Multi-band selection of quasars: probing the large-scale structure in the Universe

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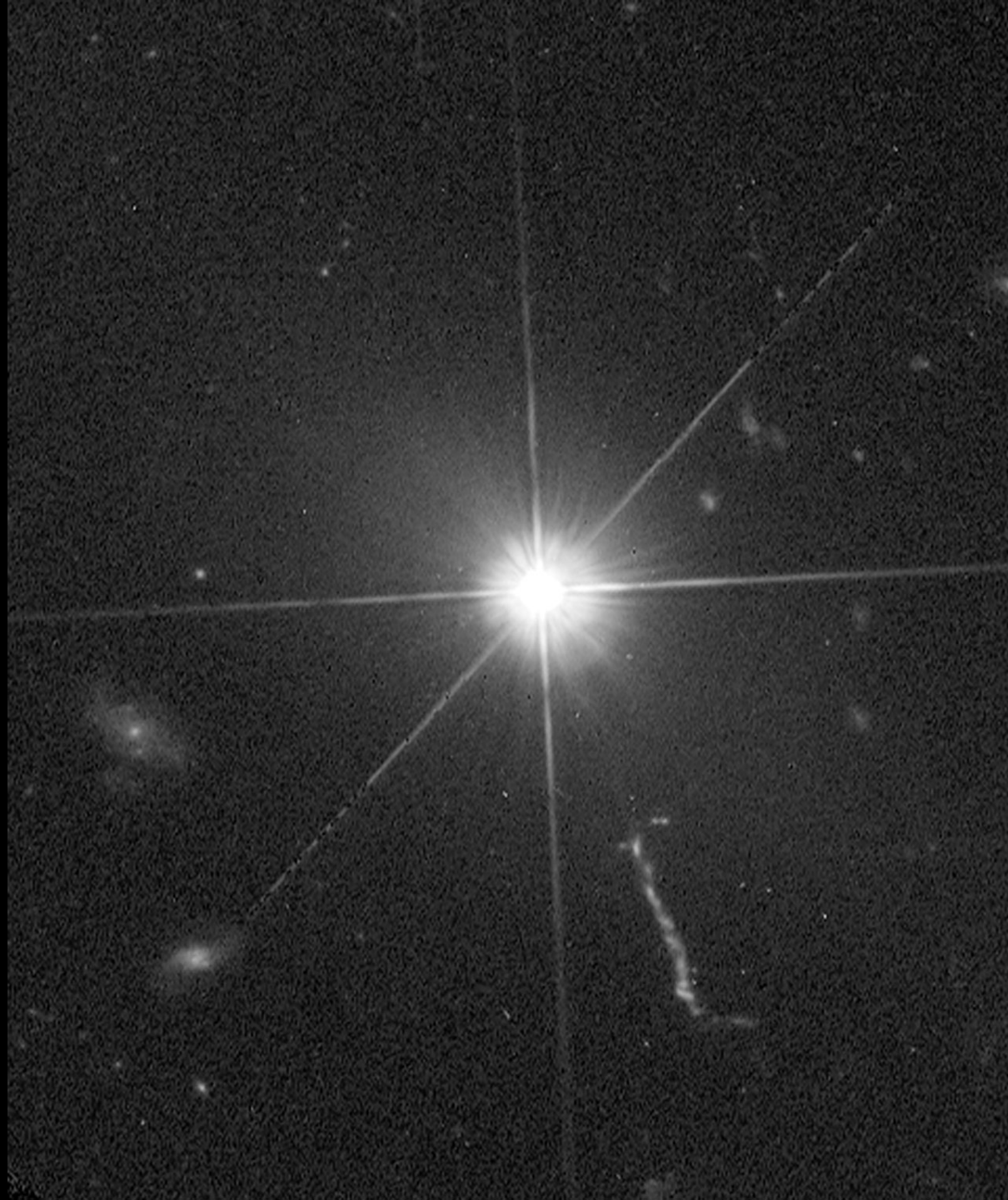
How can we obtain a complete and accurate catalog of quasars in the context of narrow-band filter surveys?

Can we retrieve robust redshift probability distributions for the quasars?

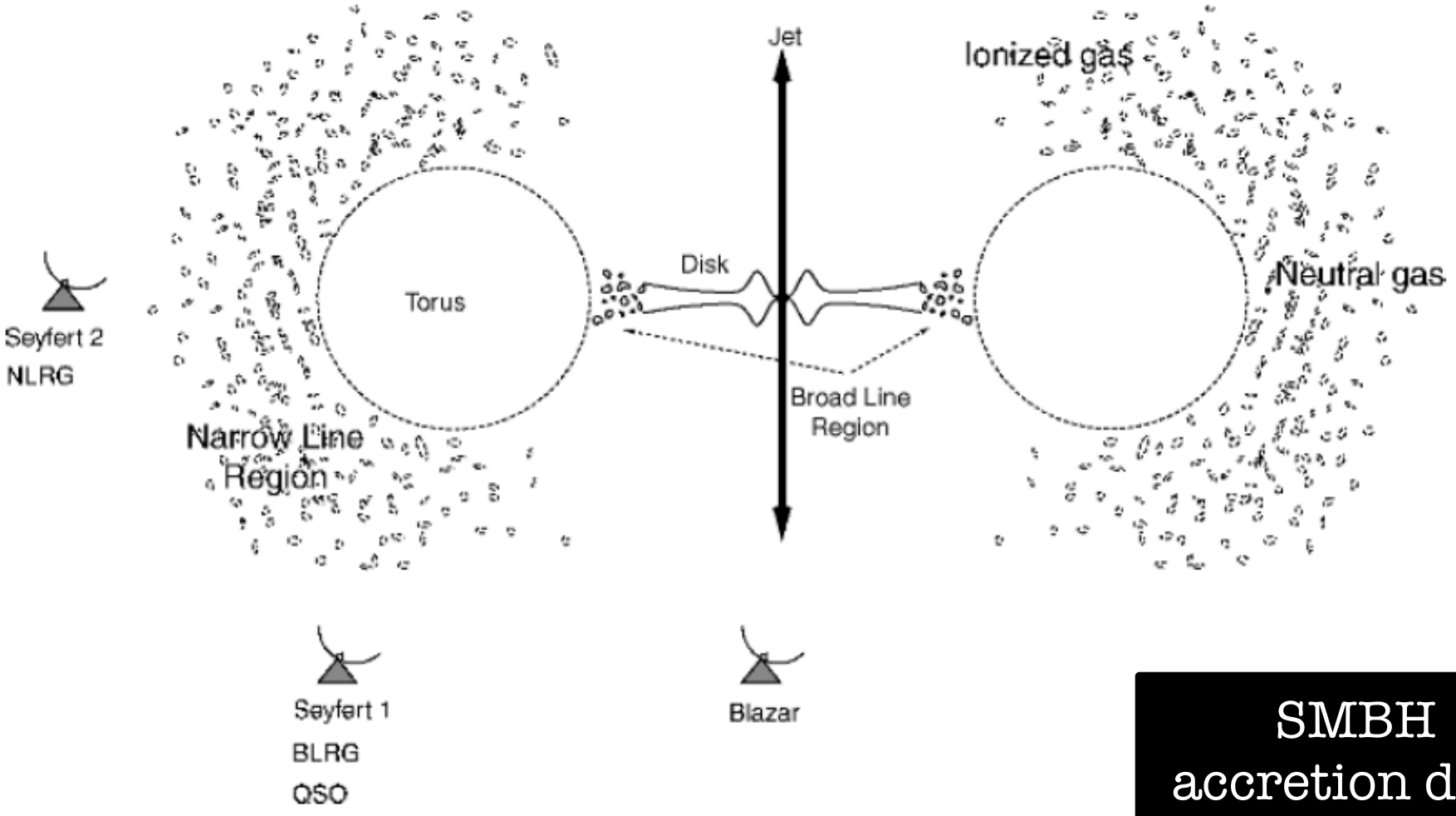
By employing our tools, what kind of properties can we derive for the quasar candidates?

