A CONNECTION BETWEEN p-ADIC BANACH SPACES AND LOCALLY CONVEX COMPACTOIDS

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ABSTRACT. For a vector space $E$ over a non-archimedean valued field $K$ a correspondence $p \leftrightarrow p^0$ is established between seminorms $p$ on $E$ and compactoids $p^0$ in $E^*$. Examination of it yields the solution of two open problems (see §4 and §8) and a reformulation of Serre's renorming problem (see §2). As a by-product results on metrizable compactoids are obtained (see §6).

§0 THE CORRESPONDENCE $p \leftrightarrow p^0$.

Throughout this note $K$ is a non-archimedean valued field, complete with respect to the metric induced by the nontrivial valuation $|\cdot|$. Let $E$ be a $K$-vector space, let $E^*$ be its algebraic dual. A (non-archimedean) seminorm $p$ on $E$ is polar ([3], Definition 3.1), if

$$p = \sup \{|f| : f \in E^*, |f| \leq p\}$$

Let $P_E$ be the set of all polar seminorms on $E$. For each $p \in P_E$ we set

$$p^0 = \{f \in E^* : |f| \leq p\}$$

Then $p^0$ is an absolutely convex, edged ([3],§1b) subset of $E^*$. It is easy to see that $p^0$ is a closed compactoid ([3],§1e) with respect to the topology $\sigma(E^*,E)$, hence complete.
Let $C_E$ be the set of all closed absolutely convex, edged compactoids
in $E^*$ with respect to $c(E^*,E)$.

**Proposition 0.** The map $p \mapsto p^0$ is a bijection of $P_E$ onto $C_{E^*}$. Its inverse assigns to every $A \in C_{E^*}$ the seminorm $p$ given by

$$p(x) = \sup \{|f(x)| : f \in A\} \quad (x \in E)$$

**Proof.** We shall prove surjectivity of $p \mapsto p^0$ leaving the (easy) rest of the proof to the reader. So, let $A \in C_{E^*}$; we shall prove that $A = p^0$ where $p(x) = \sup \{|f(x)| : f \in A\}$.

Obviously, $A \subset p^0$. Now let $g \in E^* \setminus A$, we prove that $g \notin p^0$. The space $E^*$ is of countable type hence strongly polar ([3], Theorem 4.4). So by [3], Theorem 4.7, there exists a $0 \in (E^*, c(E^*,E))$' such that $|0| \leq 1$ on $A$, $|0(g)| > 1$. But, by [3], Lemma 7.1, $0$ has the form $f \mapsto f(x)$ for some $x \in E$. Thus, $|f(x)| \leq 1$ for $f \in A$, $|g(x)| > 1$ i.e., $p(x) \leq 1$ and $|g(x)| > 1$ and it follows that $g \notin p^0$.

**Remarks.**

1. Let $K$ be spherically (= maximally) complete. Then each nonarchimedean seminorm $p$ on $E$ for which $p(x) \in K$ $(x \in E)$ is polar ([3], Remark following 3.1).

2. Let $\tau$ be the locally convex topology on $E$ induced by all nonarchimedean seminorms i.e., $\tau$ is the strongest among all locally convex topologies on $E$. It is not hard to see that $(E,\tau)$ is a complete polar ([3], Definition 3.5) space and that $(E,\tau)$ and $(E^*, c(E^*,E))$ are each others strong dual spaces.
§1 NORMS \( p \) FOR WHICH \( p^0 \) IS \( c' \)-COMPACT

Recall that an absolutely convex subset \( A \) of a locally convex space \( F \) over \( K \) is \( c' \)-compact if for each neighbourhood \( U \) of 0 in \( F \) there exist \( x_1, \ldots, x_n \in A \) (rather than \( x_1, \ldots, x_n \in F \)) such that \( A \subseteq U + \text{co} \{x_1, \ldots, x_n\} \).

