USA Data Analysis @ SLAC

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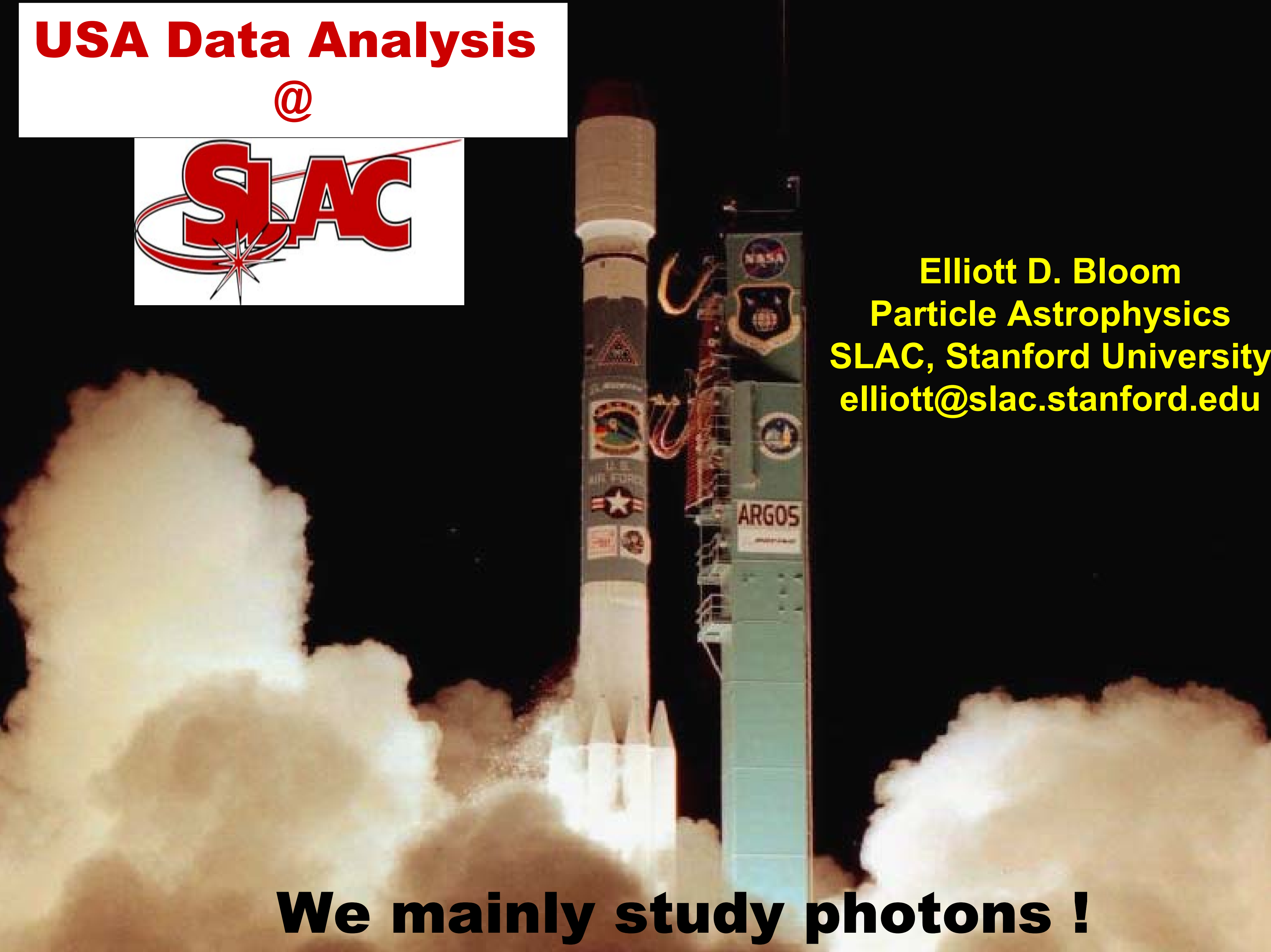
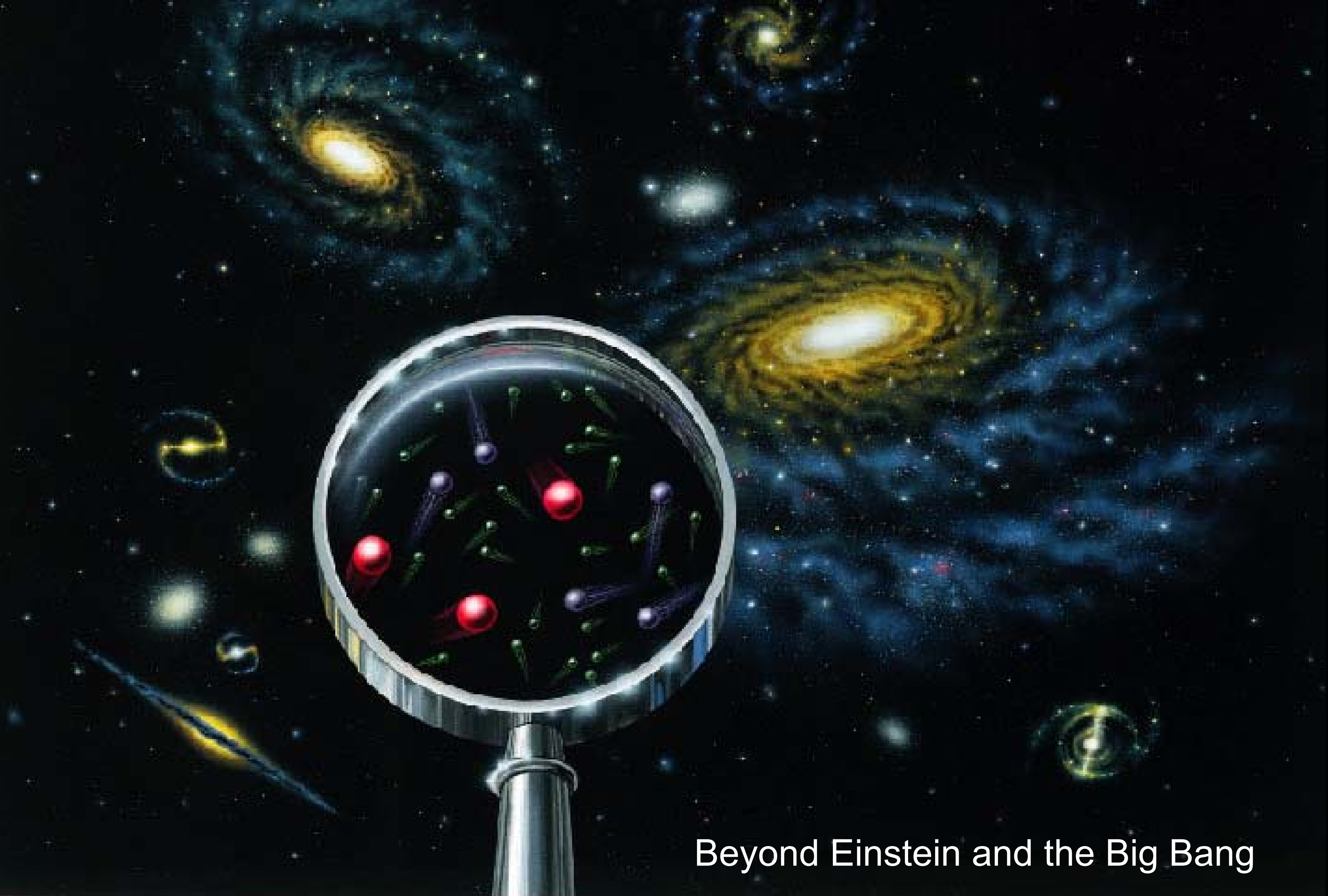


