130) Intercalations during the co-regency of Xerxes with Darius I — The chronological debate among Greek historians as to whether Xerxes died in 475 BCE, according to Herodotus and Thucydides, or in 465 BCE, according to the Babylonian royal lists, was decided by the famous Greek astronomer, Claudius Ptolemy, who published around 150 CE the Babylonian (and Achaemenid) chronology dated after the Nabonassar era, which began in 748 BCE. Claudius Ptolemy converted all Babylonian dates into the Egyptian civil calendar, which allowed him to verify historical synchronisms with Egyptian chronology. He also verified the accuracy of some lunar eclipses mentioned in astronomical tablets dated in Year of the King (Almagest). As a result of Ptolemy's reliance on verifiably-dated eclipses, all historians after 150 CE, without exception, adopted this Babylonian chronology and modified the Greek chronology to bring it into line with this new absolute chronology of the Achaemenid period. The Babylonian chronology established by Claudius Ptolemy was confirmed by the BM 34576 tablet (copy of the King List dated 99 BCE). A study of all tablets (contracts or inscriptions) dated during the period 626–331 BCE was published (Parker, Dubberstein: 1956) and demonstrated that all the durations of the Achaemenid period agreed with those of the Babylonian royal lists, providing that several short co-regencies were admitted shortly before and also during the enthronement of the new king. Although this study confirmed the Babylonian chronology from the King Lists, it also contradicted the transition between Artaxerxes I and Darius II precisely described by all Greek historians. It had to be admitted that the reign of a legitimate king, Xerxes II (425–424), and a usurper, Sogdianus (424–424), who had succeeded Artaxerxes I before Darius II came to power, was historically contradicted by Babylonian chronology. A study including all the Babylonian contracts listed, as well as all the astronomical tablets, made it possible to reconstruct the chronology of the Achaemenid period (Gertoux: 2018, 179-206). This study showed that the reigns of Xerxes and Artaxerxes had been shifted by 10 years (Reign*) with respect to astronomical dates (highlighted in black):

Babylonian king	#	Reign	Reign*	Regnal year	Year of Nabonassar	Date of eclipse (BCE)	Almagest
Nabonassar	14	748–734	748–734		1		
Merodachbaladan II	12	**722–710**	**722–710**	1st year	27	19 March 721	IV:6
				2nd year	28	8 March 720	IV:6
				2nd year	28	1 September 720	IV:6
Nabopolassar	21	**626–605**	**626–605**	5th year	127	22 April 621	V:14
Cambyses II	8	**530–522**	**530–522**	7th year	225	16 July 523	V:14
[Bardiya]			523-522		**		
Darius I	36	**522–486**	**522–486**	20th year	246	19 November 502	IV:9
				31st year	257	25 April 491	IV:9
Xerxes I	21	486–465	**496–475**	21st year	262**	26 June 475	BM 32234
				21st year		20 December 475	BM 32234
Artaxerxes I	41	465–424	**475–434**		283**		
[Darius B]			434-426				
[Artaxerxes I]			426-425				
[Xerxes II]			425-424				
Darius II	19	**424–405**	**424–405**	2nd year	326	8 August 422	LBAT 1426
Artaxerxes II	46	**405–359**	**405–359**	26th year	369	17 April 379	LBAT 1416
Artaxerxes III	23	359–336	359–336				
Darius III	5	**336–331**	**336–331**	5th year	412	20 September 331	BM 36761

The changes[1)] due to the reigns of Xerxes and Artaxerxes I forced the Babylonian scribes to reorganize the royal lists and to shift the reigns of Xerxes and Artaxerxes I by 10 years. For example, the observations in year 13 of Xerxes were moved to year 3, the observations in year 21 of Xerxes replaced those in year 10 of Artaxerxes I, in 465 BCE, the observations in year 33 of Artaxerxes I were moved to year 23, and so on (Huber, De Meis: 2004, 3,94-112). This 10-year time delay was not due to chance, as Babylonian astronomers classified lunar eclipses according to an 18-year Saros cycle, because they had noticed that astronomical phenomena were reproduced identically in the 19th year of the solar cycle and almost identically in the 11th year (to within a day). The 19 solar years last 6939.6 days = 19x365.24219 days and correspond exactly to 19 lunar years plus 7 intercalary months, which last 6939.7 days = ([19x12]+7) x 29.530588 days. The 11 solar years last 4017.6 days = 11x365.24219 days and correspond to 11 lunar years plus 4 intercalary months, which last 4016.2 days = ([11x12]+4) x 29.530588 days. Because of these astronomical cycles the two lunar eclipses of 475 BCE (total then partial) were reproduced in 465 BCE, but in reverse order (partial then total). For example, the two lunar eclipses of 475 BCE were exactly reproduced in 457 BCE on 6 July (total) and 31 December (partial). The rearrangements made by Babylonian astronomers changed the chronology of the reigns of Xerxes and Artaxerxes, including the Metonic cycle of the intercalary years. This 19-year cycle is a mathematical cycle that perfectly synchronizes the 19 lunar years with 19 solar years by adding intercalary months, a second Adar month (XIIa) or a second Ulul month (VIb), in 7 years of the 19-year cycle (3A, 6A,

