Spectrograph for COLIBRÍ

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with

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Outline

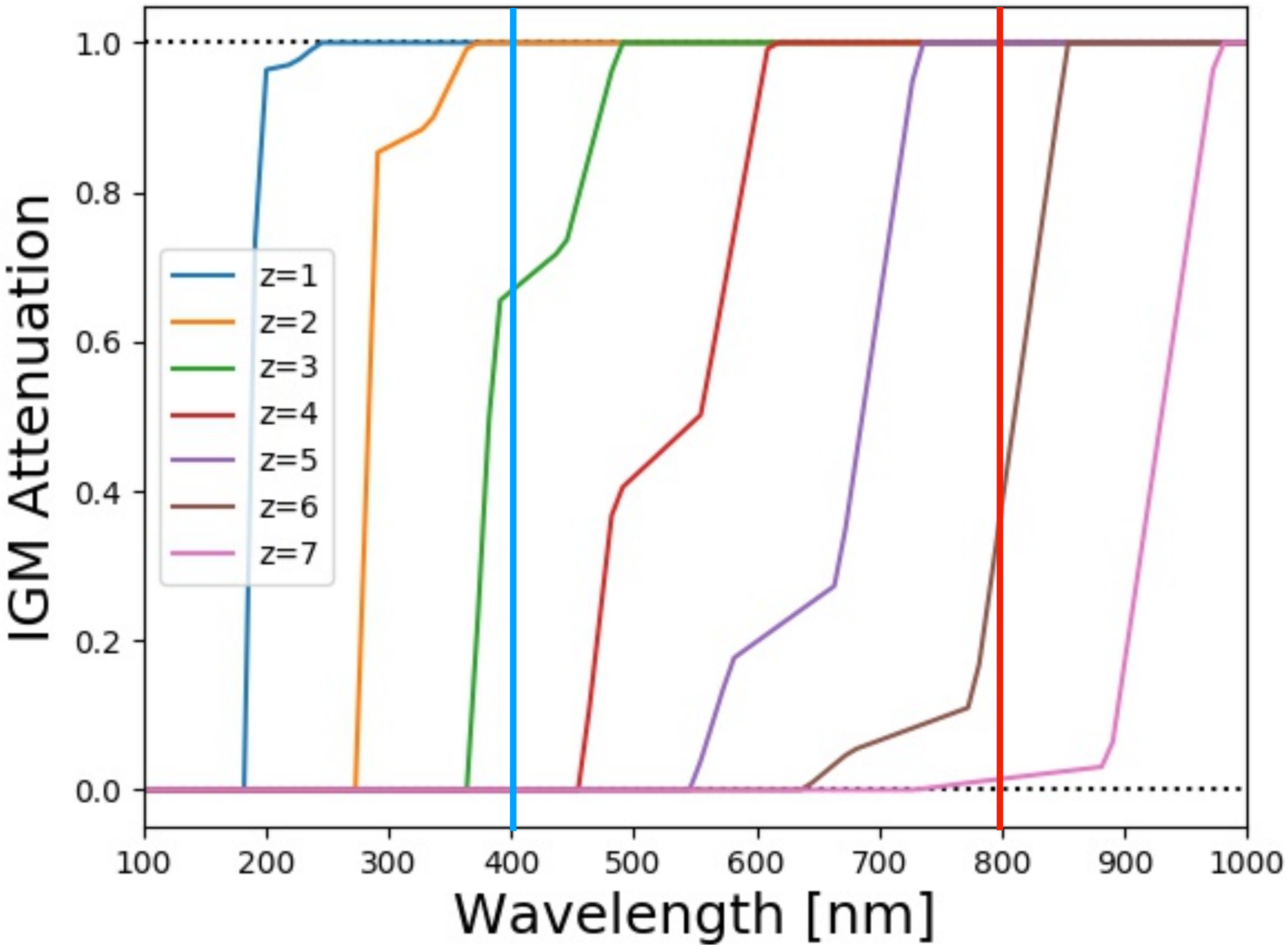
- Some science cases
- Some technological options
- Concept – capabilities and limitations
- Discussion

Science Cases

GRB Redshifts

- Why?
  - Needed to get energetics – detailed astrophysics
  - Need for population
- How?
  - IGM Lyα, Lyβ, or LyC absorption
  - Host ISM absorption line
  - Host SF emission lines

