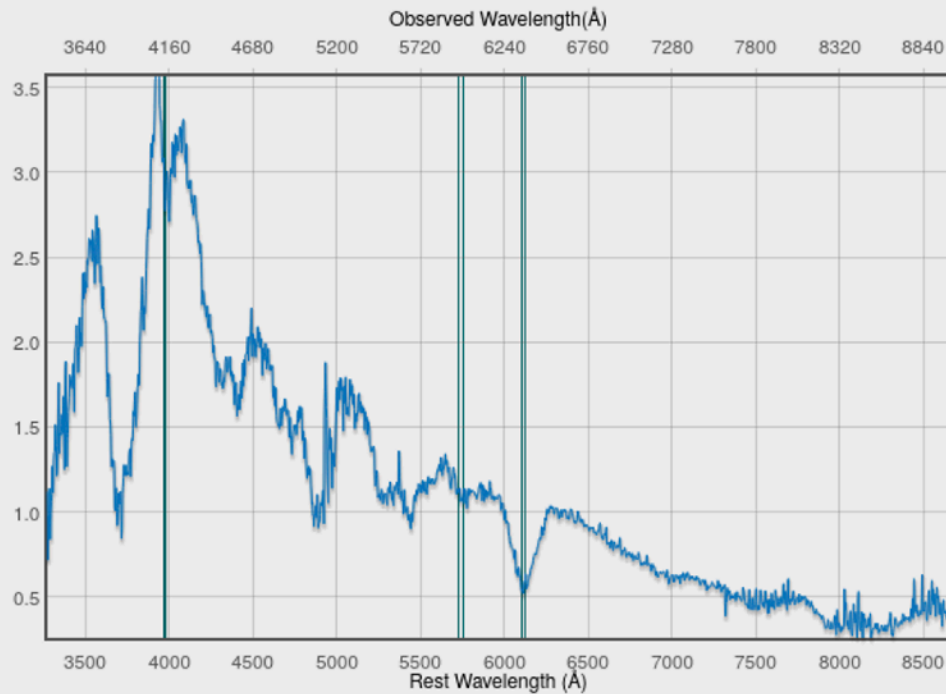
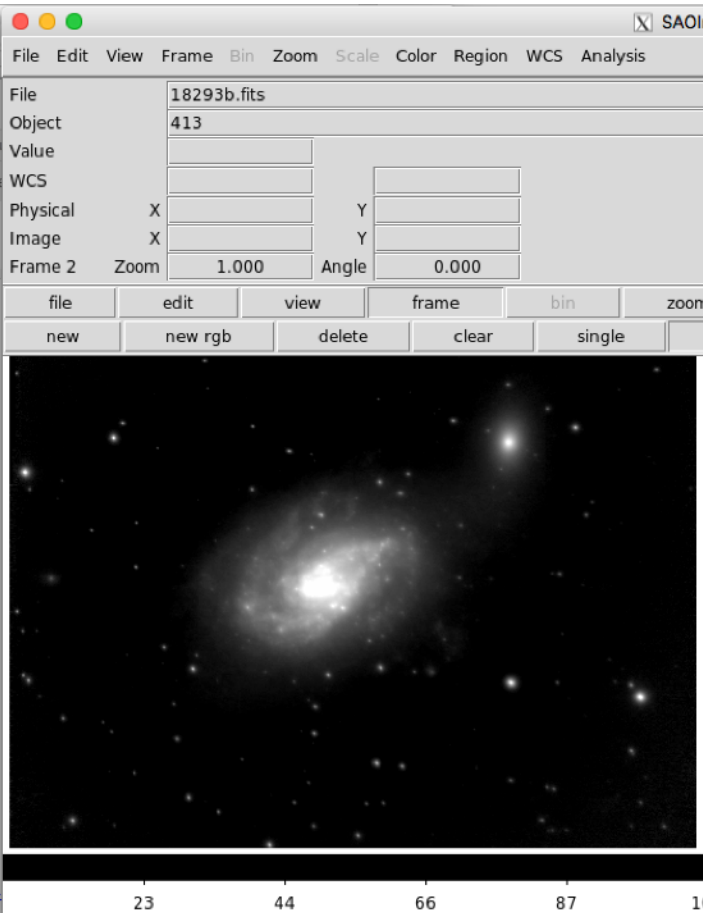


Astronomical imaging & spectroscopy

Seppo Mattila



SN 2022knm - 2022-05-27 06:50:35.00

Select all spectra

Clear spectra

- Show H at Vexp
- Show He I at Vexp
- Show He II at Vexp
- Show C II at Vexp
- Show C III at Vexp
- Show C IV at Vexp
- Show N II at Vexp
- Show N III at Vexp
- Show N IV at Vexp
- Show N V at Vexp
- Show O at Vexp
- Show [O I] at Vexp
- Show [O II] at Vexp
- Show Å at Vexp
- Show Å at Vexp
- Show Å at Vexp
- Show Å at Vexp

Zoom Full

Auto Zoom

Binning factor: (rounded to nearest integer >1)

Mouse hovers at WL: 7011.32 (rest), 7291.77 (observed)

Course report

- The minimum length is 9 pages (12 pt font) of text (2 pages based on each of the four practical sessions + 0.5 page introduction + 0.5 page summary) + figures, tables, references
- For reporting the work done in each of the sessions please follow the advice of the teachers
- Keep in mind the learning outcomes (slide 4) when preparing your report
- For writing the report you can use any word processing software that you are familiar with. Please, save the report as PDF
- **Deadline for handing-in the reports to sepmat@utu.fi on 1st August**

Learning outcomes

After completing the course the students should be able to:

- (1) Describe the principles behind some advanced astronomical imaging techniques and identify suitable topics in astrophysics that can be studied with them;
- (2) Understand the physics behind some of the most important medical imaging modalities and describe their value in clinical applications;
- (3) Identify and discuss the differences and similarities in the challenges faced when analyzing data in these two different disciplines;
- (4) Describe the theoretical basis and suitability of several image/signal processing and analysis methods commonly used in astronomy and medical imaging;
- (5) Identify suitable algorithms and apply them to astronomical and/or medical imaging datasets to enhance their scientific and/or clinical value;
- (6) Produce a written course report

Exercise 1: Convolution

Convolution

“real” signal

additive noise

$$b(\vec{x}) = f(\vec{x}) * p(\vec{x}) + n(\vec{x})$$

observed signal

PSF

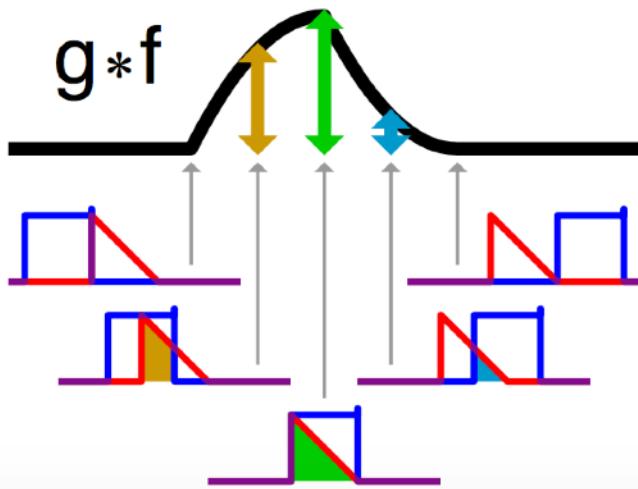
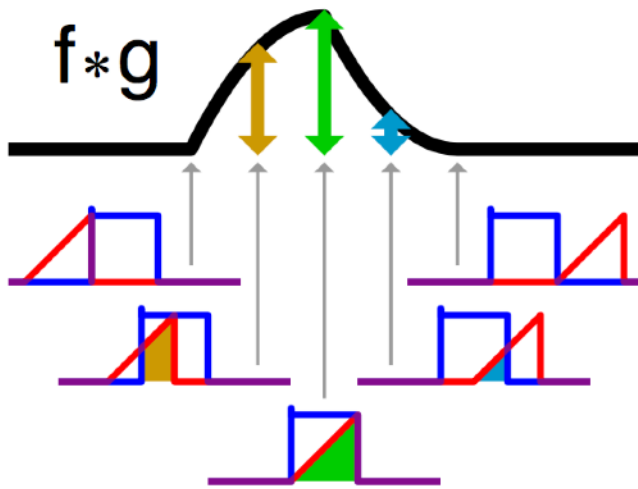
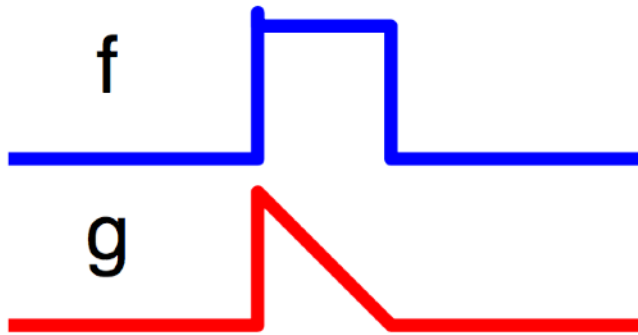
In the case of 1-D functions

$$(f * g)(x) = \int_{-\infty}^{\infty} f(\tau)g(x - \tau) d\tau$$

In the case of discrete 1-D functions

$$(f * g)_j = \sum_{k=-m/2+1}^{m/2} f_k g_{j-k}$$

Convolution



$$(f * g)(x) = \int_{-\infty}^{\infty} f(\tau)g(x - \tau) d\tau$$

$$(f * g)_j = \sum_{k=-m/2+1}^{m/2} f_k g_{j-k}$$



astropy

A Community Python Library for Astronomy

Available Kernels

AiryDisk2DKernel (radius, **kwargs)	2D Airy disk kernel.
Box1DKernel (width, **kwargs)	1D Box filter kernel.
Box2DKernel (width, **kwargs)	2D Box filter kernel.
CustomKernel (array)	Create filter kernel from list or array.
Gaussian1DKernel (stddev, **kwargs)	1D Gaussian filter kernel.
Gaussian2DKernel (x_stddev[, y_stddev, theta])	2D Gaussian filter kernel.
RickerWavelet1DKernel (width, **kwargs)	1D Ricker wavelet filter kernel (sometimes known as a “Mexican Hat” kernel).
RickerWavelet2DKernel (width, **kwargs)	2D Ricker wavelet filter kernel (sometimes known as a “Mexican Hat” kernel).
Model1DKernel (model, **kwargs)	Create kernel from 1D model.
Model2DKernel (model, **kwargs)	Create kernel from 2D model.
Moffat2DKernel (gamma, alpha, **kwargs)	2D Moffat kernel.
Ring2DKernel (radius_in, width, **kwargs)	2D Ring filter kernel.
Tophat2DKernel (radius, **kwargs)	2D Tophat filter kernel.
Trapezoid1DKernel (width[, slope])	1D trapezoid kernel.
TrapezoidDisk2DKernel (radius[, slope])	2D trapezoid kernel.

Gaussian1DKernel ¶

`class astropy.convolution. Gaussian1DKernel (stddev, **kwargs)` [\[edit on github\]](#)[\[source\]](#)

Bases: [astropy.convolution.Kernel1D](#)

1D Gaussian filter kernel.

The Gaussian filter is a filter with great smoothing properties. It is isotropic and does not produce artifacts.

Parameters: **stddev** : number

Standard deviation of the Gaussian kernel.

x_size : odd int, optional

Size of the kernel array. Default = $8 * \text{stddev}$

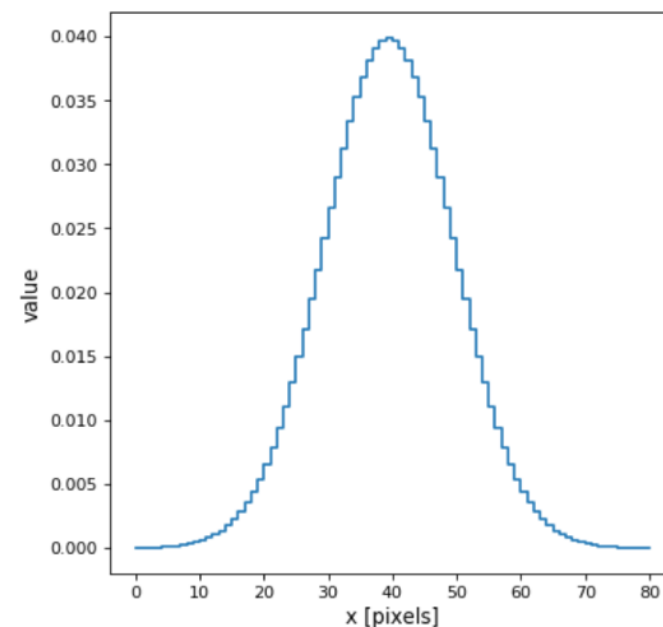
mode : str, optional

One of the following discretization modes:

- 'center' (default)
Discretize model by taking the value at the center of the bin.
- 'linear_interp'
Discretize model by linearly interpolating between the values at the corners of the bin.
- 'oversample'
Discretize model by taking the average on an oversampled grid.
- 'integrate'
Discretize model by integrating the model over the bin. Very slow.

factor : number, optional

Factor of oversampling. Default factor = 10. If the factor is too large, evaluation can be very slow.



Gaussian2DKernel

```
class astropy.convolution.Gaussian2DKernel (x_stddev, y_stddev=None, theta=0.0, \[source\]  
**kwargs) ¶ \[edit on github\]
```

Bases: [astropy.convolution.Kernel2D](#)

2D Gaussian filter kernel.

The Gaussian filter is a filter with great smoothing properties. It is isotropic and does not produce artifacts.

Parameters: **x_stddev** : float

Standard deviation of the Gaussian in x before rotating by theta.

y_stddev : float

Standard deviation of the Gaussian in y before rotating by theta.

theta : float

Rotation angle in radians. The rotation angle increases counterclockwise.

x_size : odd int, optional

Size in x direction of the kernel array. Default = 8 * stddev.

