BOOK REVIEWS

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Asymptotic analysis. A distributional approach, by Ricardo Estrada and Ram P. Kanwal, Birkhäuser, Basel and Boston, MA, 1994, ix + 258 pp., \$49.50, ISBN 0-8176-3716-8

1.

The use of asymptotic expansions is an old and well established tool of mathematical analysis which, nevertheless, is still vigorously developing, with many new applications. It is actually not correct to talk about a "tool", in fact, each individual asymptotic expansion may require a separate derivation even though there are quite a few general techniques. Thus, the label "Asymptotic Analysis" refers to a large toolbox in which the tools were forged to deal with special and rather diverse analytic questions and, consequently, are quite different, in spite of their common purpose.

Probably the oldest among all these individual expansions which was known to diverge in general is the so-called Euler-Maclaurin sum formula, discovered by Euler in 1732 and, independently, by Maclaurin around the same time. If f is in $C^{2k+1}[N,M]$ for $N, M \in \mathbb{N}$, then this formula reads

$$\begin{aligned}\sum_{i=N}^{M} f(i) = \int\limits_N^M f(x)\,dx + \frac{1}{2}(f(N)+f(M)) \\ + \sum_{j=1}^{2k} \frac{B_{2j}}{(2j)!}\left(f^{(2j-1)}(M) - f^{(2j-1)}(N)\right) \\ + \frac{1}{(2k+1)!}\int_N^M B_{2k+1}(x-[x])\, f^{(2k+1)}(x)\,dx,\end{aligned} \tag{1}$$

where $B_j(x)$ and $B_j = B_j(0) = (-1)^j B_j(1)$ denote the Bernoulli polynomial and the Bernoulli number of index j, respectively. Regarding the last term of the right hand side as a "remainder", we can view (1) as a discrete approximation of $\int_N^M f(x)\,dx$ or its comparison with a special Riemann sum. If we use in (1) e.g.

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$f(x) = \log x$ and $N = 1$, then we obtain with an easy remainder estimate

$$\begin{aligned}\log M! &= (M + 1/2)\log M - M + C_0(k) + \sum_{j=1}^{k} \frac{B_{2j}}{2j(2j-1)} M^{1-2j} \\ &\quad + O_k(M^{-2k}). \qquad (2)\end{aligned}$$

This is now an *asymptotic expansion* of the left hand side in terms of the system of functions $(x^{1-i}\log^j x)_{\substack{i\geq 0\\ 0\leq j\leq 1}}$ as $x \to \infty$ (through integers) in the sense that we have found a family of numbers, $(a_{ij})_{\substack{i\geq 0\\ 0\leq j\leq 1}}$, such that

$$\log M! = \sum_{\substack{0\leq i\leq k\\ 0\leq j\leq 1}} a_{ij}\, M^{1-i} \log^j M + R_k(M), \tag{3a}$$

and the remainder is smaller than the smallest term in the sum:

$$|R_k(M)| \leq C_k M^{-k}, \quad M \geq 1,\ k \geq 0. \tag{3b}$$

It should be remarked that the precise meaning of "asymptotic" as expressed in (3a, 3b) was established by Poincaré only in 1886, the official birth date of Asymptotic Analysis.

The most important conclusion we can draw from these facts is that the numbers a_{ij} are uniquely determined by the conditions (3). Hence the constant $C_0(k)$ in (4) must be independent of k; a little trick using Wallis' formula reveals that

$$C_0 = C_0(k) = \frac{1}{2}\log 2\pi.$$

This argument establishes Stirling's formula and, in fact, is easily expanded to give the asymptotic expansion of the Γ-function.

Of course, the expansion (3a) or its obvious counterpart for $x \to \infty$ (or $x \to 0+$) through real values may actually converge as it happens for the familiar Taylor and Laurent expansions in the analytic case. But the interesting fact is that even a divergent series representation may carry valuable numerical information. Thus, a second aspect of interest consists in the computational accuracy we may be able to obtain in spite of the possible divergence of the series (3a). For example, the function

$$f_\alpha(x) = \int_0^\infty \frac{e^{-u}}{x + \alpha u}\, du\,, \quad \alpha, x > 0,$$

exhibits, upon integration by parts, the representation

$$f_\alpha(x) = \sum_{j=1}^{n} (-1)^{j-1} \frac{(j-1)!}{x^j} + (-1)^n n! \int_0^\infty \frac{e^{-u}}{(x+\alpha u)^{n+1}}\, du, \tag{4}$$

and, as $x \to \infty$, we obtain readily the remainder estimate analogous to (3b). In this situation, we write

$$f_\alpha(x) \underset{x\to\infty}{\sim} \sum_{j\geq 1} (-1)^{j-1} \frac{(j-1)!}{x^j}. \tag{5}$$