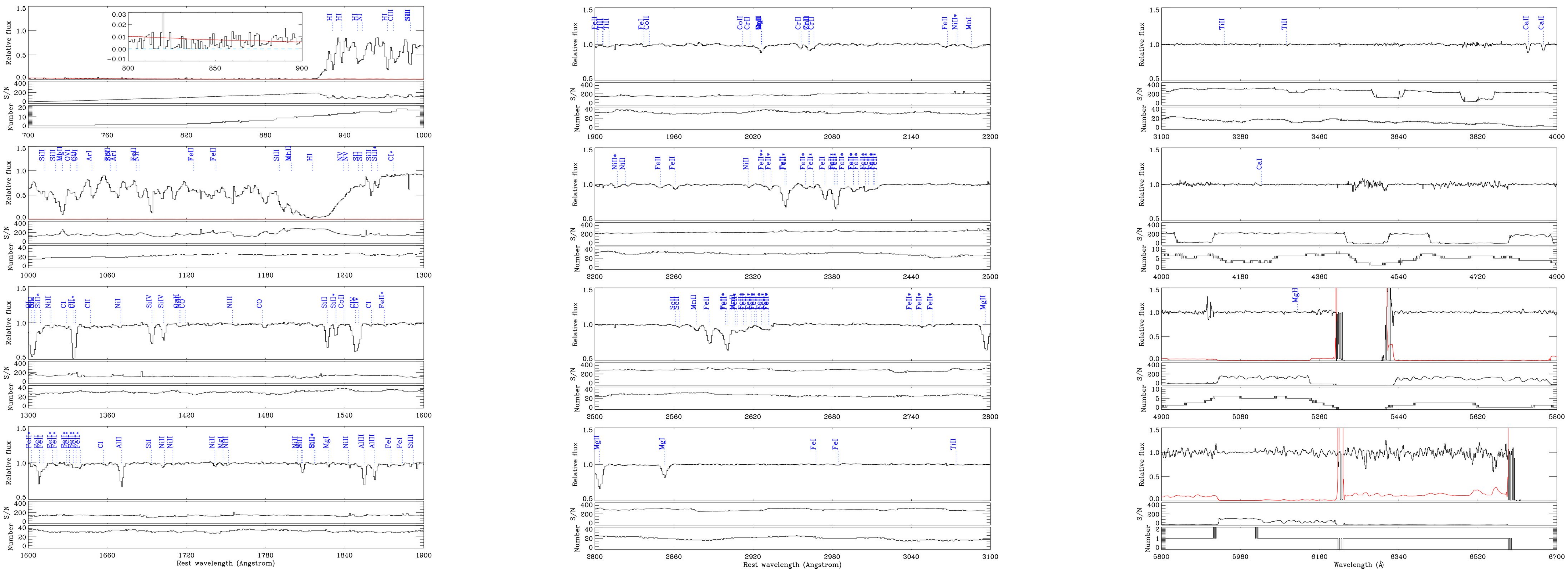
IGM Absorption



Absorption in 400–800 nm for z = 2.3 to 5.6

Madau model

Host ISM Lines



Strong metallic lines from 1250 Å to 3934 Å
Typically EW = 1 Å rest frame or 3 Å observer frame
3 lines in 400–800 nm from z = 0.55 to z = 5.0

Christiensen et al. (2011)

Feasible?

- Detection a line of equivalent width E with a SNR in the line of q requires a SNR in the continuum of p

$$p = \lambda q / E R$$

- For $q = 5$, $\lambda = 600$ nm, $E = 3$ Å, and $R = 1000$

$$p = 10$$

- This is typical of 8-10 meter spectra used for this purpose.

- With a 1.3 meter, we need to observe QUICKLY. Delays of minutes not hours.

Host Emission Lines

- SF lines – most likely in LGRBs
  - [O II] 3726, 3737
  - [O III] 4959, 5007
  - Hβ, Hα
  - [O III] leaves z = 400–800 nm at z = 0.6
- Probably better to use larger telescopes.

GRB Redshifts

- Assume 400–800 nm spectrograph
- $z < 0.6$
  - Host SF emission lines
  - Need host with SF (LGRB)
  - Probably better to use larger telescopes
- $0.6 < z < 2.3$
  - Host ISM absorption line
  - $R = 1000$ or better
  - Spectroscopy of **afterglow**: need fast response
- $2.3 < z < 5.6$
  - IGM Lyα, Lyβ, or Ly-C absorption
  - $R = 100$
  - Spectroscopy of **afterglow**: need fast response
- $5.6 < z$
  - Spectroscopy above 800 nm with 8-10 meter