(Here co indicates the absolutely convex hull)

**Theorem 1.1.** For a polar seminorm \( p \) on a \( K \)-vector space \( E \) the following are equivalent.

\( (a) \) \( p(x) \in |K| \) for each \( x \in E \). Each one-dimensional subspace of \( E \) has a \( p \)-orthocomplement.

\( (b) \) \( p^0 \) is \( c' \)-compact.

**Proof.** \( (a) \Rightarrow (b) \). By \([7]\), Theorem 3.2, it suffices to prove that for each \( \phi \in (E^*, \sigma(E^*, E))^\prime \)

\[
\max \{|\phi(f)| : f \in p^0\}
\]

exists. Since \( \phi \) is an evaluation map we therefore have to show that

\[
\max \{|f(x)| : f \in p^0\}
\]

exists for each \( x \in E \). This is obviously true if \( p(x) = 0 \). So assume \( p(x) > 0 \). Since \( p(x) \in |K| \) we may assume that \( p(x) = 1 \). For such \( x \) we must prove

\[
\max \{|f(x)| : f \in p^0\} = 1
\]

By \( (a) \), \( Kx \) has a \( p \)-orthocomplement \( H \). The function

\[
f : \lambda x + h \mapsto \lambda \quad (\lambda \in K, h \in H)
\]
is in $E^*$. We have $|f(x)| = 1$. For $\lambda \in K$, $h \in H$

$$|f(\lambda x + h)| = |\lambda| = p(\lambda x) \leq \max(p(\lambda x), p(h)) = p(\lambda x + h)$$

so that $f \in p^0$.

$f) \Rightarrow (a)$. Let $x \in E$. The map $f\mapsto |f(x)|$ ($f \in E^*$)
is a continuous seminorm on $(E^*, \sigma(E^*, E))$. By $c'$-compactness its
restriction to $p^0$ has a maximum so there exists a $g \in p^0$ with $|g(x)| = p(x)$
(It follows that $p(x) \in |K|$). We prove that Ker $g$ is a $p$-orthocomplement
of $Kx$. In fact, for $z \in \text{Ker } g$ we have

$$p(x+z) \geq |g(x+z)| = |g(x)| = p(x)$$

Then also

$$p(x+z) \geq p(z)$$

completing the proof of Theorem 1.1.

Note. It is not hard to see that (a) of above is equivalent too.

$(\gamma)$ For each $x \in E$ there exists an $f \in E^*$ with $|f(x)| = p(x)$ and $|f| \leq p$.

For spherically complete $K$ we obtain a simpler form of Theorem 1.1.

**COROLLARY 1.2.** Let $K$ be spherically complete, let $p$ be a seminorm on $E$ for which $p(x) \in |K|$ for all $x \in E$.

Then the following are equivalent.

$(a) p(x) \in |K|$ for each $x \in E$.

$(\beta) p^0$ is $c'$-compact.

*Proof.* By [1], lemma 4.35, each onedimensional subspace has a $p$-orthocomplement.
§2 APPLICATION: A NEW LIGHT ON SERRE'S RENORMING PROBLEM.

Consider the following two statements (*) and (**).

(*) Let $E$ be a $K$-vector space and let $|| \cdot ||$ be a norm on $E$. Then there exists a norm $|| \cdot ||'$ on $E$, equivalent to $|| \cdot ||$, such that $||x||' \in |K|$ for all $x \in E$.

(**) Let $K$ be spherically complete and let $A$ be a complete absolutely convex compactoid in a Hausdorff locally convex space over $K$. Then there exist a $\lambda \in K$ with $|\lambda| > 1$ and a $c'$-compact $B$ such that $A \subset B \subset \lambda A$.

The question as to whether (*) is true or not is known as Serre's renorming problem. See [2] for more details. We are able to reformulate this problem in terms of compactoids:

PROPOSITION 2.1. The above statements (*) and (**) are equivalent.

Proof. Assume (*). To prove (**) we may assume that $A$ is edged. By [8], Theorem 3, $A$, as a topological module over $B(0,1) := \{ \lambda \in K : |\lambda| \leq 1 \}$, is isomorphic to a bounded submodule of $K^I$ for some set $I$. Let $E$ be the algebraic direct sum $\oplus K_i$ where $K_i = K$ for all $i \in I$.