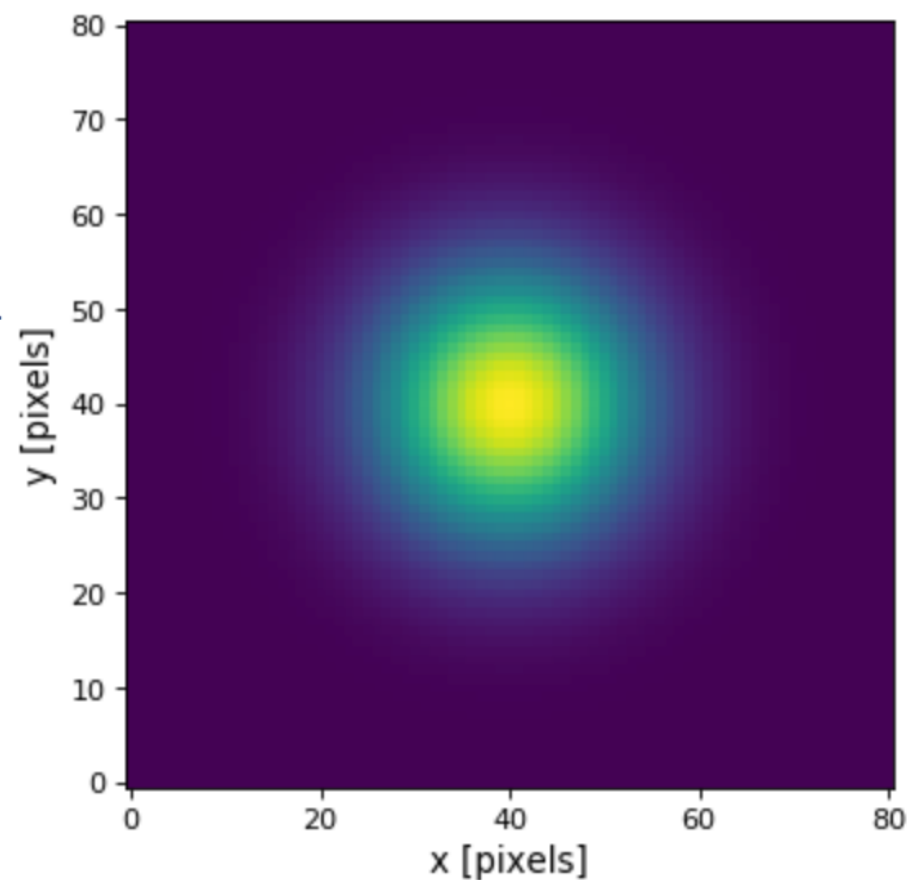
y_size : odd int, optional

Size in y direction of the kernel array. Default = 8 * stddev.

mode : str, optional

One of the following discretization modes:

- 'center' (default)
Discretize model by taking the value at the center of the bin.
- 'linear_interp'
Discretize model by performing a bilinear interpolation between the values at the corners of the bin.
- 'oversample'
Discretize model by taking the average on an oversampled grid.
- 'integrate'
Discretize model by integrating the model over the bin.



Exercise 1: practical work

Experiment using different types of convolution kernels for 1D or 2D data, present your experiment in the report

Gaussian1DKernel ¶

class `astropy.convolution.Gauss`

Bases: `astropy.convolution.Kernel1D`

1D Gaussian filter kernel.

The Gaussian filter is a filter with great smoothing properties.

Parameters: `stddev` : number

Standard deviation

`x_size` : odd int, optional

Size of the kernel array

`mode` : str, optional

One of the following

- 'center' (default)

Discretize mode

- 'linear_interp'

Discretize mode

the bin.

- 'oversample'

Discretize mode

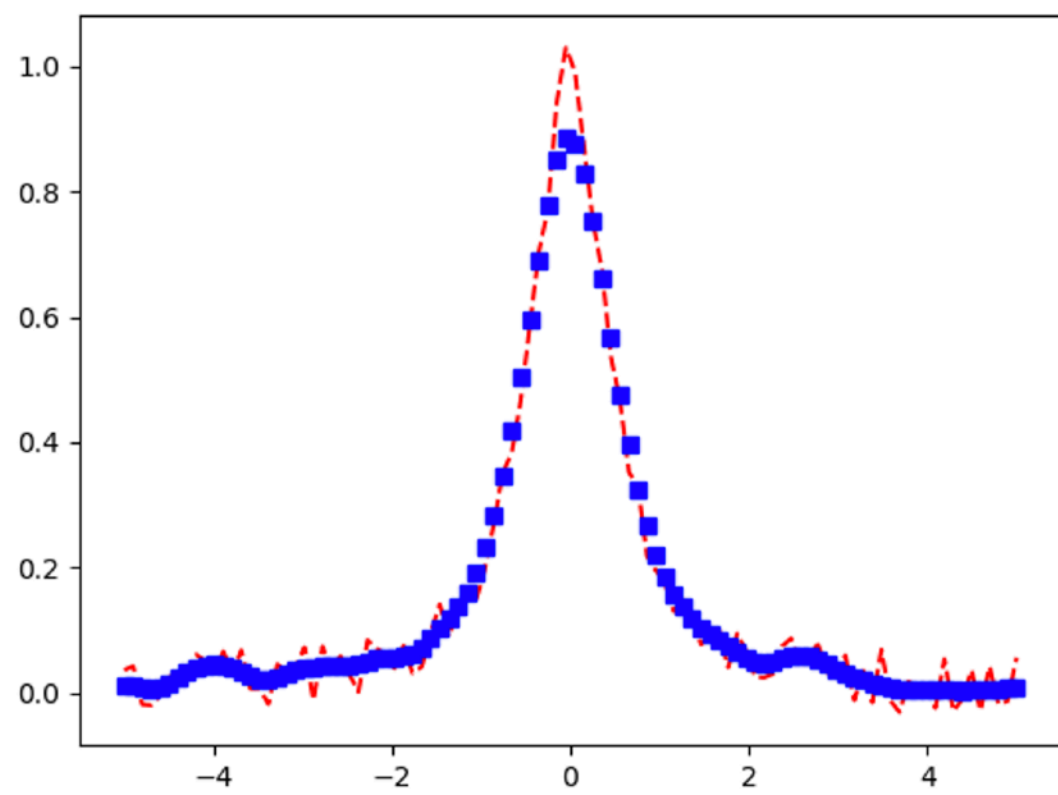
- 'integrate'

Discretize mode

`factor` : number, optional

Factor of oversampling

be very slow.

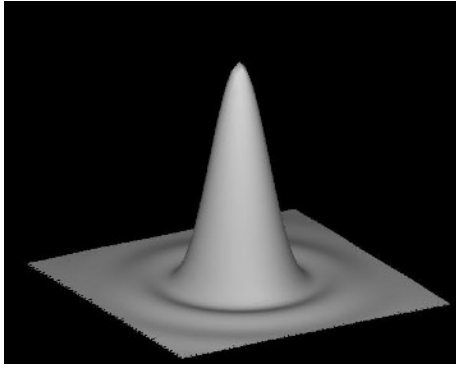


x=3.19355 y=0.683779

```
not3@course2021: ~
not3@course2021: ~ 80x15
>>> import numpy as np
>>> from astropy.modeling.functional_models import Lorentz1D
>>> from astropy.convolution import convolve, Gaussian1DKernel, Box1DKernel
>>> lorentz = Lorentz1D(1, 0, 1)
>>> x = np.linspace(-5, 5, 100)
>>> data_1D = lorentz(x) + 0.1 * (np.random.rand(100) - 0.5)
>>> gauss_kernel = Gaussian1DKernel(2)
>>> smoothed_data_gauss = convolve(data_1D, gauss_kernel)
>>> import matplotlib.pyplot as plt
>>> plt.plot(x, data_1D, 'r--', x, smoothed_data_gauss, 'bs')
[<matplotlib.lines.Line2D object at 0x7f975c025ad0>, <matplotlib.lines.Line2D ob
ject at 0x7f975c025b90>]
>>> plt.show()
```

Exercise 2: image matching and subtraction of astronomical images to detect variability over time

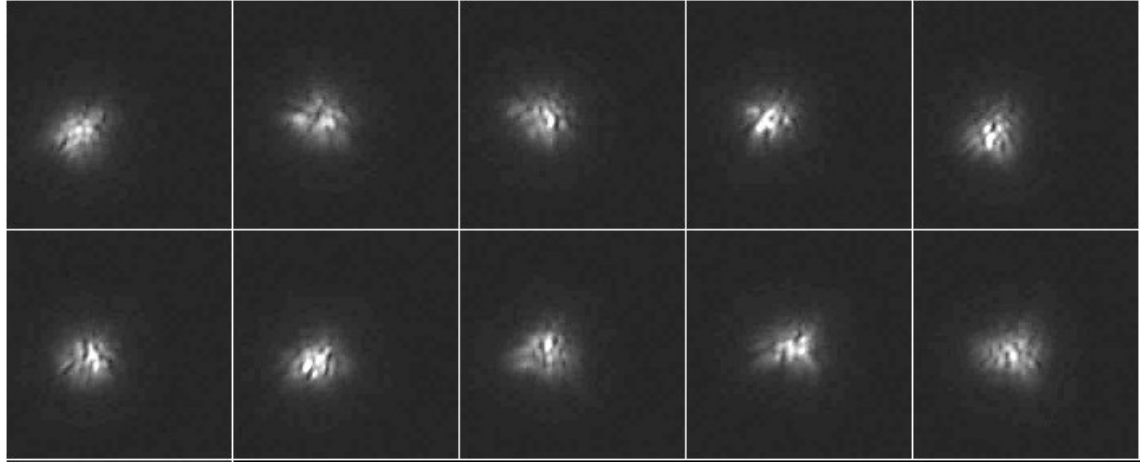
Point spread function (PSF)



Ideal (diffraction limited)
PSF if no atmosphere

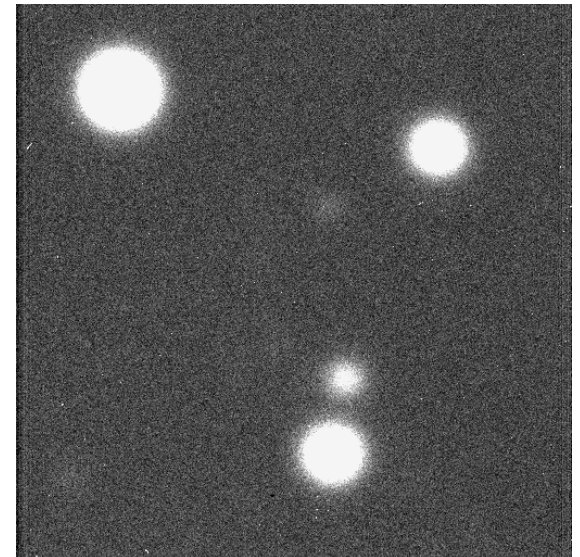
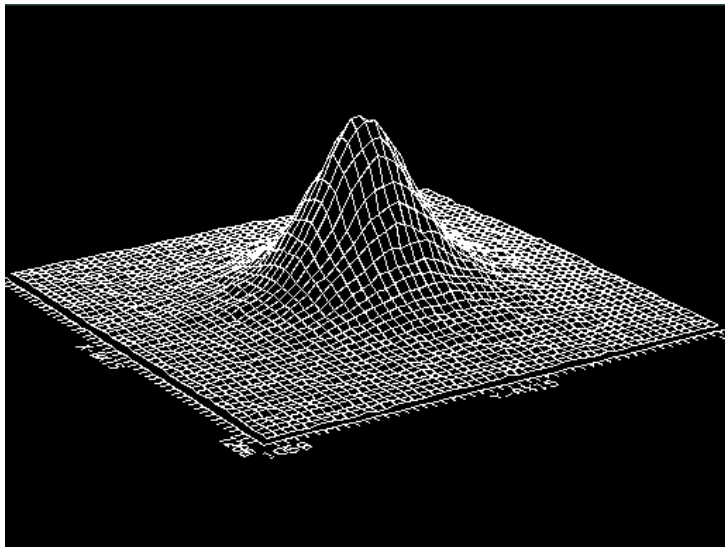
$$\theta \sim 1.22 \times \lambda / D$$

(where λ is wavelength,
D the diameter of the
telescope and θ is in radians)



