Chapter 14

The architecture of complex cardinals in relation to numeral classifiers

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This paper investigates properties of multiplicative and additive complex cardinals in several languages. The starting point in the discussion will be recent work by Ionin & Matushansky (2018), who show that complex cardinals are not primitive units without complex structure. This paper observes some data that are problematic for their analysis. Based on the data, I argue that in multiplicative complex cardinals, a multiplicand is a syntactic head used for measurement and a multiplier is a phrase appearing in the specifier position of the phrase headed by the multiplicand. Building on the proposed analysis of multiplicative complex cardinals, I further argue that additive complex cardinals can have a non-coordinate structure in some languages, in addition to the coordination structure proposed by Ionin & Matushansky (2018). I propose that in non-coordinate additive complex cardinals, which do not include a coordinator syntactically, a lower-valued cardinal is an adjunct to a higher-valued cardinal.

Keywords: multiplicative complex cardinals, additive complex cardinals, numeral classifiers, left-branch extraction, nominal ellipsis, split topicalization

1 Introduction

This paper investigates two types of complex cardinals: MULTIPLICATIVE COMPLEX CARDINALS like (1a) and ADDITIVE COMPLEX CARDINALS like (1b).[1]

[1]In this paper, I use quotation marks for number concepts and italics for numerical expressions. For instance, *three* denotes "three" in English.

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(1) a. Ivan je pozvao [tri stotine] studenata. Multiplicative
Ivan is invited three hundred student.GEN.PL.M
'Ivan invited three hundred students.' (Serbo-Croatian)

b. Ivan je vidio [dvadeset (i) pet] studenata. Additive
Ivan is seen twenty and five students.GEN.PL.M
'Ivan saw twenty five students.' (Serbo-Croatian)

In (1a), the numeral "three" functions as a MULTIPLIER and "hundred" as a MULTIPLICAND. In (1b), the augend ("twenty") appears with the addend ("five").

Ionin & Matushansky (2018) argue that multiplicative complex cardinals have the cascading structure represented in (2).

(2) $[_{NP}$ three $[_{NP}$ hundred $[_{NP}$ student]]] (Ionin & Matushansky 2018)

Building on their analysis, this paper argues that multiplicative complex cardinals can also have a non-cascading structure in some languages.

Regarding additive complex cardinals, Ionin & Matushansky pursue an analysis in which additive complex cardinals have an NP coordination structure. According to their analysis, additive complex cardinals are derived by deletion of a noun phrase, as in (3b). This analysis is supported by the fact that additive complex cardinals can include an overt coordinator in some languages, as shown in (1b).

(3) a. three hundred three girls

b. $[_{\&P}$ $[_{NP}$ three $[_{NP}$ hundred $[_{NP}$ ~~girls~~]] & $[_{NP}$ three $[_{NP}$ girls]]]
(Ionin & Matushansky 2018)

Although I follow Ionin & Matushansky (2018) regarding the existence of the coordinate structure of additive complex cardinals, I argue in this paper that in addition to the coordinate structure as in (3b), additive complex cardinals can also have a non-coordinate structure. Specifically, I propose that a lower-valued cardinal ("three" in "three hundred three") can directly adjoin to a higher-valued cardinal ("three hundred" in "three hundred three"). The major motivation for the existence of the non-coordinate structure comes from the human classifier *ri* in Japanese and contracted forms of Chinese cardinals.

The paper is organized as follows. In §2, I provide data which pose problems for Ionin & Matushansky's (2018) analysis. §3 presents an analysis which can capture the data discussed in §2. §4 shows that the proposed analysis of multiplicative complex cardinals is compatible with Ionin & Matushansky's analysis of additive

complex cardinals. Moreover, I argue that in addition to the coordinate structure proposed by Ionin & Matushansky, additive complex cardinals can also have a non-coordinate structure in some languages. §5 is the conclusion.

2 Multiplicative complex cardinals and constituency tests

In a cascading structure like (2), the multiplicand and the main noun form a constituent to the exclusion of the multiplier. According to this analysis, a multiplicative complex cardinal should not behave as a single constituent since there is no syntactic constituent which directly corresponds to a multiplicative complex cardinal. However, I will show in this section that this prediction is not borne out, by investigating two types of split constructions; left-branch extraction and split topicalization.

2.1 Left-branch extraction

Some languages such as Latin and most Slavic languages allow movement of the leftmost constituent of an NP (Ross 1986). Sentences in (4) are examples of LEFT-BRANCH EXTRACTION (LBE) in Serbo-Croatian, taken from Bošković (2005).

(4) a. Ta$_1$ je vidio [Δ_1 kola].
that is seen car
'That car, he saw.' (Serbo-Croatian)

b. Lijepe$_1$ je vidio [Δ_1 kuće].
beautiful is seen houses
'Beautiful houses, he saw.' (Serbo-Croatian)

What is important is that in Serbo-Croatian, a multiplicative complex cardinal can undergo LBE, as shown in (5b).

(5) a. Ivan je pozvao [tri stotine studenata].
Ivan is invited three hundred.ACC.F students.GEN.M
'Ivan invited three hundred students.' (Serbo-Croatian)

b. [Tri stotine]$_1$ je Ivan pozvao [Δ_1 studenata].
three hundred.ACC.F is Ivan invited students.GEN.M
'Three hundred students, Ivan invited.' (Serbo-Croatian)

Following Corver (1992), I assume that LBE can be applied only to a phrasal constituent. Given this, the acceptability of (5b) shows that a multiplier and a multiplicand can form a phrasal constituent, excluding the main noun. Notice also

that *je* in (5b) is a second position clitic; as such it can follow only one constituent (see Bošković 2001 and references therein). The presence of *je* in (5b) then also indicates that (5b) is not derived by multiple LBE, where *tri* and *stotine* would undergo LBE separately.

