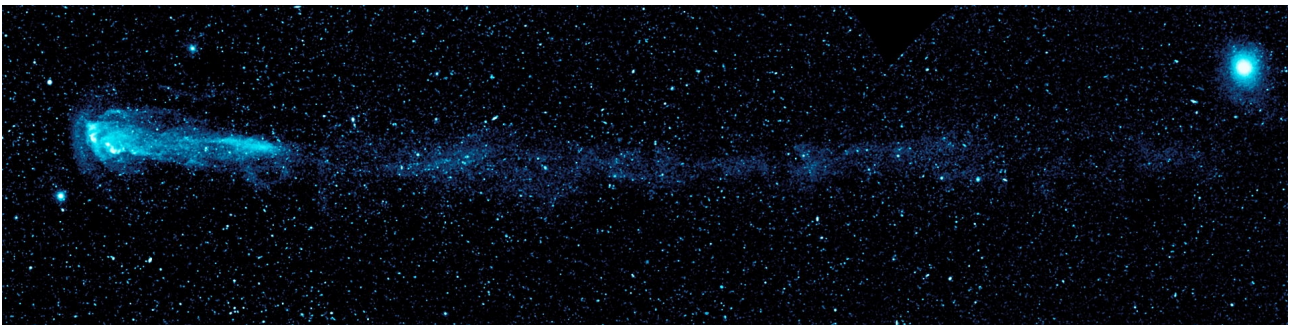


# Spectroscopic Atlas of Mira (o Ceti)

3787Å-5750Å & 5829Å-8817Å



(source: [www.nasa.gov/mission\\_pages/galex/20070815/a.html](http://www.nasa.gov/mission_pages/galex/20070815/a.html))

2014  
David Reck  
Hamburger Sternwarte

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# **1. Introduction:**

This spectroscopic atlas about Mira (o Ceti) covers the wavelengths 3787Å-5750Å and 5829Å-8817Å.

The spectra of Mira were observed with a spectral resolution of approximately  $R = \lambda/\Delta\lambda = 20000$  with the TIGRE Telescope in 2013.

TIGRE is operated by the Hamburger Sternwarte and the universities of Guanajuato and Liège at the La Luz observatory, near Guanajuato (Mexico).

## **1.1 The star Mira (o Ceti)**

Mira, or Omicron Ceti, is a red giant star and forms a binary system with Mira B, or VZ Ceti.

The spectral type of Mira is M1e-M9e (Simbad), which is changing during its variability period.

Mira has a mean diameter of approximately 400 solar diameters (550 Mio. km).

The distance to Mira amounts to  $92 \pm 10$  pc or  $300 \pm 33$  ly.

Its radial velocity is  $+63.8 \pm 0.9$  km/s.

Mira has a tail, in appearance similar to that of a comet.

However, Mira's tail extends over 13 light years in length.

## **1.2 Spectra used for the catalog**

The chosen two dates are 2013-08-08 (dotted line) and 2013-10-19 (continuous line).

I chose these two dates because the first (2013-08-08) is the earliest available of Mira and the second (2013-10-19) is the latest spectrum where the noise in the blue spectral range is so low, that a comparison with the first spectrum still allows to study most of the spectral lines visible in the first spectrum.

## **1.3 Normalization of the spectra**

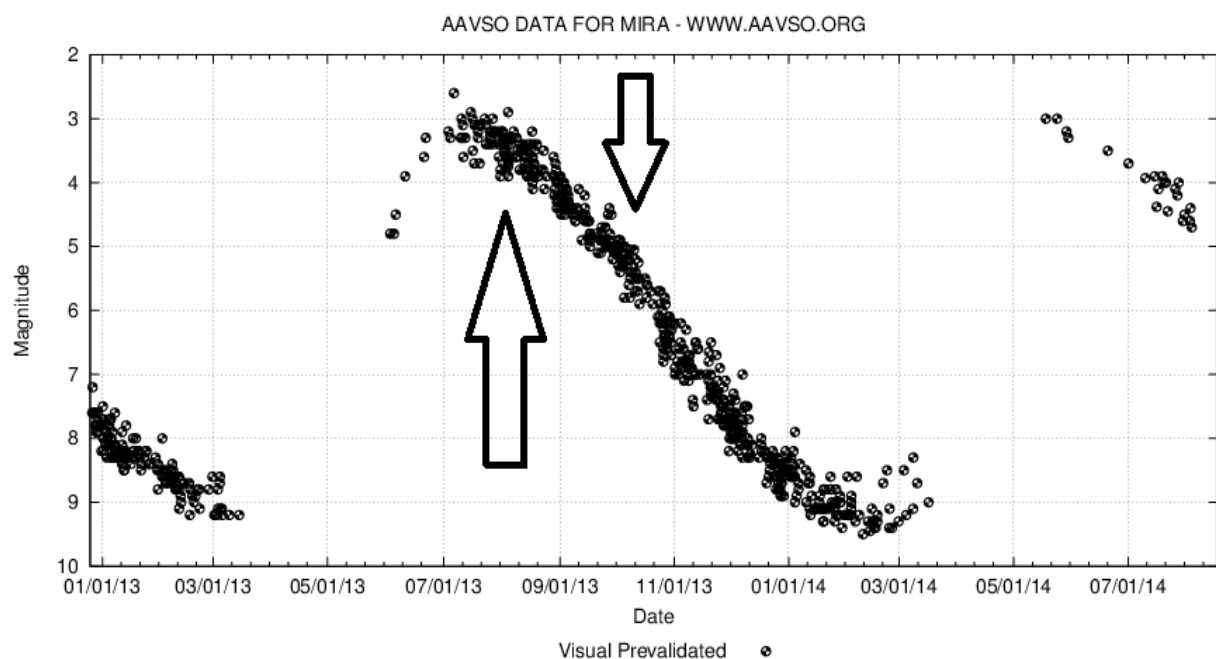
The spectra have been individually normalized on each plotted 60Å – wide

subinterval by multiplication with a constant.

The normalization was performed using the package onedspec of the program IRAF (version: 2.16).

This process was necessary to allow a common representation of both datasets in one graph.

## 2. Cycle of Mira (o Ceti):



(source: [www.aavso.org/lcg](http://www.aavso.org/lcg))

The two arrows show the observing dates of the spectra in this atlas.

Mira changes its visual brightness between typically  $V=3$  mag and  $V=9$  mag with a period of approximately 332 days (Woodruff et al. 2008, ApJ 673, 418) (for more information see [www.aavso.org/vsots-mira](http://www.aavso.org/vsots-mira))

### **3. Corrections (barycentric and radial velocity):**

The spectra are corrected for barycentric shift, but not for the radial velocity (+63.8 ± 0.9 km/s.)

For example the shift at 7000Å, caused by the radial velocity, amounts to about 1.5Å in the red spectral range.

### **4. Pronounced changes in Mira's spectrum**

The following is a list of specific lines, that markedly change their amplitude, between the two observing dates.

- 3797.514 Å Fe I
- 3852.572 Å Fe I
- 3829 Å Mg I ;8332 Å Mg I ;8338 Å Mg I
- 3905.523 Å Si I
- 3906.479 Å Fe I
- 3938.560 Å Mg I
- 4030.76 Å Mn I
- 4033.07 Å Mn I
- 4216.183 Å Fe I
- 4512 Å ?
- 4573 Å ?
- 4839.544 Å Fe I
- 4969 Å ?
- 8413 Å ?
- 8420 Å ?
- 8429 Å ?
- 8436 Å ?

## 4.1 H-Balmer Series

Most of the visible H-Balmer lines have a huge amplitude which is not covered by the given scaling of the y-axis, which was chosen in order to make the weaker lines well visible. The following list gives the amplitudes of the strongest Balmer lines relative to the surrounding quasi-continuum. They all appear in emission.

- H10 amplitude: 27.9
- H9 amplitude: 25.1
- H8 amplitude: 35.7
- H  $\epsilon$  amplitude: 4.2
- H  $\delta$  amplitude : 46.3
- H  $\gamma$  amplitude : 46.4
- H  $\beta$  visible in the plot
- H  $\alpha$  amplitude: 2.4

## **5. Telluric lines**

Below each 60Å interval I show a telluric spectrum for comparison, if the interval contains significant telluric lines.

The telluric spectrum is a synthetic spectrum computed using the LBRTM package (Clough et al., 1992, S Geophysical Research).

A good example of telluric contamination can be seen in the wavelength range between 8100Å and 8360Å.

## **6. P-Cygni lines**

Only two of the Ca II infrared triplet lines show a pronounced P-Cygni shape. These are: 8664Å and 8544Å

## 7. References

Spectroscopic Journal of Mira CETI, 1943-1952 ApJS, vol 1 p.39 (1954), A. Joy. In the atlas listed by the abbreviation (Joy).

NIST [http://physics.nist.gov/PhysRefData/ASD/lines\\_form.html](http://physics.nist.gov/PhysRefData/ASD/lines_form.html)

Atomic Spectra Database (version 5.1)

National Institut of Standards and Technology, Gaithersburg, MD.

In the atlas listed by the abbreviation (NIST).

VALD <http://vald.inasan.ru/~vald3/php/vald.php>

This work has made use of the VALD database, operated at Uppsala University, the Institute of Astronomy RAS in Moscow and the University of Vienna.

In the atlas listed by the abbreviation (VALD).

ApJ 498, 851-862, 1998, J. A. Valenti, N. Piskunov and C. M. Johns-Krull

In the atlas listed by the abbreviation (Valenti).

D. Walker, A spectroscopic Guide to Astronomical Objects and Terrestrial Light Sources, Version 5.0, 2014 [http://www.ursusmajor.ch/downloads/spectroscopic-atlas-5\\_0-english.pdf](http://www.ursusmajor.ch/downloads/spectroscopic-atlas-5_0-english.pdf)

In the atlas listed by the abbreviation (Walker).

Wikipedia:

- [de.wikipedia.org/wiki/Mira\\_\(Stern\)](http://de.wikipedia.org/wiki/Mira_(Stern))
- [en.wikipedia.org/wiki/Mira](http://en.wikipedia.org/wiki/Mira)



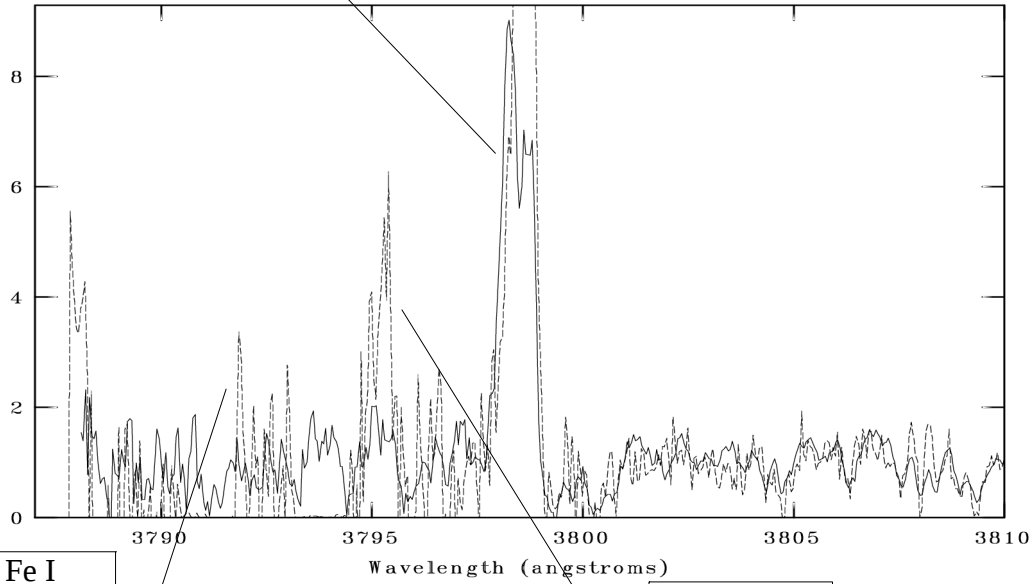
## **9. Acknowledgements**

I thank Dr. Uwe Wolter and Dr. Dieter Engels for supporting me during this work.

**Appendix**  
**A: Blue spectrum (3787Å-5750Å)**

H<sub>10</sub>  
3 797.904 Å  
Joy

NOAO/IRAF V2.16 st4b417@hspc13 Tue 15:18:14 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



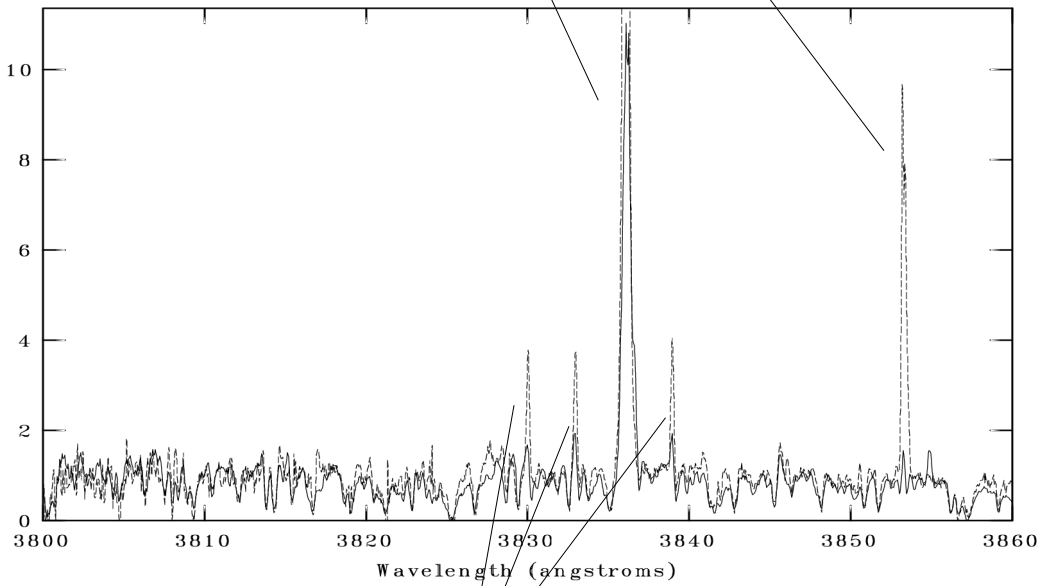
Fe I  
3 794.339 Å  
NIST

Fe I  
3 797.514 Å  
NIST

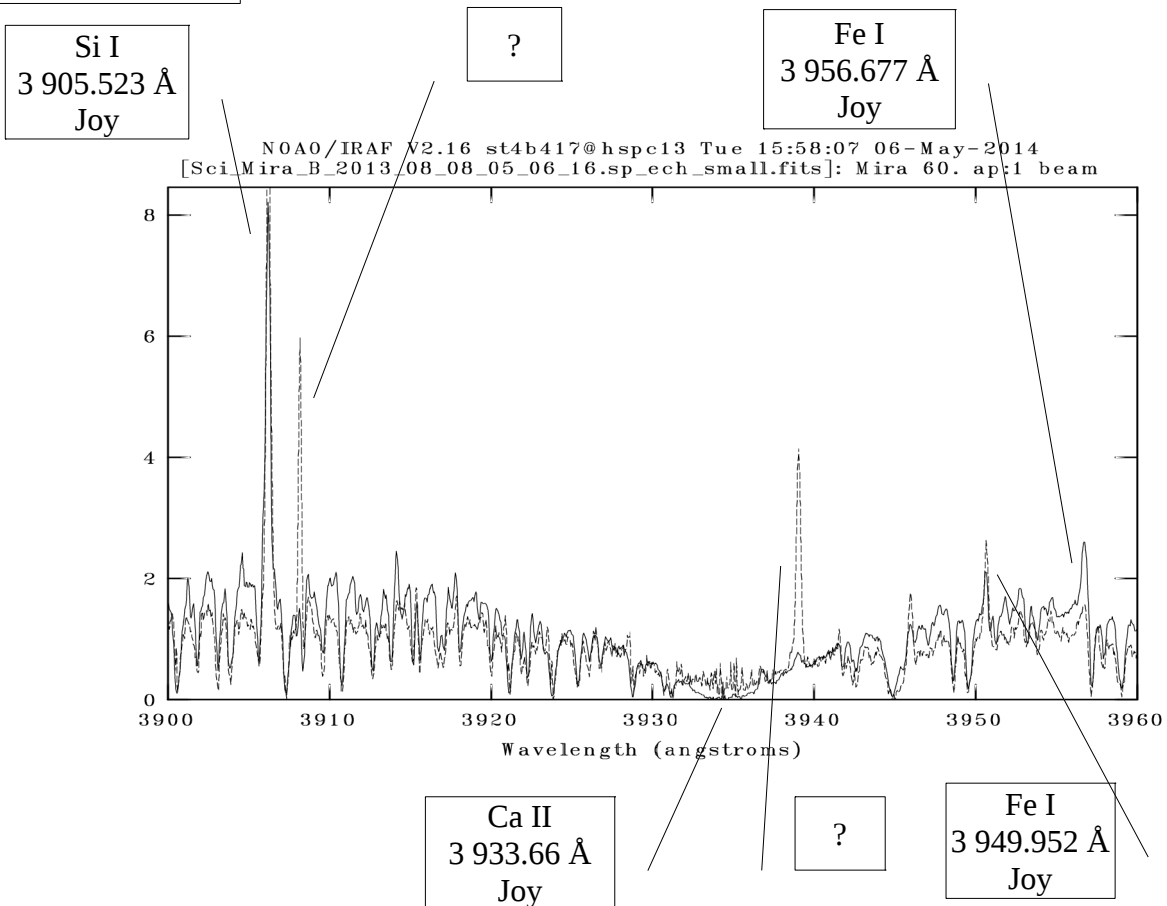
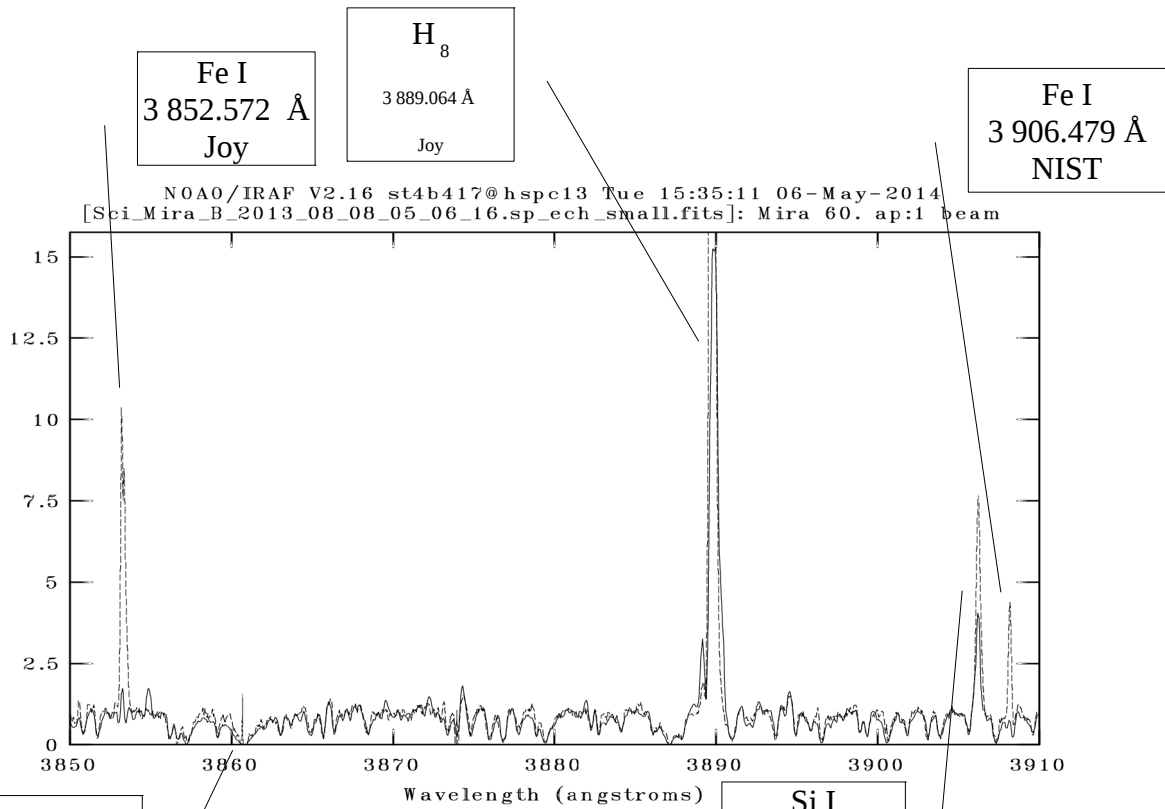
H<sub>9</sub>  
3 835.390 Å  
NIST

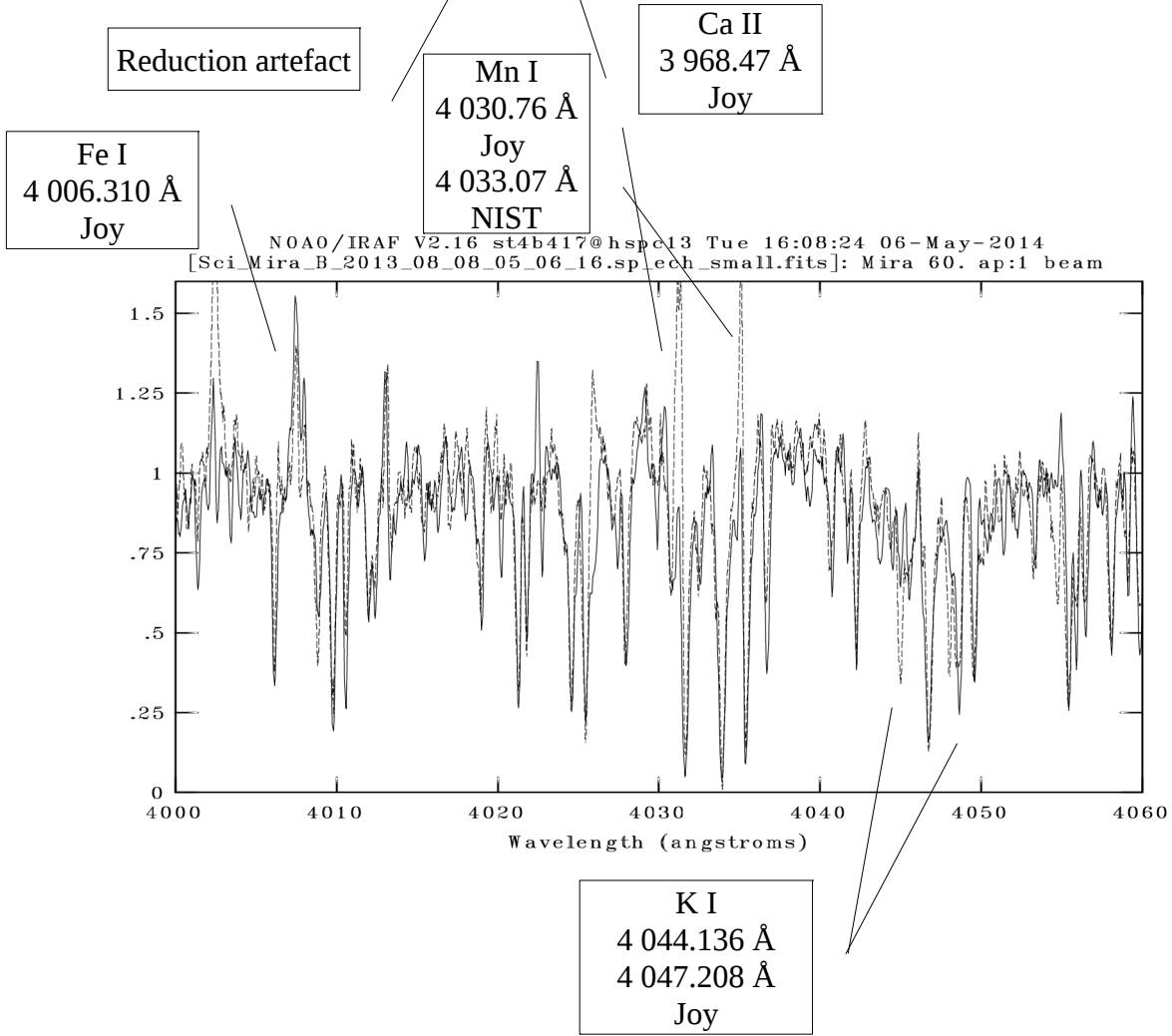
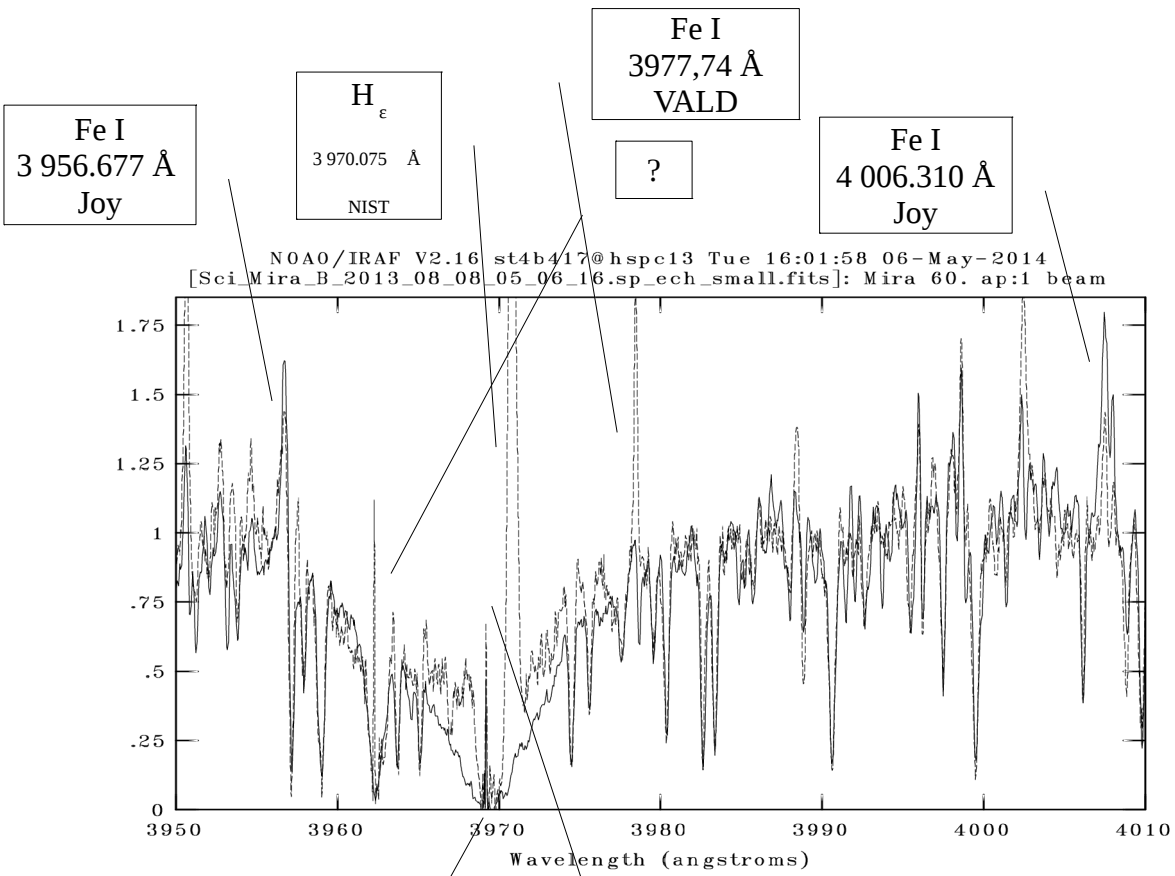
Fe I  
3 852.572 Å  
Joy

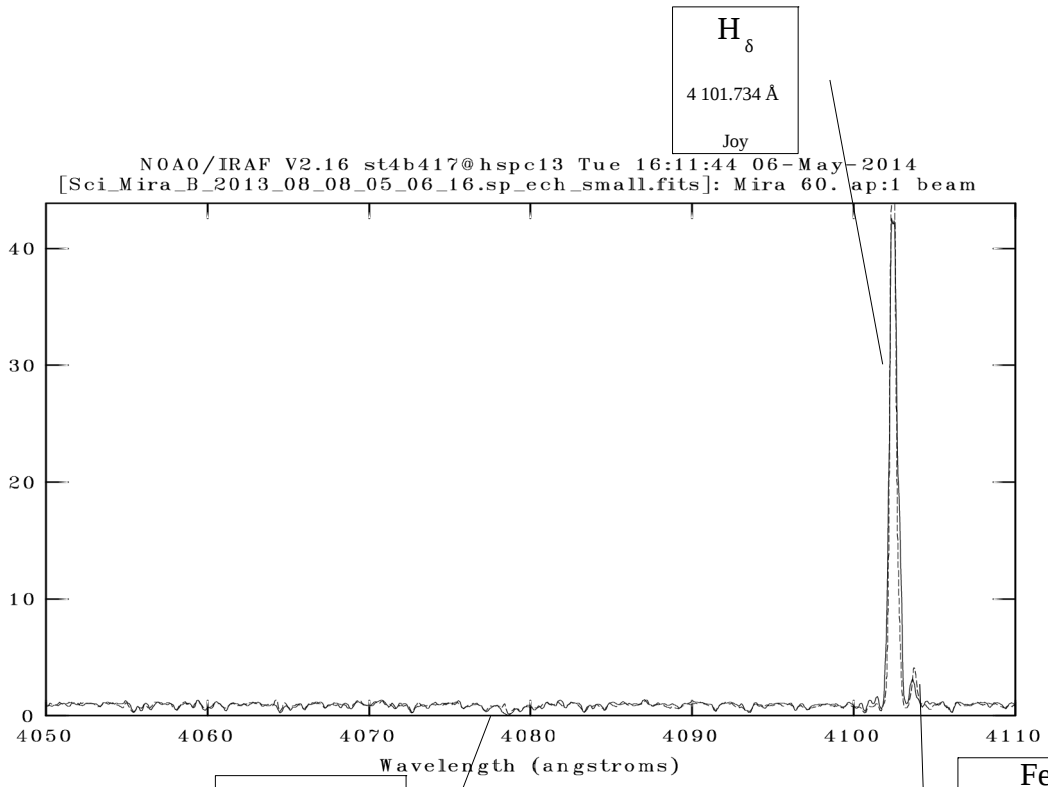
NOAO/IRAF V2.16 st4b417@hspc13 Tue 15:29:08 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



Mg I  
3 829,32,38 Å  
Joy





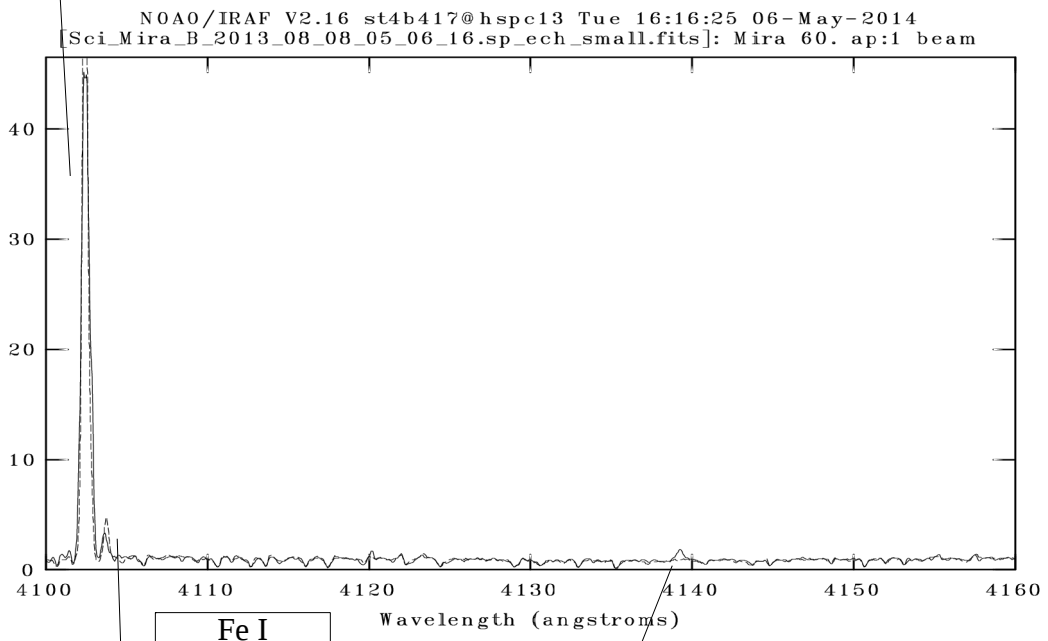


H<sub>δ</sub>  
 4 101.734 Å  
 Joy

Sr II  
 4 077.714 Å  
 Joy

Fe I  
 4 103.613 Å  
 NIST

H<sub>δ</sub>  
 4 101.734 Å  
 Joy



Fe I  
 4 103.613 Å  
 NIST

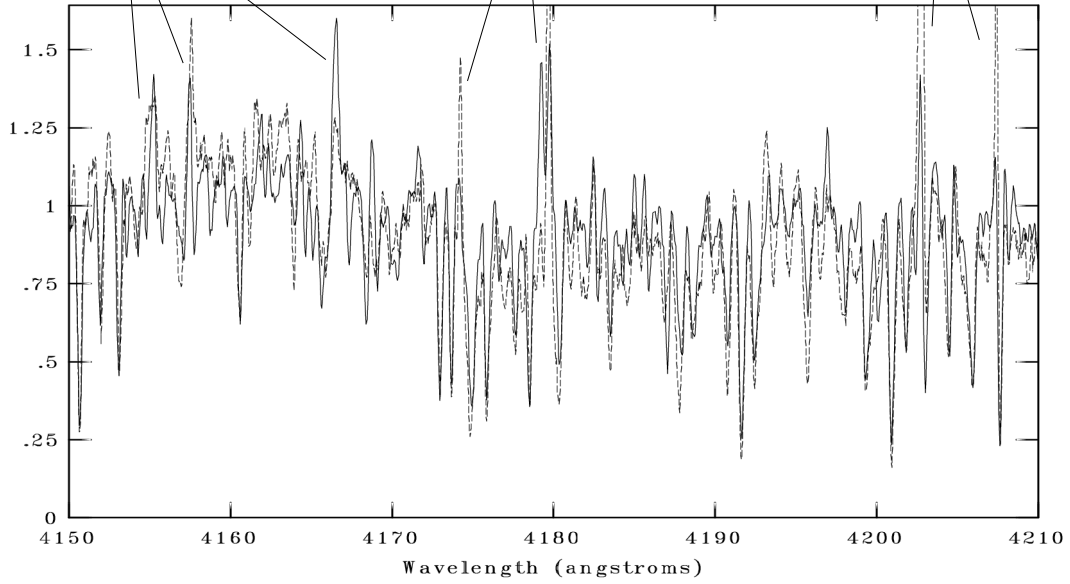
Fe I  
 4 139.927 Å  
 NIST

Fe I  
4 154.805 Å  
4 156.798 Å  
4 167.858 Å  
NIST

Fe II  
4 173.450 Å  
4 178.854 Å  
Joy

Fe I  
4 202.029 Å  
4 206.696 Å  
Joy

NOAO/IRAF V2.16 st4b417@hspc13 Tue 16:19:36 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



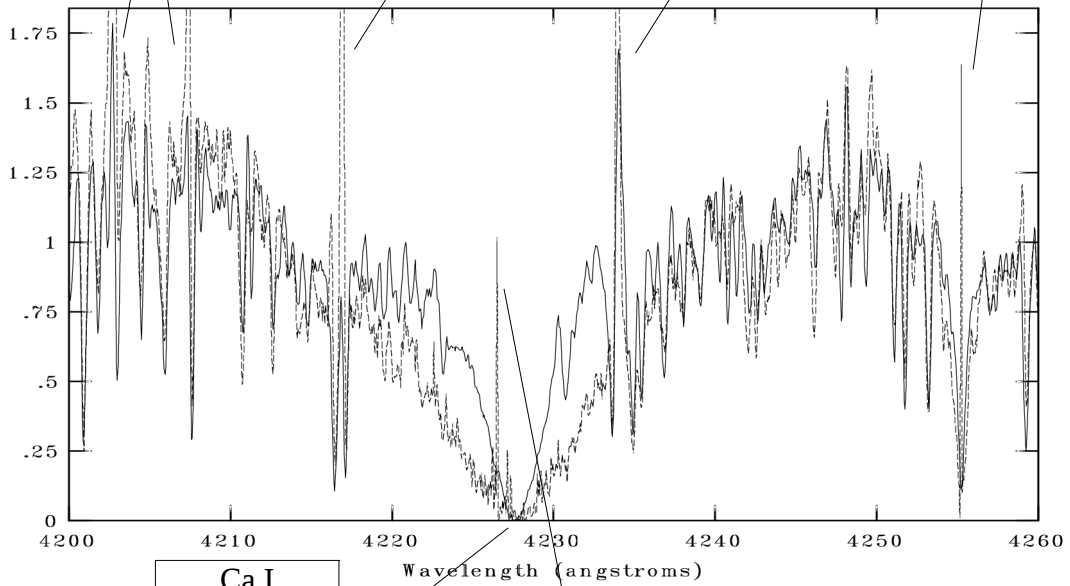
Fe I  
4 202.029 Å  
4 206.696 Å  
Joy

Fe I  
4 216.183 Å  
NIST

Fe II  
4 233.162 Å  
Joy

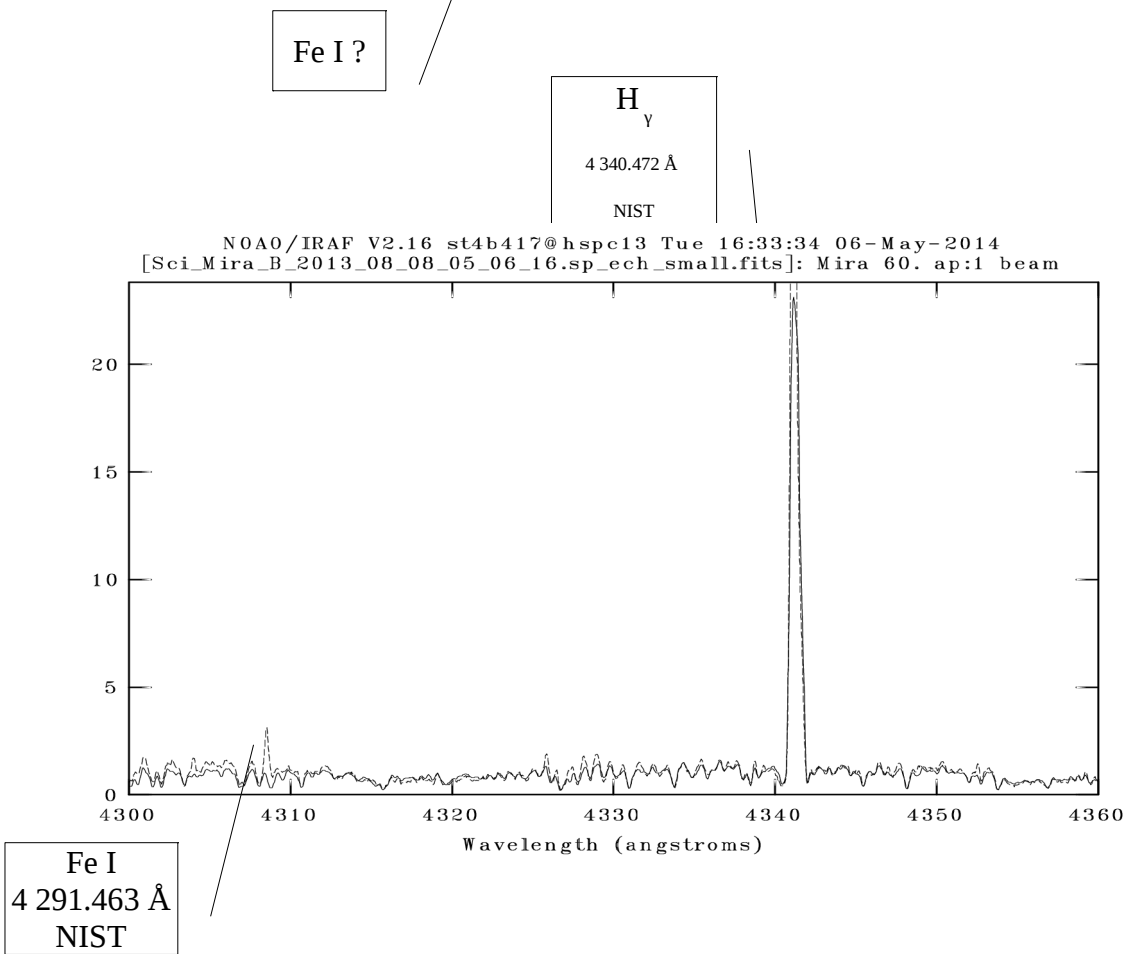
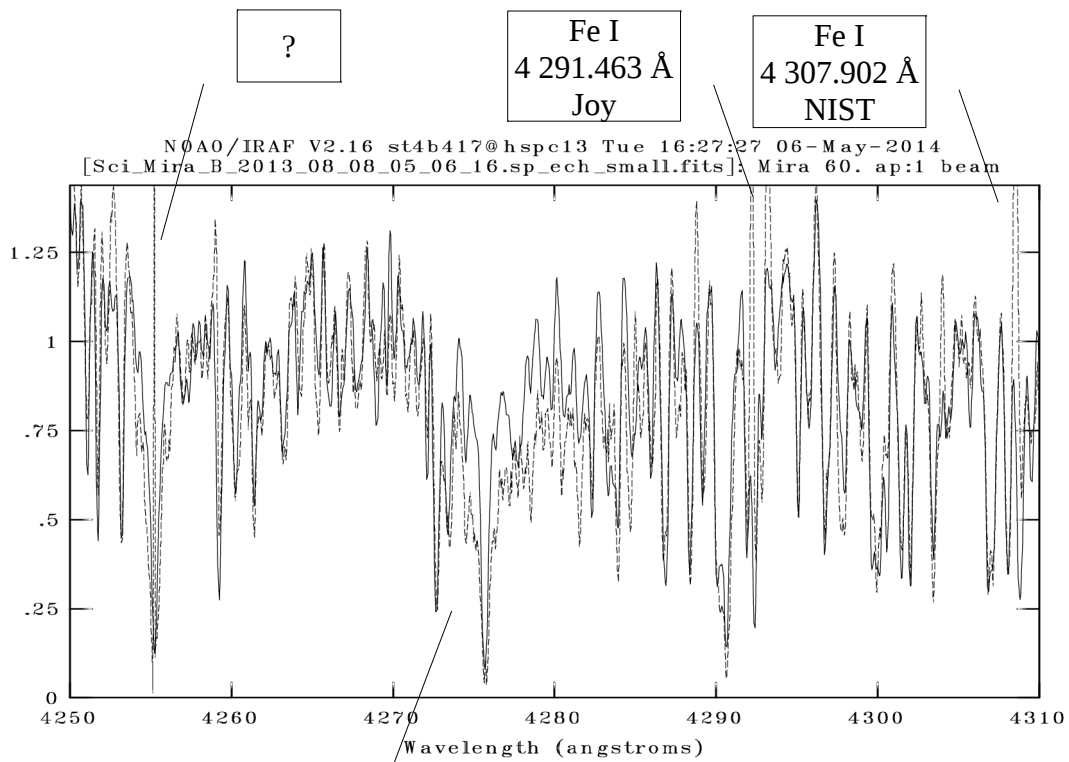
?

NOAO/IRAF V2.16 st4b417@hspc13 Tue 16:22:52 06-May-2014  
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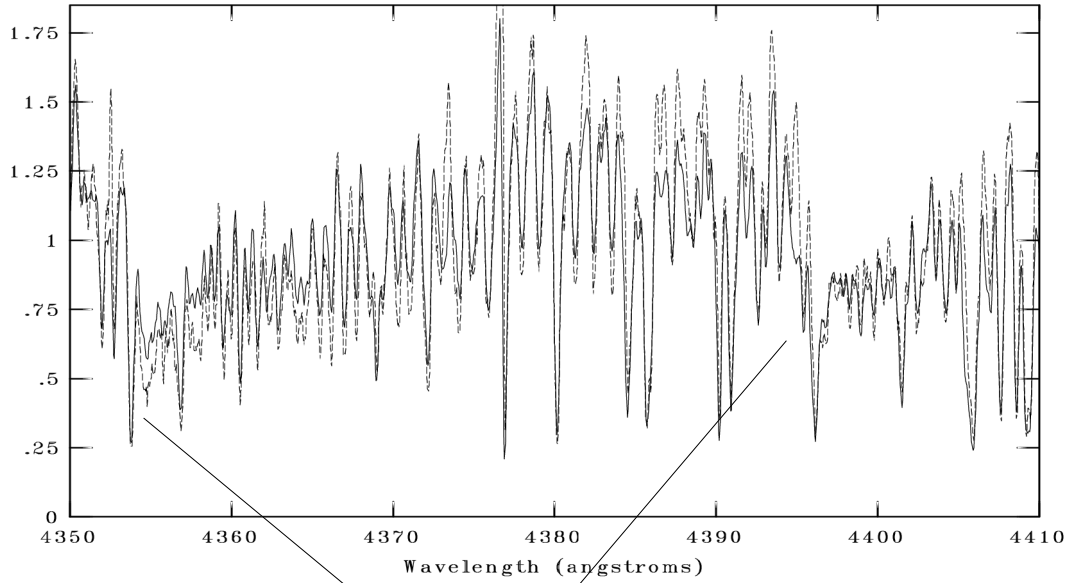
Ca I  
4 226.72 Å  
NIST

?

