

CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO EXPERIMENTO PROTOMIRAX E DETERMINAÇÃO DE PARÂMETROS DINÂMICOS DO CANDIDATO A BURACO NEGRO 1E 1740.7-2942 COM DADOS EM RAIOS X

Paulo Eduardo F. Stecchini

João Braga, Flávio D'Amico, Manuel Castro, Jurandi Leão

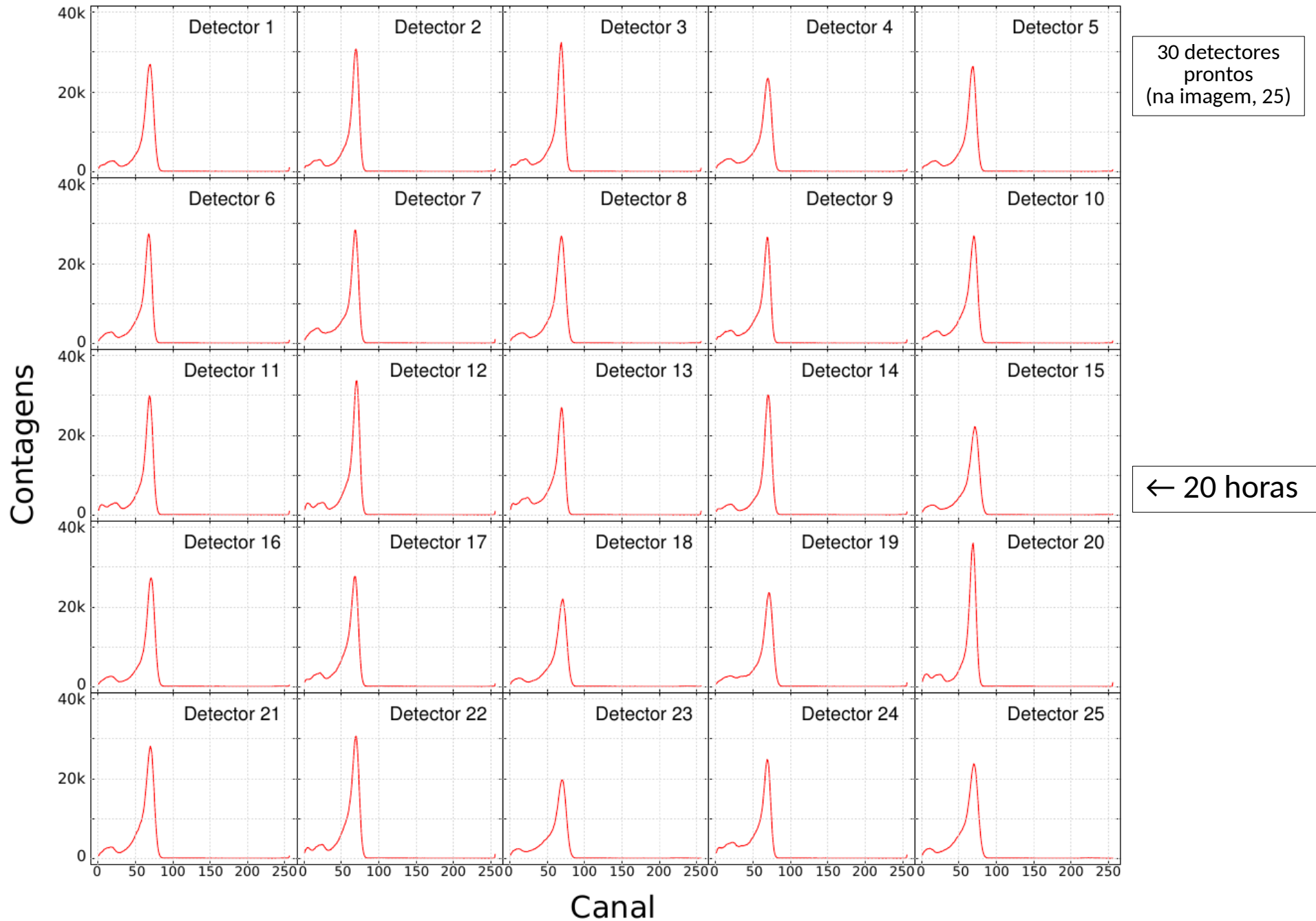
Workshop da Divisão de Astrofísica

9 e 10 de Abril de 2019

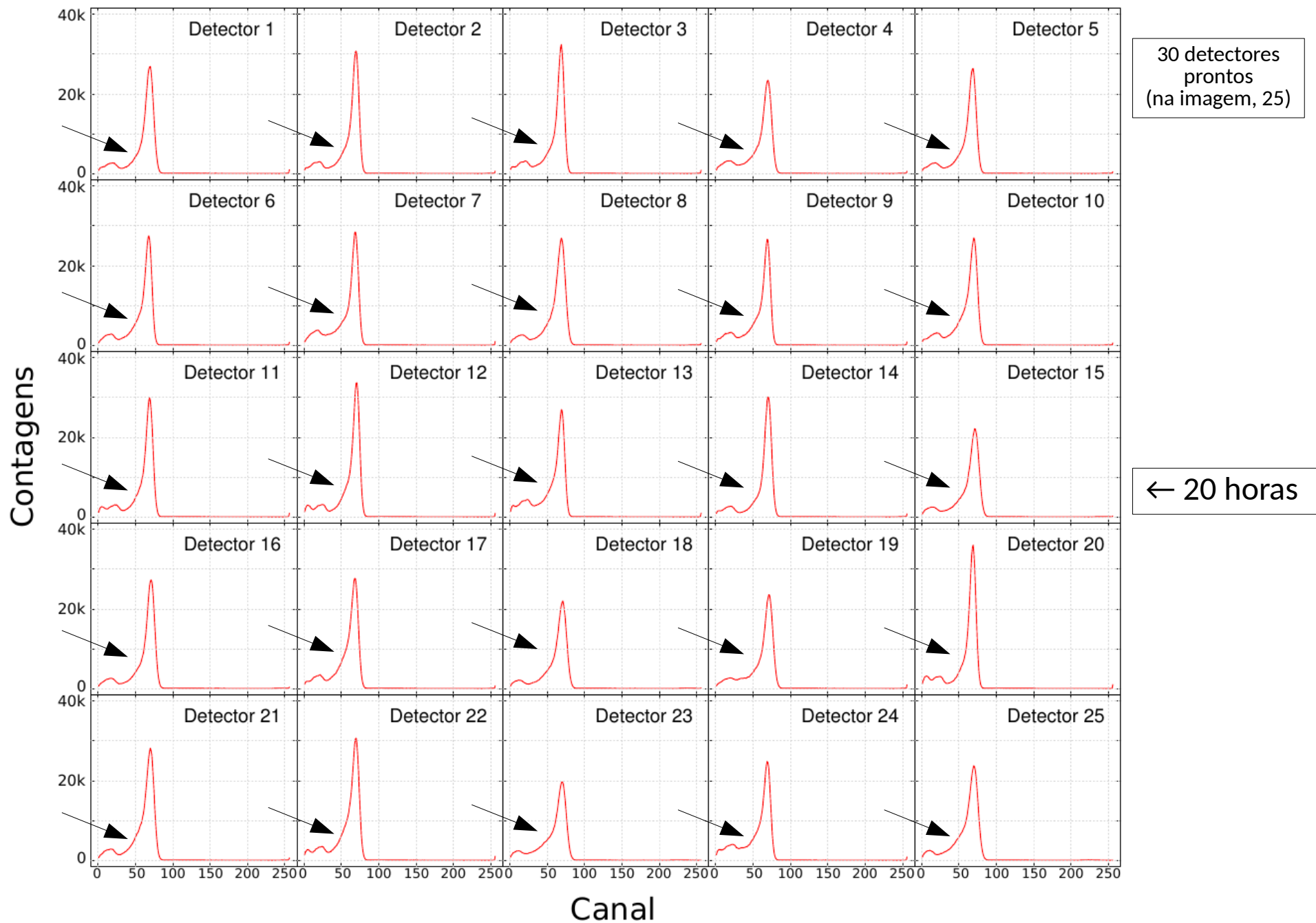
São José dos Campos - SP



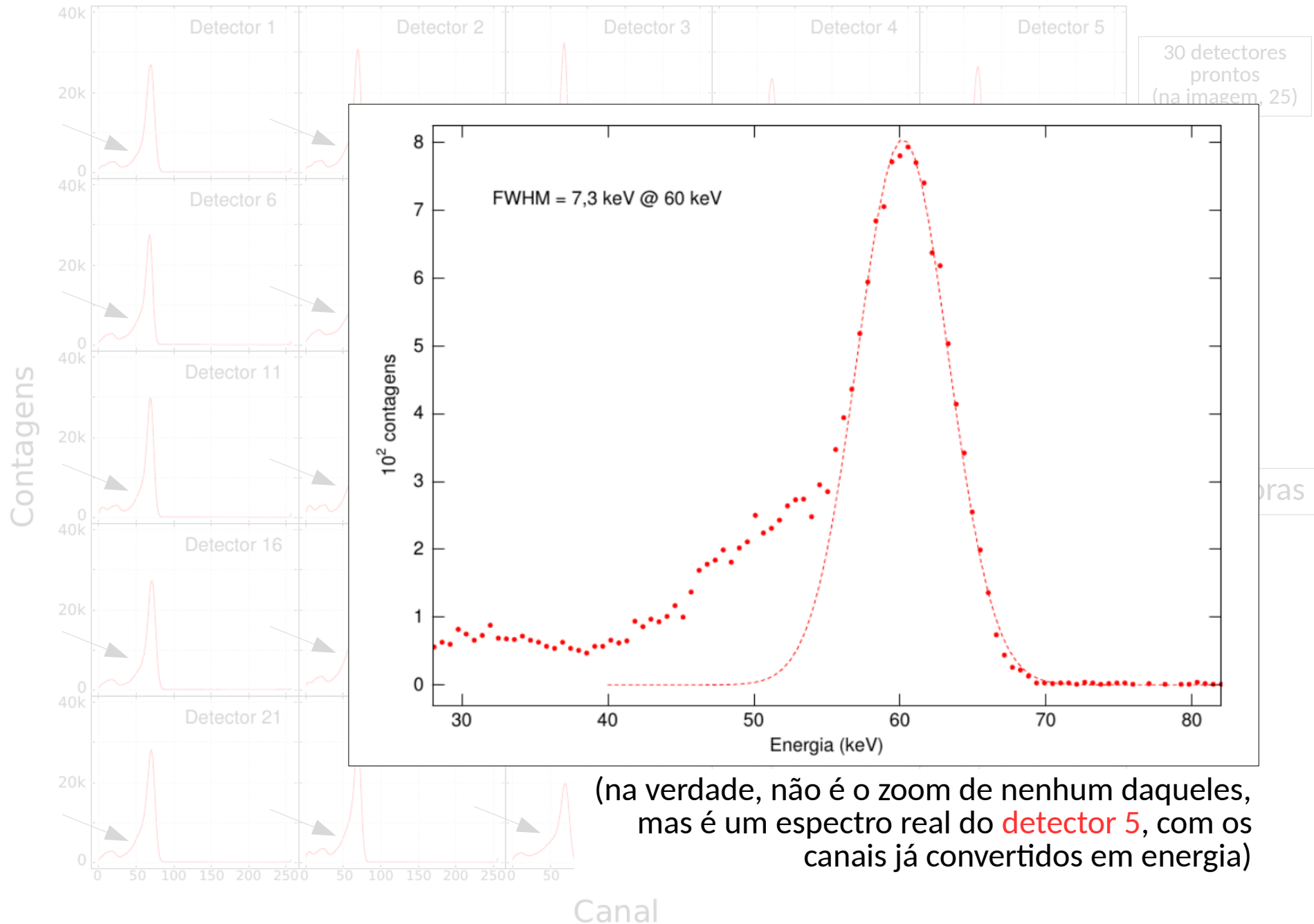
CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX