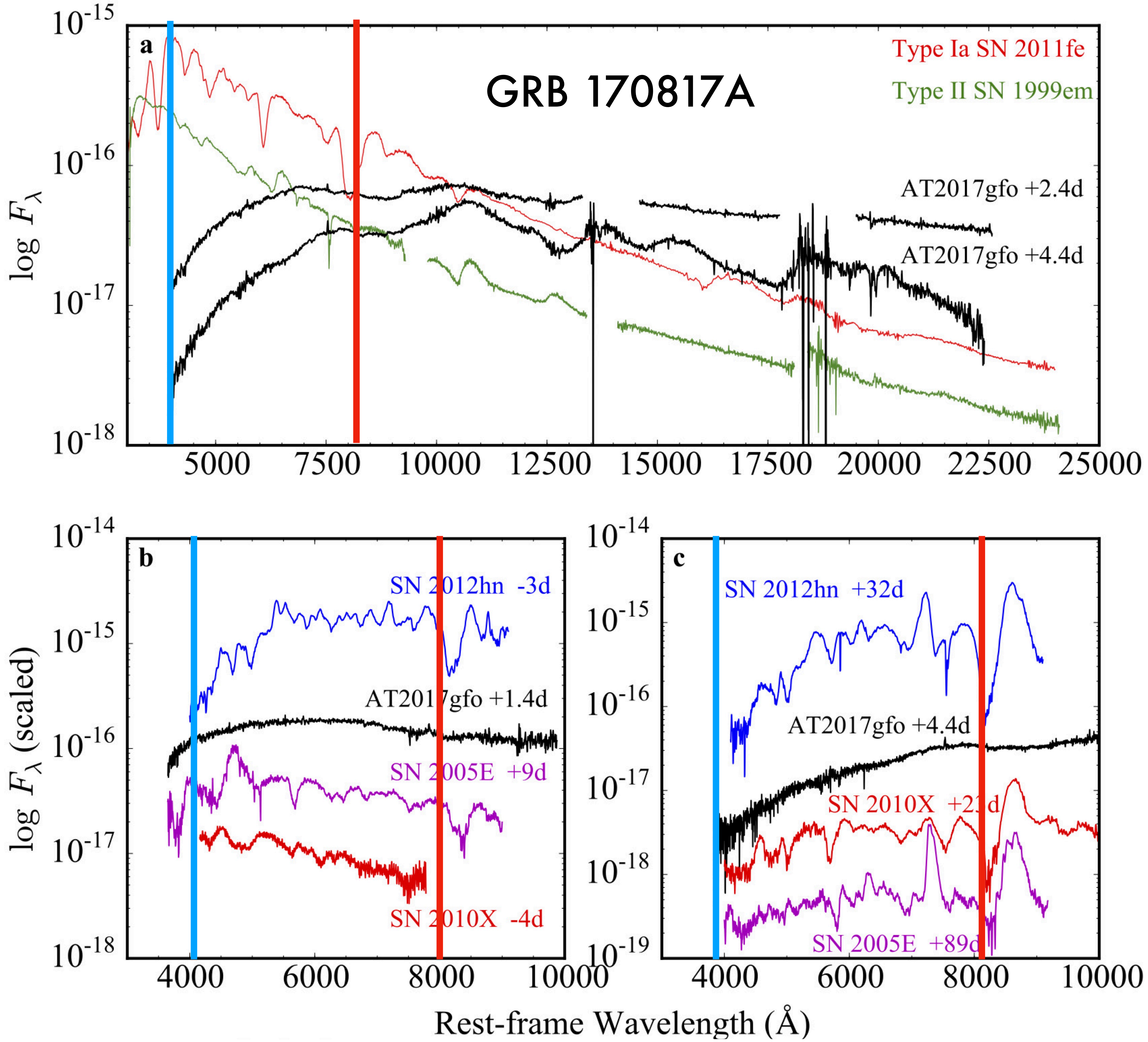
GRB Dust

- Discussed by Veronique Buat & David Corre
- 2175 Å bump in 400–800 nm for $0.9 < z < 2.6$
- $R = 30$?
- $SNR = 20$?

AGN Reverberation Mapping and Changing-Look AGN

- See Diego González's and Elena Jiménez's talks
- R = 1000 to 4000
- SNR = 30?
- Lots of repeat visits (days, weeks, months)

Looking for Kilonovae



- Identification as “not a normal SN” can be done in 400–800 nm
- Detailed astrophysics requires observations above 800 nm … and really out to 2 microns … and realistically a larger telescopes

Smartt et al. (2017)

Other Science Cases

- Looking for these here!

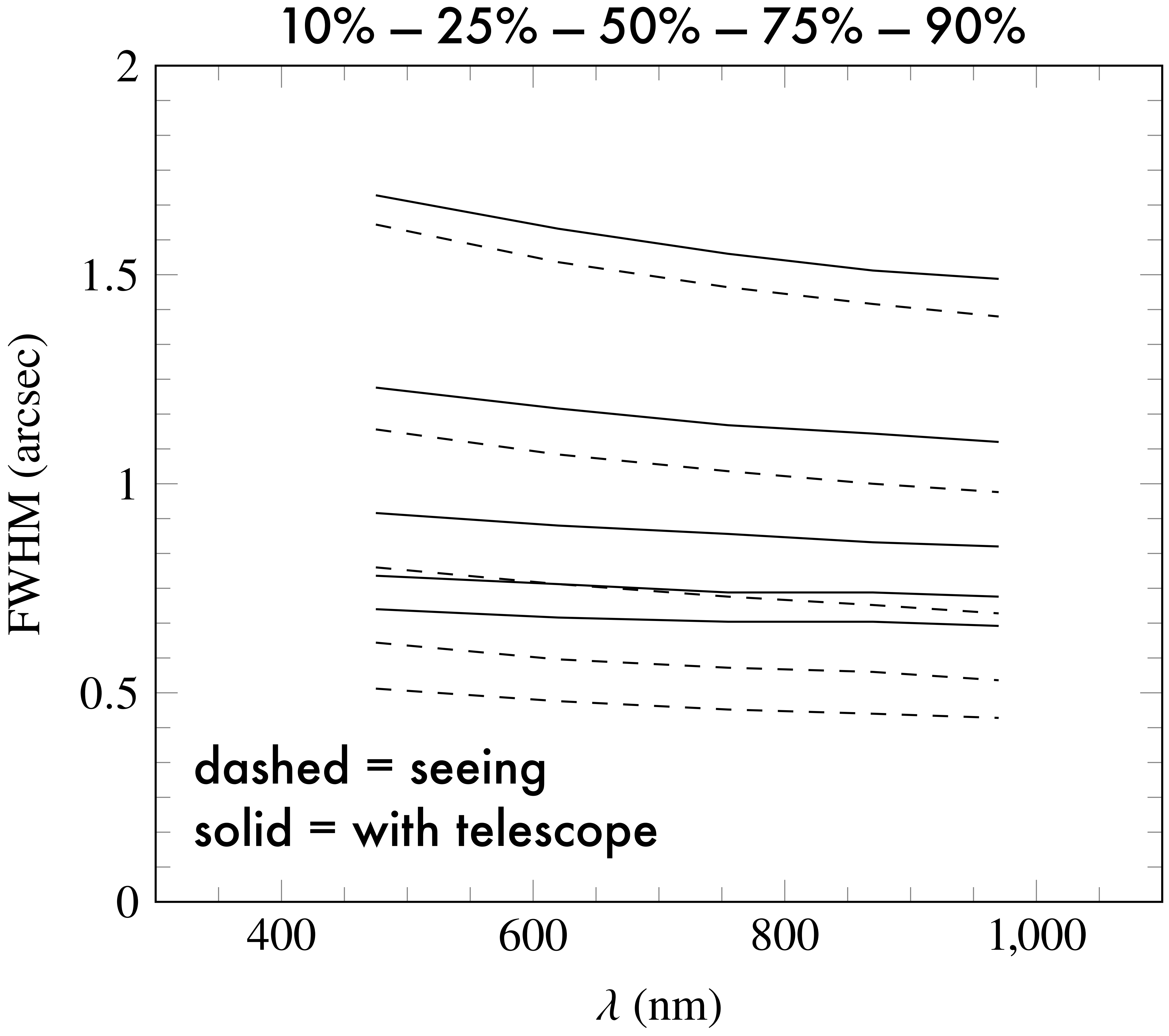
Technical Considerations

Technical Considerations

- Image quality and field
- Slit width
- Acquisition/guiding/monitoring camera
- Wavelength range
- Resolutions
- Dispersing elements
- Detectors
- Spectrograph optics
- Slit rotation
- Lamps

