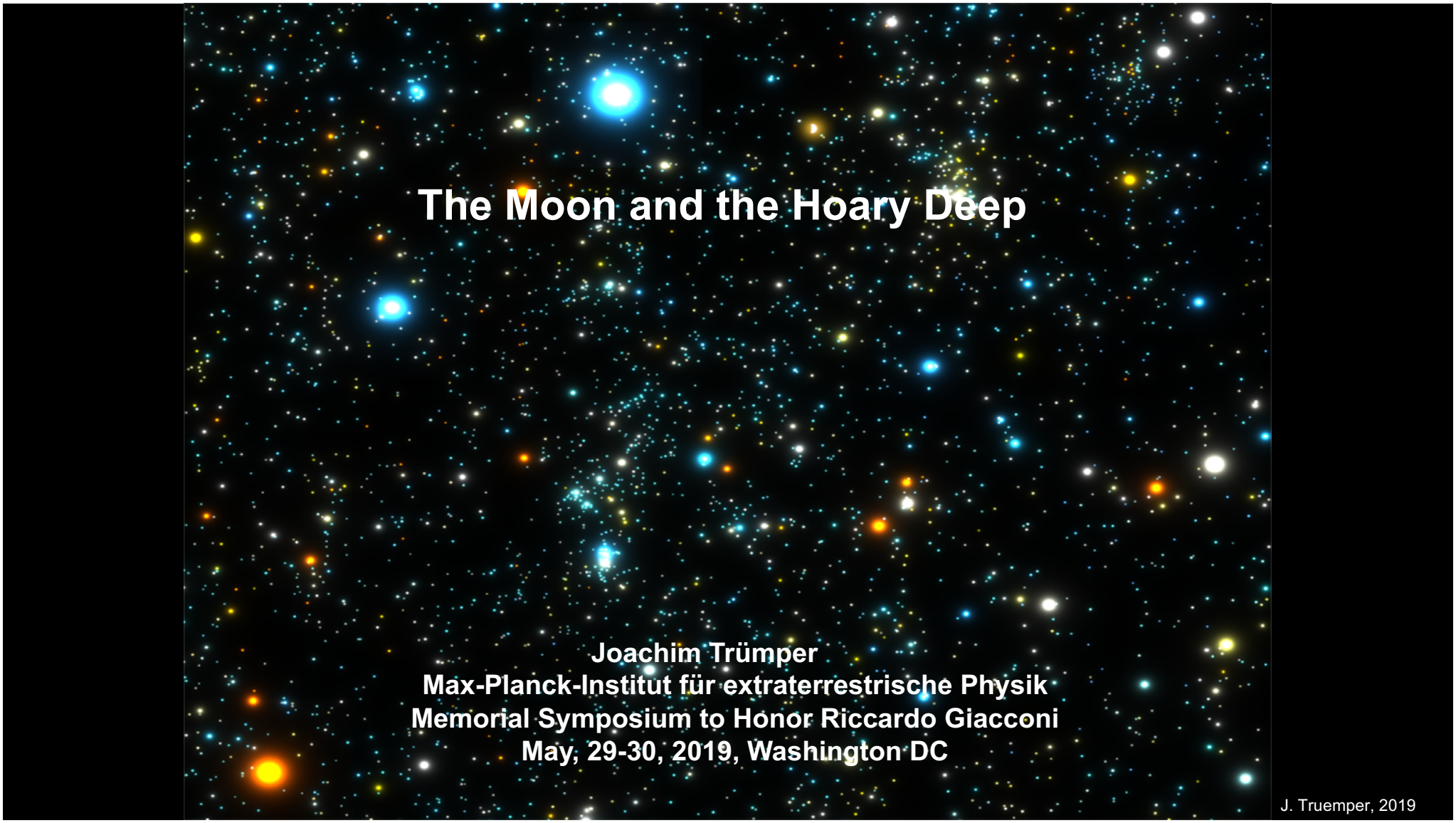
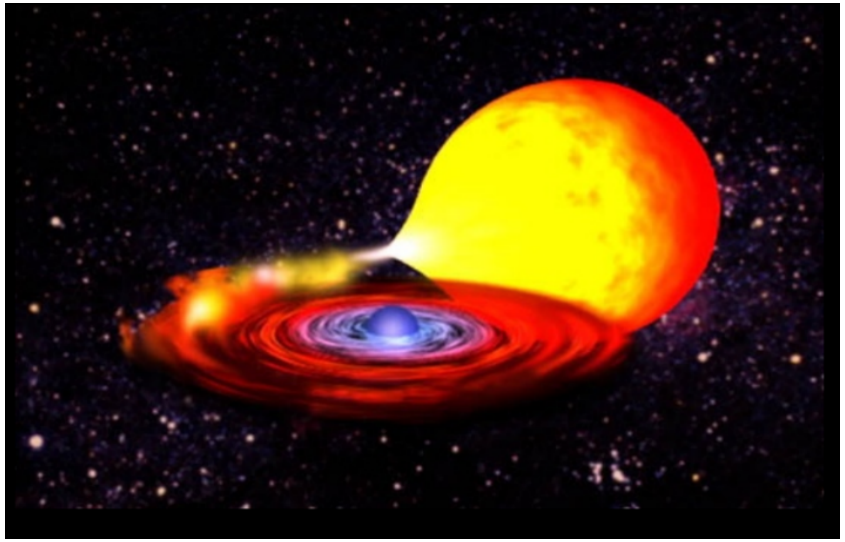
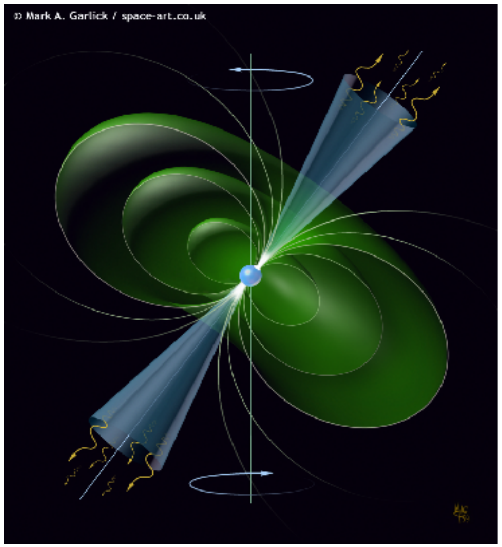

The Moon and the Hoary Deep
Joachim Trümper
Max-Planck-Institut für extraterrestrische Physik
Memorial Symposium to Honor Riccardo Giacconi
May, 29-30, 2019, Washington DC
J. Truemper, 2019

Two Discoveries that changed Astrophysics

Sco X-1 and the Cosmic X-Ray Background
(R. Giacconi et al. 1962)



Radiopulsars
(J. Bell & A. Hewish 1968)



These discoveries also changed my life!