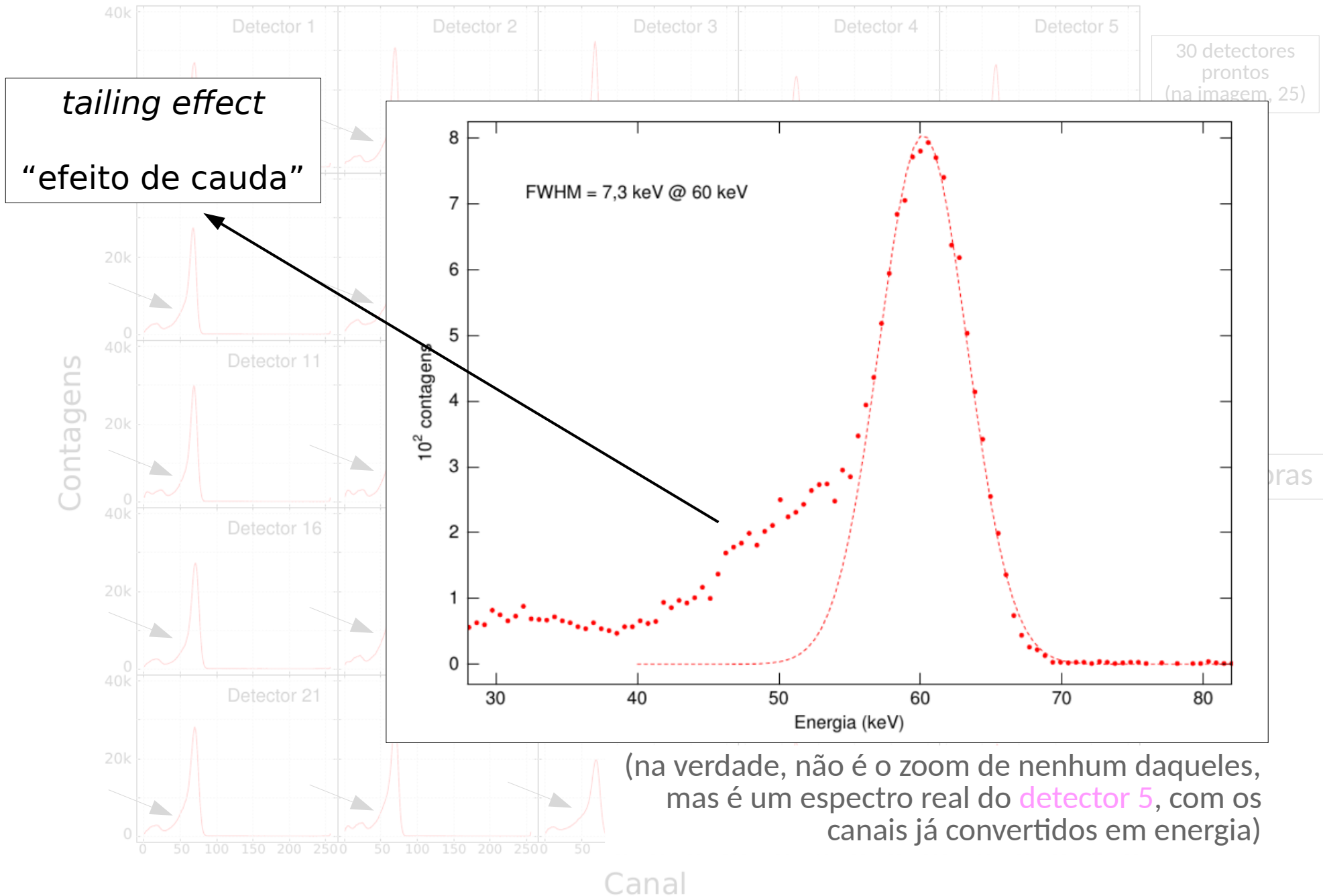
CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX



CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX



CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX



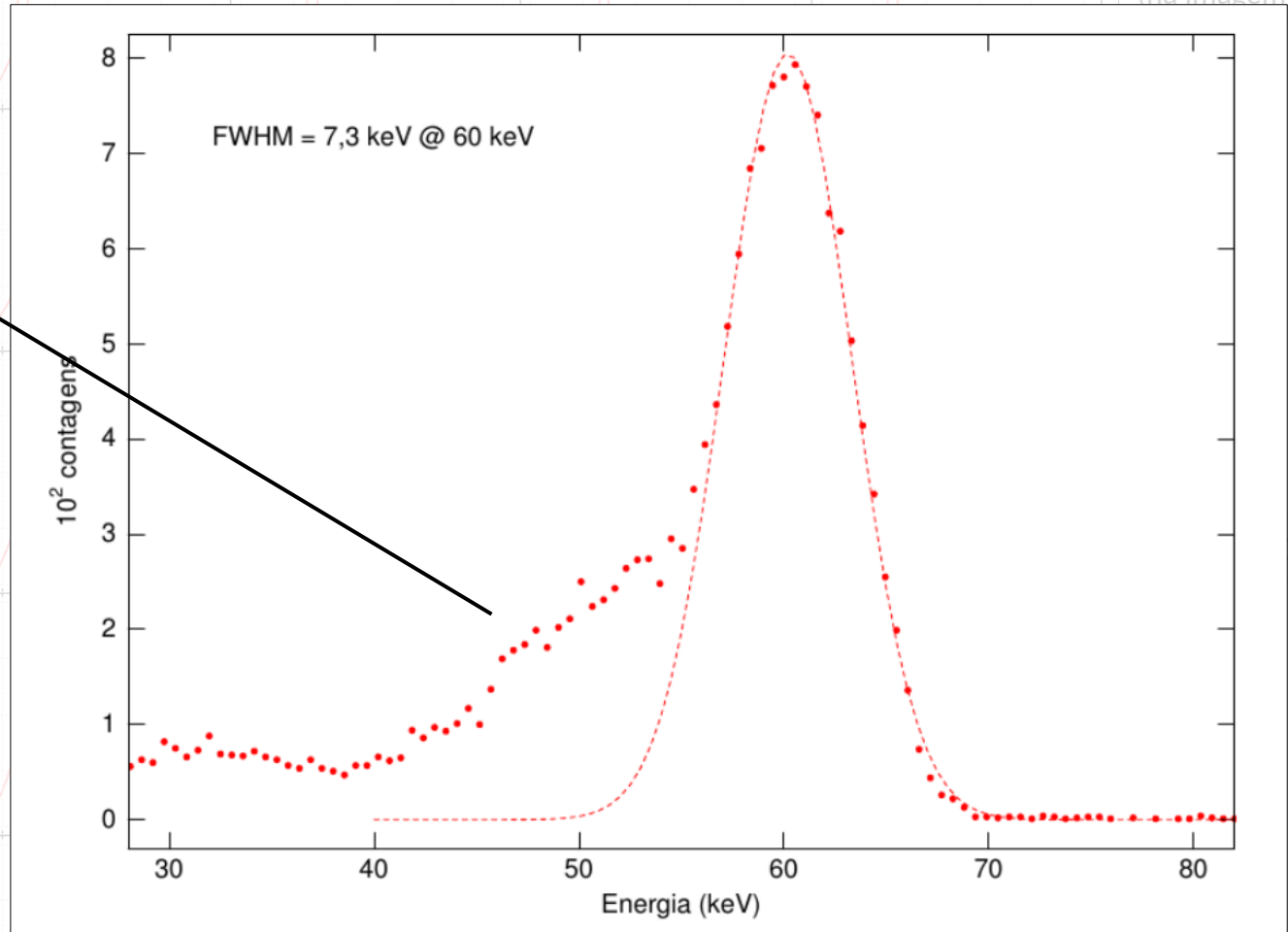
CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX



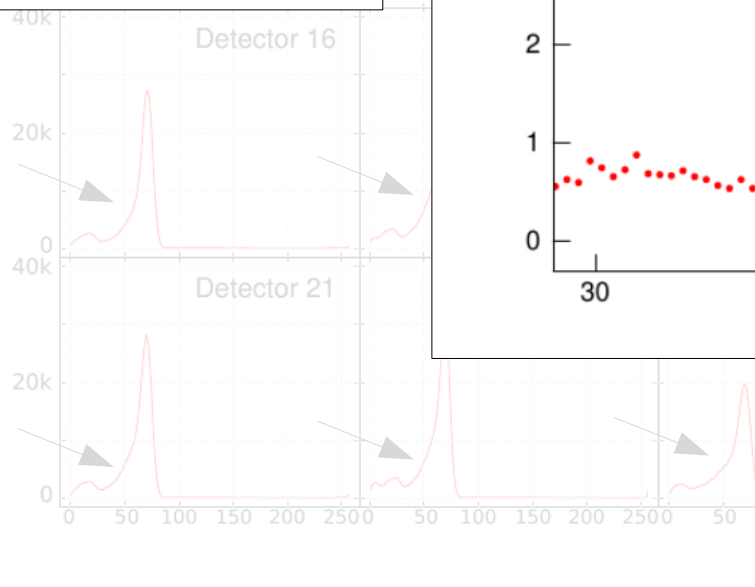
tailing effect
“efeito de cauda”

