

The Drake Equation and More

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Outline

- My Background
- Big Questions
- Probability Basics
- The Drake Equation
- The Amateur Astro Equation
- Resources



My Background

- Observing since 1998
- Imaging since 2006
- Current imaging setup:
 - **Camera:** SBIG STL-11000M with L, R, G, B and H-alpha filters
 - **Telescopes:** 10" f/3.6 (or f/6.8) ASA reflector; SV 80 mm f/6 refractor
 - **Mount:** Paramount MX
 - **Software:** TheSkyX, FocusMax, CCDCommander, PixInsight
- Reach me at
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Big Questions

- How many intelligent civilizations are there in the Milky Way Galaxy?
 - Are we alone?
 - Is anybody out there?
 - Is there intelligent life in space?



Big Questions

- How productive am I likely to be as an active astronomer, given all the challenges?
 - Weather
 - Other commitments
 - Technology
 - Aging



Probability Basics

- Probability is the chance of something happening
 - Probability can be expressed as a fraction, a decimal or a percent
 - $\frac{1}{2} = 0.5 = 50\% = \text{"50/50 chance"}$
 - Probability of 1 coin flip of “tails”: $\frac{1}{2} = 0.5$
 - Probability of you being born on a weekend: $2/7 = 0.285$
- Many probabilities are multiplicative
 - Probability of 5 coin flips of “tails”:
 - $0.5 \times 0.5 \times 0.5 \times 0.5 \times 0.5 = 1/32$
 $= 0.03125$



Drake Equation History

- Developed in 1961 by Frank Drake
- Provides a way to think about the number of intelligent, communicating civilizations in our Galaxy
- Focuses on the most important factors
 - Others have added to it
 - Can help inform research
 - Value of some variables may be extremely difficult to determine with confidence

The Drake Equation

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

Where

N = the number of planets in our galaxy with intelligent life

And

R_* = average rate of star formation in our galaxy

f_p = fraction of those stars that have planets

n_e = average number of planets that might support life per star with planets

f_l = fraction of planets that could support life that actually develop life

f_i = fraction of planets with life that actually go on to develop intelligent life

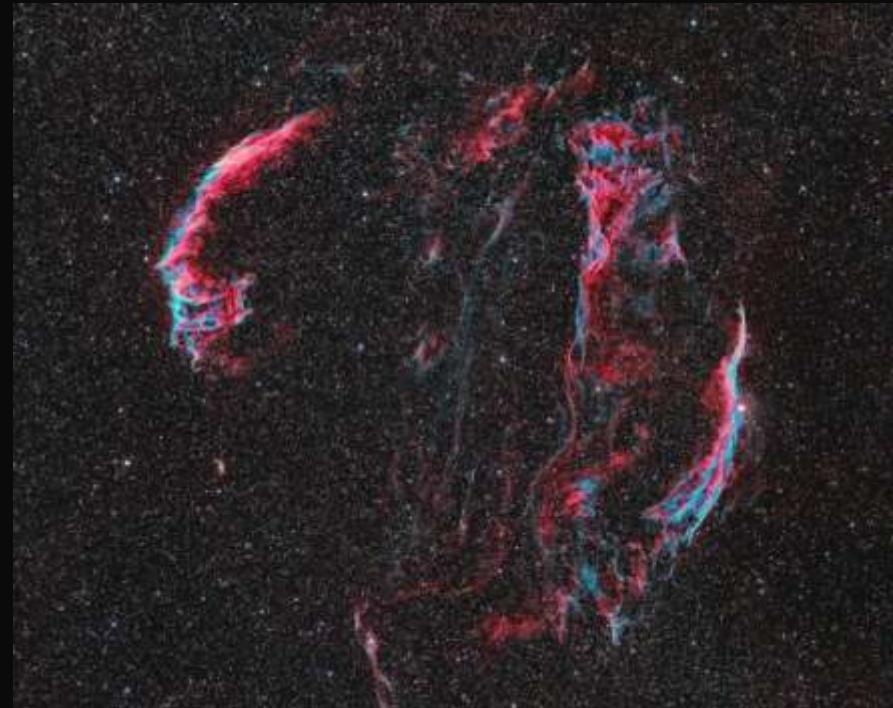
f_c = fraction of civilizations that reveal their existence via signals released to space

