SIMPLE-ABC:
Statistical Inference for Multiple PLanet systems Employing Approximate Bayesian Computation

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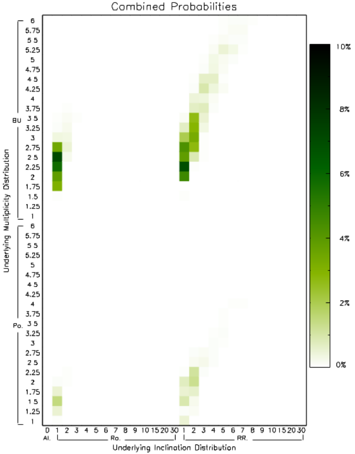
We would like to make inferences about the underlying distribution(s) of *Kepler* Planets.

-What is the number of planets per star?

-What is the distribution of mutual inclinations?

-What is the distribution of planet eccentricities?



Fang & Margot (2012)

We want to infer the posterior probability of some model with parameters θ.

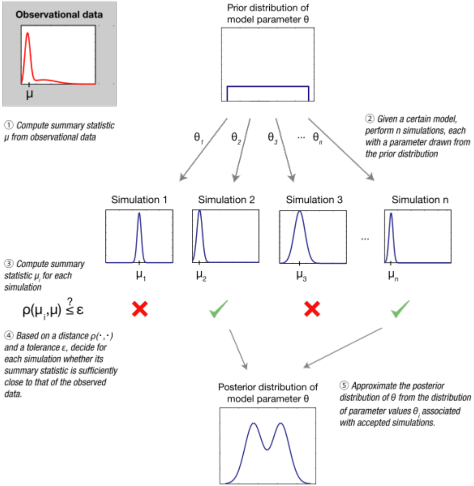
Posterior

Prior

Likelihood

$$\Pr(\theta \mid \text{Data}) = \frac{\Pr(\theta)\,\Pr(\text{Data} \mid \theta)}{\Pr(\text{Data})}$$

Approximate Bayesian Computation (ABC) is a likelihood-free method to infer posterior distributions.



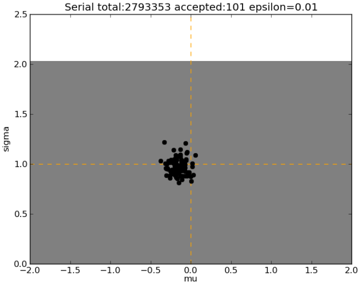
Sunnåker et al. (2013)

I took an object-oriented approach using Python.

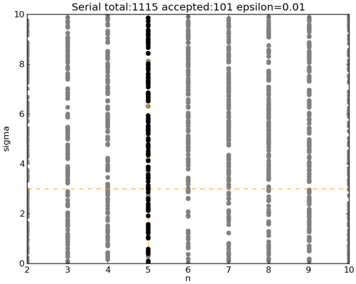
```
class Model(object):

    def __call__(self, theta):
        return self.generate_data_and_reduce(theta)

    def set_data(self, data):
            self.data = data
            self.data_sum_stats = self.summary_stats(self.data)

    def generate_data_and_reduce(self, theta):
        """
        A combined method for generating data, calculating summary statistics
        and evaluating the distance function all at once.
        """
        synth = self.generate_data(theta)
        sum_stats = self.summary_stats(synth)
        d = self.distance_function(sum_stats, self.data_sum_stats)
        return d

    def draw_theta(self):
        raise NotImplementedError('You must override the draw_theta '
                                  'method in your own subclass.')

    def generate_data(self, theta):
        raise NotImplementedError('You must override the generate_data '
                                  'method in your own subclass.')

    def summary_stats(self, data):
        raise NotImplementedError('You must override the summary_stats '
                                  'method in your own subclass.')

    def distance_function(self, summary_stats, summary_stats_synth):
        raise NotImplementedError('You must override the distance_function '
                                  'method in your own subclass.')
```

For testing purposes, I implemented two models.

