Nucleosynthesis and Diffuse-Emission Studies with INTEGRAL

Assessment of AO-6 Plans, Status, Prospects

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AO-6

In the AO-6 six "Key Programme" observations (the Galactic Centre region, North Ecliptic Pole, Cygnus region, SMC and 47 Tuc, Vela cluster, and Galactic positron annihilation line) for a total of 12 Msec were included in this Call, and scientists were also invited to submit proposals for the data analysis of scientific targets located in these regions. A total number of 118 proposals (included in the 179 above), associated with the "Key Programmes", was received. These associated proposals do not require additional observatory time.

Proposals per category

In the following table we give the breakdown of number of proposals as a function of the proposal category. The numbers for proposals associated with the Key Programmes are given in brackets. Note that the numbers on requested observing times do include TOO proposals, but it has been assumed here, that a typical TOO proposal requests about 10% of its total observing time as entered into PGT from all the candidate sources included in a TOO proposal. Further analysis may modify this assumption but the impact on the overall results should not be large.

Category	Number of proposals	Requested observing time (Ms)	Oversubscription	% (# of proposals)	% (requested time)
Compact galactic objects	30 (71)	18.1 (-)	1.78 (-)	49.2	32.1
Extragalactic objects	20 (21)	30.3 (-)	2.97 (-)	32.8	53.7
Nucleosynthesis	3 (8)	1.0 (-)	0.10 (-)	4.9	1.8
Miscellany	8 (18)	7.0 (-)	0.69 (-)	13.1	12.5
Total requests for observing time	61	56.4	5.54	100	100
Total associated with KP	118	(-)	(-)	(-)	(-)
Total	**179**	**56.4**	**5.54**	**100**	**100**

Numbers for proposals associated with the Key Programmes, not requesting observing time, are given in brackets.

The Time Allocation Committee, whose purpose is to peer review all proposals and recommend a scientific observing programme to ESA, will meet from May 19 to May 22 at ESAC. Following this meeting, ESA will announce the approved programme for AO-6, which will begin on August 16, 2008.

Nucleosynthesis Studies with INTEGRAL

- **Science Goals**
  - ☆ Understand Positron Annihilation in the Galaxy
  - ☆ Understand and Use Galactic ^{26}Al Radioactivity
  - ☆ Probe Supernova Explosion Mechanism through ^{44}Ti
  - ☆ Constrain Massiv-Star Interiors through ^{60}Fe/^{26}Al Ratio
  - ☆ Be Ready for Supernova Ia Diagnostics through ^{56}Ni
  - ☆ Search for Nova Radioactivity, Line Transients, ... the unknown

- **Science Prospects**
  - ☆ INTEGRAL's Database for the Galaxy will be Unique (~COMPTEL)
  - ☆ SPI will Remain the Best-Ever Spectrometer
  - ☆ Future Missions Could Best Advance Specific-Source Constraints

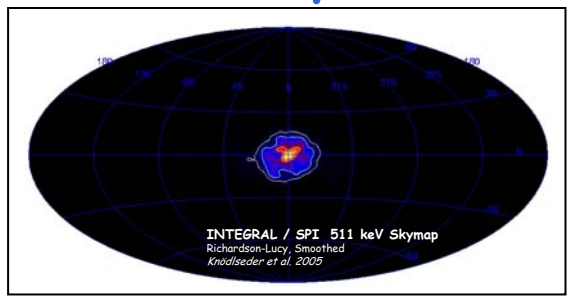
Achievements and Challenges, in more Detail

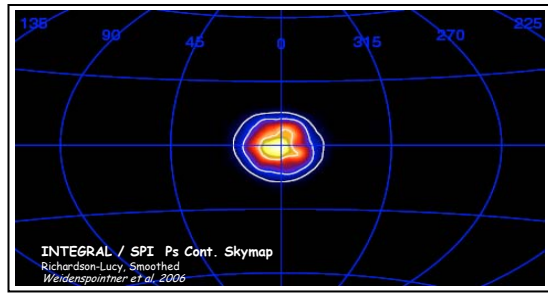
- **Positron Annihilation Emission**

☆ Is the Bright Bulge-Like Emission Symmetric and Centered?

☞ SgrA*, or Source Populations, or Dark-Matter Annihilations?

☞ Check at Intermediate Latitudes!

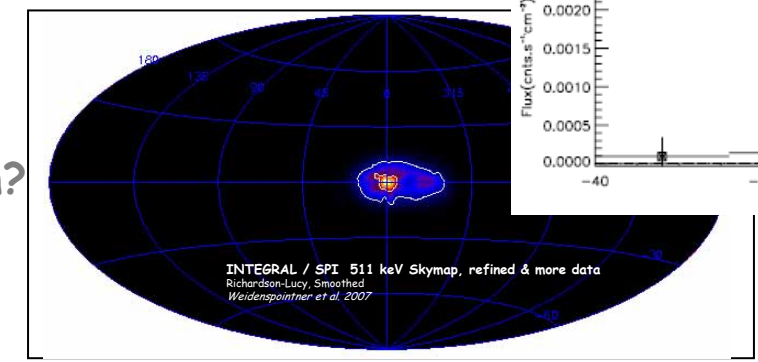


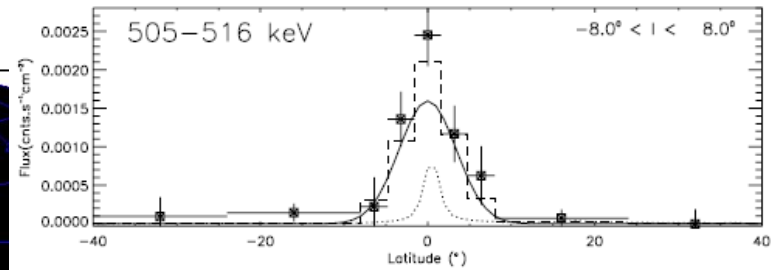


☆ What are Parameters of the Disk Emission?

☞ Asymmetric? →LMXB as main sources?

☞ Latitude Profile? →DM contribution?