Quasi-stellar objects: Strange radio sources



Source 3C273 at $z = 0.158$
(Credit: ESA/Hubble)

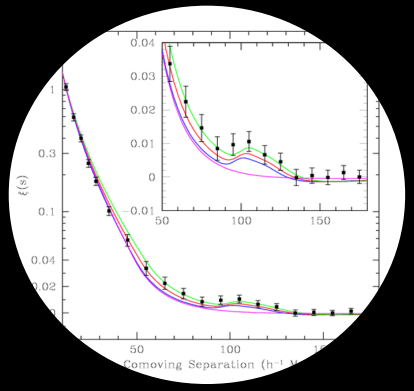
The unified model of AGNs

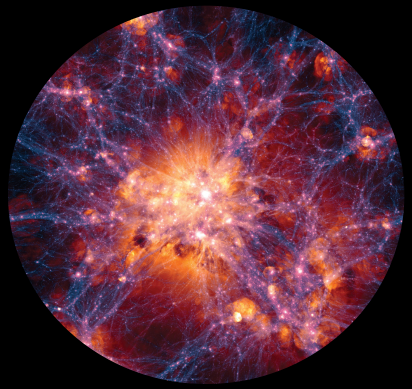


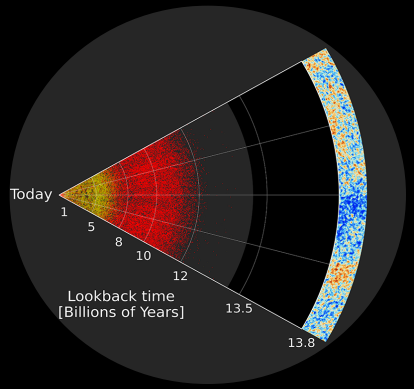
[Urry & Padovani 1995]

SMBH
accretion disc
axisymmetry

Cosmology with quasars







Most luminous types of AGNs:

they can be detected at large distances!

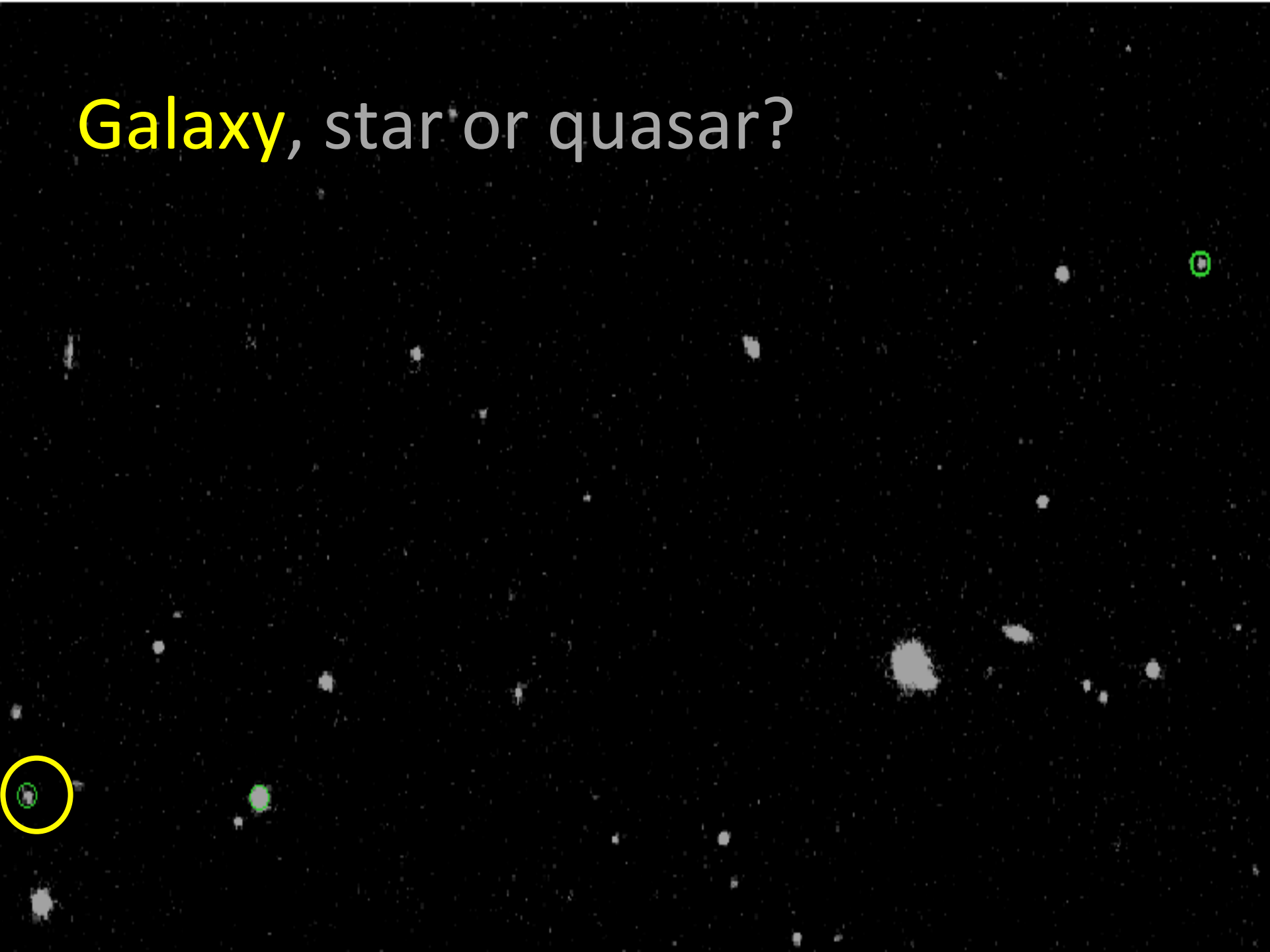
Inhabit the centers of very massive DM halos:
probe conditions in the early Universe!

Map structures on the largest scales:
non-Gaussianities, constrain cosmological parameters…

Active phase may be present in every galaxy's lifetime!

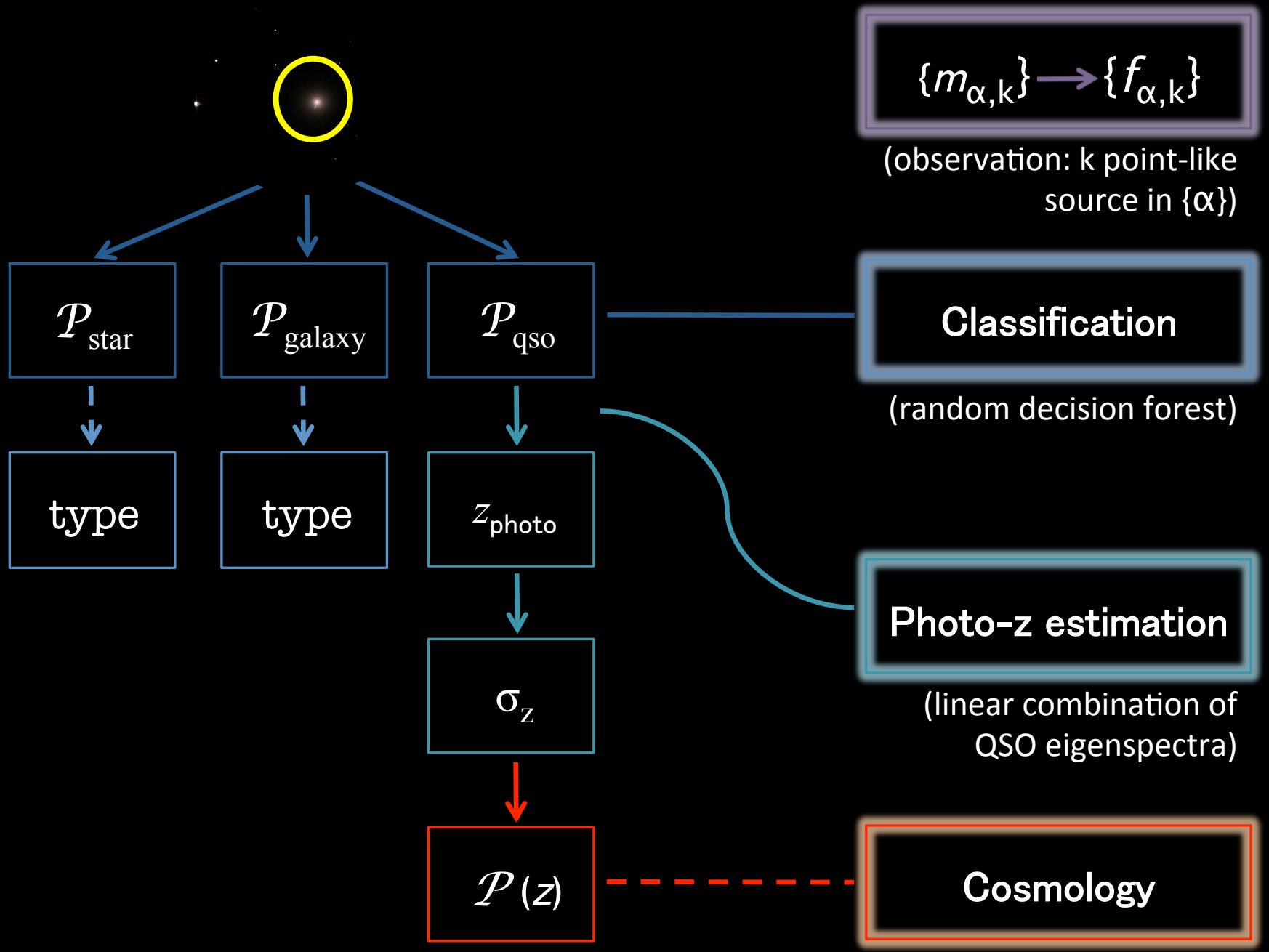
Galaxy, star or quasar?