One may consider that (5b) involves NP fronting and scattered deletion (cf. Fanselow & Ćavar 2002). However, it has been argued that LBE and the scattered deletion construction behave differently in some respects. As discussed in Bošković (2014), one of the main characteristics of the scattered deletion construction is that the remnant must be backgrounded and left in situ as in (6). As shown in (7), this is not the case with LBE.

(6) *NP-fronting + Scattered deletion*

a. ?* [Onu žutu] mu kuću pokazuje.
that yellow him house is-showing

b. [Onu žutu] mu pokazuje kuću.
that yellow him is-showing house

'He is showing him that yellow house.'

(Serbo-Croatian; Bošković 2014: 421)

(7) *Left-branch extraction*

a. [Žutu] mu kuću pokazuje.
yellow him house is-showing

b. [Žutu] mu pokazuje kuću.
yellow him is-showing house

'He is showing him the yellow house.'

(Serbo-Croatian; Bošković 2014: 421)

(5b) patterns with LBE in this respect. As shown in (8), the remnant main noun can appear in the pre-verbal position. (5b) thus should not be analyzed as a scattered deletion construction.

(8) [Tri stotine] je Ivan studenata pozvao.
three hundred.ACC.F is Ivan students.GEN.M invited

'Three hundred students, Ivan invited.'

(Serbo-Croatian; Željko Bošković, p.c.)

One may also argue that (5b) is derived by movement of the main noun out of the complex cardinal expression followed by movement of the remnant phrase. However, if this kind of remnant movement were available in Serbo-Croatian, it is not clear why (9) is unacceptable.

(9) * Visoke lijepe je on vidio [Δ Δ djevojke].
tall beautiful is he watches girls
'He is watching tall beautiful girls.' (Serbo-Croatian; Bošković 2005: 2)

Attributive adjectives can undergo LBE in Serbo-Croatian, as shown in (4b). However, when a noun is modified by two attributive adjectives, LBE of the two adjectives is impossible as in (9) (Bošković 2005). The contrast between (5b) and (9) is not expected under the remnant movement analysis. (For arguments against the remnant movement analysis of LBE more generally, see Bošković 2005, Stjepanović 2010, 2011, Despić 2011, Talić 2017, and references therein.)

Given these considerations, I conclude that the fronted multiplicative complex cardinal in (5b) must be a single phrasal constituent. The acceptability of (5b) then raises a problem for the cascading structure in (2) advanced by Ionin & Matushansky (2018), in which multiplicative complex cardinals cannot be the target of a syntactic operation as a single constituent.

2.2 Nominal ellipsis

Nominal ellipsis also provides an argument against Ionin & Matushansky's (2018) cascading structure. In (10b) and (10c), the second sentence has an elided part.

(10) a. Juan tomó seis cientas fotos, y Maria tomó tres cientas
Juan took six hundred pictures and Maria took three hundred
fotos.
pictures
'Juan took 600 pictures, and Maria took 300 pictures.'

b. Juan tomó seis cientas fotos, y Maria tomó tres cientas.
Juan took six hundred pictures and Maria took three hundred
'Juan took 600 pictures, and Maria took 300 pictures.'

c. Juan tomó seis cientas fotos, y Maria tomó tres.
Juan took six hundred pictures and Maria took three
Unavailable: 'Juan took 600 pictures, and Maria took 300 pictures.'
Available: 'Juan took 600 pictures, and Maria took 3 pictures.'
(Spanish; Gabriel Martínez Vera, p.c.)

The elided part in (10b) can receive the same interpretation as the one in (10a). On the other hand, the ellipsis in (10c) cannot mean 'three hundred pictures'. Instead, it is interpreted as 'three pictures'. The contrast between (10b) and (10c) is unexpected under Ionin & Matushansky's analysis, because the cascading structure in (11) should be available for the multiplicative complex cardinals in (10).

(11) [$_{NP}$ three [$_{NP}$ hundred [$_{NP}$ pictures]]] (Ionin & Matushansky 2018)

Under their analysis, the ellipsis in (10b) can be derived from the structure in (11) by deleting the main NP (*fotos* 'pictures'). However, we may then also expect that the same deletion operation can be applied to the intermediate NP consisting of the multiplicand and the main NP, resulting in the ellipsis in (10c). This in fact is possible for adjectives in Serbo-Croatian. In (12), the object noun phrase in the second sentence is interpreted as 'a small, square table'.

(12) Ivan je kupio veliki četvrtasti sto, a Petar je kupio mali Δ.
Ivan is bought big square table and Peter is bought small
'Ivan is bought a big square table and Peter is bought a small, square table.' (Serbo-Croatian; Željko Bošković, p.c.)

Given these data, it seems to me that Ionin & Matushansky (2018) need an account for the fact that the ellipsis in (10c) cannot mean 'three hundred pictures'.[2]

2.3 Split topicalization

Another potential problem for the cascading structure in (2) comes from split topicalization in German. As shown in (13c), the main noun alone can undergo split topicalization, while leaving a multiplicative complex cardinal in situ. However, the main noun and a multiplicand cannot move together, leaving a multiplier in situ, as shown in (13d).

