Thermal & Radiation Considerations

or

Questioning Parentage of Requirements

(plus a bit on grisms)

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Ancient history

Requirements on instrumental backgrounds

(from an early JDEM incarnation)

- Can't beat the Zodi, but can (mostly) control instrumental backgrounds
  - Stray light, thermal emission, detector dark, readnoise
- Allocate budget to each instrumental background
  - 10% of minimum zodi, or equivalent
  - Doing a lot better costs resources w/decreasing gain
    - Though 40% total background increase is already significant
  - Doing a lot worse impacts exposure time

New Background Allocations

- Context different for NRO-WFIRST
  - More diverse science program
  - Readnoise dominates in most cases contemplated by first SDT.
    - Technology unlikely to improve readnoise to point where zodi dominates again
- Reallocate budgets for remaining backgrounds based on expected observing scenario for each program

Stray light

- Prime culprit is scattered Sunlight
  - Have to consider Earth & Moon too in GEO
- Microlensing:
  - Worst-case Solar elongation is 54°
  - Zodi at this point is ~8x minimum
    - ~2x readnoise, because filter is wide
  - Suggested baffle performance requirement:
    - stray Sunlight at 54° < 0.5 * (8 x min zodi + readnoise)
    - 50% scale factor may be too loose; OK for setting scale
    - Baffles hard to spec beyond order of magnitude!

Stray Light - 2

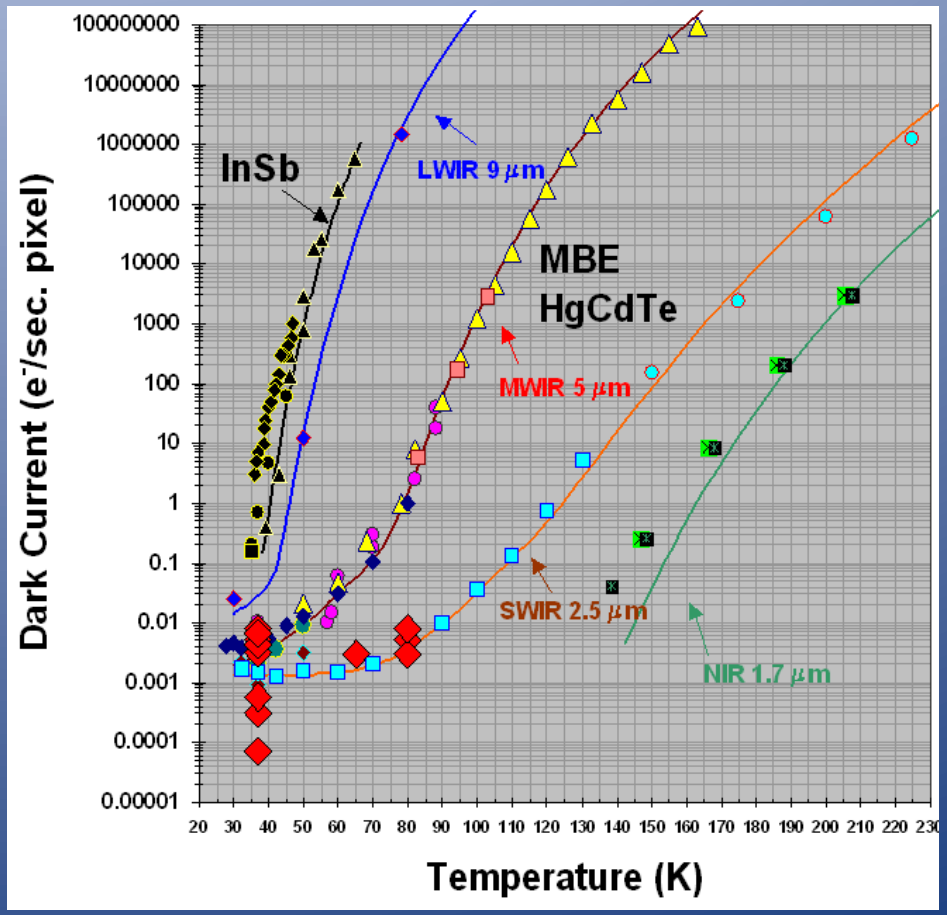
- Supernovae
  - Present field of regard is a 20-degree cone about ecliptic poles
    - Worst-case Sun angle is 70°
    - Zodi is ~1.5x minimum, or ~1.2x annual mean
    - Exposures are long, so readnoise less of a factor
  - Suggested baffle requirement:
    - Stray light at 70° Sun angle < 0.25* 1.5x minimum Zodi
      - As before, 25% scale factor is a placeholder