Galaxy, star or quasar?



Galaxy, star or quasar?

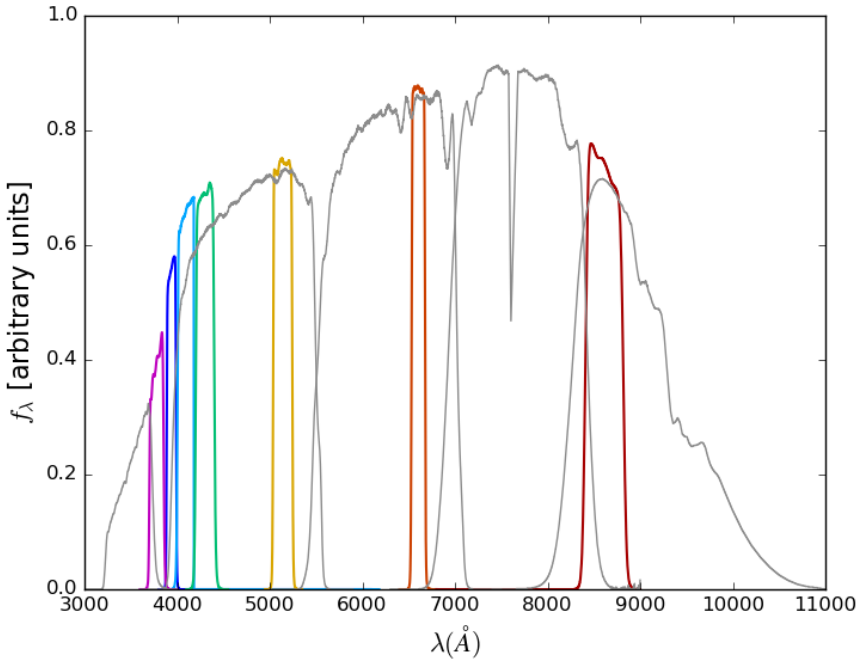
Galaxy, star or quasar?


$\{m_{\alpha,k}\} \rightarrow \{f_{\alpha,k}\}$
(observation: k point-like source in {α})
$\mathcal{P}_{\mathrm{star}}$
$\mathcal{P}_{\mathrm{galaxy}}$
$\mathcal{P}_{\mathrm{qso}}$
Classification
(random decision forest)
type
type
z_{photo}
Photo-z estimation
(linear combination of QSO eigenspectra)
σ_z
$\mathcal{P}(z)$
Cosmology

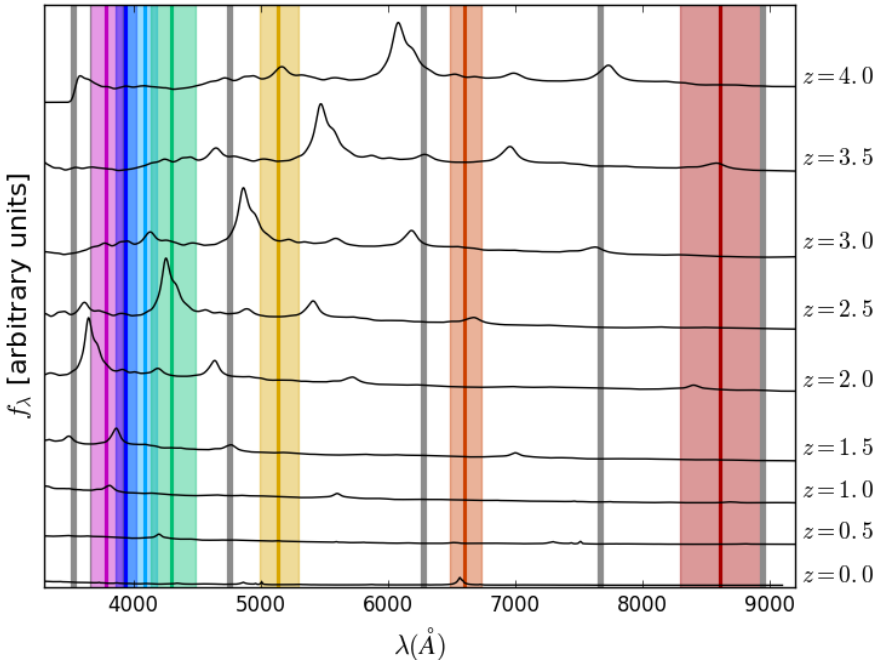
S-PLUS: Southern Photometric Local Universe Survey

14,000 deg^2 of Southern sky
2 deg^2 fov camera
0.80 m telescope (T80-S)
Cerro Tololo, Chile
Photometry: 5 BB + 7 NB
First Data Release (80 fields in Stripe 82)

S-PLUS photometric system

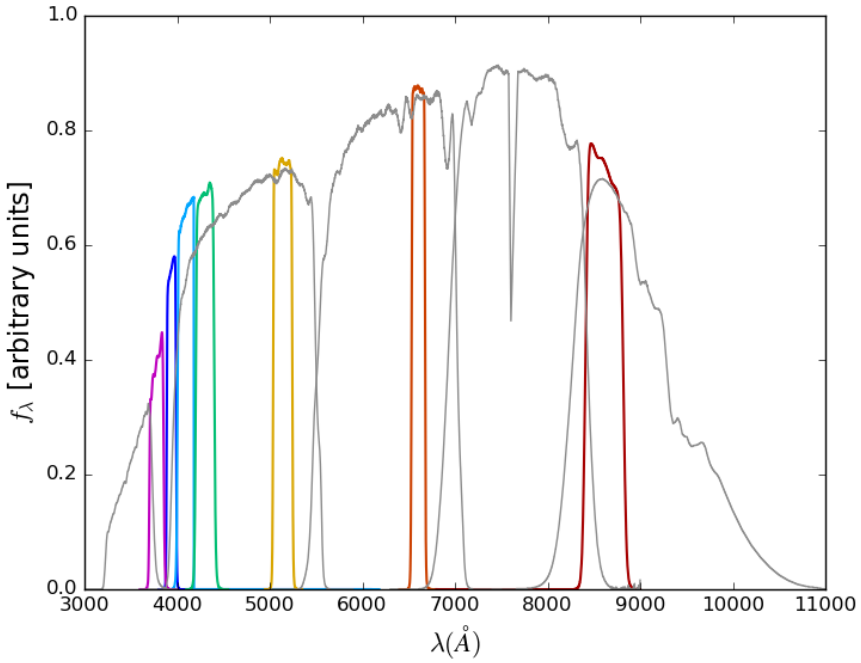


5 SDSS-like ugriz
7 narrow-band filters



Vanden Berk composite quasar spectrum at different z's

S-PLUS photometric system



5 SDSS-like ugriz
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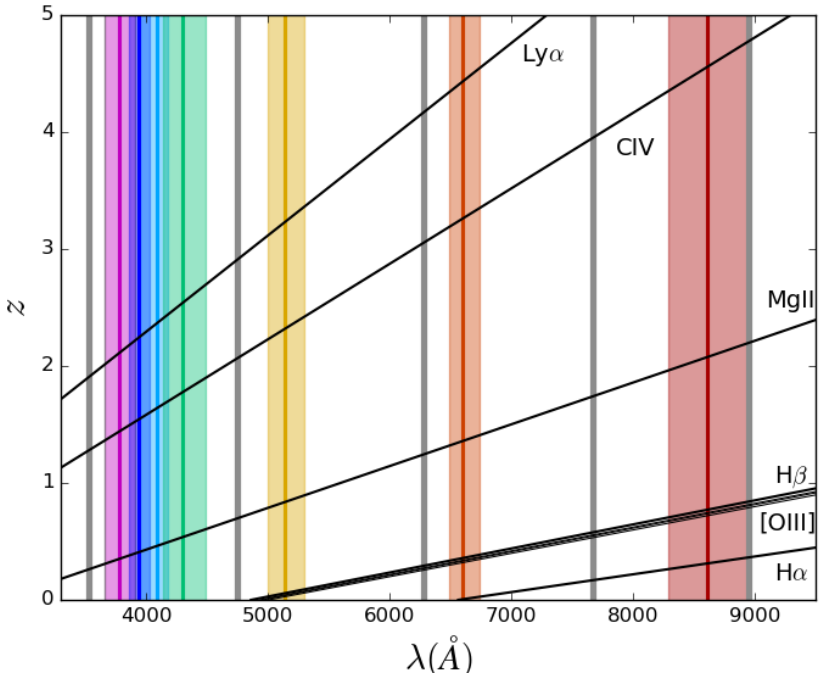
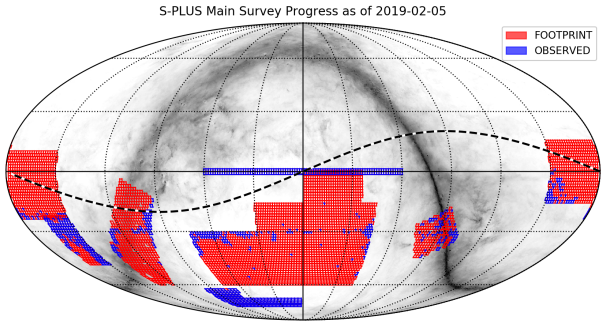


