Emergencies
Based on University Policy

- Regular attendance and participation in this class is best. However, if a class must be missed due to an illness, or other valid reason, the policy is:
  - For every necessary absence from class, a reasonable effort should be made to notify me or the TA in advance of the class. When returning to class, students must e-mail me or bring a note identifying the date of and reason for the absence.
- If a student is absent more than 5 time(s), documentation signed by a health care professional may be requested.
- If a student is absent on days when **tests are scheduled**, they should notify me in advance (if possible), and upon returning to class, bring documentation of the illness or personal reason.
- Please inform me of any other issue requiring special attention

Homework

- Homework assigned approx. once every two weeks
- HW is collected *at the start of class* on the due date (a week later)
  - **Please hand in on time**, or document the valid reason why it is late.
  - No credit after the day on which it is due, unless there is a justifiable reason.

Academic integrity

- **Always:**
  - Present your own thoughts in your own words
  - Cite any references that you use
- **Never**:
  - Copy from another student
  - Directly quote any published article unless you also give full credit to that article.
  - Allow other students to copy from you.
- Per campus policy, please write the honor pledge on each assignment

Absences, academic dishonesty

- I follow the University policy
- Absences – all must be documented
  - If scheduled (e.g. sports), bring paperwork *as soon as possible*.
  - Illness: contact me *before* missed class or assignment; arrange for make-up (if necessary) within one week
  - Let me know if you have a religious observance that will effect your attendance
- Academic dishonesty
  - Zero-tolerance policy
  - Absolutely no copying of homeworks or exams!
  - Must list all references used to complete an assignment

Syllabus- Number of Lectures is Approximate

- Introductory Lectures – what is High Energy Astrophysics 2 lectures
- Physical Processes 2 Lectures
- X-ray Detectors +Telescopes 2 Lectures
- Cluster Lectures (4)
- NS Lectures (4)
- Black Hole Lectures (4)
- SuperNova and SNR lectures (2)
- Gamma-ray bursts (1-2)
- Summary
- Other topics?? - what do you want??

Material On Clusters

A 'big' hole in these books is that clusters of galaxies are not discussed - I will present material which is not in the texts

Unfortunately the only text that I have found is at a graduate level (Longair- High Energy Astrophysics) - but it is very good!

-

a comprehensive book on clusters is
"A pan-chromatic view of clusters of galaxies and the large-scale structure
Plionis, López-Cruz, Hughes"- Springer
Lecture notes in physics, 740

Where are we going

- In the class we will discuss
  - The physical mechanisms producing high energy photons (e.g ch 5 of Melia and ch 3 of Rosswog and Bruggen)
  - The objects 'of' high energy phenomena (e.g. ch 9,10,11,12,13 of Melia and 4,5,6,7,8 of Rosswog and Bruggen)
  - How one obtains the data (e.g. instruments and telescopes) - ch 1.4-1.5 of Melia and Appendix A of

In order to understand a lot of this we will also

discuss accretion disks (ch 6 (part) +ch 7 of Melia) and part of ch 8 of Rosswog and Bruggen

Conduct of Class

- Ask questions if you do not understand what I am saying or need more explanation-
  - In other words *SLOW ME DOWN*
  - I will be happy to provide additional references and reading material
  - *If I fall into 'jargon'*

HEA

- The study of such objects and processes thus covers a VERY wide range of physics and types of physical objects.
- In order to study x-rays, γ-rays etc from astrophysical objects one needs special techniques and telescopes and the work often must be done in space (I will focus on photons)
- There is a lot of material available (see

Why Bother with High Energy At All

The energies covered by high energy astrophysics have 'unique' attributes not available in other energy regimes -e.g. for x-rays

- The Ionization balance, as in all other energy bands is a strong function of temperature and ionization parameter- but can observe most of the ions directly
- The atomic physics is extremely simple (compared to other λ bands) since the strongest lines are H and He-like.

For which calculations of cross sections and rates is particularly simple

- ‘Relatively’ easy to distinguish method of ionization (e.g. collisional, shocks photoionization)
- The x-ray band is sensitive to all stage of ionization from absorption by cold material (e.g. CI) to emission by hot material (e.g. Ni XXVII) and thus provides a wealth of diagnostics

- Unique ‘penetrating’ capabilities (e.g. most of the universe is obscured (AGN and star formation)
- Most of the baryons in the low z universe can only be observed in the x-ray band

