EXCEPTIONAL CADENTIAL CHORDS AND TONAL INTERPRETATION*

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0 Preamble

The first way I pay tribute to David Pesetsky today is by refusing to write this paper in LaTeX.

The second way I pay tribute to David Pesetsky today is by revealing that I have a private nickname for him, which I don't think I've ever said to his face. It is 'The Hardest Working Man in Show-Business'. This is not because of his accomplishments in teaching or research, although they are considerable. It's because if you are an MIT grad student, and you are stopping by the Stata Center at 6:30 p.m. on an official holiday to grab something you accidentally left in your office, you are guaranteed to find David Pesetsky in his office either meeting with a student or reading over a student's paper. David has a genuine, single-minded *devotion* to his students that is unlike anything I've seen in academia. And he has a *lot* of students to be devoted to. It seems like he's supervising half of the dissertations in progress in the department at any given time, and he still finds time to meet with even the students who are not writing those dissertations.

Like me, for instance. I started meeting with David early in grad school to talk about syntax, which he was teaching me at the time. At some point, it became clear that my 'official' research at MIT was going to involve vowel duration, formant measurements, and speech perception experiments, rather than anything remotely related to David's work. But the meetings did not stop; we had discovered a mutual interest in music, and we ended up with a fairly intensive reading group of two on the relationship between music theory and linguistic theory.

We continued to meet roughly once a week for several years. We wrote a paper on music and language that received a fair bit of attention but was never published. We went to several conferences together in far-flung corners of the world and presented our work. And then my dissertation was done and I left Cambridge to go out into the wide, linguistic world. But the relationship did not end when our regular meetings did: at every twist and turn of my professional life, David has been there with support, advice, and help. There are not that many

* Many thanks to Yoshi Kitagawa, Sandra Stjepanovic, and an anonymous reviewer for helpful comments.

people in life who you know will have your back no matter what; I think that all of his many, many students would say that David is one of those people.

The third way I pay tribute to David Pesetsky today is by pointing out that we missed something important in our paper. Something that supports one aspect of our theory, but may cast doubt on other aspects. I think you'll like this, David.

1 The probe-goal approach to cadences

In our paper (Katz & Pesetsky 2009), we made a number of observations about the phenomenon known as *cadence* in Western Tonal Music. A full cadence is a structural configuration that occurs at the ends of most large 'chunks' of tonal pieces (e.g. phrases, sections). It involves the *harmony* of a piece, the sequence of pitch-sets (roughly, *chords*) that provide a musical backdrop against which melodic notes are interpreted. We noted that in a full cadence, a final *tonic* chord (built on the tonal center of a section of music) must be preceded by a string-adjacent *dominant* chord, built on a pitch-class 7 or 11 semitones above the tonic. These pitch classes are the 5th or 7th *scale-degrees* of the tonal space in which the section unfolds, the *local key* or *diatonic pitch-collection*. This generalization is one clue that something 'special' is going on in a cadence: principles of chord combinatorics generally hold over syntactic sisters, not necessarily over string-adjacent terminal symbols. The adjacency requirement between a final tonic and dominant chord, then, is unusual and unexpected.

This property is one of several similarities we noted between the behavior of dominant chords in full cadences and verbs in the phenomenon known as *head movement* in natural language. While the claim that most readers seem to have taken away is that 'music has syntactic movement just like language', the displacement aspect of the analogy was actually the weakest part, and will not be particularly important here. What is important is the observation that cadential tonic chords have some requirements that are met by coming into contact with a particular class of chords called dominants.

In particular, we proposed that the string-adjacent dominant chord *values* a [tonic] feature on the final tonic chord, setting off a chain of syntactic and 'semantic' events: the [+ton] tonic chord may then function as the head of a *key domain*; the syntactic dependents of the tonic can thus be interpreted as occurring in a particular key; being interpreted with reference to a key is a general requirement of all harmonic events. In other words, the [+ton] feature both licenses and constrains the key in which the dependents of the tonic are interpreted. The key, in turn, constrains which pitch classes may appear in a harmonic event. So in a minor tonality, for instance, a chord with the 3rd scale degree as its root may contain the pitch-class 4 semitones (a major 3rd) above that root but not the pitch-class 3 semitones (a minor 3rd) above. If a chord instead has the 2nd scale degree as its root, exactly the opposite situation obtains with regard to major and minor thirds. In this way, the full cadence plays a major role in establishing the pitch-collection of a piece of music.

