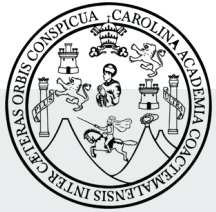


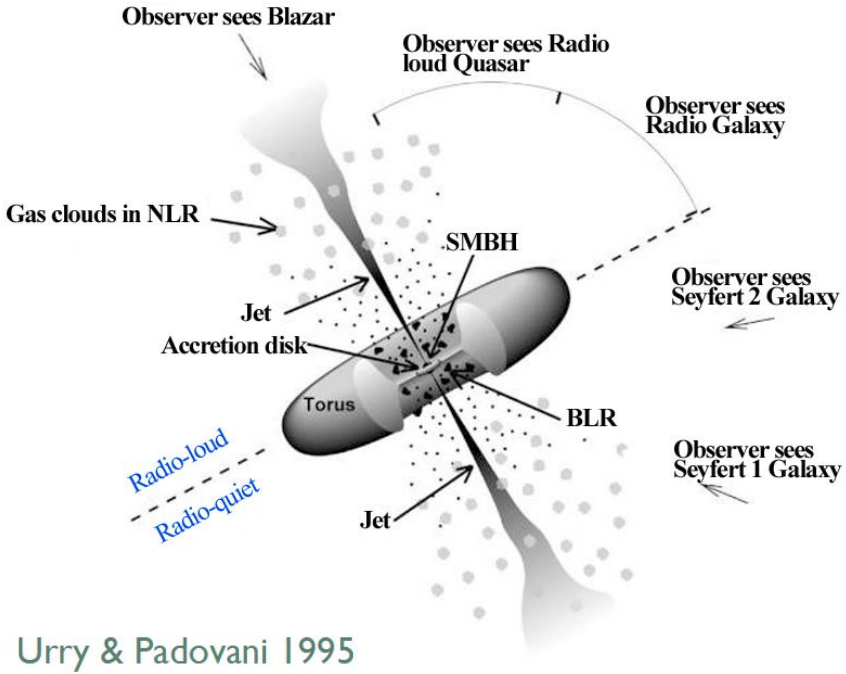
On the correlation between X-rays and TeV gamma-rays in HBL Blazars.

J. R. Sacahui[1], M. Osorio[2] & M. M. González[2]

1. IFIM, Escuela de Ciencias Físicas y Matemáticas, Universidad de San Carlos de Guatemala..

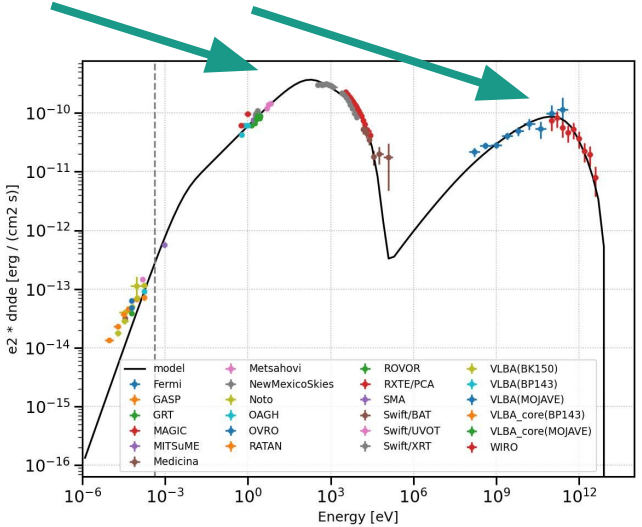
2. Instituto de Astronomía, Universidad Nacional Autónoma de México.

Blazars



Urry & Padovani 1995

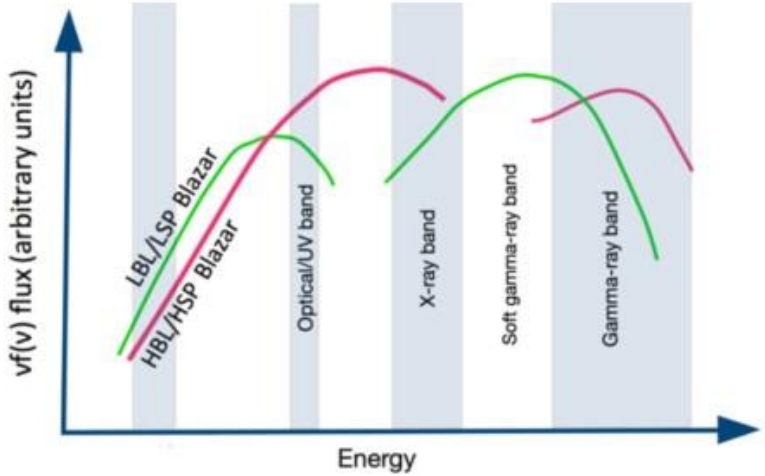
- Brightest extragalactic gamma ray sources.
- Associated to neutrinos and cosmic rays.
- SED exhibits two distinct spectral components.