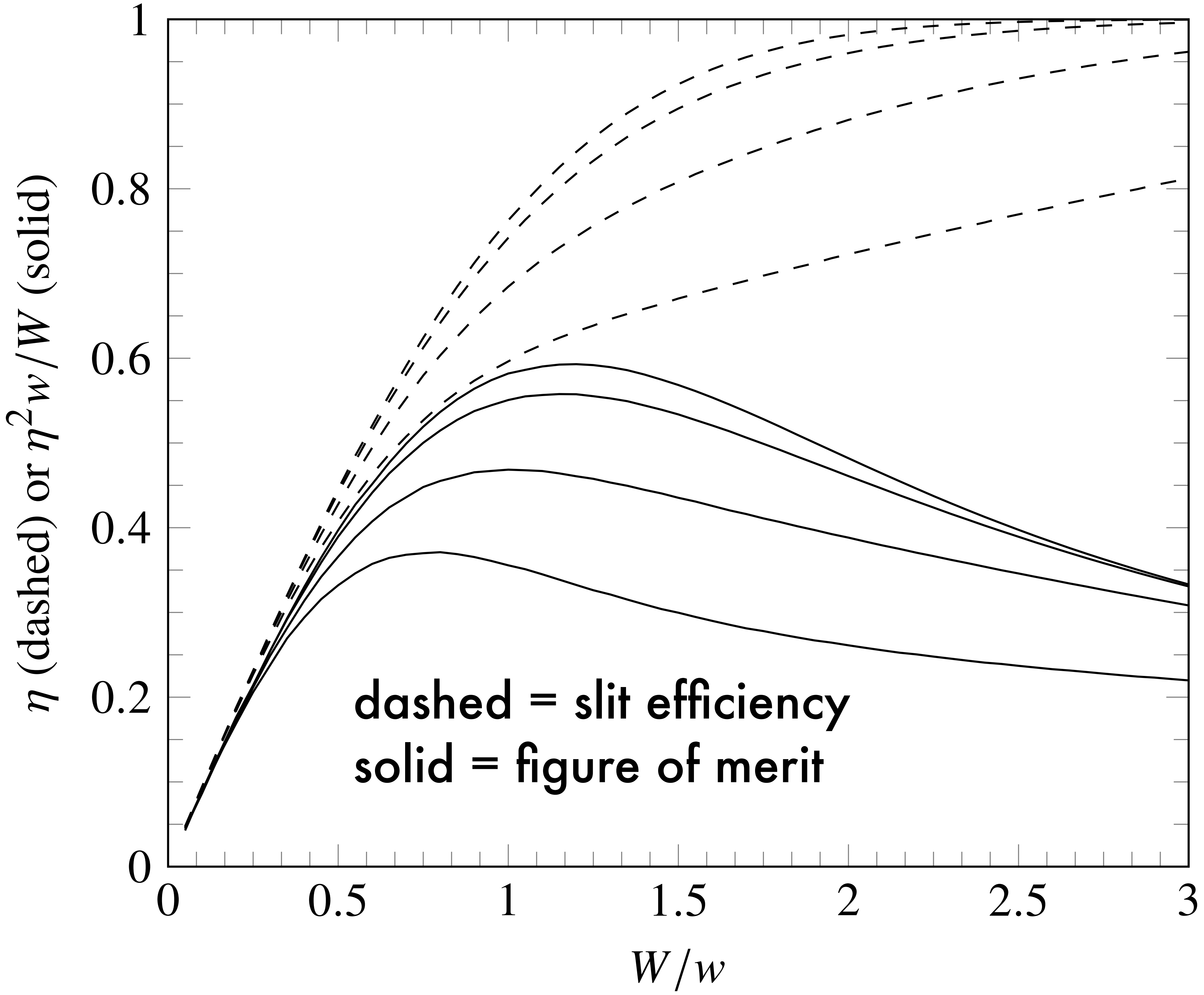
Image Quality

- Seeing, telescope optics (no aO), and telescope tracking
- Median: 0.93 arcsec FWHM at 600 nm over 5 arcmin
- 10% to 90%: 0.73 to 1.63 arcsec FWHM
- Uniform over 5 arcmin field without additional optics



Slit Width

- (Don’t have money for IFU, so slit.)
- Want slit slightly wider than FWHM
- Want object to be well centered!
- Optimum is about 1.2 arcsec



W/w = slit width in units of FWHM

Acquisition/Guiding/ Monitoring Camera

- Telescope can't point/guide well enough to blind spectroscopy. Need acquisition/guiding camera with field at least 5 x 5 arcmin
- Want astrometric stability between slit and camera
- Some science also wants photometric monitoring
- Options
  - Reflective slit – no monitoring
  - Mirror with hole – no monitoring
  - Beam splitter 10%–90% with filter wheel – multiwavelength monitoring
  - Dichroic >800 nm? or < 400 nm? – monitoring outside spectrograph range