In this paper, I point out another piece of evidence that cadential dominant chords are 'special': the relatively rigid constraints on pitch classes just described appear to be suspended for syntactic dependents of the cadential dominant chord. That is, there are some chords that contain pitch classes not generally licensed in the parent key of a piece (*chromatic chords*), and these same chromatic chords are constrained to be the syntactic dependent of a dominant chord in a full cadence. I describe and justify the validity of this generalization in section 2, then explore the consequences for the theory of tonal interpretation in section 3.

2 Typical and exceptional harmonic events

2.1 Typical chord progressions

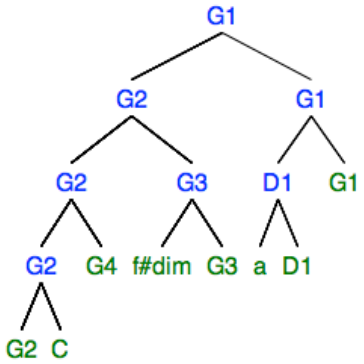
In Common Practice Period Tonal Music, (very) roughly defined as that composed by professional musicians in Europe between the early 17th and mid 19th centuries, there are very clear conventions about which types of harmonic events follow one another. Let us consider the well-known 1725 minuet in G major erroneously attributed to J.S. Bach (BWV Anh 114) as a typical example of straightforward tonal practice. In (1), we show only the harmonic progression of measures 9-16, as analyzed by Temperley (2009).[1] Note that (1) ends in a full cadence.

(1) Harmonic progression of *Minuet in G*, measures 9-16

G C G f#dim G a D G

In Katz & Pesetsky's (2009) approach, based on Lerdahl & Jackendoff's (1983) earlier work, this sequence would receive a syntactic analysis along the lines of (2), where multiple instances of the same chord are indexed with numerals (G1, G2, etc.). Trees like this are derived in principled ways from tonal tension and stability and rhythmic prominence, the details of which I can't discuss here due to space constraints.

(2) Tree structure for example (1)



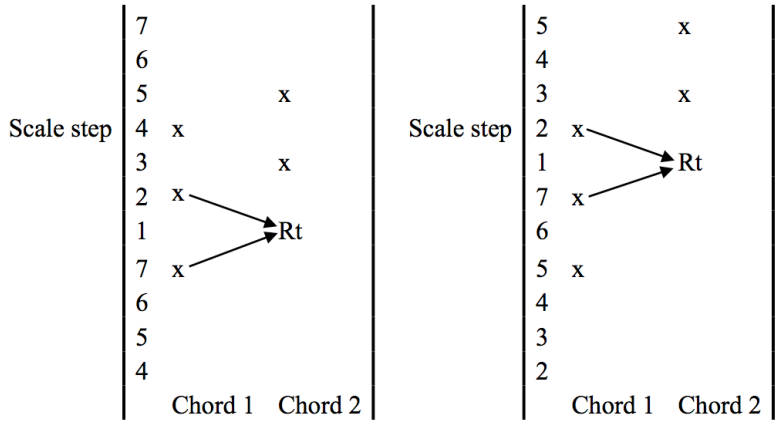
There are generalizations about the sisters in this syntactic tree. All such pairs, for instance, have roots that are either equivalent (e.g. G-G), move upwards by 3 scale steps (e.g. D-G), or move upwards by 1 scale step (e.g. f#dim-G). There are also generalizations about what types of *voice-leading*, or sequences of individual notes within sequences of chords, are attested in this analysis.