8A, 11A, 14A, 17U, 19A). However, this 19-year cycle was based on observations, not on calculations (Steele: 2007, 121-123) and the computed data in diaries (purely computational, not the combination of observational and predictive methodologies) appear a little before 350 BCE (Rochberg-Halton: 1991, 107-120). The reading of a few months in between is disputed, for example the year 7A (XIIa) of Xerxes should perhaps be replaced by the year 8U (VIb) of Xerxes (Ossendrijver: 2018, 138-143).

The chronology of the Achaemenid reigns shows that the metric cycle was respected with very few errors: 0U** instead of 0A and 3U** instead of 2A in the reign of Cambyses II; 11U** instead of 11A, 22A** instead of 22U and 30U** instead of 30A in the reign of Darius I; 2U (Persepolis) instead of 1A (Babylon) in the reign of Xerxes; 19A** instead of 19U and 38A instead of 38U in the reign of Artaxerxes I; 51/0 instead of 51/0A in the reign of Darius II (deleted parts in the royal lists have been hatched):

BCE	Meton cycle	Coregent	King	Meton cycle	King List (conventional)	Meton cycle
530	6A		0U** Cambyses II	6A	0U** Cambyses II	6A
529	7		1	7	1	7
528	8A		2	8A	2	8A
527	9		3U**	9	3U**	9
526	10		4	10	4	10
525	11A		5A	11A	5A	11A
524	12		6	12	6	12
523	13	0 Bardiya	7	13	7	13
522	14A	1/0 Nebuchadnezzar III	8/0A Darius I	14A	8/0A Darius I	14A
521	15		1	15	1	15
520	16		2	16	2	16
519	17U		3U	17U	3U	17U
518	18		4	18	4	18
517	19A		5A	19A	5A	19A
516	1		6	1	6	1
515	2		7	2	7	2
514	3A		8A	3A	8A	3A
513	4		9	4	9	4
512	5		10	5	10	5
511	6A		11U**	6A	11U**	6A
510	7		12	7	12	7
509	8A		13A	8A	13A	8A
508	9		14	9	14	9
507	10		15	10	15	10
506	11A		16A	11A	16A	11A
505	12		17	12	17	12
504	13		18	13	18	13
503	14A		19U** (*Persepolis*)	14A	19U** (*Persepolis*)	14A
502	15		20	15	20	15
501	16		21	16	21	16
500	17U		22A** (*Babylon*)	17U	22A** (*Babylon*)	17U
499	18		23	18	23	18
498	19A		24A (*Babylon*)	19A	24A (*Babylon*)	19A
497	1		25	1	25	1
496	2	0 Xerxes I	26	2	26	2
495	3A	1**	27A (*Babylon*)	3A	27A (*Babylon*)	3A
494	17U	2U (*Persepolis*)	28	4	28	4
493	18	3	29	5	29	5
492	19A	4?A (*Babylon*)	30U** (*Persepolis*)	6A	30U** (*Persepolis*)	6A
491	1	5	31	7	31	7
490	2	6	32A (*Babylon*)	8A	32A (*Babylon*)	8A
489	3A	7?A (*Persepolis*)	33	9	33	9
488	4	8	34	10	34	10
487	5	9	35A (*Babylon*)	11A	35A (*Babylon*)	11A
486	6A	10A (*Babylon*)	36	12	36/0 Xerxes I	12
485	7	11		13	1**	13
484	8A	12A (*Persepolis*)		14A	2U (*Persepolis*)	17U
483	9	13	LBAT 1419 (18 Nov.)		[3]	18
482	10	14			4?A (*Babylon*)	19A
481	11A	15A (*Babylon*)	Papyrus B23 (15 Sep.)		5	1
480	12	16			6	2
479	13	17			7?A (*Persepolis*)	3A
478	14A	18A (*Babylon*)			8	4
477	15	19			9	5
476	16	20			10A (*Babylon*)	6A
475	17U	21U-0 Artaxerxes I	LBAT 1419 (26 Jun.; 20	Dec.)	11	7
474	18	1	Papyrus B24 (5 Jan.)		12A (*Persepolis*)	8A
473	19A	2A			13	9
472	1	3			14	10
471	2	4			15A (*Babylon*)	11A
470	3A	5A			16	12

