SIM Science Studies Workshop

SIM Lite Operations

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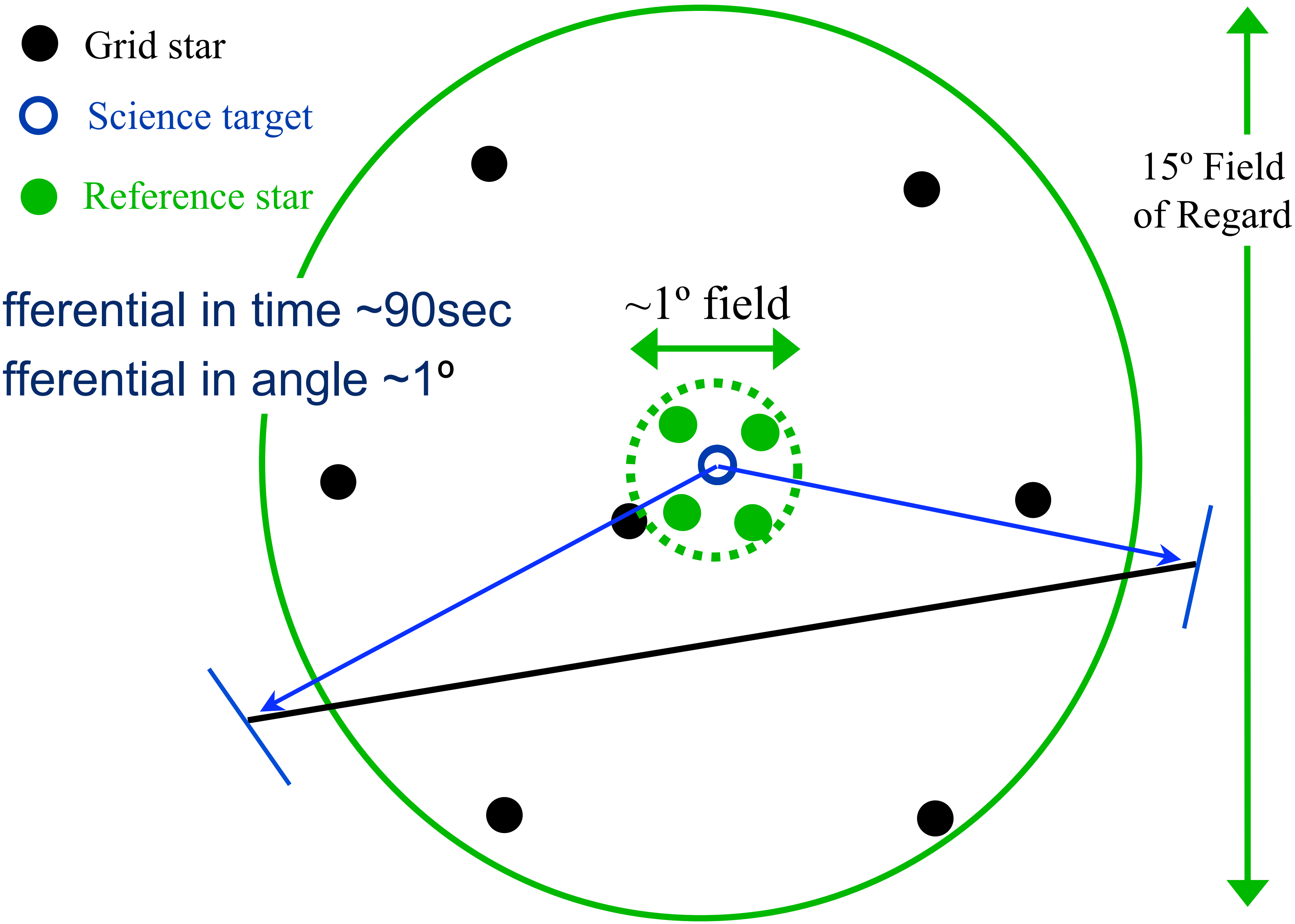
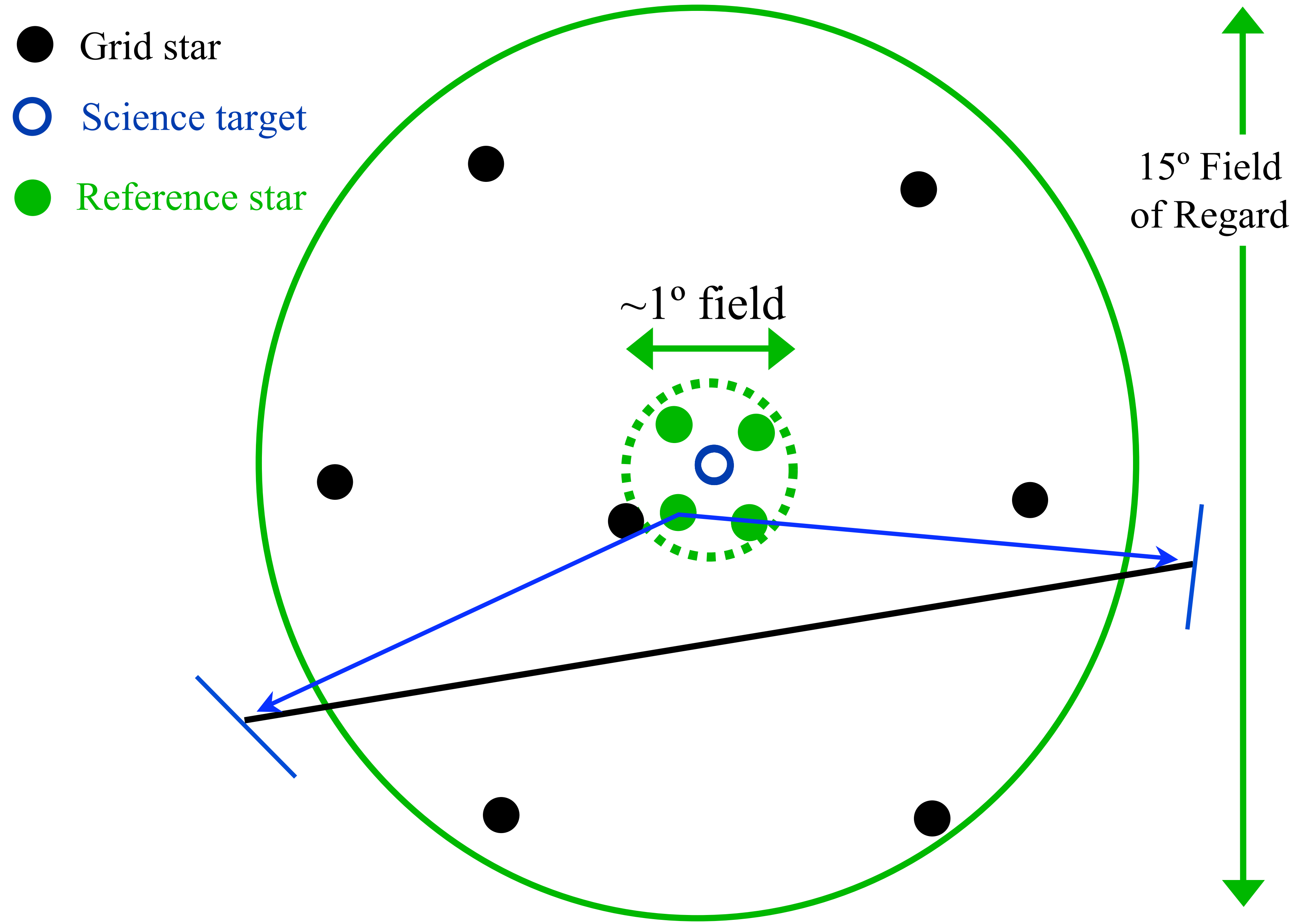
Summary

