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Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Reviewing the Mid-First Millennium BC ¹⁴C "warp" using ¹⁴C/bristlecone pine data

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ARTICLE INFO

Article history: Received 16 June 2011 Received in revised form 21 August 2012 Available online 15 September 2012

Keywords: Radiocarbon Calibration Bristlecone Pine Dendrochronology AMS 10-Be

ABSTRACT

AMS-based ¹⁴C measurements have been obtained on 53 dendrochronologically-dated Bristlecone pine (*Pinus longaeva*) wood samples in decadal increments spanning 2300–2750 cal BP with particular interest focused on the decades centered on 2405 cal BP and 2625 cal BP. In general, there is overall agreement with the current IntCal04/09 consensus calibration curve for this period. For the 2400–2410 cal BP interval, our Bristlecone-based ¹⁴C value is consistent with the ¹⁴C value obtained by Belfast on Irish oak for that decade but not on German oak values obtained by Seattle. Our ¹⁴C value for the 2620–2630 cal BP interval is consistent with the German oak (Heidelberg)-based ¹⁴C decadal value. The ¹⁰Be-based reconstruction of ¹⁴C variations over the 2620–2630 cal BP interval also supports the Heidelberg data although clearly additional clarifications are required before the current tree ring-based ¹⁴C and ice core-based ¹⁰Be data for this interval can be accurately interpreted and valid inferences obtained.

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BEAM INTERACTIONS WITH MATERIALS AND ATOMS

1. Introduction

The current IntCal09 calibration data set for the period 2360–2740 cal BP documents the longest ¹⁴C "warp/wiggle" of the middle and late Holocene, the deVries effect III b ¹⁴C time scale excursion [1]. The values currently used for this time interval are based on ¹⁴C measurements obtained at the University of Washington (Seattle), Queen's University (Belfast), and Heidelberger Akademie der Wissen-shaften (Heidelberg) on dendrochronologically-(tree ring-) dated wood. For this period, the tree-ring data used for IntCal09 is identical to that used in IntCal04 [2,3].

The study being reported here is a progress report on the first set of bristlecone pine measurements originally undertaken, in part, to address questions that had been raised about two decadal episodes within the III b period. These two episodes are centered on 2405 cal BP and 2625 cal BP. The immediate general context for our interest in this period is based on results of ¹⁴C measurements obtained on human skeletons associated with a 612 BCE event at the archaeological site of Nineveh in ancient Mesopotamia. Nine ¹⁴C values obtained on three skeletons directly associated with an historically-documented event which occurred in 612 BCE yielded calibration values ~150 years too old. One explanation offered to explain at least part of this result was the existence of a regional Δ^{14} C offset [4]. To provide a baseline against

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which to compare possible regional data, we wished to reexamine calibration data for the III b interval which included obtaining new ¹⁴C data on tree ring-dated bristlecone pine (*Pinus longaeva*).

2. Materials and methods

AMS-based ¹⁴C measurements have been obtained on 53 treering dated Bristlecone pine (*P. longaeva*) wood samples in decadal increments spanning 2300 to 2750 cal BP. In 7 instances, we undertook duplicate measurements of the same decadal wood sample. The tree ring-dated ages of these samples had been determined in the 1960s by the late C. Wesley Ferguson of the Laboratory of Tree Ring Research (LTRR), University of Arizona [5,6]. All of these samples had been collected at an elevation above 3000 meters in the White Mountains of east central California (USA). Dr. Paul Creasman of the LTRR kindly made these samples available to us.

After physically cleaning the surface by abrasion and sizing to $\sim 1 \times 3$ mm segments making sure that multiple annual ring increments in each decadal sample was represented, each sample was chemically pretreated by heating at 90 °C for at least 30 min each in 1 N HCl, 1 N NaOH, 1 N HCl, and milli-Q H₂O followed by drying for at least 8 h at 90 °C. The same pretreatment was applied simultaneously to infinite ¹⁴C age wood blanks and known-age wood standards. We are not aware of any data which supports the view that the isolation of alpha cellulose from bristlecone pine wood samples used for dendrochronological purposes results in more accurate ¹⁴C age determinations than the chemical pretreatment

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Table 1

Decadal bristlecone pine ¹⁴C measurements: 360-800 BC.

