Results from the SCP VLT Spectroscopic Campaigns

1 Introduction

This report presents VLT spectra of 42 SNe Ia candidates that were taken during four observing campaigns: Spring 2000, Spring 2001, Spring 2002 and Fall 2002. The instruments and telescopes that were used during these campaigns are listed in Tab. 1.

Table 1: Instruments and telescopes used for spectroscopic follow-up of SNe candidates.

Campaign	Instrument and Telescope	ESO program ID	Mode
Spring 2000	FORS1 on Antu (VLT-UT1)	265.A-5721(A)	Service
Spring 2001	FORS1 on Antu (VLT-UT1)	67.A-0361(A) and	Visitor
		267.A-5688(A)	Service
Spring 2002	FORS2 on Yepun (VLT-UT4) and	169.A-0382(B)	Service
	FORS1 on Melipal (VLT-UT3)		Service
Fall 2002	FORS2 on Yepun (VLT-UT4)	169.A-0382(A)	Service

For the purposes of spectroscopy, FORS1 and FORS2, are very similar instruments. The principle difference is that the detector in FORS1 is a single 2kx2k CCD, while the detector in FORS2 is a mosaic of two 2kx4k CCDs. The FORS2 detector is more sensitive than the FORS1 detector, especially at red wavelengths.

Three grisms (300V, 300I and 600z) and two slit widths (0.7 and 1.0 arc seconds) were used for the observations. In general, the grism was chosen to match the expected redshift of the SNe and the slit was matched to the seeing.

The grisms were used in cojunction with order sorting filters. The 300V grism was used with the GG435 filter and the 300I and 600z grisms was used with the OG590 filter.

2 Observations

Nearly all targets were acquired in the same way. The slit was placed through the SN candidate and a relatively bright offset star. The offset stars and the slit angles are listed in Tab. 2. After the offset star was acquired and centered, the telescope was moved to the SN candidate. Since through slit images were taken before and the offset, we can check that the SN has been acquired correctly, which is an important check when the observations are done in service mode. There were only four exceptions: SuF02-026 and SuF02-012 were observed together and C00-008 and S01-035 were acquired directly.

Generally speaking, three exposures with small offsets along the slit were taken for each candidate. Exceptions occurred when we aborted the observations because we thought that we had sufficient data to identify the candidate.

3 Data Reduction

The data were largely reduced in the standard way. The bias was removed by subtracting a constant from the entire frame or by fitting the overscan region with a low order polynomial; flat-fielding was done with lamp flats and wavelength calibration was done with arcs. There are; however, differences in the way the sky and fringes were were removed.

3.1 FORS1/2 observations with the 300V grism

Fringing is not a significant limitation in the data so the sky can be removed by estimating the flux on either side of the spectrum.

3.2 FORS1/2 observations with the 300I and 600z grisms

Fringing is more significant, especially with FORS2. If it is not treated carefully, the systematic error can be large. Before combining individual spectra, a fringe correction is applied to the data. The fringe correction consists of the following steps:

- Data are sorted with respect to grism, slit width, date and the location of the candidate on the 2d spectrum.
- Fringe frames are created by clipping object pixels and averaging the remainder. Since the intensity of columns (the spatial direction of the spectra are along columns) can vary with respect to one another, each column is treated individually. Flexures for FORS1 and FORS2 are small, so some fringe frames were created from data that were taken on different nights.
- The fringe frames are subtracted from the data after suitable scaling. Again, each column is treated individually.
- An average sky spectrum (done by averaging along columns) is added back to the data. This helps with the clipping of cosmic rays when the 2d data are combined.
- The data is combined by clipping and the sky is removed by estimating the flux on either side of the spectrum.

The sky subtraction is not always perfect. One can sometimes see the negative ghost of object pixels that have not been clipped. However, the fringes are removed very well.

4 Results

The results of the four campaigns are summarized in Tables 2 and 3. The spectra are plotted in Figs. 2 to 68. The arrows in the plots mark the location of the strongest night sky lines and horizontal bars mark regions of strong telluric absorption.

For those candidates that have been classified as Ia, Ia? or I, a comparison spectrum is also plotted. A question mark indicates some degree of uncertainty. No question mark indicates a secure identification. We also produce comparison plots for some of the candidates that have not been classified. These comparisons are the output from Andy Howell's SN matching program[1], which varies templates, redshifts, host galaxy templates, and reddening to find the best fit. In the comparison plots the reddened or dereddened template SNe are shown in blue, while the observations minus host galaxy template are shown in black. In most cases, the observations have been rebinned to 20Å for these plots. In cases where the redshift of the host galaxy was known, it was fixed as a parameter in the fits

Many of the candidates that have not been spectroscopically classified may indeed be SN. From the spectra alone, we cannot tell. Additional speculation as to the how some of the unidentified candidates could be classified are given in the comments field of Tab. 3.

The spectra of T02-047 and Ravel were taken long after these supernovae had faded, so I will exclude these two candidates from the following discussion.

The results can be summarized as follows:

[1] http://panisse.lbl.gov/ howell/superfit/superfit.htm

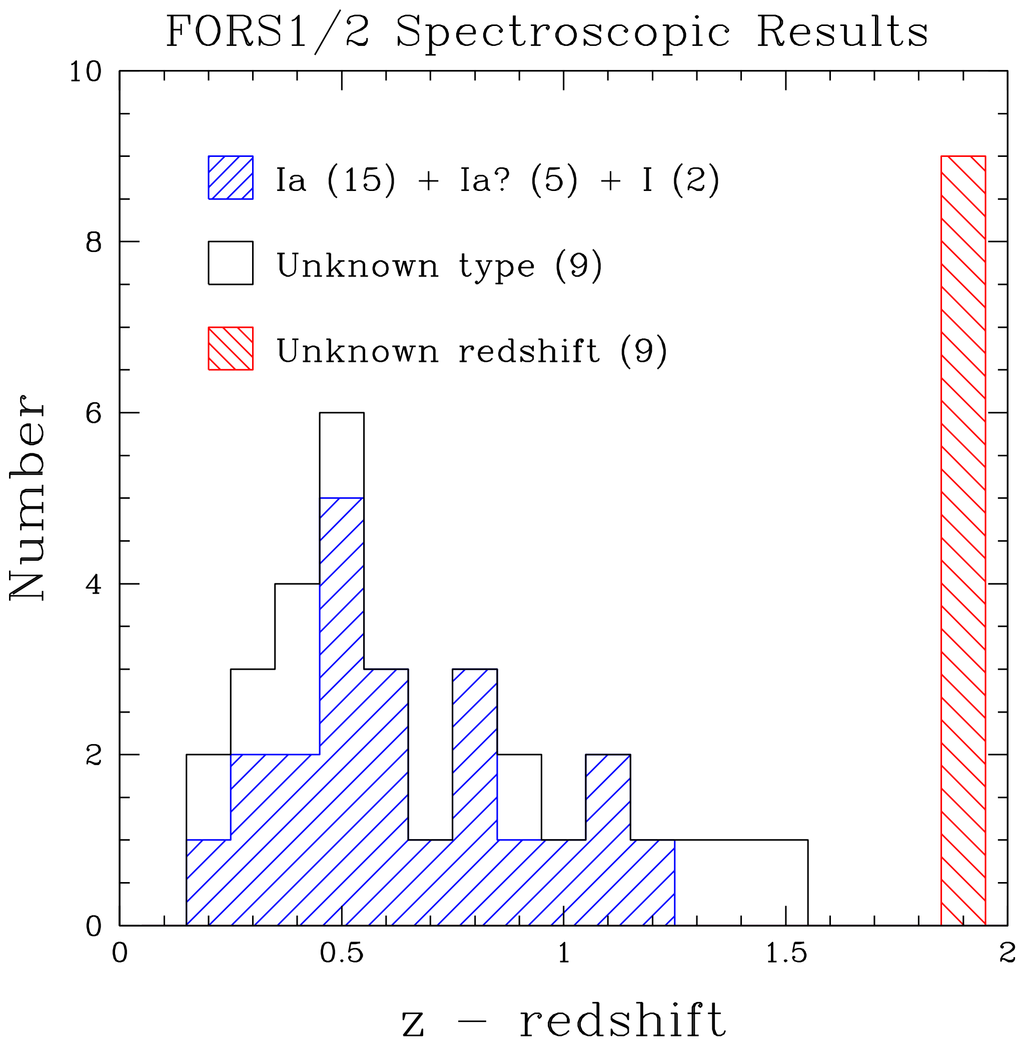

Figure 1: Histogram of classifed and unclassifed candidates.

- 40 Candidates were observed
- 30 have redshifts, 2 others have tentative redshifts
- 22 have been spectroscopically identified as some type of type I SN, ie Ia, Ia?, or I.
- 15 have beed secure classified as Ia.

The histogram of the number of classified and unclassified candidates as a function of redshift is shown in Figure 1.

Table 2: Summary of the observations.

SCP Name	IAU Name	Campaign	Civil Date	Inst. and Telescope	Grism	Offset Star	PA	Exp. (sec)
C00-008	2000fr	Spring 00	11/05/00	FORS1 UT1	300V	- [1]	40.00	7200
S01-004	2001gl	Spring 01	21/04/01	FORS1 UT1	300V	A	92.41	3600
S01-005	2001gm	Spring 01	21/04/01	FORS1 UT1	300V	Hex	43.97	2400
S01-007	2001go	Spring 01	21/04/01	FORS1 UT1	300V	Hex	97.42	2400
S01-007	2001go	Spring 01	27/04/01	FORS1 UT1	300V	Hex	97.43	7200
S01-007	2001go	Spring 01	28/05/01	FORS1 UT1	300V	Hex	97.43	9000
S01-017	2001gr	Spring 01	21/04/01	FORS1 UT1	300V	Box	22.19	3600
S01-031	2001gu	Spring 01	21/04/01	FORS1 UT1	300V	C	84.89	4800
S01-033	2001gw	Spring 01	21/04/01	FORS1 UT1	300V	Hex	156.37	1200
S01-035	-	Spring 01	21/04/01	FORS1 UT1	300V	- [1]	136.59	1200
S01-036	2001gy	Spring 01	21/04/01	FORS1 UT1	300V	Hex	88.85	2400
S01-037	-	Spring 01	21/04/01	FORS1 UT1	300V	Hex	119.68	3600
S01-054	2001ha	Spring 01	22/04/01	FORS1 UT1	300V	Hex	30.74	3600
S01-028	2001gs	Spring 01	21/04/01	FORS1 UT1	300V	Box	24.75	4800
S01-065	2001hc	Spring 01	22/04/01	FORS1 UT1	300V	Hex	-16.96	1800
S02-000	2002fd	Spring 02	11/04/02	FORS2 UT4	300V	Box	112.01	600
S02-025	-	Spring 02	11/04/02	FORS2 UT4	300I	Hex	0.34	2700
S02-002	2002fe	Spring 02	11/04/02	FORS2 UT4	300I	B	100.15	2700
S02-001	-	Spring 02	11/04/02	FORS2 UT4	300I	Hex	144.54	2700
C02-016	2002fr	Spring 02	05/05/02	FORS2 UT4	300V	Hex	145.65	900
C02-031	-	Spring 02	11/05/02	FORS1 UT3	300I	Box	178.69	3600
C02-030	2002fp	Spring 02	12/05/02	FORS1 UT3	300I	Hex	-4.43	3600
T02-015	2002gi	Spring 02	12/05/02	FORS1 UT3	300I	Hex	-0.97	7200
C02-034	-	Spring 02	18/05/02	FORS2 UT4	300V	Hex	-14.34	1800
C02-028	2002fm	Spring 02	18/05/02	FORS2 UT4	300V	B	128.28	1800
T02-030	2002gl	Spring 02	18/05/02	FORS2 UT4	300V	Hex	-176.98	3000
T02-028	2002gj	Spring 02	18/05/02	FORS2 UT4	300V	Hex	147.06	3000
T02-029	2002gk	Spring 02	18/05/02	FORS2 UT4	300V	C	129.99	900
S02-075	2002fg	Spring 02	05/06/02	FORS2 UT4	300V	Hex	-68.76	7200
T02-047[3]	-	Spring 02	07/08/02	FORS2 UT4	300V	Hex	55.74	3000
Ravel[3]	1999??	Spring 02	12/09/02	FORS2 UT4	300V		55.79	6000
SuF02-002	2002kq	Fall 02	07/11/02	FORS2 UT4	300I	Hex	79.18	3600
SuF02-005	-	Fall 02	07/11/02	FORS2 UT4	300I	Hex	-90.19	3600
SuF02-065	2002ks	Fall 02	07/11/02	FORS2 UT4	300I	A	50.69	3600
SuF02-051	-	Fall 02	07/11/02	FORS2 UT4	300I	C	79.76	3600
SuF02-028	-	Fall 02	08/11/02	FORS2 UT4	300I	Hex	-28.84	3600
SuF02-083	-	Fall 02	08/11/02	FORS2 UT4	300I	Box	92.65	7200
SuF02-060	2002kr	Fall 02	08/11/02	FORS2 UT4	300I	A	-48.75	3600
SuF02-025	2002km	Fall 02	09/11/02	FORS2 UT4	300I	Box	125.15	3600
SuF02-007	-	Fall 02	09/11/02	FORS2 UT4	300I	Hex	-9.26	13200
SuF02-012	2002lc	Fall 02	09/11/02	FORS2 UT4	600z	-[2]	8.81	7200
SuF02-026	-	Fall 02	09/11/02	FORS2 UT4	600z	-[2]	8.81	7200
SuF02-081	-	Fall 02	10/11/02	FORS2 UT4	300I	A	61.71	9600
SuF02-017	2002kn	Fall 02	11/11/02	FORS2 UT4	300I	Hex	89.37	1800

[1] Centered on the candidate.
[2] The slit passed through SuF02-012 and SuF02-026
[3] The spectra were taken many months after maximum light.

Table 3: Summary of the results. Redshifts based on the host are quoted to an accuracy of three decimal places. Redshift based on the SN quoted to two.

SCP Name	IAU Name	SN Class	Redshift	Template Match & Speculations	Galaxy Lines, Comments
C00-008	2000fr	Ia	0.543	1999bp -2 days	[OII]
S01-004	2001gl	?[2]	?	1996X -1 day	Heavily reddened Ia at z=0.4?
S01-005	2001gm	Ia	0.478	1999av +5 days	[OII]
S01-007	2001go	Ia	0.552	1992A +5 days	[OII], 3 epochs available
S01-017	2001gr	Ia	0.540	1996X +2 days	[OII], H+K
S01-031	2001gu	Ia?[2]	0.76?	1994D +2 days	H+K at z=0.778?
S01-033	2001gw	Ia	0.363	1992A -1 day	Weak [OII]
S01-035	-	II?	?	1980K +7 days	z=0.38?
S01-037	-	II?	?	1987B +7 days	z=0.16?
S01-036	2001gy	Ia	0.511	1994D -9 days	[OII]
S01-054	2001ha	Ia	0.58	1981B Max.	
S01-028	2001gs	Ia?[2]	0.658	1991T Max.	[OII],H+K,H_δ, H_8
S01-065	2001hc	Ia	0.35	1996X +2 days	
S02-000	2002fd	Ia	0.279	1999aa -11 days	H and K
S02-025	-	?	?		
S02-002	2002fe	Ia?[2]	1.086	1999ee -8 days	[OII],H+K?
S02-001	-	?	1.424		[OII]
C02-016	2002fr	?[2]	0.303?		[OII]?, Blue spectrum, A type II?
C02-031	-	II?	0.541	1999em Max.	[OIII],H_β, H_γ
C02-030	2002fp	?	0.352		[OIII], H_α, H_β. A Ia or late II?
T02-015	2002gi	Ia	0.912	1996X +2 days	[OII]
C02-034	-	?	0.243		H_α, [OII], H+K. A II or Ic?
C02-028	2002fm	?	0.448		H_α, H_β[OII] and H+K
T02-030	2002gl	Ia	0.510	1998B -1 day	[OII]
T02-028	2002gj	I	0.440	1999ao +5 days	[OII], H+K. A Ic also matches.
T02-029	2002gk	Ia	0.212	1992A +5 days	H+K
S02-075	2002fg	Ia?[3]	0.80	1999bm +3 days	[3]
T02-047[1]	-	?	0.489		[OII], [OIII], H_β, H_γ, H_δ,[NeIII]
Ravel[1]	1999??	?	?		
SuF02-002	2002kq	I	0.823	1999ac Max.	[OII] and [OIII],
SuF02-005	-	?	0.863		[OII], H and K
SuF02-065	2002ks	Ia	1.181	1981B Max.	[OII].
SuF02-051	-	?	?		
SuF02-028	-	?	0.347		[OIII], H_α
SuF02-083	-	?	1.272		[OII]
SuF02-060	2002kr	Ia	1.063	1989B -5 days	H and K
SuF02-025	2002km	Ia	0.606	1994D -7 days	[OIII]
SuF02-007	-	?	?	1996X +2 days	Broad features (z=1.14 or 0.91)
SuF02-012	2002lc	?	?		Broad features
SuF02-026	-	?	?		2 unidentified lines
SuF02-081	-	?	1.478		[OII]
SuF02-017	2002kn	Ia?	1.03	1990N -14 days	

[1] The spectra were taken many months after discovery.
[2] Revised classifications - May 2003.
[3] The spectrum was taken 1 month after discovery.

4.1 Reclassification

All earlier classifications have been revised. Some of the new classifications differ from those that were given in the IAU circulars. These differences are noted in Tab. 4.

Table 4: Reclassified SNe.

SCP Name	IAU Name	New SN Class and redshift	Old SN Class and Redshift (In the IAU Circular)
S01-004	2001gl	? at z=?	Ib/c at z=0.36
S01-031	2001gu	Ia? at z=0.76	Ia at z=0.32
S01-028	2001gs	Ia? at z=0.658	? at z=0.658
S02-002	2002fe	Ia? at 1.086	Ia at z=1.086
C02-016	2002fr	? at z=0.303?	I? at z=0.31?
S02-075	2002fg	Ia? at z=0.80	Ia? at z=0.79