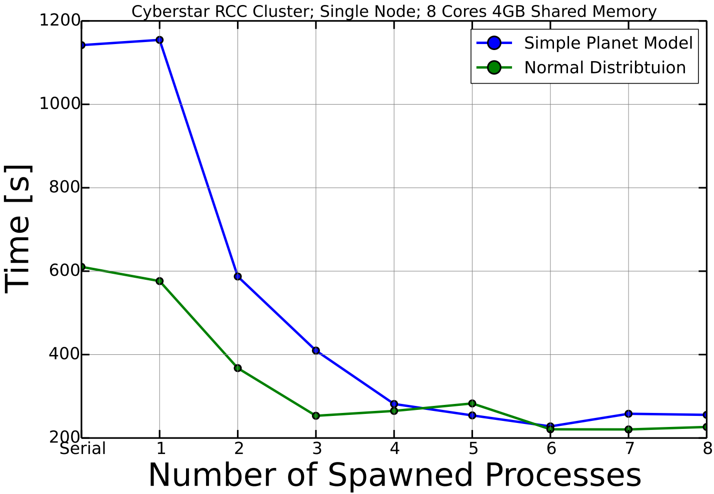
Normal Distribution



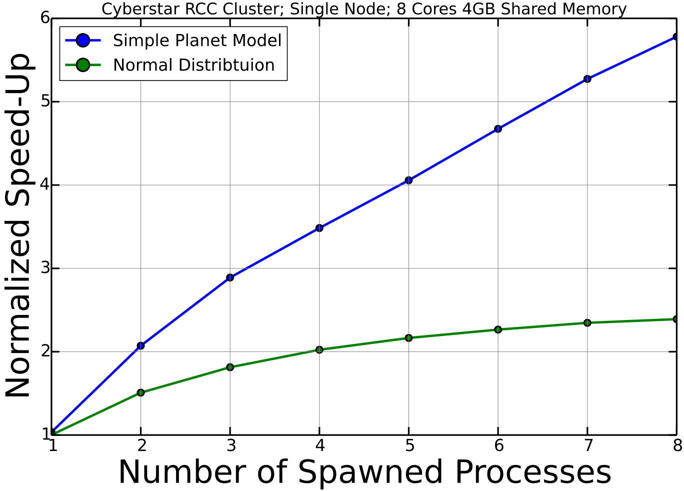
Simple Planet Model



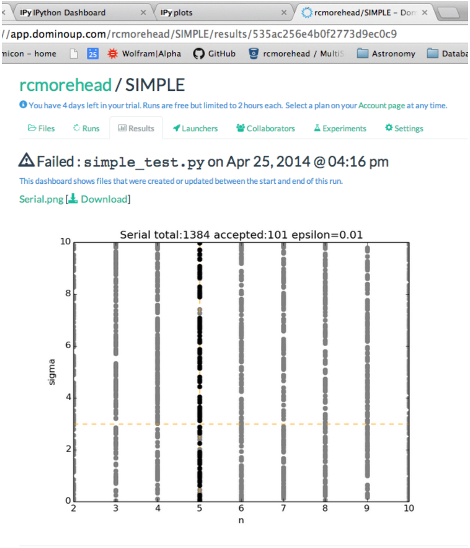
Parallelization via multiprocessing.pool.map works pretty well...



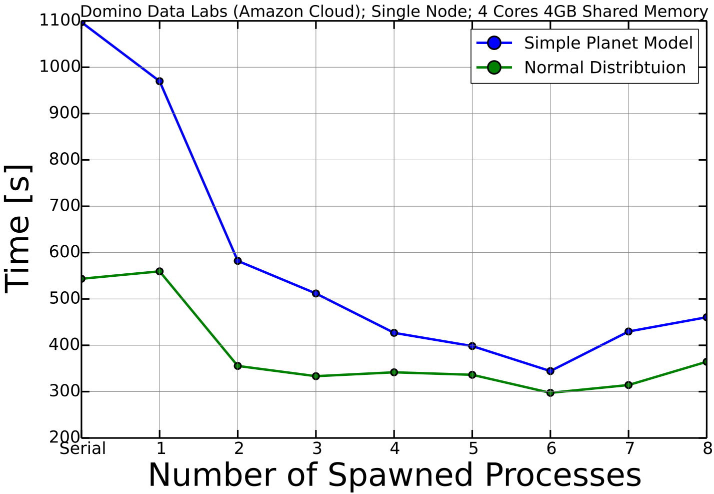
and even better for complex models!



