LETTER TO THE EDITOR

Kepler-432 b: a massive warm Jupiter in a 52-day eccentric orbit transiting a giant star

Mauricio Ortiz1, Davide Gandolfi1, Sabine Reffert1, Andreas Quirrenbach1, Hans J. Deeg2,3, Raine Karjalainen4, Pilar Montañés-Rodríguez2,3, David Nespral2,3, Grzegorz Nowak4, Yeisson Osorio5, and Enric Palle2,3

1 Landessternwarte, Zentrum für Astronomie der Universität Heidelberg, Königstuhl 12, 69117 Heidelberg, Germany; e-mail: mortarlsw.uni-heidelberg.de
2 Instituto de Astrofísica de Canarias, C. Vía Láctea S/N, E-38205 La Laguna, Tenerife, Spain
3 Departamento de Astrofísica, Universidad de La Laguna, E-38200 La Laguna, Tenerife, Spain
4 Isaac Newton Group of Telescopes, Apartado de Correos 321, E-38700 Santa Cruz de Palma, Spain
5 Nordic Optical Telescope, Apartado 474, 38700 Santa Cruz de La Palma, Spain

Received 11 October 2014 / Accepted 28 November 2014

ABSTRACT

We study the Kepler object Kepler-432, an evolved star ascending the red giant branch. By deriving precise radial velocities from multi-epoch high-resolution spectra of Kepler-432 taken with the CAFE spectrograph at the 2.2m telescope of Calar Alto Observatory and the FIES spectrograph at the Nordic Optical Telescope of Roque de los Muchachos Observatory, we confirm the planetary nature of the object Kepler-432 b, which has a transit period of 52 days. We find a planetary mass of $M_p = 5.84 \pm 0.05$ $M_{\text{Jup}}$ and a high eccentricity of $e = 0.478 \pm 0.004$. With a semi-major axis of $a = 0.303 \pm 0.007$ AU, Kepler-432 b is the first bona fide warm Jupiter detected to transit a giant star. We also find a radial velocity linear trend of $\dot{\gamma} = 0.44 \pm 0.04$ m s$^{-1}$ d$^{-1}$, which suggests the presence of a third object in the system. Current models of planetary evolution in the post-main-sequence phase predict that Kepler-432 b will be most likely engulfed by its host star before the latter reaches the tip of the red giant branch.

Key words. Planets and satellites: general – Individual: (Kepler-432 KOI-1299 KIC 10864656) – Techniques: radial velocity

1. Introduction

The number of Jupiter-like planets found to orbit evolved stars has constantly been growing in recent years. This includes planets around subgiant (Johnson et al. 2010, 2011) and giant stars (Gettel et al. 2012; Sato et al. 2013; Trifonov et al. 2014). These discoveries have provided evidence that the gas-giant planet population around evolved stars possesses different orbital properties than the population orbiting main-sequence (MS) stars (e.g., Jones et al. 2014a). The most notable trend is the apparent lack of close-in Jupiter-like planets orbiting giant or subgiant stars, although these objects are easily found around many MS stars by Doppler surveys (e.g., Jones et al. 2013). Specifically, there seems to be a lack of planets around giant stars with semi-major axis $a < 0.5$ AU. Exceptions to this apparent trend are the recently discovered planet HIP 76851 b (Jones et al. 2014b) and Kepler-91 b, the only hot Jupiter known to transit a giant star (Lillo-Box et al. 2014).

There are two different mechanisms that have been proposed to explain the paucity of close-in Jupiter-like planets around giant stars. The first one states that, as a result of stellar evolution, the inner planets are tidally engulfed by their host stars as the outer planets move farther out (Kunitomo et al. 2011; Adamów et al. 2012; Schlaufman et al. 2013). The second one suggests that although giant planets may form around intermediate-mass stars, they do not migrate inwards, owing to the short dissipation timescale of protoplanetary disks (Kretke et al. 2009; Currie 2009). By searching specifically for close-in Jupiter-like planets around giant stars, we can help to place constraints on the theoretical models that try to explain these observations and, possibly, also learn something about the evolution of planetary systems after the host star leaves the MS.