Stray Light - 3

- High latitude survey:
  - Zodi range for survey is 1.0 to 1.4 x minimum
  - Minimum Sun angle is 90°
  - Sources are faint, so background is important
  - Suggested baffle performance requirement:
    - Scattered Sunlight @ 90° < 0.25* min zodi

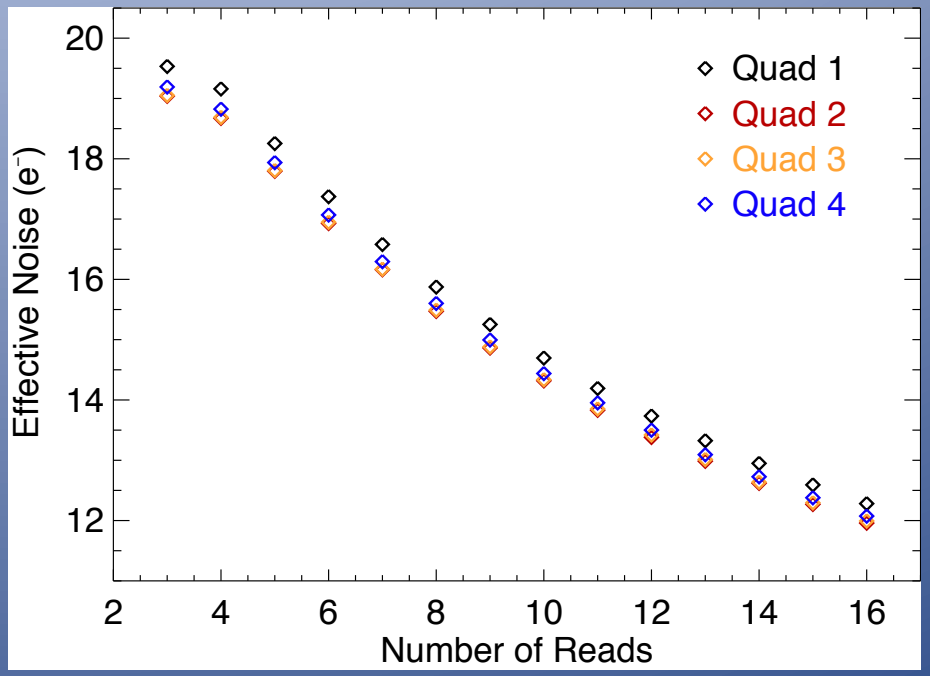
Detector Dark Current

- Ordinarily: set detector temperature so dark current is negligible
- May be difficult if telescope is warm
- Don't yet know if we need significant allocation for dark



Readnoise

- Assume 20e- CDS readnoise for now
  - Hope to improve
- SUTR improves net readnoise for long exposures
  - Eventually hit floor of 4-5e-



From WFC3 instrument handbook

Thermal emission

- Prior JDEM/WFIRST studies:
  - Set bandpass to meet scientific objectives
  - Set telescope and instrument thermal zones to meet background allocation (i.e. 10% min zodi)
- Now:
  - Telescope temperature constrained
    - Instrument temperatures may be elevated as well
  - Set bandpass to observing time pain threshold

Telescope Temperature

- NRO Telescope is designed for "room temperature" operation.
  - Actual temperature limits are TBD.
- **Nominal WFIRST band pass of 0.7 – 2.0 microns is viable at 280K.**
- Extension to 2.4 microns is possible with 2.5x higher background at T=250K.

