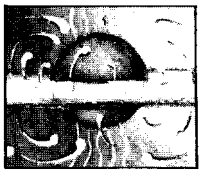


New Analysis Techniques

Coupled with the new satellites (see "The Next Generation of Satellites"), new analysis techniques will help reveal the underlying astrophysics in ever greater detail. Recently, for example, new methods of data handling have substantially improved the precision with which the orbits of pulsars in binary systems can be determined. As discussed in the section entitled "Pulse Timing" in the main text, precise determination of the orbit yields valuable information about key astrophysical questions, such as the masses of the pulsar and its companion, the internal structure of the companion, and the evolution of the system.

The principal method used to determine the orbit of a pulsar relies on measuring the changes in the arrival times at earth of pulses emitted by the pulsar as it moves around its orbit (Fig. 3 of the main text). The precision of such measurements is limited by fluctuations in the measured pulse shape caused by photon-counting noise and variations in the emission process, by the limited time resolution of the detectors, and by fluctuations in the spin rate of the neutron star.

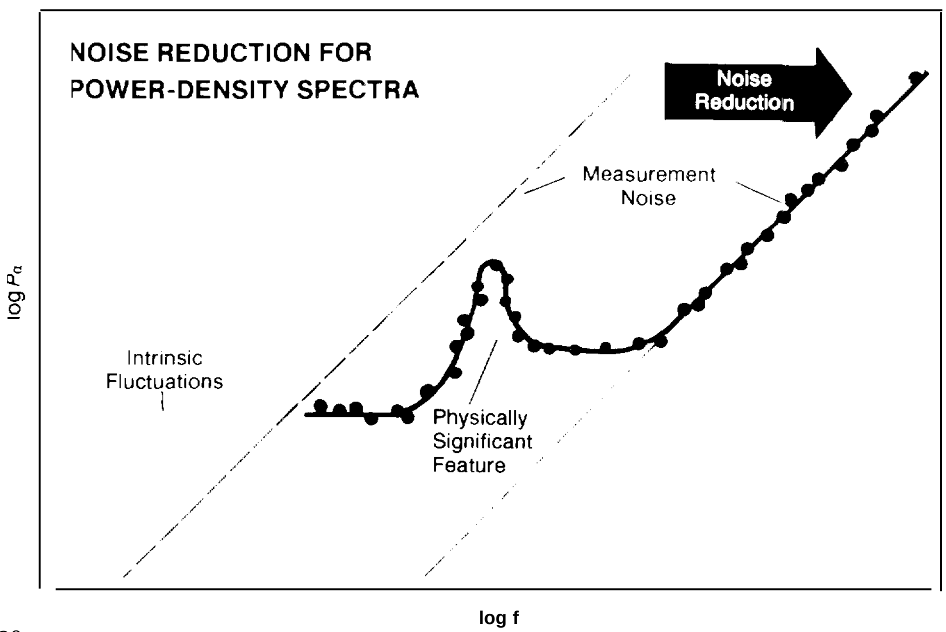
The large-area x-ray detectors on the next generation of satellites will provide very high counting rates (20,000 counts per second from bright sources) and make possible microsecond time resolution. This will greatly reduce fluctuations in the measured pulse shape caused by photon statistics and the imprecision in arrival times introduced by the finite time resolution of the detectors.

New analysis methods in which the pulse waveform is filtered have substantially reduced the uncertainty in pulse-arrival times caused by pulse-shape variations associated with the emission process. In a recent study of the accretion-powered pulsar Vela X-1, for example, filtering increased the precision of pulse-arrival times by a factor of two—equivalent to an increase in the area of the x-ray detector by a factor of four.

As the precision of pulse-arrival times is increased—by enlarging the detector area and filtering the pulse waveform—arrival-time variations caused by fluctuations in the rotation rate of the neutron star become more apparent (figurc). These spin-rate fluctuations can then be studied better, providing valuable tests of our understanding of neutron stars (see "Internal Dynamics of Neutron Stars").

For sources with unknown orbits, new algorithms will be needed to search efficiently for periodic and quasiperiodic oscillations in the x-ray flux. This is because the power in such oscillations is spread over a range of frequencies by the Doppler shift associated with the orbital motion of the source, making the oscillations difficult to detect. Thus, to find oscillations efficiently, new search algorithms must be developed that can quickly and systematically remove the effects of orbital motion for a wide variety of possible orbits.

New analysis techniques are also needed to uncover the origins of the large but erratic (aperiodic) variability seen in many compact x-ray sources. For example, fresh insights into the physical causes of this variability may be gained by applying the techniques recently developed to analyze nonlinear dynamical phenomena and chaos. ■



Schematic angular-acceleration power-density spectrum P.(f), showing the contributions made by spin-rate fluctuations and measurement noise. Here f is the analysis frequency. This example illustrates how a reduction in measurement noise can reveal a physically important peak in the spectrum of neutron-star spin-rate fluctuations. Measurement noise—caused by, say, the random nature of photon counting in the detectors—can be reduced by increasing the area of the detector or by using more powerful analysis methods, such as waveform filtering. Any such reduction uncovers more information about intrinsic fluctuations in the spin rate of the star and thus reveals more about their physical cause.