

COMPOSITION OPERATORS AND THE CLOSURE OF DIRICHLET–MORREY SPACES IN THE BLOCH SPACE

MAO XIAO, JUNMING LIU* AND YUTIAN WU

Abstract. In this paper, we characterize the closure of the Dirichlet–Morrey spaces in the Bloch space by higher-order derivatives. Moreover, the boundedness and compactness of the products of composition and differentiation operators from the Bloch space to the closure of the Dirichlet–Morrey spaces in the Bloch space are investigated. A criterion for an interpolating Blaschke product to be in the closures is given.

Mathematics subject classification (2020): 47B33, 30H30.

Keywords and phrases: Composition operators, Dirichlet–Morrey spaces, Bloch space, closure.

REFERENCES

- [1] J. ANDERSON, J. CLUNIE, CH. POMMERENKE, *On Bloch functions and normal functions*, J. Reine Angew. Math. 270 (1974) 12–37.
- [2] R. AULASKARI, R. ZHAO, *Composition operators and closures of some Möbius invariant spaces in the Bloch space*, Math. Scand. 107 (2010) 139–149.
- [3] G. BAO, N. GÖÇÜŞ, *On the closures of dirichlet type spaces in the bloch space*, Complex Analysis and Operator Theory, vol. 13, no. 1, pp. 45–59, 2019.
- [4] G. BAO, Z. LOU, X. ZHOU, *Closure in the logarithmic Bloch norm of Dirichlet type spaces*, Complex Anal. Oper. Theory 15 (2021), no. 4, Paper No. 74, 16 pp.
- [5] G. BAO, J. PAU, *Boundary multipliers of a family of Möbius invariant function spaces*, Ann. Acad. Sci. Fenn. Math. 41 (2016), no. 1, 199–220.
- [6] L. CARLESON, *An interpolation problem for bounded analytic functions*, Amer. J. Math. 80 (1958), 921–930.
- [7] P. DUREN, *Theory of H^p spaces*, Pure and Applied Mathematics, vol. 38 Academic Press, New York–London 1970, 258 p.
- [8] J. GARNETT, *Bounded analytic functions*, Revised first edition. Graduate Texts in Mathematics, 236, Springer, New York, 2007.
- [9] P. GALANOPOULOS, D. GIRELA, *The closure of Dirichlet spaces in the Bloch space*, Ann. Acad. Sci. Fenn. Math. 44 (2019), no. 1, 91–101.
- [10] P. GALANOPOULOS, N. MERCHÁN, A. SISKAKIS, *A family of Dirichlet–Morrey spaces*, Complex Var. Elliptic Equ. 64 (2019), no. 10, 1686–1702.
- [11] D. GIRELA, J. PELÁEZ, D. VUKOTIĆ, *Integrability of the derivative of a Blaschke product*, Proc. Edinb. Math. Soc. (2) 50 (2007), no. 3, 673–687.
- [12] N. HU, X. ZHU, *Composition operators and the closure of Morrey space in the Bloch space*, J. Funct. Spaces 2019, Art. ID 2834865, 6 pp.
- [13] P. LI, J. LIU, Z. LOU, *Integral operators on analytic Morrey spaces*, Sci. China Math. 57 (2014), no. 9, 1961–1974.
- [14] J. LIU, Z. LOU, *Carleson measure for analytic Morrey spaces*, Nonlinear Anal. 125 (2015), 423–432.
- [15] S. LI, S. STEVIĆ, *Composition followed by differentiation between Bloch type spaces*, J. Comput. Anal. Appl. 9 (2007), no. 2, 195–205.
- [16] S. LI, S. STEVIĆ, *Composition followed by differentiation between weighted Bergman spaces and Bloch type spaces*, J. Appl. Funct. Anal. 3 (2008), no. 3, 333–340.

- [17] D. LI, L. YANG, *Multipliers and closures of Besov-type spaces in the Bloch space*, *Filomat* 35 (2021), no. 2, 645–655.
- [18] N. MONREAL GALÁN, A. NICOLAU, *The closure of the Hardy space in the Bloch norm*, *Algebra I Analiz* 22 (2010) 75–81, translation in *St. Petersburg Math. J.* 22 (2011) 55–59.
- [19] J. M. ORTEGA, J. FÀBREGA, *Pointwise multipliers and corona type decomposition in BMOA*, *Annales de l'Institut Fourier*, vol. 46, no. 1, pp. 111–137, 1996.
- [20] R. QIAN, S. LI, *Composition operators and closures of Dirichlet type spaces \mathcal{D}_μ in Bloch type spaces*, *Anal. Math.* 45 (2019), no. 1, 121–132.
- [21] R. QIAN, S. LI, *Composition operators and closures of Dirichlet type spaces \mathcal{D}_α in the logarithmic Bloch space*, *Indag. Math. (N.S.)* 29 (2018), no. 5, 1432–1440.
- [22] J. RÄTTYÄ, *On some complex function spaces and classes*, *Ann. Acad. Sci. Fenn. Math. Diss.* no. 124 (2001), 73 p.
- [23] J. RÄTTYÄ, *n -th derivative characterisations, mean growth of derivatives and $F(p, q, s)$* , *Bull. Austral. Math. Soc.* 68 (2003), no. 3, 405–421.
- [24] W. RAMEY, D. ULLRICH, *Bounded mean oscillation of Bloch pull-backs*, *Mathematische Annalen*, vol. 291, no. 4, pp. 591–606, 1991.
- [25] Y. SUN, B. LIU, J. LIU, *The characterizations of distances from Bloch functions to some Möbius invariant spaces by high order derivatives*, *Filomat* 36 (2022), no. 1, 141–150.
- [26] J. XIAO, *Geometric Q_p Functions*, *Frontiers in Mathematics*, Birkhäuser, Basel, Switzerland, 2006.
- [27] K. ZHU, *Bloch type spaces of analytic functions*, *Rocky Mountain J. Math.* 23 (1993), no. 3, 1143–1177.
- [28] K. ZHU, *Operator Theory in Function Spaces*, American Mathematical Society, Providence (2007).
- [29] L. ZHANG, *Product of composition and differentiation operators and closures of weighted Bergman spaces in Bloch type spaces*, *J. Inequal. Appl.* 2019, Paper No. 310, 12 pp.
- [30] L. ZHANG, *Composition operators and closures of Dirichlet type spaces in logarithmic Bloch-type spaces*, *J. Math. Inequal.* 14 (2020), no. 4, 1123–1134.
- [31] R. ZHAO, *Distances from Bloch functions to some Möbius invariant spaces*, *Ann. Acad. Sci. Fenn. Math.* 33 (2008) 303–313.
- [32] R. ZHAO, *Essential norms of composition operators between Bloch type spaces*, *Proceedings of the American Mathematical Society*, vol. 138, no. 7, pp. 2537–2546, 2010.
- [33] X. ZHU, *Essential norm and compactness of the product of differentiation and composition operators on Bloch type spaces*, *Math. Inequal. Appl.* 19 (2016), no. 1, 325–334.
- [34] J. ZHOU, X. ZHU, *Product of differentiation and composition operators on Bloch type spaces*, *Publ. Inst. Math. (Beograd) (N.S.)* 99 (113) (2016), 295–300.