L = length of time for which such civilizations release detectable signals into space



Drake Equation Variables

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Drake Equation Variables

- R_* = average rate of star formation in our galaxy
 - NASA and ESA estimate 7 stars per year
- f_p = fraction of those stars that have planets
 - Most recent evidence suggests $f_p = 1$
 - Planets around stars seem to be the rule, not the exception
 - One or more planets per Milky Way star is the norm

Drake Equation Variables

- n_e = average number of planets that might support life per star with planets
 - Includes planets and satellites
 - Considers the “Goldilocks” zone
 - Estimated in 2013 from Kepler mission data
 - 11 billion Earth-sized planets orbiting Sun-like stars in the habitable zone
 - If $f_p = 1$ and the Milky Way has 100 billion stars, then $n_e=0.11$

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 - If $f_p = 1$ and the Milky Way has 100 billion stars, then $n_e=0.11$
- f_l = fraction of planets that could support life that actually develop life
 - Based on Earth’s geologic record, f_l may be high
 - Life appears to have arisen quickly once conditions were good
 - But – no way of knowing if this is common, rare or unique

Drake Equation Variables

- f_i = fraction of planets with life that actually go on to develop intelligent life
 - Value is particularly uncertain
 - Some say f_i should be tiny: Only one of the billions of species on earth has developed intelligence
 - Others think f_i should be high: Life has steadily evolved in complexity on Earth, implying that once life takes root, intelligence is inevitable
 - Research into life on Mars is relevant
 - If life, but not intelligent life, developed on Mars, then it develops half the time
 - $f_i = 0.5$
 - Sample size of only 2. Better than 1, but not much.

Drake Equation Variables

- f_c = fraction of civilizations that reveal their existence via signals released to space
 - Earth sends relatively few deliberate signals into space
 - We only started recently
 - We're only signaling a tiny fraction of stars that could have intelligent civilizations capable of detecting us
 - But signals don't need to be deliberate...
 - Current and near-future Earth technology could detect signals
 - Distance limits the size of this variable
 - Only a small percentage of civilizations (if they exist) may be close enough for us to detect

Drake Equation Variables

- L = length of time for which such civilizations release detectable signals into space
 - Some estimates based on past civilizations on Earth
 - 60 historical civilizations: $L = 420$ yr
 - 28 post Roman-era civilizations: $L = 304$ yr
 - Many problems with this approach
 - Some civilizations build on others' technologies
 - Only one civilization has deliberately sent signals into space, and for much less than 100 years ("accidental" signals since early 20th century)

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 - Carl Sagan speculated that all terms in the Drake equation are quite high except L
 - L depends on a civilization's ability to avoid self-destruction
 - Strong argument for environmentalism
 - Civilizations that succeed may be "immortal," so L could be large

Drake Equation Results

- *N depends on the values assigned to parameters*
 - Interpretation of estimates of N
 - A result much less than 1 suggests we are alone in the galaxy
 - A result much greater than 1 suggests there are many civilizations out there that we might detect
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 - Drake Equation Calculator:
 - <http://www.pbs.org/wgbh/nova/space/drake-equation.html>

The Amateur Astro Equation

$$N = Y \times f_c \times f_m \times f_w \times f_t \times f_e \times (1-f_{wu}) \times f_{mv} \times L$$

Where

N = the number of productive astronomy nights in an amateur astronomer's lifetime

and

Y = number of nights in a year

f_c = fraction of nights that are clear

f_m = fraction of nights that are more or less moon-free

f_w = fraction of "free" nights

f_t = fraction of nights with low enough wind for imaging

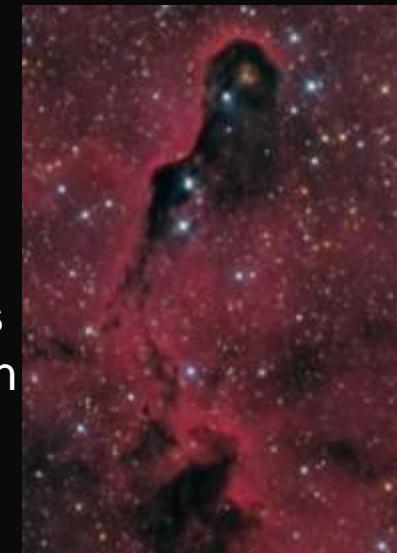
f_{bt} = fraction of nights with bearable temperature

f_e = fraction of time that all equipment works properly

f_{wu} = fraction of Windows Update and other unplanned shutdowns

f_{mv} = fraction of time motivated enough to start an imaging session

L = number of years of active imaging



The Amateur Astro Equation Portable Imaging

$$N = Y \times f_c \times f_m \times f_w \times f_t \times f_e \times (1-f_{wu}) \times f_{mv} \times L$$