Then $(E^*,\sigma(E^*,E))$ is in a natural way isomorphic to $K^I$ with the product topology. So we may assume that $A = p^0$ where $p$ is a seminorm on $E$.

By (*) there exists a seminorm $q$, equivalent to $p$, such that $q(x) \in |K|$ for all $x \in E$. By a suitable scalar multiplication we can arrange that, in addition, $p \leq q \leq |\lambda|p$ for some $\lambda \in K$, $|\lambda| > 1$. Then

$$p^0 \leq q^0 \leq \lambda p^0$$
and $q^0$ is $c'$-compact by Corollary 1.2. This proves (**). Now assume (**).

To prove (*) we may assume (see [2]), that $K$ is spherically complete.

Let $p$ be a norm on $E$. By (**) there is a $c'$-compact $B$ and a $\lambda \in K$, $|\lambda| > 1$
with $p^0 \subset B \subset \lambda p^0$. Then $B = q^0$ for some seminorm $q$ on $E$. We have

$$p \leq q \leq |\lambda|p$$

and $q(x) \in |K|$ for all $x \in E$ by Corollary 1.2.

**Note.** Serre's renorming problem is still unsettled as far as I know.

§3 NORMS $p$ FOR WHICH $p^0$ IS A KREIN-MILMAN COMPACTOID.

Recall that an absolutely convex subset $A$ of a locally convex space
over $K$ is a KM-compactoid if it is complete and if $A = \overline{\text{co} X}$ where $X$ is compact. (Here $\text{co} X$ is the closure of $\text{co} X$).

Before stating the theorem we first make some simple observations. Let

$p$ be a norm on $E$. We say that a collection $(e_i)$ in $E$ is a $p$-orthonormal base of $E$ if for each $x \in E$ there exist a unique $(\lambda_i)_{i \in I} \subset K^I$ such that $\{i \in I, |\lambda_i| \geq \epsilon \}$ is finite for each $\epsilon > 0$ and

$$x = \sum_{i \in I} \lambda_i e_i$$

$$p(x) = \max_{i} |\lambda_i|$$

If $(E, p)$ is complete this definition coincides with the usual one.

**Lemma 3.1.** Let $(E, p)$ be a normed space, let $(\hat{E}, \hat{p})$ be its completion. Then $(\hat{E}, \hat{p})$ has a $p$-orthonormal base if and only if $(E, p^\prime)$ has a $p^\prime$-orthonormal base.
Proof. It is not hard to see that each $p$-orthonormal base of $(E,p)$ is also a $p$-orthonormal base of $(\hat{E},p)$. Conversely, let $(e_i)_{i \in I}$ be a $p$-orthonormal base of $(\hat{E},p)$. For each $i \in I$, choose an $f_i \in E$ with $p(e_i - f_i) \leq \frac{1}{2}$.

By [1], Exercise 5.C, $(f_i)_{i \in I}$ is a $p$-orthonormal base of $(\hat{E},p)$.

Clearly $(f_i)_{i \in I}$ is a $p$-orthonormal base of $(E,p)$.

**Theorem 3.2.** For a polar norm $p$ on a K-vector space $E$ the following are equivalent.

(a) $(E,p)$ has a $p$-orthonormal base

(b) $p^0$ is a KM-compactoid.

Proof. (a) $\Rightarrow$ (b). Let $(e_i)_{i \in I}$ be a $p$-orthonormal base of $(E,p)$. The formula

$$\phi(f) = (f(e_i))_{i \in I}$$

defines a map $\phi : p^0 \to B(0,1)^I$. Straightforward verifications show that $\phi$ is an isomorphism of topological $B(0,1)$-modules. From [8], Theorem 16 we obtain that $B(0,1)^I$, hence $p^0$, is a KM-compactoid.

