

# A High Sensitivity Measurement of the $\gamma$ -Ray Spectrum of Cygnus X-1 Near 1 MeV

M. McConnell, D. Forrest, J. Ryan

*Space Science Center, University of New Hampshire, USA*

W. Collmar, V. Schönfelder, H. Steinle, A. Strong

*Max Planck Institut für Extraterrestrische Physik, Garching*

H. Bloemen, R. van Dijk, W. Hermsen

*SRON-Utrecht, Utrecht, The Netherlands*

K. Bennett, R. Much

*ESTEC, Noordwijk, The Netherlands*

## Analysis of COMPTEL Data

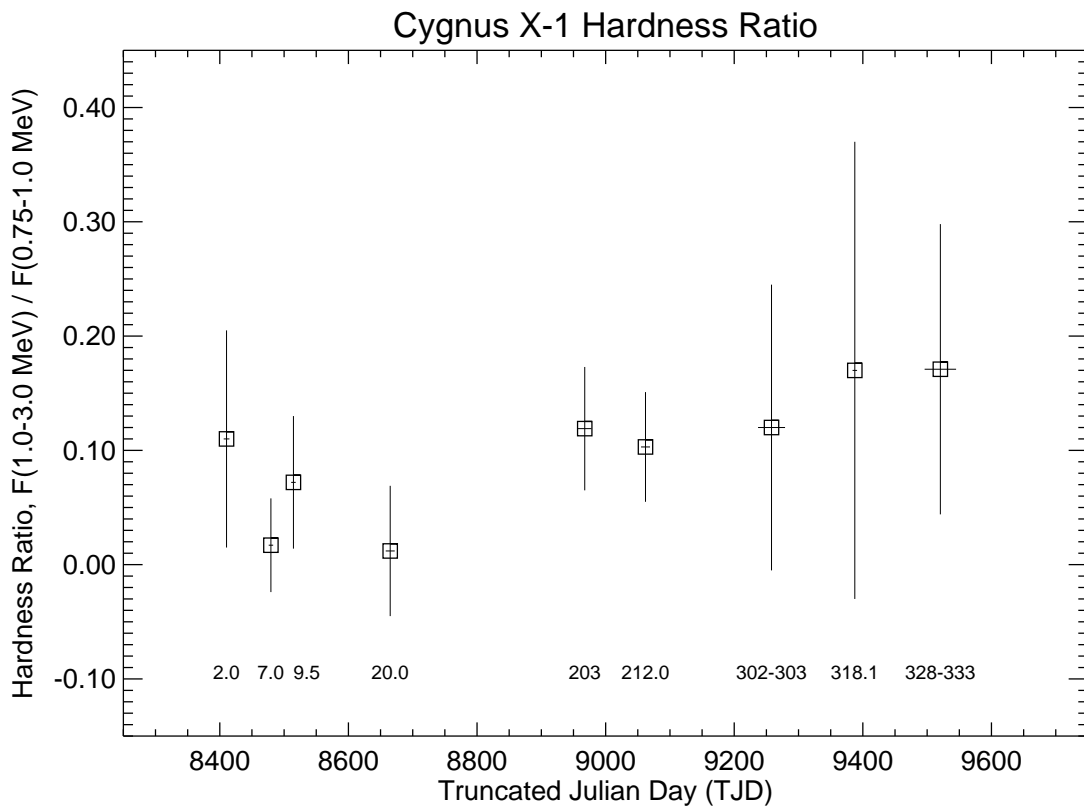
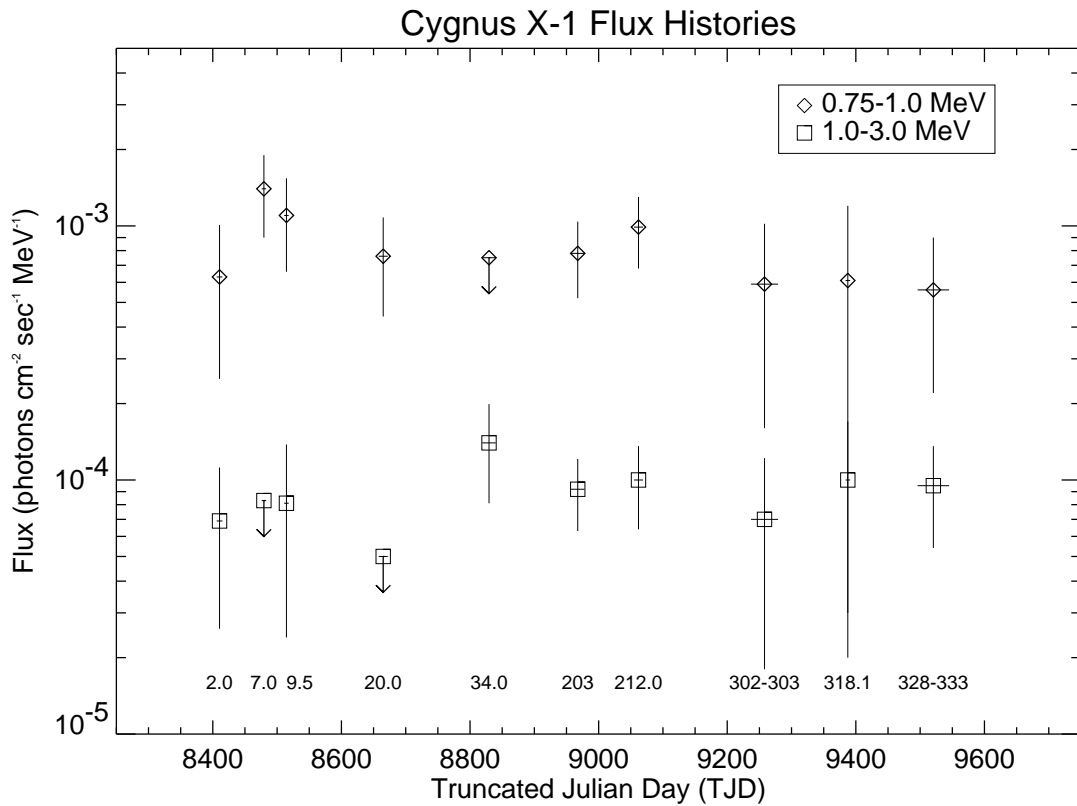
- The latest analysis includes all available data where Cyg X-1 lies within  $40^\circ$  of COMPTEL z-axis.
- The available statistics now permit a much more detailed spectral analysis.
- Maximum likelihood imaging for each energy interval gives flux values and associated errors.
- A PSF derived from a 200 keV Wien spectrum is used for imaging (although the results are relatively insensitive to the exact spectral form assumed for the PSF).
- An estimate of the diffuse galactic component ( $HI + CO$ ) is included in the background model. (The spectral results remain essentially unchanged without this background component.)
- The maximum likelihood maps for several energy intervals are shown in the following panels.