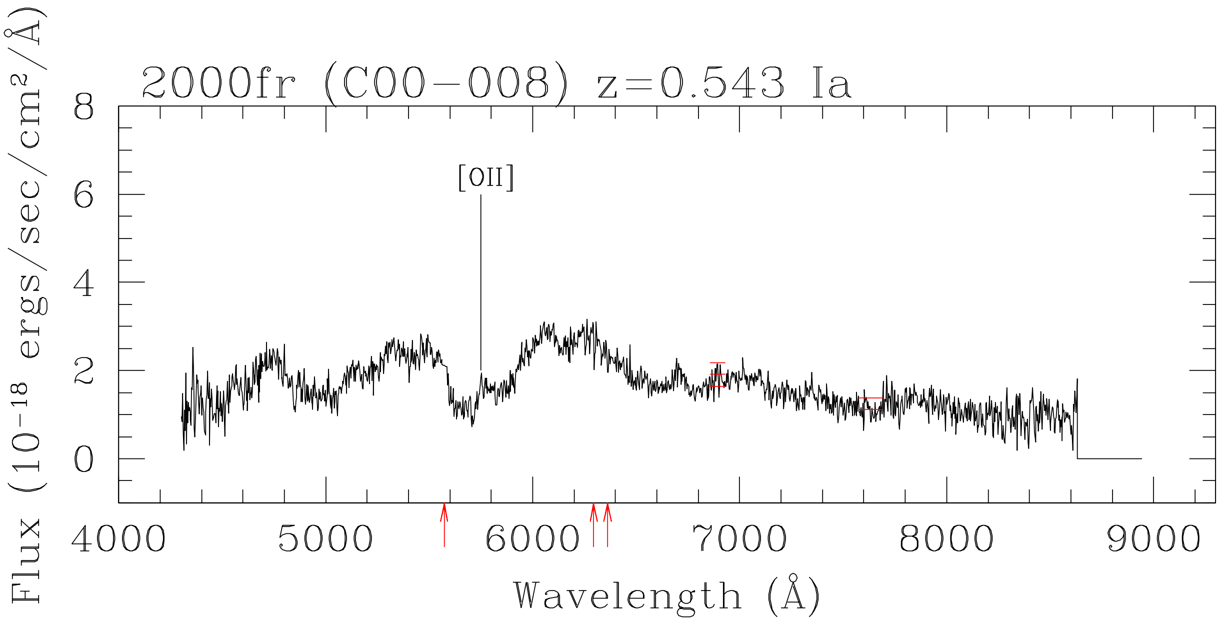

Figure 2: C00-008

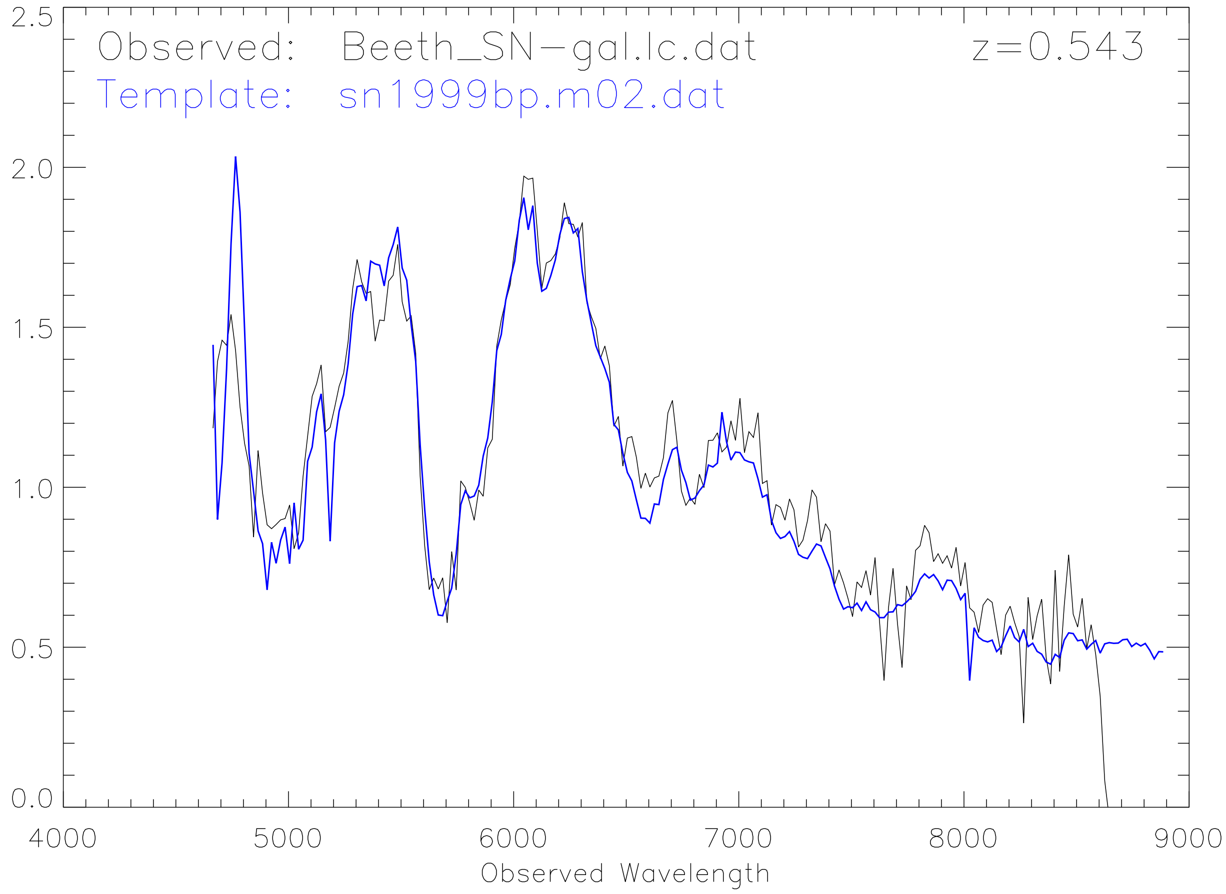

Figure 3: C00-008 and comparison

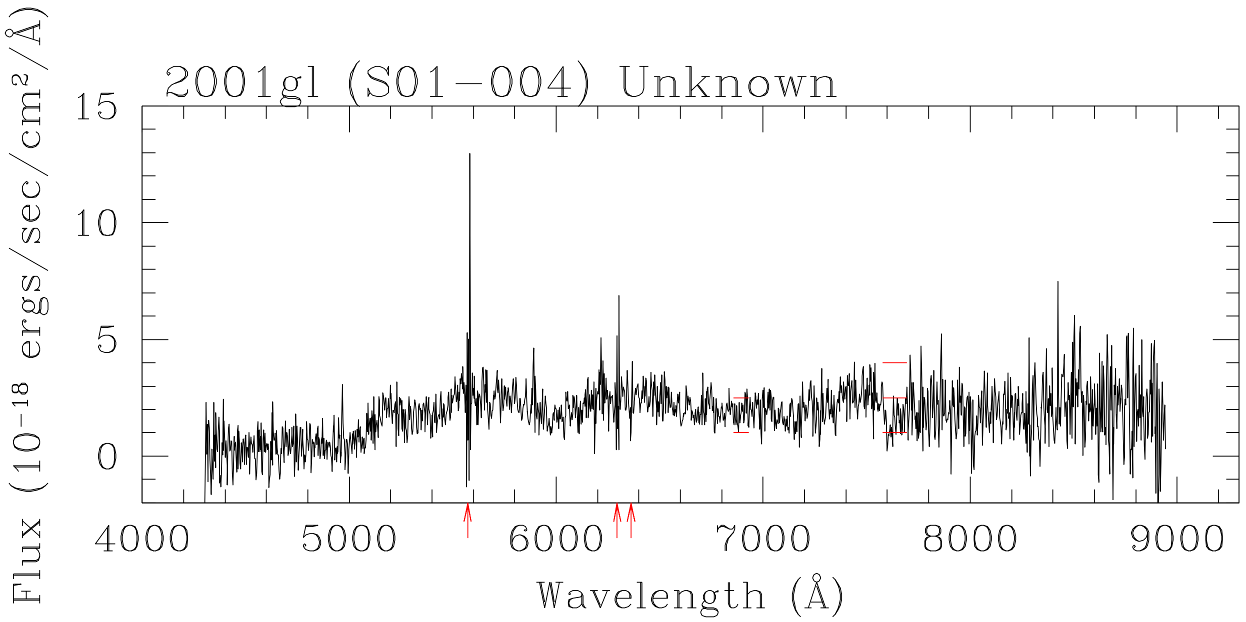

Figure 4: S01-004

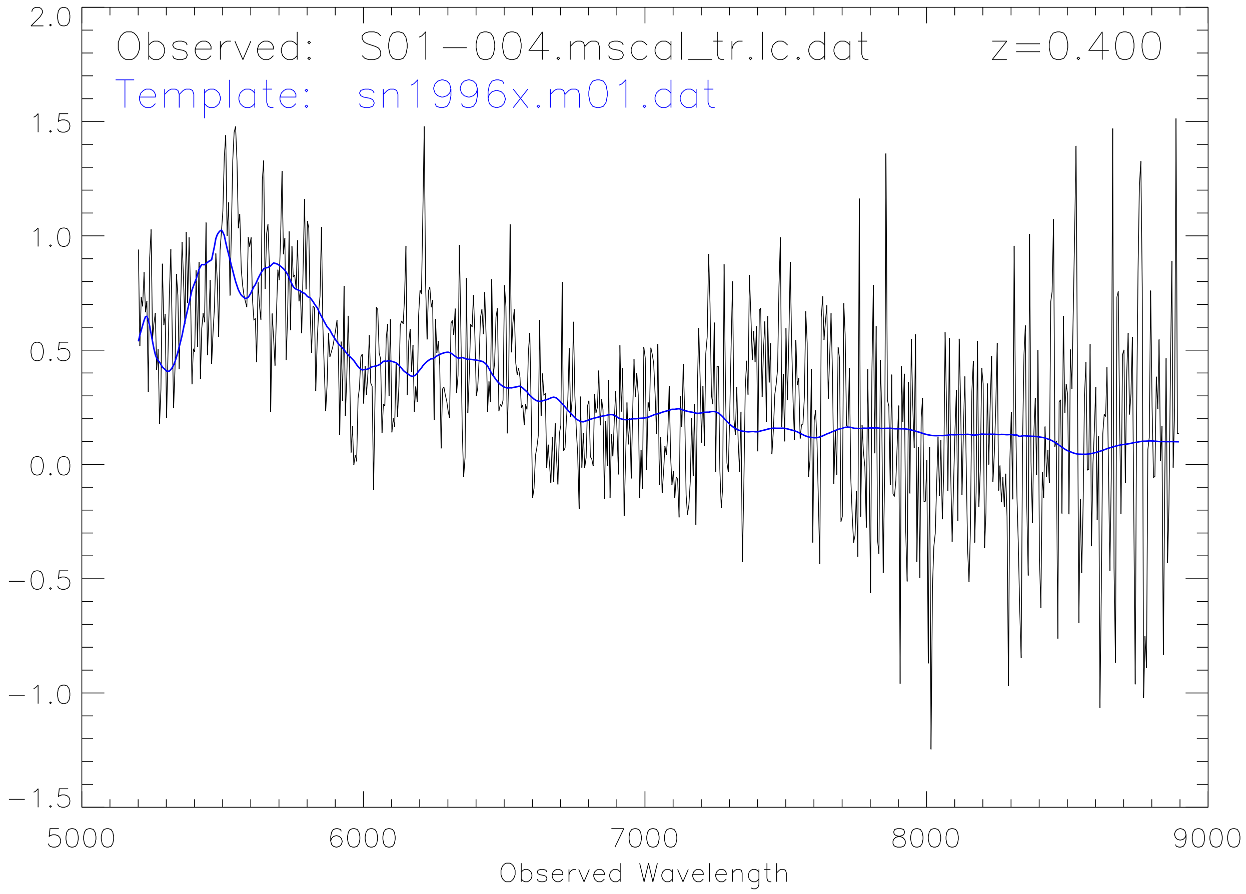

Figure 5: S01-004 comparison

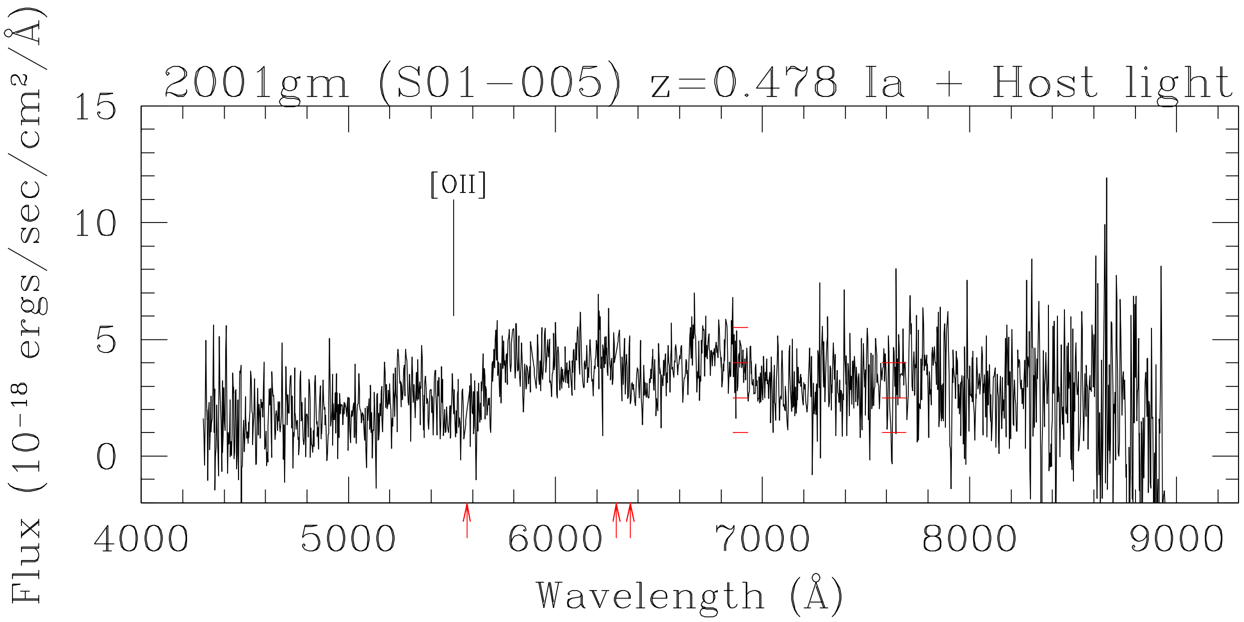

Figure 6: S01-005

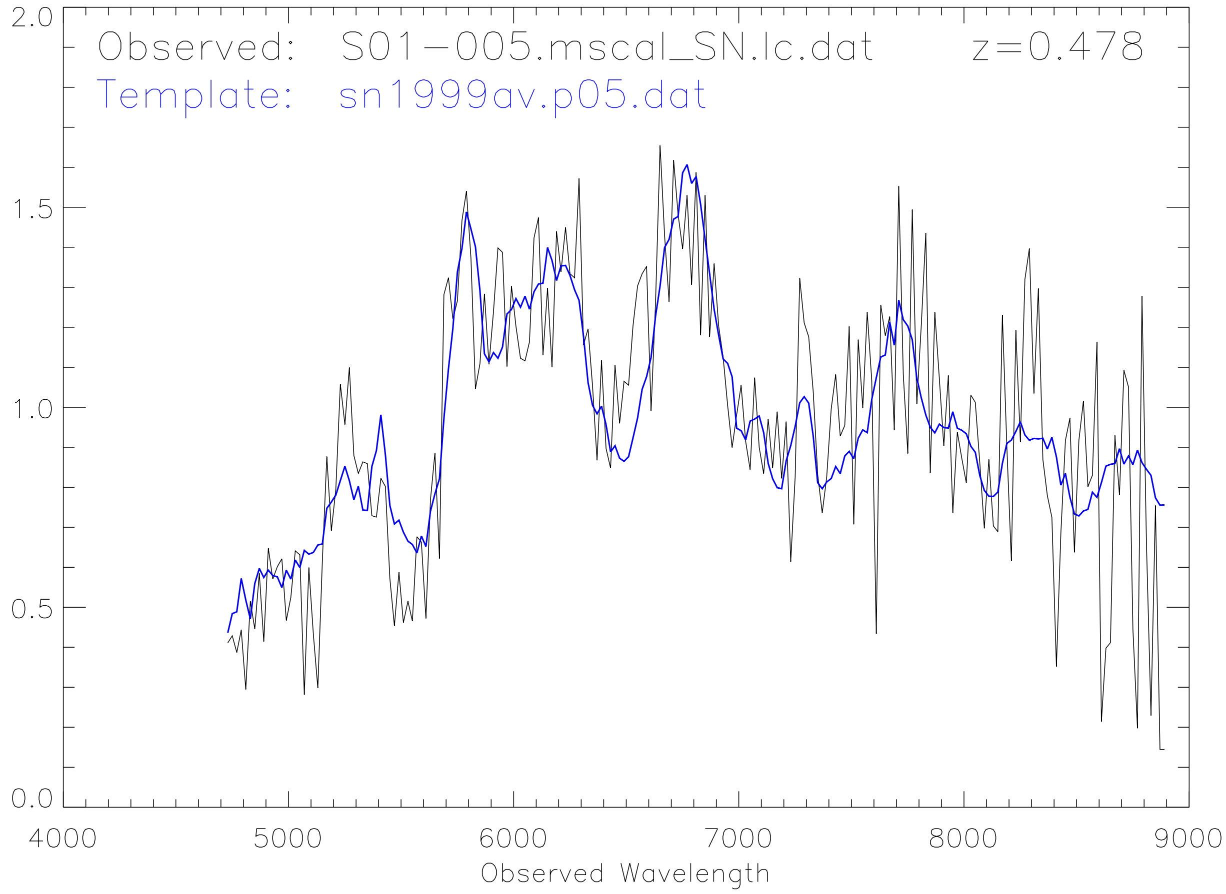

Figure 7: S01-005 and comparison

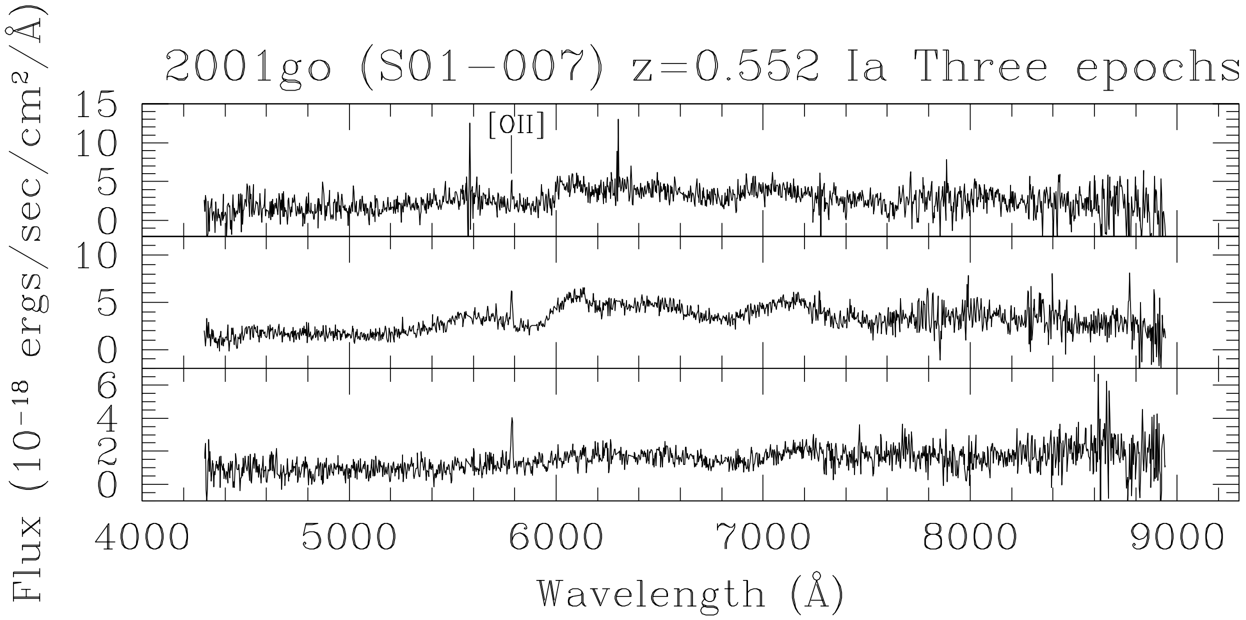

Figure 8: S01-007

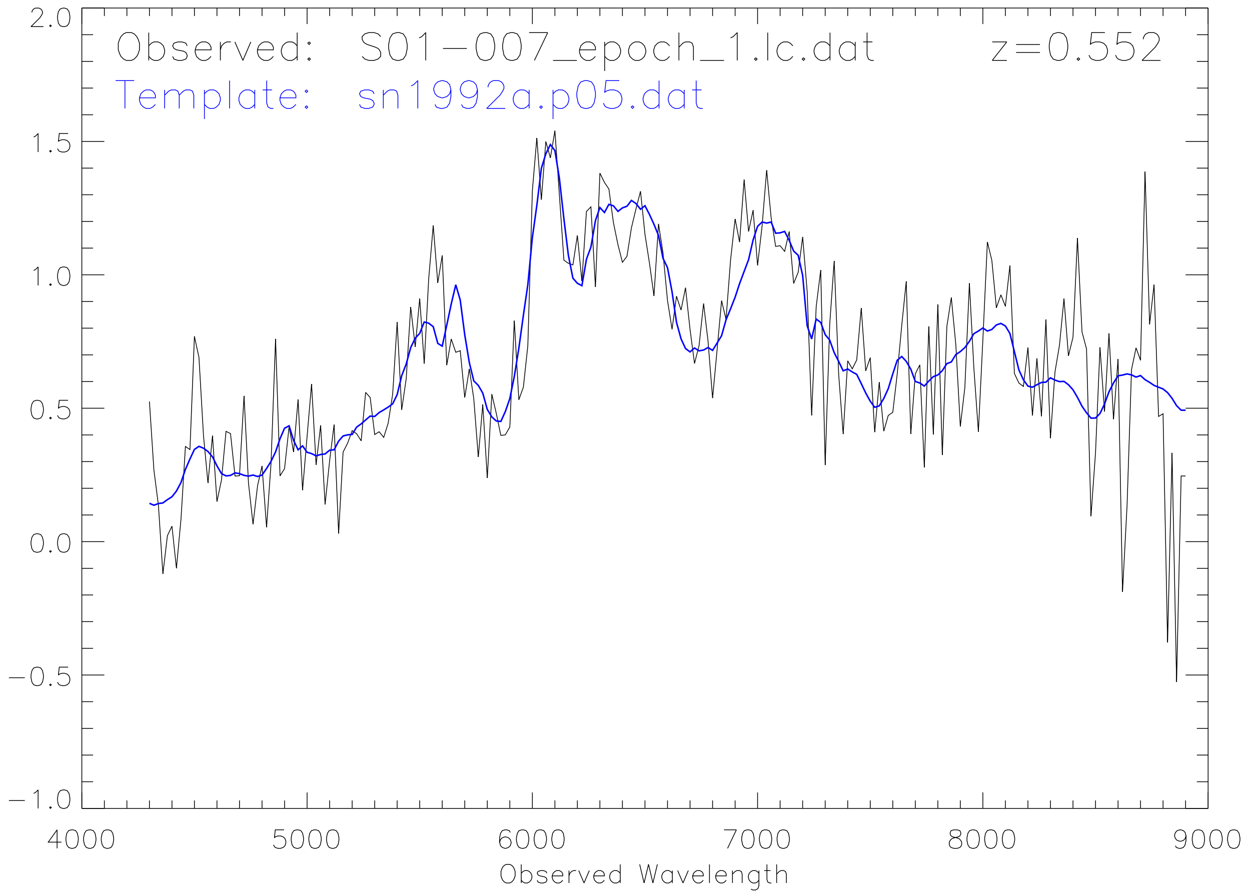

Figure 9: S01-007 (first epoch) and comparison

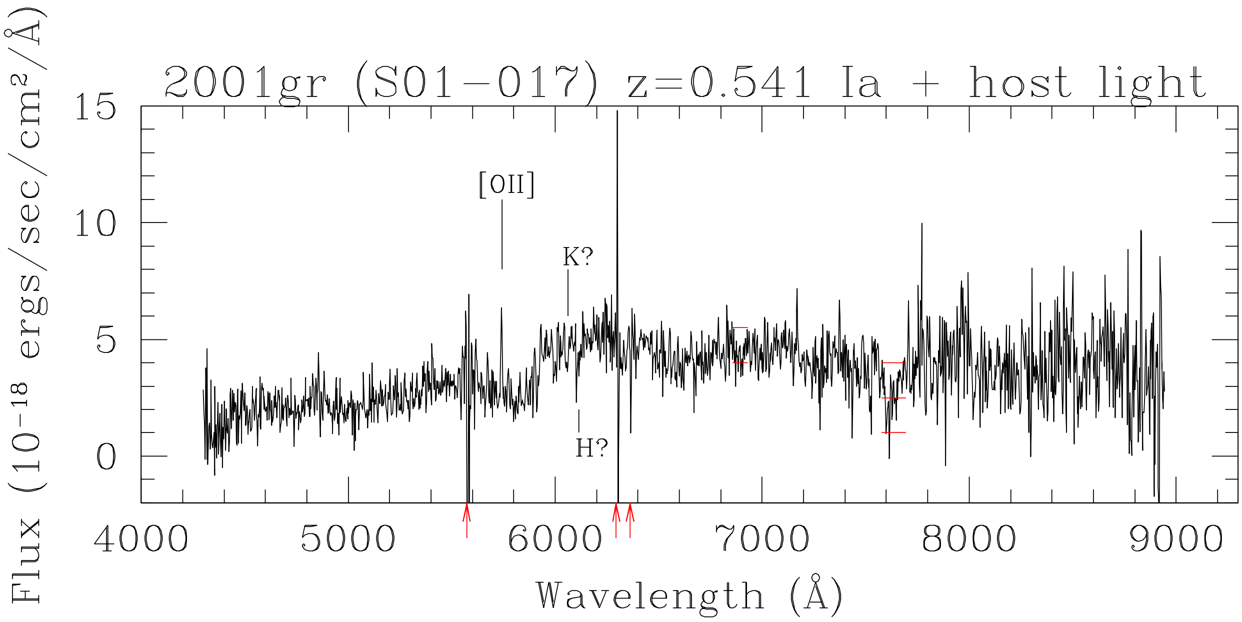

Figure 10: S01-017

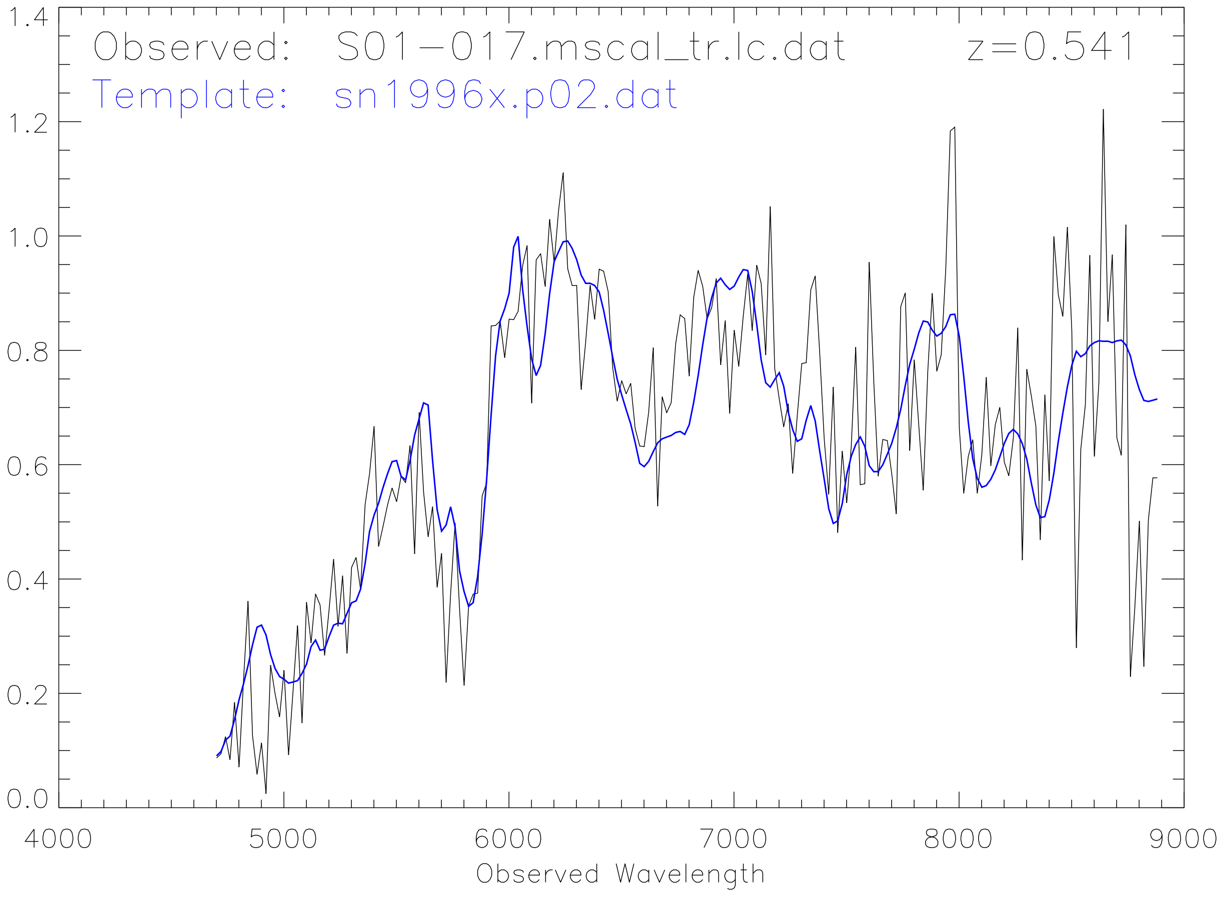