| sample No.age* (BC yrs)(%e)(yrs \bar{P})87267360-350-21.8 3.1 ± 2.0 2215 ± 20 87300370-360-22.4 -2.4 ± 1.9 2270 ± 15 87268380-370-22.4 -3.4 ± 1.9 2295 ± 15 87269400-390-20.6 -1 ± 2.1 2295 ± 15 87302410-440-22.2 -8.7 ± 1.9 2360 ± 15 87270420-410 -22.2 -8.7 ± 1.9 2360 ± 15 87271440-430-22.0 -12 ± 1.9 2415 ± 20 87303430-420 -22.1 -7.9 ± 1.3 2385 ± 15 87271440-430 -22.2 -1.7 ± 1.9 2415 ± 15 87272460-450 -22.2 -7.7 ± 1.9 2415 ± 15 87304450-440 -22.2 -9.7 ± 2.0 2435 ± 20 87305470-460 -22.1 -7.6 ± 1.9 2415 ± 15 87275520-510 -11.9 -7.6 ± 1.9 2445 ± 20 87306530-520 -22.1 -2 ± 1.9 2420 ± 15 87276540-530 -22.1 -2 ± 1.9 2420 ± 15 87276540-530 -22.1 -2 ± 1.9 2420 ± 15 87277560-550 -22.2 -5.4 ± 2.0 2470 ± 15 87278580-570 -22.4 -4.4 ± 2.2 2490 ± 20 63351610-600 -2.2 -3.3 ± 2.0 2455 ± 15 87278560-550 -22.2 -5.4 ± 2.0 2470 ± 15 87313630-620 -1.7 3 ± 2.0 2455 ± 15 <t< th=""><th>UCIAMS</th><th>Bristlecone tree ring</th><th>$\delta^{13}C^{b}$</th><th>Δ^{14}C (‰)</th><th>¹⁴C age</th></t<> | UCIAMS | Bristlecone tree ring | $\delta^{13}C^{b}$ | Δ^{14} C (‰) | ¹⁴ C age |
|---|----------------|---------------------------|--------------------|--------------------------------|--------------------------------|
| 87267 360.350 -21.8 3.1 ± 2.0 2215 ± 20 87300 370.360 -22.4 -2.4 ± 1.9 2270 ± 15 87268 380.370 -22.1 -4 ± 2.1 2295 ± 15 87301 390.380 -22.4 -3.4 ± 1.9 2295 ± 15 87302 410.400 -22.2 -8.7 ± 1.9 2360 ± 15 87770 420.410 -22.2 -14.3 ± 2.0 2415 ± 20 87303 430.420 -22.1 -9.3 ± 1.3 2365 ± 15 87271 440.430 -22.0 -12 ± 1.9 2415 ± 20 87304 450.440 -22.2 -7.1 ± 2.1 2395 ± 20 87305 470.460 -22.2 -7.1 ± 2.1 2435 ± 20 87306 490.480 -22.3 -6.2 ± 1.9 2410 ± 15 87273 480.470 -22.3 -6.2 ± 1.9 2440 ± 20 87307 510.500 -21.9 -7.4 ± 1.9 2440 ± 20 87307 510.500 -21.9 -4 ± 2.0 2420 ± 15 87275 520.510 -21.6 -7 ± 1.9 2420 ± 15 87276 540.530 -22.2 -5.4 ± 2.0 2470 ± 15 87277 560.550 -22.2 -5.4 ± 2.0 2470 ± 15 87278 580.570 -22.4 -4.4 ± 2.2 2400 ± 15 87311 590.580 -22.3 -3.9 ± 2.4 2480 ± 15 87312 610.600 -22.4 -1.2 ± 2.2 2500 ± 15 87313 630.620 -21.7 $3.$ | sample No. | age ^a (BC yrs) | (‰) | | (yrs BP) |
| 87300370.360 -22.4 -2.4 ± 1.9 22.70 ± 15 87268380-370 -22.1 -4 ± 2.1 2290 ± 20 87301390.380 -22.4 -3.4 ± 1.9 2295 ± 15 87269400.390 -20.6 -1 ± 2.1 2285 ± 20 87302410-400 -22.2 -8.7 ± 1.9 2360 ± 15 87270420-410 -22.2 -14.3 ± 2.0 2415 ± 20 87303430-420 -22.1 -9.3 ± 1.3 2385 ± 15 87271440-430 -22.5 -10.7 ± 1.9 2415 ± 20 87304450-440 -22.5 -10.7 ± 1.9 2415 ± 15 87272460-450 -22.2 -7.1 ± 2.1 2395 ± 20 87305470-460 -22.3 -62 ± 1.9 2415 ± 15 87273480-470 -22.2 -9.7 ± 2.0 2435 ± 20 87306490-480 -22.3 -62 ± 1.9 2415 ± 15 87274500-490 -19.9 -7.6 ± 1.9 2440 ± 20 87307510-500 -21.9 -4 ± 2.0 2420 ± 15 87275520-510 -21.6 -7 ± 1.9 2450 ± 20 87308530-520 -22.1 -2.24 ± 2.0 2470 ± 15 87276540-530 -22.2 -5.8 ± 1.9 2490 ± 15 87277560-550 -22.0 -6.2 2485 ± 20 87310570-560 -22.4 -4.4 ± 2.2 2490 ± 15 87278580-570 -22.4 -4.4 ± 2.2 2490 ± 15 87312610-600 | 87267 | 360-350 | -21.8 | 3.1 ± 2.0 | 2215 ± 20 |
| 87268380-370 -22.1 -4 ± 2.1 2290 ± 20 87301390-380 -22.4 -3.4 ± 1.9 2295 ± 15 87269400-390 -20.6 -1 ± 1.2 2285 ± 20 87302410-400 -22.2 -8.7 ± 1.9 2360 ± 15 87270420-410 -22.2 -8.7 ± 1.9 2360 ± 15 87271440-430 -22.0 -12 ± 1.9 2415 ± 20 87303430-420 -22.1 -9.3 ± 1.3 2385 ± 15 87271440-430 -22.5 -10.7 ± 1.9 2415 ± 20 87304450-440 -22.5 -10.7 ± 1.9 2415 ± 15 87272460-450 -22.2 -7.1 ± 2.1 2395 ± 20 87306490-480 -22.3 -6.2 ± 1.9 2415 ± 15 63349500-490 $ -7.4\pm 1.9$ 2440 ± 20 87274500-490 -19.9 -7.6 ± 1.9 2435 ± 20 87307510-500 -21.9 -4 ± 2.0 2420 ± 15 87276540-530 -22.1 0.2 ± 2.2 2410 ± 20 87308530-520 -22.1 0.2 ± 2.2 2410 ± 20 87305590-580 -22.2 -5.8 ± 1.9 2490 ± 15 87276540-530 -22.2 -5.8 ± 1.9 2490 ± 15 87277560-550 -22.0 -6 ± 2.0 2485 ± 20 63350590-580 $ -1.9\pm 2.0$ 2495 ± 20 63351610-600 -22.4 -4.2 ± 2.2 240 ± 15 87278680-670 -22.4 -4.2 ± 2.0 $2495\pm$ | 87300 | 370-360 | -22.4 | -2.4 ± 1.9 | 2270 ± 15 |
| 87301390-380 -22.4 -3.4 ± 1.9 2295 ± 15 87269400-390 -20.6 -1 ± 2.1 2285 ± 20 87302410-400 -22.2 $-8.71.9$ 2360 ± 15 87270420-410 -22.2 -14.3 ± 2.0 2415 ± 20 87303430-420 -22.1 -9.3 ± 1.3 2385 ± 15 87271440-430 -22.0 -12 ± 1.9 2415 ± 20 87304450-440 -22.5 -10.7 ± 1.9 2415 ± 15 87272460-450 -22.2 -7.1 ± 2.1 2395 ± 20 87305470-460 -22.1 -7.6 ± 1.9 2415 ± 15 87273480-470 -22.2 -9.7 ± 2.0 2435 ± 20 87306490-480 -22.3 -6.2 ± 1.9 2435 ± 20 87307510-500 -21.9 -4 ± 2.0 2420 ± 15 87275520-510 -21.6 -7 ± 1.9 2420 ± 15 87308530-520 -22.1 -2 ± 1.9 2420 ± 15 87309550-540 -22.2 -5.4 ± 2.0 2470 ± 15 87275580-570 -22.4 -4.4 ± 2.2 2490 ± 15 87278580-570 -22.4 -4.4 ± 2.2 2490 ± 15 87279600-590 -22.1 -5.6 ± 1.9 2495 ± 20 63311590-580 -2.3 -3.9 ± 2.4 2495 ± 15 87280620-610 -22.4 -4.2 ± 2.2 2495 ± 15 87312610-600 $-2.2.4$ -1.2 ± 2.2 2495 ± 15 87313630-620 | 87268 | 380-370 | -22.1 | -4 ± 2.1 | 2290 ± 20 |
