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Chapter 3

Offset Pointing, Visibility, and other Constraints

3.1 Introduction

This chapter gathers together several topics pertaining to observation planning, irrespective of focal-plane instrument and grating configuration, to serve as additional guidelines for preparing proposals. Most of these topics are automatically addressed by the target visibility interface webtool (*PRoVis*) or the observation visualizer software (*ObsVis*) available as part of CIAO. The intention here is to familiarize the user with the consideratons.

3.2 Offset Pointing

The offset pointing convention for *Chandra* is that a negative offset of a coordinate moves the image to more positive values of the coordinate and vice-versa. Examples of offset pointings of the ACIS instrument are shown in Figure 3.1. Examples using the HRC are shown in Figure 3.2.

3.3 Visibility

There are a number of factors that limit when observations can be performed. These are discussed in the following:

3.3.1 Radiation Belt Passages

High particle-radiation levels are encountered as the Observatory approaches perigee. Data acquisition ceases whenever certain particle-radiation thresholds are exceeded. A work-

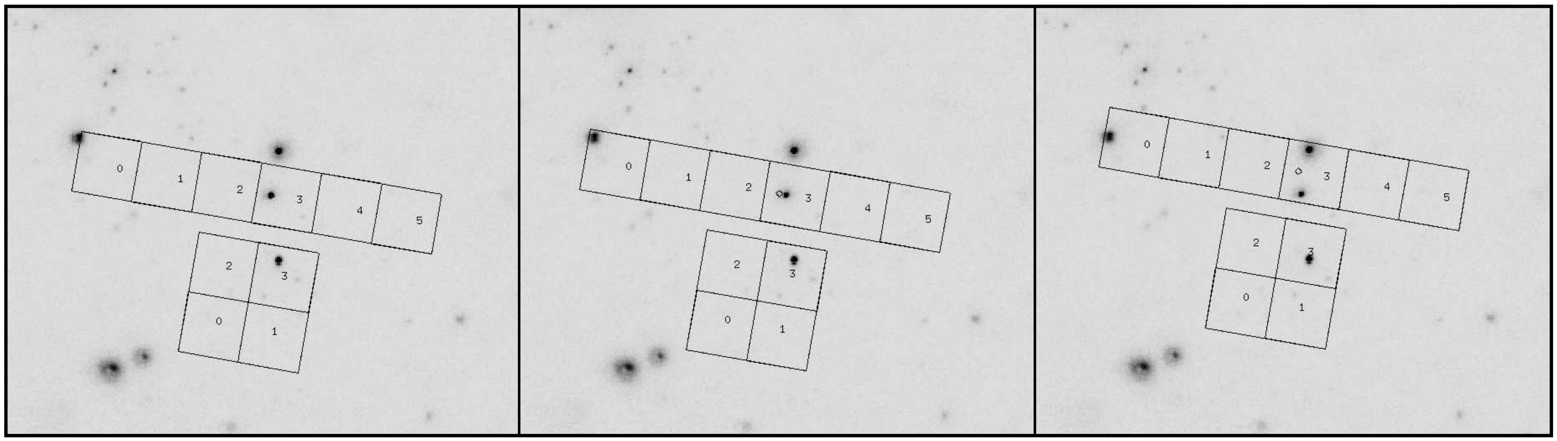

Figure 3.1: Examples of offset pointing with ACIS. North is up and East is to the left. Roll is measured positive, West of North. The roll angle shown is 10°. Left Panel: The target, a bright x-ray source, is centered at the nominal ACIS-S aimpoint. Middle Panel: The target is offset with (Y,Z) offset of (-1,0) arcmin. In the Right Panel the offset is (-1,-3). Note the small circle at the location of the ACIS-S aimpoint.

