TIME-DOMAIN ASTRONOMY

Science Case 4: AGN and Blazars

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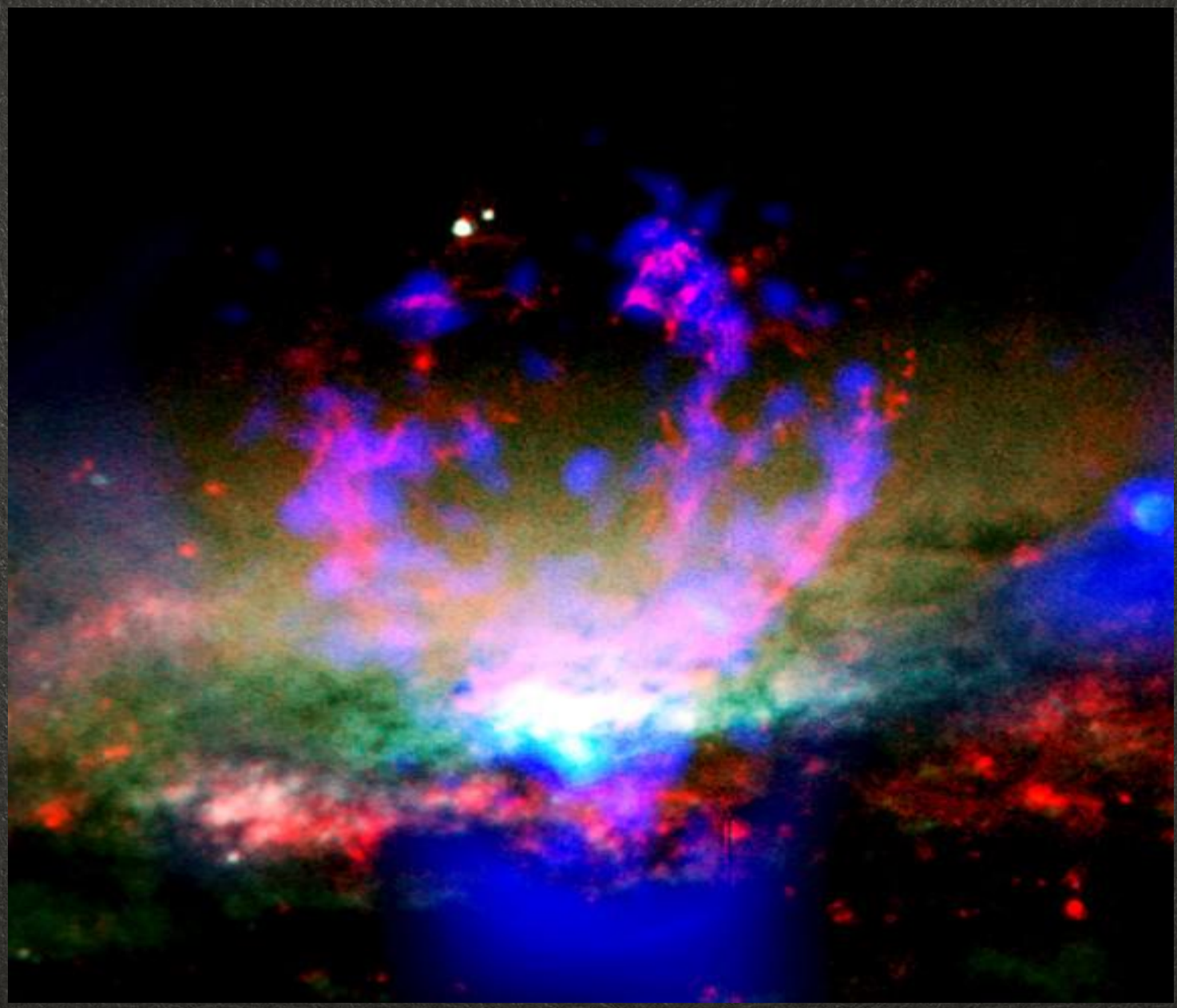
THE PHENOMENON OF ACTIVE GALACTIC NUCLEI: AN INTRODUCTION



OUTLINE

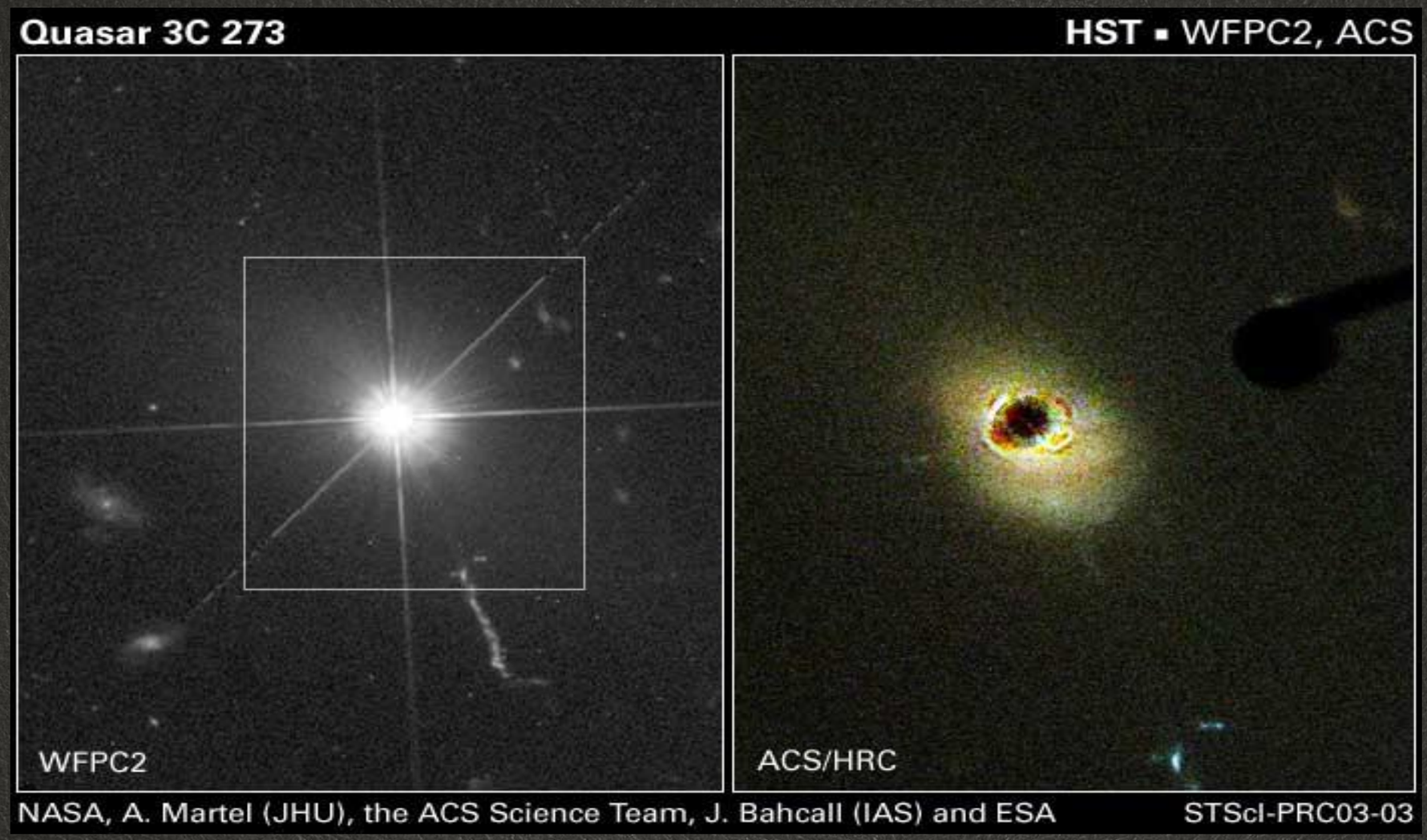
Active Galactic Nuclei (AGN):