The voice-leading facts are illustrated in example (3), which depicts voice-leading based on the f#dim-G (left) and D-G (right) progressions from (2). Chords are formed by adding to the root at least two notes taken from the local pitch-collection by moving up in succesive intervals of a musical 3rd (2 steps upward within the scale). For example, chord 2 in the figure below is formed with a root of scale degree 1, by adding scale degrees 3 and 5. One condition that holds

[1] Here and throughout we use upper-case letters or roman numerals for major chords, lower-case for minor, and labels for all other chords (e.g. 'dim' for diminished in example 1).

on all of the (non-equivalent) syntactic sisters in (2) is that 2 notes from the 1st chord may move 1 step in opposite directions to the root of the 2nd chord. There are only 2 note-pairs in each chord that can move 1 step in opposite directions and end on the same note: the 1st and 3rd of the chord, and the 3rd and 5th. Thus there are only 2 possible roots for the 2nd chord: the note 1 step up from the 1st chord's root or the note 3 steps up.[2]

(3) Canonical voice-leading



While this may not be the only way of licensing syntactic dependents in tonal music, it is an important one.[3] Root motions up by 4th and 2nd, of the type shown here, are amongst the most frequent surface bigrams in corpus studies (e.g. Tymoczko 2005, 2010; Rohrmeier 2007; Temperley 2011), and correspond to frequently-invoked rules in Rohrmeier's (2011) phrase-structure approach to harmony.

Another thing to note about these 'canonical progressions' is that they involve chords constructed from pitch classes that are *contained in the local key*. There also exist pitch classes that are not contained in the local key, but these are generally barred from appearing in a chord. For instance, it is common for a chord with its root on the 4th scale degree (notated IV) to be preceded by a iii or I chord, but far less common for it to be preceded by a bIII chord or a i minor chord. This is because the latter two, while they contain two voices that may resolve in opposite directions to the root of the IV chord, in accordance with the condition sketched above, also contain a pitch class 3 semitones above the local tonic, which is not in the major-key collection. In other words, chord sequences in general obey certain generalizations about voice-leading and/or root-motion, *and* they obey constraints from the local tonality. That tonality, in turn, is hypothesized in the Katz & Pesetsky (2009) theory to come from a [+ton]-marked tonic chord.

2.2 Exceptional chords

The main empirical contribution of this paper is to note that dependents preceding a cadential dominant chord, while still subject to the voice-leading convention sketched above, are generally *not* subject to the tonality restriction. What this means is that virtually any chord with two notes

[2] Note that this genre does not require that this voice-leading *actually occur*, only that it is possible.

[3] A reviewer suggests that this contrary-motion principle, applied at higher levels of pitch space, may be able to derive other types of attested chord motion. I find this idea intriguing, but don't have space to explore it here.

that can resolve by step (half- or whole-) to the 5th scale degree, regardless of whether that chord is constructed from the local diatonic collection, is licensed before a cadential dominant.

The notes within a major key that are 1 step away from the 5th degree, on which the dominant chord is built, are 2 semitones (a *whole* step) above and below that 5th degree. The chords with these notes that are wholly contained within the pitch-collection of a major key are the ii and IV chords. These are allowed to precede a V chord anywhere within a piece of music. There are a number of other chords that contain 2 notes one step away from the 5th scale degree, but are not licensed within the pitch-collection of a major key. These are chords where one or both of the notes flanking the 5th scale degree are 1 semitone (a half-step) away from it and are not in the diatonic collection. Such chords are not generally licensed before a V chord, but some of them *are* licensed if that V is itself contained in a cadence. In fact, many of these chords have special labels in traditional music theory, precisely because they occur and are exceptional. Possibilities in non-cadential and cadential contexts, along with traditional music-theoretic labels for exceptional cadential chords, are shown in (4). The cells here represent the crossing of all kinds of half-step and whole-step motion up and down that end on the 5th scale degree.