# COMPTEL Observations of Cyg X-1

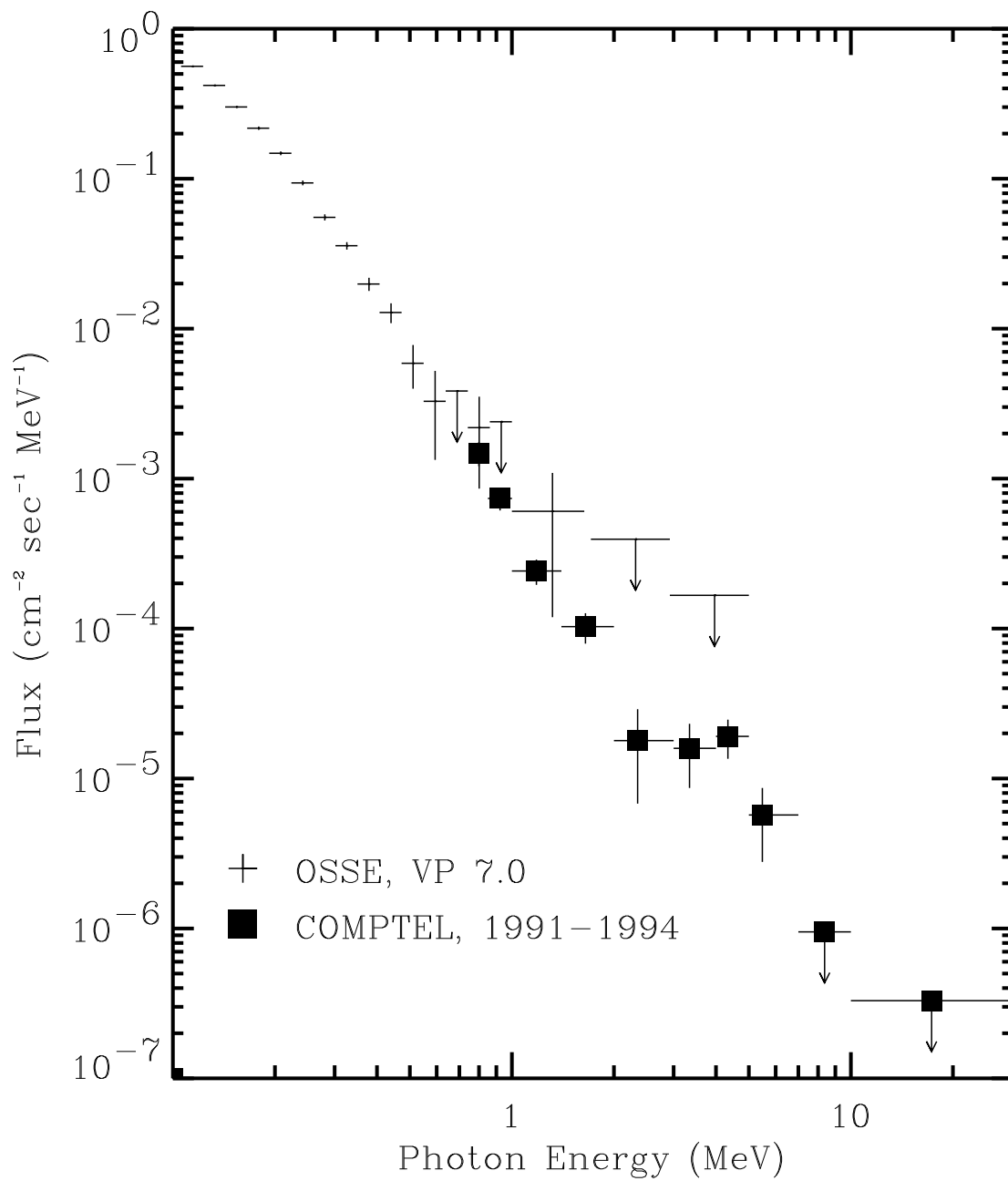
Viewing Period	Start Date	End Date	Viewing Angle	Effective Exposure <sup>a</sup>
2.0	30-May-1991	8-Jun-1991	1.7°	3.65
7.0	8-Aug-1991	15-Aug-1991	11.2°	2.72
9.5	12-Sep-1991	19-Sep-1991	38.3°	0.69
20.0	6-Feb-1992	20-Feb-1992	31.3°	2.19
201.0	17-Nov-1992	24-Nov-1992	36.1°	0.31
202.0	24-Nov-1992	1-Dec-1992	36.9°	0.31
203.0	1-Dec-1992	8-Dec-1992	7.0°	1.75
203.3	8-Dec-1992	15-Dec-1992	7.0°	1.75
203.6	15-Dec-1992	22-Dec-1992	7.0°	1.68
212.0	9-Mar-1993	23-Mar-1993	15.4°	2.71
302.0	7-Sep-1993	9-Sep-1993	18.3°	0.32
303.2	22-Sep-1993	1-Oct-1993	18.3°	1.43
303.7	17-Oct-1993	19-Oct-1993	18.3°	0.32
318.1	1-Feb-1994	8-Feb-1994	4.5°	1.78
328.0	24-May-1994	31-May-1994	7.0°	1.56
331.0	7-Jun-1994	10-Jun-1994	7.0°	0.95
331.5	14-Jun-1994	18-Jun-1994	7.0°	1.34
333.0	5-Jul-1994	12-Jul-1994	7.0°	1.87
403.0	1-Nov-1994	9-Nov-1994	37.0°	0.54
410.0	24-Jan-1995	14-Feb-1995	37.5°	1.42
TOTAL				29.3