| 87269 $400-390$ -20.6 -1 ± 2.1 2285 ± 20 87302 $410-400$ -22.2 -8.7 ± 1.9 2360 ± 15 87270 $420-410$ -22.2 -14.3 ± 2.0 2415 ± 2.0 87303 $430-420$ -22.1 -9.3 ± 1.3 2385 ± 15 87271 $440-430$ -22.5 -10.7 ± 1.9 2415 ± 20 87304 $450-440$ -22.5 -10.7 ± 1.9 2415 ± 15 87273 $480-470$ -22.2 -7.1 ± 2.0 2435 ± 20 87306 $490-480$ -22.3 -6.2 ± 1.9 2415 ± 15 87273 $480-470$ -22.2 -9.7 ± 2.0 2435 ± 20 87306 $490-480$ -22.3 -6.2 ± 1.9 2445 ± 20 87274 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87308 $530-520$ -22.1 0.2 ± 2.2 2410 ± 15 87276 $540-530$ -22.1 0.2 ± 2.2 2410 ± 15 87309 $550-540$ -22.2 -5.4 ± 2.0 2470 ± 15 87276 $540-530$ -22.4 -4.4 ± 2.2 2490 ± 20 63350 $590-580$ -22.4 -4.4 ± 2.2 2490 ± 20 63351 $610-600$ -22.4 -1.2 ± 2.2 240 ± 10 87278 $580-570$ -22.4 -4.4 ± 2.2 2400 ± 20 63351 $610-600$ -22.4 -2.4 ± 2.2 2490 ± 20 63351 $610-600$ -22.7 61 ± 2.0 2495 ± 20 87312 $610-630$ | 87301 | 390-380 | -22.4 | -3.4 ± 1.9 | 2295 ± 15 |
| 87302 $410-400$ -22.2 -8.7 ± 1.9 2360 ± 15 87270 $420-410$ -22.2 -14.3 ± 2.0 2415 ± 20 87303 $430-420$ -22.1 -9.3 ± 1.3 2385 ± 15 87271 $440-430$ -22.0 -12 ± 1.9 2415 ± 120 87304 $450-440$ -22.5 -10.7 ± 1.9 2415 ± 15 87272 $460-450$ -22.2 -7.1 ± 2.1 2395 ± 20 87305 $470-460$ -22.1 -7.6 ± 1.9 2410 ± 15 87273 $480-470$ -22.2 -9.7 ± 2.0 2435 ± 20 87306 $490-480$ -22.3 -62 ± 1.9 2415 ± 15 87274 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87307 $510-500$ -21.6 -7 ± 1.9 2420 ± 15 87275 $520-510$ -21.6 -7 ± 1.9 2420 ± 15 87276 $540-530$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.0 -6 ± 2.0 2485 ± 20 87310 $570-560$ -22.2 -5.8 ± 1.9 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 15 87311 $590-580$ -22.3 -3.9 ± 2.4 2485 ± 15 87312 $610-600$ -22.4 -1.2 ± 2.2 2400 ± 15 87313 $610-600$ -22.4 -1.2 ± 2.2 2495 ± 15 87314 $630-620$ -20.0 -0.3 ± 1.9 2495 ± 15 87281 $640-630$ | 87269 | 400-390 | -20.6 | -1 ± 2.1 | 2285 ± 20 |
| 87270 $420-410$ -22.2 -14.3 ± 2.0 2415 ± 20 87303 $430-420$ -22.1 -9.3 ± 1.3 2385 ± 15 87271 $440-430$ -22.0 -12 ± 1.9 2415 ± 20 87304 $450-440$ -22.5 -10.7 ± 1.9 2415 ± 20 87305 $470-460$ -22.2 -7.1 ± 2.1 2395 ± 20 87305 $470-460$ -22.2 -9.7 ± 2.0 2435 ± 20 87306 $490-480$ -22.3 -6.2 ± 1.9 2415 ± 15 63349 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87307 $510-500$ -21.9 -4 ± 2.0 2420 ± 15 87276 $520-510$ -21.6 -7 ± 1.9 240 ± 20 87308 $530-520$ -22.1 0.2 ± 2.2 2410 ± 120 87309 $550-540$ -22.2 -5.4 ± 2.0 2470 ± 15 87276 $540-530$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.2 -5.4 ± 1.9 2490 ± 15 87278 $880-570$ -22.4 -4.4 ± 2.2 2490 ± 20 63350 $590-580$ $ -1.9\pm 2.0$ 2495 ± 20 63351 $610-600$ $ -2.3\pm 2.0$ 2470 ± 15 87279 $600-590$ -22.4 -1.4 ± 2.2 2490 ± 15 87313 $630-620$ -21.7 3.9 ± 2.4 2480 ± 15 87314 $650-640$ -22.9 8.1 ± 1.9 2495 ± 20 63356 $690-680$ -20.0 1.4 ± 1.9 2490 ± 15 <td>87302</td> <td>410-400</td> <td>-22.2</td> <td>-8.7 ± 1.9</td> <td>2360 ± 15</td> | 87302 | 410-400 | -22.2 | -8.7 ± 1.9 | 2360 ± 15 |
| 87303 $430-420$ -22.1 -9.3 ± 1.3 2385 ± 15 87271 $440-430$ -22.0 -12 ± 1.9 2415 ± 15 87304 $450-440$ -22.5 -10.7 ± 1.9 2415 ± 15 87272 $460-450$ -22.2 -7.1 ± 2.1 2395 ± 20 87305 $470-460$ -22.1 -7.6 ± 1.9 2410 ± 15 87273 $480-470$ -22.2 -9.7 ± 2.0 2435 ± 20 87306 $490-480$ -22.3 -6.2 ± 1.9 2410 ± 15 87273 $480-470$ -22.3 -6.2 ± 1.9 2440 ± 20 87274 $500-490$ -19.9 -7.4 ± 1.9 2440 ± 20 87307 $510-500$ -21.6 -7 ± 1.9 2420 ± 15 87275 $520-510$ -21.6 -7 ± 1.9 2420 ± 15 87276 $540-530$ -22.1 0.2 ± 2.2 2410 ± 20 87300 $50-540$ -22.2 -5.8 ± 1.9 2490 ± 15 87277 $560-550$ -22.2 -5.8 ± 1.9 2490 ± 15 87278 $80-570$ -22.4 -4.4 ± 2.2 2490 ± 20 63350 $590-580$ $ -1.9 \pm 2.0$ 2495 ± 20 63351 $610-600$ $ -2.3 \pm 2.0$ 2495 ± 15 87279 $600-590$ -22.1 -5.6 ± 1.9 250 ± 20 63351 $610-600$ -22.7 6.1 ± 1.9 2495 ± 15 87312 $610-600$ -22.7 7.5 ± 1.9 2405 ± 15 87313 $630-620$ -21.7 < | 87270 | 420-410 | -22.2 | -14.3 ± 2.0 | 2415 ± 20 |
| 87271 $440-430$ -22.0 -12 ± 1.9 2415 ± 120 87304 $450-440$ -22.5 -10.7 ± 1.9 2415 ± 15 87272 $460-450$ -22.2 -7.1 ± 2.1 235 ± 20 87305 $470-460$ -22.1 -7.6 ± 1.9 2415 ± 15 87277 $480-470$ -22.2 -9.7 ± 2.0 2435 ± 20 87306 $490-480$ -22.3 -62 ± 1.9 2415 ± 15 63349 $500-490$ $ -7.4\pm 1.9$ 2440 ± 20 87274 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87307 $510-500$ -21.6 -7 ± 1.9 2420 ± 15 87275 $520-510$ -21.6 -7 ± 1.9 2420 ± 15 87276 $540-530$ -22.1 0.2 ± 2.2 2410 ± 20 87309 $550-540$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.0 -6 ± 2.0 2485 ± 20 87310 $570-560$ -22.4 -4.4 ± 2.2 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 15 87311 $590-580$ $ -1.9\pm 2.0$ 2495 ± 20 63351 $610-600$ $ -2.3\pm 2.0$ 2495 ± 15 87279 $600-590$ -22.4 -1.2 ± 2.2 200 ± 15 87312 $610-630$ -21.7 3.9 ± 2.4 2480 ± 15 87281 $640-630$ -21.7 3.9 ± 2.4 2495 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2495 ± 20 <t< td=""><td>87303</td><td>430-420</td><td>-22.1</td><td>-9.3 ± 1.3</td><td>2385 ± 15</td></t<> | 87303 | 430-420 | -22.1 | -9.3 ± 1.3 | 2385 ± 15 |