(4) Pre-dominant chords in non-cadential and cadential major-key contexts

Non-cadential	**half step down**	**whole step down**
half step up	* (out of key)	* (out of key)
whole step up	* (out of key)	√ (IV or ii)

Cadential	**half step down**	**whole step down**
half step up	'augmented 6th'	'applied dominant'
whole step up	'neapolitan 6th' 'modal borrowing'	IV or ii

Out of the chords licensed in cadential context, the 'normal' chords in the bottom right cell are also licensed in non-cadential context. The applied dominant chords II(7) and #iv-dim in the top right cell are not licensed in the parent key, but are licensed if the key temporarily changes to that of the dominant, which it sometimes does in this genre. The chords in the left two cells are not licensed in the parent key or the key of the dominant, although the ii-dim and iv chords, labeled as modal borrowing, are licensed in the 'parallel' minor key. So while some of the exceptional cadential chords in example (4) may be licensed outside cadential contexts by temporary shifts in key, at least two of these types are not: the augmented and neapolitan 6th chords. Modal borrowing and applied dominant chords, while possible outside of a cadential context, should at least be less common outside that context than the 'normal' chords ii and IV. An attempt to test these generalizations against a small corpus is shown in (5).

(5) Distribution of exceptional chords by cadential context

	Cad	**Non-cad**
Aug 6th	8	11
bVI	3	23

	Cad	**Non-cad**
Nea 6th	2	1
Other bII	0	8

	Cad	**Non-cad**
II dom7	9	9
All {II, ii}	23	54

	Cad	**Non-cad**
#iv dim	7	8
All {IV, iv}	8	56

The corpus consists of 46 excerpts from common-practice-period pieces contained in a music-theory textbook (Kostka & Payne 1995), compiled and annotated by David Temperley (2009). As a first pass, I compare the distribution of the 'exceptional' chords from (4) and their 'normal'

counterparts, using a finite-state notion of cadential context: all and only chords that precede a V-{I, i} sequence are treated as cadential, the left column of each table in (5). The top row in each table is a putatively exceptional chord, the bottom row its closest 'normal' counterpart.

A few generalizations stand out here. First, the corpus contains zero instances of (the relevant types of) modal borrowing and only 3 possible neapolitan 6th chords. I think David Pesetsky would take this opportunity to point out that this is one of the shortcomings of corpus analysis in general: the most interesting and distinctive predictions of a theory often involve precisely those structures that are out of the ordinary and unlikely to occur frequently in corpora. That said, we can still glean some information from (5). Exceptional chords all appear to be relatively more frequent immediately preceding a cadential dominant-tonic sequence than their non-exceptional counterparts. Even with this small amount of data, Fisher's exact test suggests that, if exceptionality and cadential context were completely independent of one another, the probability of observing the asymmetries in (5) would be under 10% for all chords, under 5% for augmented 6th chords, and under 1% for the #iv-dim chord. Grouping all of the data in (5) together results in similar conclusions: odds ratio = 3.7, $p < 0.0001$.[4]

While these data do suggest that exceptional chords are more likely in cadential contexts, there are a number of counterexamples in (5). Most notably, while the applied dominants can be licensed by mechanisms other than a cadence (namely tonicization of the V chord), the augmented and neapolitan 6th chords are predicted not to occur outside cadential contexts; this is not what we find. This is partly because the notion of cadential context used here is a finite-state one: chords that immediately precede a dominant-tonic progression. Expanding this notion to include anything that branches off of a cadential dominant in phrase structure immediately explains most of the exceptions.

Of the 11 augmented 6th chords that do not immediately precede a dominant-tonic progression, 7 of them are contained in passages with multiple repetitions of augmented 6th (or near-equivalent bVI) to dominant motion before eventual resolution to the tonic. An 8th case immediately precedes a cadential 6-4 chord, which is essentially a variant of a dominant chord. One of the remaining instances, from Schumann's 'Tragodie', precedes a subdominant chord in a cadential progression. In a phrase-structure approach, this chord would be the syntactic sister not of the following subdominant chord, but of the dominant chord following that. Under the plausible hypothesis that long-distance syntactic attachments are in some sense more 'costly' than local ones, we might predict that this type of progression would be less frequent than the others seen here. For the neapolitan chords, the one that fails to occur in a cadential context is the first ('pivot') chord in an unprepared modulation to the key of bII (Haydn string quartet Op. 76, no. 6, II). I'm happy to consider this an idiosyncratic use of the bII^6 not reflecting the norms of the genre, or perhaps not a bII at all but only a I in the new key.