<sup>a</sup> Effective on-axis exposure, in days

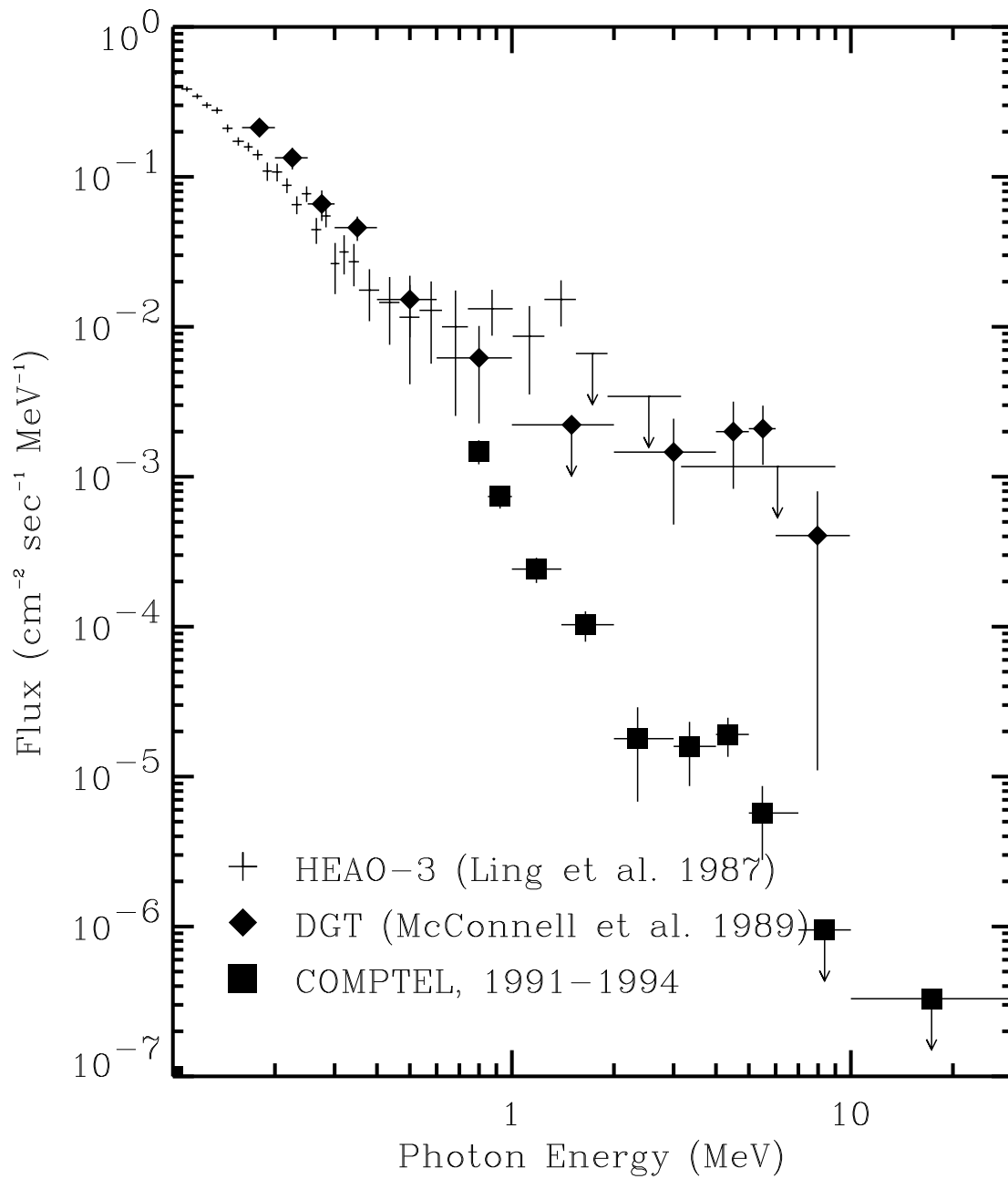
# Flux Time Histories