Atmospheric turbulence broadens the PSF resulting in a
Gaussian PSF

$$I(r) = I(0) \exp(-r^2/2\sigma^2)$$



Adaptive Optics (AO) imaging

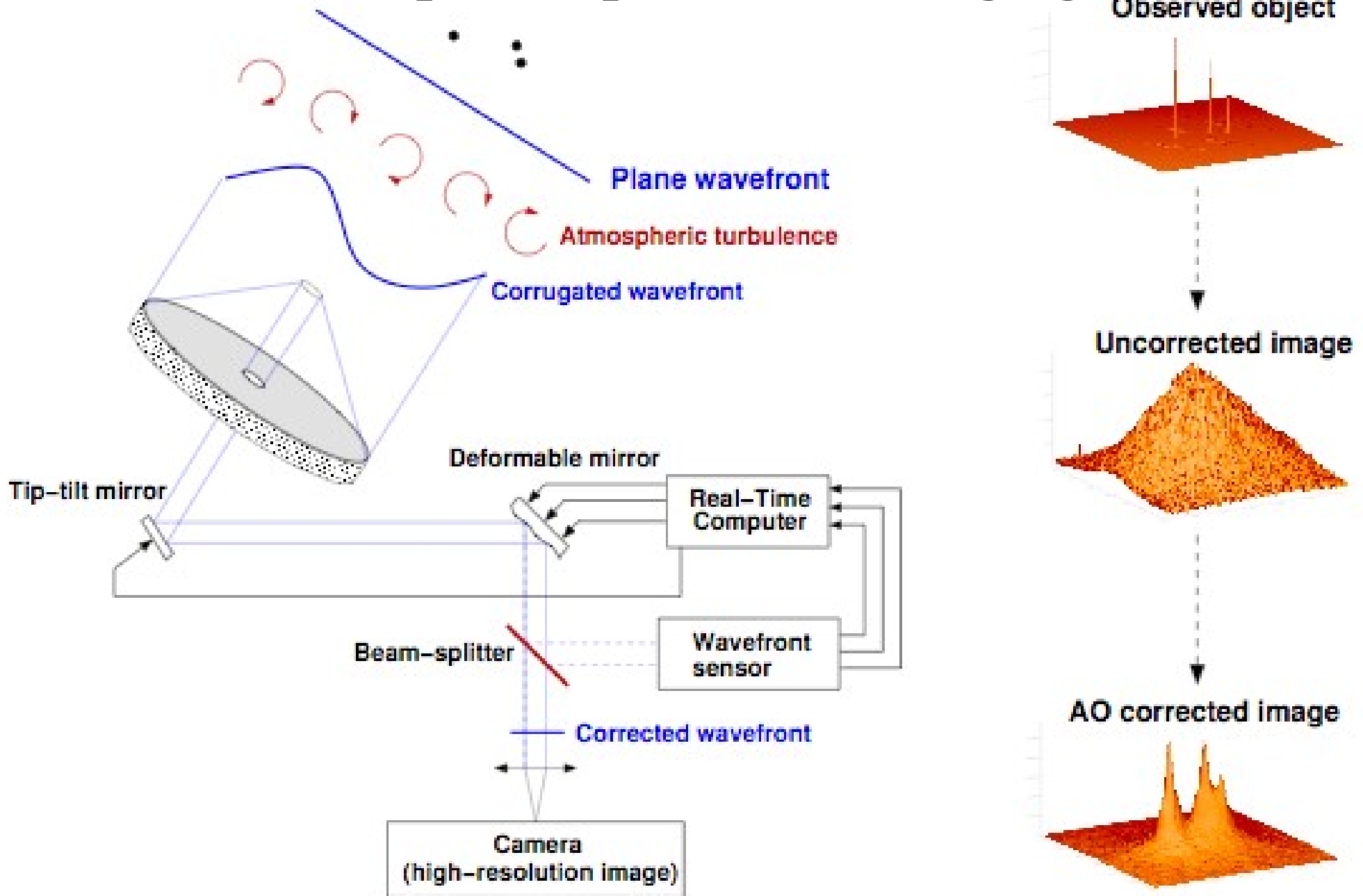
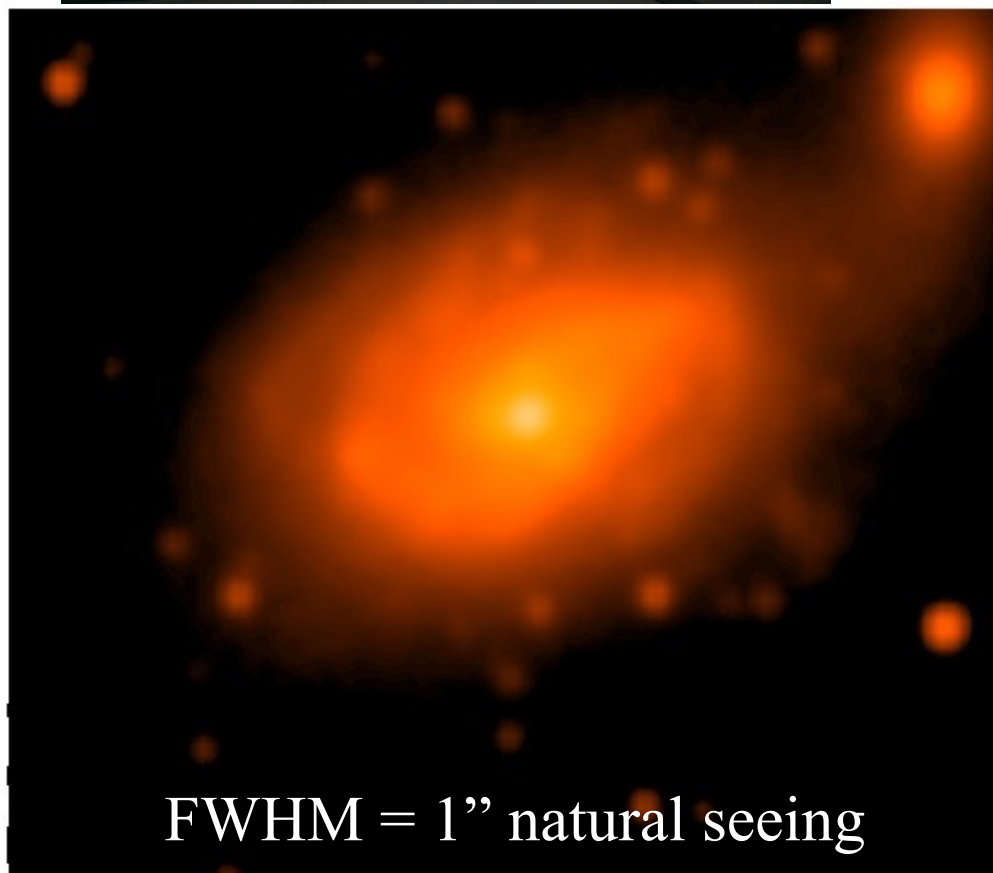
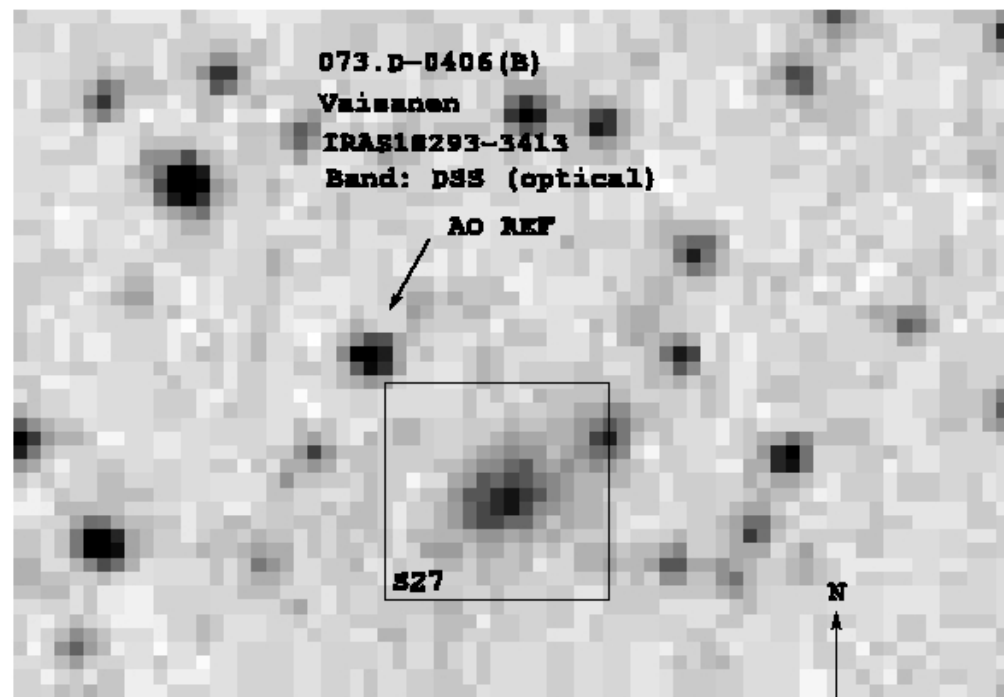
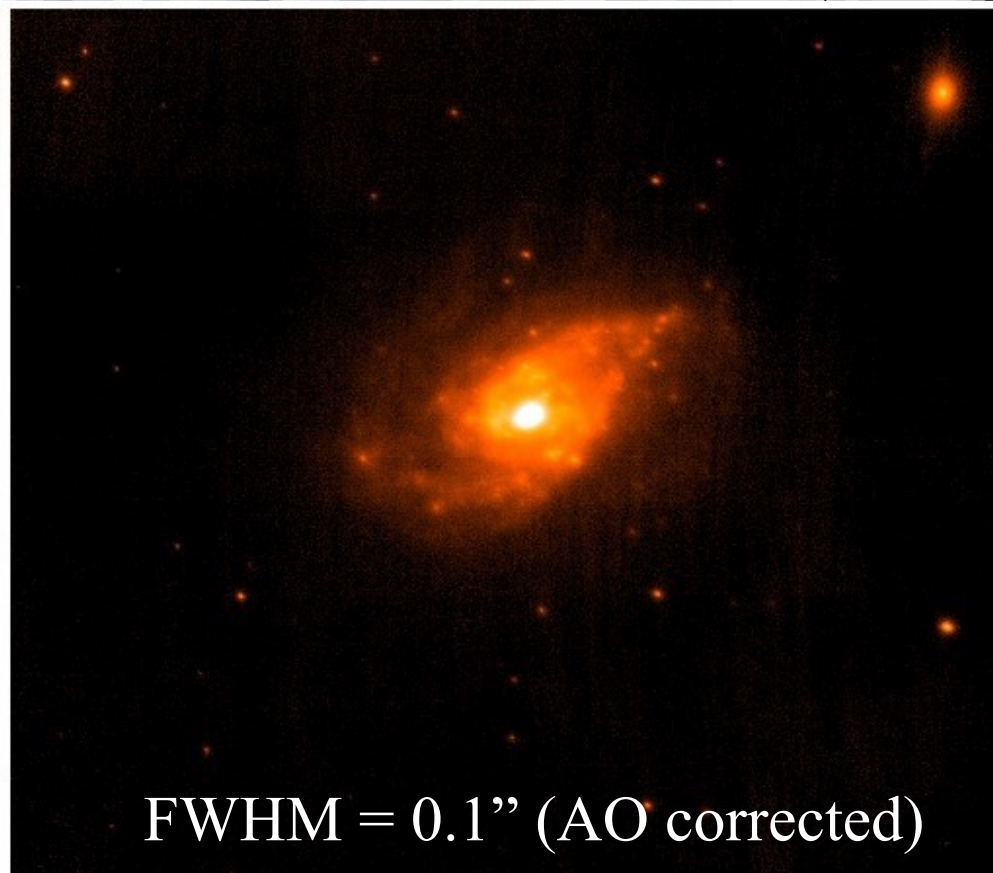


Figure 3-1: Principle of Adaptive Optics



FWHM = 1" natural seeing



FWHM = 0.1" (AO corrected)

Convolution of images

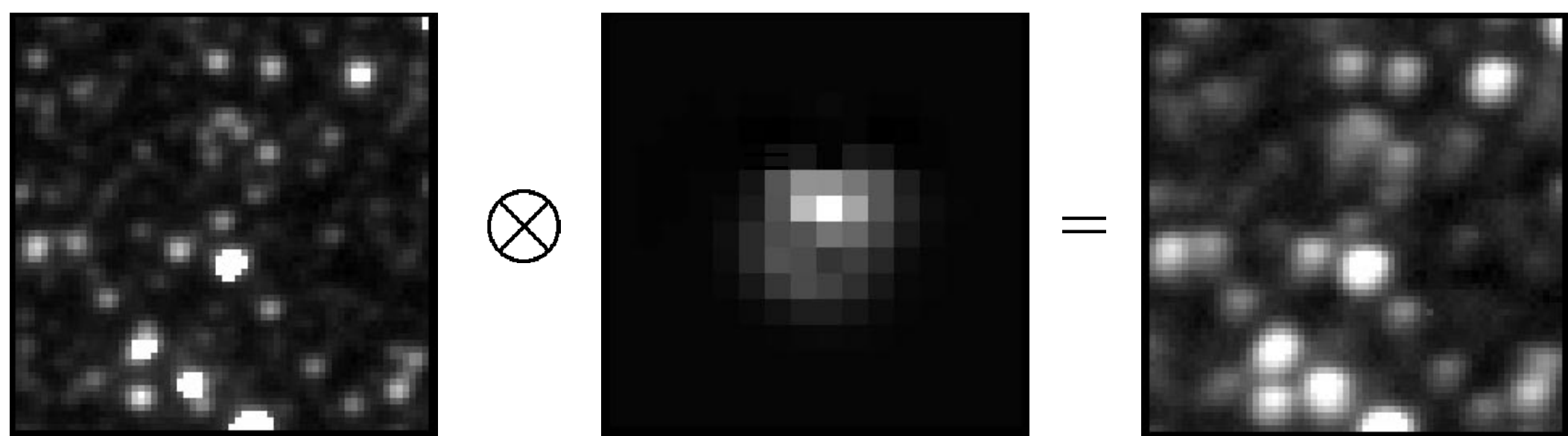
“real” signal

additive noise

$$b(\vec{x}) = f(\vec{x}) * p(\vec{x}) + n(\vec{x})$$

observed signal

PSF



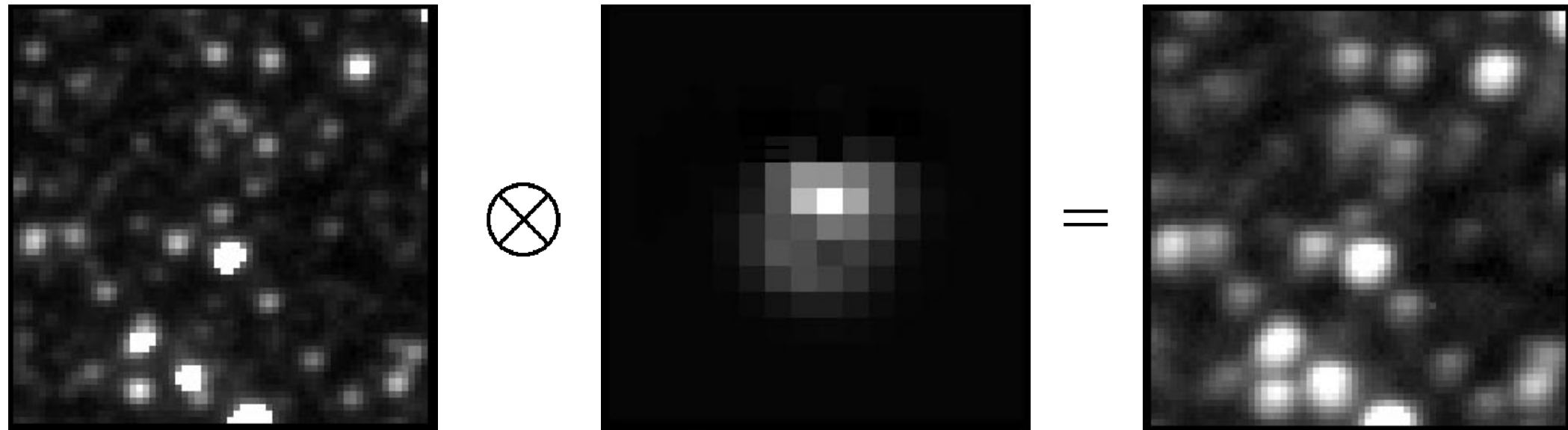
$$ref(x, y) \otimes kernel(x, y, u, v) = im(x, y)$$

Optimal Image Subtraction

$$ref(x, y) \otimes kernel(x, y, u, v) = im(x, y) + bg(x, y)$$

$$kernel(x, y, u, v) = \sum_n \sum_{d_n^x} \sum_{d_n^y} \sum_{\delta^x} \sum_{\delta^y} [a_n \underbrace{x^{\delta^x} y^{\delta^y}}_3 \underbrace{e^{-(u^2+v^2)/2\sigma_n^2}}_1 \underbrace{u^{d_n^x} v^{d_n^y}}_2]$$

The convolution kernel consists of a set of Gaussian functions (1) which are modified by polynomials (2) and a model for the spatial variations of the kernel (3) where $0 < d_n^y + d_n^x \leq D_n$, and $0 < \delta^y + \delta^x \leq D^k$.