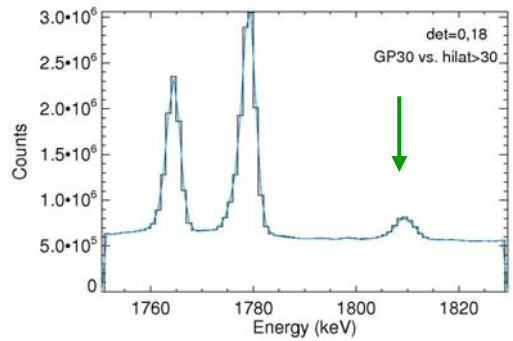


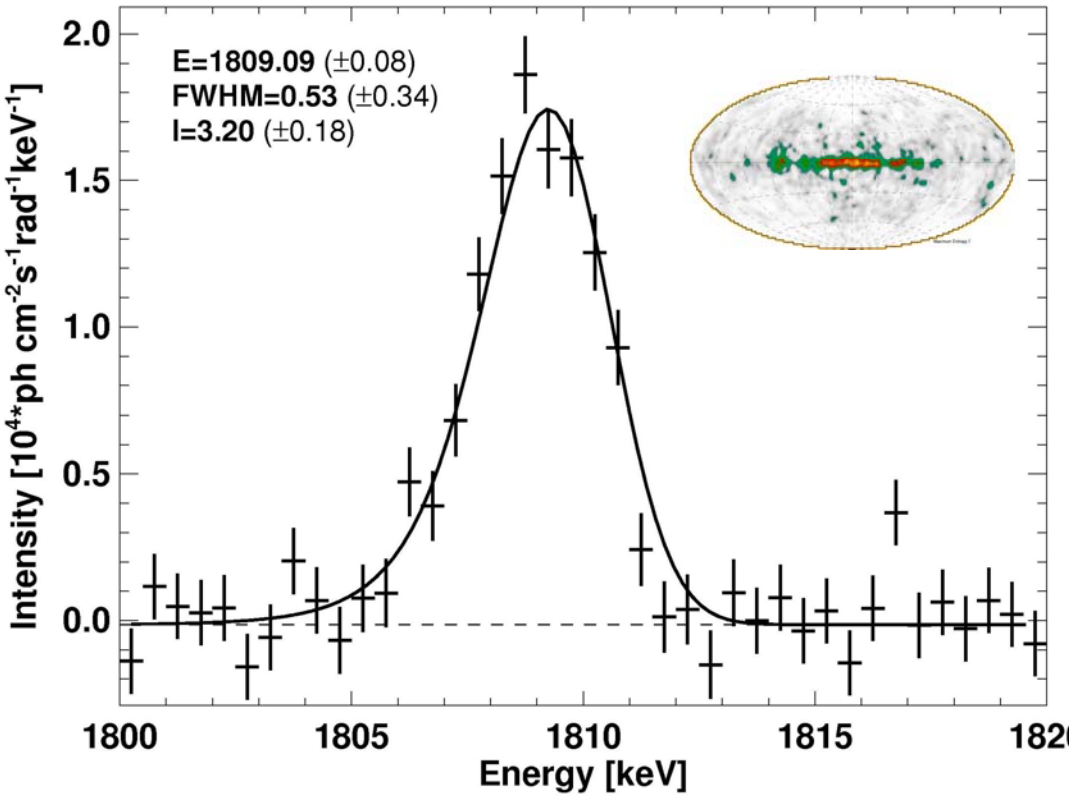


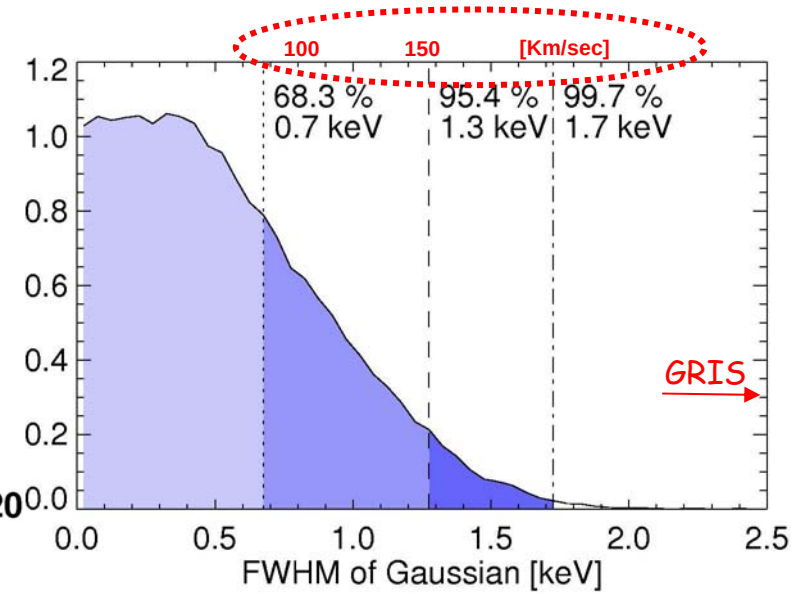
☞ Check in Diffent Galactic-Plane Regions!

Science Result: ^{26}Al

☆ **SPI High-Resolution Spectroscopy Pushed the Velocity Contraints Towards the Astrophysically-Meaningful ISM Velocity Range**



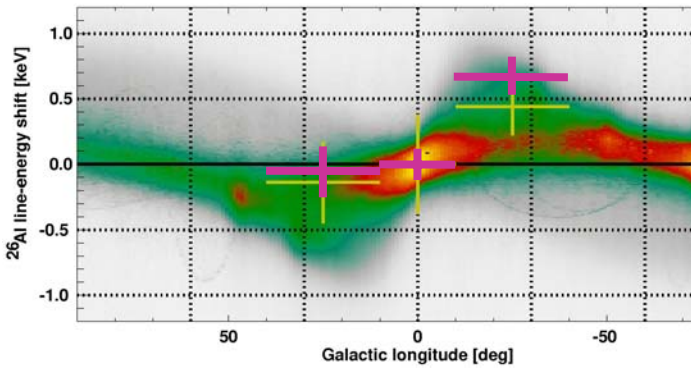


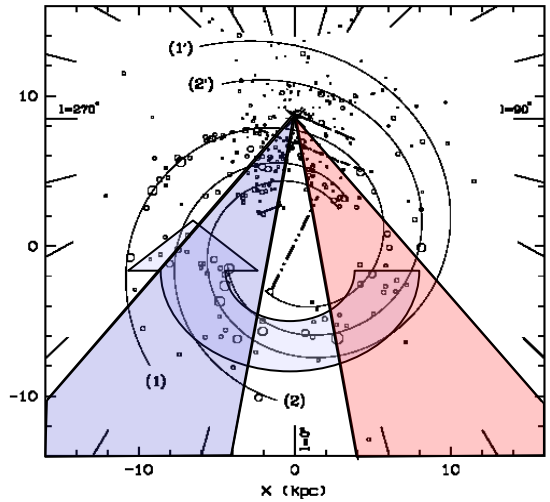


-> Data up to mid 2006; W.Wang et al., in prep.
Line Width Probability Distribution by K.Kretschmer

