A World-Wide Network of Robotic Imaging Telescopes

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Abstract

The long-term monitoring of AGNs and massive stars, the search for extrasolar planets via the transit method and the detection of unpredictable transient events such as gamma-ray bursts require continuous observations by a world-wide network of telescopes. Two telescopes of this network are located in the USA (Kitt Peak and Kentucky). Western Kentucky University (USA) along with National Central University (Taiwan) and Yunnan Observatory (China) plan to place a fully robotic imaging telescope at Gao Meigu in Li Jiang, China.

1 The Science

We consider a number of diverse astronomical research projects.

1.1 Active Galactic Nuclei

BL Lacertae (BL Lac) objects are members of a broader class of objects known as Active Galactic Nuclei (AGN). The BL Lac objects are the most variable AGN known, with many varying their brightness by more than 5 magnitudes (100-fold) on timescales of years. The general interpretation of a BL Lac object is that the extreme variations are the result of a relativistic jet of material pointed at or very near our line of sight. The synchrotron emission coming from the electrons in the jet is so strong, due to relativistic beaming effects, that it masks the spectral features commonly seen in other AGN. Without spectral features, the only diagnostic we have of these objects and their energy generation mechanism is their continuum variation. Their featureless continuum displays variations on timescales from minutes to decades.

1.2 Massive Stars

More than half of all main-sequence OB stars exhibit brightness variations of typical amplitudes ranging from millimagnitudes to a few hundreds of a magnitude on time scales of minutes to months. These magnitude changes are thought to be caused by both radial and non-radial pulsations. However, for the OB stars known to be pulsating from spectroscopic observations there is no clear correlation with the photometric variability. In order to clarify the source of the photometric variability and most likely associate it with radial and non-radial pulsations as well as rotational modulation (surface inhomogeneities), we will employ the method of differential two-color CCD photometry of OB stars in clusters and associations with a precision of $\sigma \lesssim 1$ mmag. for $V \sim 10-15$ mag.

1.3 Extrasolar Planets

So far $\sim$ 100 extrasolar planets have been discovered, all of them via the radial-velocity method. To date this approach is limited to relatively bright stars ($V \lesssim 11$) of the solar neighborhood. Employing the method of ensemble differential photometry on CCD images we will achieve a photometric precision for a single exposure (few minutes) of $\sigma \sim 500$ μmag. at $V \sim 12^{\rm m}$ and $\sigma \sim 10$ mmag. at $V \sim 18^{\rm m}$. This precision will allow the detection of extrasolar Jupiters and Neptunes via the transit method around faint stars at distances $d \lesssim 1$ kpc beyond the solar neighborhood, which is inaccessible to spectroscopic radial-velocity studies.

1.4 Gamma-ray Bursts

Gamma-ray bursts (GRB) are transient gamma-ray events. They appear at random times from unpredictable positions on the sky. We now know that gamma-ray bursts are by far the most energetic events in the entire universe. The implied isotropic total energy output of some bursts is $\sim 10^{54}$ ergs. Such bursts produce 1000 times more energy in a few seconds then the Sun will generate over its entire 10 billion year lifetime ($\sim 10^{51}$ ergs). They are also the most luminous (energy/time) objects in the universe. For instance GRB 970508 attained an optical magnitude of $M_V = -24$, which is a full two orders of magnitude brighter than a type Ia supernova. It was the optical detection of GRBs that allowed us to understand what GRBs are. We plan to detect the optical radiation from GRBs shortly after they are found by NASA's spacecraft.

2 Need for 24-hour Continuous Observations

All of the above projects have in common that they require continuous round the clock observations. For the search for extrasolar planets via the transit method observations should be conducted 24 hours/day because the times for transits of undiscovered extrasolar planets are completely unknown. Because the outburst of AGNs are unpredictable, AGNs should also be observed continuously. In particular continuous coverage (daily and sub-daily) is required to characterize the variations of BL Lacertae objects and continuous observations are required to test models of the continuum emission of these objects. The complex multi-mode variability of massive stars ($M \gtrsim 20 M_\odot$) on time scales from minutes to months requires observations around the clock. Finally, unpredictable transient events such as gamma-ray bursts require the ability to respond at any time to such events.

3 Need for Robotic Telescopes

In order to ensure continuous nocturnal observations classical observations require a minimum of two observers per telescope. We estimate this means $\sim$ \$150 000 in external funding/year/telescope. For a complete world-wide network of $\sim$ 12 telescopes covering both the northern and southern hemispheres, the manpower cost in external funding would be $\sim$ \$1 800 000, which is prohibitive. Thus, since continuous observations are essential for the above projects, robotic observatories must be employed in order to eliminate the need for unaffordable manpower.

4 World-Wide Network of Telescopes

Because of the day-night cycle, continuous astronomical observations can only be accomplished through a world-wide network of longitudinally spaced robotic telescopes. Each telescope will be a meter-class imaging telescope. Two telescopes of this network already exist. Both are located in the USA (in Arizona and Kentucky). Western Kentucky University (WKU) in the USA along with Yunnan Observatory (China) and the National Central University (Taiwan) plan to place a fully robotic imaging telescope at Gao Meigu in Li Jiang, China. We briefly discuss each of these telescopes.

4.1 Arizona, USA

This telescope (Gelderman, 2001) is located at Kitt Peak National Observatory (longitude: $7^{\rm h}26^{\rm m}23^{\rm s}$ W, latitude: 31°25′1") near Tucson. Its aperture is 1.3 m and it is run by a consortium of institutions – Francis Marion University, the Planetary Science Institute, South Carolina State University, Villanova and WKU, which is the lead institution. WKU will receive over 50% of the observing time and half of this time plus the 18% allotted to one of its partners, the Planetary Science Institute (PSI), will be devoted to the search for extrasolar planets via the photometric method and the data collected will also be used for variable star research. We expect the telescope to be fully operational at some time in 2003.

4.2 Kentucky, USA

This 0.6-m telescope is located (longitude: 86 °36′42.2" W, latitude: 36°55′10.9" N) at a dark-sky site on a rural hilltop about 20 km southwest of WKU. It is a Cassegrain telescope with an f/11 focal ratio. Group 128 in Waltham, MA, built it in 1975. We estimate for differential photometric work about 146 usable nights per year. Over 40% of the observing time will be used for the extrasolar planet search project.

The telescope was refurbished and automated by Astronomical Consulting and Equipment, Inc. (ACE). We operate it remotely from campus. As part of the refurbishment contract ACE is required to provide a fully automated robot. All of the hardware is in place but some of the software modules necessary for fully automated robotic operation remain to come on line.

4.3 Yunnan, China

This telescope will be located at Gao Meigu (longitude: $100°02'$E, latitude: $26°42'$N) near Li Jiang in Yunnan Province, China. We plan to place a fully robotic imaging telescope of $1 - 3$ m aperture at Gao Meigu.

References

Gelderman, R. 2001, 'The 1.3-meter Robotically Controlled Telescope: Developing a Fully Autonomous Observatory' in 'Small-Telescopes Astronomy on Global Scales', ASP Conf. Ser., 246, 89

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