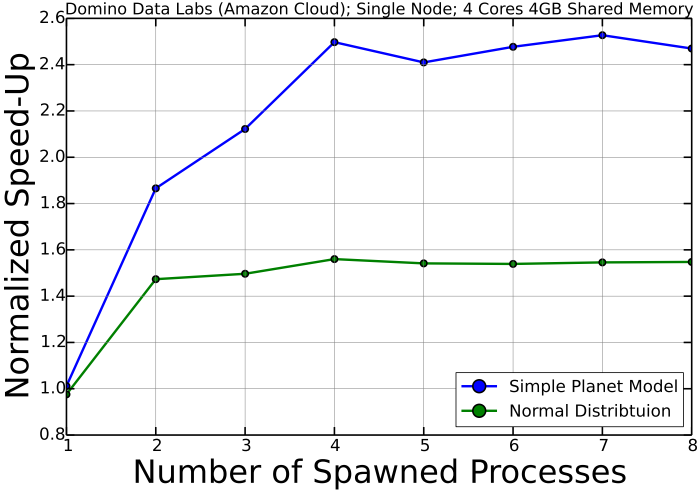
I tried cloud computing with Domino Data Labs.



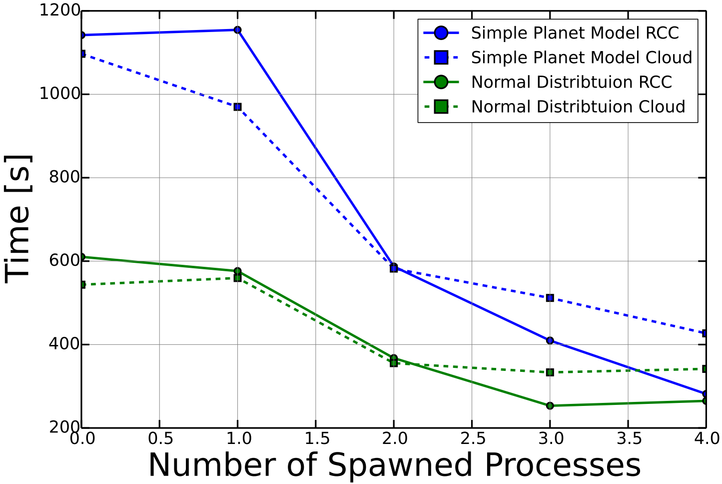
If I had presented on Monday, that would have been it...



The gains in performance are *almost* as good.



But in the cloud system does not scale quite as well.



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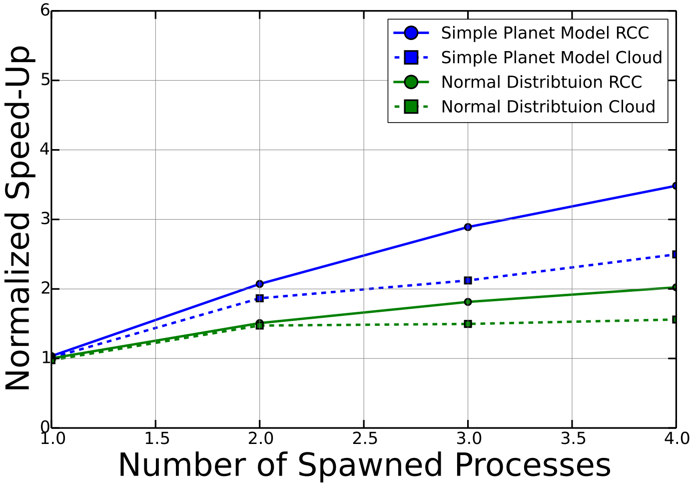

The End

Nothing to see here!

For testing purposes, I implemented two models.

Normal Distribution

$\theta = (\mu, \sigma)$

$(\mu = 0, \sigma = 1)$

$\widehat{S} = (\text{25th, 75th percentiles})$

$D = \sqrt{\widehat{S}_0^2 + \widehat{S}_1^2}$

$\epsilon = 0.01$

Minimum particles $= 100$

Simple Planet Model

$\theta = (n, \sigma)$

$(n = 5, \sigma = 3)$

$\widehat{S} = (\text{N transits per star}, \ b)$

$D = \sqrt{D_{KS}(\widehat{S}_0)^2 + D_{KS}(\widehat{S}_1)^2}$

$\epsilon = 0.01$

Minimum particles $= 100$

Fang, J., & Margot, J.-L. 2012, , 761, 92

Sunnåker, M., Busetto, A. G., Numminen, E., Corander, J., Foll, M., & Dessimoz, C. 2013, PLoS Comput Biol, 9, e1002803