Space Astrophysics

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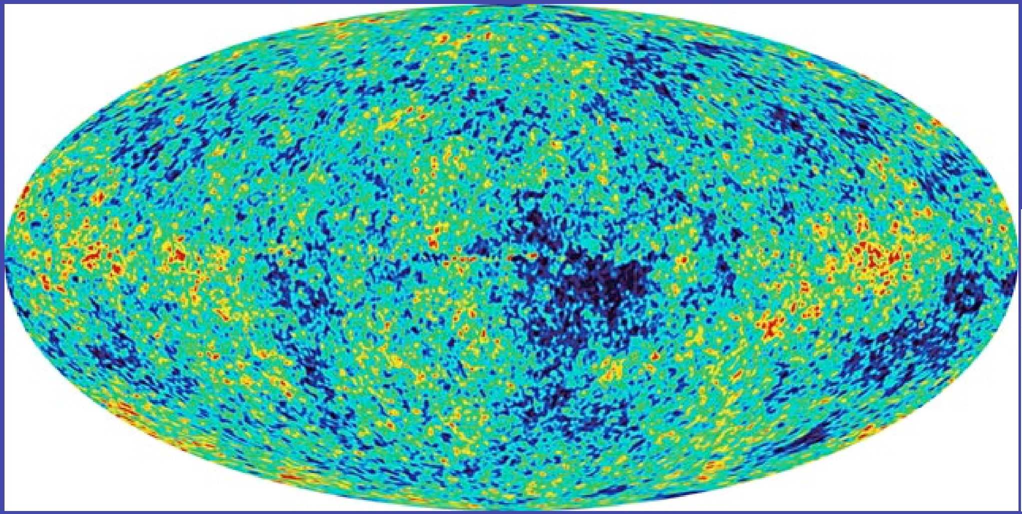
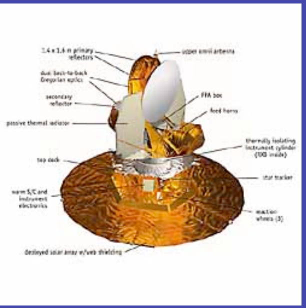
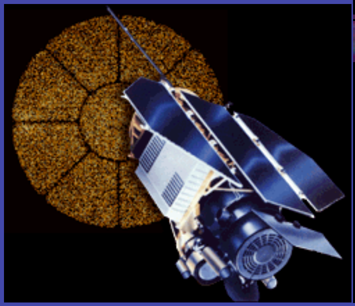
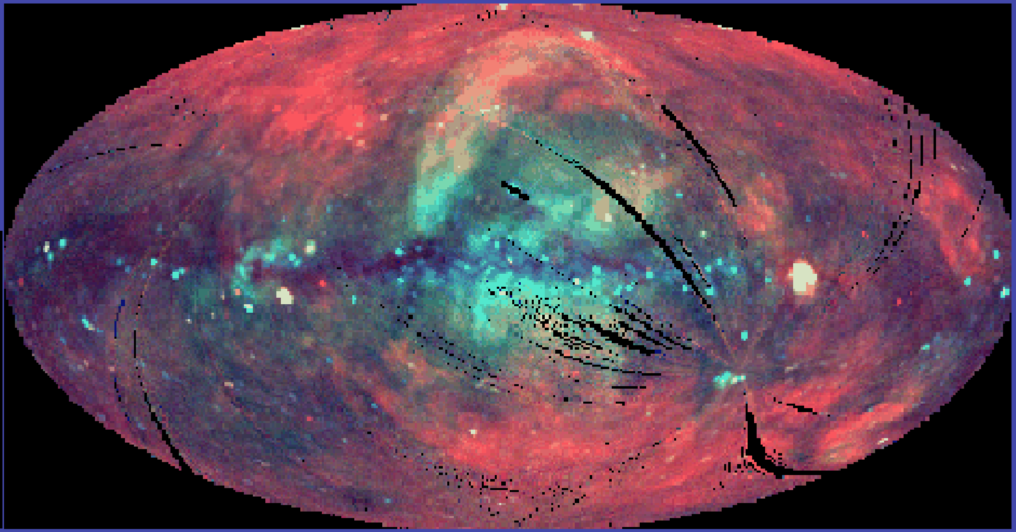