469	4	6	Papyrus B25/26 (4 Dec.)			17	13
468	5	7				18A (*Babylon*)	14A
467	6A	8				19	15
466	7	9	Papyrus B34 (16 Dec.)			20	16
465	8A	10A				**21U-0 Artaxerxes I**	**17U**
464	9	11				1	18
463	10	12				2A	19A
462	11A	13A				3	1
461	12	14	Papyrus B35 (9 Jul.)			4	2
460	13	15				5A	3A
459	14A	16	Papyrus B28 (17 Oct.)			6	4
458	15	17				7	5
457	16	18				8	6A
456	**17U**	**19A****	Papyrus B29 (19 Nov.)			9	7
455	18	20				10A	8A
454	19A	21A				11	9
453	1	22				12	10
452	2	23				13A	11A
451	3A	24				14	12
450	4	25	Papyrus B30 (29 Aug)			15	13
449	5	26				16	14A
448	6A	27				17	15
447	7	28	Papyrus B37 (17 Sep.)			18	16
446	8A	29A				**19A****	**17U**
445	9	30				20	18
444	10	31	Papyrus B38 (1 Nov.)			21A	19A
443	11A	32				22	1
442	12	33	**LBAT 1426 (24 Mar.)**			[23]	2
441	13	34				24	3A
440	14A	35A				25	4
439	15	36				26	5
438	16	37				27	6A
437	**17U**	**38A****	Papyrus B39 (15 Jun.)			28	7
436	18	39				29A	8A
435	19A	40A				30	9
434	1	41 CBS 4986	0 **Darius B**			31	10
433	2	42	1			32	11A
432	3A	(43)	2A			33	12
431	4	(44)	3			34	13
430	5	(45)	4 Papyrus B31 (4 Oct.)			35A	14A
429	6A	(46)	5A			36	15
428	7	(47)	6			37	16
427	8A	(48)	7A			**38A****	**17U**
426	9	(49)	8 Papyrus B42 (25 Sep.)			39	18
425	10	50 BM 65494	(0) **Xerxes II**			40A	19A
424	1**	**[51]-0 Darius II**	(1A) LBAT 1426	11A		**[51]-0 Darius II**	1
423	2	1		12		1	2
422	3A	**2A**		13		**2A**	3A
421	4	3				3	4
420	5	4				4	5
419	6A	5A				5A	6A
418	7	6				6	7
417	8A	7A				7A	8A
416	9	8				8	9
415	10	9				9	10
414	11A	10A				10A	11A
413	12	11				11	12
412	13	12				12	13
411	14A	13A				13A	14A
410	15	14				14	15
409	16	15				15	16
408	**17U**	**16A****				**16A****	**17U**
407	18	**17**				**17**	18

406	19A	18A				18A	19A
405	1	19 **Artaxerxes II**				19 **Artaxerxes II**	1
404	2	1				1	2
403	3A	2A				2A	3A

Elephantine papyri are letters (B23 to B42) dated in both the lunar calendar and the Egyptian civil calendar, so they provide absolute dates (Porten: 1996, 152–234), assuming that the lunar calendar started at the new moon to be in line with conventional Babylonian chronology, but it doesn't work well (Stern: 2000, 159–171). In fact, the Egyptian lunar calendar began with the full moon, which corresponds perfectly to the absolute dates of the Babylonian astronomical tablets (highlighted in sky blue).

Abnormal intercalary years with respect to the Metonic cycle (A** and U**) are simply the result of the observation process[2)] . If the first lunar crescent of the 7th month (VII) appeared before the autumnal equinox (29 September), a second month Adar (XIIa) was added (for example in 514 BCE), and if the first lunar crescent of the 1st month (I) appeared before the spring equinox (26 March), a second Ulul (VIb) was added (for example in 511 BCE). The coincidence of the intercalary years with the Metonic cycle thus comes from the meticulous astronomical observation of the Babylonian astronomical priests.