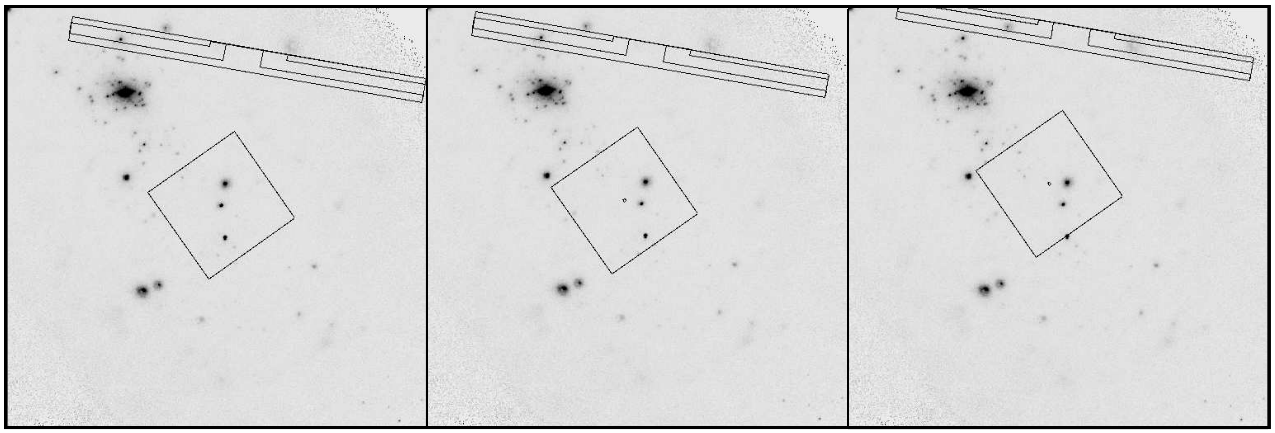

Figure 3.2: Example of offset pointing with HRC. North is up and East is to the left. Roll is measured positive, West of North. The roll angle shown is 10°. Left Panel: The target, the middle source in a group of three aligned N-S, is at the nominal HRC-I aimpoint. Center Panel: The target is offset with (Y,Z) offset of (-5,0) arcmin. Right Panel: The offset is (-5,-5). Note the small dot at the location of the HRC-I aimpoint.

ing number for the altitude at which this takes place is about 60,000 km. Cessation of observations and protection of the instruments in regions of high radiation results in approximately 30% of the 63.5 hour *Chandra* orbit being unusable.

3.3.2 Avoidances

The following constraints are necessary to ensure the health and safety of the spacecraft and science instruments. Proposals which violate these constraints may not be accepted.

1. Sun avoidance – cannot be overridden – viewing is restricted to angles larger than 46 degrees from the limb of the Sun. This restriction makes about 15% of the sky inaccessible on any given date, but no part of the sky is ever inaccessible for more than 3 months.

2. Moon avoidance – viewing is restricted to angles larger than 6 degrees from the limb of the Moon. This restriction makes less than 1% of the sky inaccessible at any time. This avoidance can be waived, but at the price of a reduced-accuracy aspect solution (see Chapter 5).

3. Bright Earth avoidance – viewing is restricted to angles larger than 10 degrees from the limb of the bright Earth. This restriction makes less than 5% of the sky inaccessible at any time, but there are certain regions which can only be viewed, continuously, for up to about 30 ks. The avoidance can be waived, but at the price of a reduced-accuracy aspect solution (see Chapter 5). Figure 3.4 illustrates the point that the Earth avoidance region is nearly stationary. This is a consequence of the combination of high elliptical orbit and radiation belt passages. This partially blocked region moves several degrees per year, reflecting the evolution of the orbital elements.

   The greatest amount of observing time is available in the vicinity of apogee, when the satellite moves most slowly and the earth and its avoidance zone occupy an approximately stationary location on the sky, visible in Figure 3.4 as the extension to the south of the sun avoidance band.

