The Drake Equation and More

Ron Brecher

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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 rbrecher@rogers.com

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 an 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
    - ½ = 0.5 = 50% = “50/50 chance”
  - Probability of 1 coin flip of “tails”: ½= 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 x 0.5 x 0.5 x 0.5 x 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

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- 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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    - 36,400,000 (the galaxy is crowded)
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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

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

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 (weekend plus stat holidays+ 14 nights)	0.351
f_t =	fraction of nights with low enough wind for imaging	0.66
f_{bt} =	fraction of nights with bearable temperature	0.75
f_e =	fraction of time that all equipment works properly	0.90
f_{wu} =	fraction of Windows Update and other unplanned shutdowns	0.02
f_{mv} =	fraction of time motivated enough to start an imaging session	0.75
L =	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

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	0.85
f_w = fraction of “free” nights (weekday plus 14 nights)	0.751
f_t = fraction of nights with low enough wind for imaging	0.80
f_{bt} = fraction of nights with bearable temperature	0.75
f_e = fraction of time that all equipment works properly	0.99
f_{wu}= fraction of Windows Update and other unplanned shutdowns	0.00
f_{mv}= fraction of time motivated enough to start an observing session	0.75
L = 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

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?