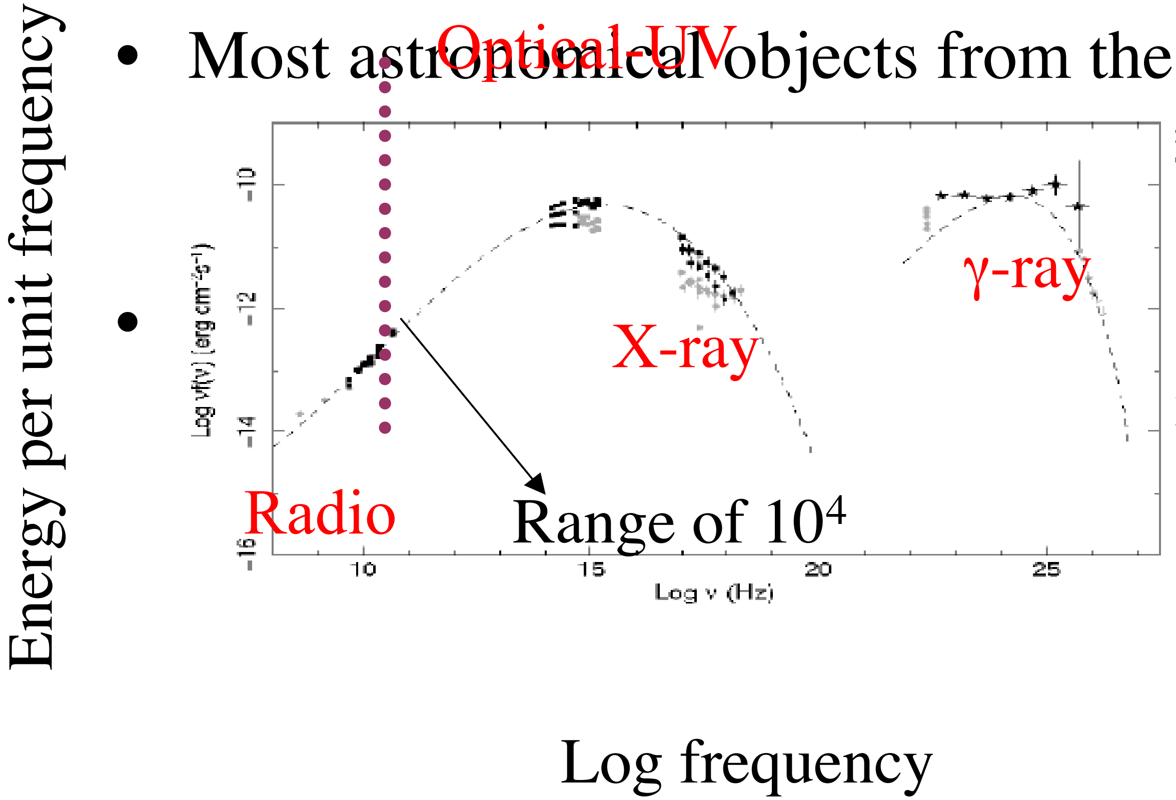
For certain classes of objects (AGN, x-ray binaries, clusters of galaxies) a large fraction of the emitted energy is in the high energy band

In the 0.6-1000Mev γ-ray band most of **the universe** is transparent
However at higher energies γ-rays are 'absorbed' by photons and thus the opacity at very high energies is a measure of the photon density of the universe

γ-rays are the emitted by radioactive isotopes and thus are a measure of creation of the elements

Multi-Wavelength Astronomy

- Astronomy is a multi-wavelength *observational* science
- Most astronomical objects from the comets to ... ectromagnetic
- ... one has to ... rays (17 orders