4. Roll angles – the spacecraft and instruments were designed to take advantage of the Observatory having a hot and a cold side. Thus, the spacecraft is preferentially oriented with the Sun on the $-Z$ side of the $X - Y$ plane, where $+X$ is in the viewing direction, the Y-axis is parallel to the solar panel axes, and $+Z$ is in the direction of the ACIS radiator (see Figure 1.1). In this orientation there is only one "roll angle" (rotation about the viewing- or X-axis - positive West of North) for which the solar panels can be rotated so that they are directly viewing the sun - the nominal roll angle. Small deviations ($\sim$degrees) from the nominal roll angle may

Table 3.1: *Chandra* observing limitations due to solar pitch angle constraints. (Warning: this table summarizes the limitations expected to be typical during calendar year 2009; please consult *CXC* web pages for updates.)

Angle range	Restriction	Reason
0-46	No observations	HRMA Sun aviodance
46-56	Observations with 6 ACIS chips may be limited to ∼35 ks	ACIS PSMC temperature
56-60	unrestricted	
60-135	Observations range from ∼10 ks to substantial fraction of full orbit, depending on pitch of current observation and pitch history	EPHIN temperature limitations
135-156	Unrestricted	
156-170	∼7 to 25 ks duration, depending on length of previous observations at low pitch angle	Propulsion line temperature
170-180	No observations	Propulsion line temperature limitations

be allowed depending on the viewing geometry. The roll-angle constraint imposes further visibility restrictions. These can also be evaluated with the *PRoVis* tool.

3.3.3 Pitch Angle Constraints

Changes in the thermal properties of the spacecraft with time are causing us to impose new restrictions in the solar pitch angle (i.e., angle between the viewing direction and the direction to the Sun, see Figure 3.3) that can be observed. **These restrictions are evolving with time; observers are urged to consult the *CXC* web pages for updates.** The pitch restrictions are of four kinds:

1. The EPHIN detector is subject to possibly degraded performance at elevated temperatures that may affect its use in safing the science instruments from high levels of particle radiation. During long observations at pitch angles of between approximately 60 and 135 degrees the EPHIN may reach temperatures that may result in anomalous performance. If this isn't complicated enough, the exact performance depends on the near term thermal history. The *CXC* has developed a model to