Wilkinson Microwave Anisotropy Probe: Universe temperature fluctuations



ROSAT: An X-ray Image of the Universe





Overview

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1. Course Structure and Requirements
   a) Logistics
   b) Contact
   c) Structure
   d) Requirements

2. Introduction to high energy astrophysics
   a) Cosmic Laboratory
   b) Anomalies
   c) EM Spectrum & wavelength disciplines
   d) history, current status, future goals

Logistics

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Course Website:

http://lheawww.gsfc.nasa.gov/docs/outreach/GWU_Space_Astrophysics/Spring05/

or

http://tinyurl.com/6yoce

Accessing the Website: astr191, highea

Course Description:

We will discuss the physics of celestial phenomena as determined primarily from observations with space-based instrumentation. While the entire electromagnetic spectrum will be covered, the high-energy (X-ray and gamma ray) region will be heavily emphasized. Where appropriate, some results from ground-based instrumentation (e.g. radio and optical) will also be introduced.

ASTR 191 Section 10 Space Astrophysics, 3.0 credits
Is taught by Dr. Mike Corcoran and Dr. Bill Parke
In SAMS 311 on Tuesday, at **03:55pm-04:55pm**
In SAMS 311 on Thursday , at **03:55pm-05:25pm**
CRN: 67111
From: 01/18/05 To: 05/05/05

Contact

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Structure

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- (Most) lectures on Thursday by Mike
- (Most) Tuesdays will be a review and discussion of Thursday's lectures & assignments by Bill

Text: *The Physical Universe* by Frank Shu

⇒ good discussion of astrophysical processes

⇒bit out of date; not focused on high energy phenomena

Supplemental readings and handouts

Reserve reading: *Exploring the X-ray Universe* by Phil Charles and Fred Seward

Requirements

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Problem Sets	40%
Midterm	15-30%
Cumulative Final	30%
Proposal	0-15%

Proposal: Define a problem of astrophysical interest and technical requirements needed to help resolve it using current technology

Intro to HEA

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Astrophysics: the application of small-scale physical principles to the Universe at large

Astrophysics is an observational science

- discoveries based on analysis of information from population studies, not experiments
- effects of composition, angular momentum, mass, EM fields on phenomena
- Information: photons, matter particles from near (solar wind, asteroids, meteorites) and far (cosmic rays)

References:

http://imagine.gsfc.nasa.gov/docs/science/science.html

The Cosmic Laboratory

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The Universe provides an opportunity to study matter and energy under extreme conditions not easily producible on earth:

- effects of extreme temperatures & densities
- rapid spins
- enormous magnetic fields
- extreme speeds

Examples:
- What happens to matter when it’s squeezed to densities higher than the density of the atomic nucleus?
- What are the conditions of matter at temperatures above a billion degrees K?

Anomalies I - Positions

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- Astrophysicists typically use the cgs system (centimeters, grams, seconds) not mks (meters, kilometers, seconds)
- angular measures in arc-seconds
- celestial positions: equatorial coordinates
  - **Declination:** North-south position (in degrees, arc-minutes and arc-seconds)
  - **Right Ascension:** East-West position (in hours, minutes and seconds)
- Other coordinate systems: Galactic; ecliptic; etc.

