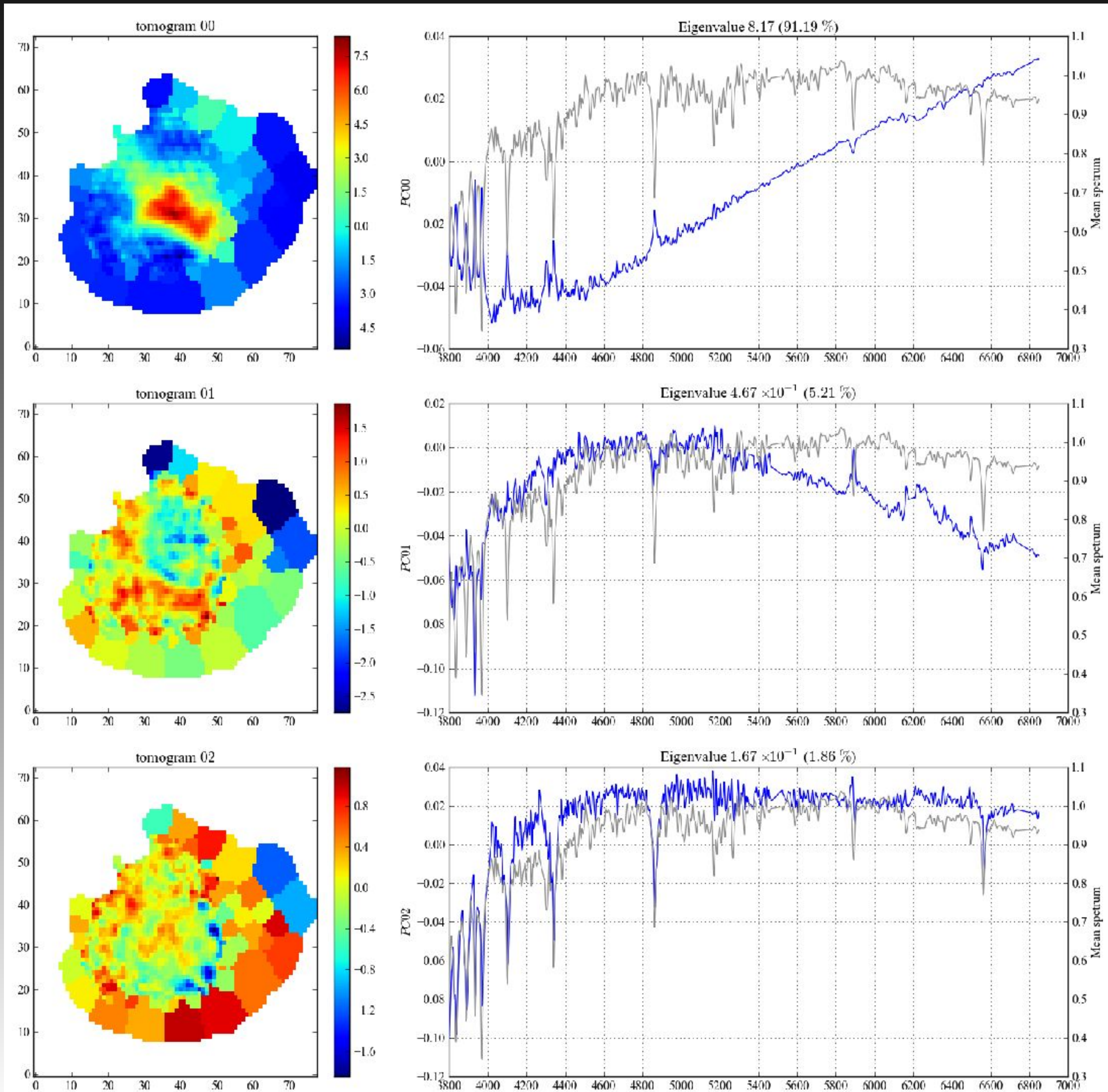
PCA Tomograms



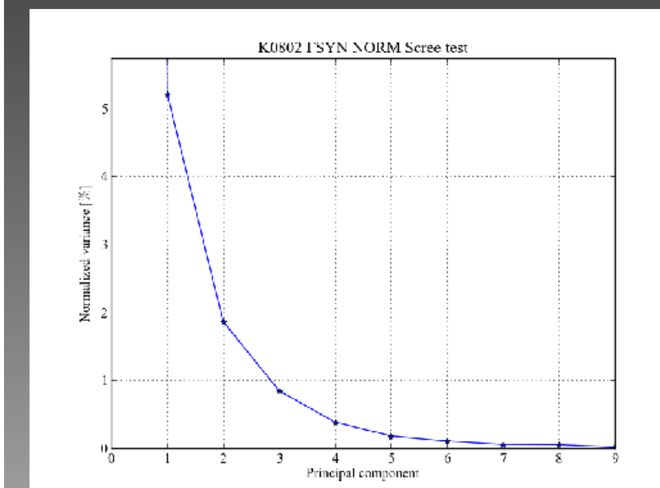
Scree test

Observed flux without emission lines