BCE	cycle	spring	< 1/I	1/VI	1/VIb	autumn	< 1/VII	1/XII	1/XIIb	
517	19A	26 Mar.	29 Mar.	24 Aug.		29 Sept.	22 Sep.**	17 Feb.	19 Mar.	5A
516	1	26 Mar.	17 Apr.	11 Sep.		29 Sept.	11 oct.	8 Mar.		6
515	2	27 Mar.	7 Apr.	1 Sep.		29 Sept.	30 Sep.	26 Feb.		7
514	3A	27 Mar.	27 Mar.	21 Aug.		29 Sept.	19 Sep.**	15 Feb.	16 Mar.	8A
513	4	26 Mar.	14 Apr.	8 Sep.		29 Sept.	7 Oct.	5 Mar.		9
512	5	26 Mar.	3 Apr.	29 Aug.		29 Sept.	27 Sep.	22 Feb.		10
511	6A	27 Mar.	23 Mar.**	18 Aug.	17 Sep.	29 Sept.	16 Oct.	13 Mar.		**11U**

The accession of Xerxes in year 26 of Darius I (496 BCE) occurred in a normal year, his first year of reign should have been an intercalary year (in Babylon), but as Xerxes resided in Persepolis the Persian astronomical priests did not add an intercalary month at the end of the year (XIIb), they visibly started a new intercalation cycle from the 2nd year of Xerxes (2U), which shifted the intercalation cycle for Xerxes, which had started in Persepolis (Ossendrijver: 2018, 141), from that of Darius. The cycle of intercalations begun during the reign of Xerxes continued until the end of the reign of Artaxerxes I, but the very complicated transition between Year 50 of Artaxerxes and Year 1 of Darius II (Xerxes II and Sogdianus) made it impossible to count the intercalation during Year 1 of Xerxes II (1A) corresponding to the 11th year of the cycle (11A). The astronomical priests thus began a new 19-year cycle from the 1st year of Darius II.

The realization of a 19-year cycle with its 7 intercalary months by Babylonian astronomers is truly remarkable. However, this 19-year cycle was based on observations, not on calculations and the computed data in diaries appear a little before 350 BCE. It was not a theoretical cycle, like the cycle of Meton, but an empirical cycle based on observations. The presence of four months Elul2 (VIb) in the period 603-596, instead of only one, proves that the Babylonian system of intercalary months was empirical. These intercalary months (VIb) were mainly used to calibrate the 1st Tishri (month VII) just after the autumn equinox. Historians of Babylonian astronomy have in recent decades come to the conclusion that the cycle was known to the Babylonians by about 500 BCE, but it must be admitted, however, that there are still problems with the list of intercalary months during the later years of the Achaemenid empire. For instance, in the 16th year of Darius II, three sources suggest an intercalary Ulul2 but one an intercalary Adar2; in the 16th year of Artaxerxes II, two sources suggest an intercalary Ulul2 but one an intercalary Adar2; and two sources (including a contemporary astronomical Diary) suggest an intercalary Adar2 in the 20th year of Artaxerxes II whereas two other sources (including the Saros canon) attribute the intercalary month to his 21st year (Walker: 1997, 23-24). A table of intercalary months gives the impression that the 19-year cycle was standardized from 500 or 483 BCE, depending on the way to group periods (Britton: 2002, 25-35), with some exceptions. However, Parker and Dubberstein assumed, because of these anomalies that the Babylonian calendar had really been standardized as from 367 BCE instead of 500 BCE (Parker, Dubberstein: 1956, 1-6). In the 19-year cycle there can be only 7 intercalary months. However, during the reign of Cyrus to the reign of Darius I, two cycles contain 10, which means that multiple calendars depended on several Persian capitals (Persepolis, Suse, Ecbatana, Pasargadae), not just on Babylon. In the reign of Artaxerxes II we find an intercalary month in the year 40 (Steele: 2007, 123), but also in the years 42, 43, 44 and 45 (Hunger: 2001, 215, 217, 227, 247, 261), which is unlikely. Anomalies (have been hatched) are much more numerous than in the study of Parker and Dubberstein (1956). The intercalary years of the reign of Xerxes come from astronomical tablets copied late in Babylon after the reign of Artaxerxes I. It is thus probable that the compiler of these texts might not have possessed a complete list of intercalations for earlier periods. It is therefore conceivable that some intercalations during the reign of Xerxes were extrapolated backwards, especially if they agree with the final pattern (Ossendrijver: 2018, 142-143).