CdTe, CdZnTe

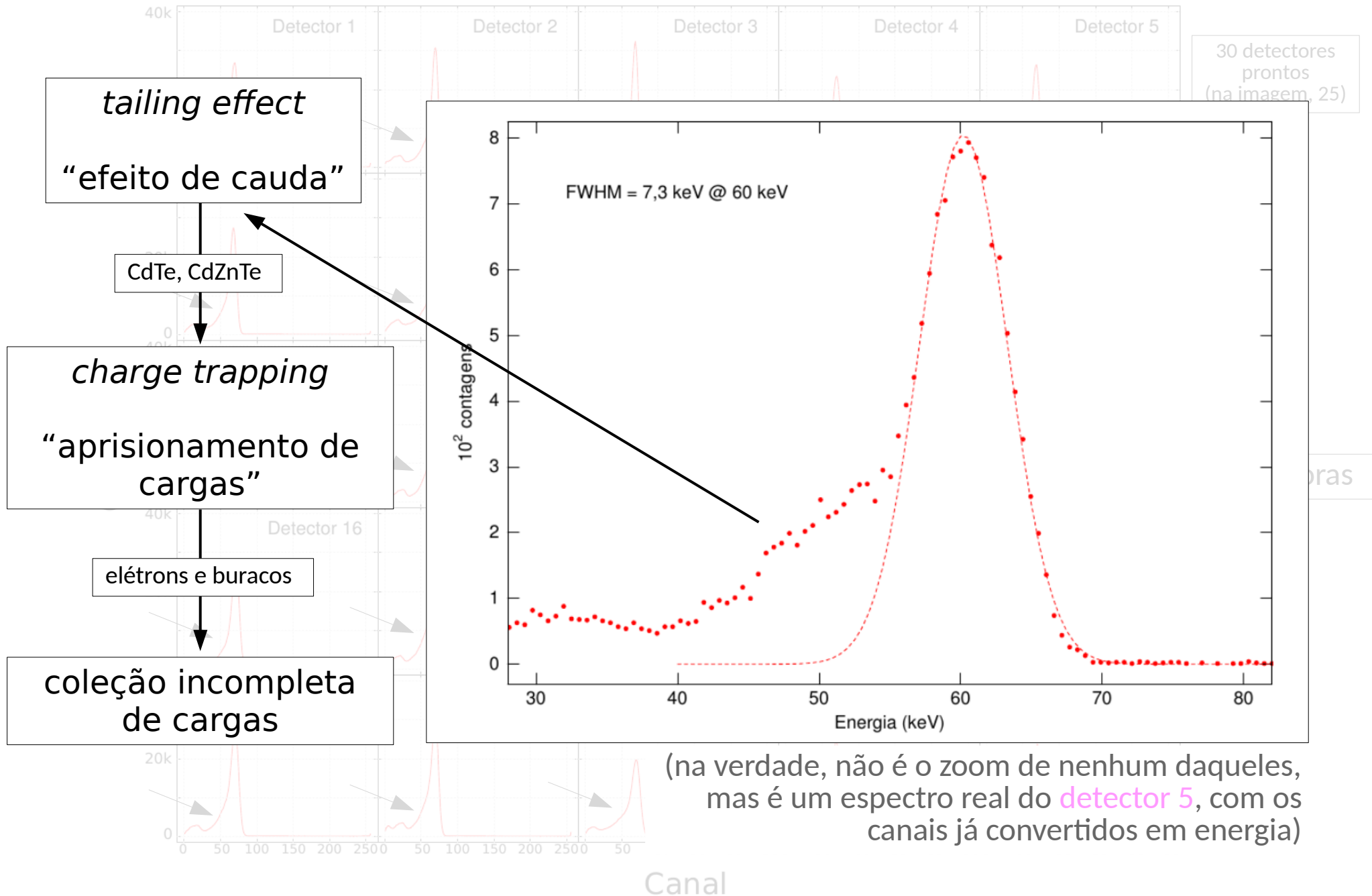
charge trapping
“aprisionamento de cargas”



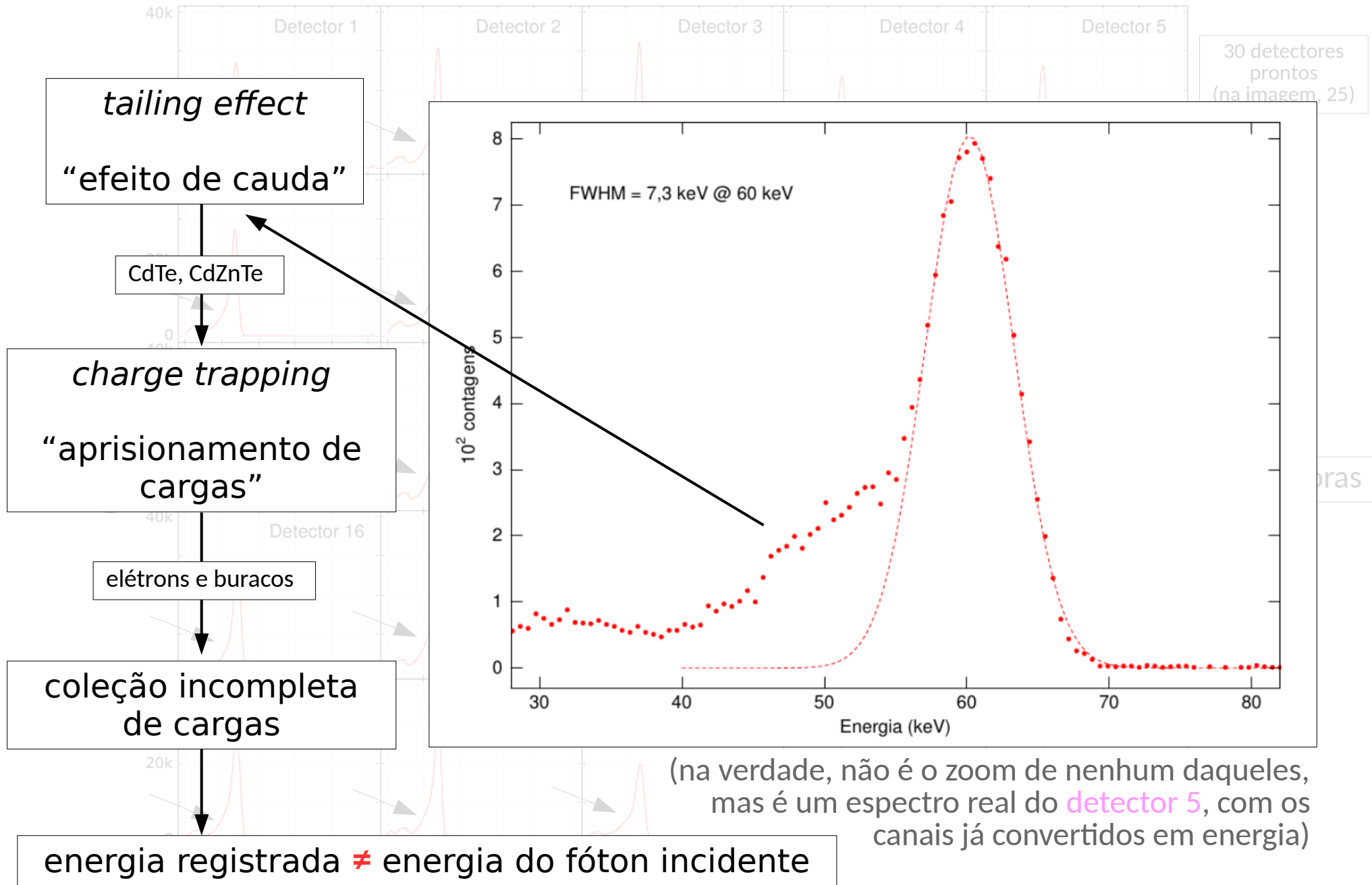
(na verdade, não é o zoom de nenhum daqueles, mas é um espectro real do **detector 5**, com os canais já convertidos em energia)



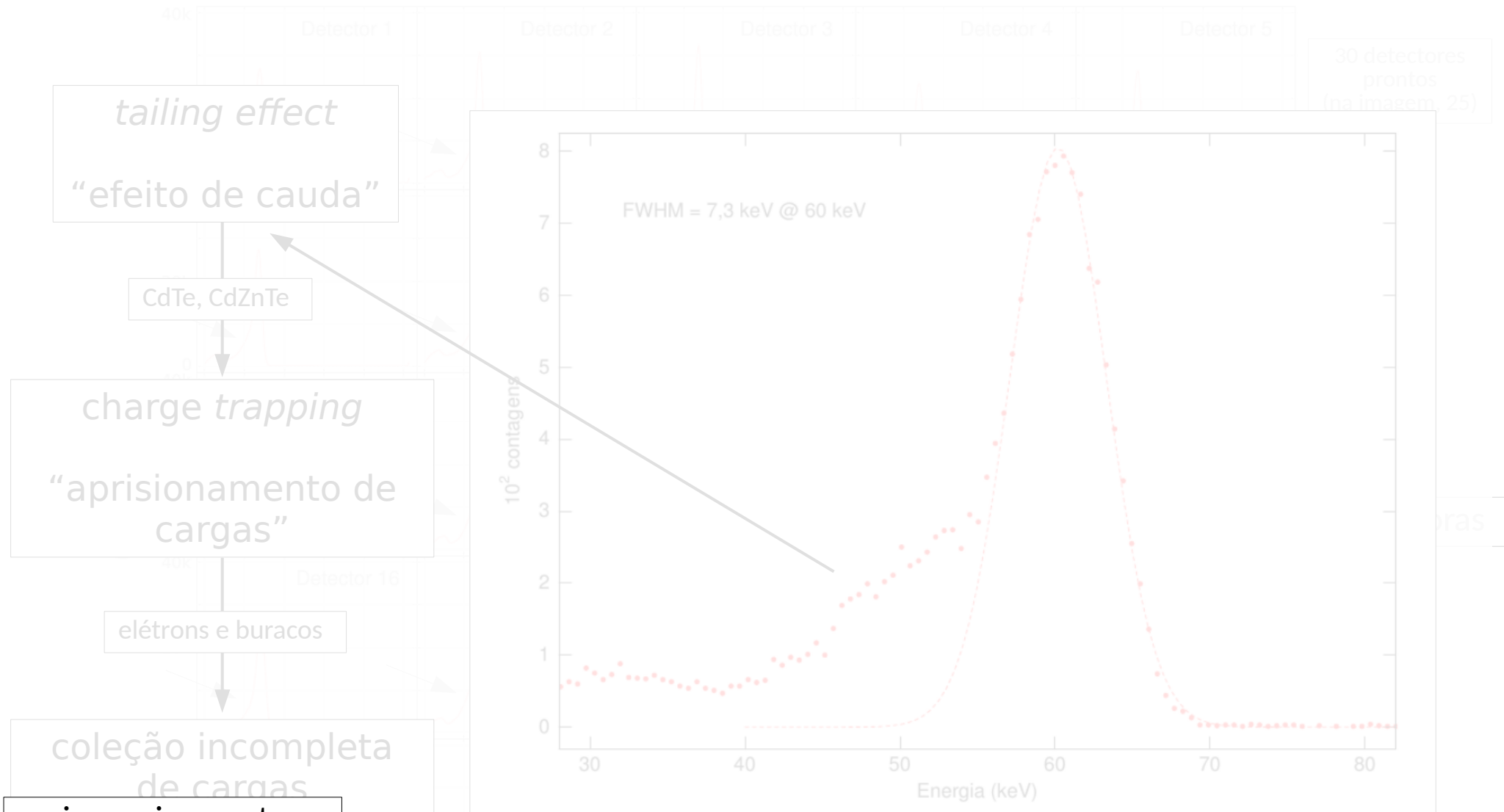
CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX



CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX



CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX



(na verdade não é o zoom de nenhum daqueles, com os energia)

energia registrada $<$ energia do fóton incidente

CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX

→ equilíbrio térmico é perturbado

→ retorno ao equilíbrio via recombinação

→ número de cargas livres decai exponencialmente com tempos τ_{buraco} e $\tau_{\text{elétron}}$

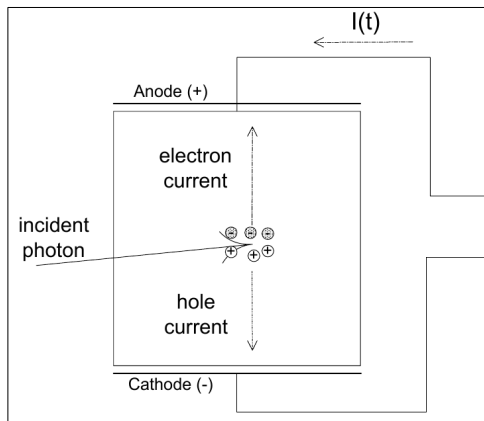
→ $\tau_{\text{buraco}} \ll$ “tempo de trânsito”

→ corrente induzida menor

$$\tau_{\text{buraco}} \ll \tau_{\text{elétron}}$$



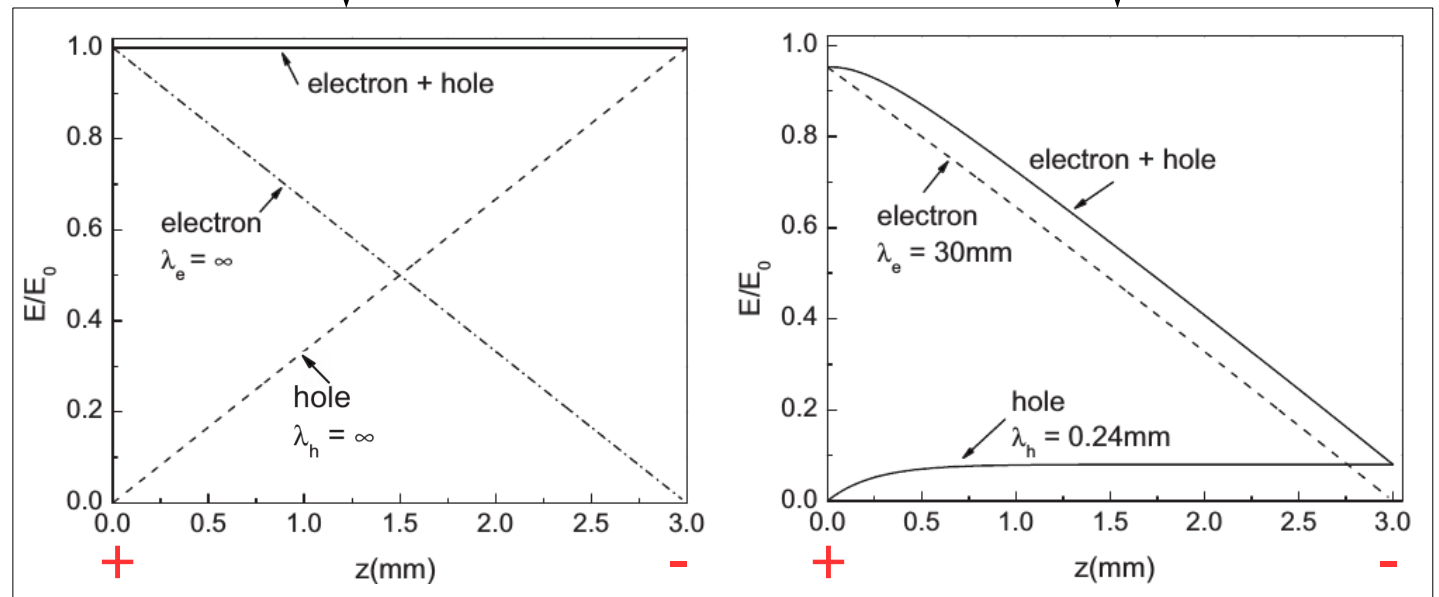
... → profundidade de interação...



Fonte: <http://www.amptek.com/pdf/anczt2.pdf>

sem aprisionamento

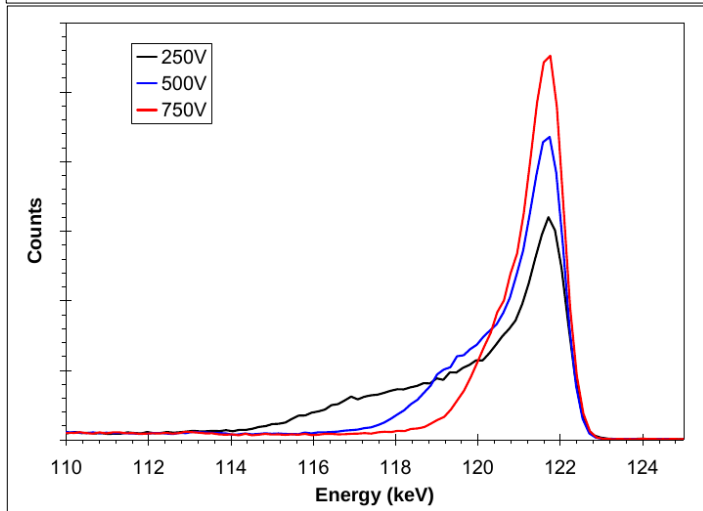
com aprisionamento



Fonte: Fritz et al., 2009

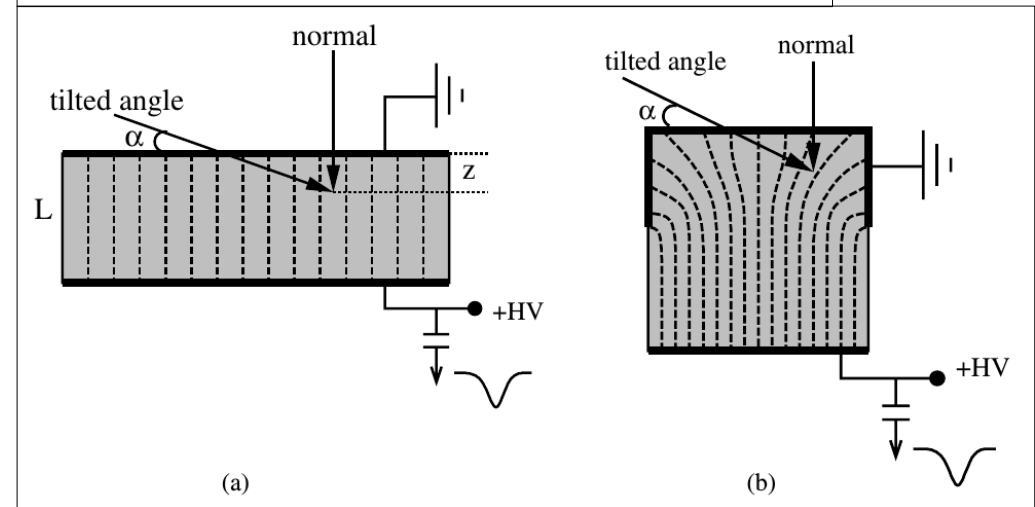
CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX

- aumentando a tensão aplicada



Fonte: <http://www.amptek.com/pdf/anczt2.pdf>

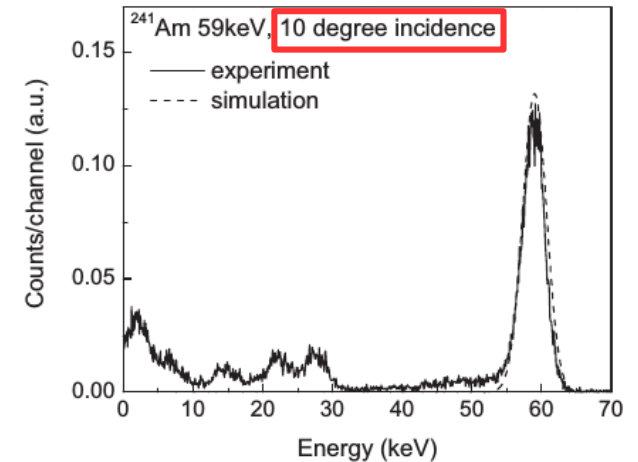
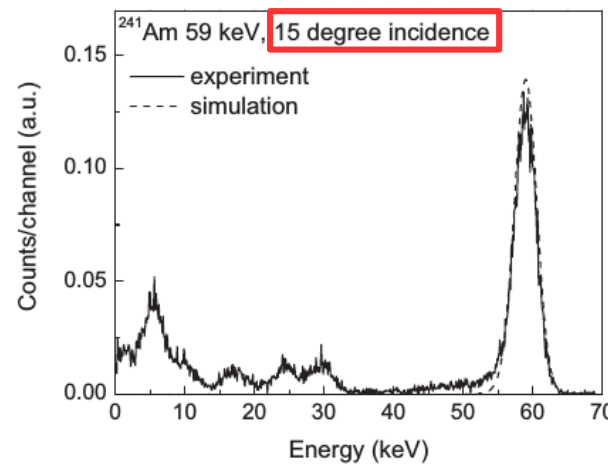
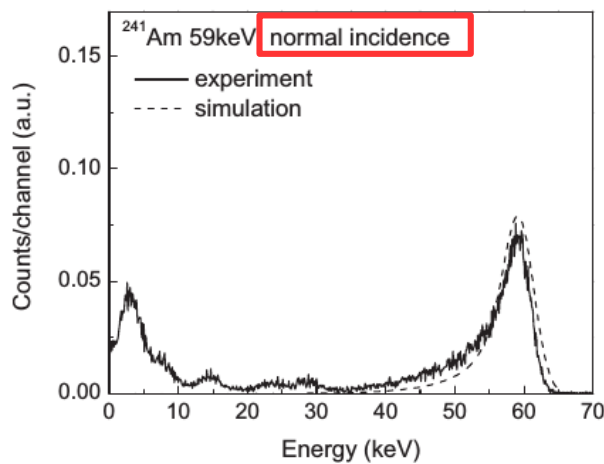
- alterando a geometria dos eletrodos