of Cyg X-1



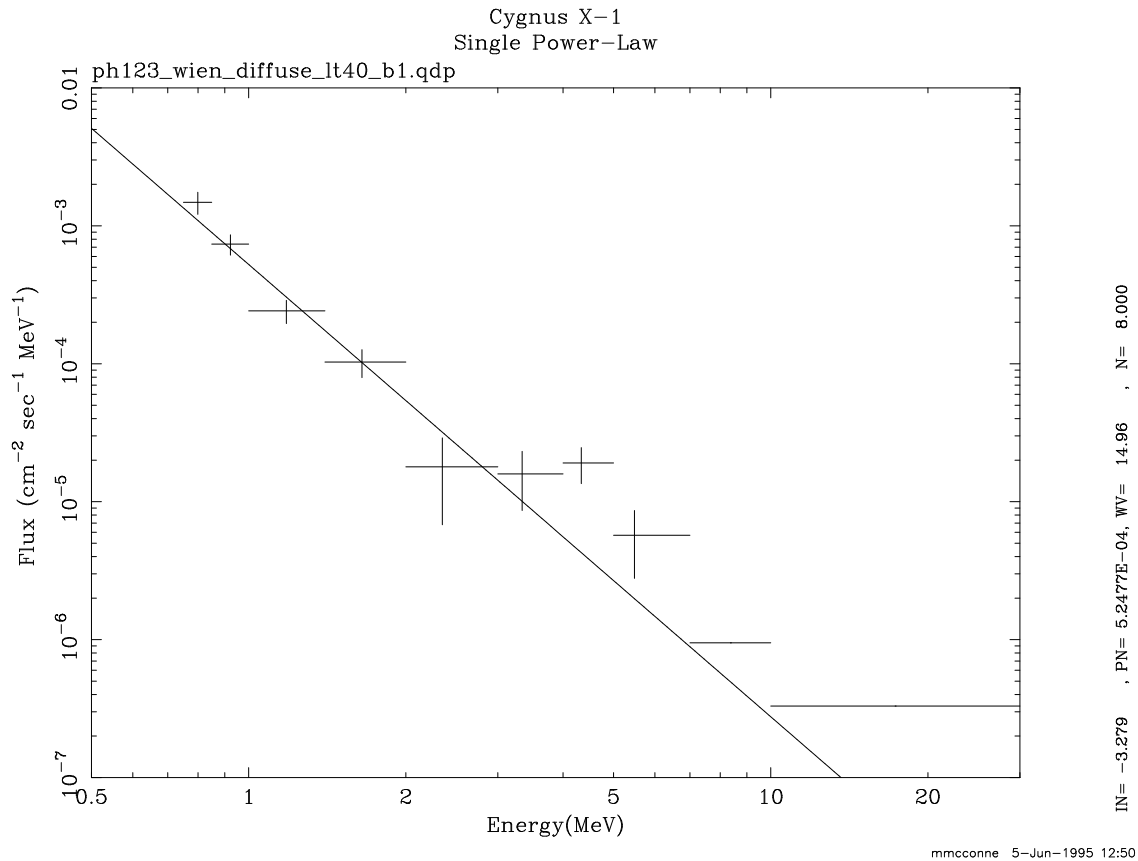
# COMPTEL Spectrum of Cyg X-1



# Comparison with Earlier