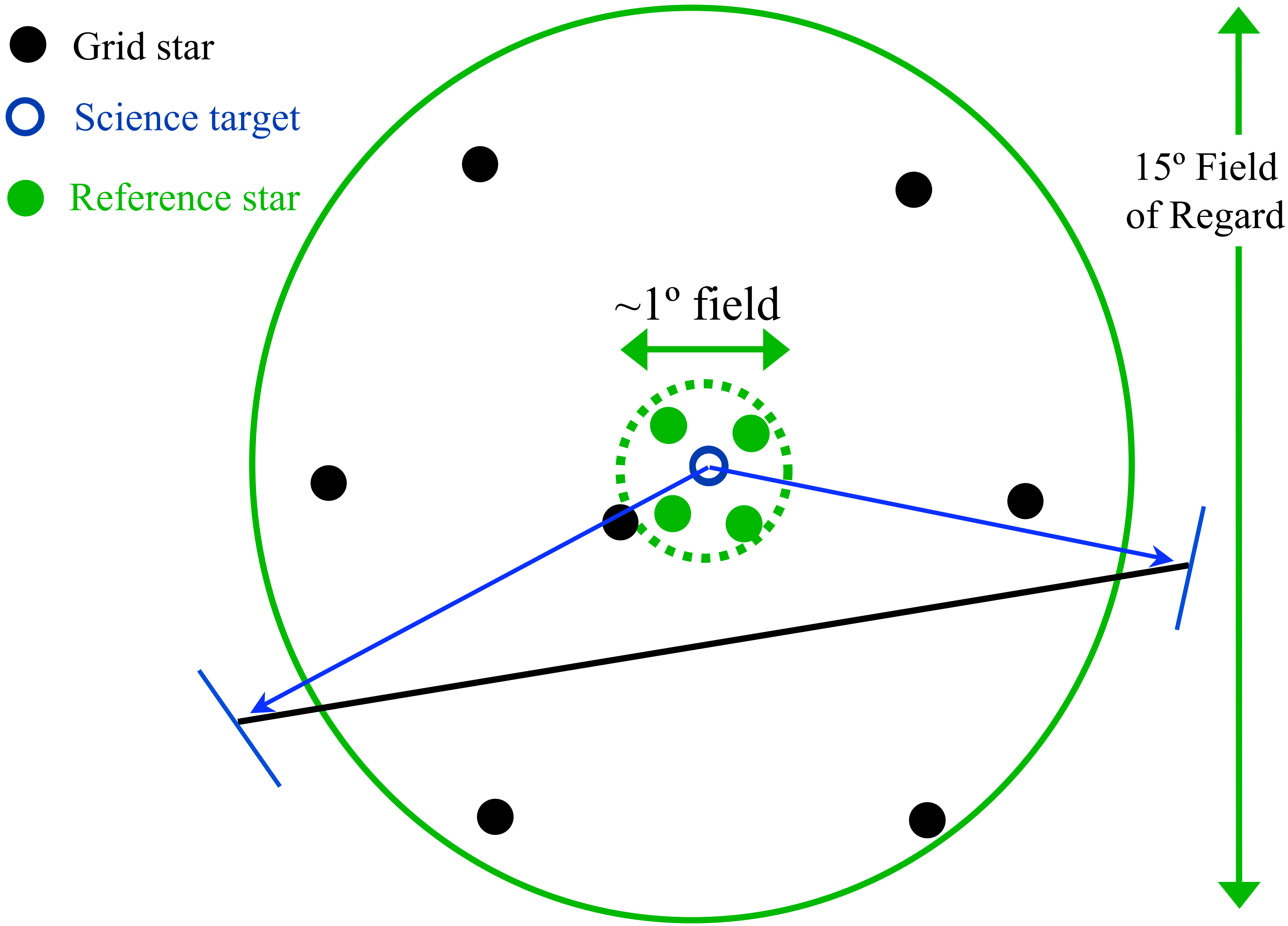
- Observing modes
  - Narrow-angle (differential) astrometry
  - Wide-angle (global) astrometry
  - Astrometric grid
- Orbit
- Notional scheduling timeline
- A tile-oriented view of time allocation
- Global view of science observing time assignment
- Planning an observation campaign
  - Wide-angle
  - Narrow-angle
  - TOO
- Color shift astrometry
- Web-based time estimators

Planet Search Observing Scenario



- Differential in time ~90sec
- Differential in angle ~1°


Grid star
Science target
Reference star
~1° field
15° Field
of Regard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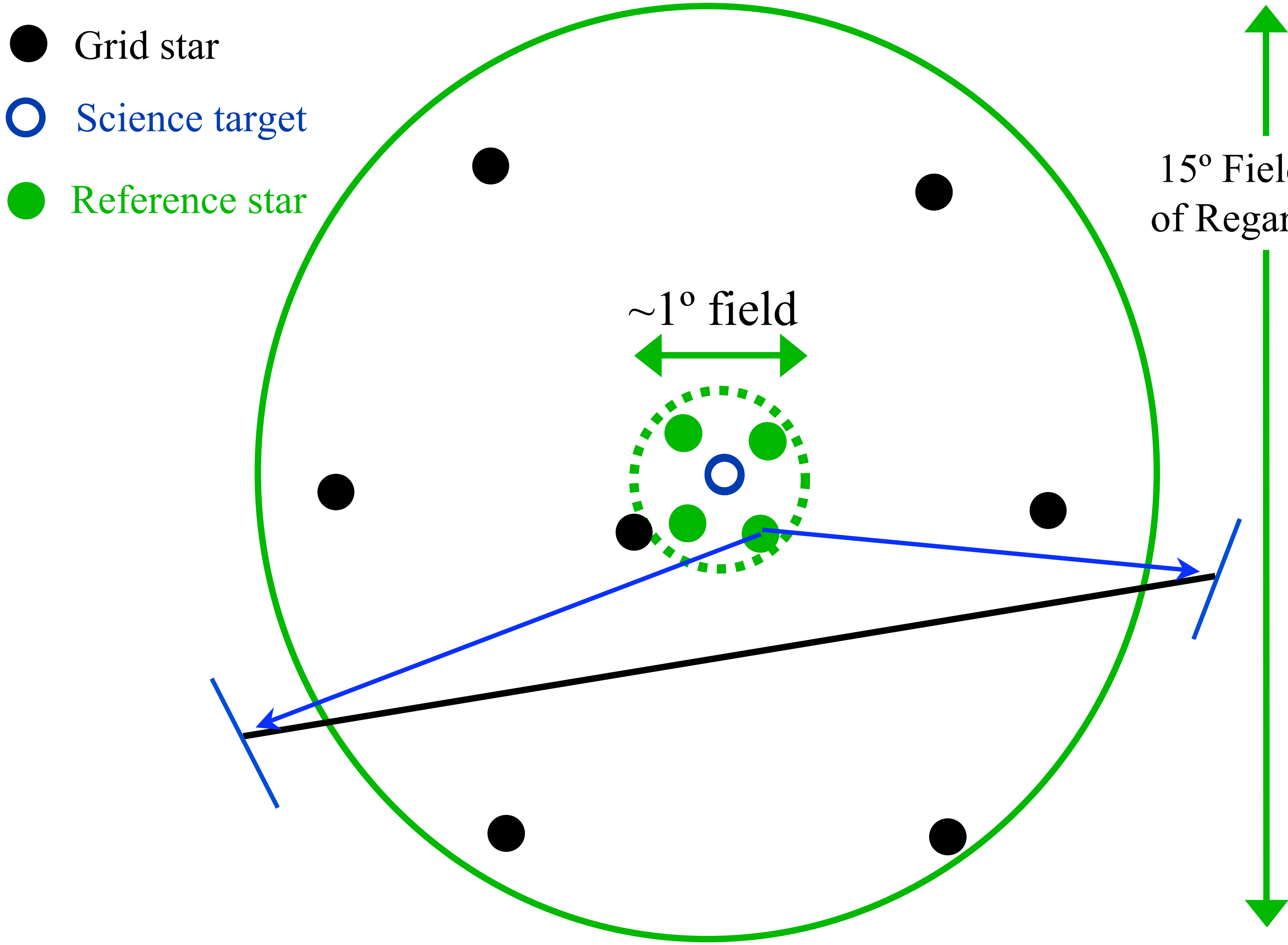