- Why are they special?
- The power source
- Sources of continuum emission
- Emission & absorption features
- Jets and radio emission
- AGN classification & unification
- The co-evolution of black holes and galaxies

WHAT MAKES AGN SPECIAL?

- Very large luminosities are possible (up to 10,000 times a typical galaxy)
- The emission spans a huge range of photon energy (radio to gamma-rays)
- The source of energy generation is very compact (< size of the solar system)
- In some cases, there is significant energy transported in relativistic jets

THE HIGH LUMINOSITY OF AGN

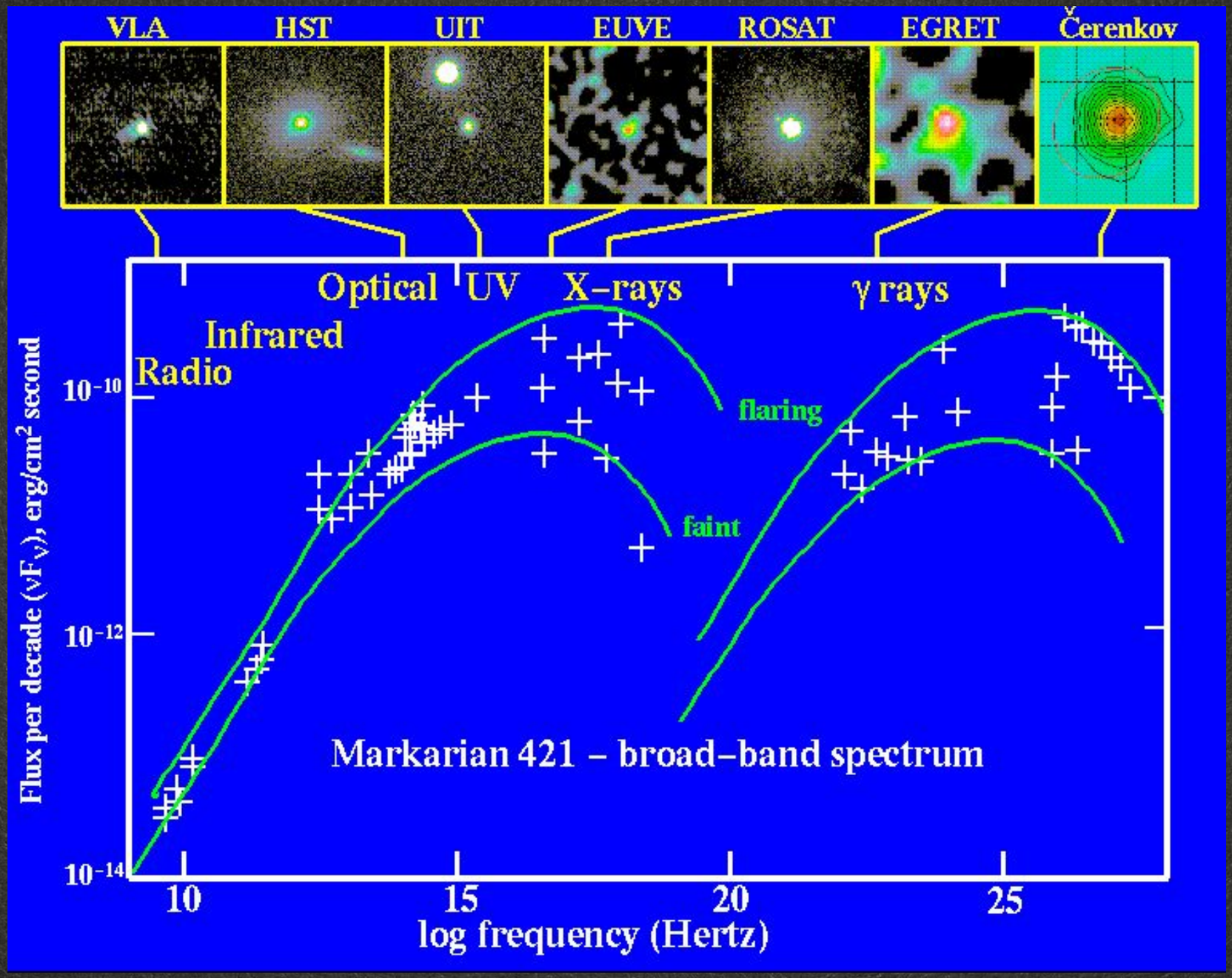


- The AGN here is several hundred times brighter than its host galaxy, just in visible light alone