The series (5) is divergent for every positive x, hence does not allow us to compute $f_\alpha(x)$ with arbitrary exactness; but in view of the remainder estimate in (5) we can e.g. compute $f_1(1000)$ with an error less than 10^{-10} from only three terms in the series. This is, obviously, of great practical value, so asymptotic expansions have been widely used to establish numerical tables of the special functions. We note in passing that the series (5) is independent of α; thus, whereas the expansion coefficients are uniquely determined by the function, the function is not at all determined by the coefficients.

In many cases of great analytic interest a full asymptotic expansion does not exist or cannot be established with existing techniques. Then information of importance is simply the order of magnitude of the first few coefficients. Consider, for example, a bounded domain $\Omega \subset \mathbb{R}^m$ with nice boundary $\partial\Omega$, and introduce the function

$$L_\Omega(t) := \#(t\Omega \cap \mathbb{Z}^m), \quad t \geq 1,$$

the number of lattice points in Ω after stretching with the factor t. An easy application of the Poisson summation formula shows that

$$L_\Omega(t) \underset{t\to\infty}{\sim} t^m \operatorname{vol}\Omega, \tag{6}$$

in the sense that the quotient of both sides converges to 1 as $t \to \infty$, a geometrically plausible result. Then we may ask whether we can actually obtain a full asymptotic expansion for L_Ω in powers of t and $\log t$ - but it turns out to be already extremely difficult just to determine the correct order of the next term (cf. e.g. [Wal])!

Problems of this type are quite frequent in number theory. To take an example from Mathematical Physics, we consider Ω as above and the self-adjoint operator Δ_D, determined in $L^2(\Omega)$ by the Dirichlet problem for the Laplacian on functions in Ω. The spectrum of this operator consists entirely of eigenvalues with finite multiplicity, accumulating only at ∞. Counting them with multiplicity, we can introduce the spectral counting function

$$N_D(\Omega; \lambda) = \#\{\mu \in \operatorname{spec}\Delta_D \mid \mu \leq \lambda\}, \tag{7}$$

and we may again ask for its asymptotic behavior. A celebrated result of Hermann Weyl [W] asserts that

$$N_D(\Omega; \lambda) \underset{\lambda\to\infty}{\sim} \frac{\operatorname{vol}\Omega}{(4\pi)^{m/2}\Gamma(m/2+1)}\,\lambda^{m/2}. \tag{8}$$

In this case it is actually known that, in general, no asymptotic expansion can exist with more than two terms due to the heavy oscillations of the remainder term in general. Weyl proved his result in 1911 using the variational properties of the eigenvalues, thus establishing a conjecture of the physicist H. A. Lorentz. But it took more than 40 years until, in 1952, Avakumović [A] and Levitan [L] independently came up with the first sharp remainder estimate. Their result implied that on a closed Riemannian manifold M of dimension m, for the Laplacian on functions Δ_M, we have

$$\left| N_M(\lambda) - \frac{\operatorname{vol} M}{(4\pi)^{m/2}\Gamma(m/2+1)}\,\lambda^{m/2} \right| \leq C\lambda^{(m-1)/2} \tag{9}$$