Achievements and Challenges, in more Detail

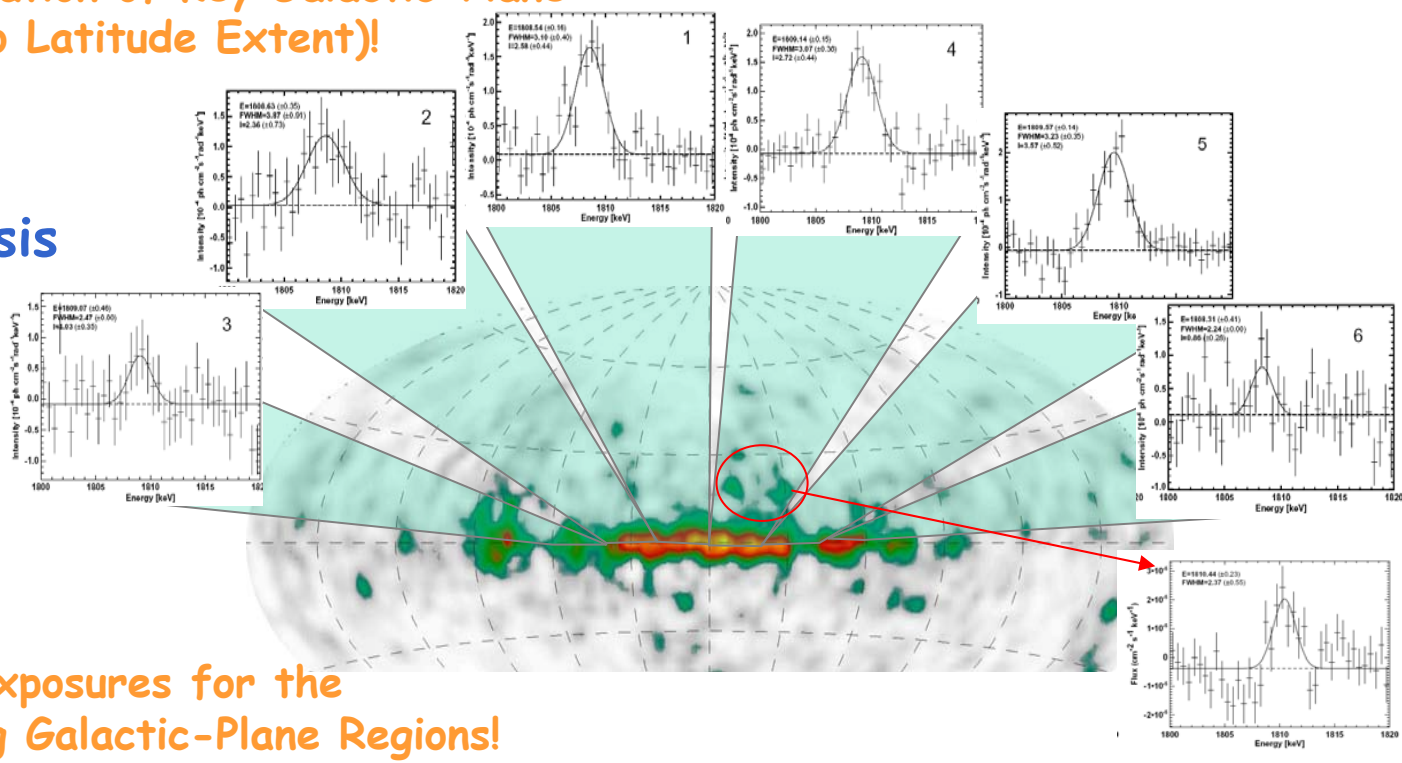
- ^{26}Al Emission
  - ☆ Peculiar Dynamics in the inner Galaxy?



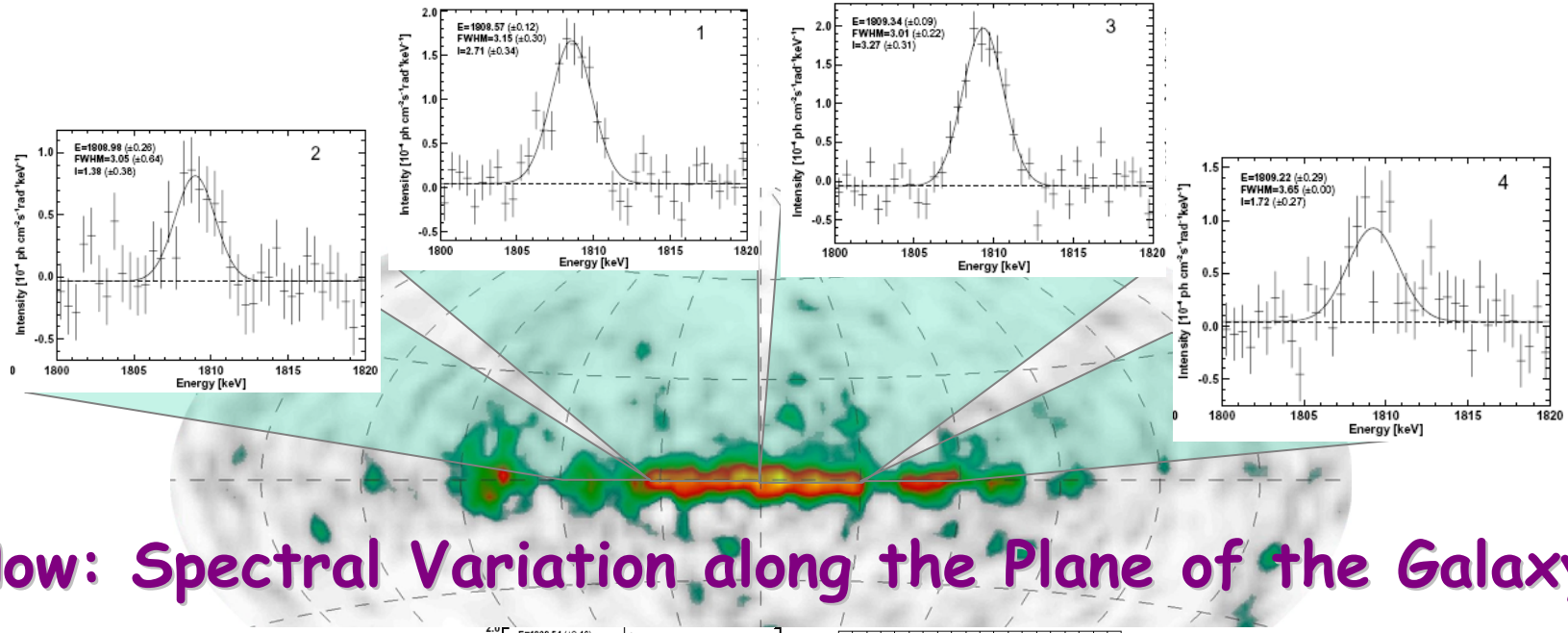


☞ Deep Exploration of Key Galactic-Plane Regions (also Latitude Extent)!

