A. Finding the Size of an Active Galaxy Flare Region

1) Use the equation: diameter = cΔt = (3 \times 10^8 \text{ m/s}) \times \Delta t to determine the diameter of the active regions of AGs in meters and in units of the solar system diameter (use 10^{13} \text{ meters for the solar system diameter}), for flares of duration Δt = 1 hour, 1 day, 1 week and 1 year.

<table>
<thead>
<tr>
<th>Time</th>
<th>Size (meters)</th>
<th>Size (solar system)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
<td></td>
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<tr>
<td>1 day</td>
<td></td>
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<tr>
<td>1 week</td>
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<tr>
<td>1 year</td>
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2) Given the diameter of the sun (1.4 \times 10^9 \text{ meters}), what is the fastest the entire sun can vary in brightness, as measured in seconds?

Question 1: Time for solar variation (seconds): ________________

B. Measuring the Size of an Active Galaxy Flare Region

The plot to the right is real astronomical data taken by the EGRET gamma-ray instrument that was onboard NASA’s Compton Gamma Ray Observatory. It observed the active galaxy 3C279 for several years, and found many flares and other variations in the AG’s light.
There are two characteristic timescales for the variation shown. One is the “rise time,” or time it takes the brightness to reach its peak. The other is the “decay time,” or the time it takes for the brightness to drop back down to the normal level.

For the following exercise, assume the normal level of brightness for 3C279 is about $1 \times 10^{-2}$ photons/m$^2$s$^{-1}$ (that is, the “1” on the graph’s y-axis).

Using only the data points where the flare is brightening, draw a “best-fit” line through the points. Do the same for the points where the flare is fading.

Use your hand-drawn line to determine the time duration ($\Delta t$) for the rise time of the flare. From that, calculate the size of the emitting region using $\text{size} = c\Delta t$ in both meters and in solar systems.

**Question 2:** Time scale of rise
(days):________________________

**Question 3:** Size of emitting region
(meters):_______________________

**Question 4:** Size of emitting region
(solar systems):_________________

Use your hand-drawn line to determine $\Delta t$ for the decay time duration of the flare. From that, calculate the size of the emitting region using $\text{size} = c\Delta t$ in both meters and in solar systems.

**Question 5:** Time scale of decay
(days):________________________

**Question 6:** Size of emitting region
(meters):_______________________

Using your hand-drawn line to the rising portion of the flare, determine the slope and intercept of the line ($y = mx + b$).

**Question 9:** Slope of growth:
______________________________

Y-intercept:
____________________________

Do it again, but for the decaying portion of the flare.

**Question 10:** Slope of decay:
______________________________

Y-intercept:
____________________________
If the flare had continued to rise for two more weeks, how bright would it have been?

**Question 11:** Brightness of flare after two more weeks (in the same units as the graph):

______________________________

**Question 12:** Assuming the flare took two more weeks to rise than shown in the plot, but still decayed at the same rate, what does this imply about the size of the flaring region? Would it be bigger, smaller, or the same size as you found in the original plot?

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**C: Measuring the Energy Emitted by an Active Galaxy Flare**

From the graph, it’s possible to determine the total energy emitted during the maximum of the flare and compare it to the energy emitted by the Sun. First, convert the units of the graph from photon flux to energy flux. Assume that each gamma ray hitting the detector has an energy of 100 MeV. Calculate the **maximum** flux in MeV m\(^{-2}\) s\(^{-1}\).

**Question 13:** Flux of flare in MeV m\(^{-2}\) s\(^{-1}\): __________

A more standard unit of energy is the **Joule**, which is equal to \(6.3 \times 10^{18}\) eV. Remembering that 1 Mev is \(10^{6}\) eV, what is the flare flux in Joule m\(^{-2}\) second\(^{-1}\)?

**Question 14:** Flux of flare in Joule m\(^{-2}\) s\(^{-1}\): __________

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The flux is the amount of energy hitting a square meter here on Earth. The total energy emitted by the flare every second is spread out over a sphere centered on the flare, with a radius equal to the distance from the Earth to the flare. The distance to 3C279 is about \(4 \times 10^9\) light years, and there are \(9.5 \times 10^{15}\) m in a light year. The surface area of a sphere is \(A = 4\pi r^2\) where “r” is the radius of the sphere. What is the total surface area of the sphere?

**Question 15:** Surface area of sphere (m\(^2\)): __________

The total luminosity emitted in the flare each second, is given by \(E = (\text{Area}) \times (\text{Flux})\). Calculate the energy in Joules/sec.

**Question 16:** Total energy emitted per second by the flare (Joules/second):

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The Sun’s luminosity is about \(4 \times 10^{26}\) Joules/second. What is the ratio of the luminosity at the flare maximum to the solar luminosity?

**Question 17:** Total luminosity of the flare in Solar units:

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There are about \(3 \times 10^7\) seconds in a year. How many years would it take for the Sun to emit as much energy as the flare did in a single second?

**Question 18:** Number of years for the Sun to emit as much energy as the flare did in 1 second:

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