| 87304 $450-440$ -22.5 -10.7 ± 1.9 2415 ± 15 87272 $460-450$ -22.2 -7.1 ± 2.1 2395 ± 20 87305 $470-460$ -22.1 -7.6 ± 1.9 2410 ± 15 87273 $480-470$ -22.2 -9.7 ± 2.0 2435 ± 20 87306 $490-480$ -22.3 -6.2 ± 1.9 2415 ± 15 63349 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87274 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87307 $510-500$ -21.9 -4 ± 2.0 2420 ± 15 87275 $520-510$ -21.6 -7 ± 1.9 2450 ± 20 87308 $530-520$ -22.1 -2 ± 1.9 2420 ± 15 87276 $540-530$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.0 -6 ± 2.0 2485 ± 20 87310 $570-560$ -22.4 -4.4 ± 2.2 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 15 87311 $590-580$ -22.3 -3.9 ± 2.4 2480 ± 15 87278 $580-570$ -22.4 -1.2 ± 2.2 2500 ± 15 87312 $610-600$ -22.4 -1.2 ± 2.2 2495 ± 10 87313 $630-620$ $ 0.3 \pm 2.0$ 2495 ± 15 87280 $620-610$ -22.7 4.945 ± 15 87281 $640-630$ -21.7 3.9 ± 2.1 | 87271 | 440-430 | -22.0 | -12 ± 1.9 | 2415 ± 20 |
| 87272 $460-450$ -22.2 -7.1 ± 2.1 2395 ± 20 87305 $470-460$ -22.1 -7.6 ± 1.9 2410 ± 15 87273 $480-470$ -22.2 -9.7 ± 2.0 2435 ± 20 87306 $490-480$ -22.3 -6.2 ± 1.9 2415 ± 15 63349 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87307 $510-500$ -21.9 -4 ± 2.0 2420 ± 15 87275 $520-510$ -21.6 -7 ± 1.9 2420 ± 20 87308 $530-520$ -22.1 -2 ± 2.2 2410 ± 20 87309 $550-540$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.0 -6 ± 2.0 2485 ± 20 87310 $570-560$ -22.2 -5.8 ± 1.9 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 15 87278 $580-570$ -22.4 -1.4 ± 2.2 2490 ± 15 87311 $590-580$ $ -1.9 \pm 2.0$ 2495 ± 20 87311 $590-580$ $ -2.2.4$ -1.2 ± 2.2 87311 $590-580$ -22.1 -5.6 ± 1.9 2520 ± 15 87279 $600-590$ -22.4 -1.2 ± 2.2 2500 ± 15 87312 $610-600$ -22.4 -1.2 ± 2.2 2500 ± 15 87313 $630-620$ -21.7 39 ± 2.1 2500 ± 15 87281 $640-630$ -21.7 2.2 ± 2.0 2495 ± 20 87314 $650-640$ -22.9 | 87304 | 450-440 | -22.5 | -10.7 ± 1.9 | 2415 ± 15 |
| 87305 $470-460$ -22.1 -7.6 ± 1.9 2410 ± 15 87306 $490-480$ -22.3 -6.2 ± 1.9 2415 ± 15 63349 $500-490$ $ -7.4\pm 1.9$ 2440 ± 20 87274 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87307 $510-500$ -21.9 -4 ± 2.0 2420 ± 15 87275 $520-510$ -21.6 -7 ± 1.9 2420 ± 15 87276 $540-530$ -22.1 0.2 ± 2.2 2410 ± 20 87308 $530-520$ -22.1 0.2 ± 2.2 2410 ± 20 87309 $550-540$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.2 -5.8 ± 1.9 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 20 63350 $590-580$ $ -1.9\pm 2.0$ 2495 ± 20 87311 $590-580$ -22.1 -5.6 ± 1.9 2520 ± 20 87311 $590-580$ -22.4 -1.2 ± 2.2 2500 ± 15 87278 $620-610$ -22.4 -1.2 ± 2.2 2495 ± 15 87312 $610-600$ -22.4 -1.2 ± 2.2 2500 ± 15 87313 $630-620$ -21.7 3.9 ± 2.4 2490 ± 15 87314 $650-640$ -22.9 8.1 ± 1.9 2455 ± 20 87315 $670-660$ -2.0 14 ± 1.9 2490 ± 15 87316 $690-680$ -2.0 7.7 ± 1.9 2450 ± 120 63353 $670-660$ -2.0 14 ± 1.9 2460 ± 20 <t< td=""><td>87272</td><td>460-450</td><td>-22.2</td><td>-7.1 ± 2.1</td><td>2395 ± 20</td></t<> | 87272 | 460-450 | -22.2 | -7.1 ± 2.1 | 2395 ± 20 |
| 87273 480-470 -22.2 -9.7 ± 2.0 2435 ± 20 87306 490-480 -22.3 -6.2 ± 1.9 2415 ± 15 63349 500-490 -19.9 -7.6 ± 1.9 2435 ± 20 87274 500-490 -19.9 -7.6 ± 1.9 2435 ± 20 87307 510-500 -21.9 -4 ± 2.0 2420 ± 15 87275 520-510 -21.6 -7 ± 1.9 2450 ± 20 87308 530-520 -22.1 0.2 ± 2.2 2410 ± 20 87309 550-540 -22.2 -5.4 ± 2.0 2470 ± 15 87277 560-550 -22.0 -6 ± 2.0 2485 ± 20 87310 570-560 -22.2 -5.8 ± 19 2490 ± 15 87278 580-570 -22.4 -4.4 ± 2.2 2490 ± 20 63350 590-580 - -1.9 ± 2.0 2495 ± 20 87279 600-590 -22.1 -5.6 ± 1.9 2495 ± 20 87312 610-600 - -2.3 ± 2.0 2495 ± 15 87313 630-620 - 0.3 ± 2.0 2495 ± 15 87314 | 87305 | 470-460 | -22.1 | -7.6 ± 1.9 | 2410 ± 15 |
| 87306 $490-480$ -22.3 -6.2 ± 1.9 2415 ± 15 63349 $500-490$ $ -7.4 \pm 1.9$ 2440 ± 20 87274 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87307 $510-500$ -21.9 -4 ± 2.0 2420 ± 15 87275 $520-510$ -21.6 -7 ± 1.9 2420 ± 15 87276 $540-530$ -22.1 0.2 ± 2.2 2410 ± 20 87308 $530-520$ -22.1 0.2 ± 2.2 2410 ± 20 87309 $550-540$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.2 -5.4 ± 2.0 2470 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 15 87278 $580-580$ $ -19 \pm 2.0$ 2495 ± 20 87311 $590-580$ $ -1.9 \pm 2.2$ 2490 ± 15 87279 $600-590$ -22.1 -5.6 ± 1.9 2520 ± 20 63351 $610-600$ $ -2.3 \pm 2.0$ 2495 ± 15 87280 $620-610$ -22.0 -0.3 ± 1.9 2495 ± 20 63352 $630-620$ $ 0.3 \pm 2.0$ 2470 ± 15 87281 $640-630$ -21.7 3.9 ± 2.1 2500 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2455 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2455 ± 15 87284 $700-690$ -22.7 4.1 ± 1.9 2450 ± 20 87316 $690-680$ -22.0 14.7 ± 2 | 87273 | 480-470 | -22.2 | -9.7 ± 2.0 | 2435 ± 20 |
| 63349 $500-490$ - -7.4 ± 1.9 2440 ± 20 87274 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87307 $510-500$ -21.9 -4 ± 2.0 2420 ± 15 87275 $520-510$ -21.6 -7 ± 1.9 2420 ± 15 87276 $540-530$ -22.1 -2 ± 1.9 2420 ± 15 87309 $550-540$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.2 -6 ± 2.0 2485 ± 20 87310 $570-560$ -22.4 -4.4 ± 2.2 2490 ± 15 87277 $560-570$ -22.4 -4.4 ± 2.2 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 120 63350 $590-580$ -1.9 ± 2.0 2495 ± 20 87311 $590-580$ -22.3 -3.9 ± 2.4 2480 ± 15 87279 $600-590$ -22.1 -5.6 ± 1.9 2520 ± 20 63351 $610-600$ -22.4 -1.2 ± 2.2 2495 ± 15 87312 $610-600$ -22.4 -1.2 ± 2.2 2495 ± 15 87313 $630-620$ -21.7 3.9 ± 2.1 2500 ± 15 87314 $650-640$ -22.7 6.1 ± 1.9 2495 ± 20 63353 $670-660$ -22.7 6.1 ± 1.9 2495 ± 20 63353 $670-660$ -22.7 6.1 ± 1.9 2495 ± 20 63354 $720-730$ -22.6 15.9 ± 1.5 87284 $700-690$ -21.0 14.7 ± 2.1 2445 ± 1.5 < | 87306 | 490-480 | -22.3 | -6.2 ± 1.9 | 2415 ± 15 |