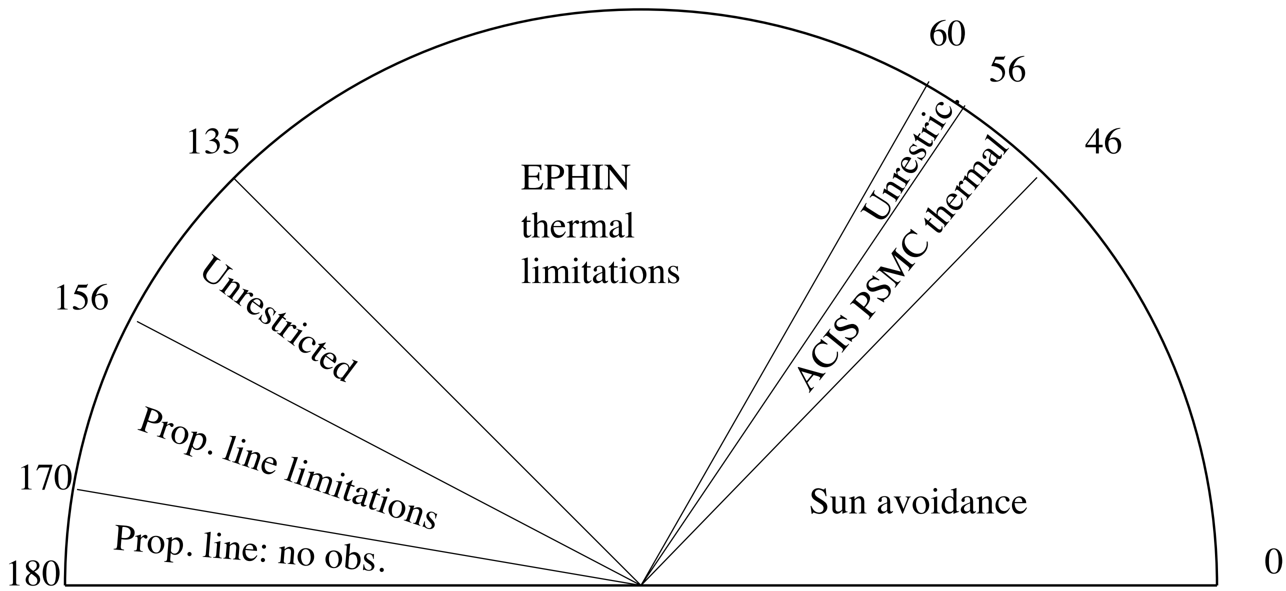

Figure 3.3: Diagram to illustrate ranges of solar pitch angle (the angle between the pointing direction and the satellite-Sun line) within which different observing limitations apply. Table 3.1 provides quantitative estimates for the observing limitations in the solar pitch angle ranges shown in the drawing.

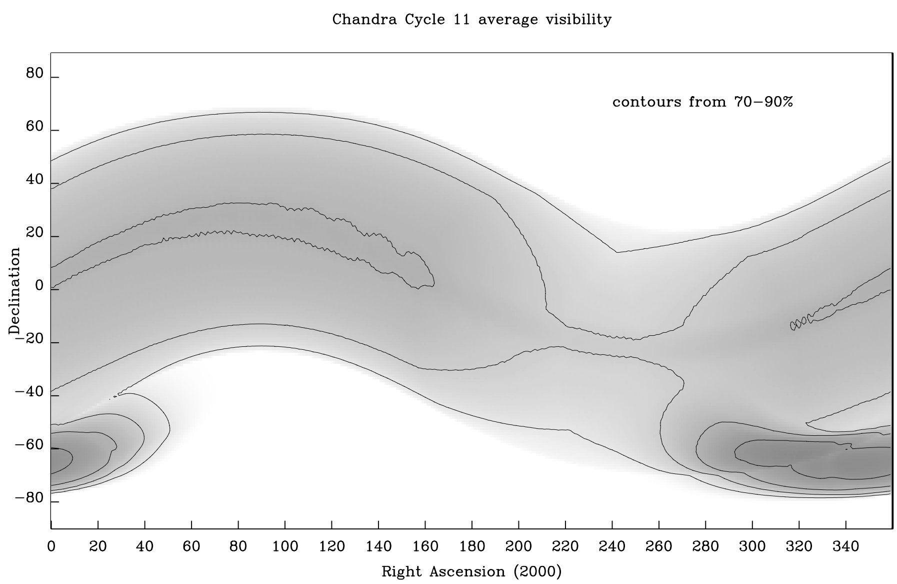

Figure 3.4: The *Chandra* visibility showing contours of fractional visibility averaged over the 12-month interval of Cycle 11. The darker the shade of gray, the lower the visibility. The three contour levels correspond to 70%, 80%, and 90% average visibility

predict EPHIN temperature as a function of time and pitch angle to aid in Mission Planning.

2. Solar pitch angles greater than 170 degrees are not accessible. This is necessary to prevent excessive cooling of the propellant lines, which might then rupture. For cycle 11 we urge that you carefully consider how to configure your observation such that it does not require a pitch angle greater than 170 degrees. This may be done, for example, by imposing no constraints on the observation, or by using the *Chandra* Pitch Roll and Visibility tool (*PRoVis*) at http://cxc.harvard.edu/soft/provis/ to see if your time or roll constraint is acceptable within the allowable pitch angles, i.e. between 46 and 170 degrees. Even this must be tempered by considering the EPHIN-imposed pitch-angle constraints discussed above. It is possible that a peer-review accepted proposal may, in fact, not be accomplished because of these safety constraints. To avoid this unpleasant possibility, observers are urged to carefully plan their observations using all the proposal preparation tools and contacting the *CXC* HelpDesk if necessary.

3. There are observing restrictions in the pitch angle range 156-170 degrees imposed by the need to prevent propellant lines from dipping to low temperatures before line heaters switch on.