The final two probelmatic cases are augmented 6th chords from a passage in the 1840 Schumann song 'Die Beiden Grenadiere' with a series of roots descending by half-step in a constantly shifting (perhaps indeterminate) tonal space. The piece is from the mid-to-late Romantic era, when composers began to dramatically loosen the constraints of traditional tonality. The approach presented here cannot explain these chords, and I believe that's a positive thing. Any reasonable theory of common-practice harmony should reflect the fact that Schumann uses a number of harmonic practices that would have been well outside the 'grammar' of Bach or

[4] Fisher's exact test assumes that the observations in question are independent, but in this case some of them are 'linked' by a common composer or piece of music. There is not nearly enough data here to model this in a principled way with random effects, so we present this anti-conservative test as a rough measure of significance.

Mozart.[5] This passage is a case in point: whatever analysis the theorist wants to assign to this ambiguous passage, it is clearly not a straightforward instance of a common tonal progression.

We observed no cases of (the relevant type of) modal borrowing in the corpus. Such phenomena do occur, however. The two cases that most readily spring to my mind both occur in Bach chorales: a iv minor chord in the first phrase of BWV 422 'Warum sollt ich mich denn grämen' and a ii half-diminished 7 chord in BWV 281 'Christus, der ist mein Leben'. Both of these precede a cadential dominant-tonic complex, which is not strong evidence by any means, but at least suggestive.

I take these results to broadly justify the empirical observation formulated above. As a general rule, chords are constrained by considerations of both voice-leading and local key: pitch-classes must be members of the local collection. But chords that are syntactic dependents of a dominant in a full cadence are subject only to voice-leading constraints, *not* constraints on pitch-class imposed by the local key. In the final section, I gesture towards an explanation of why this might be so.

3 Tonic-marking and tonal interpretation

As a first step towards understanding the generalization, I restate it in slightly more abstract terms based on the Katz & Pesetsky (2009) cadence theory: dependents of a head that enters the derivation valued for the [ton] feature, and only those dependents, are exempt from the requirements that valuing a [ton] feature normally imposes on chords.

In that theory, recall, the tonic chord that heads a piece enters the derivation unvalued for [ton], leaving it unable to head a key domain and precluding the possibility of assigning other chords in the piece to a key. Merging that tonic with a dominant head that is valued [+ton] then values the [ton] feature of the tonic head, establishes a key domain, and allows the interpretation of other events in the structure. It is also possible for a dominant to Merge without valuation of [ton], but in that case it won't end up in a cadence. We have now seen that the special cadential dominant chord also removes some constraints associated with the feature [ton] from its own syntactic dependents.

Given that the cadential dominant chord is singled out as 'special' in this approach, it is at least possible to describe the empirical facts about exceptional chords: a dominant chord that isn't marked [+ton] licenses a particular set of dependents, and a dominant chord that *is* marked [+ton] licenses these as well as a list of other possible dependents. While this is an improvement on a theory that has no way of singling out cadential dominants, it doesn't really capture the connections between the key-establishing role of the [ton] feature and the suspension of key-based constraints within the cadential dominant projection, nor the voice-leading commonalities amongst the various exceptional chords. In the remainder of this paper, I sketch a theoretical approach to capturing these connections. As my final tribute to David Pesetsky today, I offer him an opportunity to figure out what I'm doing wrong and fix it.

The general idea that I pursue here is that valuation of the [ton] feature in the syntactic component, in addition to establishing a key domain, also has as a *precondition* the requirement that the domain in question contain only tones consistent with the local key. So a tonic chord unvalued for [ton] can only be valued in the syntax when all chords that it dominates are