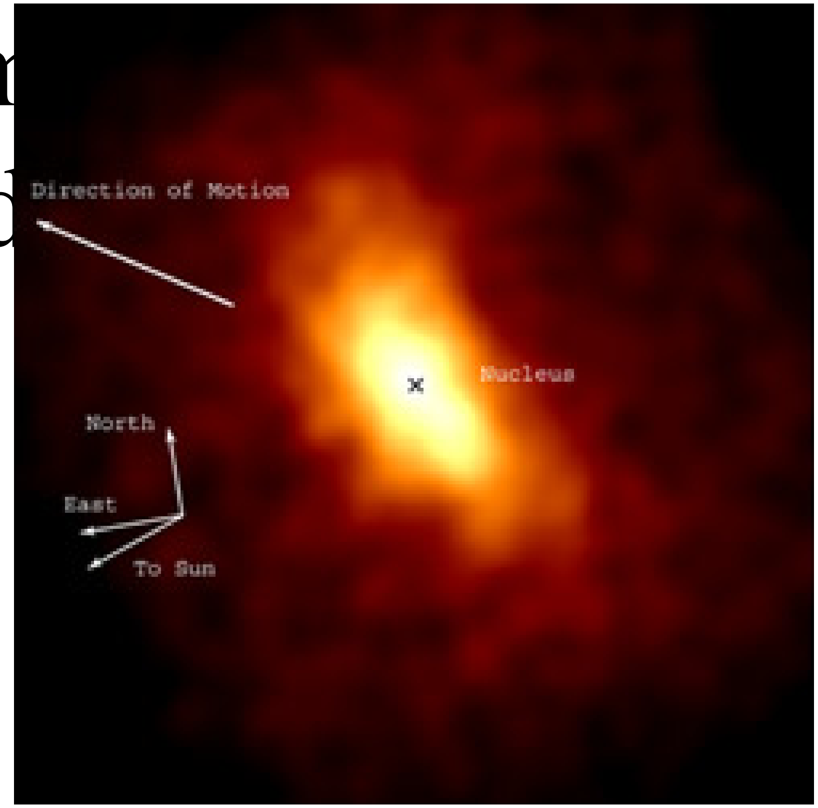


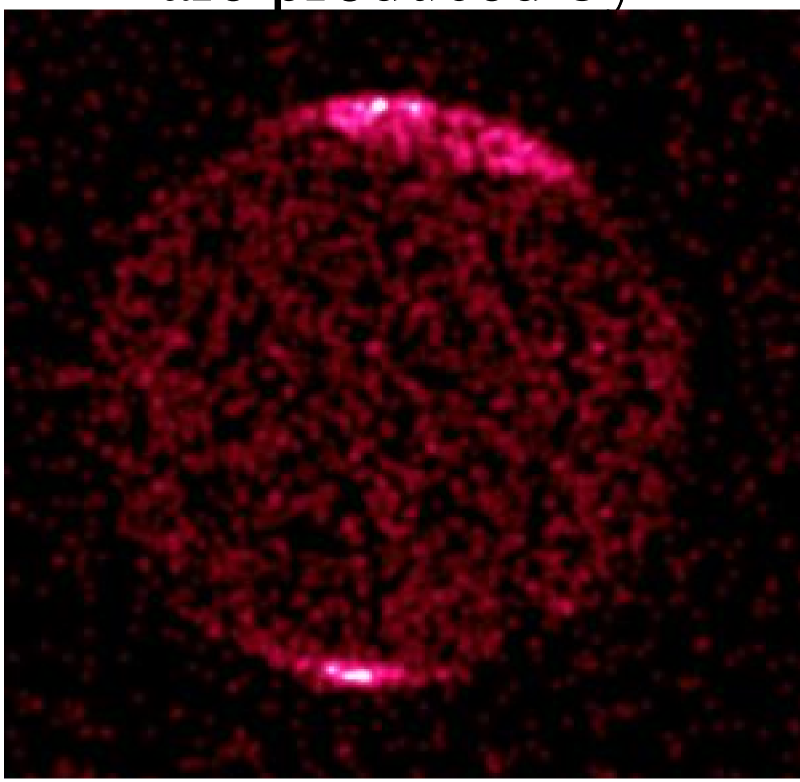
Broadband spectral energy distribution (SED) of a 'blazar' (an active galaxy whose observed radiation is dominated by a relativistic jet 'coming at' us

A large fraction of the total energy appears in the γ-ray band

Chandra X-ray Im
LINER and

- X-rays from Jupiter are produced by





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Energetic solar wind ions impact the coma, capturing electrons from neutral atoms. As the electrons become attached to their new parent nuclei (the solar wind ion), energy is released in the form of X-rays. Comets become significant X-ray generators when they interact strongly with solar wind ions.

Read more: http://www.universetoday.com/21826/swift-detects-x-ray-emissions-from-comets

Astrophysics (Astronomy) and Physics

- Astrophysics is a branch of physics like geophysics and meteorology
- One does observations not experiments
- This gives a very different flavor to the field