SED Mkn421 (G. Xol 2024)

State of the art and motivation I

- High Synchrotron Peaked Blazars (HBL): the majority of the emission is concentrated in X-rays and TeV gamma-rays.
- Low energy component → Synchrotron
- High energy gamma-ray component→ **??**
  Leptonic SSC or EC
  Hadronic models
  Combinations



Middei, R. et al. 2022

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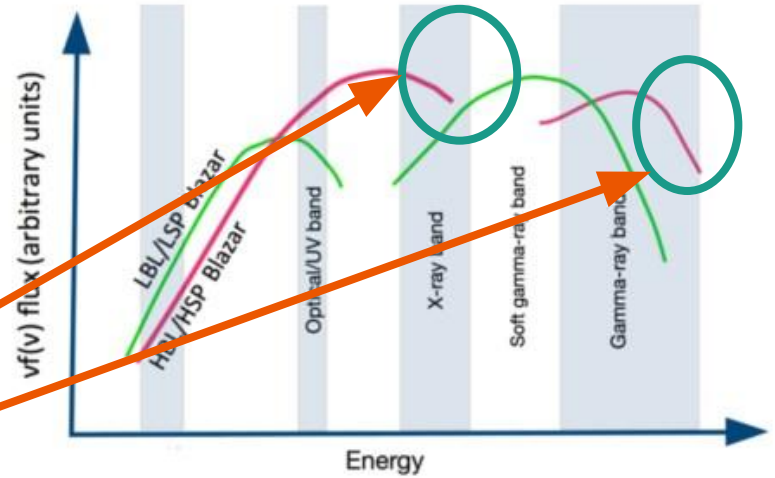


Middei, R. et al. 2022

Leptonic: Correlations expected

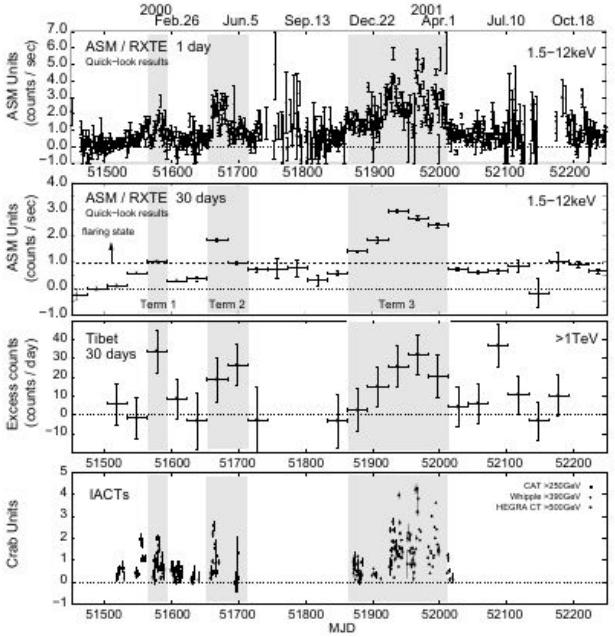
State of the art and motivation II

Different correlations reported:
linear, quadratic and between.

- ➔ Specific blazar
- ➔ Time scale of observations
- ➔ Observational campaign

Katarzyński & Walczewska (2010): different correlation indices can be explained by considering a jet with multiple emission zones.