| 87274 $500-490$ -19.9 -7.6 ± 1.9 2435 ± 20 87307 $510-500$ -21.9 -4 ± 2.0 2420 ± 15 87275 $520-510$ -21.6 -7 ± 1.9 2420 ± 15 87308 $530-520$ -22.1 0.2 ± 2.2 2410 ± 20 87308 $530-520$ -22.1 0.2 ± 2.2 2410 ± 20 87309 $550-540$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.2 -5.8 ± 1.9 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 20 63350 $590-580$ $ -1.9 \pm 2.0$ 2495 ± 20 87311 $590-580$ -22.3 -3.9 ± 2.4 2480 ± 15 87279 $600-590$ -22.1 -5.6 ± 1.9 2520 ± 20 63351 $610-600$ $ -2.3 \pm 2.0$ 2495 ± 15 87312 $610-600$ -22.4 -1.2 ± 2.2 2500 ± 15 87280 $620-610$ -22.0 -0.3 ± 1.9 2495 ± 20 63352 $630-620$ $ 0.3 \pm 2.0$ 2495 ± 20 87314 $650-640$ -22.9 8.1 ± 1.9 2455 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2490 ± 15 87316 $690-680$ -22.0 7.7 ± 1.9 2500 ± 15 87316 $690-680$ -22.0 14.7 ± 2.1 2490 ± 15 87284 $700-690$ -21.0 14 ± 1.9 2455 ± 15 87285 $720-710$ -22.4 1 | 63349 | 500-490 | - | -7.4 ± 1.9 | 2440 ± 20 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87274 | 500-490 | -19.9 | -7.6 ± 1.9 | 2435 ± 20 |
| 87275 $520-510$ -21.6 -7 ± 1.9 2450 ± 20 87308 $530-520$ -22.1 -2 ± 1.9 2420 ± 15 87276 $540-530$ -22.1 0.2 ± 2.2 2410 ± 20 87309 $550-540$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.2 -5.8 ± 1.9 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 20 63350 $590-580$ $ -1.9 \pm 2.0$ 2495 ± 20 87311 $590-580$ -22.3 -3.9 ± 2.4 2480 ± 15 87279 $600-590$ -22.1 -5.6 ± 1.9 2520 ± 20 63351 $610-600$ $ -2.3 \pm 2.0$ 2495 ± 15 8712 $610-600$ -22.4 -1.2 ± 2.2 2405 ± 15 87280 $620-610$ -22.0 -0.3 ± 1.9 2495 ± 20 63352 $630-620$ $ 0.3 \pm 2.0$ 2470 ± 15 87281 $640-630$ -21.7 3.9 ± 2.1 2500 ± 15 87281 $640-630$ -22.7 6.1 ± 1.9 2490 ± 15 87313 $630-620$ -22.7 6.1 ± 1.9 2490 ± 15 87283 $680-670$ -22.7 4.5 ± 2.0 2515 ± 20 87316 $670-660$ -22.7 4.5 ± 2.0 2515 ± 20 87317 $710-700$ -22.6 15.9 ± 1.9 2455 ± 15 87284 $700-690$ -21.0 14.7 ± 2.1 2446 ± 2.0 87318 $730-720$ -22.2 1 | 87307 | 510-500 | -21.9 | -4 ± 2.0 | 2420 ± 15 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87275 | 520-510 | -21.6 | -7 ± 1.9 | 2450 ± 20 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87308 | 530-520 | -22.1 | -2 ± 1.9 | 2420 ± 15 |
| 87309 $550-540$ -22.2 -5.4 ± 2.0 2470 ± 15 87277 $560-550$ -22.0 -6 ± 2.0 2485 ± 20 87310 $570-560$ -22.2 -5.8 ± 1.9 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 20 63350 $590-580$ $ -1.9\pm 2.0$ 2495 ± 20 87311 $590-580$ -22.3 -3.9 ± 2.4 2480 ± 15 87279 $600-590$ -22.1 -5.6 ± 1.9 2520 ± 20 63351 $610-600$ $ -2.3\pm 2.0$ 2495 ± 120 63352 $630-620$ $ 0.3\pm 2.0$ 2470 ± 15 87313 $630-620$ -21.7 3.9 ± 2.1 2500 ± 15 87281 $640-630$ -21.7 3.9 ± 2.1 2500 ± 120 63353 $670-660$ -22.9 8.1 ± 1.9 2455 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2450 ± 20 63353 $670-660$ -22.7 6.1 ± 1.9 2490 ± 15 87315 $670-660$ -22.7 6.1 ± 1.9 240 ± 15 87283 $680-670$ -22.0 14.7 ± 2.1 2440 ± 15 87284 $700-690$ -21.0 14 ± 1.9 2460 ± 20 87317 $710-700$ -22.6 15.9 ± 1.9 2455 ± 15 87285 $720-710$ -22.2 17.2 ± 2.4 2465 ± 15 87318 $730-720$ -22.1 1.4 ± 2.0 2475 ± 20 87319 $750-740$ -22.2 17.2 ± 1.9 2480 ± 15 < | 87276 | 540-530 | -22.1 | 0.2 ± 2.2 | 2410 ± 20 |
| 87277 $560-550$ -22.0 -6 ± 2.0 2485 ± 20 87310 $570-560$ -22.2 -5.8 ± 1.9 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 20 63350 $590-580$ $ -1.9\pm 2.0$ 2495 ± 20 87311 $590-580$ -22.3 -3.9 ± 2.4 2480 ± 15 87279 $600-590$ -22.1 -5.6 ± 1.9 2520 ± 20 63351 $610-600$ $ -2.3\pm 2.0$ 2495 ± 15 8712 $610-600$ -22.4 -1.2 ± 2.2 2500 ± 15 87280 $620-610$ -22.0 -0.3 ± 2.0 2470 ± 15 87313 $630-620$ $ 0.3\pm 2.0$ 2470 ± 15 87313 $630-620$ $ 21.7$ 3.9 ± 2.1 2500 ± 15 87281 $640-630$ -21.7 3.9 ± 2.1 2500 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2450 ± 20 63353 $670-660$ -22.7 6.1 ± 1.9 2490 ± 15 87282 $660-650$ -22.0 10.1 ± 2.0 2450 ± 20 63353 $670-660$ -22.7 4.5 ± 2.0 2515 ± 20 87316 $690-680$ -2.0 7.7 ± 1.9 2500 ± 15 87284 $700-690$ -21.0 14.7 ± 2.1 2445 ± 15 87284 $700-690$ -21.0 14.7 ± 2.0 2455 ± 15 87318 $730-720$ -22.2 17.2 ± 1.9 2455 ± 15 87319 $750-740$ -22.2 17.2 ± 1.9 2465 ± 15 | 87309 | 550-540 | -22.2 | -5.4 ± 2.0 | 2470 ± 15 |
| 87310 $570-560$ -22.2 -5.8 ± 1.9 2490 ± 15 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 20 63350 $590-580$ $ -1.9 \pm 2.0$ 2495 ± 20 87311 $590-580$ -22.3 -3.9 ± 2.4 2480 ± 15 87279 $600-590$ -22.1 -5.6 ± 1.9 2520 ± 20 63351 $610-600$ $ -2.3 \pm 2.0$ 2495 ± 15 87312 $610-600$ -22.4 -1.2 ± 2.2 2500 ± 15 87313 $630-620$ $ 0.3 \pm 2.0$ 2470 ± 15 87313 $630-620$ -21.7 3.9 ± 2.1 2500 ± 15 87281 $640-630$ -21.7 3.9 ± 2.1 2500 ± 15 87281 $640-630$ -21.7 2.2 ± 2.0 2495 ± 20 87314 $650-640$ -22.9 8.1 ± 1.9 2455 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2450 ± 20 63353 $670-660$ -22.7 6.1 ± 2.1 2490 ± 15 87315 $670-660$ -22.7 4.5 ± 2.0 2515 ± 20 87316 $690-680$ -22.0 14.7 ± 2.1 2445 ± 15 87284 $700-690$ -21.0 14.7 ± 2.1 2445 ± 15 87318 $730-720$ -22.2 17.7 ± 2.4 2466 ± 20 87319 $750-740$ -22.2 17.2 ± 1.9 2480 ± 15 87286 $740-730$ -21.8 15.6 ± 2.0 2505 ± 20 87319 $750-740$ -22.2 <t< td=""><td>87277</td><td>560-550</td><td>-22.0</td><td>-6 ± 2.0</td><td>2485 ± 20</td></t<> | 87277 | 560-550 | -22.0 | -6 ± 2.0 | 2485 ± 20 |