(13) a. Hans kaufte [acht tausend Bücher].
Hans bought eight thousand books

b. [Acht tausend Bücher]$_1$ kaufte Hans Δ$_1$
eight thousand books bought Hans

[2]I have examined the data regarding nominal ellipsis in English. Some of my consultants found that although there is a contrast between (i.b) and (i.c), it is not completely impossible for *two* in (i) to be interpreted as 'two hundred books'. Ionin & Matushansky (2006: 338) also reported a similar observation in a footnote.

(i) a. John read three hundred books, but Mary read [two hundred books].
b. John read three hundred books, but Mary read [two hundred].
c. John read three hundred books, but Mary read [two].

This suggests that at least for some speakers, English multiplicative complex cardinals have the cascading structure as in (11). I leave this issue for future research.

c. Bücher$_1$ kaufte Hans [acht tausend Δ_1]
books bought Hans eight thousand

d. * [Tausend Bücher]$_1$ kaufte Hans [acht Δ_1]
thousand books bought Hans eight

(Intended:) 'Hans bought eight thousand books.'

(German; Sabine Laszakovits, p.c.)

Split topicalization in German has received close attention in the literature (van Riemsdijk 1989, Fanselow & Ćavar 2002, van Hoof 2006, Ott 2011, 2015, among others). The problem here is that the unacceptability of (13d) seems to be unexpected under Ionin & Matushansky's analysis, regardless of the details of the analysis of split topicalization. Under Ionin & Matushansky's analysis, the object phrase in (13) has the structure in (14).

(14) [$_{NP}$ eight [$_{NP}$ thousand [$_{NP}$ books]]] (Ionin & Matushansky 2018)

The acceptability of (13b) and (13c) shows that either the topmost NP in (14) or the lowest NP (i.e. the main noun) can be a target of topicalization in German. We may then expect that the intermediate NP in (14) can also undergo topicalization. (It should also be noted that Ionin & Matushansky propose that both multipliers and multiplicands are of type $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$.) It is not clear how to account for the unacceptability of (13d) under Ionin & Matushansky's analysis.

3 Proposal

In §2, I showed that Ionin & Matushansky's cascading structure faces some problems. To solve the problems, I pursue an analysis in which multiplicative complex cardinals can in principle have two structures cross-linguistically.

First, I propose that multiplicands are syntactic heads used for measurement whereas multipliers are phrases appearing in the specifier position of a phrase headed by the multiplicand, cross-linguistically. The noun phrase *three hundred students* in English has the structure given in Figure 1 under the present analysis. What is important is that multipliers and multiplicands are syntactically different from each other.

In Figure 1, the multiplicand is a syntactic head taking the main NP as the complement. Structurally, Figure 1 is similar, at least in spirit, to Ionin & Matushansky's (2018) analysis given in (2) in the sense that a multiplicand takes the main NP as its complement. However, the present analysis departs from Ionin & Matushansky's analysis with regard to the syntactic status of multipliers and

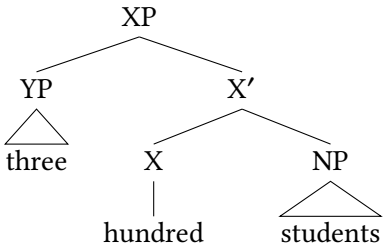

Figure 1: Complementation structure

multiplicands. I propose that multipliers are phrases whereas multiplicands are heads in multiplicative complex cardinals, cross-linguistically.

Regarding semantics, I propose that multipliers are of type n, as in (15a), whereas multiplicands such as *hundred* are of type $\langle\langle e,t\rangle,\langle n,\langle e,t\rangle\rangle\rangle$, as in (15b).[3] A multiplicand used in multiplicative complex cardinals includes a measurement function μ. The denotation of the multiplicand "hundred" is given in (15b).

(15) a. $[\![\text{three}]\!] = 3$

b. $[\![\text{hundred}]\!]$
$= \lambda P.\lambda n.\lambda x.\exists S.[\Pi(S)(x) \wedge \mu(x) = n$
$\wedge\ \forall y \in S.[\underbrace{|\{z : z \leq_{\text{AT}} y\}| = 100}_{\text{cardinality restriction}} \wedge \forall z \leq_{\text{AT}} y.[P(z)]]]$

Following Ionin & Matushansky, I make use of the cover S and the partition function Π defined in (16), to prevent multiple counting of the same members of S. In addition, multiplicands have a restriction on the cardinality of the set of atomic individuals in the cover S.

(16) $\Pi(S)(x)$ is true iff (Ionin & Matushansky 2018: 13)

a. S is a *cover* of x, and

b. $\forall z, y \in S[z = y \vee \neg\exists a[a \leq_i z \wedge a \leq_i y]]$

The topmost XP in Figure 1 has the denotation in (17).

[3] In this respect, the proposed analysis is similar to a series of works by Rothstein (2013, 2017), where multipliers and multiplicands have different semantic types. However, the present analysis is also different from Rothstein's analysis in several crucial aspects. For instance, Rothstein assumes that multiplicands are of type $\langle n,\langle e,t\rangle\rangle$, not $\langle\langle e,t\rangle,\langle n,\langle e,t\rangle\rangle\rangle$. Moreover, my proposal given in (15b) does not include any arithmetic functions such as $\times$, unlike Rothstein's. Ionin & Matushansky argue against Rothstein's assumption regarding the presence of arithmetic functions in semantics. However, this issue does not arise under the current analysis.