We mainly study photons !

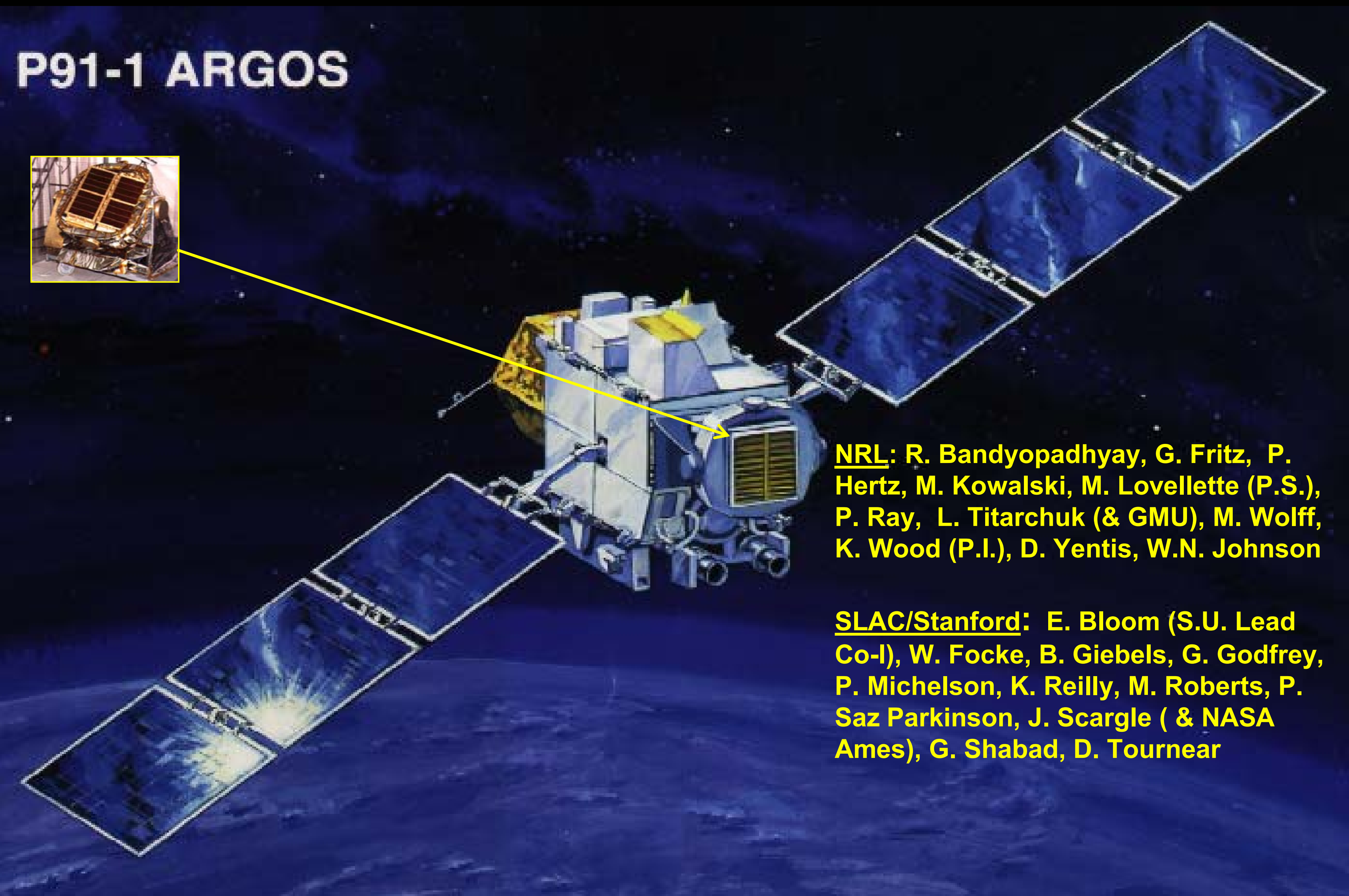
Connections: **Quarks to the Cosmos**



Connections…Some of Humanity's Deepest Questions About the Nature of Our Universe

- What powered the big bang?
- What is the dark matter that binds together the universe? (GLAST)
- What is the dark energy that drives apart the universe?
- What is the nature of black holes and gravity beyond Einstein? (GLAST, USA)
- Are there hidden spacetime dimensions? (GLAST)