Anomalies II - Distances

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Astronomical Unit: basic distance; mean distance between the earth and sun; 1.5×10^{13} cm

Parsec: basic measure of distance

1 parsec is the distance at which 1 AU subtends 1 second of arc

Light-year: Distance (not time!) equal to the speed of light x 1 year ~ 3.086×10^{18} cm

1 pc = 3.26 ly

Anomalies III - Brightness

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Flux: amount of energy passing through a surface (units: ergs cm^{-2} s^{-1} cgs). Brighter objects have higher fluxes

Magnitude scale: brighter objects have numerically lower magnitudes (magnitude 6 object fainter than magnitude 1 object)

Absolute Magnitude: “apparent” magnitude of an object placed at a standard distance of 10 pc

Caution: astrophysicists make “order of magnitude” estimates, i.e. approximation to nearest power of 10. *Don’t get confused!*

EM Radiation

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Most information about the Universe comes in the form of EM radiation: self-sustaining, coupled electric-magnetic waves/particles produced by the motion of charged particles and propagating at c.

measurable quantities: wavelength, intensity, polarization

Different physical processes produce different characteristic radiation

The EM Spectrum

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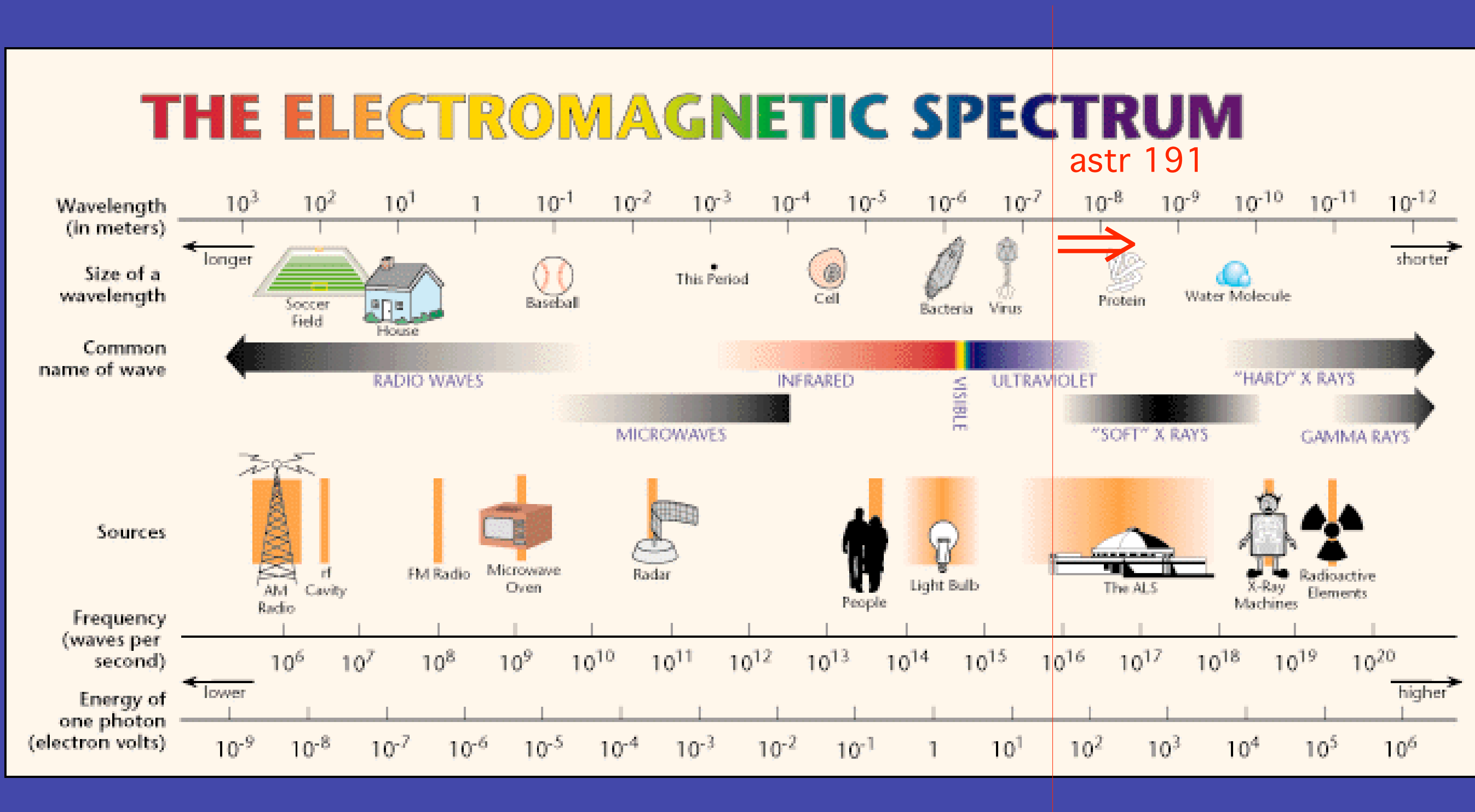