1968-1970 I moved from High Energy Cosmic Rays (10^{15} – 10^{17} eV) to X-Ray Astronomy

1970 I joint the HELOS (later EXOSAT) mission definition group

1971 We started a balloon program (20-200 keV) to observe Uhuru sources (2-20 keV)

1976 Highlight: Discovery of the cyclotron line in Her X-1 (Truemper 1977/78)

J. Trümper, 2019

Discussions and cooperation with Riccardo (1974 – 2012)

I first met Riccado in 1974/75 in the High Energy Astrophysics Management Operations Working Group at NASA HQ
In the following years I had many discussions with Riccardo about science and projects.

1972 we had started to develop Wolter Telescopes in cooperation with Carl Zeiss.
1975 I proposed to the Ministry of Science to build a shuttle-launched satellite carrying an 80 cm Wolter telescope
1979 our Ministry decided that big projects like ROSAT must show substantial international contributions.

At the Uhuru Memorial Symposium 1980 I described our ROSAT plans and possible foreign contributions
Riccardo and Steve Holt (at that time at NASA HQ) as well as Ken Pounds were very interested. That led to the American involvement: NASA providing the shuttle launch, SAO with an improved copy of the Einstein HRI and the European contribution: SERC, Ken's group with the WFC (XUV)

After the Challenger explosion in 1986 Riccardo and Steve Holt helped to replace the shuttle by a rocket launch

In the mid 1980's I invited Riccardo to work with us on the ROSAT deep surveys. He brought Maarten Schmidt along and I asked the young bright postdoc Günther Hasinger to work with us. We had yearly planning meetings at MPE.

After the launch of ROSAT in 1990 we often met to prepare deep survey proposals and to discuss the results
During his time at ESO Riccardo was very close – just across the Karl Schwarzschild street.

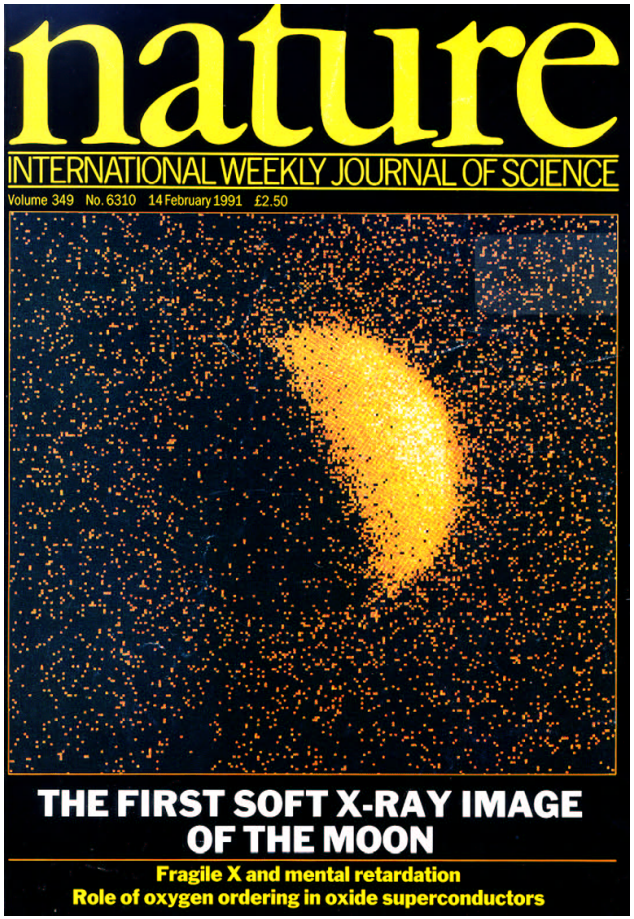
My last discussion with Riccardo took place at the Symposium „50 Years of X-ray Astronomy" 2012 in Milano

J. Truemper, 2019

One of the first ROSAT pictures taken in June 1990 just two weeks after first light!

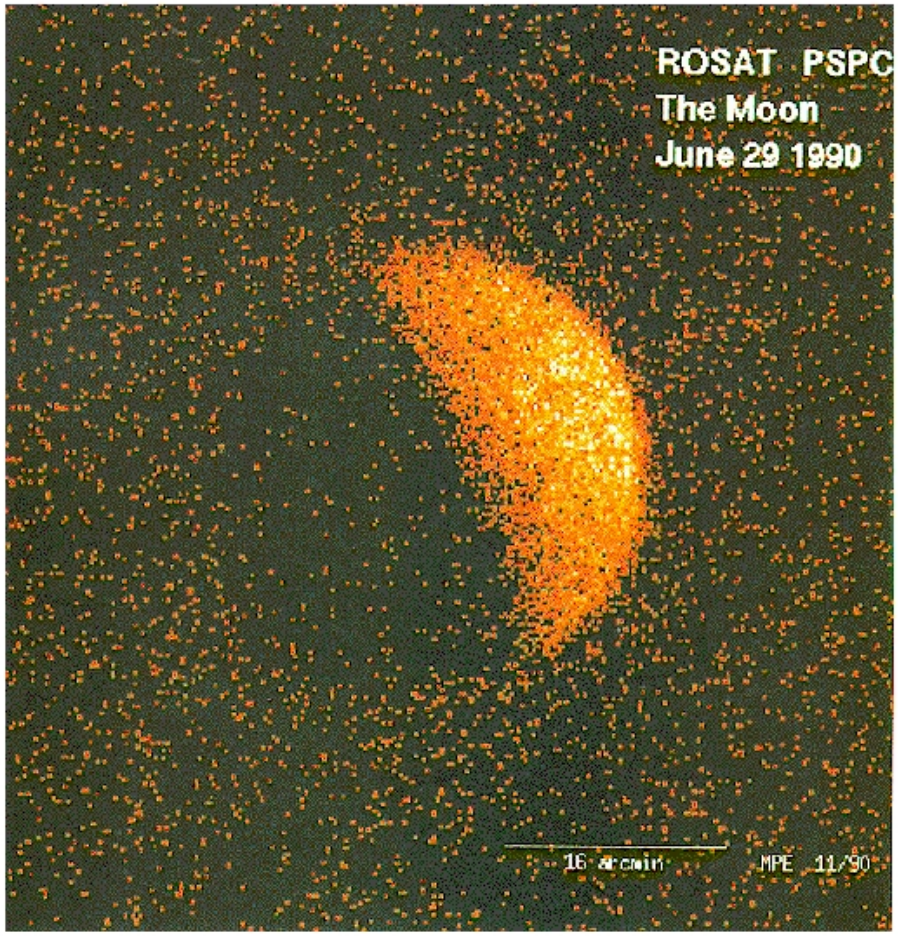
The Moon occults the X-ray background!

