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A Spectral Dilation
Of
Some Non-Dirichlet Algebra

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Abstract. A Dirichlet algebra has always a spectral dilation for any operator representation. We don't know the examples of non-Dirichlet algebras which have spectral dilations for any operator representations. In this paper we give an example of such an algebra.

Let X be a compact Hausdorff space, let $C(X)$ be the algebra of complex-valued continuous functions on X , and let A be a uniform algebra on X . Let H be a complex Hilbert space and $L(H)$ the algebra of all bounded linear operators on H . I is the identity operator in H . An algebra homomorphism $f \rightarrow T_f$ of A in $L(H)$, which satisfies

$$T_1 = I$$

and

$$\|T_f\| \leq \|f\|$$

is called a representation of A on H . A representation $\phi \rightarrow U_\phi$ of $C(X)$ on a Hilbert space K is called a spectral dilation of the representation $f \rightarrow T_f$ of A on H if H is a Hilbert subspace of K and

$$T_f x = P U_\phi x \quad \text{for } f \in A \text{ and } x \in H$$

where P is the orthogonal projection of K on H .

If A is a Dirichlet algebra on X and $f \rightarrow T_f$ a representation of A on H , then there exists a spectral dilation. This was proved by Foias and Suciú (cf. [3, Theorem 8.7.1]). However it is unknown whether any representation of a non-Dirichlet algebra has a spectral dilation. In this paper we give an example of a uniform algebra which has a spectral dilation for any operator representation and is a subalgebra of a disc algebra, of codimension one.

If $f \rightarrow T_f$ is a representation of A on a Hilbert space H with the inner product (x,y) ($x,y \in H$), then there are measures $\mu_{x,y}$ ($x,y \in H$) such that $\|\mu_{x,y}\| \leq \|x\| \|y\|$ for $x,y \in H$ and

$$(T_f x,y) = \int f d\mu_{x,y} \quad \text{for } f \in A \text{ and } x,y \in H.$$

(see [3, p173]). Let τ be in the maximal ideal space of A and G the Gleason part of τ . We say that the representation $f \rightarrow T_f$ of A is G -continuous (G -singular) if there exists a system of finite measures $\{\mu_{x,y}\}$ such that $\mu_{x,y}$ is G -absolutely continuous (G -singular) and $(T_f x,y) = \int f d\mu_{x,y}$ for all $f \in A$ and all $x,y \in H$ (cf. [2, p182]). We need the following three lemmas to give a theorem. The first one is a theorem of Mlak [2, Theorem 2.3] and the second one is one result of Foias and Suciú (cf. [3, p173]).

Lemma 1. Let $f \rightarrow T_f$ be a representation of A on H . Then $f \rightarrow T_f$ is a unique orthogonal sum $T_f = T_f^a \oplus T_f^s$ where the representation $f \rightarrow T_f^a$ ($f \rightarrow T_f^s$) of A is G -absolutely continuous (G -singular).

Lemma 2. Let $f \rightarrow T_f$ be a representation of A on H . Then there are measures $\mu_{x,y}$ ($x,y \in H$) such that $\|\mu_{x,y}\| \leq \|x\| \|y\|$ for $x,y \in H$ and

$$((T_f + T_g^*)x, y) = \int f + \bar{g} d\mu_{x,y}$$

for $f, g \in A$ and $x, y \in H$.

A family $\lambda_{x,y}$ ($x, y \in H$) of measures on X is called semispectral if it satisfies the following properties:

$$(1) \lambda_{\alpha x + \beta y, z} = \alpha \lambda_{x, z} + \beta \lambda_{y, z},$$

$$(2) \int \phi d\lambda_{x,y} = \overline{\int \bar{\phi} d\lambda_{y,x}} \quad (\phi \in C(X)),$$

$$(3) \lambda_{x,x} \geq 0,$$

$$(4) |\lambda_{x,y}| \leq \gamma \|x\| \|y\|$$

where α and β are complex numbers, and γ is a positive number.

Now we can give an example of a uniform algebra which has a spectral dilation for any operator representation and is not a Dirichlet algebra. Let T be the unit circle and A the algebra of those continuous functions on T which have analytic extensions \tilde{f} to the interior such that $\tilde{f}(0) = f(1)$. Then A is a uniform algebra on T and T is the Shilov boundary of A . The complex homomorphism τ on A is defined by $\tau(f) = \tilde{f}(0) = f(1)$. Both $d\theta/2\pi$ and the unit point mass δ_1 at 1 represent the same linear functional τ on A . Therefore A is not a logmodular algebra and hence not a Dirichlet algebra on T (cf. [1, p38]).

Lemma 3. If μ is an annihilating measure on \mathcal{T} for $A + \bar{A}$ then $d\mu = c(d\theta/2\pi - d\delta_1)$ for some constant c .

Proof. We may assume that μ is a real measure on \mathcal{T} . If μ annihilates A then

$$\int z d\mu = \int z^2 d\mu = \int z^3 d\mu = \dots$$

because the functions $z - z^2, z^2 - z^3, z^3 - z^4, \dots$ are all in A . Hence for any positive integer n

$$\int z^n (d\mu - c_1 d\delta_1) = 0,$$

where $c_1 = \int z d\mu$. By a theorem of F. and M. Riesz (cf. [1, p45]),

$d\mu - c_1 d\delta_1 = h d\theta/2\pi$ for some h in the usual Hardy space H^1 .