First results - CALIFA 802 (Arp220)



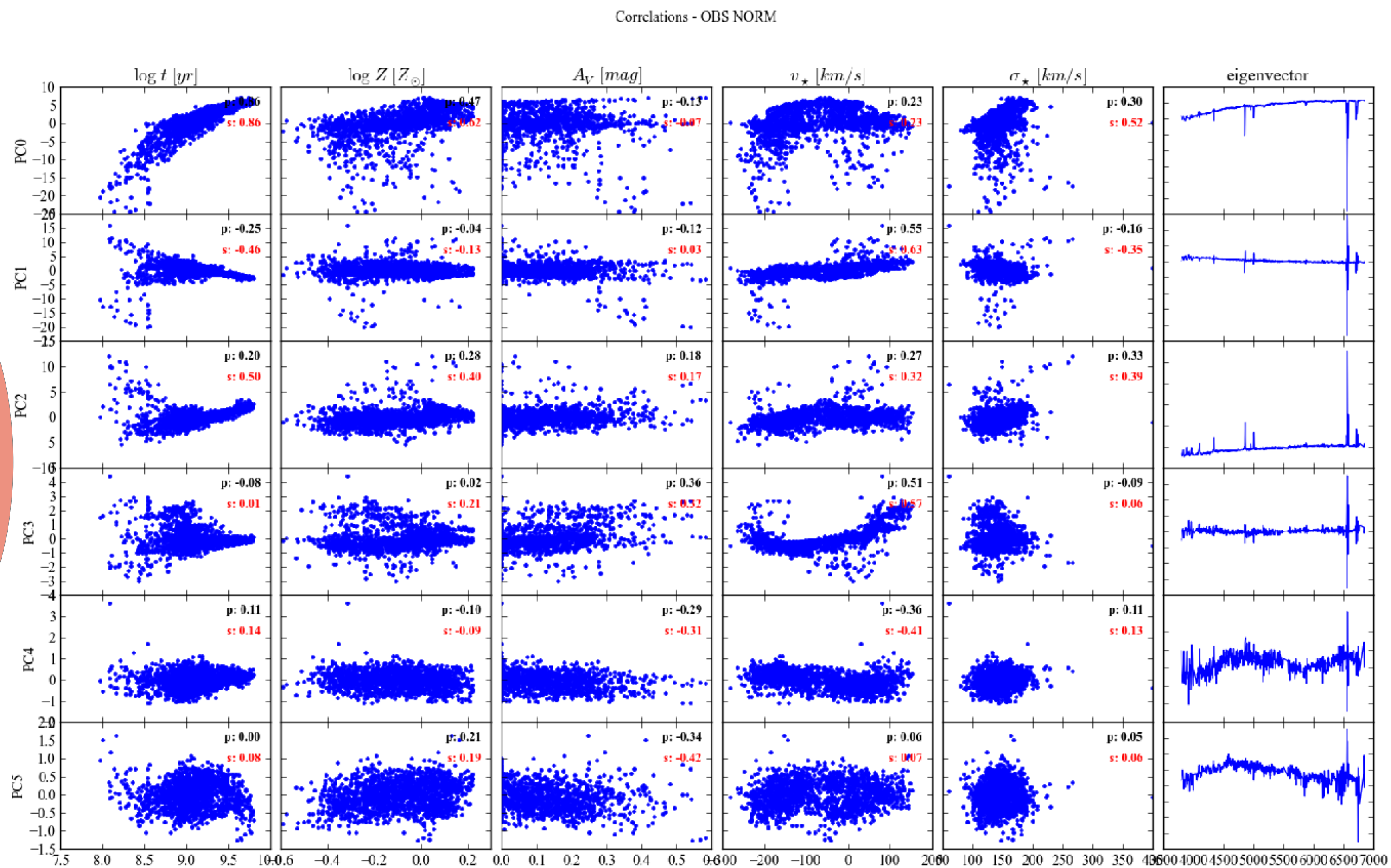
PCA Tomograms



Scree test

Normalized synthetic flux

Correlations – CALIFA 277 (NGC2916)