The universe is a very big, complex and exciting place

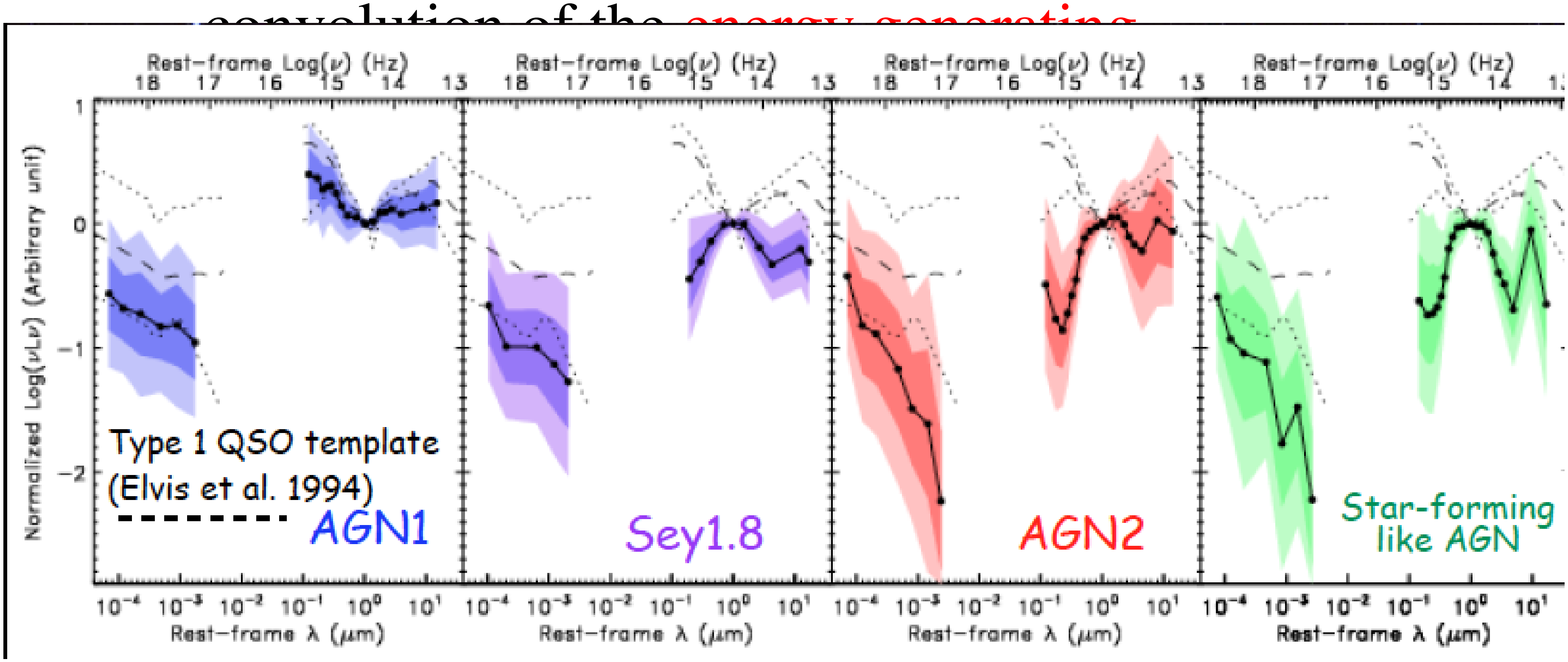
Most of what we have learned in the last 50 years have come from unexpected discoveries

Much of this has been driven by new instrumentation and the opening up of new observing windows and the rapid advance of computing

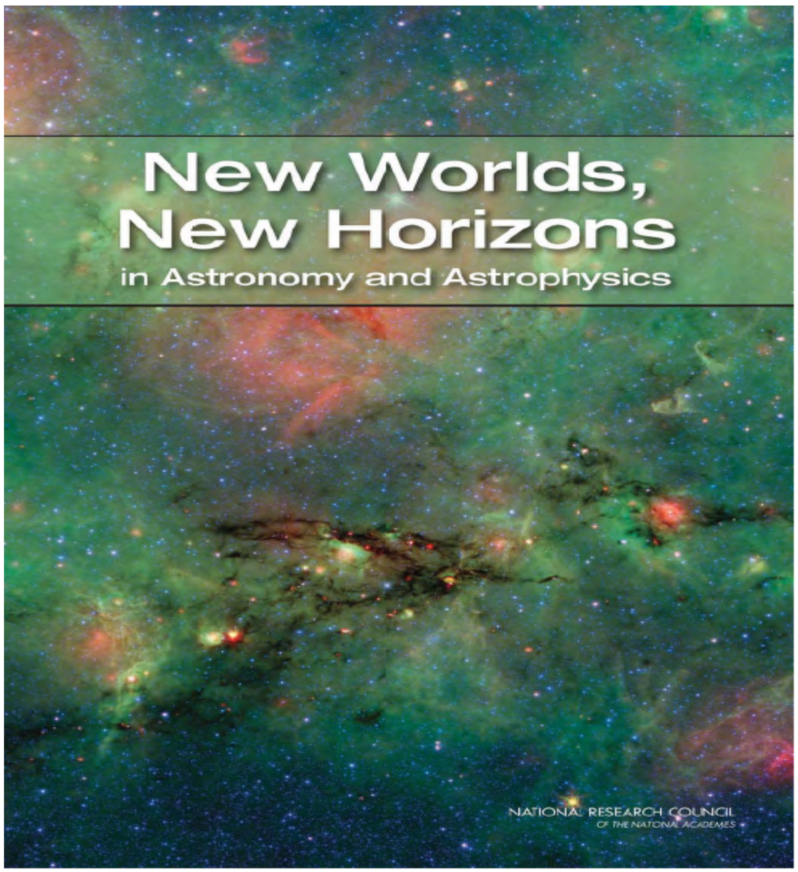
The wide range of astrophysical conditions involves virtually all of physics (plasma, atomic, nuclear, quantum etc) and thus astrophysicists have to be knowledgeable about almost all of physics