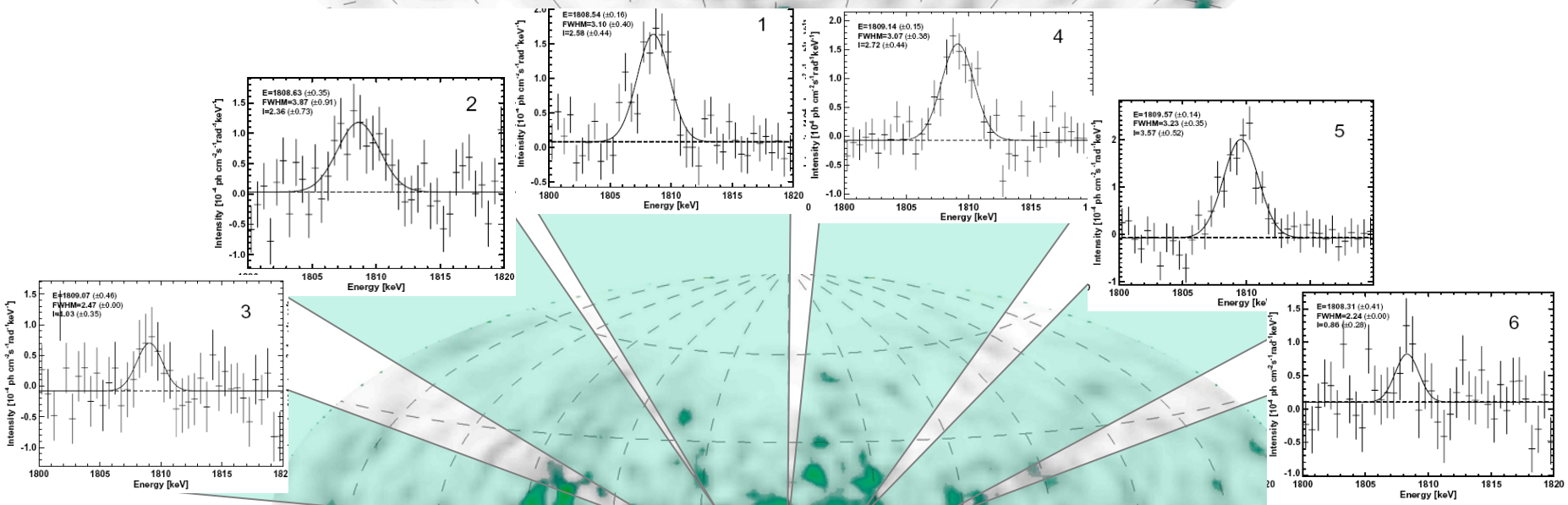
- ☆ A Window to Active Nucleosynthesis Regions in the Galaxy?



☞ Sufficient Exposures for the ^{26}Al-emitting Galactic-Plane Regions!

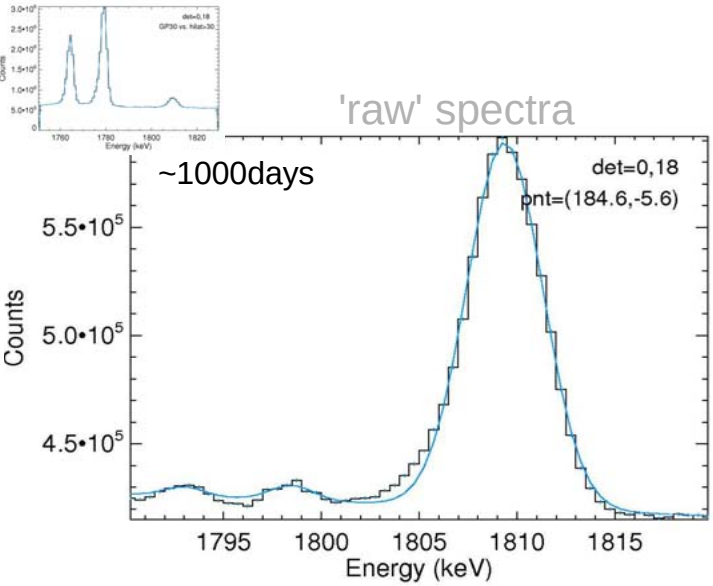


Now: Spectral Variation along the Plane of the Galaxy



☆ Spatially-Resolved ^{26}Al Signals are Weak (again)

Contaminations from Underlying or Nearby Instrumental Lines?



SPI Instrumental Bgd Paper:
(Weidenspointner et al. 2003)

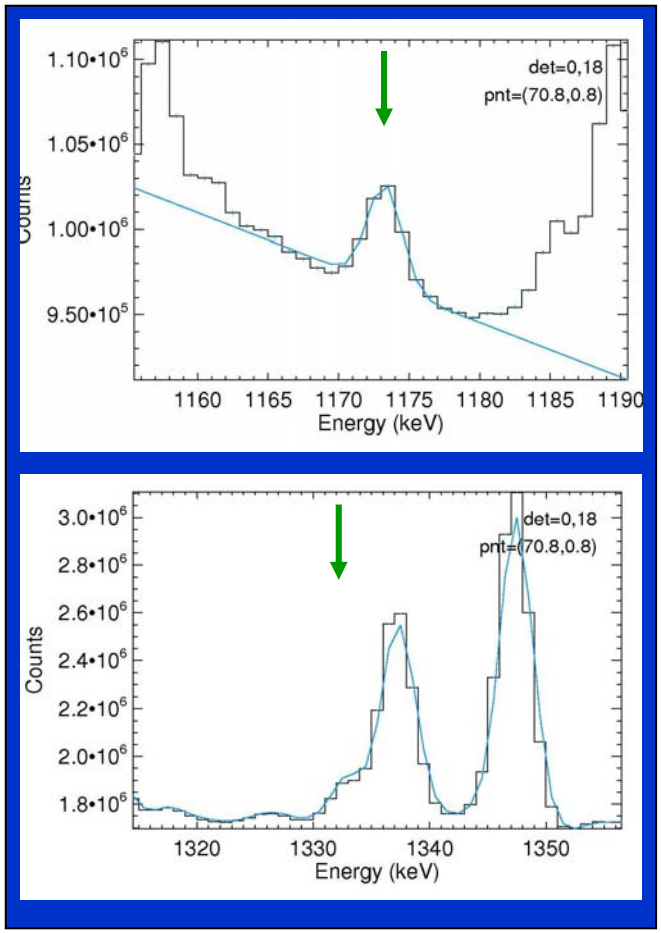
1778.961(8)	0.365(4)	^{28}Al(β^-)^{28}Si	1778.969(12)	blend
1805.8(3)	0.007(1)	?	?	blend
1808.7(1)	0.029(2)	^{26}Na(β^-)^{26}Mg	1808.66(3)	blend
		^{26}Mg*	1808.66(3)	blend
1810.9(2)	0.017(2)	^{56}Mn(β^-)^{56}Fe	1810.772(17)	blend