(17) $[\![[_{\text{XP}}$ three hundred students $]]\!]$
$= \lambda x.\exists S.[\Pi(S)(x) \wedge \mu(x) = 3$
$\wedge \forall y \in S.[|\{z : z \leq_{\text{AT}} y\}| = 100 \wedge \forall z \leq_{\text{AT}} y.[\textsc{student}(z)]]]$

What is important is that the current proposal is different from Ionin & Matushansky's analysis in that the former assumes that multipliers and multiplicands are different syntactically and semantically.

Recall that in §2, I showed that the acceptability of LBE of a multiplicative complex cardinal is not expected under Ionin & Matushansky's analysis. To solve the problems, I propose that multiplicative complex cardinals can occur in the adjunction structure as represented in Figure 2, in addition to Figure 1.

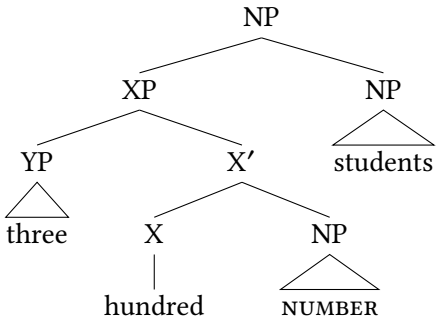

Figure 2: Adjunction structure

In Figure 2, the multiplicand takes the silent NUMBER as the complement, instead of an overt common noun like *students* (see Kayne 2005 and Zweig 2006 for an independent argument for the presence of the silent numerical noun). However, the structural relation between the multiplier and the multiplicand is the same as in Figure 1. The multiplier occurs in the specifier position of the phrase head by the multiplicand.

With regard to the semantics, I assume that the silent NUMBER is interpreted as a property of being a number (i.e. $\lambda x[\textsc{number}(x)]$). The topmost XP in Figure 2 has the following denotation.

(18) $[\![[_{\text{XP}}$ three hundred NUMBER $]]\!]$
$= \lambda x.\exists S.[\Pi(S)(x) \wedge \mu(x) = 3$
$\wedge \forall y \in S.[|\{z : z \leq_{\text{AT}} y\}| = 100 \wedge \forall z \leq_{\text{AT}} y.[\textsc{number}(z)]]]$

Following Rothstein (2013, 2017), I assume that the topmost XP in Figure 2 can be converted into a singular term of type n by the $^{\cap}$ function (Chierchia 1985). In

(18), each atomic individual of S has the property of being a number. When the $^{\cap}$ function applies, the topmost XP, which is of type $\langle e,t\rangle$, becomes a numerical expression of type n as in (19).[4]

(19) $[\![^{\cap}\text{XP}]\!] = 300$

In order to modify a noun phrase, cardinals of type n need the covert measurement function ϵ defined as in (20a).[5]

(20) a. $[\![\epsilon]\!]$
$= \lambda P.\lambda x.\exists S.[\Pi(S)(x) \wedge \mu(x) = n$
$\wedge \forall y \in S.[|\{z : z \leq_{\text{AT}} y\}| = 1 \wedge \forall z \leq_{\text{AT}} y.[P(z)]]]$

b. $[\![[[_{\text{XP}}$ three hundred NUMBER] $[\epsilon$ students]]$]\!]$
$= \lambda x.\exists S.[\Pi(S)(x) \wedge \mu(x) = 300$
$\wedge \forall y \in S.[|\{z : z \leq_{\text{AT}} y\}| = 1 \wedge \forall z \leq_{\text{AT}} y.[\text{STUDENT}(z)]]]$

Although the denotation in (20b) is different from the one in (17), they denote the same set; a set of students whose cardinality is "three hundred" in total. Importantly, the topmost XP in Figure 2 can be the target of syntactic operations such as LBE, while keeping the main noun intact, as discussed below.

[4]When the XP including the silent NUMBER is modified by the $^{\cap}$ function, it functions as a numerical expression of type n. Therefore, the multiplicative complex cardinal *three hundred* can be used as a multiplier, combining with another multiplicand as in (i).

(i) a. $[_{\text{X1P}}\ ^{\cap}[_{\text{X2P}}$ three $[_{\text{X2'}}$ hundred NUMBER]] $[_{\text{X1'}}$ thousand students]]
b. $[\![$three hundred thousand students$]\!]$
$= \lambda x.\exists S.[\Pi(S)(x) \wedge \mu(x) = 300$
$\wedge \forall y \in S.[|\{z : z \leq_{\text{AT}} y\}| = 1000 \wedge \forall z \leq_{\text{AT}} y.[\text{STUDENT}(z)]]]$

[5]The covert function ϵ is also used when a noun phrase is modified by a numerical expression in the absence of a multiplicand. For instance, the denotation of *three students* is given in (i.b). (See Scontras 2014 (CARD) and Champollion 2017 (MANY) for a similar covert element in the numeral construction.)

(i) a. [$[_{\text{YP}}$ three] [ϵ $[_{\text{NP}}$ students]]]
b. $[\![$three ϵ students$]\!]$
$\lambda x.\exists S.[\Pi(S)(x) \wedge \mu(x) = 3 \wedge \forall y \in S.[|\{z : z \leq_{\text{AT}} y\}| = 1 \wedge \forall z \leq_{\text{AT}} y.[\text{STUDENT}(z)]]]$

Note also that the covert function ϵ must be unavailable in obligatory classifier languages, where classifiers are generally indispensable in numerical expressions. I speculate in this paper that the existence of numeral classifiers blocks the covert function ϵ in obligatory classifier languages. (See Chierchia 1998 for a similar blocking effect.)