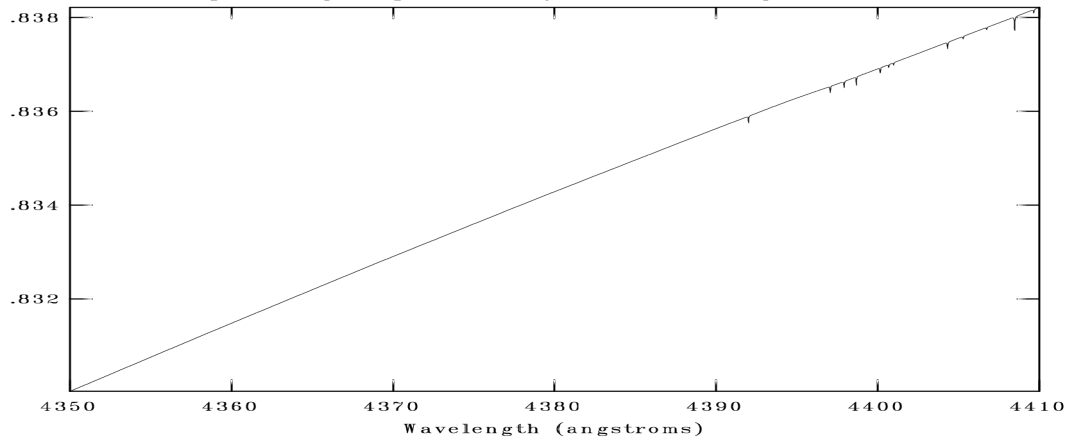




NOAO/IRAF V2.16 st4b417@hspc13 Tue 16:41:03 06-May-2014  
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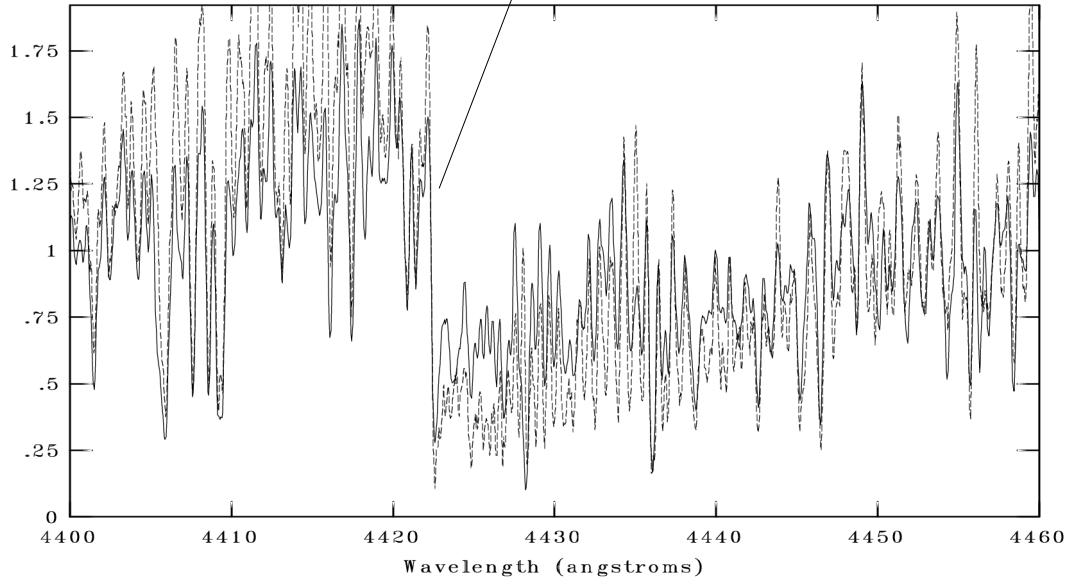


NOAO/IRAF V2.16 st4b417@hspc13 Mon 14:58:27 12-May-2014  
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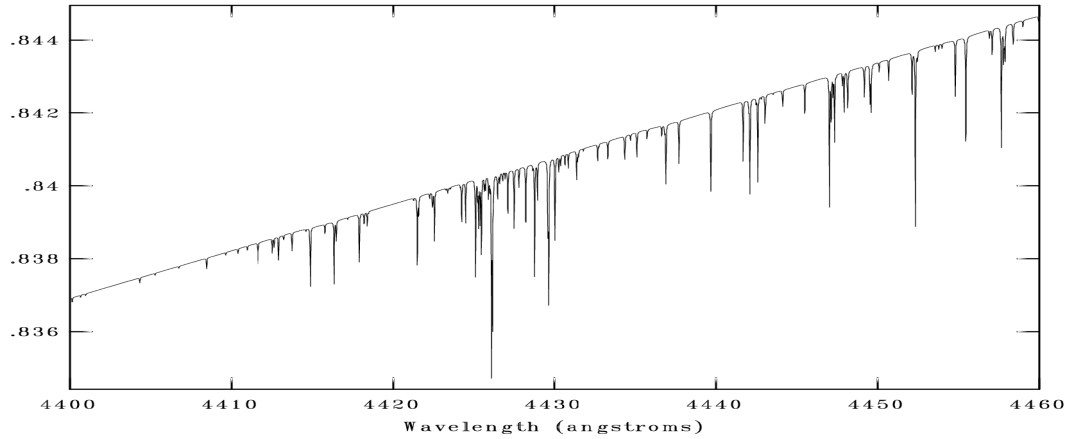


TiO  
4 422.599 Å  
Walker

NOAO/IRAF V2.16 st4b417@hspc13 Tue 16:45:40 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam

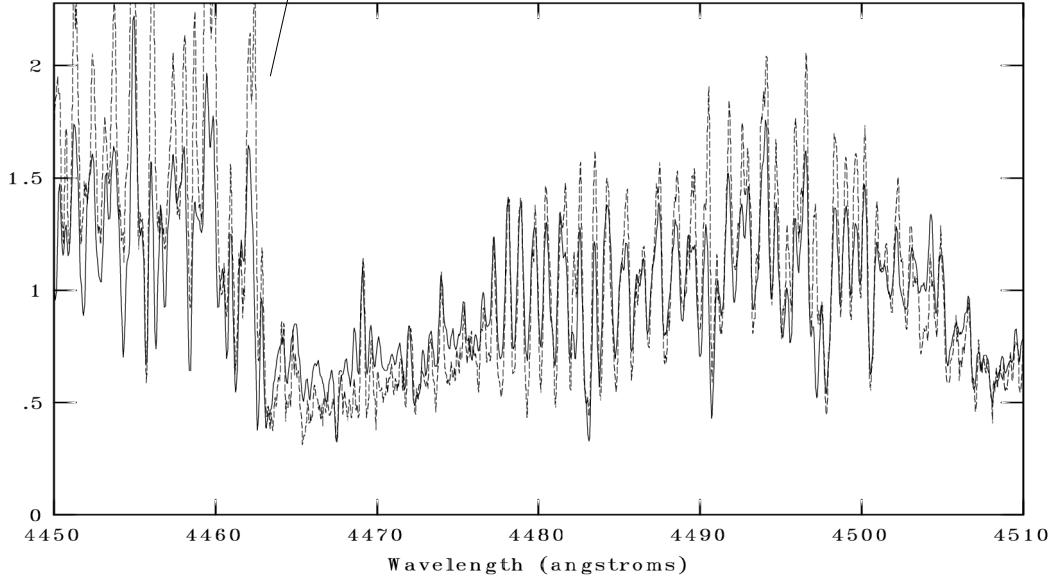


NOAO/IRAF V2.16 st4b417@hspc13 Mon 14:59:10 12-May-2014  
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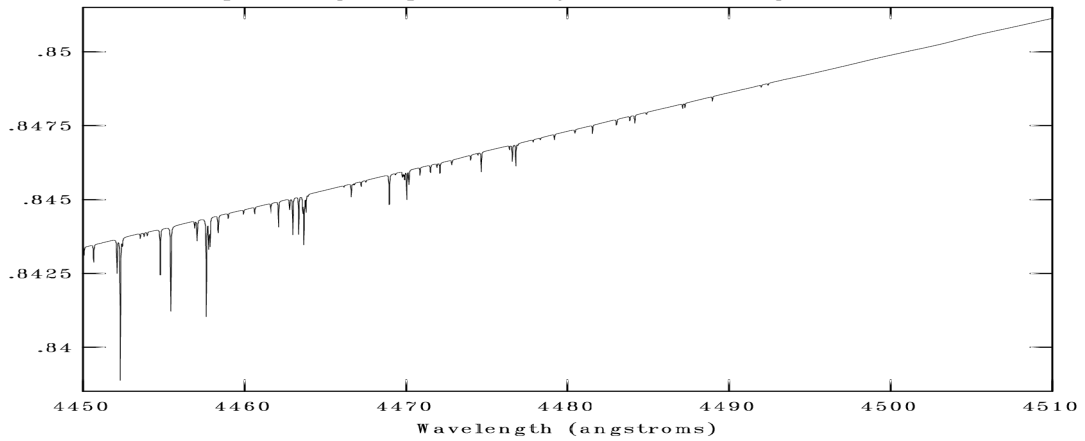


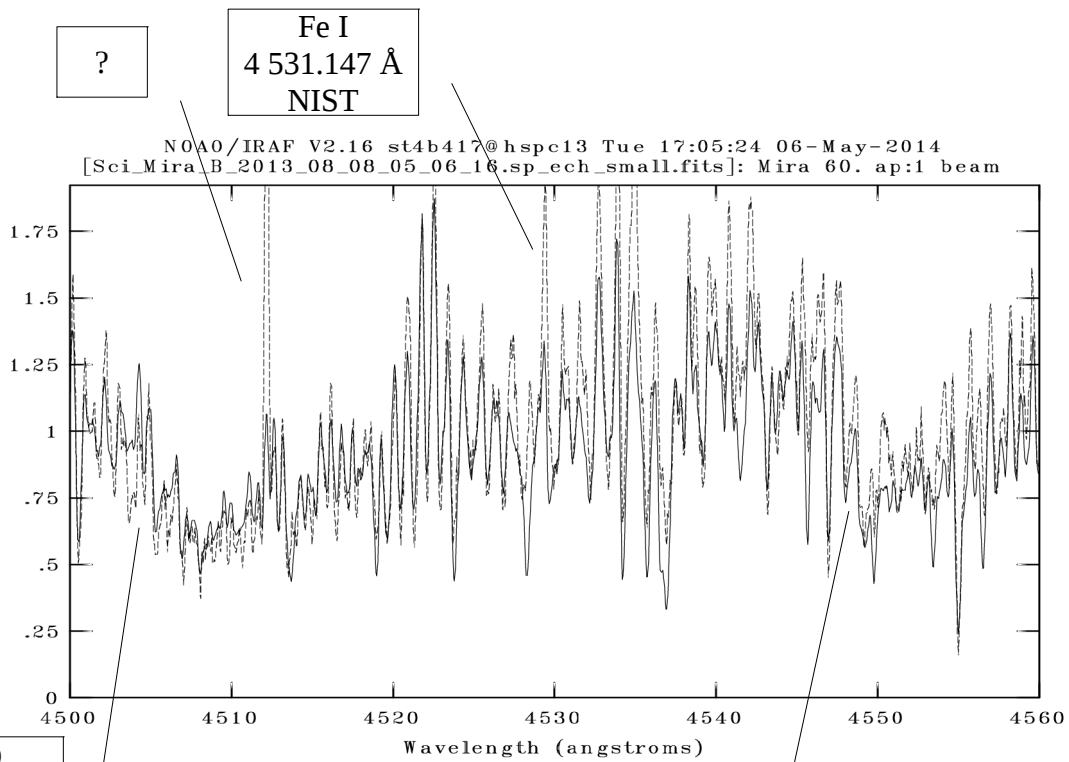
TiO  
4 462.025 Å  
Walker

NOAO/IRAF V2.16 st4b417@hspc13 Tue 16:50:20 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



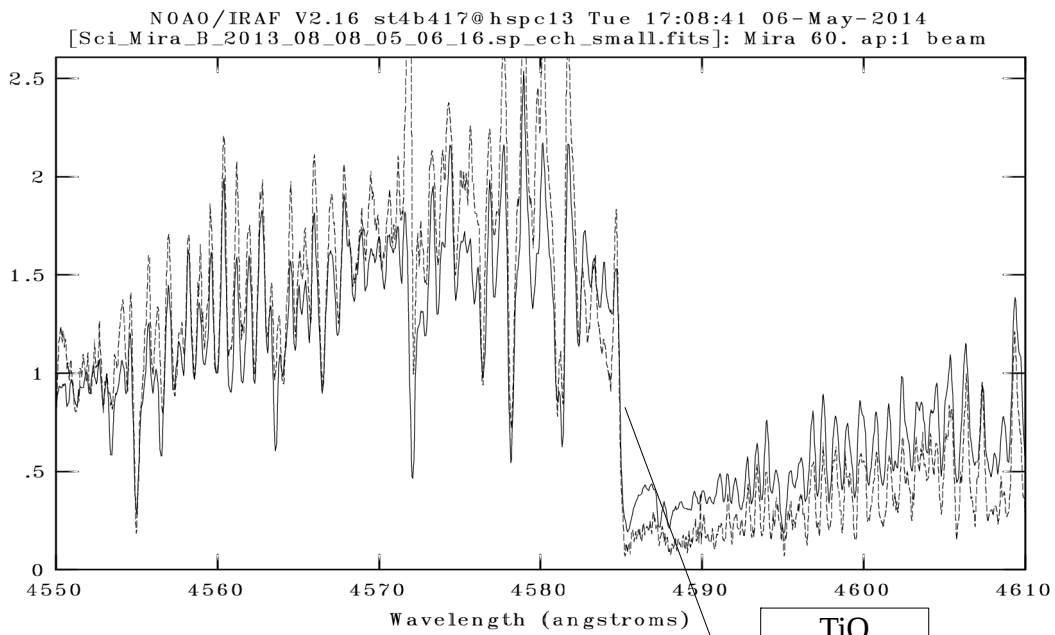
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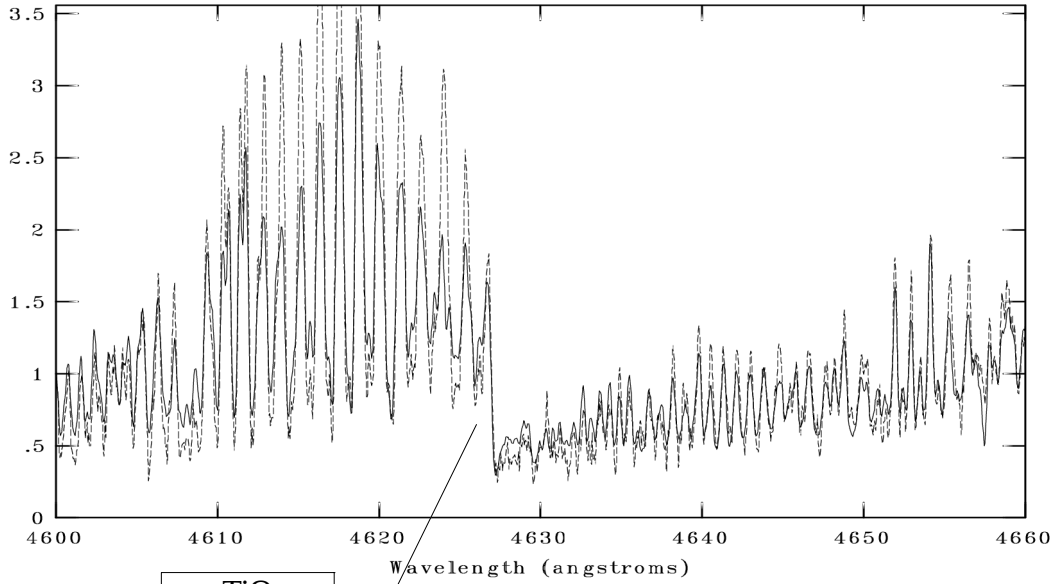
TiO  
 4 506.142 Å  
 Walker

TiO  
 4 548.986 Å  
 Walker



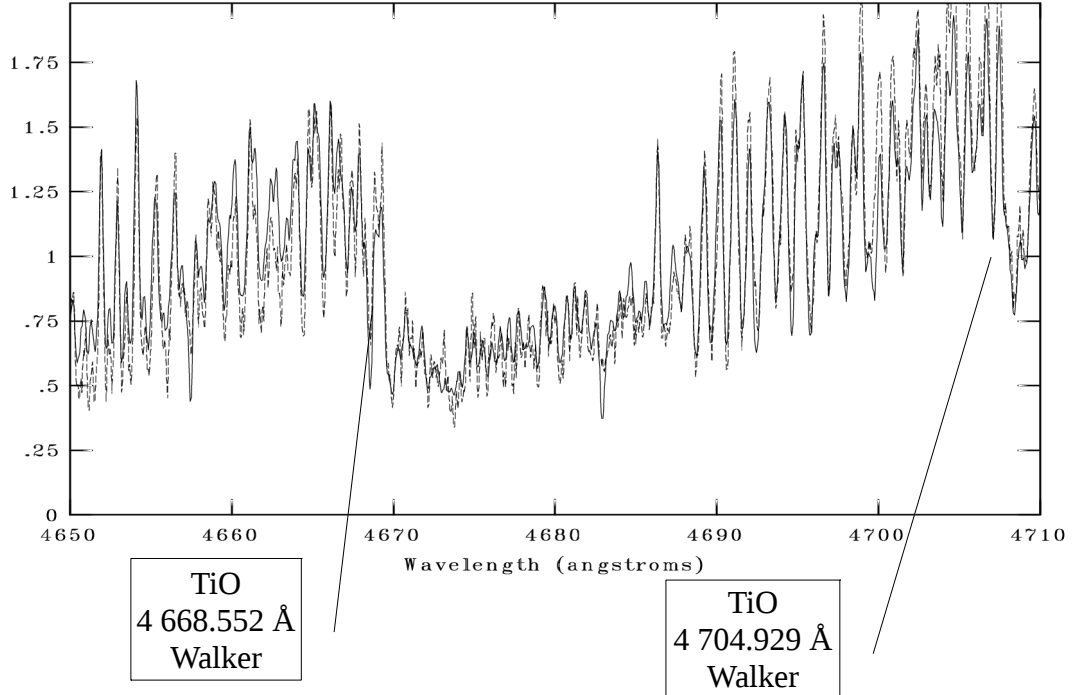
TiO  
 4 584.817 Å  
 Walker

NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:11:10 06-May-2014  
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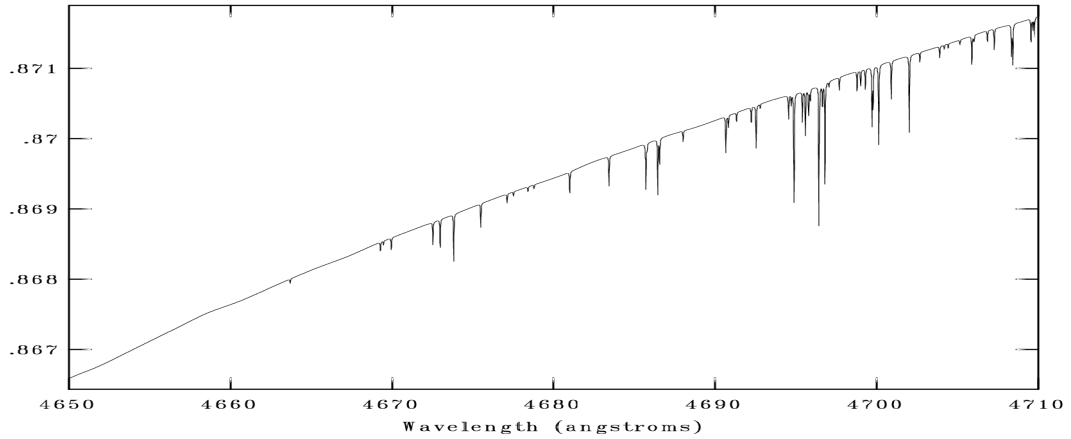


TiO  
4 626.934 Å  
Walker

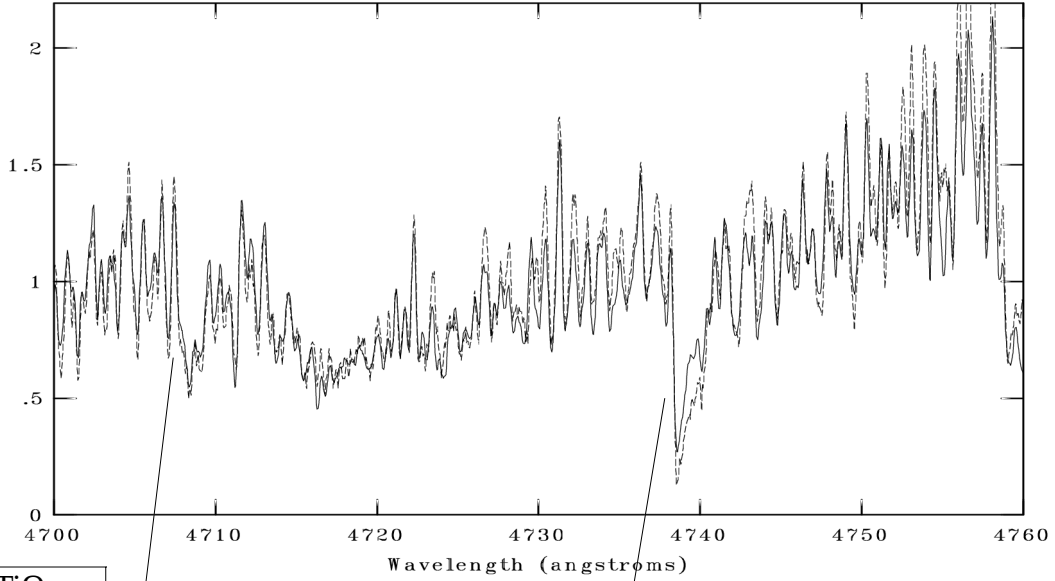
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[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:00:41 12-May-2014  
[all\_4000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



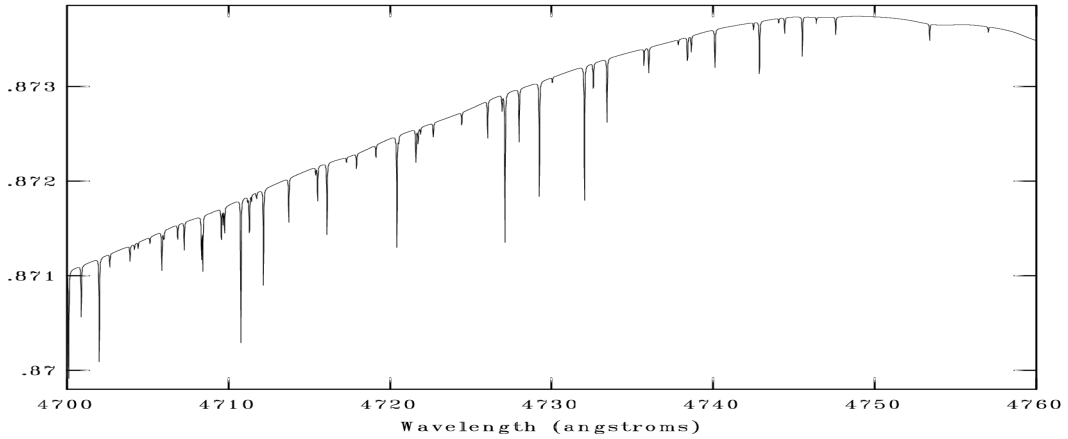
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[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



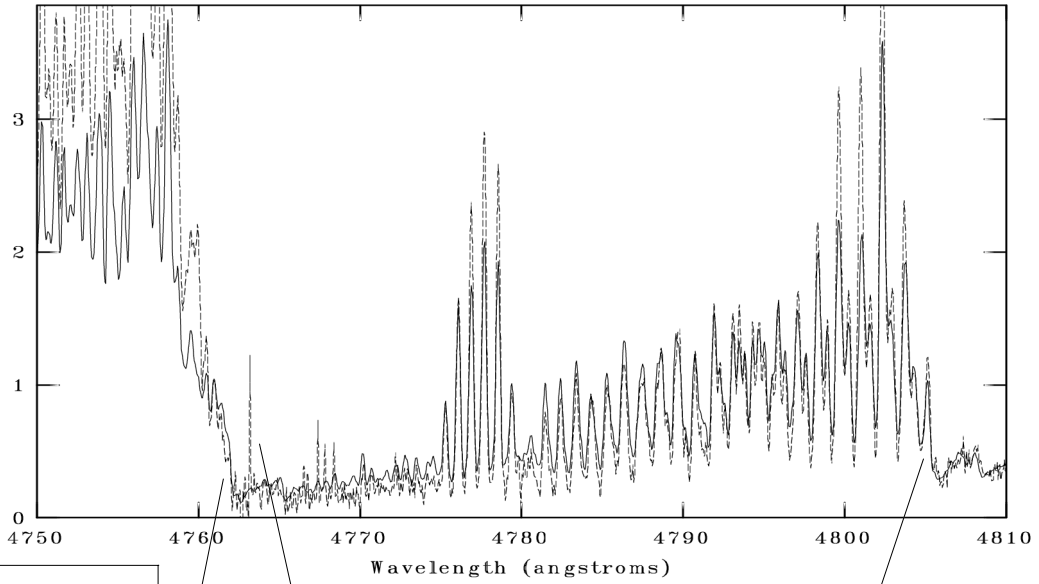
TiO  
4 704.929 Å  
Walker

Maybe TiO  
4 739.637 Å  
or several others like  
Mn I or Fe I  
VALD/NIST

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:01:25 12-May-2014  
[all\_4000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:18:22 06-May-2014  
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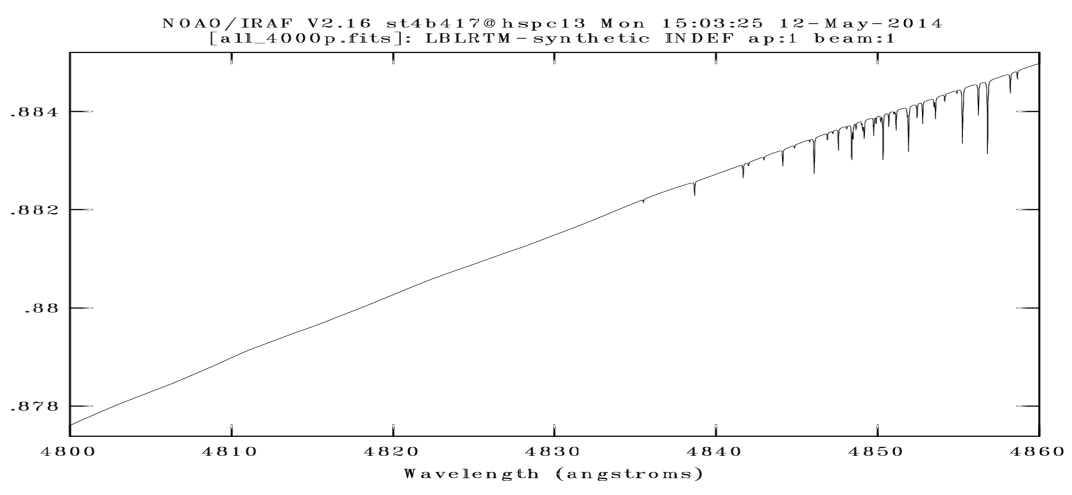
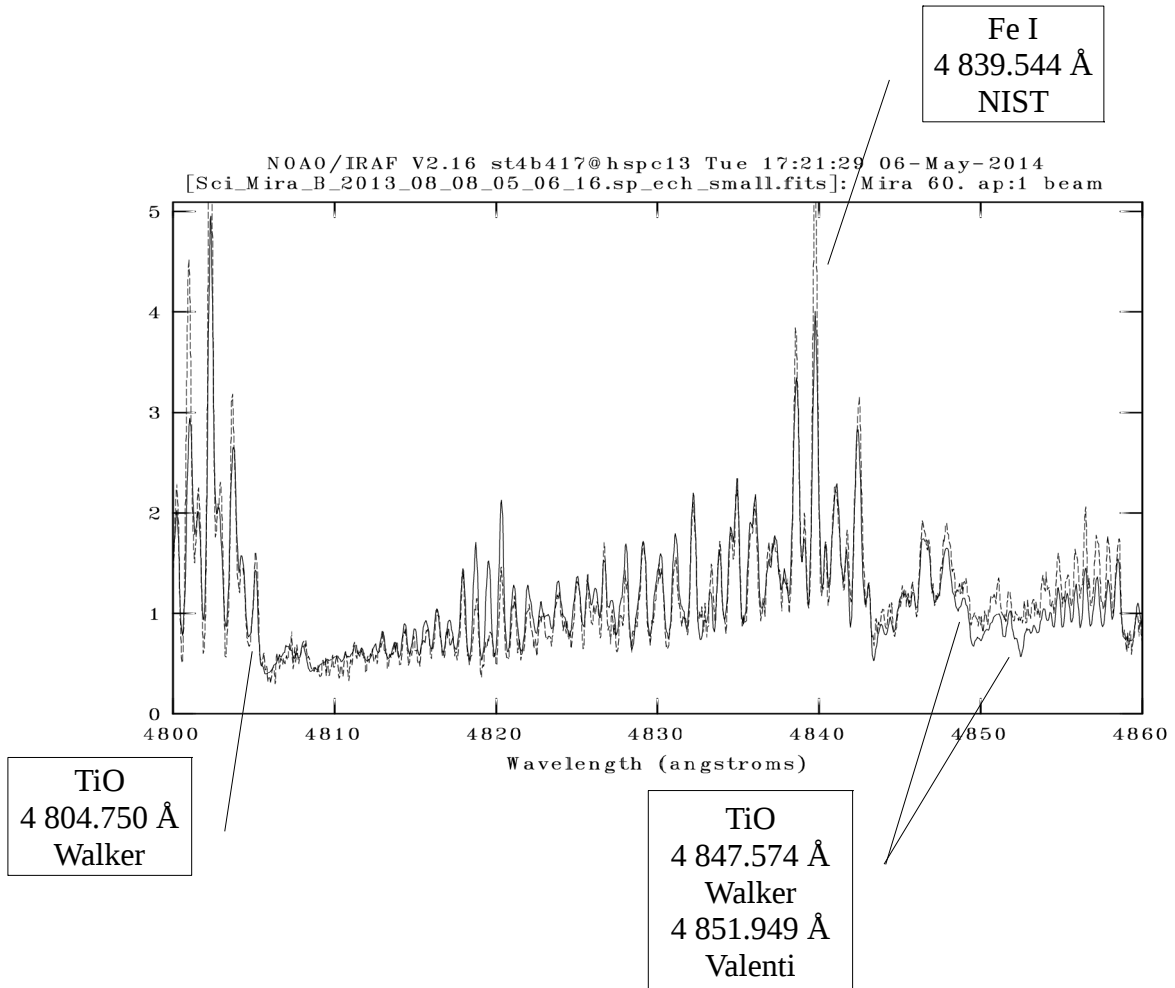


TiO  
4 761.931 Å  
Walker

Reduction artefact

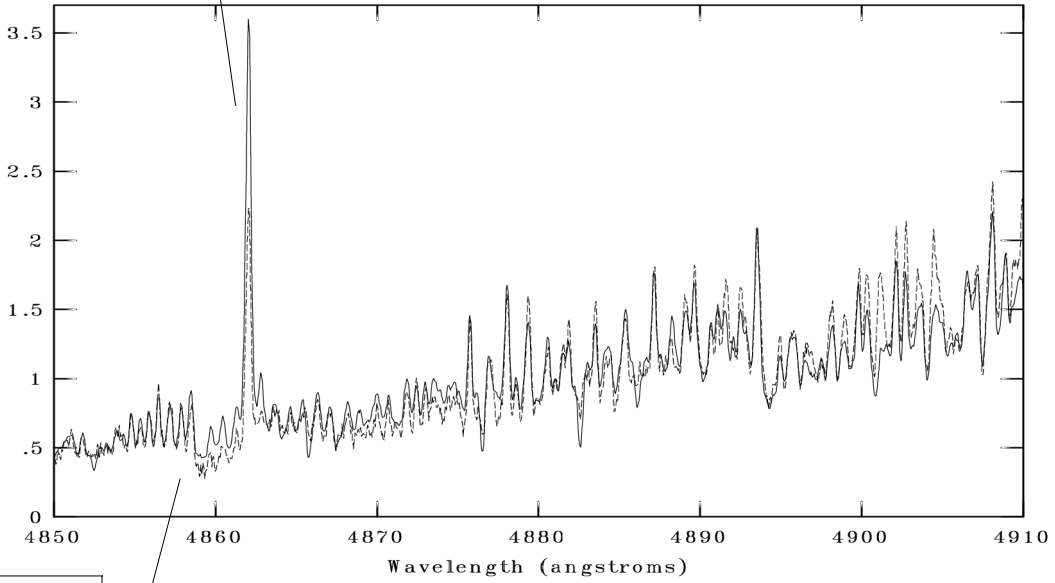
TiO  
4 804.750 Å  
Walker





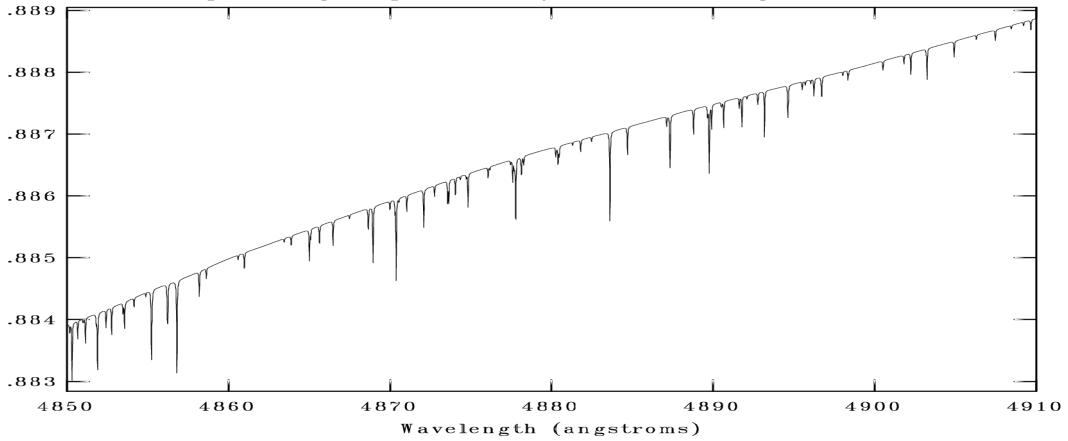
$H_{\beta}$   
4861.35 Å  
NIST

NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:23:34 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



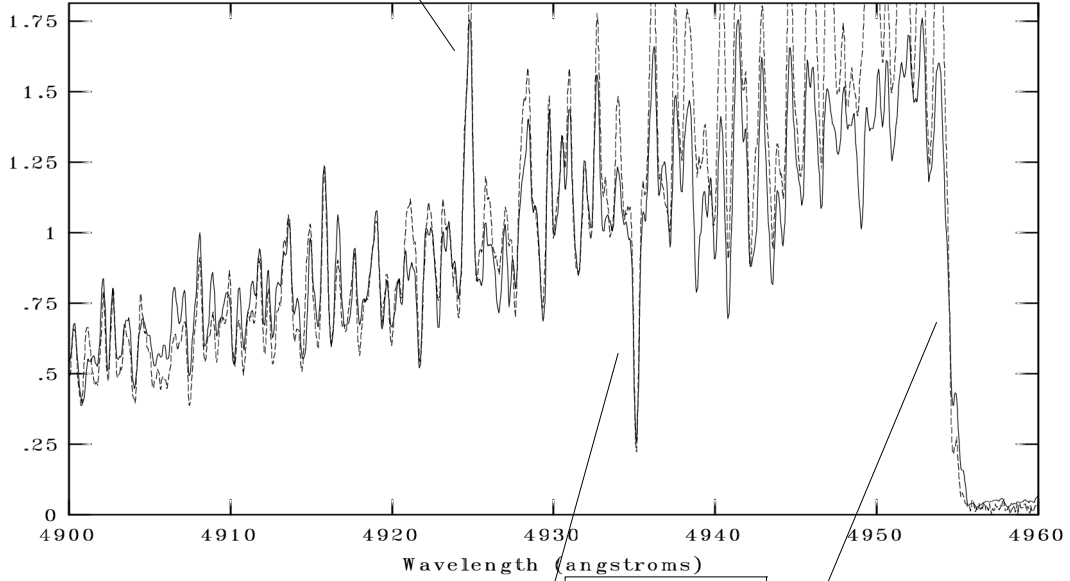
TiO  
4 856.791 Å  
Valenti

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:03:56 12-May-2014  
[all\_4000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



Fe I  
4 924.769 Å  
NIST

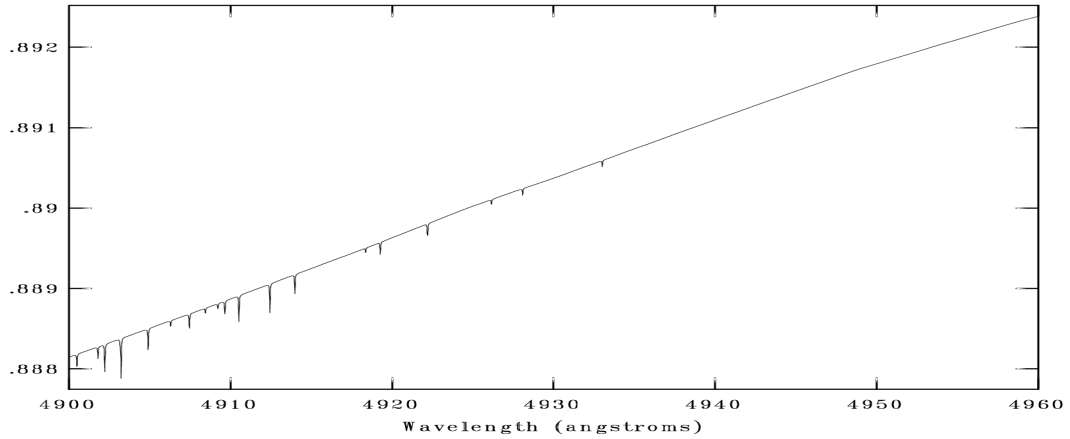
NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:25:55 06-May-2014  
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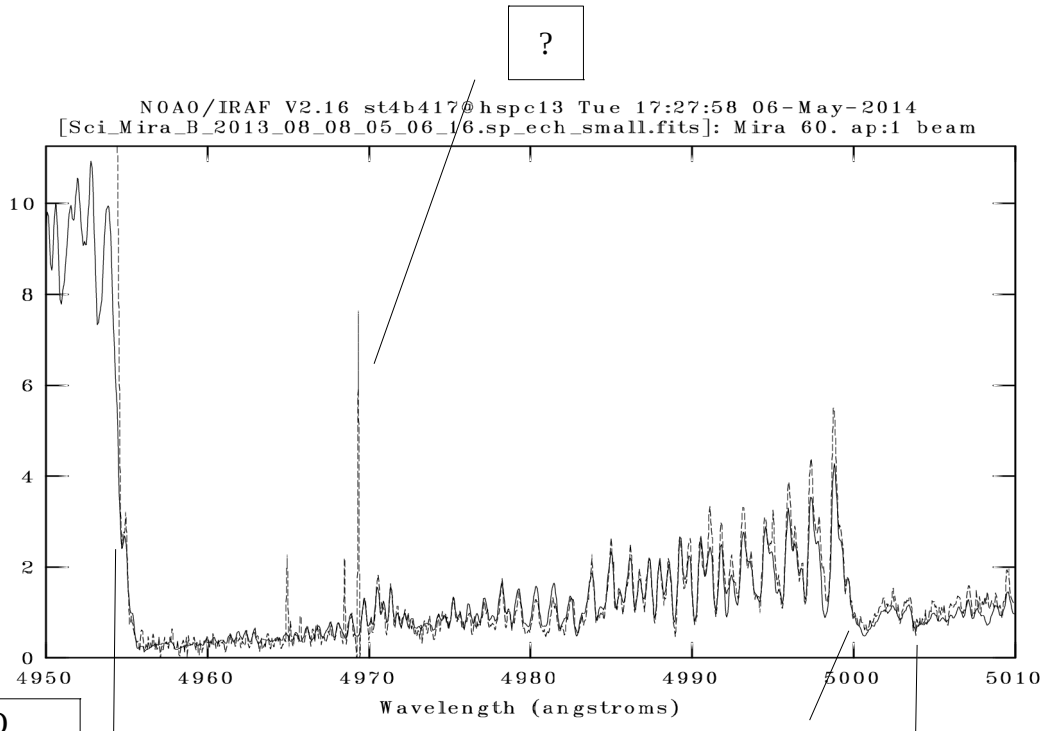


Blend of  
Fe I : 4 934.005 Å  
and  
Ba II : 4 934.076 Å (?)  
NIST/VALD

TiO  
4 955.475 Å  
Walker

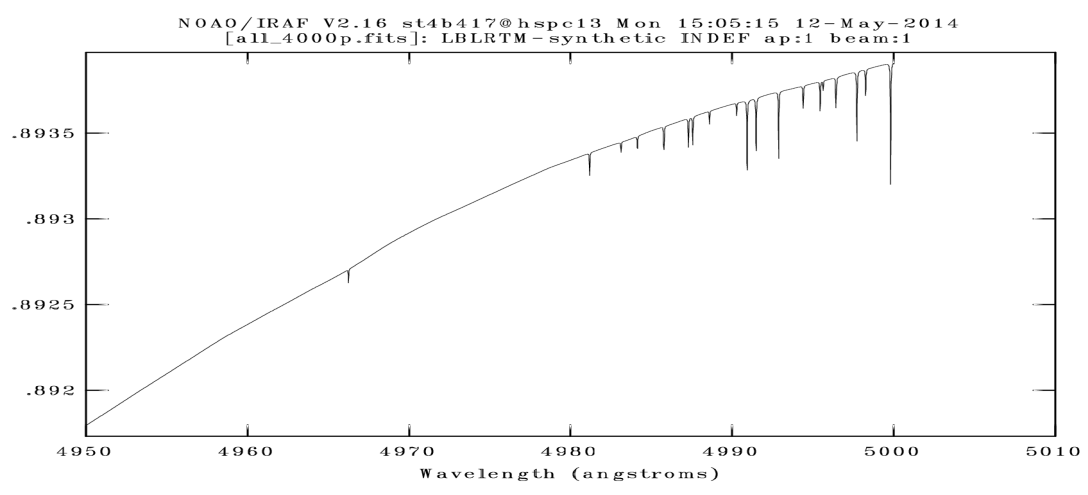
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[all\_4000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



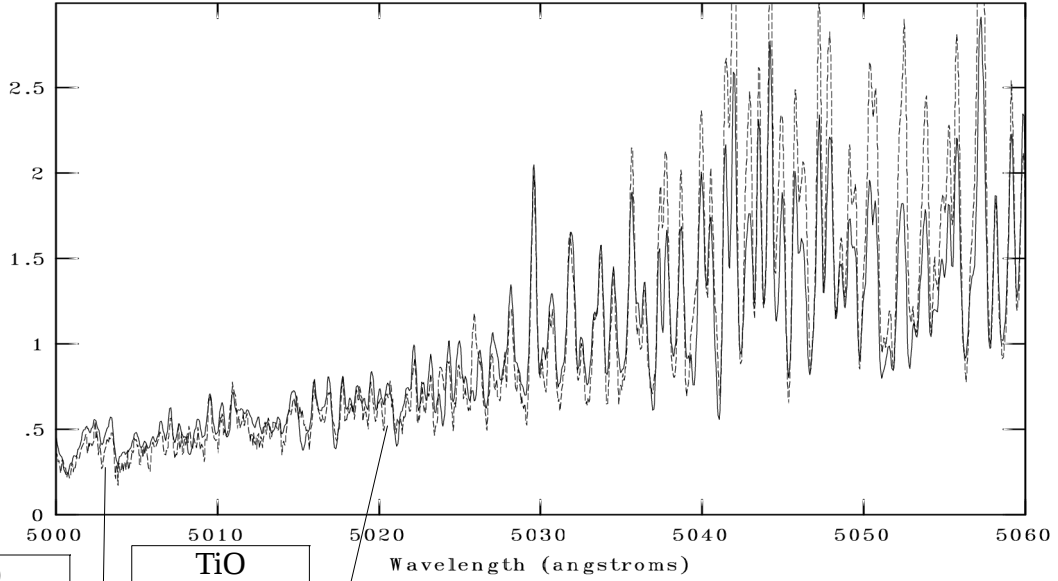


TiO  
 4 955.475 Å  
 Walker

TiO  
 4 998.882 Å  
 Valenti  
 5 003.028 Å  
 Walker



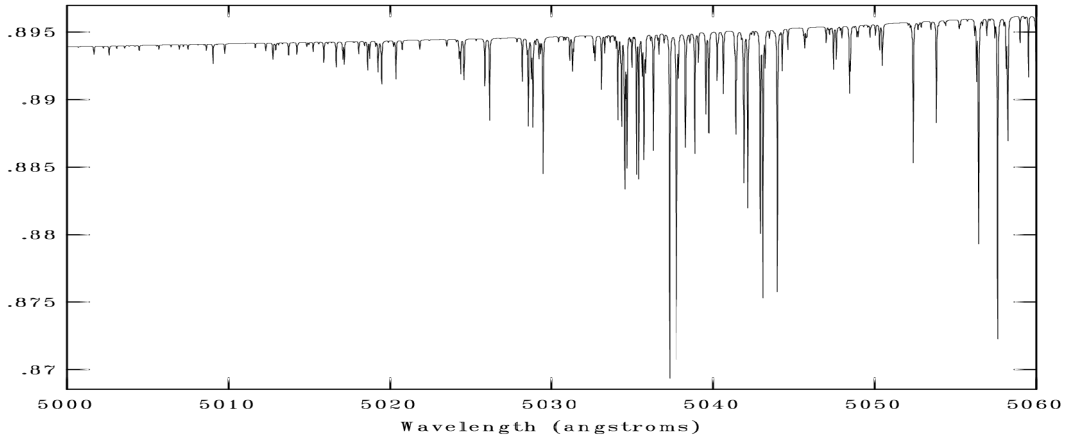
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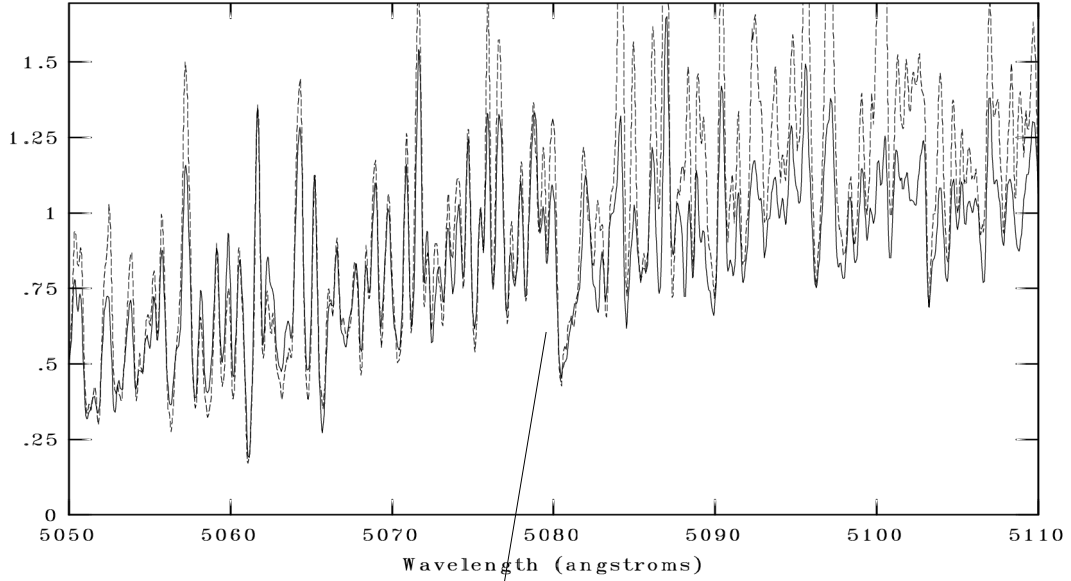
TiO  
5 003.028 Å  
Walker