In this letter, we confirm and characterize Kepler-432 b, a massive warm gas-giant planet orbiting a star ascending the red giant branch (RGB).

2. High-resolution spectroscopic follow-up

The radial velocity (RV) follow-up of Kepler-432 was carried out between June and October 2014 using the Calar Alto Fiber-fed Échelle spectrograph (CAFE; Aceituno et al. 2013) – mounted at the 2.2m telescope of Calar Alto Observatory (Almería, Spain) – and the Fibre-fed Échelle Spectrograph (FIES: Telting et al. 2014) – mounted at the 2.56m Nordic Optical Telescope of Roque de los Muchachos Observatory (La Palma, Spain). We acquired 11 RVs with CAFE (R ~ 62000), and 16 with FIES (R ~ 67000) at different epochs. To remove cosmic-ray hits, three consecutive exposures were usually taken per epoch observation. Following the observing strategy described in Aceituno et al. (2013) and Buchhave et al. (2010), we traced the RV drift of

Article number, page 1 of 5
Table 1. Stellar parameters of Kepler-432.

| Parameter                      | Value                        |
|-------------------------------|------------------------------|
| Effective temperature $T_{\text{eff}}$ (K) | 5020 ± 60                   |
| Spectroscopic surface gravity log $g$ (log$_{10}$ g cm$^{-2}$) | 3.35 ± 0.07 |
| Metallicity [M/H] (dex)       | −0.02 ± 0.06                |
| Microturbulent velocity $v_{\text{micro}}$ (km s$^{-1}$) | 1.3 ± 0.3                  |
| Macroturbulent velocity $v_{\text{macro}}$ (km s$^{-1}$) | 3.5 ± 0.5                   |
| Projected rotational velocity $v \sin i$ (km s$^{-1}$) | ≤ 1                        |
| Stellar mass $M_*(M_\odot)$   | 1.35 ± 0.10                  |
| Stellar radius $R_*(R_\odot)$ | 4.15 ± 0.12                 |
| Age (Gyr)                     | 3.6$^{+0.6}_{-0.1}$         |
| Distance (pc)                 | 874 ± 30                     |
| Interstellar extinction $A_V$ (mag) | 0.26 ± 0.04               |
| Spectral type                 | K2 III                       |

CAFE and FIES by acquiring long-exposed ($T_{\text{exp}}$=60–80 sec) ThAr spectra immediately before and after each epoch observation. The data were reduced using IRAF and IDL standard routines, which include bias subtraction, flat fielding, order tracing and extraction, and wavelength calibration. Radial velocities were derived via multi-order cross-correlation with the RV standard stars HD 182572 (CAFE) and HR 5777 (FIES).

The CAFE and FIES RVs are listed in Table 3 – along with their uncertainties, total exposure times, signal-to-noise (S/N) ratios per pixel at 5500 Å, and cross-correlation function (CCF) bisector spans – and are plotted in Fig. 1 together with the Keplerian fit to the data (upper panel) and residuals to the fit (middle panel). The lower panel of Fig. 1 shows the FIES CCF bisector spans plotted against the RV measurements, assuming that the error bars of the former are twice those of the latter. We followed the method described in Loyd & France (2014) to account for the uncertainties of our measurements and found a ~50% probability that an uncorrelated set of points (null hypothesis) can reproduce the data. The lack of a significant correlation between the CCF bisector spans and the RVs indicates that the Doppler shifts observed in Kepler-432 are most likely induced by the orbital motion of a planet and not by a blended eclipsing binary or stellar activity (see, e.g., Queloz et al. 2001). Moreover, the analysis of the centroid motion during the transit reported in the Kepler data validation report excludes, at the 3-$\sigma$ level, any scenario in which the transit signal is caused by a contaminating eclipsing binary at a distance of more than 0.4" from the source.