Fonte: Fritz et al., 2011

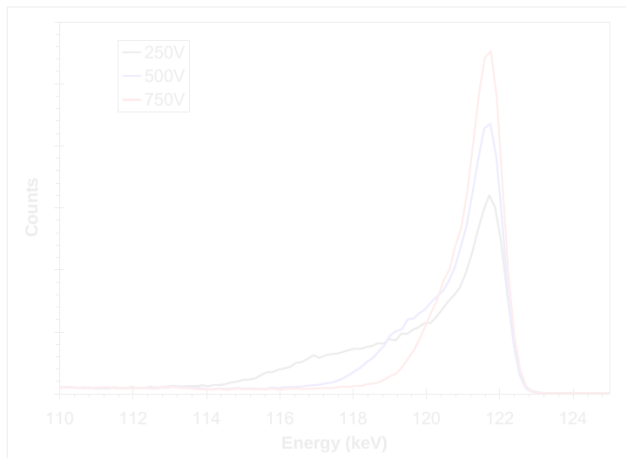
- alterando o ângulo de incidência

Fonte: Fritz et al., 2009



CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX

- aumentando a tensão aplicada



Fonte: <http://www.amptek.com/pdf/anczt2.pdf>

- alterando a geometria dos eletrodos

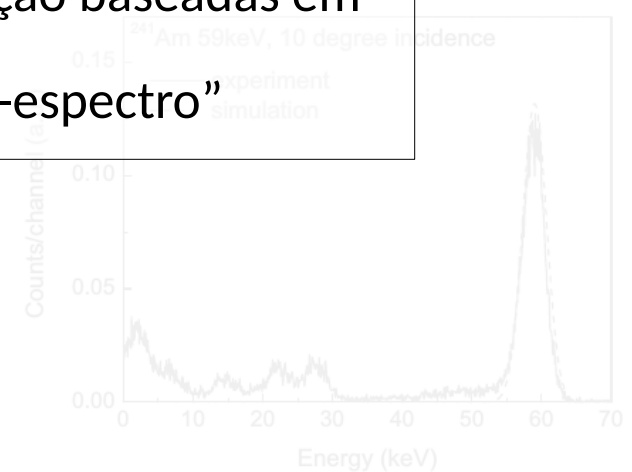
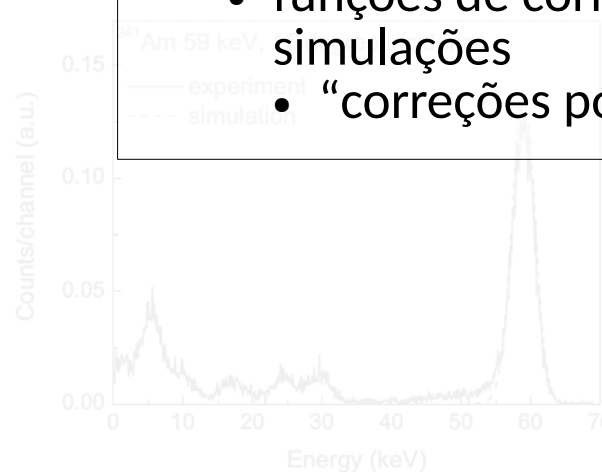
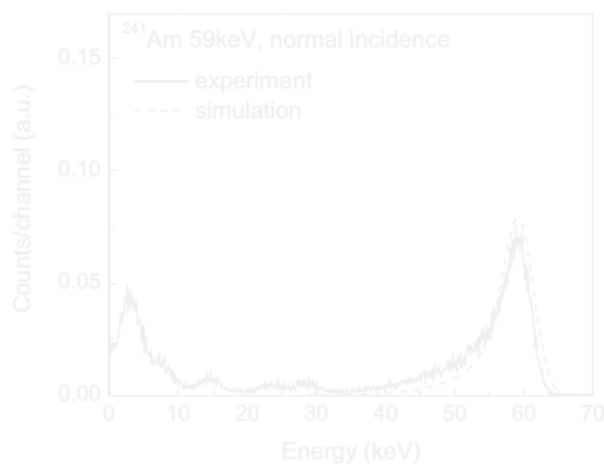


- corrigindo **depois** da interação

- *risetime discrimination*
 - = rejeitar pulsos que excedam determinado tempo

- funções de correção baseadas em simulações
 - “correções pós-espectro”

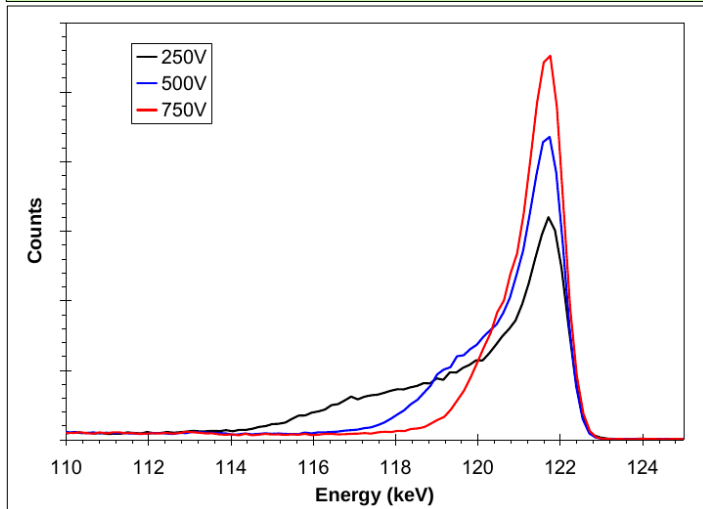
- alterando o ângulo de incidência



Fonte: Fritz et al., 2009

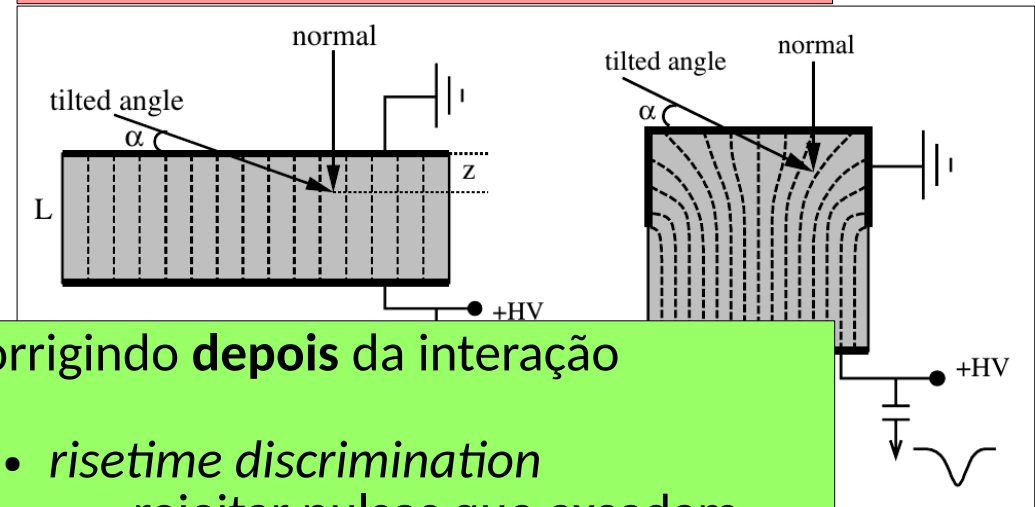
CARACTERIZAÇÃO DO SISTEMA IMAGEADOR DO PROTOMIRAX

- aumentando a tensão aplicada



Fonte: <http://www.amptek.com/pdf/anczt2.pdf>

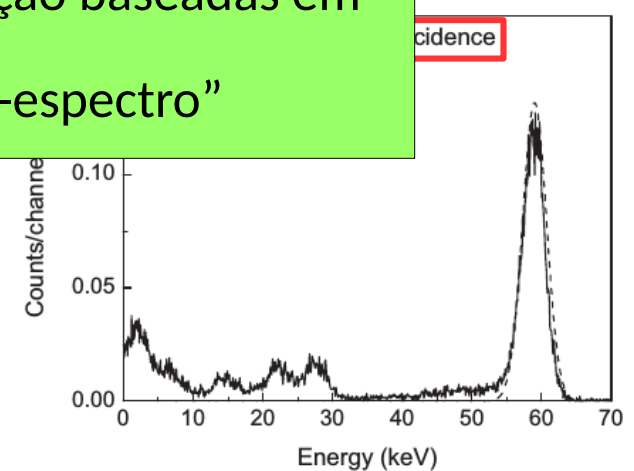
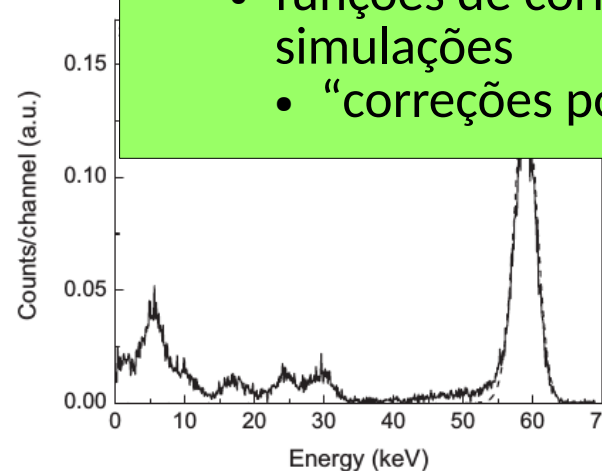
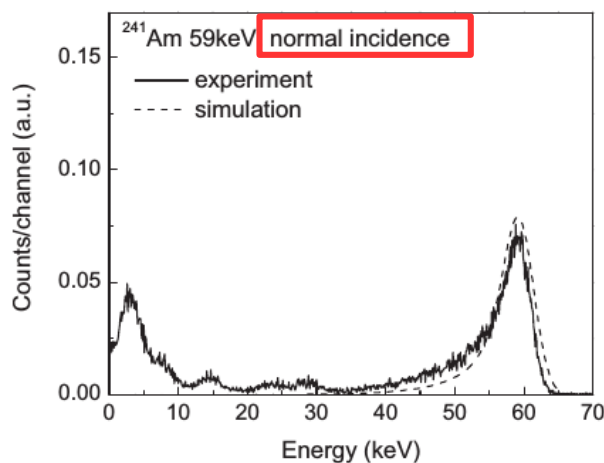
- alterando a geometria dos eletrodos



- corrigindo depois da interação

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- funções de correção baseadas em simulações
 - “correções pós-espectro”