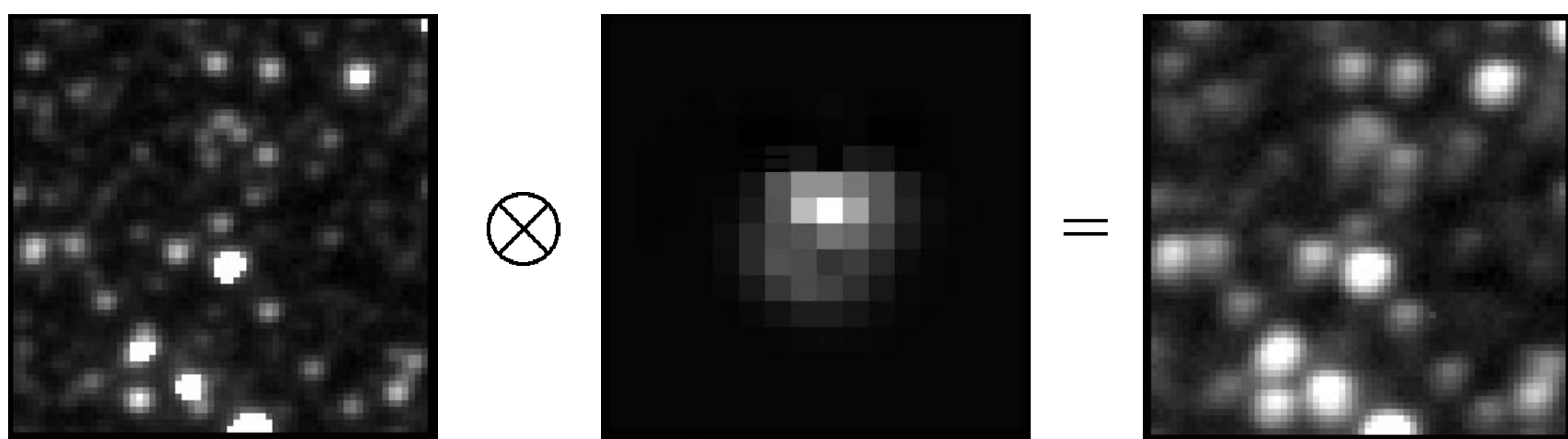


Optimal Image Subtraction

$$ref(x, y) \otimes kernel(x, y, u, v) = im(x, y) + bg(x, y)$$

$$kernel(x, y, u, v) = \sum_n \sum_{d_n^x} \sum_{d_n^y} \sum_{\delta^x} \sum_{\delta^y} [a_n \underbrace{x^{\delta^x} y^{\delta^y}}_3 \underbrace{e^{-(u^2+v^2)/2\sigma_n^2}}_1 \underbrace{u^{d_n^x} v^{d_n^y}}_2]$$

$$bg(x, y) = \sum_i \sum_j a_i x^i y^j$$



Convolution: Optimal Image Subtraction

$$kernel(x, y, u, v) = \sum_n \sum_{d_n^x} \sum_{d_n^y} \sum_{\delta^x} \sum_{\delta^y} \left[a_n \underbrace{x^{\delta^x} y^{\delta^y}}_3 \underbrace{e^{-(u^2+v^2)/2\sigma_n^2}}_1 \underbrace{u^{d_n^x} v^{d_n^y}}_2 \right]$$

$$bg(x, y) = \sum_i \sum_j a_i x^i y^j$$

n	number of Gaussian functions in the kernel
σ_n	sigmas of the Gaussians
D_n	polynomial degrees associated with each of the n gaussians
D^k	degree of the polynomial transform for the spatial variations of the kernel
D^{bg}	degree of the polynomial used to model the background variations
N_x	number of stamps along x-axis
N_y	number of stamps along y-axis
S_k	width of the convolution kernel
S_s	width of the region used for fitting the background
N_c	minimum number of counts in the middle of a stamp
N_{min}	minimum value of a pixel to be included in the fit
N_{sat}	maximum value of a pixel to be included in the fit

Exercise 2: practical work

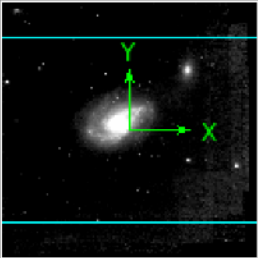
Experiment with matching and subtraction of AO images from two different dates present your results in the report

Can you spot the supernova? Maybe, image subtraction would help ...

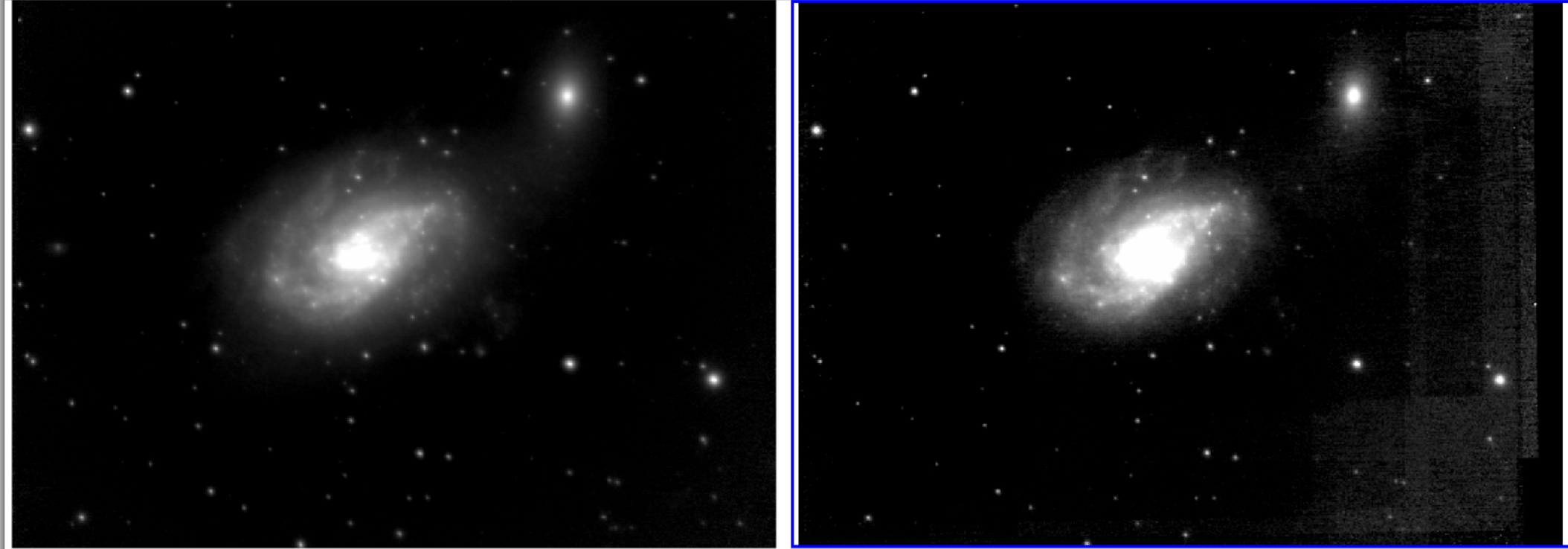
SAOImage ds9

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help

File: 18293b.fits
Object: 413
Value:
WCS:
Physical X: Y:
Image X: Y:
Frame 2 Zoom: 1.000 Angle: 0.000



file edit view frame bin zoom scale color region wcs help
new new rgb delete clear single tile blink first previous next last



23 44 66 87 109 131 152 174 195

image matching and subtraction of astronomical images

```
not3@course2021: ~/imagesubtraction
not3@course2021: ~/imagesubtraction 80x7
(iraf27) not3@course2021:~$ mkdir imagesubtraction
(iraf27) not3@course2021:~$ cd imagesubtraction
(iraf27) not3@course2021:~/imagesubtraction$ cp /home/not3/sub/* .
(iraf27) not3@course2021:~/imagesubtraction$ ls
i18293A.fits i18293B.fits iiconfig.txt
(iraf27) not3@course2021:~/imagesubtraction$ mrj_phot i18293A.fits i18293B.fits
-c iiconfig.txt
```

```
not3@course2021: ~/imagesubtraction
not3@course2021: ~/imagesubtraction 80x56
Reading Image1
name: i18293A.fits
width: 1562 height: 1562 bitpix: -32 offset_header: 46080
name: i18293B.fits
width: 1562 height: 1562 bitpix: -32 offset_header: 46080
offsets: 46080 46080
ss: 1 1 1562 1562
ss: 1562 1562 1562 1562
nsx: 8 nsy: 8
mesh_size: 25 stam_size: 33
ng: 3 6
sg: 0.500000
sat: 9999999999999999.000000 pix_min: 0.000000 max_stamp 2
deg_spatial: 2 deg_bg: 1
subs: 1562 1562
Allocate: 64
Getting Stamps
bitpix: -32 4
width: 1562 height: 1562 1562 1562
bitpix: -32 4
width: 1562 height: 1562 1562 1562
sub_ref: 32.391235 10.000000
Making defect map
Looking for Stamps
nb: 64
Building Zero Order Matrix
Checking Stamps
x: 71 y: 125 -1.375231
```

image matching and subtraction of astronomical images

```
emacs@course2021
File Edit Options Buffers Tools Text Help
Save Undo
stamps_x      8
nstamps_y     8
sub_x         1
sub_y         1
half_mesh_size 12
half_stamp_size 16
deg_bg        1
saturation    9999999999999999.
pix_min       0.
min_stamp_center 2
ngauss        3
deg_gauss1    6
deg_gauss2    4
deg_gauss3    3
sigma_gauss1  1
sigma_gauss2  2
sigma_gauss3  4
deg_spatial   2
automatic     no

-:--- iiconfig.txt All L1 (Text)
Welcome to GNU Emacs, one component of the GNU/Linux operating system.
Emacs Tutorial Learn basic keystroke commands
U:%%- *GNU Emacs* Top L3 (Fundamental)
```

```
not3@course2021: ~/imagesubtraction
not3@course2021: ~/imagesubtraction 80x10
(iraf27) not3@course2021:~/imagesubtraction$ ls
conv0.fits i18293A.fits iiconfig.txt kt_.fits
conv.fits i18293B.fits kc_0i18293B.fits
(iraf27) not3@course2021:~/imagesubtraction$ emacs iiconfig.txt &
[3] 17936
[1] Done emacs iiconfig.txt (wd: ~/sub)
(wd now: ~/imagesubtraction)
(iraf27) not3@course2021:~/imagesubtraction$ ds9 i18293A.fits i18293B.fits conv.
fits
```