Figure 11: S01-017 and comparison

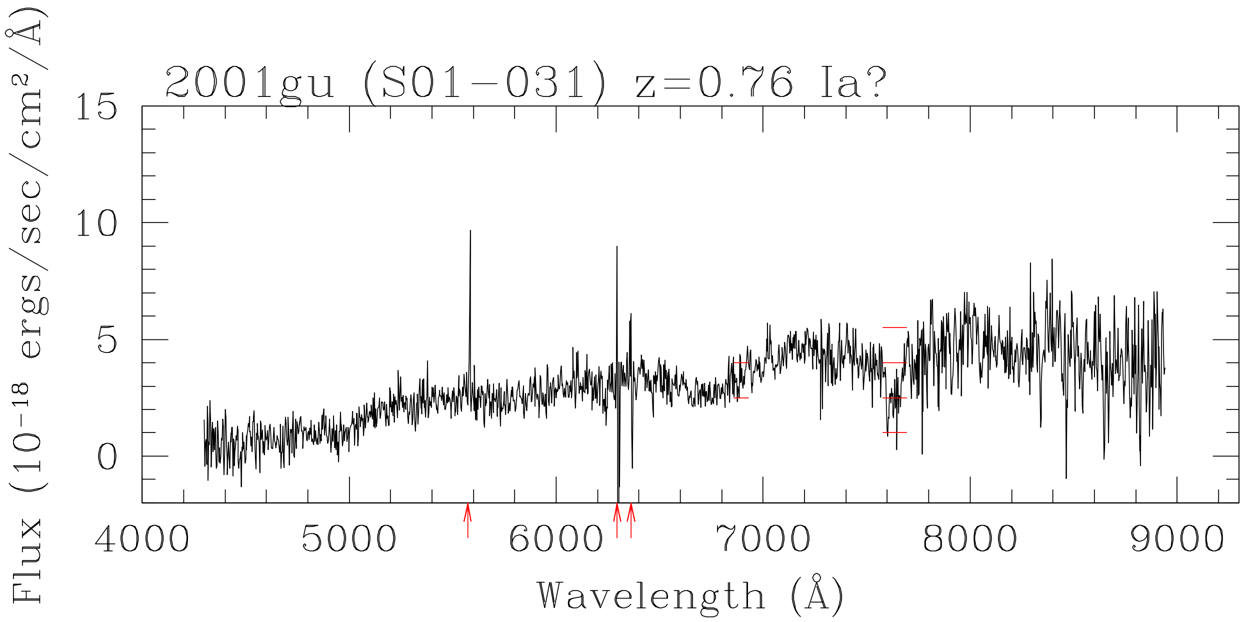

Figure 12: S01-031

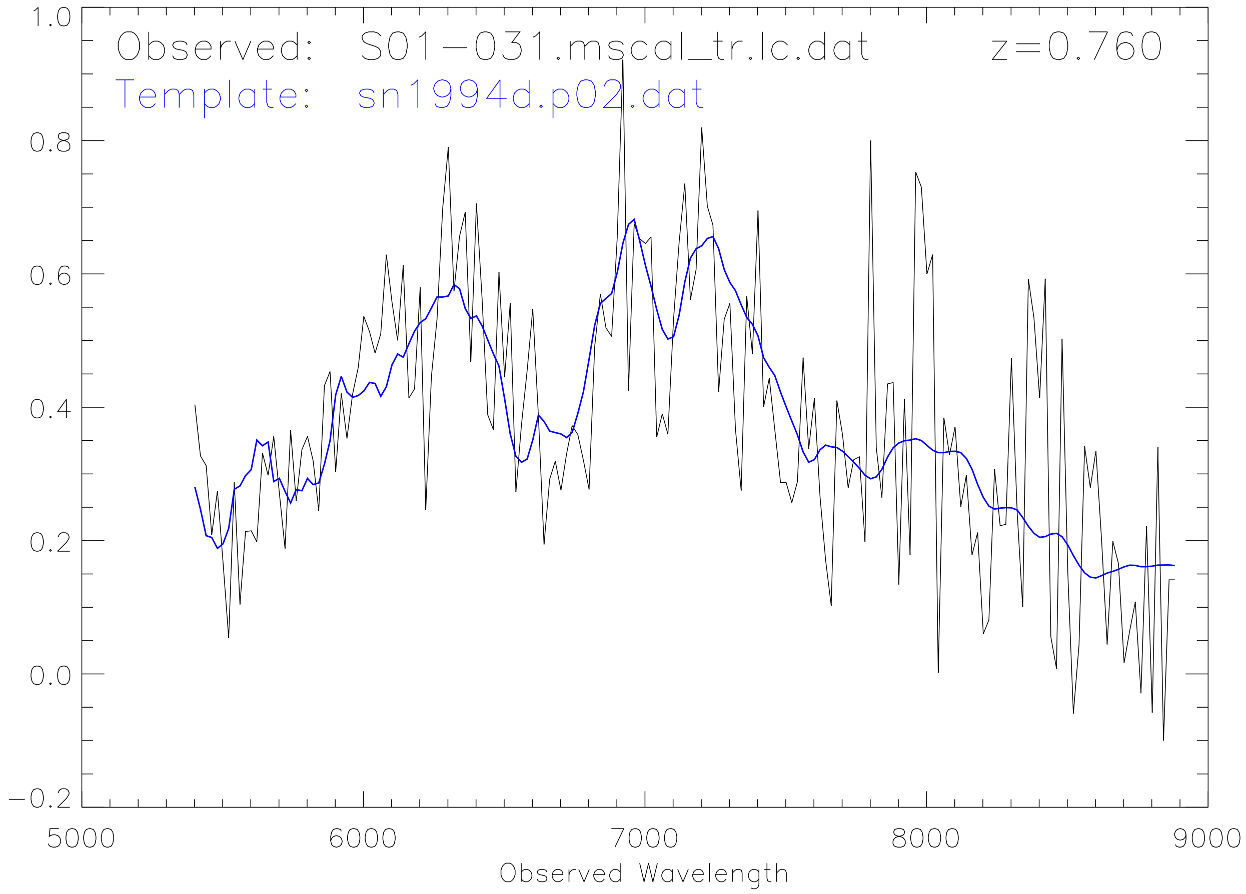

Figure 13: S01-031 and comparison

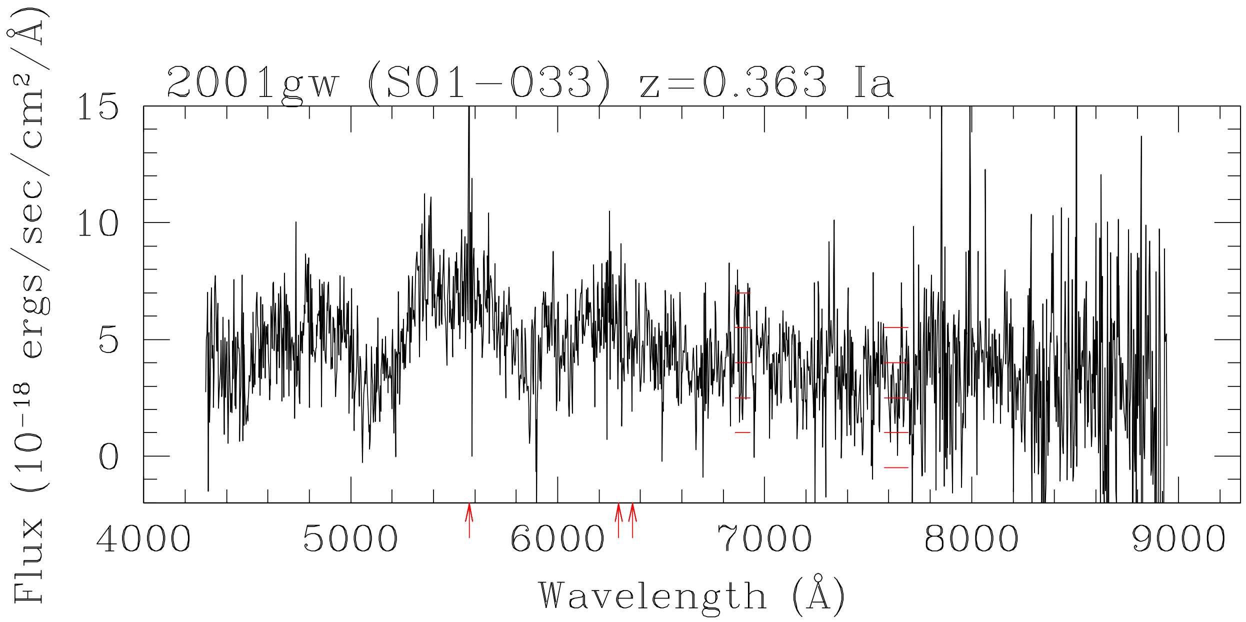

Figure 14: S01-033

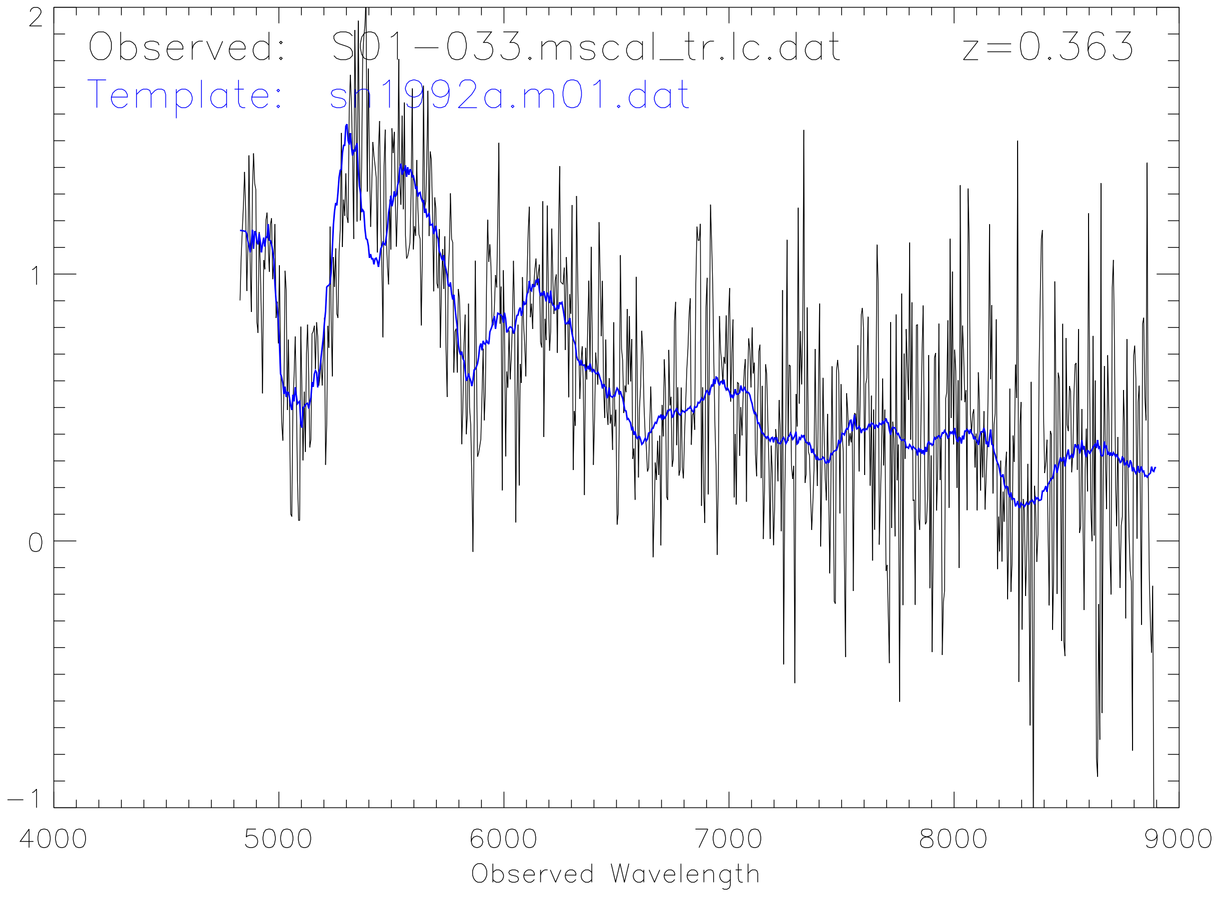

Figure 15: S01-033 and comparison

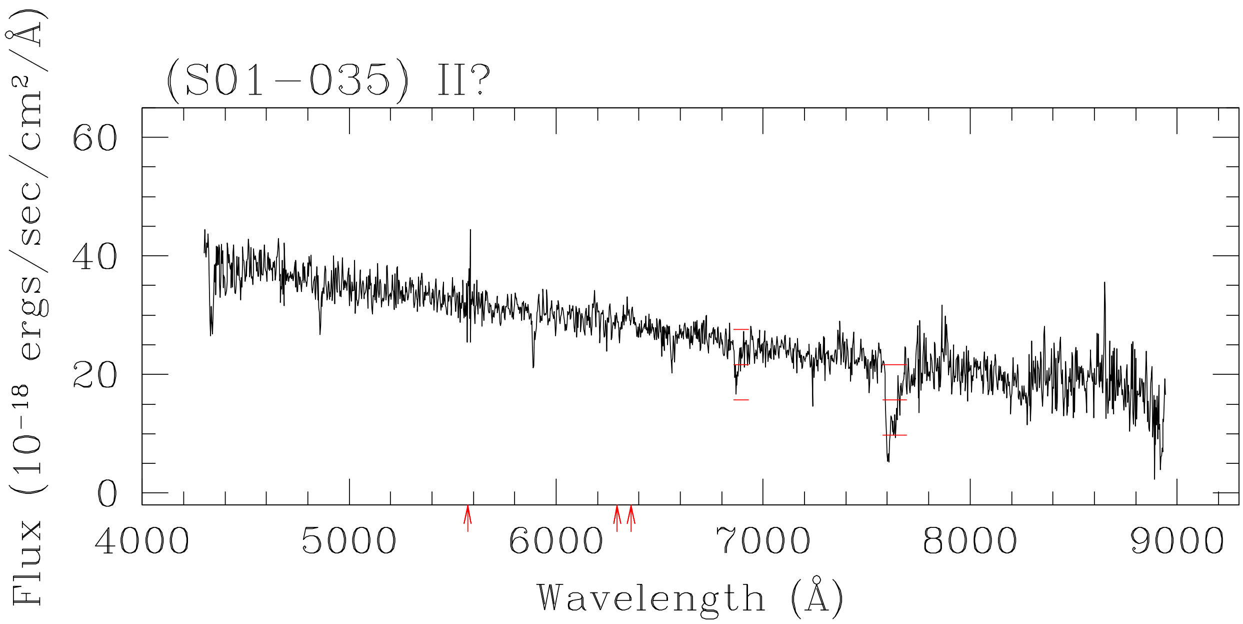

Figure 16: S01-035

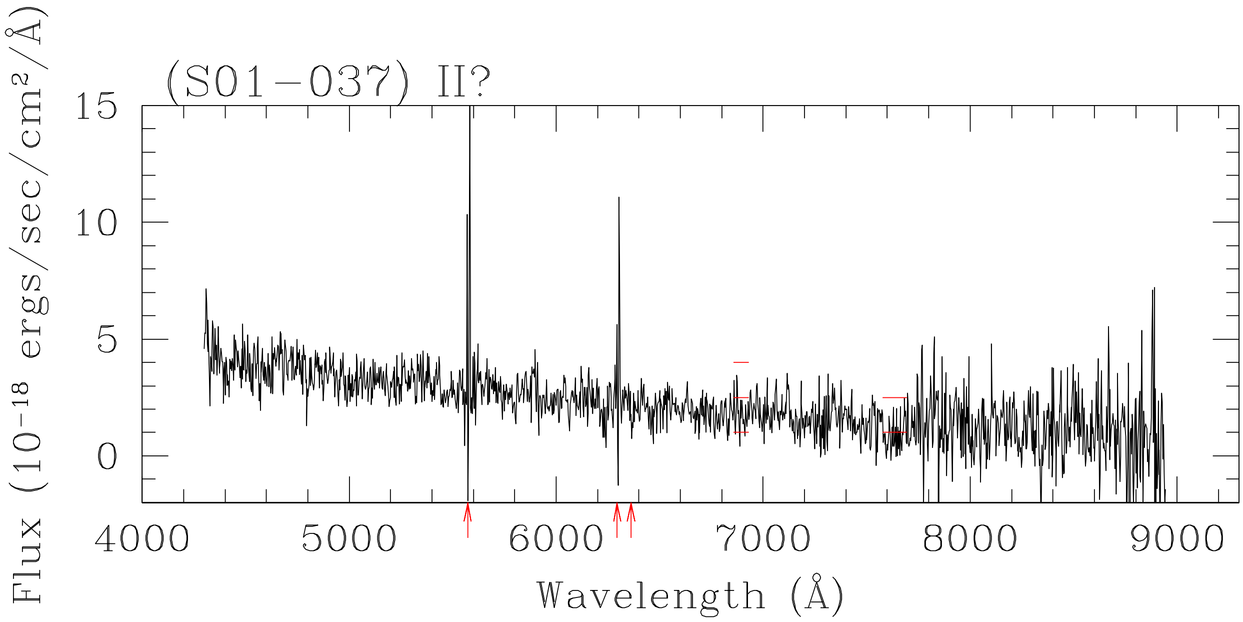

Figure 17: S01-037

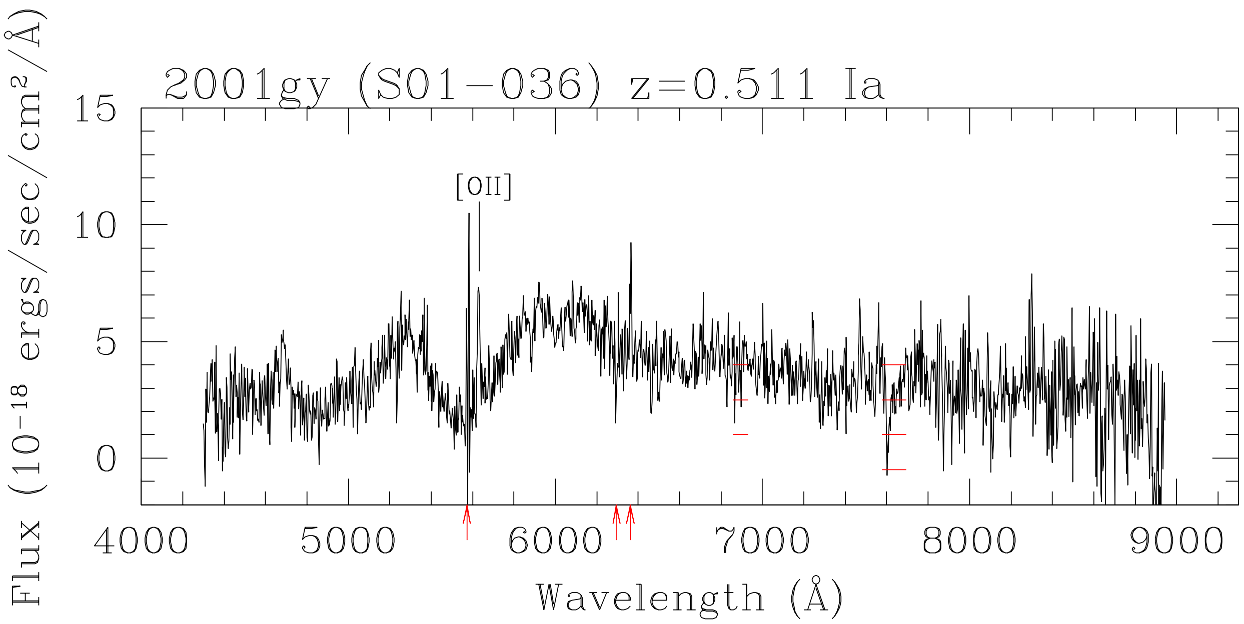

Figure 18: S01-036

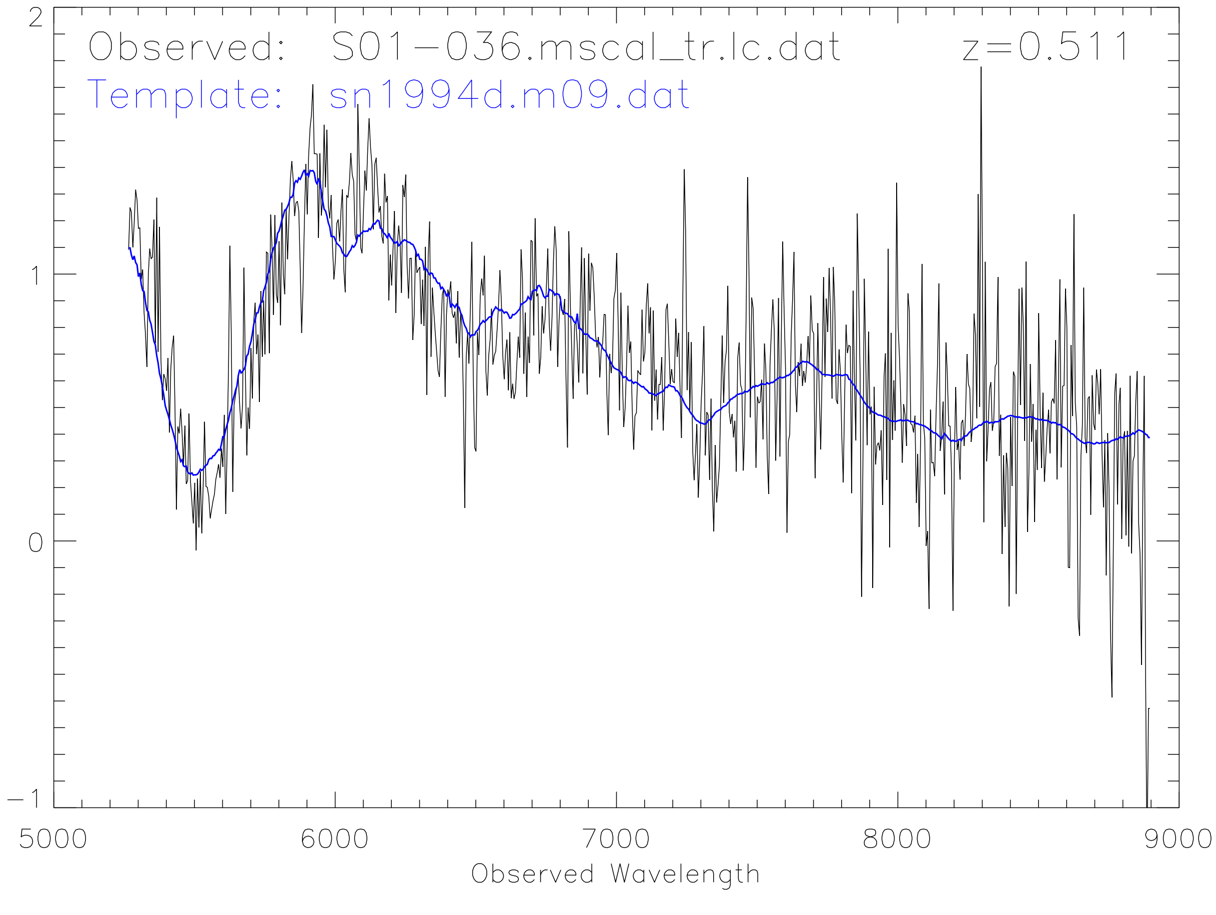

Figure 19: S01-036 and comparison

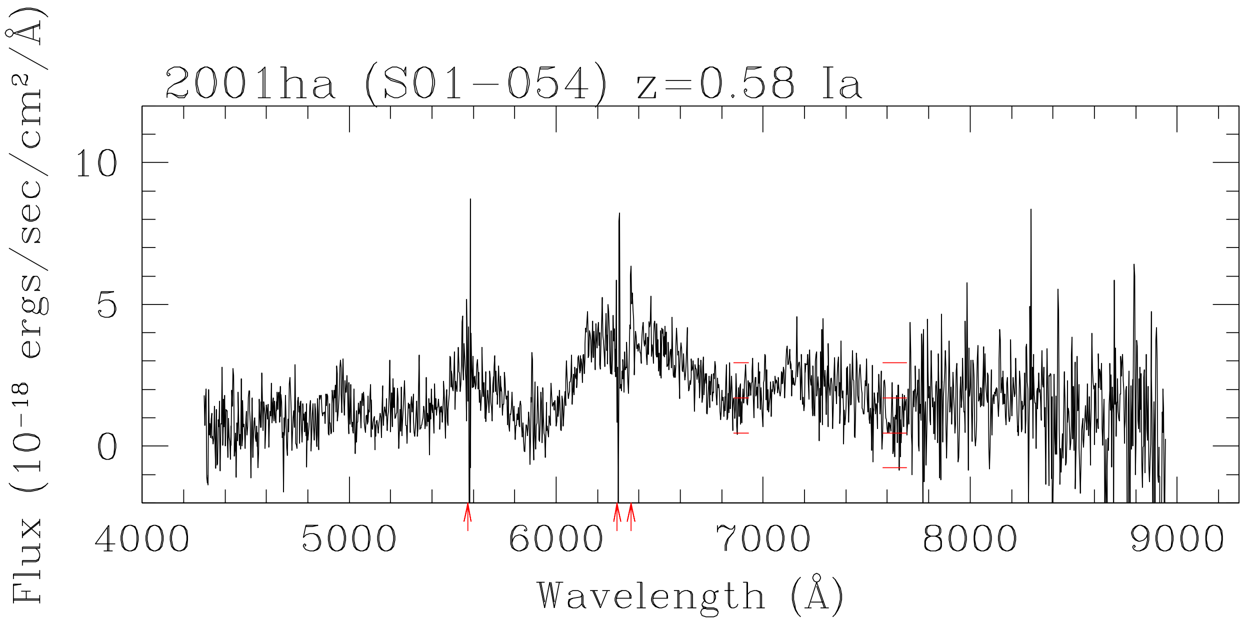

Figure 20: S01-054