Different Types of Objects Have Different Spectral Energy Distributions-SEDS

- The broad band spectrum represents the convolution of the energy generating



From the National Academy of Sciences
Report issued 8-13-2010

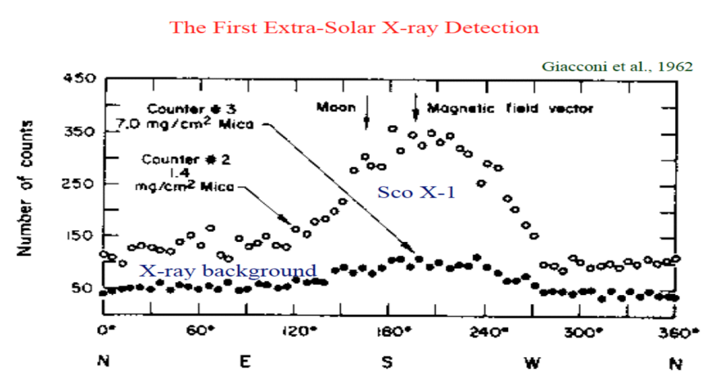


In order to carry out astronomical research, there are increasing demands for detailed knowledge across many sub-fields of physics, statistics, and computational methods. In addition, as astronomy and astrophysics projects have become more complex, both in space and on the ground, there has been a greater need for expertise in areas such as instrumentation, project http://heasarc.gsfc.nasa.gov/docs/history/

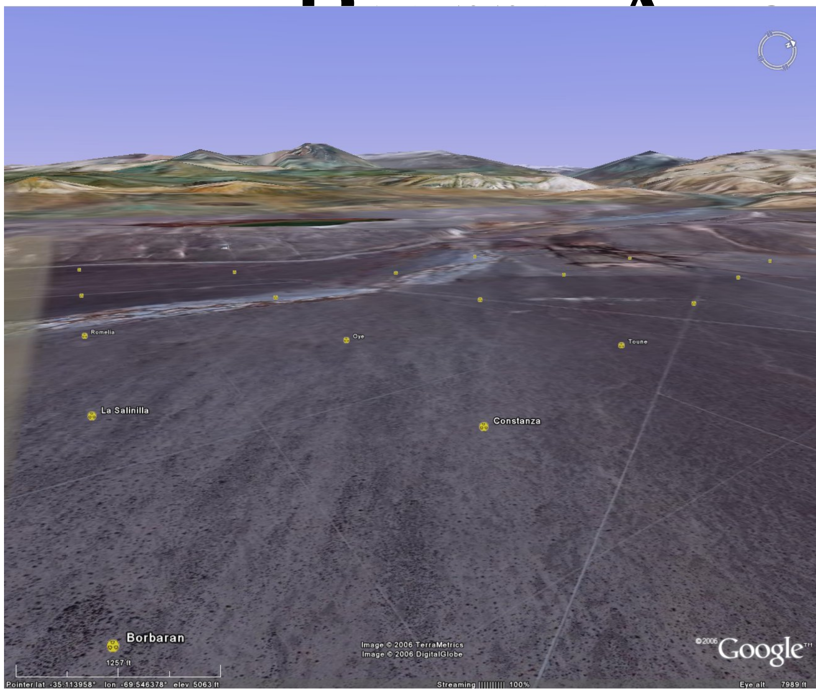
- Astronomy is the 1st science-back to Mesopotamia
- High energy astrophysics
  - cosmic rays were discovered in 1912 (centenial last year) by Victor Hess (Nobel prize 1936),
    - he found that an electroscope discharged more rapidly as he ascended in a balloon.
      - source of radiation entering the atmosphere from above-
      - Cosmic' rays' are electrically charged particles coming from