(here we can drop the index "D", since on a closed manifold we do not encounter boundary conditions). The question remained whether the analogue of (9) holds for N_D, too. This was answered in the affirmative another 25 years later by Seeley [S] and Pham The Lai [Ph]. Since Avakumović had already pointed out that the remainder estimate cannot be replaced, in general, by a two-term asymptotic of the form

$$\left| N_D(\Omega;\lambda) - C_m(\Omega)\lambda^{m/2} - C_{m-1,D}\,(\Omega)\lambda^{(m-1)/2} \right| = o(\lambda^{(m-1)/2}), \tag{10}$$

the asymptotic analysis seemed complete. But in 1980, building on important work by Hörmander [H] and Duistermaat and Guillemin [DG], Ivrii [I] proved that (10) can, nevertheless, be established if we require a certain regularity property for Ω, expressed in terms of its "billiard map", i.e. the flow along straight lines reflected in the boundary. This fairly difficult problem in Asymptotic Analysis illustrates another very important fact, namely that the existence of a full asymptotic expansion for a given function requires and reflects a certain smoothness. To take another example, "smoothing out" N_M using the Laplace transform, we obtain

$$\theta_M(t) := \int_0^\infty e^{-t\lambda} dN_M(\lambda), \tag{11}$$

and we can, in fact, obtain a full asymptotic expansion for this function of the form

$$\theta_M(t) \underset{t\to 0+}{\sim} \sum_{j\geq 0} a_j t^{j-m/2}. \tag{12}$$

It is easy to see that

$$a_0 = (4\pi)^{-m/2}\operatorname{vol} M. \tag{13}$$

This together with a well known Tauberian theorem gives the analogue of (8) in this case (but no useful remainder estimates). The proof of (12) is based on the trace relation

$$\theta_M(t) = \operatorname{tr}_{L^2(M)}\, e^{-t\Delta_M}$$

and a fundamental idea of Hadamard [Ha] to solve the heat equation associated with the semigroup $e^{-t\Delta_M}$.

This brings us to the fourth aspect of asymptotic expansions we want to mention: the coefficients of the expansions can be viewed as "generalized coordinates" for the situation at hand. Whereas this statement has little content e.g. for the expansion (4), it becomes powerful in the situation (12). Namely, a careful execution of Hadamard's analysis on compact Riemannian manifolds (as carried out in a fundamental paper by Minakshisundaram and Pleijel [MPl]) shows that the a_j are integrals of certain functions u_j:

$$a_j = \int_M u_j(p)\, d\operatorname{vol}_M(p). \tag{14}$$

In a normal coordinate system centered at $p \in M$, $u_j(p)$ is given by an $O(m)$ - invariant polynomial in the components of the curvature tensor and its covariant derivatives at p [McKS], which fostered the hope that knowing the spectrum of Δ_M - and hence the a_j - would imply more or less knowledge of the isometry class of M. This is, unfortunately, not true; i.e. "isospectrality does not imply isometry" (cf. for this the exhaustive surveys in [BeGaMa], [Ber]). It is, however, not yet clear how exceptional these nonisometric isospectral metrics are; one feels that, generically, the (nontrivial) isospectral set ought to be empty (for some positive results in small dimensions cf. [OPS]).

The situation becomes different if we ask different and less detailed questions. For example, if we allow certain singularities for Riemannian metrics on a smooth compact manifold such that the spectral analysis still makes sense, then we may ask whether the singular nature of any given metric is detectable from its spectrum. In the case of algebraic curves embedded in some complex projective space - which can be viewed as closed Riemann surfaces with singular metrics via normalization - this is in fact so, cf. [BL], and one wonders to what extent this statement carries over to algebraic varieties.

This short tour d' horizon in Asymptotic Analysis - which could easily be enriched with many more examples of current interest from Number Theory, Global Analysis, or Mathematical Physics - may illustrate the usefulness and ubiquity of asymptotic expansions in Analysis: such an expansion determines the order of growth of the function in question through a hierarchy of comparison functions; it provides a possibly valuable numerical approximation and a set of possibly interesting coefficients. We also want to emphasize the main analytic difficulty involved in establishing any particular asymptotic expansion: it is always the remainder estimate. In the extremely important case of a smooth function f near $x_0 \in \mathbb{R}$ we have a very explicit and beautiful form of the remainder in Taylor's formula:

(15)

$$f(x) = \sum_{j=0}^{n} \frac{f^{(j)}(x_0)}{j!}\,(x-x_0)^j + \frac{(x-x_0)^{n+1}}{n!}\int_0^1 (1-t)^n f^{(n+1)}(x_0 + t(x-x_0))dt.$$

In general, as in the derivation of (1), the whole effort has to concentrate on writing the remainder term in a tractable form.

2.