3. Results

3.1. Stellar properties

We determined the spectral parameters of Kepler-432 by fitting the co-added FIES spectrum (S/N~145 per pixel at 5500 Å) to a grid of synthetic spectra calculated with the SPECTRUM code (Gray & Corbally 1994) using ATLAS9 models (Castelli & Kurucz 2004). Microturbulent ($v_{\text{micro}}$) and macroturbulent ($v_{\text{macro}}$) velocities were derived following Hekker & Meléndez (2007). Stellar mass and radius were determined via the asteroseismic scaling relations given by White et al. (2011), using our estimate for the effective temperature along with the large frequency separation and the frequency at which oscillations have the maximum power, as derived by Huber et al. (2013). We estimated the stellar age using theoretical isochrones from Bressan et al. (2012). Distance and interstellar extinction were calculated following the method described in Gandolfi et al. (2008). The derived stellar parameters are listed in Table 1.

4. Discussion

4.1. Internal structure and equilibrium temperature

Kepler-432 b is the first bona fide confirmed transiting warm Jupiter found to orbit a red giant star. About 70% of the known transiting giant planets have densities in the range 0.35–1.20 g cm$^{-3}$ and masses between 0.3 and 3 $M_{\text{Jup}}$, with a peak around 1 $M_{\text{Jup}}$ (Fig. 2). With $M_p$=5.84 ± 0.05 $M_{\text{Jup}}$ and $\rho_\text{p}$=5.4 ±
Table 2. Orbital parameters of Kepler-432 b.

| Parameter | Value |
|-----------|-------|
| RV semi-amplitude $K$ (m s$^{-1}$) | 294.6 ± 2.1 |
| Eccentricity $e$ | 0.478 ± 0.004 |
| Argument of periastron $\omega$ (deg) | 68.4 ± 0.7 |
| Periastron time $T_p$ (BJD=2450000) | 6841.06 ± 0.03 |
| Systemic velocity $v_{sys}$ (km s$^{-1}$) | $-33 ± 0.3$ |
| CAFE-FIES offset velocity (m s$^{-1}$) | 634 ± 5 |
| RV linear trend $\gamma$ (m s$^{-1}$ d$^{-1}$) | 0.44 ± 0.04 |
| Planet mass $M_p$ (MJup) | 5.84 ± 0.05 |
| Semi-major axis $a$ (AU) | 0.303 ± 0.007 |

Notes. Period and mid-transit epoch fixed to $P_{obs}$=52.5010768 days and $T_{0}$=5004.519 (BJD=2450000). To derive the true planet mass, we use an orbital inclination value of $i=89.95^\circ$ from the KOI database.

0.5 g cm$^{-3}$, Kepler-432 b is one of the most dense and massive gas-giant planets known so far. The mass of Kepler-432 b agrees with the general trend found by Doppler surveys, that is, planets around giant stars tend to be more massive (3-10 $M_{\text{Jup}}$) than planets orbiting solar-like planets (see e.g., Döllinger et al. 2009; Reffert et al. 2015). In fact, around 96% of the known planets orbiting solar-type MS stars have masses lower than 5 $M_{\text{Jup}}$.

We investigated the internal structure of Kepler-432 b using the models from Fortney et al. (2007), which couple planetary evolution to stellar irradiation for H-He-rich planets (dashed blue lines in Fig. 2). The planet radius of $R_p=1.102 ± 0.032$ $R_{\text{Jup}}$ is consistent within 2-$\sigma$ with theoretical values for giant planets with core masses of $\lesssim 100 M_{\text{Jup}}$. This implies that the planet core accounts most likely for 6% or less of the total mass, that is, similar to the fractional core mass of Jupiter (Saumon & Guillot 2004). We note that the solar-like metallicity of the host star [Fe/H] = $-0.02 ± 0.06$ dex supports the low-fractional core mass scenario for Kepler-432 b.