(Schmitt et al. 1991)



Solar coronal X-rays reflected by the lunar surface: reflectivity < 1%
L_x (moon) ~ 10^{11} erg s^{-1}

Talk at the annual meeting of the Italian Astronomical Society in Trento October 1990



Dear Riccardo,

The Moon occulting the X-ray background – 28 years after your famous rocket experiment…

With best wishes,

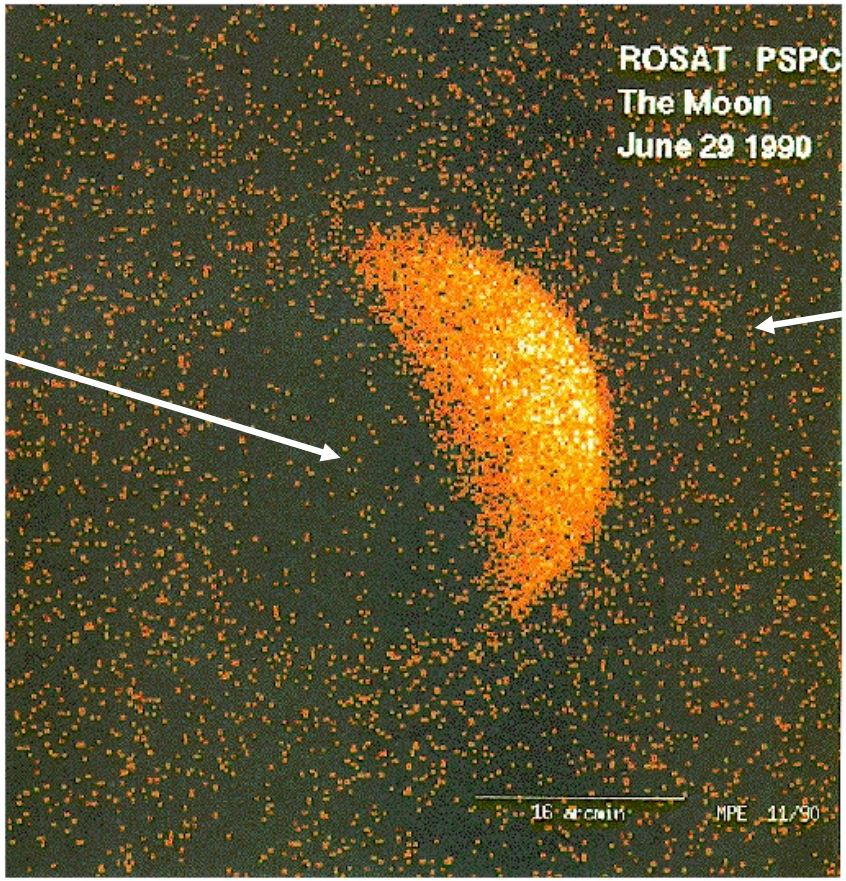
Joachim

Trento, October 8, 1990

J. Truemper, 2019

This emission is coming from the earth. It is produced by charge exchange of solar wind ions with geocoronal hydrogen
Robertson & Lisse 2003)

(similar to the X-rays from comets discovered by ROSAT)
(Lisse et al. 1996)

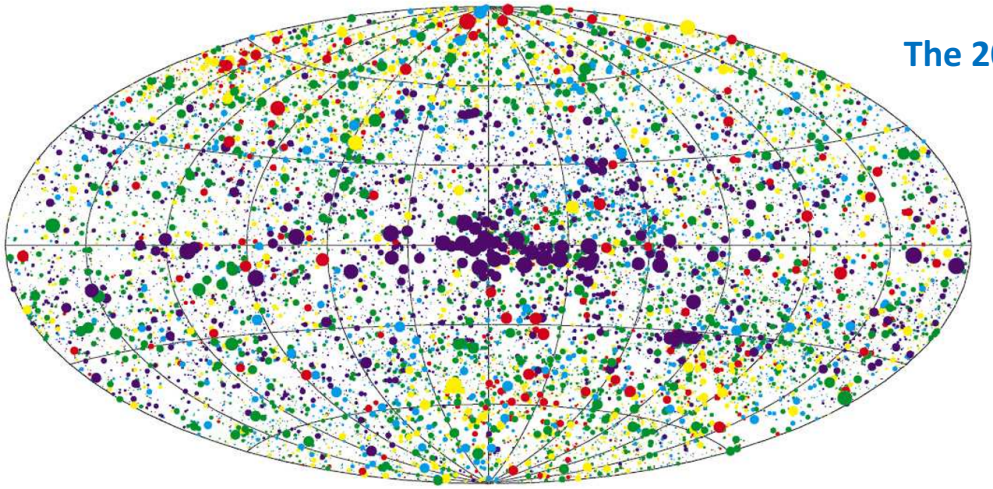


This is the X-ray background.
The pollution by charged particles is only 1-2 %
(Schmitt et al. 1991, Freyberg 2019)

A unique feature of ROSAT was that it imaged the cosmic X-ray background directly!