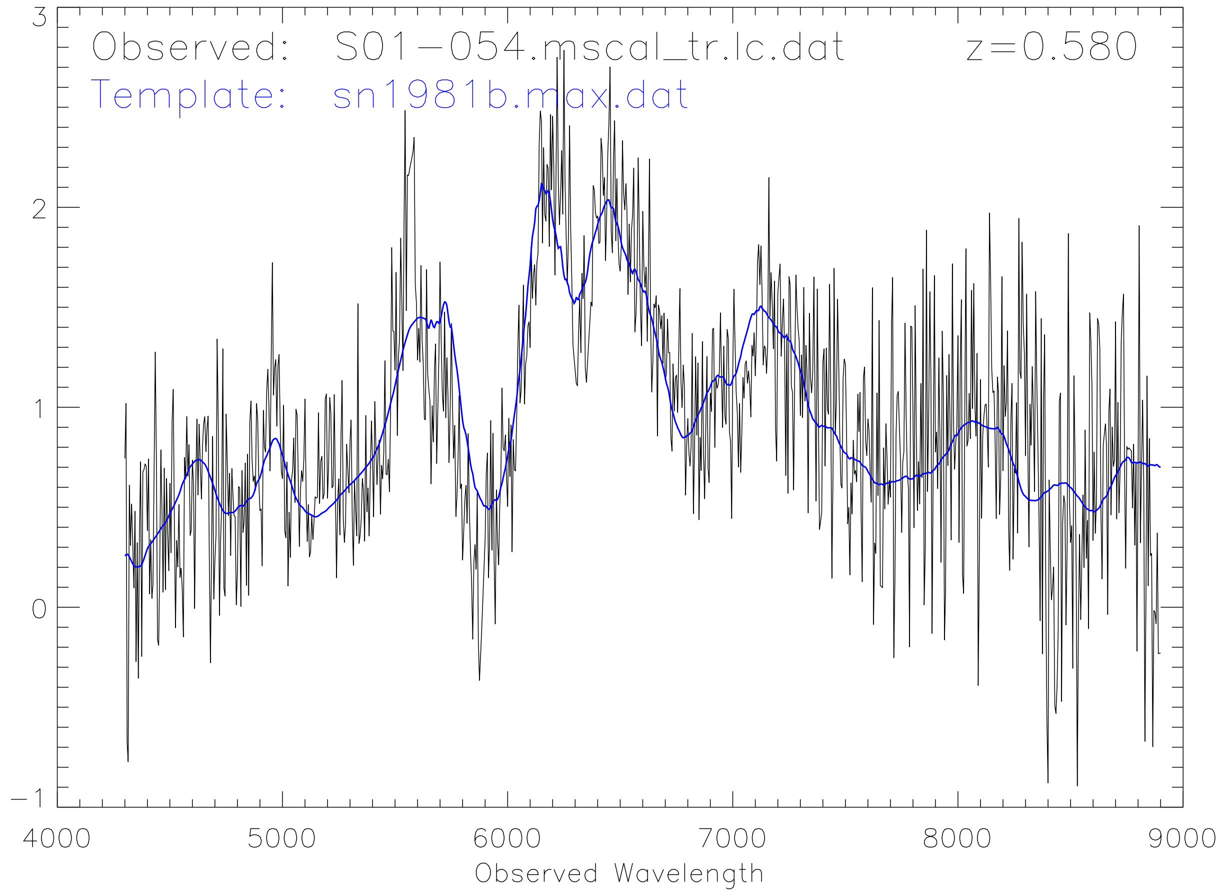

Figure 21: S01-054 and comparison

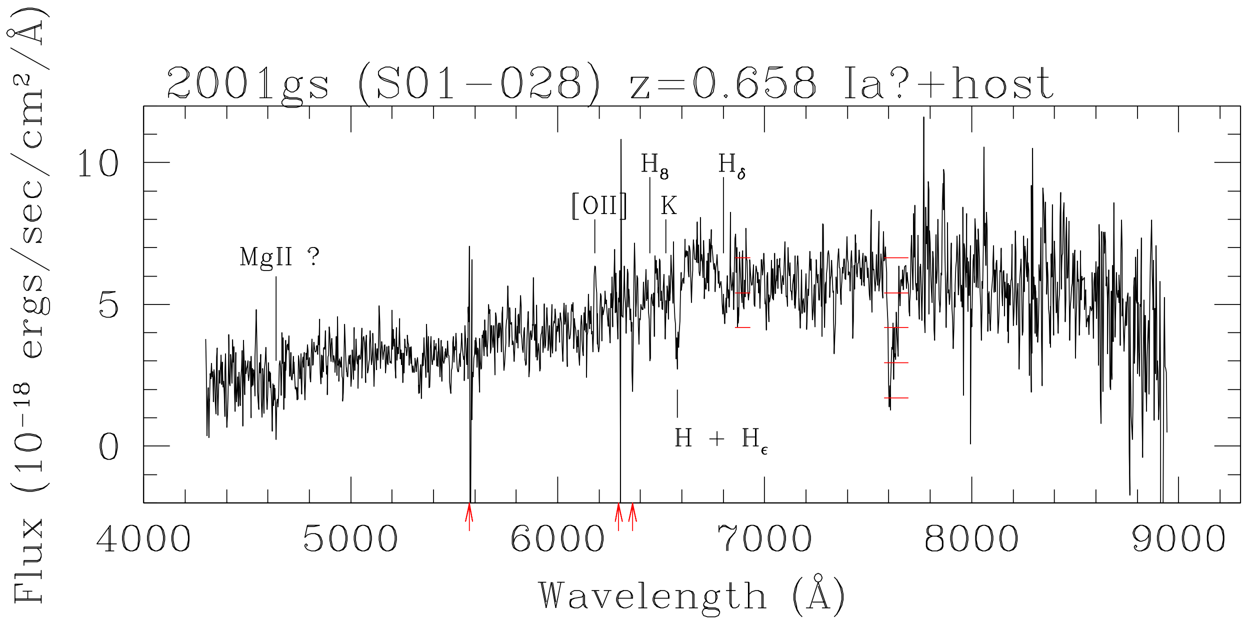

Figure 22: S01-028

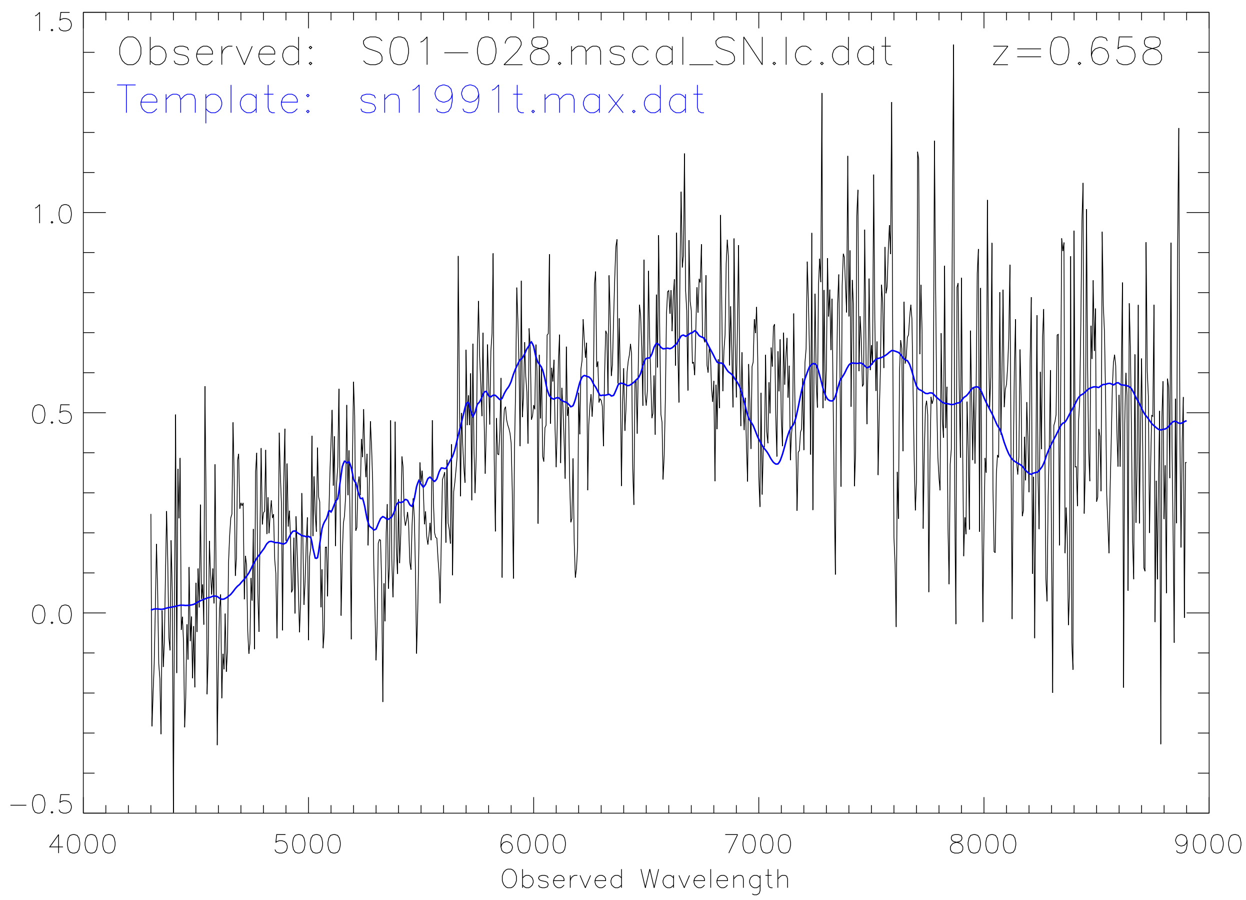

Figure 23: S01-028 and comparison

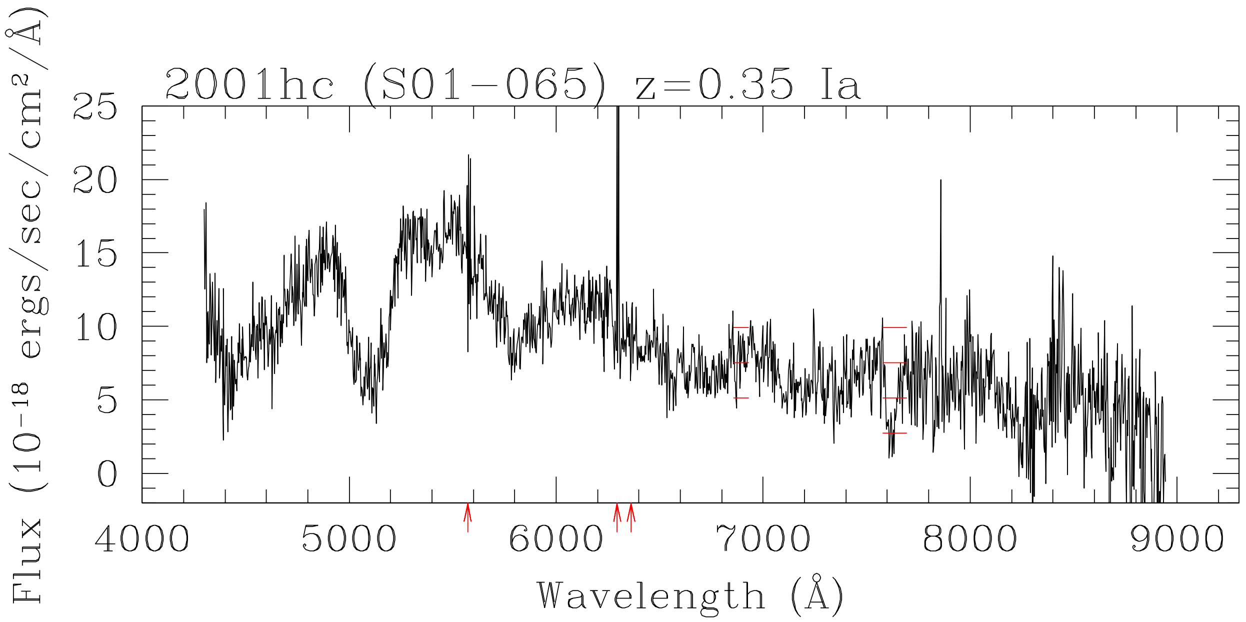

Figure 24: S01-065

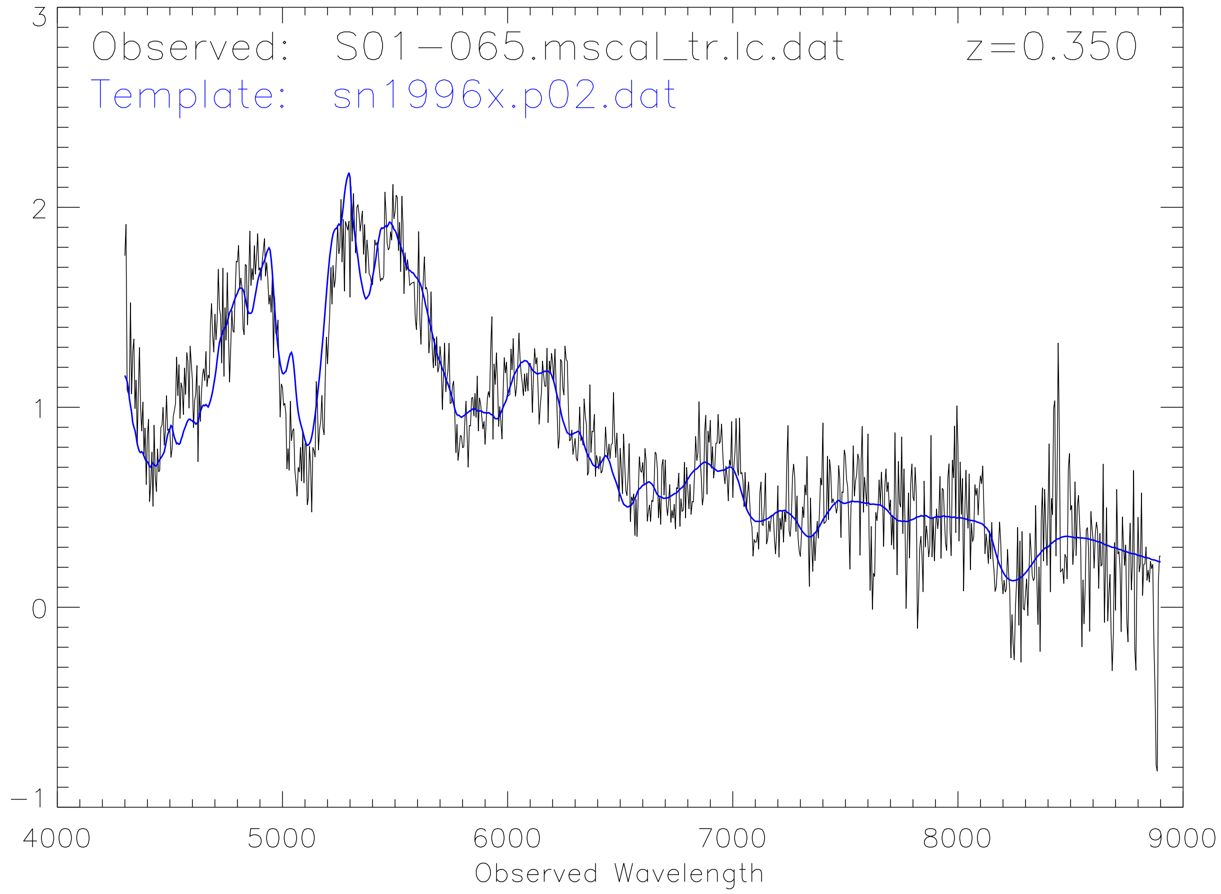

Figure 25: S01-065 and comparison

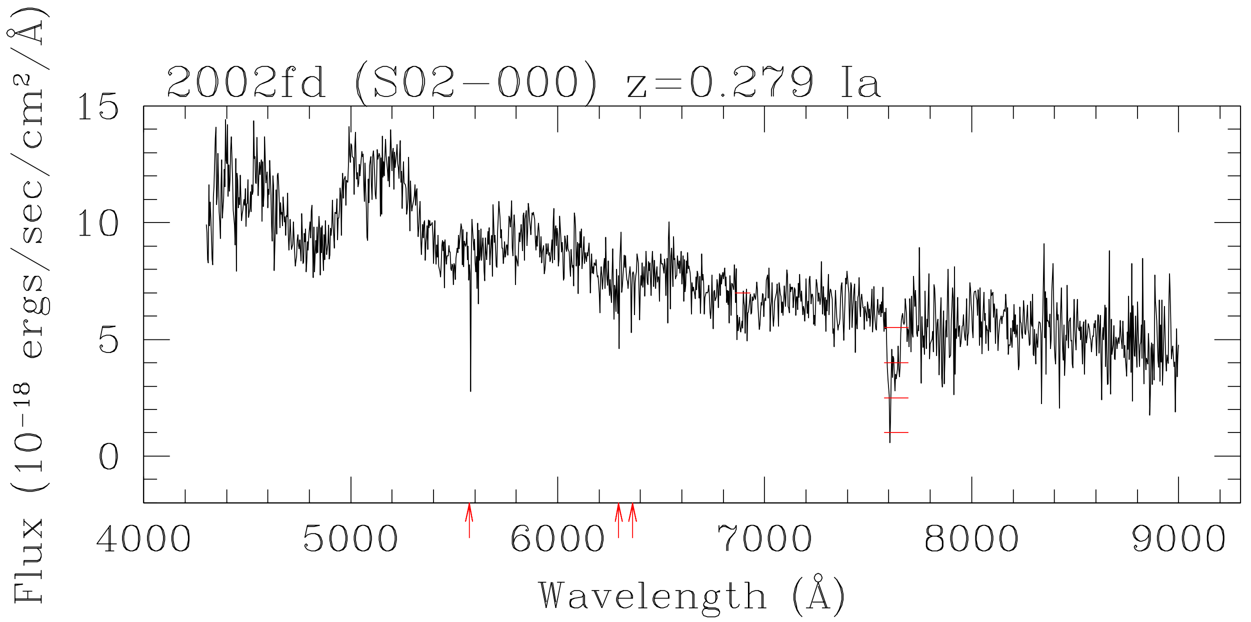

Figure 26: S02-000

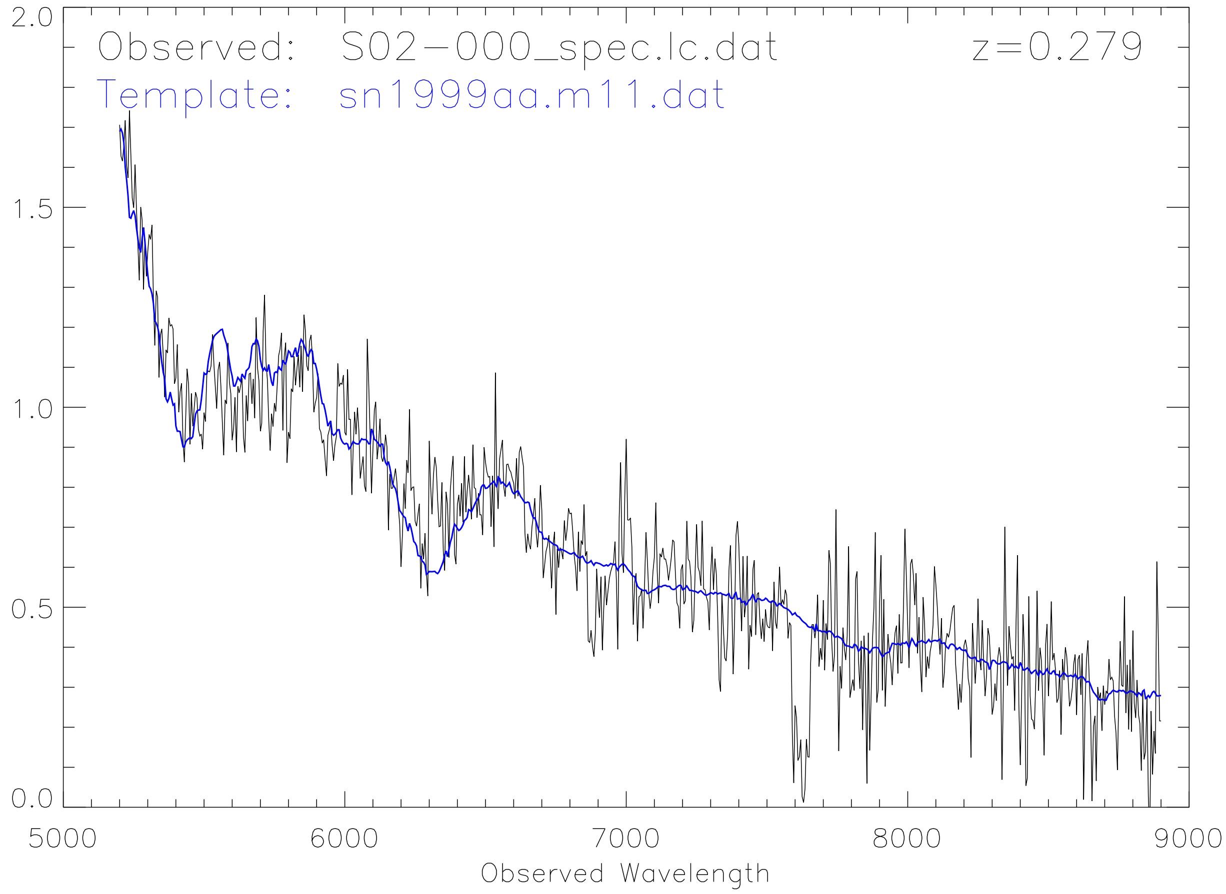

Figure 27: S02-000 and comparison

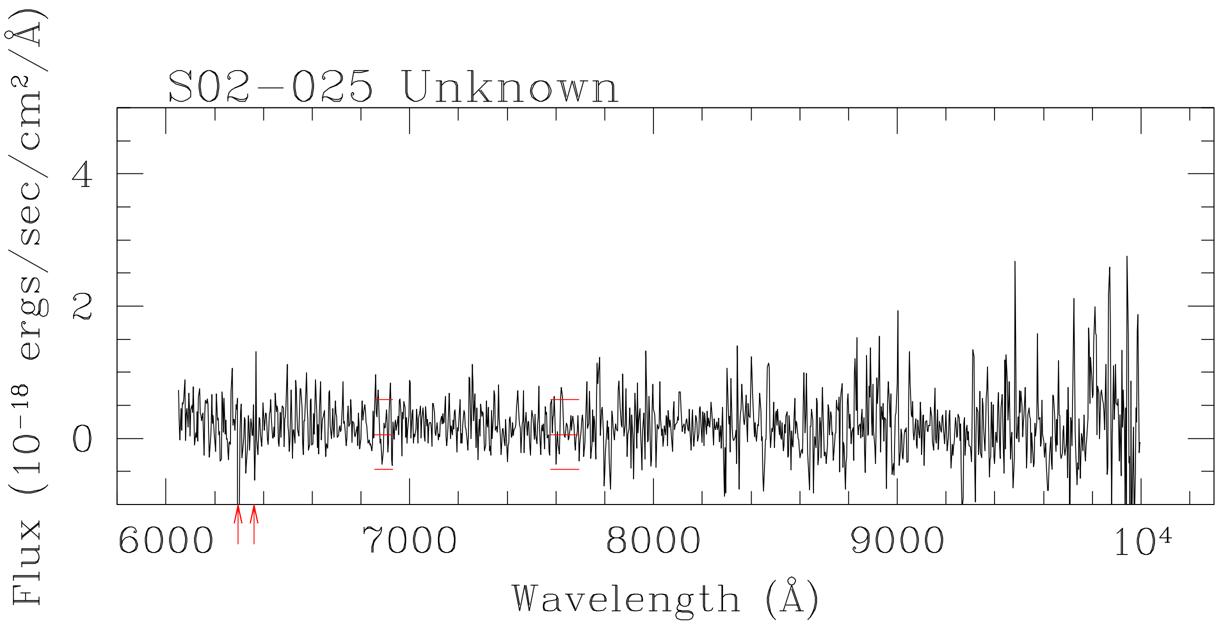

Figure 28: S02-025

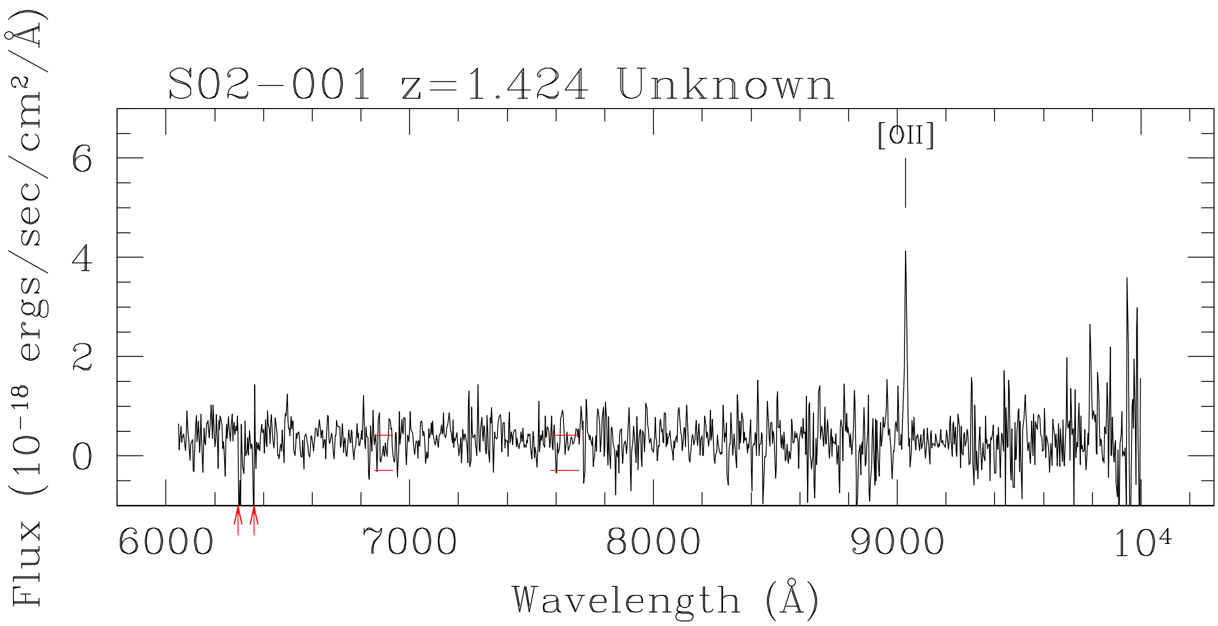

Figure 29: S02-001

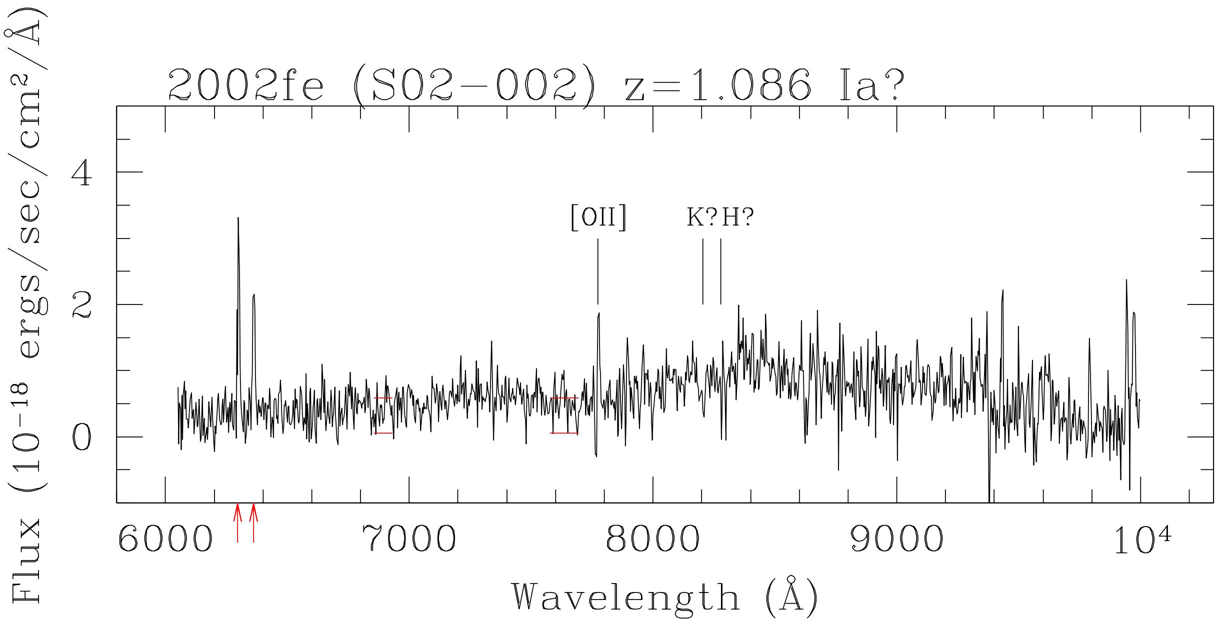