Main quasar emission lines at different z's

Quasar identification: S-PLUS DR1



Tiles completed: 754 / 4520 (16.6814159292%)

Machine learning

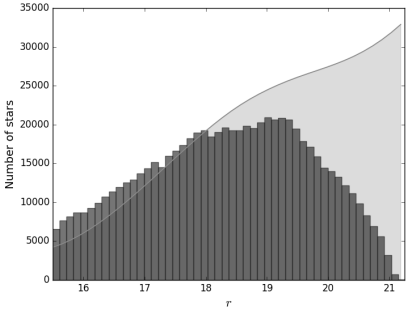
(in collaboration w/ Eloi Patarro):

Random forest algorithm

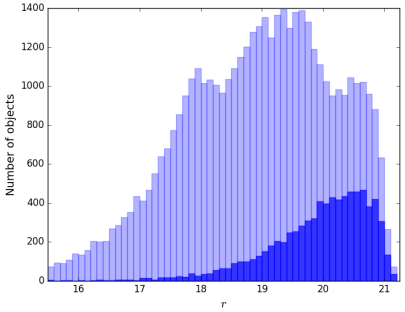
Training sets with synthetic fluxes

Probability that any given point-like source is a **star**, **galaxy** or **quasar**

stars



gals/**qsos**



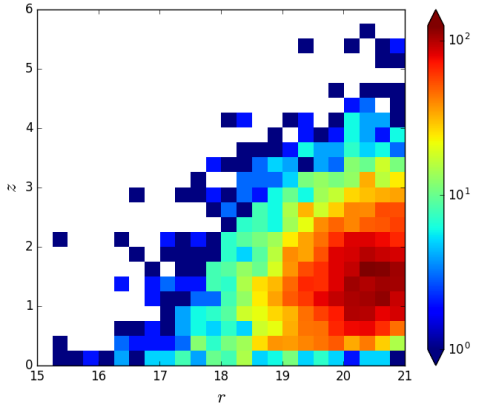
Sample test:

61,717 point-like sources in Stripe-82 region w/ spectroscopic match

15 < *r* < 22 / CLASS = 6 / PhotoFlag < 3

7,404 quasars

qsos

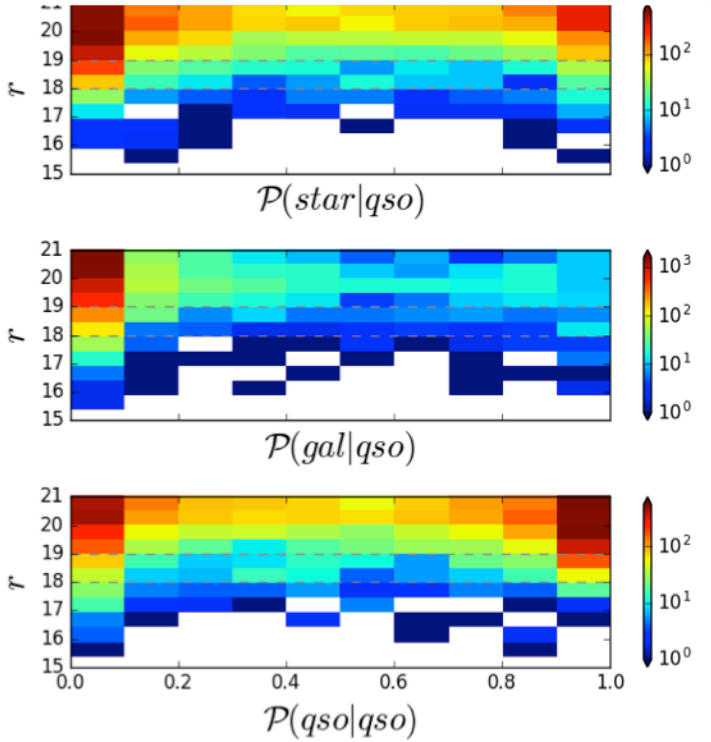


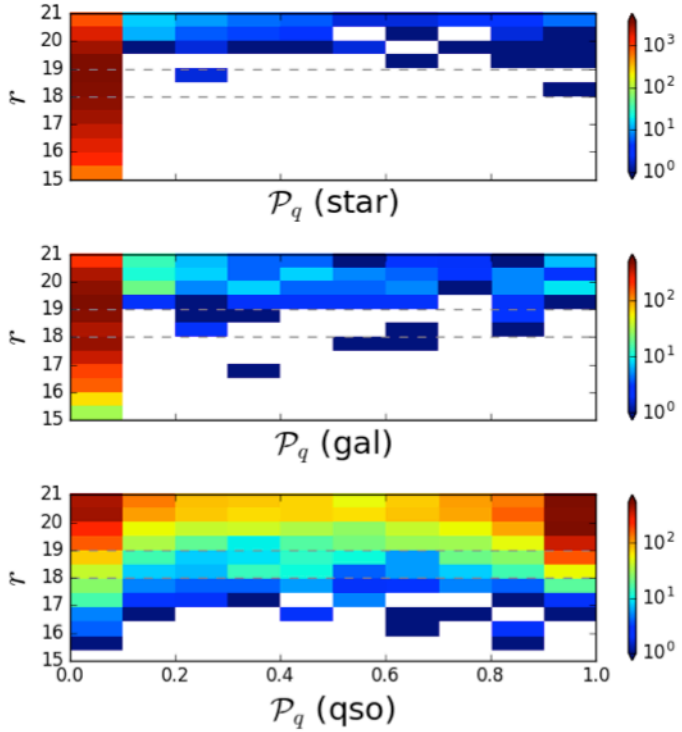
★ https://datalab.noao.edu/splus/index.php

Classification quality

Completeness: $\frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}}$

Purity: $\frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}}$





r<20 (r<18) & P_q>0.1: completeness 77% (59%) & purity of 95% (97%)

r<18: no stars classified as quasars

Photo-z estimation:
The role of different components

Model the quasar fluxes through a linear combination of the amplitudes of the principal components of quasar spectra in a 6-dimension space (Yip+04) + reddening law.

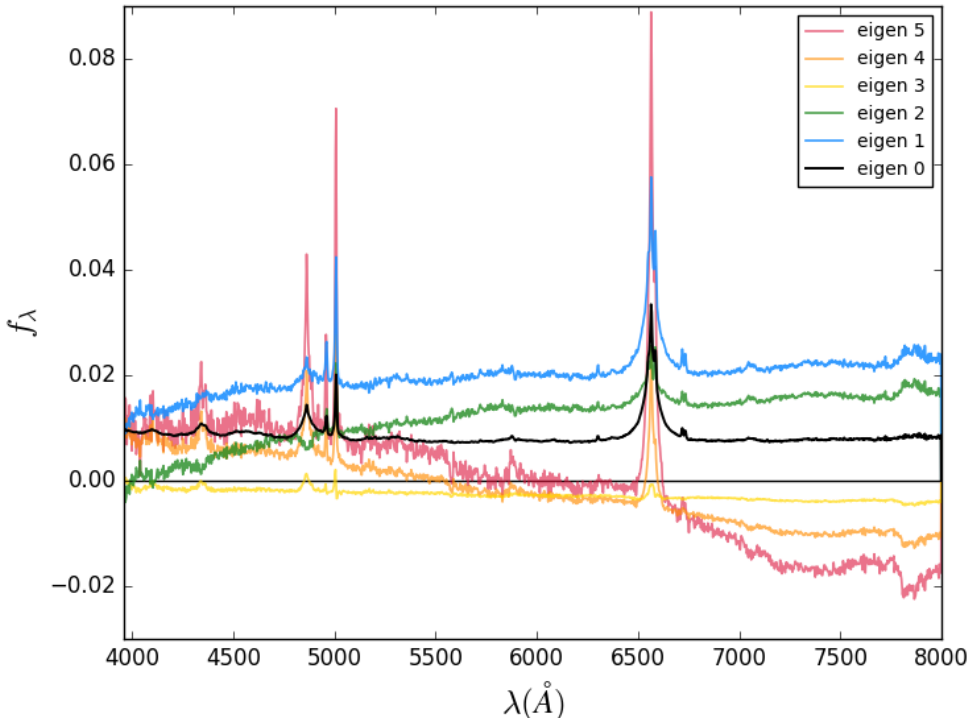


Photo-z estimation

Model:

$$F_\mu^k(z) = \sum_{n=0}^{5} \alpha_n E_{n,\mu}(z) \left(\frac{\lambda_\mu}{\lambda_0}\right)^{-\beta}$$