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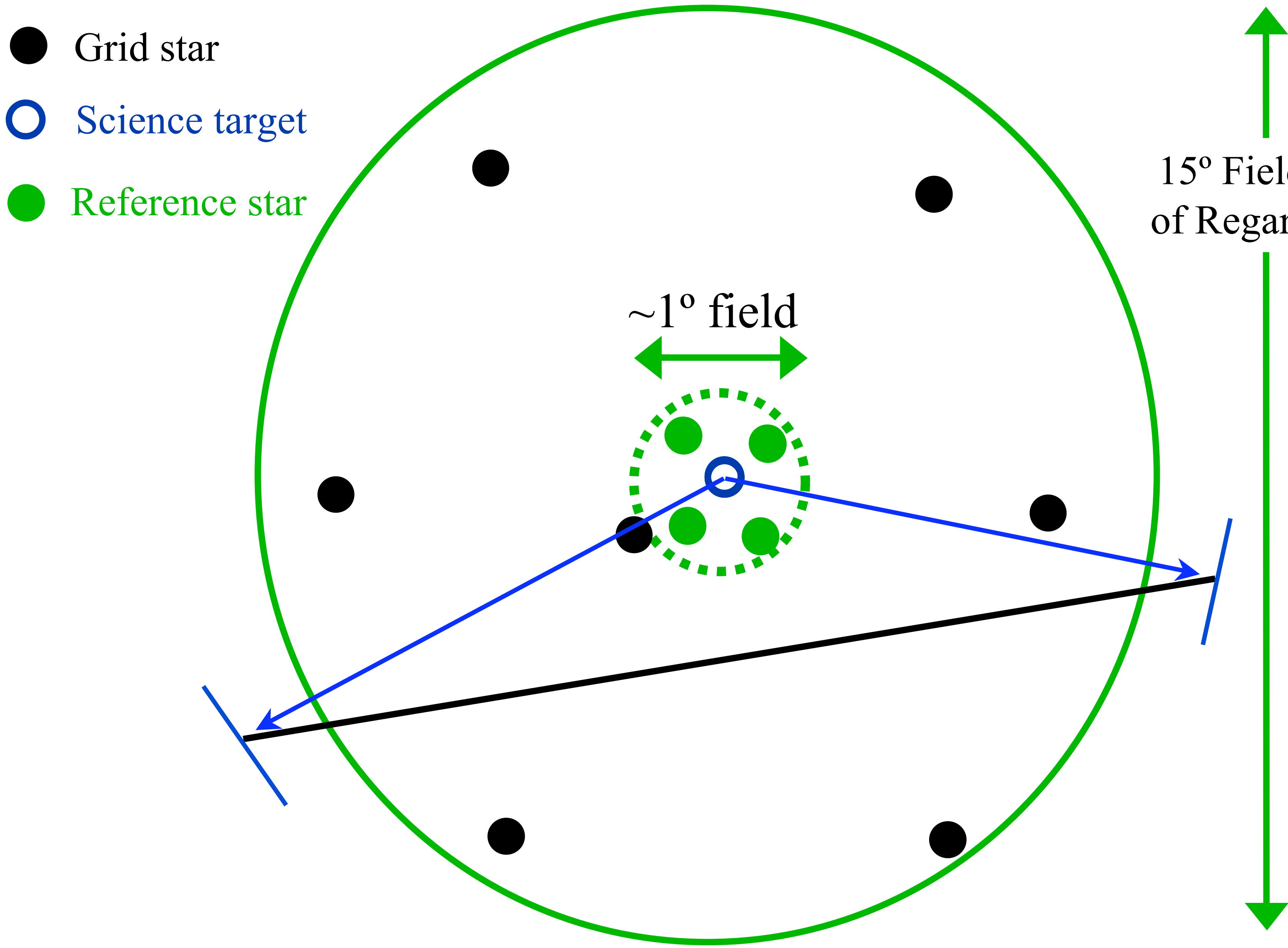
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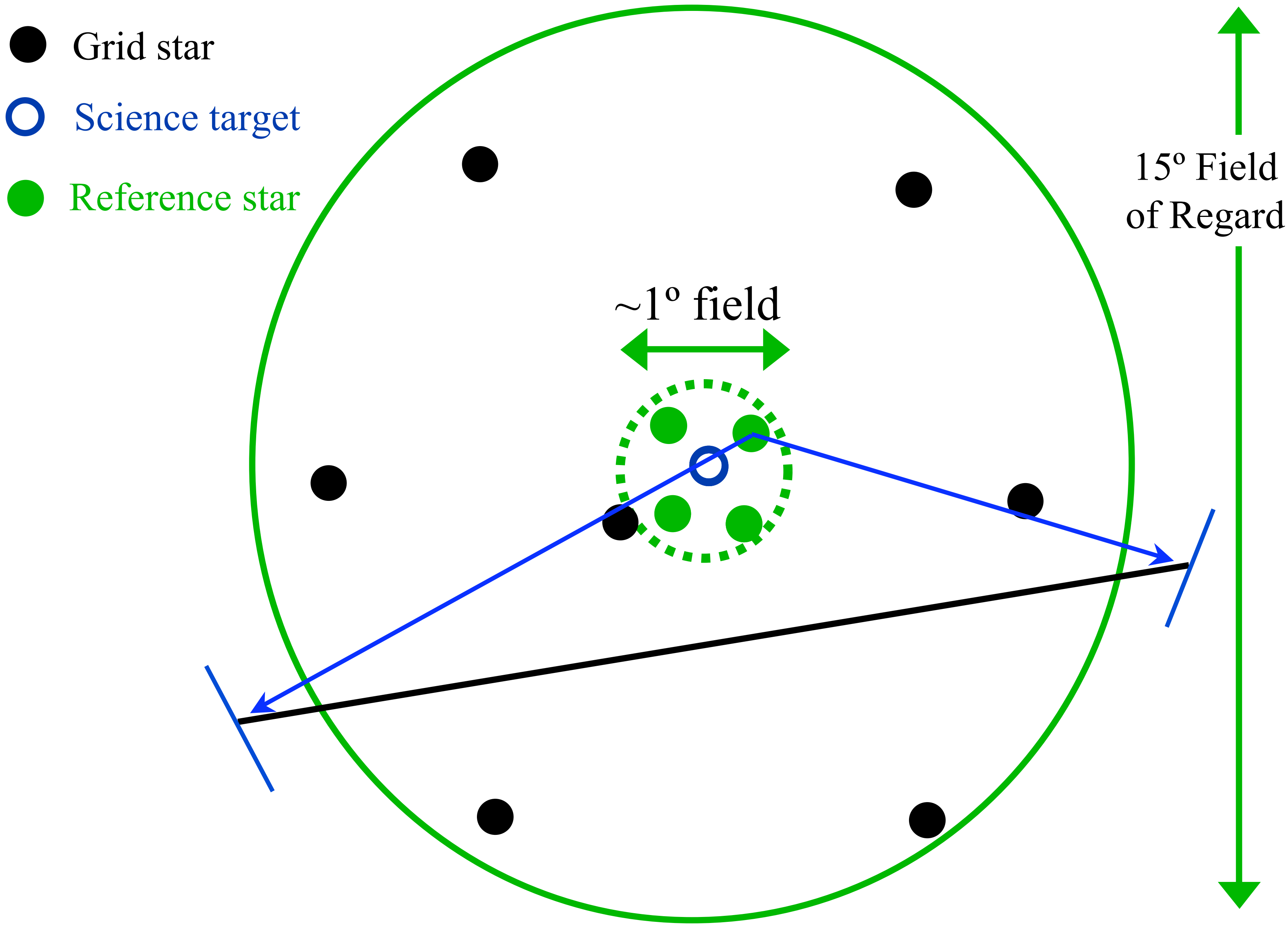
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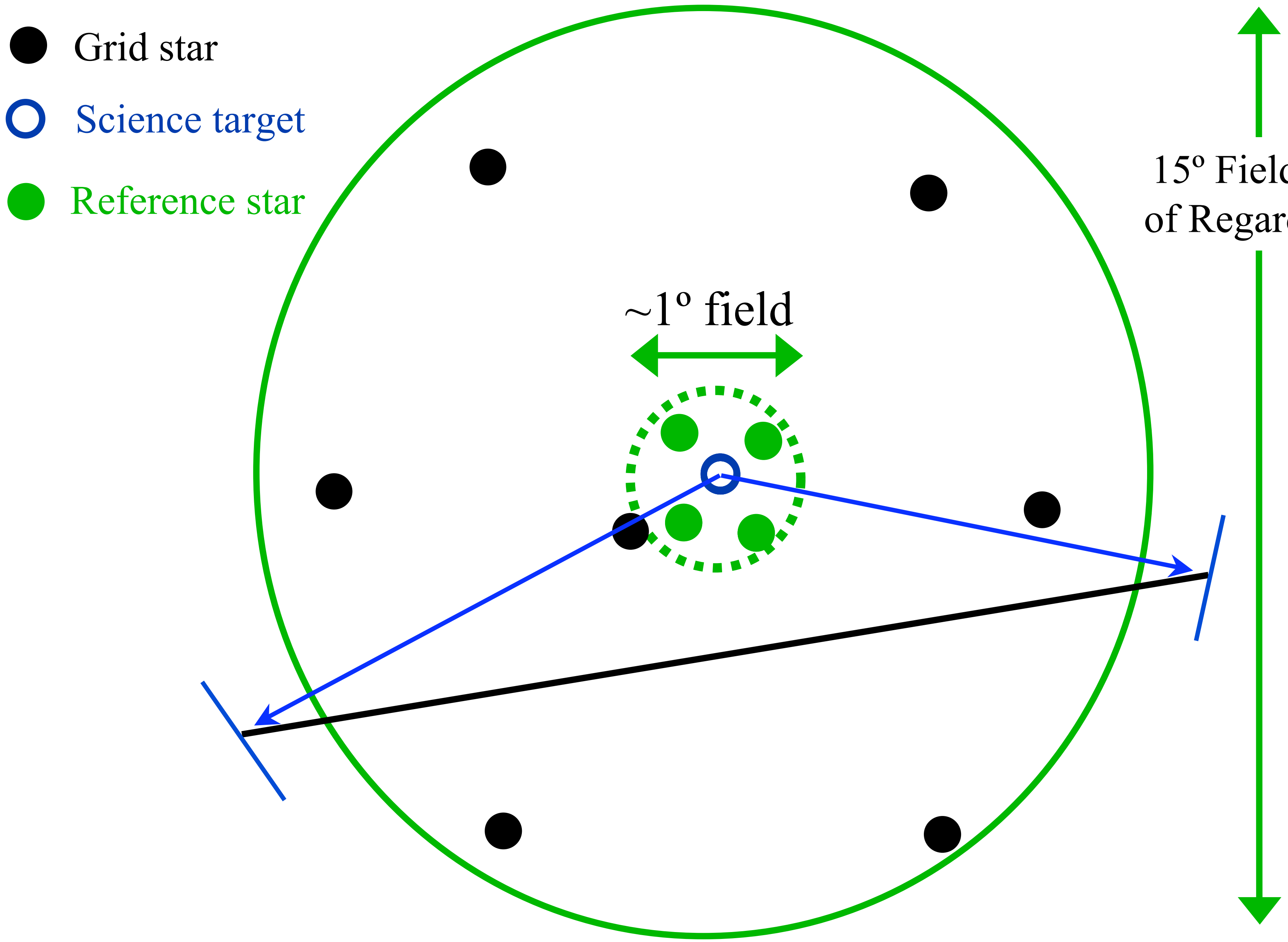