| 87278 $580-570$ -22.4 -4.4 ± 2.2 2490 ± 20 63350 $590-580$ $ -1.9\pm 2.0$ 2495 ± 20 87311 $590-580$ -22.3 -3.9 ± 2.4 2480 ± 15 87279 $600-590$ -22.1 -5.6 ± 1.9 2520 ± 20 63351 $610-600$ $ -2.3\pm 2.0$ 2495 ± 15 87312 $610-600$ -22.4 -1.2 ± 2.2 2500 ± 15 87280 $620-610$ -22.0 -0.3 ± 2.0 2470 ± 15 87313 $630-620$ $ 0.3\pm 2.0$ 2470 ± 15 877313 $630-620$ -21.7 3.9 ± 2.1 2500 ± 15 87281 $640-630$ -21.7 2.2 ± 2.0 2495 ± 20 87314 $650-640$ -22.9 8.1 ± 1.9 2455 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2450 ± 20 63353 $670-660$ -22.7 4.5 ± 2.0 2515 ± 20 87316 $690-680$ -22.0 7.7 ± 1.9 2500 ± 15 87386 $690-680$ -22.0 14.7 ± 2.1 2445 ± 15 87284 $700-690$ -21.0 14 ± 1.9 2460 ± 20 87317 $710-700$ -22.4 14.5 ± 2.0 2475 ± 20 63354 $720-730$ $ 17.1\pm 1.9$ 2425 ± 15 87286 $740-730$ -21.8 15.6 ± 2.0 2475 ± 20 87318 $730-720$ -22.2 21.7 ± 2.4 2466 ± 15 87287 $760-750$ -21.8 15.6 ± 2.0 2505 ± 20 <t< td=""><td>87310</td><td>570-560</td><td>-22.2</td><td>-5.8 ± 1.9</td><td>2490 ± 15</td></t<> | 87310 | 570-560 | -22.2 | -5.8 ± 1.9 | 2490 ± 15 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87278 | 580-570 | -22.4 | -4.4 ± 2.2 | 2490 ± 20 |
| 87311 $590-580$ -22.3 -3.9 ± 2.4 2480 ± 15 87279 $600-590$ -22.1 -5.6 ± 1.9 2520 ± 20 63351 $610-600$ $ -2.3\pm 2.0$ 2495 ± 15 87312 $610-600$ -22.4 -1.2 ± 2.2 2500 ± 15 87280 $620-610$ -22.0 -0.3 ± 1.9 2495 ± 20 63352 $630-620$ $ 0.3\pm 2.0$ 2470 ± 15 87313 $630-620$ -21.7 3.9 ± 2.1 2500 ± 15 87281 $640-630$ -21.7 2.2 ± 2.0 2495 ± 20 87314 $650-640$ -22.9 8.1 ± 1.9 2455 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2450 ± 20 63353 $670-660$ -2 6.1 ± 1.9 2490 ± 15 87315 $670-660$ -22.7 6.1 ± 2.1 2490 ± 15 87316 $690-680$ -2.0 7.7 ± 1.9 2500 ± 15 63356 $690-680$ -22.0 14.7 ± 2.1 2440 ± 15 87284 $700-690$ -21.0 14 ± 1.9 2460 ± 20 87317 $710-700$ -22.6 15.9 ± 1.9 2455 ± 15 87285 $720-710$ -22.2 21.7 ± 2.4 2465 ± 15 87286 $740-730$ -21.8 15.6 ± 2.0 2475 ± 20 87318 $730-720$ -21.8 15.6 ± 2.0 2505 ± 20 87319 $750-740$ -22.2 17.2 ± 1.9 2480 ± 15 87287 $760-750$ -21.8 15.6 ± 2.0 2505 ± 20 | 63350 | 590-580 | - | -1.9 ± 2.0 | 2495 ± 20 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 8/311 | 590-580 | -22.3 | -3.9 ± 2.4 | 2480 ± 15 |
| 63331610-600 $ -2.3 \pm 2.0$ 2495 ± 13 87312610-600 -22.4 -1.2 ± 2.2 2500 ± 15 87280620-610 -22.0 -0.3 ± 2.0 2470 ± 15 87313630-620 $ 0.3 \pm 2.0$ 2470 ± 15 87313630-620 -21.7 3.9 ± 2.1 2500 ± 15 87281640-630 -21.7 2.2 ± 2.0 2495 ± 20 87314650-640 -22.9 8.1 ± 1.9 2450 ± 20 63353670-660 $ 0.1 \pm 2.0$ 2450 ± 20 63353670-660 $ 0.1 \pm 1.9$ 2490 ± 15 87315670-660 -22.7 6.1 ± 2.1 2490 ± 15 87316690-680 -22.0 1.7 ± 2.2 2515 ± 20 87316690-680 -22.0 14.7 ± 2.1 2445 ± 15 87284700-690 -21.0 14.7 ± 2.1 2445 ± 15 87285720-710 -22.4 14.5 ± 2.0 2475 ± 20 63354720-730 $ 17.1 \pm 1.9$ 2425 ± 15 87318730-720 -22.2 21.7 ± 2.4 2465 ± 15 87286740-730 -22.0 16.9 ± 2.0 2475 ± 20 63355770-760 -21.8 15.6 ± 2.0 2505 ± 20 63355770-760 -21.8 15.6 ± 2.0 2505 ± 15 87288780-770 -21.9 14.2 ± 2.0 2535 ± 20 87321790-780 -22.2 15.3 ± 1.9 2505 ± 15 87289800-790 -22.2 <td>87279</td> <td>600-590</td> <td>-22.1</td> <td>-5.0 ± 1.9</td> <td>2520 ± 20</td> | 87279 | 600-590 | -22.1 | -5.0 ± 1.9 | 2520 ± 20 |
| 87312 $610-600$ -22.4 -1.2 ± 2.2 2300 ± 13 87280 $620-610$ -22.0 -0.3 ± 1.9 2495 ± 20 63352 $630-620$ $ 0.3\pm 2.0$ 2470 ± 15 87313 $630-620$ -21.7 3.9 ± 2.1 2500 ± 15 87281 $640-630$ -21.7 2.2 ± 2.0 2495 ± 20 87314 $650-640$ -22.9 8.1 ± 1.9 2455 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2450 ± 20 63353 $670-660$ $ 6.1\pm 1.9$ 2490 ± 15 87315 $670-660$ -22.7 6.1 ± 2.1 2490 ± 15 87283 $680-670$ -22.7 4.5 ± 2.0 2515 ± 20 87316 $690-680$ -2.0 7.7 ± 1.9 2500 ± 15 63356 $690-680$ -22.0 14.7 ± 2.1 2445 ± 15 87284 $700-690$ -21.0 14 ± 1.9 2450 ± 20 87317 $710-700$ -22.6 15.9 ± 1.9 2455 ± 15 87285 $720-710$ -22.4 14.5 ± 2.0 2475 ± 20 63354 $720-730$ $ 17.1\pm 1.9$ 2452 ± 15 87318 $730-720$ -22.2 21.7 ± 2.4 2465 ± 15 87286 $740-730$ -22.3 17.2 ± 1.9 2480 ± 15 87287 $760-750$ -21.8 15.6 ± 2.0 275 ± 20 87320 $770-760$ -21.9 14.2 ± 2.0 2535 ± 20 87321 $790-780$ -22.2 17.2 ± 2.1 2505 ± 15 <tr< td=""><td>03331 97212</td><td>610-600</td><td>-</td><td>-2.3 ± 2.0</td><td>2495 ± 15 2500 ± 15</td></tr<> | 03331 97212 | 610-600 | - | -2.3 ± 2.0 | 2495 ± 15 2500 ± 15 |
| 37260 $620-610$ -221.0 -0.3 ± 1.9 249 ± 20 63352 $630-620$ $ 0.3 \pm 2.0$ 2470 ± 15 87313 $630-620$ -21.7 3.9 ± 2.1 2500 ± 15 87281 $640-630$ -21.7 2.2 ± 2.0 2495 ± 20 87314 $650-640$ -22.9 8.1 ± 1.9 2455 ± 15 87282 $660-650$ -20.0 10.1 ± 2.0 2450 ± 20 63353 $670-660$ $ 6.1 \pm 1.9$ 2450 ± 20 63353 $670-660$ -22.7 4.5 ± 2.0 2515 ± 20 87315 $670-660$ -22.7 4.5 ± 2.0 2515 ± 20 87316 $690-680$ -2.0 7.7 ± 1.9 2500 ± 15 63356 $690-680$ -22.0 14.7 ± 2.1 2445 ± 15 87284 $700-690$ -21.0 14.7 ± 2.1 2445 ± 15 87285 $720-710$ -22.4 14.5 ± 2.0 2475 ± 20 87318 $730-720$ -22.2 21.7 ± 2.4 2465 ± 15 87286 $740-730$ -22.0 16.9 ± 2.0 2475 ± 20 87319 $750-740$ -22.3 17.2 ± 1.9 2480 ± 15 87287 $760-750$ -21.8 15.6 ± 2.0 2505 ± 20 87320 $770-760$ -21.9 14.2 ± 2.0 2535 ± 20 87321 $790-780$ -22.2 15.3 ± 1.9 2535 ± 15 87289 $800-790$ -22.2 13.3 ± 2.0 2560 ± 20 | 0/012 | 610-600 | -22.4 | -1.2 ± 2.2 | 2300 ± 13 2405 ± 20 |