- alterando o ângulo de incidência



Fonte: Fritz et al., 2009

ESTUDO DE 1E 1740.7-2942

→ Candidato a **buraco negro** - similaridades com Cyg X-1 (Sunyaev et al., 1991)

→ **Microquasar** - jatos em rádio (Mirabel et al., 1992)

→ Brilhante em **raios X duros** - mais brilhante do Centro Galáctico

→ Maior parte do tempo no estado **low/hard** de emissão (del Santo et al., 2005)

→ Espectro em raios X duros bem descrito por modelos de **Comptonização** (Castro et al., 2014)

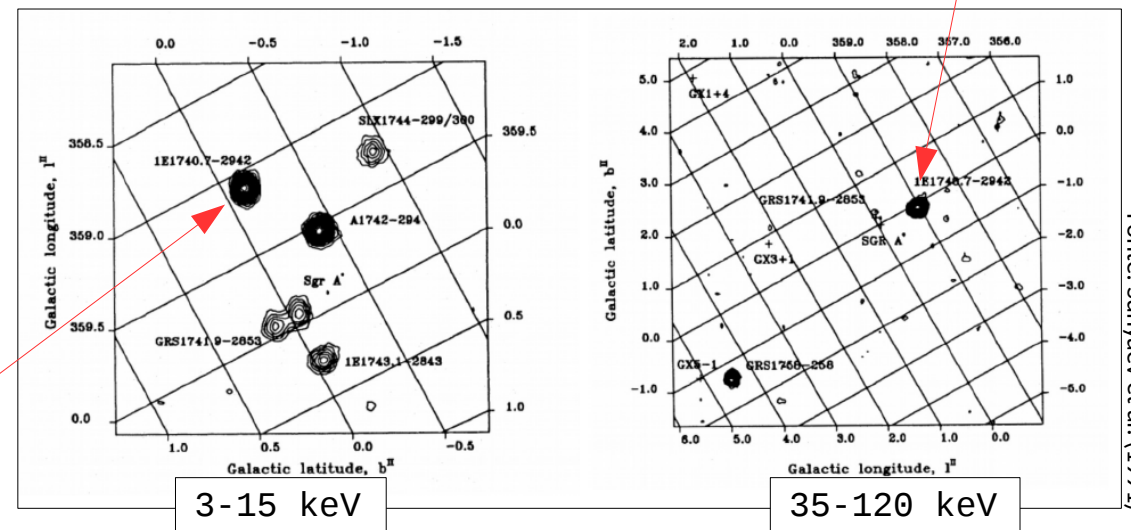
→ Lei de potência $1.4 < \Gamma < 2.1$ (Remillard & McClintock, 2006)

→ Contrapartida no **óptico/infravermelho** não confirmada

→ Estudo temporal (Smith et al., 2002)

→ ~**12,73 dias**

→ Período orbital?



ESTUDO DE 1E 1740.7-2942

THE ASTROPHYSICAL JOURNAL, 578:L129–L132, 2002 October 20
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ORBITAL AND SUPERORBITAL PERIODS OF 1E 1740.7–2942 AND GRS 1758–258

D. M. SMITH,¹ W. A. HEINDL,² AND J. H. SWANK³

Received 2002 July 23; accepted 2002 September 12; published 2002 September 23

ABSTRACT

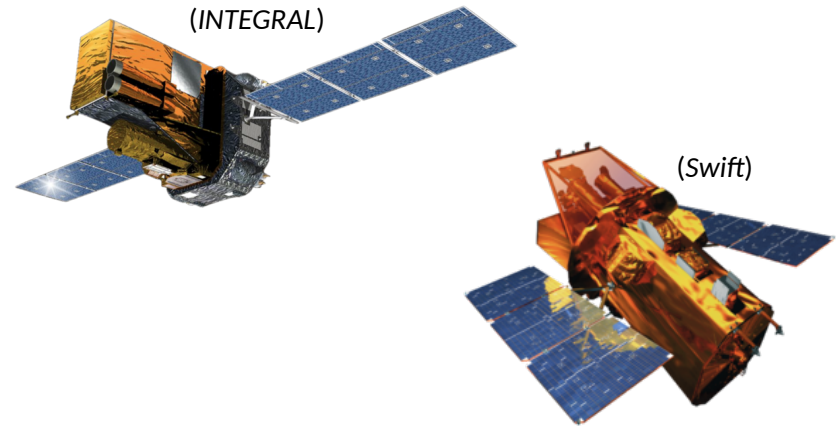
Five years of Rossi X-Ray Timing Explorer (RXTE) observations of the Galactic black hole candidates 1E 1740.7–2942 and GRS 1758–258 show a periodic modulation with an amplitude of 3%–4% in each source at 12.73 ± 0.05 and 18.45 ± 0.10 days, respectively. We interpret the modulations as orbital, suggesting that the objects have red giant companions. Combining the *RXTE* data with earlier data (Zhang, Harmon, & Liang) from the Burst and Transient Source Experiment on the *Compton Gamma Ray Observatory*, we find a long period or quasi-period of about 600 days in 1E 1740.7–2942 and a suggestion of a similar 600 day period in GRS 1758–258. These timescales are longer than any yet found for either precessing systems like Hercules X-1 and SS 433 or binaries like LMC X-3 and Cygnus X-1 with more irregular long periods.

Subject headings: stars: individual (GRS 1758–258, 1E 1740.7–2942) — X-rays: stars

- 5 anos
- Telescópio não-imageador
- 12 - 25 keV
(não é a faixa em que 1E é mais brilhante)

ESTUDO DE 1E 1740.7-2942

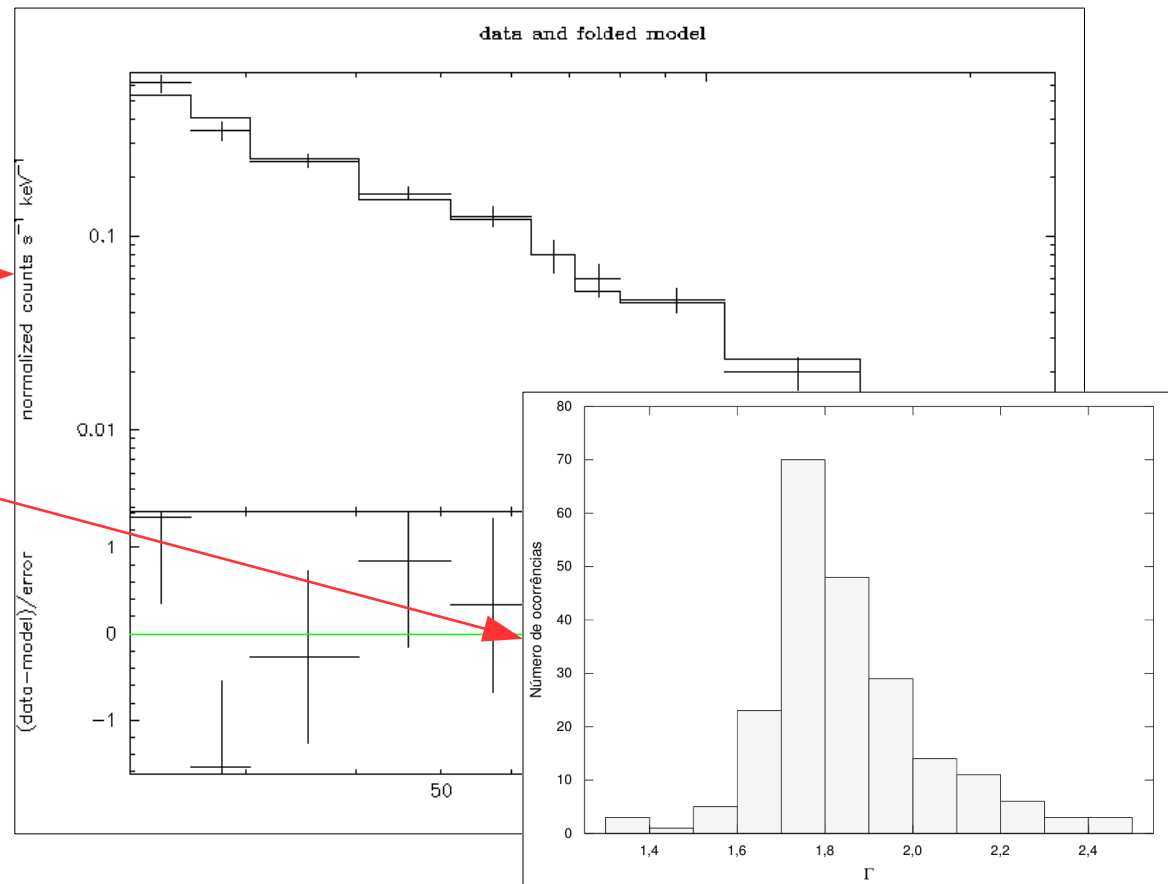
→ mais de 10 anos
→ 2005-2015



→ 2 telescópios imageadores em raios X duros
→ ISGRI: 20-200 keV (*INTEGRAL*)
→ BAT: 15-50 keV (*Swift*)

→ seleção baseada em análise espectral (ISGRI)
→ *low/hard*: Γ

→ medidas (*quase*) diárias (BAT)



ESTUDO DE 1E 1740.7-2942

THE ASTROPHYSICAL JOURNAL LETTERS, 843:L10 (4pp), 2017 July 1

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<https://doi.org/10.3847/2041-8213/aa7942>



Tandem *Swift* and *INTEGRAL* Data to Revisit the Orbital and Superorbital Periods of 1E 1740.7–2942

Paulo Eduardo Stecchini, Manuel Castro, Francisco Jablonski, Flavio D’Amico, and João Braga

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Received 2017 May 4; revised 2017 May 30; accepted 2017 June 7; published 2017 June 30

Abstract

The black hole candidate 1E 1740.7–2942 is one of the strongest hard X-ray sources in the Galactic Center region. No counterparts in longer wavelengths have been identified for this object yet. The presence of characteristic timing signatures in the flux history of X-ray sources has been shown to be an important diagnostic tool for the properties of these systems. Using simultaneous data from NASA’s *Swift* and ESA’s *INTEGRAL* missions, we have found two periodic signatures at 12.61 ± 0.06 days and 171.1 ± 3.0 days in long-term hard X-ray light curves of 1E 1740.7–2942. We interpret those as the orbital and superorbital periods of the object, respectively. The reported orbital period is in good agreement with previous studies of 1E 1740.7–2942 using NASA’s *RXTE* data. We present here the first firm evidence of a superorbital period for 1E 1740.7–2942, which has important implications for the nature of the binary system.