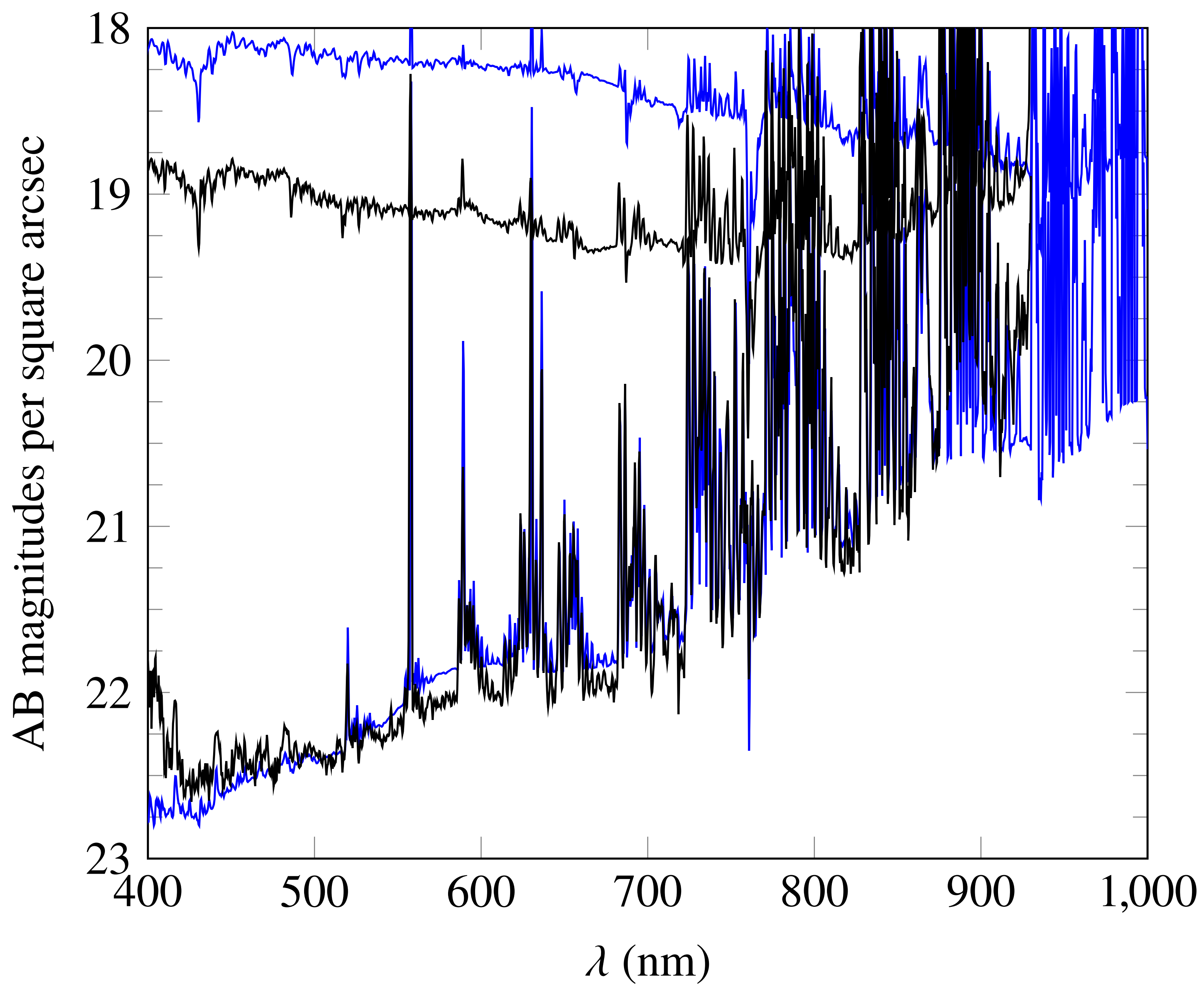
Spectrograph Detectors

- **Standard 2k x 2k CCD**
  - low RN – low dark – high fringe amplitude
- **Deep-depleted 2k x 2k CCD**
  - high RN – high dark – low fringe amplitude
- **Standard 1k x 1k EMCCD in PC mode**
  - zero RN – moderate dark – fringes?
- **Standard 2k x 2k sCMOS**
  - low RN – high dark – fringes?
- (Don’t have funds for 4k detector)