Chi2 minimization (least squares):

$$\chi^2 = \sum_{\mu=1}^{12} \frac{\left[f_{k,\mu} - F_\mu^k(z)\right]^2}{\sigma_{k,\mu}^2 + \sigma_{t,\mu}^2(z)}$$

1. Observation: $\{m_\mu^k\}$
2. Start: initial guess $\{\alpha_n^0\}$
3. Variation around the relative weights: $\{w_0 \Rightarrow w_5\}$ = {1.0, 0.213, 0.135, 0.109, 0.084, 0.072}
4. β varies between [-1.5, 1.5]
5. λ_0 = 3506.8 Å (scale wavelength)
6. *z* varies between [0, 5]
7. $\sigma_{t,\mu}^2$: additional variance (contributions of eigenspec 6 to 11 plus uncertainty on Lyman-α break)

Photo-z estimation

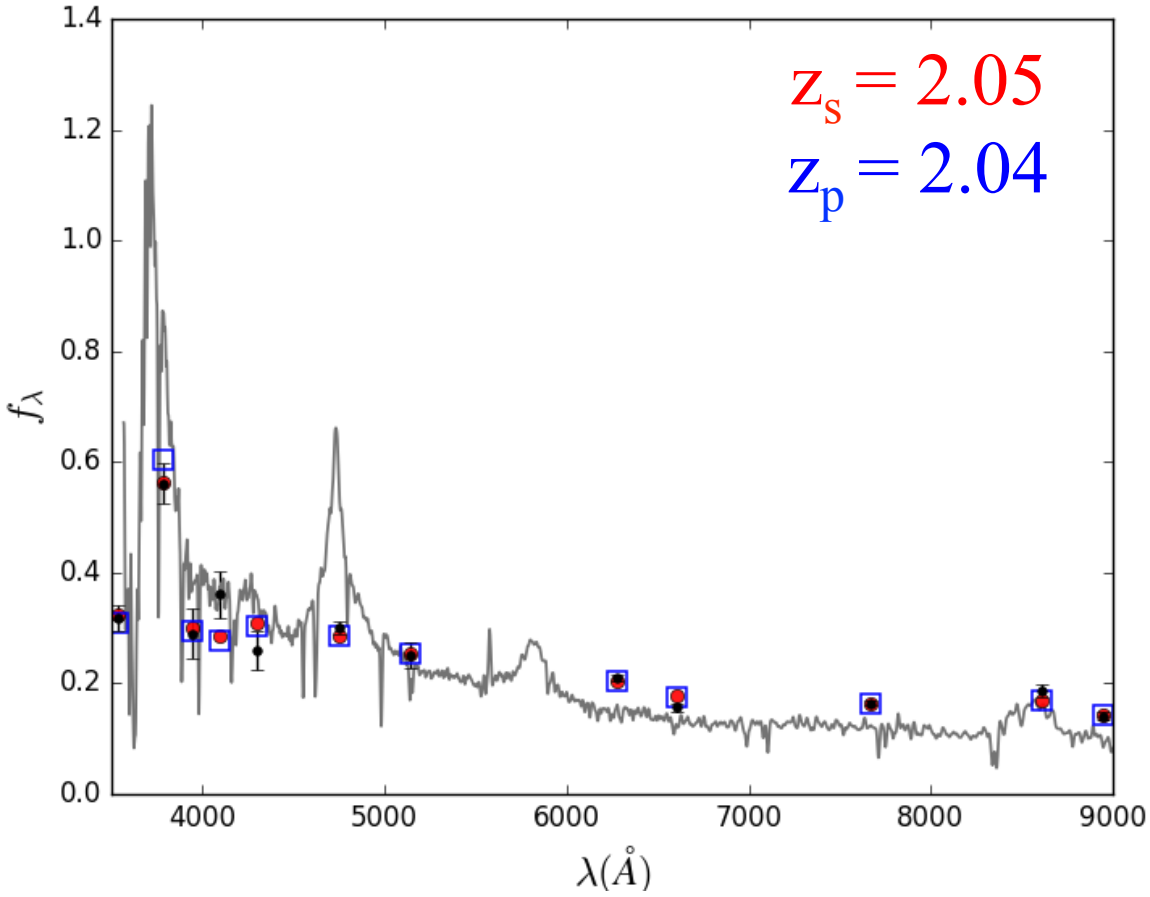
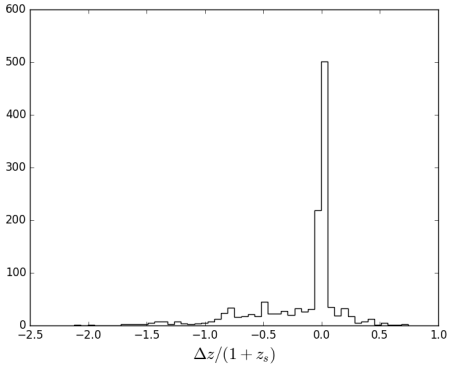


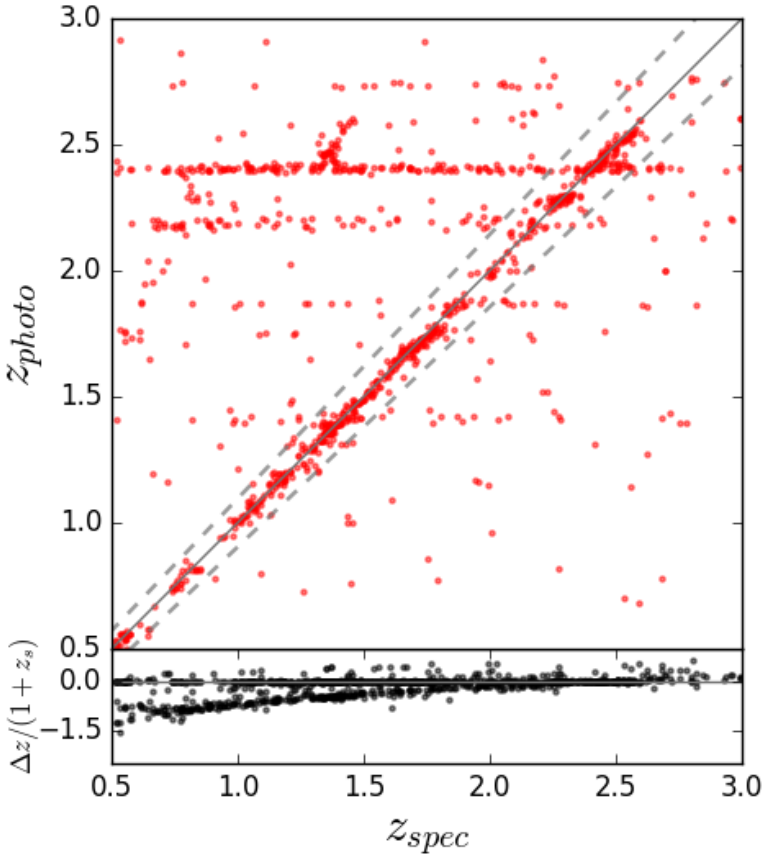
Photo-z quality

$$\sigma_{nmad} = 1.48 \text{ x median}\left|\frac{\Delta z - \text{median}(\Delta z)}{1+z_{spec}}\right|$$

$$\left|\frac{\Delta z}{1+z_{spec}}\right| > 2\ \sigma_{nmad}$$

$$odds = \frac{\int_{z_{peak}-1\sigma}^{z_{peak}+1\sigma} p(z)dz}{\int_{z_{min}}^{z_{max}} p(z)dz}$$