(b) $\Rightarrow$ (a). Suppose $p^0 = \text{co} X$ where $X$ is a compact subset of $E^*$. Let $C(X^*K)$ be the Banach space of all continuous functions $X \to K$, with the supremum norm $\|\cdot\|_\infty$. Then $C(X^*K)$ has an orthonormal base. ([1], Theorem 5.22).

The formula

$$\phi(x)(f) = f(x) \quad (f \in X)$$

defines a K-linear map $\phi : E \to C(X^*K)$. From
\[ \| \phi(x) \|_\infty = \max_{f \in X} |f(x)| = \sup_{f \in \text{co}X} |f(x)| = \sup_{f \in p} |f(x)| = p(x) \]

we obtain that \( \phi \) is an isometry \((E,p) \rightarrow (C(X^+K), \| \|_\infty)\).

By Gruson's Theorem ([1], 5.9) \( \overline{\phi(E)} \) has an orthonormal base. Then so has \( \phi(E) \) by Lemma 3.1 and has \( E \).

§4 APPLICATION: A COMPLETE \( c' \)-COMPACT SET WHICH IS NOT A KM-COMPACTOID.

We shall give a negative answer to the Problem following Theorem 1.7 of [6].

PROPOSITION 4.1. Let \( K \) be spherically complete, let \( |X| = [0,\infty) \).

Then there exist a locally convex space \( F \) over \( K \) and a complete \( c' \)-compact subset \( A \subset F \) which is not a KM-compactoid.

**Proof.** Let \( E := l^\infty \) and let \( F := (l^\infty)^* \) (with the topology we agreed upon in §0). Let \( p \) be the standard norm on \( l^\infty \), and set \( A := p^0 \). Since, trivially, \( p(x) \in |X| \) for all \( x \in l^\infty \), we have that \( p^0 \) is \( c' \)-compact (Corollary 1.2).

However, it is known ([1], Cor. 5.19) that \( l^\infty \) has no orthogonal base so that (Theorem 3.2) \( p^0 \) is not a KM-compactoid.

§5 NORMS \( p \) FOR WHICH \( p^0 \) IS METRIZABLE.

THEOREM 5.1. For a polar seminorm \( p \) on a \( K \)-vector space \( E \) the following are equivalent.

(\( \alpha \)) \((E,p)\) \ is \ of \ countable \ type \ ([3], \ Definition \ 4.3). \n
(\( \beta \)) \( p^0 \) \ is \ metrizable.
Proof. (a) \Rightarrow (b). There exist \( e_1, e_2, \ldots \) in \( E \) with \( p(e_i) \leq 1 \) for each \( i \) such that the \( K \)-linear span of \( e_1, e_2, \ldots \) is \( p \)-dense in \( E \). The formula

\[
\phi(f) = (f(e_1), f(e_2), \ldots)
\]

defines a map \( \phi : p^0 \to B(0,1)^\mathbb{N} \). Straightforward verifications show that \( \phi \) is an isomorphism of topological \( B(0,1) \)-modules of \( p^0 \) onto a submodule of \( B(0,1)^\mathbb{N} \).

Now \( B(0,1)^\mathbb{N} \) is metrizable (the product topology is induced by the metric 

\[
(a,b) \mapsto \sup_{i \in \mathbb{N}} |a_i - b_i| 2^{-i}
\]

hence so is \( p^0 \).

(b) \Rightarrow (a). Let \( \lambda \in K, |\lambda| > 1 \). Since \( p^0 \) is a metrizable compactoid there exist, by [3], Proposition 8.2, \( f_1, f_2, \ldots \in \lambda p^0 \) with \( \lim_{n \to \infty} f_n = 0 \) such that 

\[
p^0 \subset \overline{\{f_1, f_2, \ldots\}} \subset \lambda p^0
\]

The map 

\[
\phi : x \mapsto (f_1(x), f_2(x), \ldots) \quad (x \in E)
\]

is \( K \)-linear, \( \phi(E) \subset c_0 \). We have for \( x \in E \)

\[
|\phi(x)| = \sup_{n \in \mathbb{N}} |f_n(x)| = \sup \{ |g(x)| : g \in \overline{\{f_1, f_2, \ldots\}} \}
\]

It follows that 

\[
p(x) \leq ||\phi(x)|| \leq |\lambda| p(x)
\]

so that \( p \) is equivalent to \( x \mapsto ||\phi(x)|| \), a seminorm of countable type. Hence, \( p \) is of countable type.
§6 APPLICATION: DESCRIPTION OF METRIZABLE COMPACTOIDS.