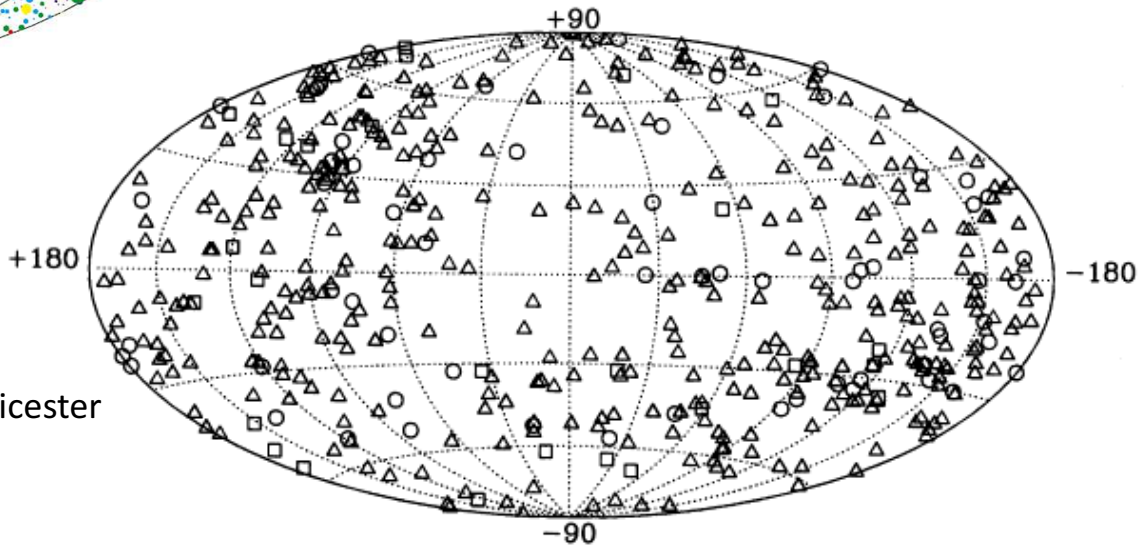
J. Truemper, 2019

The ROSAT All Sky Surveys in X-Rays and in the XUV



The 20.000 brightest of > 100.000 X-Ray sources

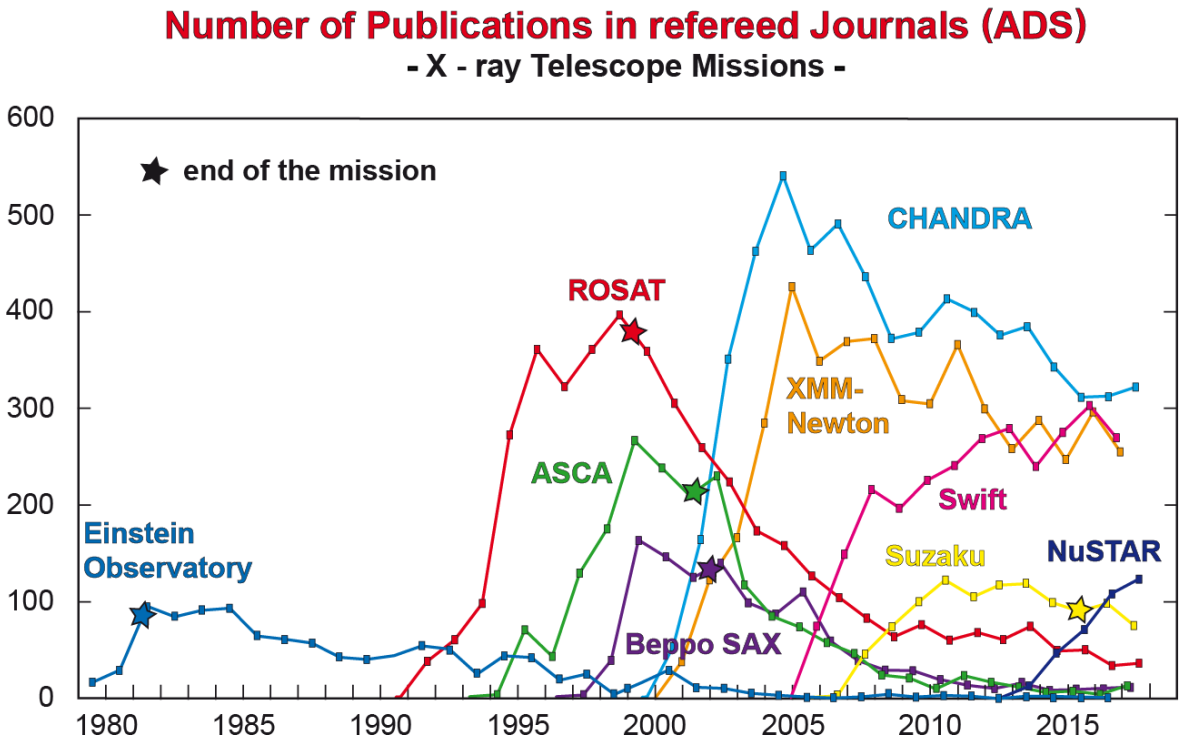
W.Voges et al. 1999, MPE Garching



The 479 XUV-sources

J.Pye et al. 1995, University Leicester

J. Trümper, 2019



The impact of ROSAT: Many new sources ~ 100.000 from the All Sky Survey (1/2 year) and the pointed observations (8 years). Total number of new sources ~ 200.000.

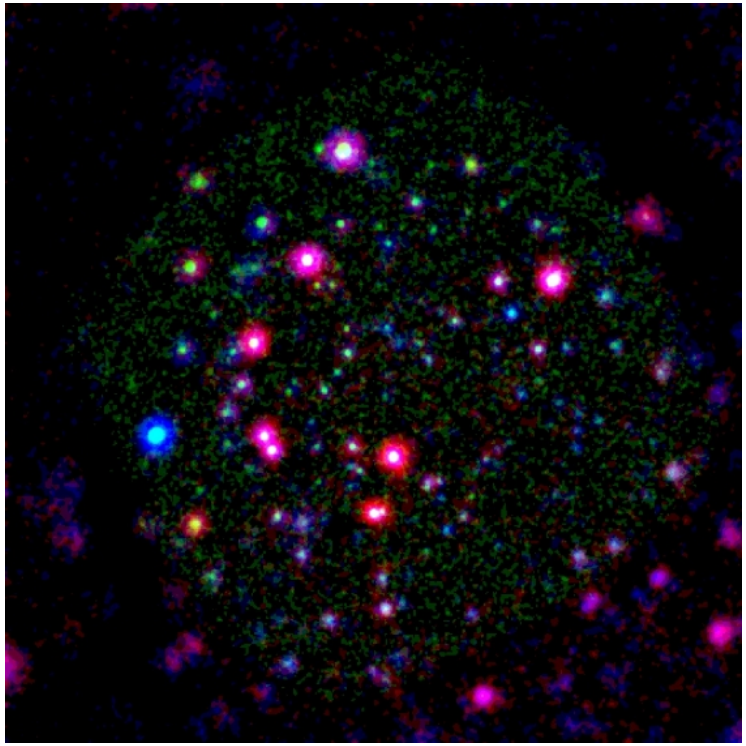
Discovery of new classes of X-ray sources: Supersoft Sources, comets, neutron stars showing only thermal emission, X-ray emitting ms-pulsars, ….

J. Truemper, 2019

Diving into the Hoary Deep - Ultradeep X-ray survey of the Lockman Hole

Hasinger et al., 1998

- **2.5 weeks of net observation time (ROSAT PSPC + HRI)**
- **red (PSPC soft), blue (PSPC hard), green (HRI)**