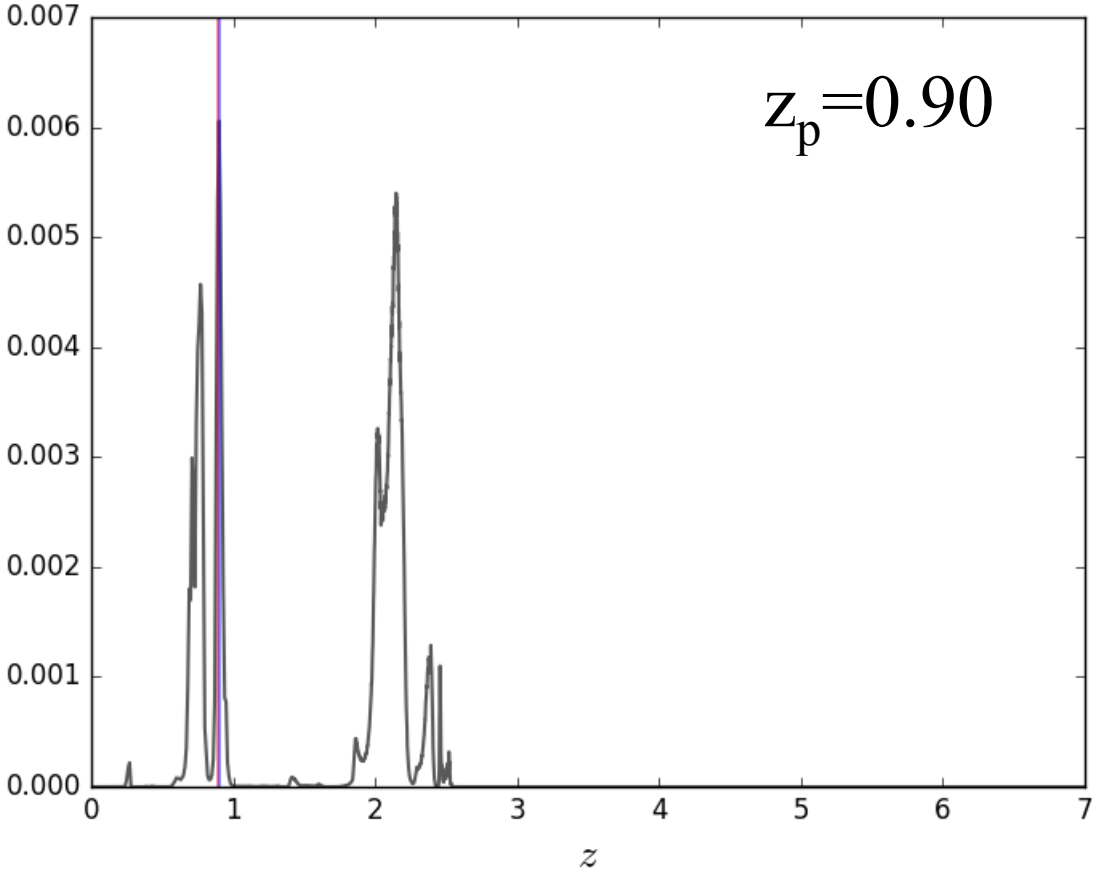




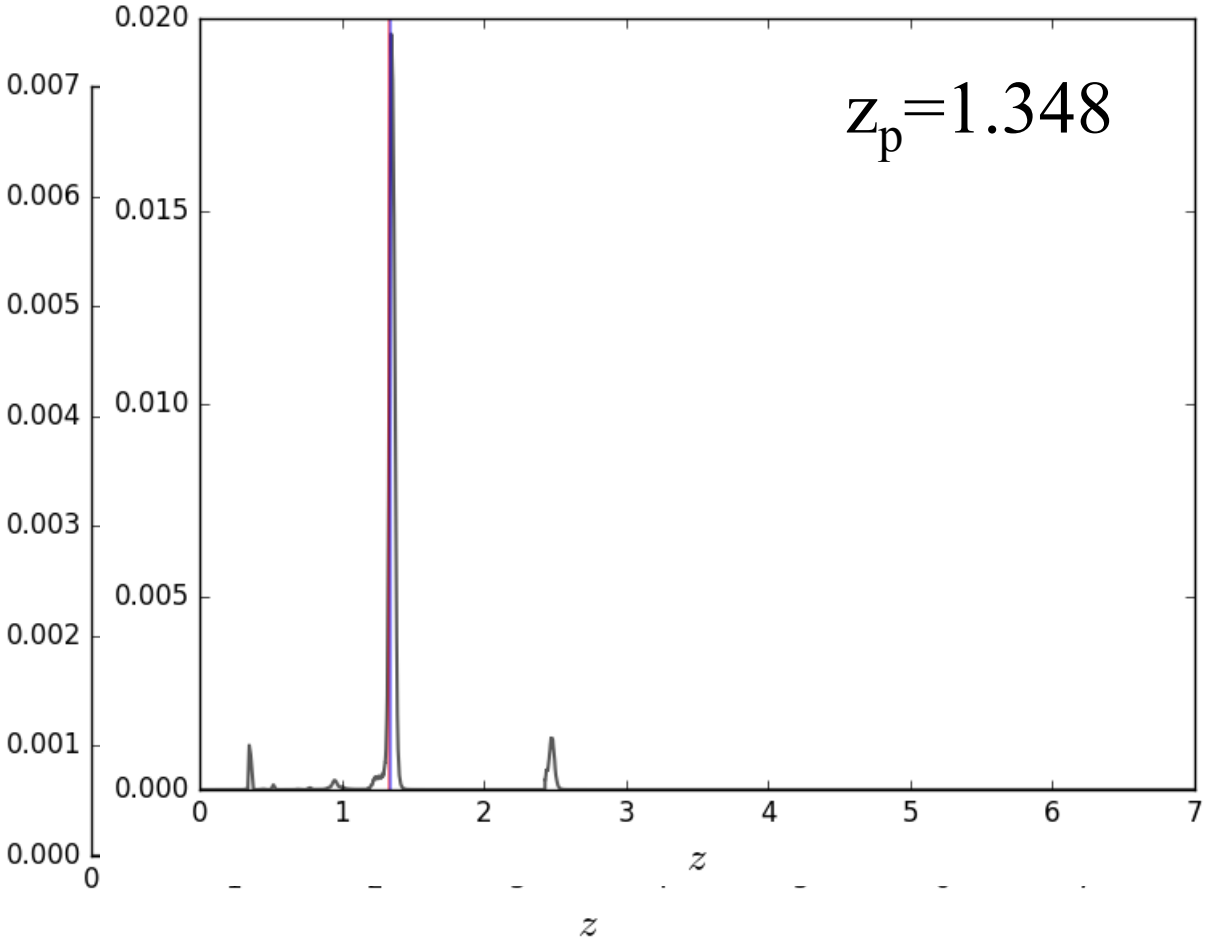
$\sigma_{nmad} = 0.024$

$\eta = 45\%$

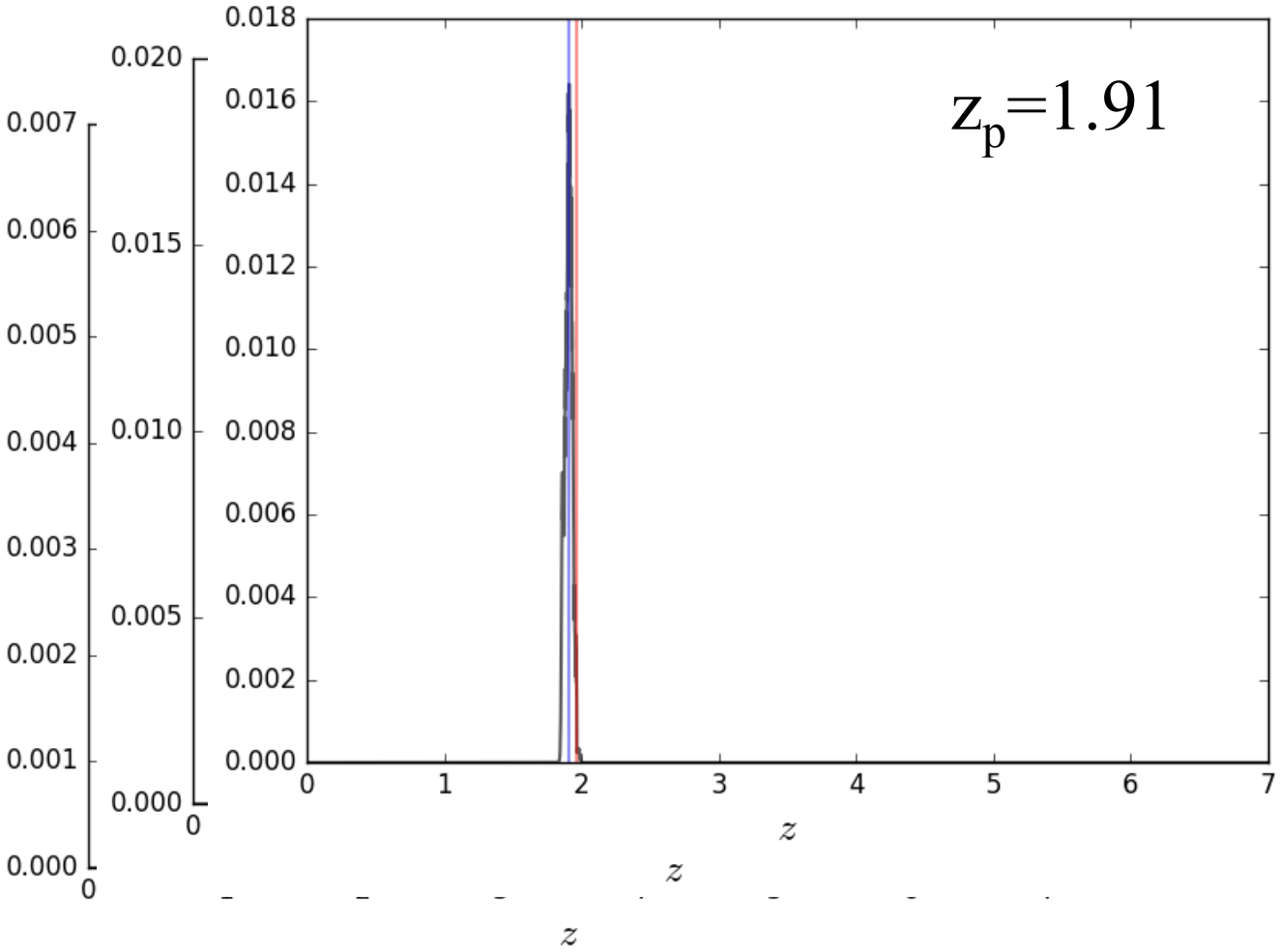