As a consequence of the high eccentricity of the orbit ($e=0.478±0.004$), the planet is at nearly $0.16$ AU ($\sim 8 R_{\text{Jup}}$) from its host star during periapsis, receiving a flux of $F_{\text{per}}=(6.1 ± 0.6) \times 10^8$ erg s$^{-1}$ cm$^{-2}$. At apastron, Kepler-432 b travels as far out as $-0.45$ AU ($\sim 23 R_{\text{Jup}}$), receiving an incoming radiation of $F_{\text{ap}}=(7.6 ± 0.8) \times 10^7$ erg s$^{-1}$ cm$^{-2}$. The time-averaged incident flux on Kepler-432 b is $F=\langle F \rangle=(1.66 ± 0.17) \times 10^7$ erg s$^{-1}$ cm$^{-2}$.

Assuming a black-body stellar emission and planetary heat redistribution factor $f$ between 0.25 (instantaneous energy redistribution into the planet atmosphere) and 0.67 (instantaneous energy reradiation to space; see López-Morales & Seager 2007), we derive an average equilibrium temperature of $T_{\text{eq}}=943 ± 20$ K for a bond albedo of 0.27 (based on Kane & Gelino 2010). Following the planet classification in Sudarsky et al. (2000), Kepler-432 b would be a member of the class IV planets with temperatures in the range $900 < T_{\text{eq}} < 1500$ K, for which a tropospheric silicate layer is expected to exist. However, we note that eccentric orbits can lead to significant changes in the atmospheric compositions, owing to the large variation of the incident stellar flux (Sudarsky et al. 2005). For Kepler-432 b, we expect temperature differences of $\sim 500$ K between periapsis and apastron.

4.2. Kepler-432 b: a close-in eccentric planet

Among planets orbiting giant stars, Kepler-432 b is very peculiar both in terms of eccentricity and orbital period, as it occupies scarcely populated regions of the $P_{\text{obs}}$ versus $M_p$, and $a$ versus $e$ diagrams (Fig. 3). While planets with orbital periods between 1 and $10^4$ days are common around MS stars, there is a clear lack of short-period planets around giant stars, and Kepler-432 b is one of the few habitable planets of the region with $P_{\text{obs}} < 100$ days.

The value of $e=0.478±0.004$ for the eccentricity is among the highest for planets orbiting giant stars. Most planets around giant stars tend to have low eccentricity ($63\%$ have $e < 0.2$), with a median of $e = 0.15$, whereas planets around MS stars tend to be more eccentric. If we consider objects with $a \geq 0.5$ AU – where most of the planets around giant stars are found – only $39\%$ of planets orbiting solar-type stars exhibit $e < 0.2$, and a K-S test gives a probability of $0.1\%$ that the eccentricity of planets around giant and MS stars is drawn from the same distribution. Because Kepler-432 b is dynamically young (circularization timescale $\tau_{\text{circ}} \sim 150$ Gyr; see Jackson et al. 2008), the non-zero eccentricity of the planet might be a tracer of its migration history. In this context, it is expected that some kind of high-eccentricity migration (HEM) mechanism might have operated to excite the eccentricity of Kepler-432 b to its current value (see Socrates et al. 2012, and references therein). Within this scenario, it has been proposed that warm Jupiters can form via tidal dissipation at the high-e stage during Kozai-Lidov oscillations (Wu & Lithwick 2011; Dong et al. 2014). Moreover, Dong et al. (2014) suggested that these planets need close companions for HEM to occur. They calculated upper limits for the perturber separation $b_{\text{per}}$ to allow an efficient tidal dissipation of the orbit. Assuming a perturber mass of between 1 and 10 $M_{\text{Jup}}$, we find an upper limit of $b_{\text{per}} = 6 – 13$ AU for an additional object in the Kepler-432 system.

Following Montet et al. (2014), for example, the detected RV acceleration $\dot{y} = 0.44$ m s$^{-1}$ d$^{-1}$ requires a perturbing object in a circular orbit at $a \sim 1$ and $a \sim 3$ AU for masses of 1 and 10 $M_{\text{Jup}}$, respectively, consistent with the HEM scenario. We consider it unlikely that spot-induced variability might be the source of the RV drift because no emission in the core of the Ca H and K
lines is detected in the FIES co-added spectrum. Furthermore, McQuillan et al. (2013) found no significant modulation in the Kepler light curve of Kepler-432, which suggests that this is a magnetically quiet star. A second companion in the system might thus account for the observed RV drift. Additional observations are needed to better assess the nature of this trend.