TiO  
5 020.893 Å  
Walker

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:06:21 12-May-2014  
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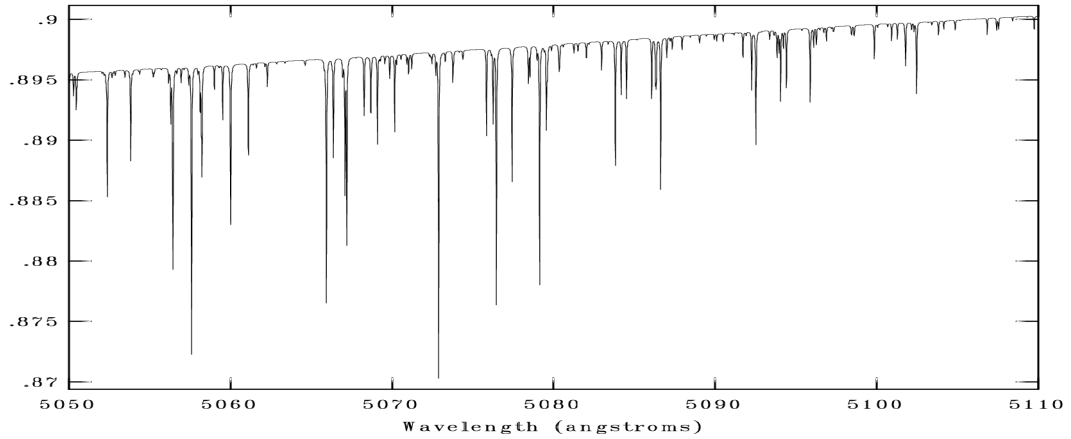


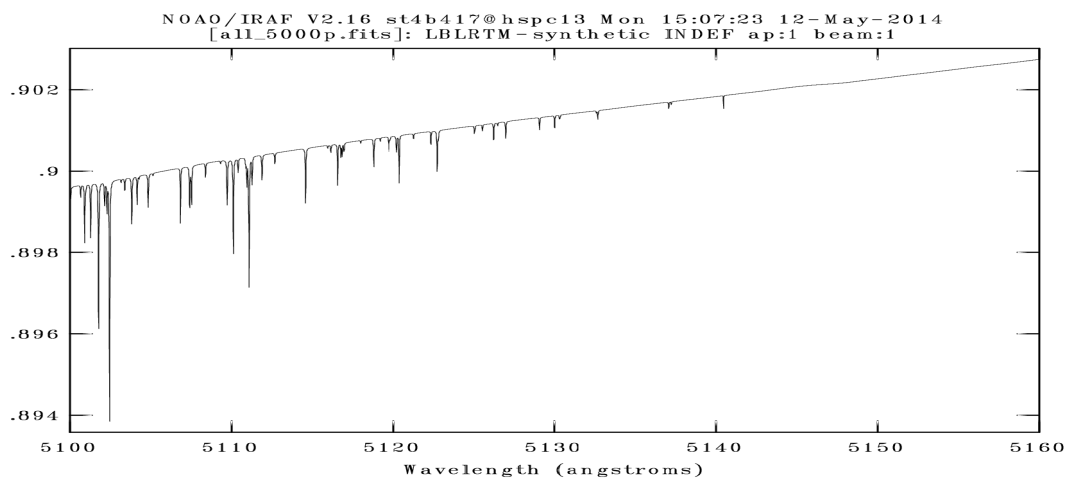
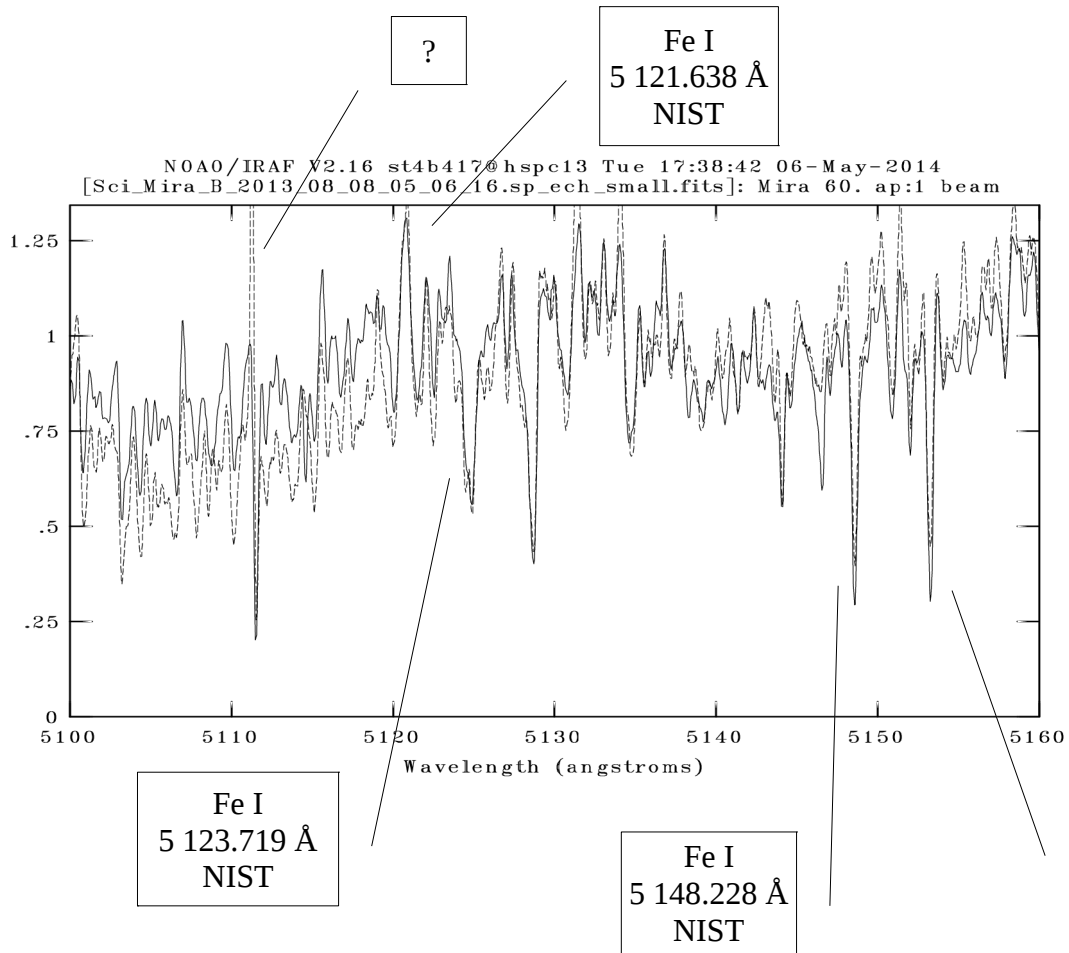
NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:33:39 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



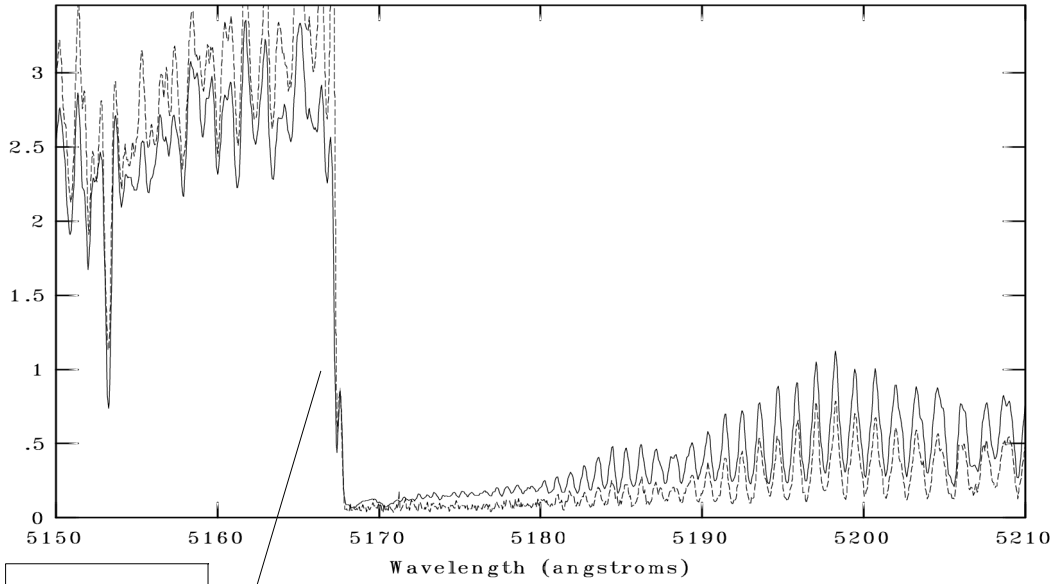
TiO  
5 080.282 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:06:55 12-May-2014  
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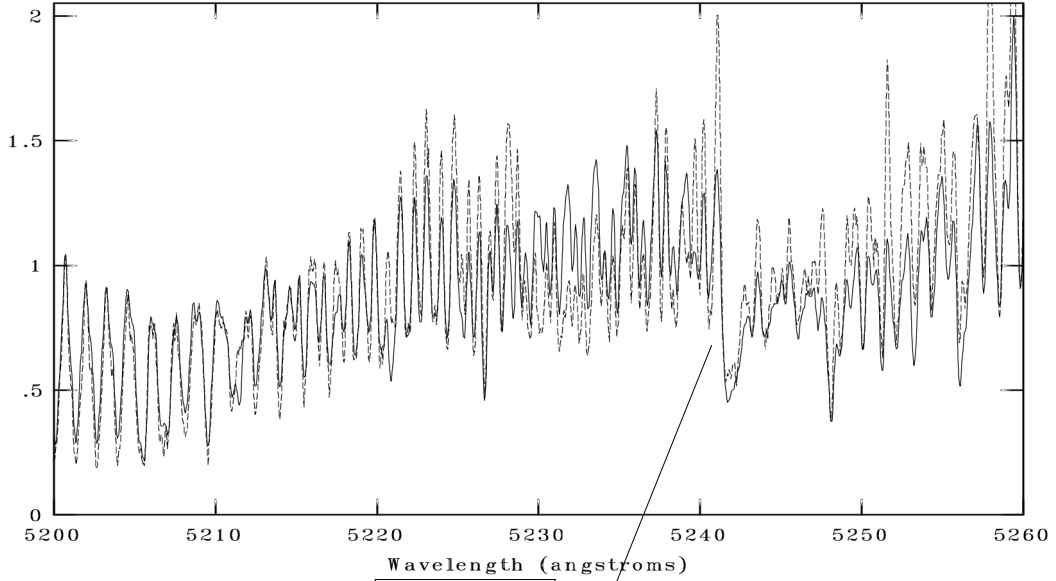
NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:41:11 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



TiO  
5 167.777 Å  
Walker

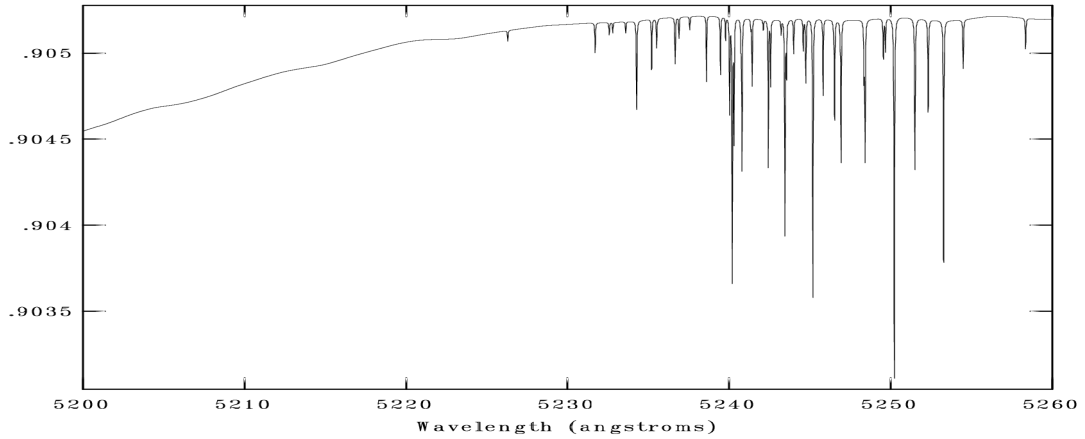


NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:43:18 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam

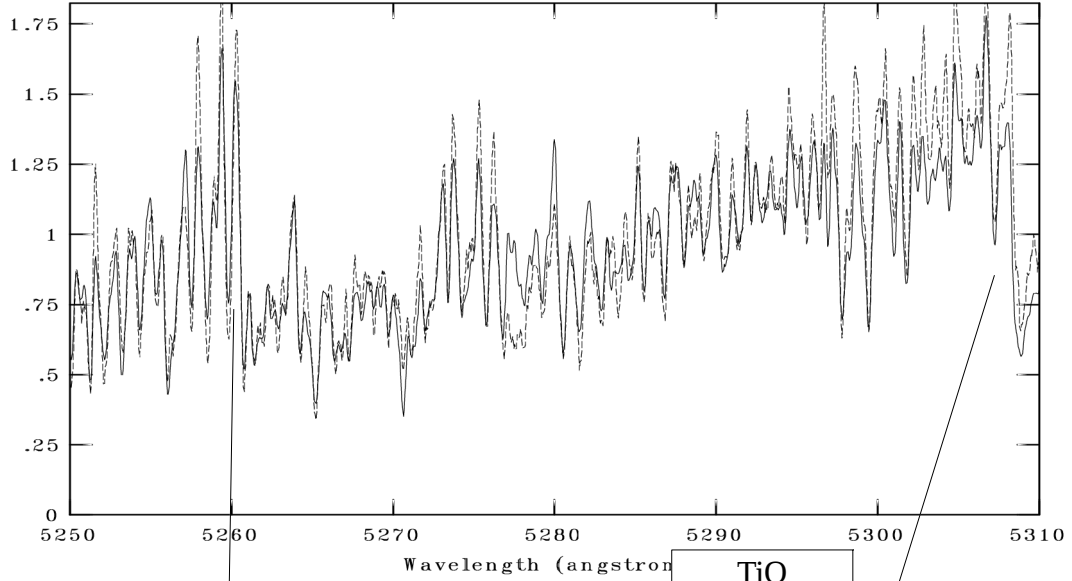


TiO  
5 240.878 Å  
Walker

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:08:07 12-May-2014  
[all\_5000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



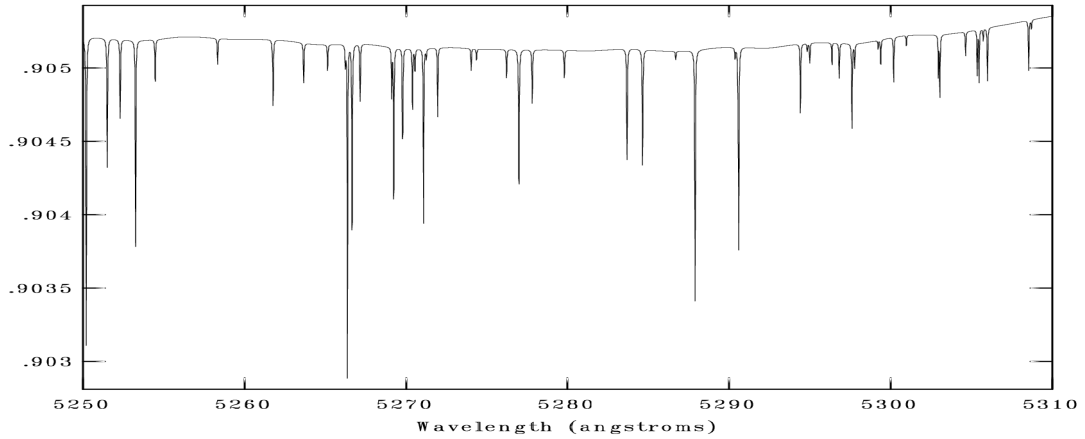
NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:45:20 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



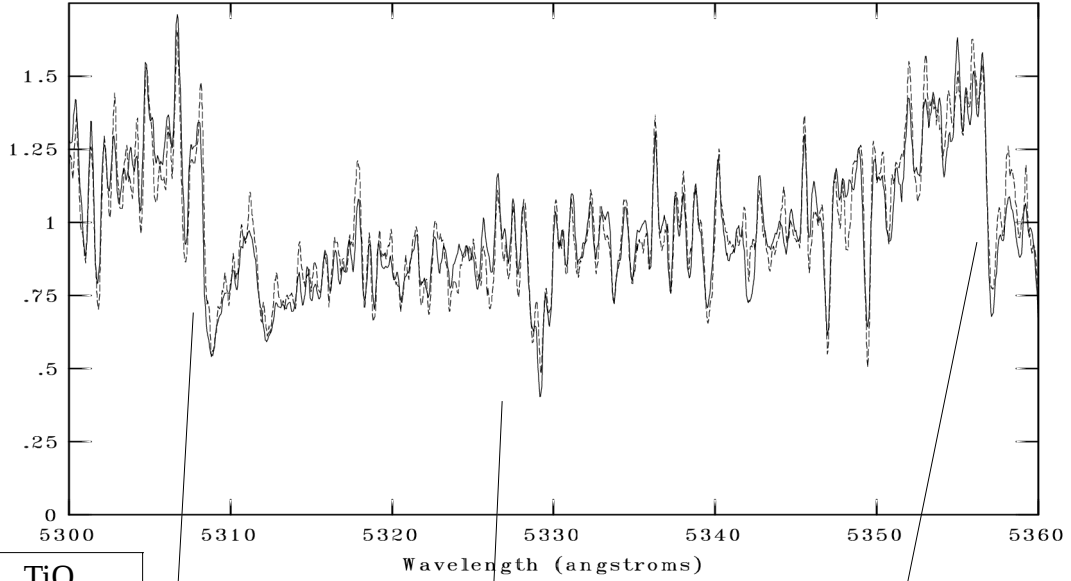
TiO  
5 262.759 Å  
VALD

TiO  
5 308.010 Å  
Walker

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:09:00 12-May-2014  
[all\_5000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:47:16 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam

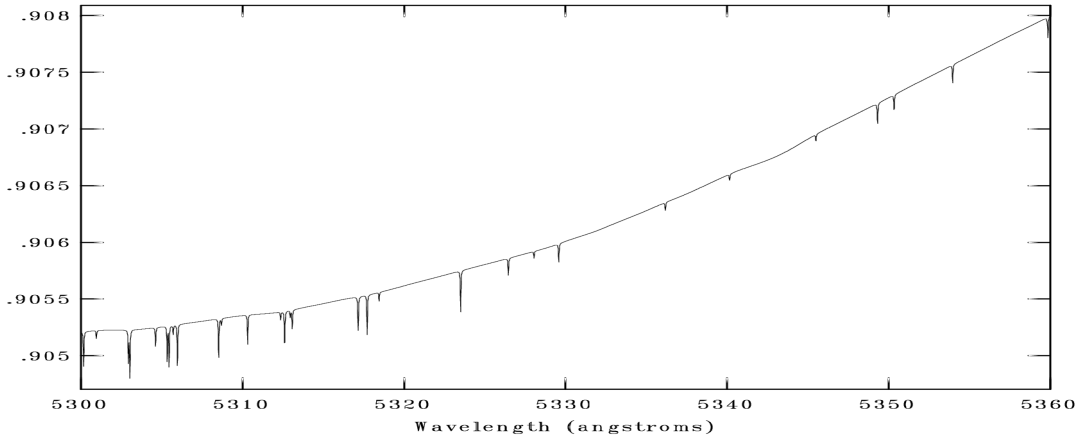


TiO  
5 308.010 Å  
Walker

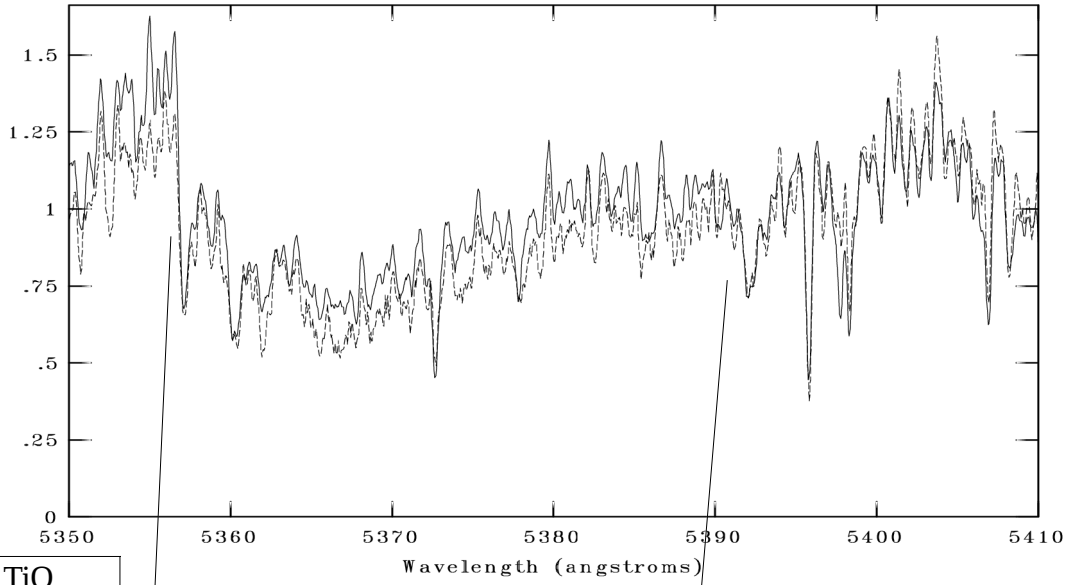
TiO  
5 328.310 Å  
Valenti

TiO  
5 359.913 Å  
Walker

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:09:36 12-May-2014  
[all\_5000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



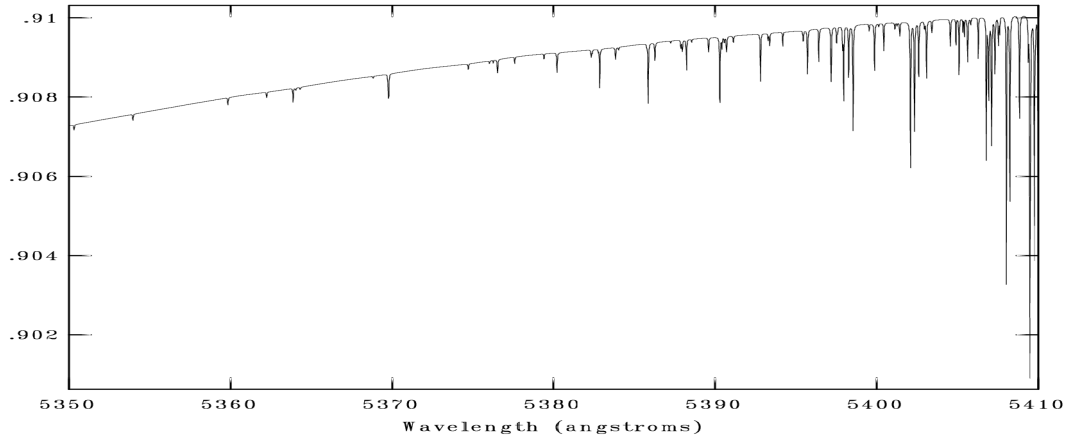
NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:49:29 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



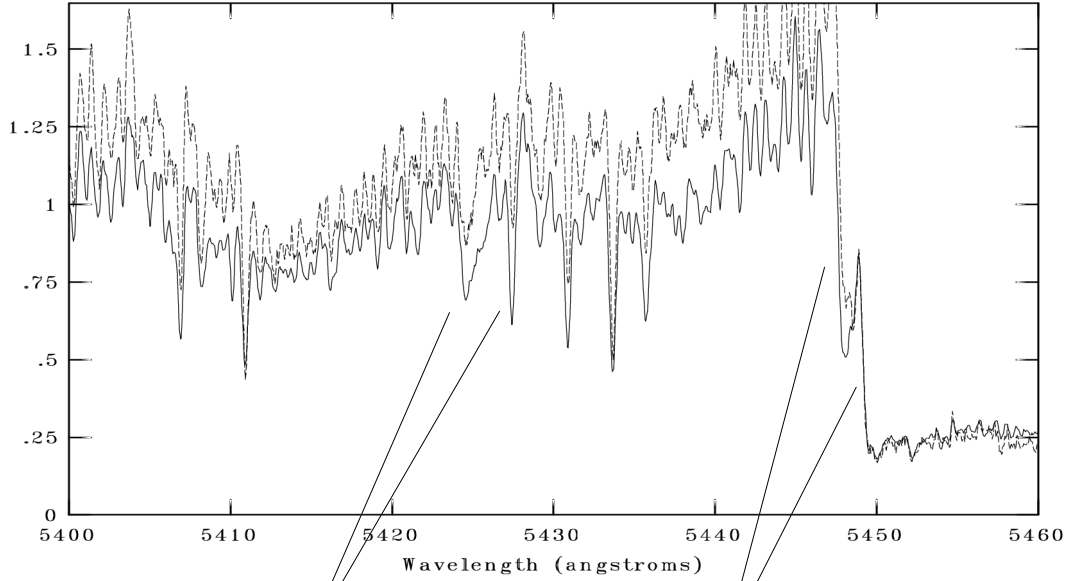
TiO  
5 359.913 Å  
Walker

TiO  
5 391.153 Å  
Valenti

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:10:04 12-May-2014  
[all\_5000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



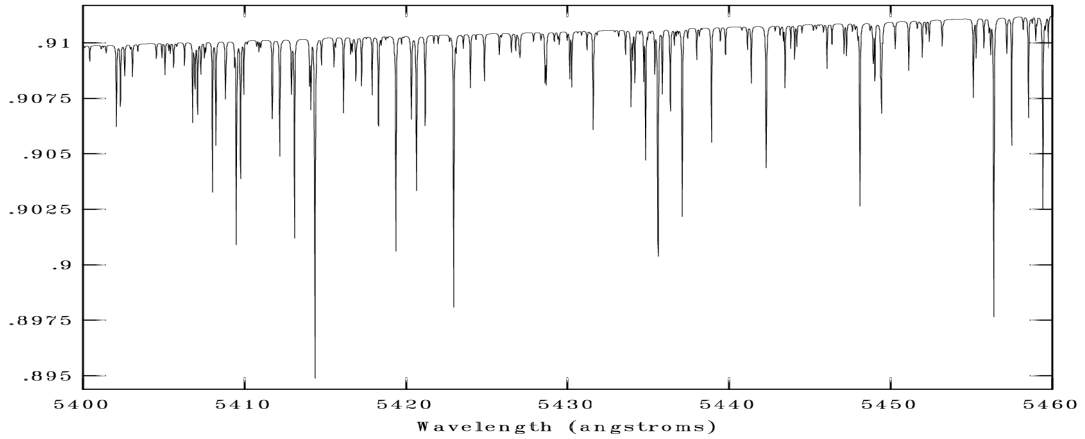
NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:51:31 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



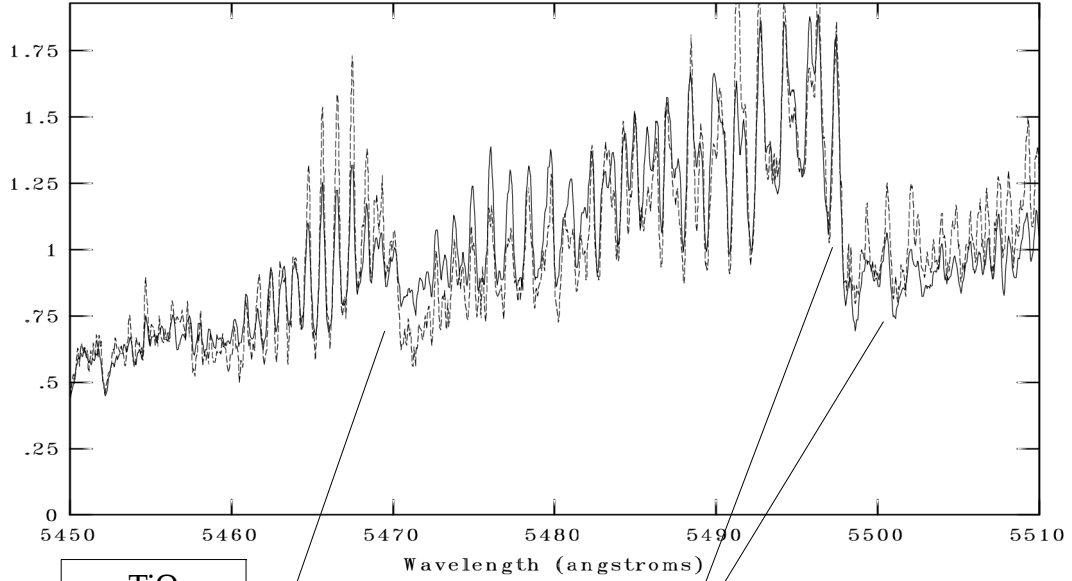
TiO  
5 423.564 Å  
Valenti  
5 427.390 Å  
VALD

TiO  
5 448.282 Å  
5 451.981 Å  
Walker

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:10:30 12-May-2014  
[all\_5000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



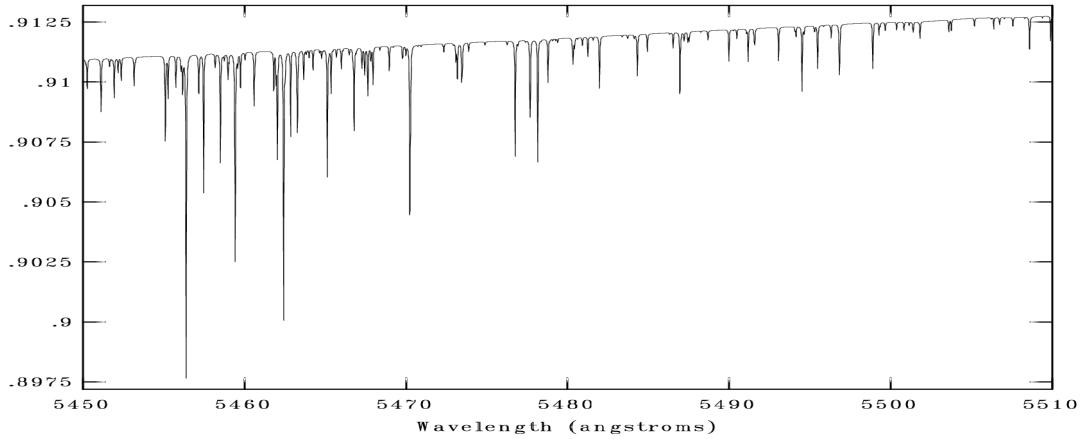
NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:54:25 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



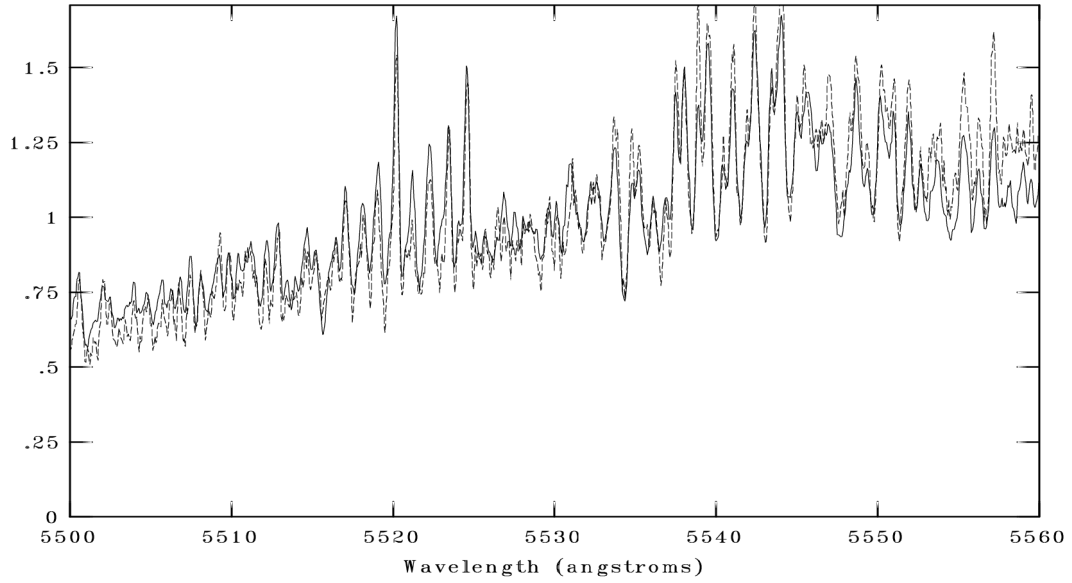
TiO  
5 472.289 Å  
VALD

TiO  
5 497.392 Å  
Walker  
5 499.455 Å  
Valenti

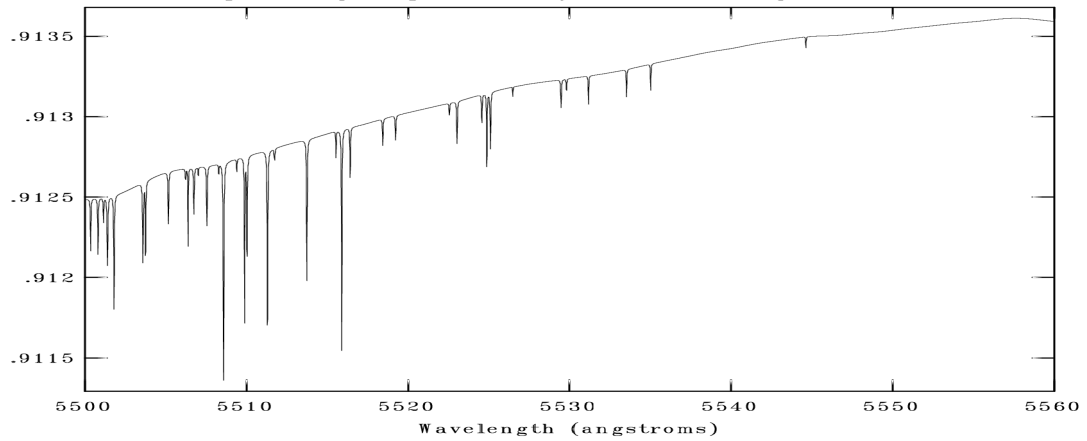
NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:10:53 12-May-2014  
[all\_5000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



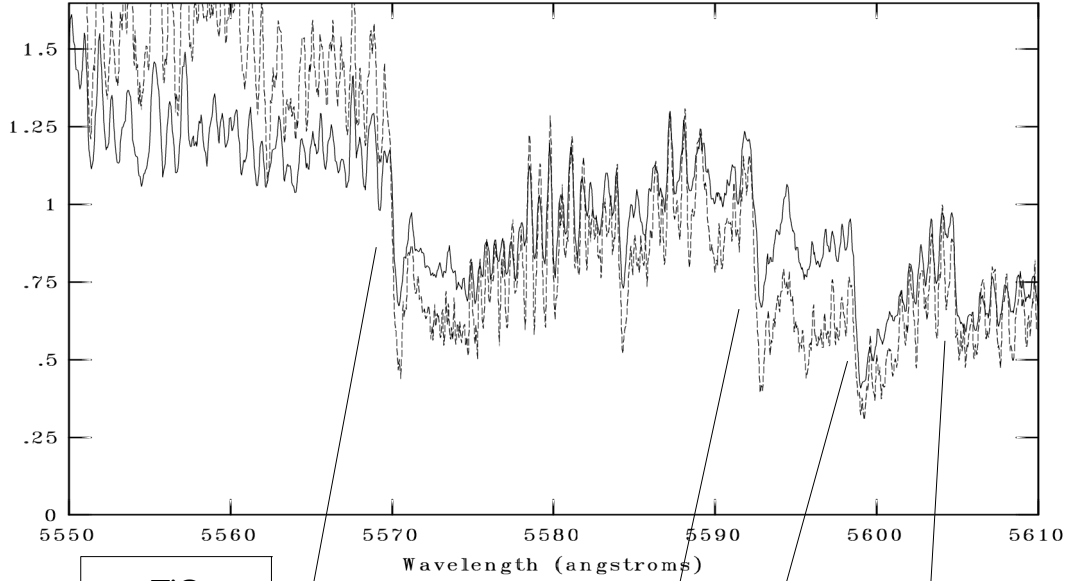
NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:56:29 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:11:29 12-May-2014  
[all\_5000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



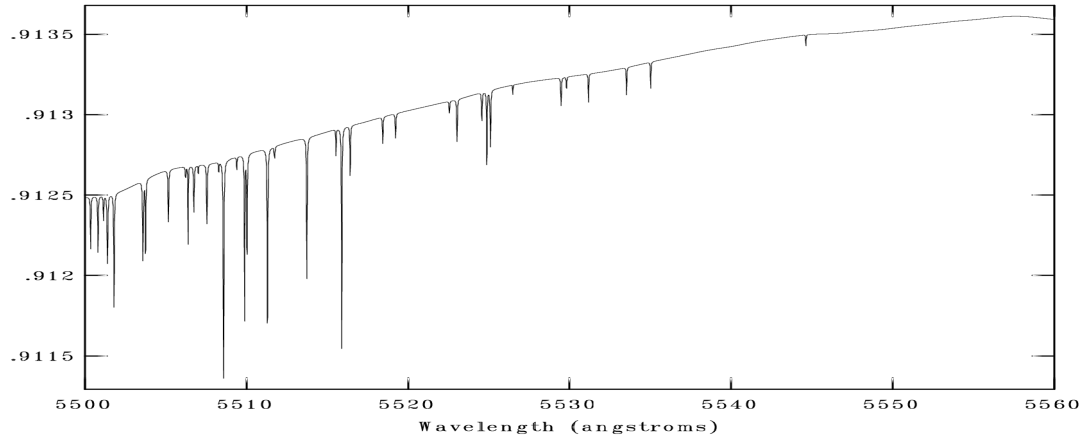
NOAO/IRAF V2.16 st4b417@hspc13 Tue 17:58:41 06-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam



TiO  
5 570.470 Å  
VALD

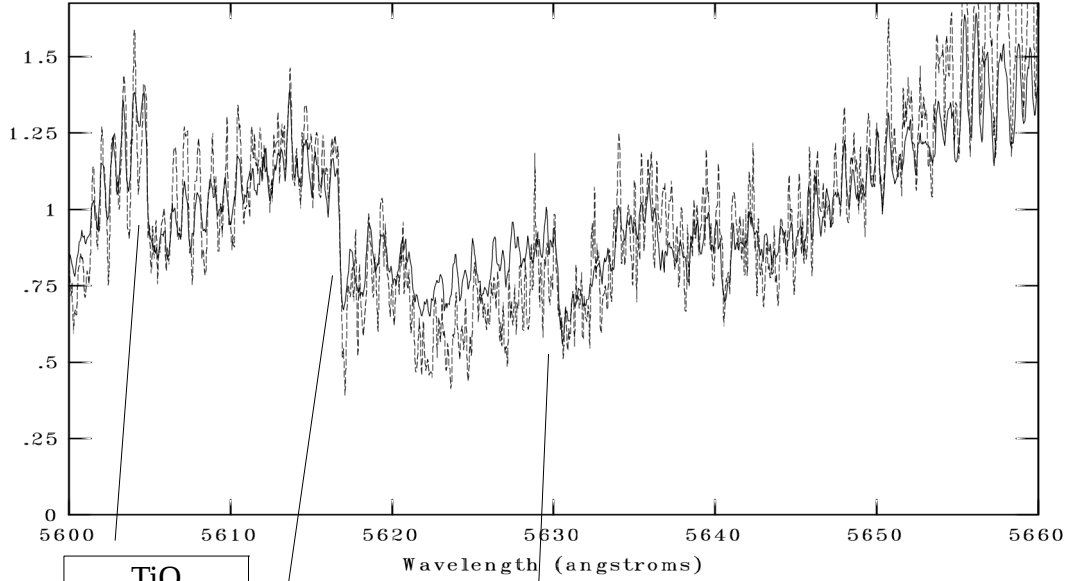
TiO  
5 593.932 Å  
VALD  
5 597.973 Å  
5 603.706 Å  
Walker

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:11:29 12-May-2014  
[all\_5000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

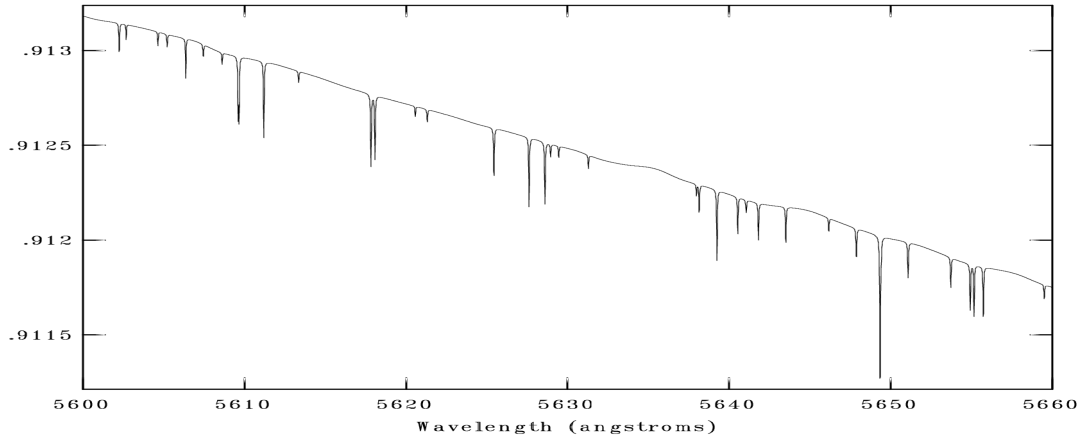


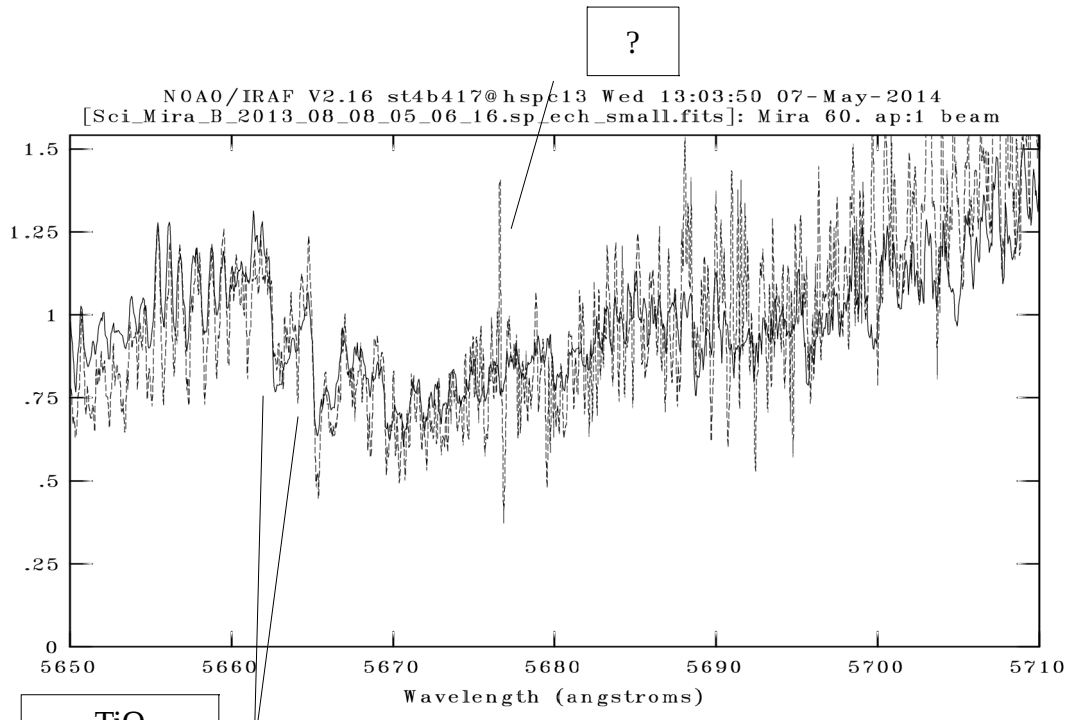


NOAO/IRAF V2.16 st4b417@hspc13 Wed 13:00:43 07-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam

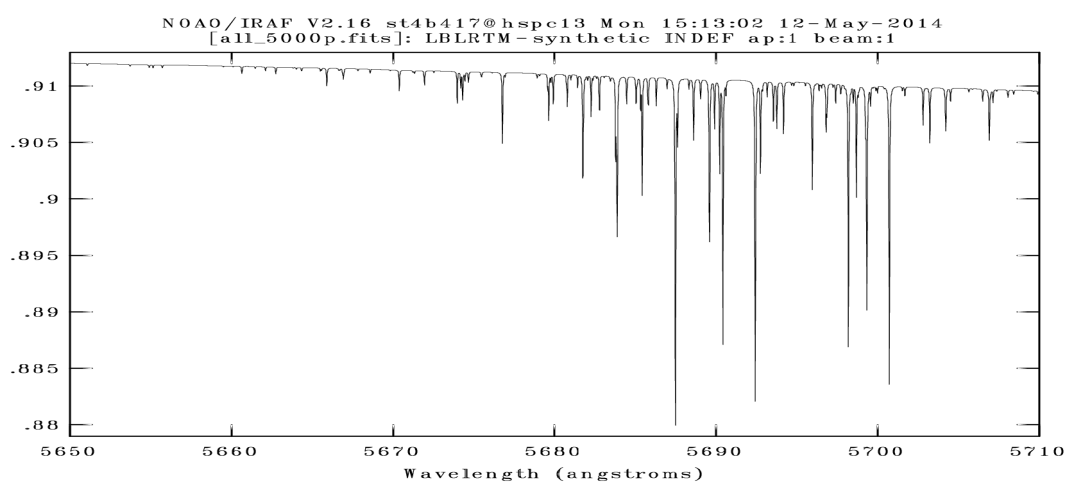


NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:12:34 12-May-2014  
[all\_5000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

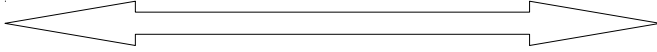




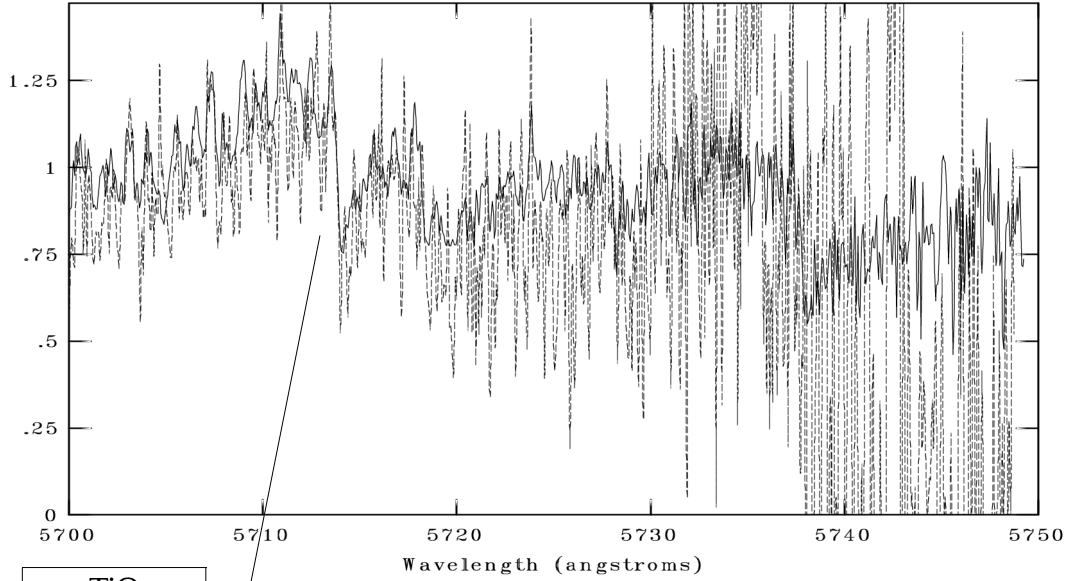
TiO  
 5 662.221 Å  
 Valenti  
 5 668.187 Å  
 Walker



noise due to the transition from blue to red spectral range

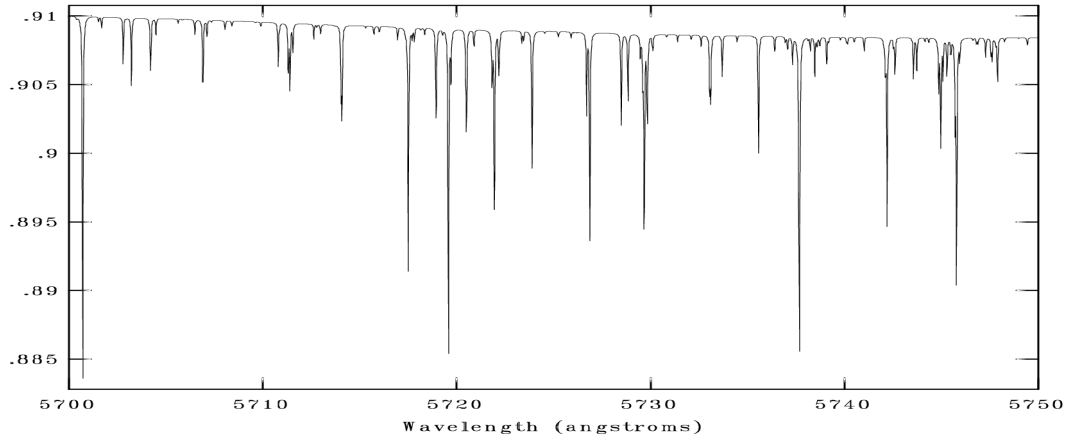


NOAO/IRAF V2.16 st4b417@hspc13 Wed 13:10:23 07-May-2014  
[Sci\_Mira\_B\_2013\_08\_08\_05\_06\_16.sp\_ech\_small.fits]: Mira 60. ap:1 beam

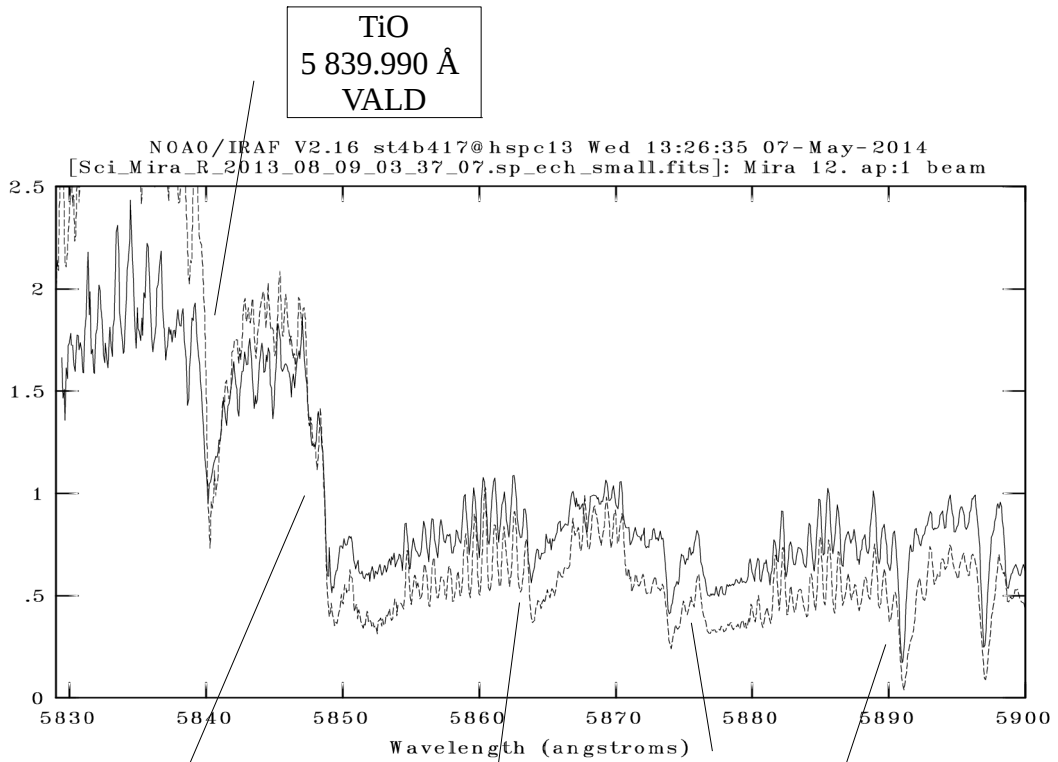


TiO  
5 716.052 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Mon 15:13:35 12-May-2014  
[all\_5000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



**Appendix**  
**B: Red spectrum (5829Å-8817Å)**

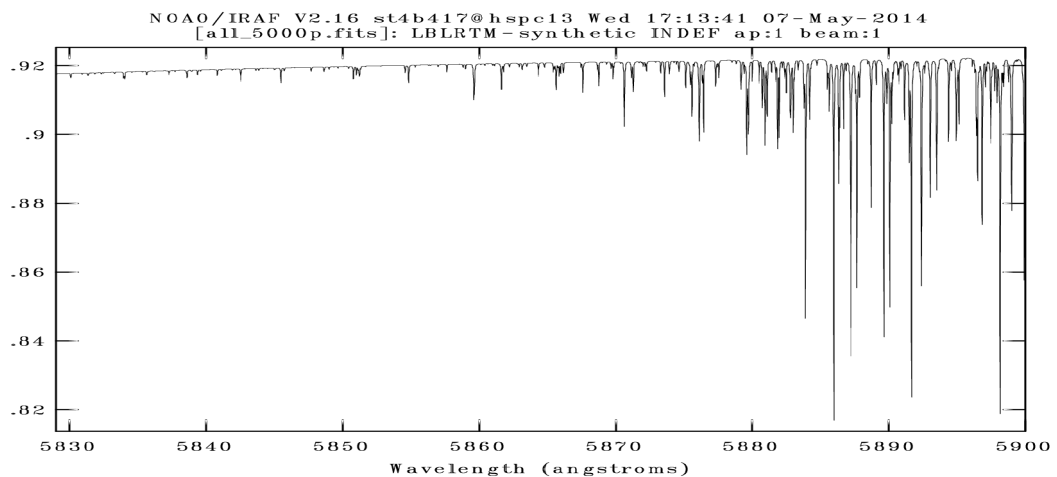


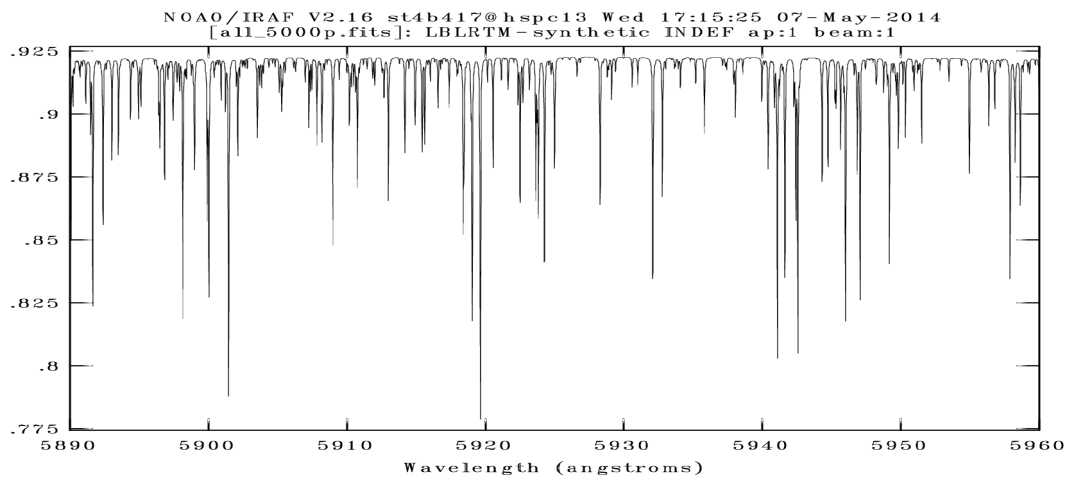
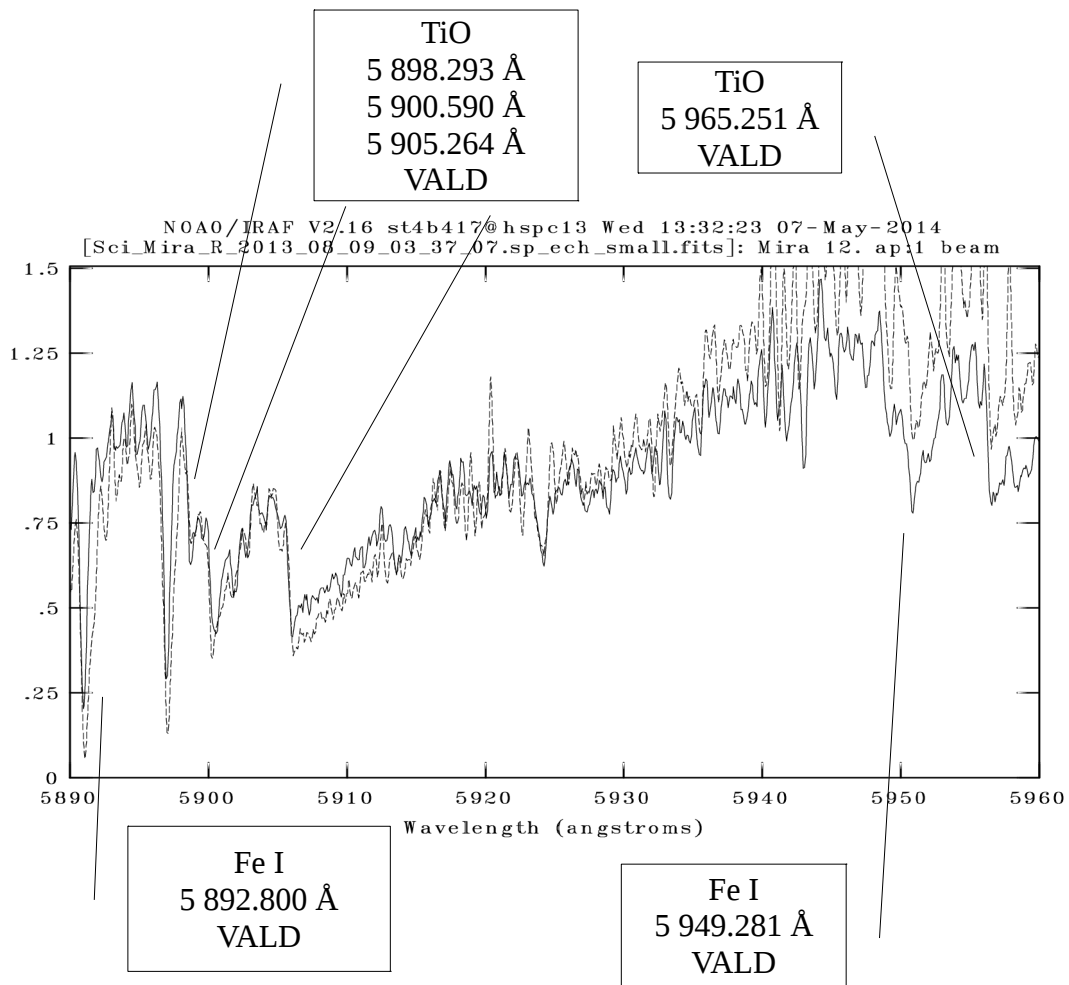
TiO  
 5 839.990 Å  
 VALD

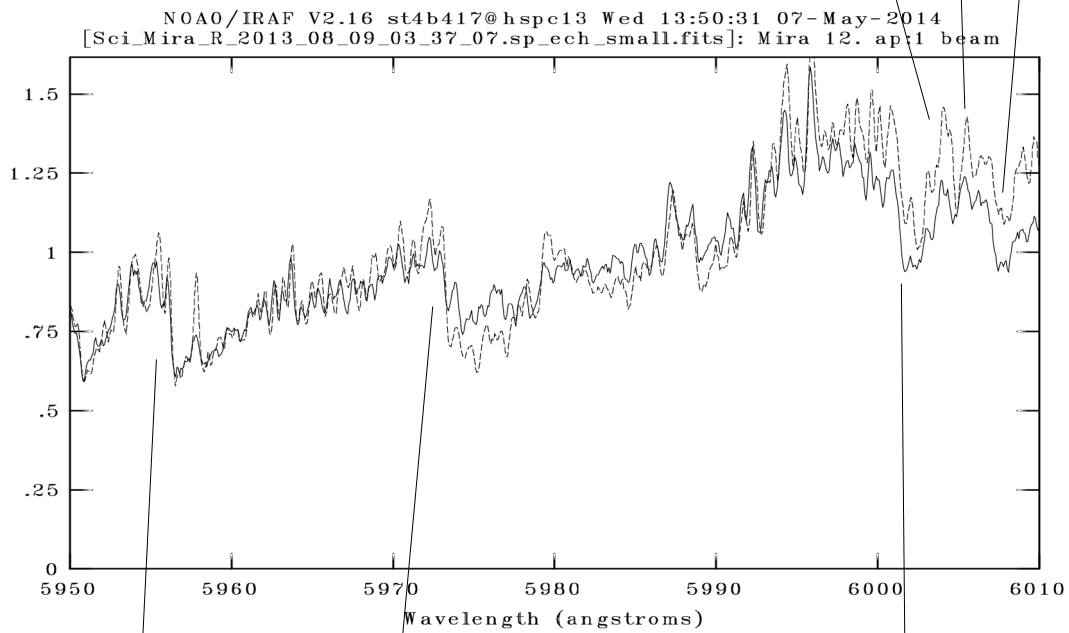
TiO  
 5 847.861 Å  
 Walker

TiO  
 5 865.431 Å  
 5 875.162 Å  
 VALD

Fe I  
 5 892.800 Å  
 VALD





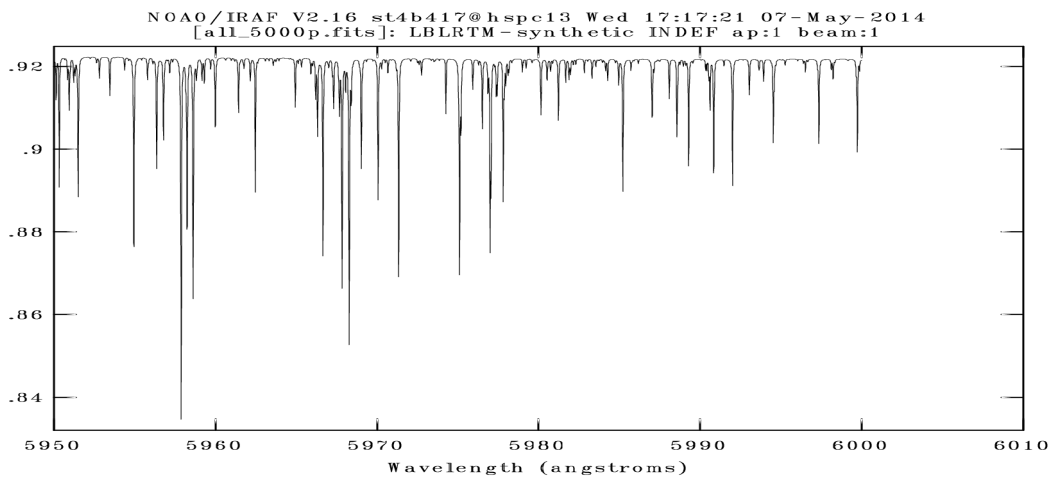


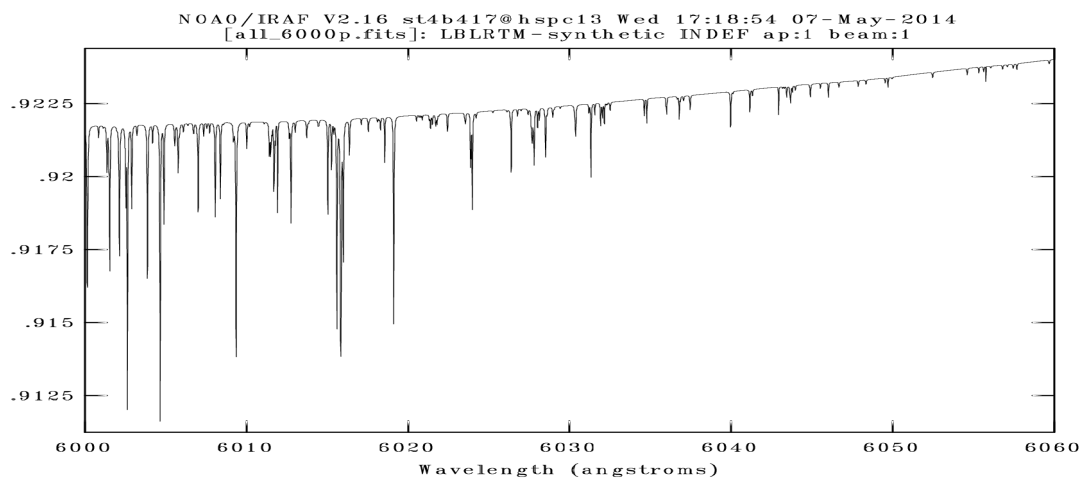
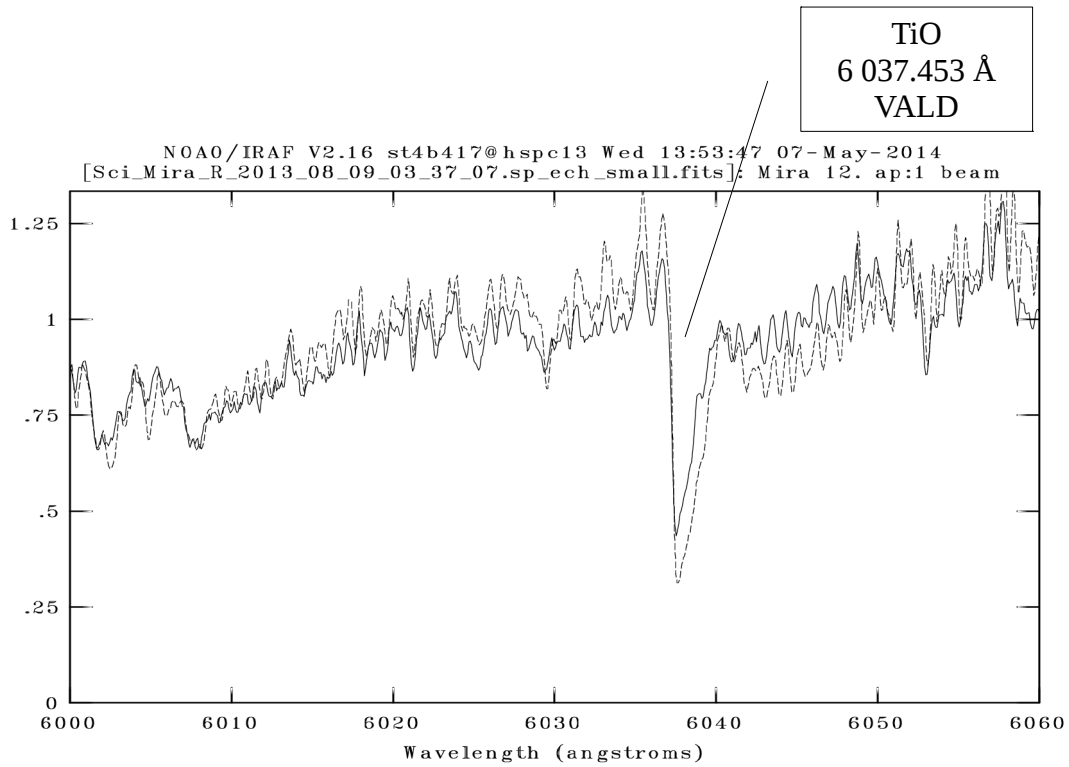
Fe I  
 6 003.011 Å  
 6 005.541 Å  
 6 008.555 Å  
 VALD

TiO  
 5 965.251 Å  
 VALD

TiO  
 5 972.728 Å  
 VALD

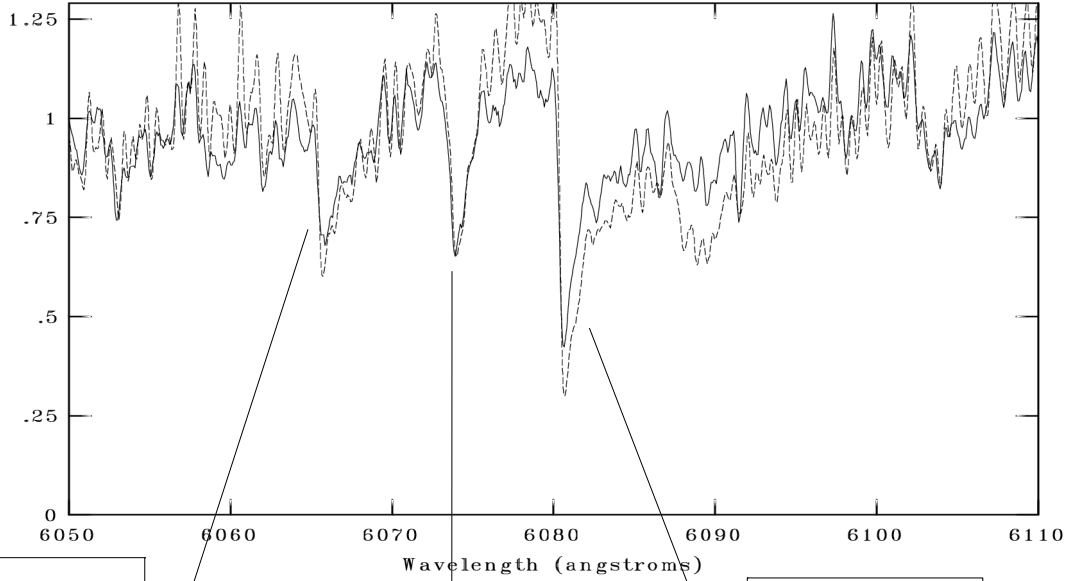
?







NOAO/IRAF V2.16 st4b417@hspc13 Wed 13:57:09 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

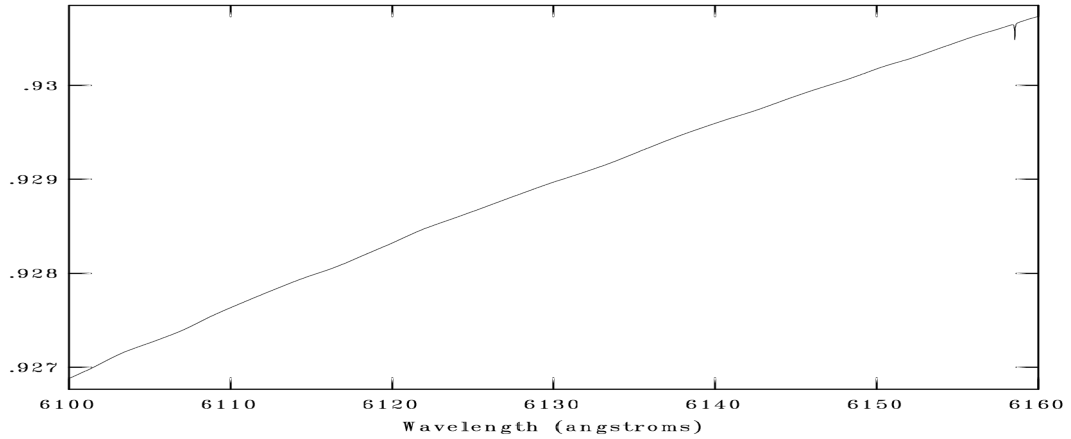


TiO  
6 064.235 Å  
VALD

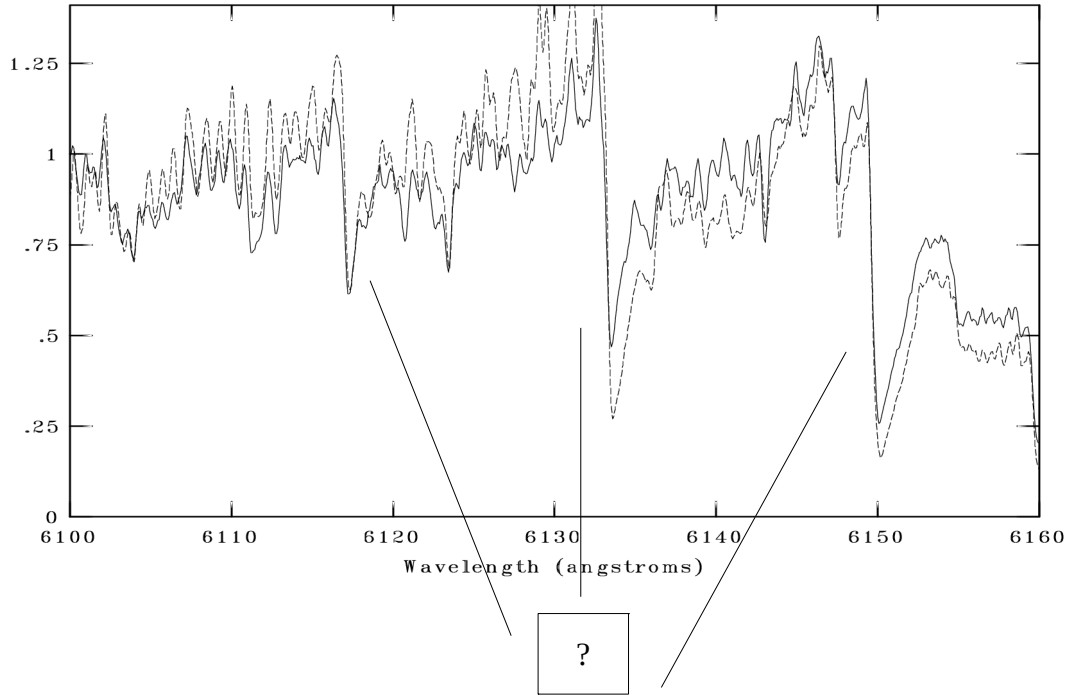
TiO  
6 071.251 Å  
VALD

TiO  
6 082.103 Å  
VALD

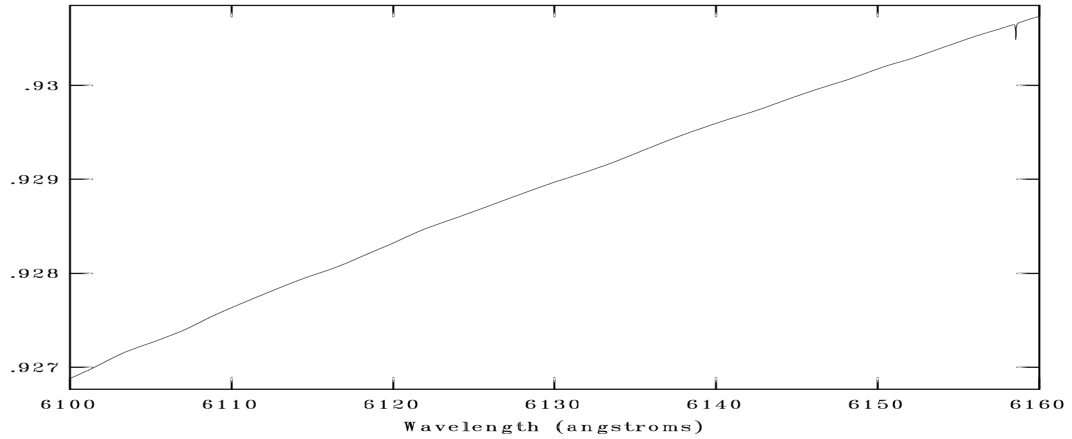
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:20:46 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



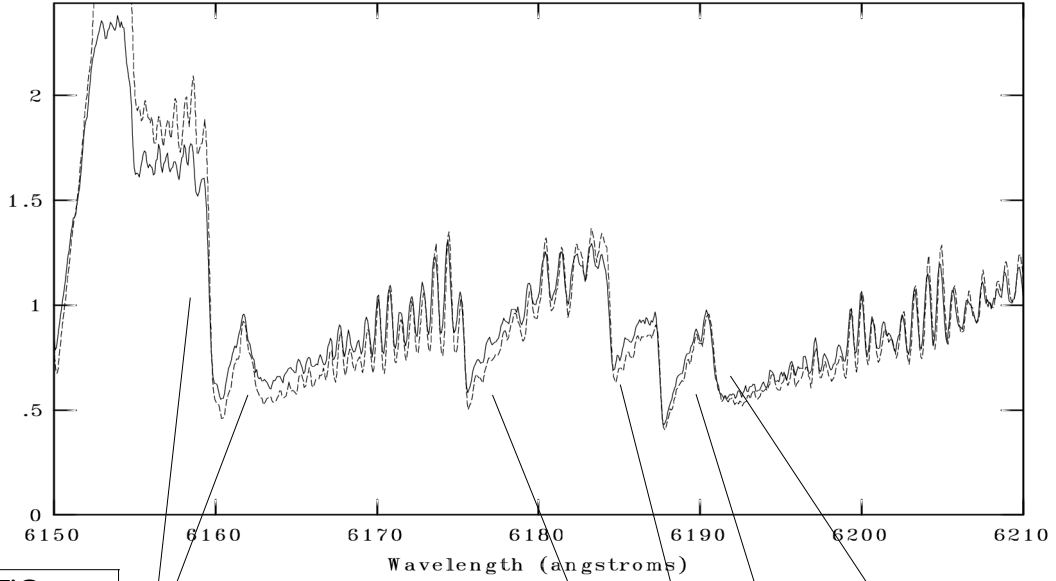
NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:02:13 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:20:46 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



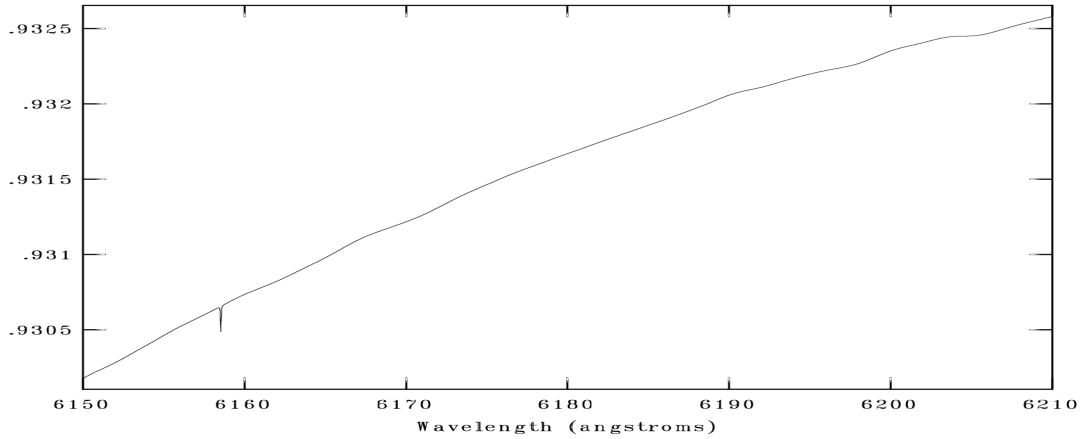
NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:04:42 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



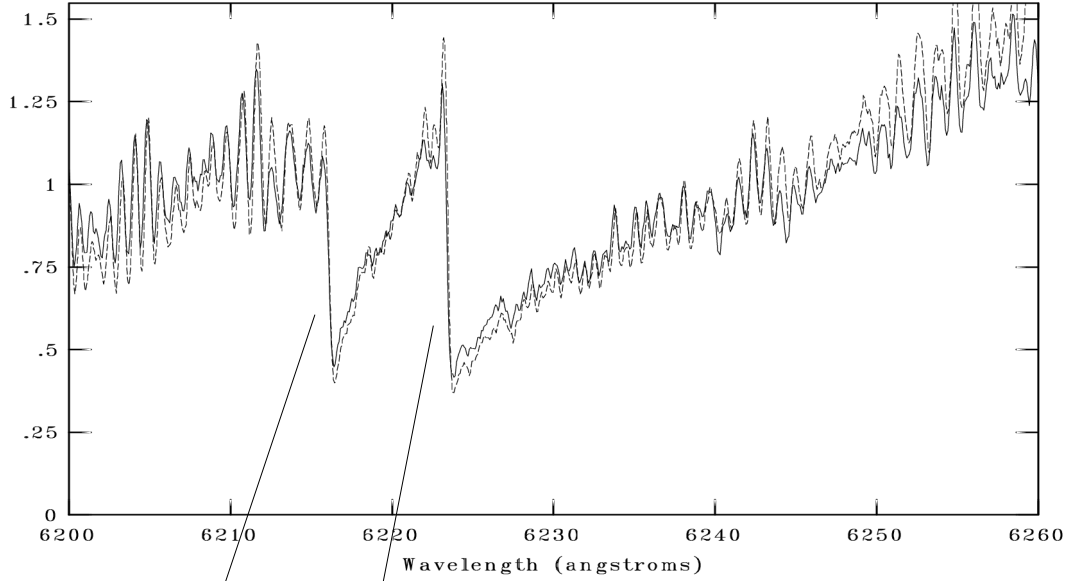
TiO  
6 159.721 Å  
Walker  
6 163.484 Å  
VALD

TiO  
6 176.175 Å  
6 186.996 Å  
6 188.750 Å  
6 192.756 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:23:12 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

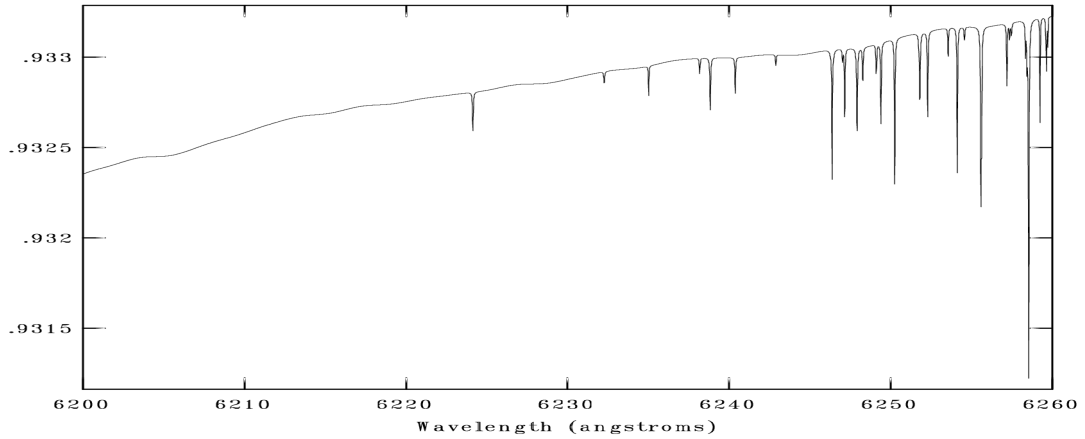


NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:07:46 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



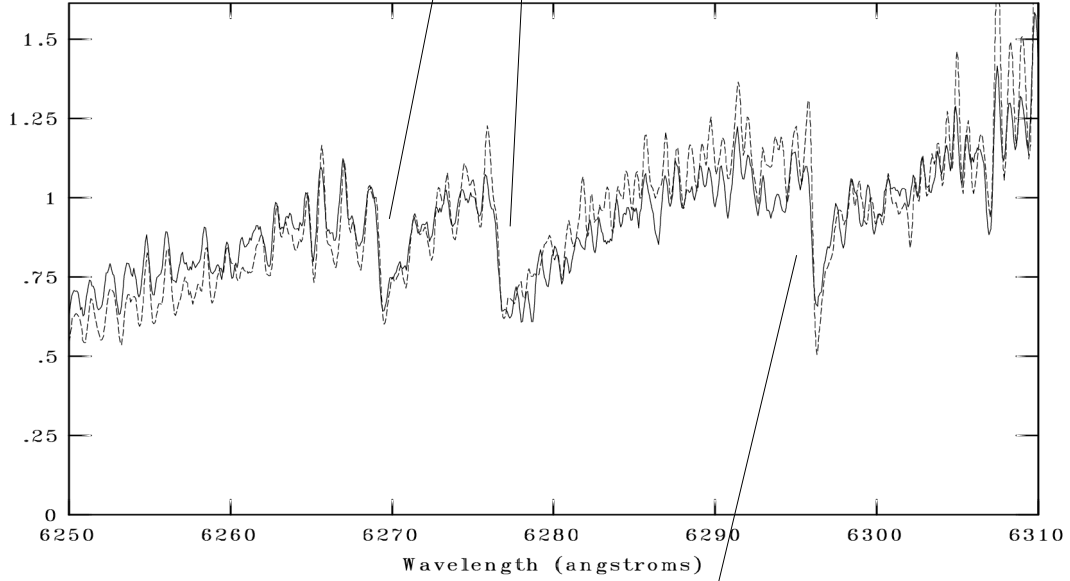
TiO  
6 218.399 Å  
5 224.038 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:23:43 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



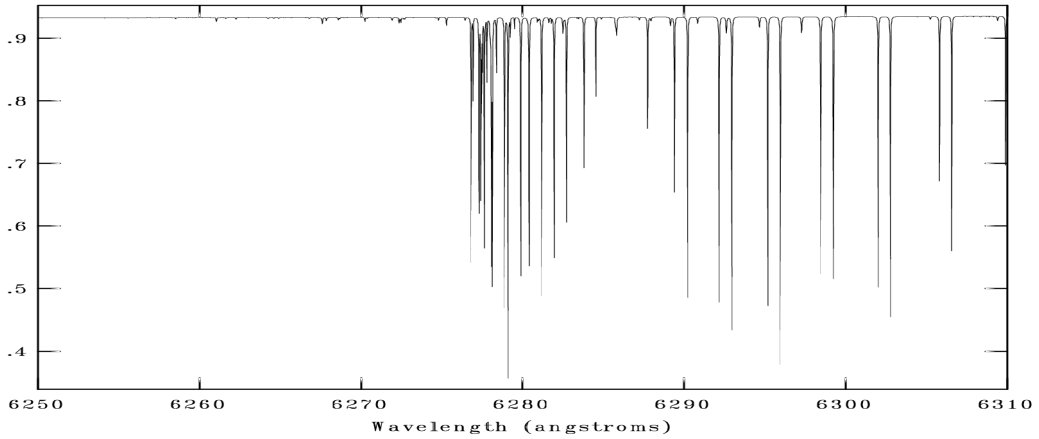
TiO  
6 269.132 Å  
Walker  
6 276.248 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:10:19 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

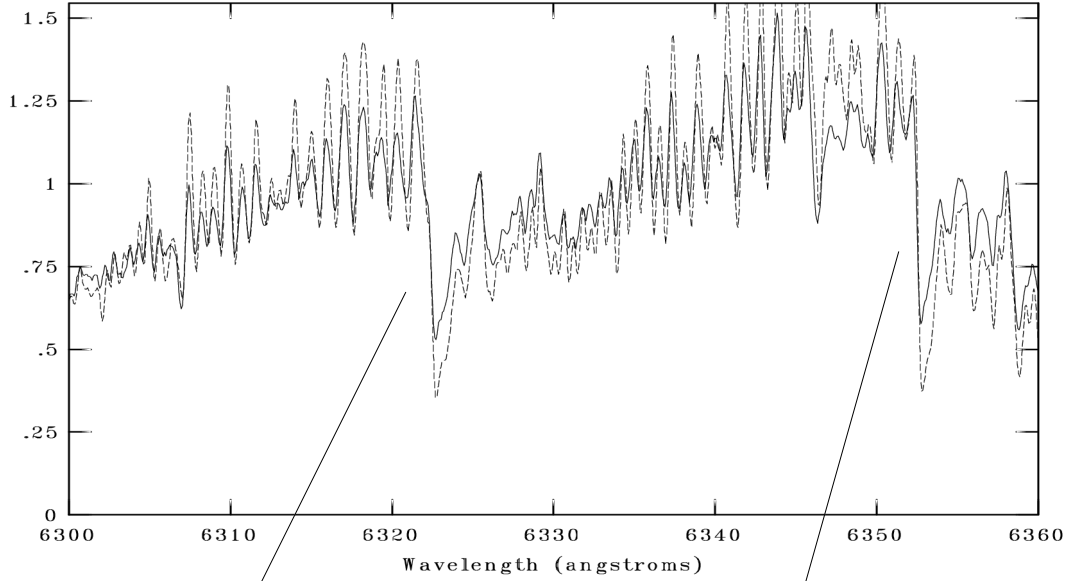


TiO  
6 297.720 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:24:11 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