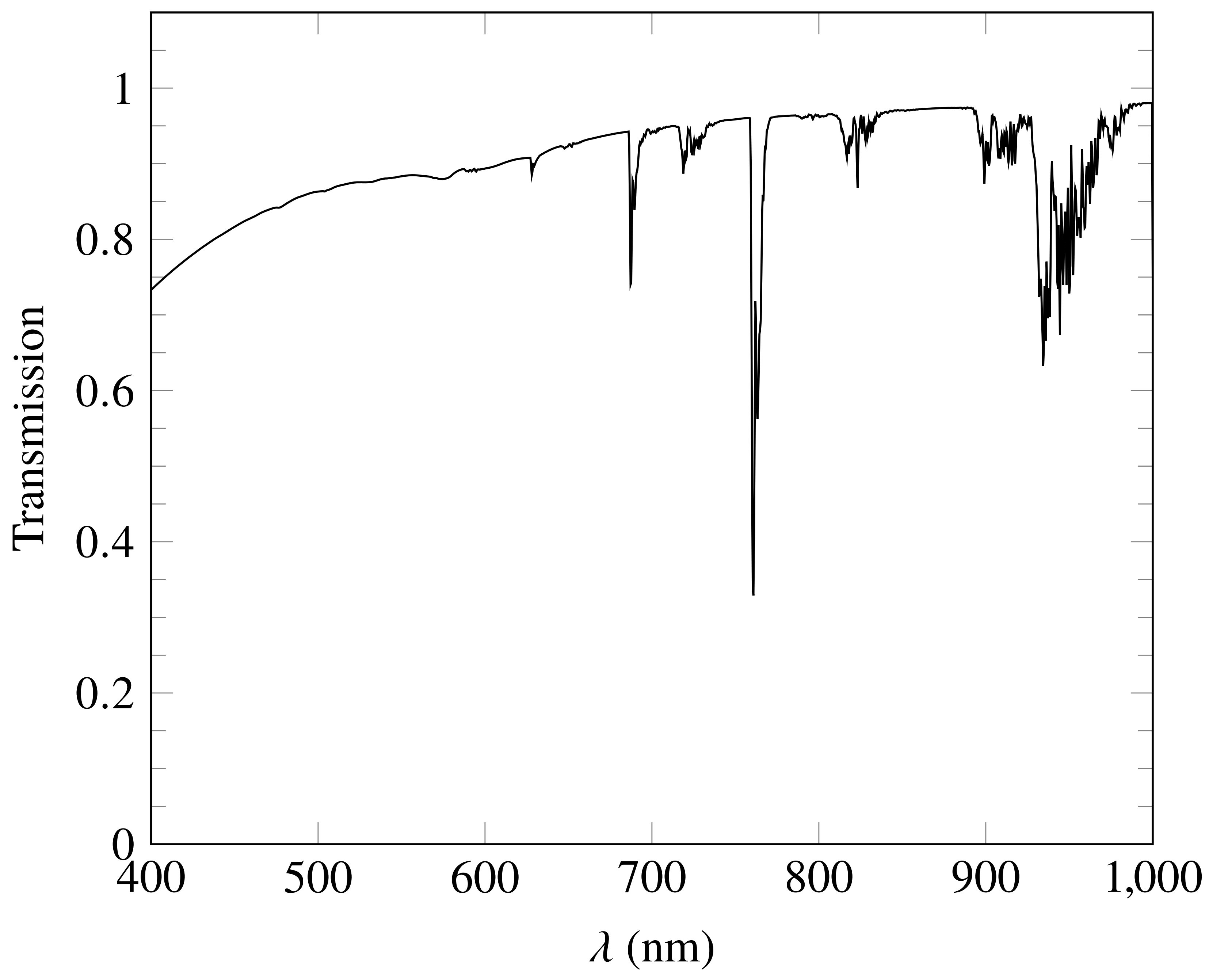
Wavelength Range

Spectroscopy is difficult above 720 nm –
especially at lower resolutions and especially for lines

Sky brightness



Sky transmission



Dispersing Elements

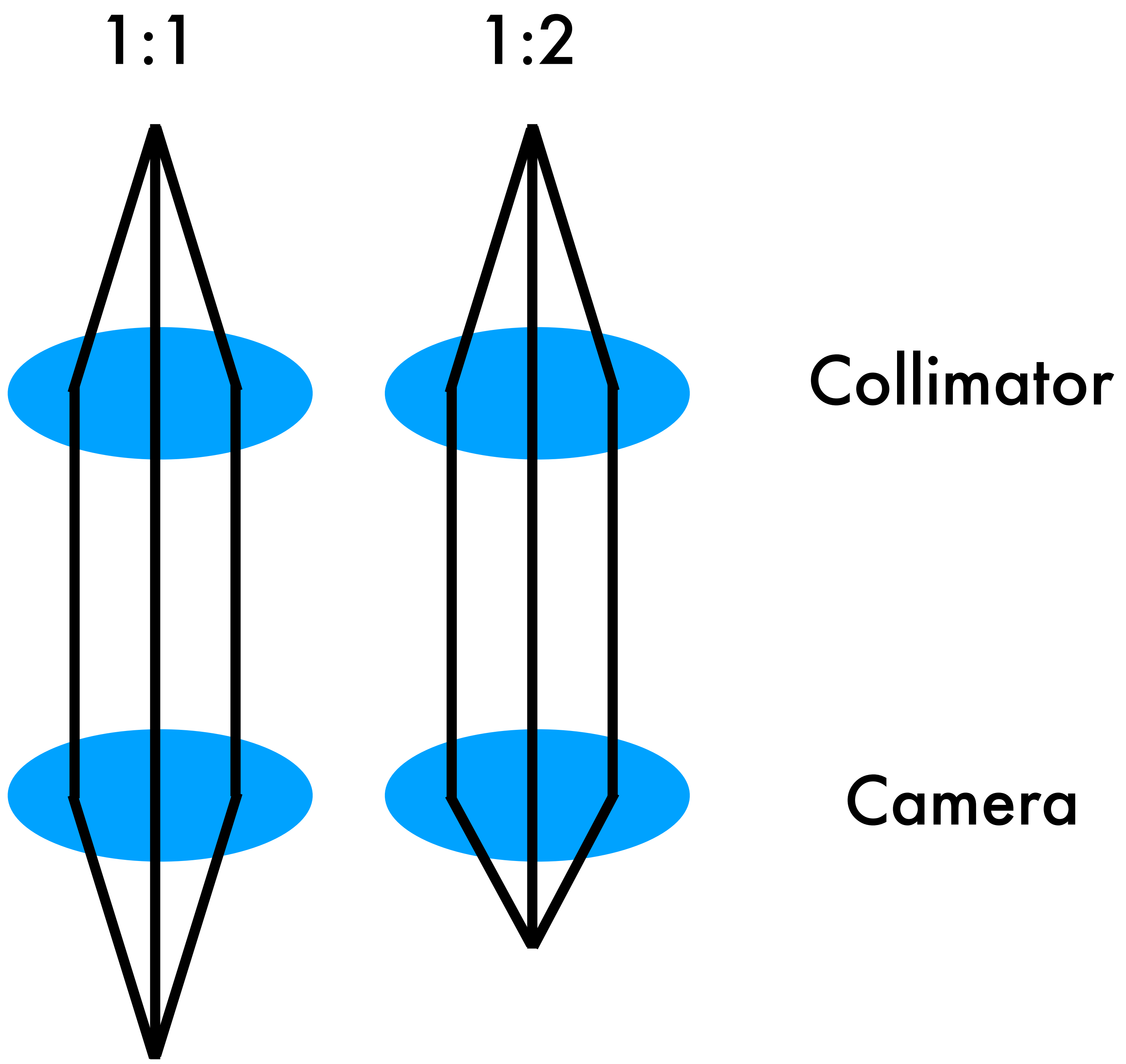
- Prism – difficult to get R > 100
- VPH grating – high efficiency but narrow blaze – not necessarily ideal for a low-resolution spectrograph
- Conventional grating or gris – lower efficiency by wider blaze