THEOREM 6.1. Let $A$ be an absolutely convex subset of a Hausdorff locally convex space $F$ over $K$. The following are equivalent.

(a) $A$ is a metrizable compactoid.

(b) As a topological $B(0,1)$-module, $A$ is isomorphic to a submodule of $B(0,1)^\mathbb{N}$.

(c) As a topological $B(0,1)$-module, $A$ is isomorphic to a compactoid in $c_0$.

(d) For each $\lambda \in K$, $|\lambda| > 1$ then exist $e_1,e_2,\ldots \in \lambda A$ with $\lim_{n \to \infty} e_n = 0$ and $A \subset \overline{\text{co}} \{e_1,e_2,\ldots\}$.

(e) There exist $e_1,e_2,\ldots \in F$ with $\lim_{n \to \infty} e_n = 0$ and $A \subset \overline{\text{co}} \{e_1,e_2,\ldots\}$.

(f) There exists an ultrametrizable compact $X \subset F$ with $A \subset \overline{\text{co}} X$.

Proof. (a) $\Rightarrow$ (b). It is not hard to see, by using the absolute convexity of $A$, that $\overline{A}$ is also metrizable. As there is no harm in taking $F$ complete we therefore may assume that $A$ is complete. To prove (b) we also may assume that $A$ is edged. By [8], Theorem 3, $A \subset B(0,1)_{\mathbb{I}} \subset K_{\mathbb{I}}$ for some set $\mathbb{I}$. Like in the proof of Proposition 2.1 we may conclude that $A = p^0$ where $p$ is a polar seminorm on $\oplus_{i \in \mathbb{I}} K_i$ ($K_i = K$ for each $i$). Then $p$ is of countable type by Theorem 5.1. From the proof of (a) $\Rightarrow$ (b) of that Theorem we obtain an isomorphism $A = p^0 \cong B(0,1)^\mathbb{N}$.

(b) $\Rightarrow$ (c). Choose $\lambda_1,\lambda_2,\ldots \in K$, $|\lambda_1| > |\lambda_2| > \ldots$, $\lim_{n \to \infty} \lambda_n = 0$. The formula

$$\phi((a_i))_{i \in \mathbb{N}} = (\lambda_1 a_1, \lambda_2 a_2, \ldots) \in c_0$$

defines a $B(0,1)$-module isomorphism of $B(0,1)^\mathbb{N}$ onto $C := \overline{\text{co}} \{\lambda_1 e_1, \lambda_2 e_2, \ldots\}$ where $e_1,e_2,\ldots$ are the standard unit vectors in $c_0$. $\phi$ is a homeomorphism.
B(0,1) \to C, and maps A onto a compactoid in c_0.

(γ) ⇒ (δ). See [3], Proposition 8.2.

(δ) ⇒ (ε) is trivial.

(ε) ⇒ (η), [0,e_1,e_2,...] is compact and ultrametrizable.

(η) ⇒ (α). We may assume that F is complete. It suffices to prove the

metrizability of B := co X.

B is a complete, edged compactoid. As before we may assume that B = \alpha^0

for some polar seminorm \alpha on some K-vector space E while B \subset E^*.

The

map \phi : E \to C(X \times K) defined by

\phi(x)(f) = f(x) \quad (f \in X)

is an isometry \((E,\alpha) \cong (C(X \times K), ||||_\omega).\)

Now X is ultrametrizable so by [1], Exercise 3.5, C(X \times K) is of

countable type. Hence so is \alpha. By Theorem 5.1, B = \alpha^0 is metrizable.