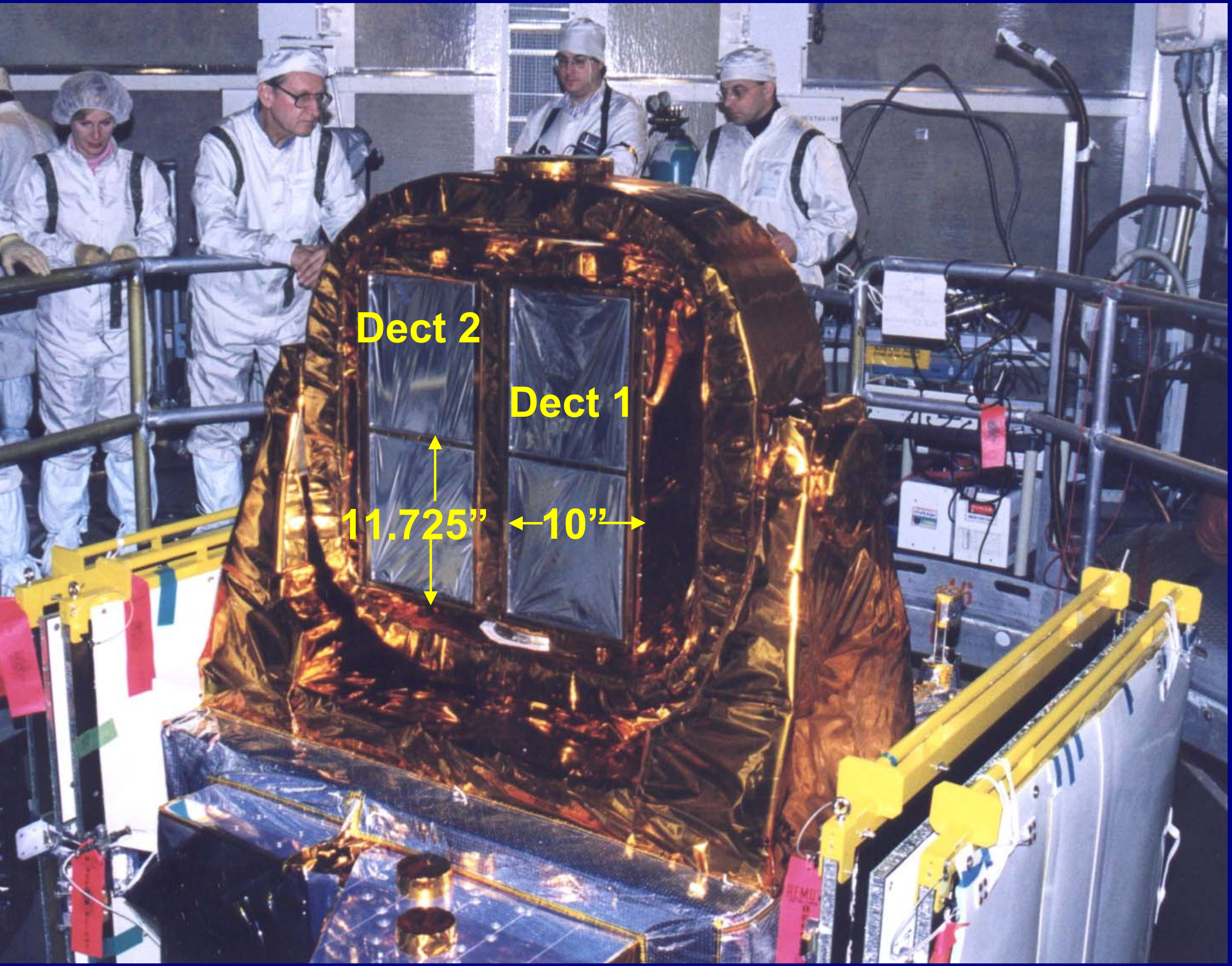
USA Collaboration



NRL: R. Bandyopadhyay, G. Fritz, P. Hertz, M. Kowalski, M. Lovellette (P.S.), P. Ray, L. Titarchuk (& GMU), M. Wolff, K. Wood (P.I.), D. Yentis, W.N. Johnson

SLAC/Stanford: E. Bloom (S.U. Lead Co-I), W. Focke, B. Giebels, G. Godfrey, P. Michelson, K. Reilly, M. Roberts, P. Saz Parkinson, J. Scargle (& NASA Ames), G. Shabad, D. Tournear

USA Instrument



The USA, installed on top of the ARGOS satellite.

- 5000 lb spacecraft built by Boeing.
- Delta-II launch from Vandenberg AFB, CA Feb. 1999.
- Orbit: 800 km. altitude, sun synchronous, 98° inclination.
- 9 experiments, including USA.
- Mission ended November 2001.

USA DATA SUMMARY

About 90 Sources Observed by USA

Class	Exposure (ks)
Black Hole Candidates	1837
Neutron Star Binaries	1484
Accretion Powered Pulsars	1302
Rotation Powered Pulsars	1022
Anomalous X-ray Pulsars	768
Active Galactic Nuclei	652
Supernova Remnant	209
Cataclysmic Variables	128
	7401 + 1850 (off source-background)

USA Top 17 in ks

Source	Class	Compact Object	Exposure (ks)
Cyg_X-1	HMXB	BH	728.6
Crab Pulsar	PSR	NS	603.5
Cyg_X-2	LMXB	NS	357.3
XTE_J1118+480	LMXB	BH	332.8
SMC_X-1	XPSR	NS	314.2
Mkn_421	AGN	AGN	306.1
GRS_1915+105	HMXB	BH	292.0
X0142+614	AXP	NS	247.7
Cir_X-1	LMXB	NS?	234.5
EXO_0748-676	LMXB	NS	231.5
X1820-30 (NGC 6624)	PSR	NS	226.3
4U_0614+09	LMXB	NS	225.3
GX_349+2 (Sco_X-2)	LMXB	NS	222.6
Cen_X-3	XPSR	NS	211.0
Cas_A	SNR	SNR	209.2
E_2259+586_SNR	AXP	NS	205.1
PSR_1509-58	PSR	NS	203.8