ObsTime (sec) to reach AB=26 5σ (Imaging), or Hα flux $1*10^{-16}$ at z=1.8, 6.5σ(SPC)

Temp	z085	Y106	J134	H168	K211	SpC	SpC
	0.732-0.962	0.92-1.209	1.156-1.52	1.453-1.91	1.826-2.40	1.1-2.0	1.1-2.4
200K	800	755	755	800	830	1200	1342
220K	800	755	755	800	855	1200	1373
240K	800	755	755	800	1220	1200	1934
250K	800	755	755	800	2260	1210	3151
280K	800	755	755	885	28050	1620	31000
300K	800	755	755	1480	125600	3640	136000

S/N Budget example

H-band imaging

CDS ◆ readnoise	Dark current	Thermal Bkgd -250K	Zodi (med)	Pixel scale	Pix per point src	Pix per galaxy*
20 c/p	0.05 c/p/s	0.006 c/p/s	0.352 c/p/s	0.11”	16	63

*0.2” half-light radius

◆Readnoise: SUTR floor=5e-

$$N_{pix} = 1 / \sum_{i,j} PSF_{i,j}^2$$

Stray light = 10% min zodi

AB	Src rate c/s	RN eq rate c/p/s	Tot Bkgd c/p/s	Exptime sec
26	1.471	0.562	1.005	830
27	0.586	0.082	0.525	2830
28	0.233	0.009	0.452	15600

Stray light = min zodi

RN eq rate c/p/s	Tot Bkgd c/p/s	Exptime sec
0.462	1.222	935
0.051	0.811	3950
0.006	0.766	23425

Exptime distributed over 5 exposures

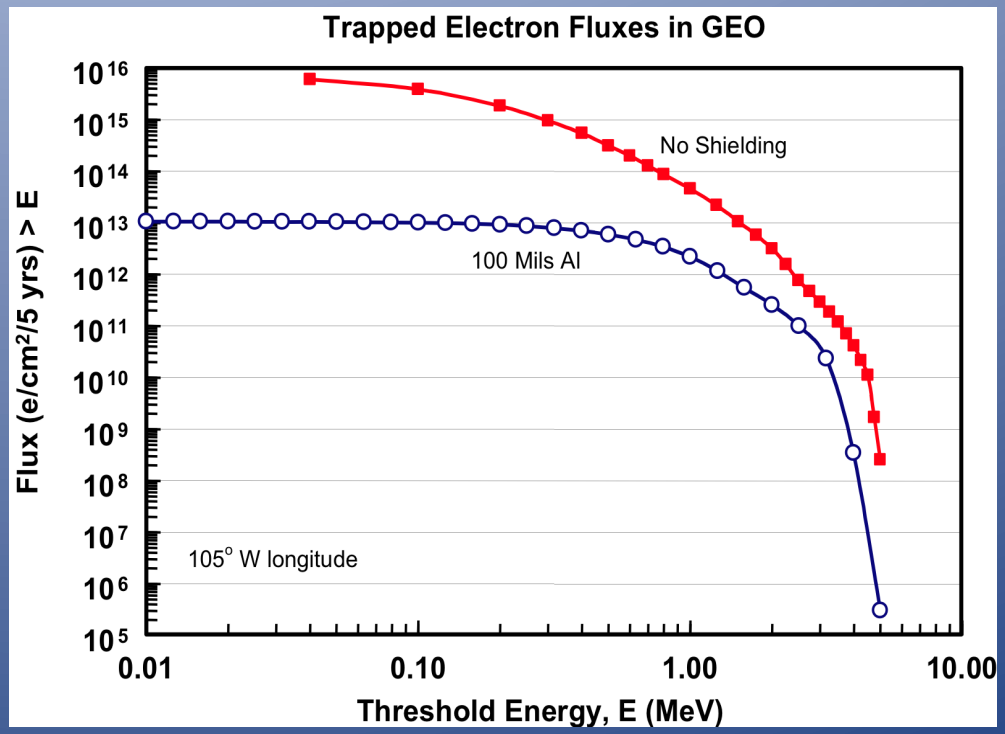
Other Performance Requirements

- Detector
  - Number of hot or dead pixels
  - Flat-field uniformity
  - Persistence
  - Inter-pixel capacitance
  - Etc
- Calibration
  - Too many items to list…

Save for Phase A?