Where

N = the number of productive astronomy nights in an amateur astronomer's lifetime

and

f_c =	number of nights in a year	365.25
f_m =	fraction of nights that are clear	0.4
f_w =	fraction of nights that are more or less moon-free	0.5
f_t =	fraction of "free" nights (weekend plus stat holidays+ 14 nights)	0.351
f_{bt} =	fraction of nights with low enough wind for imaging	0.66
f_e =	fraction of nights with bearable temperature	0.75
f_{wu} =	fraction of time that all equipment works properly	0.90
f_{mv} =	fraction of Windows Update and other unplanned shutdowns	0.02
L =	fraction of time motivated enough to start an imaging session	0.75
	number of years of active imaging (35-70)	35

The Amateur Astro Equation Permanent Imaging

$$N = Y \times f_c \times f_m \times f_w \times f_t \times f_e \times (1-f_{wu}) \times f_{mv} \times L$$

Where

N = the number of productive astronomy nights in an amateur astronomer's lifetime

and

Y = number of nights in a year	365.25
f_c = fraction of nights that are clear	0.4
f_m = fraction of nights that are more or less moon-free	0.5
f_w = fraction of "free" nights (weekdays+14 nights)	0.751
f_t = fraction of nights with low enough wind for imaging	0.9
f_{bt} = fraction of nights with bearable temperature	0.95
f_e = fraction of time that all equipment works properly	0.99
f_{wu} = fraction of Windows Update and other unplanned shutdowns	0.01
f_{mv} = fraction of time motivated enough to start an imaging session	0.95
L = number of years of active imaging (35-80)	45

The Amateur Astro Equation Portable Observing

$$N = Y \times f_c \times f_m \times f_w \times f_t \times f_e \times (1-f_{wu}) \times f_{mv} \times L$$

Where

N = the number of productive astronomy nights in an amateur astronomer's lifetime

and

f_c =	number of nights in a year	365.25
f_m =	fraction of nights that are clear	0.4
f_w =	fraction of nights that are more or less moon-free	0.85
f_t =	fraction of "free" nights (weekday plus 14 nights)	0.751
f_{bt} =	fraction of nights with low enough wind for imaging	0.80
f_e =	fraction of nights with bearable temperature	0.75
f_{wu} =	fraction of time that all equipment works properly	0.99
f_{mv} =	fraction of Windows Update and other unplanned shutdowns	0.00
L =	fraction of time motivated enough to start an observing session	0.75
	number of years of active imaging (35-85)	50

The Amateur Astro Equation Results

- Imaging
 - Portable: 8 nights/yr; 295 nights in a lifetime
 - Permanent: 44 nights/yr; 1,965 nights in a lifetime
 - Remote: limited only by availability and \$\$\$
- Visual
 - Portable setup: 42 nights/yr; 2,077 nights in a lifetime

