

Weak Baire measurability of the balls in a Banach space

José Rodríguez

University of Valencia

35th Winter School in Abstract Analysis

Lhota nad Rohanovem – January 2007

$X \equiv$ Banach space

$X \equiv$ Banach space

Theorem (Edgar, 1977)

Baire(X , weak) is the σ -algebra on X generated by X^* .

$X \equiv$ Banach space

Theorem (Edgar, 1977)

Baire(X, weak) is the σ -algebra on X generated by X^* .

Baire(X, weak)

$X \equiv$ Banach space

Theorem (Edgar, 1977)

$\text{Baire}(X, \text{weak})$ is the σ -algebra on X generated by X^* .

$\text{Baire}(X, \text{weak}) \subset \text{Borel}(X, \text{weak})$

$X \equiv$ Banach space

Theorem (Edgar, 1977)

$\text{Baire}(X, \text{weak})$ is the σ -algebra on X generated by X^* .

$$\text{Baire}(X, \text{weak}) \subset \text{Borel}(X, \text{weak}) \subset \text{Borel}(X, \text{norm})$$

$X \equiv$ Banach space

Theorem (Edgar, 1977)

Baire(X , weak) is the σ -algebra on X generated by X^* .

$$\text{Baire}(X, \text{weak}) \subset \text{Borel}(X, \text{weak}) \subset \text{Borel}(X, \text{norm})$$

- In general, the inclusions are strict (Talagrand, 1978).

$X \equiv$ Banach space

Theorem (Edgar, 1977)

$\text{Baire}(X, \text{weak})$ is the σ -algebra on X generated by X^* .

$$\text{Baire}(X, \text{weak}) \subset \text{Borel}(X, \text{weak}) \subset \text{Borel}(X, \text{norm})$$

- In general, the inclusions are strict (Talagrand, 1978).
- $\text{Borel}(X, \text{weak}) = \text{Borel}(X, \text{norm})$
if X admits an equivalent **Kadec** norm (Edgar, 1977).

$X \equiv$ Banach space

Theorem (Edgar, 1977)

Baire(X , weak) is the σ -algebra on X generated by X^* .

$$\text{Baire}(X, \text{weak}) \subset \text{Borel}(X, \text{weak}) \subset \text{Borel}(X, \text{norm})$$

- In general, the inclusions are strict (Talagrand, 1978).
- $\text{Borel}(X, \text{weak}) = \text{Borel}(X, \text{norm})$
if X admits an equivalent **Kadec** norm (Edgar, 1977).
- All σ -algebras coincide if X is **separable**.

$X \equiv$ Banach space

Theorem (Edgar, 1977)

Baire(X , weak) is the σ -algebra on X generated by X^* .

$$\text{Baire}(X, \text{weak}) \subset \text{Borel}(X, \text{weak}) \subset \text{Borel}(X, \text{norm})$$

- In general, the inclusions are strict (Talagrand, 1978).
- $\text{Borel}(X, \text{weak}) = \text{Borel}(X, \text{norm})$
if X admits an equivalent **Kadec** norm (Edgar, 1977).
- All σ -algebras coincide if X is **separable**.

$\|\cdot\| \equiv$ equivalent norm on X

$\|\cdot\| \equiv$ equivalent norm on X

$$B(X, \|\cdot\|) = \{x \in X : \|x\| \leq 1\}$$

$\|\cdot\| \equiv$ equivalent norm on X

$\|\cdot\|^* \equiv$ its dual norm on X^*

$$B(X, \|\cdot\|) = \{x \in X : \|x\| \leq 1\}$$

$\|\cdot\| \equiv$ equivalent norm on X

$\|\cdot\|^* \equiv$ its dual norm on X^*

$$B(X, \|\cdot\|) = \{x \in X : \|x\| \leq 1\}$$

$B(X^*, \|\cdot\|^*)$ is weak*-separable



$(X, \|\cdot\|)$ is isometric to a subspace of $(\ell^\infty(\mathbb{N}), \|\cdot\|_\infty)$

$\|\cdot\| \equiv$ equivalent norm on X

$\|\cdot\|^* \equiv$ its dual norm on X^*

$$B(X, \|\cdot\|) = \{x \in X : \|x\| \leq 1\}$$

$B(X^*, \|\cdot\|^*)$ is weak*-separable



$(X, \|\cdot\|)$ is isometric to a subspace of $(\ell^\infty(\mathbb{N}), \|\cdot\|_\infty)$

If $B(X^*, \|\cdot\|^*)$ is weak*-separable ...