It is clear from what we have said before that writing a book on Asymptotic Analysis is not an easy task. It seems hopeless to present systematic derivations of only the most important asymptotic expansions used in Analysis, Geometry, and Mathematical Physics; the goal has to be much more modest. A natural aim for a useful book of reasonable length could be an introduction to the subject at the level of a graduate course; this has been reached reasonably well in [Je] and [Mu]. The other possibility is to restrict attention to a special class of applications like ordinary differential equations [Wa] or special functions [Ol]. Of course, the selection of the material will always reflect the taste and the research work of the author(s).

The book under review appears to be a mixture of the two possibilities: it starts out as a general introduction to the subject and ends up with some rather special (though interesting) applications. The first chapter gives an introduction to some "classical" asymptotic expansions like (1) and some of their applications, in the spirit of [WhWat] but, naturally, much more cursory. Also, the basic calculus of asymptotic expansions is introduced with a special emphasis on asymptotic power series. Here one could have mentioned their essential application in the solution of singular differential equations, certainly helpful and educational in a graduate course.

The second chapter preludes to the unifying idea of the book: the distributional interpretation and derivation of asymptotic expansions. The chapter is intended to provide a reasonably self-contained introduction to the general theory of distributions in $\mathbb{R}^m$, together with quite a few (useful) examples. But here is certainly not the place to meet distributions for the first time, and a solid background in analysis and functional analysis seems necessary for a fruitful reading. In addition, proofs are usually sketchy, and likewise the calculations. To some extent, this can be seen as a good compensation for the lack of exercises, but many facts which are stated without proof or reference have to be believed or researched in the literature.

Special emphasis is given to regularization techniques. Here, I would have liked the authors to explain the connection between the various methods, e.g. the analytic continuation and the finite part method which have to be related in many applications. Another complaint with this approach is the downplay of the importance of remainder estimates: they are hidden in the seminorms defining the appropriate spaces of distributions (as in Sections 2.9 and 2.10). As a matter of fact, the Taylor remainder term (15) does not occur explicitly anywhere in this book.

The heart of the matter is developed in Chapter 3. The prototypical result for practically all other applications is the so-called *moment asymptotic expansion*: if $f \in \mathcal{E}'(\mathbb{R})$ (the space of distributions with compact support), then we can expand the dilated distribution f_λ (with $f_\lambda(x) = f(\lambda x)$ for functions and $f_\lambda(\phi) = \lambda^{-1} f(\phi_{1/\lambda})$) as

$$f_\lambda \sim \sum_{j=0}^{\infty} (-1)^j \, \frac{\mu_j(f)}{j!} \, \delta_0^{(j)} \lambda^{-j-1}, \tag{16}$$

where

$$\mu_j(f) := f(x^j) \tag{17}$$

is the jth moment of f and δ_0 the Dirac measure at 0. The precise meaning of (16) is that for any $\phi \in C_0^\infty(\mathbb{R})$ and $n \in \mathbb{Z}_+$ there is an estimate

$$\left| \left(f_\lambda - \sum_{j=0}^{n} (-1)^j \, \frac{\mu_j(f)}{j!} \, \delta_0^{(j)} \lambda^{-j-1} \right) (\phi) \right| \leq C_{n,\phi} \lambda^{-n-2}. \tag{18}$$

As a typical application, we get an asymptotic expansion for series of the type

$$\sum_{j=0}^{\infty} \alpha_j \, \phi(\lambda^{-1} j) \tag{19}$$

in applying (18) to

$$f = \sum_{j \geq 0} \alpha_j \delta_j. \tag{20}$$

Series of type (19) have been considered by Ramanujan, and their analysis has important applications to number theory; this is explained in more detail in Chapter 5. The crux of the argument is to extend the fairly obvious expansion (18) to spaces of distributions other than $\mathcal{D}'(\mathbb{R})$ (or equivalently, to establish more general remainder estimates) in order to include given examples of e.g. the type (20).

Besides, the third chapter displays other familiar methods as well as particular examples of Asymptotis Analysis which can be subsumed under the above scheme, like “Laplace’s method” or the “method of steepest descent”, introducing along the way many well known and sometimes not so well known asymptotic expansions from classical Analysis. The body of material presented in this chapter is certainly extremely useful, and the distributional point of view developed convinces by its unifying potential. But it comes as a surprise that the *method of stationary phase* - in spite of its kinship with Laplace's method - is not mentioned, nor its great importance in Geometry and Global Analysis.