Key words: stars: individual (1E 1740.7-2942) – X-rays: binaries

Supporting material: data behind figure

ESTUDO DE 1E 1740.7-2942

→ Candidato a **buraco negro** - similaridades com Cyg X-1 (Sunyaev et al., 1991)

→ Microquasar - jatos em rádio (Mirabel et al., 1992)

→ Brilhante em raios X duros - mais brilhante que o sistema binário

impede que a função de massa do sistema seja conhecida!

$$f = \frac{M_2^3 \sin^3 i}{(M_1 + M_2)^2} = \frac{P_{\text{orb}} K^3}{2\pi G}$$

→ Maior parte do tempo no estado **low/hard** de emissão (del Santo et al., 2005)

→ Espectros em raios X duros bem descrito por modelos de comptonização (Castro et al., 2014)

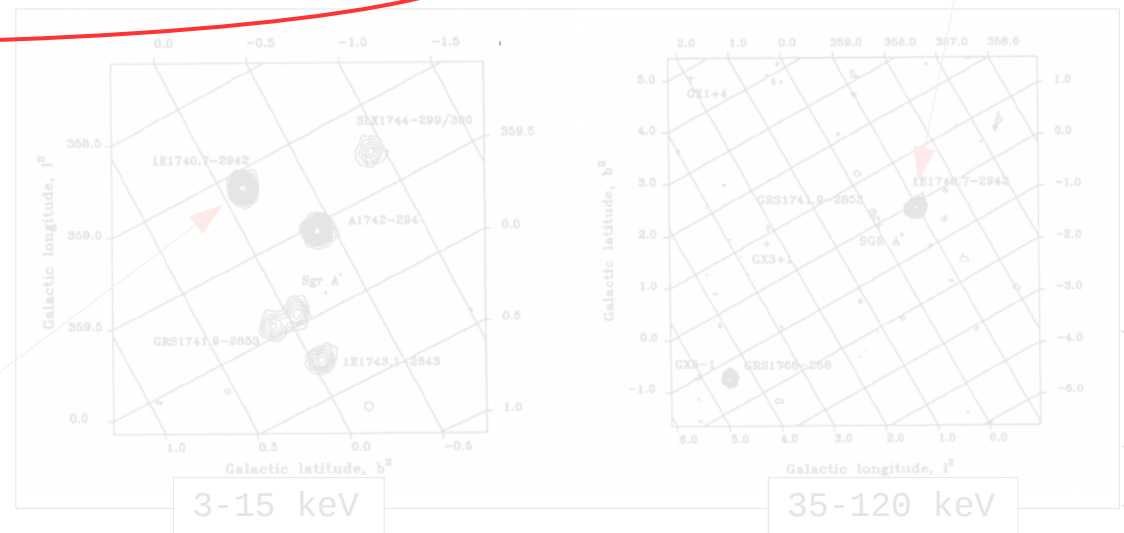
→ Lei de potência $1.4 < \Gamma < 2.1$ (Remillard & McClintock, 2006)

→ **Contrapartida no óptico/infravermelho não confirmada**

→ Estudo temporal (Smith et al., 2002)

→ ~12,73 dias

→ Período orbital?



ESTUDO DE 1E 1740.7-2942

THE ASTROPHYSICAL JOURNAL LETTERS, 821:L6 (6pp), 2016 April 10
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doi:10.3847/2041-8205/821/1/L6



NuSTAR AND *SWIFT* OBSERVATIONS OF THE VERY HIGH STATE IN GX 339-4: **WEIGHING THE BLACK HOLE WITH X-RAYS**

M. L. PARKER¹, J. A. TOMSICK², J. A. KENNEA³, J. M. MILLER⁴, F. A. HARRISON⁵, D. BARRET⁶, S. E. BOGGS², F. E. CHRISTENSEN⁷,
W. W. CRAIG^{2,8}, A. C. FABIAN¹, F. FÜRST⁵, V. GRINBERG⁹, C. J. HAILEY¹⁰, P. ROMANO¹¹, D. STERN¹²,
D. J. WALTON¹², AND W. W. ZHANG¹³

- **Continuum-Fitting Method**

Modelo que descreve o espectro térmico de um disco de acreção em volta de um buraco negro de Kerr (c/ rotação)

Depende de: M , \dot{M} , D , i e a_*

- **Spectroscopy Reflection Method (or Iron line Method)**

Estudo do espectro de reflexão e da linha do ferro (6,4 keV)

Independente de M e D e pode inferir diretamente i e a_*

APENAS RAIOS X

$$9.0_{-1.2}^{+1.6} M_{\odot}$$
$$8.4 \pm 0.9 \text{ kpc}$$

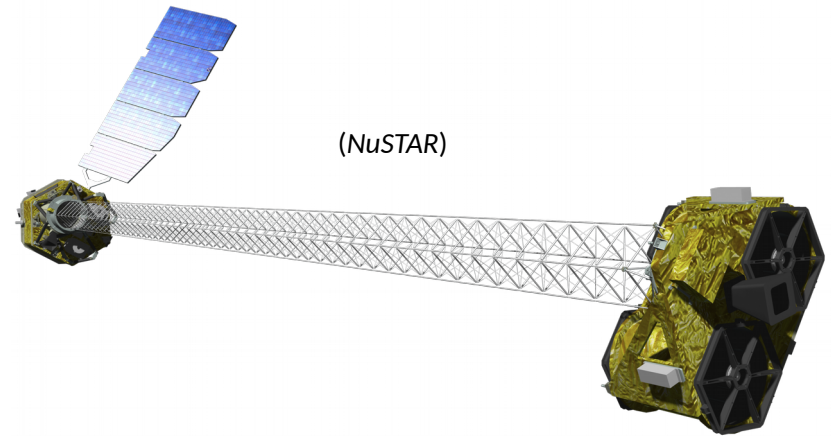
Mas já se sabia que:

$$M > 5.8 M_{\odot}$$
$$d > 7 \text{ kpc}$$

+ medidas independentes de i , a_* , etc

ESTUDO DE 1E 1740.7-2942

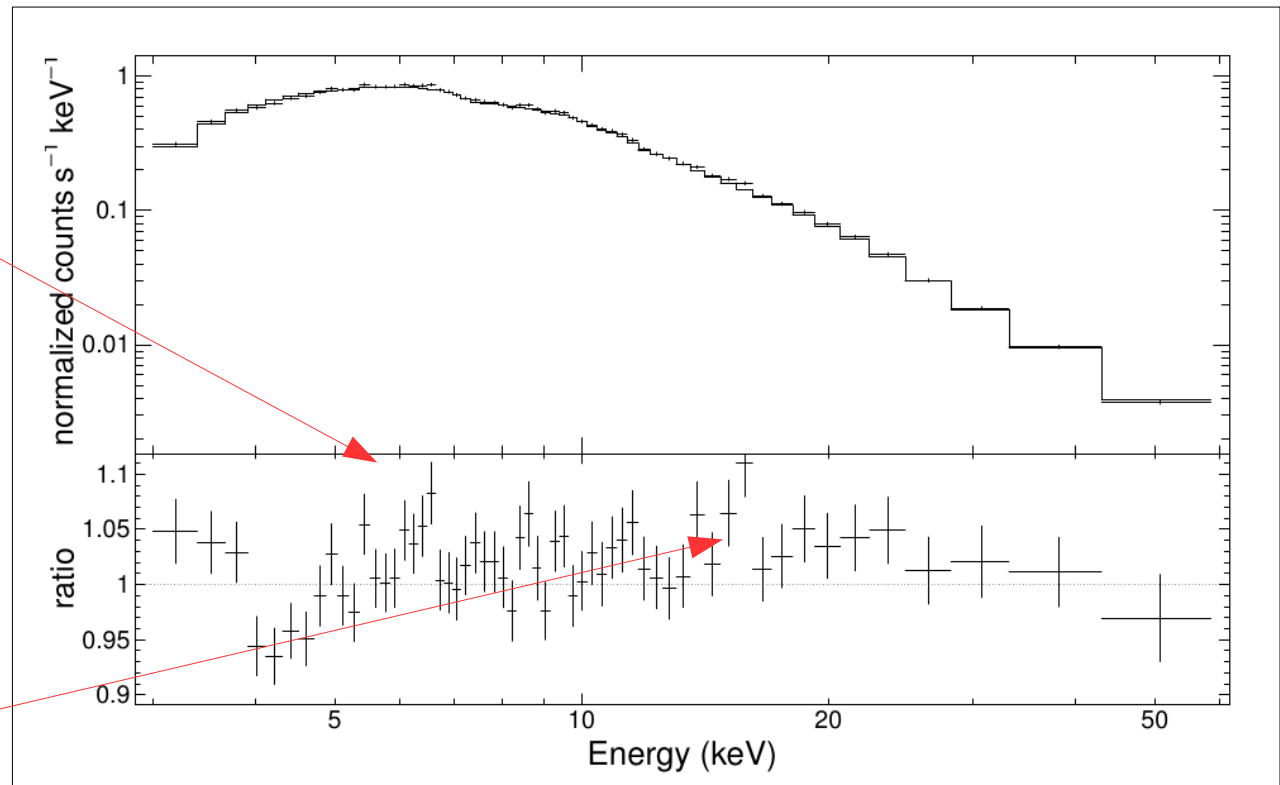
- observação do *NuSTAR* (~3 - 70 keV)
- não estudada ainda
- componente de reflexão