cycle	BCE	538	519	500	481	462	443	424	405	386	367	348
1			U	A								
2	537	U								A		
3 A	536	A	A	A	a	A	a	A	A		A	a
4	535		U									
5	534	A								A	A	
6 A	533	A	A	A	a	a	a	A	A		A	a
7	532										A	
8 A	531				A	A	A	A	a	a	A	a
9	530	U	U	U								
10	529											
11 A	528	U	A	A	a	A	a	A	a	A	a	a
12	527	U										
13	526		U									
14 A	525	A	A	A	a	a	A	A	A	A	a	a
15	524		U									
16	523	A										
17 U	522	A	U/A	U	U	A	A	U	u	U	U	u
18	521											
19 A	520			A	a	A	A	A	A	a	a	a
total		10	10	8	7	7	7	7	7	7	9	7

(A: attested Adar2; U: attested Ulul2; a: supposed Adar2; u; supposed Ulul2)

Assuming that the dates actually come from two Persian capitals: Babylon (B.) and Persepolis (P.) whose cycle has been shifted by one year, all anomalies disappear. This hypothesis remains fragile because the provenance of several tablets is unknown, moreover, the main production centre for dated contracts was in Babylon not Persepolis. We notice that many intercalary months are not attested (months a and u) for Persepolis (10 out of 14). The synchronization of the lunar calendar in the Achaemenid Empire was due to the quality of astronomical observations (excellent in Babylon for more than a millennium), but the choice of the intercalary years depended on the astronomical priests of each capital of the Achaemenid Empire, but also exceptionally on the king who could decide to fix an identical intercalary year for his whole kingdom when there was a debt remission or to celebrate an important festival. The decision as to whether to intercalate was important for the ritual calendar, and in particular for the preparations for the major festivals3) . The desynchronization of the intercalary years between Babylon and Persepolis was of no consequence because the dated contracts were managed by the capital that had dated them.

BCE	Per.	cycle^{P}	Bab.	cycle^{B}	P.+B.
386		2		1	
385	A^{P}	3A		2	A^{P}
384		4	A	3A	A
383		5		4	
382	A^{P}	6A		5	A^{P}
381		7	A	6A	A
380	a^{P}	8A		7	
379		9	A	8A	A
378		10		9	
377	a^{P}	11A		10	
376		12	A	11A	A
375		13		12	
374	a^{P}	14A		13	
373		15	A	14A	A
372		16		15	
371	u^{P}	17U		16	
370		18	U	17U	U
369	a^{P}	19A		18	
368		1	A	19A	A

BCE	Per.	cycle^{P}	Bab.	cycle^{B}	P.+B.
367		2		1	
366	a^{P}	3A		2	
365		4	A	3A	A
364		5		4	
363	A^{P}	6 A		5	A^{P}
362		7	A	6A	A
361	A^{P}	8 A		7	A^{P}
360		9	A	8A	A
359		10		9	
358	a^{P}	11 A		10	
357		12	A	11A	A
356		13		12	
355	a^{P}	14 A		13	
354		15	A	14A	A
353		16		15	
352	u^{P}	17 U		16	
351		18	U	17U	U
350	a^{P}	19A		18	
349		1	A	19 A	A

(A: attested Adar2; U: attested Ulul2; a: supposed Adar2; u; supposed Ulul2)

Notes

1. The foregoing table shows that the Babylonian royal lists have been purged of all co-regencies: Bardiya (523- 522) with Cambyses II (530-522); Xerxes I (496-475) with Darius I (522-486); Darius B (434-426) with Artaxerxes I (475-425), as well as all usurpers (Nebuchadnezzar III and IV, Bel-shimanni; Shamash-eriba; Sogdianus) including kings who were later considered illegitimate Bardiya (523-522) and Xerxes II (425-424).

2. https://promenade.imcce.fr/fr/pages4/441.html – https://promenade.imcce.fr/fr/pages4/439.html

3. For example, in the sixth month of 671 BCE, Marduk-šakin-šumi, the chief exorcist, wrote to the king after his decision to insert an intercalary Month VI asking when a festival should take place. However, most letters do not mention king's authority. For example, a letter reads: A word from the king to Kurbanni-[Marduk]: I am well, you can be happy. For your information: I have intercalated this Addar (Month XII) of the 15th year [of Nabonidus]. Interestingly, two similar letters from the reigns of either Cyrus or Cambyses were written by officials in the Esangila temple and do not mention the king's authority. The absence of a reference to the king seems to suggest a shift in responsibility from the king to the temple, although it may be that the temple was merely the conduit through which the king chose to communicate at this time (Steele: 2011, 477-478).

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