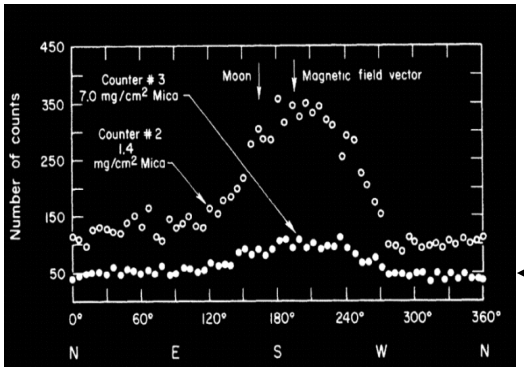


~ 80% of the sky background resolved into sources, mostly AGN

Thirteen refereed papers with Riccardo on the ROSAT deep fields in 1992-2001

History of the „diffuse“ X-Ray Background

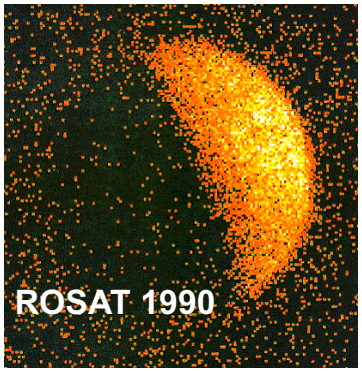
Courtesy Guenther Hasinger



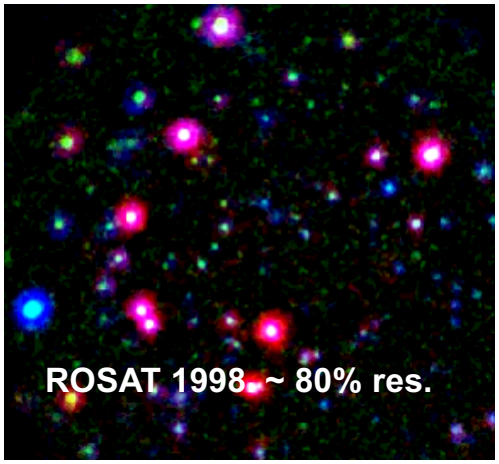
Giacconi et al. 1962

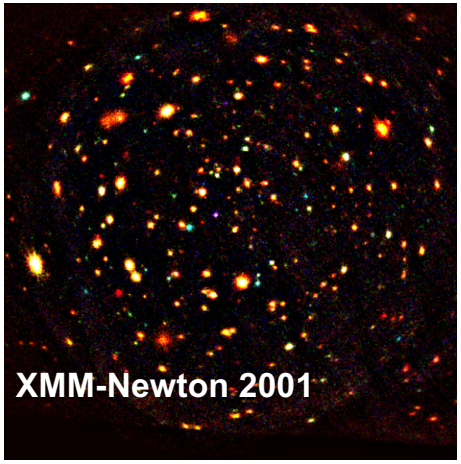
Occultation by the moon →

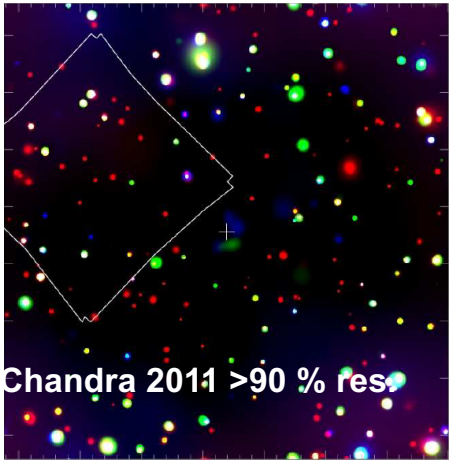
← **Discovery**



Schmitt et al. 1991



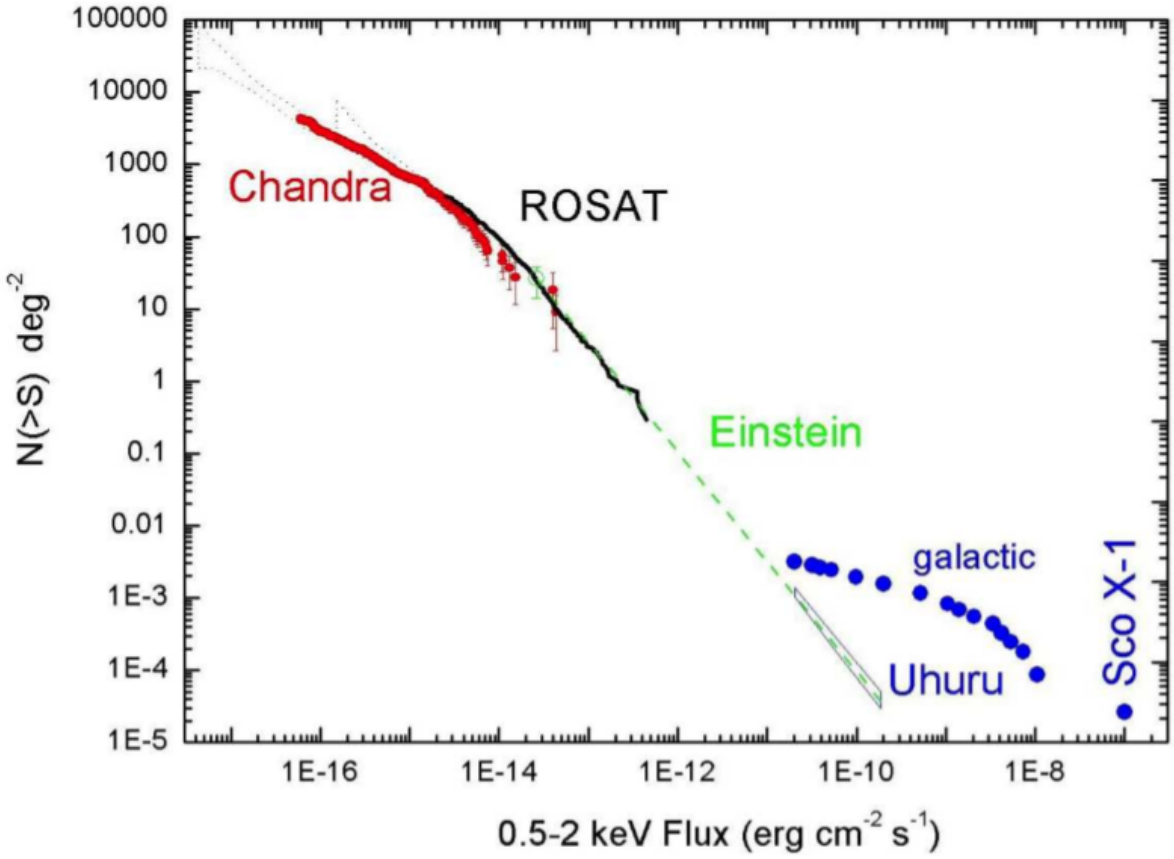




The X-ray background is the echo of black hole formation and growth over cosmic time.

J. Trümper, 2019

Guenther Hasinger‘s contribution to Riccardo‘s Nobel Lecture 2002



J. Truemper, 2019

A few personal reminiscences

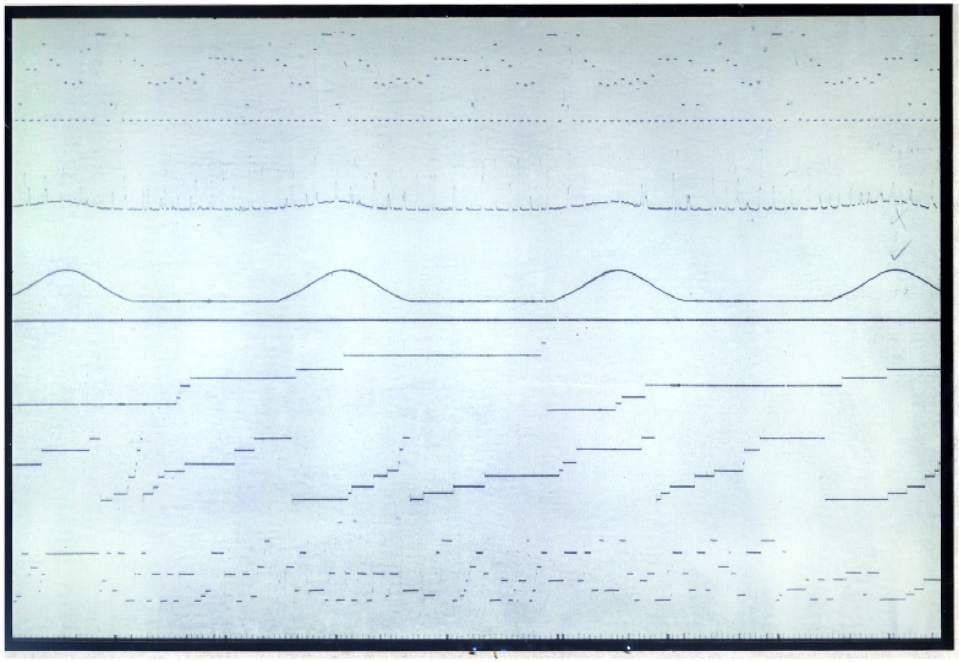
Symposium „Highlights of X-ray Astronomy in 1998 at MPE

Riccardo Giacconi

Joachim Trümper
Gregor Morfill

Maarten Schmidt
NN
Minoru Oda
Guenther Hasinger
Peter Predehl
Livio Scarsi:

J. Truemper, 2019



Sco X-1 on
June 12, 1962

Dear Joachim,
To remember a
time when we
were young

Rocardo

Garching, June 1998

J. Truemper, 2019

After our deep survey meetings we often had dinner at the old Munich beer hall - the „Augustiner“….