Energy Disciplines

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Low Energy: radio, microwave

- physics of cold or low energy matter; molecules
- small & large scale flows
- galactic structure
- highest angular resolution: micro-arcseconds

Medium Energy: optical, UV

- bright matter: stars, nebulosities
- normal/high density material
- highest angular resolution: milli-arcseconds

High Energy: X-ray, Gamma-ray

- high temperatures; plasmas
- extreme gravity
- poorly-understood accelerations
- highest angular resolution: arcsecond

The Advantage of Space

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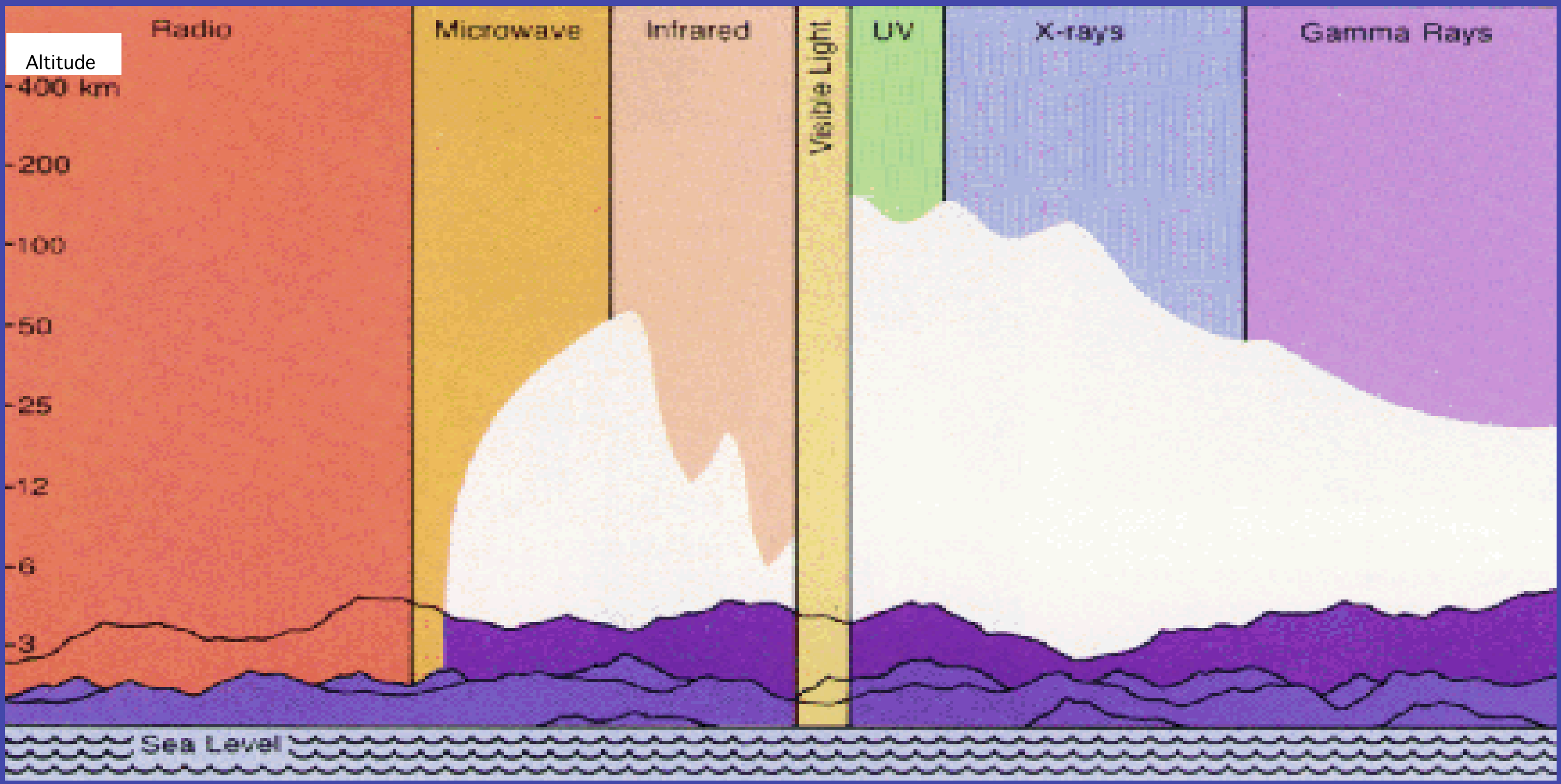

