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Impact of crosshatch patterns in H2RGs on high precision radial velocity measurements: Exploration of measurement and mitigation paths with HPF

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Habitable-zone Planet Finder (HPF)

- HETのファイバーRV分光器：0.81-1.28um
- 1.53m/sのモニタが目標
- H2RG1.7um cutoff
    - QEにsub-pixelのスクラッチパターンがある(cross-hatch patters)
    - MCT結晶構造の欠陥によるものの模様
    - RVの測定に大きな影響を与える(サブピクセルで吸収線位置を決めないといけないから)

Intra-pixel QE variation

- モデル化
    - 傾きSのillumination pattern
    - フラット補正した測定されたカウント値は (Csは本来測定されるべき値)

$$C_{sMeasuredFlatCorrected} = C_s + \frac{Sw(q-q_d)[\frac{1-w}{2} - x]}{[wq_d + (1-w)q]}. \quad (1)$$

- RV測定値への影響は

$$\frac{\delta V(i)}{c} = \frac{\Delta\lambda}{\lambda(i)} \frac{1}{N} \sum_{j}^{N} \frac{w(q-q_d)[\frac{1-w}{2} - x(j)]}{[wq_d + (1-w)q]} = \frac{\Delta\lambda}{\lambda(i)}\xi. \quad (4)$$

where

$$\xi = \frac{1}{N} \sum_{j}^{N} \frac{w(q-q_d)[\frac{1-w}{2} - x(j)]}{[wq_d + (1-w)q]}. \quad (5)$$

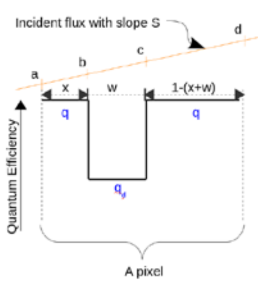

Fig 1 Our simple one dimensional step function model of intra-pixel QE difference due to a crosshatch in the pixel.

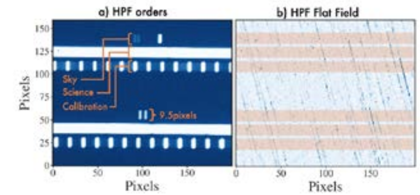

Fig 2 a) A zoom in on-sky science image showing only two orders showing the HPF science, sky and calibration order traces. b) The same as a) but during a filtered flat field exposure to illustrate the size of the cross hatch pattern with order traces overlaid.

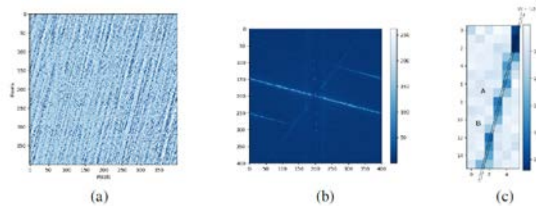

Fig 4 a) A sample crosshatch pattern region in HPF. b) 2D Fourier power spectrum of the region showing the angle of the crosshatches, as well as the power extending all the way to Nyquist sampling hinting the sub-structure nature of cross-hatches. c) Zoomed image of a typical 14.8 degree crosshatch QE variation pattern. Labels A and B mark two column crossover points of the subpixel crosshatch defect. A best fitted rectangular sub-pixel crosshatch with a width of 1/3.78 pixels is also overlayed on the pixels.

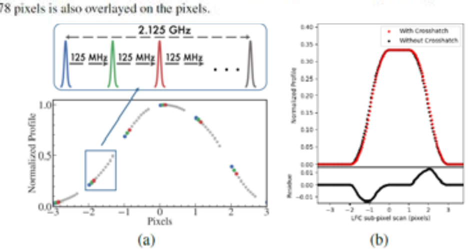

Fig 5 a) Current capability of the HPF LFC: Experimental results showing the 1pixel scanning (in 125 MHz steps) of the HPF's PSF. b) Red curve shows the simulated LFC profile traced by a pixel with intra-pixel QE defect, during a full profile scan with the future upgraded LFC. Black curve is the reference curve when all the pixels are free of crosshatch defects.

- HPFのH2RGでは scratchの傾き~14.8度
    - 図4-cをみると、列がかわるさいに2ピクセルほどかかっているのでdefectの幅は w~1/3.78pix~5umくらい
    - scratchのところのQEは周りに比べて88%くらいなので、defectの底のQEはq_d/q ~0.55
- これによる影響は最大0.4m/sくらいの誤差になる
- 実際のスペクトルの補正は
    1. フラットで割る
    2. crosshatchによる変位パラメータ($df_s/d\lambda$)マップは別に求めておく
    3. そのマップにG(各ピクセルのフラックスペクトル)・P(QEベクトル)をかけて、補正項とする
- 変位パラメータマップは
    - これはtunable Laser Frequency Combのスペクトルでやる
    - コムの波長を少しずつずらしてマッピングする