Riccardo‘s favorite choice was Schweinshaxn & Apfelstrudel

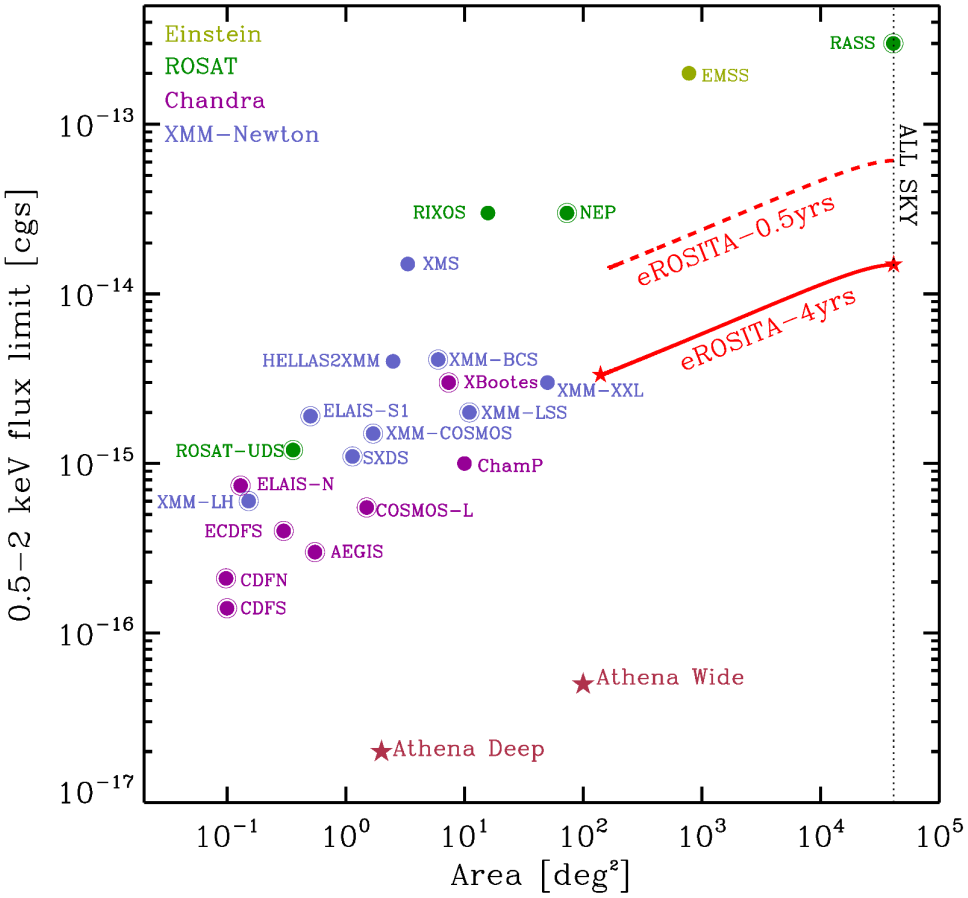
… and parties at MPE‘s Beergarden – here celebrating 6 years ROSAT in 1996

J. Truemper, 2019

A few words about the future

X-ray surveys in the past and future

Courtesy Andrea Merloni



eROSITA 2019

Athena 2032?

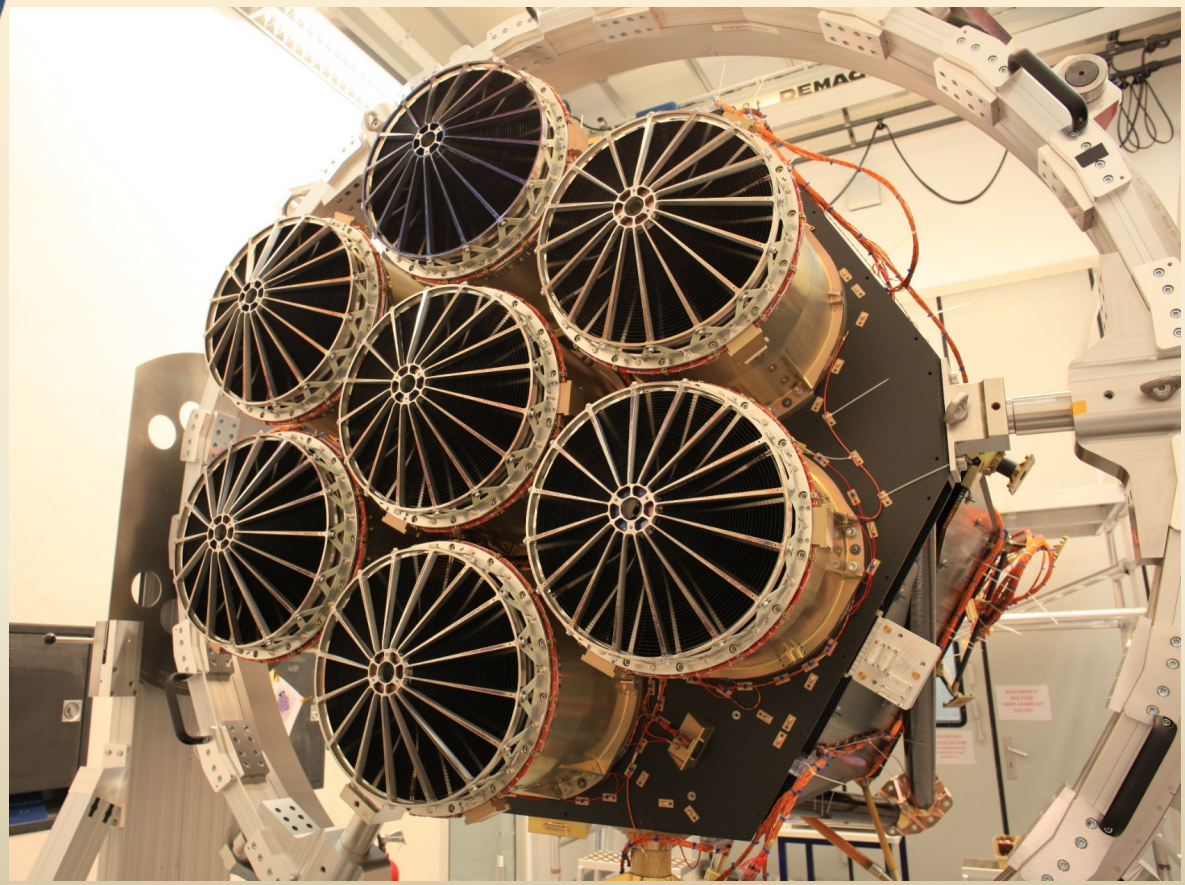
Lynx 2038?