The Amaterur Astro Equation

Interpretation of Results

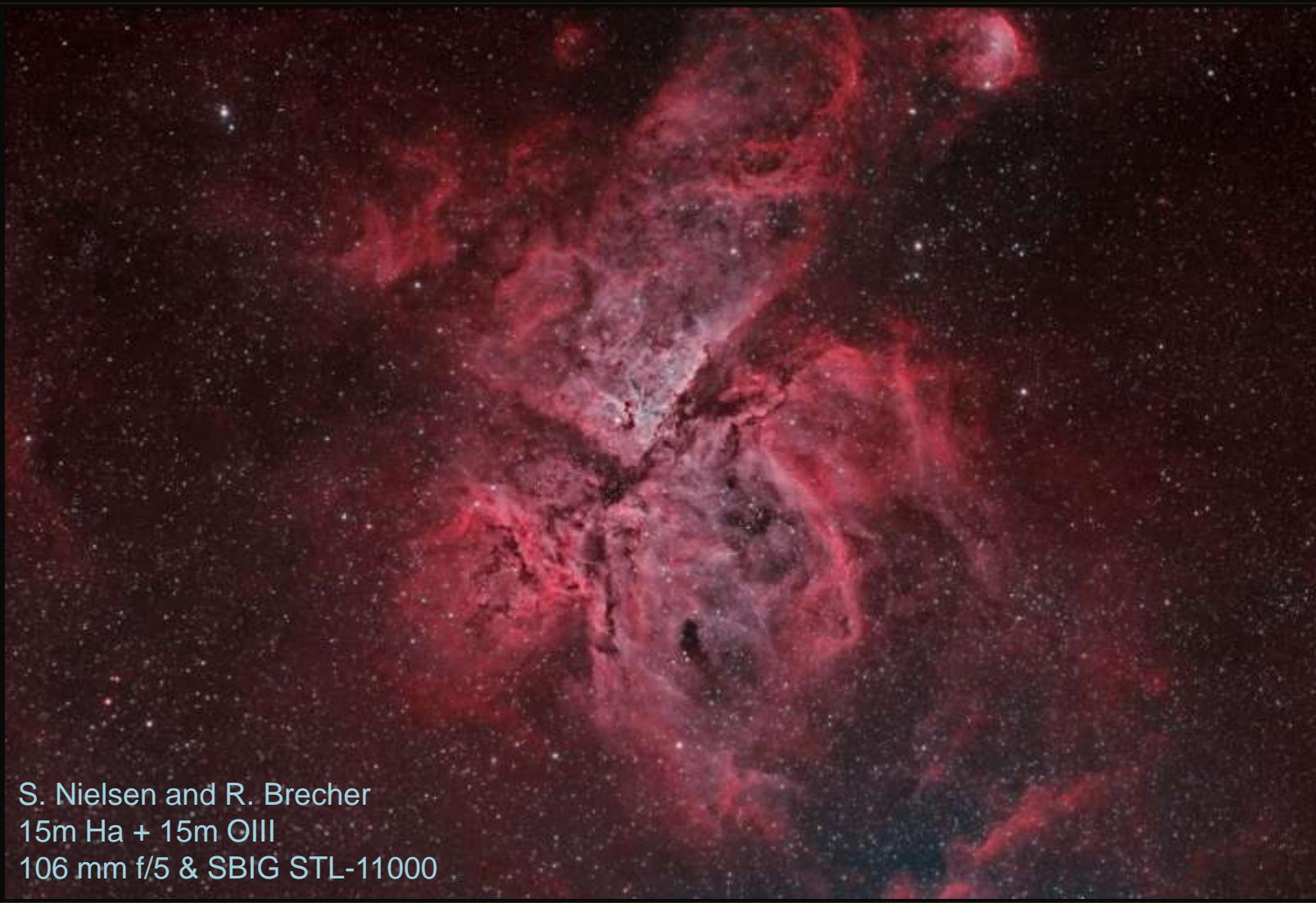
- A permanent setup can make astrophotography more productive
 - RB productivity increased by at least 5x with observatory
 - Remote imaging is a viable option
 - access to a variety of dark sky sites and equipment
 - low capital cost

The Amaterur Astro Equation

Interpretation of Results

- A permanent setup can make astrophotography more productive
 - RB productivity increased by at least 5x with observatory
 - Remote imaging is a viable option
 - access to a variety of dark sky sites and equipment
 - low capital cost
- Visual observing (portable or permanent setup) can be more satisfying than imaging
 - Less to go wrong
 - Object selection suited to conditions
 - More sociable than imaging

Remote Imaging: Eta Carina



S. Nielsen and R. Brecher
15m Ha + 15m OIII
106 mm f/5 & SBIG STL-11000

Remote Imaging: NGC 253



B. Soames and R. Brecher
150mm f/11.1 refractor & SBIG 6303E

Resources

- The Drake Equation and alternatives
 - <http://www.seti.org/drakeequation>
 - <http://www.space.com/22648-drake-equation-alien-life-seager.html>
- Kepler Mission
 - <http://kepler.nasa.gov/>
 - <http://news.nationalgeographic.com/2016/01/160108-kepler-nasa-planets-alien-space/>
- Remote Imaging
 - <http://www.itelescope.net/>
 - <http://deepskywest.com/>

Questions?