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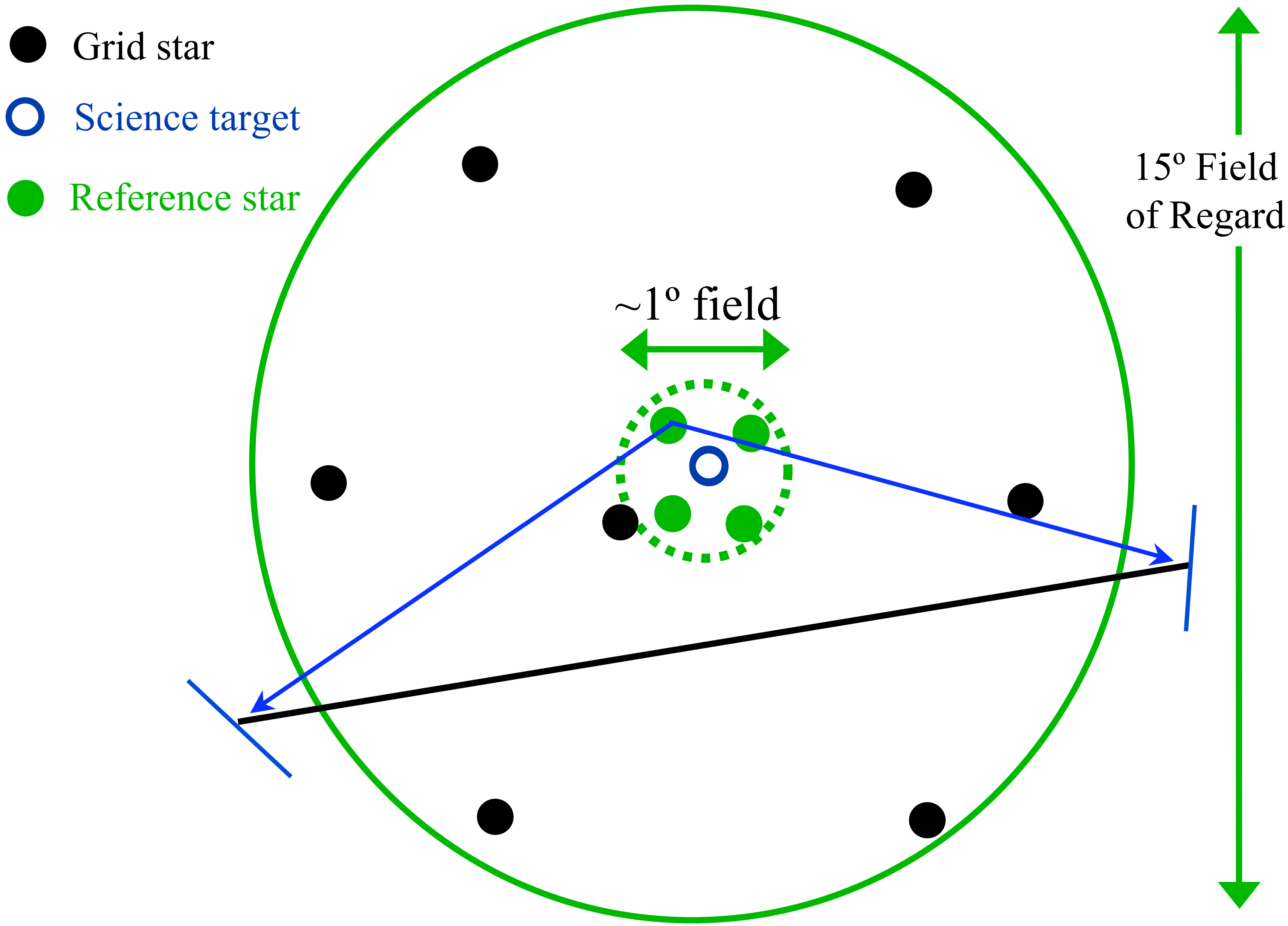
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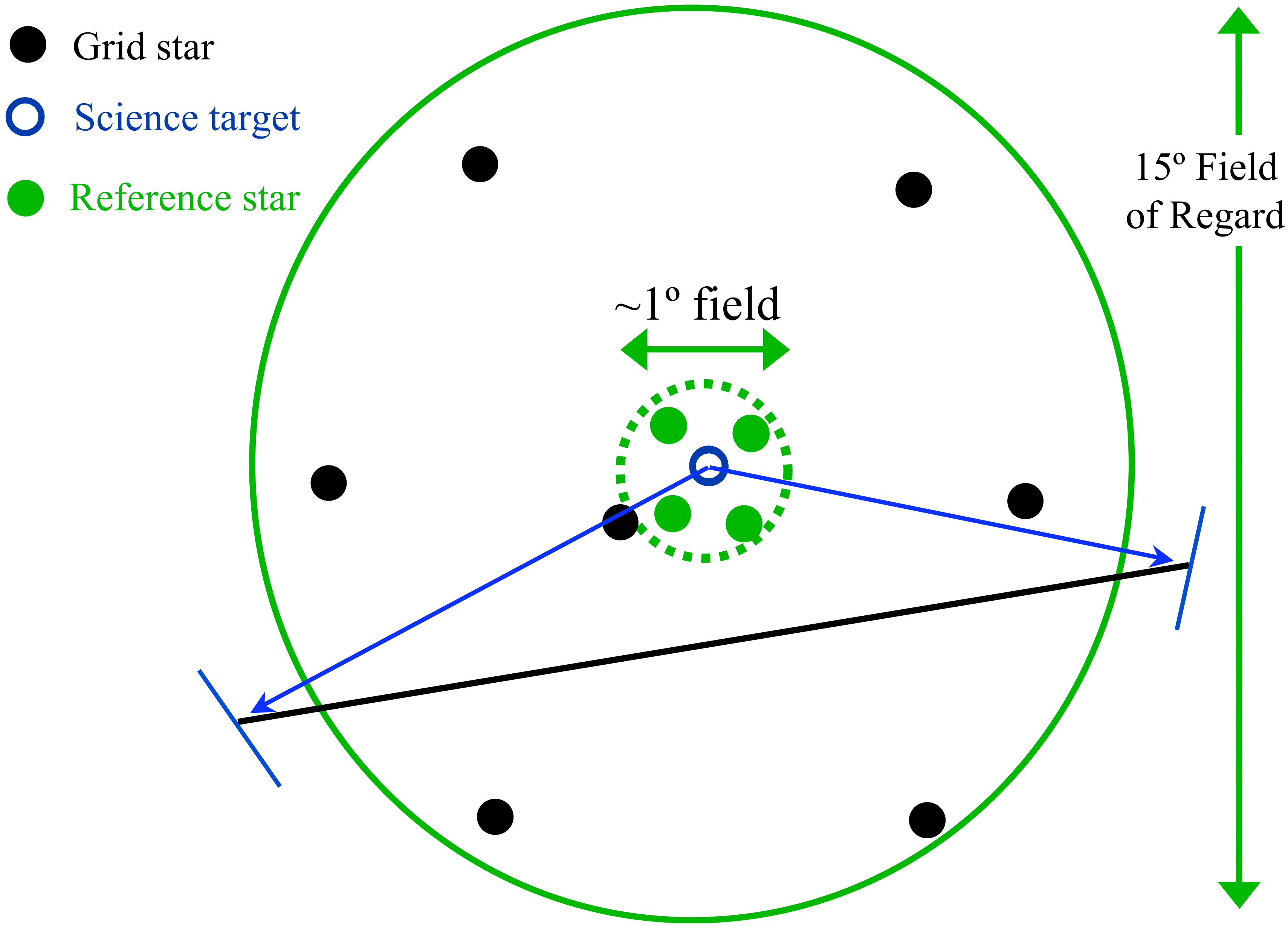
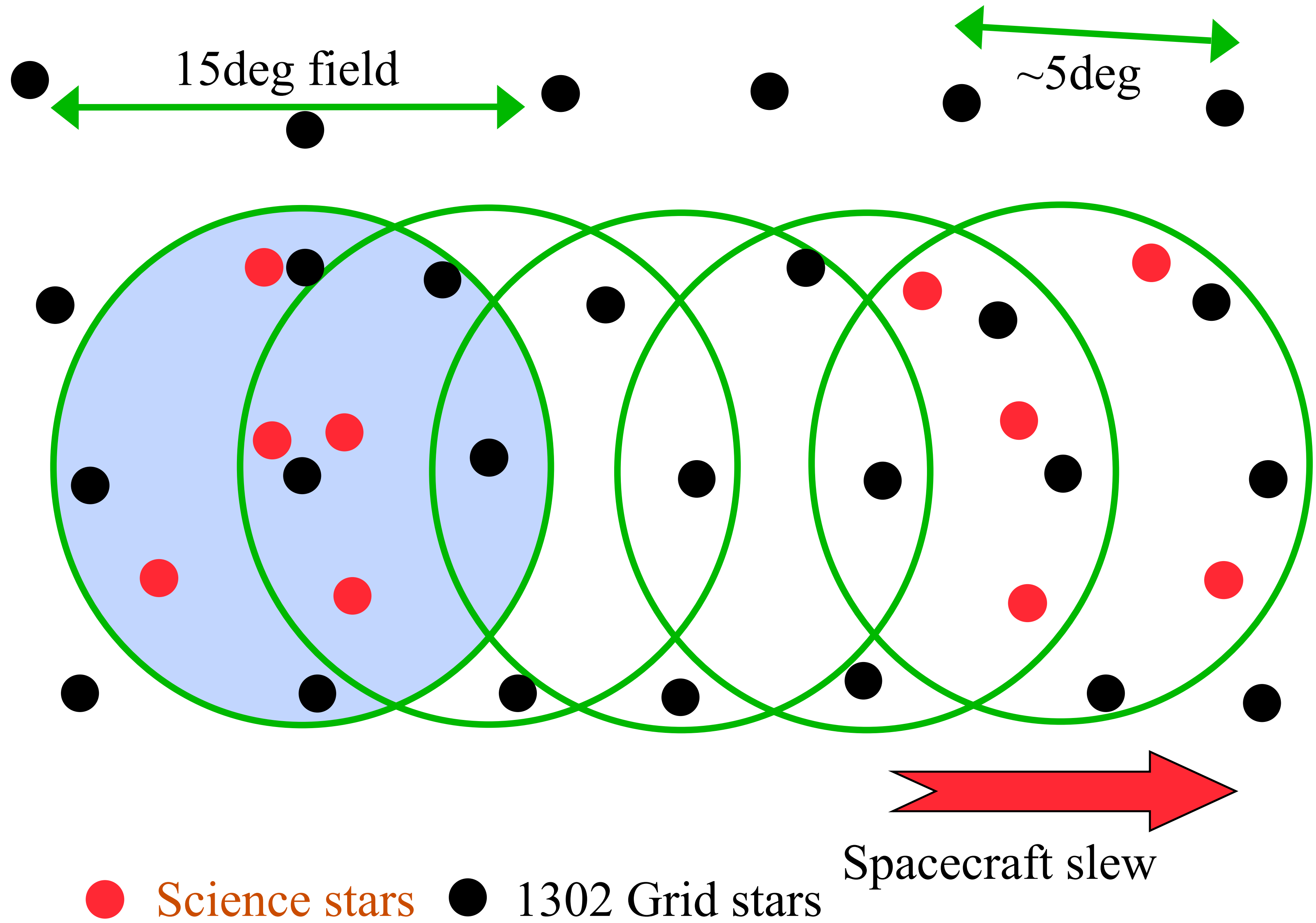
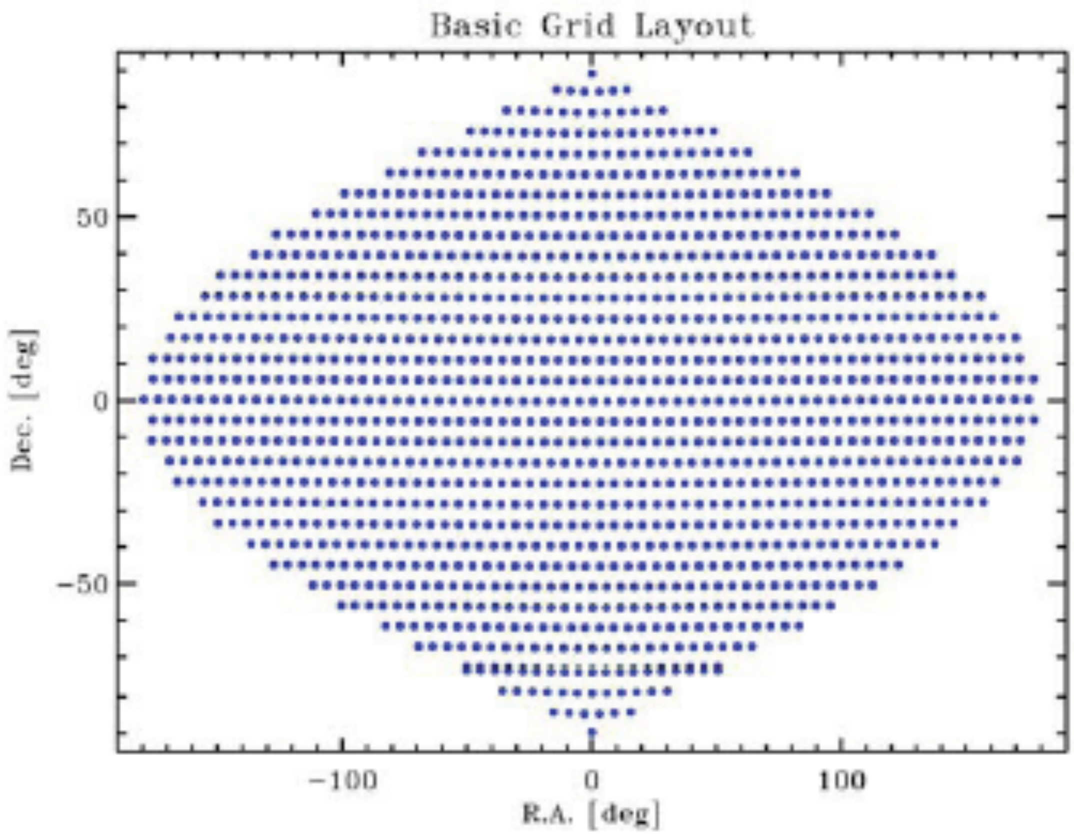