$\|\cdot\| \equiv$ equivalent norm on X

$$B(X, \|\cdot\|) = \{x \in X : \|x\| \leq 1\}$$

$\|\cdot\|^* \equiv$ its dual norm on X^*

$B(X^*, \|\cdot\|^*)$ is weak*-separable



$(X, \|\cdot\|)$ is isometric to a subspace of $(\ell^\infty(\mathbb{N}), \|\cdot\|_\infty)$

If $B(X^*, \|\cdot\|^*)$ is weak*-separable ...

Take a weak*-dense sequence $\{x_n^*\}_{n \in \mathbb{N}} \subset B(X^*, \|\cdot\|^*)$.

$\|\cdot\| \equiv$ equivalent norm on X

$\|\cdot\|^* \equiv$ its dual norm on X^*

$$B(X, \|\cdot\|) = \{x \in X : \|x\| \leq 1\}$$

$B(X^*, \|\cdot\|^*)$ is weak*-separable



$(X, \|\cdot\|)$ is isometric to a subspace of $(\ell^\infty(\mathbb{N}), \|\cdot\|_\infty)$

If $B(X^*, \|\cdot\|^*)$ is weak*-separable ...

Take a weak*-dense sequence $\{x_n^*\}_{n \in \mathbb{N}} \subset B(X^*, \|\cdot\|^*)$. Then

$$B(X, \|\cdot\|) = \bigcap_{n \in \mathbb{N}} \{x \in X : |x_n^*(x)| \leq 1\}$$

$\|\cdot\| \equiv$ equivalent norm on X

$\|\cdot\|^* \equiv$ its dual norm on X^*

$$B(X, \|\cdot\|) = \{x \in X : \|x\| \leq 1\}$$

$B(X^*, \|\cdot\|^*)$ is weak*-separable



$(X, \|\cdot\|)$ is isometric to a subspace of $(\ell^\infty(\mathbb{N}), \|\cdot\|_\infty)$

If $B(X^*, \|\cdot\|^*)$ is weak*-separable ...

Take a weak*-dense sequence $\{x_n^*\}_{n \in \mathbb{N}} \subset B(X^*, \|\cdot\|^*)$. Then

$$B(X, \|\cdot\|) = \bigcap_{n \in \mathbb{N}} \{x \in X : |x_n^*(x)| \leq 1\} \in \mathbf{Baire}(X, \text{weak}).$$

Summarizing ...

$B(X^*, \|\cdot\|^*)$ is weak*-separable

Summarizing ...

$B(X^*, \|\cdot\|^*)$ is weak*-separable



$B(X, \|\cdot\|)$ belongs to $\text{Baire}(X, \text{weak})$

Summarizing ...

$B(X^*, \|\cdot\|^*)$ is weak*-separable



$B(X, \|\cdot\|)$ belongs to $\text{Baire}(X, \text{weak})$



X^* is weak*-separable

Summarizing ...

$B(X^*, \|\cdot\|^*)$ is weak*-separable



$B(X, \|\cdot\|)$ belongs to $\text{Baire}(X, \text{weak})$



X^* is weak*-separable

Question (Okada)

What about the reverse implications ??

Summarizing ...

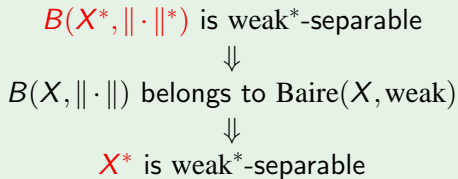
$B(X^*, \|\cdot\|^*)$ is weak*-separable
 \Downarrow
 $B(X, \|\cdot\|)$ belongs to $\text{Baire}(X, \text{weak})$
 \Downarrow
 X^* is weak*-separable

Question (Okada)

What about the reverse implications ??

Some Banach spaces admitting an equivalent norm with
non weak*-separable dual unit ball

Summarizing ...



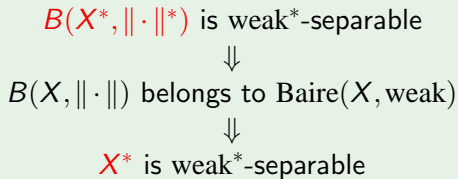
Question (Okada)

What about the reverse implications ??

Some Banach spaces admitting an equivalent norm with **non** weak*-separable dual unit ball

- Spaces failing property (C) (Granero et al., 2003),

Summarizing ...