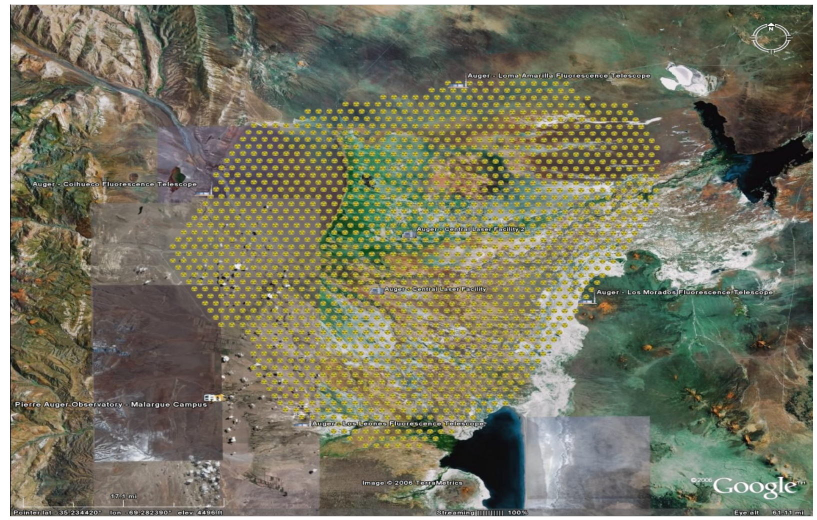
The first astronomical X-ray source- the sun (1948): using captured WWII V2 rockets. Herb Friedman and collaborators at the US Naval Research Lab (in Washington DC).

First non-solar x-ray source Sco X-1 rocket 1962 (Giacconi et al **Nobel prize** 2002)



Pierre Auger Observatory- Google Earth





X-ray Images of the Sun

- In addition to being the '1st' x-ray source the sun

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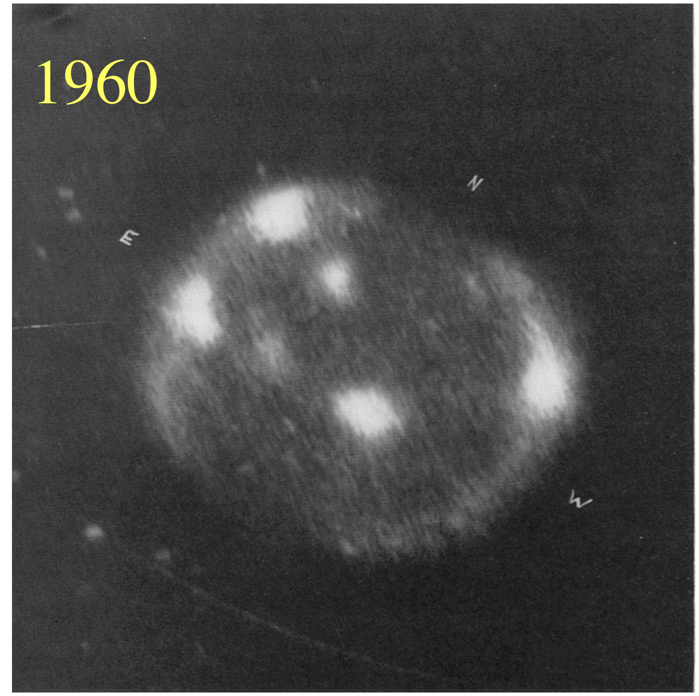
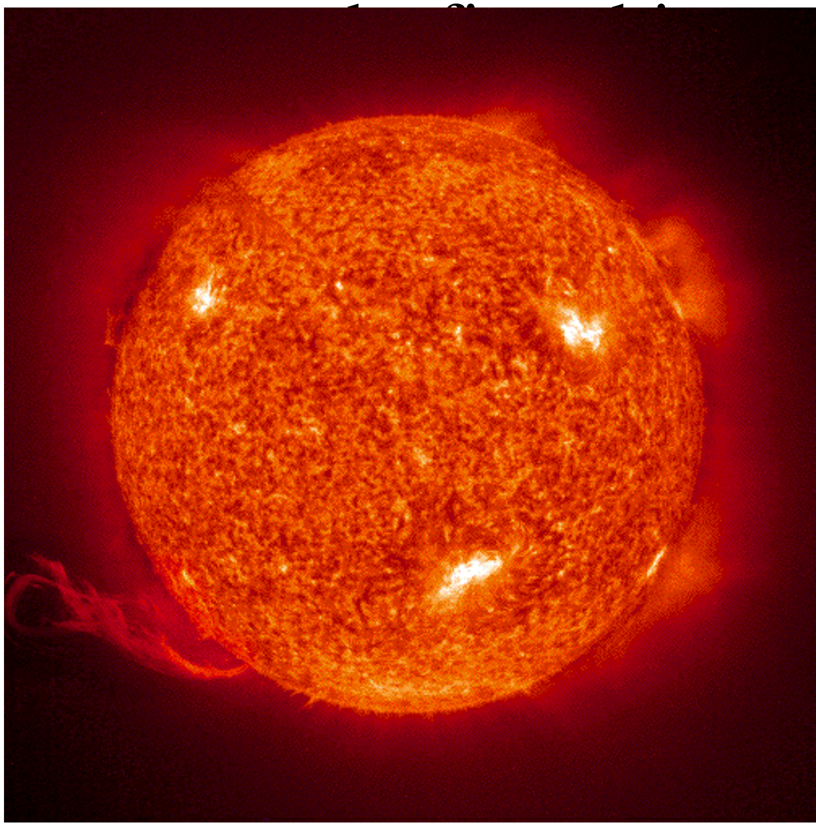
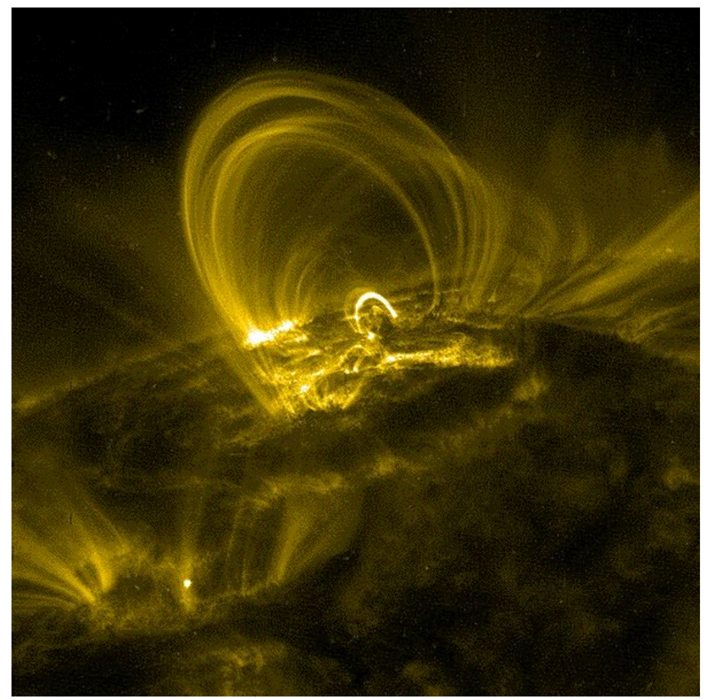
ect