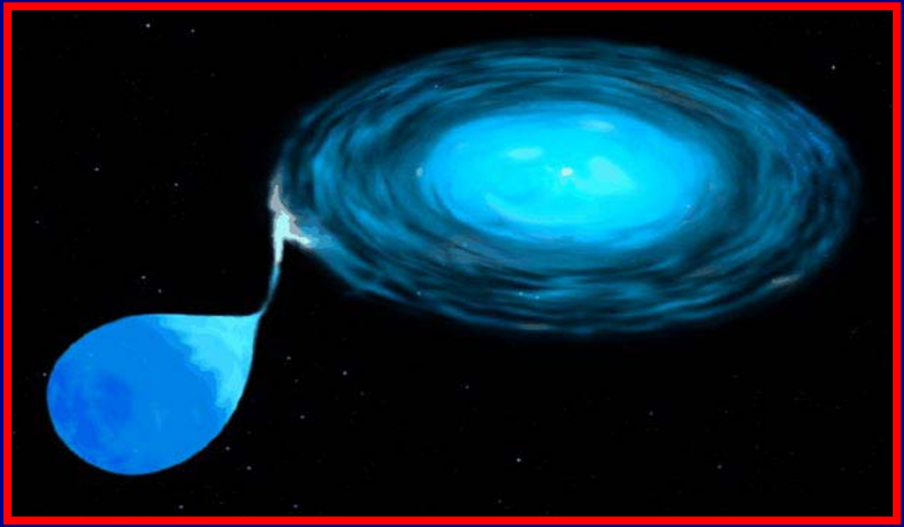
USA AGN Data

Source AGN	Class	Compact Object	Exposure (ks)
Mkn_421	AGN	AGN	306.1
3C273	AGN	AGN	120.4
1es1959+650	AGN	AGN	59.0
Mkn_501	AGN	AGN	58.5
1es2344+514	AGN	AGN	26.8
NGC_1275	AGN	AGN	14.5
H1426+427	AGN	AGN	13.8
BL_Lac	AGN	AGN	13.0
PKS2005-489	AGN	AGN	12.1
2EG1224+2155	AGN	AGN	10.1
1es1741+196	AGN	AGN	9.8
MK_501	AGN	AGN	6.0
1Zw187	AGN	AGN	5.9
PG_1448+273	AGN	AGN	1.5

USA Publications

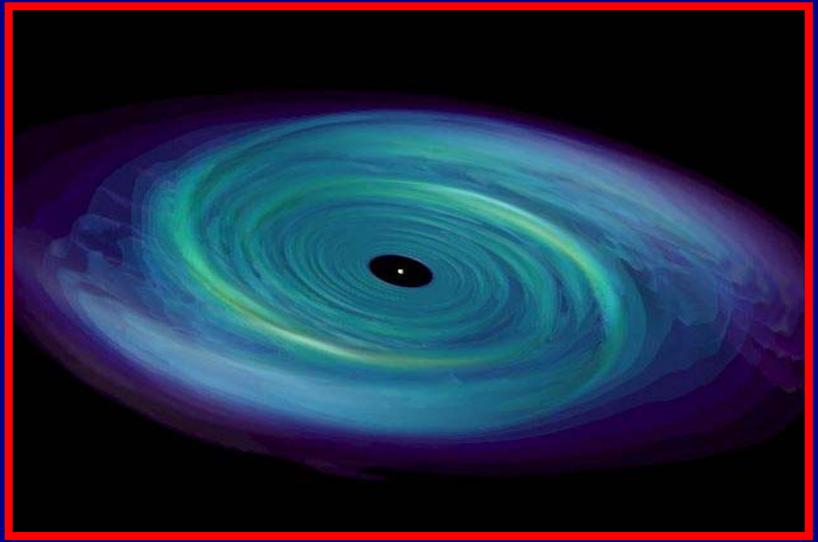
- "Observation of X-ray Variability in the BL Lac Object 1ES 1959+65," 2002, *The Astrophysical Journal*, Volume 571, Issue 2, pp. 763-770 (Found to be TeV emitter after USA publication.)
- "Eclipse Timings of the LMXB EXO 0749-676. III. Orbital Period Jitter Observed with the USA Experiment and RXTE," 2002, *The Astrophysical Journal*, Volume 575, Issue 1, pp. 384-396
- "USA Experiment Observations of Spectral and Timing Evolution During 2000 Outburst of XTE J1550+564," 2001, *The Astrophysical Journal*, Volume 561, Issue 2, pp. L183-L186,
- "Observations of GRS 1915+105 from the USA Experiment on ARGOS," 2001, *Astrophysics and Space Science Supplement,* Volume 276, pp. 23-24
- "USA Experiment and RXTE Observations of a Low-Frequency Quasi-Periodic Oscillation in XTE J1118+480," 2000, *The Astrophysical Journal,* Volume 544, Issue 1, pp. L45-L48
- "USA Experiment on the ARGOS Satellite: a Low Cost Instrument for Timing X-ray Binaries", 1994, *proc. SPIE,* Volume 2280, pp. 19-30