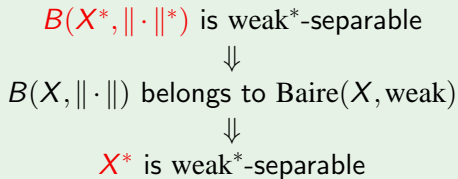
Question (Okada)

What about the reverse implications ??

Some Banach spaces admitting an equivalent norm with **non** weak*-separable dual unit ball

- Spaces failing property (C) (Granero et al., 2003), like $\ell^\infty(\mathbb{N})$.

Summarizing ...



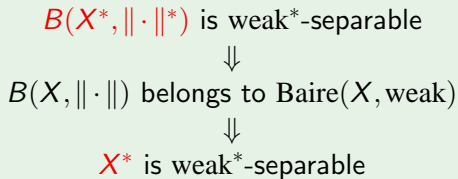
Question (Okada)

What about the reverse implications ??

Some Banach spaces admitting an equivalent norm with **non** weak*-separable dual unit ball

- Spaces failing property (C) (Granero et al., 2003), like $\ell^\infty(\mathbb{N})$.
- The spaces JL_0 and JL_2 of (Johnson-Lindenstrauss, 1974).

Summarizing ...



Question (Okada)

What about the reverse implications ??

Some Banach spaces admitting an equivalent norm with **non** weak*-separable dual unit ball

- Spaces failing property (C) (Granero et al., 2003), like $\ell^\infty(\mathbb{N})$.
- The spaces JL_0 and JL_2 of (Johnson-Lindenstrauss, 1974).

Theorem A

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$,

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$, JL_0

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$, JL_0 or JL_2 .

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$, JL_0 or JL_2 .

Then there is an equivalent norm $\|\cdot\|$ on X such that

$B(X, \|\cdot\|)$ does **not** belong to $\text{Baire}(X, \text{weak})$.

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$, JL_0 or JL_2 .

Then there is an equivalent norm $\|\cdot\|$ on X such that

$B(X, \|\cdot\|)$ does **not** belong to $\text{Baire}(X, \text{weak})$.

Example

$\ell^1(\omega_1)$ has weak*-separable dual and fails property (C),

Our results

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$, JL_0 or JL_2 .

Then there is an equivalent norm $\|\cdot\|$ on X such that

$B(X, \|\cdot\|)$ does **not** belong to $\text{Baire}(X, \text{weak})$.

Example

$\ell^1(\omega_1)$ has weak*-separable dual and fails property (C), but

$\text{Baire}(\ell^1(\omega_1), \text{weak}) = \text{Borel}(\ell^1(\omega_1), \text{norm})$ (Fremlin, 1980).

Our results

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$, JL_0 or JL_2 .

Then there is an equivalent norm $\|\cdot\|$ on X such that

$B(X, \|\cdot\|)$ does **not** belong to $\text{Baire}(X, \text{weak})$.

Example

$\ell^1(\omega_1)$ has weak*-separable dual and fails property (C), but

$\text{Baire}(\ell^1(\omega_1), \text{weak}) = \text{Borel}(\ell^1(\omega_1), \text{norm})$ (Fremlin, 1980).

Theorem B

Our results

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$, JL_0 or JL_2 .

Then there is an equivalent norm $\|\cdot\|$ on X such that

$B(X, \|\cdot\|)$ does **not** belong to $\text{Baire}(X, \text{weak})$.

Example

$\ell^1(\omega_1)$ has weak*-separable dual and fails property (C), but

$\text{Baire}(\ell^1(\omega_1), \text{weak}) = \text{Borel}(\ell^1(\omega_1), \text{norm})$ (Fremlin, 1980).

Theorem B

There is an equivalent norm $\|\cdot\|$ on $\ell^\infty(\mathbb{N})$ such that:

Our results

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$, JL_0 or JL_2 .

Then there is an equivalent norm $\|\cdot\|$ on X such that

$B(X, \|\cdot\|)$ does **not** belong to $\text{Baire}(X, \text{weak})$.

Example

$\ell^1(\omega_1)$ has weak*-separable dual and fails property (C), but

$\text{Baire}(\ell^1(\omega_1), \text{weak}) = \text{Borel}(\ell^1(\omega_1), \text{norm})$ (Fremlin, 1980).

Theorem B

There is an equivalent norm $\|\cdot\|$ on $\ell^\infty(\mathbb{N})$ such that:

- $B(\ell^\infty(\mathbb{N}), \|\cdot\|)$ belongs to $\text{Baire}(\ell^\infty(\mathbb{N}), \text{weak})$.