### 4.3. Post-main-sequence evolution

After Kepler-91 b and HIP67851 b, Kepler-432 b is the third planet found to orbit a giant star at a distance closer than $a = 0.5$ AU (Fig. 3), and the second found to transit a star ascending the RGB. Although the current sample is not statistically significant, the discovery of Kepler-432 b confirms that close-in planets around intermediate-mass giant stars do exist. Given the short dissipation time-scale of protoplanetary disks, gravitational interaction seems to be the favorite migration channel for close-in planets of intermediate-mass stars. Their paucity might be ascribed to enhanced tidal dissipation and subsequent stellar engulfment during the RGB phase.

Villaver & Livio (2009) and Kunitomo et al. (2011) have computed the planetary orbit evolution during the post MS phase for stars more massive than the Sun. They concluded that short-period planets are swallowed by their host stars as a result of the increased star-planet tidal interaction during the RGB phase. Both studies predict a critical semi-major axis below which planets are engulfed by their host star. The expected values for a star as massive as Kepler-432 are much higher than the current semi-major axis of Kepler-432 b. This implies that the planet will not survive the RGB phase and will be swallowed by its host star before it reaches the tip of the RGB.

### 5. Conclusions

We spectroscopically confirmed the planetary nature of the transiting candidate Kepler-432 b, derived a planetary mass of $M_p = 5.84 \pm 0.05 \, M_{\oplus}$, and found that the orbit is eccentric ($e = 0.478 \pm 0.004$). Kepler-432 b is the first bona fide warm Jupiter planet found to orbit a giant star, and, after Kepler-91 b, is the second found to transit a giant star. The semi-major axis $a = 0.303 \pm 0.007$ AU and eccentricity of the planet suggest that some kind of migration mechanism must have operated (or is operating now) to bring the planet to its current position. In this context, we discussed the high-eccentricity migration scenario as a plausible mechanism for the formation of this system. This possibility, although not directly verifiable with the currently available data, would account for the high eccentricity and small semi-major axis of the planet, provided that a second massive object is also orbiting the system. The latter scenario is corroborated by the detection of a significant radial velocity trend in our data. Additional spectroscopic follow-up observations are needed to better characterize the system.

Although our discovery confirms that close-in ($a \leq 0.5$ AU) giant planets can exist around giant stars, more detections are needed to properly characterize the population of these objects around post-MS stars. According to current post-MS evolution models, Kepler-432 b will not survive the RGB phase and will be engulfed by its host star.

**Note added in proof.** This letter was submitted in parallel with that of Ciceri et al. (2014), who independently also confirmed the planetary nature of Kepler-432 b. Their results agree with ours within the observational errors.

**Acknowledgements.** M.O. and S.R. acknowledge funding from the Deutsche Forschungsgemeinschaft, DFG under project number RE 2694/3-1 611328 to carry out the observations at Calar Alto. H.J.D and D.N. acknowledge support by grant AYA2012-39346-C02-02 of the Spanish Ministerio de Economía y Competitividad. We are very grateful to the staff members at Calar Alto and at the Nordic Optical Telescope for their valuable and unique support during the observations. M.O thanks N. Kudryavtseva and S. Ciceri for useful discussion.