SAOImage ds9

File Edit View Frame Bin Zoom Scale Color Region WCS Analysis

File i18293A.fits

Object Final combined image: iras18293-3413

Value 26.8196

FK5 α 18:32:41.5649 δ -34:11:25.695

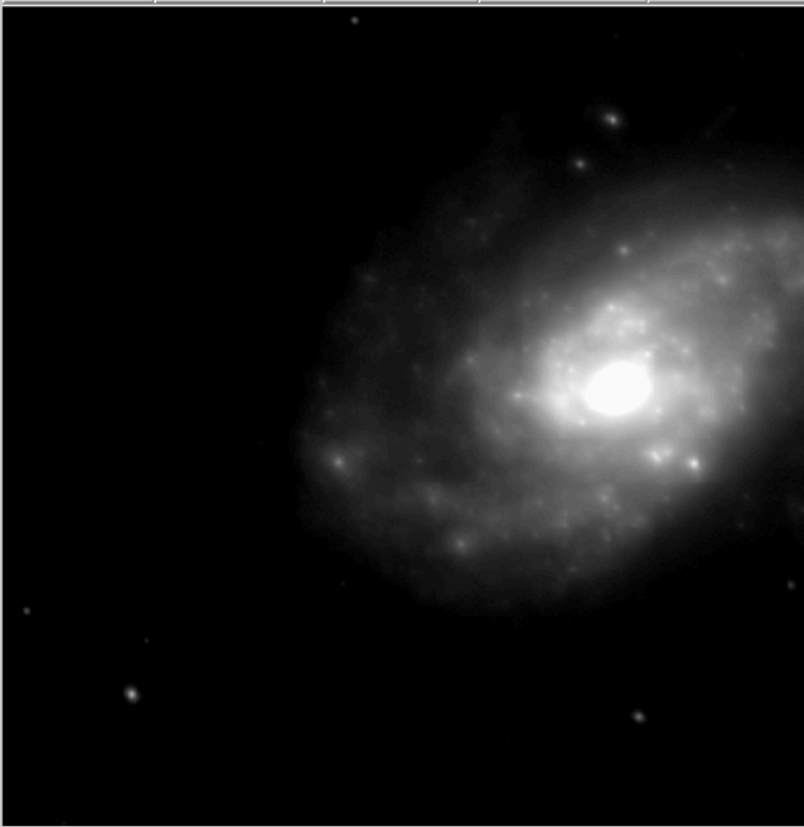
Physical x 214.186 y 627.81

Image x 483.186 y 897.81

Frame 1 x 0.962939 0 °

file edit view frame bin zoom scale color

zoom in zoom out zoom fit zoom 1/4 zoom 1/2



8 32 80 177 370 754

extract relevant information from the fits headers incl. dates of the observations, telescope and instrument used, wavelength of the observation, atmospheric conditions?

```
not3@course2021: ~/imagesubtraction
not3@course2021: ~/imagesubtraction 80x53
(iraf27) not3@course2021:~/imagesubtraction$ more i18293A.fits
SIMPLE = T / Fits standard
BITPIX = -32 / Bits per pixel
NAXIS = 2 / Number of axes
NAXIS1 = 1562 / Axis length
NAXIS2 = 1562 / Axis length
EXTEND = T / File may contain extensions
IRAF-TLM= '2022-05-30T15:10:15' / Time of last modification
OBJECT = 'Final combined image: iras18293-3413'
DATE = '2022-05-30T15:10:15'
IRAF-MAX= 0.000000E0 / DATA MAX
IRAF-MIN= 0.000000E0 / DATA MIN
ORIGIN = 'NOAO-IRAF FITS Image Kernel July 2003' / FITS file originator
DATE = '2005-08-03T11:53:46' / Date this file was written
EXPTIME = 1 / Total integration time
MJD_OBS = 53262.98191961 / MJD start (2004-09-14T23:33:57.854)
DATE-OBS= '2004-09-14T23:33:57.8545' / Observing date
ORIGFILE= 'NACO_0010.fits' / Original File Name
INSTRUME= 'NAOS+CONICA' / Instrument used
TELESCOP= 'ESO-VLT-U4' / ESO Telescope Name
RA = 278.170930 / 18:32:41.0 RA (J2000) pointing
DEC = -34.19111 / -34:11:27.9 DEC (J2000) pointing
EQUINOX = 2000. / Standard FK5
RADECSYS= 'FK5' / FK5
LST = 66541.046 / 18:29:01.046 LST
UTC = 84812.000 / 23:33:32.000 UTC
OBSERVER= 'UNKNOWN' / Name of observer
PI-COI = 'UNKNOWN' / Name(s) of proposer(s)
ALARM = ' ' / Active alarm(s), if any.
AIRMASS = 1.01400 / Averaged air mass
CRVAL1 = 278.17093 / Coordinate at reference pixel in <axis
CRVAL2 = -34.19111 / Coordinate at reference pixel in <axis
CRPIX1 = 731.2 / Ref pixel in <axis direction>
CRPIX2 = 812.9 / Ref pixel in <axis direction>
CDELTA1 = -7.527780000000000E-6 / Increment in <axis direction>
CDELTA2 = 7.527780000000000E-6 / Increment in <axis direction>
CTYPE1 = 'RA--TAN' / Coordinate system of <axis direction>
CTYPE2 = 'DEC--TAN' / Coordinate system of <axis direction>
CD1_1 = -7.52778E-06 / Translation matrix element
CD2_2 = 7.52778E-06 / Translation matrix element
ARCFILE = 'NACO.2004-09-14T23:33:57.854.fits' / Archive File Name
UT = '23:33:32.000' / UT at start
ST = '18:29:01.046' / ST at start
IMAGETYP= 'OBJECT' / Observation type
HIERARCH ESO OBS DID = 'ESO-VLT-DIC.OBS-1.10' / OBS Dictionary
HIERARCH ESO OBS EXEETIME = 3620 / Expected execution time
HIERARCH ESO OBS GRP = '0' / linked blocks
HIERARCH ESO OBS ID = 200141584 / Observation block ID
HIERARCH ESO OBS NAME = 'T00_I18293-3413Ks' / OB name
HIERARCH ESO OBS OBSERVER = 'UNKNOWN' / Observer Name
HIERARCH ESO OBS PI-COI ID = 5889 / ESO internal PI-COI ID
HIERARCH ESO OBS PI-COI NAME = 'UNKNOWN' / PI-COI name
HIERARCH ESO OBS PROG ID = '073.D-0406(B)' / ESO program identification
HIERARCH ESO OBS TARG NAME = 'iras18293-3413' / OB target name
```


inspect the images using the ds9 tool: different contrast settings, comparison between different images, identifying the subtraction residuals with image sources, astronomical coordinates, estimate the spatial resolution of the images

The screenshot displays the SAOImage ds9 software interface. The main window shows a large astronomical image of a star cluster. The interface includes a menu bar (File, Edit, View, Frame, Bin, Zoom, Scale, Color, Region, WCS, Analysis, Help) and a toolbar with various processing options. The 'Scale' menu is open, showing options like 'linear', 'log', 'power', 'sqrt', 'squared', 'asinh', and 'sinh'. The 'min max' option is selected. The 'Scale Parameters' dialog box is open, showing a 'Pixel Distribution' histogram with a logarithmic y-axis (1E0 to 1E6) and a linear x-axis (0 to 10000). The 'Limits' section shows 'Low' set to 10 and 'High' set to 100000. The background image shows a bright star with a surrounding cluster of fainter stars. The 'Scale Parameters' dialog box also has an 'Apply' button and a 'Close' button.

File	Object	Value	FK5	Physical	Image	Frame 1
i18293A.fits	Final combined image: iras18293-3413	439.56	α 18:32:41.0238	x 461.92	x 730.92	x 2.88469
			δ -34:11:27.469	y 562.346	y 832.346	y 0

file	edit	view	frame	bin	zoom	scale	color	region	wcs	analysis	help
linear	log	power	sqrt	squared	asinh	sinh	histogram	min max	zscale		

File	Edit	Scale	Limits	Scope	Min Max	Parameters	Graph
Pixel Distribution							
1E6	1E5	1E4	1E3	1E2	1E1	1E0	
0	5000	10000					
Limits	Low 10	High 100000					
	Apply	Close					

The screenshot displays the SAOImage ds9 software interface. The main window shows a large astronomical image of a star cluster. The interface includes a menu bar (File, Edit, View, Frame, Bin, Zoom, Scale, Color, Region, WCS, Analysis, Help) and a toolbar with various processing options. The 'Scale' menu is open, showing options like 'linear', 'log', 'power', 'sqrt', 'squared', 'asinh', and 'sinh'. The 'min max' option is selected. The 'Scale Parameters' dialog box is open, showing a 'Pixel Distribution' histogram with a logarithmic y-axis (1E0 to 1E6) and a linear x-axis (0 to 10000). The 'Limits' section shows 'Low' set to 10 and 'High' set to 100000. The background image shows a bright star with a surrounding cluster of fainter stars. The 'Scale Parameters' dialog box also has an 'Apply' button and a 'Close' button.

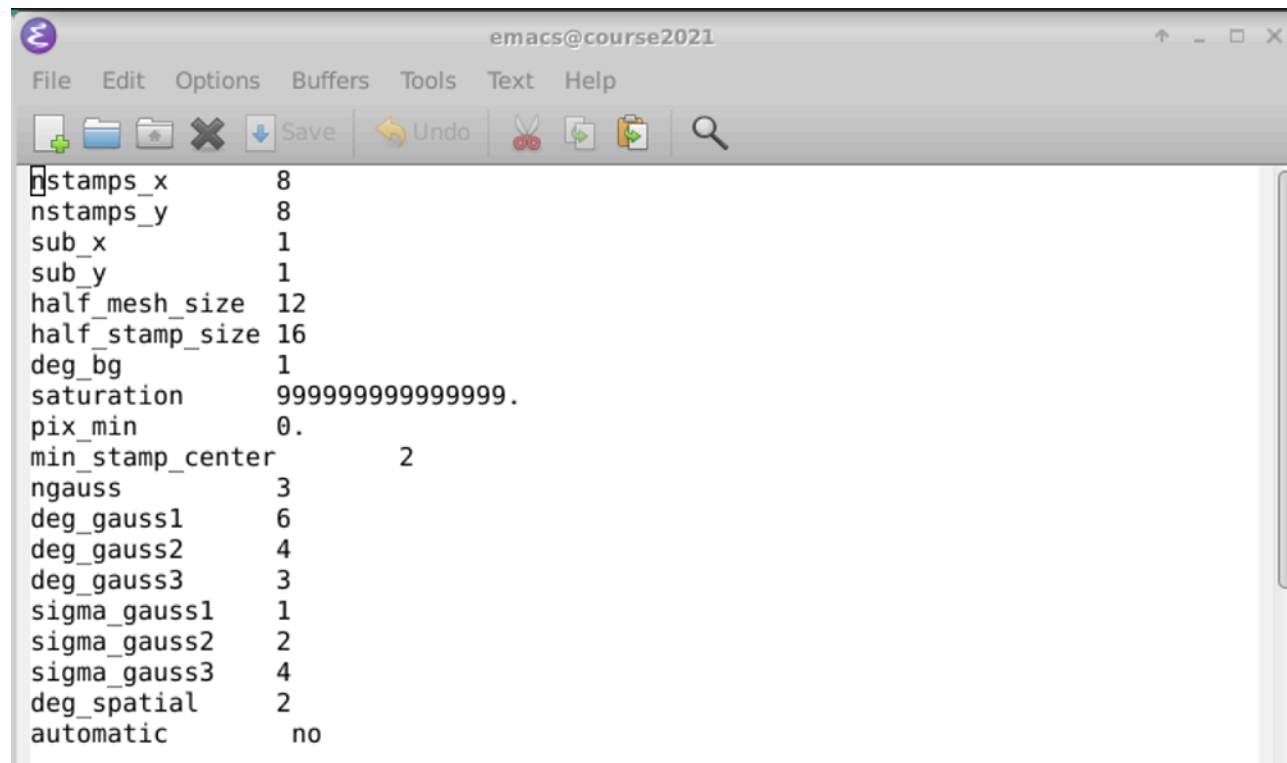
File	Object	Value	FK5	Physical	Image	Frame 1
i18293A.fits	Final combined image: iras18293-3413					
			α 18:32:41.0238	x	x	x
			δ -34:11:27.469	y	y	y

file	edit	view	frame	bin	zoom	scale	color	region	wcs	analysis	help
linear	log	power	sqrt	squared	asinh	sinh	histogram	min max	zscale		

File	Edit	Scale	Limits	Scope	Min Max	Parameters	Graph
Pixel Distribution							
1E6	1E5	1E4	1E3	1E2	1E1	1E0	
0	5000	10000					
Limits	Low 10	High 100000					
	Apply	Close					

experiment what happens if we change the subtraction parameters?

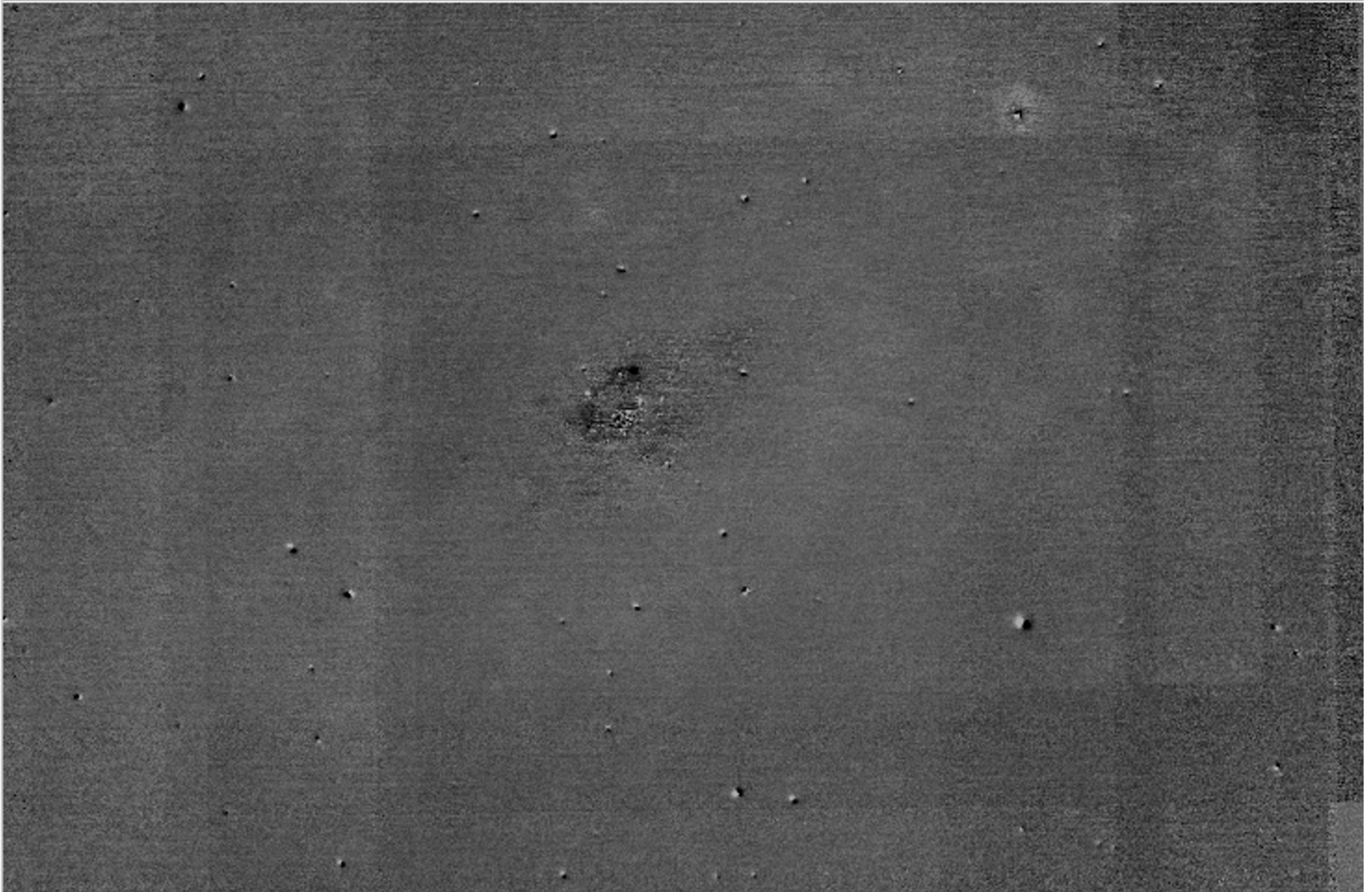
n	number of Gaussian functions in the kernel
σ_n	sigmas of the Gaussians
D_n	polynomial degrees associated with each of the n gaussians
D^k	degree of the polynomial transform for the spatial variations of the kernel
D^{bg}	degree of the polynomial used to model the background variations
N_x	number of stamps along x-axis
N_y	number of stamps along y-axis
S_k	width of the convolution kernel
S_s	width of the region used for fitting the background
N_c	minimum number of counts in the middle of a stamp
N_{min}	minimum value of a pixel to be included in the fit
N_{sat}	maximum value of a pixel to be included in the fit



The screenshot shows an Emacs window titled 'emacs@course2021'. The menu bar includes 'File', 'Edit', 'Options', 'Buffers', 'Tools', 'Text', and 'Help'. The toolbar contains icons for file operations and editing. The main text area displays a list of parameters and their values:

```
stamps_x      8
nstamps_y     8
sub_x         1
sub_y         1
half_mesh_size 12
half_stamp_size 16
deg_bg        1
saturation    9999999999999999.
pix_min       0.
min_stamp_center 2
ngauss        3
deg_gauss1    6
deg_gauss2    4
deg_gauss3    3
sigma_gauss1  1
sigma_gauss2  2
sigma_gauss3  4
deg_spatial  2
automatic     no
```

how does the subtracted image look like? what is causing the different residuals? any real variability between the two images?