4. Owing to the changing thermal environment, the ACIS Power Supply and Mechanism Controller (PSMC) Detector Electronics Assembly (DEA) has been warming and is expected to continue so doing. The temperature is affected by both the solar pitch angle and by the number of ACIS chips in use. As a result, allowable durations for 6-chip ACIS observations at solar pitch angles of less than about 56 degrees will be limited. ACIS observers are being asked to specify optional chips and the priority order in which these may be turned off; this information will be used as needed during the mission planning process to control ACIS temperatures (see 6.20.1). Observers are encouraged to avoid specifying ACIS observations that require 5 or 6 chips and that must also be executed at solar pich angle below about 56 degrees.

These spacecraft constraints have several implications for proposers:

- Observations in the 60-135 degree pitch zone can be performed, but if too long will be broken into shorter durations, which may be separated by a day or more. The maximum continuous duration depends on the target pitch and thermal history of the spacecraft. It can be estimated from tables and figures given on the *MaxExpo* web page (http://cxc.harvard.edu/proposer/maxexpo.html. If such observations have roll constraints, the observations must either be brief or the roll constraints must be generous enough to allow multiple segments at their different, time-dependent, roll angles. Constraining roll angles to be constant for multiple segments is discouraged, as achieving off-nominal roll angles creates additional thermal problems/concerns and can only be done for a very limited range of off-nominal roll angles around the nominal value.

- Simultaneous longer-duration observations with telescopes (such as XMM-Newton) with a preferred pitch angle in the 60-135 degree range may be very difficult, or even impossible, to schedule.

- Targets near the ecliptic poles (such as the Magellanic Clouds) are especially affected by these considerations since their pitch angles are always close to 90 degrees.

Proposers should check that time (or equivalently roll) constrained observations do not force *Chandra* to unfavorable pitch angles unless the observations are short or can be segmented. Pitch, roll and visibility for any sky position as a function of time can be viewed using (*PRoVis*) at http://cxc.harvard.edu/soft/provis/. The *MaxExpo* web page (http://cxc.harvard.edu/proposer/maxexpo.html) can be used to obtain an estimate of the maximum exposure as a function of pitch angle.

3.4 Other Constraints and Considerations

The instrument constraints are discussed in the chapters devoted specifically to the instruments. User-imposed constraints are discussed in the instructions for completing the *Chandra* Remote Proposal Submission (RPS) form. We summarize these here.

3.4.1 Instrument Constraints and Considerations

- The HRC has a brightness limit which limits the flux per microchannel plate pore.

- The HRC has a telemetry limit. Exceeding this limit, amongst other consequences, reduces observing efficiency.

- The HRC has linearity limits. Exceeding these limits voids the effective area calibrations.

- The ACIS has a telemetry limit. Exceeding this limit, amongst other consequences, reduces observing efficiency.

- The ACIS is subject to the effects of pulse pileup. Dealing with this effect requires careful planning of the observation.

- The ACIS has a limit for the total amount of allowed flux in a pixel during an observation. The limit only impacts a small number of potential observations, primarily those of very bright sources that request the dither to be turned off. Please see Section 6.18

3.4.2 User-Imposed Constraints

Chandra users may need to specify a number of observing constraints particular to their observations. In general, the specification of a user-imposed constraint decreases the efficiency of the observatory and therefore should be well justified in the proposal. Note that only a limited number of constrained observations can be accommodated (see the *CfP* for details). User imposed constraints are summarized here.

Time Constraints:

Time Windows – specific time intervals in which observation must be scheduled. Such constraints are primarily for use in coordinated observing campaigns or for arranging an observation to coincide with some time-critical aspect of the target.

Monitoring Intervals – for observing a target at semi-regular intervals for a specified duration.

Phase Interval – specific phase intervals for observing sources with long, regular periods.

Coordinated Observations – targets specified to be observed by Chandra and another observatory in a give time period are time constrained.

Continuity of observation – specifying that an observation may not be interrupted (up to 160 ks).

Group Observation – a target which needs to be observed within a particular time range with other targets in the program.

Roll Constraints: – specifying a particular roll angle and tolerance.