PDZ



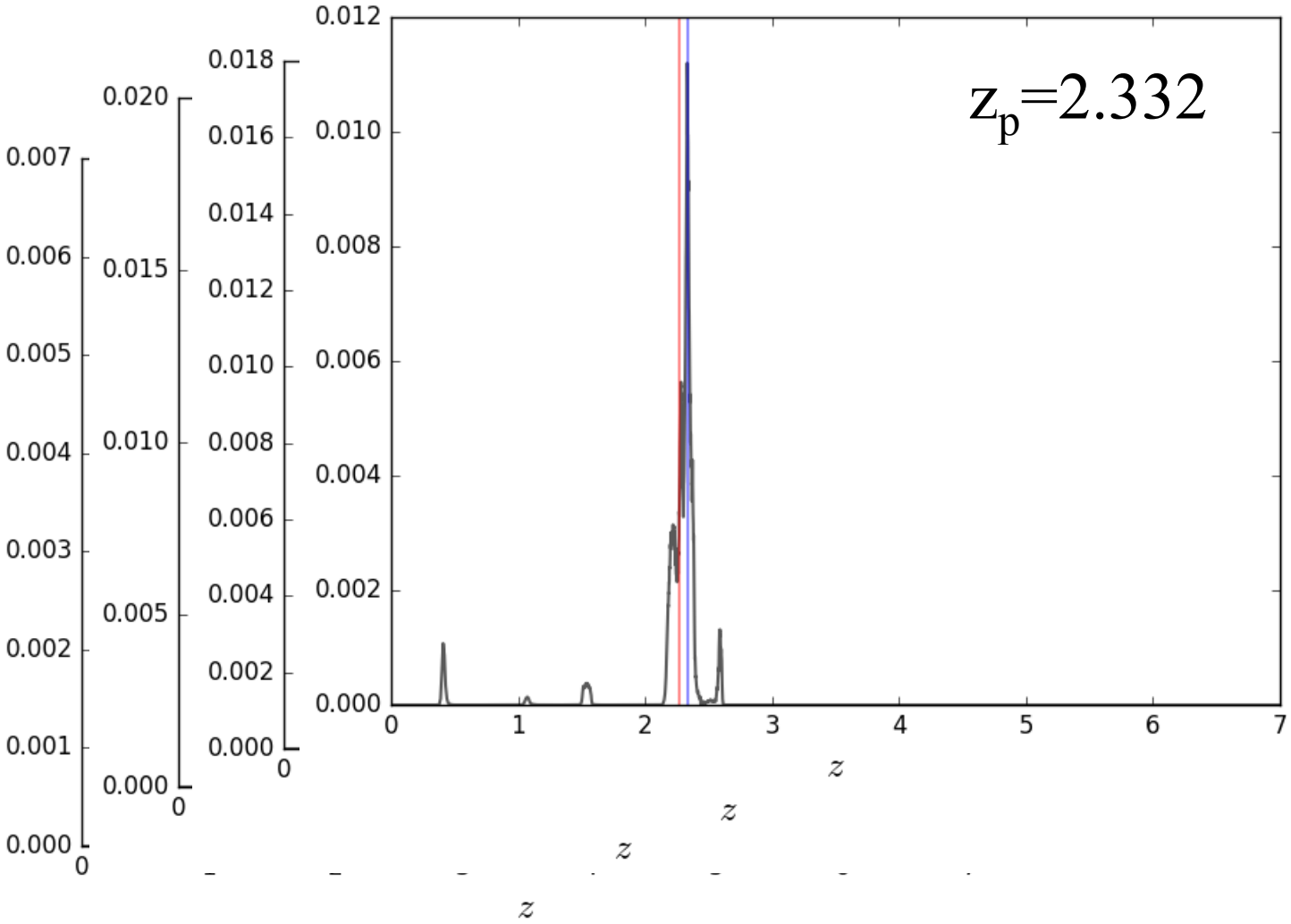
PDZ


z_p=1.348
0.020
0.015
0.010
0.005
0.000
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0
1
2
3
4
5
6
7
z
z