1990's



X-ray Astronomy

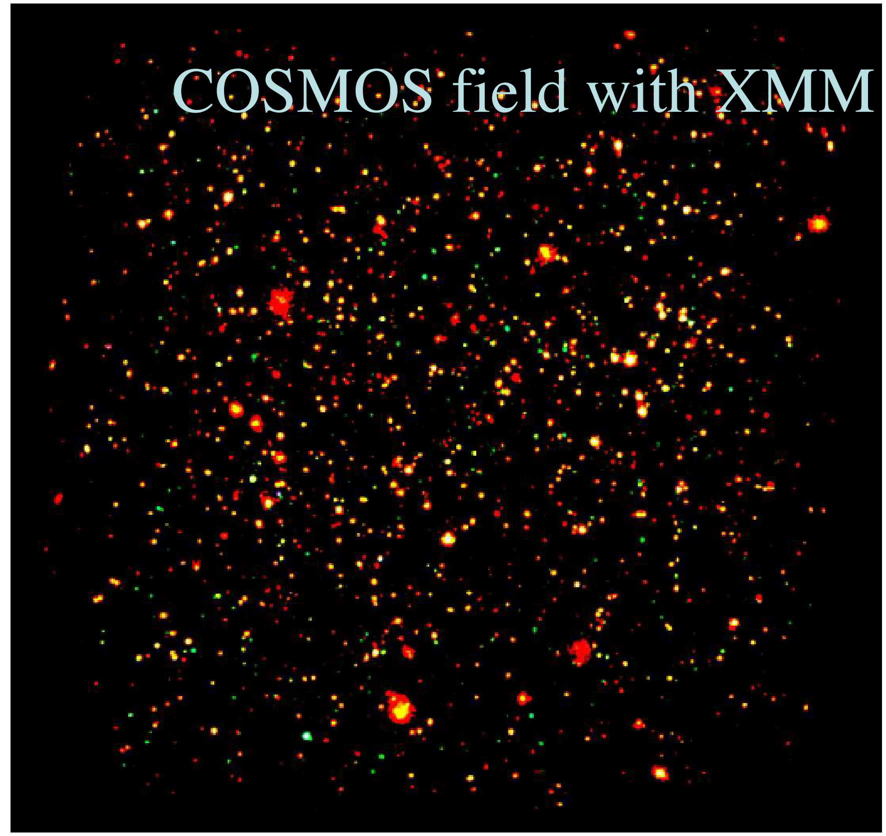
- From its start in 1962, sensitivity has increased by 10^7