AGN: Observational data

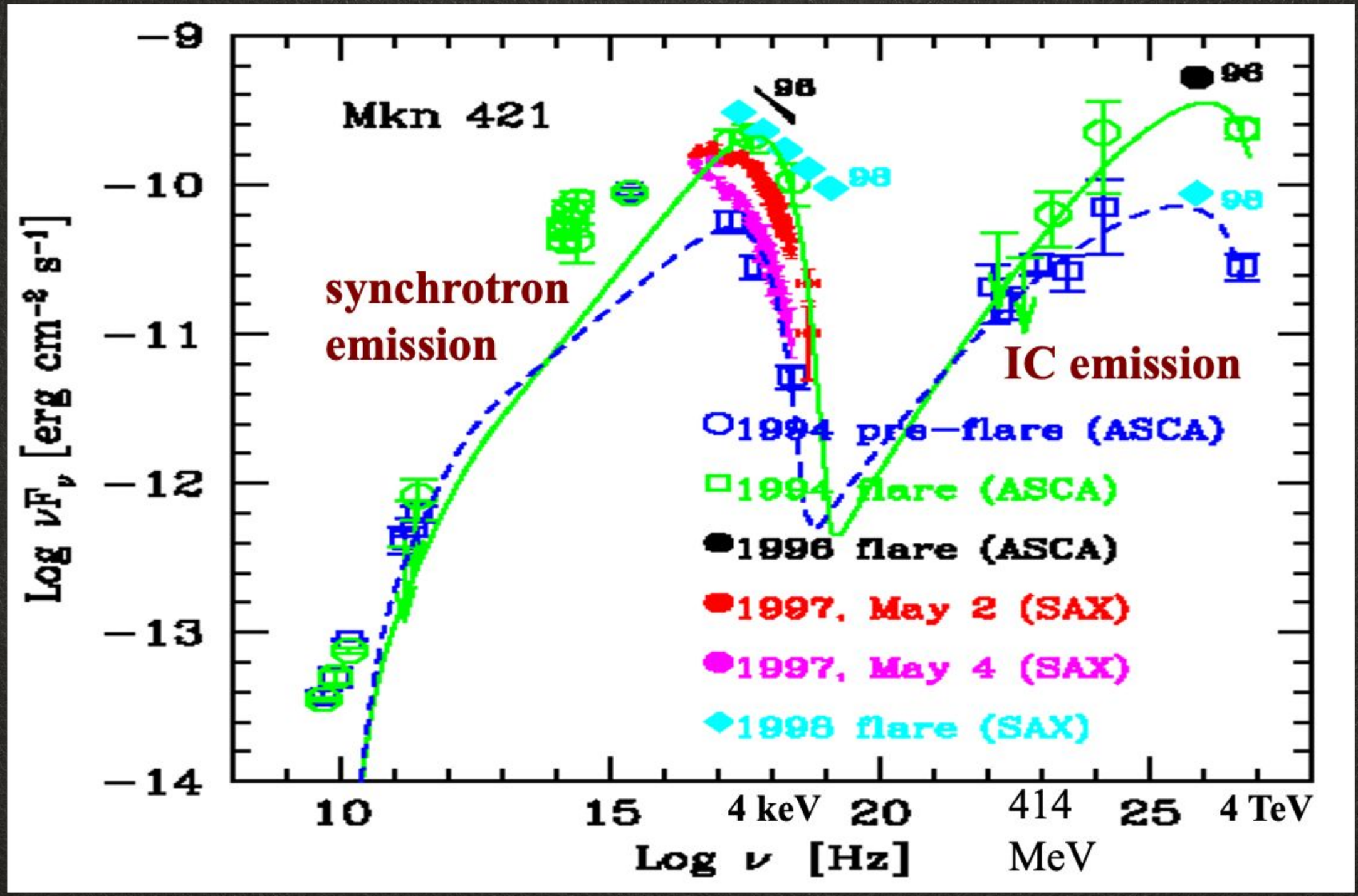
- **Highly luminous:** L_{bol}~10^{42}–10^{48} ergs s^{-1} (10^{9}-10^{15} L_{sun})
- **Compact**: size << 1pc
- **Broad-band** continuum emission:
  - dL/dlog f = const. From IR to X-rays and γ-rays
- **Variable:** on different times scales. Rapid variability in the X-ray indicate that emission comes from the innermost region
- **Strong Radio emitters:** in some sources extended, jets are present
- **Polarized**