The absolutely continuous part of μ with respect to $d\theta/2\pi$ is a real measure and coincides with $h d\theta/2\pi$. Since H^1 has no nonconstant real functions, h is constant. Thus $d\mu = c d\theta/2\pi + c_1 d\delta_1$ and $c = -c_1$ because $\int 1 d\mu = 0$.

Theorem. Let $f \rightarrow T_f$ be a representation of A on a Hilbert space H . There exists a spectral dilation $\phi \rightarrow U_\phi$ of $f \rightarrow T_f$.

Proof. By Lemma 1 we may assume that the representation $f \rightarrow T_f$ of A is G -continuous or G -singular, where G is the Gleason part of τ in the maximal ideal space of A . Suppose the

representation is G -continuous. By Lemma 2 there are measures $\mu_{x,y}$ ($x, y \in H$) such that $\|\mu_{x,y}\| \leq \|x\| \|y\|$ and $((T_f + T_g^*)x, y) = \int f + \bar{g} d\mu_{x,y}$ for $f, g \in A$ and $x, y \in H$. Since the representation of A is G -continuous, by the definition $\mu_{x,y}$ is absolutely continuous with respect to $d\theta/2\pi + d\delta_1$. Hence

$$d\mu_{x,y} = h_{x,y} d\theta/2\pi + c_{x,y} d\delta_1$$

where $h_{x,y}$ is in the usual Lebesgue space $L^1(d\theta/2\pi)$ and $c_{x,y}$ is constant.

Put

$$d\lambda_{x,y} = (h_{x,y} + c_{x,y}) d\theta/2\pi .$$

We shall prove that the family $\lambda_{x,y}$ ($x, y \in H$) of measures on T is semispectral, that is, it satisfies (1) ~ (4). (4) is clear.

$d\mu_{\alpha x + \beta y, z} - (\alpha d\mu_{x,z} + \beta d\mu_{y,z})$ annihilates $A + \bar{A}$. Therefore by Lemma 3 for some constant $a_{x,y,z}$

$$d\mu_{\alpha x + \beta y, z} - (\alpha d\mu_{x,z} + \beta d\mu_{y,z}) = a_{x,y,z} (d\theta/2\pi - d\delta_1),$$

consequently

$$h_{\alpha x + \beta y, z} - (\alpha h_{x,z} + \beta h_{y,z}) = a_{x,y,z}$$

and

$$c_{\alpha x + \beta y, z} - (\alpha c_{x, z} + \beta c_{y, z}) = -a_{x, y, z} .$$

This implies (1). $d\mu_{x, y} - d\bar{\mu}_{y, x}$ annihilates $A + \bar{A}$.

Therefore by Lemma 3 for some constant $b_{x, y}$

$$d\mu_{x, y} - d\bar{\mu}_{y, x} = b_{x, y} ,$$

consequently

$$h_{x, y} - \bar{h}_{y, x} = b_{x, y}$$

and

$$c_{x, y} - \bar{c}_{y, x} = -b_{x, y} .$$

This implies (2). By Proposition 7.8 in [3], if $f \in A$ and $\operatorname{Re} T_f \geq 0$ then $\operatorname{Re} T_f \geq 0$. Hence if $u \in A + \bar{A}$ and $u \geq 0$ then

$$\int u d\mu_{x, x} \geq 0 . \text{ Thus for } u \in A + \bar{A}$$

with $u \geq 0$

$$\begin{aligned} \int u d\lambda_{x, x} &= \int u (h_{x, x} + c_{x, x}) d\theta/2\pi = \int u h_{x, x} d\theta/2\pi + c_{x, x} \int u d\theta/2\pi \\ &= \int u h_{x, x} d\theta/2\pi + c_{x, x} \int u d\delta_1 = \int u d\mu_{x, x} \geq 0 \end{aligned}$$

By the Riemann-Lebesgue lemma we know that $z^n \rightarrow 0$ in the weak* topology of $L^\infty(d\theta/2\pi)$. Hence the functions z, z^2, z^3, \dots are all in the weak*-closure of A because $z^k = (z^k - z^{k-1}) + \dots$

+ $(z^n - z^{n-1}) - z^n$ for $n > k$. Therefore for $u \in C(\gamma)$ with $u \geq 0$
 $\int u d\lambda_{x,x} \geq 0$ and this implies (3).

Since the family $\lambda_{x,y}$ ($x,y \in H$) of measures on γ is semispectral, there is a positive definite map $\phi \rightarrow T'_\phi$ of $C(\gamma)$ in $L(H)$ (cf. [3, Theorem 7.11]). By a dilation theorem of Naimark (cf. [3, Theorem 7.51]), we obtain a representation $\phi \rightarrow U_\phi$ of $C(\gamma)$ on a Hilbert space K which is a spectral dilation of $\phi \rightarrow T'_\phi$. If $f \in A_0$ then $\int f d\theta/2\pi = \int f d\delta_1 = 0$ and hence

$$\begin{aligned} (T'_f x, y) &= \int f d\lambda_{x,y} = \int f h_{x,y} d\theta/2\pi \\ &= \int f d\mu_{x,y} = (T_f x, y), \quad (x, y \in H). \end{aligned}$$

Thus $T'_f = T_f$ if $f \in A$ and the representation $\phi \rightarrow U_\phi$ is the spectral dilation of $f \rightarrow T_f$.

If the representation is G -singular the family $\mu_{x,y}$ ($x,y \in H$) in the case of the proof of G -continuous is singular with respect to $d\theta/2\pi + d\delta_1$. Then Lemma 3 implies that it is semispectral immediatly.

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