Mkr 421

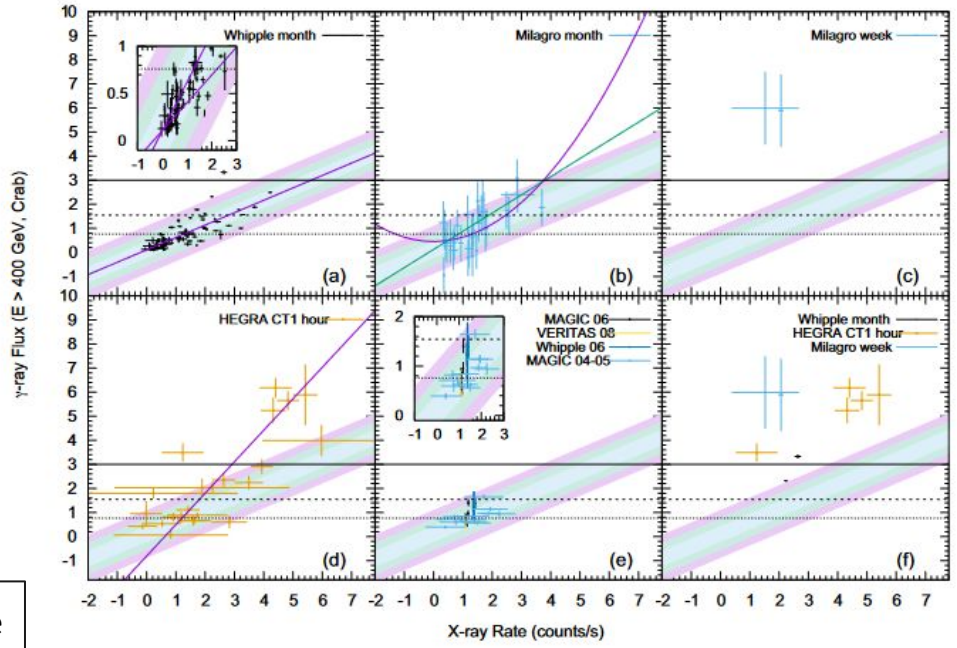


Amenomori, M. et al. 2009

State of the art and motivation III

González et al. (2019) → Correlation analysis of Mrk 421 (1992-2009):
X-ray data: 2-10 keV
Gamma-ray data: > 400 GeV

- ➔ Linear correlation breaks for high gamma ray fluxes
- ➔ Correlation consistent with one value of B



González, M. M. et al. 2019

Long-term studies with wider range in fluxes are important to confirm/validate

Sample selection

HBL spectral type BL Lacs:

1. Detection threshold > 200 GeV
2. Spectral index ~ 2
3. Redshift < 0.15

14 sources in the TeVCAt catalog

4 sources with quasi-simultaneous X-ray and gamma-ray observations

Source	RA	Dec	Redshift
Mrk 501	$16^h53^m52.21^s$	39.76^o	0.00337
1ES 1959+650	$19^h59^m59.85^s$	65.15^o	0.048
PKS 2155-304	$21^h58^m52.06^s$	-30.22^o	0.117
1ES 2344+514	$23^h47^m04.83^s$	31.70^o	0.044

→ 11 % EBL absorption

Observations

Quasi-simultaneous data from low to high fluxes

Data homogenization → Integral flux to the predetermined energy threshold

→ X-ray data unified to cgs system

Source	Period yy-yy	Number of campaigns	Instruments X-rays	Instruments Gamma-rays
Mrk 501	1997-2013	6	RXTE-PCA Swift-BAT	HEGRA
1ES 1959+650	2002-2016	5	RXTE-PCA Swift-BAT	Whipple, HEGRA MAGIC, VERITAS
PKS 2155-304	2006-2016	4	Swift-XRT Chandra-LETG	HESS
1ES 2344+514	2007-2008	1	RXTE-PCA Swift-XRT	VERITAS

Statistical method

Bayesian statistical method (D'Agostini 2005):