THE "BROADBAND" EMISSION

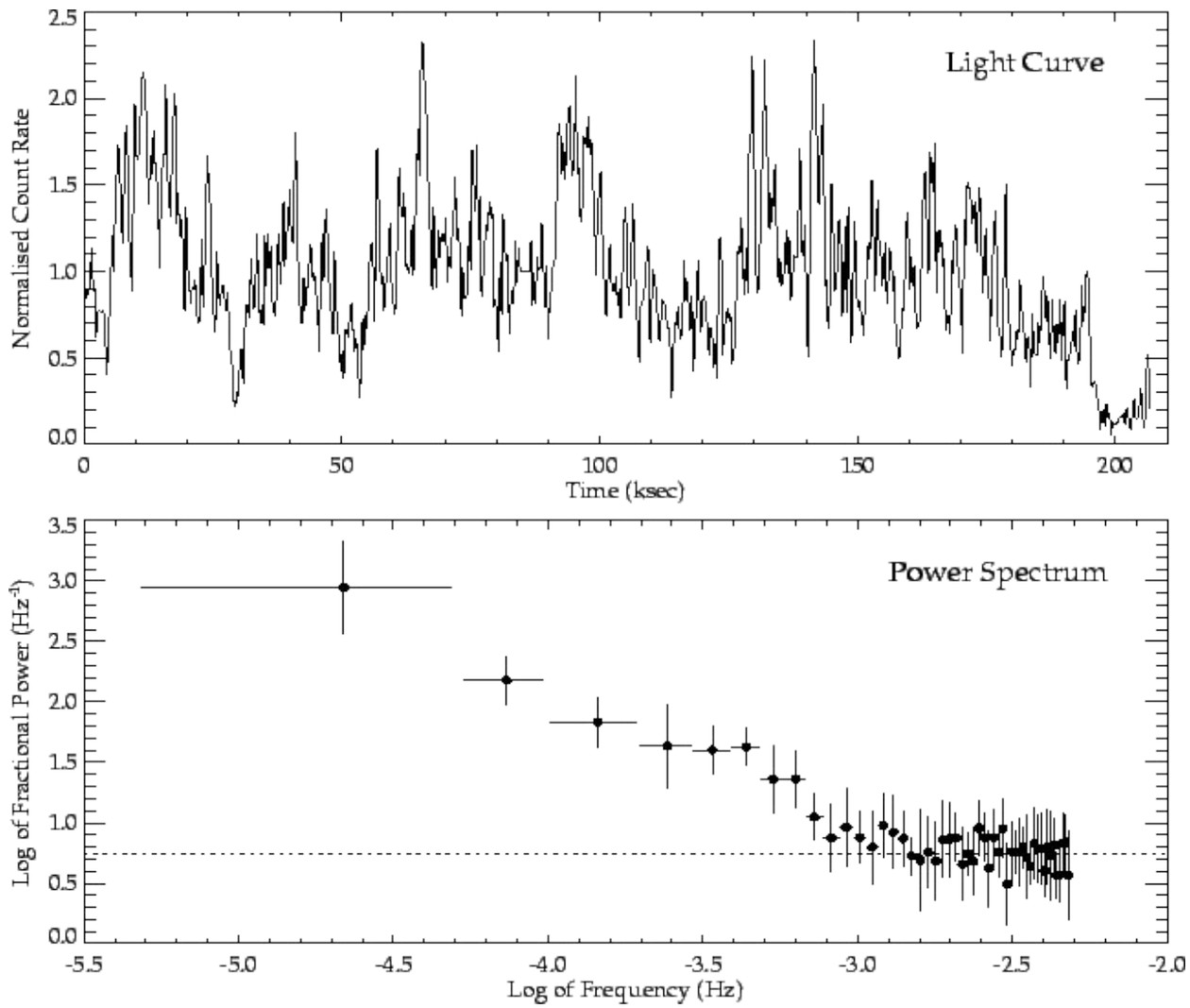


- Comparable power emitted across ~seven orders of magnitude in photon energy

Spectrum of TeV Blazars



THE SMALL SIZE



- Light travel time argument: a source that varies significantly in time t must have size $R < ct$

For Mrk421 observed at ~100keV

Shortest variability time scale: 2.9 hours ➔ size of emission region

$$l \leq \frac{c \cdot t_{flare} \cdot \delta}{1+z}$$

δ = Doppler factor (≅ 10)
z = 0.031 (redshift)
c = speed of light

} $l < 3 \cdot 10^{15}$ cm = 203 AU

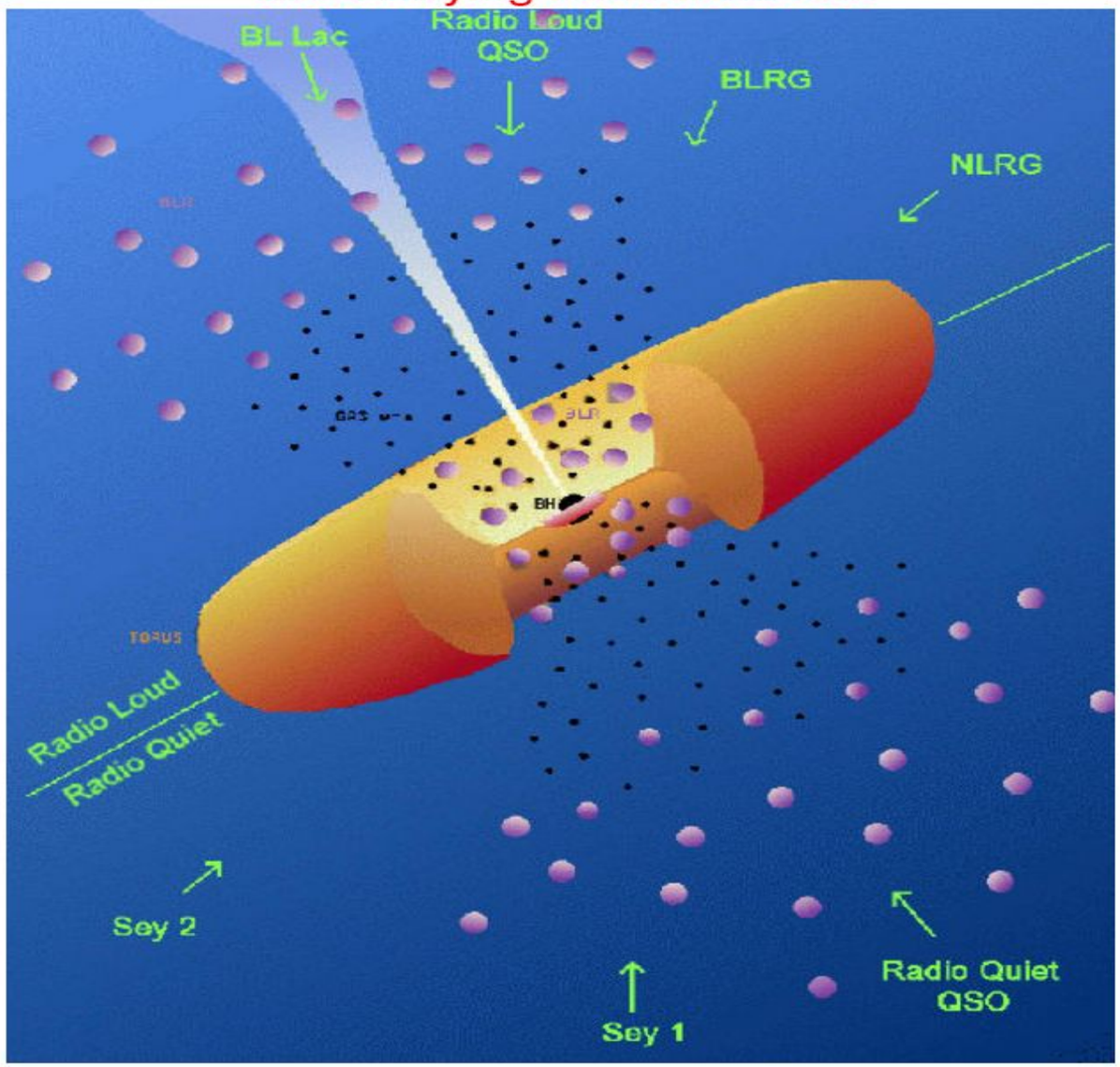
$$\delta = \frac{1}{\Gamma \cdot (1 - \beta \cdot \cos\Theta)} = \frac{\sqrt{1-\beta^2}}{1-\beta\cos\Theta}$$