J. Truemper, 2019

eROSITA

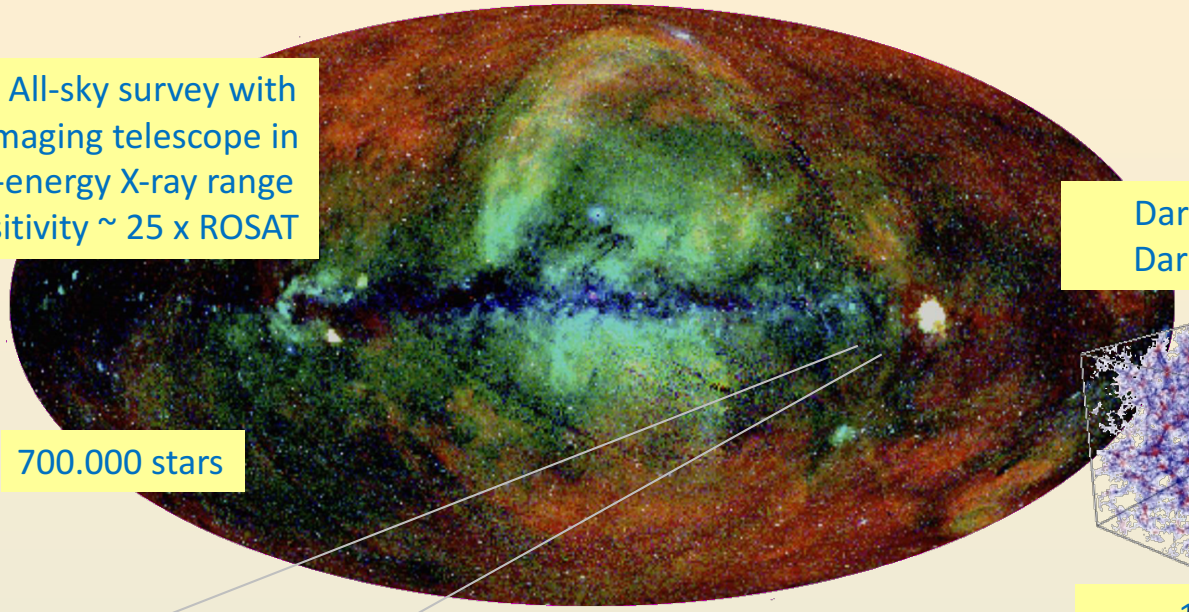
PI: Peter Predehl

To be launched on the Russian satellite Spectrum-Roentgen-Gamma on June 21, 2019



J. Truemper, 2019

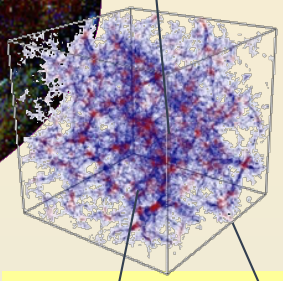
Science with eROSITA



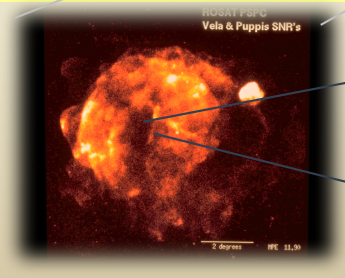
First All-sky survey with an imaging telescope in mid-energy X-ray range sensitivity ~ 25 x ROSAT