Figure 30: S02-002

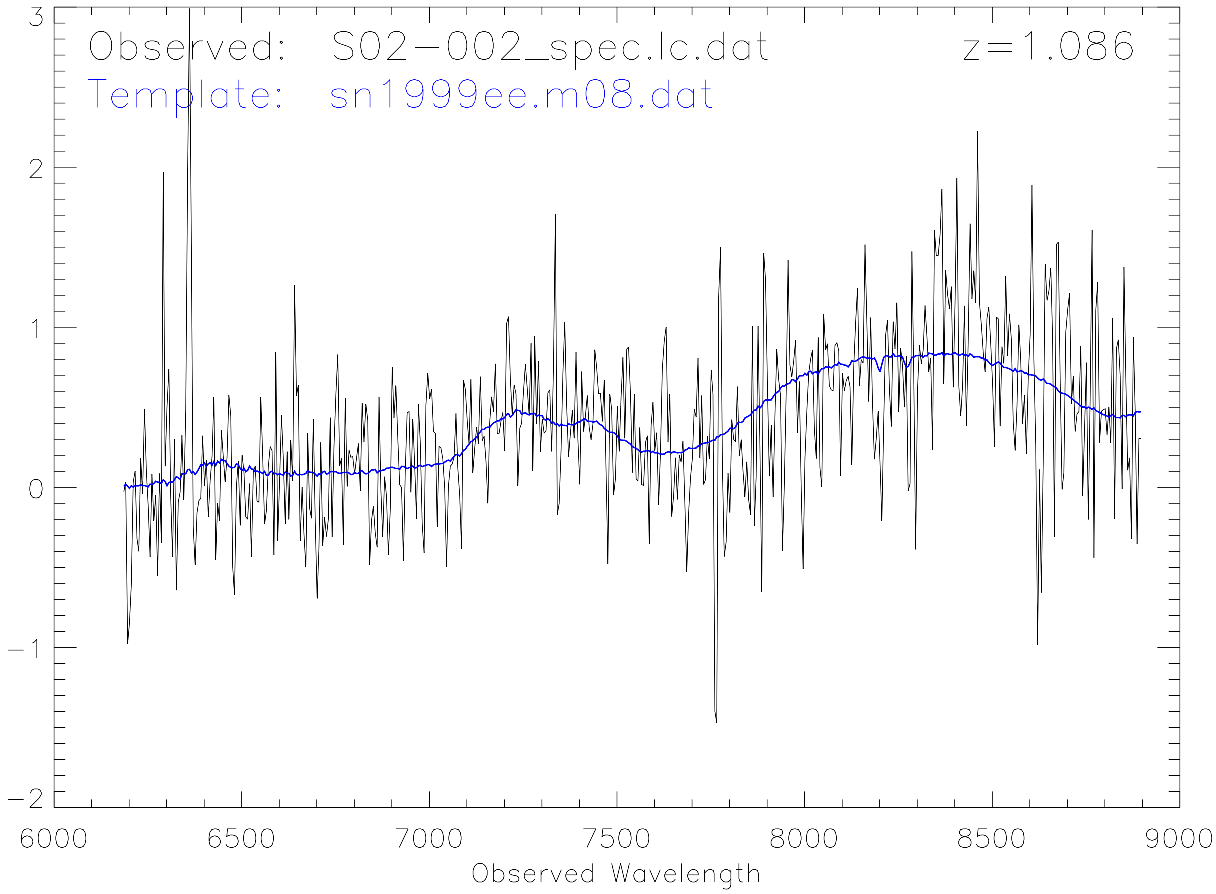

Figure 31: S02-002 and comparison

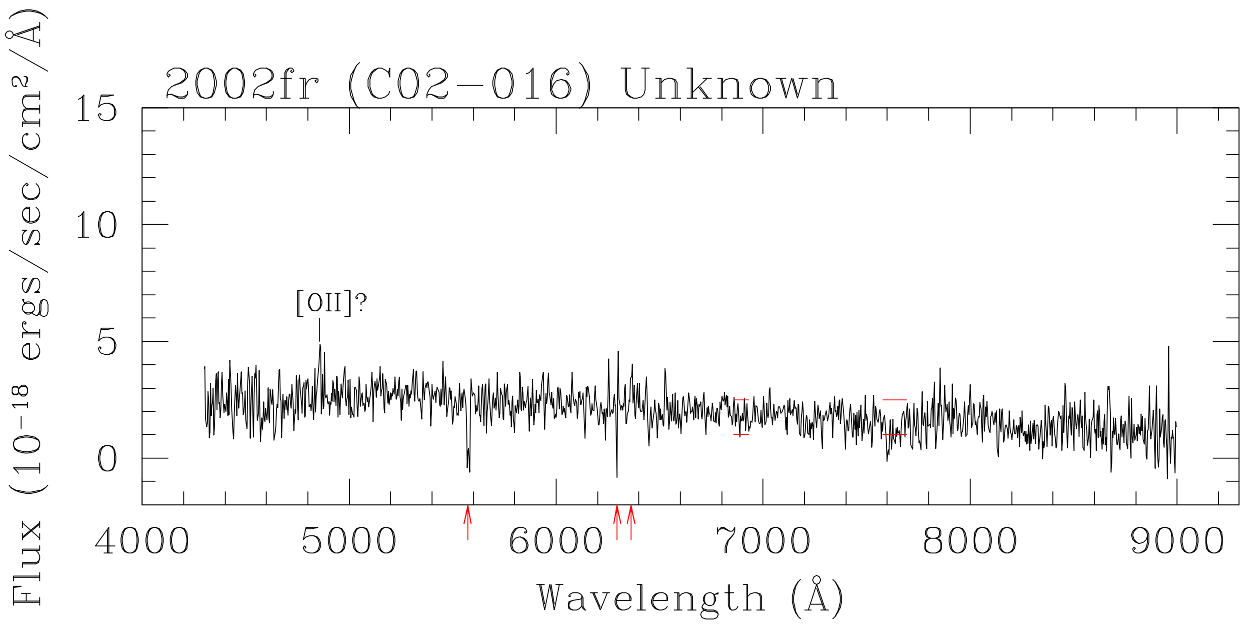

Figure 32: C02-016

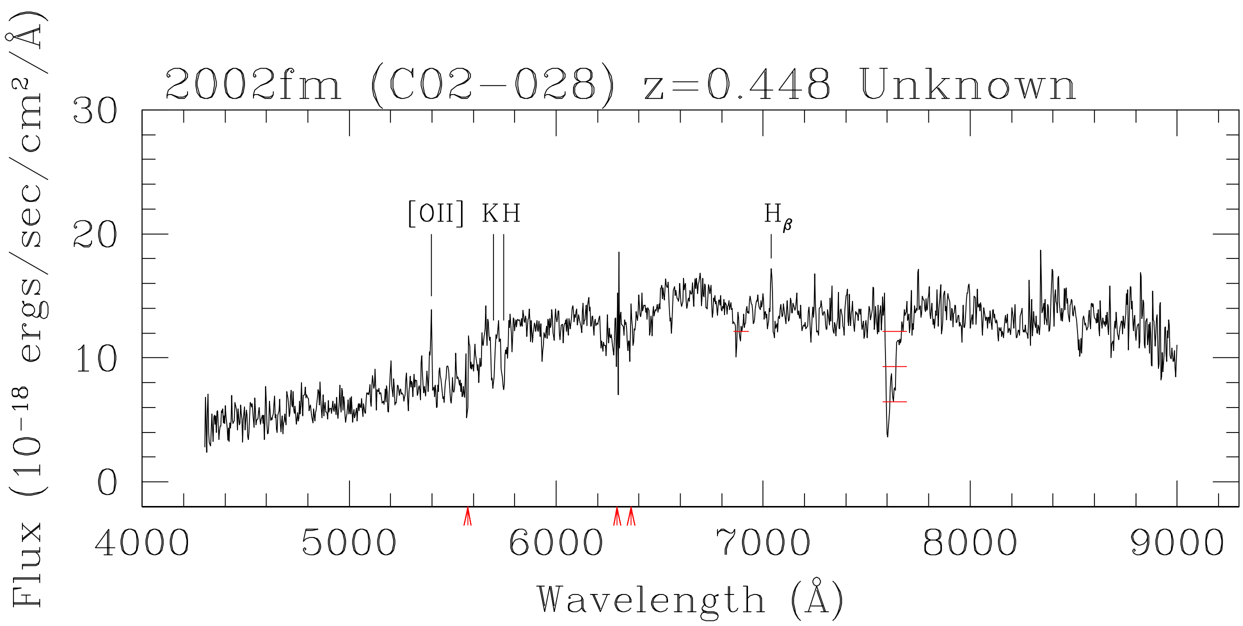

Figure 33: C02-028

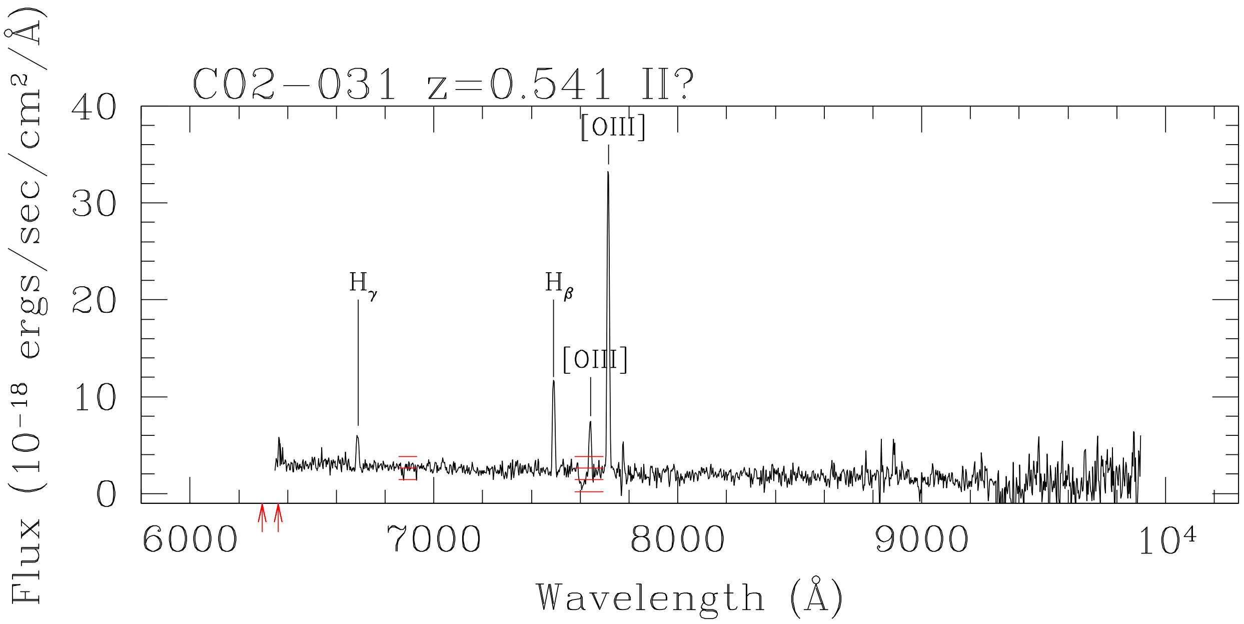

Figure 34: C02-031

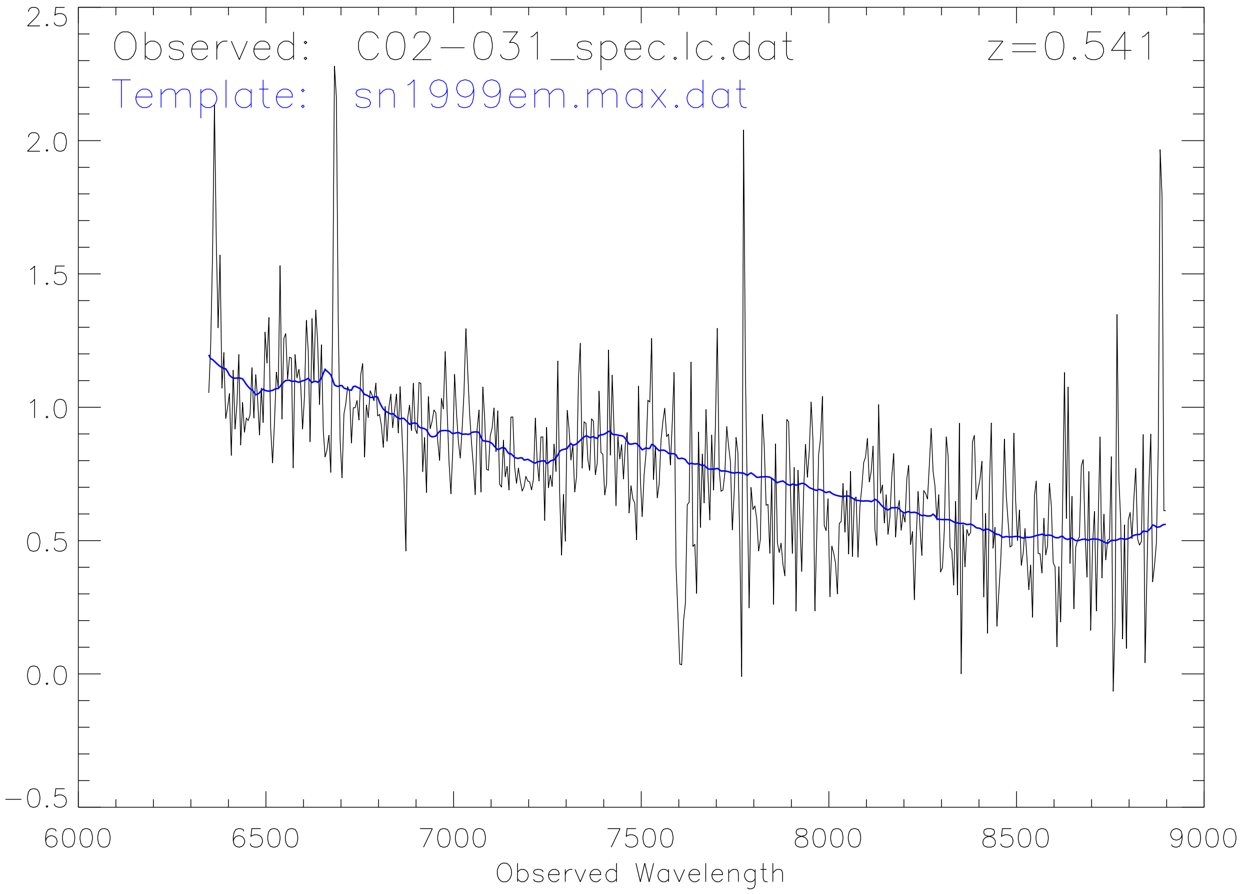

Figure 35: C02-031 and comparison

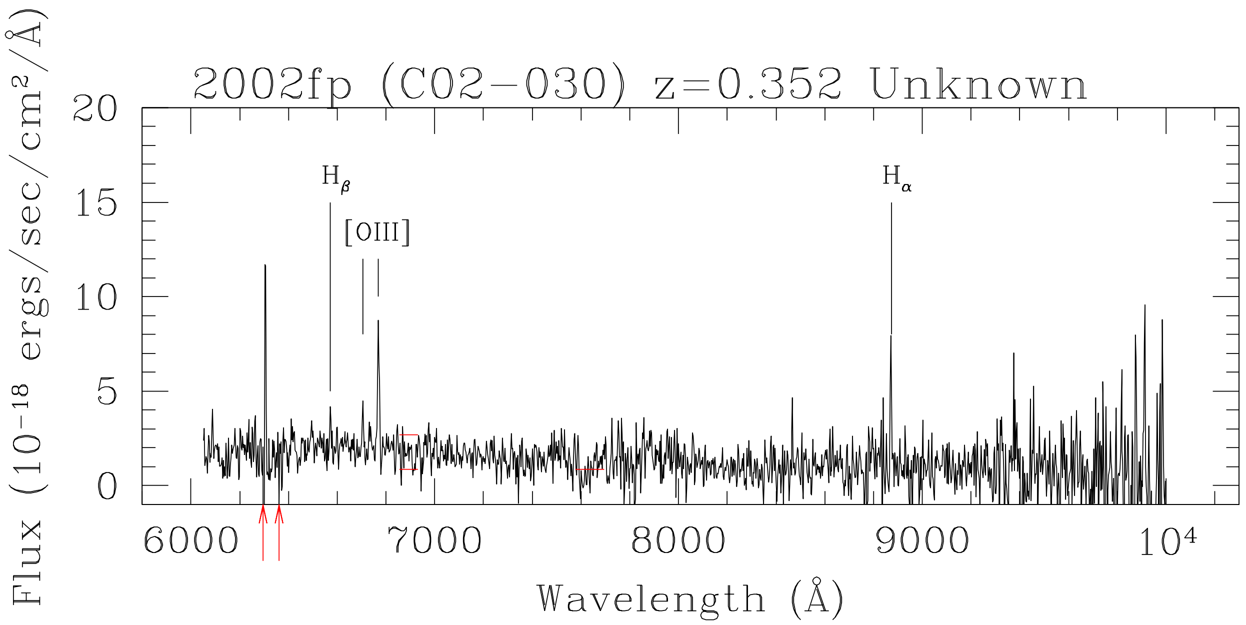

Figure 36: C02-030

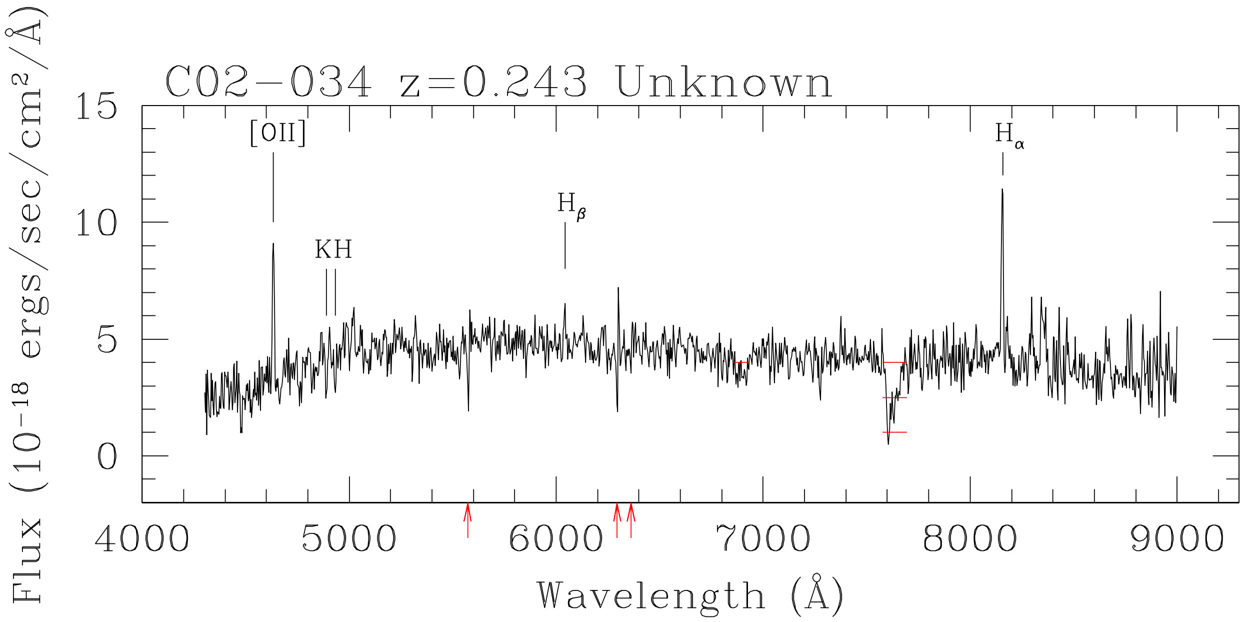

Figure 37: C02-034

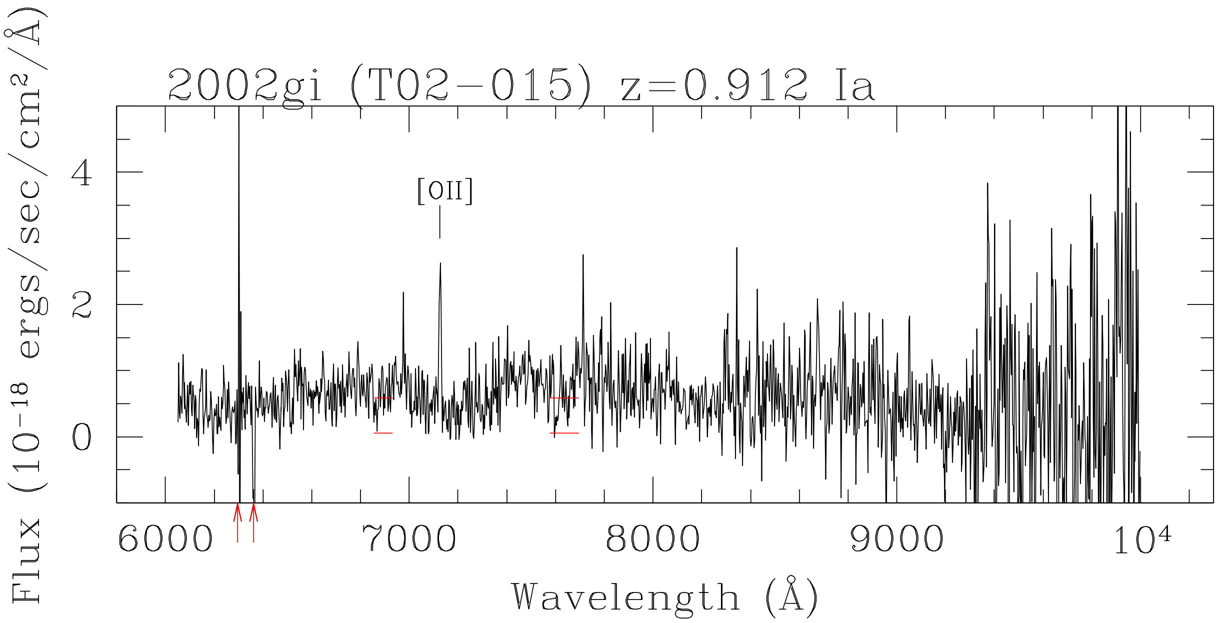

Figure 38: T02-015

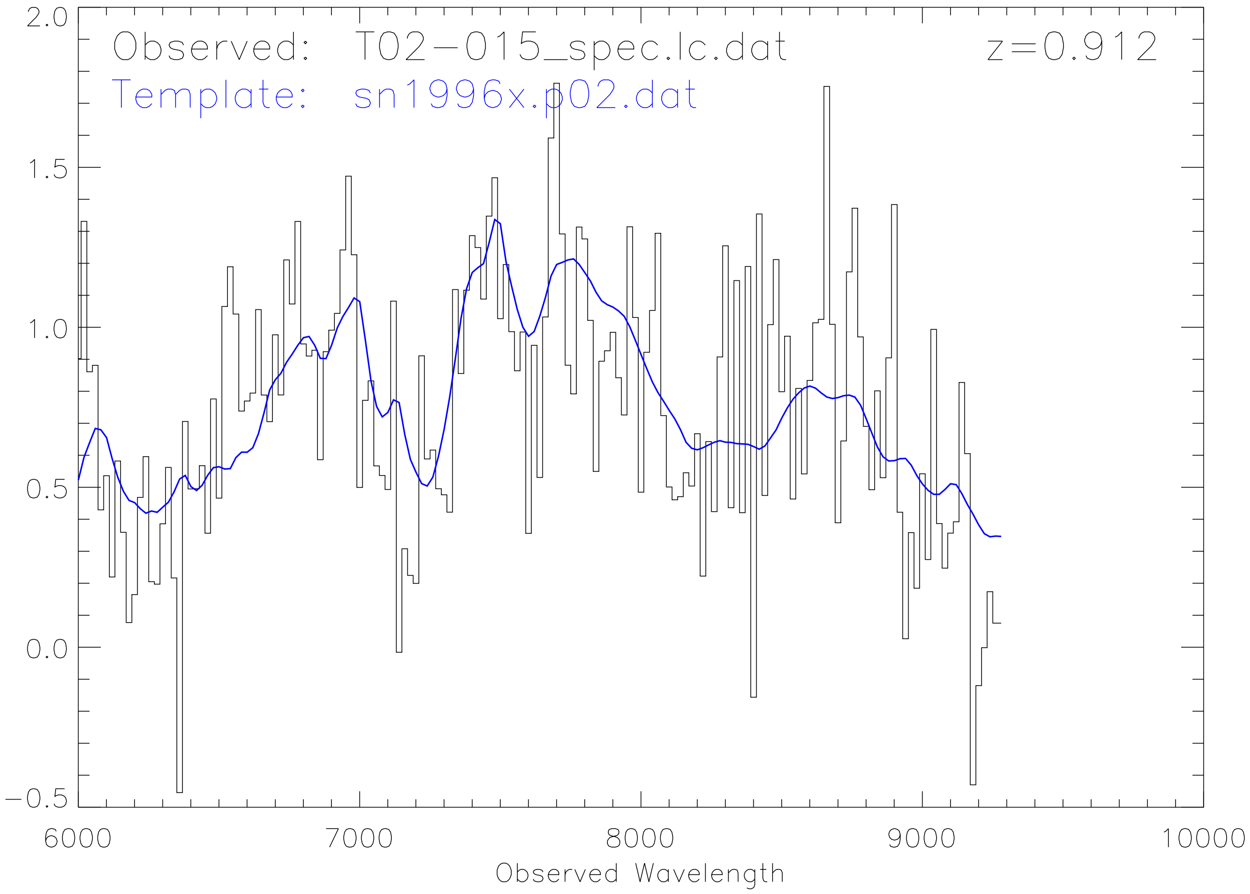

Figure 39: T02-015 and comparison

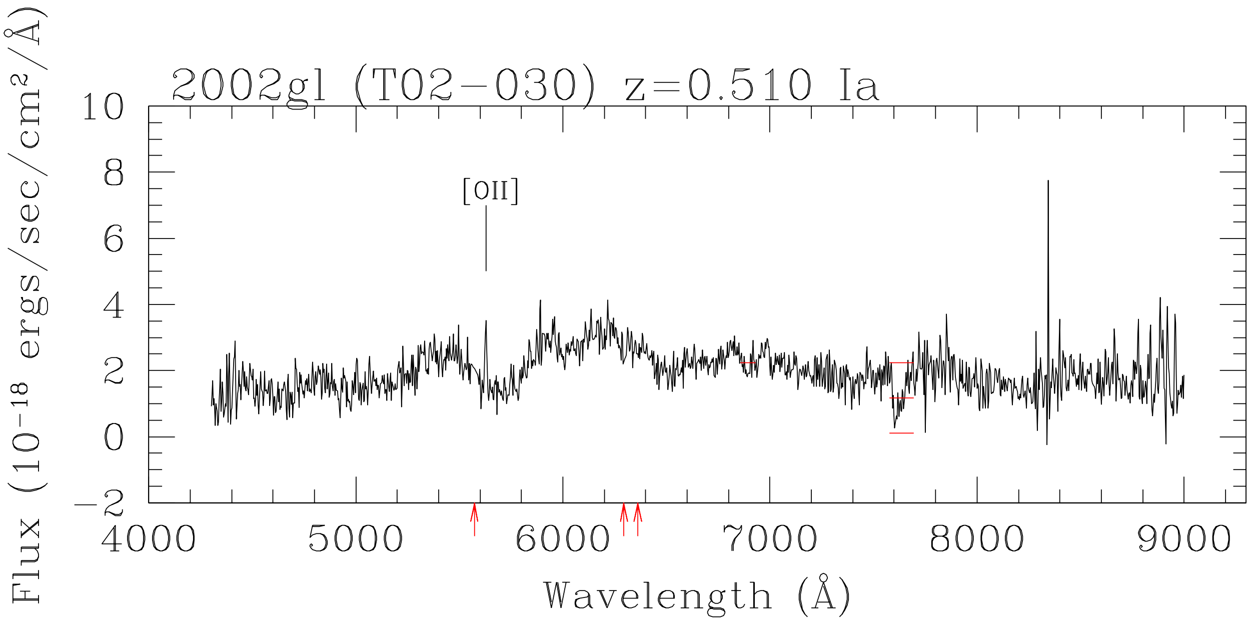