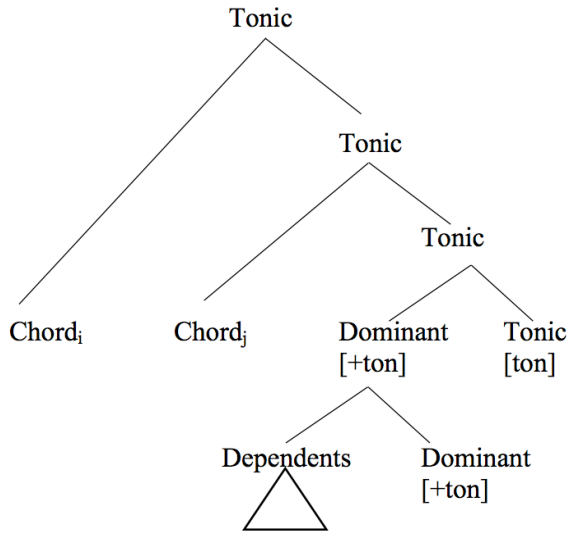
[5] A reviewer suggests that some novel harmonic practices in later Romantic music might be approached as a loosening and eventual abandonment of the contrary-motion constraint. Again, I find this suggestion intriguing but don't have space to explore it here.

consistent with the local key. When a chord enters the syntactic derivation already valued [+ton], however, as we proposed for the cadential dominant, this precondition doesn't need to be met.

Katz & Pesetsky (2009) suggested a series of relations along these lines: (1) a [+ton] dominant head Merges with a tonic unvalued for [ton] and values that tonic's feature; (2) the feature [+ton] 'percolates' up to all projections of the tonic head, establishing key domains across all events dominated by those projections; (3) the interpretation function is satisfied only if all harmonic events in a piece are contained within a key domain. Implicit in this theory was the idea that the derivation for a piece 'crashes' on step (3) if the realization of some chord cannot be parsed within the pitch-class collection established by step (2). The current study suggests that this derivation and the interpretation function may both need to be characterized differently. First, the voice-leading condition and the pitch-collection condition discussed in section 2 must be separated. In addition, the mere presence of a [+ton] feature must be enough to license key-domain establishment, even if the domain in question contains chromatic material (material outside the local pitch-collection). Below we sketch such an approach.

First, during the construction of the maximal projection of the cadential dominant chord, it must be the case that the [+ton] feature with which the dominant head entered the syntactic derivation automatically projects along with the label of the chord when Merge selects that chord as the head of a branching structure. So every instance of the dominant chord's label in a cadential dominant projection is [+ton]. In the next step, that dominant projection will be Merged with some syntactic sister into the larger phrase structure; for concreteness, we assume here that it Merges with the final tonic. This constituent, headed by the final tonic, then undergoes some number of additional Merge operations, joining it to whatever material precedes the cadential dominant projection. Before the cadential dominant chord has undergone whatever operation allows it to value the [ton] featue of the final tonic, we will have a structure along the lines of (6).