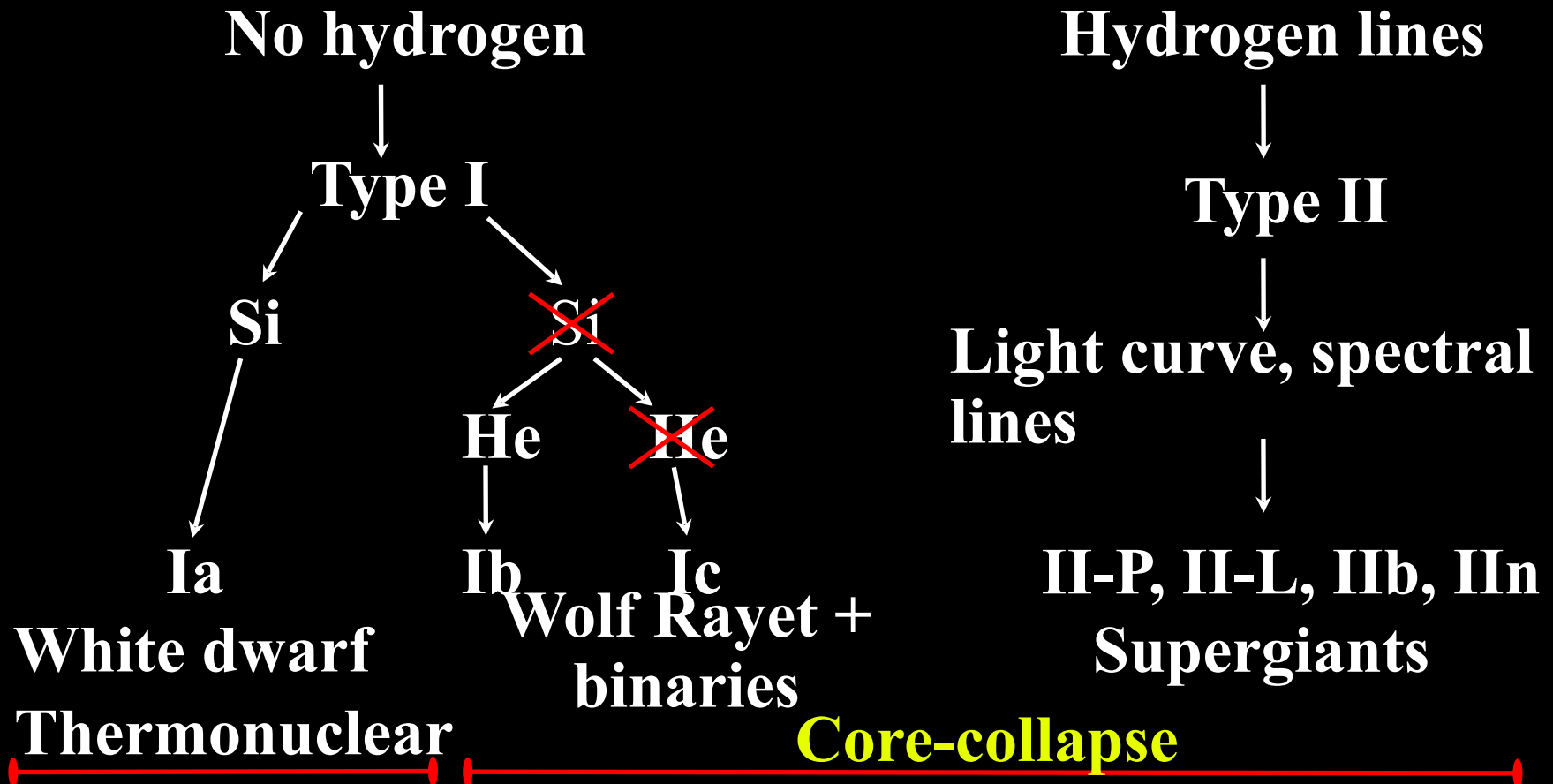
Exercise 3: Deep learning for the automated spectral classification of supernovae

<https://github.com/daniel-muthukrishna/DASH>

Muthukrishna et al. 2019, ApJ, 885, 18

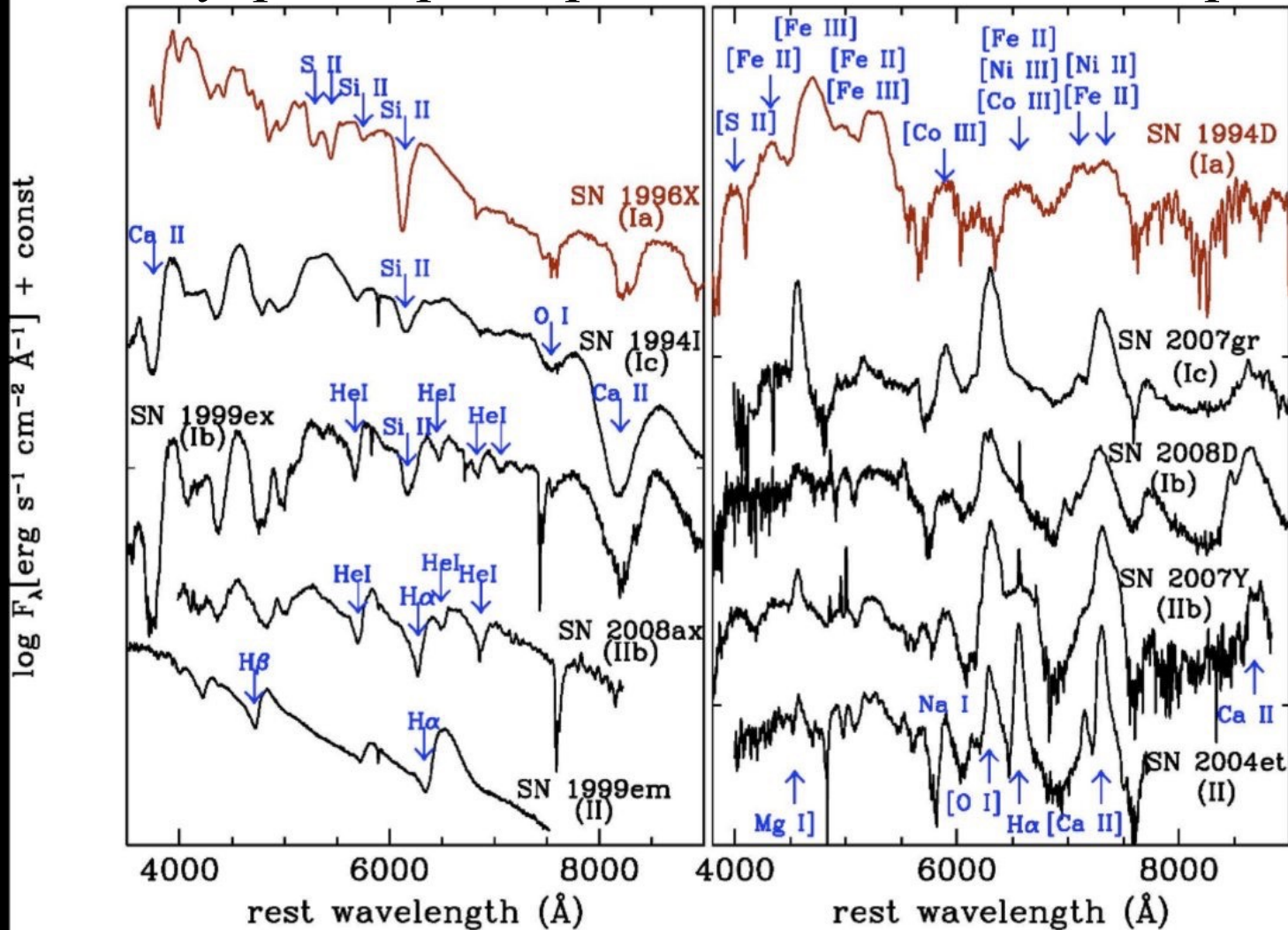
<https://iopscience.iop.org/article/10.3847/1538-4357/ab48f4/pdf>

Supernova types

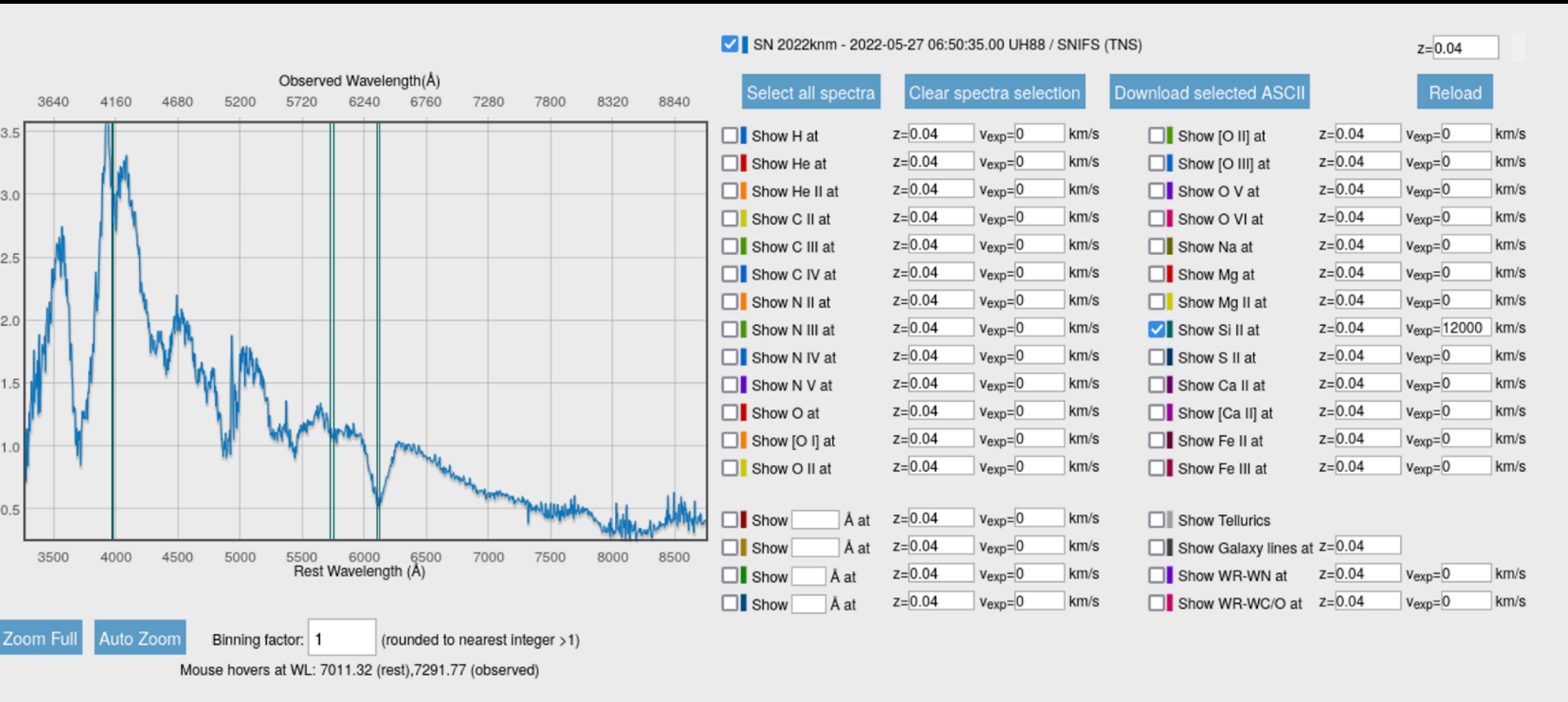


Supernova types

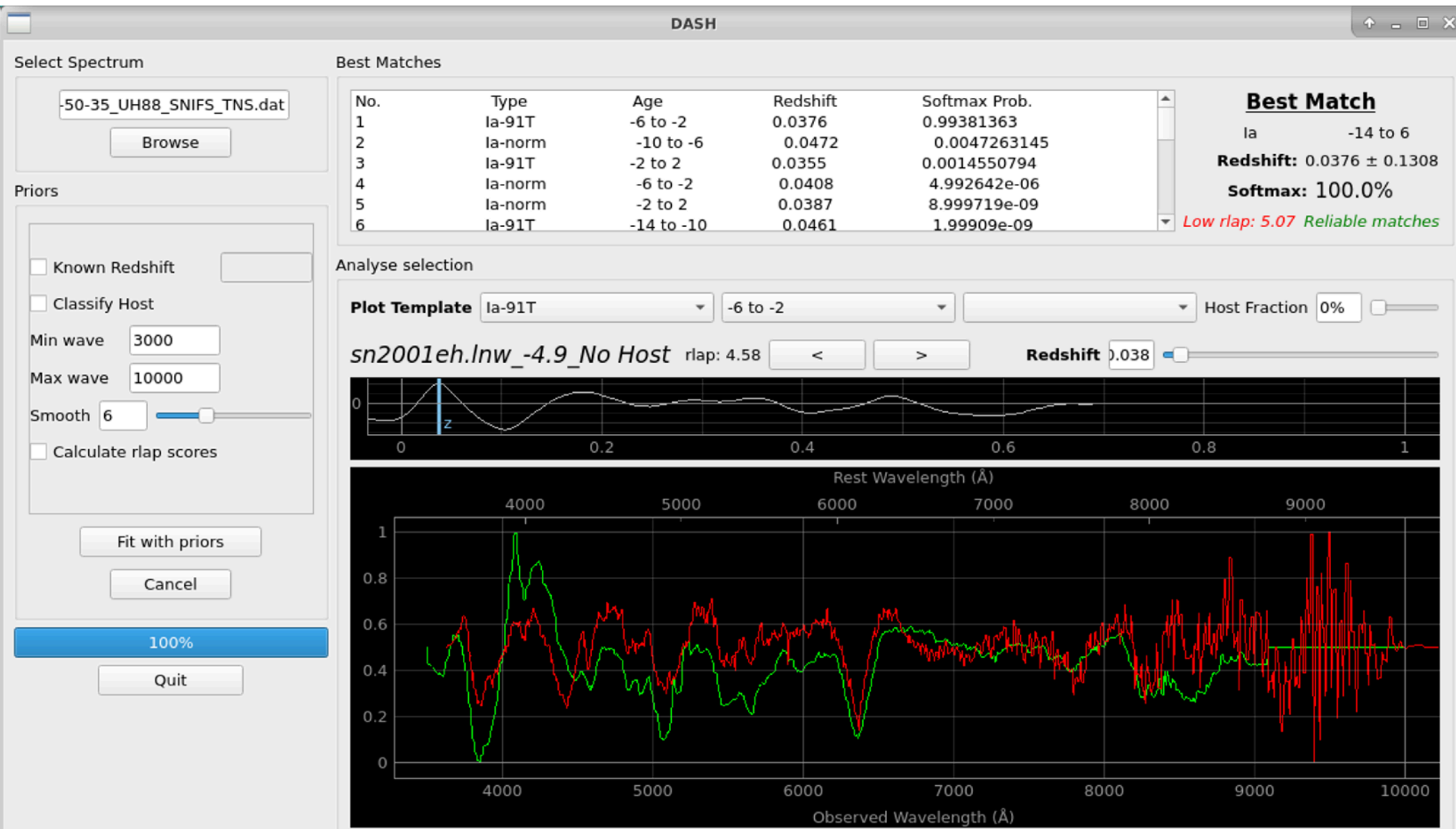
Early 'photospheric' phase Late time 'nebular' phase