Our results

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$, JL_0 or JL_2 .

Then there is an equivalent norm $\|\cdot\|$ on X such that

$B(X, \|\cdot\|)$ does **not** belong to $\text{Baire}(X, \text{weak})$.

Example

$\ell^1(\omega_1)$ has weak*-separable dual and fails property (C), but

$\text{Baire}(\ell^1(\omega_1), \text{weak}) = \text{Borel}(\ell^1(\omega_1), \text{norm})$ (Fremlin, 1980).

Theorem B

There is an equivalent norm $\|\cdot\|$ on $\ell^\infty(\mathbb{N})$ such that:

- $B(\ell^\infty(\mathbb{N}), \|\cdot\|)$ belongs to $\text{Baire}(\ell^\infty(\mathbb{N}), \text{weak})$.
- $B(\ell^\infty(\mathbb{N})^*, \|\cdot\|^*)$ is not weak*-separable.

Theorem A

Let X be either $\ell^\infty(\mathbb{N})$, JL_0 or JL_2 .

Then there is an equivalent norm $\|\cdot\|$ on X such that

$B(X, \|\cdot\|)$ does **not** belong to $\text{Baire}(X, \text{weak})$.

Example

$\ell^1(\omega_1)$ has weak*-separable dual and fails property (C), but

$\text{Baire}(\ell^1(\omega_1), \text{weak}) = \text{Borel}(\ell^1(\omega_1), \text{norm})$ (Fremlin, 1980).

Theorem B

There is an equivalent norm $\|\cdot\|$ on $\ell^\infty(\mathbb{N})$ such that:

- $B(\ell^\infty(\mathbb{N}), \|\cdot\|)$ belongs to $\text{Baire}(\ell^\infty(\mathbb{N}), \text{weak})$.
- $B(\ell^\infty(\mathbb{N})^*, \|\cdot\|^*)$ is not weak*-separable.

Measurability of the “norm” of a function taking values in a Banach space

Measurability of the “norm” of a function taking values in a Banach space

$X \equiv$ Banach space

Measurability of the “norm” of a function taking values in a Banach space

$X \equiv$ Banach space

$f \equiv$ X -valued function defined on a complete probability space

Measurability of the “norm” of a function taking values in a Banach space

$X \equiv$ Banach space

$f \equiv$ X -valued function defined on a complete probability space

A consequence of Edgar's theorem

f is **scalarly measurable**

Measurability of the “norm” of a function taking values in a Banach space

$X \equiv$ Banach space

$f \equiv$ X -valued function defined on a complete probability space

A consequence of Edgar's theorem

f is **scalarly measurable** (i.e. x^*f is measurable $\forall x^* \in X^*$)

Measurability of the “norm” of a function taking values in a Banach space

$X \equiv$ Banach space

$f \equiv$ X -valued function defined on a complete probability space

A consequence of Edgar's theorem

f is **scalarly measurable** (i.e. x^*f is measurable $\forall x^* \in X^*$)



f is Baire(X, weak)-measurable

Measurability of the “norm” of a function taking values in a Banach space

$X \equiv$ Banach space

$f \equiv$ X -valued function defined on a complete probability space

A consequence of Edgar's theorem

f is **scalarly measurable** (i.e. x^*f is measurable $\forall x^* \in X^*$)



f is Baire(X, weak)-measurable

$\|\cdot\| \equiv$ equivalent norm on X

Measurability of the “norm” of a function taking values in a Banach space

$X \equiv$ Banach space

$f \equiv$ X -valued function defined on a complete probability space

A consequence of Edgar's theorem

f is **scalarly measurable** (i.e. x^*f is measurable $\forall x^* \in X^*$)



f is Baire(X, weak)-measurable

$\|\cdot\| \equiv$ equivalent norm on X

If $B(X, \|\cdot\|)$ belongs to Baire(X, weak) ...

Measurability of the “norm” of a function taking values in a Banach space

$X \equiv$ Banach space

$f \equiv$ X -valued function defined on a complete probability space

A consequence of Edgar’s theorem

f is **scalarly measurable** (i.e. x^*f is measurable $\forall x^* \in X^*$)



f is Baire(X, weak)-measurable

$\|\cdot\| \equiv$ equivalent norm on X

If $B(X, \|\cdot\|)$ belongs to Baire(X, weak) ...