Figure 40: T02-030

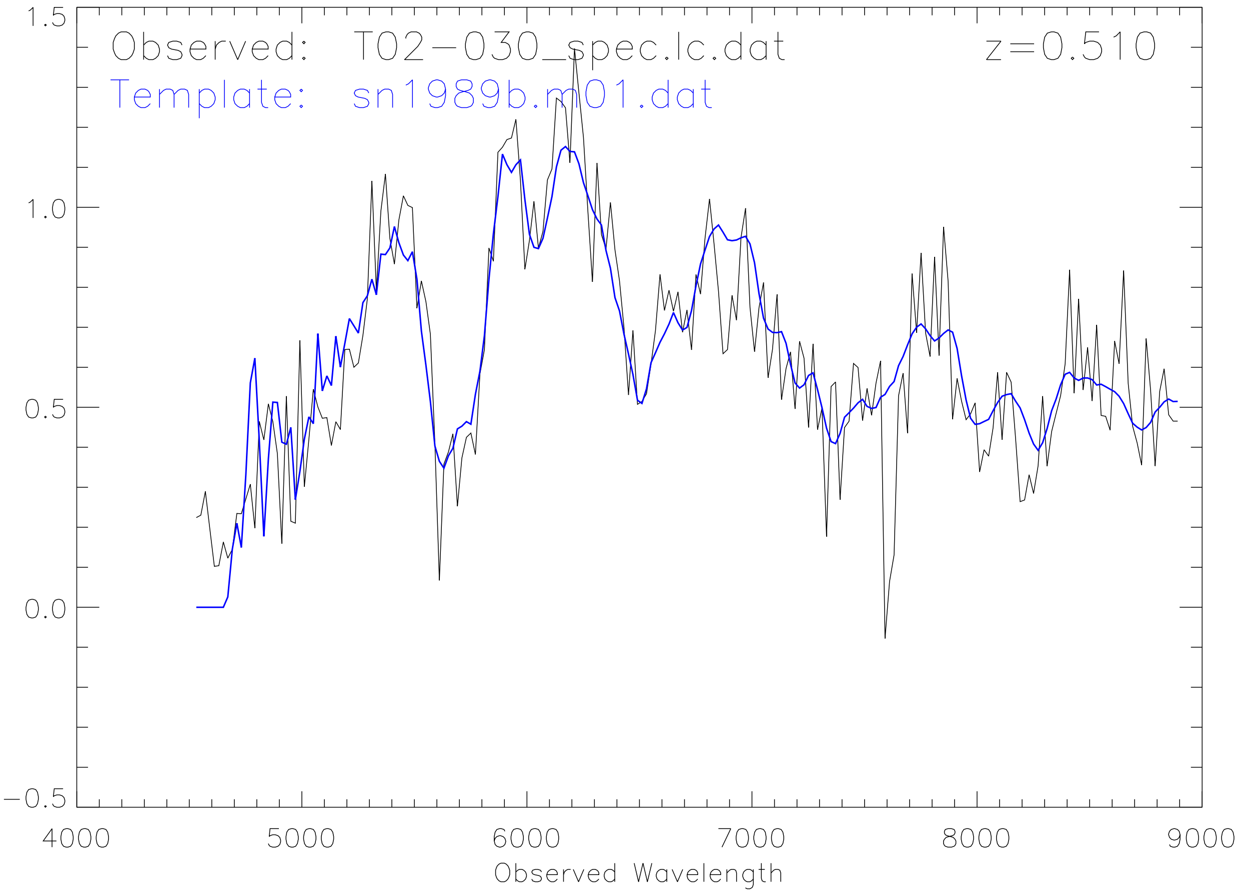

Figure 41: T02-030 and comparison

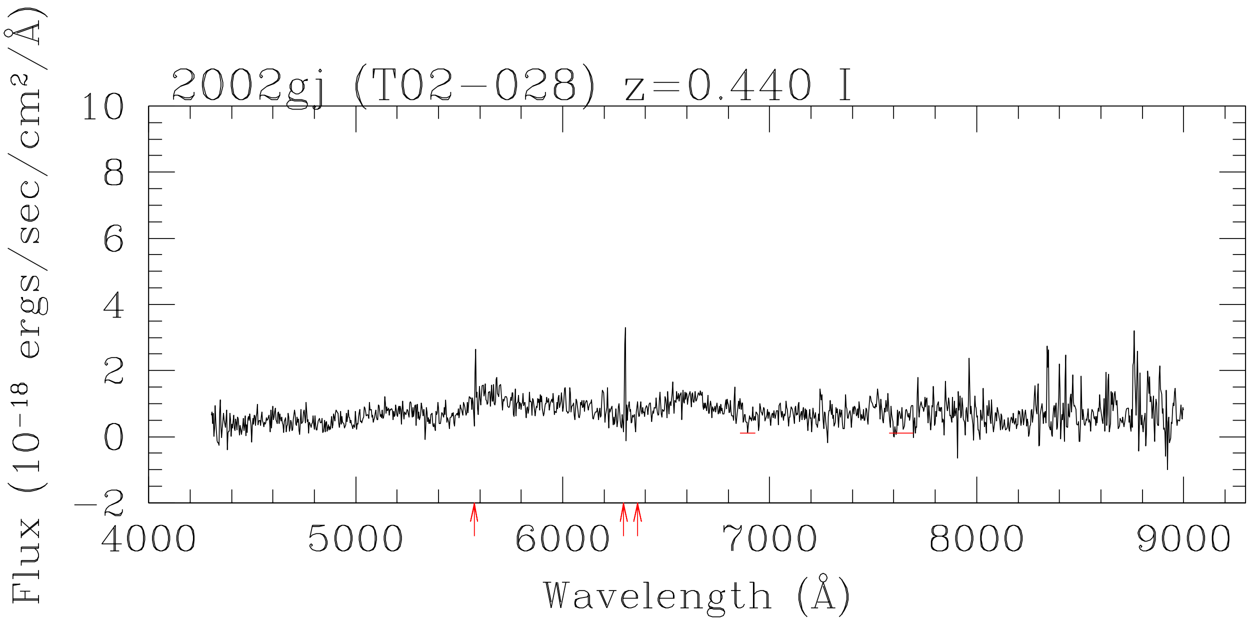

Figure 42: T02-028

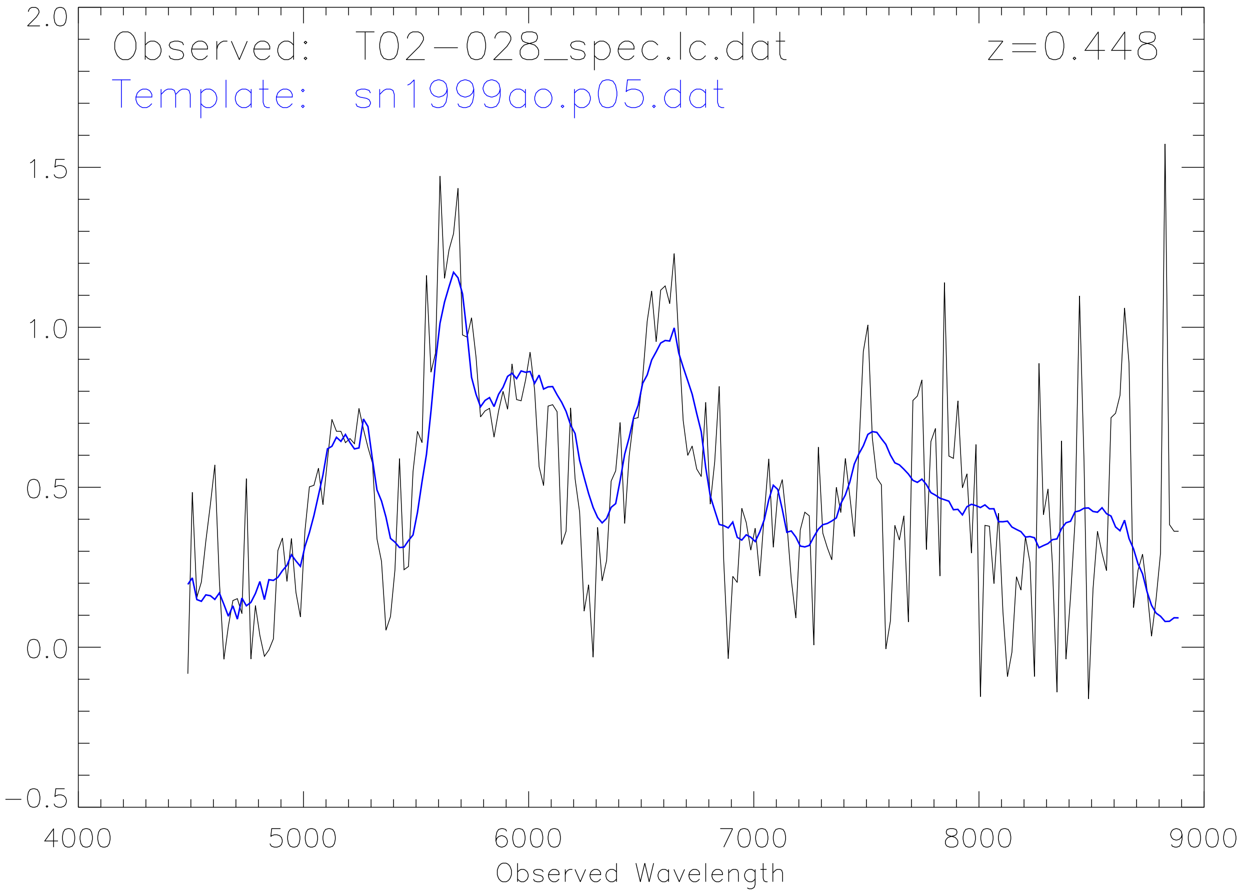

Figure 43: T02-028 and comparison

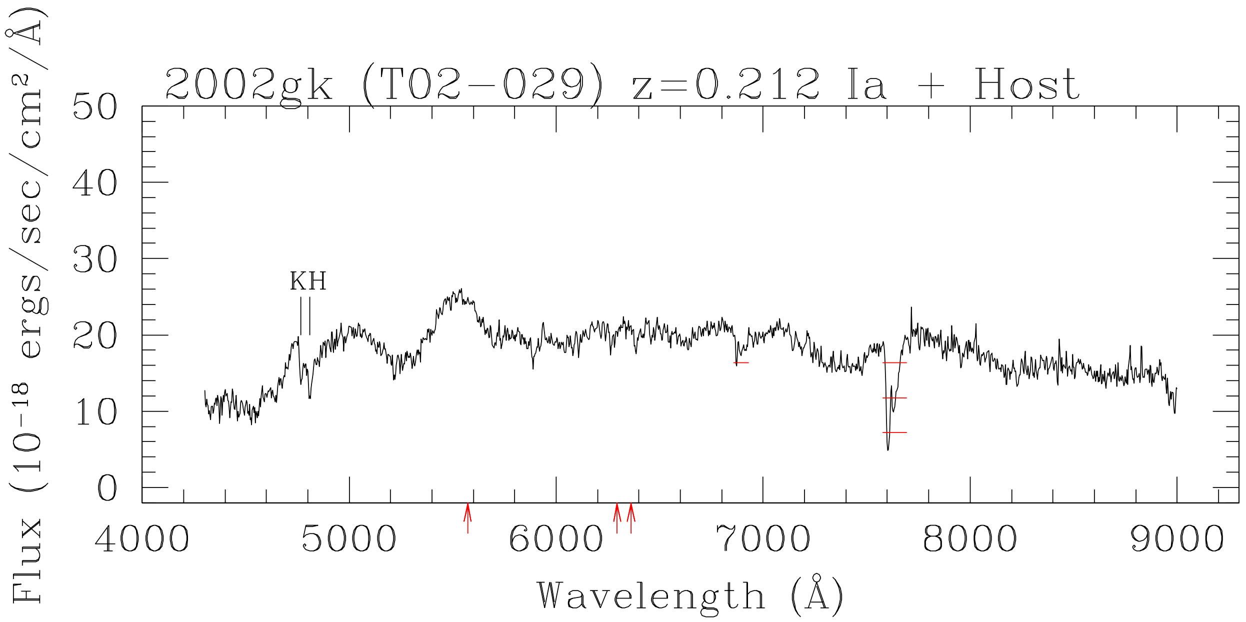

Figure 44: T02-029

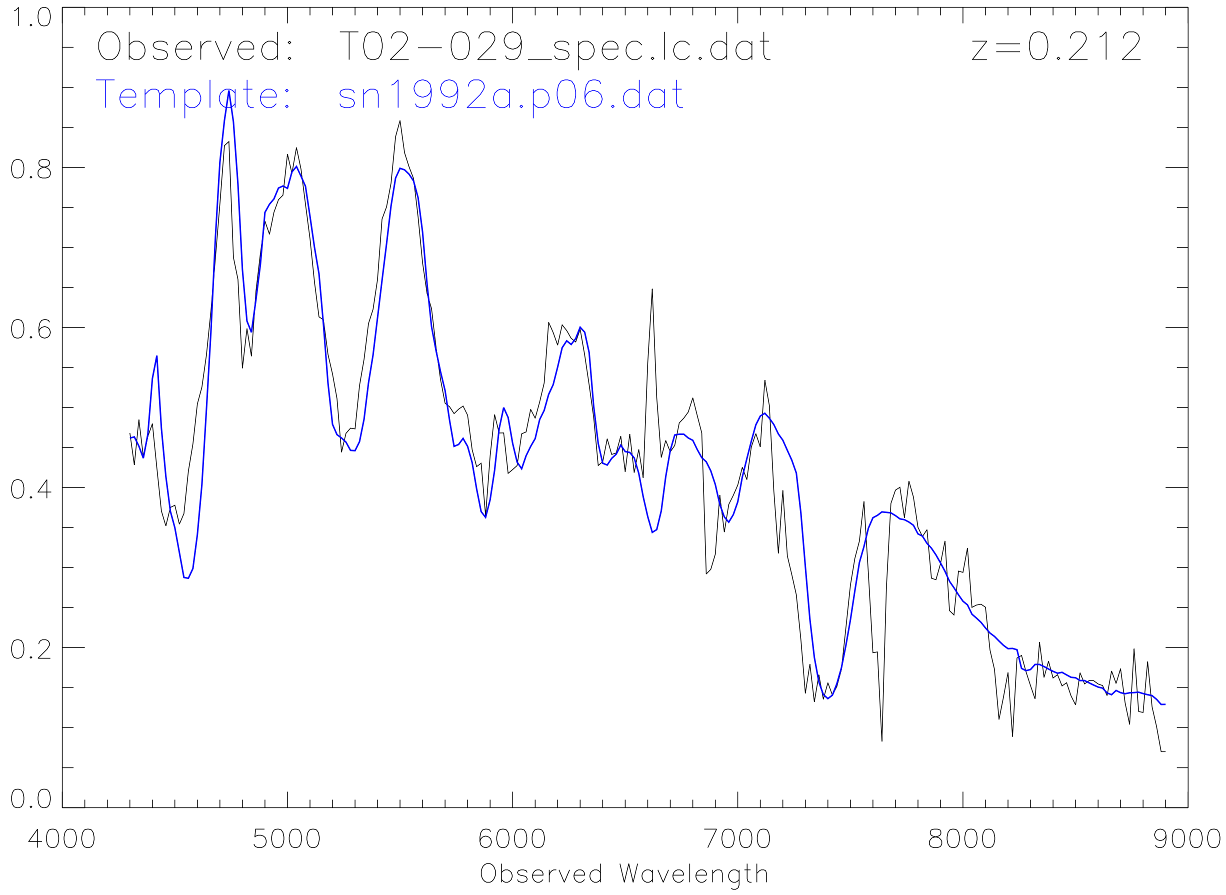

Figure 45: T02-029 and comparison

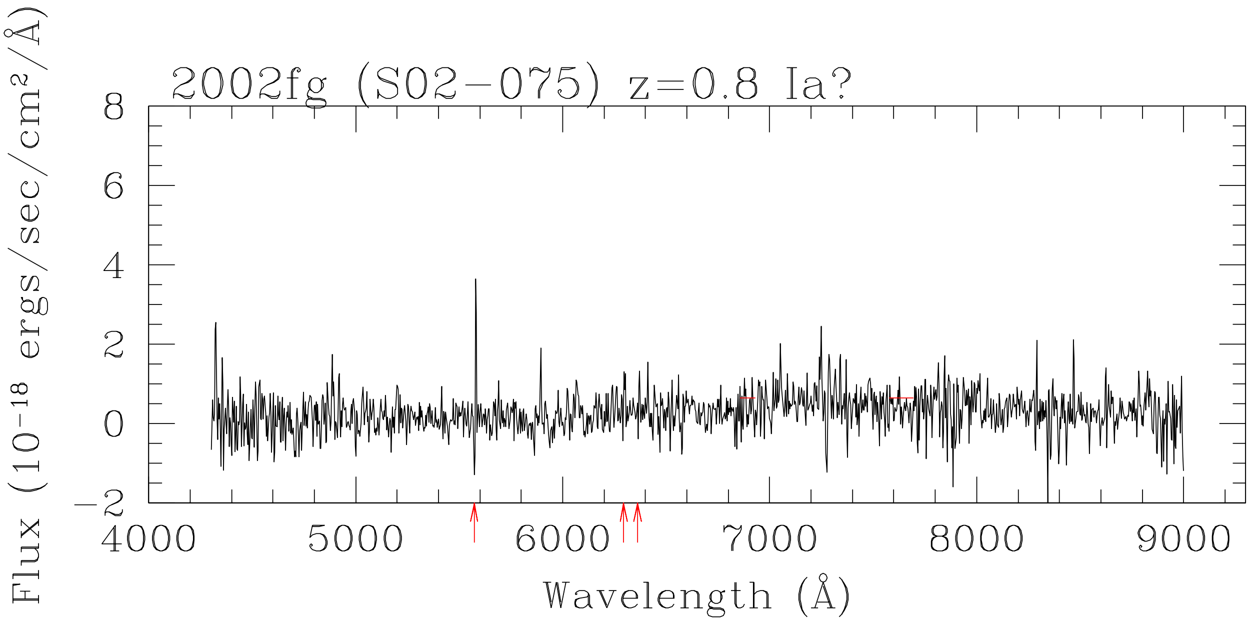

Figure 46: S02-075

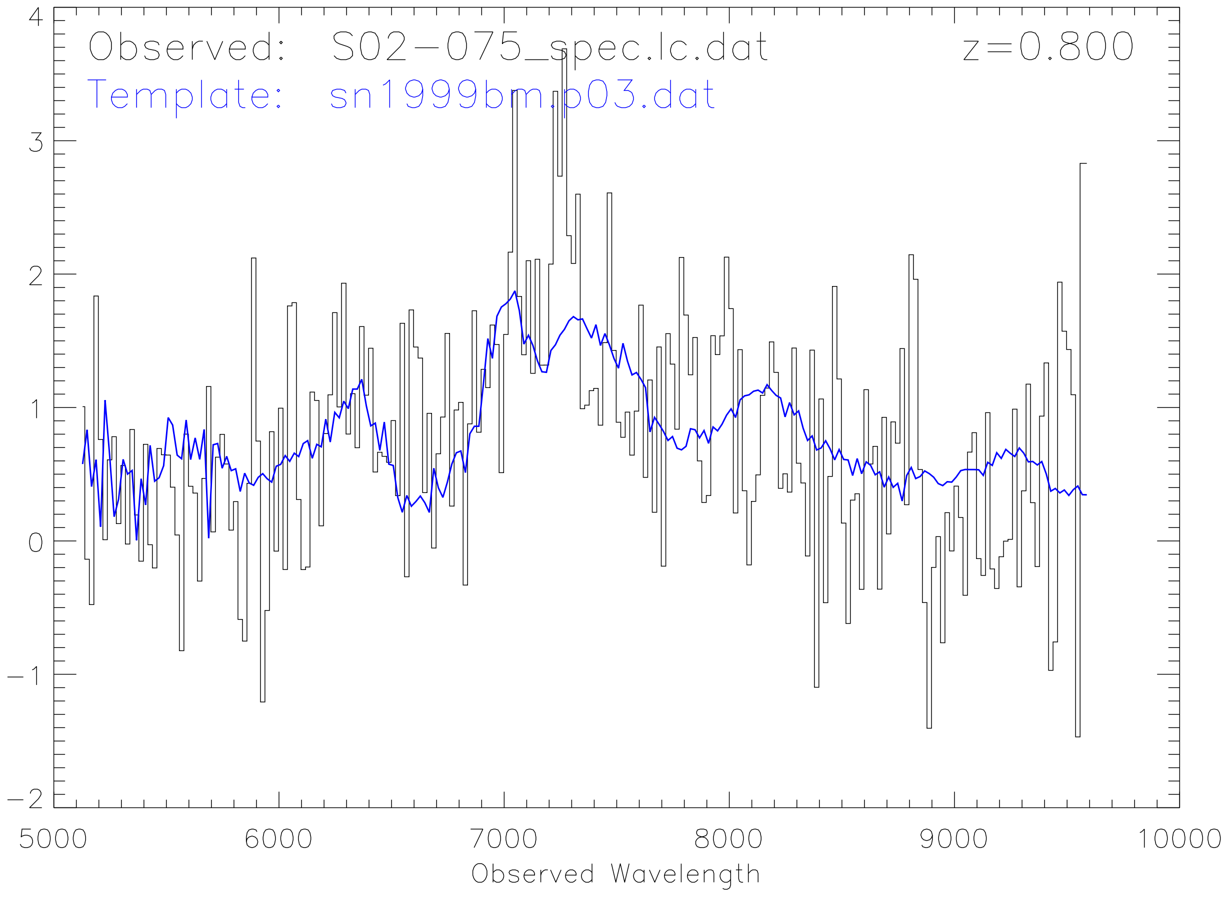

Figure 47: S02-075 and comparison

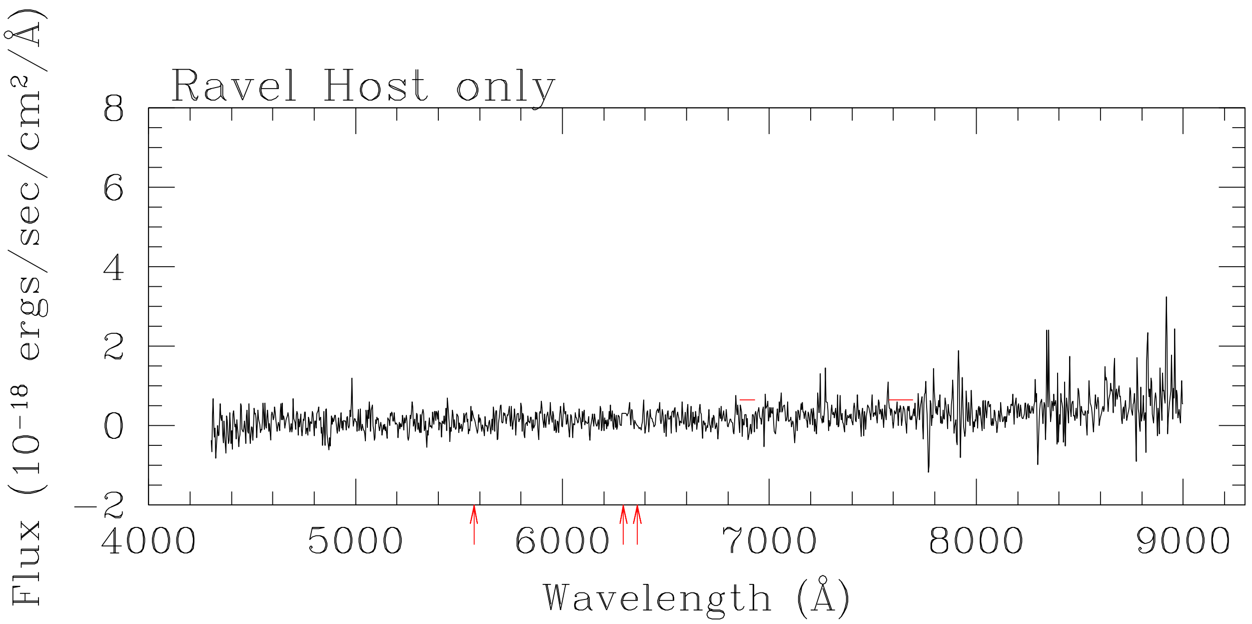

Figure 48: Ravel

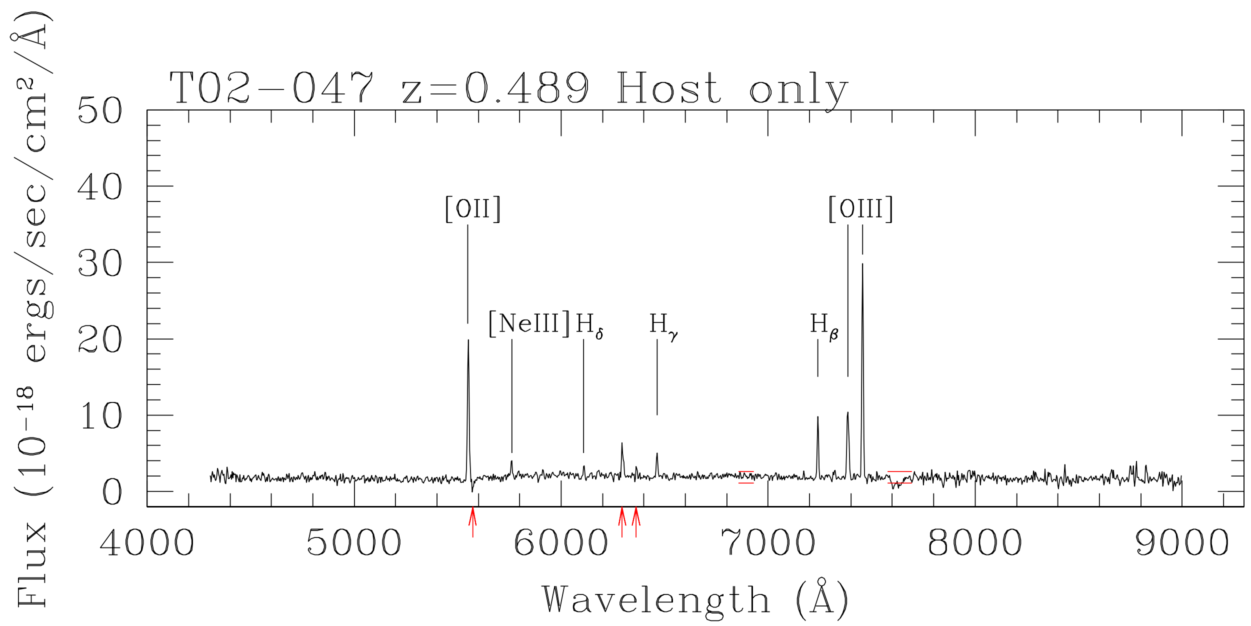

Figure 49: T02-047