Radiation in GEO

- ~$5*10^5$ e-/cm^2/s @ 1MeV and above*
- Shielding:
  - ~1cm Al for 4MeV
  - ~0.3cm for Pb
  - ~0.8cm CaF_2
- Don't want more refractive elements in beam
  - Extend enclosure to filter wheel?
- Studies under way:
  - Optimize materials
  - Relax hermeticity?
  - Cabling, heat straps,…
- *How good is good enough?*



*based on 5-yr avg – 'typical' day will be lower

Grism vs Prism

- Grism efficiency is 60% - 80% if bandpass isn't too wide
- Reduced background in split bands doesn't make up for serial obs
- Added confusion from overlapping orders

T(exp) to reach 1.0 10^{-16} (6 exp total)

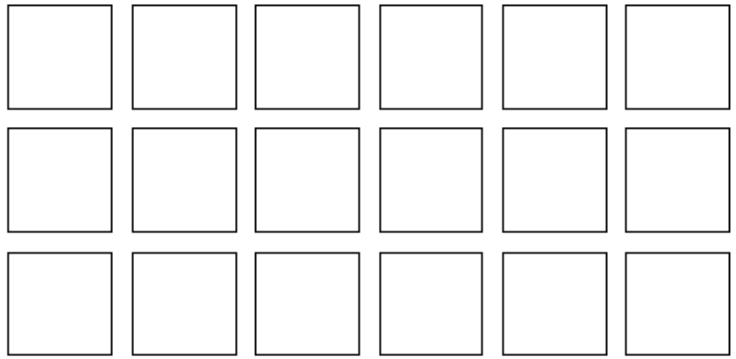
Wave µm	Prism 1.3-2.4µ	Blue grism 1.3-1.86µ	Red grism 1.85-2.4µ
1.4	520	218	
1.5	458	203	
1.6	416	198	
1.7	385	198	
1.8	359	203	
1.9	333		374
2.0	302		322
2.1	276		296
2.2	260		291
2.3	255		296

Backup slides

2.4m FOV diagram

(investigating additional detectors)

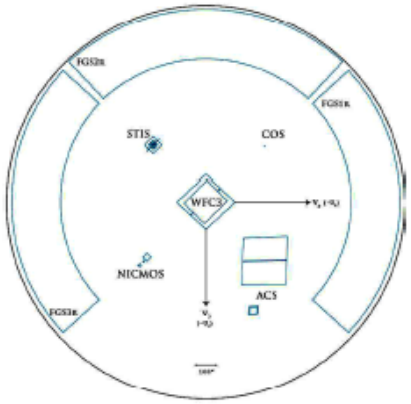
6x3 H4RG @ 0.11"/p, 0.28 sq.deg



0.425 wide°

288 Mpix

0.874°



HST [all instruments]

JWST [all instruments]