(~$5x10^{-17}$ ergs cm^{-2} sec in the 0.5-2 keV band)

  - angular resolution by 10^5 (0.5")
  - spectral resolution by 10^4 ($E/\Delta E$~1000)

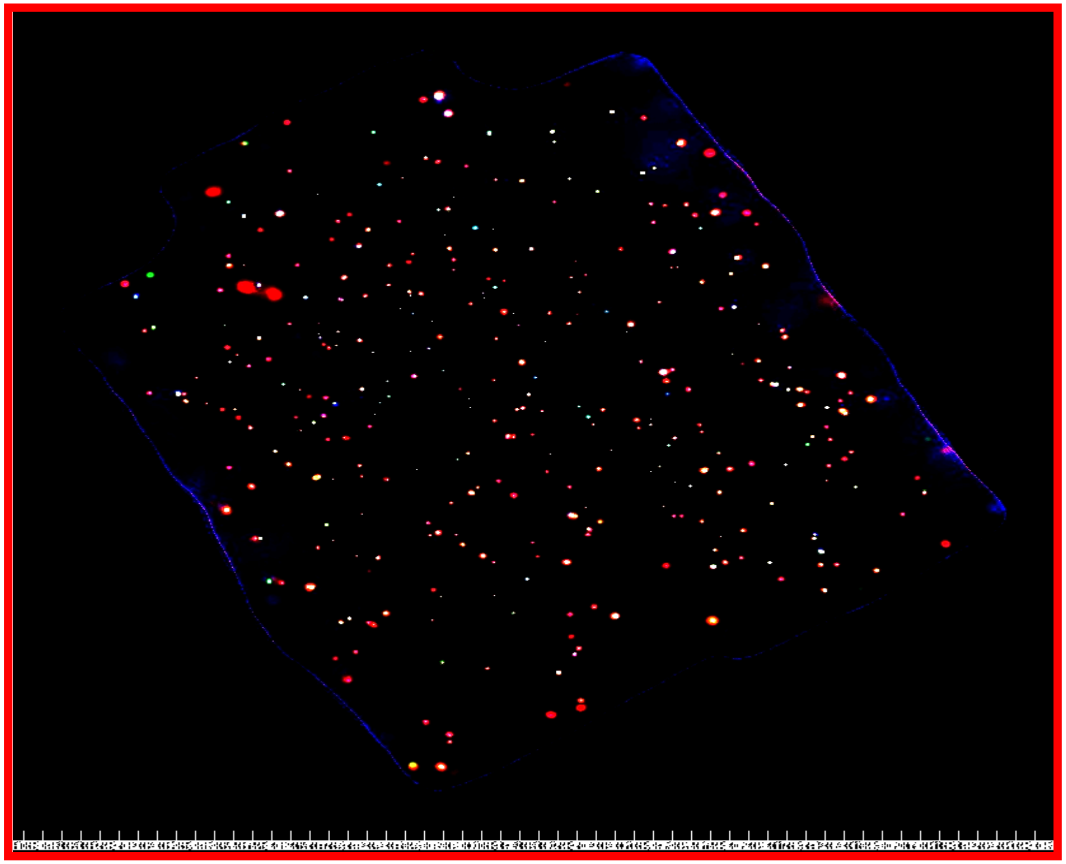
- There are now >300,000 known x-ray sources (in 1977~1000 sources, in 1969~25)
- At the faintest levels probed by Chandra there are >2000 x-ray sources/deg^2 (e.g. 10^8 all sky)
- Despite these spectacular advances x-ray astronomy is photon limited (the largest x-ray telescopes have collecting areas of 3000 cm^2 compared to 10^6 cm^2 for the largest optical telescopes)

2 deg



Nature of Faint X-ray Sources

- Most of the faint x-ray sources are active galaxies (AGN, quasars, Seyfert galaxies)
- At a median redshift of 0.7 (D_L=4260 Mpc =



Chandra medium deep field-1 sq deg