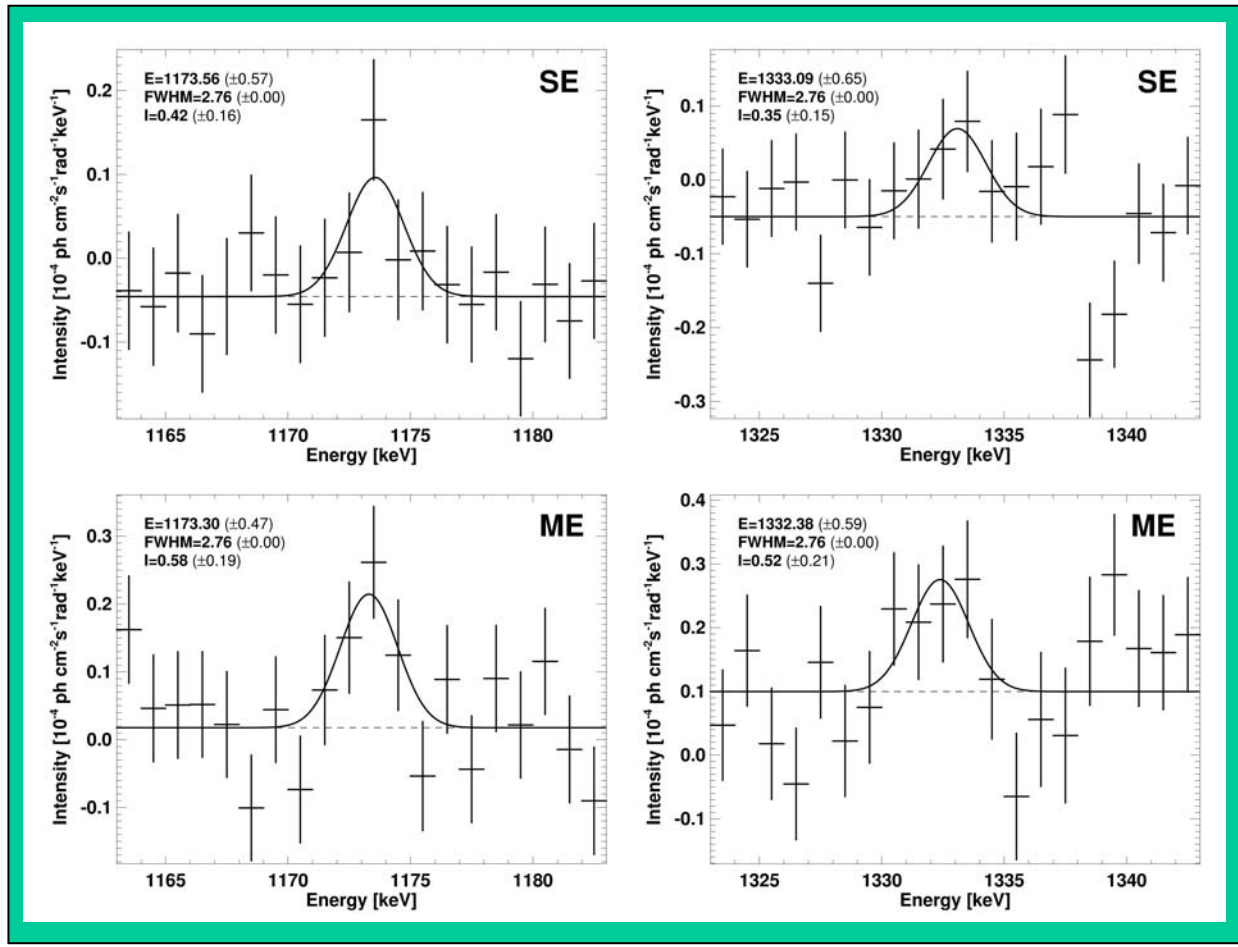
1792.63 6	0.017 5	ε+β+	1808.65 7	99.76 4	ε+β+
1792.63 22	0.0480 16	β-	1808.7 5	0.087 17	ε+β+
1793.0 5	0.062 11	β-			
1793 3	0.07 3	ε+β+			
1793.0 2	0.124 25	ε+β+			
1793.0 4	0.71 14	β-			
1793.1 4	0.013 6	ε+β+			
1793.10 20	0.22 4	ε+β+			
1793.1 3	4.6 6	ε+β+			
1793.12 7	0.11 5	β-			
1793.12 7	0.618 25	β-			
1793.17 15	0.20	ε+β+			
1793.2 5	1.10 14	ε+β+			
1793.21 7	2.61 17	ε+β+			
1793.24 10	0.043 7	ε+β+			
1793.25 25	0.0126 18	ε+β+			
1793.3 3	0.035 14	β-			

1808.98 8	1.32 15	ε+β+	18.9 m 3	^{67}Ge
1809	0.00024 19	β-	4.44 h 2	^{105}Ru
1809.0 4	0.023 5	ε+β+	55.5 m 4	^{105}Cd
1809.0	~0.24	ε+β+	1.83 m 6	^{147m}Tb
1809.0 3	2.5 2*	ε+β+	5.04 m 16	^{197m}Bi
1809.04 10	0.00369 8	β-	1.17 m 3	^{234m}Pa
1809.2 3	0.102 8	β-	24.94 s 6	^{141}Cs
1809.2 4	0.18 5	β-	3.1 m 3	^{190}Re
1809.2 3	0.32 6	β-	0.78 s 1	^{121}Ag
1809.30 14	2.05 10	β-	6.49 s 7	^{138}I
1809.42 22	0.0113 19	ε+β+	6.70 d 3	^{172}Lu
1809.5 3	0.400 22	ε+β+	3.204 s 7	^{58}Cu
1809.5 4	0.48 7	ε+β+	3.14 m 3	^{164}Lu
1809.50 15	0.795 23	ε+β+	2.012 d 20	^{170}Lu
1809.50 9	1.70 18	β-	2.10 s 2	^{123}Cd
1809.6 4	0.020 5	ε+β+	59.7 s 6	^{93}Ru
1809.7 3	0.53 7	ε+β+	21.1 s 2	^{149}Ho
1809.8 6	0.098 20	ε+β+	17.5 h 1	^{152}Tb
1809.8 3	2.7 4	ε+β+	4.17 s 10	^{151}Tm
1809.9 3	0.00040 10	β-	17.005 h 4	^{188}Re
1809.9 3	0.34 3	ε+β+	41.5 h 5	^{188}Ir
1810.0 2	0.0070 5	ε+β+	3.66 m 2	^{128}Cs
1810.0 2	0.043 5	ε+β+	5.41 h 5	^{209}At
1810.1 4	0.5 2*	ε+β+	36.1 s 3	^{160}Lu
1810.1 2	2.01 24	β-	2.3 s 1	^{101}Zr
1810.20 18	0.038 5	β-	11.30 h 1	^{77}Ge
1810.4 2	1.566 24	ε+β+	12.0 m 5	^{194}Pb
1810.5 6	0.041 14	β-	2.68 h 2	^{150}Pm
1810.5 4	0.14 9	β-	7.52 m 8	^{152m}Pm
1810.6 5	0.019 6	ε+β+	7.70 h 3	^{166}Tm
1810.6 2	0.062 9	ε+β+	4.118 h 25	^{149}Tb
1810.64 13	0.024 4	ε+β+	34.06 h 5	^{169}Lu
1810.7 5	0.149 14	ε+β+	42.8 m 10	^{190}Au
1810.7 5	0.149 14	ε+β+	42.8 m 10	^{190}Au
1810.7 1	0.172 16	β-	122 s 3	^{230}Ac
1810.7 10	5.9 3	β-	4.35 m 7	^{102m}Tc
1810.73 20	0.141 16	β-	3.15 m 4	^{89}Kr
1810.772 17	0.640 10	ε+β+	77.27 d 3	^{56}Co
1810.772 17	27.2 8	β-	2.5785 h 2	^{56}Mn
1810.9 1	0.080 5	β-	12.44 m 7	^{151}Nd