Grid star
Science target
Reference star
15º Field
of Regard
~1º field

Combined grid star + science target observing scenario



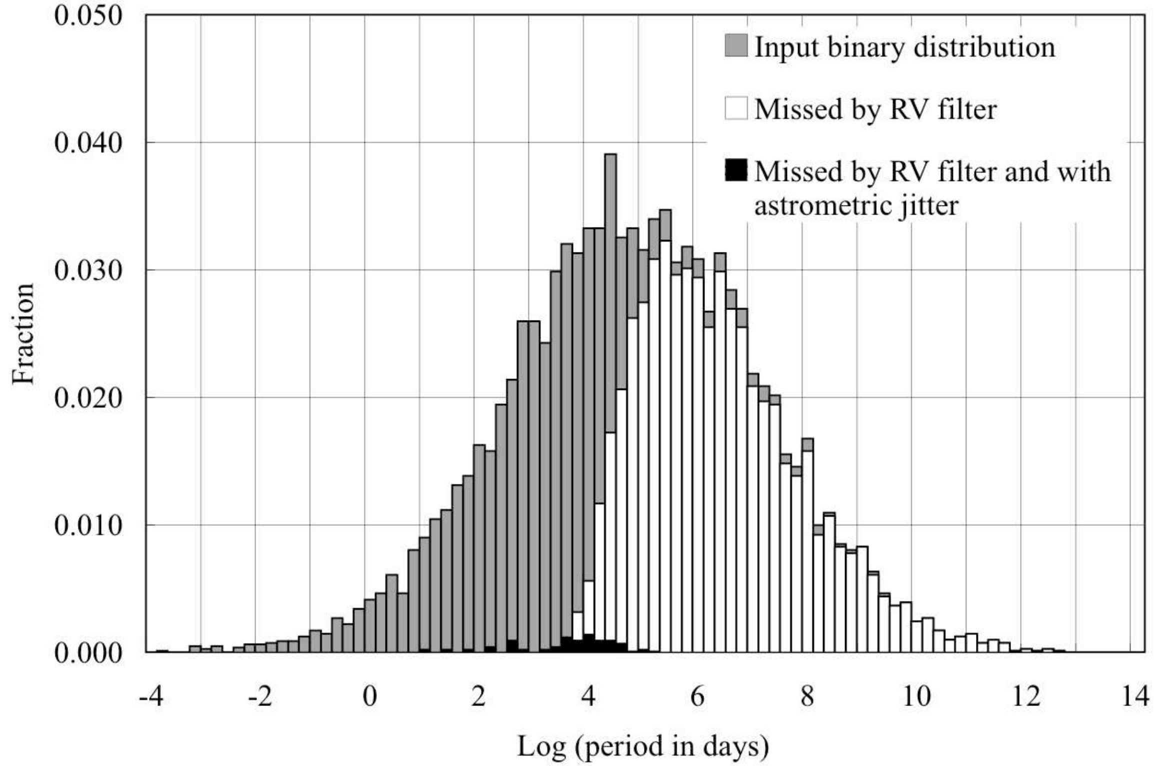
SIM astrometric grid: 1302 'bricks'

- Bricks are ~evenly spaced at ~ 5º
- Candidates stars are K-giants at ~0.6-2kpc, selected by a rank-order metric
- SIM uses the best candidate star in each 'brick'
- All candidates in each brick are screened with radial velocity