for $\Theta \approx 0°$ ➔ $\beta > 0.98$

THE BUILDING BLOCKS OF AGN

Unified Model

The Unifying Model of AGN



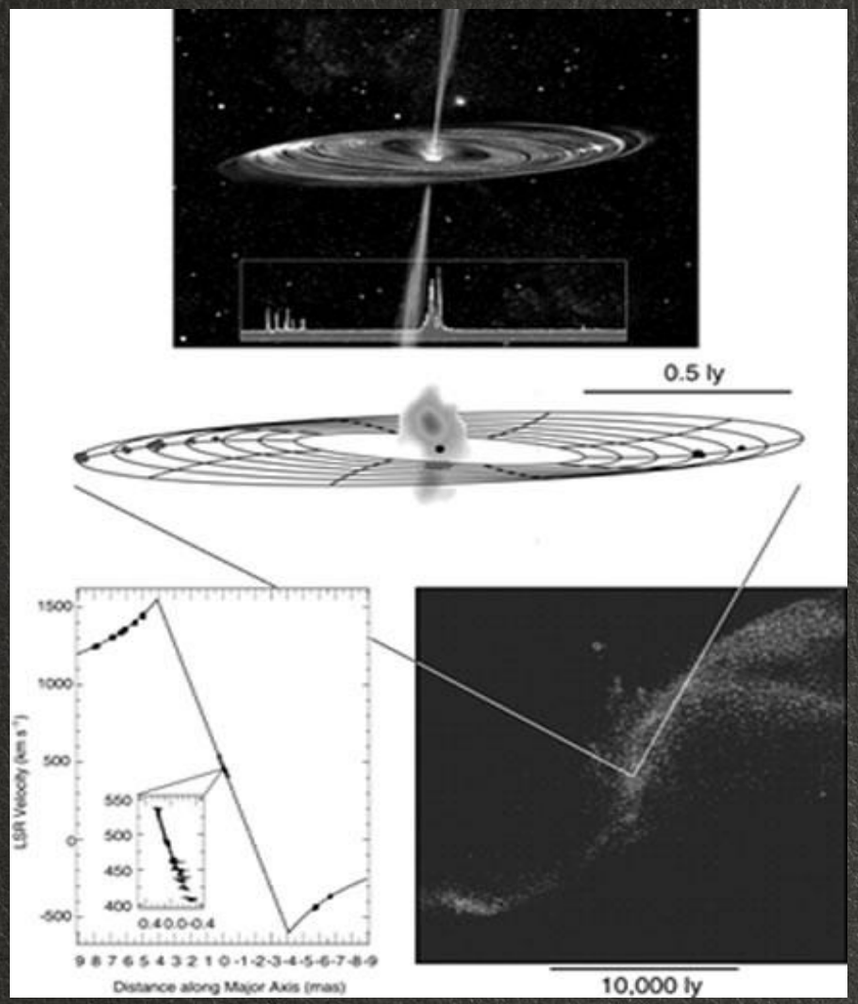
Urry & Padovani

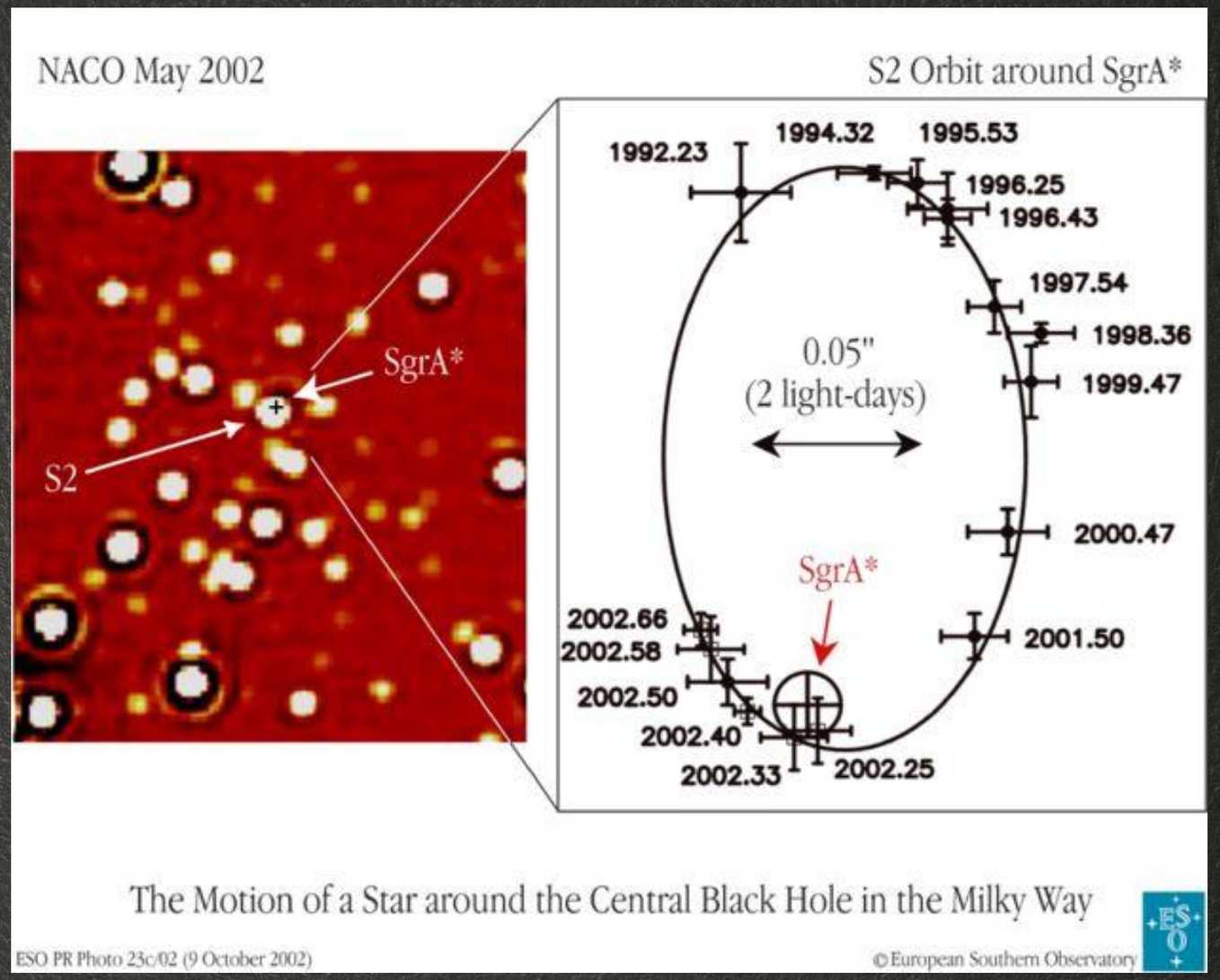
IAAT

THE POWER SOURCE: ACCRETION ONTO A SUPERMASSIVE BLACK HOLE