Data



# Power-Law Fit



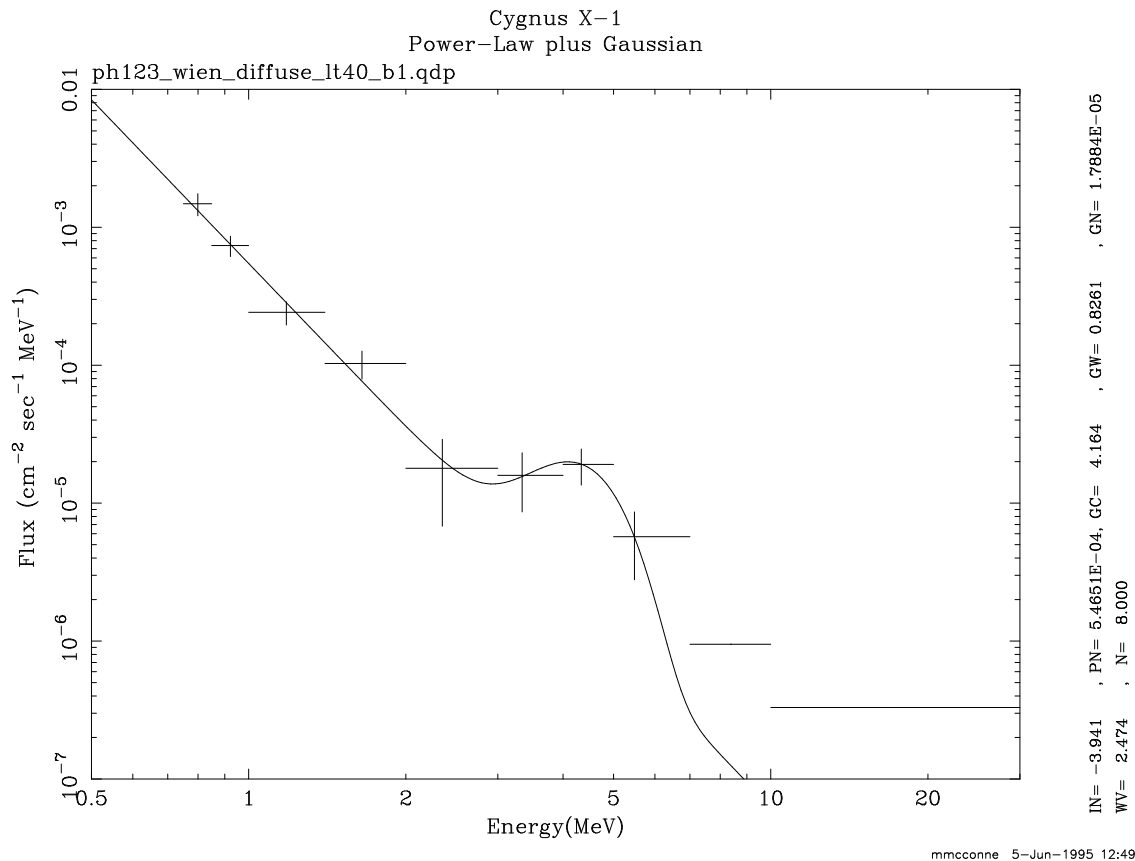
$$\text{Spectral Index} = -3.3 \pm 0.5$$