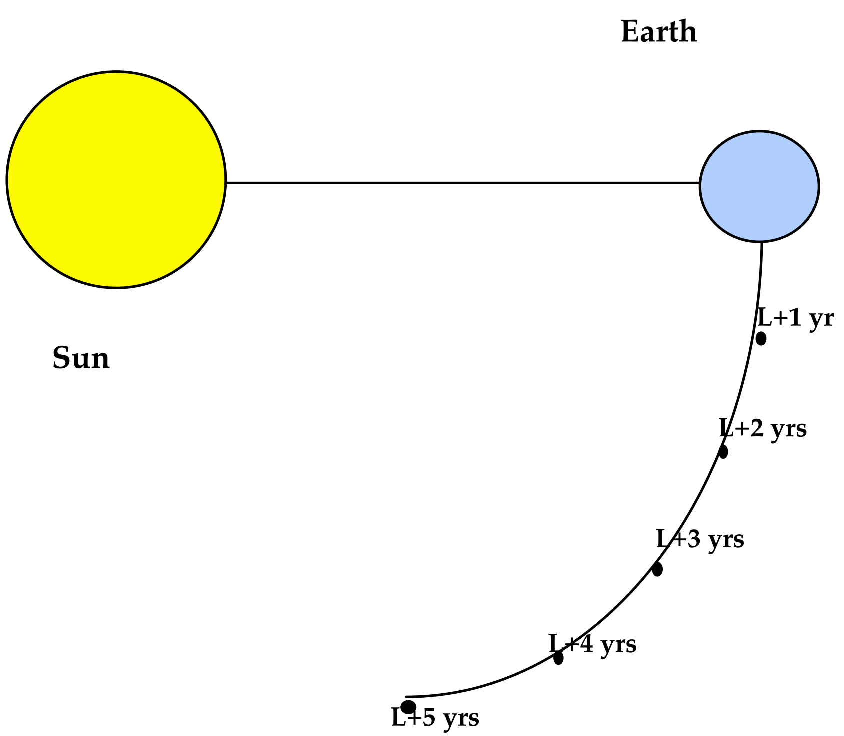


SIM astrometric grid star screening

- Extensive modeling shows that there will be many binaries in the candidate grid catalog with predicted jitter > 4 μas
- RV screening at 50 m/s is *very effective* at removing companions
- Final grid catalog will have few binaries with jitter > 4μas
  - Typically binaries with ~10^4 day periods

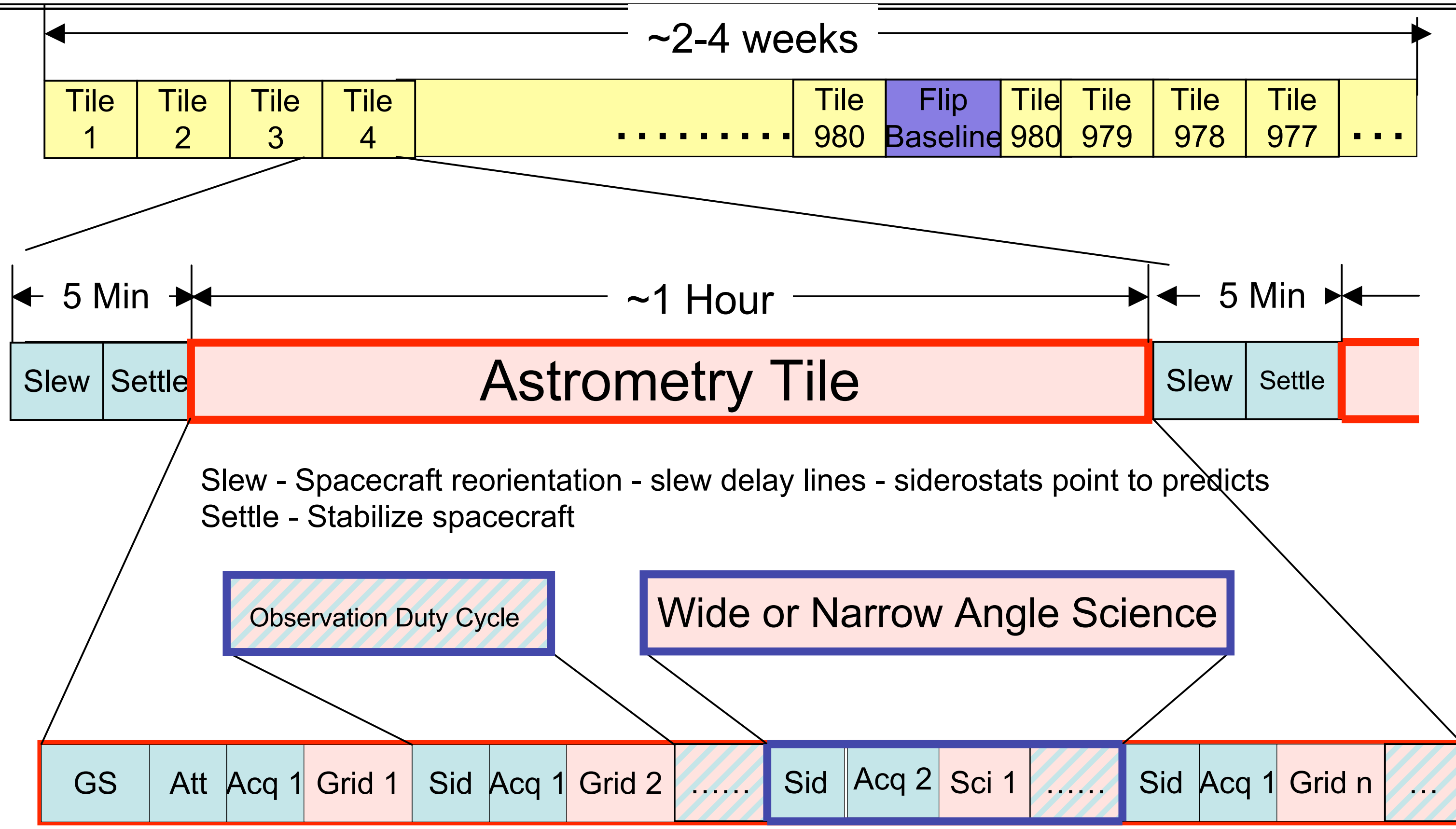


Spacecraft Orbit: Earth Trailing



CHARACTERISTICS

C_3	0.6 km^2/s^2
Occultations	None
5.5-yr Radiation Dose	20 krad
Launch Vehicle	Delta IV/Atlas V
RCS System	Mono-Prop/RWA
Propulsion System	Hydrazine
Orbit Determination	Range/Doppler
Earth-S/C Range	Up to 100 Million km
Mission Duration	5.5 Years



GS -	Acquire Guide Stars with angle tracker - Acquire Fringes and Track
Att -	Stabilize spacecraft attitude
Acq 1-	Acquire Star with angle tracker - Acquire fringes
Grid 1 -	Integrate on grid target
Sid -	Feedforward - Repoint science siderostats - Slew science delay line
Acq 1-	Acquire Grid Star 2 with angle tracker - Acquire fringes
Grid 2 -	Integrate on grid target
……. -	Continue through all grid stars in tile
Sid -	Feedforward - Repoint science siderostats - Slew delay line
Acq 2-	Acquire Science Star 1 with angle tracker - (if bright, acquire/track fringes?)
Sci 1 -	Integrate on first science target
…….-	Continue through Science Target list (variable number of targets)
Grid n -	Reobserve n=3 to 6 Grid Stars to finish tile

Overhead
Science Return
Repeated Observations

A Tile-Oriented View of Time Allocation

- Grid tiles (science targets embedded) 0.18 (fraction of 5 years)
  - Shutter-open 0.03
  - Retarget 0.06
  - S/C slewing and settle 0.09

- Science tiles (in addition to the grid) 0.78
  - Shutter-open 0.45
  - Retarget 0.25
  - Scheduling margin 0.03
  - S/C slewing and settle 0.05

- Engineering time 0.04
- **TOTAL** **1.00**

- Assumes:
  - average integration time
    - science target = 60s
    - grid stars = 15s
  - Retarget time = 30s (15s for narrow angle)
  - Grid schedule carries no schedule margin