- Efficient, compact, and capable of producing high-energy emission and jets

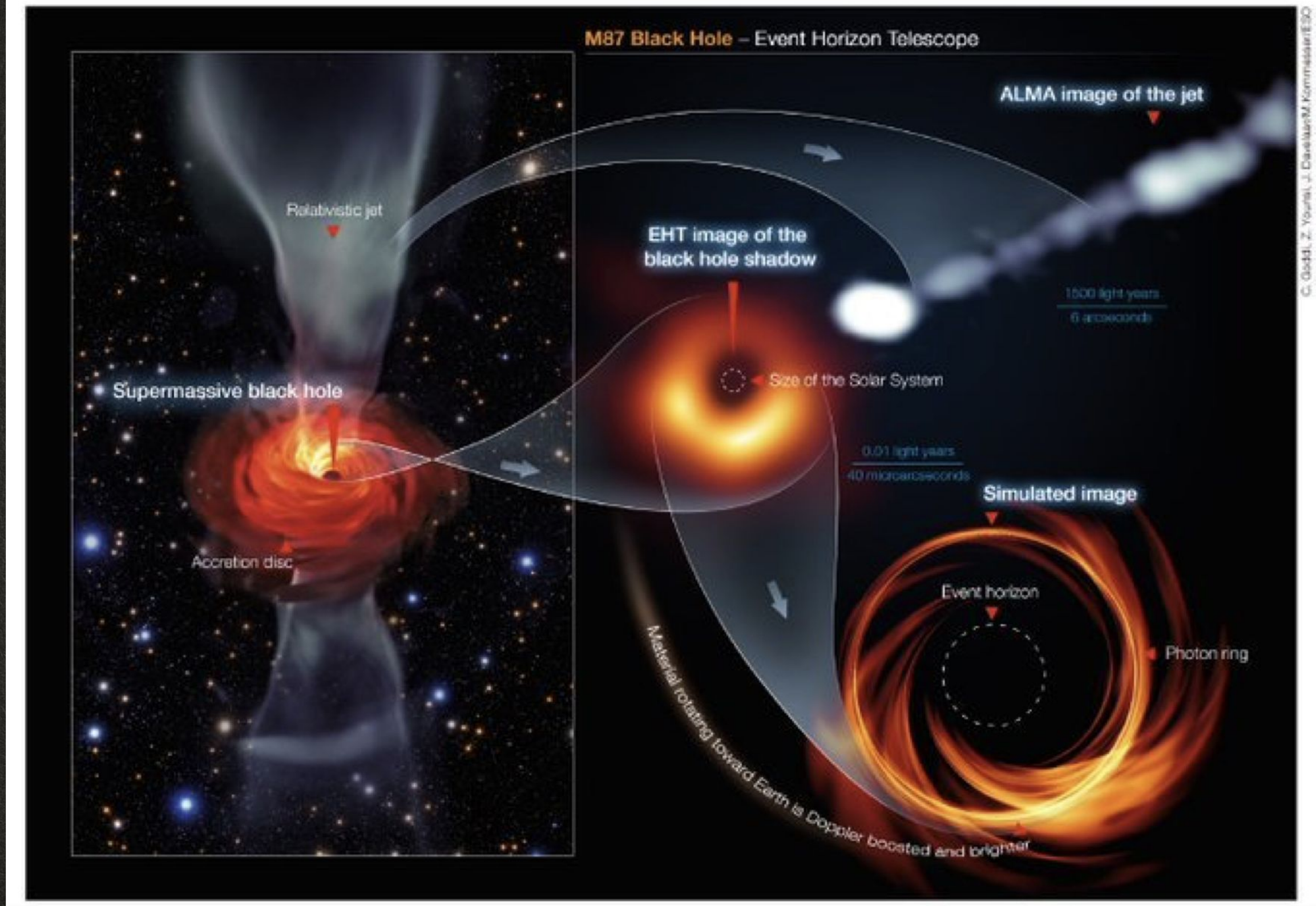
BLACK HOLES MASSES





- Newtonian dynamics: $M = v^2 R/G$!
- Water masers mapped in NGC 4258: M = 40 million solar masses
- Orbits of stars in the Galactic Center: M = 3 million solar masses