- **What are the Origins of Lines?**
  - ☆ **We care, because of characteristic time variations, e.g. after belt passages**
    - ☞ This example: 19 Detectors fitted with 3 Gaussians & Exponential:
      - 1793.0 keV 1.0 keV wide 21877 cnts
      - 1798.5 keV 1.1 keV wide 37829 cnts
      - 1809.4 keV 1.9 keV wide 1640280 cnts
  - ☆ **We are analyzing celestial ^{26}Al at**
    - **1808.65 keV, expecting ~300000 cnts**

Science Result: ^{60}Fe





☆ Marginal Result

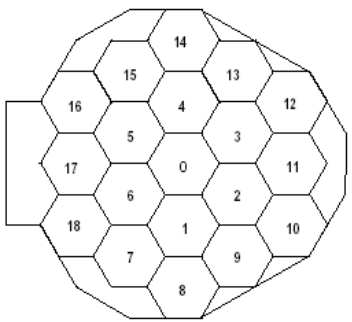
☞ Problematic Instrumental Lines

- **^{60}Co Buildup, 1337 keV Ge Line**

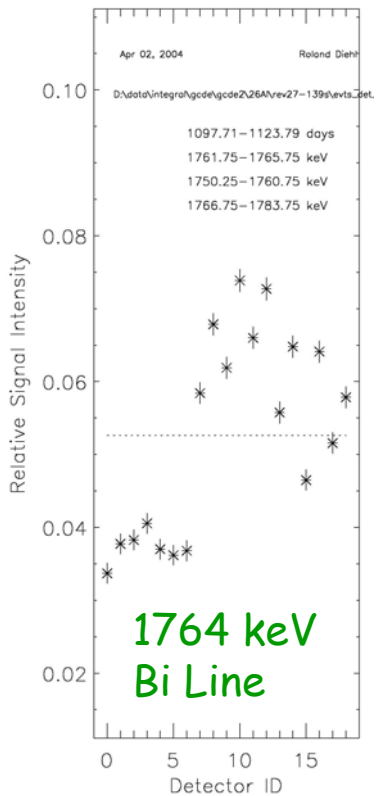
"Imaging" Bgd: Interior, or from Outside

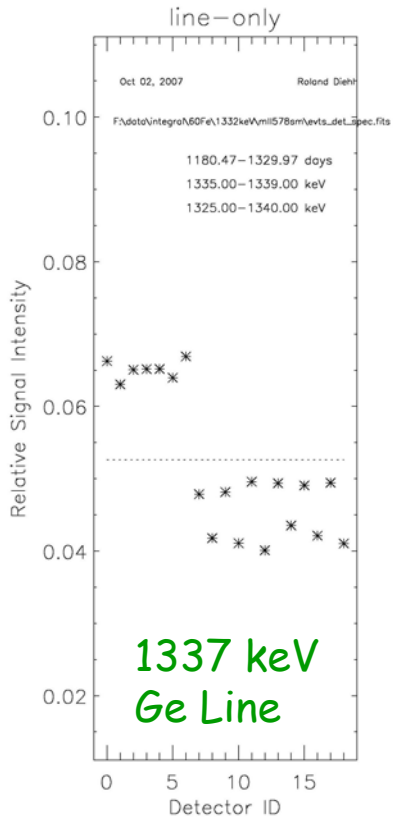
- **SPI 19-Ge Detector Arrangement within BGO Shield**
  - ☆ Use Relative Contributions to Signal per Detector
    - ☞ Homogeneous Irradiation & Performance <-> Equal Shares

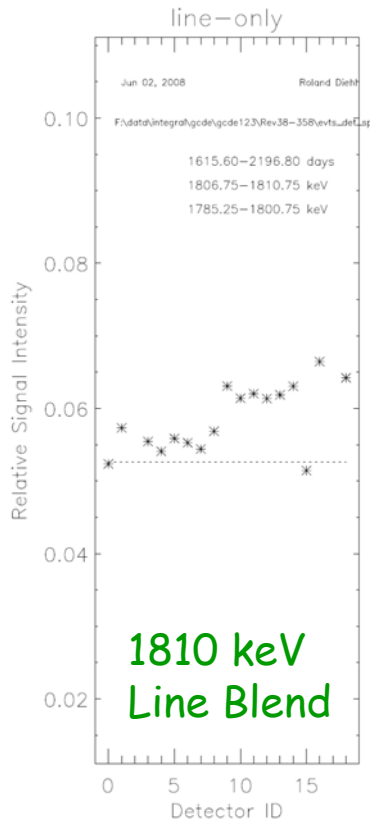
- ☆ **Hints for Location of Bgd Source**
  - ☞ Discriminate among Candidates