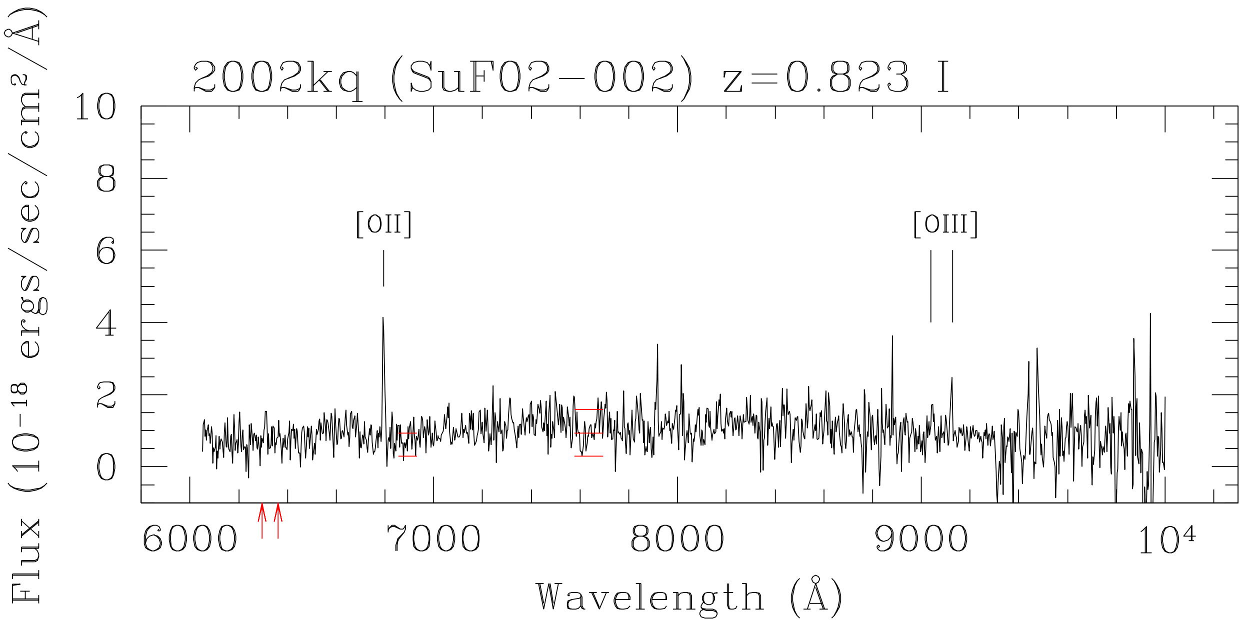

Figure 50: SuF02-002

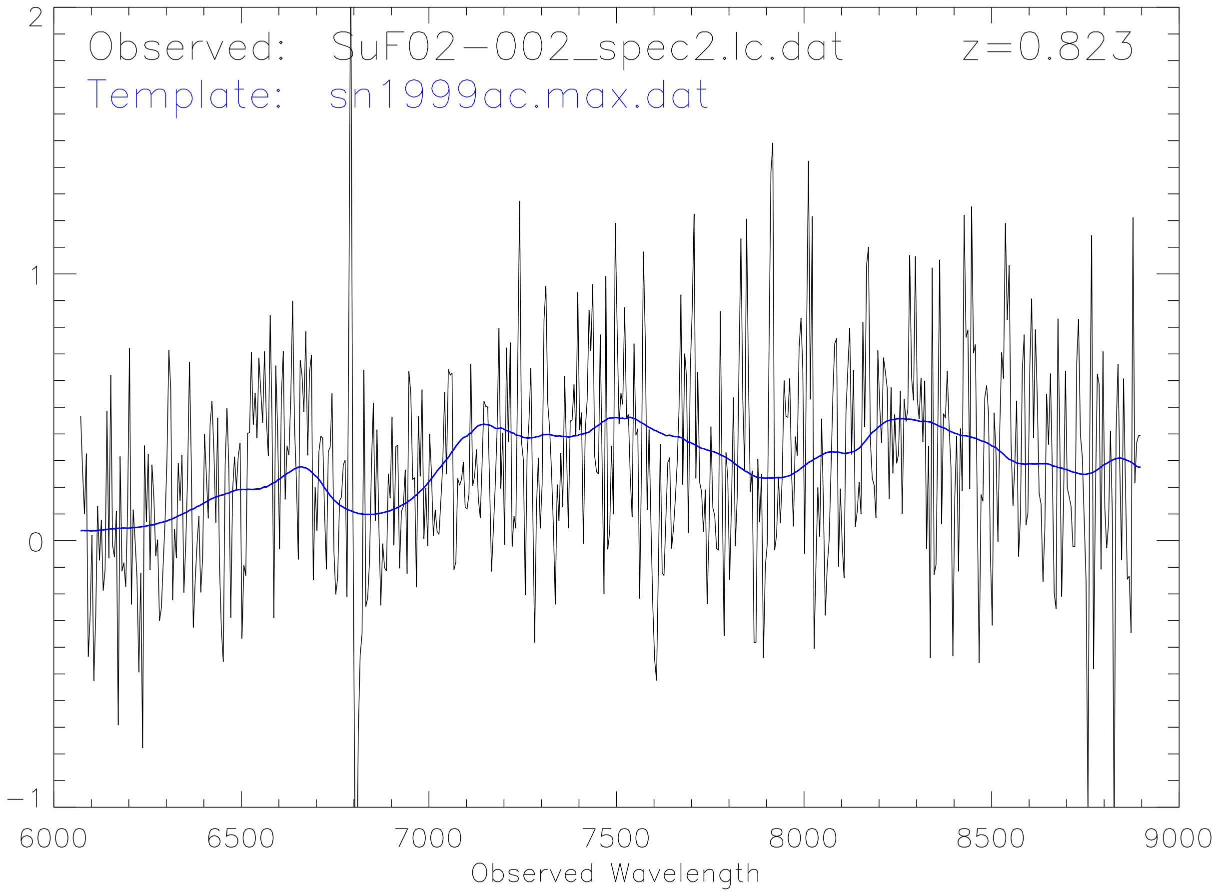

Figure 51: SuF02-002 and comparison

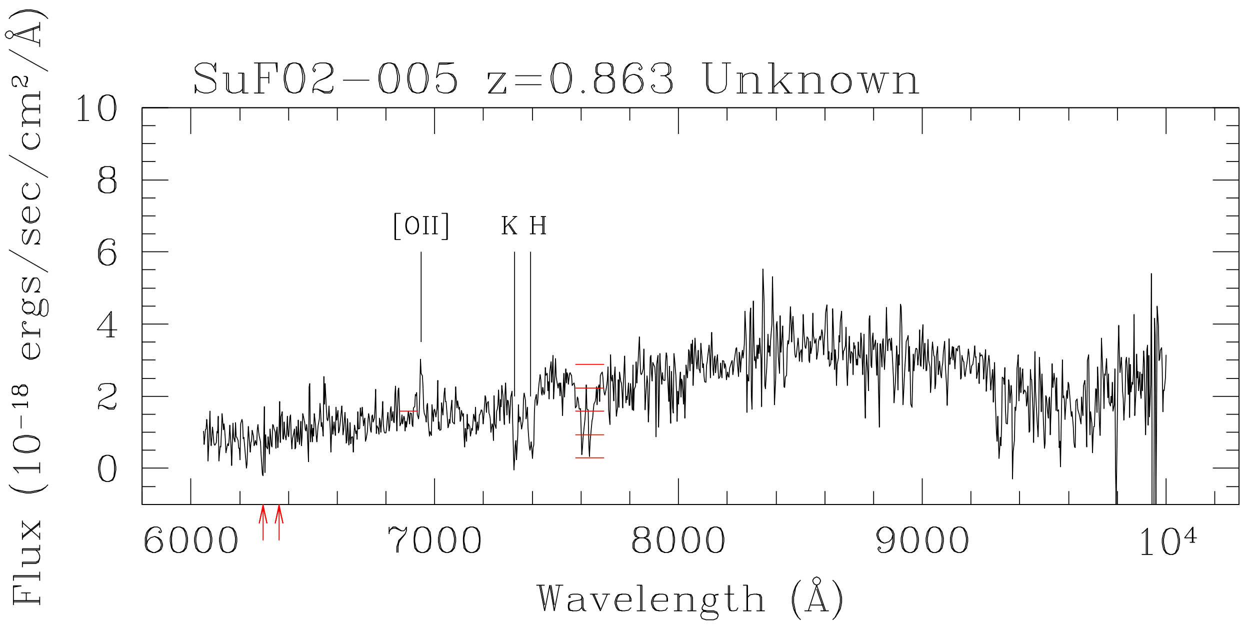

Figure 52: SuF02-005

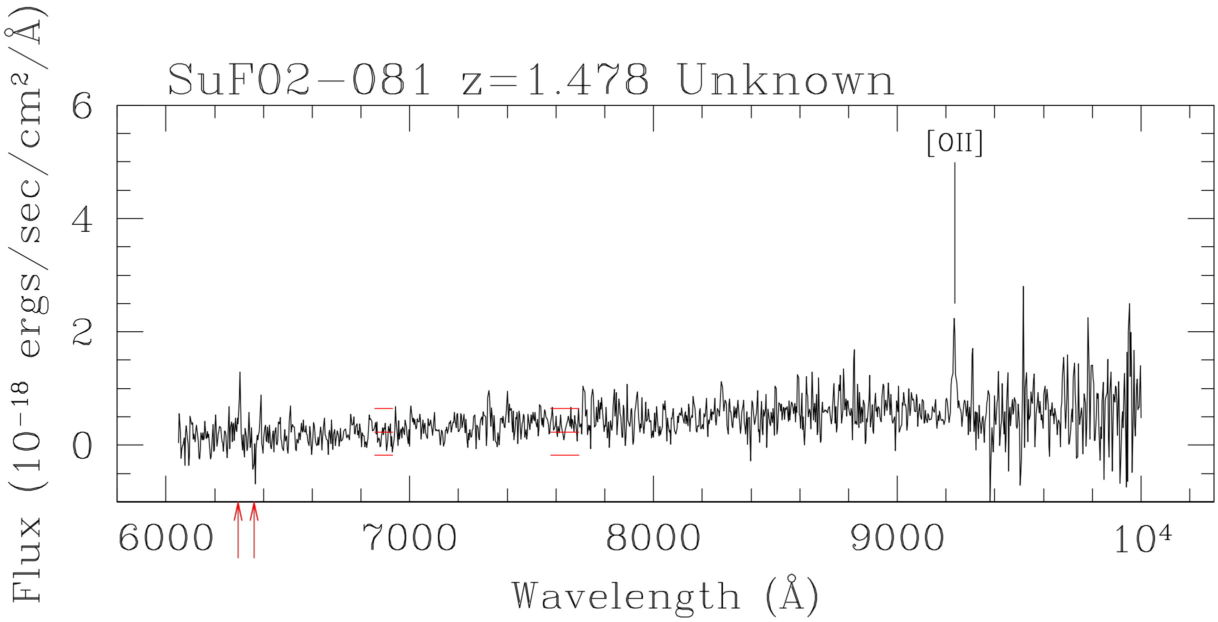

Figure 53: SuF02-081

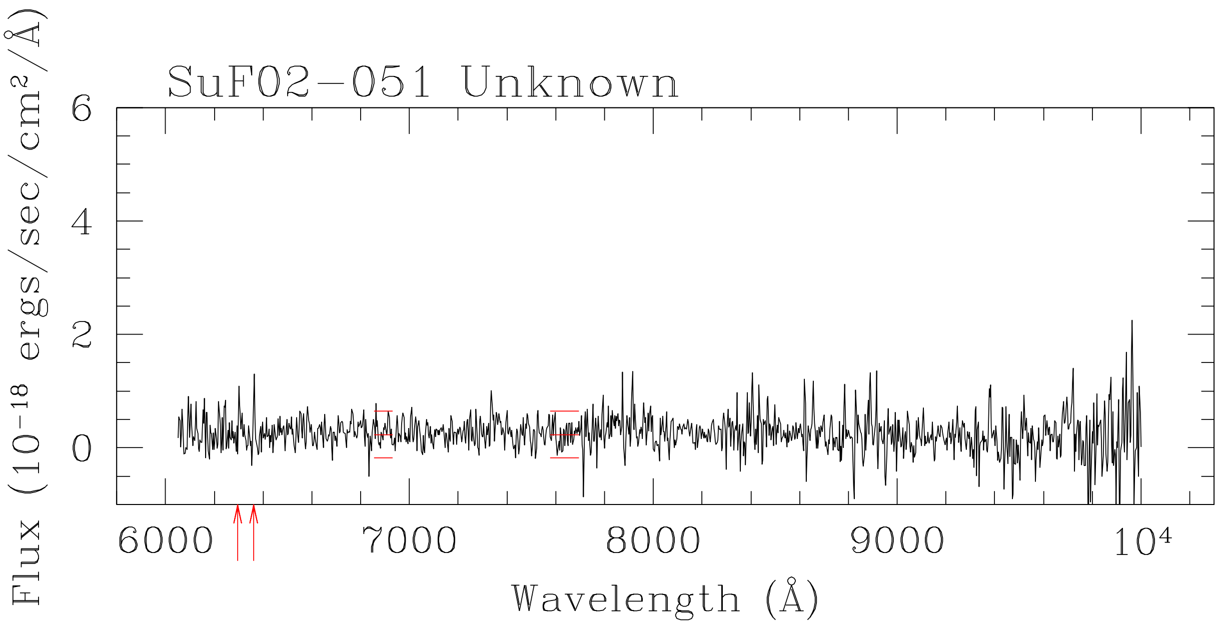

Figure 54: SuF02-051

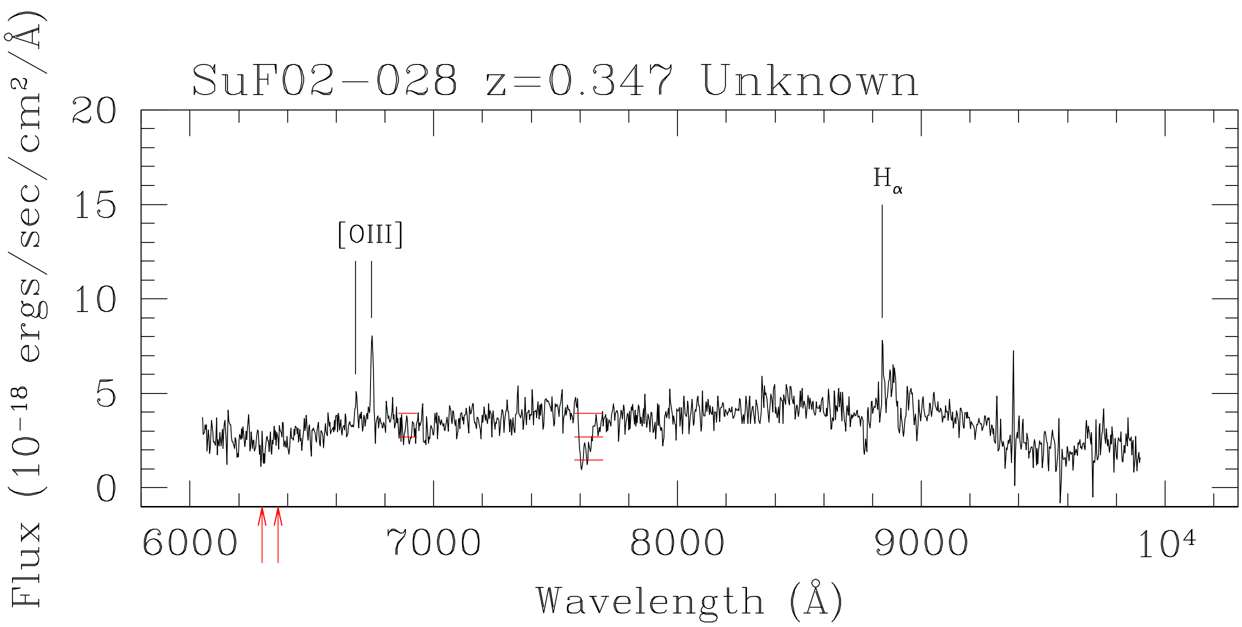

Figure 55: SuF02-028

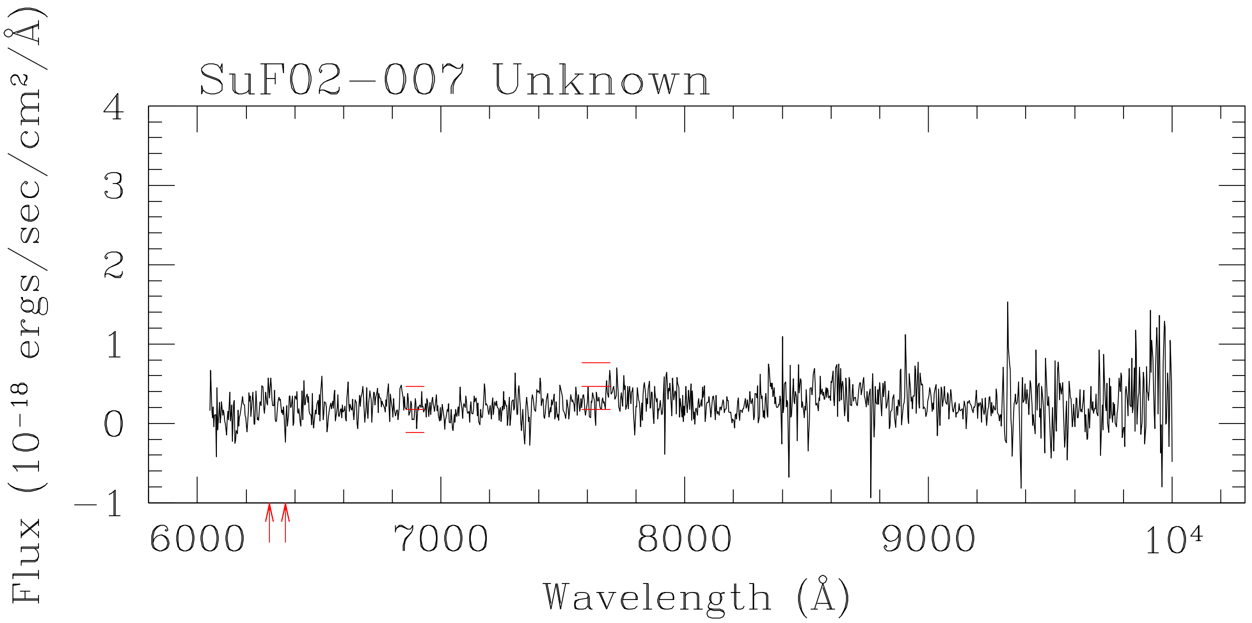

Figure 56: SuF02-007

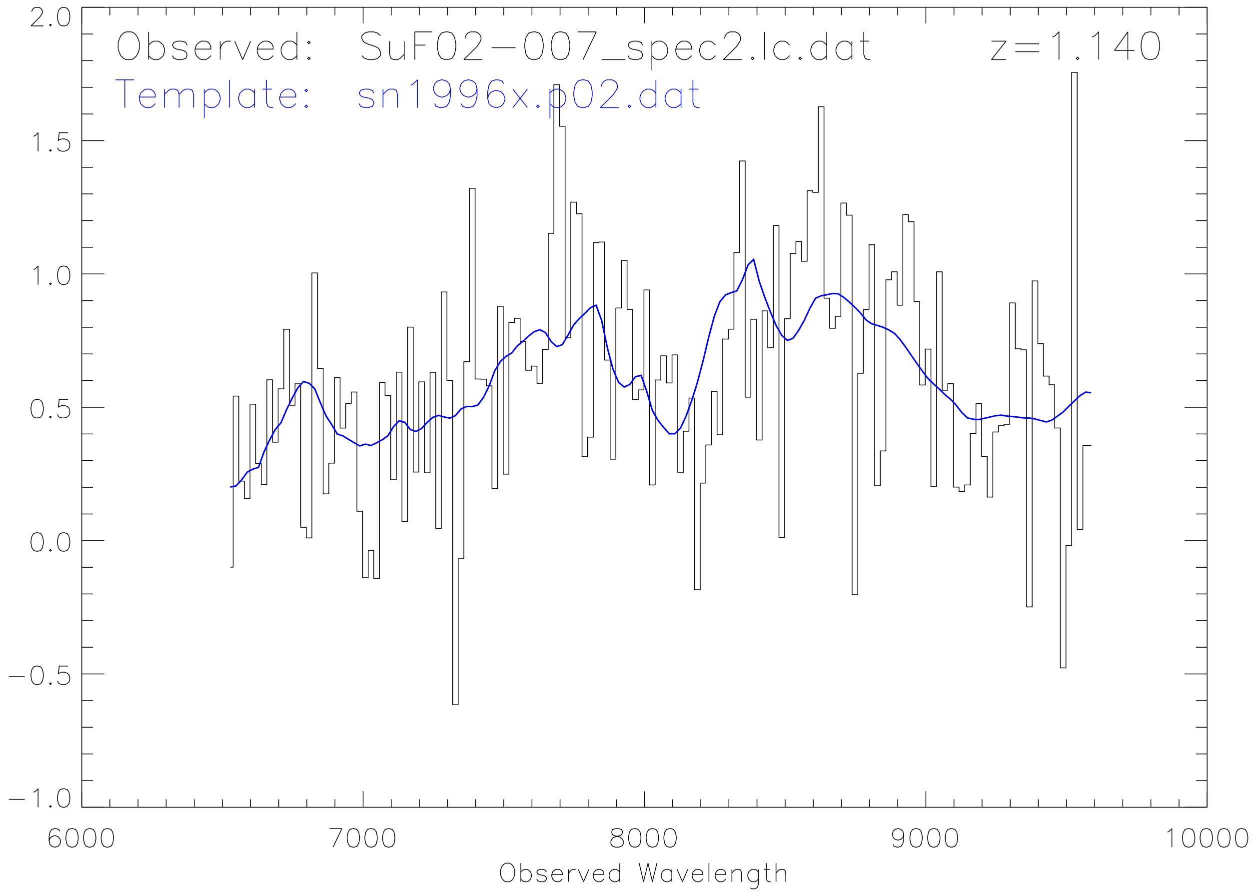

Figure 57: SuF02-007 and comparison

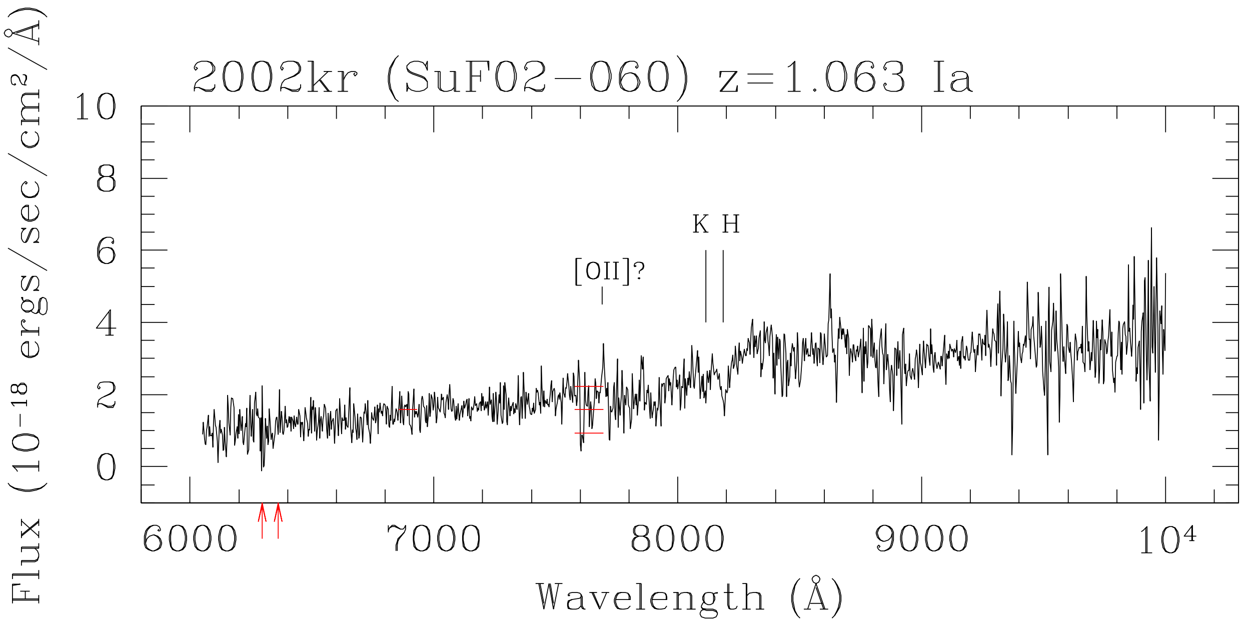

Figure 58: SuF02-060

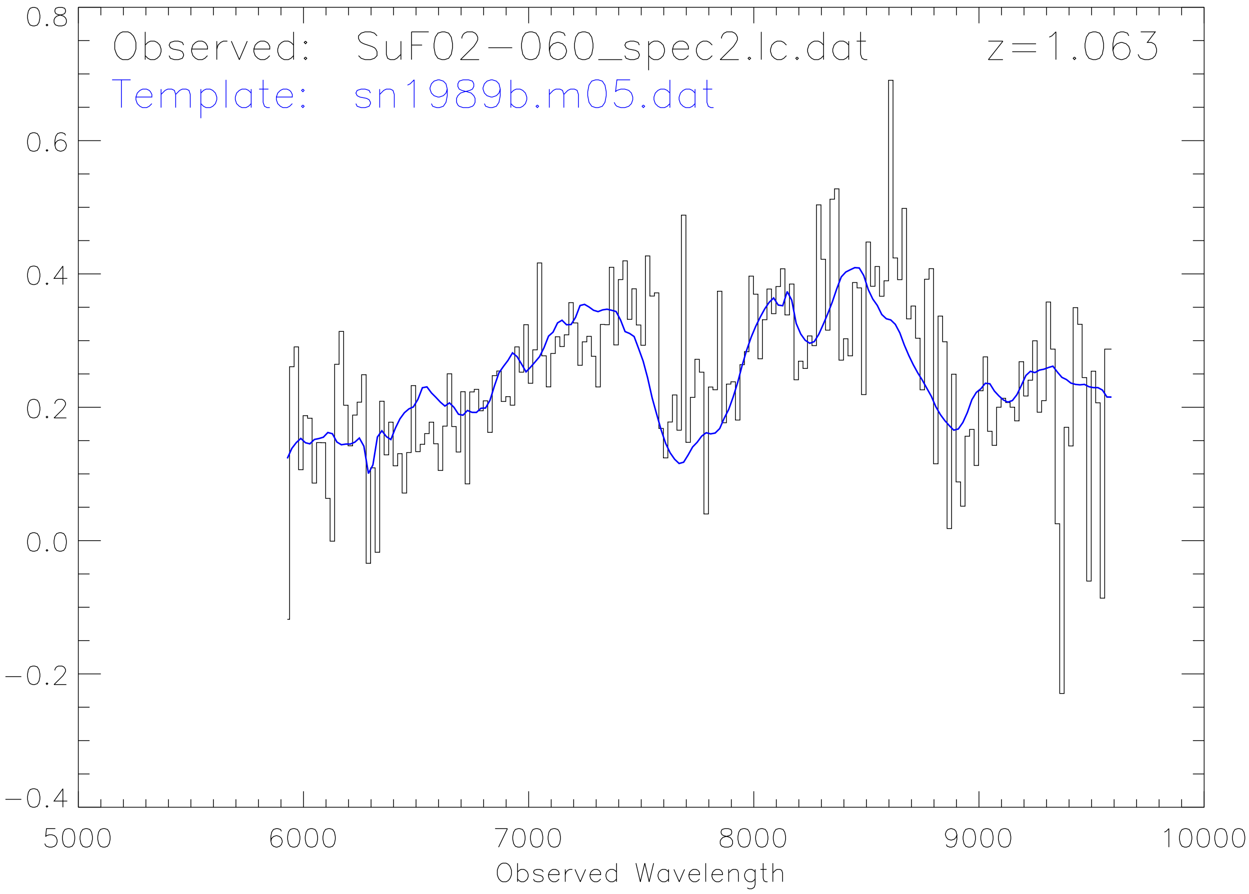

