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UTC AT THE HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS (CFA) AND ENVIRONS

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The Smithsonian Astrophysical Observatory is involved in the operation of observatories across the entire electromagnetic spectrum and associated with several other data providers. Although the reliance on UTC and constraints on the value of DUT1 vary, there is considerable apprehension about changing the definition. In particular there is a sense that it may cause considerable confusion and misunderstanding in the context of the Virtual Observatory.

STATUS AT SAO

At the CfA, the Smithsonian Astrophysical Observatory (SAO) operates (or is a partner in the operations of) observatories across the entire spectrum. Some of these "run on" UTC, but there are differences when it comes to whether the observatories depend on |*DUT1*| < 0.9 s. I will provide an overview of how the observatories and related activities would be affected by the abolition of leap seconds in UTC.

Sub-Millimeter Array

The Sub-Millimeter Array (SMA, on Mauna Kea, HI) synchronizes its clock to GPS and keeps track of leap seconds and *DUT1* as published by International Earth Rotation and Reference Systems Service (IERS). As long as IERS continues to publish *DUT1* there will be no impact.

Ground-based Optical Observatories

The optical ground-based observatories are not terribly sensitive to UTC definition changes, but it would help them if a timescale were maintained that is related to earth rotation. This may sound cryptic, but it does express a preference to leave things as they are – because one never knows.

Chandra X-Ray Observatory

The Chandra X-Ray Observatory is space-based, where UTC is an irrelevant concept. Chandra's clock is calibrated in UTC, but the first thing we do is to convert it to Terrestrial Time (TT) for science data. Not all space missions manage time in the same way on board. Chandra's onboard clock essentially runs on linear time. But since commanding is done in UTC, it needs to be made aware of what UTC is doing. As a result, each leap second creates a problem, since it is never inserted at the right moment, but rather when internal ephemerides are (necessarily) updat-

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ed to include that second. Specifically, it is inserted while no scientific observing is going on and there is always something that goes wrong; at the last leap second insertion orbit ephemeris files needed to be recreated due to a 1-second error that was found several weeks after the fact. So, in a sense, Chandra would be better off without any leap seconds. On the other hand, the idea that one would use UTC on board a spacecraft (rather than, say, TT or TAI) is a bit absurd by itself. Even for ground-to-space communications a 1-second error in the on-board clock amounts to no more than a 3-arcminute offset, which is well within the spacecraft antenna's beam size.

VERITAS

VERITAS (Mt Hopkins, AZ) observes at the very high energy end. It uses GPS clocks and is in the same position as the optical observatories: as long as IERS continues to publish *DUT1* or UT1 – UTC, they will not be affected by any changes. VERITAS commonly works at 10 μs precision.

Minor Planet Center

The Minor Planet Center (MPC) converts all its times to TT, but prefers UTC to stay close to earth rotation, since it is close to UT1 and thereby reduces chances of confusion.

BEYOND SAO

There is strong involvement in the Virtual Observatory (VO) at CfA. Although the VO can in principle ensure, through its metadata standards, that time is handled correctly, one needs to be extremely careful. Data in the VO comes from many places all over the world and, even though that may be regrettable, there is no guarantee that all of them will get it right.

CfA has always had a close relationship with the American Association of Variable Star Observers (AAVSO). Arne Henden, its director, did not think the disappearance of leap seconds would cause great problems for AAVSO members, but summarized his position as: "Don't fix it if it ain't broke" – meaning: keep UTC as it is.

CONCLUDING REMARKS

There is a consideration regarding ground-based moderately-high accuracy timing data. Right now we know that, with the observatory's ITRS coordinates and UTC, one can get timing accurate to $1.5 \times \cos(latitude)$ μs. That will not hold true anymore if $|DUT1|$ is not constrained to be less than 0.9 s.

Staff at the SAO is involved in the formulation of two standards in astronomy that touch on time issues. The Flexible Image Transport System (FITS) World Coordinate System (WCS) standard for Time is finally getting close to becoming reality. The International Virtual Observatory Alliance (IVOA) has had a Space-Time Coordinate metadata standard since 2007. Both provide guidance for the proper usage of time scales and the completeness of metadata. However, both are also agnostic with respect to any constraints on *DUT1*.

The bottom line that emerges from polling users across the spectrum is that people are apprehensive about changing something that has worked for a very long time. It may not break everybody's software, but it is guaranteed to cause confusion. This is particularly true for the Virtual Observatory where we have little control over how data providers and users choose to interpret the standards and where they may or may not be aware of any implicit assumptions (*e.g.*, about constraints on the value of *DUT1*).

The inescapable conclusion appears to be that, if time services prefer to broadcast a linear timescale, it would be preferable that they choose a proper one (TAI would be an excellent choice), continue the leap seconds in UTC, and include TAI – UTC, as well as the traditional *DUT1* or UT1 – UTC, in the distribution.

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