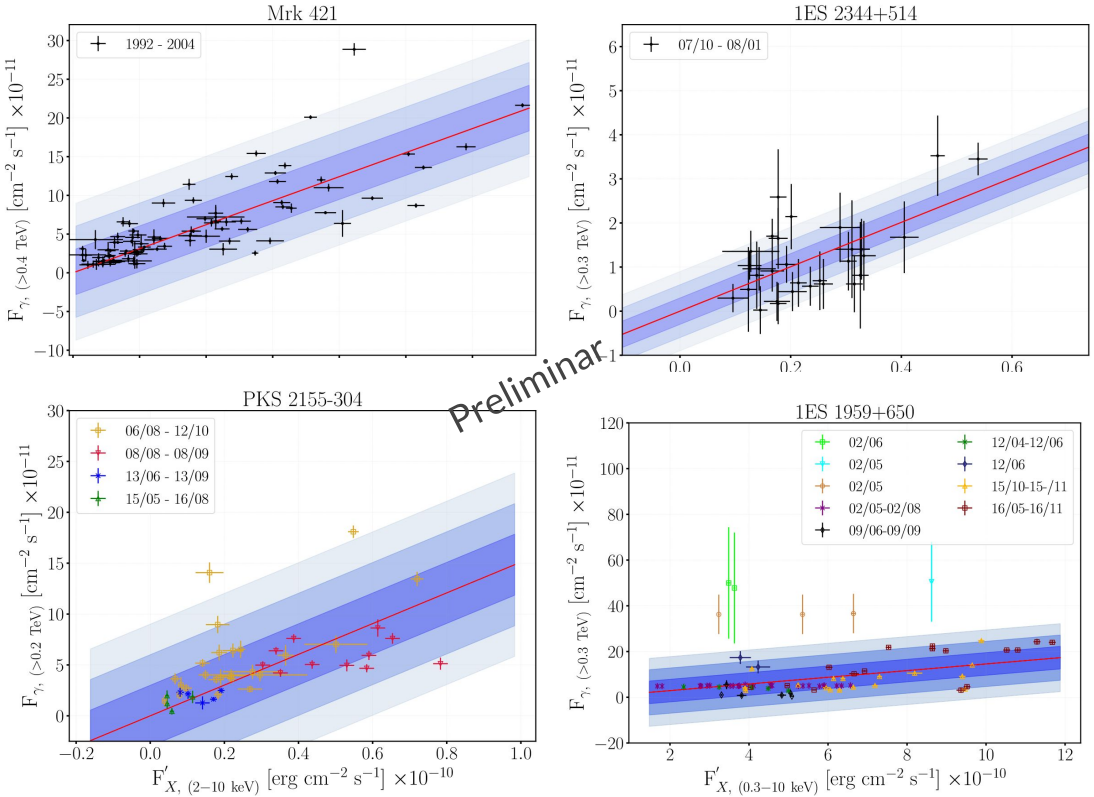
Power Law model to describe the correlation: $F_y = b\, F_x^{\alpha}$

$$L(\omega, \sigma_s; x, y) = \frac{1}{2}\sum log[\sigma_s^2 + \sigma_y^2 + F_y'^2(x,\omega)\sigma_x^2] + \frac{1}{2}\sum \frac{[y - F_y]^2}{\sigma_s^2 + \sigma_y^2 + F_y'^2(x,\omega)\sigma_x^2},$$

- Maximum Likelihood estimation.
- Takes into account an inherent unknown data scattering ($\boldsymbol{\sigma}_s$)
- 3 possible scenarios were tested: Linear, quadratic and free

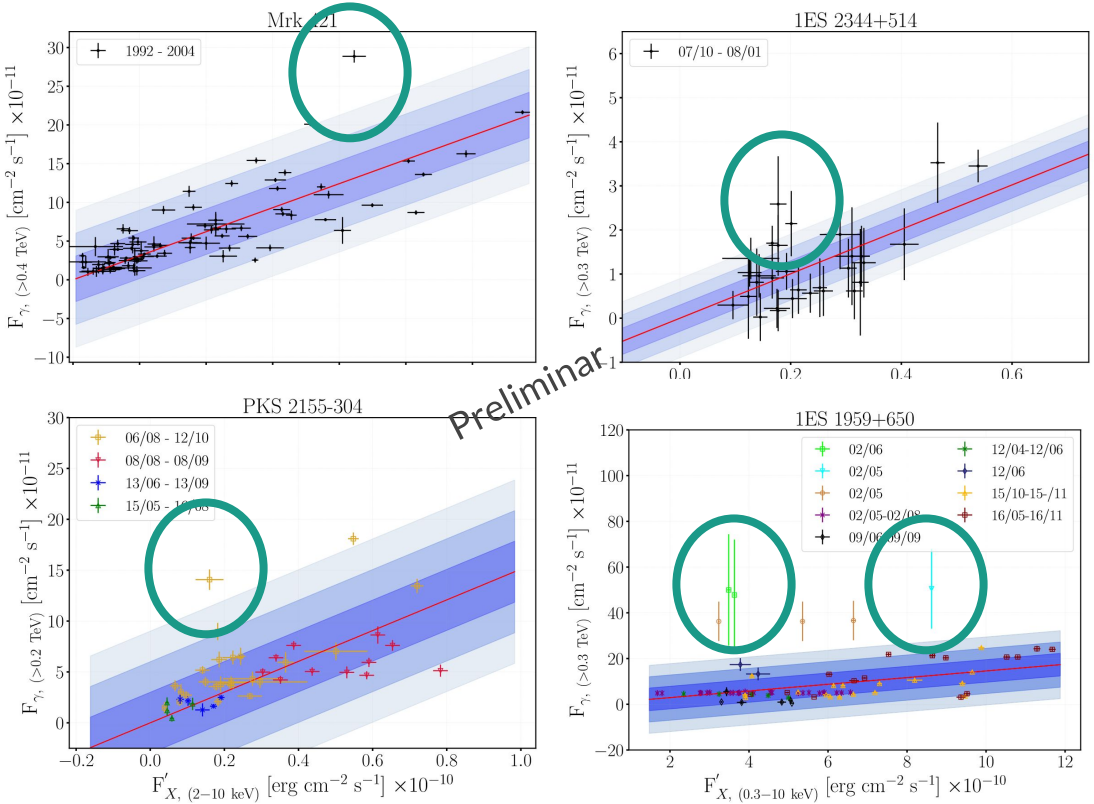
$\boldsymbol{w}$ is the set of free parameters (b, $\boldsymbol{\alpha}$).