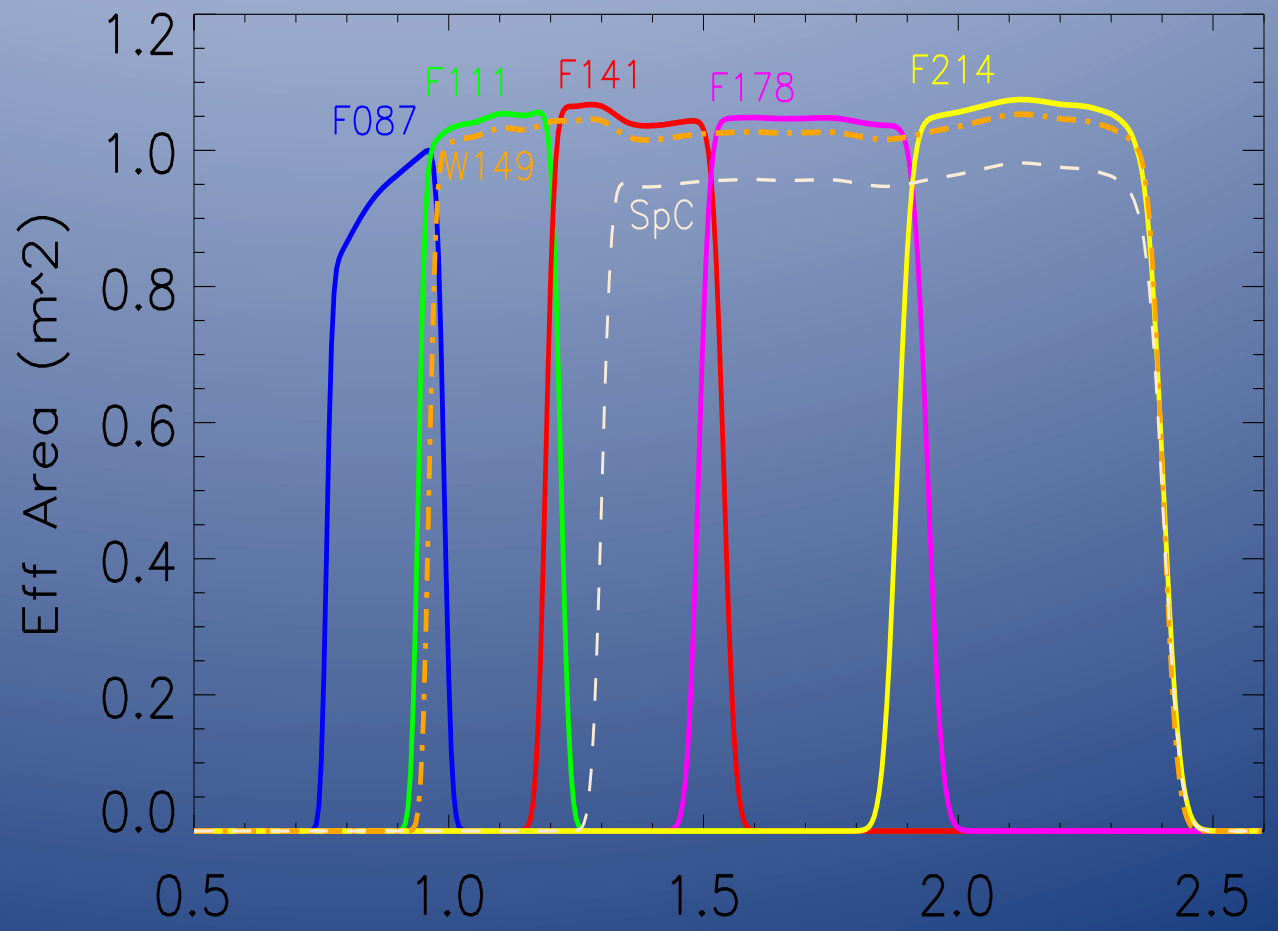
Moon (average size seen from Earth)

FILTERS

Filter	Bandpass
z	0.732 – 0.962
Y	0.920 - 1.209
J	1.156 – 1.520
H	1.453 – 1.910
K	1.826 – 2.400
W	0.962 – 2.400

SN prism throughput is ~5% lower than the filters.

DRM-1 Effective Area
(scale by 2.5 for NRO)



DISPERSERS

Supernova Prism

	Bandpass (microns)	Resolving power per pixel	Spectral length (pixels)
DRM1	0.6 – 2.0	100-200	160
DRM2	“	“	“
2.4m	“	“	“

Galaxy Redshift Prism

	Bandpass (microns)	Ext’d source Resolution (km/s/arcsec)	Point Source Resolution (per pixel)	Spectral length (pixels)
DRM1	1.3-2.4	950-1760	950-1800	680
DRM2	1.7-2.4	1050-1860	900-1600	380
2.4m	1.3-2.0(TBD)	1150-1760	1540-2350	723

Dynamic Range

- Baseline: 32-channel output @ 100kHz: 5.3s frame time
- What is impact of persistence on your data?
  - Good (new process, still developing): rate = $5*10^{-7}$ of prior integrated signal 100 sec after reset
  - Typical (prior baseline process): 10X higher, likely worse