(6) Pre-feature-checking structure

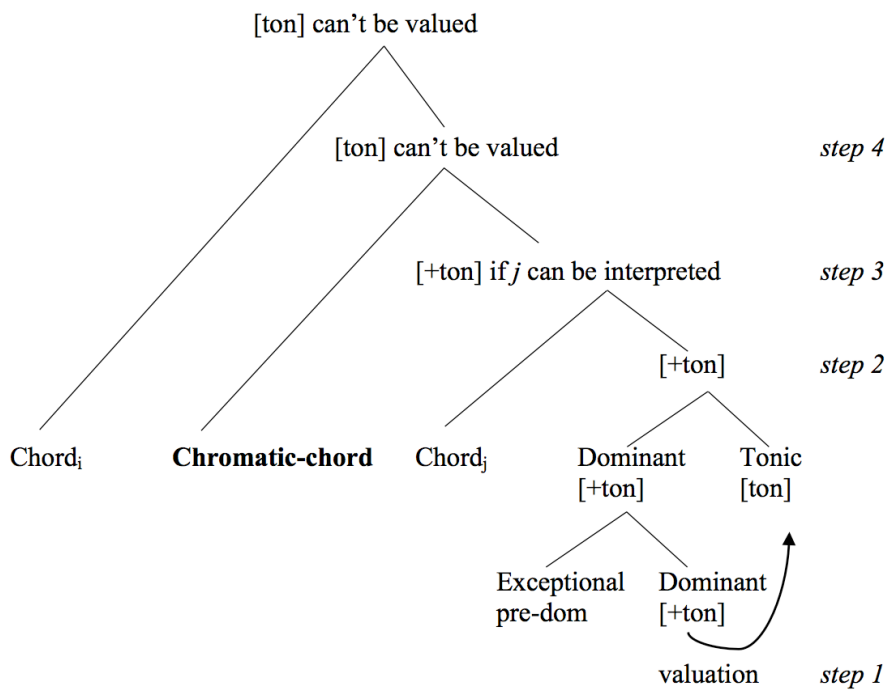


In the next step, the cadential dominant chord values the [ton] feature of the tonic head, and that valuation percolates up through all projections of the tonic head. I propose that the interpretation function fed by syntactic structure imposes the following condition at this point (but crucially not at the earlier stage where structure is being built):

(7) In a structure containing $A_{[+ton]}$ and *B*, [+ton] may be copied to the node that dominates {A, B} just in case both *A* and *B* are consistent with the key of [*ton*].

So in order to value the [ton] feature of the final tonic, it must be the case that the dominant is the dominant *of the same key* that the tonic is tonic of. In order for the [+ton] value to be copied up to the projection that dominates chord *j* in (6), it must be the case that chord *j* consists of pitch-classes licensed by the tonic's key, and so on. It should be clear, then, that any harmonic events in such a structure outside the projection of the final dominant (chords *i* and *j* in this example) must be licensed by the key of the entire piece, or by some other occurrence of [+ton]. Otherwise, the [+ton] feature will fail to project, a key domain will fail to be established, and the interpretation function will be unable to assign an interpretation to one or more events in the syntactic structure. This is illustrated schematically in (8), which is similar to (6) but with an unlicensed chromatic chord intervening between *i* and *j*:

(8) Failure of tonic-marking and key-domain establishment



The remaining issue is how the dependents of the dominant are exempt from this logic. The idea is that, because the [ton] feature in this projection enters the derivation already valued, and that value is copied to higher projections through Merge and labeling rather than the interpretation function, the condition in (7) doesn't need to be satisfied. There is still a second constraint from the interpretation function that *does* need to be satisfied, namely the constraint on voice-leading:

(9) If *A* and *B* are syntactic sisters and *A* linearly precedes *B*, then *A* must contain two pitch-classes that can resolve to the root of *B* by step.

Finally, the interpretation function imposes the principle of Full Interpretation on every object in the tree. In the current approach, the statement of this principle involves only the [ton] feature:

(10) Every terminal element must be immediately dominated by an instance of [+ton].

In this way, every terminal element in the trees in (6) and (8) is subject to the conditions in (9) and (10). Chords that do not form part of the cadential dominant projection are additionally subject to condition (7). The structure in (8) fails because [+ton] can't project past the chromatic chord due to principle (7) and Full Interpretation, as stated in (10), is violated. Dependents of the cadential dominant, on the other hand, are always dominated by an instance of [+ton] because that valued feature is present during Merge, as in (6).[6] This means that they trivially satisfy Full Interpretation, and while they are still subject to the voice-leading principle in (9), the pitch-collection principle in (7) is entirely irrelevant. Hence, for dependents of cadential dominants, any well-formed voice-leading progression is licensed, regardless of whether the pitch-classes in question are drawn from the local diatonic collection. Finally, this proposal relates the general phenomenon of cadence to the exceptional cadential chords discussed here: both the attraction of a cadential dominant to a final tonic and the lack of key constraints on a cadential dominant's dependents result from the fact that it enters the syntax valued as [+ton].

I end by noting one further issue: an anonynous reviewer notes that there is an intuition that exceptional pre-dominant chords tonicize the dominant in much the way that the dominant does the tonic. As far as I can tell, there is no reason why an exceptional pre-dominant can't also be Merged with [+ton] valuation, as long as its sister dominant can be interpreted as local tonic within its projection. So I believe this intuition can be accommodated in the current approach.

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[6] It is less clear that they are always *immediately* dominated by [+ton]. The principle in (10) was revised to refer to immediate dominance in response to an astute observation by Yoshi Kitagawa about erroneous licensing of chromatic material in non-cadential contexts. But it is possible that this revised version will create difficulties with some complex cadential projections where chromatic chords *are* licensed. I leave this as an open problem.