3.1 Left-branch extraction

The acceptability of (5b), repeated here as (21), in which a multiplicative complex cardinal undergoes LBE, can be captured under the proposed analysis.

(21) [Tri stotine]$_1$ je Ivan pozvao [Δ_1 studenata].
3 100.ACC.F is Ivan invited students.GEN.M
'Three hundred students, Ivan invited.' (Serbo-Croatian)

Under the current analysis, the multiplicative complex cardinal in (21) can be an adjunct to the main NP, as represented in (22) (cf. Figure 2).

(22) [$_{NP}$ $^{\cap}$[$_{XP}$ three hundred] [$_{NP}$ students]]

The XP in (22) can undergo LBE, while leaving the main noun in situ.

3.2 Nominal ellipsis

The current analysis can also account for the (im)possible interpretations of elliptical examples. The crucial example is repeated here as (23).

(23) Juan tomó seis cientas fotos, y Maria tomó tres.
Juan took six hundred pictures and Maria took three
Unavailable: 'Juan took 600 pictures, and Maria took 300 pictures.'
Available: 'Juan took 600 pictures, and Maria took 3 pictures.' (Spanish)

What is important is that the elided part in (23) cannot be interpreted as 'three hundred pictures'. The current proposal can capture the interpretation of the elliptical example in (23). The structure of the object phrases in (23) is represented in (24) (cf. Figure 1).

(24) [$_{XP}$ three [$_{X'}$ hundred [$_{NP}$ pictures]]]

The elliptical example in (23) cannot be derived from the structure in (24) because there is no phrasal constituent that can undergo ellipsis in (24), to the exclusion of the multiplier "three".[6] The present analysis can thus capture the fact that the elliptical part in (23) cannot mean 'three hundred pictures'.

[6]I assume that X′-level cannot be a target of ellipsis.

3.3 Split topicalization

The data about split topicalization in German can also be captured under the current analysis. What is problematic for Ionin & Matushansky's analysis is the unacceptability of (13d), repeated here as (25).

(25) * [Tausend Bücher]$_1$ kaufte Hans [acht Δ_1]
thousand books bought Hans eight
Intended: 'Hans bought eight thousand books.' (German)

The contrast in question is expected by assuming that the multiplicative complex cardinal in (25) has the structure given in (26) underlyingly.

(26) [$_{XP}$ eight [$_{X'}$ thousand [$_{NP}$ books]]]

The NP *Bücher* can be a target of split topicalization because it is a phrasal constituent. On the other hand, the constituent composed of the multiplicand and the main noun cannot be a target of topicalization because it is not a phrasal projection.

It is worth noting here that numeral classifiers in Mandarin and Vietnamese behave like multiplicands in German regarding leftward movement, as shown in (27) and (28).

(27) a. Qiang mai le [wu tiao xianglian].
Qiang buy ASP five CLS necklace
b. xianglian$_1$ Qiang mai le [wu tiao Δ_1].
necklace Qiang buy ASP five CLS
c. * [tiao xianglian]$_1$ Qiang mai le [wu Δ_1].
CLS necklace Qiang buy ASP five
(Intended:) 'Qiang bought five necklaces.' (Mandarin; Shengyun Gu, p.c.)

(28) a. Khanh mua [năm cuón sách].
Khanh bought five CLS book
b. sách$_1$ Khanh mua [năm cuón Δ_1].
book Khanh bought five CLS
c. * [cuốn sách]$_1$ Khanh mua [năm Δ_1].
CLS book Khanh bought five
(Intended:) 'Khanh bought five books.' (Vietnamese; Thuy Bui, p.c.)

As shown in the b-examples of (27) and (28), the main noun moves to the sentence initial position, while leaving the cardinal and the numeral classifier in situ. However, it is impossible to move the numeral classifier and the main noun together, as in the c-examples in these classifier langugages.

The current analysis can capture the similarity between numeral classifiers and multiplicands in German. Huang & Ochi (2014) propose that Chinese numeral classifiers project their own phrases, taking a noun phrase as its complement. I assume that the classifier phrases in Chinese and Vietnamese have the complementation structure given in (29).[7]

(29) $[_{XP}$ five $[_{X'}$ $[_{X}$ CLS] $[_{NP}$ ...]]]

The c-examples in (27) and (28) are unacceptable because the non-maximal projection (i.e. X′) cannot be a target of the relevant movement, similarly to split topicalization in German.

One piece of supporting evidence for the structure in (29) comes from the fact that it is impossible to move a cardinal and a numeral classifier while leaving the main noun in situ, as shown in (30) and (31).

(30) * [wu tiao]$_1$ Qiang mai le [Δ_1 xianglian].
five CLS Qiang buy ASP necklace
Intended: 'Qiang bought three necklaces.' (Mandarin; Shengyun Gu, p.c)

(31) * [năm cuón]$_1$ Khanh mua [Δ_1 sách].
five CLS Khanh bought book
Intended: 'Khanh bought five books.' (Vietnamese; Thuy Bui, p.c.)

The unacceptability of (30) and (31) follows from the current analysis. They are unacceptable because there is no constituent composed of the cardinal and the classifier to the exclusion of the NP in (29). Notice that multiplicative complex cardinal in German cannot undergo split topicalization while leaving the main noun in situ, as in (32).

(32) * [Acht tausend]$_1$ kaufte Hans [Δ_1 Bücher].
eight thousand bought Hans books
Intended: 'Hans bought eight thousand books.'
(German; Sabine Laszakovits, p.c.)