Results I



- 4 blazars are consistent with a linear correlation:
  Mkn 421, 1ES 2344+514, PKS 2155-304 and 1ES 1959+650
  → KN regime??

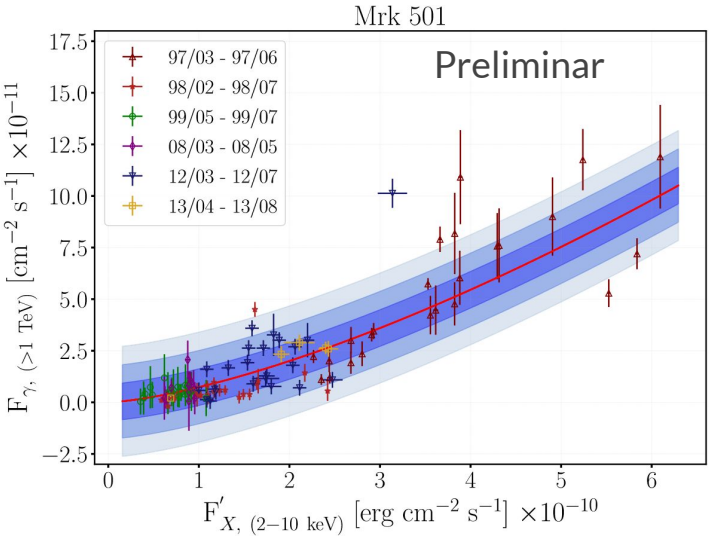
Results I

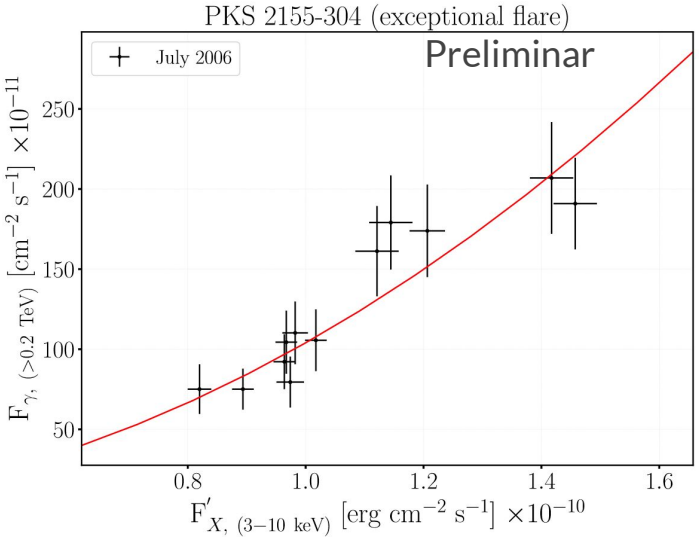


- 4 blazars are consistent with a linear correlation:
  Mkn 421, 1ES 2344+514, PKS 2155-304 and 1ES 1959+650
  → KN regime??