Accretion Disks in NS/BHCs



Most sources discussed here are in a binary system. This allows for the creation of an accretion disk that forms around the compact object. Inner edge of disk:

$$\nu_{orb} \sim 1200\text{Hz}(r_{orb}/15\text{km})^{-3/2}\, M_{1.4}^{1/2}$$

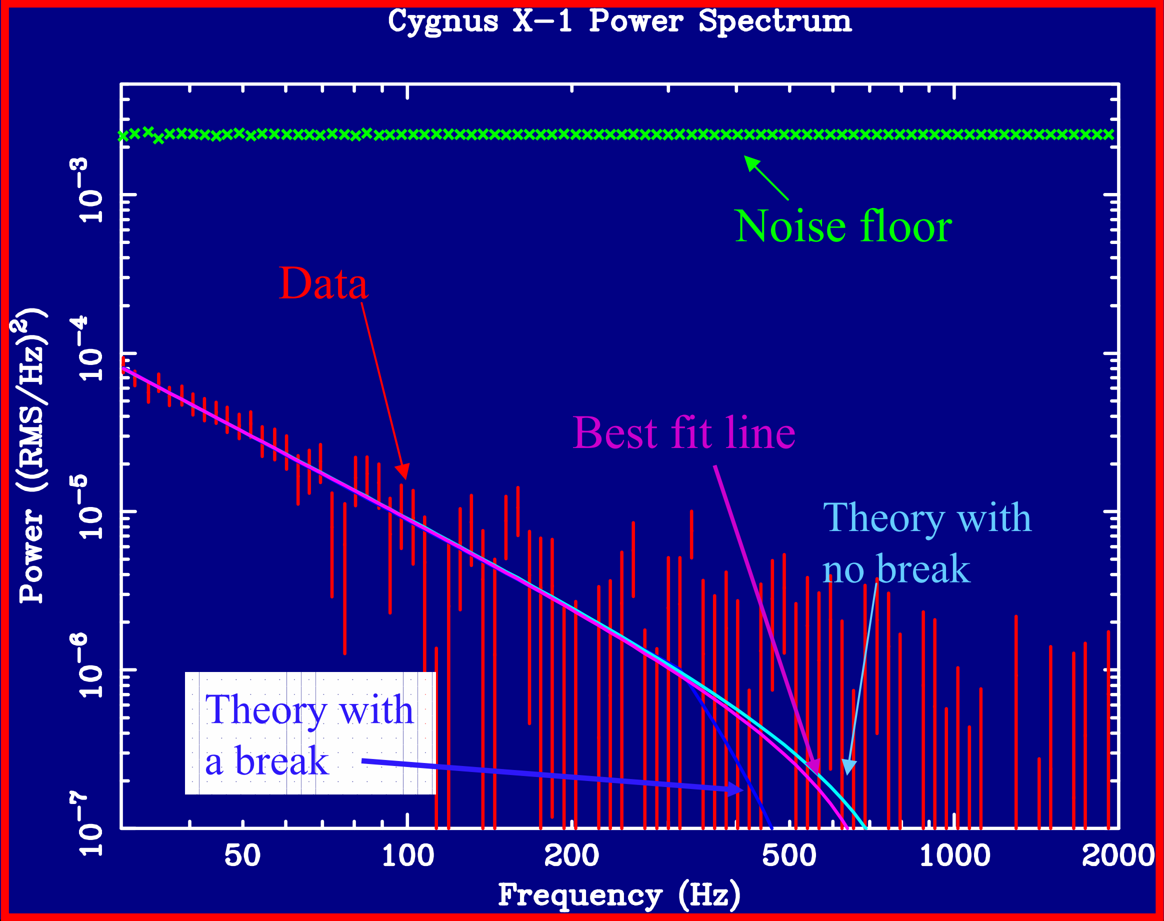


The behavior of the material inside the accretion disk and the behavior of the material immediately accreted onto the compact object are studied. The physics of the accretion disk leads to interesting outbursts in BHCs lasting for months. The newly accreted material leads to short bursts on neutron stars lasting 10-100s of seconds