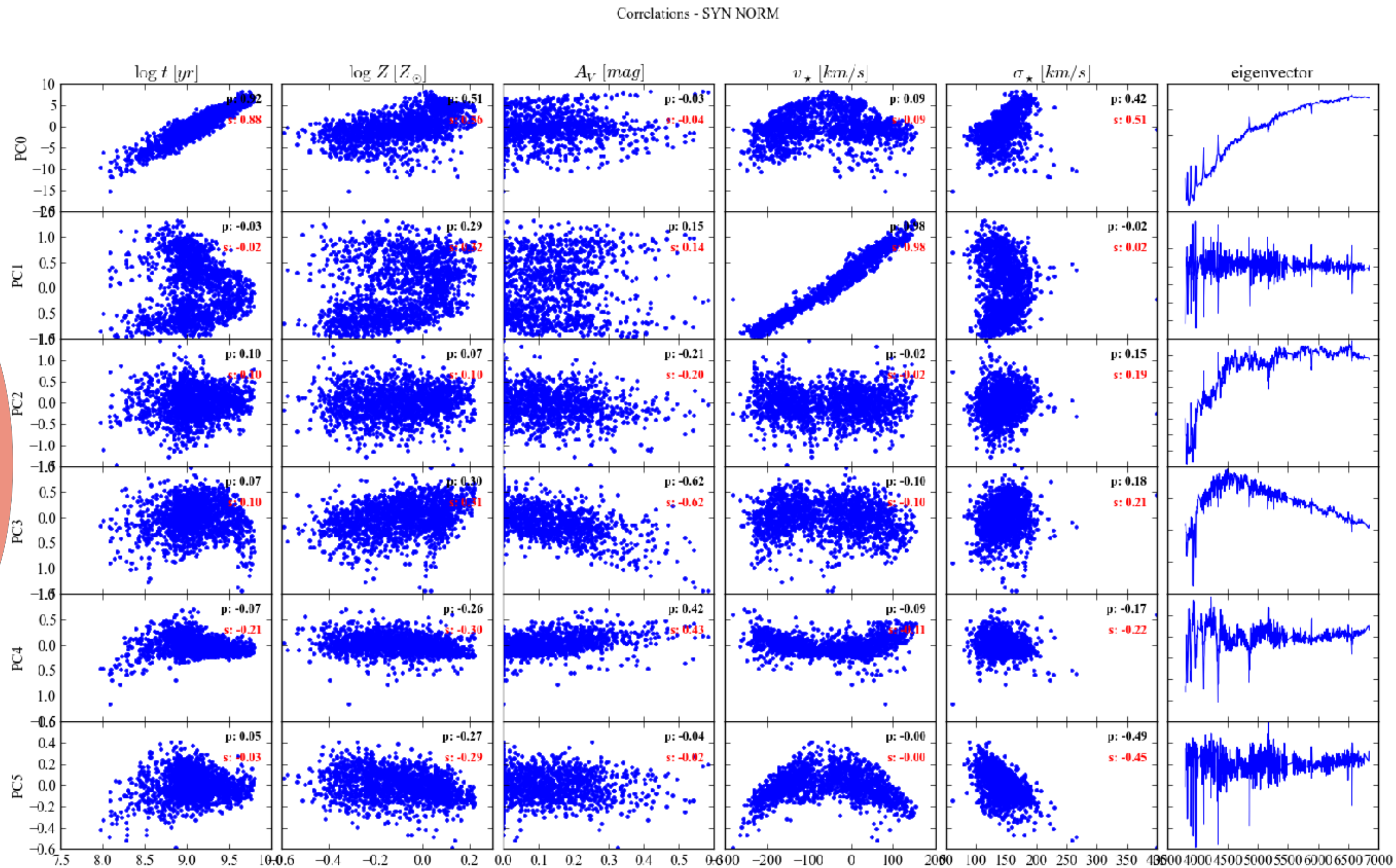


Normalized observed flux

Reverse Engineering

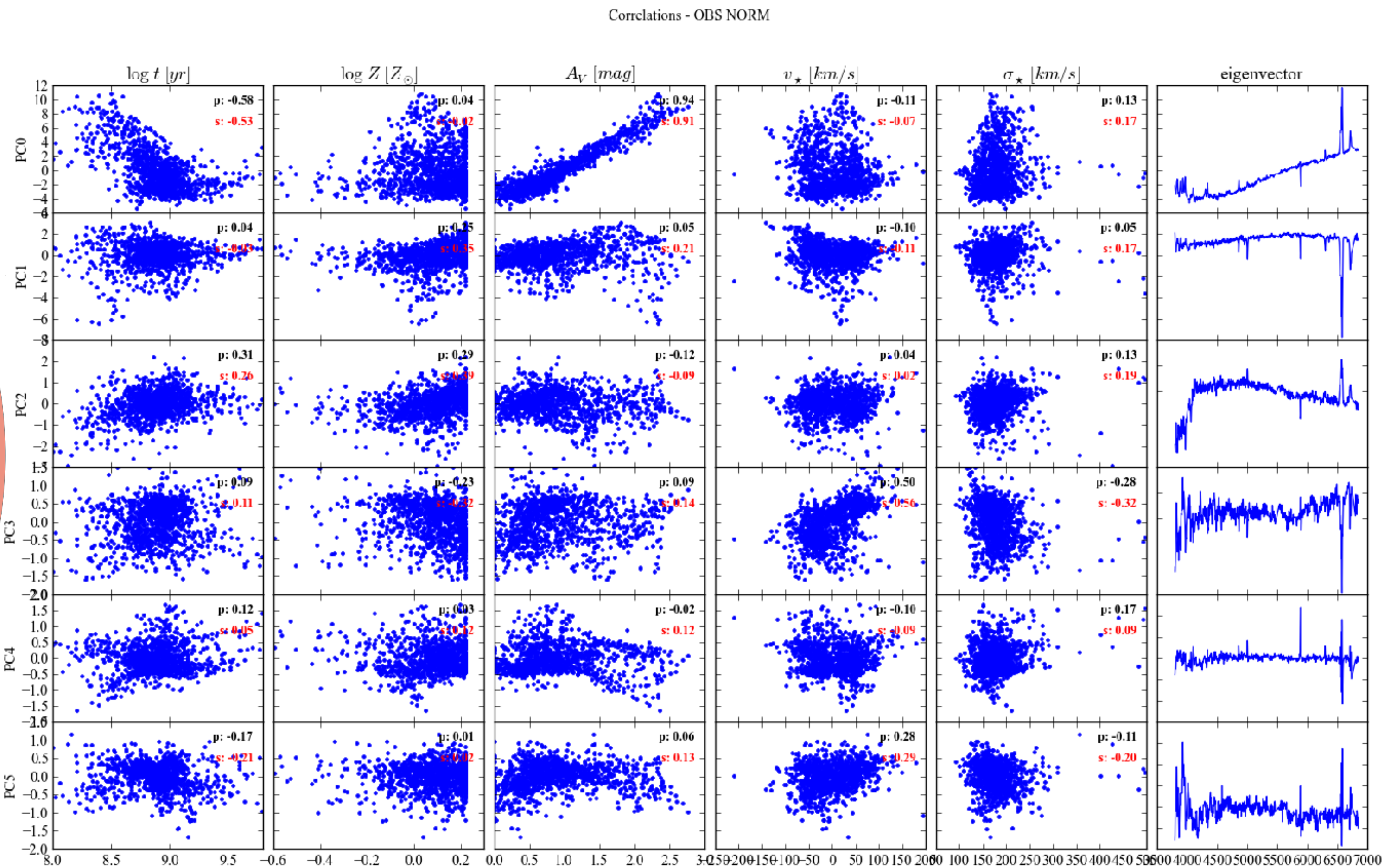
Correlations – CALIFA 277 (NGC2916)

Normalized synthetic flux



Reverse Engineering

Correlations – CALIFA 802 (Arp220)