The fourth chapter expands the methods centering around the moment expansion to the multidimensional case. The procedure is essentially familiar by now, but the fun comes with more examples. This time, they touch also upon applications to partial differential equations and problems in Mathematical Physics, unfortunately, without describing much of the impact of the expansion derived on each particular problem. Filling in the details also becomes a more challenging but certainly very fruitful job for the motivated reader.

Chapter 5 deals, as already indicated, with the moment expansion applied to distributions of the type (20). Here occurs the problem that, in general, we cannot expect the moments to exist unless the sequence (α_j) has rapid decay. For example, if $\alpha_0 = 0$, $\alpha_j = 1$ for all $j \geq 1$, and hence

$$f = \sum_{j \geq 1} \delta_j,$$

then we use (1) to write, for $\phi \in \mathcal{D}(\mathbb{R})$ and $M = M(\phi)$ large,

$$\begin{aligned} f(\phi) &= \sum_{i=1}^{M} \phi(i) = \int_0^\infty \phi(x)dx - \frac{1}{2}\phi(o) - \sum_{j=1}^{2k} \frac{B_{2j}}{(2j)!}\, \phi^{(2j-1)}(o) \\ &\quad + \frac{1}{(2k+1)!} \int_0^M B_{2k+1}(x-[x])\, \phi^{(2k+1)}(x)dx. \end{aligned}$$

But this implies that

$$f =: H + f_1$$

where H is the Heaviside function and f_1 can be extended to test functions whose derivations decay suitably (e.g. elements of $\mathcal{K}(\mathbb{R}^m)$ as introduced on p. 81). In particular, we can compute the moments of f_1 as

$$f_1(x^l) = \zeta(-l),$$

ζ the Riemann Zeta function. But this argument depends on the special structure of f. In general, the authors call the sequence (α_j) *distributionally small* if f (given by (20)) possesses a moment asymptotic expansion in the sense of (16). This turns out to be a fruitful definition because, for such distributions, the "moment function"

$$\mu(\alpha) := \sum_{j \geq 1} \alpha_j j^\alpha \tag{21}$$

exists in the sense of Cesaro summability and represents an entire function. In fact, distributional smallness is equivalent to the Cesaro summability of all moments. Throughout the chapter, the idea is tested on a variety of interesting sequences, among them many old friends from number theory.

The last chapter of the book is concerned with series of delta functions, i.e. series of the type

$$\sum_{j\geq 0} \alpha_j \, \delta_0^{(j)}, \tag{22}$$

which figure asymptotically in the moment expansion. These series cannot converge in $\mathcal{D}'(\mathbb{R})$ unless $\alpha_j = 0$ for all but a finite number of j's, but certain formal manipulations are possible. The authors select a few topics where such series are formally useful; the connection is again often through the moment expansion.

In summary, the book under review contains lots of interesting and nontrivial examples from classical Analysis, so everybody interested in deeper aspects of the field will benefit from browsing through it. The title is, however, somewhat misleading since one does not find, after all, an introduction to the field of modern Asymptotic Analysis in any wider sense. Problems and applications in Geometry or Physics are hardly mentioned even though they are intensely studied today and sometimes by methods very closely related to the contents of the book. To mention just one example we go back to the source of the moment expansion, i.e. an integral

$$\int_0^\infty f(\lambda x)\phi(x)dx =: F(\lambda),$$

where $\phi \in \mathcal{D}(\mathbb{R})$ and f is a function. If f is controlled by suitable asymptotic expansions as $x \to 0+$ and $x \to \infty$, then F has an asymptotic expansion as $\lambda \to \infty$, too,

$$F(\lambda) \underset{\lambda\to\infty}{\sim} \sum_{\substack{\Re\alpha\to-\infty \\ 0\leq k\leq k(\alpha)}} F_{\alpha k} \, \lambda^\alpha \log^k \lambda.$$

This is a special case of the Singular Asymptotics Lemma proved in [BS]. Such expansions have proved to be very important in the spectral analysis of elliptic operators on singular spaces.