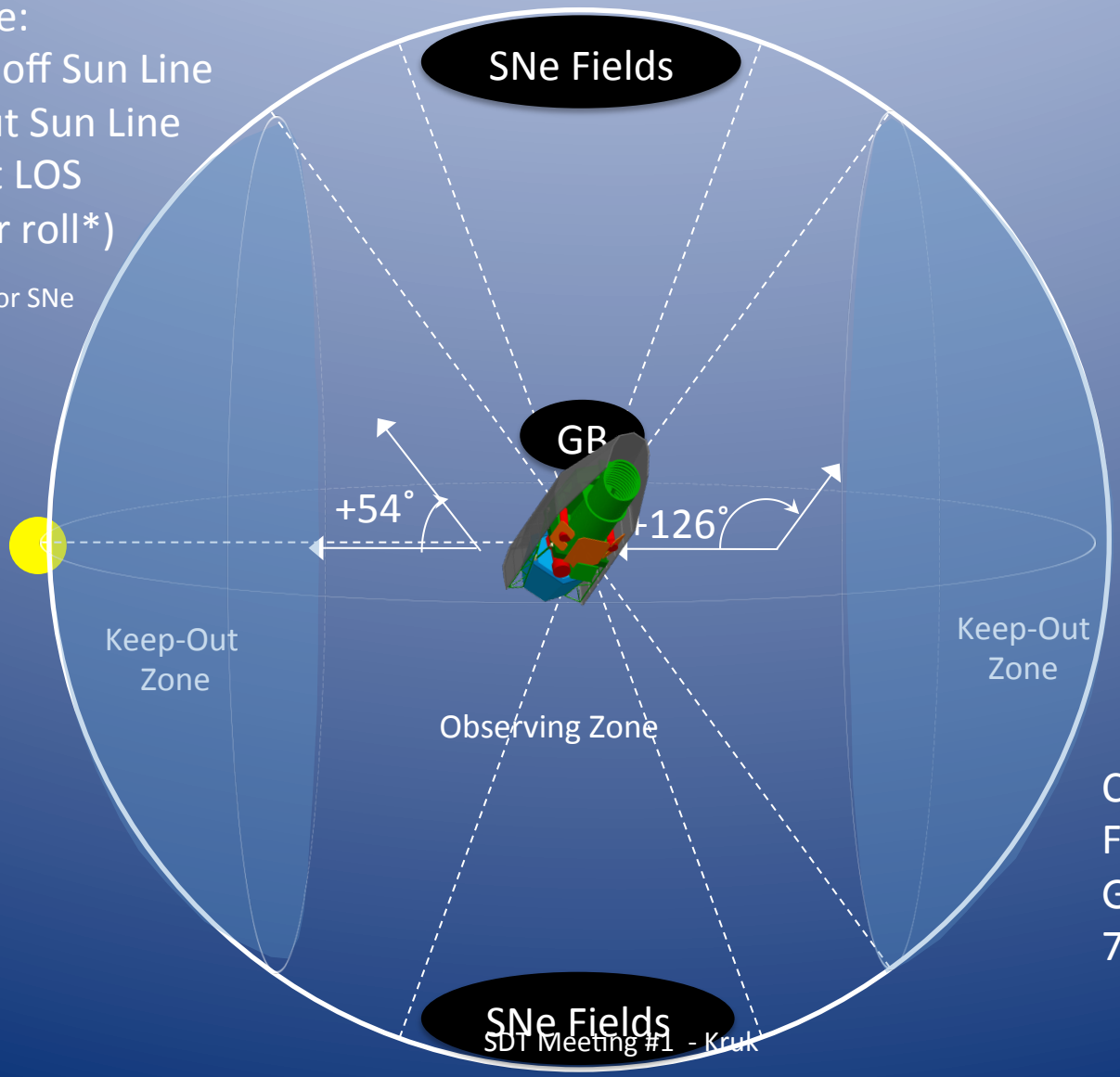
Magnitude at which signal=60000e- in peak pixel						
T(sec)	Z	Y	J	H	K	W
15*	15.9	15.9	15.7	15.5	15.3	16.8
40	17.1	17.1	16.9	16.7	16.5	18.0
250	19.0	19.0	18.8	18.6	18.3	N/A