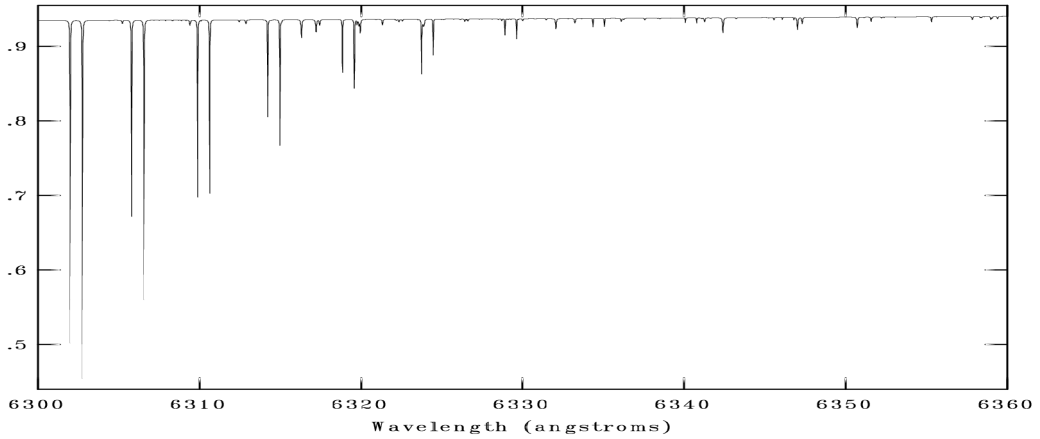
NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:20:42 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



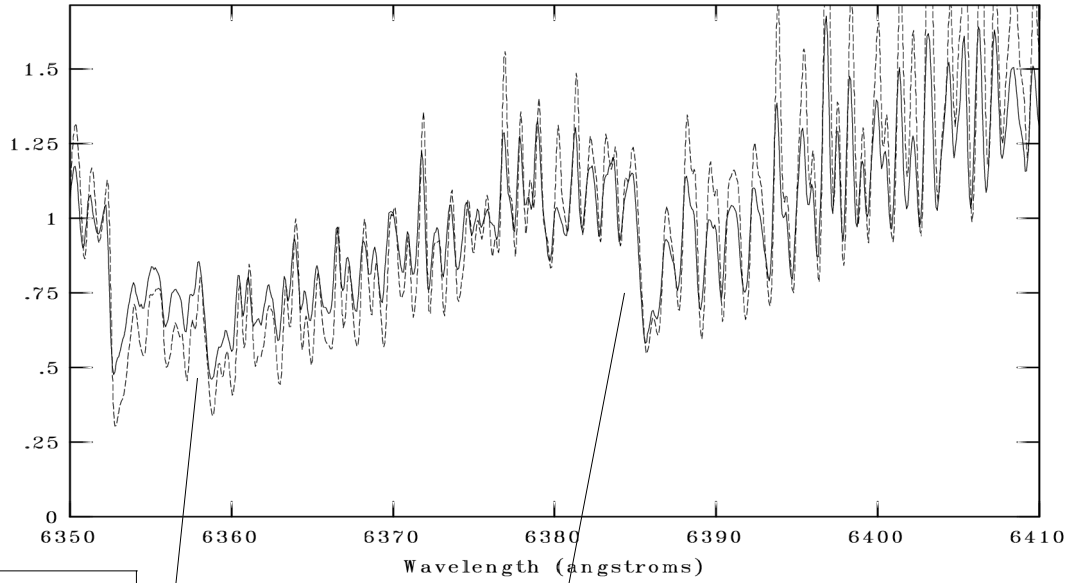
TiO  
6 321.750 Å  
VALD

TiO  
6 353.195 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:24:37 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



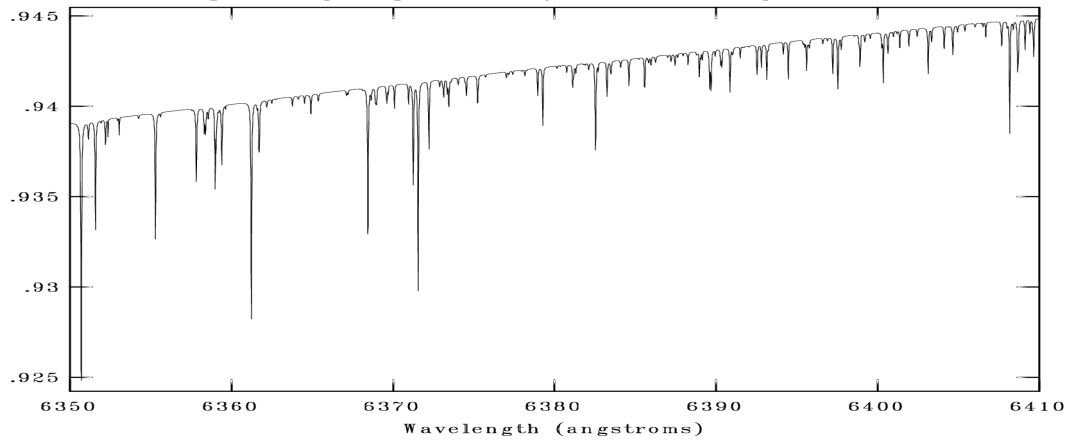
NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:22:37 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



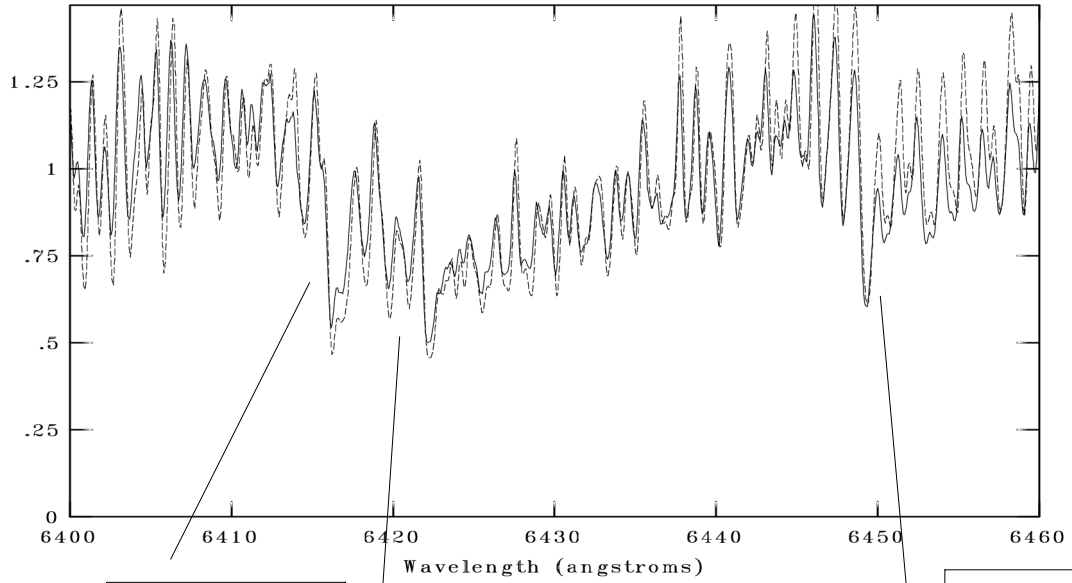
TiO  
6 358.610 Å  
Joy

TiO  
6 384.526 Å  
Joy

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:24:58 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



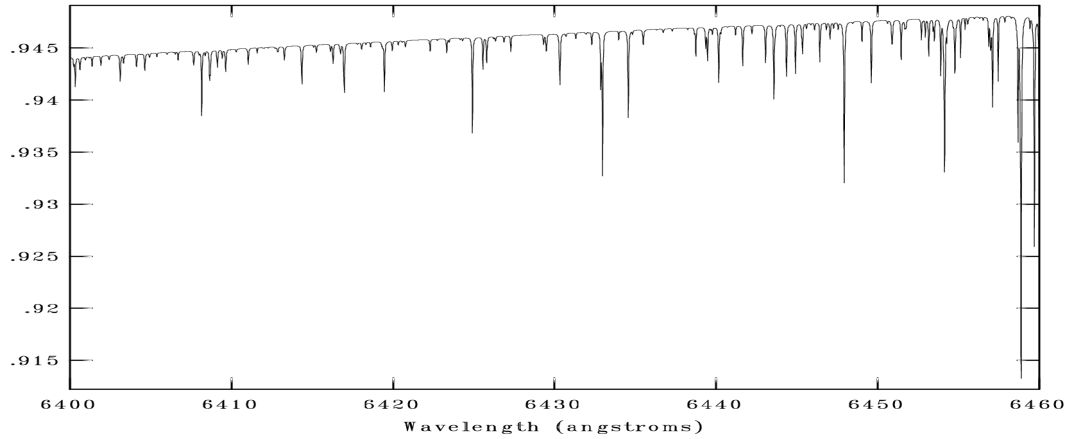
NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:27:06 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



TiO  
6 417.535 Å  
6 421.682 Å  
VALD

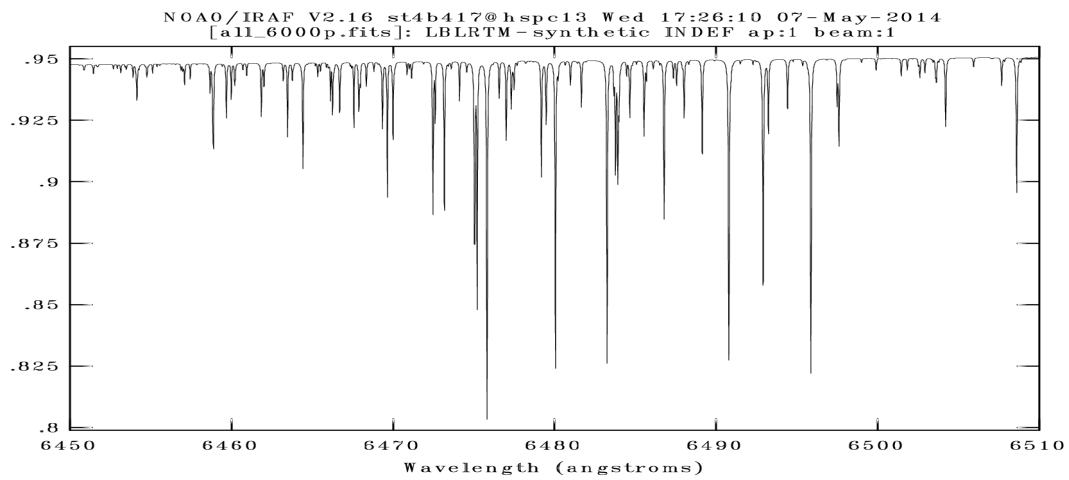
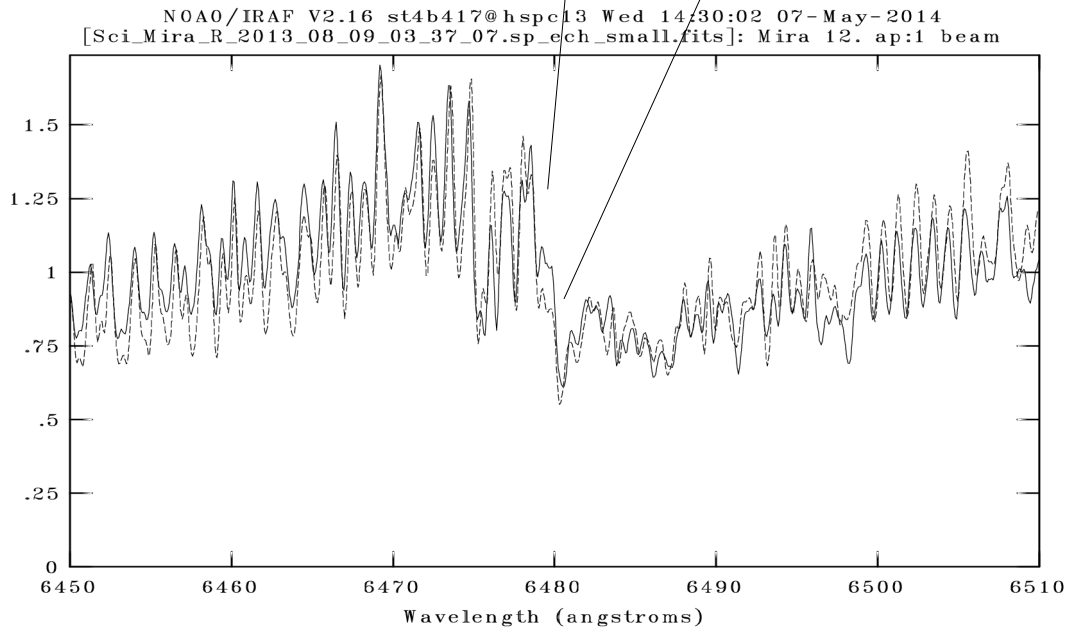
TiO  
6 449.855 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:25:29 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

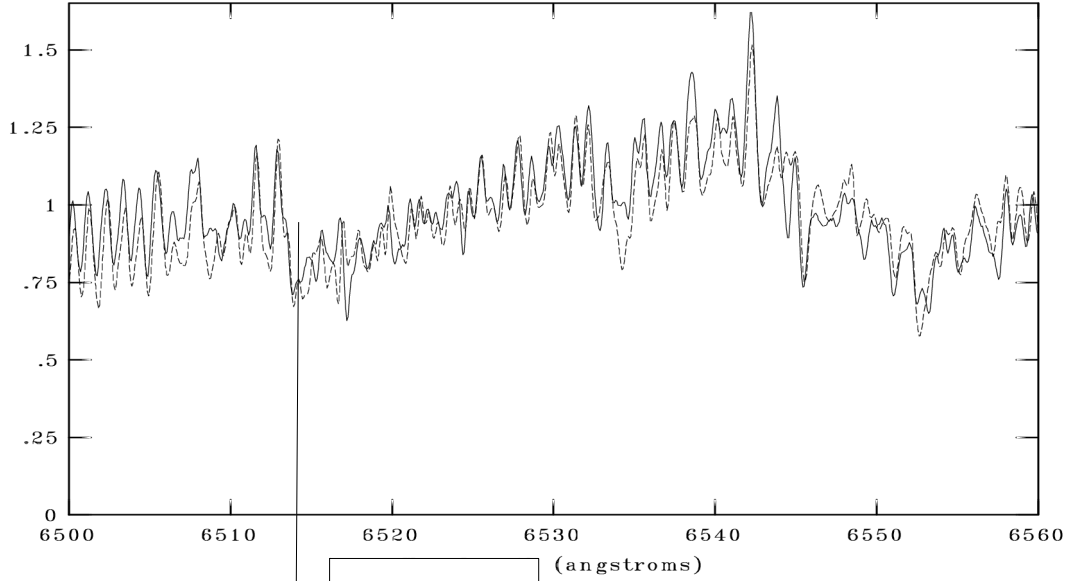




TiO  
6 478.108 Å  
Walker  
6 479.972 Å  
VALD

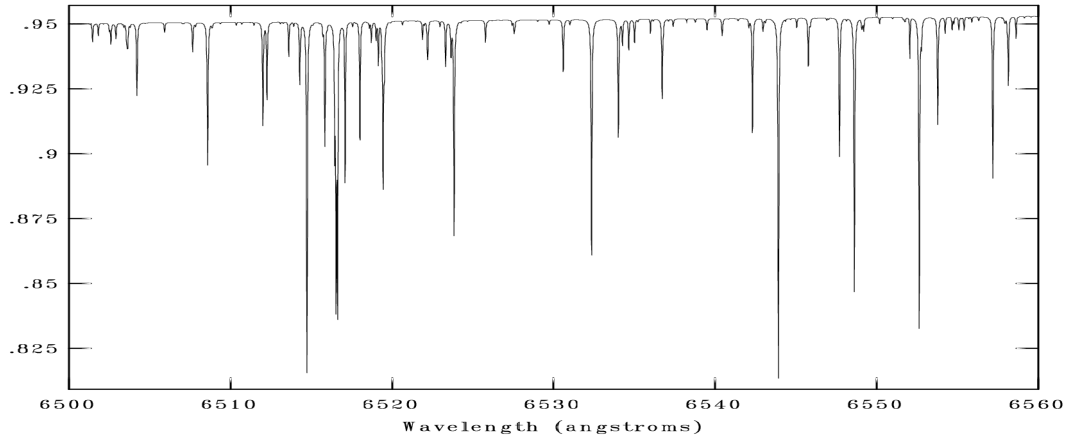


NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:34:19 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



TiO  
6 514.878 Å  
VALD

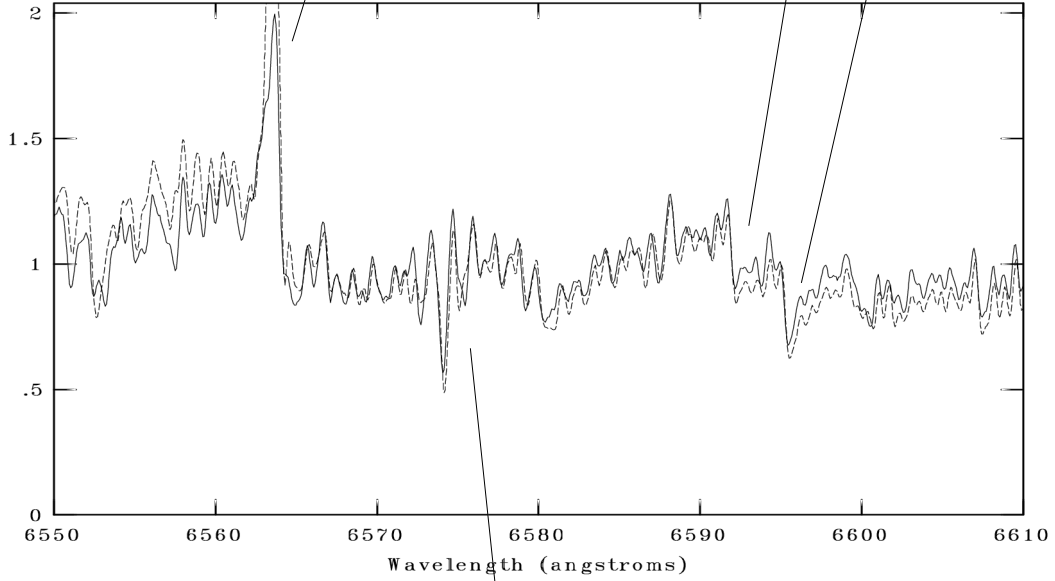
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:26:42 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



H<sub>α</sub>  
6 562.79 Å  
NIST

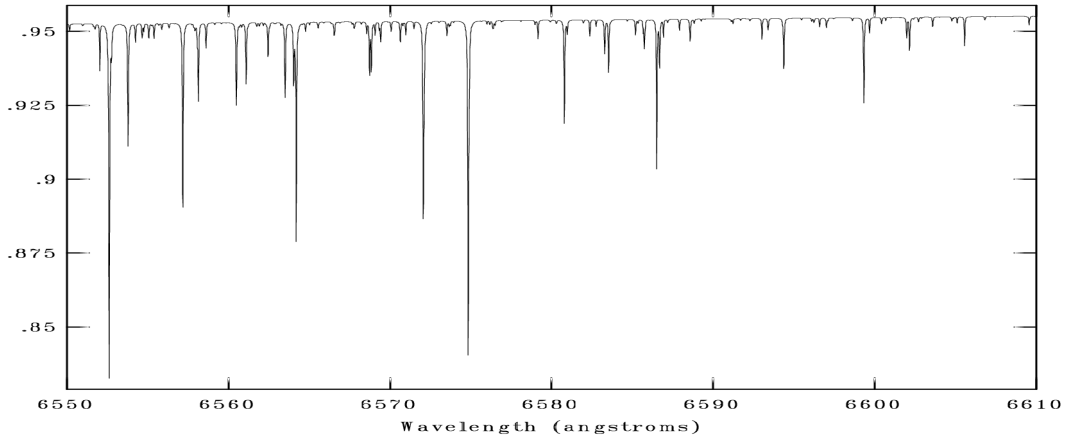
TiO  
6 592.923 Å  
6 596.016 Å  
VALD

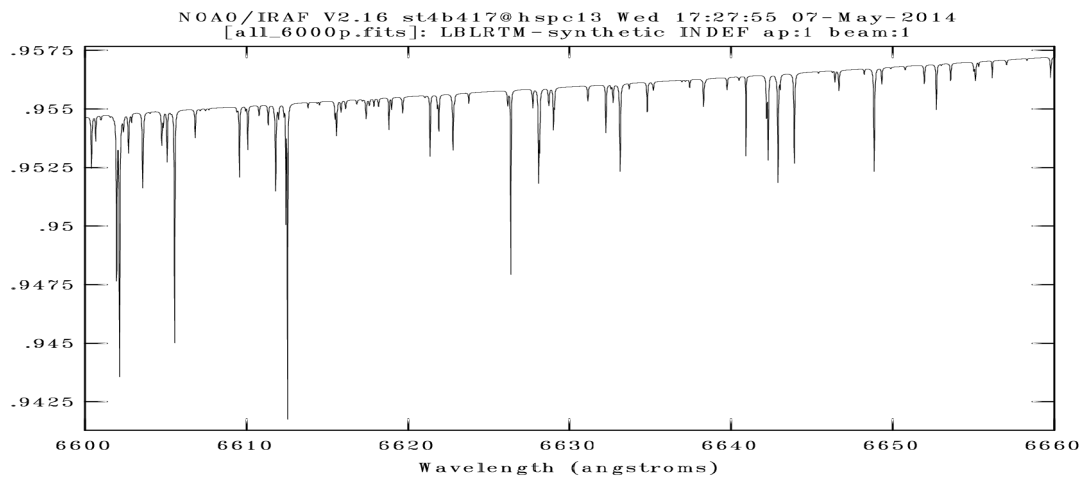
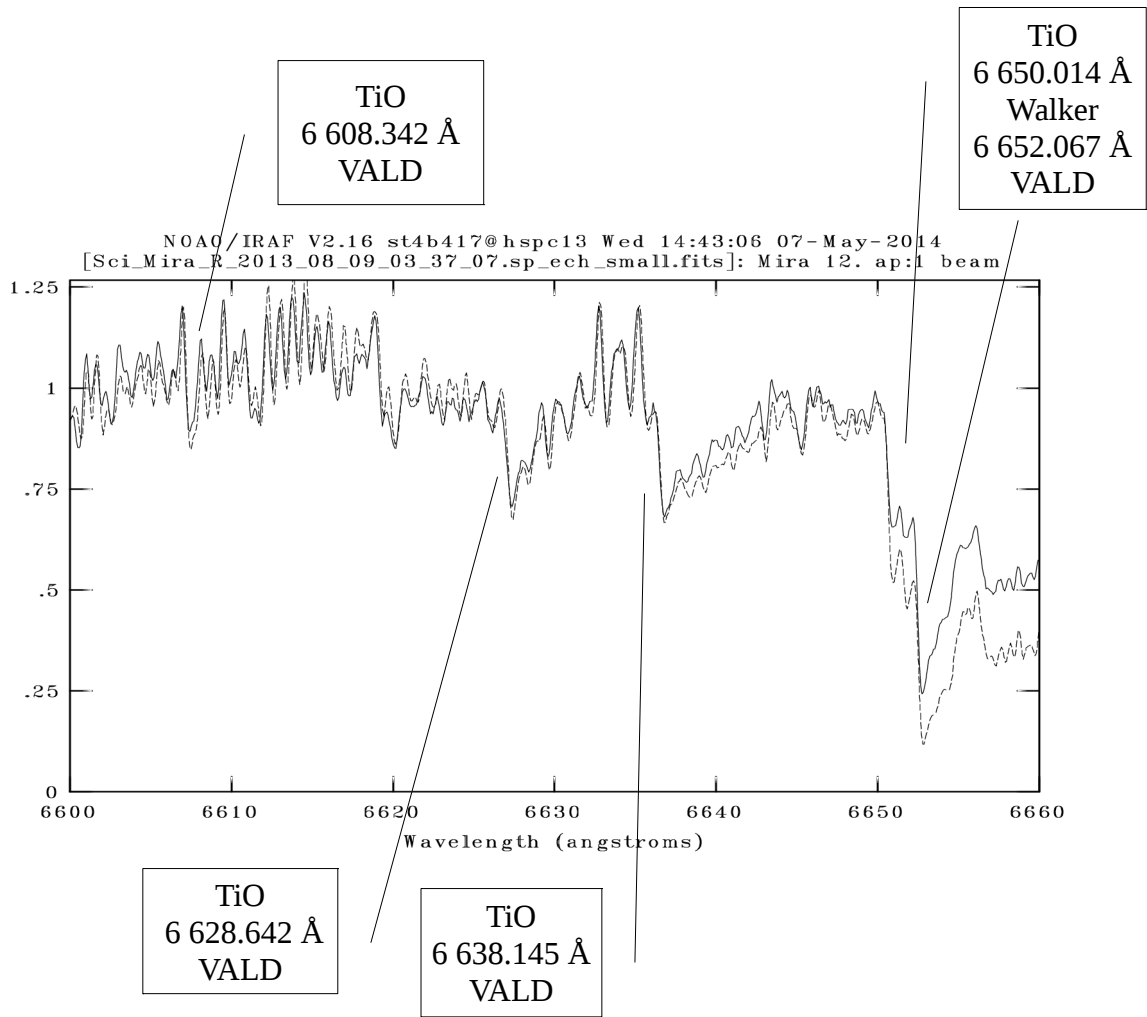
NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:41:10 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

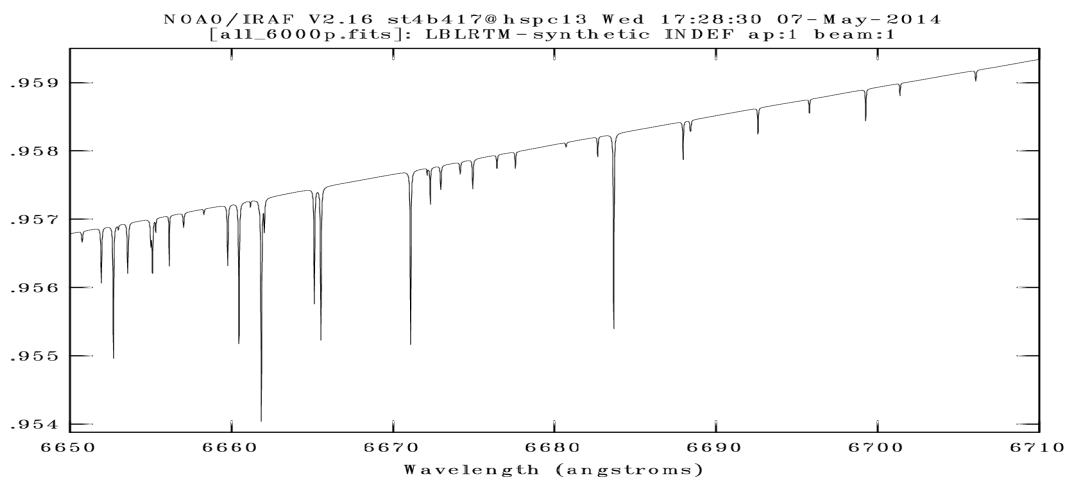
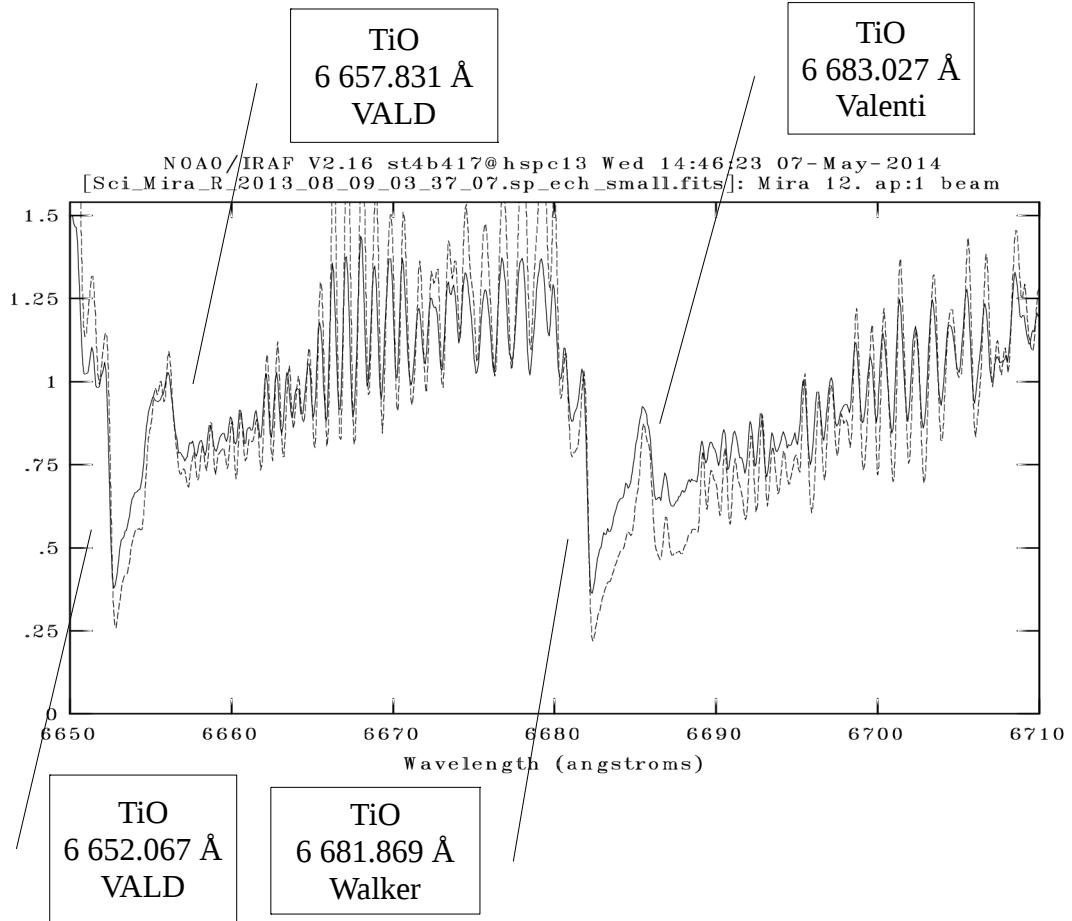


TiO  
6 574.323 Å  
VALD

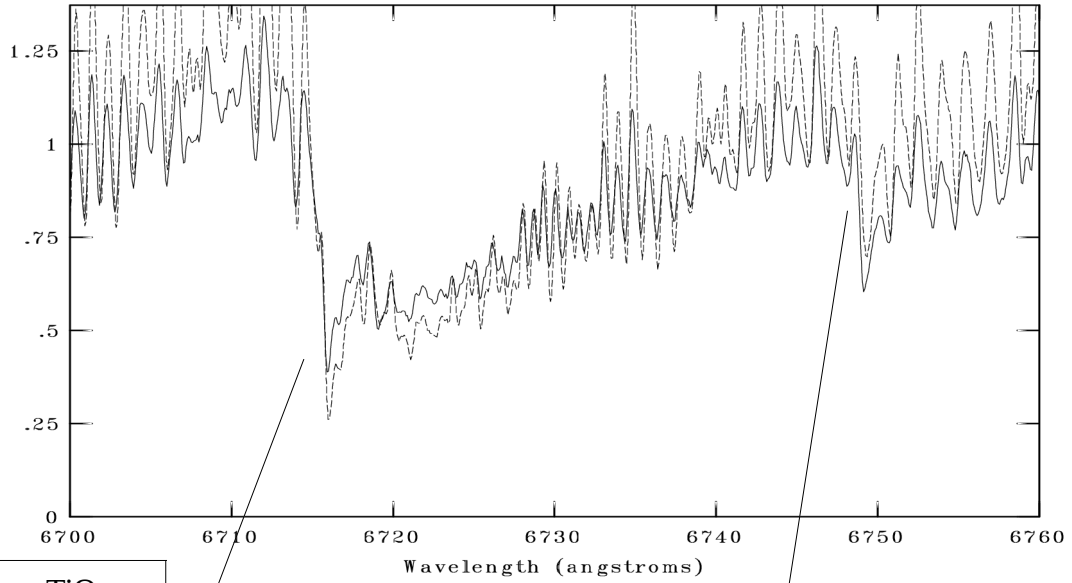
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:27:18 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1







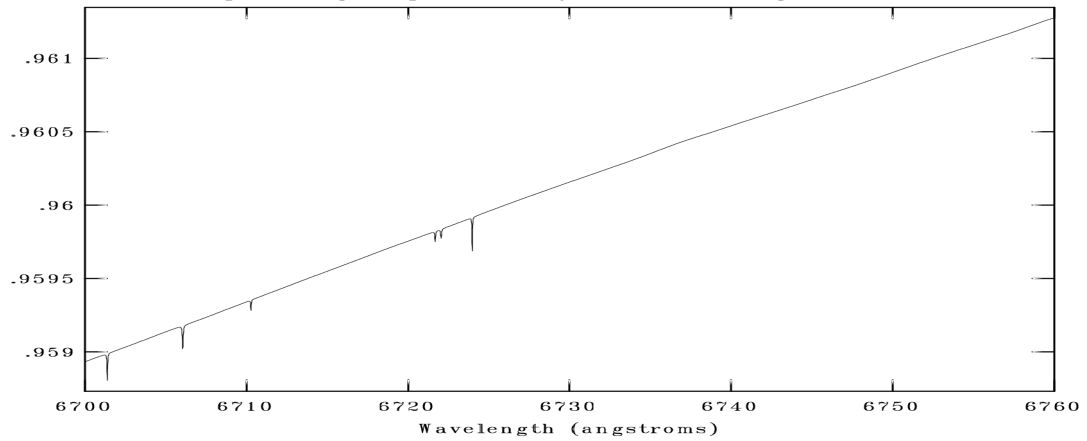
NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:52:44 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



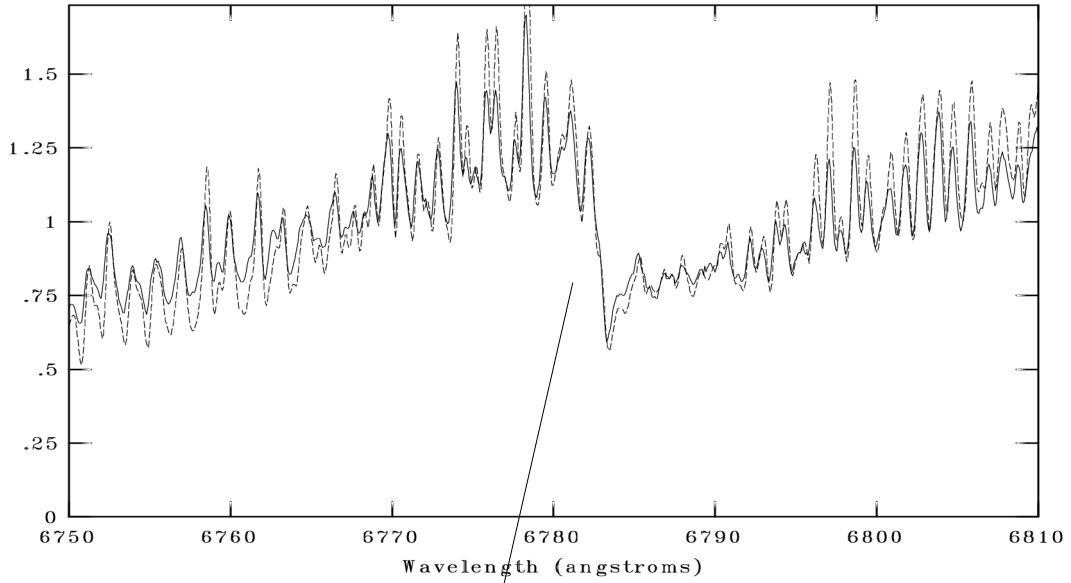
TiO  
6 715.488 Å  
Walker

TiO  
6 749.510 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:29:06 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

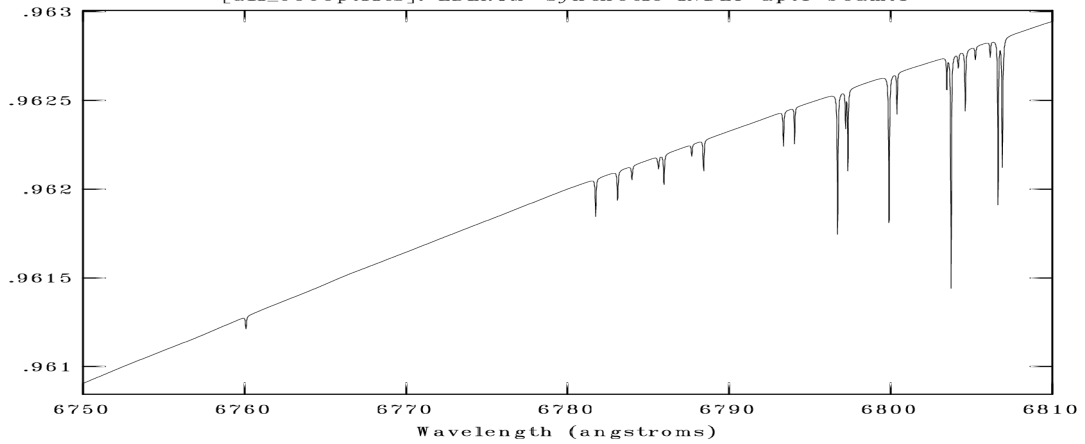


NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:55:36 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

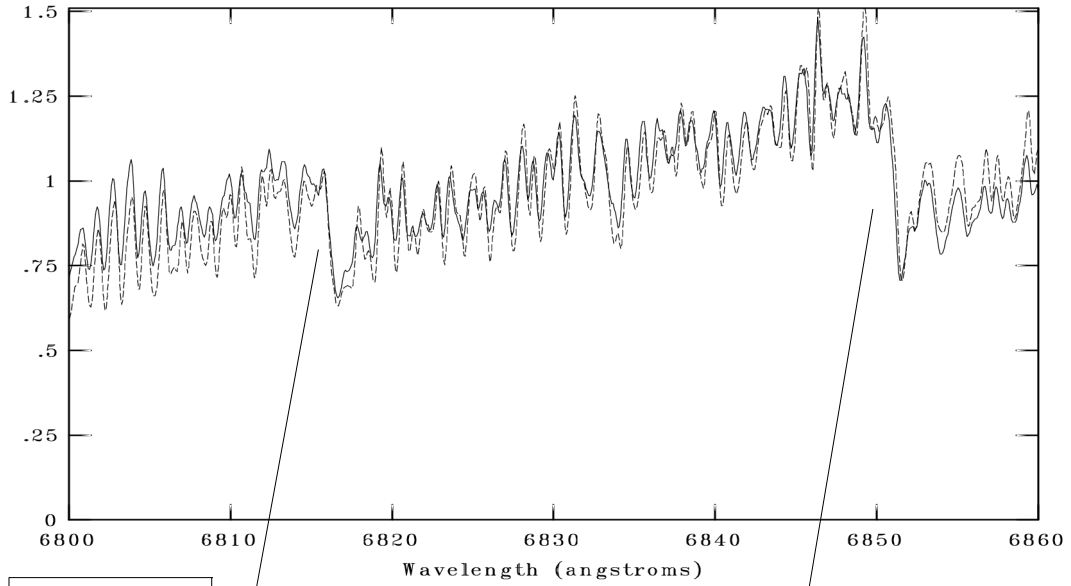


TiO  
6 781.785 Å  
Walker

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:30:09 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



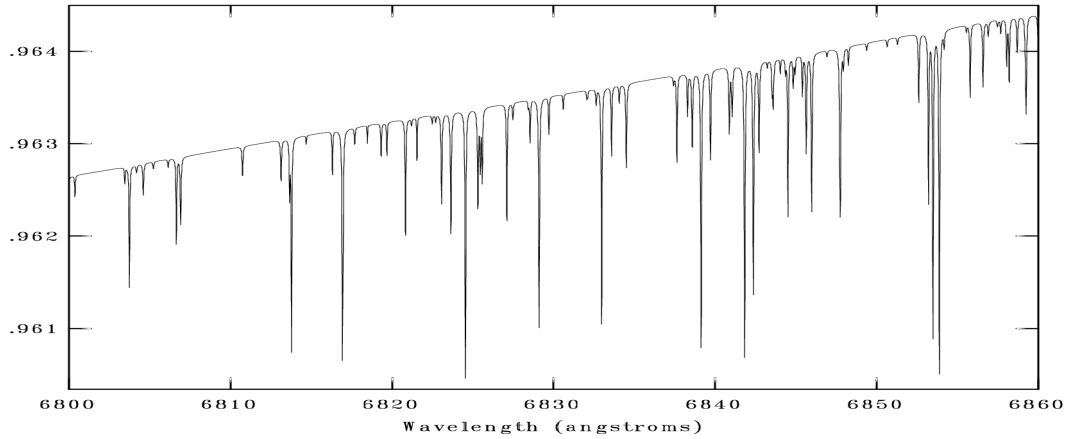
NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:57:29 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



TiO  
6 815.964 Å  
Walker

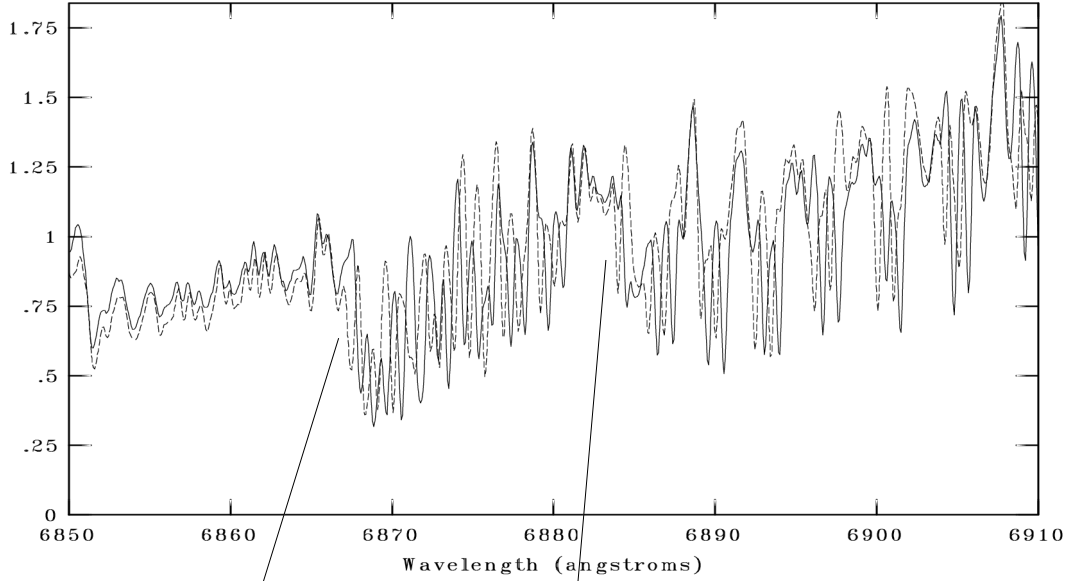
TiO  
6 851.362 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:30:37 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1





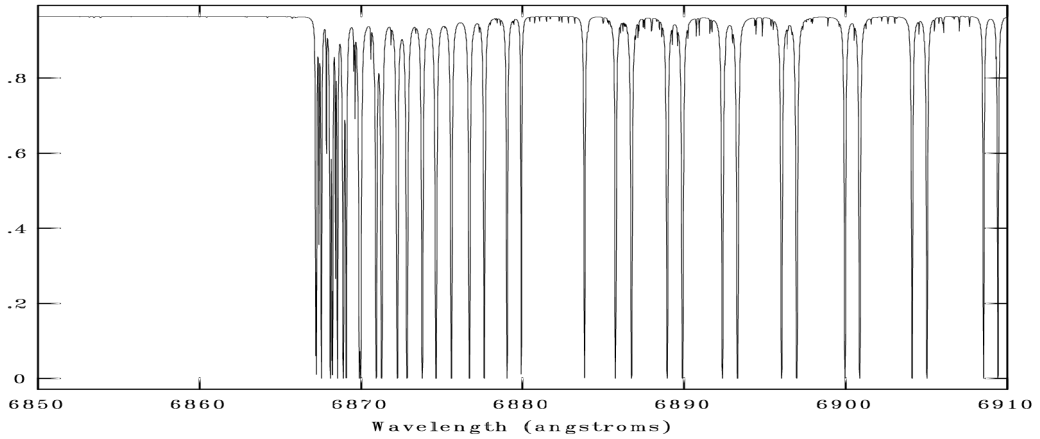
NOAO/IRAF V2.16 st4b417@hspc13 Wed 14:59:20 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