Resolutions

- To detect weak lines, want largest resolution that does not resolve the line.
- Maximum resolution for 400–800 nm
  - 2048 pixels — 1024 resolution elements — R = 1000–2000
  - 1024 pixels — 512 resolution elements — R = 500–1000
- Lower resolution by
  - using a mechanism with multiple gratings?
  - rebinning — no penalty if sky-limited

Spectrograph Optics

- Simple 1:1 optics
  - 0.3 arcsec/pixel – good spatial sampling
  - 4 pixels/slit – waste detector pixels in dispersion direction – use 1 x 2 binning
- More complex 1:2 optics
  - 0.6 arcsec/pixel – worse spatial sampling
  - 2 pixels/slit – optimal use of detector pixels in dispersion direction



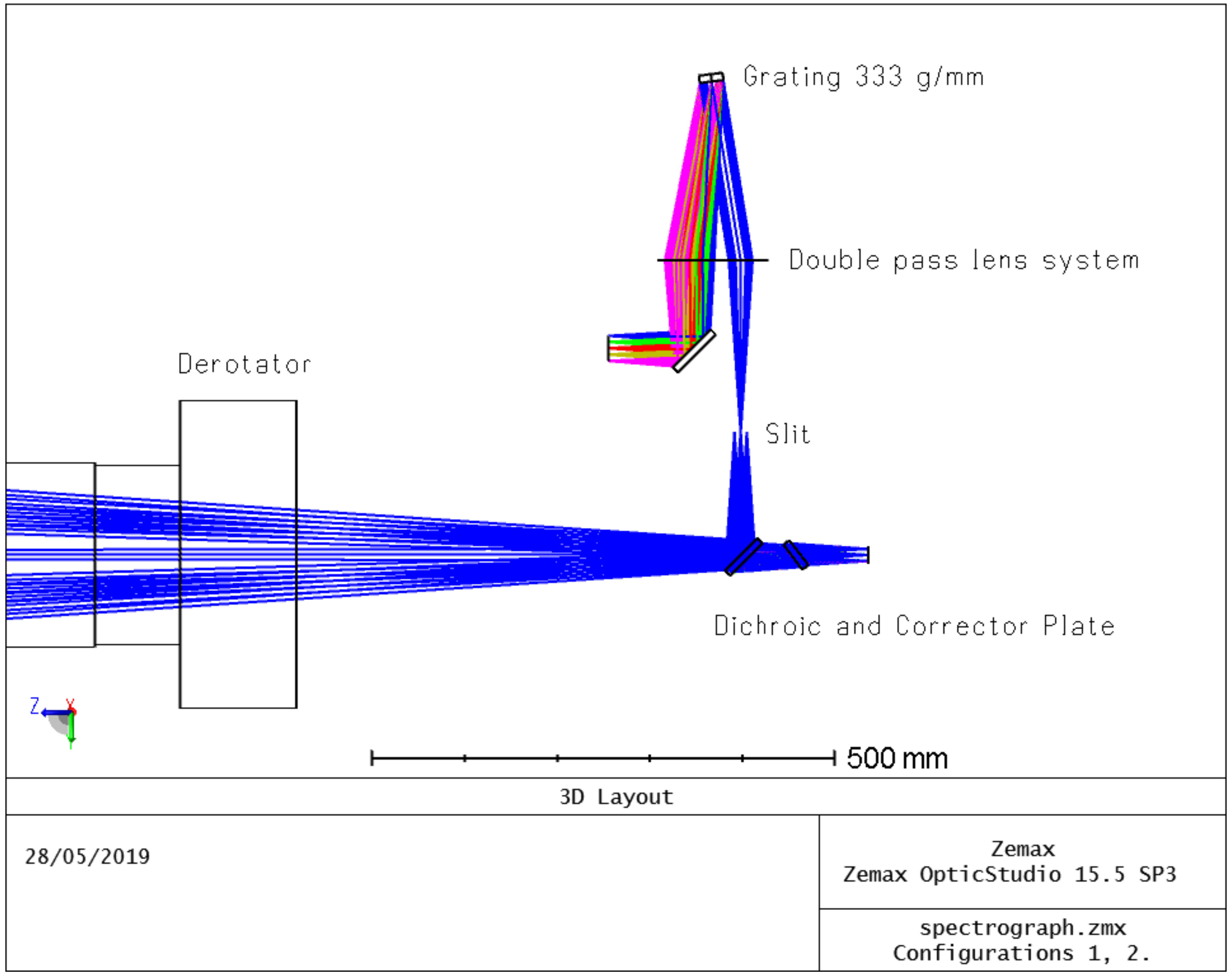
Possible Concepts

Concept

- Switch from imaging in <60 seconds
- Dichroic at 815 nm
- Acquisition camara > 825 nm
  - 1k x 1k deep-depleted CCD
  - Fixed zy filter
  - 0.3 arcsec/pixel
  - 5 arcmin field

- Spectrograph 400–800 nm
  - Standard 2k CCD
  - Fixed 5 arcmin slit (with variable width?)
  - Option A: 1:1 optics
    - R = 500–1000 with 1.2 arcsec slit
    - R = 1000–2000 with 0.6 arcsec slit
    - R = 333–667 with 1.8 arcsec slit
  - Option B: 1:2 optics
    - R=1000–2000 with 1.2 arcsec slit
    - R= 667–1333 with 1.8 arcsec slit
  - Rebin for lower resolution.