Upper Limit on Inner edge of BHC Accretion Disk

W. Focke, Group K Post doc. Analysis of USA data.

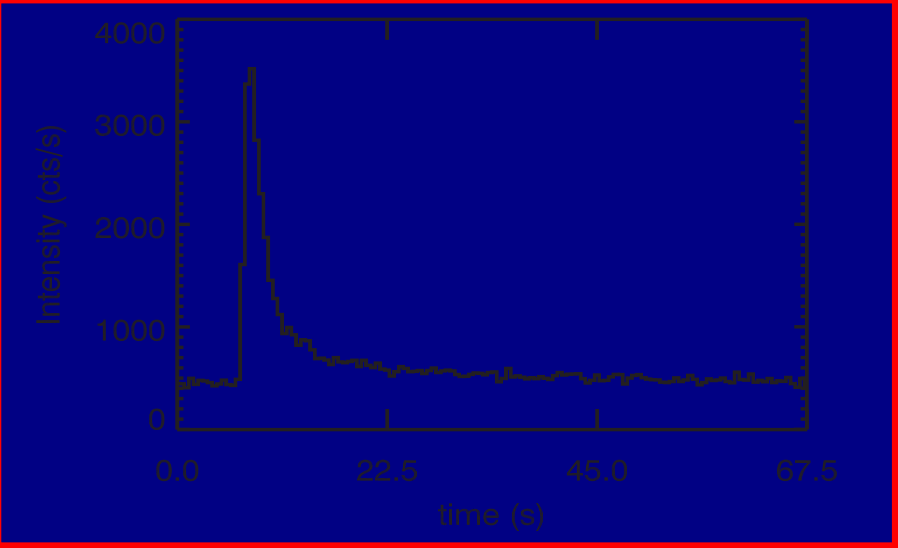
The data below are fit to a broken power-law plus noise ($A + B\cos(\pi f/f_{Ny})$), with the slope of the power law above the break locked to f^{-5} (R. Wagoner's prediction for the disk inner edge signature). The best-fit value of the breakpoint is **756 Hz.** The breakpoint was then moved down, while fitting the other parameters, until χ^2 rose by 2.7, giving a 90% lower limit on the break frequency of **315 Hz.**



$\nu_{orb} \sim 1200\text{Hz}(r_{orb}/15\text{km})^{-3/2} M_{1.4}^{1/2}$

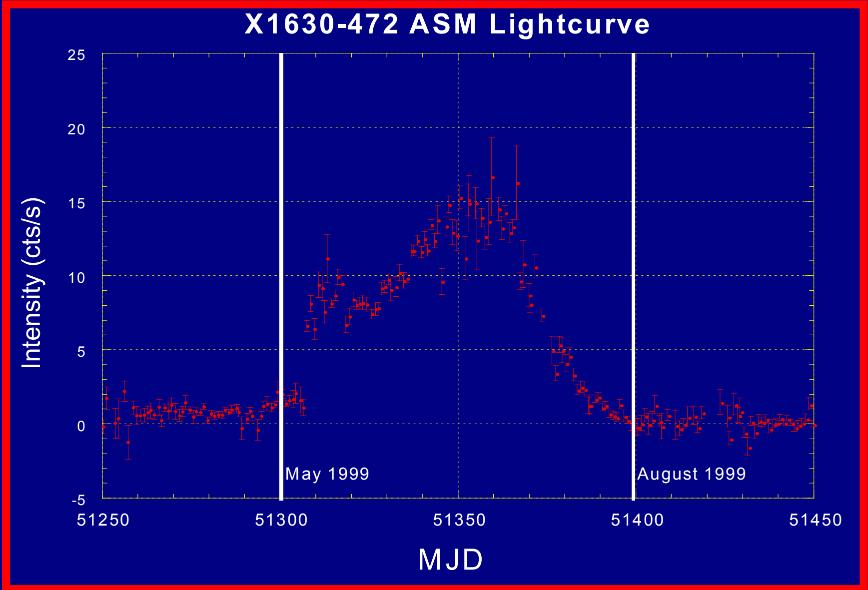
Expect ~200 Hz for a 10 solar mass non-spinning BH. This implies that the disk extends very close to the hole, and the hole has spin in the direction of the rotation of the accretion disk. The right most line has no break point ($\Delta\chi^2 = 0.8$). Thus it is not likely that we have yet seen the inner edge of the disk, thought our best fit suggests the possibility. Systematic errors are not yet included (Crab studies are in process).