linha em 6,4 keV

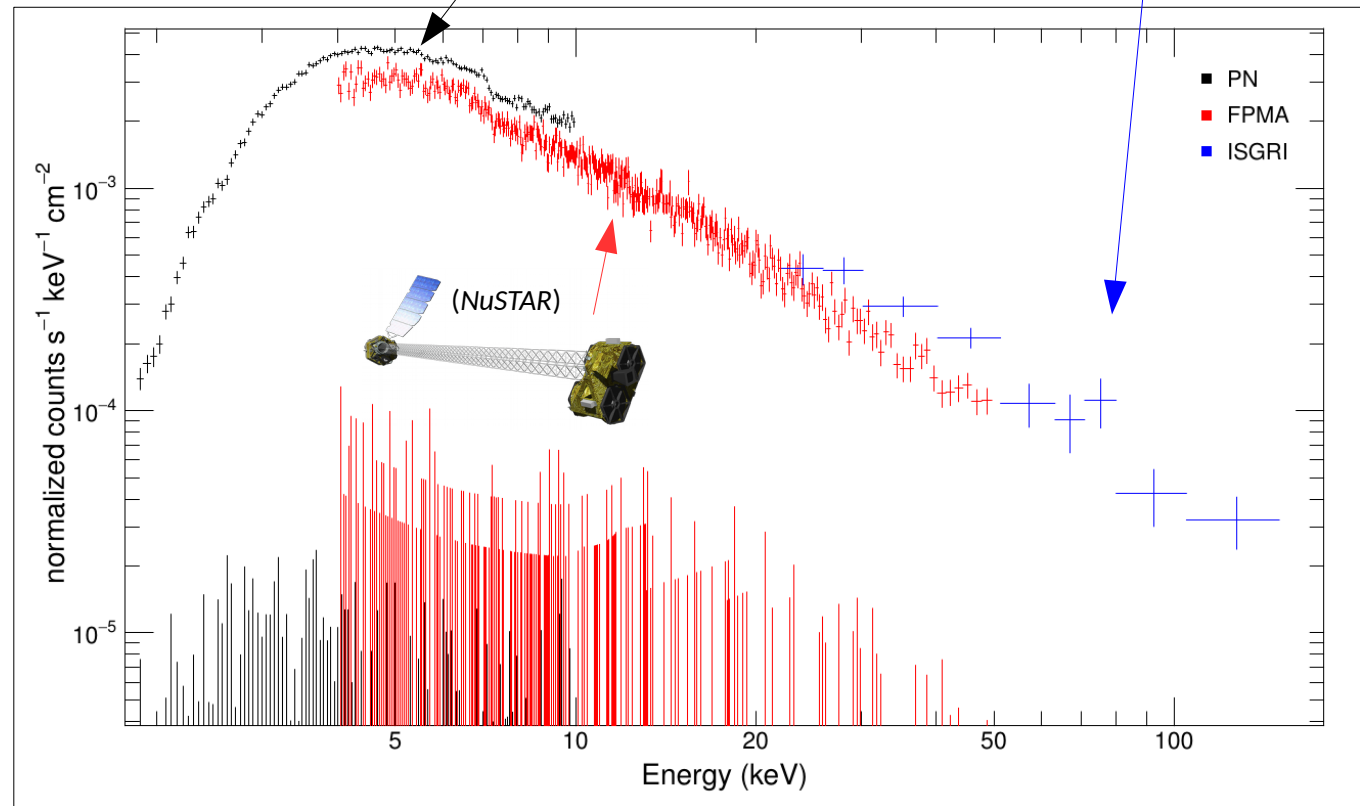
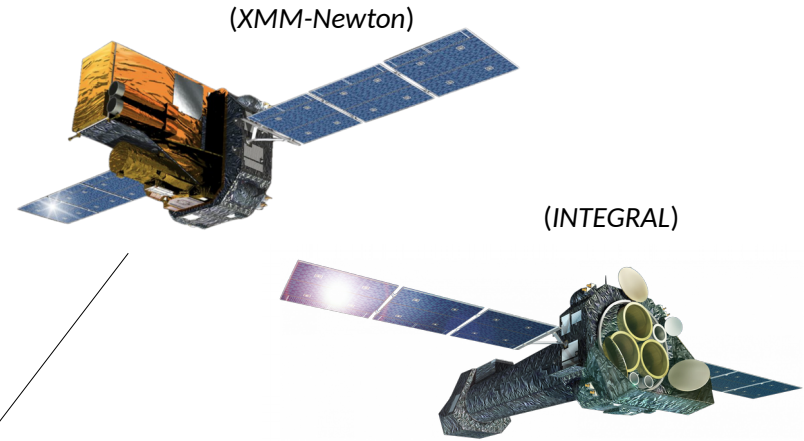


Compton hump



ESTUDO DE 1E 1740.7-2942

- *XMM-Newton* + *INTEGRAL*
- não contemporâneas
- Γ similares
- mesmo estado espectral
- ajuste simultâneo



- *XMM-Newton*
- espectro do disco
- *INTEGRAL*
- composição do espectro hard
- Cobertura total: 2-200 keV

ESTUDO DE 1E 1740.7-2942

- considerando uma distância de 8,5 kpc (Centro Galáctico)
- massa $\sim 4 M_{\text{sol}}$
- spin > 0.9
- inclinação $\sim 65-75^\circ$
- concorda com estudos dos jatos em rádio (Mirabel, 1992)

DRAFT VERSION MARCH 29, 2019
Preprint typeset using L^AT_EX style AASTeX6 v. 1.0

A $4 M_{\odot}$ BLACK HOLE IN 1E 1740.7–2942 BASED ON X-RAY SPECTRA WEIGHTING

PAULO EDUARDO STECCHINI, FLAVIO D'AMICO,
MANUEL CASTRO, AND JOÃO BRAGA
Instituto Nacional de Pesquisas Espaciais - INPE
Av. dos Astronautas 1758, 12227-010, S.J.Campos-SP, Brazil

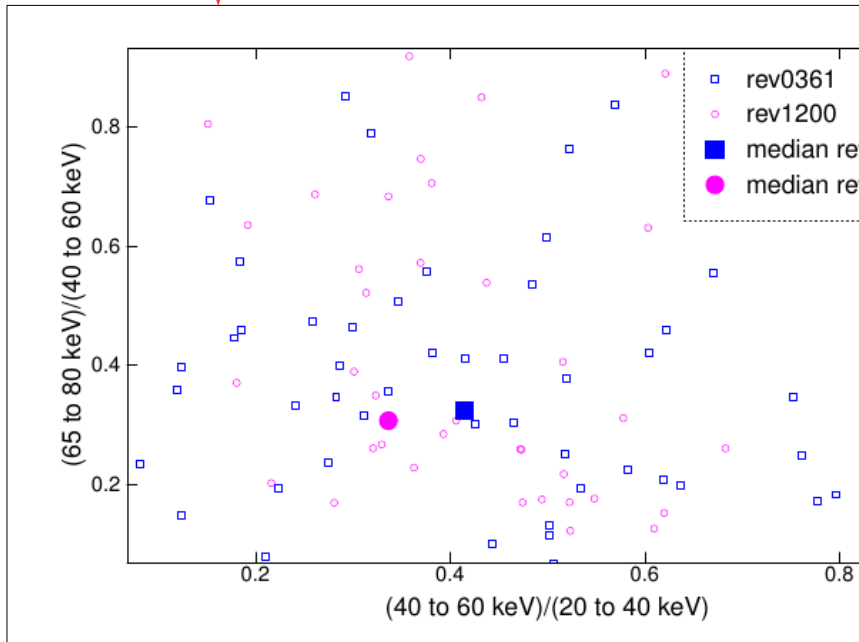
ABSTRACT

1E 1740.7–2942 is one of the strongest hard X-ray emitters around the Galactic Center region, believed to be a black hole and member of a high-mass X-ray binary system. The lack of any known counterpart

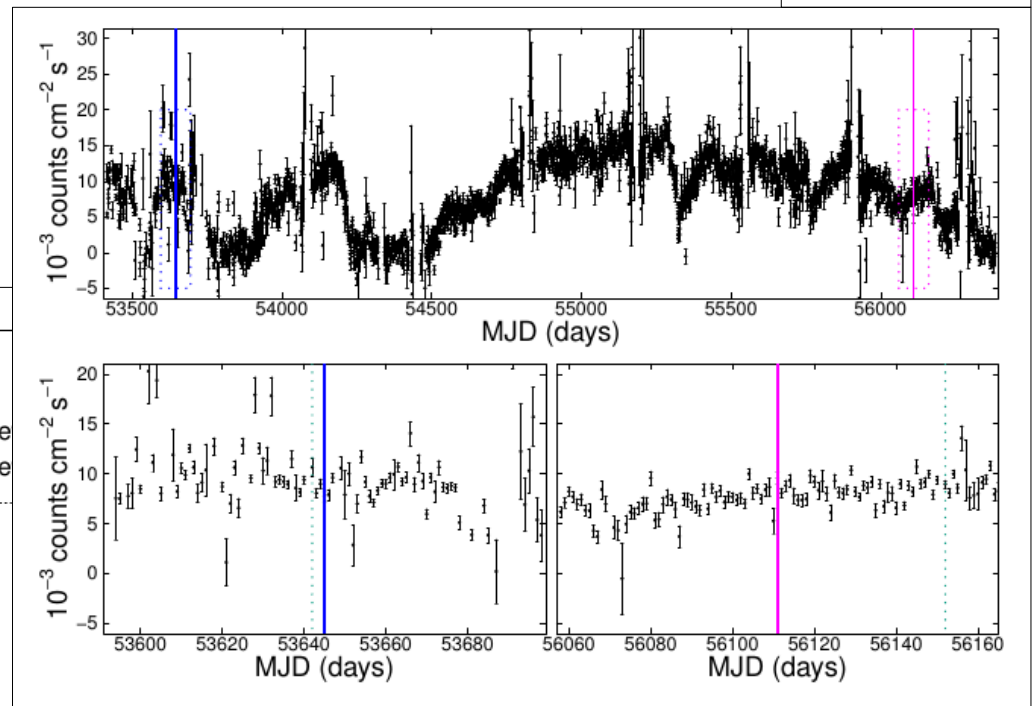
ESTUDO DE 1E 1740.7-2942

Telescope	Observation Date	Exposure Time (s)	Γ
XMM - PN	02/10/2005	16,040	1.77 ± 0.04
NuSTAR - FPMA	03/07/2012	10,970	1.76 ± 0.03
INTEGRAL - ISGRI	13/08/2012	9,332	1.79 ± 0.10

diagramas cor-cor



Swift - BAT



comparação dos fluxos nos dias das observações

ESTUDO DE 1E 1740.7-2942

Astron. Astrophys. 363, 184–187 (2000)

ASTRONOMY
AND
ASTROPHYSICS

Very Large Telescope

Research Note

VLT search for the infrared counterpart of 1E 1740.7–2942

J. Martí¹, I.F. Mirabel^{2,3}, S. Chaty⁴

THE ASTROPHYSICAL JOURNAL, 556:1–5, 2001 July 20
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Keck Telescope

DEEP INFRARED IMAGING OF THE MICROQUASARS 1E 1740–2942 AND GRS 1758–258¹

S. S. EIKENBERRY,^{2,3} W. J. FISCHER,^{2,4} E. EGAMI,³ AND S. G. DJORGOVSKI⁵

Received 2001 January 26; accepted 2001 March 27

ESTUDO DE 1E 1740.7-2942

Astron. Astrophys. 363, 184–187 (2000)

ASTRONOMY
AND
ASTROPHYSICS

Very Large Telescope

Research Note

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Keck Telescope

DEEP INFRARED IMAGING OF THE MICROQUASARS 1E 1740–2942 AND GRS 1758–258¹

S. S. EIKENBERRY,^{2,3} W. J. FISCHER,^{2,4} E. EGAMI,³ AND S. G. DJORGOVSKI⁵

Received 2001 January 26; accepted 2001 March 27

- elaboramos um pedido de tempo para observar 1E 1740.7-2942 com o *Gemini South* e tentar identificar a contrapartida
- foi aceito!
- observação será no fim de abril
- primeira vez com **óptica adaptativa**



OBRIGADO!