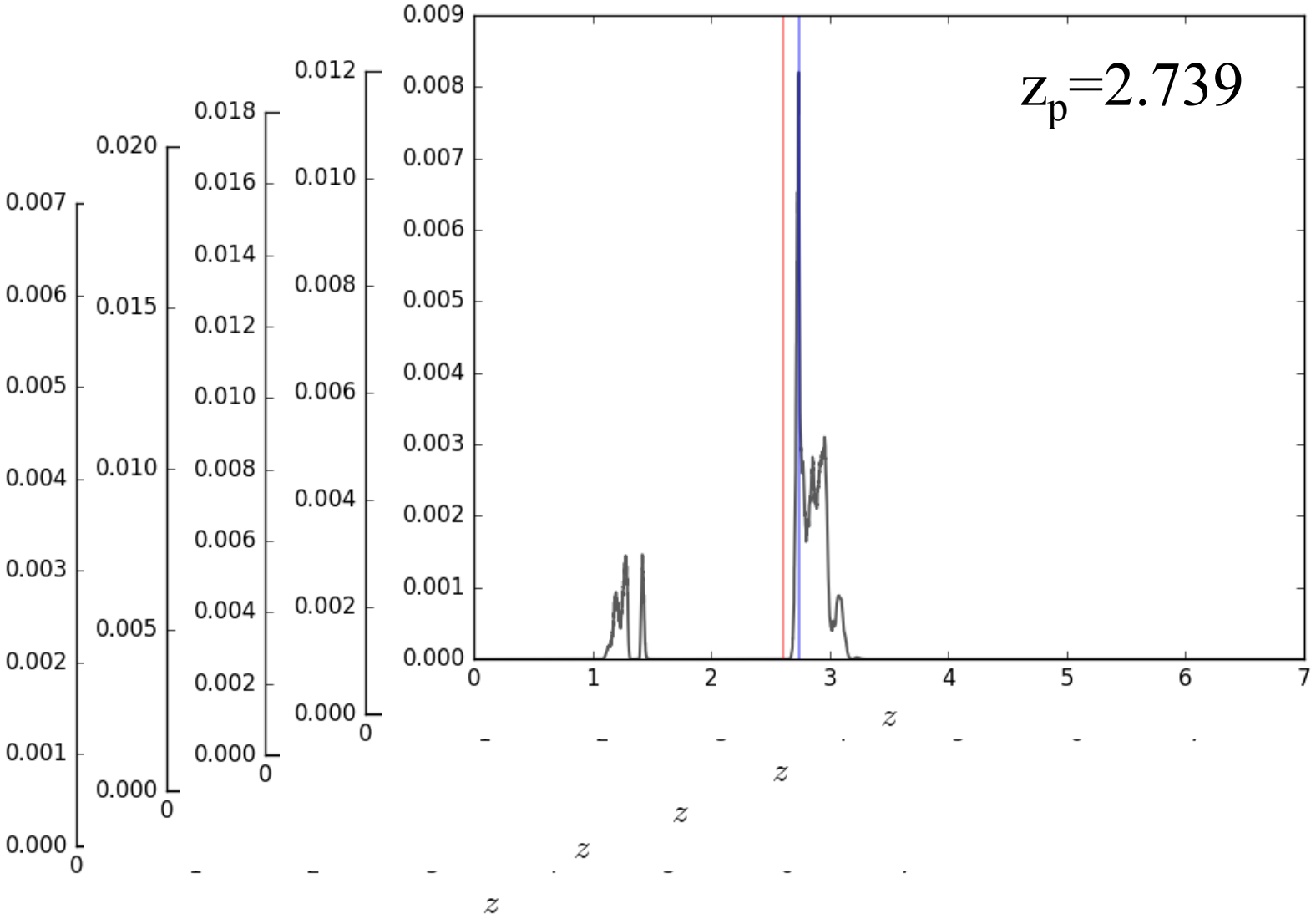
PDZ



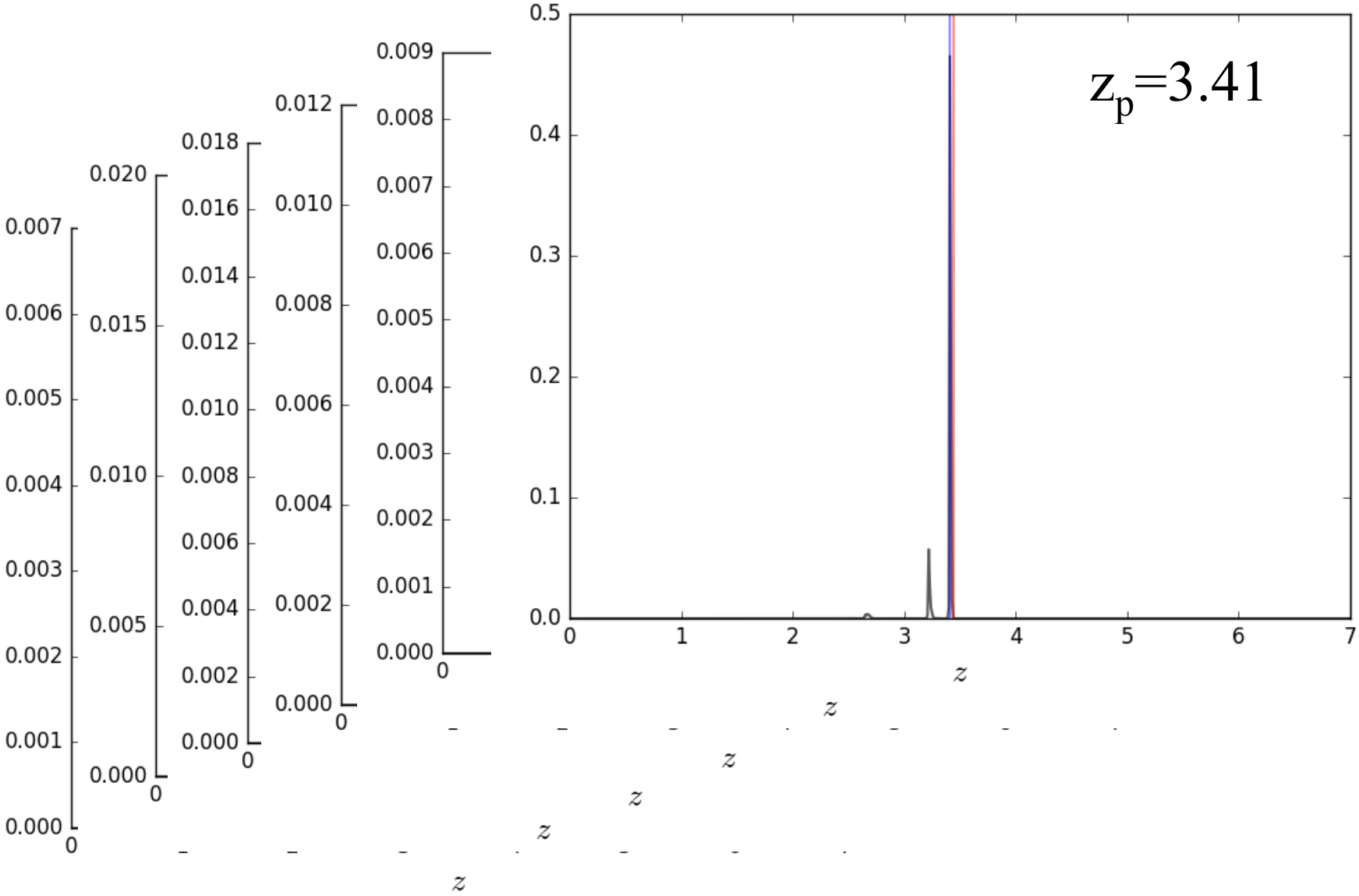
PDZ

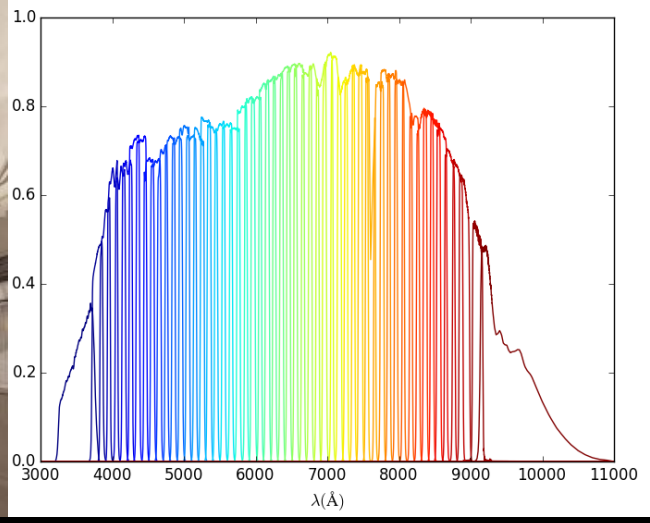


PDZ



PDZ





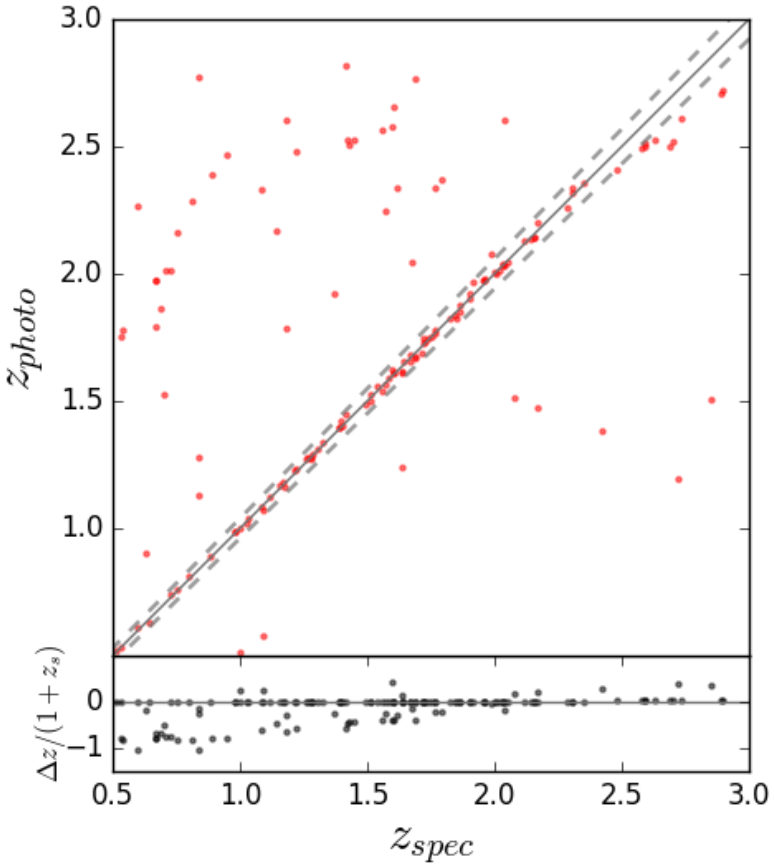
J-PAS:
Javalambre
Physics
of the
Accelerating
Universe
Astrophysical
Survey

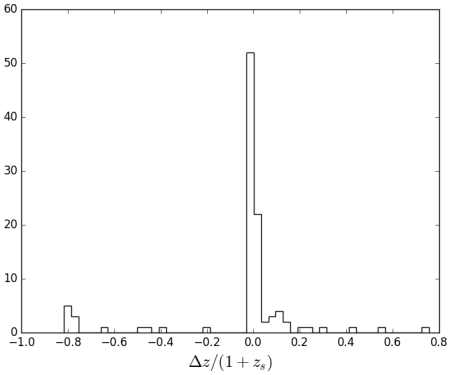
8,000 deg^2
7 deg^2 fov camera
2.5 m telescope (T250)
Sierra de Javalambre, Teruel, Spain
Photometry: ugrz + 54 NB + 2 MB
"Low-resolution spectrum"
Internal *J-PAS*-like data

Photo-z quality

Sample:

209 quasars in 4 AEGIS fields





$\sigma_{nmad} = 0.009$

$\eta = 12\%$

Summary

So far, our tools allow us to obtain **(a)** an accurate (redshift precision of 2% for S-PLUS, 0.1% for J-PAS) and **(b)** high purity (up to 97%) catalog of quasars.

Optimal estimator (Abramo+15) to construct simulated maps of quasars. These maps **(a)** will have the same properties drawn by the quasar samples and **(b)** will take into account both selection effects and redshift errors (through the PDZs).

Exploit the potential of quasar catalogs to map the growth of structures on large-scales.

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