[7] See however Nguyen (2004) for a different analysis of classifier phrases in Vietnamese. See also Zhang (2013) and references therein for a detailed syntactic analysis of Chinese numeral classifier phrases.

The unacceptability of (32) indicates that multiplicative complex cardinals in German do not appear in the adjunction structure as in Figure 2.

It should be noted here that it is possible to front a cardinal and a numeral classifier together in some classifier languages such as Ch'ol and Japanese, as shown in (33b) and (34b).

(33) a. Ta' jul-i-y-ob [ux-tyikil x'ixik]$_1$.
PFV arrive-ITV-EP-PL three-CLS woman
'Three women arrived.'

b. [Ux-tyikil]$_1$ ta' jul-i-y-ob [Δ_1 x'ixik].
three-CLS PFV arrive-ITV-EP-PL woman
'[Three]$_{foc}$ women arrived.' (Ch'ol; Bale et al. 2019: 19)

(34) a. kyoositsu-ni [zyosei san-nin]-ga toochaku-sita .
classroom-LOC woman three-CLS-NOM arrive-DID
'Three women arrived at the classroom.'

b. [san-nin]$_1$ kyoositu-ni [zyosei Δ_1]-ga toochaku-sita .
three-CLS classroom-LOC woman -NOM arrive-DID
'[Three]$_{foc}$ women arrived at the classroom.' (Japanese)

Following Huang & Ochi (2014), I assume that there are in principle two structures for numeral classifier phrases; the complementation structure as in (29) and the adjunction structure as in (35).[8]

(35) [$_{NP}$ [$_{XP}$ THREE [$_X$ CLS]] [$_{NP}$ ...]]

I take the acceptability of (33b) and (34b) as evidence that numeral classifier phrases in these languages make use of the adjunction structure in (35). The XP in (35) can be a target of the relevant movement operation, similarly to LBE in Serbo-Croatian.

3.4 Section summary

In the present paper, I assume that the two structures are in principle available for multiplicative complex cardinals; the complementation structure Figure 1 and the adjunction structure Figure 2. The current analysis differs from Ionin & Matushansky's (2018) analysis regarding the treatment of multipliers and multiplicands. I have proposed in this section that multiplicands are syntactic heads used

[8]See §4 for further references and discussion regarding Japanese numeral classifiers in relation to additive complex cardinals.

for measurement, whereas multipliers are phrases appearing in the specifier position of the phrase headed by a multiplicand. In addition, I have shown some similarities and differences between multiplicands and numeral classifiers, on the basis of the data about topicalization and fronting. The cross-linguistic data are summarized in Table 1.

Table 1: Multiplicative complex cardinals & numeral classifier phrases

	multiplicands	numeral classifiers
complementation	German	Mandarin Chinese, Vietnamese
adjunction	Serbo-Croatian	Ch'ol, Japanese

Building on the proposed analysis of multiplicative complex cardinals, I will investigate additive complex cardinals in the next section.

4 Additive complex cardinals

In this section, I discuss Ionin & Matushansky's treatment of additive complex cardinals, showing that the proposed analysis of multiplicative complex cardinals is compatible with their analysis of additive complex cardinals. Ionin & Matushansky pursue an analysis in which additive complex cardinals have an NP coordination structure. According to their analysis, additive complex cardinals are derived by deletion of a noun phrase, as in (36).

(36) a. three hundred three girls (Ionin & Matushansky 2018)
b. [$_{\&P}$ [$_{NP}$ three [$_{NP}$ hundred [$_{NP}$ ~~girls~~]] & [$_{NP}$ three [$_{NP}$ girls]]]

The current analysis of multiplicative complex cardinals is compatible with the coordination analysis of additive complex cardinals. For instance, *three hundred three students* has the coordinate structure given in Figure 3.

The first conjunct in Figure 3 is headed by the multiplicand *hundred*, and the X1P has the complementation structure of multiplicative complex cardinals. In the second conjunct (X2P), the simplex cardinal *three* appears in the specifier of X2P. Recall that the covert function ϵ is used for simplex cardinals in non-classifier languages, as in Figure 3.

Although I follow Ionin & Matushansky (2018) regarding the existence of the coordinate structure of additive complex cardinals, I argue in this section that in addition to the coordinate structure as in (36), additive complex cardinals can

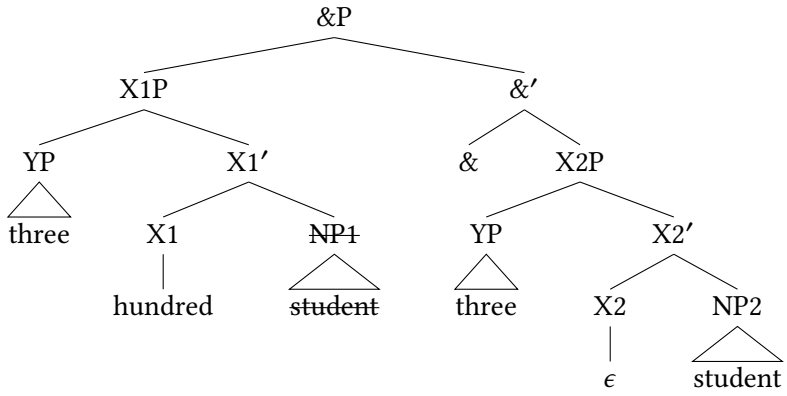

Figure 3: Coordinate structure under the present analysis

also have a non-coordinate structure. Specifically, I propose that a lower-valued cardinal ("three" in "three hundred three") can directly adjoin to a higher-valued cardinal ("three hundred" in "three hundred three"). The major motivation for the existence of the non-coordinate structure comes from the human classifier *ri* in Japanese and contracted forms of Chinese cardinals.