* Assume minimum of 3 readouts before saturation

Field of Regard

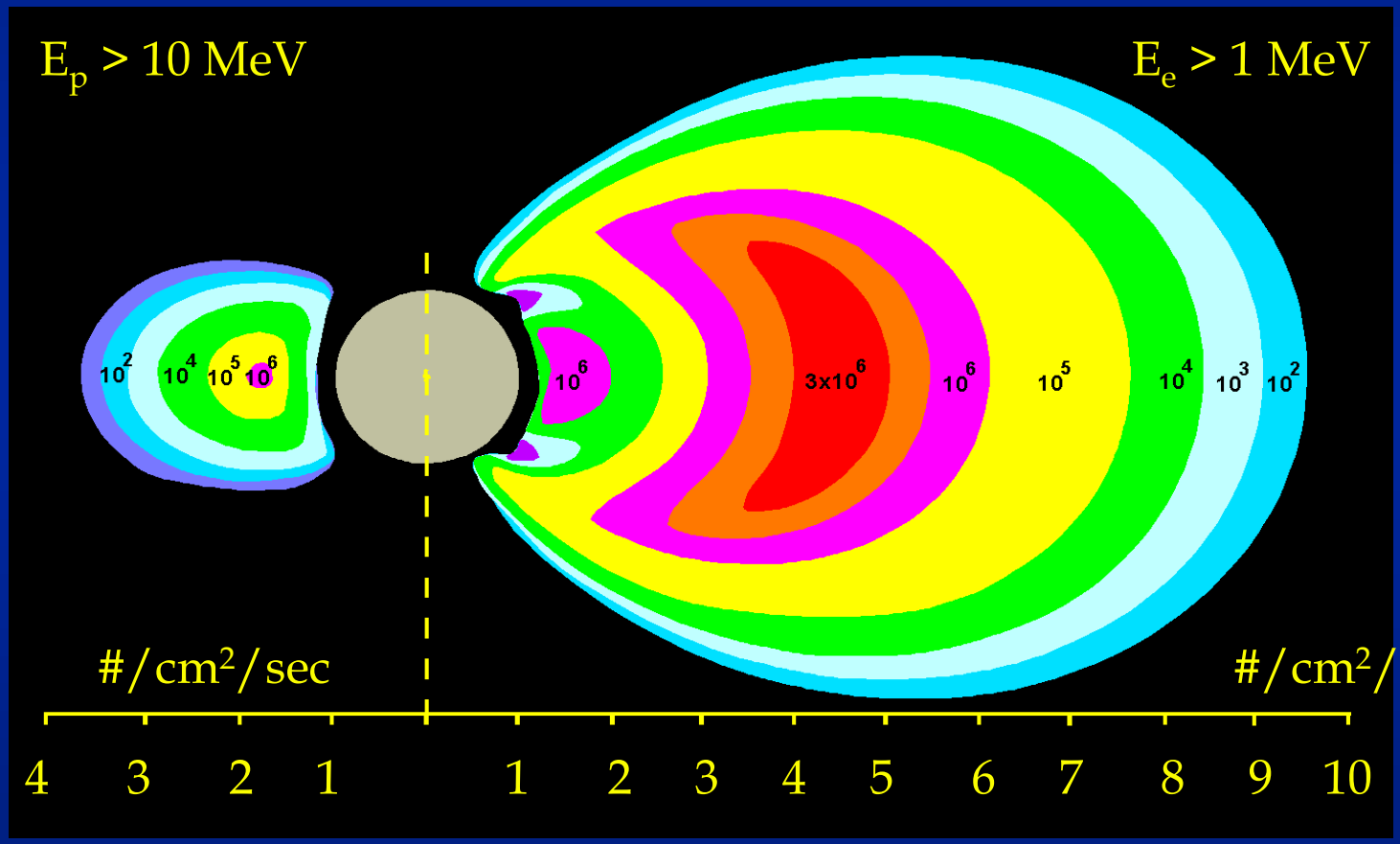
Observing Zone:
54°-126° Pitch off Sun Line
360° Yaw about Sun Line
±10° roll about LOS
(off max power roll*)

* Larger roll allowed for SNe



SNe Inertially Fixed Fields must be within 20° of one of the Ecliptic Poles, will be rotated every ~45 days

Can observe Inertially Fixed Fields in the Galactic Bulge (GB) for 72 days twice a year

Proton & Electron Intensities

AP-8 Model AE-8 Model