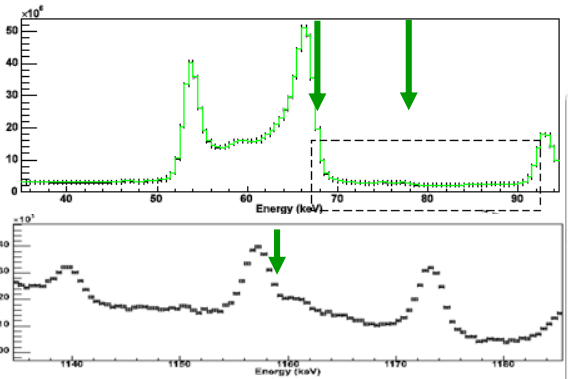
Top PA 1 array view

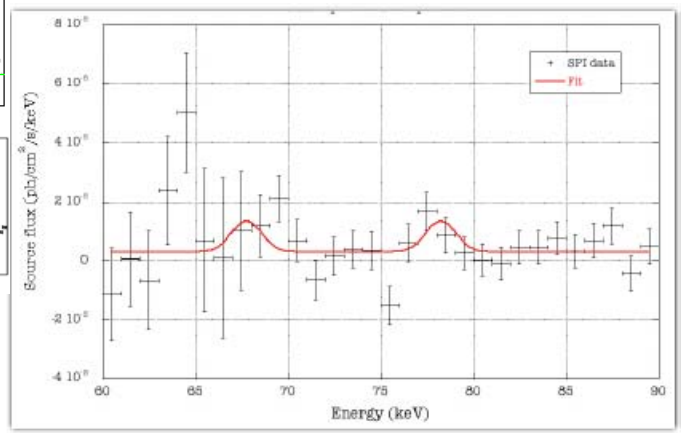


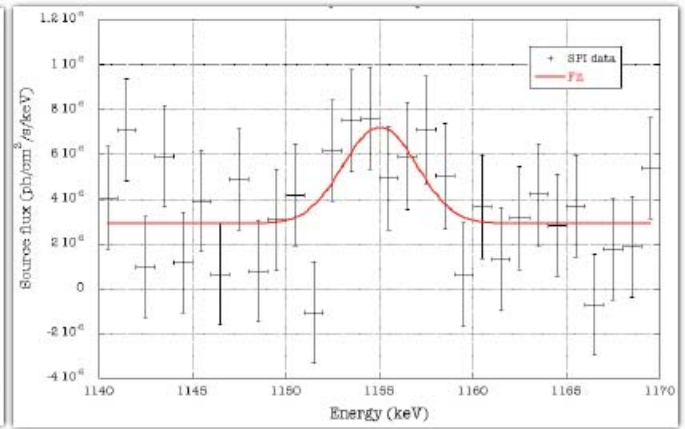




Science Result: ^{44}Ti from Cas A





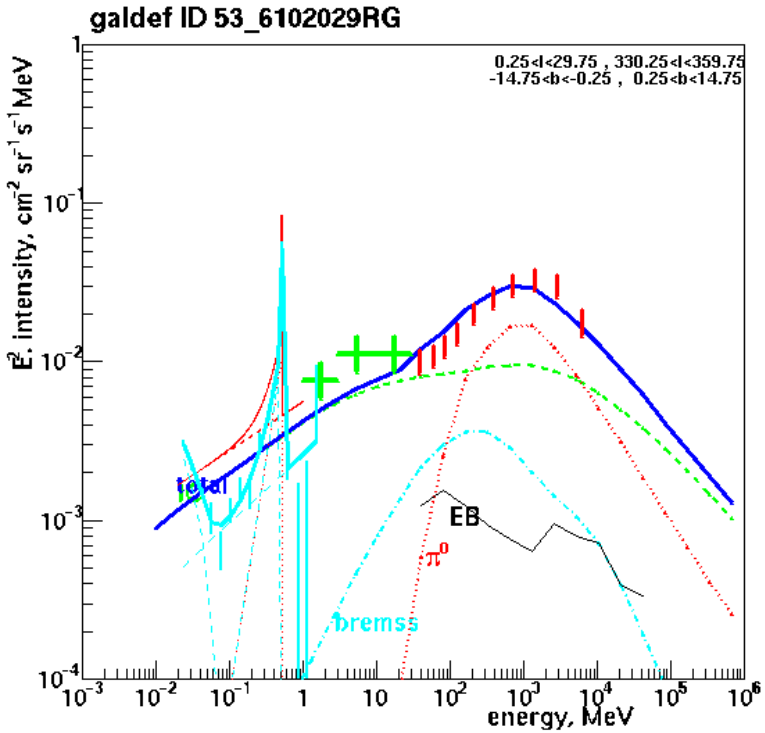


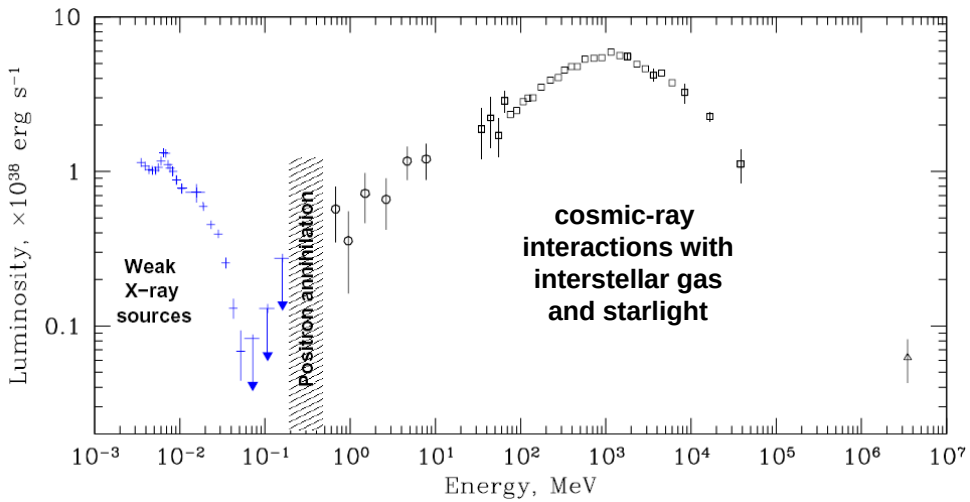
- Joint analysis of all lines with SPI (INTEGRAL's spectrometer)
- Total significance ~3 sigma
- Flux consistent with IBIS $(2.1\pm0.7)\times10^{-5}$ ph cm^{-2}s^{-1}
- Additional line broadening: 430±240 km/s
- Bulk velocity: 500±200 km/s (redshifted, like Fe-K?)
- I.e. ^{44}Ti is within reverse shock (i.e. cold/freely expanding)

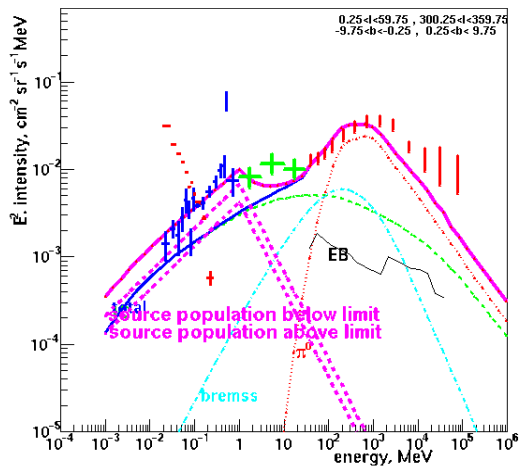
- **SNR Kinematics with γ-Ray Lines**
  - ☞ Internal Consistency Checks on Intensity, Systematics

Achievements: Galactic Ridge Emission

- ☆ Ridge Emission Decomposed into:
  - Identified Sources
  - + Unresolved Sources
  - + Diffuse Emission
    - ☞ Sources Dominate up to ~100 keV
      - IBIS Studies: Mostly Unresolved CV's and XRB
    - ☞ Diffuse/Unresolved Emission Dominating at >150 keV
      - Truly-Diffuse Emission Explains Measurements (SPI Range)
      - There May be an Unresolved Source Contributi (COMPTEL Range)