4.1 The human classifier *ri* in Japanese

Firstly, I consider human classifiers in Japanese. Japanese is an obligatory classifier language, and cardinals must co-occur with an appropriate classifier to modify a noun phrase. Japanese has two classifiers for common nouns referring to human beings; *nin* and *ri*. Crucially, the classifier *ri* has a contextual restriction regarding the type of a cardinal it combines with. It co-occurs with the native Japanese cardinals *hito* 'one' and *huta* 'two' as in (37a), but not with the Sino-Japanese cardinals *ichi* 'one' and *ni* 'two', as shown in (37a).

(37) a. {hito / huta}-ri-no gakusei
one two-CLS-GEN student
'{one/two} student(s)'

b. {*ichi / *ni}-ri-no gakusei
one two-CLS-GEN student
'{one/two} student(s)' (Japanese)

I assume that the noun phrase in (37a) has the adjunction structure as in (38) (cf. 35 in §3.3).[9]

[9]See Saito & Murasugi (1990) and Huang & Ochi (2014) for the adjunct status of pre-nominal classifier phrases in Japanese.

(38) [$_{NP}$ [$_{XP}$ {one / two} [$_{X}$ CLS]] [$_{NP}$ student]]

In Japanese, when a nominal modifier precedes a noun phrase, the genitive linker *no* intervenes between the pre-nominal modifier and the noun phrase (e.g. *gengo-gaku-no gakusei* 'students of linguistics', lit. linguistics-GEN student). Following Kitagawa & Ross (1982), and Watanabe (2006), I assume that the genitive linker *no* is inserted, post-syntactically.

I propose that the classifier *ri* is selected as an exponent of the classifier head when the human classifier head is a sister of *hito* or *huta*. In (38), the cardinal is a sister of Cls and the relevant contextual restriction is satisfied.

Crucially, the contextual restriction is violated when a cardinal occurs in an additive complex cardinal, as in (39a). In this environment, the classifier *nin*, which is the elsewhere exponent of the classifier head dedicated to human beings (Watanabe 2010), must be used together with the Sino-Japanese cardinals, as shown in (39b).

(39) a. [yon zyuu {*hito / *huta}]-ri-no gakusei
four ten one two-CLS-GEN student
'forty {one / two} students'

b. [yon zyuu {ichi / ni}]-nin-no gakusei
four ten one two-CLS-GEN student
'forty {one / two} students' (Japanese)

The coordination analysis predicts that the additive complex cardinal in (39a) includes the structure in (38) as the second conjunct of the coordinate structure. Therefore, the coordination analysis does not expect the contrast between (37a) and (39a).

However, if a non-coordinate structure is available for Japanese additive complex cardinals, the contrast can be accounted for. Specifically, I propose that (39a) has the non-coordinate structure as in (40).

(40) Non-coordinate additive complex cardinal
[$_{NP}$ [$_{X2P}$ [[$_{XP}$ four [$_{X'}$ ten NUMBER]] {one / two}] [$_{X2}$ CLS]] [$_{NP}$ ...]]

In (40), the lower-valued cardinal (i.e. {one / two}) combines directly with the higher-valued cardinal (i.e. XP), which includes the silent NUMBER. The lower-valued cardinal is not a sister of the classifier, and the relevant contextual restriction cannot be satisfied in (40). This problem does not arise when *hito* and *huta* do not occur in complex cardinals. In the non-complex cardinal construction, a

cardinal is a sister of the classifier head and nothing intervenes between them, as shown in (38). The contrast between (37a) and (39a) can thus be accounted for by assuming the non-coordinate structure of additive complex cardinals.

It should be noted here that it seems that Japanese additive complex cardinals can have the coordinate structure in some cases. As shown in (41), Japanese additive complex cardinals can contain the overt coordinator *to* 'and' (Hiraiwa (2016)). What is important is that the contextual restriction of the classifier *ri* is respected in the presence of *to*.

(41) [yon zyuu to {hito / huta}]-ri-no gakusei
four ten and one two-CLS-GEN student
'forty and {one / two} students' (Japanese)

I assume that when an additive complex cardinal contains the overt coordinator, it has the coordinate structure as in (42) (see Figure 3).

(42) [$_{\&P}$ [$_{X1P}$ four [$_{X1'}$ [$_{X1}$ ten] ~~NP~~]] & [$_{NP}$ [$_{X2P}$ {one / two} [$_{X2}$ CLS]] student]]

In (42), the lower-valued cardinal is a sister of the classifier head in the second conjunct. The contextual restriction is therefore satisfied in (42). (The Japanese conjunctive particle *to* appears between two nominal conjuncts, e.g. *Yuta to Hiro* 'Yuta and Hiro'.)

Ionin & Matushansky (2018) propose that additive complex cardinals generally involve coordinate structures, and a coordinator can be overtly realized in some languages. In fact, the presence/absence of an overt coordinator seems to be superficial in some languages such as Serbo-Croatian (see 1b). However, I showed in this section that Japanese additive complex cardinals have different structures, according to the presence/absence of an overt coordinator, which makes a significant difference regarding morphosyntactic behaviors.