Figure 59: SuF02-060 and comparison

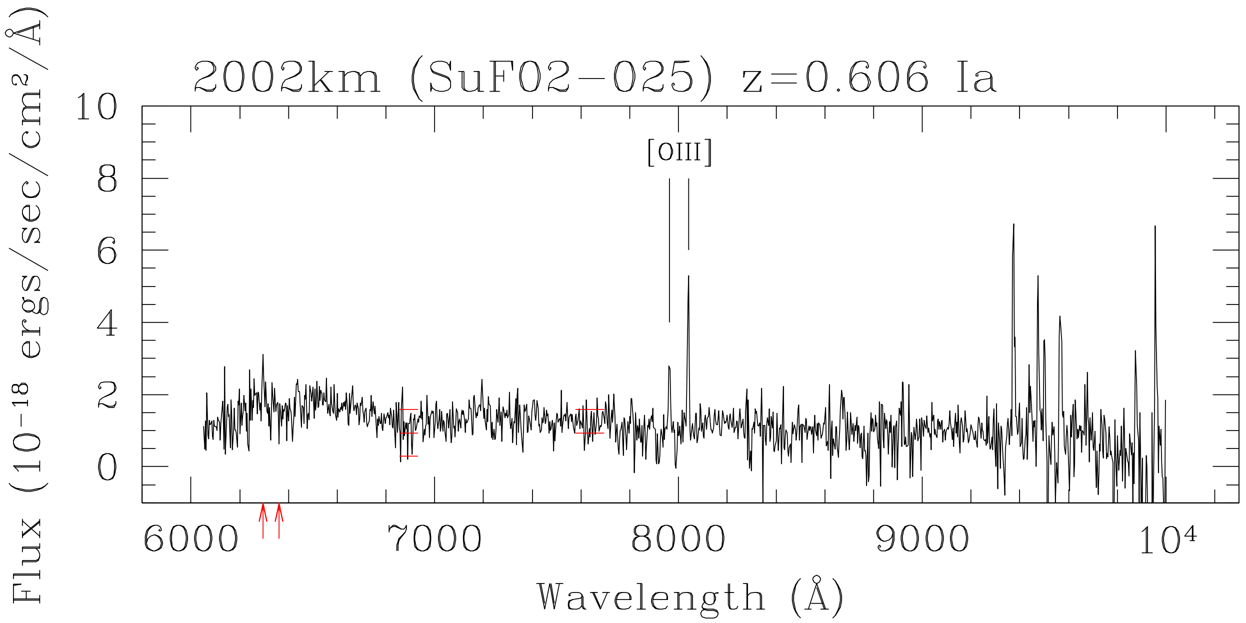

Figure 60: SuF02-025

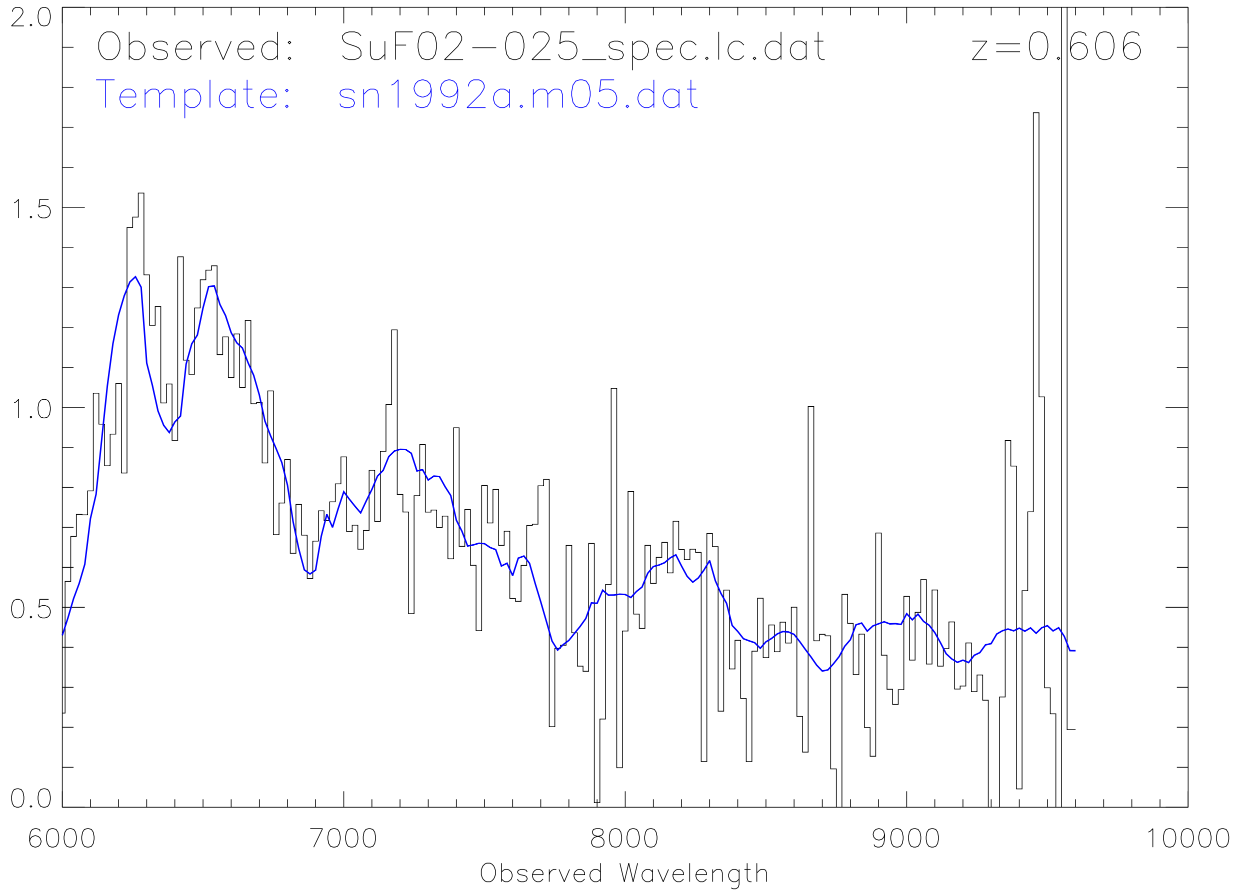

Figure 61: SuF02-025 and comparison

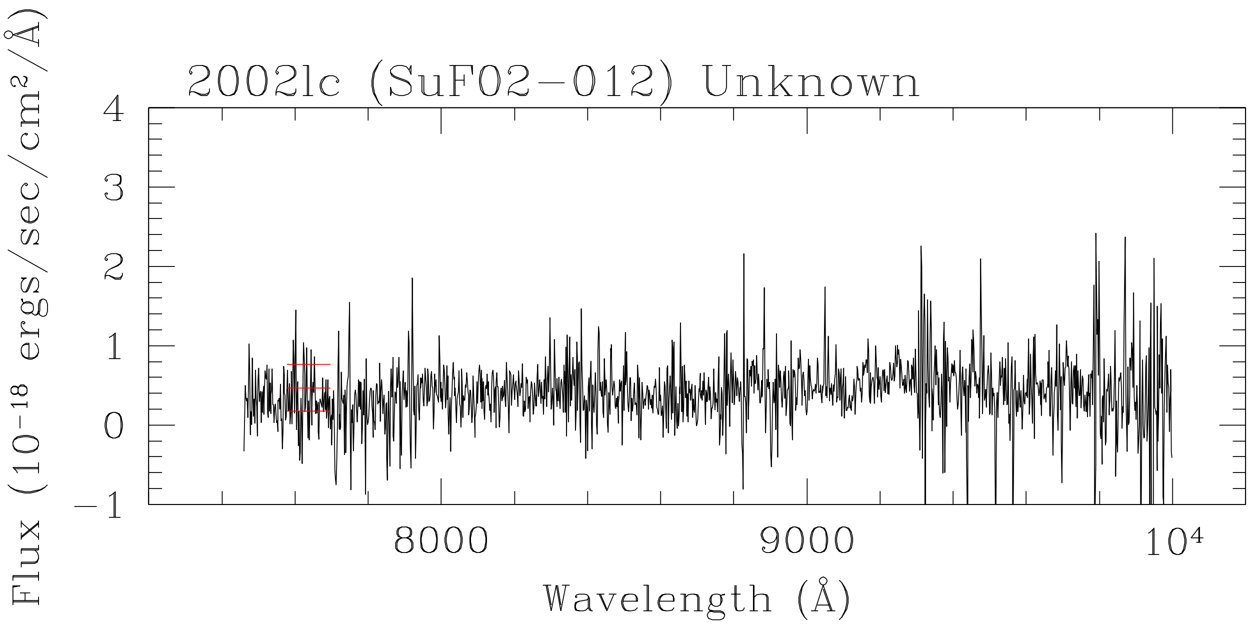

Figure 62: SuF02-012

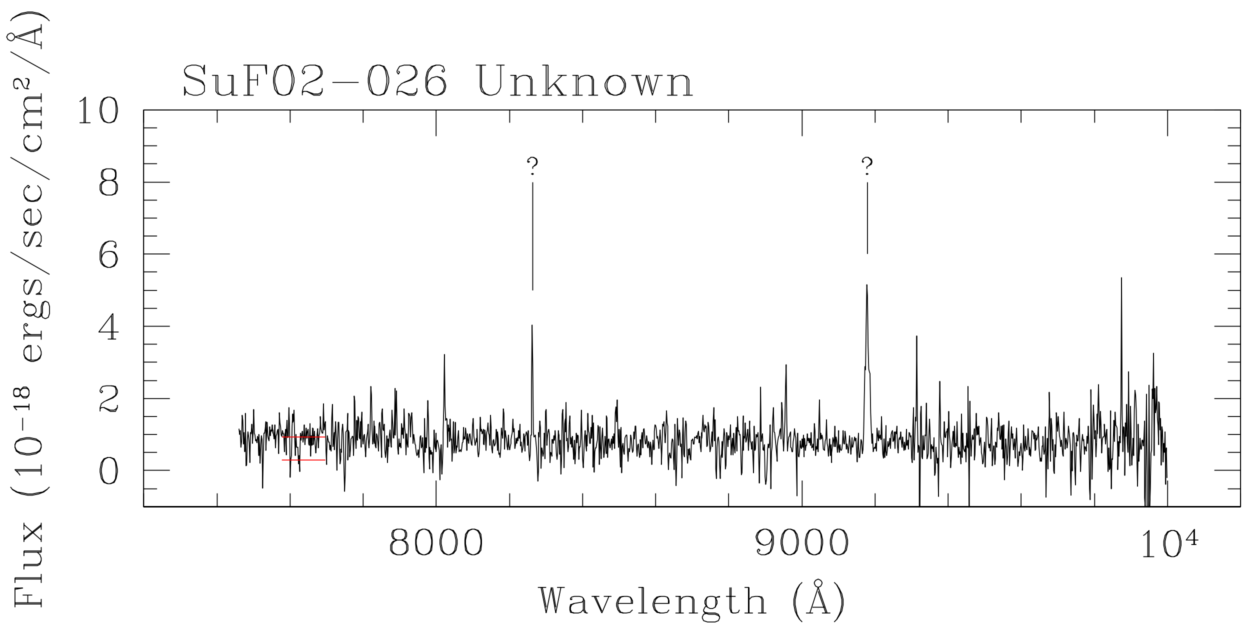

Figure 63: SuF02-026

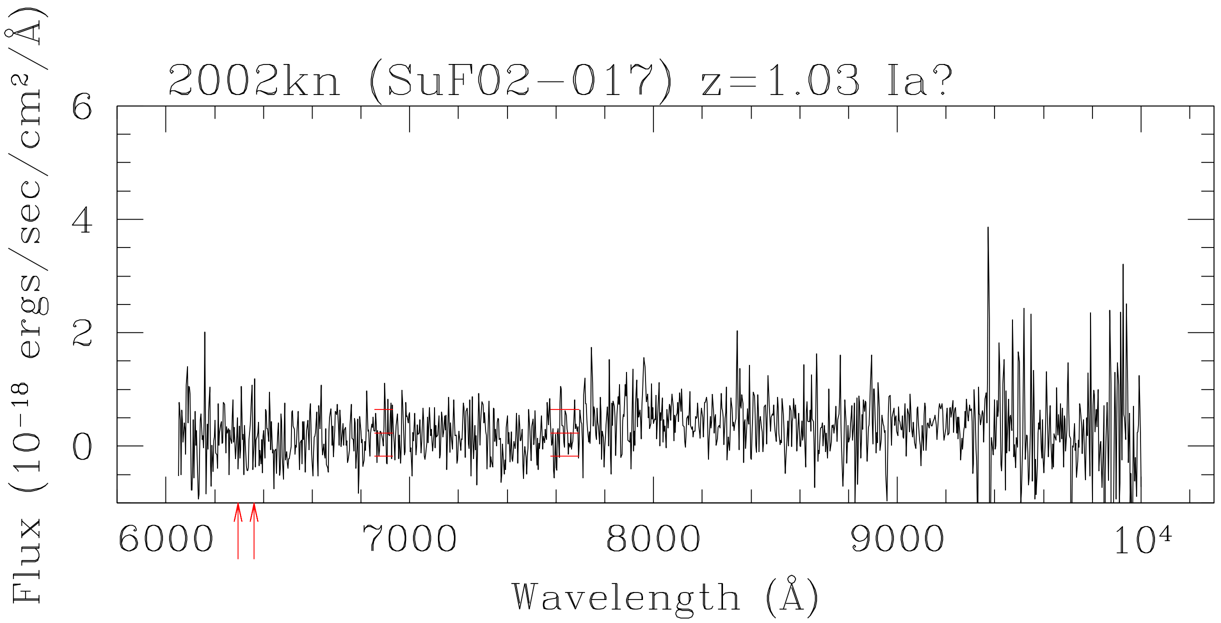

Figure 64: SuF02-017

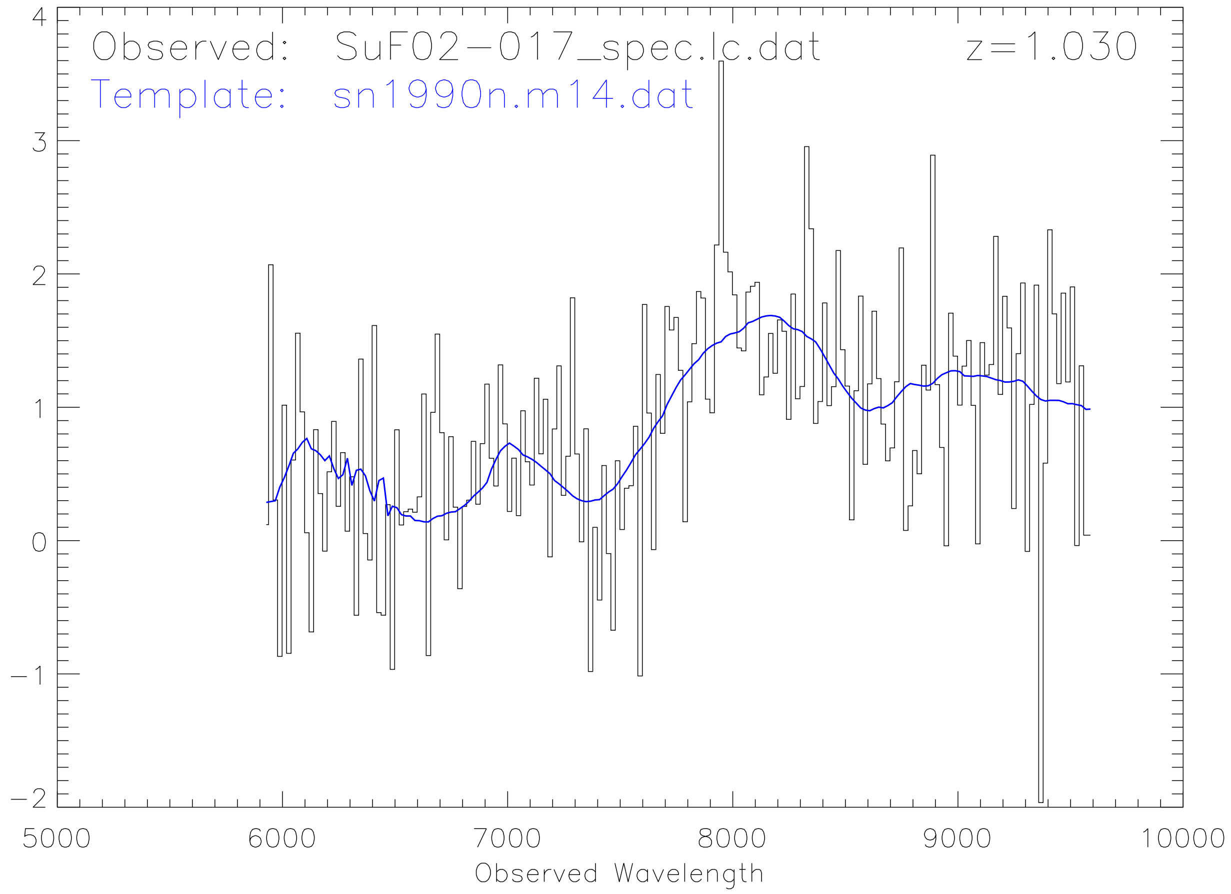

Figure 65: SuF02-017 and comparison

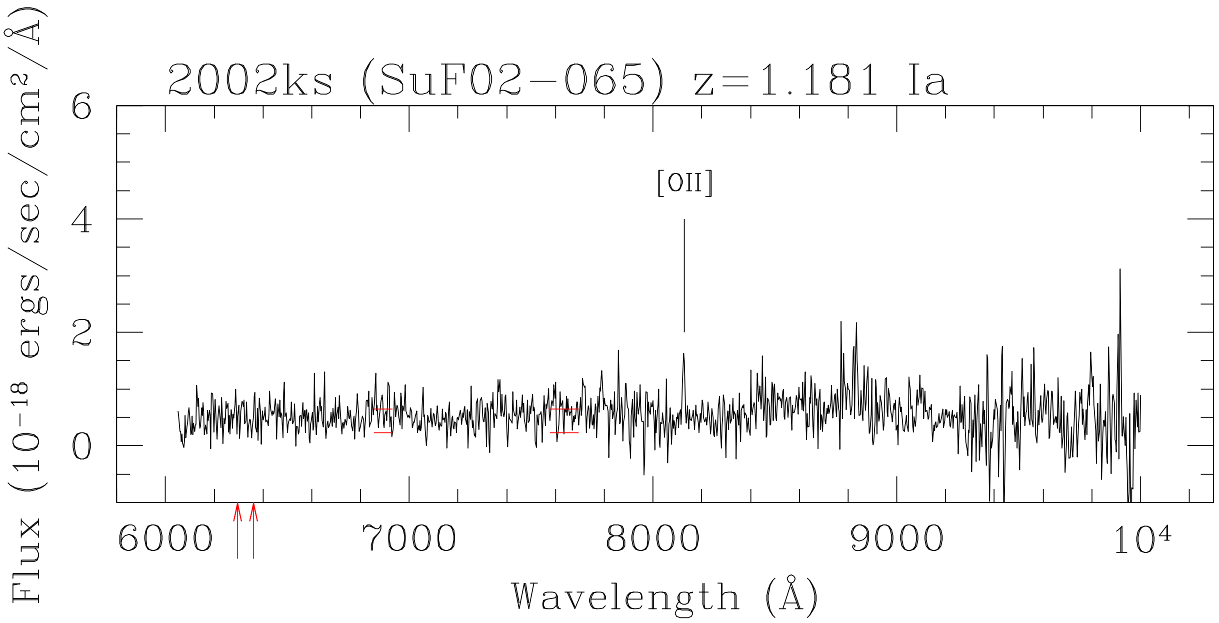

Figure 66: SuF02-065

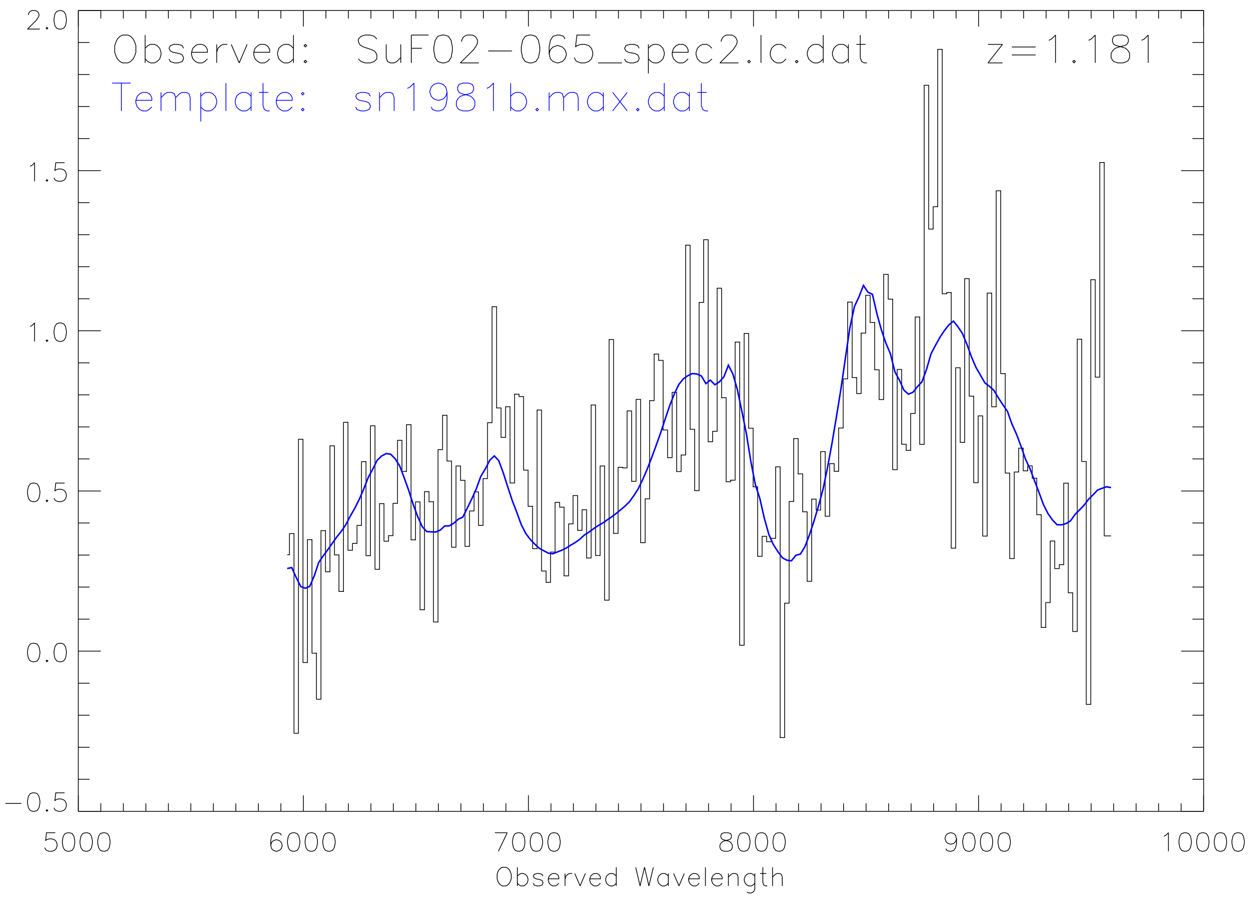

Figure 67: SuF02-065 and comparison

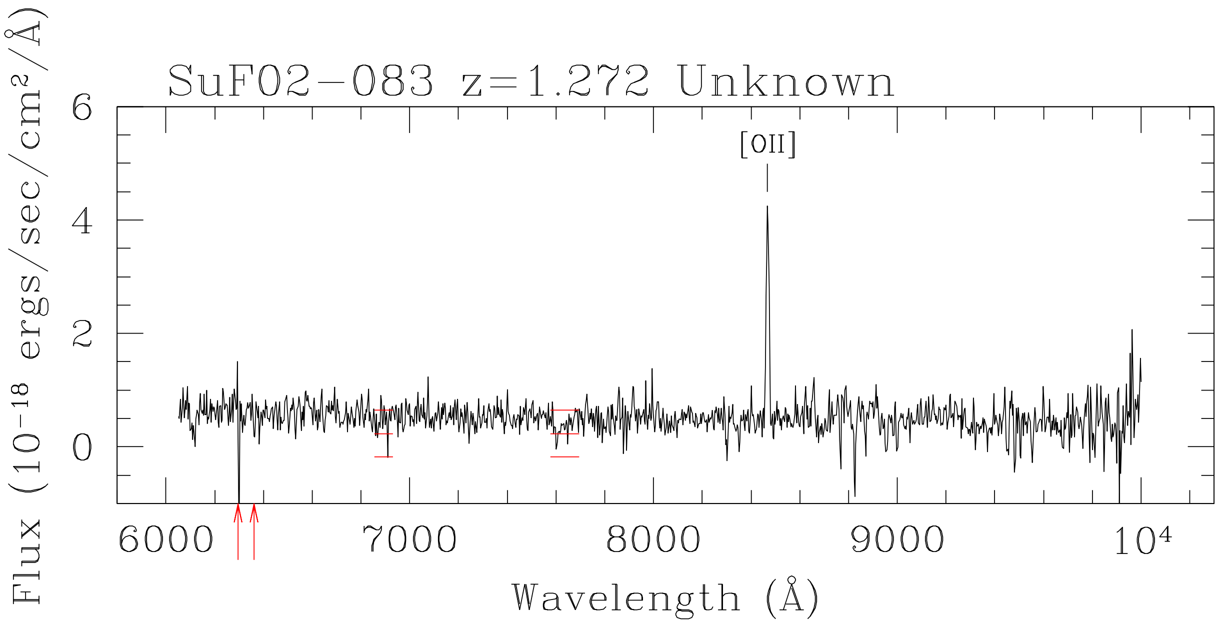

Figure 68: SuF02-083