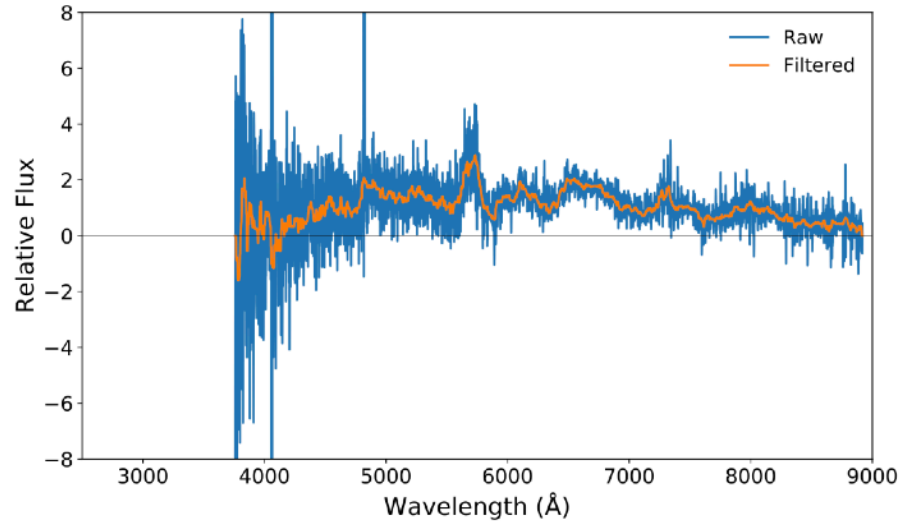
Supernova spectral classification by identifying characteristic spectral lines (and elements)



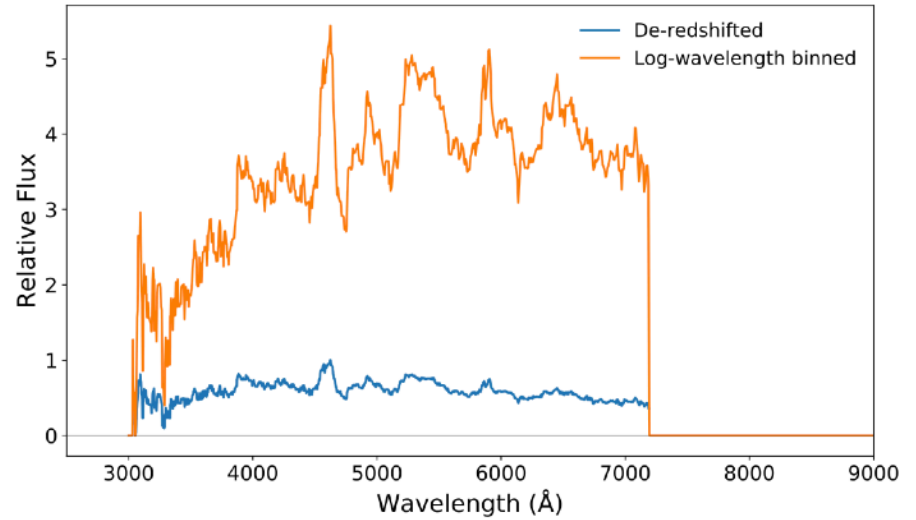
Automatic supernova classification based on a deep learning approach



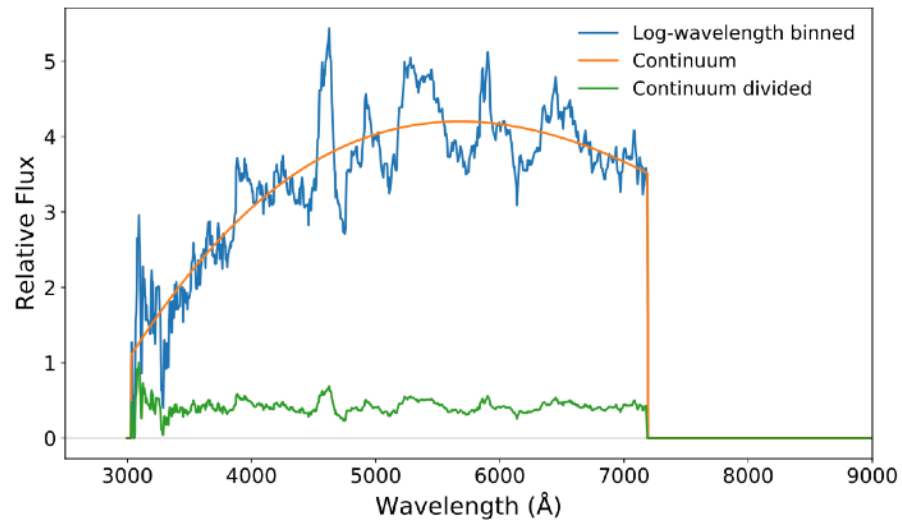
Automatic supernova classification based on a deep learning approach



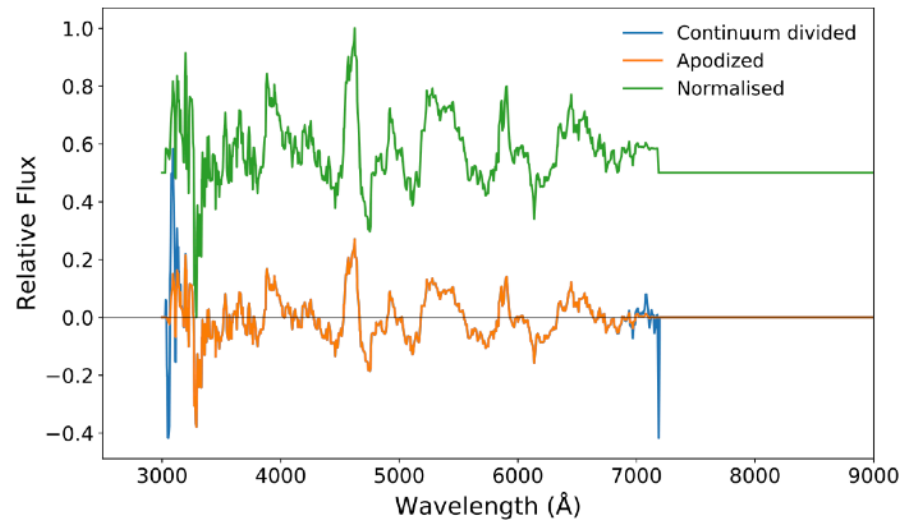
(a)



(b)



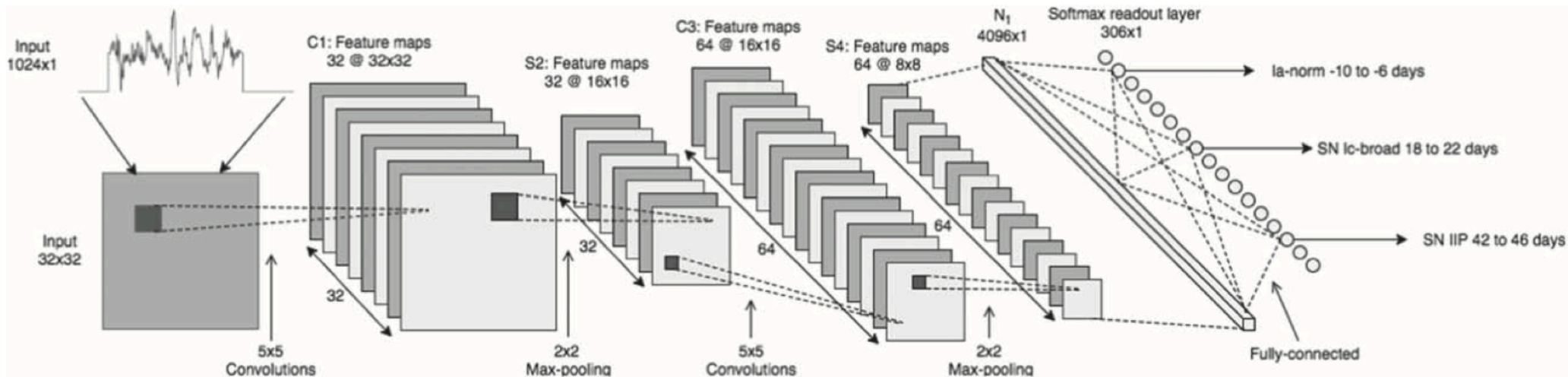
(c)



(d)

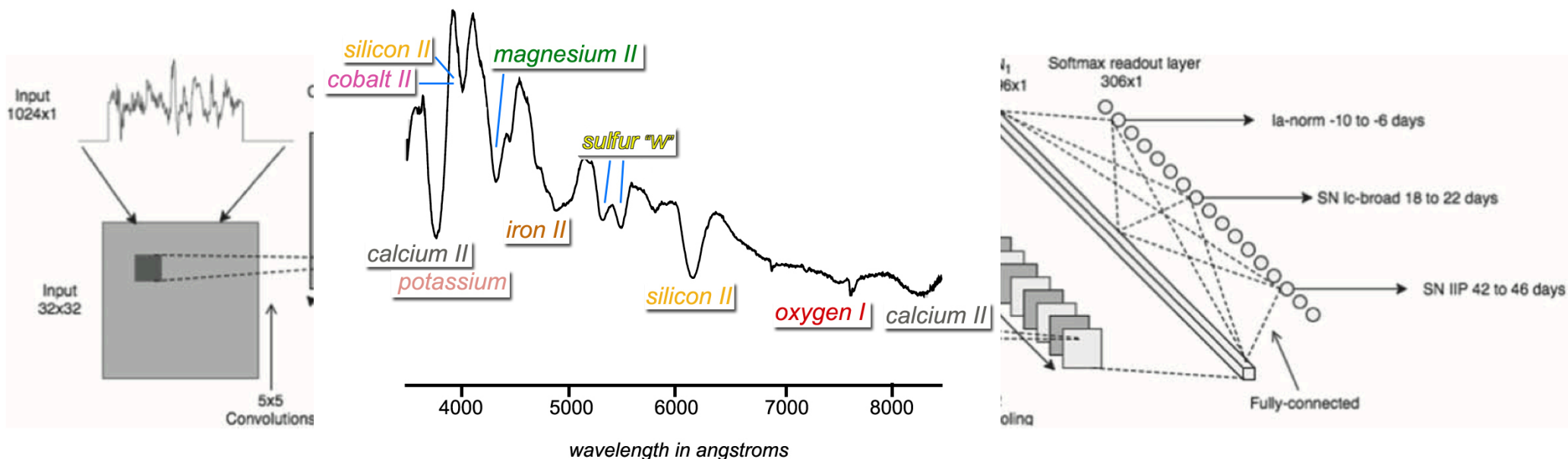
Automatic supernova classification based on a deep learning approach

- Developed a convolutional neural network with TensorFlow's Python library
- 1st input layer is made up of 1024 neurons representing fluxes of an input spectrum
- Additional layers captures a more abstract representation of the original input layer
 - DASH classifies based on spectral features (different SN types & ages)
- Final layer is a 306-point vector, with a score for each SN type and age bin
 - Training + validation using different datasets