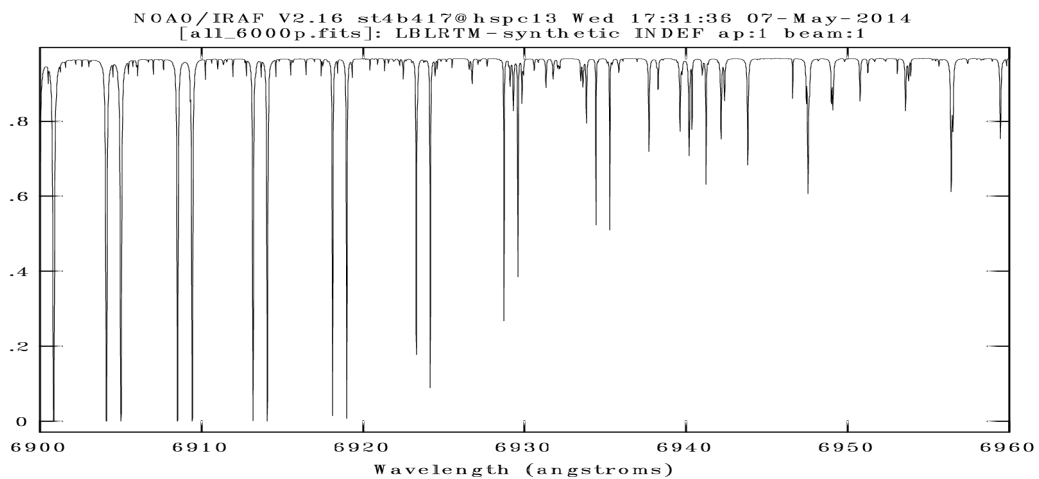
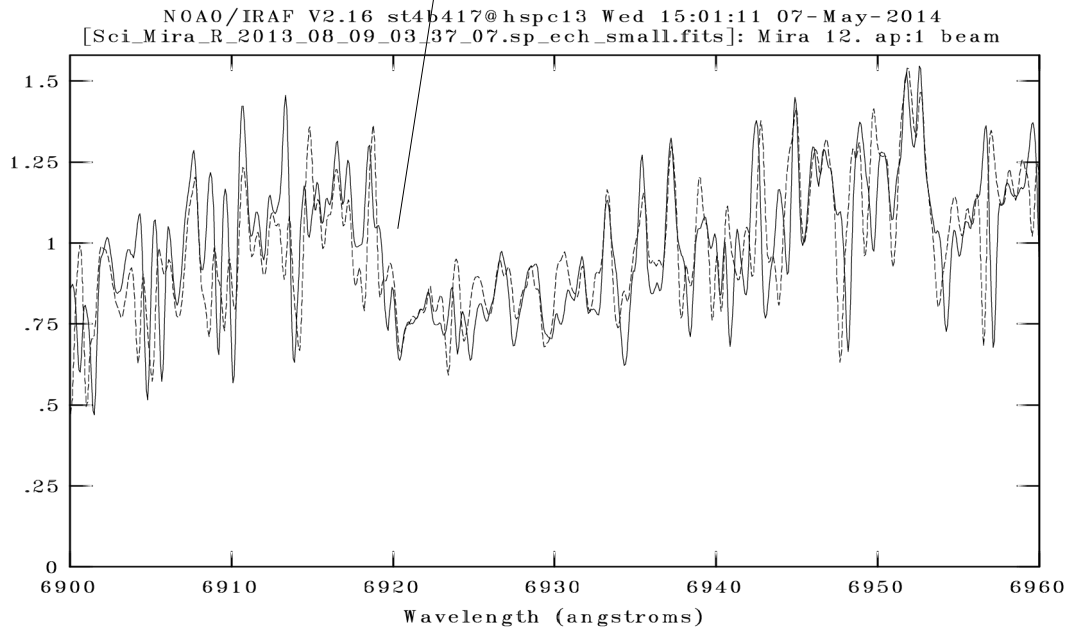
TiO  
6 867.935 Å  
VALD

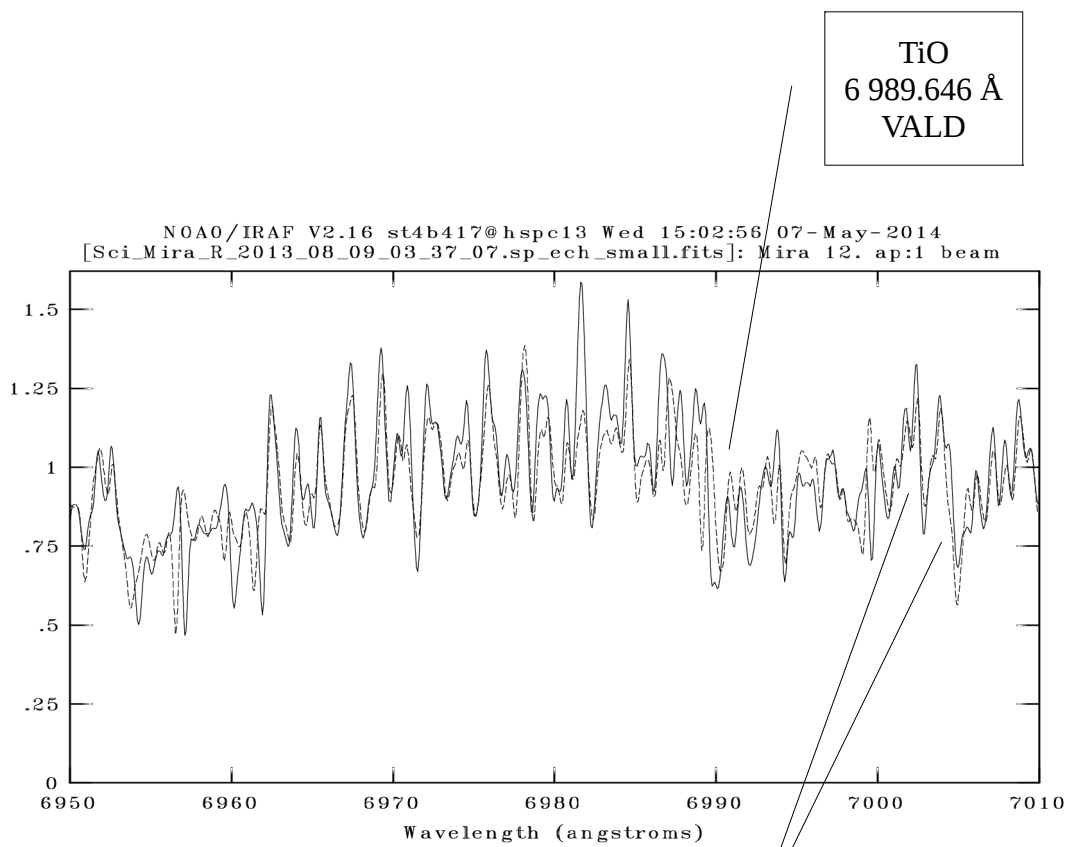
TiO  
6 884.123 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:31:09 07-May-2014  
[all\_6000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

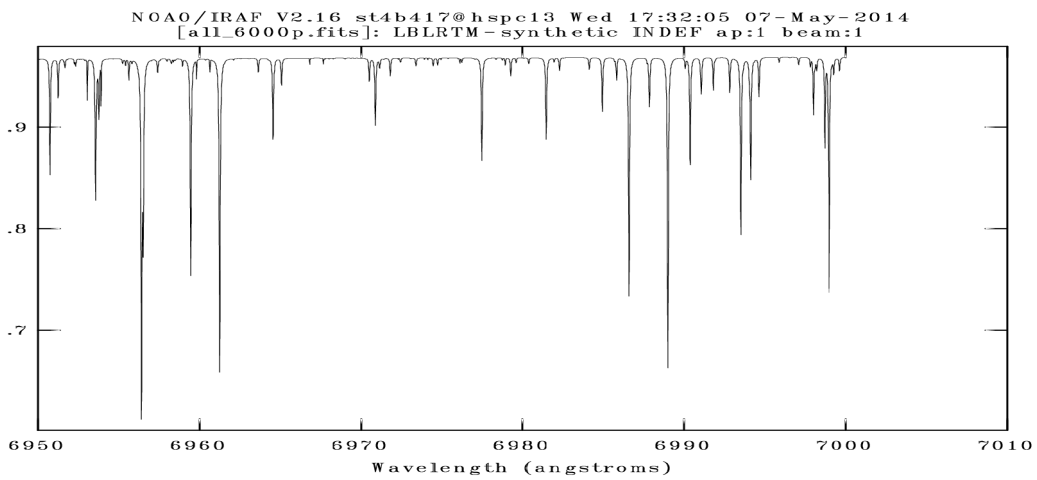


TiO  
6 919.344 Å  
VALD

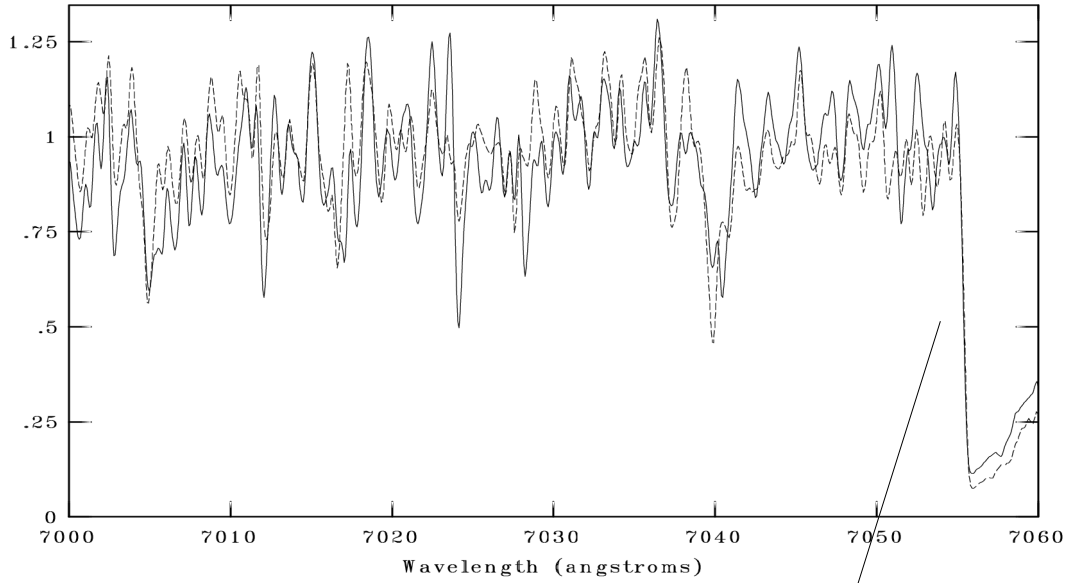




TiO  
7 002.101 Å  
7 005.324 Å  
VALD

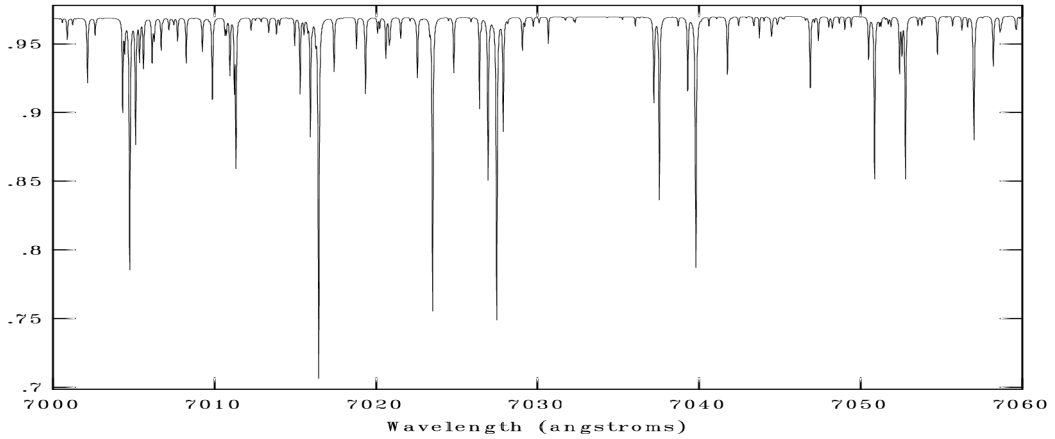


NOAO/IRAF V2.16 st4b417@hspc13 Wed 15:17:12 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

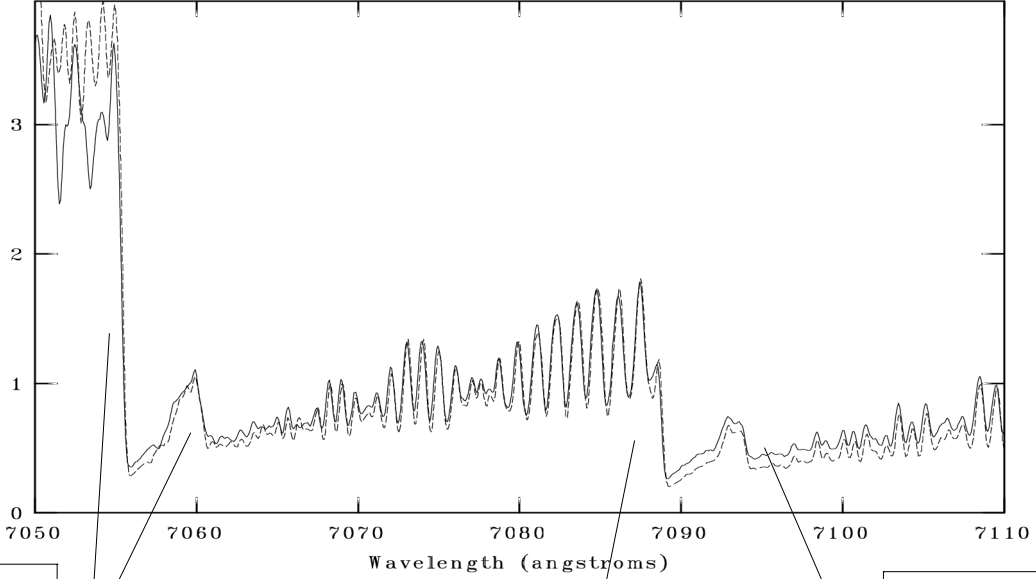


TiO  
7 055.421 Å  
Walker

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:33:09 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



NOAO/IRAF V2.16 st4b417@hspc13 Wed 15:19:13 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

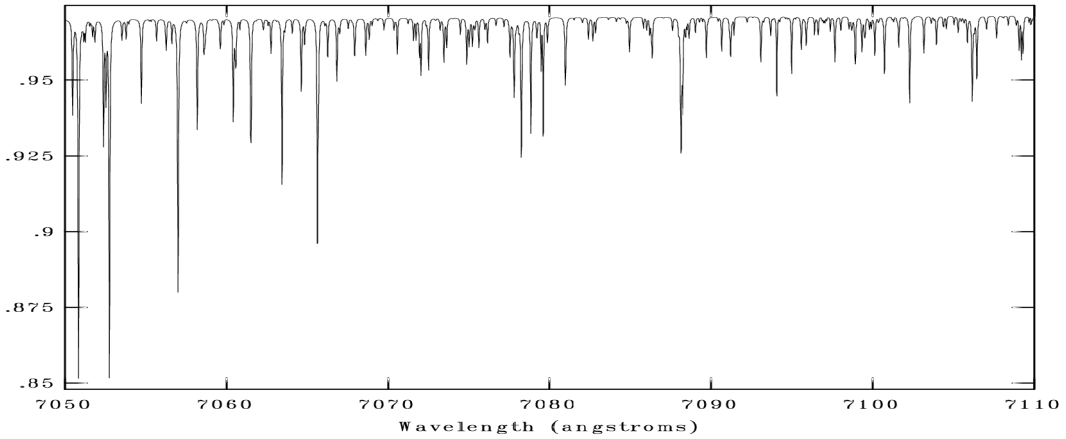


TiO  
7 055.421 Å  
Walker  
7 060.374 Å  
VALD

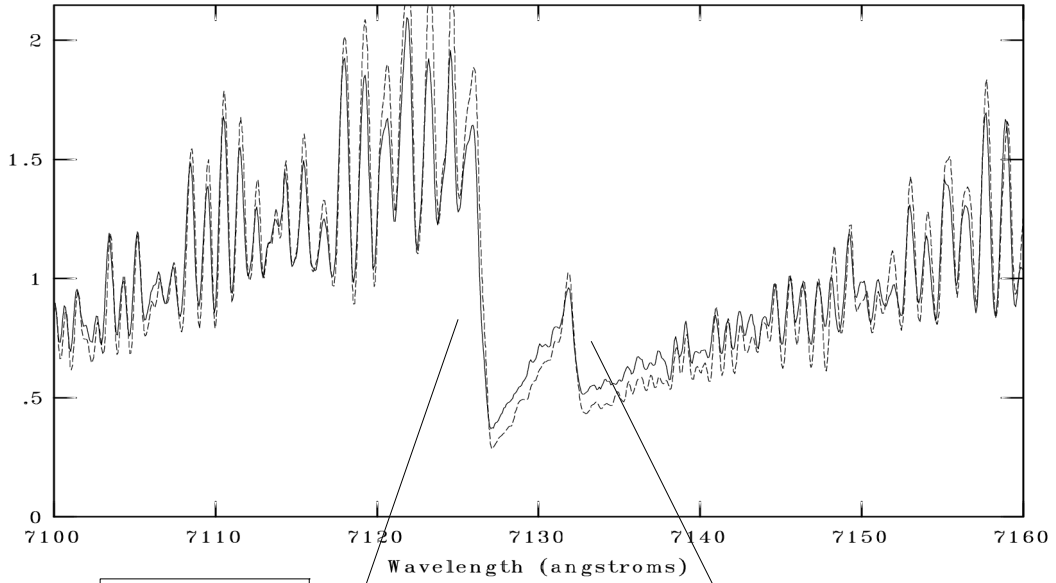
TiO  
7 088.031 Å  
Walker

TiO  
7 095.348 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:33:34 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



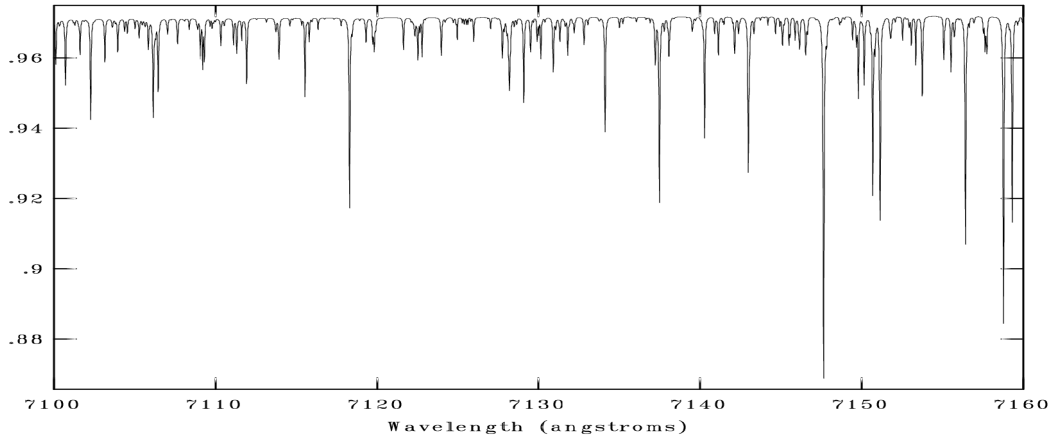
NOAO/IRAF V2.16 st4b417@hspc13 Wed 15:23:32 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



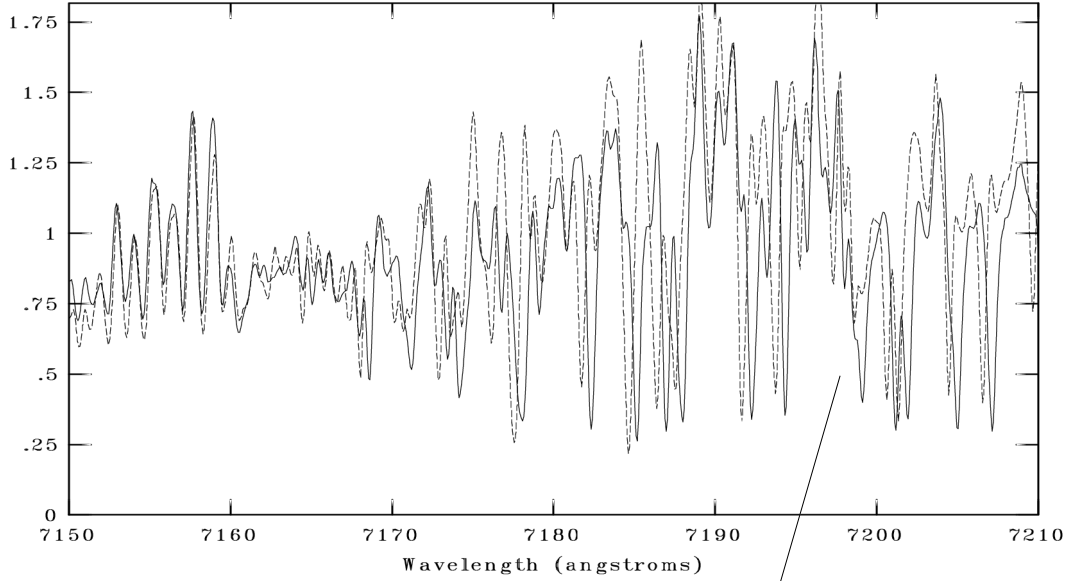
TiO  
7 126.975 Å  
Walker

TiO  
7 132.238 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:33:59 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

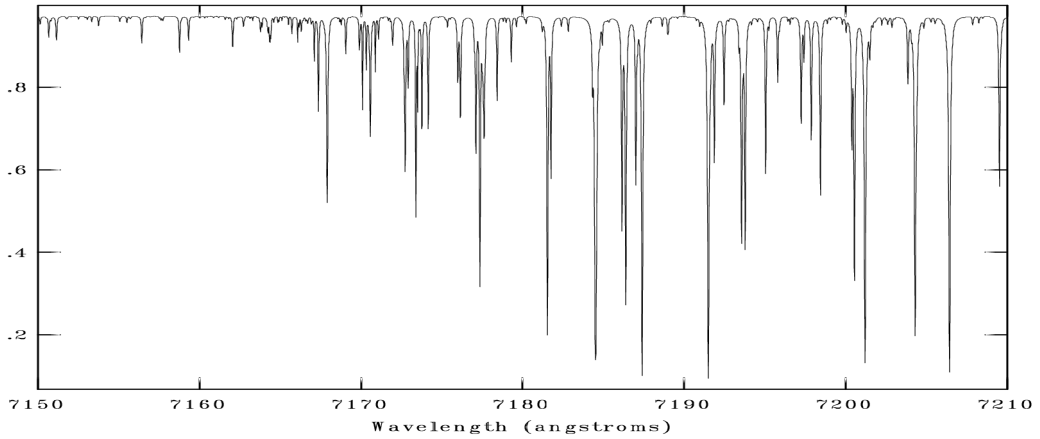


NOAO/IRAF V2.16 st4b417@hspc13 Wed 15:25:49 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

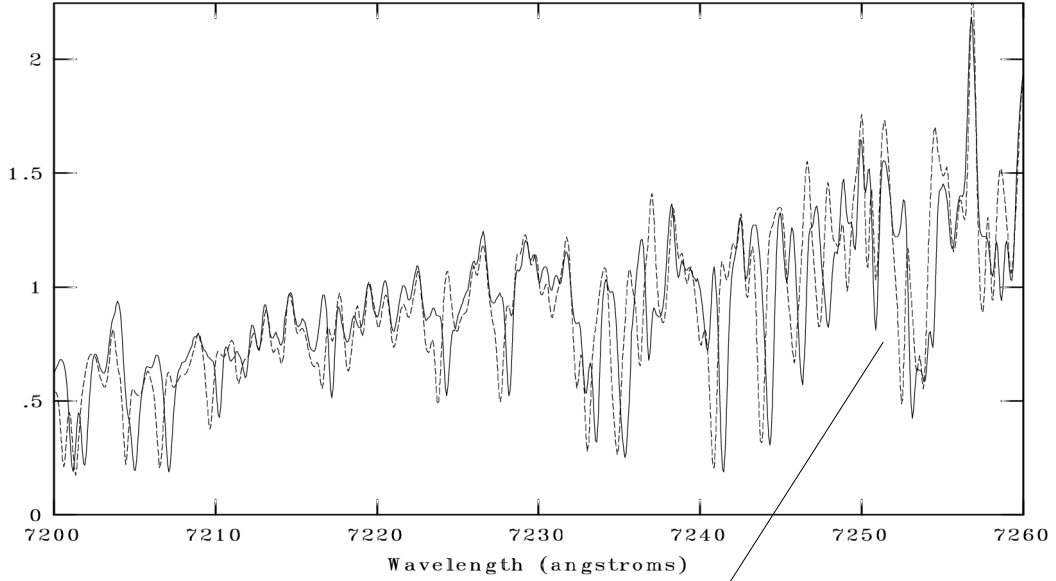


TiO  
7 197.374 Å  
Valenti

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:34:32 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

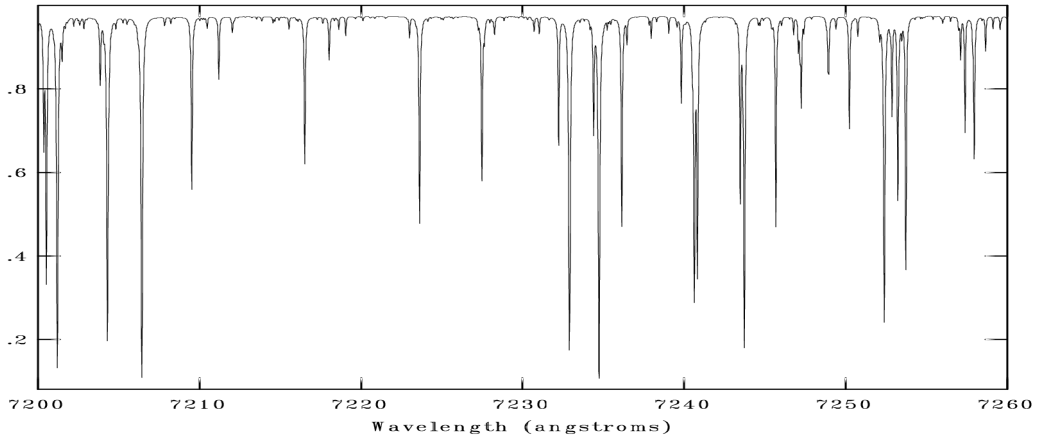


NOAO/IRAF V2.16 st4b417@hspc13 Wed 15:27:40 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



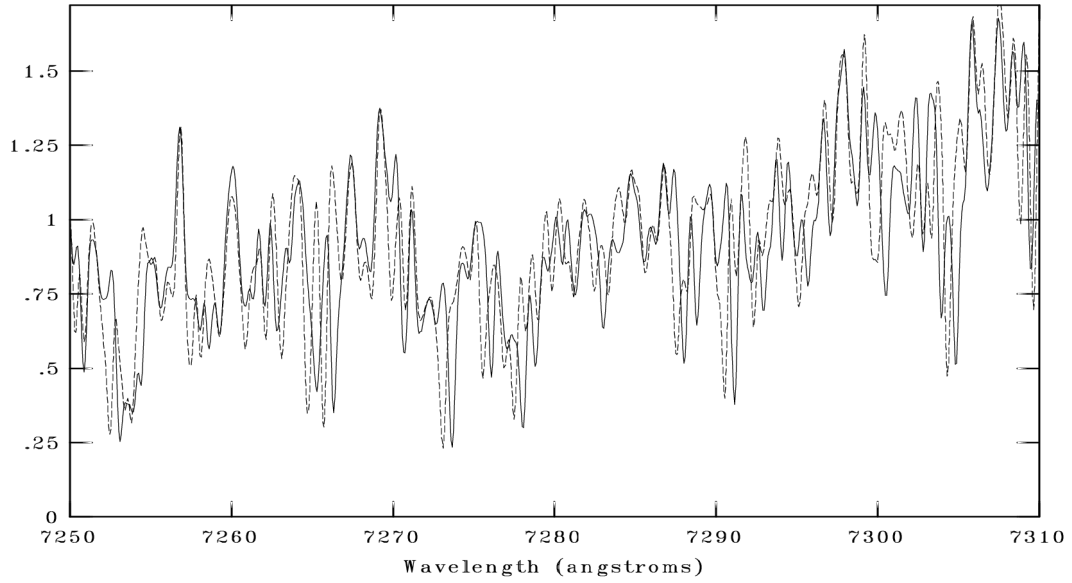
TiO  
7 252.021 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:34:52 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

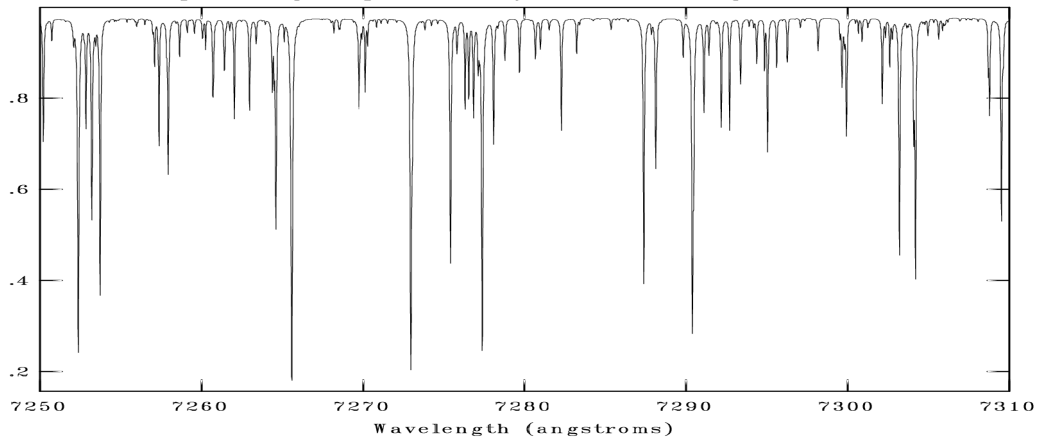


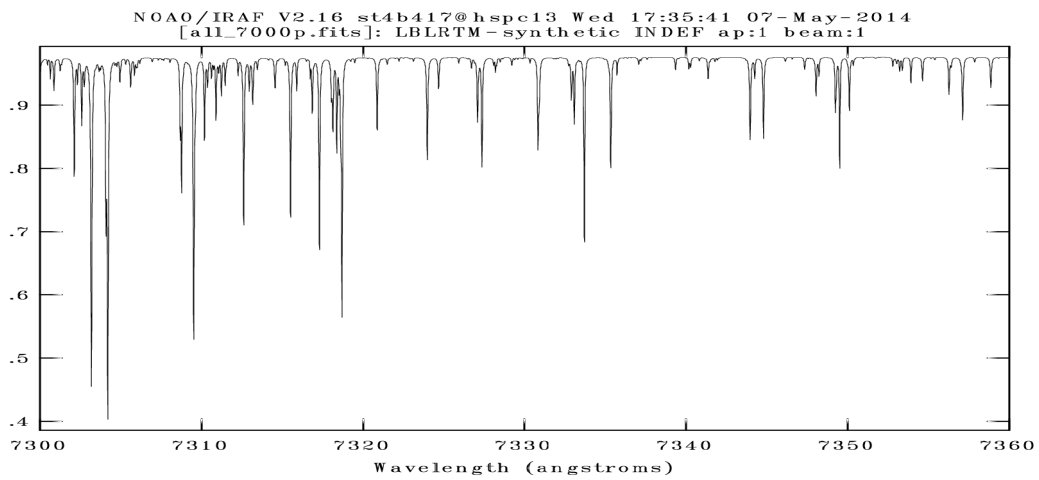
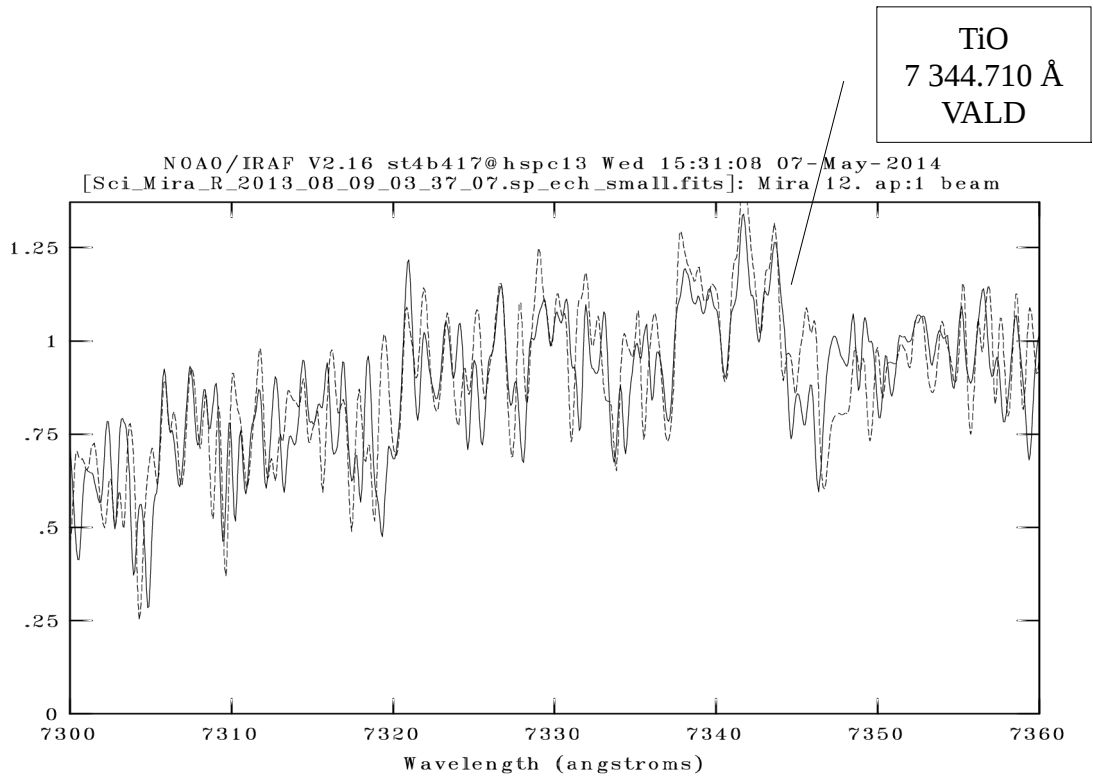


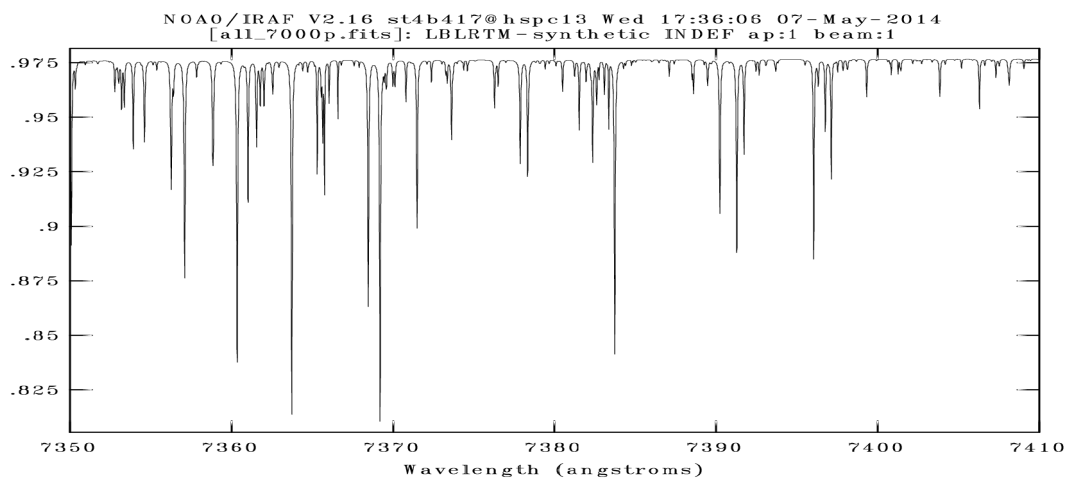
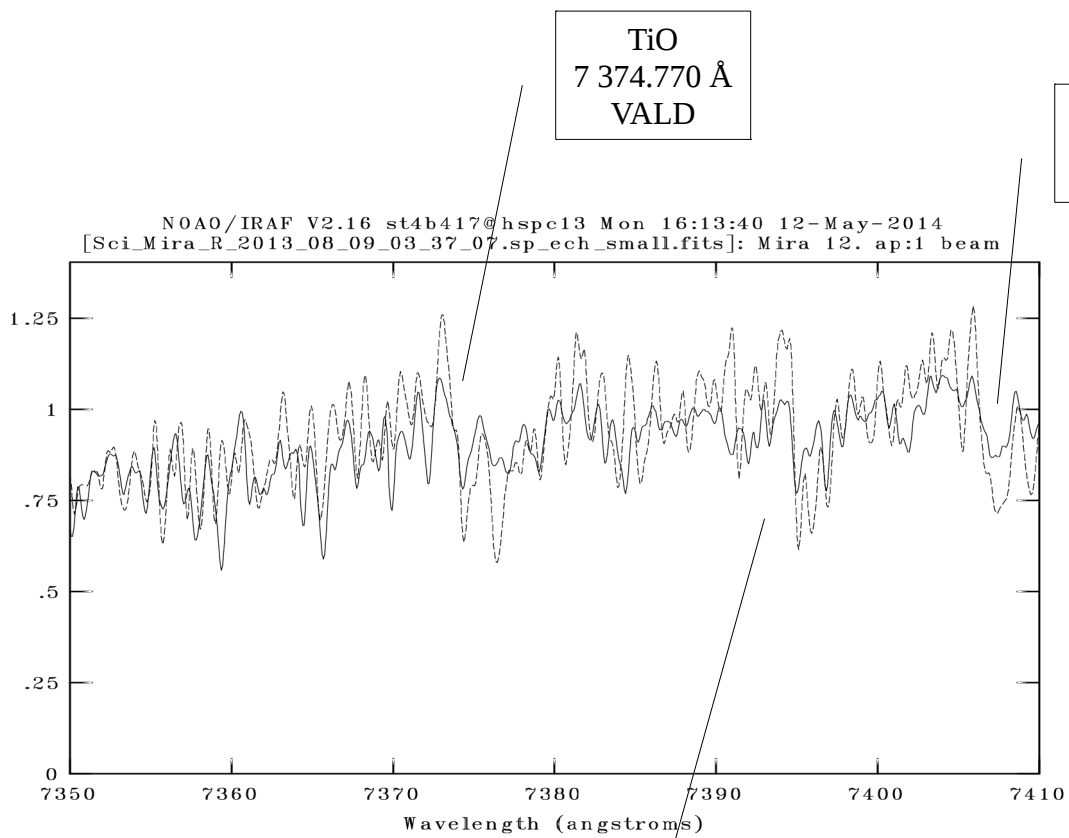
NOAO/IRAF V2.16 st4b417@hspc13 Wed 15:29:22 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

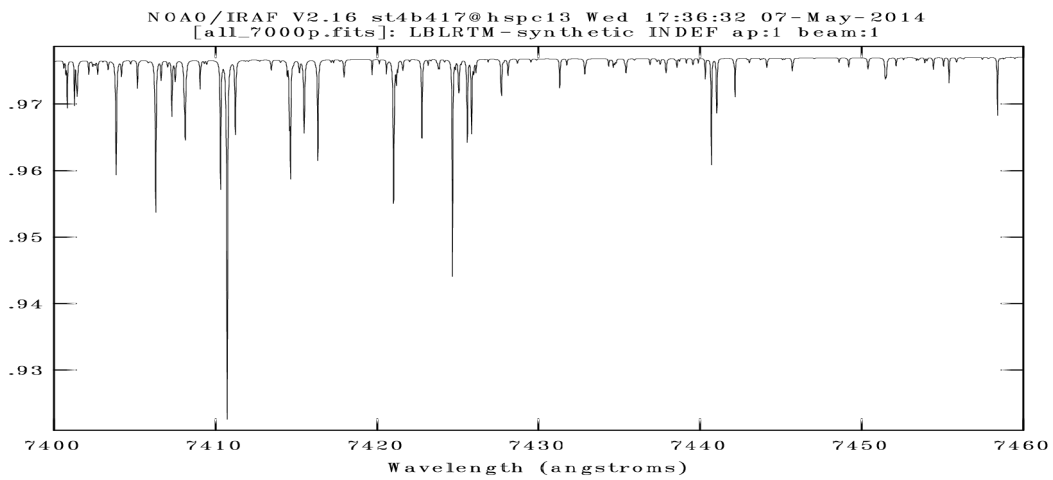
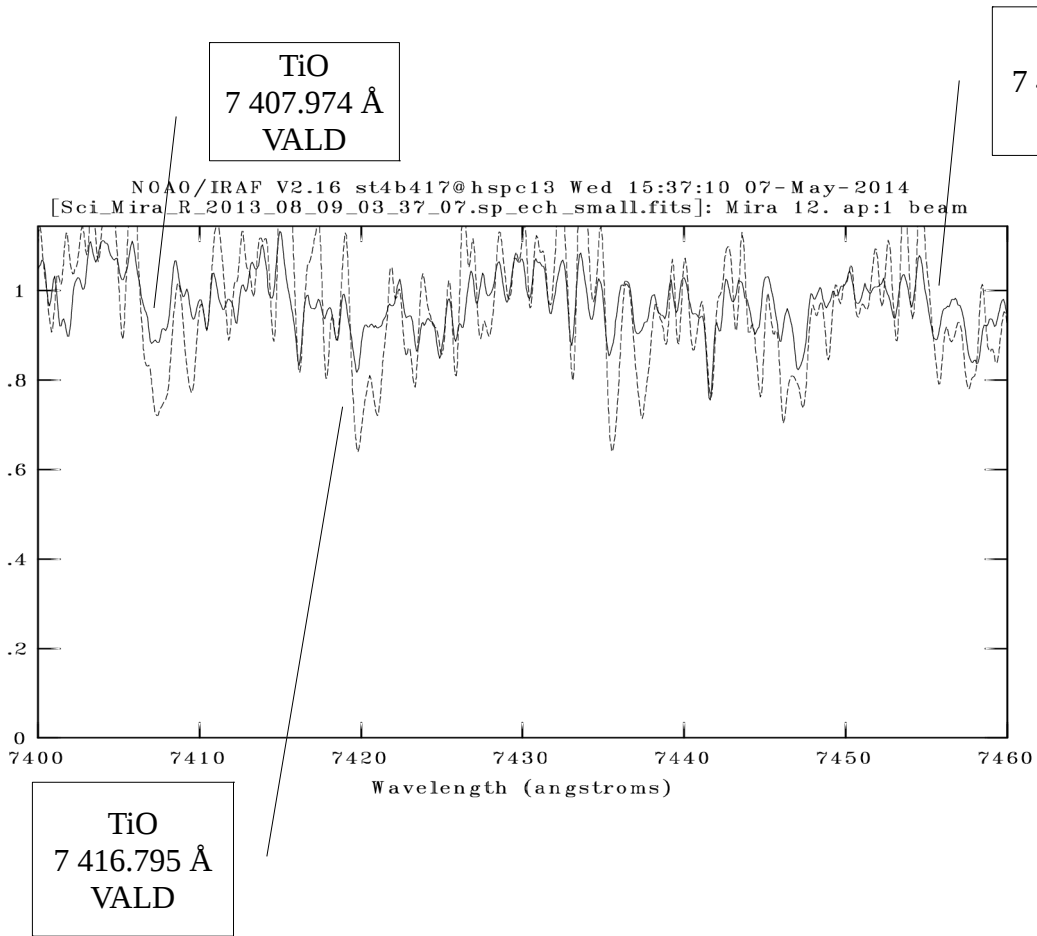


NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:35:14 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



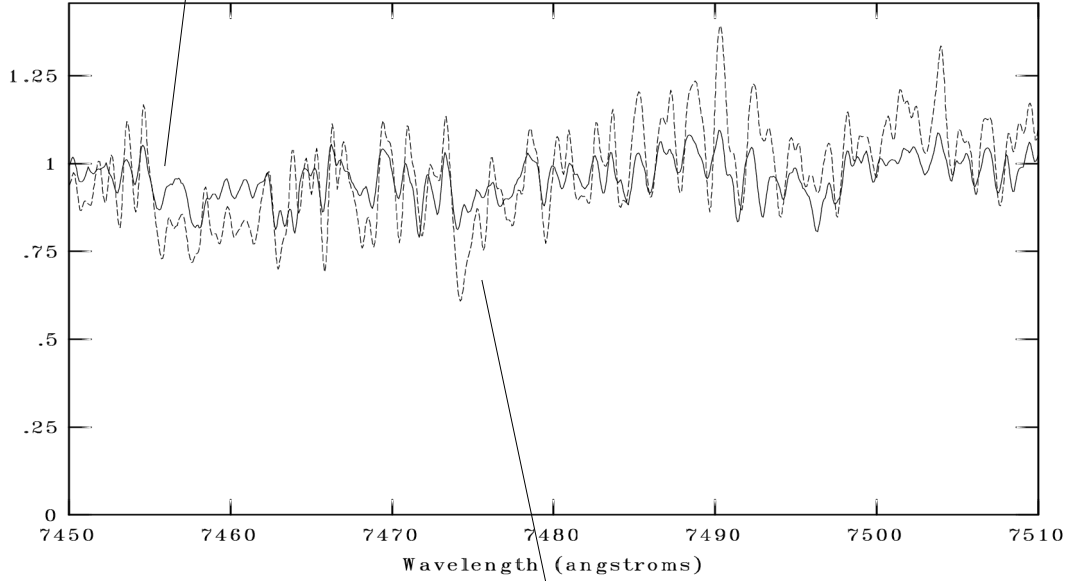






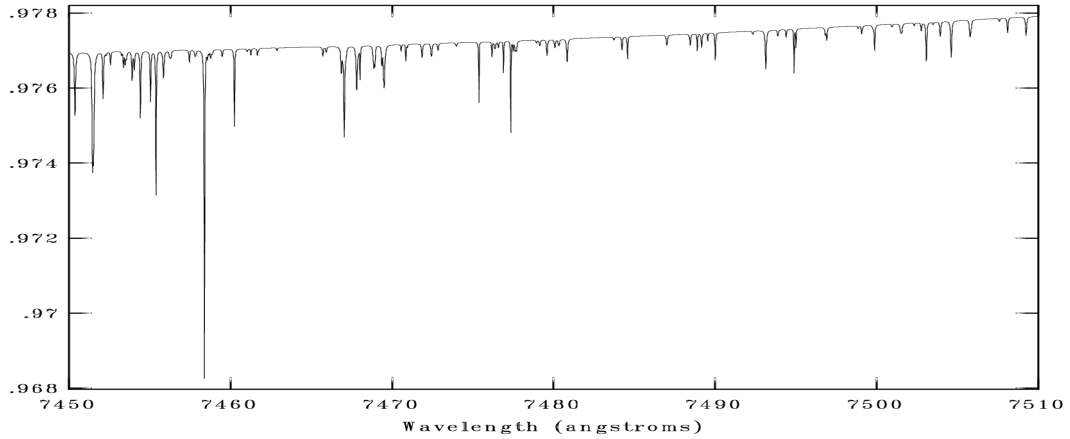
TiO  
7 455.279 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Mon 16:15:28 12-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