But the methods chosen, in particular the moment asymptotic expansion, and the authors' own work dictate the selection of the material. This is fully justified for a research monograph, but it surely limits the usefulness of this book for the reader with general interests. Another considerable obstacle for the user is the huge number of misprints. Usually, they are not difficult to correct, but the wrong page numbers in the table of contents (for Chapters 4, 5, and 6) are a nuisance.

Thus, there seems room for improvement, but for what material Estrada and Kanwal treat, the book is a useful addition to the department library.

References

[A] V. G. Avakumović: *Über die Eigenfunktionen auf geschlossenen Riemannschen Mannigfaltigkeiten.* Math. Z. **65** (1956), 327-394. MR **18:**316a

[Ber] P. Bérard: *Spectral geometry: direct and inverse problems.* Lecture Notes in Mathematics **1207**. Springer: Heidelberg 1986. MR **88f:**58146

[BeGaMa] M. Berger, P. Gauduchon, and E. Mazet, *Le spectre d'une variété Riemannienne.* Lecture Notes in Mathematics **194**. Springer: Heidelberg 1971. MR **43:**8025

[BL] J. Brüning and M. Lesch: *On the spectral geometry of algebraic curves.* J. reine angewandte Math. **474** (1996), 25-66. MR **97d:**58193

[BS] J. Brüning and R. T. Seeley: *Regular singular asymptotics.* Adv. Math. **58** (1985), 133-148. MR **87b:**41032

[DG] H. Duistermaat and V. Guillemin: *The spectrum of positive elliptic operators and periodic bicharacteristics.* Inventiones math. **29** (1975), 39-79.

[H] L. Hörmander: *The spectral function of an elliptic operator.* Acta Math. **121** (1968), 193-218. MR **58:**29418

[Ha] J. Hadamard: *Lectures on Cauchy's problem in linear partial differential equations.* Dover Publ.: New York 1952.

[I] V. Ya. Ivrii: *Second term of the spectral asymptotic expansion of the Laplace-Beltrami operator on manifolds with boundary.* Functional Analysis Appl. **14** (1980), 98-106. MR **82m:**58057

[Je] H. Jeffreys: *Asymptotic approximations.* Clarendon Press; Oxford 1962. MR **26:**5334

[L] B. M. Levitan: *On the asymptotic behavior of the spectral function of a self-adjoint differential equation of second order.* Izv. Akad. Nauk SSR ser. Mat. **16** (1952), 325-352. MR **15:**315e

[McKS] H. P. Mckean and I. M. Singer: *Curvature and the eigenvalues of the Laplacian.* J. Diff. Geom. **1** (1967), 43-69. MR **36:**828

[MPl] S. Minakshisundaram and Å. Pleijel: *Some properties of the eigenfunctions of the Laplace-operator on Riemannian manifolds.* Canadian J. Math. **1** (1949), 242-256. MR **11:**108b

[Mu] J. D. Murray: *Asymptotic Analysis.* Springer: Heidelberg 1984. MR **85m:**34085

[Ol] F. W. J. Olver: *Asymptotics and special functions.* Academic Press: New York 1974. MR **55:**8655

[OPS] B. Osgood, R. Phillips, and P. Sarnak: *Compact isospectral sets of surfaces.* J. Funct. Analysis **80** (1988), 212-234. MR **90d:**58160

[Ph] Pham The Lai: *Meilleures estimations asymptotiques des restes de la fonction spectrale et des valeurs propres relatifs au laplacien.* Math. Scand. **48** (1981), 5-38. MR **83b:**35127a

[S] R. T. Seeley: *An estimate near the boundary for the spectral function of the Laplace operator.* Am. J. Math. **102** (1980), 869-902. MR **82k:**58097

[W] H. Weyl: *Das asymptotische Verteilungsgesetz der Eigenwerte linearer partieller Differentialgleichungen (mit einer Anwendung auf die Theorie der Hohlraumstrahlung).* Math. Ann. **71** (1912), 441-479.

[Wa] W. Wasow: *Asymptotic expansions for ordinary differential equations.* John Wiley: New York 1965. MR **34:**3041

[Wal] A. Walfisz: *Gitterpunkte in mehrdimensionalen Kugeln.* Monografie Matematyczne **33**. Warschau 1957. MR **20:**3826

[WhWat] E. T. Whittacker and G. N. Watson: *A course of modern analysis.* Cambridge University Press: Cambridge 1965. MR **31:**2375

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