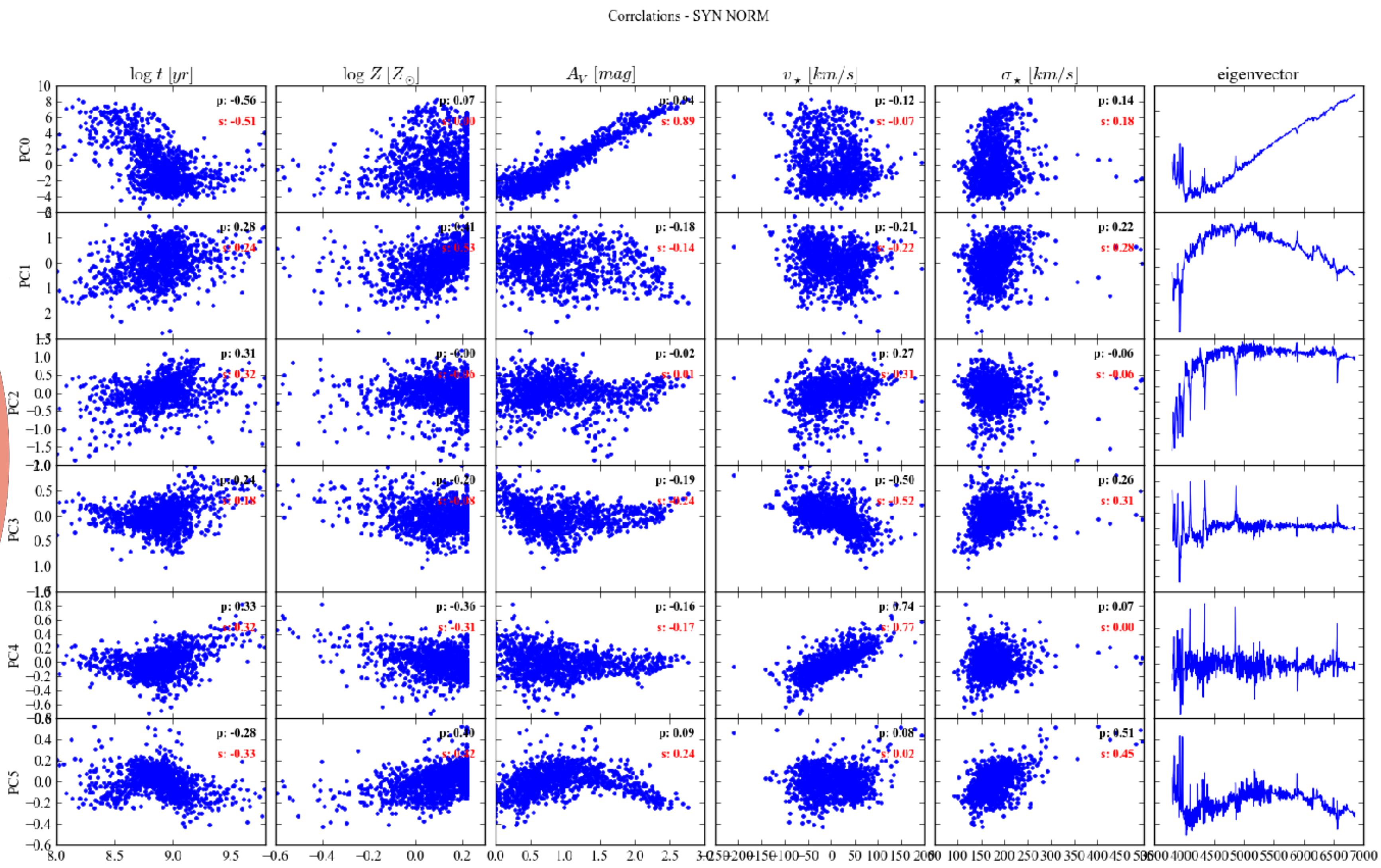


Normalized observed flux

Reverse Engineering

Correlations – CALIFA 802 (Arp220)

Normalized synthetic flux



Reconstruct spectra

With the eigenvectors matrix $(\mathbf{E}_{\lambda k})$, we reconstruct the matrix $\mathbf{I}^{rec}_{z\lambda}$ with $k \leq r$ eigenvectors as:

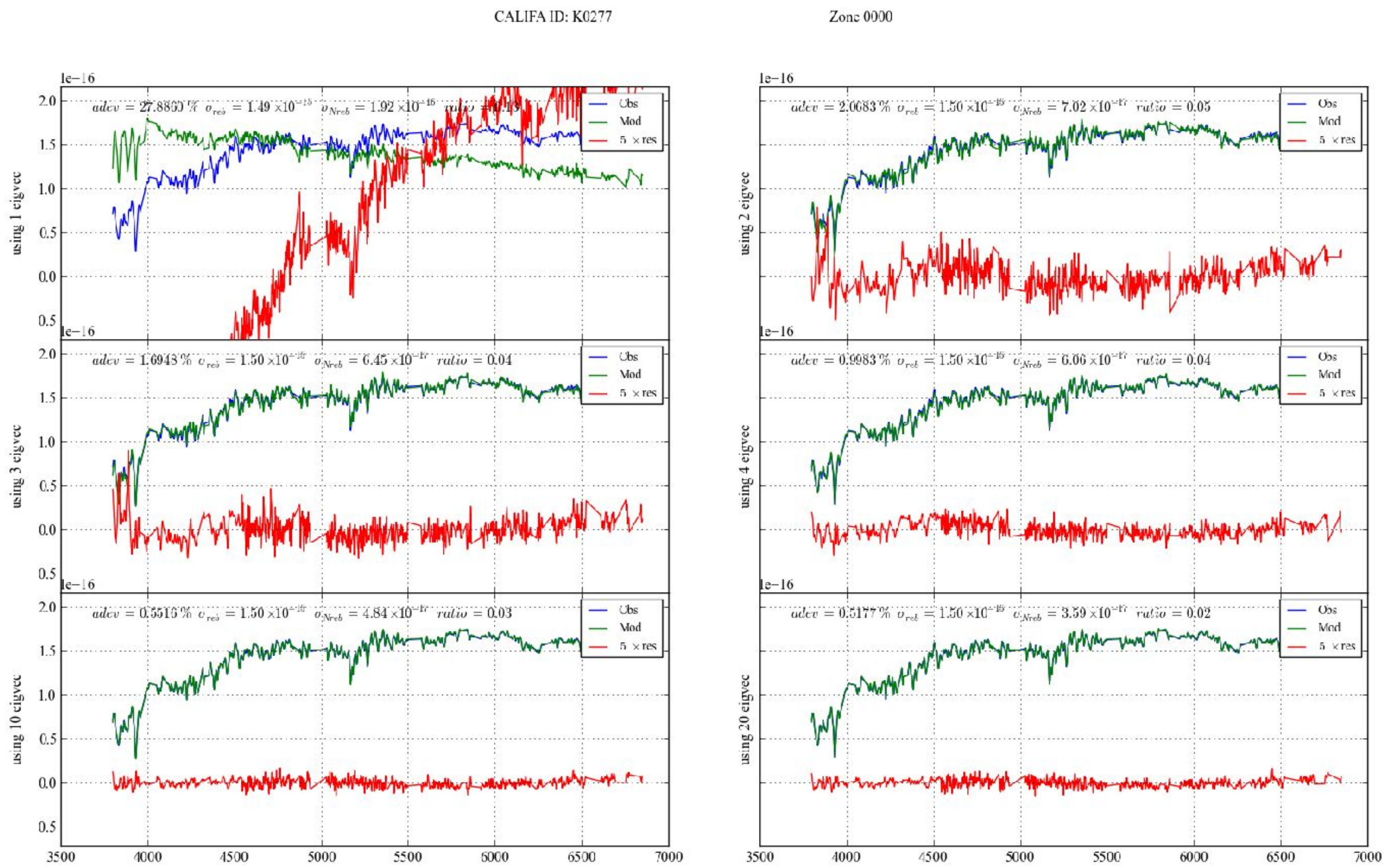
$$\mathbf{I}^{rec}_{z\lambda}(k \leq r) = \mathbf{T}_{zk}(k \leq r) \cdot [\mathbf{E}_{\lambda k}(k \leq r)]^T \quad (6)$$

The reconstructed flux matrix $(\mathbf{F}^{rec}_{z\lambda})$ now can be obtained adding $\langle \mathbf{F}_\lambda \rangle$ to $\mathbf{I}^{reb}_{z\lambda}$:

$$\mathbf{F}^{rec}_{z\lambda} = \mathbf{I}^{rec}_{z\lambda} + \langle \mathbf{F}_\lambda \rangle \quad (7)$$

Reconstruct spectra

CALIFA 277 (NGC2916) – central pixel (zone 0)



Conclusions

Ask me in one year !!!





¡Gracias!