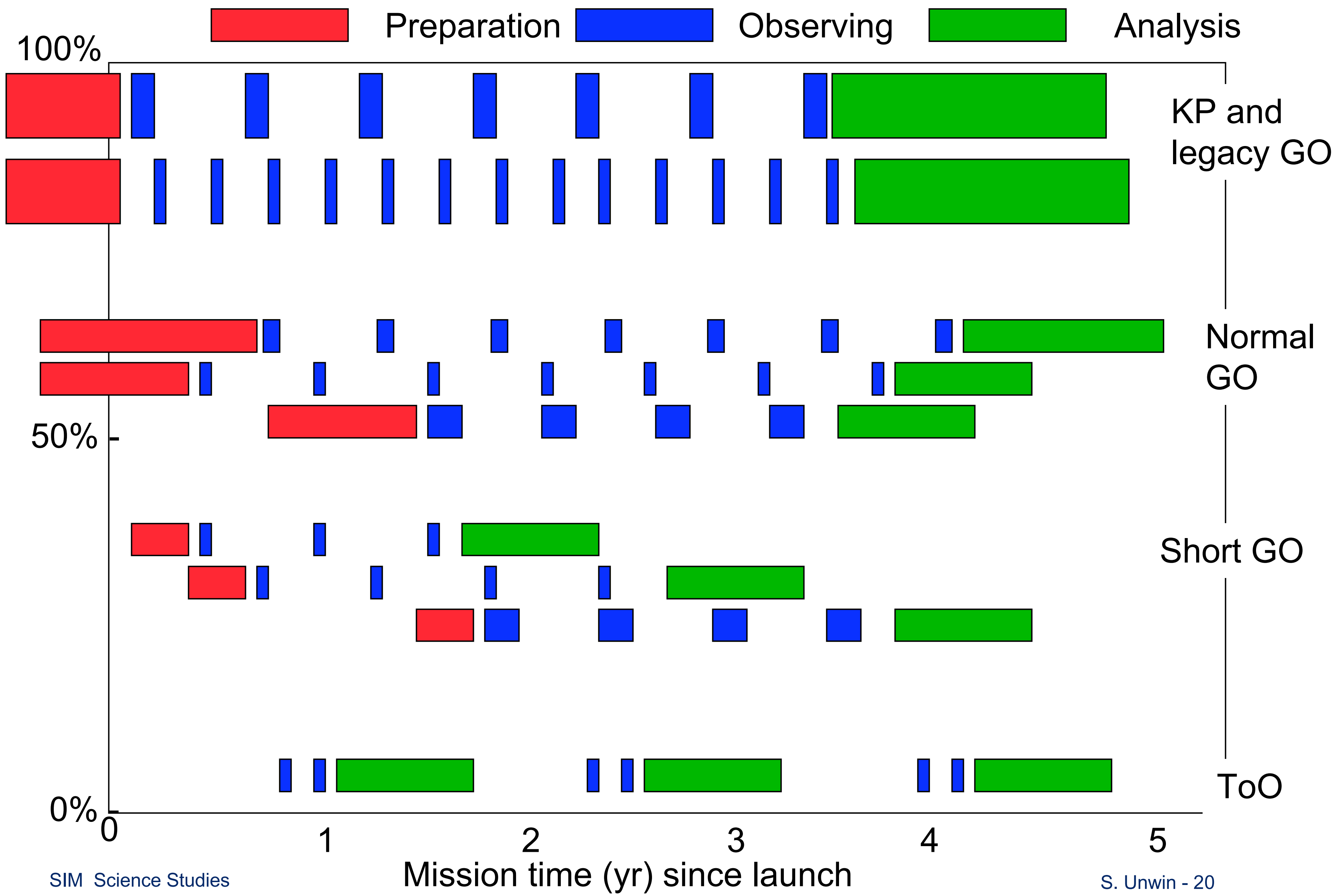
SIM Lite Time Allocation - Global View

Task	**Targets**	**Mission**
Key Projects	Various	36%
Guest Observer	Various	36%
Grid	44,000 tiles	9%
Quasars	50 quasars	1%
S/C Slewing	~63,000 slews	14%
Alignment/Cal	50 min/day	4%
Total	**5 years**	**100 %**

Observation Stragegy

- Planning philosophy:
  - Maximize the accuracy of astrometric parameters with the minimum observing time
- General considerations: optimize for the science objective, e.g.
  - Absolute parallax (luminosity)
  - Absolute proper motion (galactic dynamics)
  - Relative parallax (cluster depth)
  - Relative proper motions (intra-cluster dynamics)
  - Absolute position (quasar astrometry)
  - Color-shift astrometry (quasar jets)
  - Differential position (planet search)
  - Differential position (masses of known binaries)
  - Microlensing (lens parallax)
  - Targets of Opportunity (?)
- All of these "science modes" use the SIM Lite (at the instrument level) *in essentially the same way*
  - All use the science interferometer to measure group delay
  - May select different readout modes for the CCD (~10 patterns have been defined)
- What distinguishes the different "science modes"?
  - Observing strategy
  - Target brightness and desired accuracy
  - Interaction with the reference frame (narrow or wide angle?)

Observation Timeline



Accounting of Observing Time - who pays?

- Accounting depends on how observations are scheduled
- A quasi-continuous grid campaign underlies the entire mission throughput 5 years
- Does the observation ‘fit’ the grid campaign?

Wide-angle (global) experiments

- Schedule is assumed to be integrated with the grid campaign
  - For parallax and proper motion there are plenty of scheduling opportunities
- Observer is *not charged* for slew to the tile or grid star observations within their tile
- Observer must "share" the tile with other wide and narrow angle targets
- Observer pays for:
  - Siderostat slew from the previous target in a tile
  - Angle and delay acquisition on target
  - On-target ("shutter open") time
  - Spacecraft slew and settle for any observation which does not fit into the regular grid campaign

Narrow-angle (global) experiments

- Schedule is driven by the needed cadence for detection of a periodic signal
  - For binary stars (period known), may be able to integrate into the grid campaign
  - For planet-seach science, need a non-regular (e.g. log sampling) cadence
  - Can't ever observe in the Sun exclusion zone (60deg)
- May be partially integrated with the grid campaign
- Observer must "share" the tile with other wide and narrow angle targets
- Observer not charged for slew to the tile, or grid star observations within their tile
- Observer pays for:
  - Siderostat slew from the previous target in a tile
  - Angle and delay acquisition on target
  - On-target ("shutter open") time
- Observer pays for spacecraft slew and settle for tiles which are inserted into the regular grid campaign
- Optimal experiment planning for planet-searching is a tough problem
  - Currently an area of active research
  - Problem understood enough to make estimates of additional time required

Targets of Opportunity

- ***Caveat**: Targets of Opportunity are a major complexity and cost driver for the ground system, scheduling, and operations*

- True targets of opportunity (competely unanticipated) are “DTOOs” - distruptive to the schedule
  - Disruption depends on the time-criticality
  - Observer pays for all time that SIM Lite spends outside of the normal (grid-based) observing campaign, including slews to the exit and re-entry points
  - If observation can wait a few days to a week, then slew penalty can be minimized and may even disappear
- ‘Regular’ targets of opportunity “RTOOs” are TOOs for which the location (approx.), but not the time of an event, are known
  - Example - galactic bulge microlensing events (galactic center tile)
- Schedule is assumed to be integrated with the grid campaign
  - Schedule contains a placeholder for RTOO observation
- Observer not charged for slew to the tile, or grid star observations within their tile
- Observer must “share” the tile with other wide and narrow angle targets
- Observer pays for:
  - Siderostat slew from the previous target in a tile
  - Angle and delay acquisition on target
  - On-target (“shutter open”) time

Color Dependent Astrometry

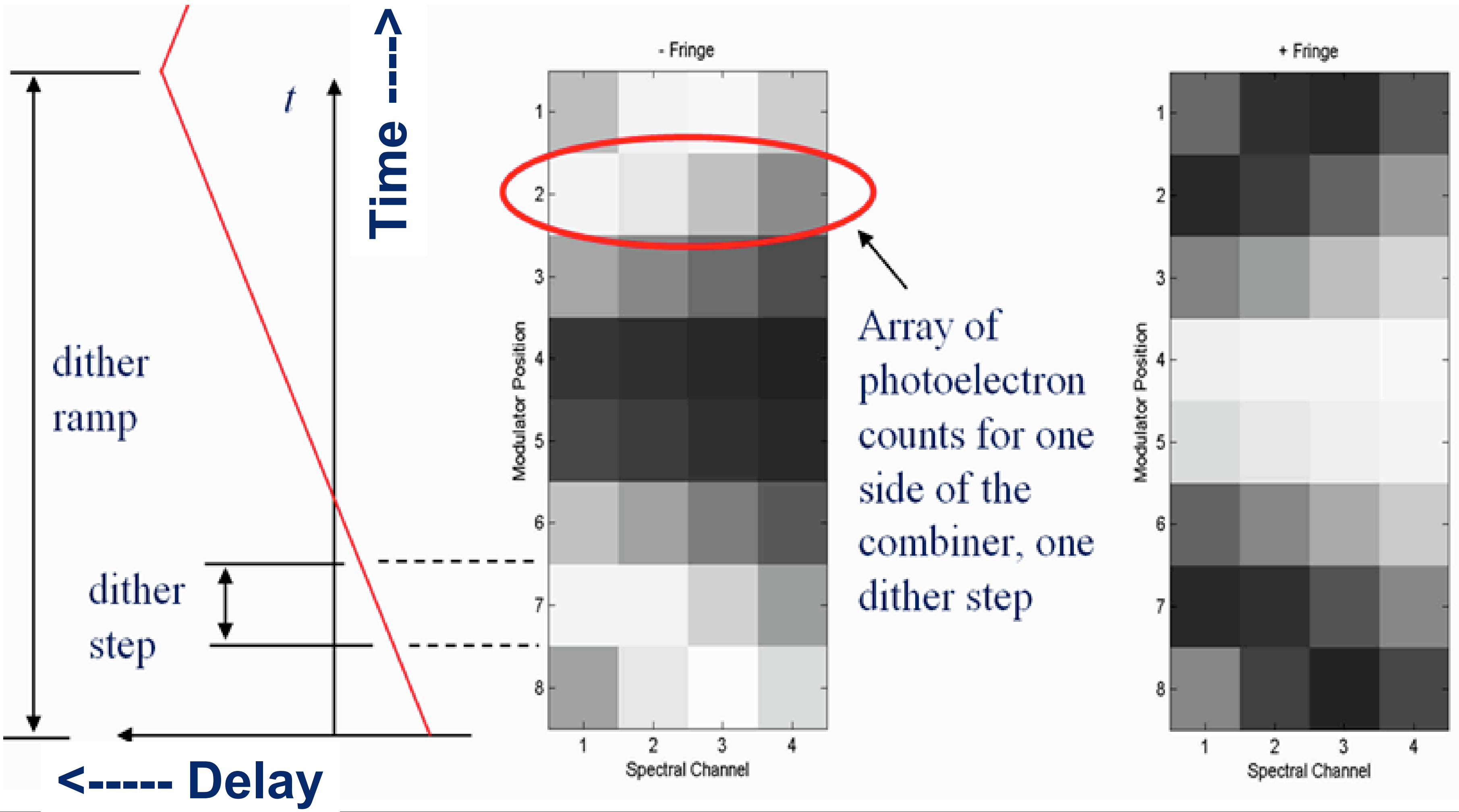
- Color shift astrometry of quasars is part of the Wehlre et al. Key Project