... then $\|f(\cdot)\|$ is **measurable** whenever f is scalarly measurable.

A family of equivalent norms on $\ell^\infty(\mathbb{N})$

A family of equivalent norms on $\ell^\infty(\mathbb{N})$

- $\mathcal{B} := \bigcup_{n \in \mathbb{N}} \{0, 1\}^n$ countable set

A family of equivalent norms on $\ell^\infty(\mathbb{N})$

- $\mathcal{B} := \bigcup_{n \in \mathbb{N}} \{0, 1\}^n$ countable set
- Given $u = (u_1, u_2, \dots) \in \{0, 1\}^{\mathbb{N}}$,

A family of equivalent norms on $\ell^\infty(\mathbb{N})$

- $\mathcal{B} := \bigcup_{n \in \mathbb{N}} \{0, 1\}^n$ countable set
- Given $u = (u_1, u_2, \dots) \in \{0, 1\}^{\mathbb{N}}$, define

$$\mathcal{B}_u := \{u|n : n \in \mathbb{N}\} \subset \mathcal{B},$$

A family of equivalent norms on $\ell^\infty(\mathbb{N})$

- $\mathcal{B} := \bigcup_{n \in \mathbb{N}} \{0, 1\}^n$ countable set
- Given $u = (u_1, u_2, \dots) \in \{0, 1\}^{\mathbb{N}}$, define

$$\mathcal{B}_u := \{u|n : n \in \mathbb{N}\} \subset \mathcal{B}, \quad \text{where } u|n := (u_1, \dots, u_n).$$

A family of equivalent norms on $\ell^\infty(\mathbb{N})$

- $\mathcal{B} := \bigcup_{n \in \mathbb{N}} \{0, 1\}^n$ countable set
- Given $u = (u_1, u_2, \dots) \in \{0, 1\}^{\mathbb{N}}$, define

$$\mathcal{B}_u := \{u|n : n \in \mathbb{N}\} \subset \mathcal{B}, \quad \text{where } u|n := (u_1, \dots, u_n).$$

Consider the **seminorm** $\|\cdot\|_u$ on $\ell^\infty(\mathcal{B})$ defined by

A family of equivalent norms on $\ell^\infty(\mathbb{N})$

- $\mathcal{B} := \bigcup_{n \in \mathbb{N}} \{0, 1\}^n$ countable set
- Given $u = (u_1, u_2, \dots) \in \{0, 1\}^{\mathbb{N}}$, define

$$\mathcal{B}_u := \{u|n : n \in \mathbb{N}\} \subset \mathcal{B}, \quad \text{where } u|n := (u_1, \dots, u_n).$$

Consider the **seminorm** $\|\cdot\|_u$ on $\ell^\infty(\mathcal{B})$ defined by

$$\|x\|_u := \limsup_{n \rightarrow \infty} |x(u|n)|.$$

A family of equivalent norms on $\ell^\infty(\mathbb{N})$

- $\mathcal{B} := \bigcup_{n \in \mathbb{N}} \{0, 1\}^n$ countable set
- Given $u = (u_1, u_2, \dots) \in \{0, 1\}^{\mathbb{N}}$, define
$$\mathcal{B}_u := \{u|n : n \in \mathbb{N}\} \subset \mathcal{B}, \quad \text{where } u|n := (u_1, \dots, u_n).$$

Consider the **seminorm** $\|\cdot\|_u$ on $\ell^\infty(\mathcal{B})$ defined by

$$\|x\|_u := \limsup_{n \rightarrow \infty} |x(u|n)|.$$

Definition (Edgar, see (Talagrand, 1984))

A family of equivalent norms on $\ell^\infty(\mathbb{N})$

- $\mathcal{B} := \bigcup_{n \in \mathbb{N}} \{0, 1\}^n$ countable set
- Given $u = (u_1, u_2, \dots) \in \{0, 1\}^{\mathbb{N}}$, define

$$\mathcal{B}_u := \{u|n : n \in \mathbb{N}\} \subset \mathcal{B}, \quad \text{where } u|n := (u_1, \dots, u_n).$$

Consider the **seminorm** $\|\cdot\|_u$ on $\ell^\infty(\mathcal{B})$ defined by

$$\|x\|_u := \limsup_{n \rightarrow \infty} |x(u|n)|.$$

Definition (Edgar, see (Talagrand, 1984))

Fix $\varphi : \{0, 1\}^{\mathbb{N}} \rightarrow [1, \infty)$ bounded.