Earth's atmosphere prevents most of the EM radiation from reaching the surface, except for long wavelengths (radio) and the narrow band of visible light.

Beginnings of Space Astronomy

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Availability of rocket systems after WWII ignited interest in the exploration of space, especially in the unexplored regions of the electromagnetic spectrum blocked by the earth's atmosphere.

One interesting region of the EM spectrum is the X-ray region. X-rays were discovered more than 50 years prior, on November 8, 1895 by Wilhelm Conrad Rontgen.

X-ray emission from the sun first detected in 1948 by a group from the Naval Research Lab, using a photographic camera carried aloft on an Aerobee rocket - distressingly low flux!

A rocket experiment by Ricardo Giacconi & a group at American Science & Engineering, designed primarily to detect X-rays from the moon, found the first cosmic X-ray source: Scorpius X-1. Surprisingly (astoundingly) bright.

Why? How Many?

Uhuru: orbiting observatory, performed X-ray all sky survey

Einstein X-ray observatory: first orbiting X-ray imaging observatory. First X-ray images of the sky.

Recent & Current Facilities

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X-ray:

- Chandra X-ray Observatory: The "Hubble Space Telescope" of X-ray astronomy. Highest spatial resolution, high spectral resolution
- XMM-Newton Observatory: Very high X-ray gathering power, good spatial resolution, high spectral resolution
- Rossi X-ray Timing Explorer (RXTE): highest X-ray timing capability
- ROSAT: 1st X-ray all-sky imaging survey

Gamma-Ray:

- Swift: identify sources of gamma-ray bursts
- INTEGRAL: good spatial and spectral resolution, studies of Milky Way
- Compton Gamma-Ray Observatory (CGRO): All sky gamma-ray survey, long-term study of GRBs, unidentified sources