**References**

Aceituno, J., Sánchez, S.F., Grupp, F., et al. 2013, A&A, 552, A31
Adamów, M., Niedzielski, A., Villaver, E., et al. 2012, ApJ, 754, 1
Bressan, A., Marigo, P., Girardi, L., et al. 2012, MNRAS, 427, 127
Buchave, L.A., Bakos, G., Hartman, J.D., et al. 2010, ApJ, 720, 1118
Castelli, F. & Kurucz, R.L. 2004, eprint astro-ph/0405087
Ciceri, S., Lillo-Box, J., Southworth, J., et al. 2014, arXiv:1410.2999
Currie, T. 2009, ApJ, 694, 173
Dong, S., Katz, B. & Socrates, A. 2014, ApJ, 781, L5
Döllinger, M.P., Hatzes, A.P., Passiani, L., et al., 2009, A&A, 505, 1311
Fortney, J.J., Marley, M.S., & Barman, T.S. 2007, ApJ, 659, 1661
Gandolfi, D., A'Alcalá, J.M., Leccia, S., et al. 2008, ApJ, 687, 1303
Gettel, S., Wolszczan, A., & Looper, S. 2014, ApJ, 756, 53
Gray, R.O. & Corbelli, C.J. 1994, AJ, 107, 742
Hekker, S. & Meléndez J. 2007, A&A, 475, 1003
Hekker, S., Snellen, I.A.G., Aerts, C., et al. 2008, A&A, 480, 215
Huber, D., Chaplin, W.J., Christensen-Dalsgaard, J., et al. 2013, ApJ, 767, 127
Jackson, B., Barnes, R. & Greenberg, R. 2008, MNRAS, 391, 237
Johnson, J.A., Bowler, B., Howard, A., et al. 2010, ApJ, 721, 153
Johnson, J.A., Payne, M., Howard, A., et al. 2011, AJ, 141, 16
Jones, M., Jenkins, J., Rojo, P., et al., 2013, A&A, 556, 78
Jones, M.I., Jenkins, J.S., Bluhm, P., et al. 2014, A&A, 566, 113
Jones, M.I., Jenkins, J.S., Rojo, P., et al. 2014, eprint arXiv:1409.7429
Kane, M.R. & Celano, D.M. 2010, ApJ, 724, 815
Kretke, K., Lin, D., Garaud, P., et al. 2009, ApJ, 690, 407
Kunitomo, M., Ikoma, M., Saito, et al., 2011, ApJ, 737, 66
Lillo-Box, J., Barrado, D., Moya, A., et al., 2014, A&A, 562, A109
Loyd R.O. & France K. 2014, ApJS, 211, 9
López-Morales, M., & Seager, S. 2007, ApJ, 667, L191
McQuillan, A., Mazeh, T., & Aigrain, S. 2013, ApJ, 775, 11M
Montet, B.T. Crepp, J.R., Johnson, J.A., et al. 2014, ApJ, 781, 26M
Nowak, G. 2013, PhD thesis, Nicolaus Copernicus University, Torun, Poland
Queloz, D., Henry, G., W., Sivan, J.P., et al. 2001, A&A, 379, 279
Reffert, S., Bergmann, C., Quirrenbach, A., et al., 2015, A&A, submitted
Sato, B., Omiya, M., Harakawa, H., et al. 2013, PASJ, 65, 83
Saumon, D. & Guillot, T. 2003, ApJ, 609, 1170
Seager, S., Kuchner, M., & Mayor, M., 2003, ApJ, 669, 1279
Schlaufman, K. & Winn, J. 2013, ApJ, 772, 143
Socrates, A., Katz, B., Dong, S., et al. 2012, ApJ, 750, 106
Sudarsky, D., Burrows, A., & Pinto, P. 2000, ApJ, 538, 885
Sudarsky, D., Burrows, A., & Hubeny, I., et al. 2005, ApJ, 627, 520
Telting, J.H., Avila, G., Buchhave, L., et al., 2014, A&A, 535, 41
Tritonov, I., Reffert, S., Xianyu, T., et al. 2014, A&A, 568, 64
Villaver, E. & Livio, M. 2009, ApJ, 705, 81
White, T.R., Bodding, T.R., Sterf, D., et al. 2011, ApJ, 743, 161
Wright, J.T. & Howard, A.W. 2009, ApJS, 182, 205
Wang, Sharon, X., Wright, J.T., Cochran, W., et al. 2012, ApJ, 761, 46
Wu, Y. & Lithwick, Y. 2011, ApJ, 735, 109

Fig. 3. **Left panel:** Eccentricity and semi-major axis of the extrasolar planets discovered around MS stars (black dots) and giant stars (magenta circles). The dashed line shows the value of $a = 0.5$ AU. **Right panel:** Orbital period versus stellar mass. The dashed lines represent the region of $10 \leq P_{	ext{orb}} \leq 100$ days. The position of Kepler-432 b is marked with a green triangle in both panels.