CENTRAL BLACK HOLES



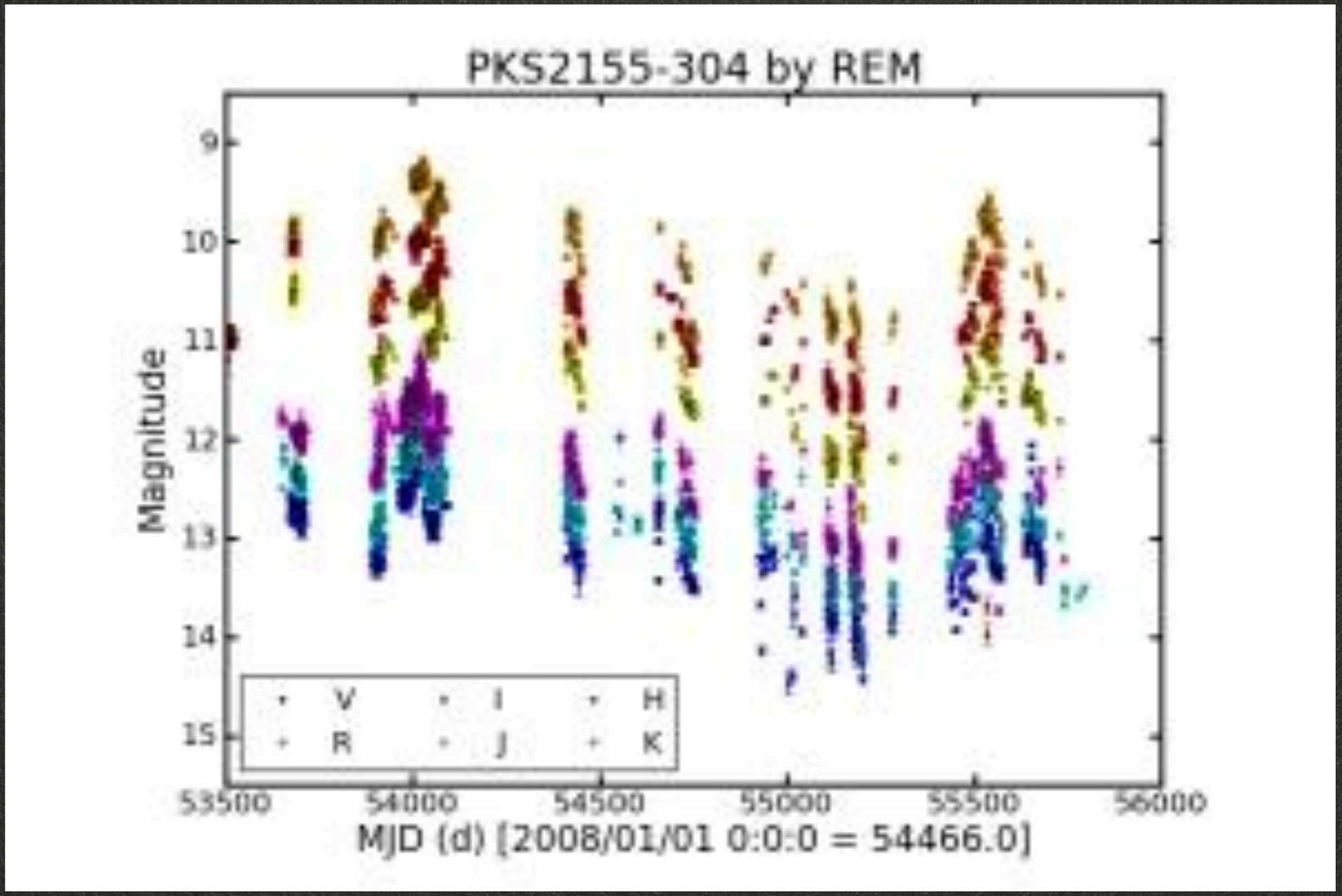
A FEW MORE THOUGHTS

- AGN are important for several reasons:
  - They have produced ~10% of all the luminous energy since the Big Bang
  - They are unique laboratories for studying physics under extreme conditions
  - They played a major role in the evolution of the baryonic component of the universe (galaxies and the inter-galactic medium)

JETS

- Jets can be one of the main features of AGN
  - If one of the two opposite jets is pointing to the observer (i.e. Earth) we call these sources “blazars”.
- There are, as usual, subtypes, but in general the jet emission outshines the whole galaxy by a large factor.
- Plenty of relativistic phenomena to take into account.
- Blazars dominate the high-energy sky.