4.2 Contracted forms in Mandarin Chinese

Contracted forms of Chinese cardinals also offer supporting evidence for the existence of non-coordinate additive complex cardinals. Chinese is an obligatory classifier language, and a cardinal must appear with an appropriate classifier when it modifies a noun. Mandarin Chinese has a contracted form consisting of *san* 'three' and the general classifier *ge*; *sa*, as shown in (43b).[10]

[10] *liang* 'two' also has a contracted form; *lia*. Since *lia* behaves like *sa*, I use examples with *sa* in this paper.

(43) a. san-ge xuesheng
three-CLS student
'three students'
b. sa xuesheng
three.CLS student
'three students' (Mandarin)

However, as observed by He (2015), the contracted form cannot appear in additive complex cardinals, as in (44).

(44) a. [si-shi san]-ge xuesheng
four-ten three-CLS student
'forty three students'
b. * [si-shi sa] xuesheng
four-ten three.CLS student
'forty three students' (Mandarin)

I propose that additive complex cardinals in Mandarin Chinese have the non-coordinate structure. First, let us consider the simplex cardinal in (43). I assume that the nouns in (43) have the structure represented in (45).[11] Here, the numeral "three" appears in SpecXP headed by the numeral classifier *ge* (cf. 29).

(45) $[_{XP}$ three $[_{X'}$ $[_{X}$ ge] $[_{NP}$ student]]]

Suppose that *san* 'three' and the classifier *ge* can be fused only when they are in a Spec-Head relation. In (45), they can then undergo morphological fusion without any problems.

On the other hand, when *san* 'three' appears inside an additive complex cardinal, *sishi* 'forty' and *san* 'three' form a constituent, resulting in the non-coordinate structure in (46).[12]

(46) Non-coordinate additive complex cardinal
$[_{X2P}$ $\boxed{[[_{XP}$ four $[_{X'}$ ten NUMBER]] three]} $[_{X2'}$ $[_{X2}$ CLS] $[_{NP}$ student]]]

[11] For a detailed syntactic analysis of Chinese classifier phrases, see Zhang (2013), Huang & Ochi (2014) and references therein.

[12] This line of approach is also taken taken by He (2015). However, the details are different from the current analysis. For instance, I assume that a higher-valued cardinal includes the silent NUMBER based on my analysis of multiplicative complex cardinals.

In (46), *san* 'three' adjoins directly to XP, which contains the silent NUMBER. In this case, morphological fusion cannot take place because *san* and *ge* are not in a Spec-Head relation. The non-coordinate structure can thus account for the unavailability of a contracted form in Mandarin Chinese, similarly to the Japanese data discussed in §4.1.

It should be noted here that the coordinate structure of additive complex cardinals should be unavailable in Mandarin Chinese. If the coordinate structure as in (47) were available in Mandarin Chinese additive complex cardinals, the numeral "three" and the general classifier *ge* would be able to undergo morphological fusion, contrary to the fact.

(47) $[_{\&P}\ [_{X1P}$ four $[_{X1'}\ [_{X1}$ ten$]$ ~~NP~~ $]]$ & $[_{X2P}$ three $[_{X2'}\ [_{X2}$ CLS $]$ student$]]]$

In fact, additive complex cardinals in Mandarin Chinese do not allow the presence of an overt coordinator, as in (48), in contrast to Japanese additive complex cardinals (cf. 41).

(48) *si-shi he san-ge xuesheng
four-ten and three-CLS student
'forty three students' (Mandarin)

The unacceptability of (48) indicates that the coordinate structure of additive complex cardinals is unavailable in Chinese.[13]

5 Summary

This paper examined properties of complex cardinals in several languages, in order to determine what kind of cascading structure is available for numerical expressions cross-linguistically. I focused on multiplicative complex cardinals and additive complex cardinals.

[13]There are certain cardinals that cannot occur in complex cardinals, cross-linguistically. Ionin & Matushansky discuss Polish examples in Chapter 6 and 7. Hurford (2003) observes that in German, the non-agreeing counting form *eins* 'one' must be used in compounding cardinals like "one hundred one", instead of *ein* 'one', which agrees with the main noun. He also reports that the presence of an overt coordinator changes the agreement pattern (e.g. **hundert eine Frau(en)* vs. *hundert und eine Frauen*, p. 616). A similar pattern is observed in Mandarin Chinese. Mandarin has two forms of the cardinal "two"; *liang* and *er*. However, *liang* cannot be used in additive complex cardinals (e.g. **si-shi liang-ge xuesheng* 'forty two students', lit. 'four-ten two-CLS student', vs. *liang-ge xuesheng* 'two students', lit. 'two-CLS student'). I thank an anonymous reviewer for bringing this point to my attention.

I argued that in multiplicative complex cardinals, a multiplicand is a syntactic head used for measurement and a multiplier is a phrase appearing in the specifier position of the phrase headed by the multiplicand. Moreover, I proposed that multiplicands and numeral classifiers can in principle appear in the two different structures: the complementation structure and the adjunction structure.

Based on the proposed analysis of multiplicative complex cardinals, I argued that additive complex cardinals can have the non-coordinate structure in some languages such as Japanese and Chinese, in addition to the coordination structure proposed by Ionin & Matushansky (2018). In non-coordinate additive complex cardinals, which do not include a coordinator syntactically, a lower-valued cardinal is an adjunct to a higher-valued cardinal.

Abbreviations

ACC	accusative	GEN	genitive
ASP	aspect	M	masculine
CLS	classifier	NOM	nominative
F	feminine	PL	plural

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