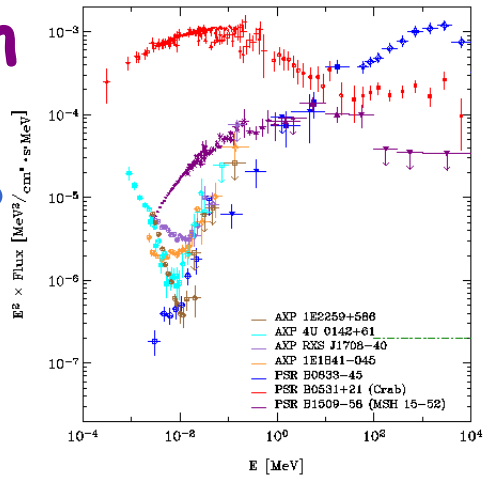


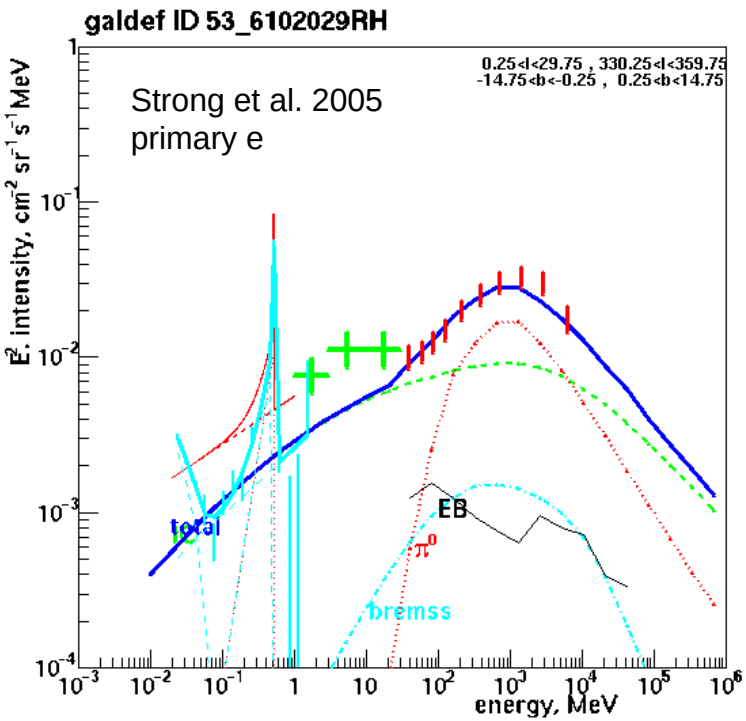


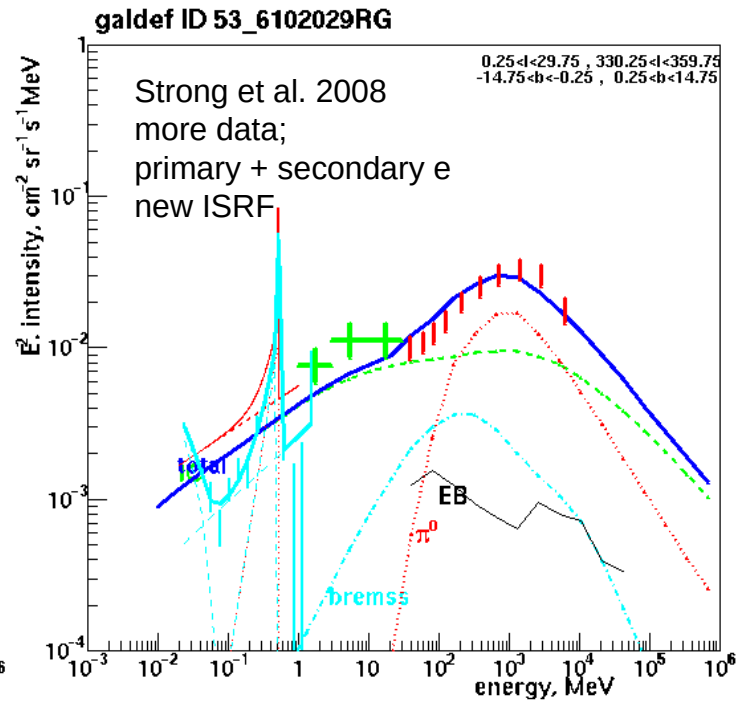


Achievements and Challenges, Diffuse Galactic Emission

- **Diffuse/Unresolved Ridge Emission**
  - ☆ Is there an unresolved-source component?
  - ☆ What is the proper ISRF and CR Spectrum?
    - ☞ see Porter et al. 2008 (new GALPROP)
  - ☆ Is the diffuse-emission model correct? (→Galactic Cosmic-Rays)
    - ☞ Test at a Variety of Galactic-Plane Regions!







Nucleosynthesis Studies with INTEGRAL

- Science Goals
  - ☆ Understand Positron Annihilation in the Galaxy
    - ☞ Imaging Survey in the Disk & Bulge 'Fringes'
    - ☞ Program Pursued OK
  - ☆ Understand and Use Galactic ^{26}Al Radioactivity
    - ☞ Deep Exposures of Star-Formation Regions
    - ☞ Program Pursued ~as Side Effect of Annihilation (?)
  - ☆ Probe Supernova Explosion Mechanism through ^{44}Ti
    - ☞ Deep Exposures of Cas A, (LMC?). Use GP Survey
    - ☞ Program Pursued ~ok
  - ☆ Constrain Massiv-Star Interiors through ^{60}Fe/^{26}Al Ratio
    - ☞ Galactic-Plance Surveys; Cygnus -> Different Regions
    - ☞ ~ok
  - ☆ Be Ready for Supernova Ia Diagnostics through ^{56}Ni
    - ☞ Hope
  - ☆ Search for Nova Radioactivity, Line Transients, ... the unknown
    - ☞ GP Survey; Hope

Diffuse Emission & Nucleosynthesis Studies

- Science Goals
  - ☆ Understand Galactic-Ridge Emission (Diffuse/Src) in Galaxy
  - ☆ Understand Positron Annihilation in the Galaxy
  - ☆ Understand and Use Galactic ^{26}Al Radioactivity
  - ☆ Probe Supernova Explosion Mechanism through ^{44}Ti
  - ☆ Constrain Massiv-Star Interiors through ^{60}Fe/^{26}Al Ratio
  - ☆ Be Ready for Supernova Ia Diagnostics through ^{56}Ni
  - ☆ Search for Nova Radioactivity, Line Transients, ... the unknown
- Next
  - ☆ Key Programmes Need **Good Complementarity**
    - ☞ Allow / Cater for Community Assessment of Best Plans
  - ☆ **Factors of ~2 are Important** for Most/All Goals
    - ☞ More Caution with "already observed", "not enough exposure" Rejections
  - ☆ **Prospects are Good**
    - ☞ Goals Benefit from Deepening of Exposures in Already-Interesting Fields
    - ☞ Replace Annual TAC by Bi-Annual KP Symposia?
      (open discussion & compromise)