$$\text{Amplitude} = 5.3(\pm 0.9) \times 10^{-4}$$

$$\chi^2 = 15.0, \nu = 6, P(> \chi^2) = .02$$

$\Rightarrow$  unacceptable fit

# Power-Law plus Gaussian Fit



$$\text{Spectral Index} = -3.9 \pm 0.6$$

$$\text{Amplitude} = 5.5(\pm 0.8) \times 10^{-4}$$

$$\text{Gaussian center} = 4.2 \pm 0.5 \text{ MeV}$$

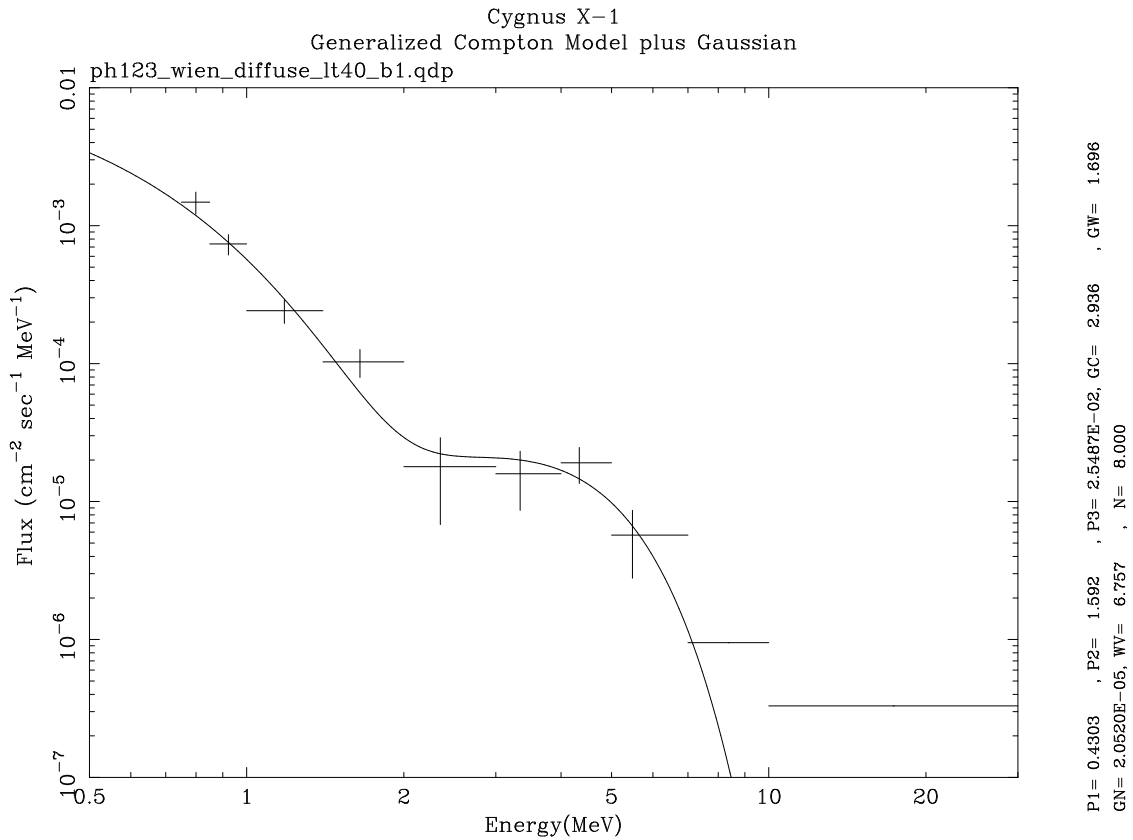
$$\text{FWHM} = 1.4 \pm 0.7 \text{ MeV}$$

$$\text{Gaussian amplitude} = 1.8(\pm 0.9) \times 10^{-5} \text{ cm}^{-2} \text{ s}^{-1}$$

$$\chi^2 = 2.5, \nu = 3, P(> \chi^2) = .48$$

$\implies$  acceptable fit

# Compton plus Gaussian Fit



$$kT = .43 \pm 2.24 \text{ MeV}$$

$$\tau = 1.6 \pm 16.4$$

$$\text{Amplitude} = 2.6(\pm 4.7) \times 10^{-2}$$

$$\text{Gaussian center} = 2.9 \pm 1.6 \text{ MeV}$$

$$\text{FWHM} = 1.7 \pm 1.1 \text{ MeV}$$

$$\text{Gaussian amplitude} = 2.1(\pm .7) \times 10^{-5} \text{ cm}^{-2} \text{ s}^{-1}$$

$$\chi^2 = 6.8, \nu = 2, P(> \chi^2) = .03$$

$\Rightarrow$  unacceptable fit

## Summary of Spectral Fitting

- Single power-law :
  - Formally unacceptable fit.
- Single power-law plus Gaussian :
  - Formally acceptable fit.
  - Fit is significantly improved over that of single power-law.
  - Significance of Gaussian contribution is  $\sim 3\sigma$ .
- Generalized Compton model plus Gaussian :
  - Formally unacceptable fit.
  - Parameters are poorly constrained.
  - Best-fit electron temperature inconsistent with previous experiments.

## Conclusions

- No significant evidence for intensity or spectral variability on time scales of weeks to months.
- The flux levels are  $\sim 2$  orders of magnitude below some previous measurements.
- The spectrum is measured out to  $\sim 5$  MeV, with a significant hardening above  $\sim 2$  MeV.
- The COMPTEL data alone can be described with a power-law plus Gaussian model.
- Several possible models for a Gaussian-like feature :
  - One or more nuclear lines (e.g., broadened 4.4 MeV line from  $^{12}\text{C}^*$ ).
  - Pion production (with  $\gamma - \gamma$  attenuation of  $\pi^0$ -decay photons).
  - Non-thermal processes.
- Improved constraints on the emission below 1 MeV can be expected to clarify the implications of the COMPTEL results (work in progress).