A family of equivalent norms on $\ell^\infty(\mathbb{N})$

- $\mathcal{B} := \bigcup_{n \in \mathbb{N}} \{0, 1\}^n$ countable set
- Given $u = (u_1, u_2, \dots) \in \{0, 1\}^{\mathbb{N}}$, define

$$\mathcal{B}_u := \{u|n : n \in \mathbb{N}\} \subset \mathcal{B}, \quad \text{where } u|n := (u_1, \dots, u_n).$$

Consider the **seminorm** $\|\cdot\|_u$ on $\ell^\infty(\mathcal{B})$ defined by

$$\|x\|_u := \limsup_{n \rightarrow \infty} |x(u|n)|.$$

Definition (Edgar, see (Talagrand, 1984))

Fix $\varphi : \{0, 1\}^{\mathbb{N}} \rightarrow [1, \infty)$ bounded. The formula

$$\|x\|_\varphi := \max \left\{ \|x\|_\infty, \sup_{u \in \{0, 1\}^{\mathbb{N}}} \varphi(u) \|x\|_u \right\}$$

defines an **equivalent norm** on $\ell^\infty(\mathcal{B})$.

Sketch of proof of Theorem A

Sketch of proof of Theorem A

$\{0,1\}^{\mathbb{N}}$ equipped with the (completion of) the usual product probability on $\text{Borel}(\{0,1\}^{\mathbb{N}})$

Sketch of proof of Theorem A

$\{0,1\}^{\mathbb{N}}$ equipped with the (completion of) the usual product probability on $\text{Borel}(\{0,1\}^{\mathbb{N}})$

Fact (Edgar, 1979)

$f : \{0,1\}^{\mathbb{N}} \rightarrow \ell^{\infty}(\mathcal{B})$ given by $f(u) := \chi_{\mathcal{B}_u}$ is scalarly measurable.

Sketch of proof of Theorem A

$\{0,1\}^{\mathbb{N}}$ equipped with the (completion of) the usual product probability on $\text{Borel}(\{0,1\}^{\mathbb{N}})$

Fact (Edgar, 1979)

$f : \{0,1\}^{\mathbb{N}} \rightarrow \ell^{\infty}(\mathcal{B})$ given by $f(u) := \chi_{\mathcal{B}_u}$ is scalarly measurable.

$\ell^{\infty}(\mathcal{B})$ equipped with $\|\cdot\|_{\varphi}$ for some $\varphi : \{0,1\}^{\mathbb{N}} \rightarrow [1,\infty)$

Sketch of proof of Theorem A

$\{0,1\}^{\mathbb{N}}$ equipped with the (completion of) the usual product probability on $\text{Borel}(\{0,1\}^{\mathbb{N}})$

Fact (Edgar, 1979)

$f : \{0,1\}^{\mathbb{N}} \rightarrow \ell^{\infty}(\mathcal{B})$ given by $f(u) := \chi_{\mathcal{B}_u}$ is scalarly measurable.

$\ell^{\infty}(\mathcal{B})$ equipped with $\|\cdot\|_{\varphi}$ for some $\varphi : \{0,1\}^{\mathbb{N}} \rightarrow [1,\infty)$

Since $\|f(\cdot)\|_{\varphi} = \varphi$, we conclude:

Sketch of proof of Theorem A

$\{0,1\}^{\mathbb{N}}$ equipped with the (completion of) the usual product probability on $\text{Borel}(\{0,1\}^{\mathbb{N}})$

Fact (Edgar, 1979)

$f : \{0,1\}^{\mathbb{N}} \rightarrow \ell^{\infty}(\mathcal{B})$ given by $f(u) := \chi_{\mathcal{B}_u}$ is scalarly measurable.

$\ell^{\infty}(\mathcal{B})$ equipped with $\|\cdot\|_{\varphi}$ for some $\varphi : \{0,1\}^{\mathbb{N}} \rightarrow [1,\infty)$

Since $\|f(\cdot)\|_{\varphi} = \varphi$, we conclude:

If φ is **non-measurable** ...

Sketch of proof of Theorem A

$\{0,1\}^{\mathbb{N}}$ equipped with the (completion of) the usual product probability on $\text{Borel}(\{0,1\}^{\mathbb{N}})$

Fact (Edgar, 1979)

$f : \{0,1\}^{\mathbb{N}} \rightarrow \ell^{\infty}(\mathcal{B})$ given by $f(u) := \chi_{\mathcal{B}_u}$ is scalarly measurable.