PKS 2155-304


PKS2155-304 by REM
Magnitude
9
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53500
54000
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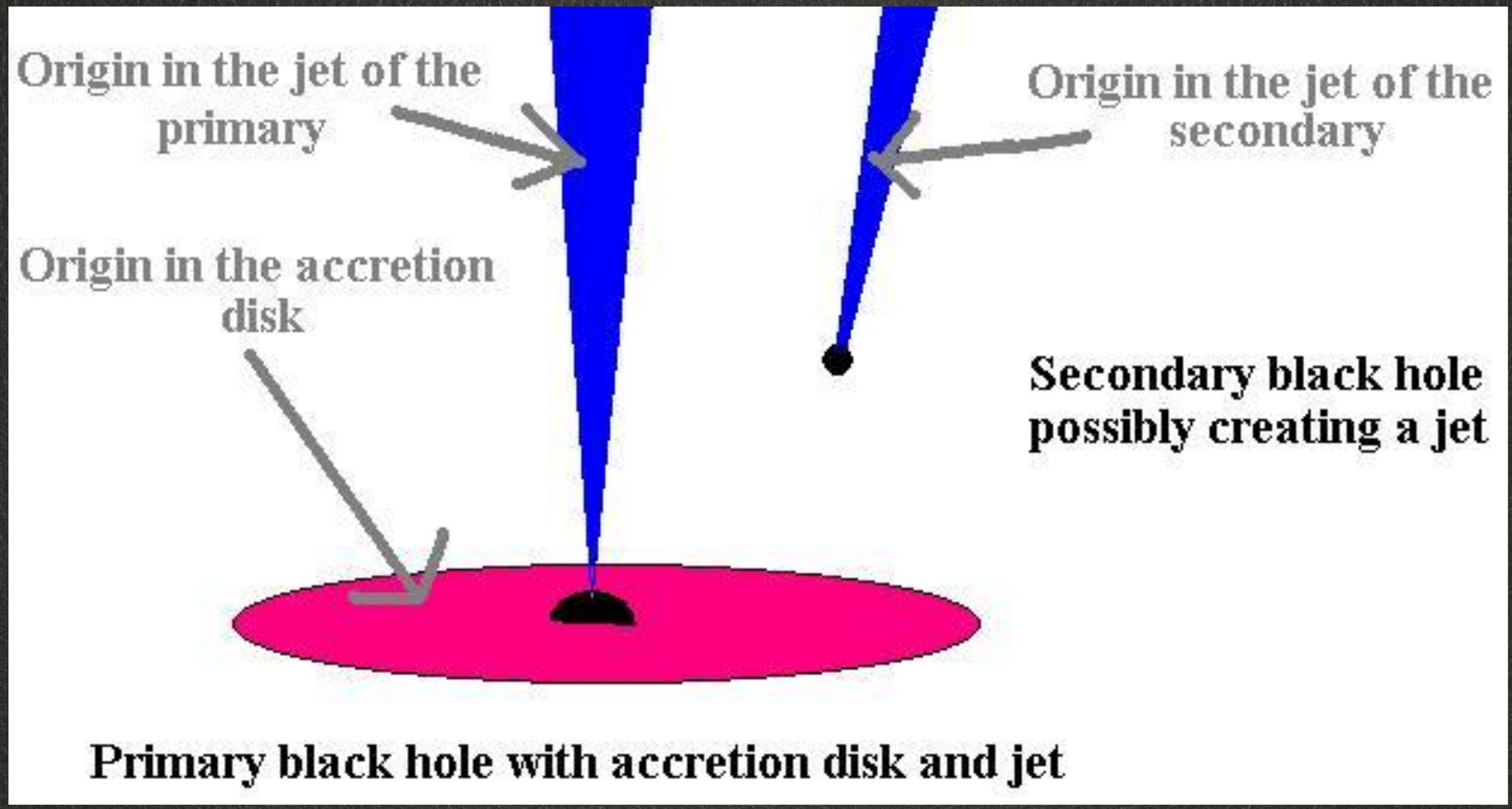
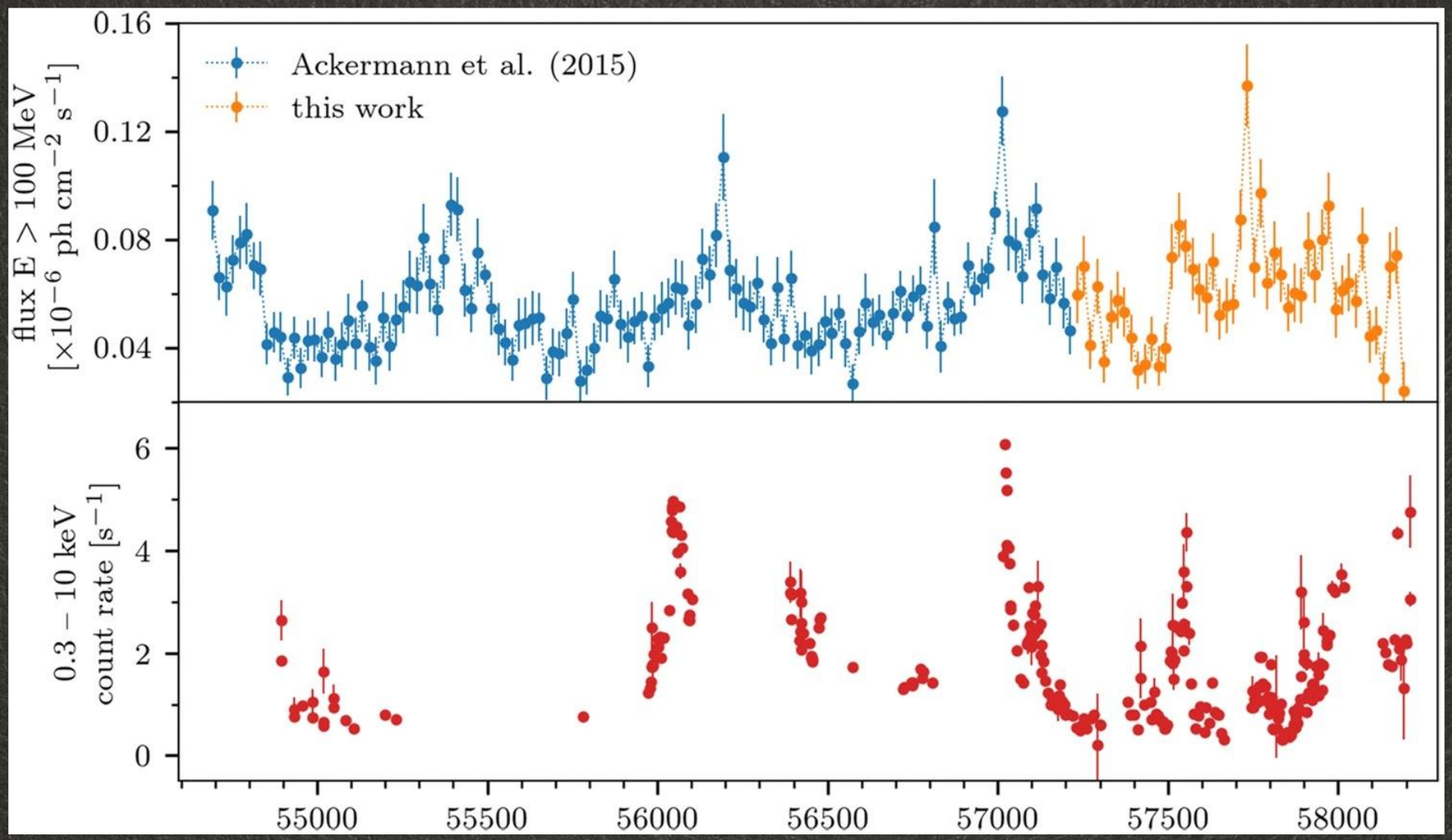
Strong interest in (possible) blazar periodicities



- It is a highly debated topic, a general agreement in the community is still missing.

Notebook: PG1553



REFERENCES AND DEEPENING

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Gamma-ray quasi-periodicities of blazars. A cautious approach

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ABSTRACT

The availability of about a decade of uninterrupted sky monitoring by the *Fermi* satellite has made it possible to study long-term quasi-periodicities for high-energy sources. It is therefore not a surprise that for several blazars in the recent literature claims for such periodicities, with various level of confidence, have been reported. The confirmation of these findings could be of tremendous importance for the physical description of this category of sources and have consequences for the gravitational wave background interpretation. In this work, we carry out a temporal analysis of the *Fermi* light curves for several of the sources mentioned in recent literature by means of a homogeneous procedure and find that, globally, no strong cases for blazar year-long quasi-periodicities can be confirmed. The computed power spectral densities are all essentially consistent with being generated by red-noise only. We further discuss the meaning and the limitations of the present analysis.

Key words: method: statistics – galaxies: active – BL Lacertae objects: general – BL Lacertae objects: individual (PKS 0301−243, PKS 0426-380, PKS 0537−441, S5 0716+714, PKS 0805−077, 4C+01.28, PG 1553+113, PKS 2052−474, PKS 2155−304, BL Lac) – galaxies: jets.