Types of Non-Quiescent Behavior



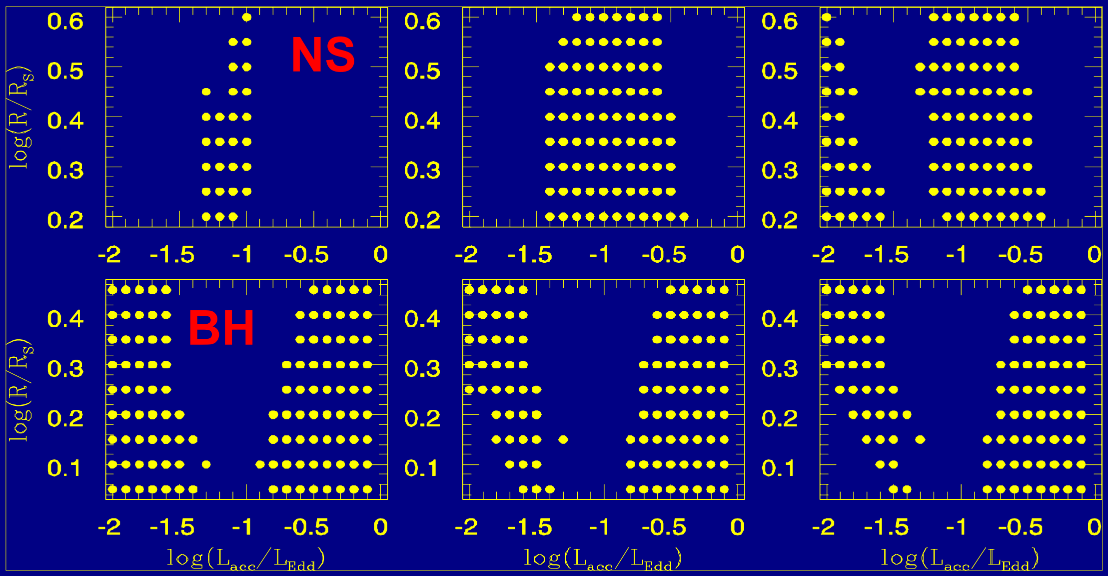
Short time scale, type I, X-ray bursts were studied with neutron star data to gather information about what luminosity regions they occurred in and BHC data were searched for evidence of these types of bursts. (LEFT) A light curve of a typical type I X-ray burst seen in 4U 1735-445.

Longer time scale X-ray outbursts were studied in BHC 4U 1630-472. From these data we can gain information about the source and properties of the accretion. (RIGHT) A light curve showing the 1999 X-ray outburst occurring in 4U 1630-472



Searching for X-ray bursts in BHCs

Narayan and Heyl Calculated Luminosity ranges where 10 solar mass objects would have X-ray bursts if they did have a surface. In addition, they applied their theory to neutron stars to predict ranges where one would observe bursts in neutron stars.



(LEFT) Figure 1 from Narayan & Heyl (2002) displaying regions of instability, shown by dots, in BHCs and Neutron Stars as a function of accretion luminosity ($\log(L_{acc}/L_{Edd})$) vs. stellar radius.

Top left: 1.4M_Θ NS with a base temperature T_{in} = $10^{8.5}$ K. Top center: T_{in} = 10^8K. Top right: T_{in} = $10^{7.5}$ K. Bottom left: 10M_Θ BH candidate with a surface, and a base temperature T_{in} = $10^{7.5}$ K. Bottom center: T_{in} = 10^7 K. Bottom right: T_{in} = $10^{6.5}$ K.

USA Type I X-ray Burst Results

	Data Sample ks	Result All data Bursts/sec	Bursting Range Bursts/sec
Neutron Stars	955 ks	1.78×10^{-5}	2.9×10^{-5}
Black Holes	926 ks	3.2×10^{-6} (95% CLUL)	3.3×10^{-5} (95% CLUL)

- Detected nineteen bursts in seven neutron stars
- Adding more data from RXTE to push BH limits lower before final publication (editor suggestion).
- Applying theoretical framework of NH02 we conclude with USA data alone that BHCs do not have a surface to a Confidence level of 93%

Summary USA Data Analysis

- Six papers published in archival journals.
- Two Papers currently under review.
- Six papers currently in draft.
- Four PhD’s awarded, with two more scheduled for this year.
- Nineteen Posters presented at Astrophysics Conferences.