§7 NORMS \alpha FOR WHICH \((\alpha^0)^*\) IS OF FINITE TYPE.

Recall that an absolutely convex set A in a locally convex space F over

K is of finite type if for each zero neighbourhood U in F there exists

a finite-dimensional bounded set S \subset A such that A \subset U + S.

Let us say that a seminorm \alpha on a K-vector space E is of finite type

if Ker \alpha = \{x \in E : \alpha(x) = 0\} has finite codimension.

LEMMA 7.1. Let A be an absolutely convex subset of a locally convex

space F whose topology is generated by a collection of seminorms of

finite type. Then the following are equivalent.

(a) A is a compactoid of finite type.

(b) For each closed linear subspace H of finite codimension there is a

finite dimensional bounded set S \subset A with A \subset H + S.
Proof. (a) $\Rightarrow$ (p). (Note. This implication holds for any locally convex space $F$.) We may assume $[A] = F$.

$H$ has the form $D^1 := \{ x \in F : f(x) = 0 \text{ for all } f \in D \}$ where $D$ is a finite dimensional subspace of $F'$. Let $f_1, \ldots, f_n$ be a base of $D$. There exist $x_1, \ldots, x_n \in F$ with $f_i(x_j) = \delta_{ij} (i, j \in \{1, \ldots, n\})$. Since $[A] = F$ there exists a $\lambda \in \mathbb{K}, \lambda \neq 0$ such that $\lambda x_i \in A$ for each $i \in \{1, \ldots, n\}$.

Set

$$U := \bigcap_{i=1}^{n} \{ x \in F : |f_i(x)| \leq |\lambda| \}$$

Then $U$ is a zero neighbourhood in $F$. $A$ is a compactoid of finite type, so there exists a finite dimensional set $S_1 \subset A$ with $A \subset U + S_1$. Let $x \in U$. Write $x = y + z$ where

$$y := x - \sum_{i=1}^{n} f_i(x) x_i$$

and

$$z := \sum_{i=1}^{n} f_i(x) x_i$$

Now, since $x \in U$, $|f_i(x)| \leq |\lambda|$ for each $i$ so that $z = \sum_{i=1}^{n} f_i(x) x_i \in A$.

Further, for each $j \in \{1, \ldots, n\}$

$$f_j(y) = f_j(x) - \sum_{i=1}^{n} f_i(x) f_j(x_i) = f_j(x) - f_j(x) = 0$$

and it follows that $y \in D^1 = H$. So $x = y + z$ $\in H + [x_1, \ldots, x_n] \cap A$. We see that

$$A \subset U + S_1 \subset H + S_2 + S_1$$

where $S_2 := [x_1, \ldots, x_n] \cap A$. Then (p) is proved with $S := S_1 + S_2$.

$(\beta) \Rightarrow (a)$. Let $U$ be a zero neighbourhood in $F$. Since continuous seminorms are of finite type, $U$ contains a closed subspace $H$ of finite codimension.

By $(\beta)$ there exists a finite dimensional set $S \subset A$ with $S$ bounded and
A ⊆ H + S. Then A ⊆ U + S.

From now on we assume that the valuation on K is dense.

Recall that for an absolutely convex set B we have $B^\perp = \bigcup_{\lambda < 1} \lambda B$.

**Theorem 7.2.** Let $p$ be a polar norm on a K-vector space $E$. Then the following are equivalent.

(a) For each finite dimensional subspace $D$ of $E$ there exists a seminorm $q$ on $E$, $q$ of finite type, $q \leq p$ and $q = p$ on $D$.

(β) $(p^0)^1$ is of finite type.

**Proof.** (α) ⇒ (β). As each continuous seminorm on $E^*$ is of finite type it suffices to prove, by Lemma 7.1, that for a closed subspace $H$ of $E^*$ of finite codimension there exists a finite dimensional set $S \in (p^0)^1$ such that $(p^0)^1 \subseteq H + S$.