- Some (non-stellar) objects may be asymmetric with respect to color
  - e.g. Quasar with relativistically beamed jet ('Blazar')
- Measurement method
  - Divide up the band into two ranges: red and blue
  - Compute group delay separately for each and difference
  - Accuracy of differential delay is poorer (factor of ~3) than broad-band delay
  - Differential delay is photon-limited for any realistic quasar scenario
    - Accuracy depends on how much time one is willing to invest

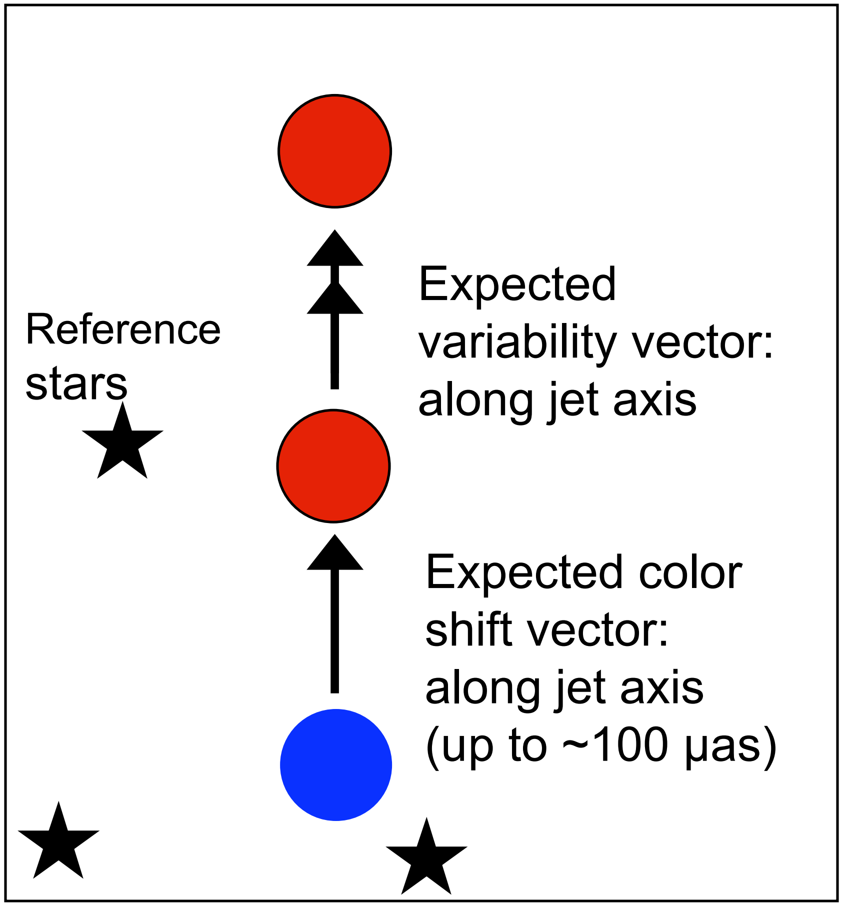
- Color shift (differential delay) is a *vector quantity* on the sky
  - SIM Lite measures the projection along B
  - Compare with other measurements, e.g. VLBI imaging
- Science in time variability
  - Blazars are typically highly variable
  - Correlate the color shift variation (itself a *vector quantity*) with other measurements
  - Spectrophotometry, polarimetry, VLBI imaging, etc.

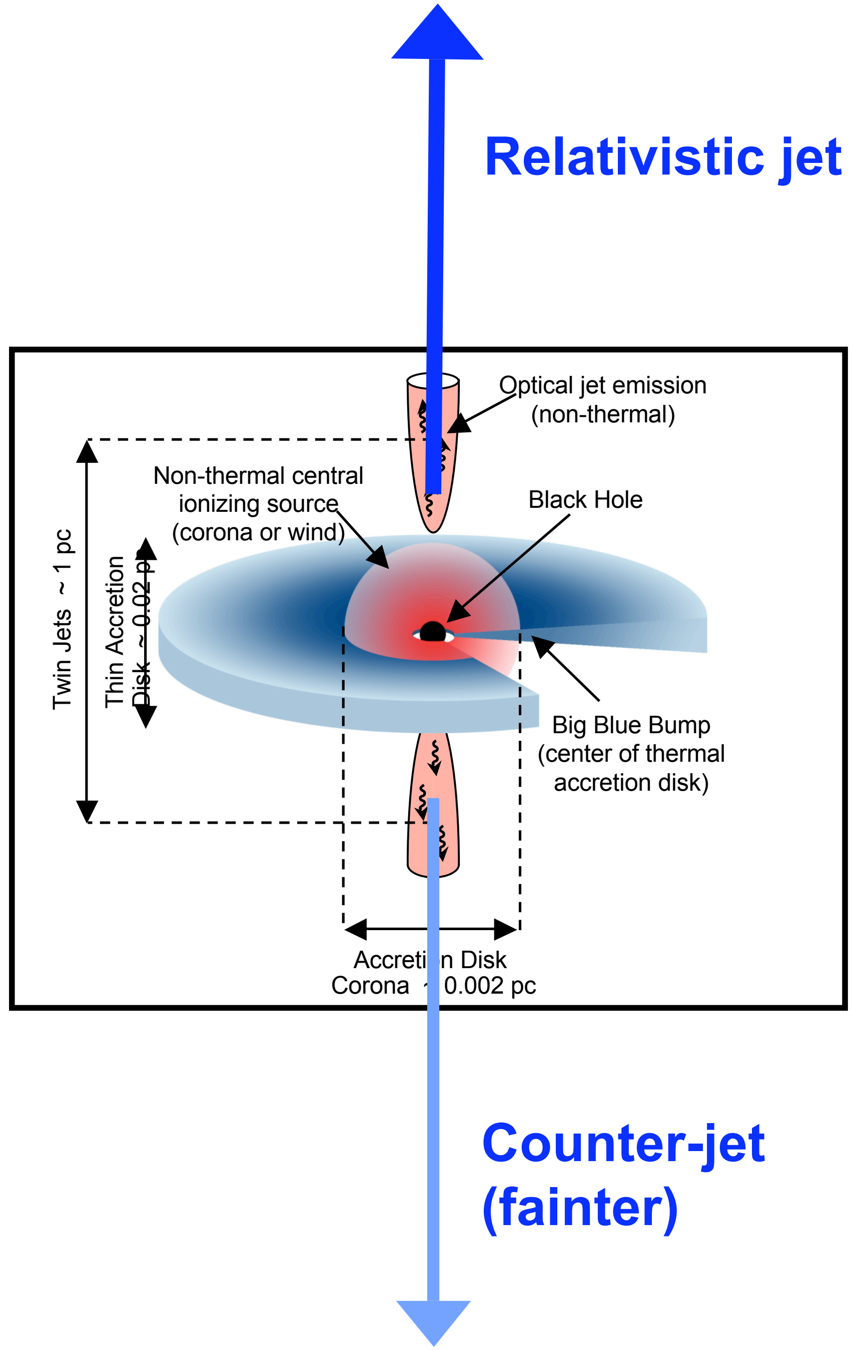
Color Dependent Astrometry

- Standard observing mode is to use the full SIM Lite band (0.45-1.0μm):
  - Compute the fringe phase in each wavelength bin
  - Calculate the SIM observable: group delay



Astrometric Motion in Quasars





SIM Lite Web Tools

- Time and performance estimation tools are available on the NExScI website
  - Global Astrometry Time Estimator (GATE)
  - Global Astrometry Performance Estimator (GAPE)
  - Differential Astrometry Performance Estimator (DAPE)
- http://mscws4.ipac.caltech.edu/simtools/

GATE and GAPE - global astrometry

- Non-obvious parameter is the # visits
- Because of overheads, the trade between integration time and number of visits isn't obvious
- Tool traps unreasonable values of derived parameters
- Recommend: use both GATE and GAPE to explore behavior as a function of #visits and integration time

DAPE - Differential Astrometry Performance Estimator

- Differential astrometry requires the observer to design an experiment with a lot of parameters
- Experiment design interacts with the instrument in a complicated way
  - Faint reference stars (or very short observations) will limit the accuracy of differential astrometry, regardless of the accuracy of the target measurement
  - Very long chop cycles (faint target and reference stars, long integrations) will eventualy encounter instrument drifts
  - Chops over wide angles may encounter field-dependent errors, depending on the locations of the reference stars
- The instrument model includes these effects to first order
- Recommend discussion with Project experts for experiments other than:
  - Planet searches - bright target, bright reference stars, rapid chops over <2deg
  - Quasar astrometry - photon-limited differential measurements (to grid stars or other quasars)