| 65352630-620- 0.3 ± 2.0 2470 ± 13 87313630-620-21.7 3.9 ± 2.1 2500 ± 15 87281640-630-21.7 2.2 ± 2.0 2495 ± 20 87314650-640-22.9 8.1 ± 1.9 2455 ± 15 87282660-650-20.0 10.1 ± 2.0 2450 ± 20 63353670-660- 6.1 ± 1.9 2490 ± 15 87315670-660-22.7 4.5 ± 2.0 2515 ± 20 87316690-680-2.0 7.7 ± 1.9 2500 ± 15 63356690-680-22.0 14.7 ± 2.1 2445 ± 15 87284700-690-21.0 14 ± 1.9 2460 ± 20 87317710-700-22.6 15.9 ± 1.9 2455 ± 15 87285720-710-22.4 14.5 ± 2.0 2475 ± 20 63354720-730- 17.1 ± 1.9 2425 ± 15 87286740-730- 22.0 16.9 ± 2.0 2475 ± 20 87319750-740-22.3 17.2 ± 1.9 2480 ± 15 87287760-750-21.8 15.6 ± 2.0 2505 ± 20 87320770-760- 16.5 ± 1.9 2500 ± 20 87320770-760- 21.9 14.2 ± 2.0 2535 ± 20 87320770-760- 21.9 14.2 ± 2.0 2535 ± 20 87321790-780-22.2 15.3 ± 1.9 2535 ± 15 87289800-790-22.2 13.3 ± 2.0 2560 ± 20 | 67260 | 620-610 | -22.0 | -0.5 ± 1.9 | 2493 ± 20 2470 ± 15 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 03332 07212 | 620 620 | - 21.7 | 0.5 ± 2.0 20 ± 2.1 | 2470 ± 15 2500 ± 15 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87313 | 640 620 | -21.7 | 3.9 ± 2.1 | 2300 ± 13 2405 ± 20 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87211 | 650-640 | -21.7 | 2.2 ± 2.0 8.1 ± 1.0 | 2493 ± 20 2455 ± 15 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87282 | 660-650 | -22.5 | 10.1 ± 1.5 | 2450 ± 15 2450 + 20 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 63353 | 670-660 | -20.0 | 61 ± 10 | 2490 ± 20 2490 ± 15 |
| 87283680-670 -22.7 4.5 ± 2.0 2515 ± 20 87316690-680 -2.0 7.7 ± 1.9 2500 ± 15 63356690-680 -22.0 14.7 ± 2.1 2445 ± 15 87284700-690 -21.0 14.7 ± 2.1 2445 ± 15 87285720-710 -22.6 15.9 ± 1.9 2455 ± 15 87385720-710 -22.4 14.5 ± 2.0 2475 ± 20 63354720-730 $ 17.1 \pm 1.9$ 2425 ± 15 87286740-730 -22.0 16.9 ± 2.0 2475 ± 20 87319750-740 -22.3 17.2 ± 1.9 2480 ± 15 87287760-750 -21.8 15.6 ± 2.0 2505 ± 20 63355770-760 $ 16.5 \pm 1.9$ 2500 ± 20 87320770-760 -22.2 17.2 ± 2.1 2505 ± 15 87288780-770 -21.9 14.2 ± 2.0 2535 ± 20 87321790-780 -22.2 15.3 ± 1.9 2535 ± 15 87289800-790 -22.2 13.3 ± 2.0 2560 ± 20 | 87315 | 670-660 | -227 | 61+21 | 2490 ± 15 2490 + 15 |
| 87316690-680 -2.0 7.7 ± 1.9 2500 ± 15 63356690-680 -22.0 14.7 ± 2.1 2445 ± 15 87284700-690 -21.0 14.7 ± 2.1 2445 ± 15 87285720-710 -22.6 15.9 ± 1.9 2455 ± 15 87285720-710 -22.4 14.5 ± 2.0 2475 ± 20 63354720-730 $ 17.1 \pm 1.9$ 2425 ± 15 87318730-720 -22.2 21.7 ± 2.4 2466 ± 15 87286740-730 -22.0 16.9 ± 2.0 2475 ± 20 87319750-740 -22.3 17.2 ± 1.9 2480 ± 15 87287760-750 -21.8 15.6 ± 2.0 2505 ± 20 63355770-760 $ 16.5 \pm 1.9$ 2500 ± 20 87320770-760 -22.2 17.2 ± 2.1 2505 ± 15 87288780-770 -21.9 14.2 ± 2.0 2535 ± 20 87321790-780 -22.2 15.3 ± 1.9 2535 ± 15 87289800-790 -22.2 13.3 ± 2.0 2560 ± 20 | 87283 | 680-670 | -22.7 | 45 ± 2.0 | 2515 ± 10 2515 ± 20 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87316 | 690-680 | -2.0 | 77+19 | 2500 ± 15 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 63356 | 690-680 | -22.0 | 147 + 21 | 2445 + 15 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87284 | 700-690 | -21.0 | 14 ± 1.9 | 2460 ± 20 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87317 | 710-700 | -22.6 | 15.9 ± 1.9 | 2455 ± 15 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87285 | 720-710 | -22.4 | 14.5 ± 2.0 | 2475 ± 20 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 63354 | 720-730 | _ | 17.1 ± 1.9 | 2425 ± 15 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87318 | 730-720 | -22.2. | 21.7 ± 2.4 | 2465 ± 15 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87286 | 740-730 | -22.0 | 16.9 ± 2.0 | 2475 ± 20 |
| $\begin{array}{cccccccccccccccccccccccccccccccccccc$ | 87319 | 750-740 | -22.3 | 17.2 ± 1.9 | 2480 ± 15 |
| 63355 770-760 - 16.5 ± 1.9 2500 ± 20 87320 770-760 -22.2 17.2 ± 2.1 2505 ± 15 87288 780-770 -21.9 14.2 ± 2.0 2535 ± 20 87321 790-780 -22.2 15.3 ± 1.9 2535 ± 15 87289 800-790 -22.2 13.3 ± 2.0 2560 ± 20 | 87287 | 760-750 | -21.8 | 15.6 ± 2.0 | 2505 ± 20 |
| 87320 770-760 -22.2 17.2 ± 2.1 2505 ± 15 87288 780-770 -21.9 14.2 ± 2.0 2535 ± 20 87321 790-780 -22.2 15.3 ± 1.9 2535 ± 15 87289 800-790 -22.2 13.3 ± 2.0 2560 ± 20 | 63355 | 770-760 | - | 16.5 ± 1.9 | 2500 ± 20 |
| 87288 780-770 -21.9 14.2 ± 2.0 2535 ± 20 87321 790-780 -22.2 15.3 ± 1.9 2535 ± 15 87289 800-790 -22.2 13.3 ± 2.0 2560 ± 20 | 87320 | 770-760 | -22.2 | 17.2 ± 2.1 | 2505 ± 15 |
| 87321 790-780 -22.2 15.3 ± 1.9 2535 ± 15 87289 800-790 -22.2 13.3 ± 2.0 2560 ± 20 | 87288 | 780-770 | -21.9 | 14.2 ± 2.0 | 2535 ± 20 |
| 87289 800-790 -22.2 13.3 ± 2.0 2560 ± 20 | 87321 | 790-780 | -22.2 | 15.3 ± 1.9 | 2535 ± 15 |
| | 87289 | 800-790 | -22.2 | 13.3 ± 2.0 | 2560 ± 20 |