- All of them present outliers with high gamma-ray flux
  → another mechanism??

Results II





➔ Consistent wit correlation with index:
$\alpha = 1.45 \pm 0.01$

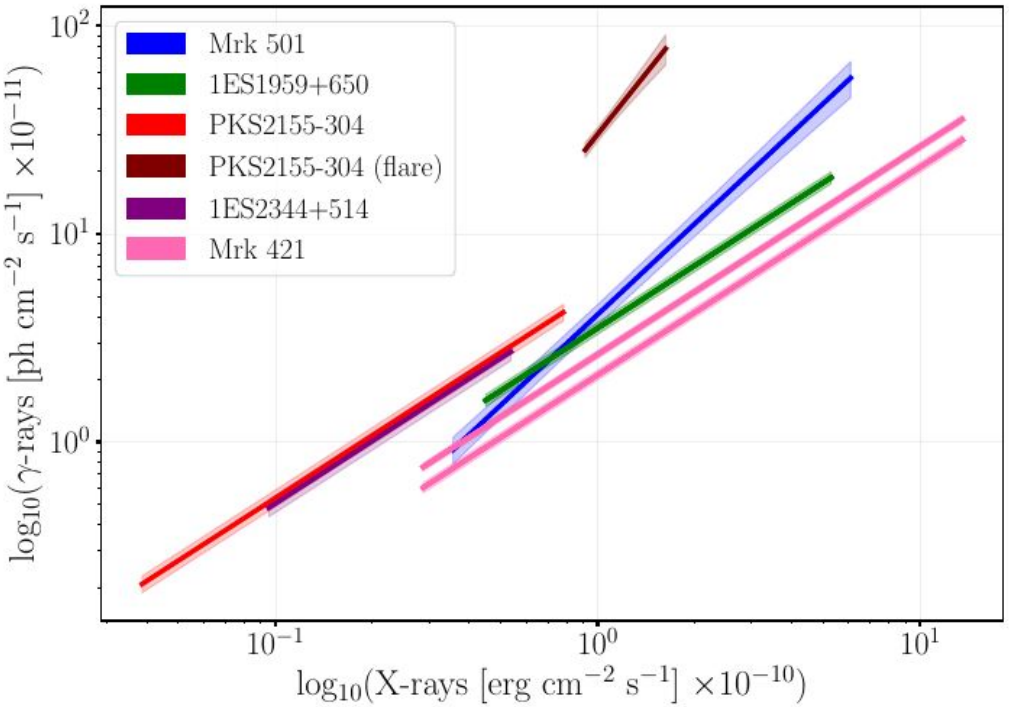
➔ Consistent wit quadratic correlation (SSC):
$\alpha = 1.95 \pm 0.29$

Summary of results

Source	Correlation index	AIC_1	AIC_{free}	AIC_2
Mkn 421	0.87 ± 0.08	**116.82**	116.69	181.48
Mkn 501	1.45 ± 0.01	168.28	**144.25**	170.03
1ES 1959+650	1.42 ± 0.22	**372.60**	370.71	374.35
PKS 2155-304	0.54 ± 0.12	**148.54**	142.72	172.59
PKS 2155-304 (flare)	1.95 ± 0.29	96.17	90.21	**86.57**
1ES 2344+514	1.25 ± 0.22	**9.73**	10.90	15.39

Summary of results

Source
Mkn 421
Mkn 501
1ES 1959+650
PKS 2155-304
PKS 2155-304 (flare)
1ES 2344+514



Summary...

- Overall the average correlations of these sources are consistent with indices values between 1 and 2, as previous work reported.
- These studies can contribute to ponderate the contribution of different radiative processes in blazar's emission.
- Outliers are present in all blazars suggesting the presence of different emission mechanisms in long term monitoring.

Thank you!

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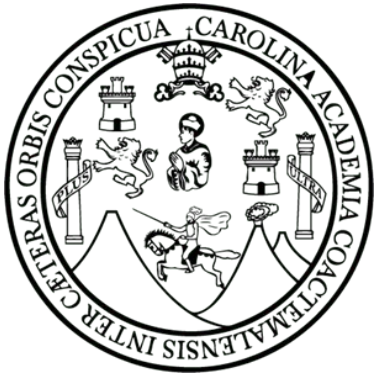

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