$\ell^{\infty}(\mathcal{B})$ equipped with $\|\cdot\|_{\varphi}$ for some $\varphi : \{0,1\}^{\mathbb{N}} \rightarrow [1,\infty)$

Since $\|f(\cdot)\|_{\varphi} = \varphi$, we conclude:

If φ is **non-measurable** ...

... then $B(\ell^{\infty}(\mathcal{B}), \|\cdot\|_{\varphi})$ does **not** belong to $\text{Baire}(\ell^{\infty}(\mathcal{B}), \text{weak})$!!

An application

Question (Musial, 1991)

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

- (i) $\|g(\cdot)\|$ is measurable and

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

- (i) $\|g(\cdot)\|$ is measurable and
- (ii) f and g are **scalarly equivalent**

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

- (i) $\|g(\cdot)\|$ is measurable and
- (ii) f and g are **scalarly equivalent**
(i.e. $\forall x^* \in X^*$, we have $x^*f = x^*g$ a.e.)

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

- (i) $\|g(\cdot)\|$ is measurable and
- (ii) f and g are **scalarly equivalent**
(i.e. $\forall x^* \in X^*$, we have $x^*f = x^*g$ a.e.) ??

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

- (i) $\|g(\cdot)\|$ is measurable and
- (ii) f and g are **scalarly equivalent**
(i.e. $\forall x^* \in X^*$, we have $x^*f = x^*g$ a.e.) ??

The answer is affirmative ...

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

- (i) $\|g(\cdot)\|$ is measurable and
- (ii) f and g are **scalarly equivalent**
(i.e. $\forall x^* \in X^*$, we have $x^*f = x^*g$ a.e.) ??

The answer is affirmative ...

... if (X, weak) is **measure compact** (e.g. Lindelöf).

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

- (i) $\|g(\cdot)\|$ is measurable and
- (ii) f and g are **scalarly equivalent**
(i.e. $\forall x^* \in X^*$, we have $x^*f = x^*g$ a.e.) ??

The answer is affirmative ...

... if (X, weak) is **measure compact** (e.g. Lindelöf). In this case g can be chosen strongly measurable !! (Edgar, 1979)

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

- (i) $\|g(\cdot)\|$ is measurable and
- (ii) f and g are **scalarly equivalent**
(i.e. $\forall x^* \in X^*$, we have $x^*f = x^*g$ a.e.) ??

The answer is affirmative ...

... if (X, weak) is **measure compact** (e.g. Lindelöf). In this case g can be chosen strongly measurable !! (Edgar, 1979)

Corollary

The answer is **negative** in general,

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

- (i) $\|g(\cdot)\|$ is measurable and
- (ii) f and g are **scalarly equivalent**
(i.e. $\forall x^* \in X^*$, we have $x^*f = x^*g$ a.e.) ??

The answer is affirmative ...

... if (X, weak) is **measure compact** (e.g. Lindelöf). In this case g can be chosen strongly measurable !! (Edgar, 1979)

Corollary

The answer is **negative** in general,
even for Banach spaces with property (C)

An application

Question (Musial, 1991)

Let X be a Banach space and $\|\cdot\|$ an equivalent norm on it.

Let $f : \Omega \rightarrow X$ be a **Pettis integrable** function defined on a complete probability space (Ω, Σ, μ) .

Is there a function $g : \Omega \rightarrow X$ such that:

- (i) $\|g(\cdot)\|$ is measurable and
- (ii) f and g are **scalarly equivalent**
(i.e. $\forall x^* \in X^*$, we have $x^*f = x^*g$ a.e.) ??

The answer is affirmative ...

... if (X, weak) is **measure compact** (e.g. Lindelöf). In this case g can be chosen strongly measurable !! (Edgar, 1979)

Corollary

The answer is **negative** in general,
even for Banach spaces with property (C) (like JL_0 and JL_2).

Sketch of proof of Theorem B

Sketch of proof of Theorem B

Recall ...

Theorem B

There is an equivalent norm $\|\cdot\|$ on $\ell^\infty(\mathbb{N})$ such that:

- $B(\ell^\infty(\mathbb{N}), \|\cdot\|)$ belongs to $\text{Baire}(\ell^\infty(\mathbb{N}), \text{weak})$.
- $B(\ell^\infty(\mathbb{N})^*, \|\cdot\|^*)$ is not weak^* -separable.

Sketch of proof of Theorem B

Recall ...