Acknowledgements. M.O. and S.R. acknowledge funding from the Deutsche Forschungsgemeinschaft, DFG under project number RE 2694/3-1 611328 to carry out the observations at Calar Alto. H.J.D and D.N. acknowledge support by grant AYA2012-39346-C02-02 of the Spanish Ministerio de Economía y Competitividad. We are very grateful to the staff members at Calar Alto and at the Nordic Optical Telescope for their valuable and unique support during the observations. M.O thanks N. Kudryavtseva and S. Ciceri for useful discussion.**
Table 3. CAFE and FIES radial velocity measurements of Kepler-432. The total exposure time, S/N ratio per pixel at 5500 Å, and CCF bisector spans are listed in the last three columns.

| BJD (-2 450 000) | RV (km s\(^{-1}\)) | \(\sigma_{RV}\) (km s\(^{-1}\)) | Exp. Time (sec) | S/N/pixel @5500 Å | BVS |
|------------------|---------------------|-------------------------------|-----------------|-------------------|-----|
| **CAFE**         |                     |                               |                 |                   |     |
| 6826.63307       | -36.018             | 0.014                         | 5400            | 25                | -   |
| 6827.64045       | -36.017             | 0.029                         | 5400            | 16                | -   |
| 6828.62402       | -35.976             | 0.019                         | 5400            | 22                | -   |
| 6835.64888       | -35.799             | 0.016                         | 5400            | 26                | -   |
| 6836.63077       | -35.808             | 0.017                         | 5400            | 22                | -   |
| 6837.63356       | -35.820             | 0.025                         | 5400            | 16                | -   |
| 6838.63076       | -35.783             | 0.024                         | 5400            | 20                | -   |
| 6839.63282       | -35.830             | 0.017                         | 5400            | 24                | -   |
| 6858.56617       | -36.314             | 0.029                         | 5400            | 18                | -   |
| 6870.39070       | -36.125             | 0.019                         | 5400            | 19                | -   |
| 6906.41528       | -36.316             | 0.023                         | 4500            | 21                | -   |
| **FIES**         |                     |                               |                 |                   |     |
| 6841.71887       | -35.409             | 0.008                         | 1800            | 31                | -0.001 |
| 6842.71994       | -35.512             | 0.009                         | 1800            | 30                | 0.004 |
| 6843.71619       | -35.610             | 0.007                         | 1800            | 33                | -0.002 |
| 6844.72316       | -35.653             | 0.009                         | 1680            | 29                | -0.001 |
| 6854.70204       | -35.704             | 0.006                         | 2400            | 41                | -0.003 |
| 6855.69674       | -35.693             | 0.008                         | 2700            | 44                | -0.007 |
| 6856.68809       | -35.680             | 0.005                         | 2700            | 41                | -0.002 |
| 6860.40078       | -35.632             | 0.008                         | 1800            | 34                | -0.005 |
| 6875.41274       | -35.418             | 0.007                         | 2400            | 36                | 0.006 |
| 6880.52282       | -35.327             | 0.006                         | 2400            | 44                | 0.002 |
| 6892.53722       | -35.223             | 0.007                         | 2400            | 35                | -0.004 |
| 6901.41459       | -35.716             | 0.007                         | 2400            | 36                | -0.006 |
| 6902.46355       | -35.719             | 0.007                         | 2400            | 31                | -0.004 |
| 6903.52509       | -35.704             | 0.006                         | 2400            | 38                | -0.001 |
| 6916.36055       | -35.565             | 0.013                         | 1800            | 24                | 0.012 |
| 6936.46518       | -35.234             | 0.006                         | 2400            | 44                | -0.001 |