Now, by (α), there is a seminorm $q$ of finite type, $q \leq p$ on $E$ and $q = p$ on $D := H^1$. Let

$$S_1 := \{ f \in E^* : |f| \leq q \}.$$  

We see that $S_1$ is finite dimensional and since $q \leq p$ we have $S_1 \subseteq p^0$.

We now shall prove that $(p^0)^1 \subseteq H + S$ where $S := (S_1)^1$.

In fact, let $f \in (p^0)^1$. Then there is a $\lambda \in K$, $0 < |\lambda| < 1$ with $|f| \leq |\lambda| p$.

Choose $\lambda' \in K$ with $|\lambda| < |\lambda'| < 1$.

We have $|f| \leq |\lambda| q$ on $D$ (since $p = q$ on $D$) so we can extend $f$ to a $g \in E^*$ with $|g| \leq |\lambda'| q$ on $E$. (This is because $q$ is of finite type so that $(E,q)$ is strongly polar.) Now write

$$f = f - g + g$$

Since $f = g$ on $D$ we have $f - g \in D^1 = H$. 

Also, \(|(\lambda')^{-1}g| \leq q\) so that \((\lambda')^{-1}g \in S_1\) i.e. \(g \in (S_1)^{1} = S\).

\[(B) \Rightarrow (a).\] By lemma 7.1 there exists a finite dimensional set \(S \subset (p_0)^1\) so that \((p_0)^1 = D^1 \cap (p_0)^1 + S.\)

Set \(q(x) := \sup_{h \in S} |h(x)|. \quad (x \in E).\)

Then \(q(x) = 0\) for all \(x\) in the space \(S^1\) which has finite codimension.

So \(q\) is of finite type.

Further, for \(x \in E\) we have

\[q(x) = \sup_{h \in S} |h(x)| = \sup_{h \in (p_0)^1} |h(x)| = \sup_{h \in p_0} |h(x)| = p(x),\]

so \(q \leq p.\) Finally, if \(x \in D\) then

\[p(x) = \sup_{f \in p} |f(x)| = \sup_{f \in (p_0)^1} |f(x)| = \sup_{h \in D \cap (p_0)^1} |h(x) + t(x)| = \sup_{t \in S} |t(x)| = q(x). \quad \text{Hence, } p = q \text{ on } D.\]

§8 APPLICATION: A COMPLETE COMPACTOID IN \(c_0\) THAT IS NOT OF FINITE TYPE.

If \(K\) is spherically complete each complete absolutely convex compactoid is of finite type (See [4], 2.3).

If \(K\) is not spherically complete the unit ball of \(c_0\) is a complete compactoid for the weak topology but not of finite type (See [5], 1.6).

This is a non-metrizable compactoid. A compactoid in \((c_0, \| \|)\), not of finite type, is given in [5], 1.4. However this compactoid is not closed. The following example provides an answer to the Problem following 1.5 in [5].
PROPOSITION 8.1. Let $K$ be not spherically complete. Then there exists an absolutely convex complete compactoid in $c_0$ that is not of finite type.

Proof. Let $(K^v, | |)$ be the spherical completion of $(K, | |)$ in the sense of [1], Theorem 4.49. Let $E$ be a $K$-subspace of $K^v$ of countably infinite dimension and let $p$ be the valuation $| |$ restricted to $E$. Then $x, y \in E$, $x \perp y$ in the sense of $p$ implies $x = 0$ or $y = 0$. Obviously, the norm $p$ is of countable type (hence polar) so, by Theorem 5.1, $p^0$ is metrizable and is by Theorem 6.1, isomorphic to a compactoid in $c_0$. Suppose $p^0$ were of finite type. Then so would $(p^0)_1$ ([5], Proposition 2.4). By Theorem 7.2 we would have a seminorm $q$ on $E$, $q \leq p$, $q$ of finite type, $q(x) = p(x)$ for some $x \in E$, $x \neq 0$. But then $x \perp \ker q$ in the sense of $p$ (If $q(y) = 0$ then $p(x-y) \geq q(x-y) = q(x) = p(x)$) which is impossible. So, $p^0$ is not of finite type.
REFERENCES