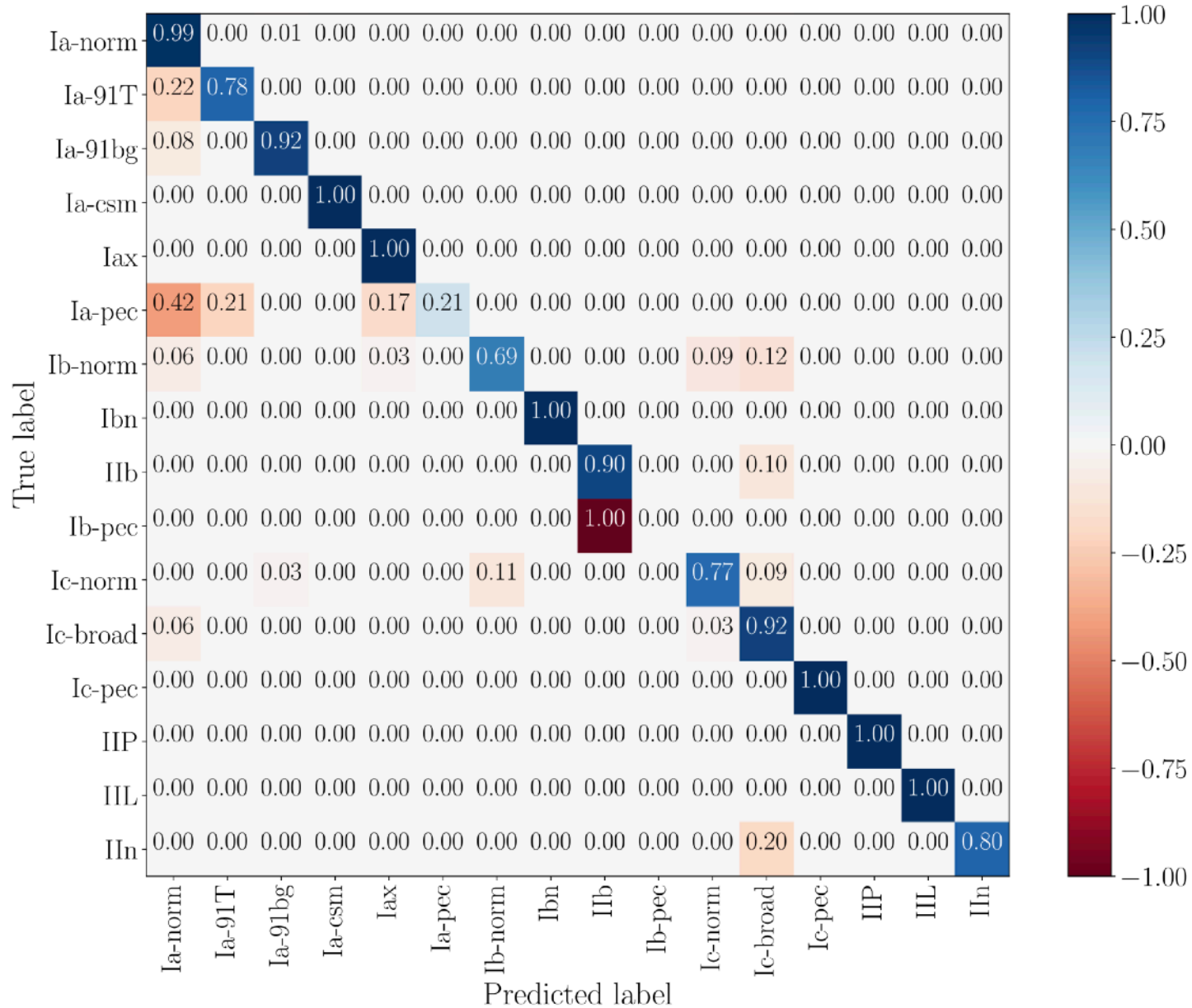


Automatic supernova classification based on a deep learning approach

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Automatic supernova classification based on a deep learning approach



Exercise 3: practical work

Experiment with a deep learning based method for supernova classification and present your findings in the report; discuss the pros and cons of the use of machine learning in supernova classification



☰ MENU

SEARCH

AUX

BOTS

CONVERSIONS

ATELS

?

✉️

LOGIN

Search by name or coordinates

Coordinates, e.g.: 23:19:44.664 +10:11:04.56 OR: 349.9361 +10.1846

Please make sure to update your WISeREP URL to: www.wiserep.org

Getting started: If new to WISeREP v2, begin by acquiring a personal account [here](#).

Then you may request to join an existing group (survey / program) or either initiate a new group if relevant.

In the new WISeREP v2, everyone can contribute and upload data (spectra / photometry / related-files) directly, either via the Report webpage or via the Bulk APIs.

Please [contact us](#) if you encounter any problems or if you have any questions.

Select suitable observed supernova spectra from the WISeREP archive, download the spectra, make notes of their types and redshifts

Object search

Object search Spectra search

Obj. Name Exact match Public Min spec. no.

RA DEC Search radius

Contributing group/s Type Type Family
ASAS-SN SN I-rapid
Asiago SN Ia-91bg-like
Star
Synthetic

Redshift Range to Added within the last

> [Advanced search](#)

Results in page

Select suitable observed supernova spectra from the WISeREP archive, download the spectra, make notes of their types and redshifts

Showing results 1 to 50 out of 11031

ID	IAU Name	Internal / Alt. Name/s	Obj. Reps	Coords X-refs	RA	DEC	Type	Redshift	Host Redshift	Host Name	Contributing Group/s	Public	Obj. Spectra	Obj. Phases	Light Curves	Related Files	Created by
20836	SN 2022lax	ZTF22aaldrem	2	Coords X-refs	14:24:50.686	-08:45:10.60	SN Ia	0.058			TNS	Y	1				TNS_Bot1
20842	SN 2022kwf	ATLAS22ozp, ZTF22aalfezt	3	Coords X-refs	17:36:17.968	+40:08:16.10	SN Ia	0.0387500003			TNS	Y	1				TNS_Bot1
20825	SN 2022koy	ZTF22aalaajn	2	Coords X-refs	00:36:32.281	+19:23:54.61	SN Ia	0.062			TNS	Y	1				TNS_Bot1
20818	SN 2022kpr	ATLAS22ogv	2	Coords X-refs	16:26:57.750	+51:07:42.95	SN Ia	0.08			TNS	Y	1				TNS_Bot1
20828	SN 2022knm	ZTF22aakkmrj, ATLAS22orp, PS22ekk	4	Coords X-refs	13:25:04.348	-24:39:24.80	SN Ia	0.04			TNS	Y	1				TNS_Bot1
20821	SN 2022kmp	ZTF22aakowgl, ATLAS22okr	3	Coords X-refs	11:50:24.455	+22:42:48.92	SN Ia	0.067			TNS	Y	1				TNS_Bot1
20839	SN 2022kim	ATLAS22oht	2	Coords X-refs	17:33:57.181	+50:33:11.43	SN Ia	0.07			TNS	Y	1				TNS_Bot1
20806	SN 2022klj	ZTF22aalykxi, PS22elq	3	Coords X-refs	16:18:24.720	+12:28:13.86	SN Ia	0.085			ePESSTO+, TNS	Y	1				WIS_Bot1
20786	SN 2022klh	ATLAS22off	2	Coords X-refs	15:21:19.265	+34:17:47.13	SN Ia	0.031492			TNS	Y	1				TNS
20816	SN 2022klg	ATLAS22ofd	2	Coords X-refs	13:52:43.849	+59:16:42.91	SN Ia	0.03			TNS	Y	1				TNS



select suitable observed supernova spectra from the WISeREP archive, download the spectra, make notes of their types and redshifts



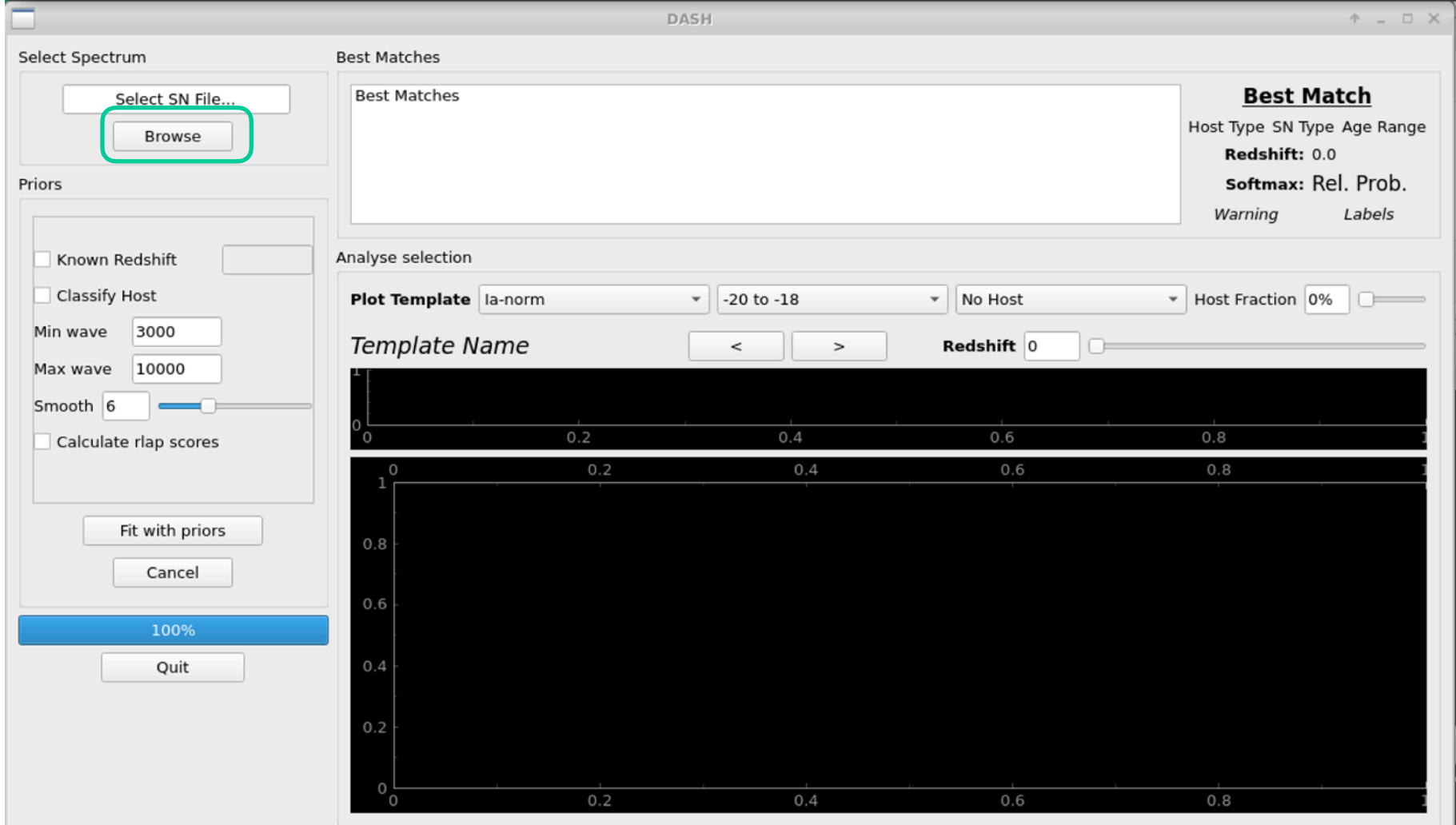
SN 2022knm - 2022-05-27 06:50:35.00 UH88 / SNIFS (TNS) z=0.04

Select all spectra Clear spectra selection Download selected ASCII Reload

- Show H at z=0.04 v_{exp}=0 km/s
- Show He at z=0.04 v_{exp}=0 km/s
- Show He II at z=0.04 v_{exp}=0 km/s
- Show C II at z=0.04 v_{exp}=0 km/s
- Show C III at z=0.04 v_{exp}=0 km/s
- Show C IV at z=0.04 v_{exp}=0 km/s
- Show N II at z=0.04 v_{exp}=0 km/s
- Show N III at z=0.04 v_{exp}=0 km/s
- Show N IV at z=0.04 v_{exp}=0 km/s
- Show N V at z=0.04 v_{exp}=0 km/s
- Show O at z=0.04 v_{exp}=0 km/s
- Show [O I] at z=0.04 v_{exp}=0 km/s
- Show O II at z=0.04 v_{exp}=0 km/s
- Show [O II] at z=0.04 v_{exp}=0 km/s
- Show [O III] at z=0.04 v_{exp}=0 km/s
- Show O V at z=0.04 v_{exp}=0 km/s
- Show O VI at z=0.04 v_{exp}=0 km/s
- Show Na at z=0.04 v_{exp}=0 km/s
- Show Mg at z=0.04 v_{exp}=0 km/s
- Show Mg II at z=0.04 v_{exp}=0 km/s
- Show Si II at z=0.04 v_{exp}=0 km/s
- Show S II at z=0.04 v_{exp}=0 km/s
- Show Ca II at z=0.04 v_{exp}=0 km/s
- Show [Ca II] at z=0.04 v_{exp}=0 km/s
- Show Fe II at z=0.04 v_{exp}=0 km/s
- Show Fe III at z=0.04 v_{exp}=0 km/s
- Show Tellurics
- Show Galaxy lines at z=0.04
- Show WR-WN at z=0.04 v_{exp}=0 km/s
- Show WR-WC/O at z=0.04 v_{exp}=0 km/s

Showing results 1 to 1 out of 1

Select	Spec. ID	Obj. ID	Obj. IAU Name	Obj. Alt. Name/s	Obj Type	Redshift	Obs-date (UT)	Phase/s	Tel / Inst	Exp-time	Observer/s	Reducer/s	Group	Spectrum ascii File	Spectrum fits File	Spec. Type	Quality	Related files	Public
<input checked="" type="checkbox"/>	66322	20828	SN 2022knm	ZTF22aakkmr1, ATLAS22orp, PS22ekk	SN Ia	0.04	2022-05-27 06:50:35.00		UH88 / SNIFS	1800	M. E. Huber		TNS	SN2022knm_2022-05-27_06-50-35_UH88_SNIFS_TNS.dat		Object			Y



```

not3@course2021: ~
not3@course2021: ~ 80x15
not3@course2021:~$ astrodash-setup
(astrodash) not3@course2021:~$ astrodash
Pandas module not installed. DASH will use numpy to load spectral files instead.
This can be up to 10x slower.
2022-05-30 19:47:58.320799: W tensorflow/stream_executor/platform/default/dso_loader.cc:64] Could not load dynamic library 'libcudart.so.11.0'; dlderror: libcudart.so.11.0: cannot open shared object file: No such file or directory
2022-05-30 19:47:58.320835: I tensorflow/stream_executor/cuda/cudart_stub.cc:29] Ignore above cudart dlerror if you do not have a GPU set up on your machine.
WARNING:tensorflow:From /opt/miniconda3/envs/astrodash/lib/python3.10/site-packages/tensorflow/python/compat/v2_compat.py:107: disable_resource_variables (from tensorflow.python.ops.variable_scope) is deprecated and will be removed in a future version.
Instructions for updating:
non-resource variables are not supported in the long term

```

make experiments with DASH for the spectra that you downloaded, do the spectral types agree with previous classifications, are priors needed?

DASH

Select Spectrum:

Priors

- Known Redshift
- Classify Host
- Min wave:
- Max wave:
- Smooth:
- Calculate rlap scores

100%

Best Matches

No.	Type	Age	Redshift	Softmax Prob.
1	la-norm	-6 to -2	0.0821	0.5152524
2	la-norm	-10 to -6	0.0888	0.30258945
3	la-norm	-2 to 2	0.0788	0.17644837
4	la-norm	2 to 6	0.0766	0.0034900813
5	la-91T	-2 to 2	0.0788	0.0012671399
6	la-91T	2 to 6	0.0799	0.0008158489

Best Match
la-norm -14 to 10
Redshift: 0.0821 ± 0.03
Softmax: 100.0%
Low rlap: 4.96 Reliable matches

Analyse selection

Plot Template: la-norm -6 to -2 Host Fraction: 0%

sn2005cf.lnw_-2.7_No Host rlap: 2.0 Redshift:

Rest Wavelength (Å)

Observed Wavelength (Å)