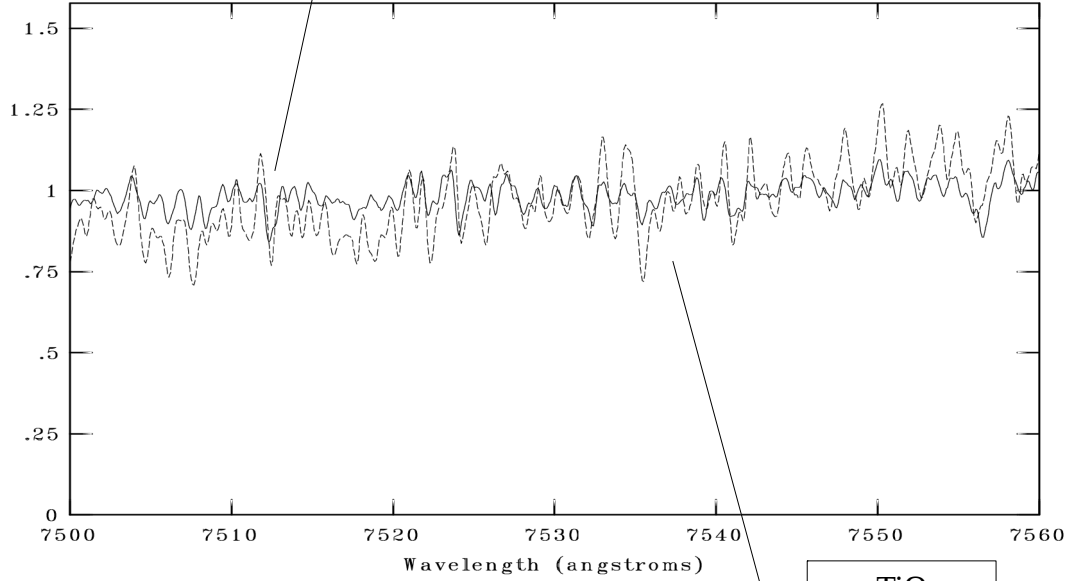
TiO  
7 474.968 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:36:55 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



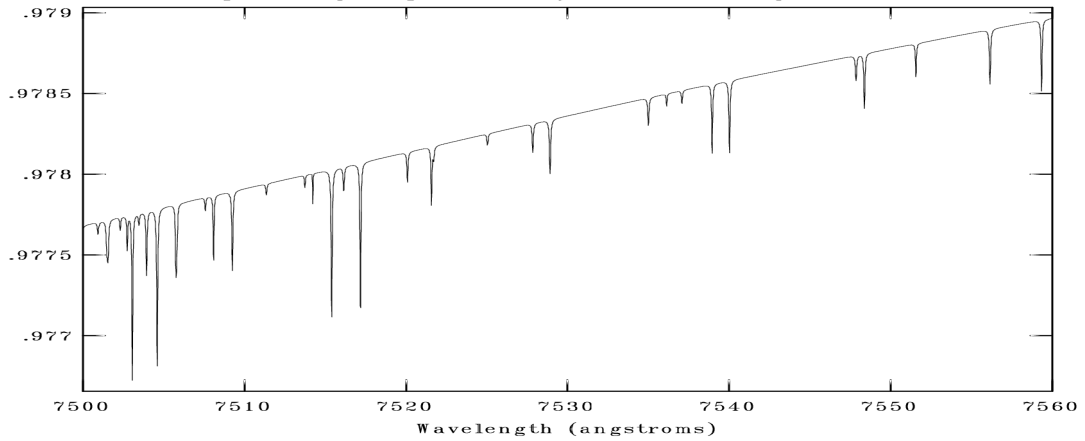
TiO  
7 512.513 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Mon 16:18:07 12-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



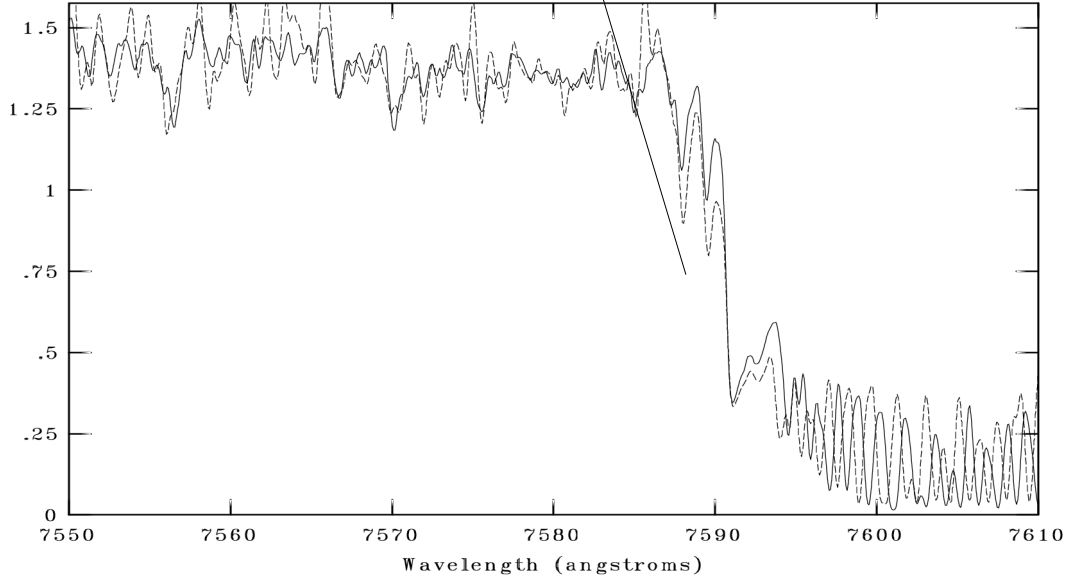
TiO  
7 535.992 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:37:59 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

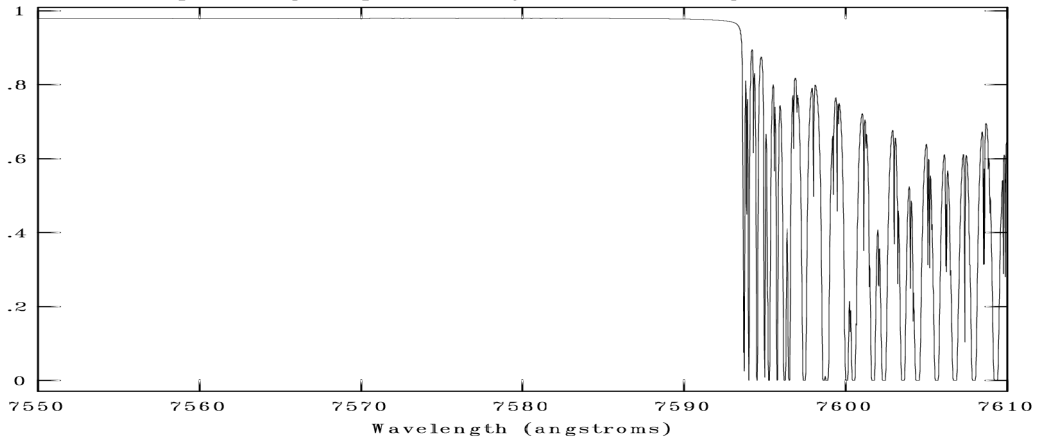


TiO  
7 589.219 Å  
Valenti

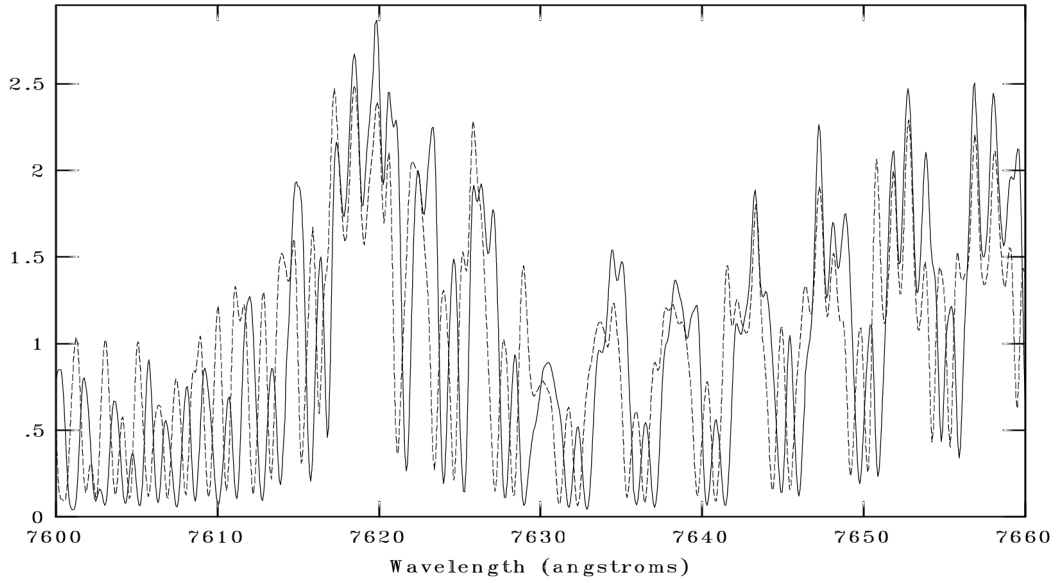
NOAO/IRAF V2.16 st4b417@hspc13 Wed 15:45:53 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



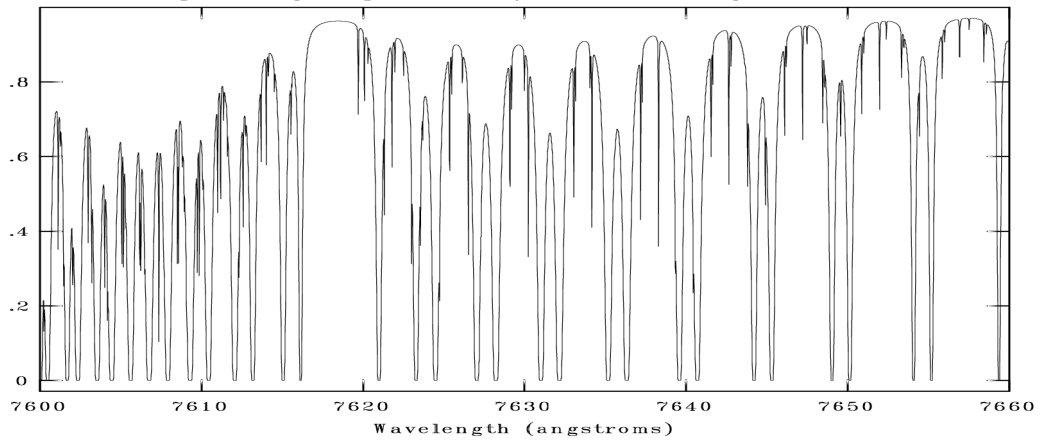
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:38:24 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



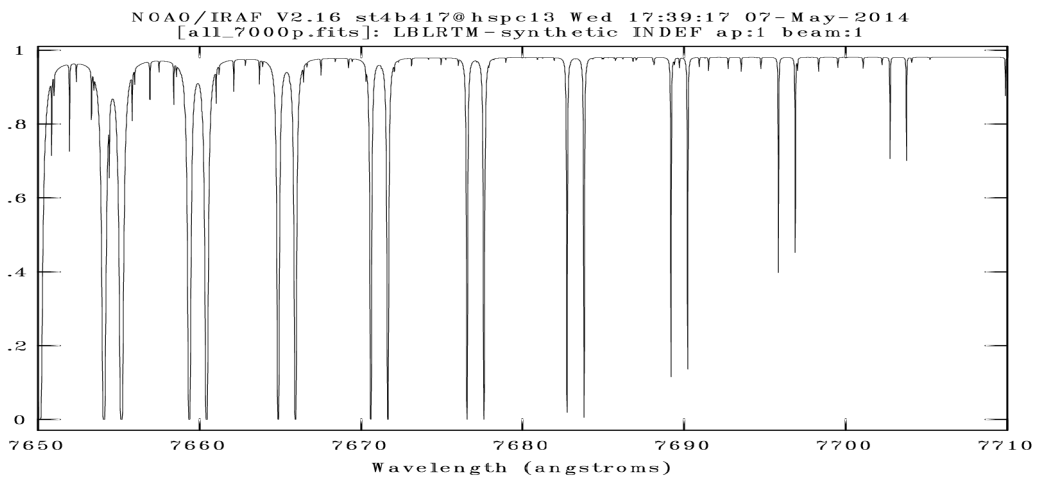
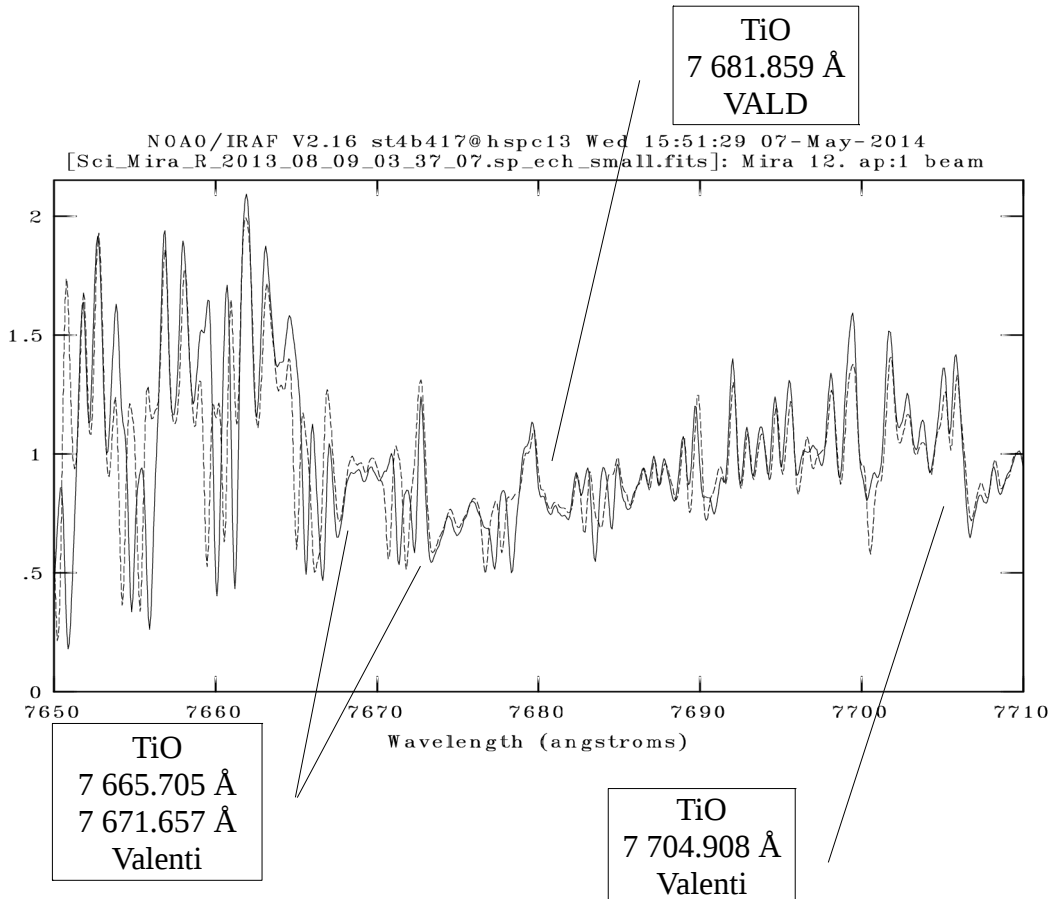
NOAO/IRAF V2.16 st4b417@hspc13 Wed 15:47:57 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



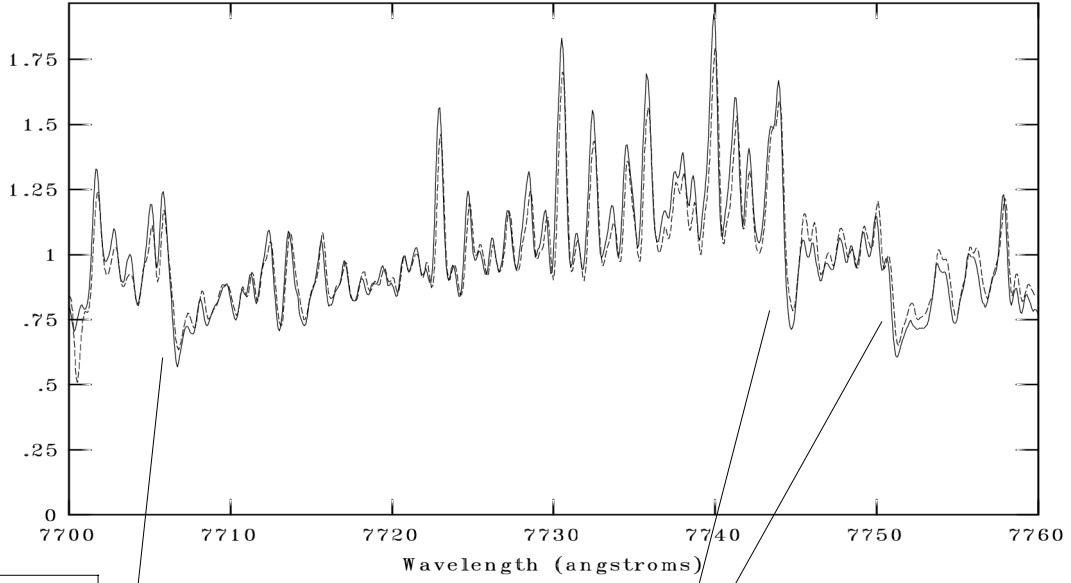
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:38:53 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1







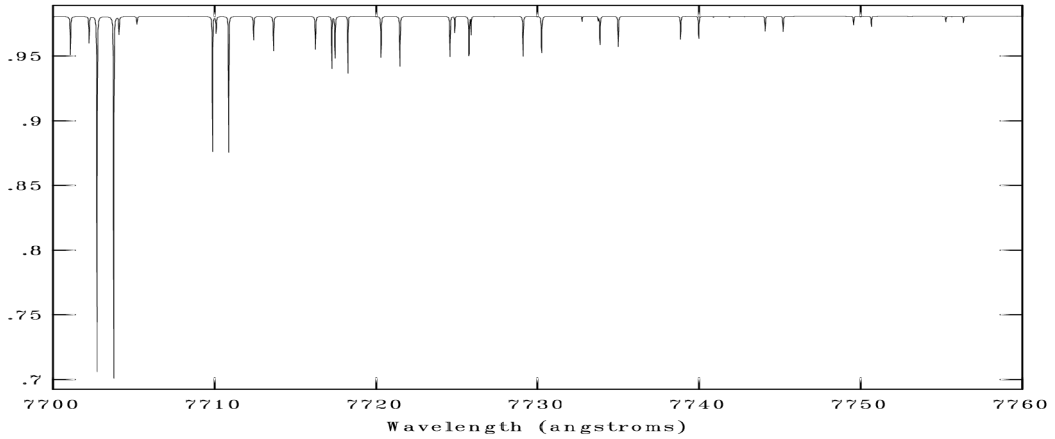
NOAO/IRAF V2.16 st4b417@hspc13 Wed 15:53:25 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



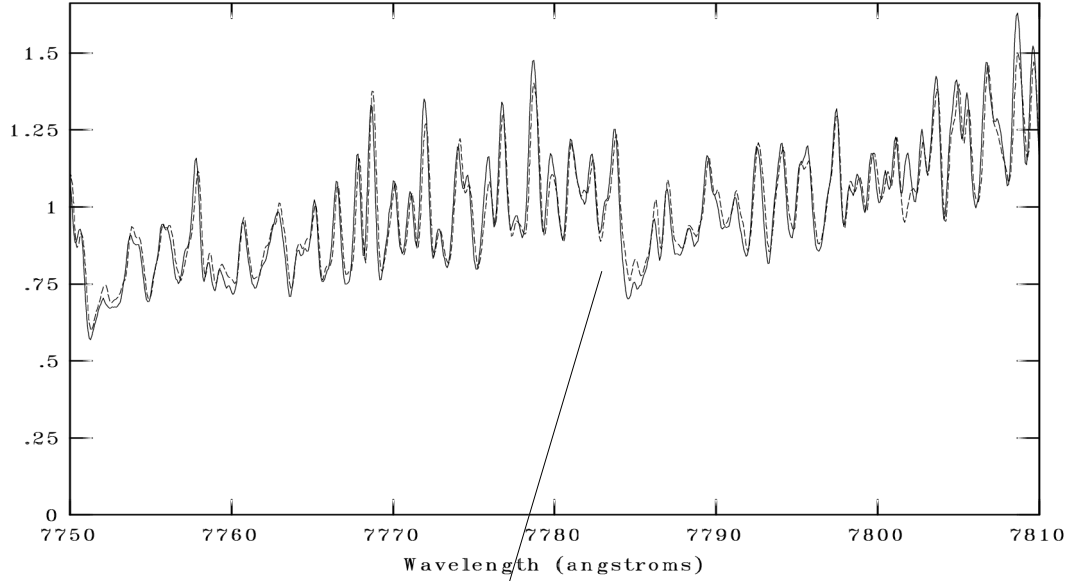
TiO  
7 704.908 Å  
Valenti

TiO  
7 743.011 Å  
7 749.499 Å  
Valenti

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:39:42 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

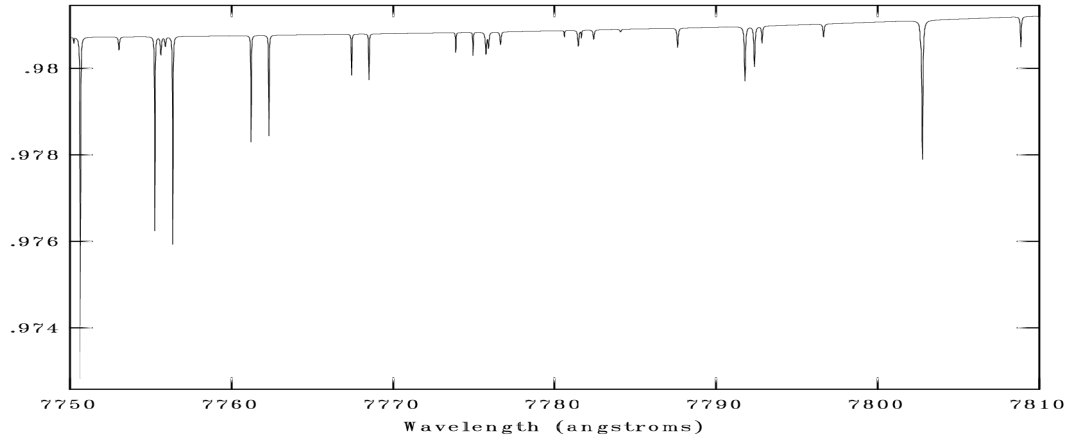


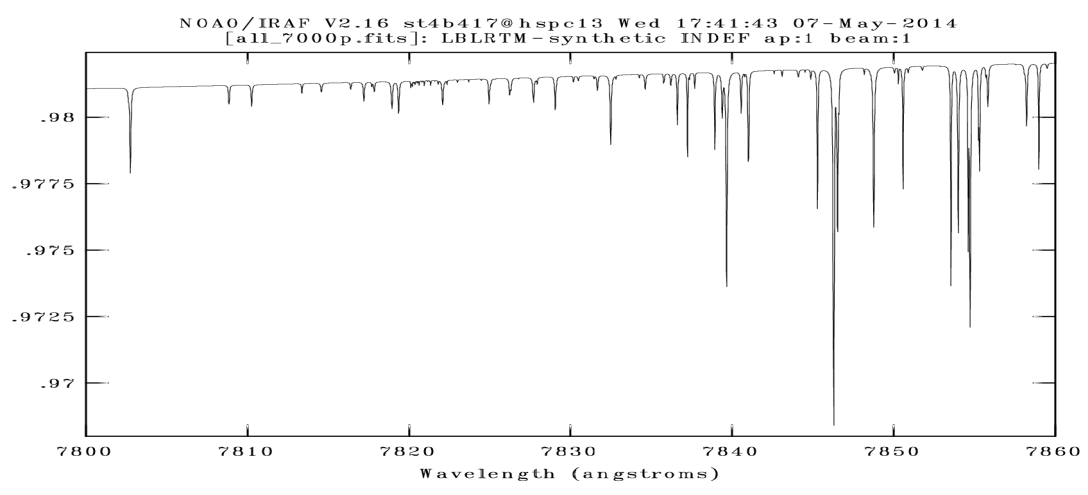
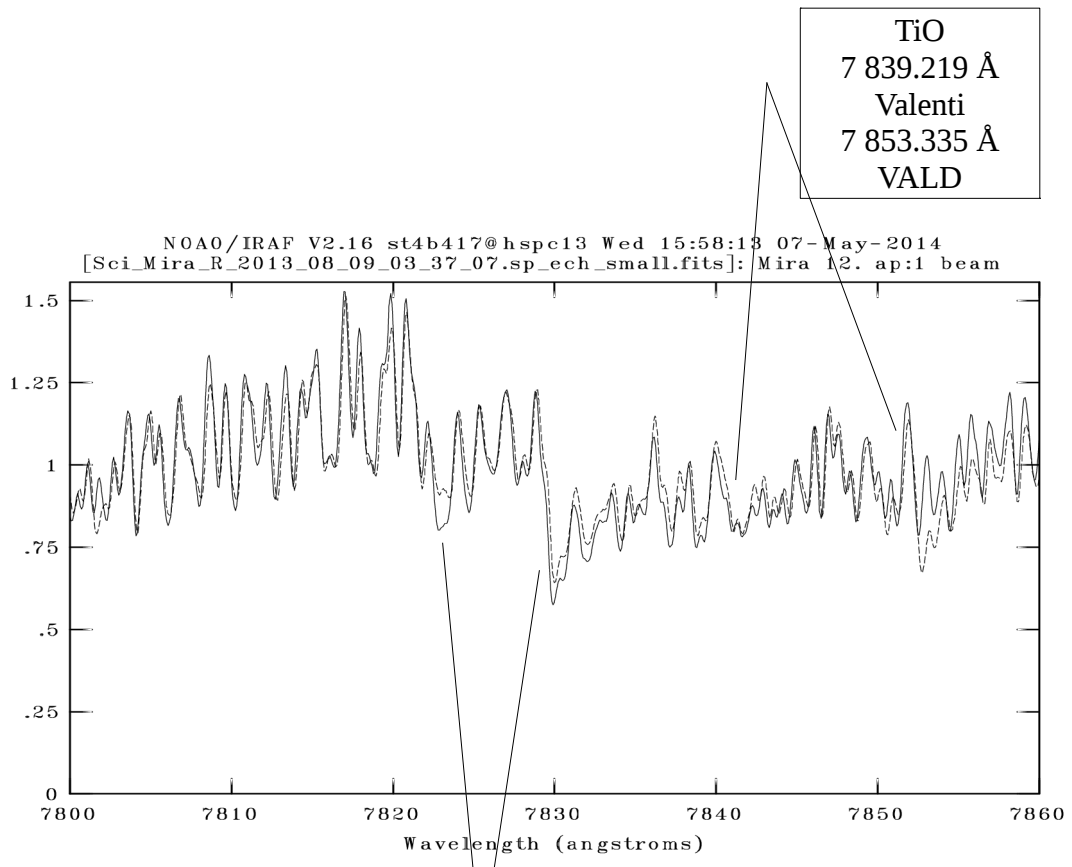
NOAO/IRAF V2.16 st4b417@hspc13 Wed 15:55:37 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



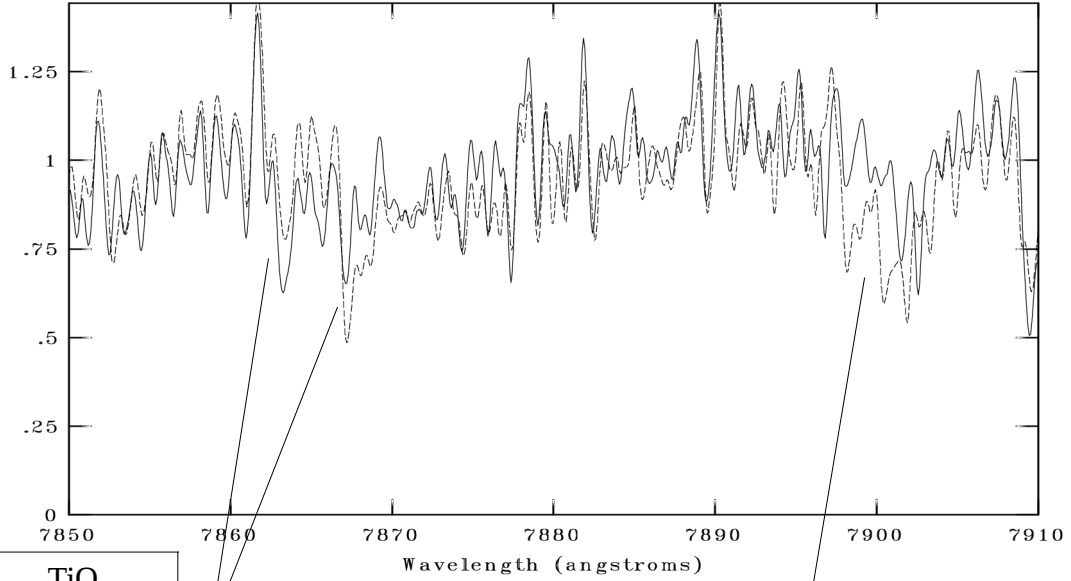
TiO  
7 782.820 Å  
Valenti

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:41:05 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1





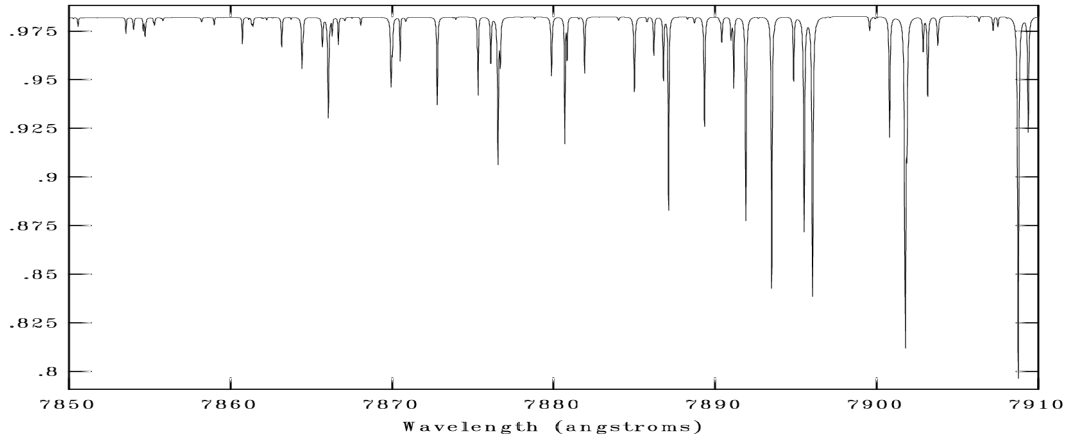
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:01:03 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



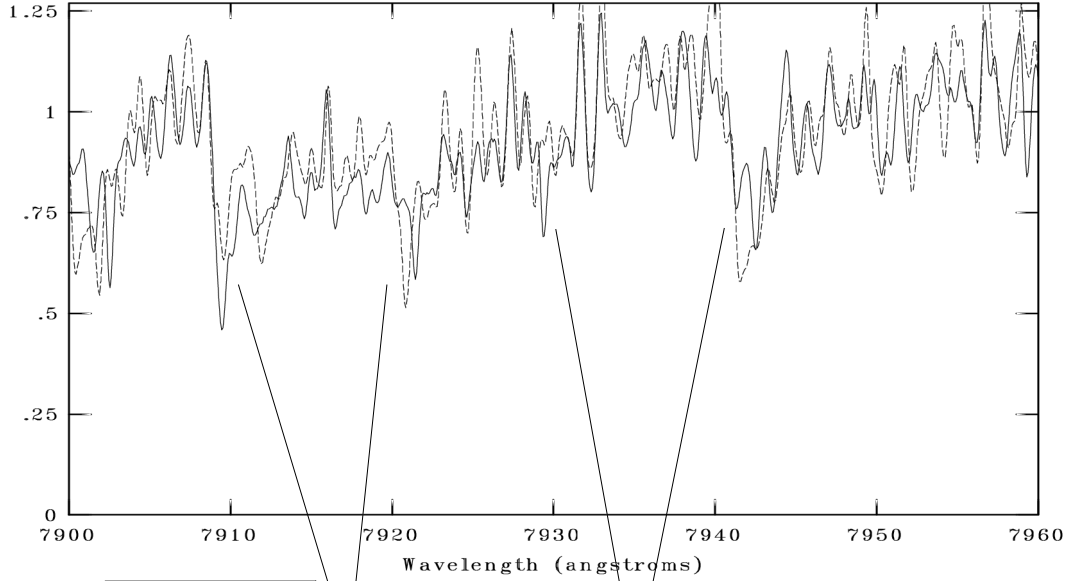
TiO  
7 861.489 Å  
Valenti  
7 866.770  
VALD

TiO  
7 899.123 Å  
Valenti

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:42:10 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



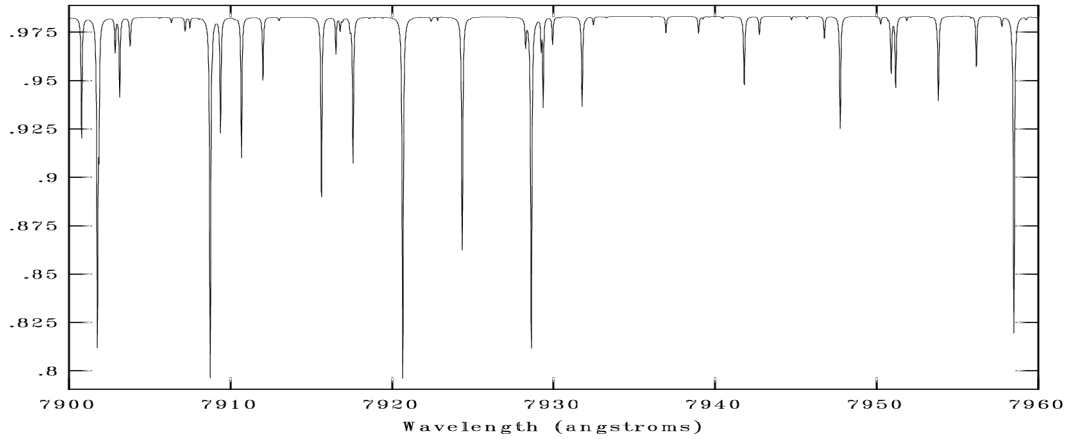
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:04:12 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



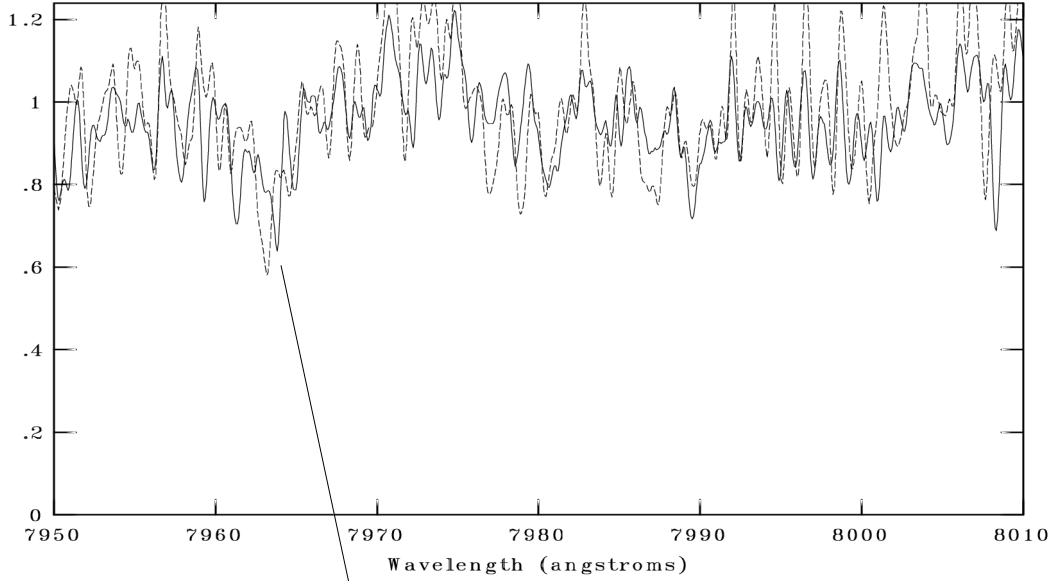
TiO  
7 907.611 Å  
Valenti  
7 922.278 Å  
VALD

TiO  
7 929.121 Å  
7 941.384 Å  
VALD

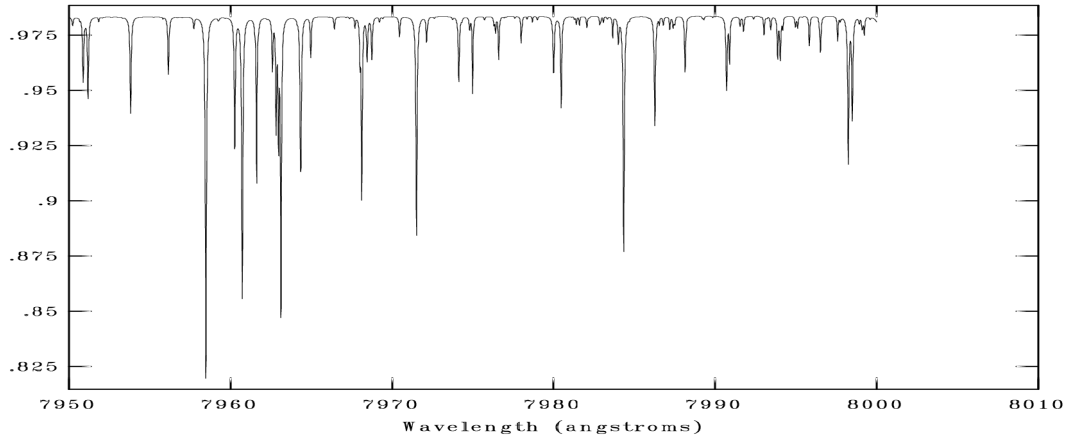
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:42:32 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



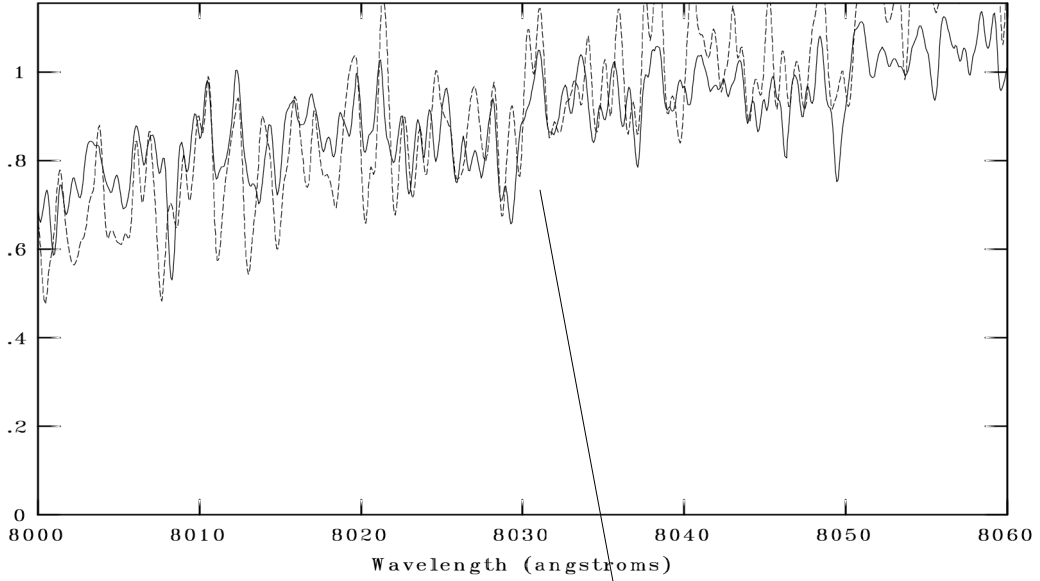
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:05:50 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:43:08 07-May-2014  
[all\_7000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

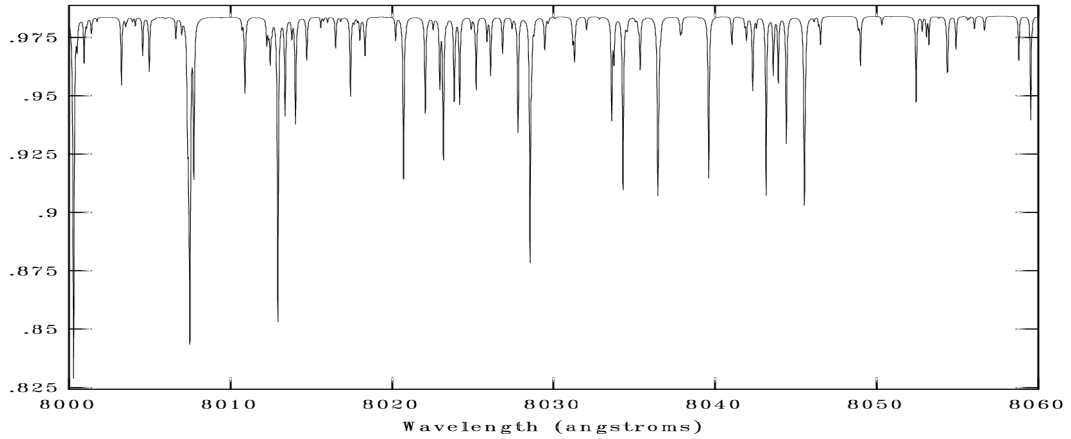


NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:07:52 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



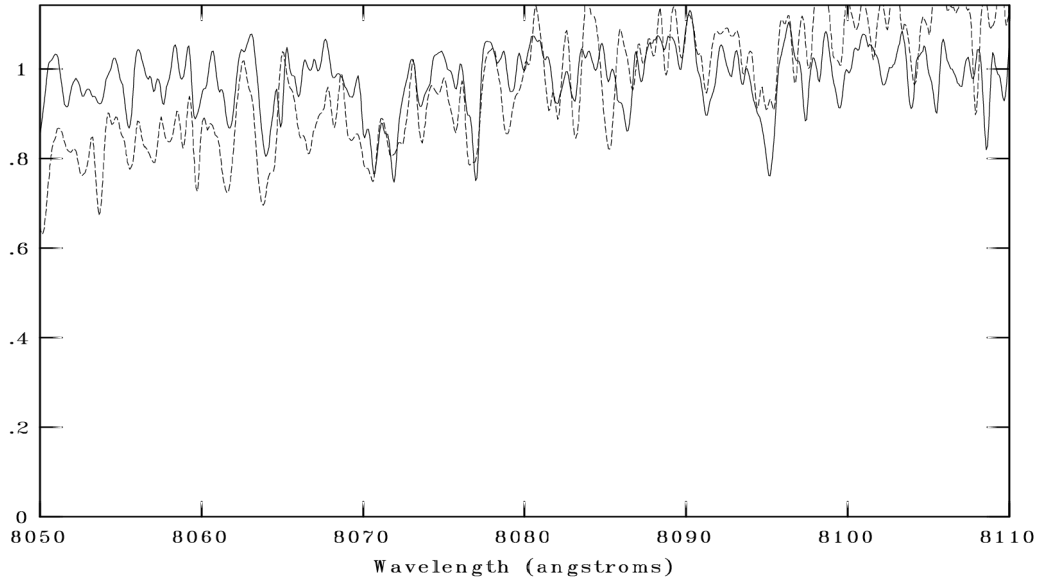
TiO  
8 029.268 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:44:19 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