^a Tree-ring ages of these samples were determined by the late C. Wesley Fergusson, Laboratory of Tree Ring Research (LTRR), University of Arizona, retained in LTRR collections, and provided from those collections by Dr. Paul Creasman of the LTRR.

 $^{\rm b}~\delta^{12}{\rm C}$ measurements were obtained by IRMS instrumentation using a Thermo Finnigan Delta Plus spectrometer with a Fisons NA 1500 elemental analyzer input.

technique we have employed. For example, Stuiver and Quay [7] noted that the measured differences were limited to 2 or 3 years.

About 2.5 mg of each sample of pretreated wood was placed in an evacuated tube along with CuO and Ag, sealed, and combusted at 900 °C for 3 h. CO₂ resulting from sample combustions was converted to catalytically-condensed carbon with H₂ using iron as the catalyst. Measurement of the ¹⁴C concentration in each sample was obtained by accelerator mass spectrometry utilizing the instrument of the Keck Carbon Cycle AMS Laboratory, Department of Earth System Science, University of California, Irvine [8]. Measure-

Table 2

Duplicate ¹⁴C measurements on the same decadal Bristlecone pine wood samples: 2470–2750 cal BP.

| | Previous measurments ^a | | UCIAMS measurements ^b | | | | | |
|-----|-----------------------------------|------|----------------------------------|------------------------|---------------------|---------------|--|--|
| | tree-ring age | | | | | | | |
| | mid-point ^c | | Sample number | ¹⁴ C age | ¹⁴ C age | Sample number | | |
| | BC | BP | | BP | BP | | | |
| 1. | 525 | 2475 | LJ-3902 | 2348 ± 41 | 2420 ± 15 | UCIAMS-87308 | | |
| | 525 | 2475 | LJ-1575 | 2399 ± 56 | | | | |
| 2. | 535 | 2485 | A-938 | 2417 ± 37 | 2410 ± 20 | UCIAMS-87276 | | |
| | 535 | 2485 | LJ-3900 | 2374 ± 42 | | | | |
| 3. | 545 | 2495 | LJ-3889 | 2288 ± 42 | 2470 ± 15 | UCIAMS-87309 | | |
| | 545 | 2495 | LJ-1578 | 2432 ± 56 | | | | |
| 4. | 575 | 2525 | LJ-3892 | 2397 ± 41 | 2490 ± 20 | UCIAMS-87278 | | |
| 5. | 585 | 2535 | LJ-1575 | 2294 ± 55 | 2495 ± 20 | UCIAMS-63350 | | |
| 6. | 595 | 2545 | A-936 | 2273 ± 58 | 2520 ± 20 | UCIAMS-87279 | | |
| | 595 | 2545 | LJ-3903 | 2441 ± 42 | 2480 ± 15 | UCIAMS-87312 | | |
| 7. | 605 | 2555 | LJ-1577 | 2358 ± 83 | 2495 ± 15 | UCIAMS-63351 | | |
| | 605 | 2555 | | | 2500 ± 15 | UCIAMS-87312 | | |
| 8. | 625 | 2575 | LJ-1574 | 2517 ± 55 | 2470 ± 15 | UCIAMS-63352 | | |
| | 625 | 2575 | | | 2500 ± 15 | UCIAMS-87313 | | |
| 9. | 645 | 2595 | LJ-3909 | 2395 ± 42 | 2455 ± 15 | UCIAMS-87314 | | |
| | 645 | 2595 | LJ-1571 | 2508 ± 55 | | | | |
| 10. | 665 | 2615 | LJ-1697 | 2418 ± 46 | 2490 ± 15 | UCIAMS-63353 | | |
| | 665 | 2615 | | | 2490 ± 15 | UCIAMS-87315 | | |
| 11. | 685 | 2535 | LJ-3906 | 2487 ± 42 | 2445 ± 15 | UCIAMS-63356 | | |
| | 685 | 2535 | LJ-1573 | 2439 ± 55 | 2500 ± 15 | UCIAMS-87316 | | |
| 12. | 695 | 2645 | LJ-3908 | 2435 ± 41 ^d | 2460 ± 20 | UCIAMS-87284 | | |
| 13. | 705 | 2655 | LJ-3910 | 2382 ± 41 | 2455 ± 15 | UCIAMS-87317 | | |
| | 705 | 2655 | LJ-1595 | 2444 ± 73 | | | | |
| 14. | 715 | 2665 | A-937 | 2565 ± 27 | 2475 ± 20 | UCIAMS-87285 | | |
| 15. | 725 | 2675 | LJ-1572 | 2423 ± 55 | 2465 ± 15 | UCIAMS-87318 | | |
| 16. | 735 | 2685 | LJ-3914 | 2496 ± 41 | 2475 ± 20 | UCIAMS-87286 | | |
| 17. | 745 | 2695 | LJ-3907 | 2414 ± 41 | 2480 ± 15 | UCIAMS-87319 | | |
| 18. | 755 | 2705 | LJ-3912 | 2398 ± 41 | 2505 ± 20 | UCIAMS-87287 | | |
| 19. | 765 | 2715 | LJ-3911 | 2465 ± 41 | 2505 ± 20 | UCIAMS-87320 | | |
| | 765 | 2715 | | | 2500 ± 20 | UCIAMS-63355 | | |
| 20. | 775 | 2725 | LJ-3915 | 2486 ± 41 | 2535 ± 20 | UCIAMS-87288 | | |
| 21. | 785 | 2735 | LJ-3913 | 2454 ± 64 | 2535±15 | UCIAMS-87321 | | |
| | 785 | 2735 | LJ-1570 | 2584 ± 56 | | | | |
| 22. | 795 | 2745 | A-938 | 2587 ± 26 | 2560 ± 20 | UCIAMS-87289 | | |

^a For University of Arizona (A-) ¹⁴C values, see reference [10]. For University of California, San Diego [La Jolla] (LJ-) ¹⁴C values, see references [11,12].
^b This study, see Table 1.

^c As determined by C. Wesley Ferguson, Tree Ring Laboratory, University of Arizona.

^d In Appendix 1 of reference [11], the value of 3435 ± 41 cal BP is listed for LJ-3908. We assume this is a typographical error and that the correct value should be 2435 ± 41 cal BP.

ments were calculated as conventional ¹⁴C ages as defined by Stuiver and Polach [9]. Table 1 lists the results of this study.

In the 1960s, 22 tree-ring dated Bristlecone pine decadal samples which we have measured had also been analyzed by decay counting by the University of Arizona [10] and University of California, San Diego (Mt. Soladad, La Jolla) ¹⁴C laboratories [11,12]. Table 2 lists the ¹⁴C measurements obtained by these laboratories with our results for comparison. In six cases, the La Jolla laboratory carried out duplicate analysis of samples of the same age while in two instances, La Jolla and Arizona carried out measurements on the same age sample. In 10 instances, there is good concordance between the results obtained by the three laboratories on the same decadal interval. However, in a number of other cases, there are from minor to major discrepancies even when the larger statistical errors associated with the decay counting results are considered.

3. Discussion

Fig. 1 is a plot of our tree-ring dated bristlecone pine/ 14 C values. Also included in this figure are the 14 C measurements obtained on tree ring-dated Irish and German oak wood samples employed to Download English Version:

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