Theorem B

There is an equivalent norm $\|\cdot\|$ on $\ell^\infty(\mathbb{N})$ such that:

- $B(\ell^\infty(\mathbb{N}), \|\cdot\|)$ belongs to $\text{Baire}(\ell^\infty(\mathbb{N}), \text{weak})$.
- $B(\ell^\infty(\mathbb{N})^*, \|\cdot\|^*)$ is not weak^* -separable.

The key for the proof ...

Sketch of proof of Theorem B

Recall ...

Theorem B

There is an equivalent norm $\|\cdot\|$ on $\ell^\infty(\mathbb{N})$ such that:

- $B(\ell^\infty(\mathbb{N}), \|\cdot\|)$ belongs to $\text{Baire}(\ell^\infty(\mathbb{N}), \text{weak})$.
- $B(\ell^\infty(\mathbb{N})^*, \|\cdot\|^*)$ is not weak^* -separable.

The key for the proof ...

Proposition

Let $\varphi : \{0,1\}^{\mathbb{N}} \rightarrow [1,\infty)$ be a bounded function. TFAE:

Sketch of proof of Theorem B

Recall ...

Theorem B

There is an equivalent norm $\|\cdot\|$ on $\ell^\infty(\mathbb{N})$ such that:

- $B(\ell^\infty(\mathbb{N}), \|\cdot\|)$ belongs to $\text{Baire}(\ell^\infty(\mathbb{N}), \text{weak})$.
- $B(\ell^\infty(\mathbb{N})^*, \|\cdot\|^*)$ is not weak^* -separable.

The key for the proof ...

Proposition

Let $\varphi : \{0,1\}^{\mathbb{N}} \rightarrow [1,\infty)$ be a bounded function. TFAE:

- (i) $B(\ell^\infty(\mathcal{B})^*, \|\cdot\|_\varphi^*)$ is weak^* -separable.

Sketch of proof of Theorem B

Recall ...

Theorem B

There is an equivalent norm $\|\cdot\|$ on $\ell^\infty(\mathbb{N})$ such that:

- $B(\ell^\infty(\mathbb{N}), \|\cdot\|)$ belongs to $\text{Baire}(\ell^\infty(\mathbb{N}), \text{weak})$.
- $B(\ell^\infty(\mathbb{N})^*, \|\cdot\|^*)$ is not weak^* -separable.

The key for the proof ...

Proposition

Let $\varphi : \{0,1\}^{\mathbb{N}} \rightarrow [1,\infty)$ be a bounded function. TFAE:

- $B(\ell^\infty(\mathcal{B})^*, \|\cdot\|_\varphi^*)$ is weak^* -separable.
- $\varphi(u) = 1 \quad \forall u \in \{0,1\}^{\mathbb{N}}$

Sketch of proof of Theorem B

Recall ...

Theorem B

There is an equivalent norm $\|\cdot\|$ on $\ell^\infty(\mathbb{N})$ such that:

- $B(\ell^\infty(\mathbb{N}), \|\cdot\|)$ belongs to $\text{Baire}(\ell^\infty(\mathbb{N}), \text{weak})$.
- $B(\ell^\infty(\mathbb{N})^*, \|\cdot\|^*)$ is not weak^* -separable.







The key for the proof ...

Proposition

Let $\varphi : \{0,1\}^{\mathbb{N}} \rightarrow [1,\infty)$ be a bounded function. TFAE:

- $B(\ell^\infty(\mathcal{B})^*, \|\cdot\|_\varphi^*)$ is weak^* -separable.
- $\boxed{\varphi(u) = 1} \quad \forall u \in \{0,1\}^{\mathbb{N}}$ (i.e. $\|\cdot\|_\varphi = \|\cdot\|_\infty$).

References

-  G. A. Edgar, *Indiana Univ. Math. J.* **26** (1977).
-  G. A. Edgar, *Indiana Univ. Math. J.* **28** (1979).
-  D. H. Fremlin, *Hokkaido Math. J.* **9** (1980).
-  A. S. Granero et al., *Studia Math.* **157** (2003).
-  W. B. Johnson and J. Lindenstrauss, *Israel J. Math.* **17** (1974).
-  K. Musial, *Rend. Istit. Mat. Univ. Trieste* **23** (1991).
-  M. Talagrand, *Indiana Univ. Math. J.* **27** (1978).
-  M. Talagrand, *Mem. Amer. Math. Soc.* **51** (1984), no. 307.

Preprint available at

<http://www.um.es/docencia/joserr/>