Concept with 1:1 Optics



Camera

- Ability to get GRB afterglow light curves simultaneously with guiding.
- Similar sensitivity to DDRAGO
- Sky-limited in 15 seconds
- 10-sigma at *zy* = 20.5 in 240 seconds

Dark Time: Sky-Limit

- Simple model with constant efficiency of 40%
- SNR = 10 for R = 750 at AB = 20.5 in 900 seconds in dark time
- Standard CCD and EMCCD close to sky limit
- DD CCD has too much read noise
- sCMOS has too much dark current
- Prefer standard CCD

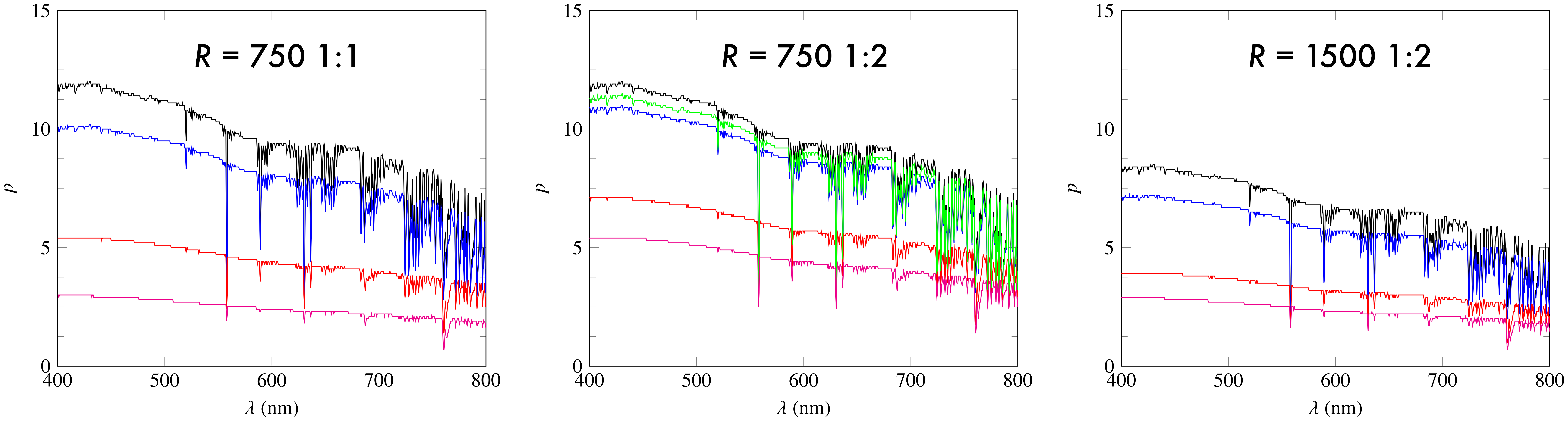
Black = sky-limited

Blue = standard CCD

Green = EMCCD

Red = DD CCD

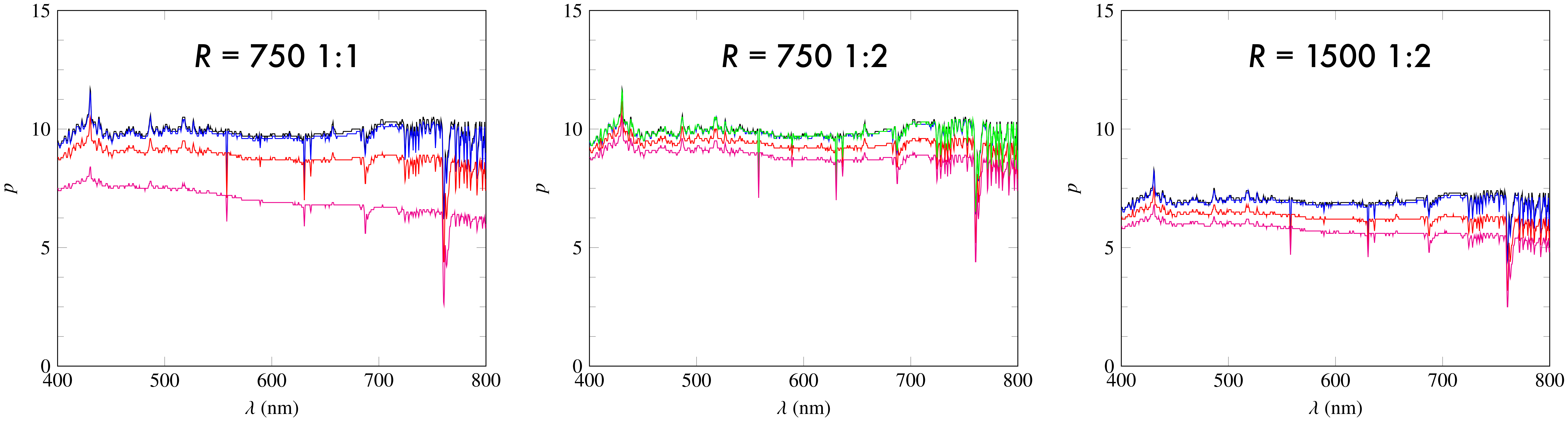
Magenta = sCMOS



Bright-Time: Sky-Limit

- Simple model with constant efficiency of 40%
- SNR = 10 for R = 750 at AB = 19.5 in 900 seconds in bright time
- All close to sky limit

Black = sky-limited
Blue = standard CCD
Green = EMCCD
Red = DD CCD
Magenta = sCMOS



Lower Resolutions

- Get to sky-limit in 900 seconds at R = 750 or R = 1500
- Can rebin to lower resolution (e.g., to look for Ly absorption) with no loss of sensitivity.
- However shorter exposure times will not be sky-limited and will have a penalty – is this acceptable?

Restrictions

- No < 400 nm?
- No > 800 nm?
- Loose sensitivity for short exposures of faint objects at low resolution
- Only track parallactic angle?
- All can be solved with cost in other capabilities or complexity