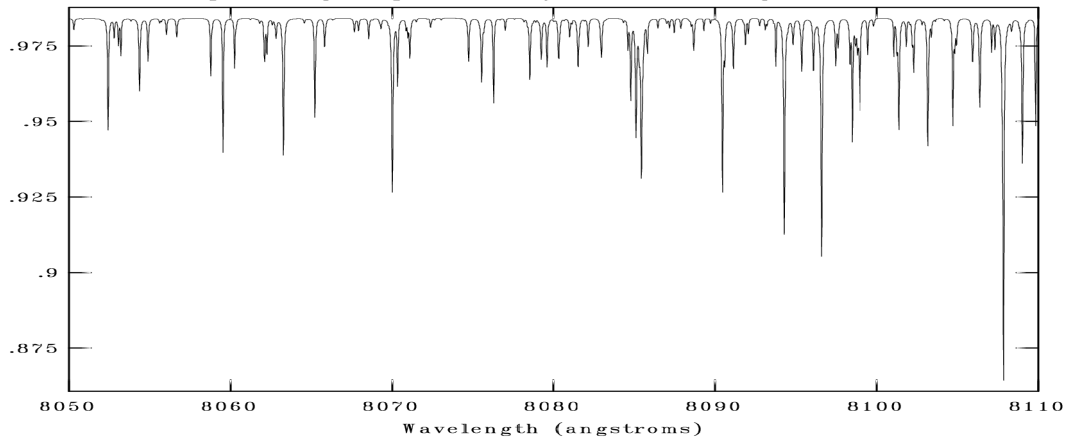




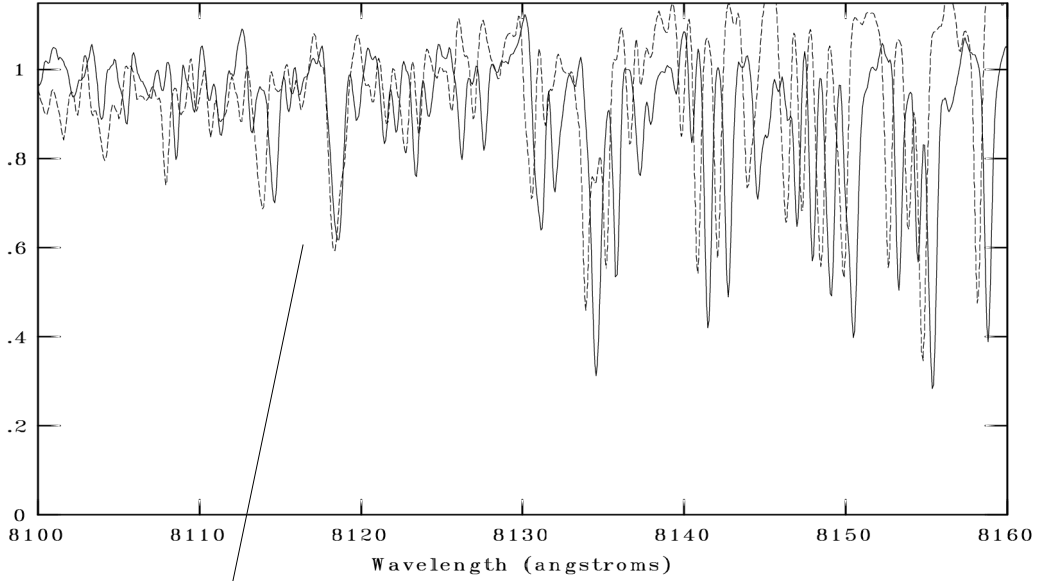
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:25:45 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:44:42 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

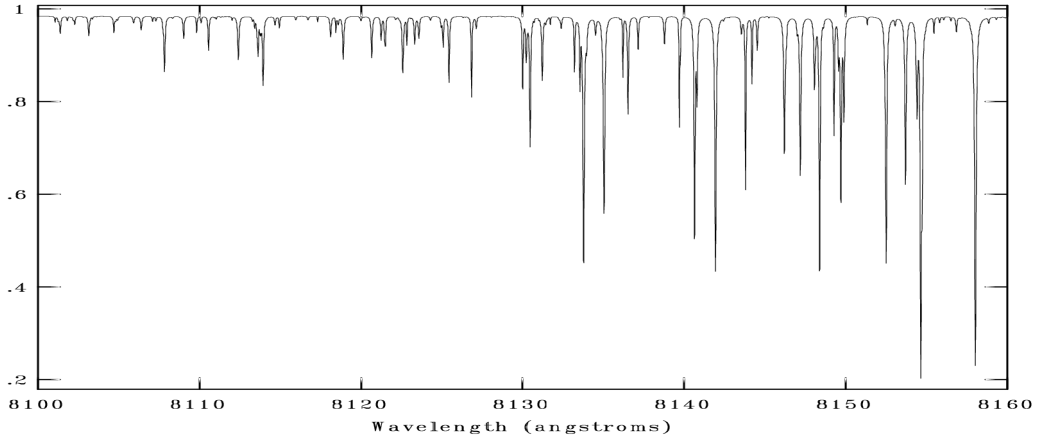


NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:27:52 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

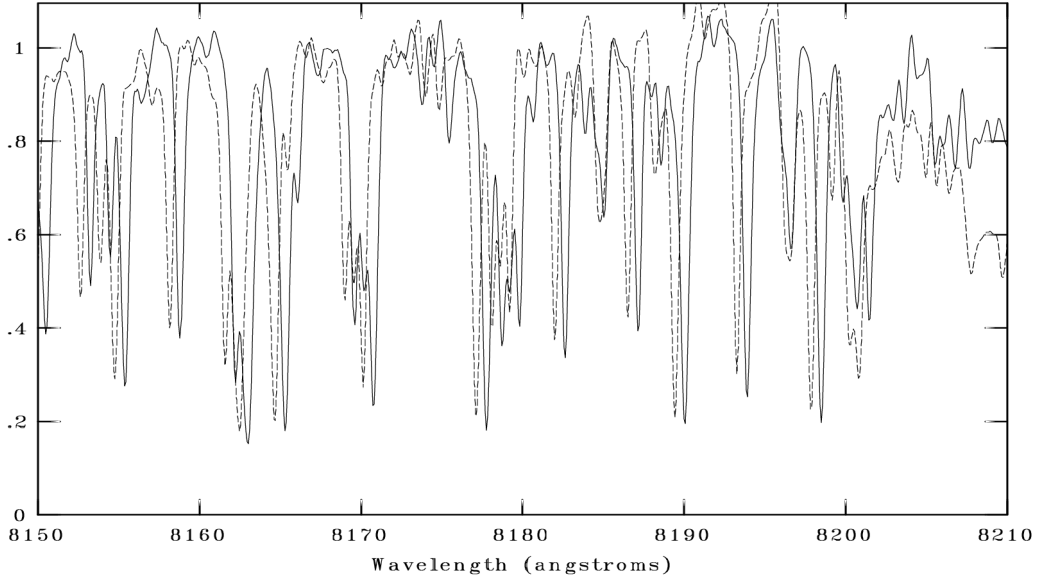


TiO  
8 118.961 Å  
VALD

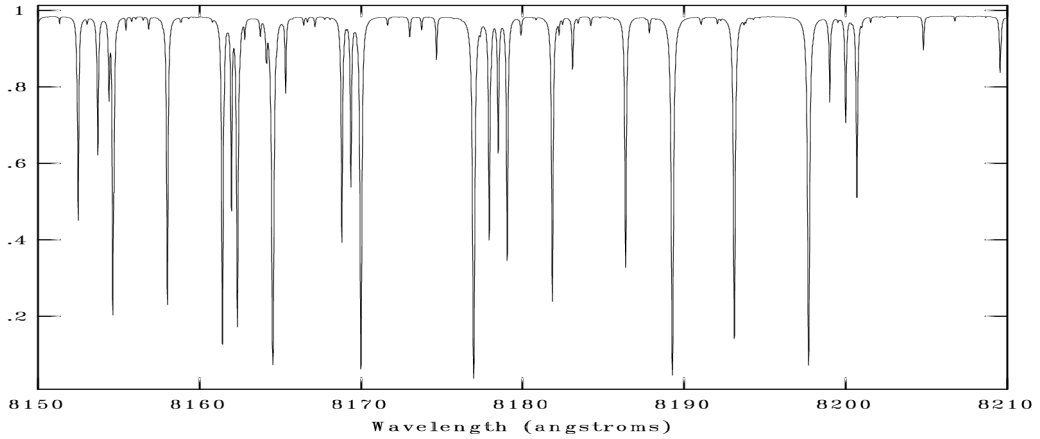
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:45:08 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



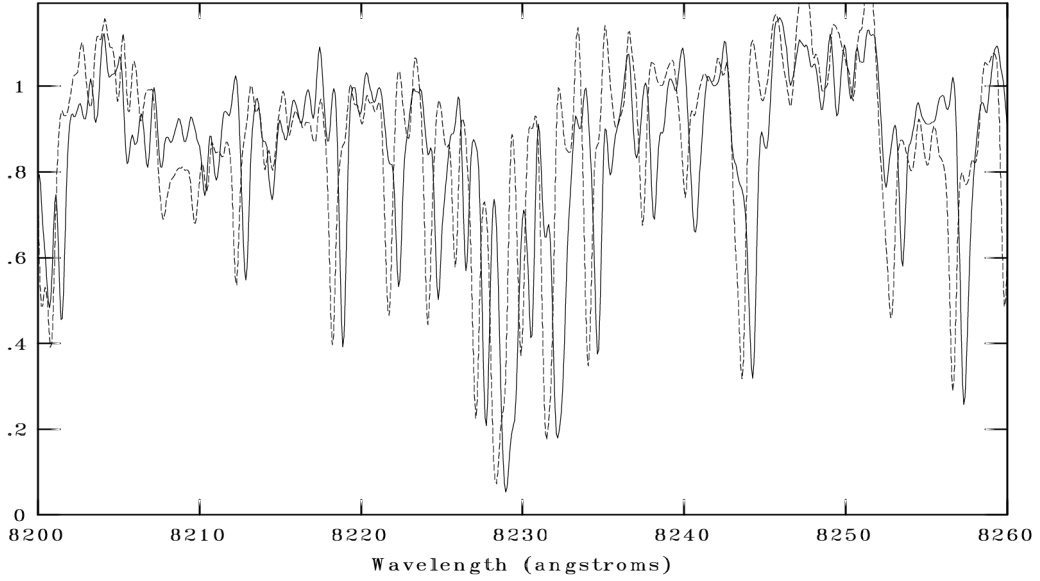
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:30:26 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



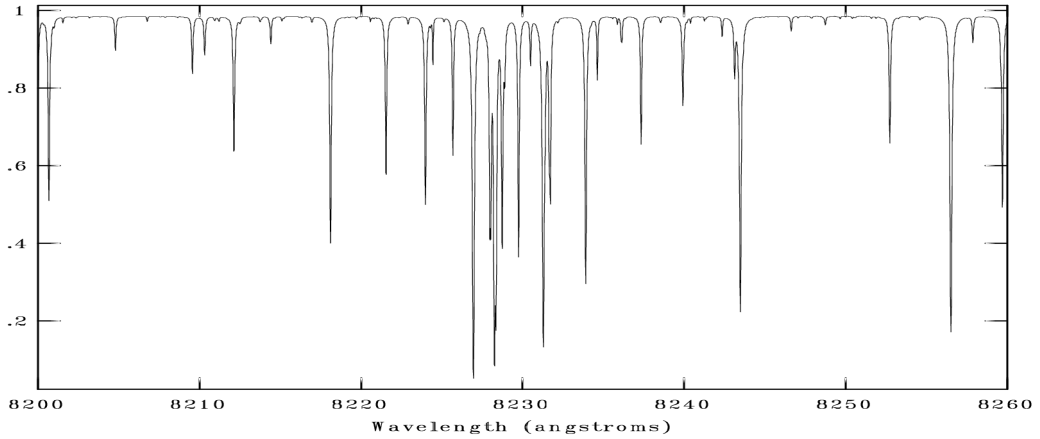
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:45:34 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:32:11 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

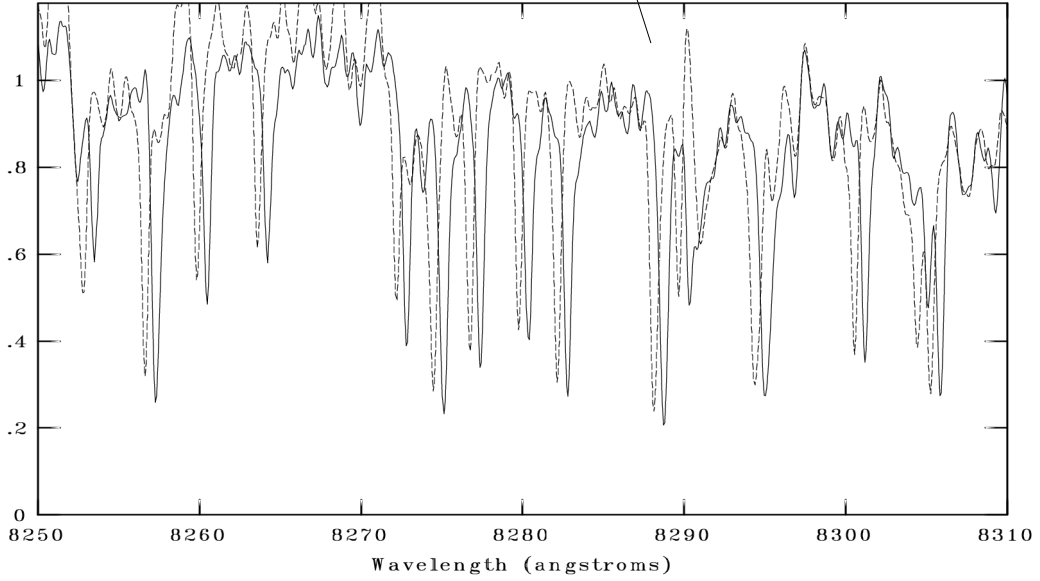


NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:45:59 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

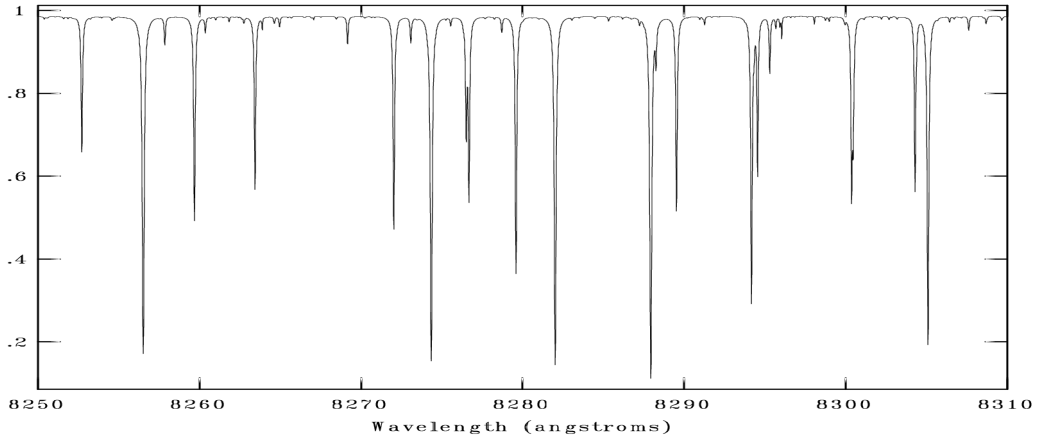


Fe I  
8 291.764 Å  
NIST

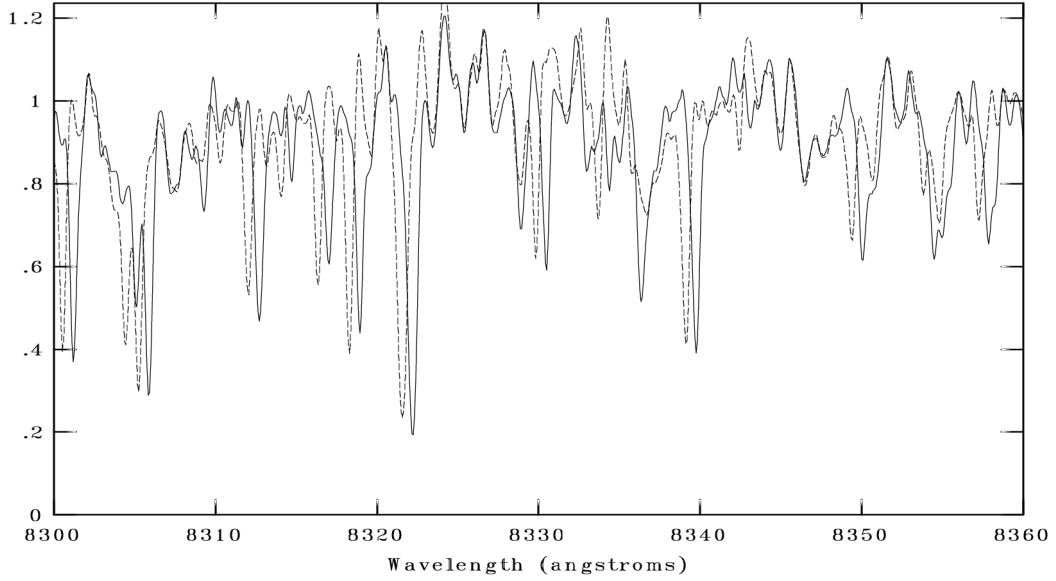
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:35:17 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



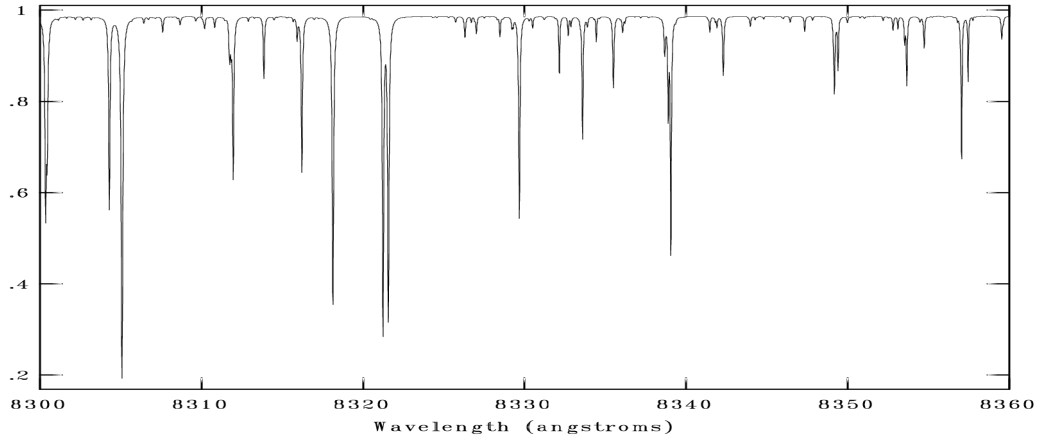
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:46:20 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



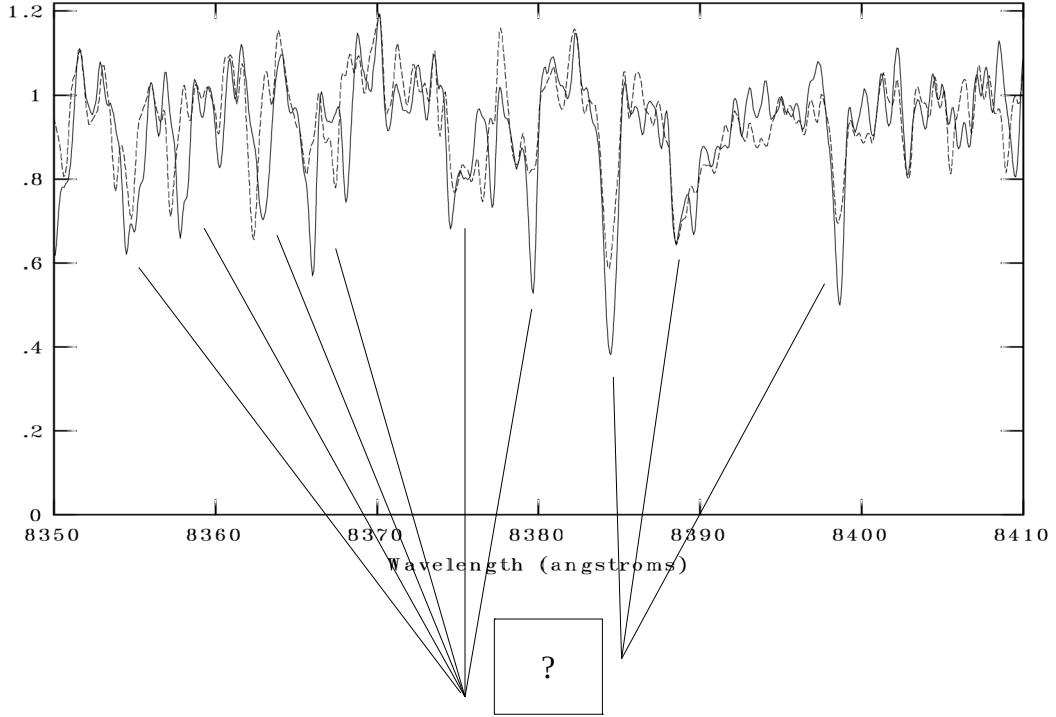
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:36:53 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



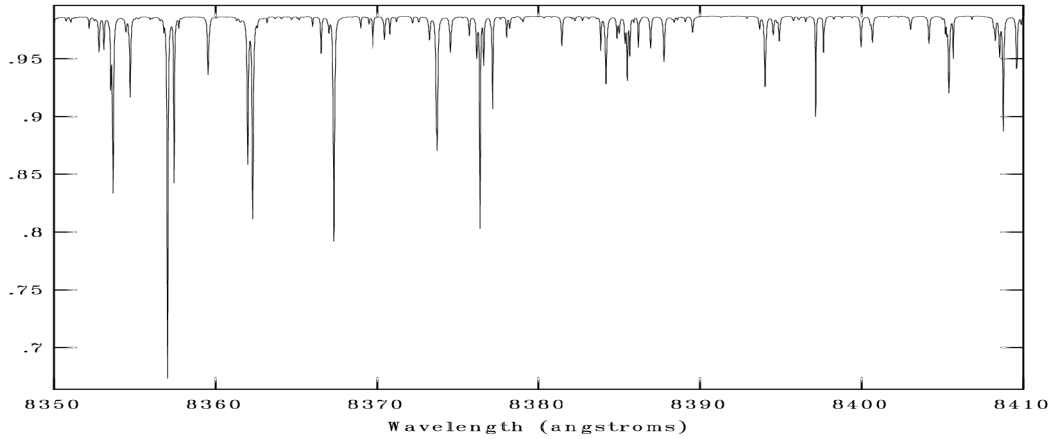
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:46:50 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



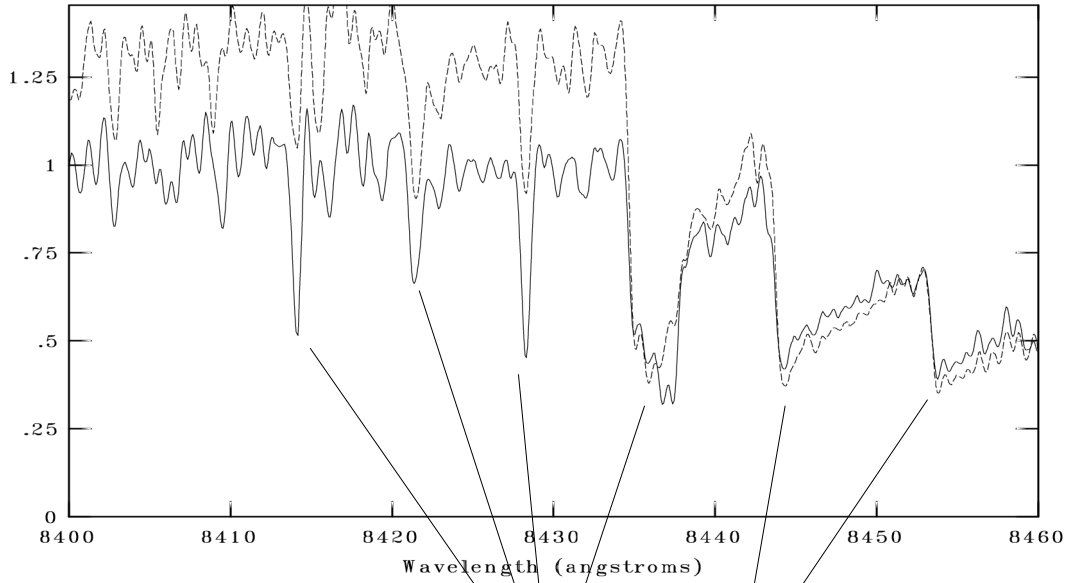
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:38:31 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



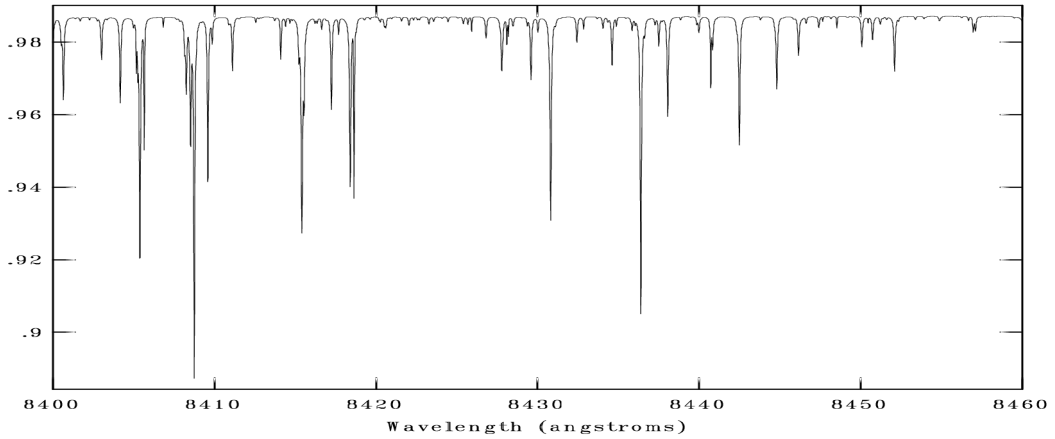
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:47:11 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



NOAO/IRAF V2.16 st4b417@hspc13 Mon 16:23:34 12-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

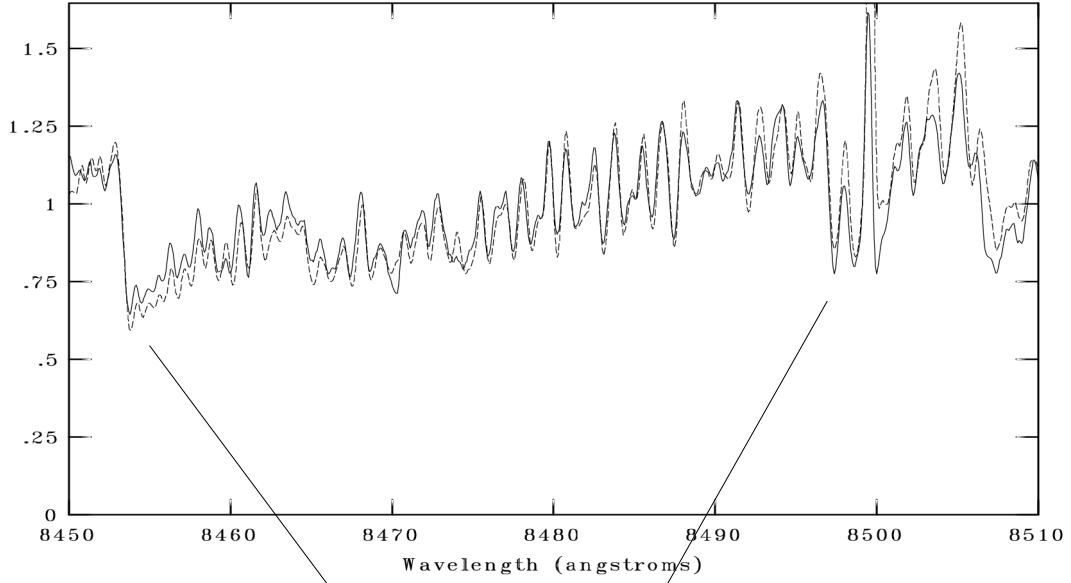


NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:47:35 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



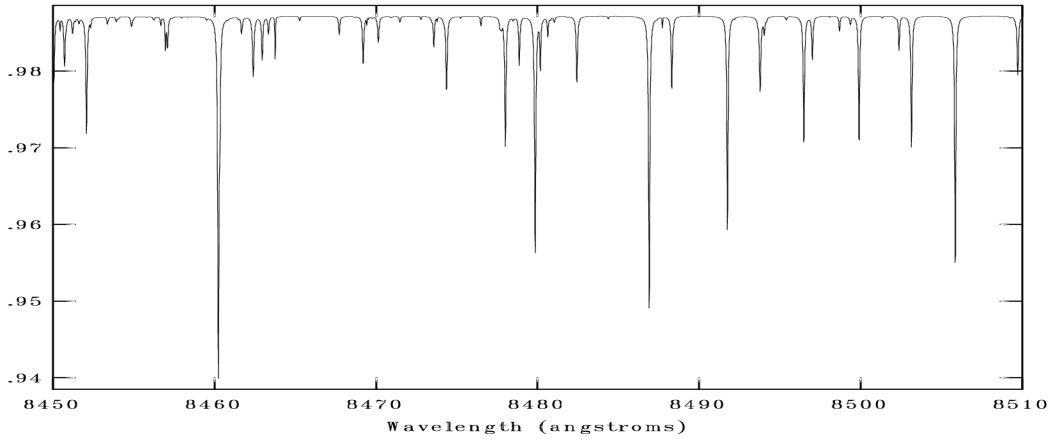


NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:41:59 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

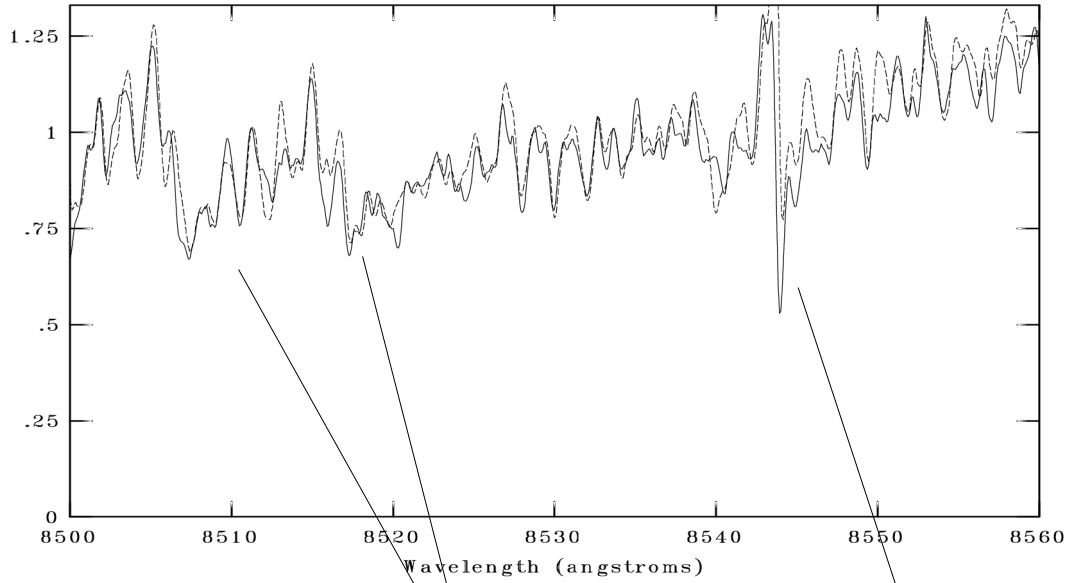


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NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:47:56 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



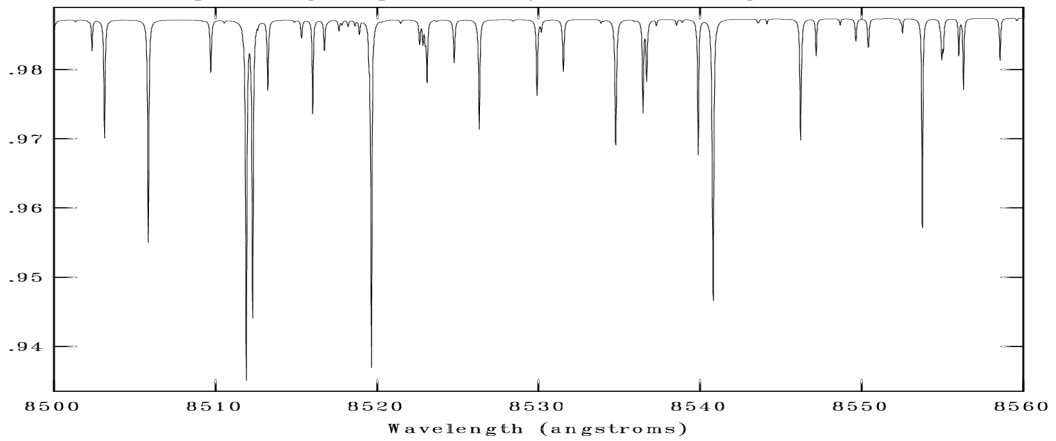
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:44:34 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



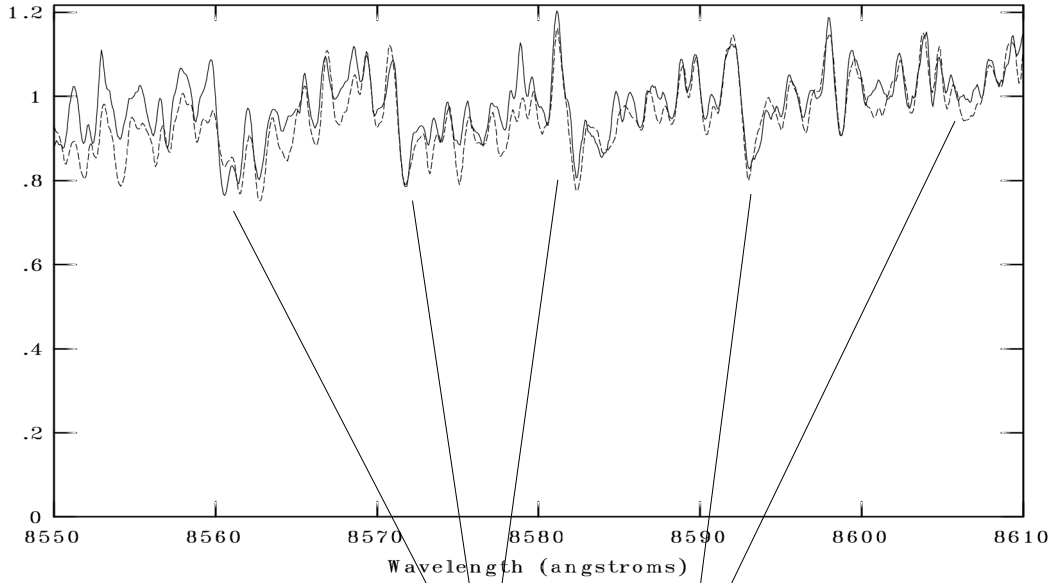
?

Ca II  
8 542.14  
NIST

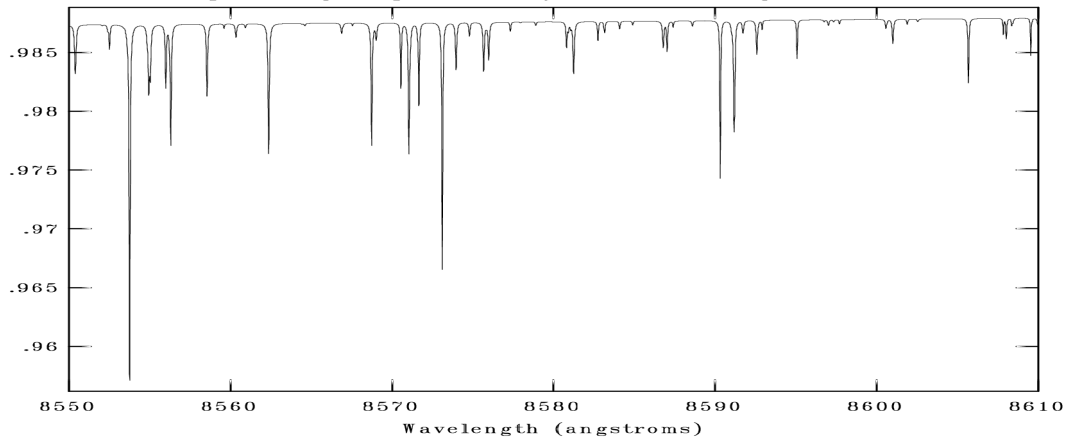
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:48:26 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



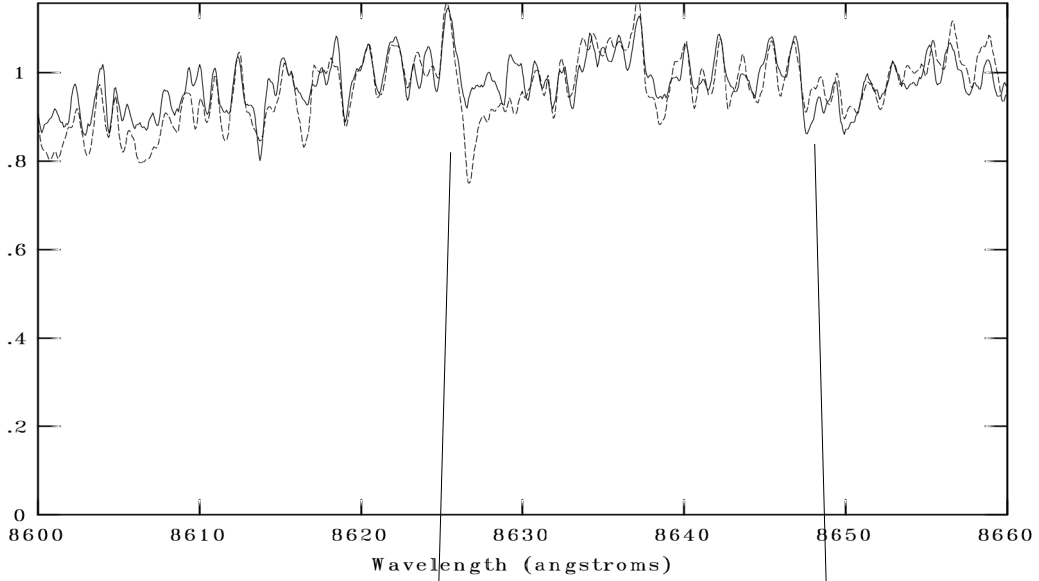
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:46:30 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:48:49 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



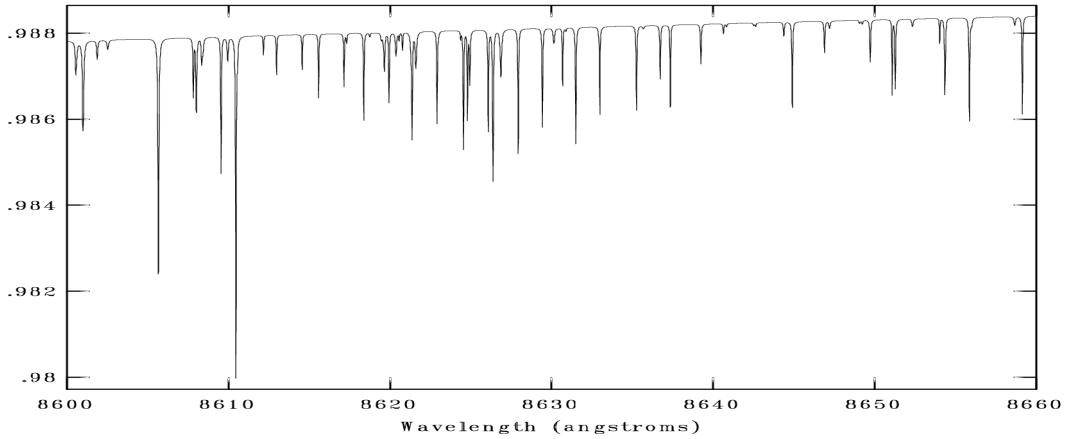
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:48:21 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



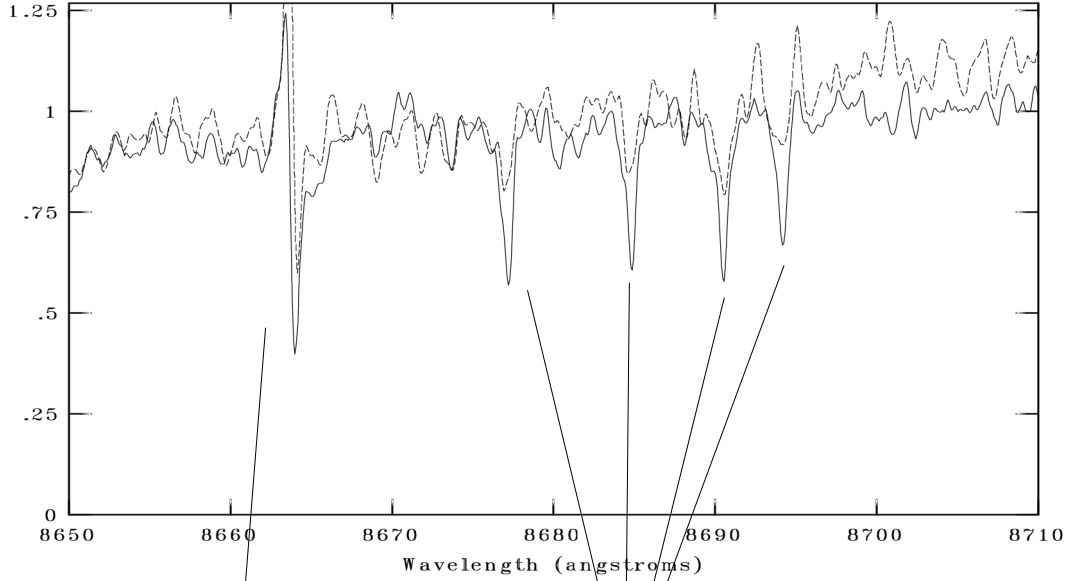
TiO  
8 626.383 Å  
VALD

TiO  
8 646.842 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:49:17 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



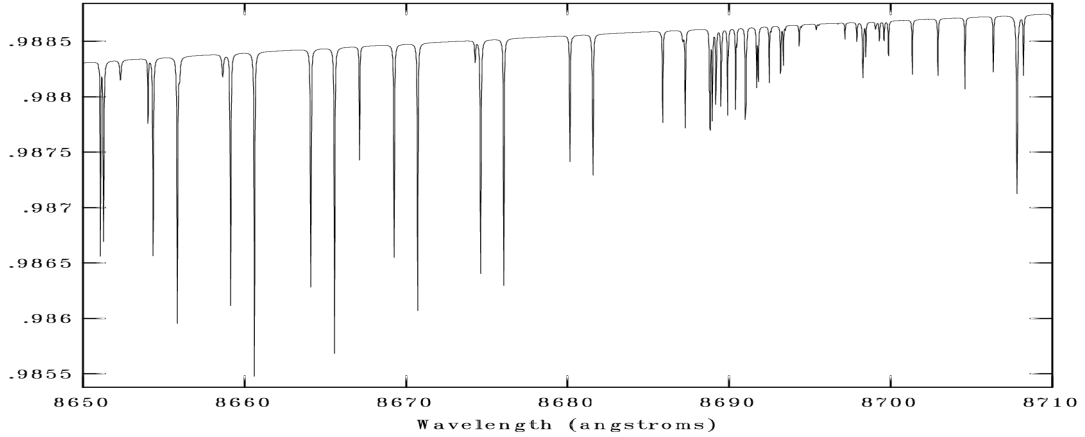
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:49:46 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam



Ca II  
8 662.17 Å  
NIST

TiO  
8 687.435 Å  
8 684.066 Å  
8 690.256 Å  
8 695.827 Å  
VALD

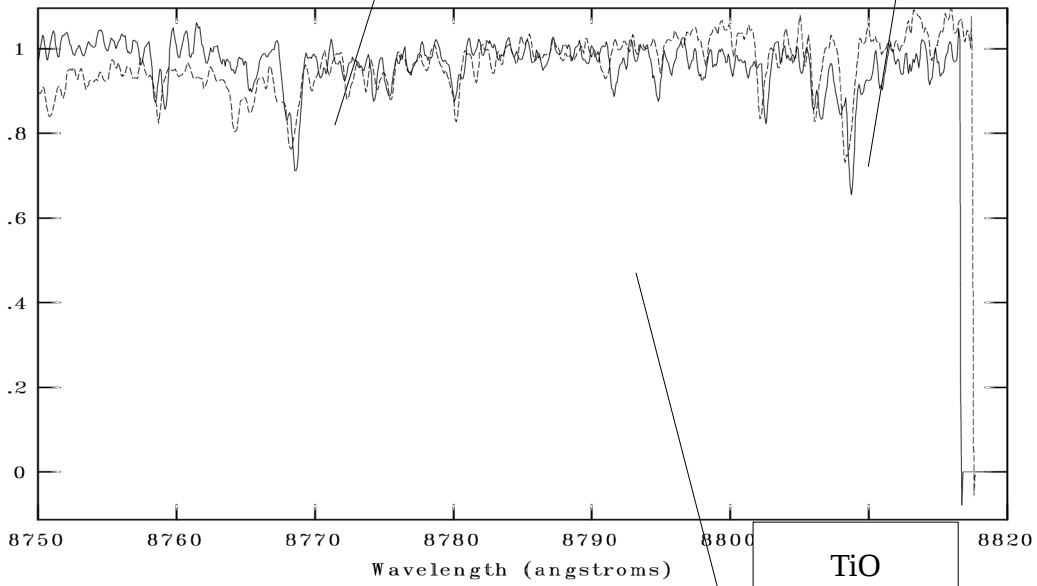
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:49:44 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1



NOAO/IRAF V2.16 st4b417 16:20:26 12-May-2014  
NOAO/IRAF V2.16 st4b417@hspc13 Wed 16:53:28 07-May-2014  
[Sci\_Mira\_R\_2013\_08\_09\_03\_37\_07.sp\_ech\_small.fits]: Mira 12. ap:1 beam

TiO  
8 768.306 Å  
VALD

?



TiO  
8 737.331 Å  
VALD

NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:50:12 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1  
NOAO/IRAF V2.16 st4b417@hspc13 Wed 17:50:52 07-May-2014  
[all\_8000p.fits]: LBLRTM-synthetic INDEF ap:1 beam:1