700.000 stars

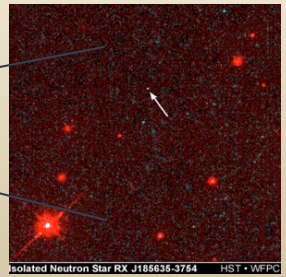
Dark Energy
Dark Matter



Supernova Explosions

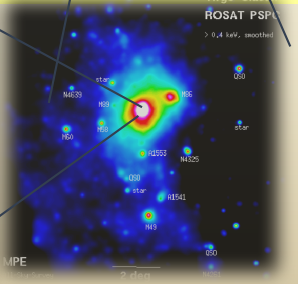


Neutron Stars



3 Mill. Black Holes

100.000
Clusters of Galaxies

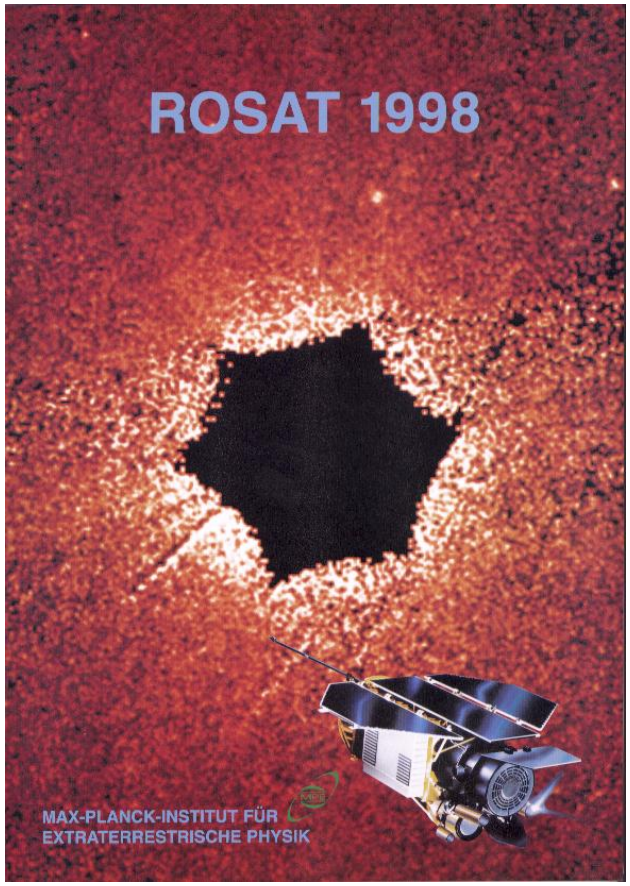


Courtesy
A. Merloni &
P. Predehl

J. Truemper, 2019

Guenther H. video

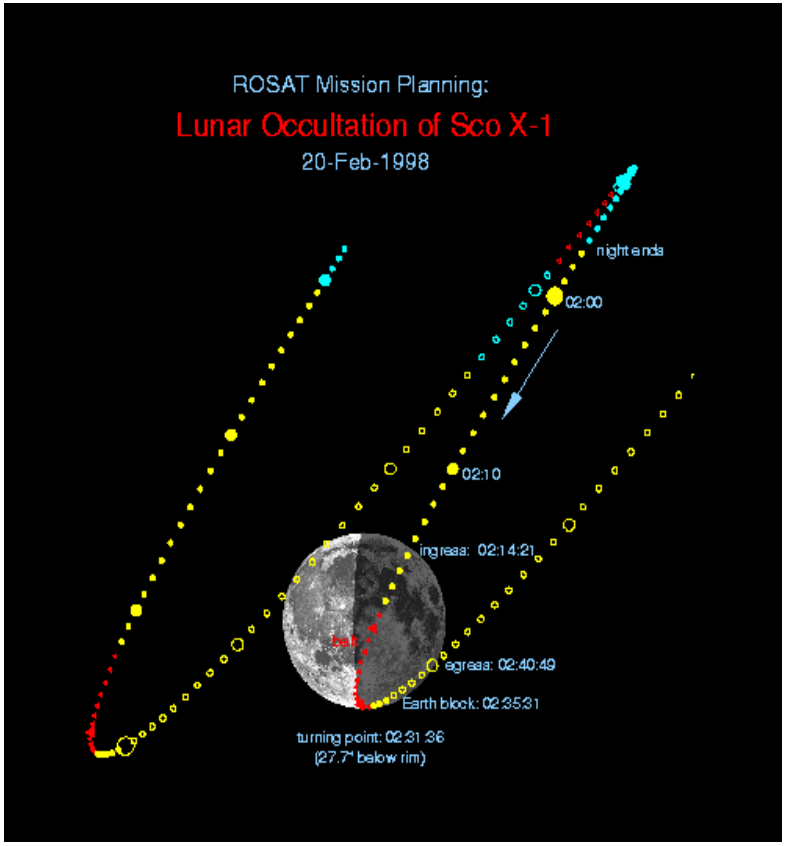
Rashid S. talk



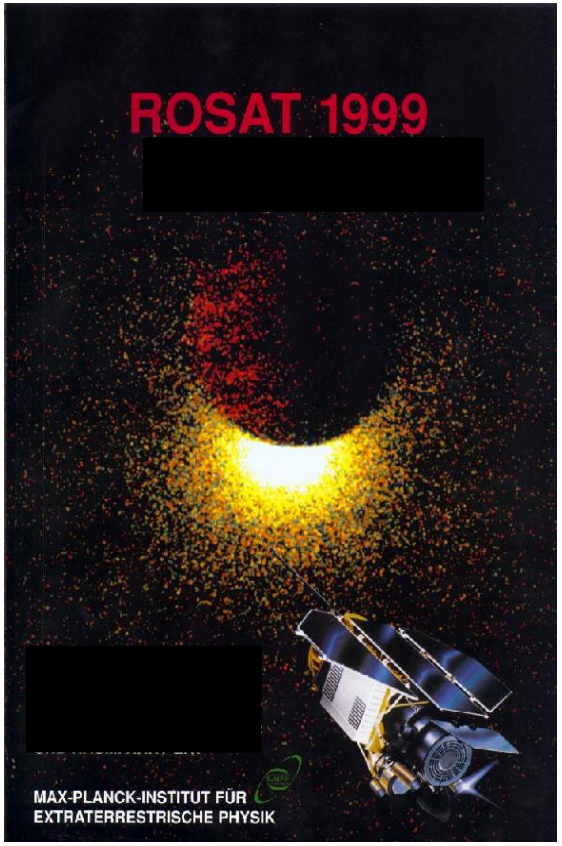
Sco X-1 was the only source in the sky that ROSAT did not look at – it was too bright!

A rare opportunity: The Moon meets Scorpius X-1 on 20 February 1998

The PSPC was switched on 1 sec after Sco X-1 had passed the lunar rim.



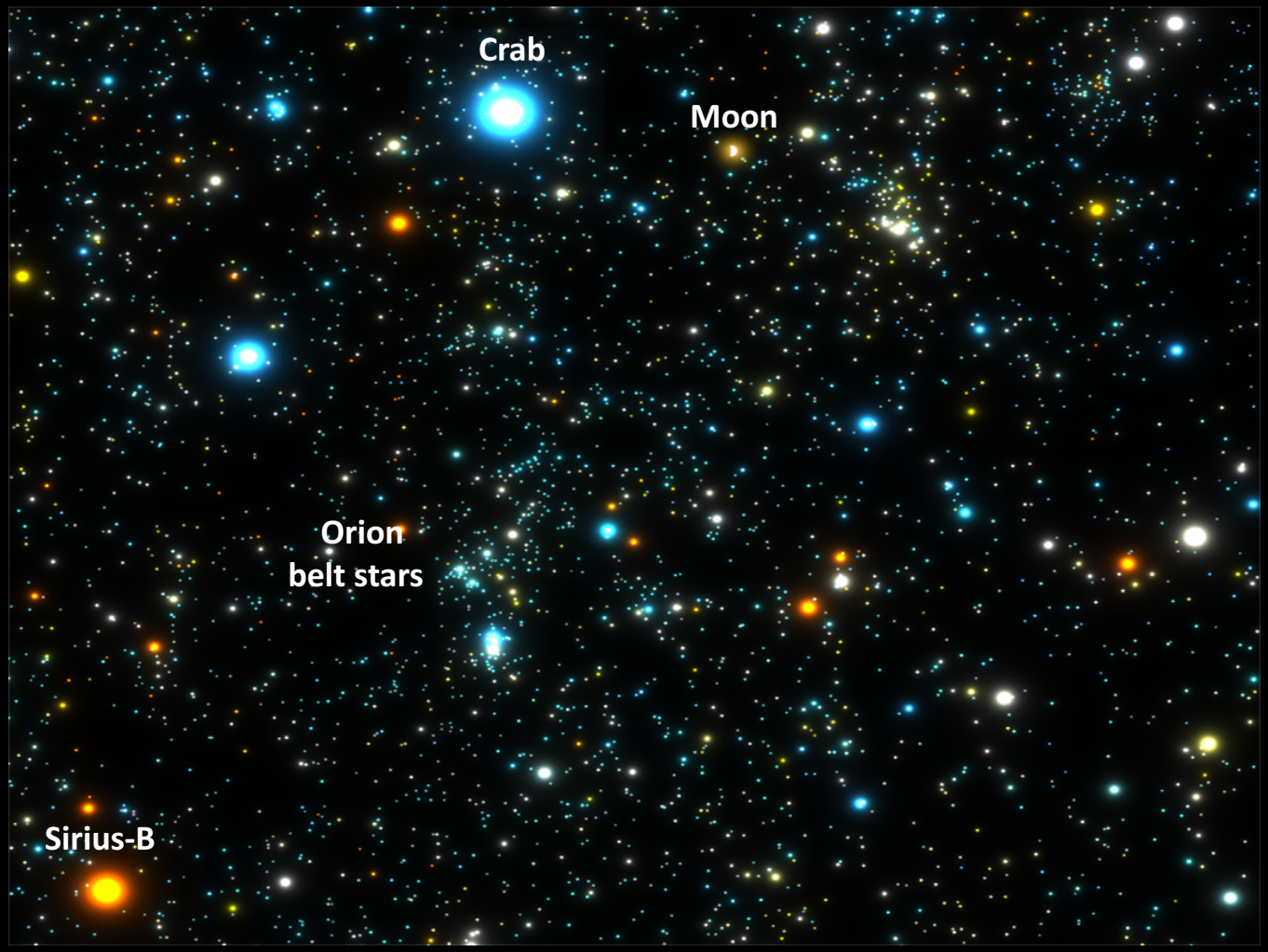
Path of Sco X-1 in the rest frame of the Moon.



The dust scattering halo

J. Trümper, 2019

The X-Ray Sky above Munich in December (5 x 5 degrees^2)



J. Trümper, 2019

The X-Ray Sky above Munich in December (5 x 5 degrees^2)

J. Trümper, 2019