

SADE: THE STELLAR ASTROPHYSICAL DYNAMO EXPLORER

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ABSTRACT

We propose a mission called SADE, the Stellar Astrophysical Dynamo Explorer, to study dynamo activity in nearby late-type stars. The onboard instruments will be a Ca-K telescope for magnetically dominated chromospheric emission, and an X-ray grazing incidence telescope to study coronal emission. We design the mission for a life-time of 15 years or longer to capture a full activity cycle for most solar-type stars. We aim to firmly establish the spectrum of the relation between chromospheric and coronal emission in late-type stars, and capture one or more stars going into or coming out of a Maunder type minimum. Operation costs will be kept to a minimum by automating mission operations to a maximum, and have the science operations be carried out by students at Montana State University.

INTRODUCTION

In soft X-rays the solar coronal radiance varies by a factor of 10-30 over the solar activity cycle. A similar variation in most stars in the existing X-ray database has not been found (Stern 2001); even stars which exhibit chromospheric activity cycles show only marginal evidence for X-ray cycles. This is rather puzzling as the time span and multiple coverage of the X-ray sky should reveal at least a hint of such a pronounced cyclical variation.

Why does the Sun exhibit such a large cyclic variation in coronal X-ray emission compared to nearby solar analogs that have similar chromospheric Ca-K variability? That is the key scientific question for this mission. In addressing it we expect to expand our knowledge of the parameter space of stellar dynamos, including the occasional observation of a transition to or from a stellar “Maunder” minimum: the Sun has gone through five documented minima in the last 2000 years, so with a frequency of $1/400 \text{ yr}^{-1}$, one expects one transition in 40 stars over a ten year observing period. Coming out of the Maunder minimum, happens, say, once per 50 years (the duration of the minimum), so again we might observe one transition if we monitor five “Maunder minimum” stars for ten years.

To achieve our science objective we propose a mission called the Stellar Astrophysical Dynamo Explorer (SADE) that measures the X-ray and Ca-K brightness of about 75 stars once every 5 days for up to 15 years. Selection of prime stars takes into account location (avoid eclipse), rotation rate, existing Ca-K observations, and magnetic field strength, to focus on the best candidates for dynamo studies.

Our systematic survey will add to the existing more sporadic Einstein and ROSAT data, and will be enriched by occasional observations by Chandra and XMM-Newton of stars from our data base.

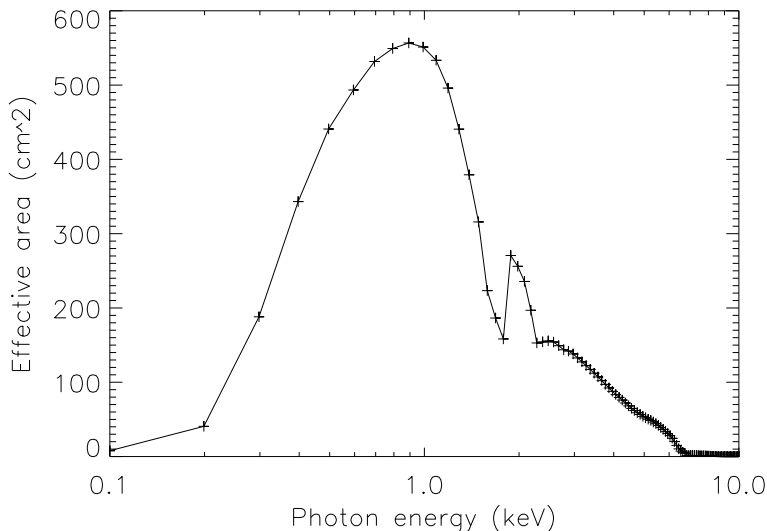


Fig. 1. Spectral response of model X-ray telescope of 1.4 meter focal length utilizing 30 mirror shells ranging in glancing angle from 1.0 to 2.5 degrees with mirror radii from 10 to 25 cm. Gold mirror coatings with 5 RMS roughness was assumed. Detector is a thinned back-illuminated CCD behind a 170 nm Al filter.

INSTRUMENT DESIGN

We baseline a nested 30 mirror system with 1085 cm² geometric area, with a 1.5 meter focal length, 15 arcsec on-axis resolution, and Au coatings. The strawman detector is a back-illuminated CCD operated as a photon counter to achieve moderate spectral resolution. The visit time per star is about an hour and a half. Fig. 1 shows the typical spectral response function for the baseline telescope.

The Ca-K telescope will be located at the axis of the nested X-ray mirrors and will have a collecting area designed to match the observing frequency of the X-ray telescope.

LAUNCH AND MISSION OPERATIONS

We are studying a number of launch options. In any case we wish to fly SADE at a low inclination orbit to minimize radiation damage and avoid interference with observations from the South Atlantic Anomaly. We are exploring options to use non-US ground stations near the equator to deal with our limited data rate.

To minimize science operations cost for this long duration mission we envisage a highly automated observing program based on a limited preset list of nearby stars. Data verification and command sequence generation will be done from a simple science operations center at Montana State, operated by students under the auspices of MSU's Space Science and Engineering Lab (SSEL). Time will be reserved to observe Targets of Opportunity and memory space will be set aside for serendipitous flare observations, automatically triggered by the on-board flare flag.

REFERENCES

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Manuscript received 17 December 2002; revised 4 March 2002, accepted 26 March 2003