X-ray & Optical Comparison

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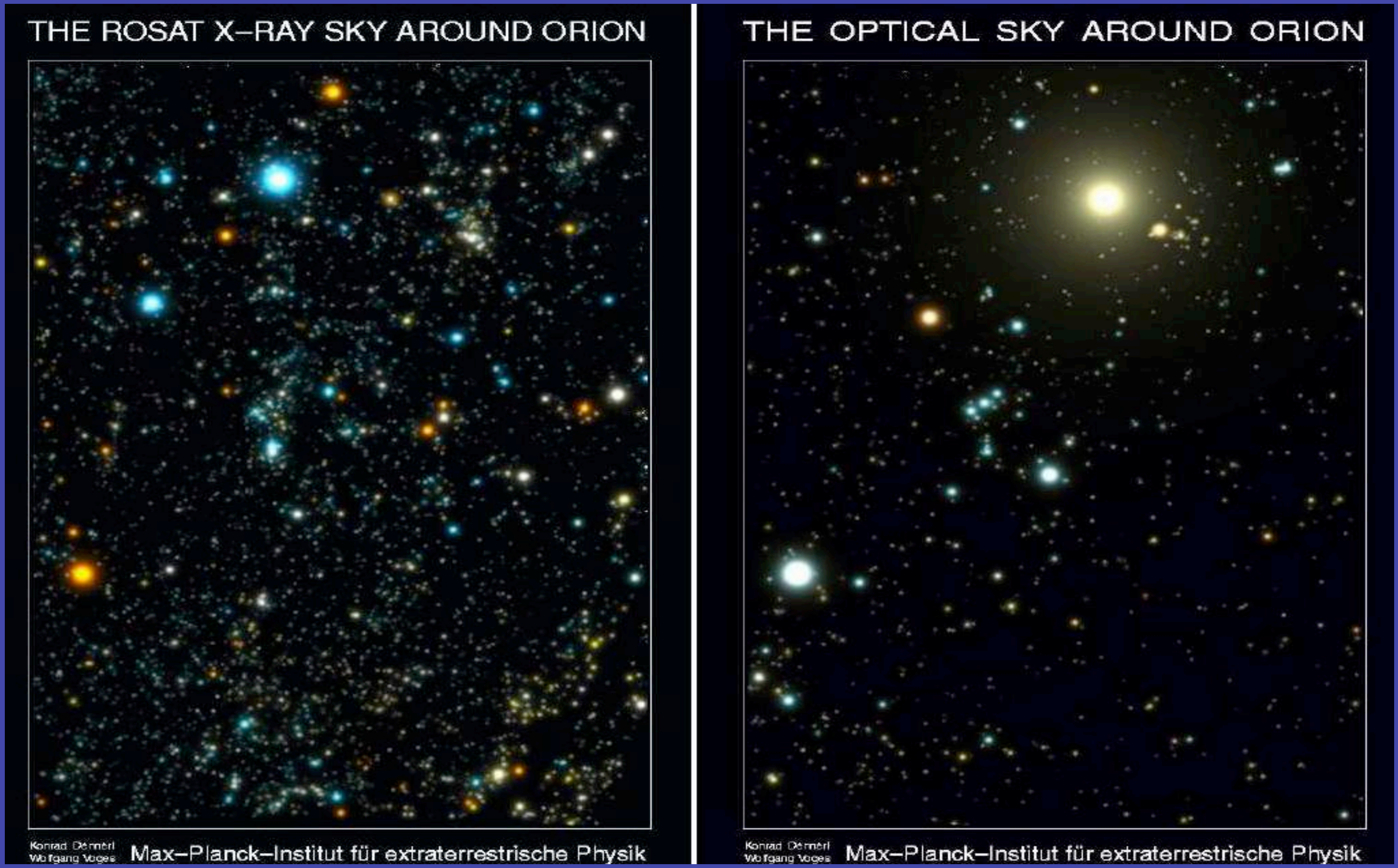

See the High Energy Astrophysics Picture of the Week
http://heasarc.gsfc.nasa.gov/docs/objects/heapow/heapow.html

The Future

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Goals of the Next Generation Observatories:

- Image matter and space near a black hole (MAXIM)
- Extremely high throughput and spectral resolution (Constellation-X)
- Identification of gamma-ray sources (GLAST)
- Determine sources of dark matter and energy (DUO)
- are there gravity waves? (LIGO, LISA)

see NASA's "Beyond Einstein" program:

http://universe.nasa.gov/